



THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Research Commons

<http://researchcommons.waikato.ac.nz/>

Research Commons at the University of Waikato

Copyright Statement:

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

The thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author's right to be identified as the author of the thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from the thesis.

A SYSTEMS APPROACH TO PHYSICS EDUCATION

AT FIRST YEAR UNIVERSITY LEVEL

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Doctor of Philosophy
at the
University of Waikato
by
ROGER JOHN OSBORNE

University of Waikato

1976

VOLUME TWO

LIST OF TABLES

	Page
5.1 The first year physics objectives at the University of Waikato	209
6.1 Perceived emphases, in teaching, on the different objectives of the first year physics courses	212
6.2 Possible variations in instructional models	213
7.1 Student percentage response concerning the textbook in 1970 and 1971	214
7.2(a) Student percentage response concerning the text as lecture notes in 1970	
(b) Student percentage response concerning lecture notes 1971 and 1972	215
7.3 Student percentage response concerning the use of the textbook in the examination room 1970, 1971 and 1972	216
7.4 Student percentage response concerning the frequency of tutorials 1970, 1971 and 1972	216
7.5 Changes in responses to an experiment from 1971 to 1972	217
7.6 Bipolar adjectives used to study attitudes towards experiments	224
7.7 Principal components analyses of semantic differential scales in 1973 and 1974	225
8.1 Principal components analysis of attitudes to physics of seventh form, and first year university, physics students	229
8.2 Principal components analyses of (A) end of year seventh form attitudes (B) beginning of university year attitudes (C) end of year university attitudes	230
8.3 Principal components analyses of objective scores—output 1973 and 1974	231
8.4 Principal components analyses of objective scores—input 1973 and 1974	232
8.5 Principal components analysis of objective scores seventh form output tests, Oct., 1974	233
9.1 Means of attitude scores in 1973 and in 1974	234

	Page	
9.2	Explicit attitude change to physics as a subject	235
9.3	Attitude objective mean scores for input-output 1974 compared with an October 1974 sample in schools	235
9.4	Correlation of student's stated attitude change with measured attitude change using Likert scales	236
9.5	Measured output attitude and student intention for the following year in 1973 and 1974	236
9.6	Retention rates from first year physics to physics majors	237
9.7	Grouping of course objectives as determined experimentally from statistical analyses of output results	238
10.1	Correlation of Bursary Physics total mark with output results in 1973 and in 1974	239
10.2	Input variables	240
10.3	Comparison of beta weights and regression factor structure coefficients	241
11.1	Estimates of the coefficients of reliability for input and output totals using the Spearman-Brown formula	244
11.2	Model 1 correlation matrix	246
11.3	Regression factor structure coefficients associated with Model 1	246
11.4	Model 2 correlation matrix	248
11.5	Regression factor structure coefficients associated with Model 2	248
11.6	Model 3 correlation matrix	250
11.7	Regression factor structure coefficients associated with Model 3	250
11.8	Model 4 correlation matrix	252
11.9	Regression factor structure coefficients associated with Model 4	252
11.10	Model 5 correlation matrix	254
11.11	Regression factor structure coefficients associated with Model 5	254
12.1	Lower limit estimates of the coefficients of reliability for variables in Chapter 12	255

	Page	
12.2	Model 6 correlation matrix	257
12.3	Model 7 correlation matrix	258
12.4	Regression factor structure coefficients associated with Model 7	258
12.5	Model 8 correlation matrix	261
13.1	Changes in student aims and factors affecting these changes in 1972	262
13.2	Students' expectation versus test results and students' change in aim in 1972	262
13.3	Model 9 correlation matrix	264
13.4	Model 10 correlation matrix	265
13.5	Principal components analyses of teachers' subjective assessments of first year physics students in 1973 and in 1974	266
13.6	Principal components analyses of lecturer's subjective assessments of first year physics students in 1973 and 1974	267
13.7	Model 11 correlation matrix	269
13.8	Regression factor structure coefficients associated with Model 11	269
13.9	Regression factor structure coefficients associated with Model 12	271
14.1	Textbook design—Senior Advanced Physics	276
14.2	Graduates in schools (1971); graduate production (1967-1971) and stage II enrolments (1965) for New Zealand	277
15.1	Types of investigations in the evaluation and elucidation of instructional systems	280

LIST OF FIGURES

	Page
2.1 Aspects of the systems approach	202
2.2 The basic and applied aspects of the systems approach (Figure 2.1) applied to curriculum development and analysis	203
2.3 Evaluative and elucidatory components of curriculum development and analysis	204
2.4 The various aspects of system development and analysis which are served by the research activities specified in Figure 2.3	205
4.1 A course of instruction as an input-output system	206
4.2 First year university physics in the wider context of physics education in New Zealand	207
4.3(a) Simple input-output model (Model Type I)	
(b) Causal relations among input variables (Model Type II)	
(c) Including feedback (Model Type III)	208
5.1 Teachers' views (1974) of the relative importance in the <u>teaching</u> of physics at school and university, of various physics education objectives	210
5.2 Mean value of teachers' views (1974)	211
7.1 Percentage of students who considered the work load in the theoretical course to be more than in any other non-physics course (1971-1974)	218
7.2 Course monitoring in the theoretical course	219
7.3 Student percentage response on the difficulty on average of the content of sections of the theoretical course	220
7.4 Monitoring student attitudes to aspects of the theoretical course	221
7.5 Student opinion on most effective learning environment in 1973 and 1974	222
7.6 Relative student opinion on the reasons for their attitude change to physics in 1972	223
7.7 Experiments 1, 2 and 4 mean score profiles in 1973	226
7.8 Experiment 2 profile in 1973 and in 1974	227

	Page
7.9	228
Experiment 1 profile in 1973 and 1974	
10.1	241
Hypothetical example where Z_6 is dependent on Z_1 to Z_5	
10.2(a)	242
Simple input-output model (Type I)	
(b)	242
Type I path diagram	
10.3(a)	243
Multiple stage model (Type II)	
(b)	243
Type II path diagram	
11.1	245
Model 1	
11.2	247
Model 2	
11.3	249
Model 3	
11.4	251
Model 4	
11.5	253
Model 5	
12.1(a)	256
Path diagram for background variables	
(b)	256
Model 6	
12.2	258
Model 7	
12.3	259
Combining models 6, 2 and 7	
12.4	260
Model 8	
13.1(a)	263
Feedback model of student attainment	
(b)	263
Respecified for path analysis	
(c)	263
Simplified model with data available for testing	
13.2(a)	264
Model 9(a) Theoretical course	
(b)	264
Model 9(b) Experimental course	
13.3(a)	265
Model 10(a) Theoretical course	
(b)	265
Model 10(b) Experimental course	
13.4	268
A simplified version of Figure 4.1 which relates to a teacher's (lecturer's) perception of student attainment	
13.5	269
Model 11 Teachers' subjective assessments	
13.6	270
Mean correlations for 1973 and 1974 of subjective assessments with examination mark	
13.7	271
Model 12 Teachers' subjective assessment and Bursary Physics total	
13.8(a)	272
Model 1(a)	
(b)	272
Model 2(a)	
(c)	272
Model 11(a) Teachers' subjective factors	
13.9	273
Correlation coefficients of the components of teachers' subjective assessment with COMPLETE	

13.10(a)	Model 1(b)	
	(b) Model 2(b)	
	(c) Model 11(b) Teachers' subjective assessment	274
13.11	Correlation coefficients of the components of teachers' subjective assessment with FUTURE PHYSICS	275
14.1	State secondary schools: seventh form roll (1st July returns)	278
14.2	New Zealand science graduate production in secondary school teaching subjects 1967-1974	279

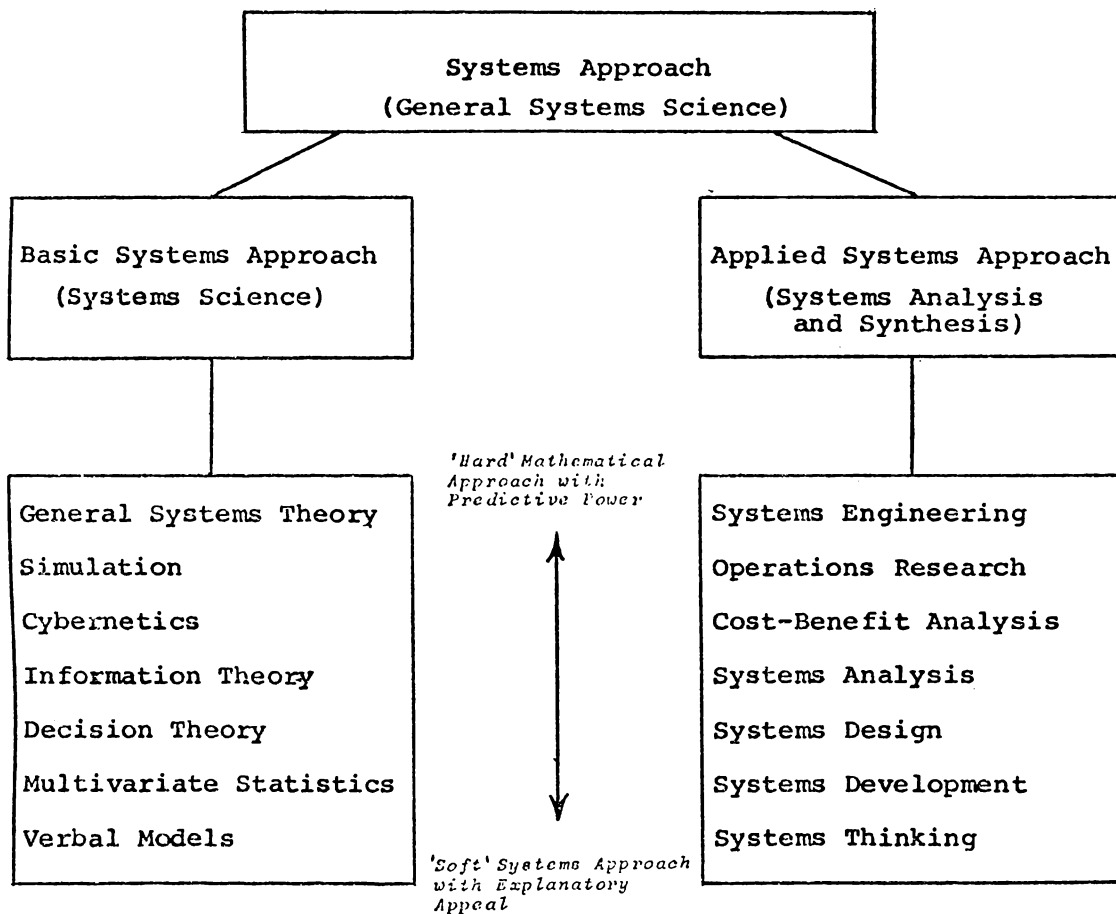


Fig 2.1 Aspects of the systems approach [adapted from Keuning (1974)]

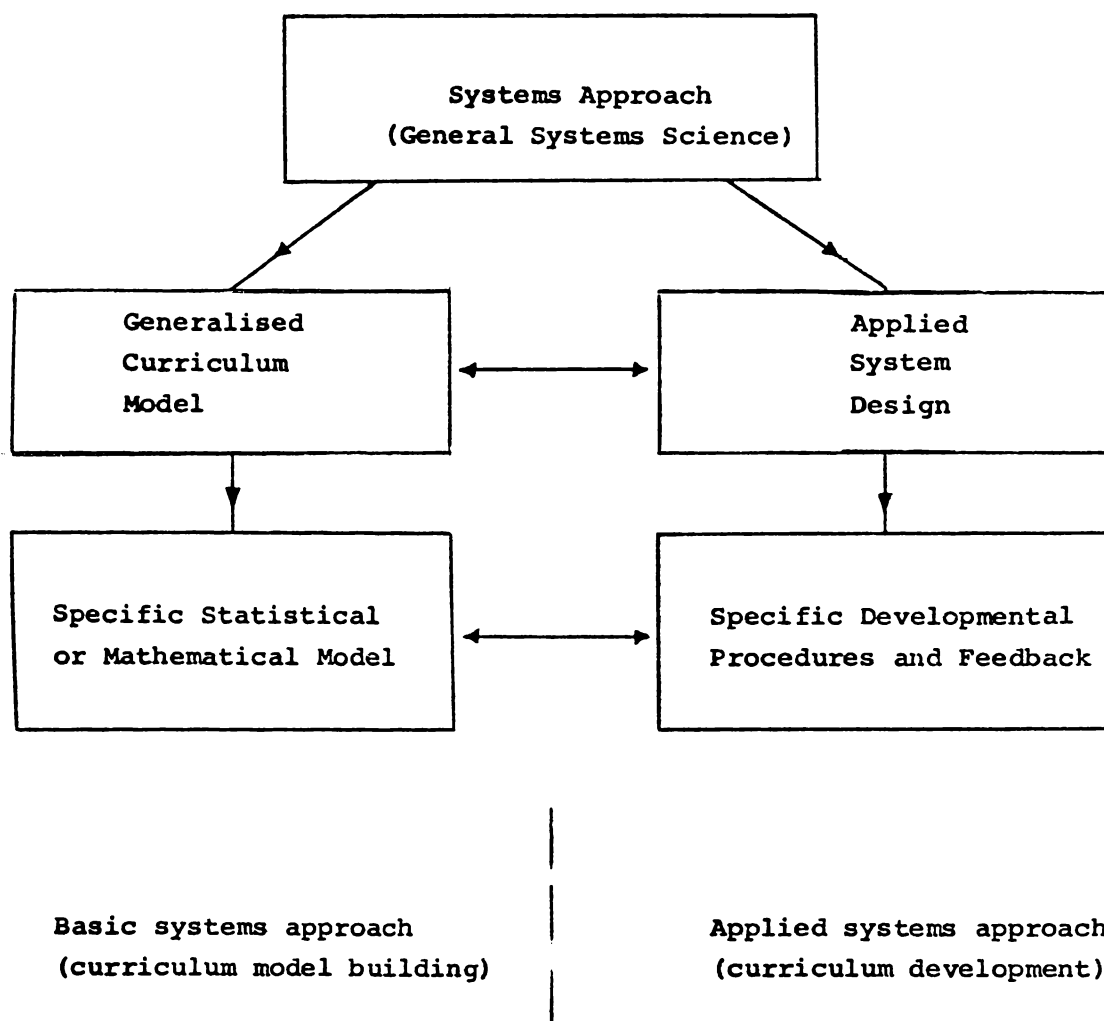


Fig 2.2 The basic and applied aspects of the systems approach
(Fig 2.1) applied to curriculum development and analysis

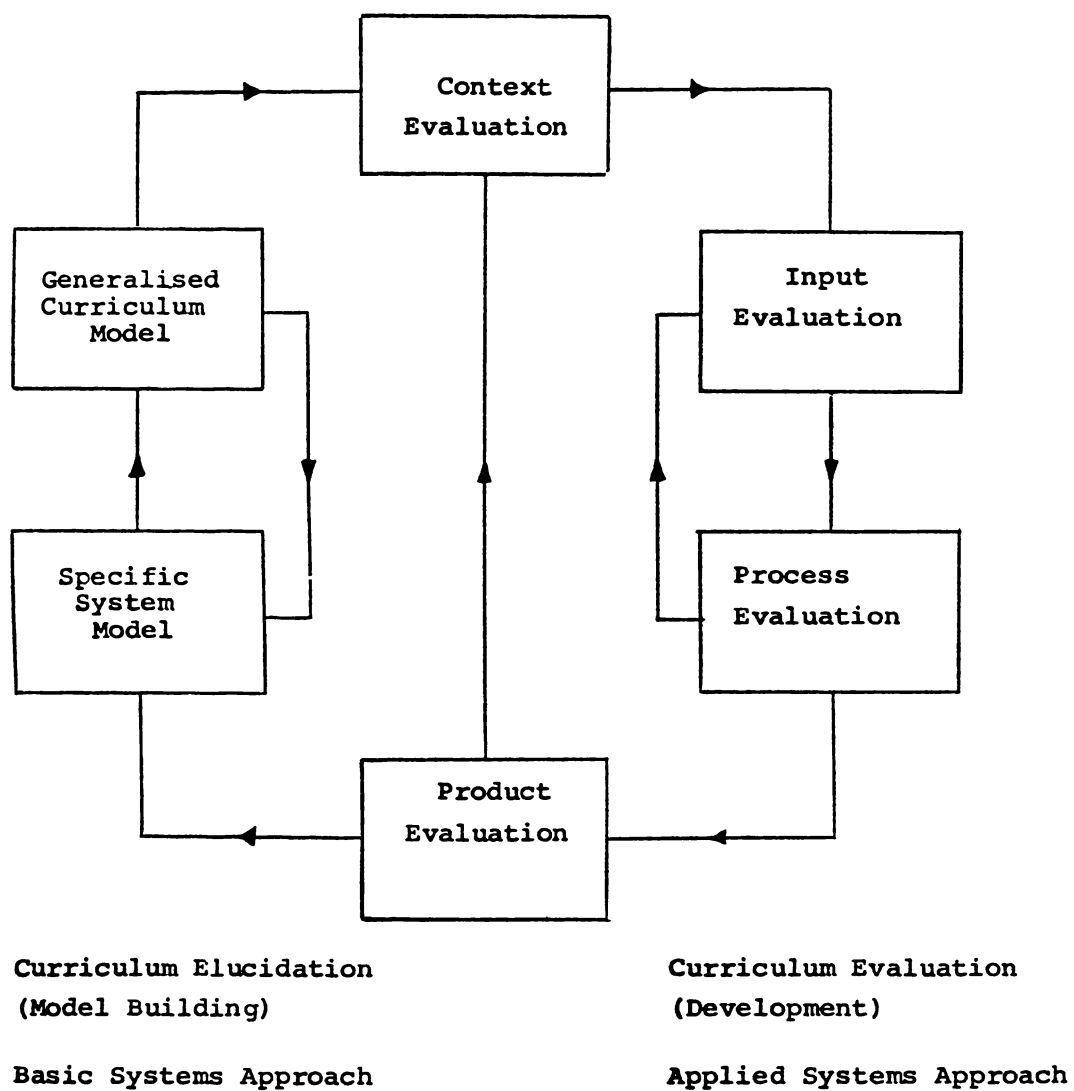


Fig 2.3 Evaluative and elucidatory components of curriculum development and analysis.

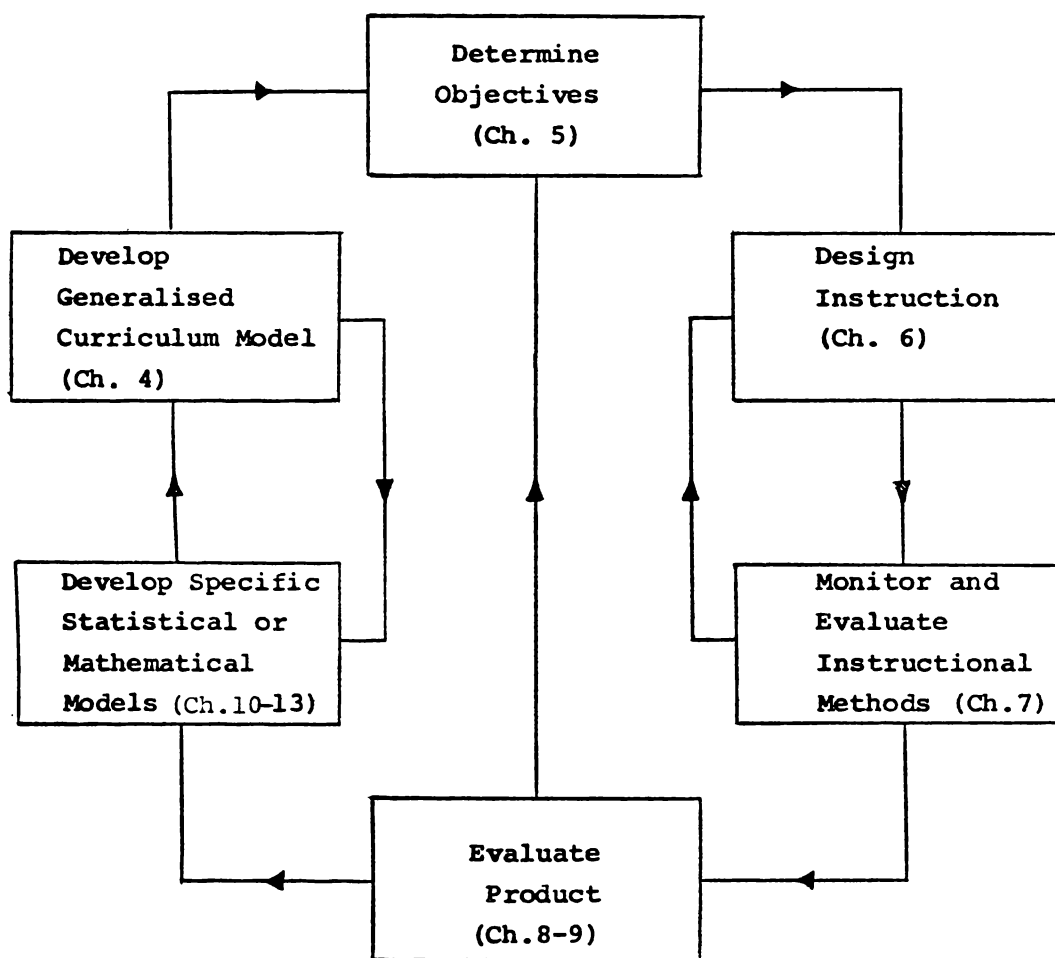


Fig 2.4 The various aspects of system development and analysis which are served by the research activities specified in Fig 2.3.

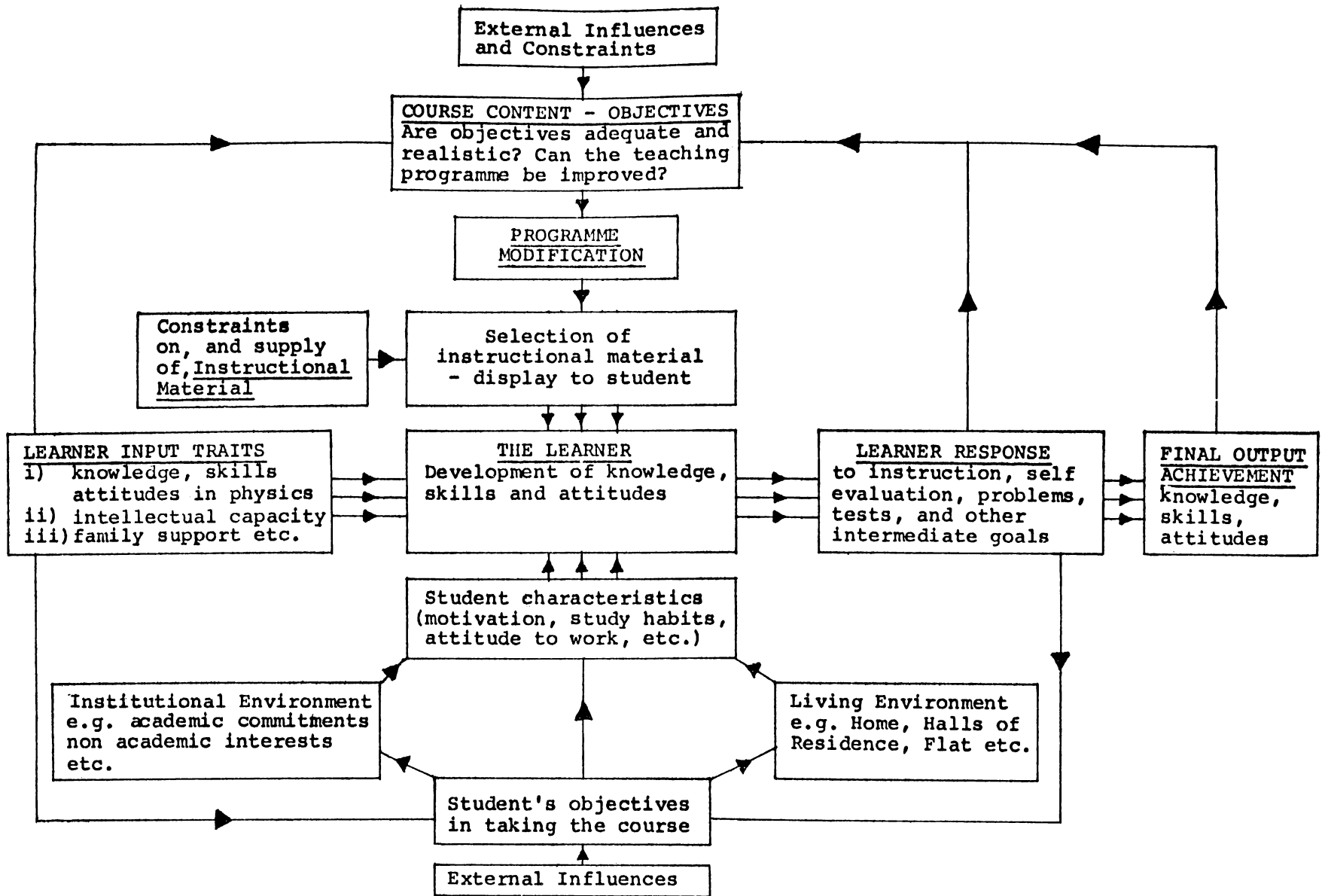


Fig 4.1 A course of instruction as an input-output system.

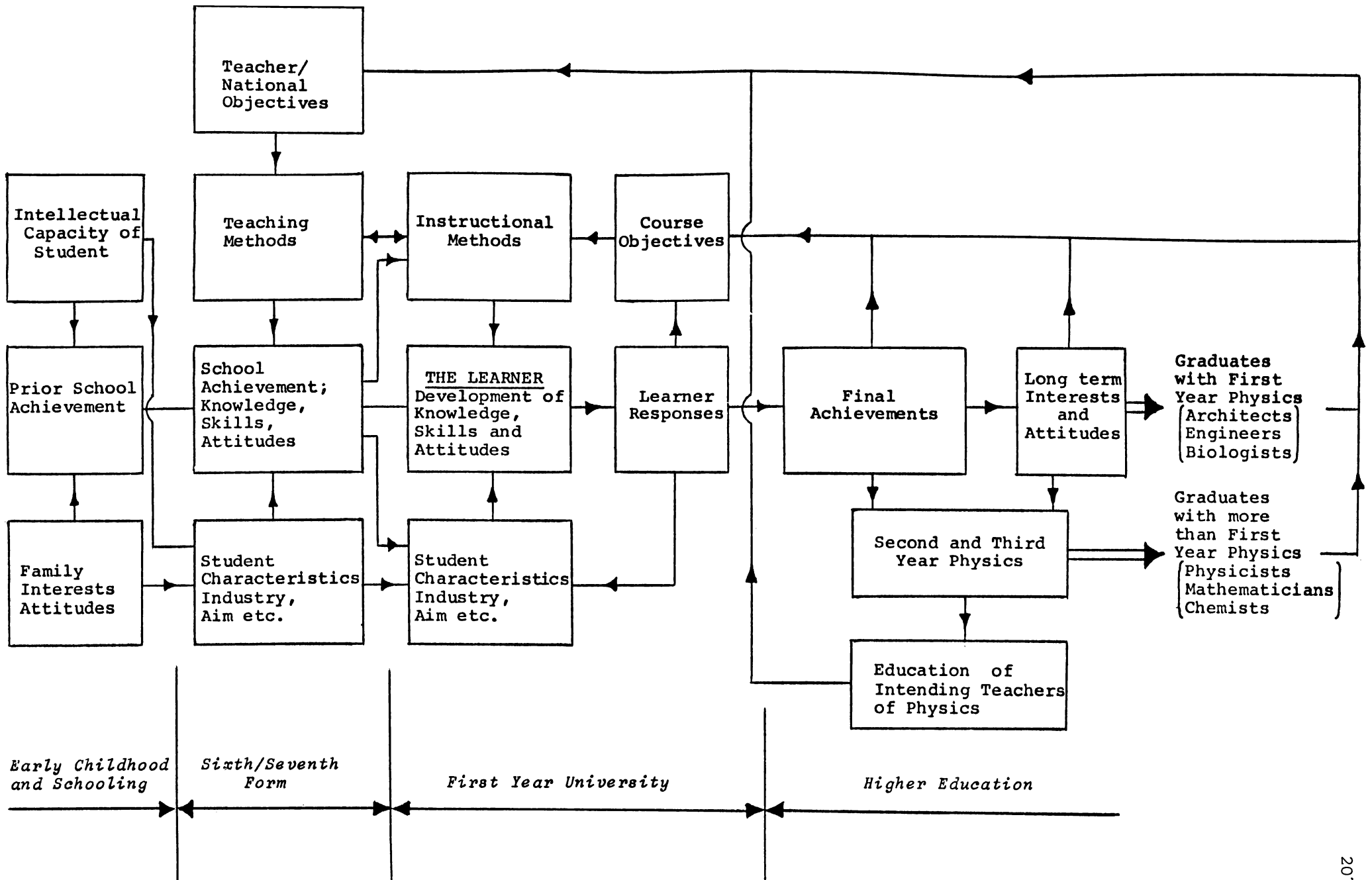


Fig 4.2 First year university physics in the wider context of physics education in New Zealand.

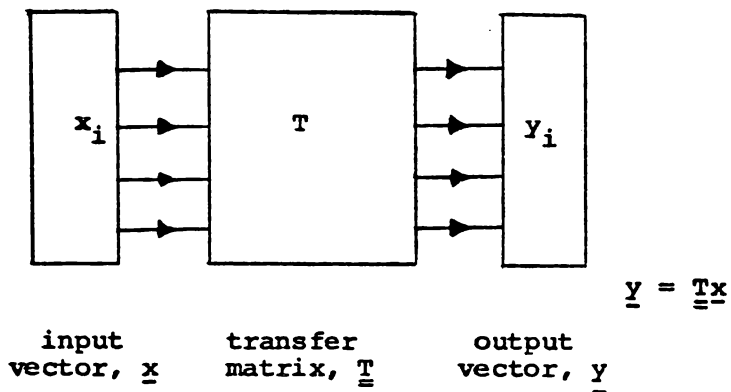


Fig 4.3 (a) Simple input output model (Model Type I)

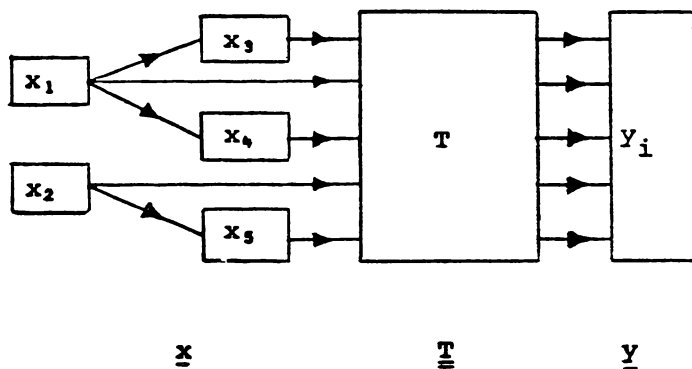


Fig 4.3 (b) Causal relations among input variables (Model Type II)

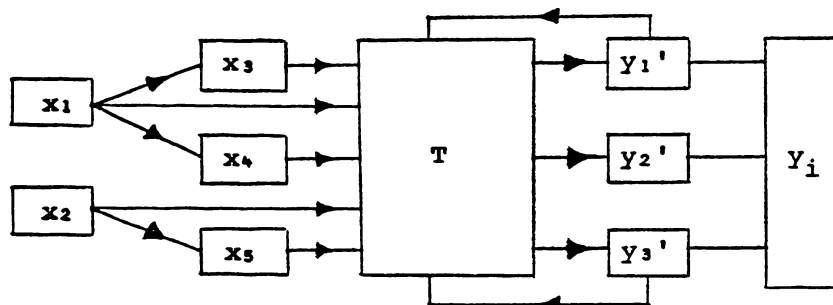


Fig 4.3 (c) Including feedback (Model Type III)

Table 5.1 The first year physics objectives at the University of WaikatoKnowledge and Comprehension of Physics

- I (A) Develop the ability to extract information (from scientific literature).
 (B) Develop the ability to interpret information, particularly to interpret mathematical and graphical descriptions.
 (C) Obtain an understanding of the facts, principles and theories of physics (as specified in the courses).

Application

- II (A) Develop the ability to apply theoretical results to relatively familiar situations.
 (B) Develop the ability to apply theory, and mathematically analyze, problem situations.
 (C) Develop the ability to apply theory to relatively unfamiliar problem situations.

Analysis

- III (A) Develop the ability to critically analyze problem situations and evaluate information.
 (B) Develop a critical attitude towards, and an ability to analyze, idealizations, approximations, and assumptions in physical theories.
 (C) Develop an understanding, and appreciation, of some of the major themes and unifying concepts of physics (including the relationship between fundamental principles and derived laws).

Processes of Experimental Inquiry I (Experimental Design)

- IV (A) Develop the ability to propose tentative ideas, and working hypotheses, and make logical and testable predictions.
 (B) Develop the ability to translate problems into experimental operations.
 (C) Develop the ability to make useful and reliable observations.

Processes of Experimental Inquiry II (Analysis and Conclusions)

- IV (D) Develop the ability to keep adequately detailed and organised records of experimental work and to be able to extract information from these.
 (E) Develop the ability to analyze experimental data mathematically and graphically
 (F) Develop the ability to draw valid conclusions from observations and data.

Orientation

- V (A) Develop an awareness of the function and limitation of physical laws.
 (B) Develop an awareness of the relationship between experimental observation and theory.
 (C) Develop an awareness of physics as a creative, open-ended and continuing development, both tentative and unfinished.

Attitude

- VI (A) Develop the attitude that mathematics is a useful, convenient and precise language, and that the use of mathematics in physics is a satisfying activity.
 (B) Develop the attitude that physics is an important, relevant and satisfying activity.
 (C) Develop a commitment to actively searching for a understanding of physical phenomena, and for the theories by which they may be explained.

Additional ObjectiveComprehension of Mathematical Physics

- VII (A) Develop the ability to manipulate, and use, the mathematical language of physics.

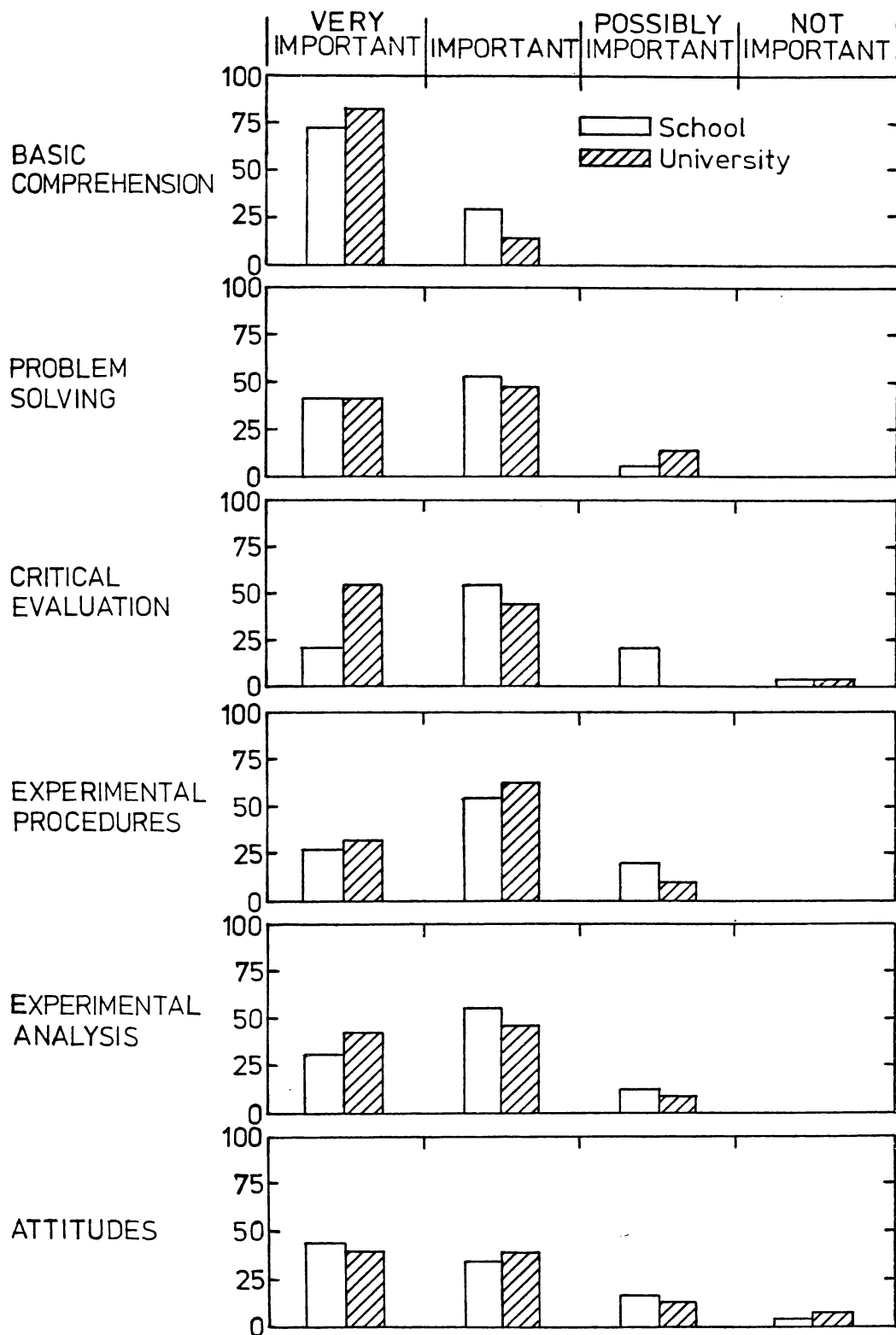


Fig 5.1 Teachers' views (1974) of the relative importance in the teaching of physics at school and university, of various physics education objectives.

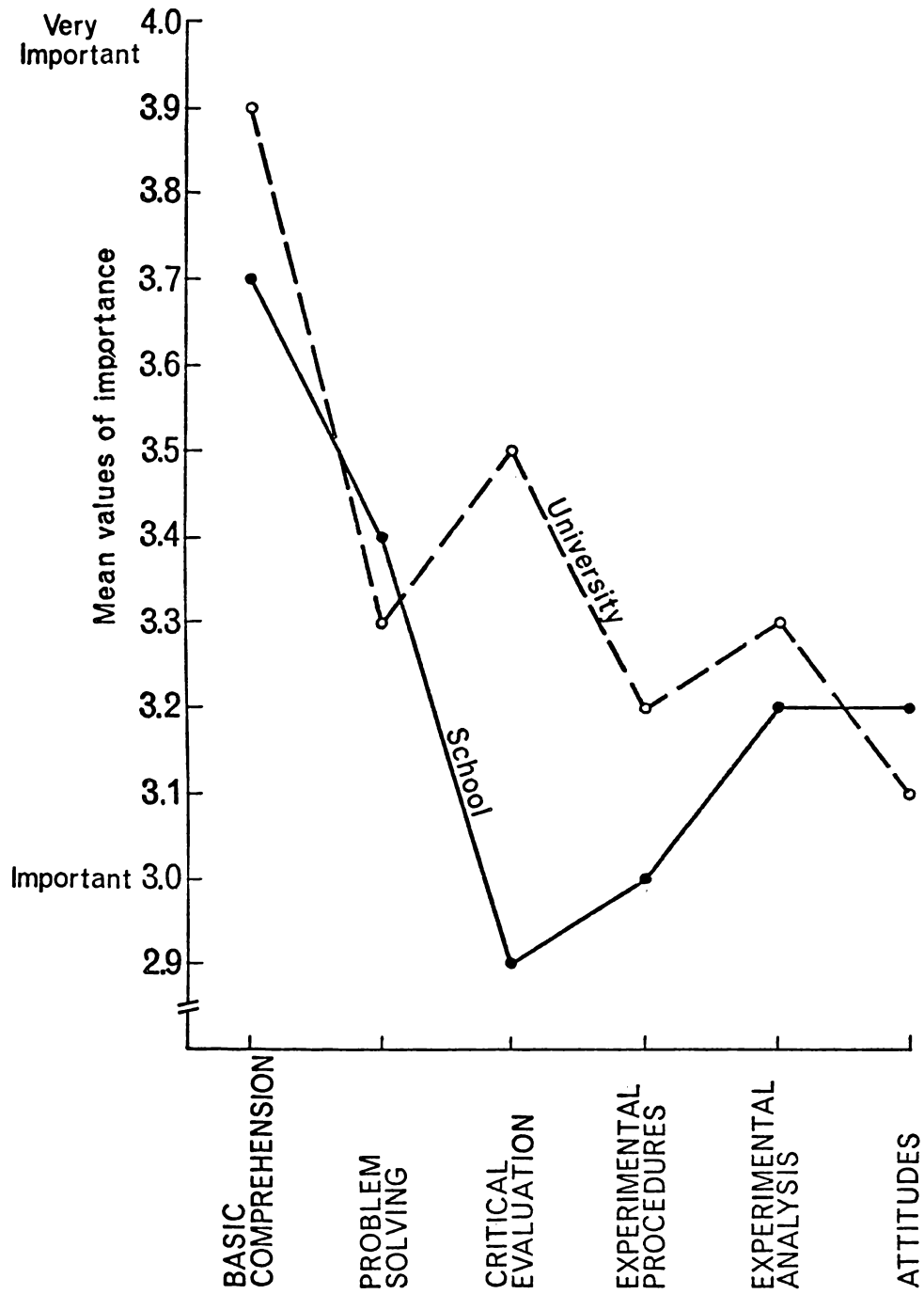


Fig 5.2 Mean value of teachers' views (1974)

Table 6.1 Perceived emphases, in the teaching activities of the first year courses, on the different objectives of the first year physics courses.

(double cross denotes major emphasis on a particular objective.)

	73.101		73.102	
	Lectures	Evaluation Sessions	Tutorials	Laboratory Work
I (A)	X X	X		X X
I (B)	X X	X		X X
I (C)	X X	X	X	X X
II (A)	X	X X	X X	X
II (B)	X	X X	X X	X
II (C)	X	X X	X X	X
III (A)			X X	X
III (B)	X			X X
III (C)	X X	X	X	
IV (A)				X X
IV (B)				X X
IV (C)				X X
IV (D)				X X
IV (E)			X	X X
IV (F)			X	X X
V (A)	X X		X	X
V (B)	X		X	X X
V (C)	X X		X	X X
VI (A)	X		X X	X X
VI (B)			X X	X X
VI (C)	X		X	X X
VII (A)	X X	X	X	X

Table 6.2 Possible variations in instructional models*

Time and Achievement	Nature of Objectives	Basis for Differentiation	Nature of Curve	Amount of Differentiation	Specificity of Instructional Objective
<p>1. Time units fixed, achievement varies among students</p> <p>2. Achievement units fixed, time required to achieve varies among students</p>	<p>1. All objectives apply to all students</p> <p>2. Some objectives apply to all students, others only apply to some students.</p> <p>3. Some objectives apply to some students, others to other students.</p>	<p>1. Normative referenced level of achievement</p> <p>2. Criteria referenced level of achievement</p>	<p>1. Normal curve assumed.</p> <p>2. Normal curve required.</p> <p>3. Normal curve neither assumed nor required.</p>	<p>1. Maximum including failure</p> <p>2. Slight (e.g. P-F; or A through C)</p>	<p>1. Very specific objectives with behavioural referents</p> <p>2. General objectives with no preidentified behavioural referents</p> <p>3. Vague or no instructional objective</p>

* Adapted from Mueller (1973)

Table 7.1 Student percentage response concerning the textbook in 1970 and 1971.

	Percentage Response	
	October 1970 (N = 70)	October 1971 (N = 80)
Do you consider the text Alonso & Finn*		
A. Very difficult	13	4
B. Difficult	57	19
C. Of a reasonable standard	32	74
D. Easy	0	3
How would you describe the text		
A. Very interesting and helpful	8	4
B. Informative and interesting	38	47
C. Informative but dull	46	44
D. Boring	8	8

*Fundamental University Physics in 1970, Physics in 1971
(Alonso & Finn, 1967 and Alonso & Finn, 1970 respectively)

Table 7.2 (a) Student percentage response concerning the text as lecture notes in 1970.

	Percentage Response	
	June 1970 (N = 80)	October 1970 (N = 70)
Do you consider the idea of using the text as lecture notes		
A. A good idea because you cannot concentrate on lectures while taking notes.	68	45
B. A poor idea because you learn best by copying	12	7
C. A poor idea because you find you do not concentrate in lectures	9	18
D. A poor idea because you do not find the text particularly easy to follow	11	28

Table 7.2 (b) Student percentage response concerning lecture notes 1971 and 1972.

	Percentage Response	
	October** 1971 (N = 80)	October 1972 (N = 85)
Do you consider the idea of writing lecture notes		
A. A poor idea because you cannot concentrate on lectures while taking notes.	18	8
B. A good idea because you learn best by copying out notes	18	17
C. A good idea because you find it helps you concentrate on lectures	44	21
D. A good idea because you do not find the textbook particularly easy to follow	17	5
E.*A good idea as it gives an alternative reference system	-	48

* 1972 only

** June responses were almost identical to October responses in both years.

Table 7.3 Student percentage response concerning the use of the textbook in the examination room 1970, 1971 and 1972.

	Percentage Response		
	October 1970 (N = 70)	October 1971 (N = 80)	October 1972 (N = 85)
Do you consider the idea of using your text in the examination room			
A. No advantage because you have to learn the work anyway	4	1	7
B. An advantage because you do not have to learn the details of formula	68	76	68
C. A doubtful privilege	29	23	24

Table 7.4 Student percentage response concerning the frequency of tutorials 1970, 1971 and 1972.

	Percentage Response		
	October 1970 (N = 70)	October 1971 (N = 80)	October 1972 (N = 85)
Do you consider tutorials should be held			
A. More frequently	42	6	12
B. As at present	44	87	76
C. Less frequently	4	4	10
D. Only in the third term	7	3	1

(Note: In 1970 one tutorial a fortnight was held.

In 1971 - 1972 one tutorial a week was held.)

Table 7.5 Changes in responses to an experiment from 1971 to 1972.

	Assigned Scale Value	Percentage Response	
		1971 (N = 80)	1972 (N = 85)
(a) What time did you spend on the experiment in post laboratory study			
A. 0 - 1 hour		0	3
B. 1 - 3 hours		0	10
C. 3 - 6 hours		19	14
D. 6 -12 hours		25	38
E. >12 hours		56	20
(b) How interesting did you find the experiment			
A. Extremely interesting	(5)	0	13
B. Very interesting	(4)	28	29
C. Interesting	(3)	33	25
D. Average	(2)	16	29
E. Dull	(1)	22	3
F. Boring	(0)	0	0
	Mean Scale Value	2.7	3.2
	Change in mean*	+0.5	
(c) How informative did you find the experiment			
A. Very informative	(5)	20	10
B. Informative	(4)	75	64
C. Learnt little new	(3)	5	26
D. Learnt nothing new	(2)	0	0
E. Waste of time	(1)	0	0
	Mean Scale Value	4.1	3.8
	Change in mean*	-0.4	

* For both (b) and (c) the change in mean value for an unaltered experiment from 1971 to 1972 (Expt 5) was -0.2, and the above changes are statistically significant $p < 0.05$.

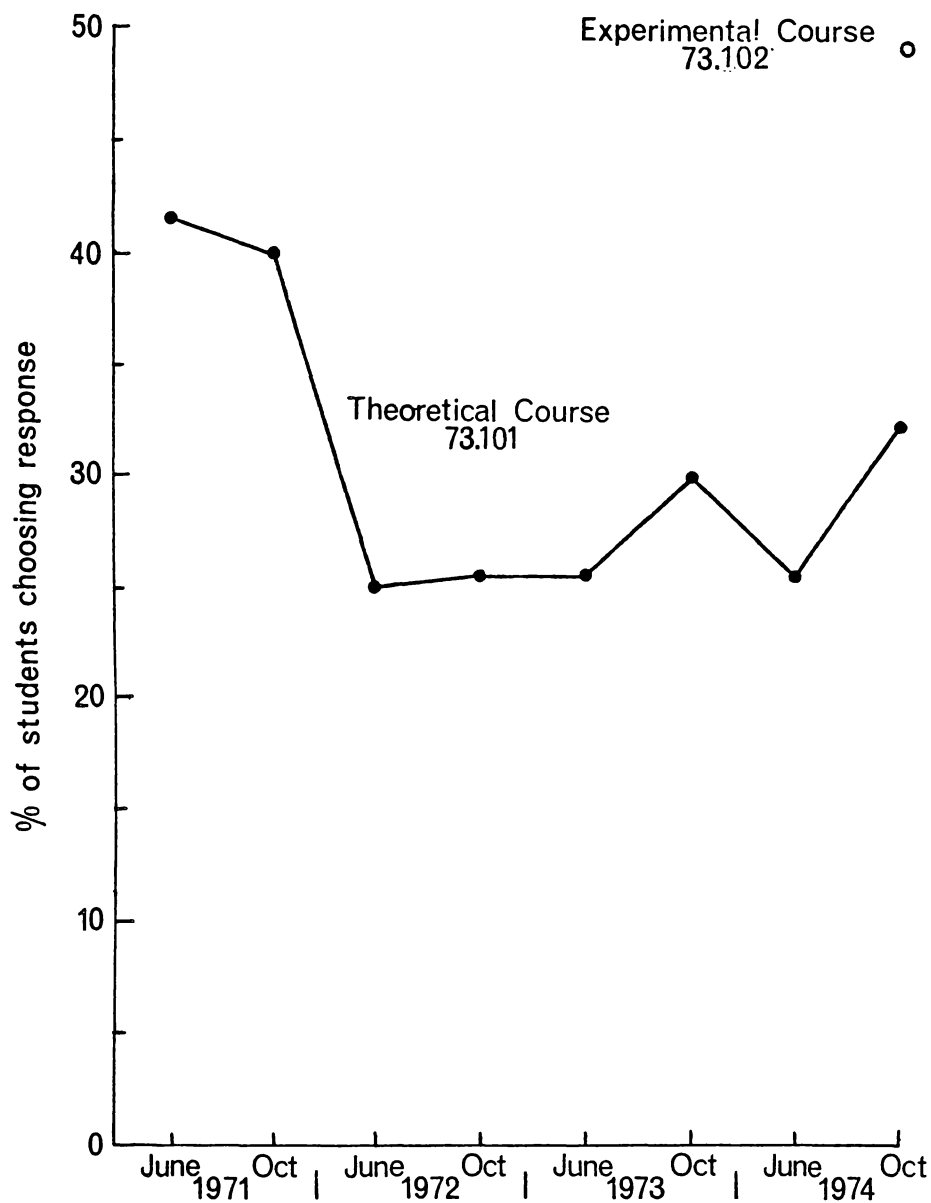


Fig 7.1 Percentage of students who considered the work load in the theoretical course (73.101) to be more than in any other non-physics course (1971 - 1974) (N = 70 - 90) (refer also Appendix G, Table G.1)

Note ○ indicates the percentage of students who considered the work load in the experimental course (73.102) to be more than in any other non-physics course (October 1974) (N = 80)

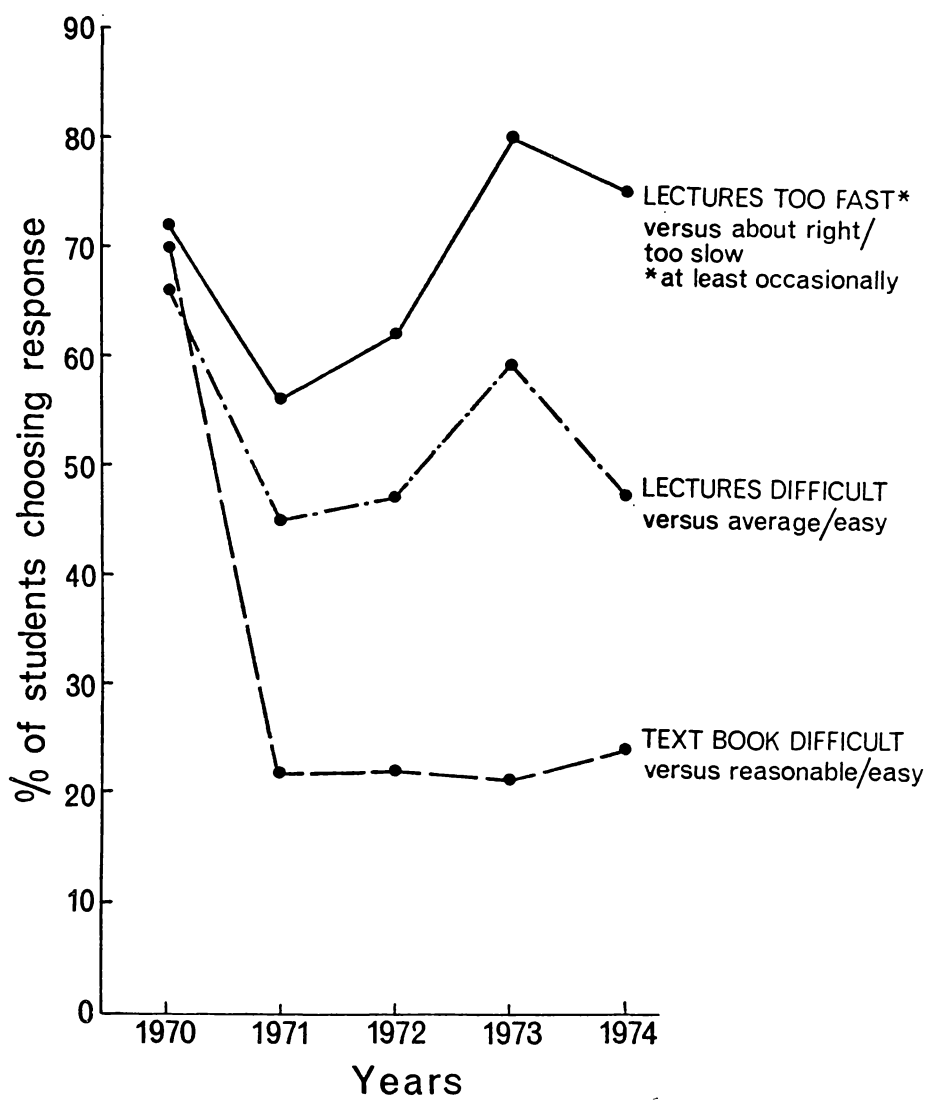


Fig 7.2 Course monitoring in the theoretical course (October)
(N = 70 - 90)

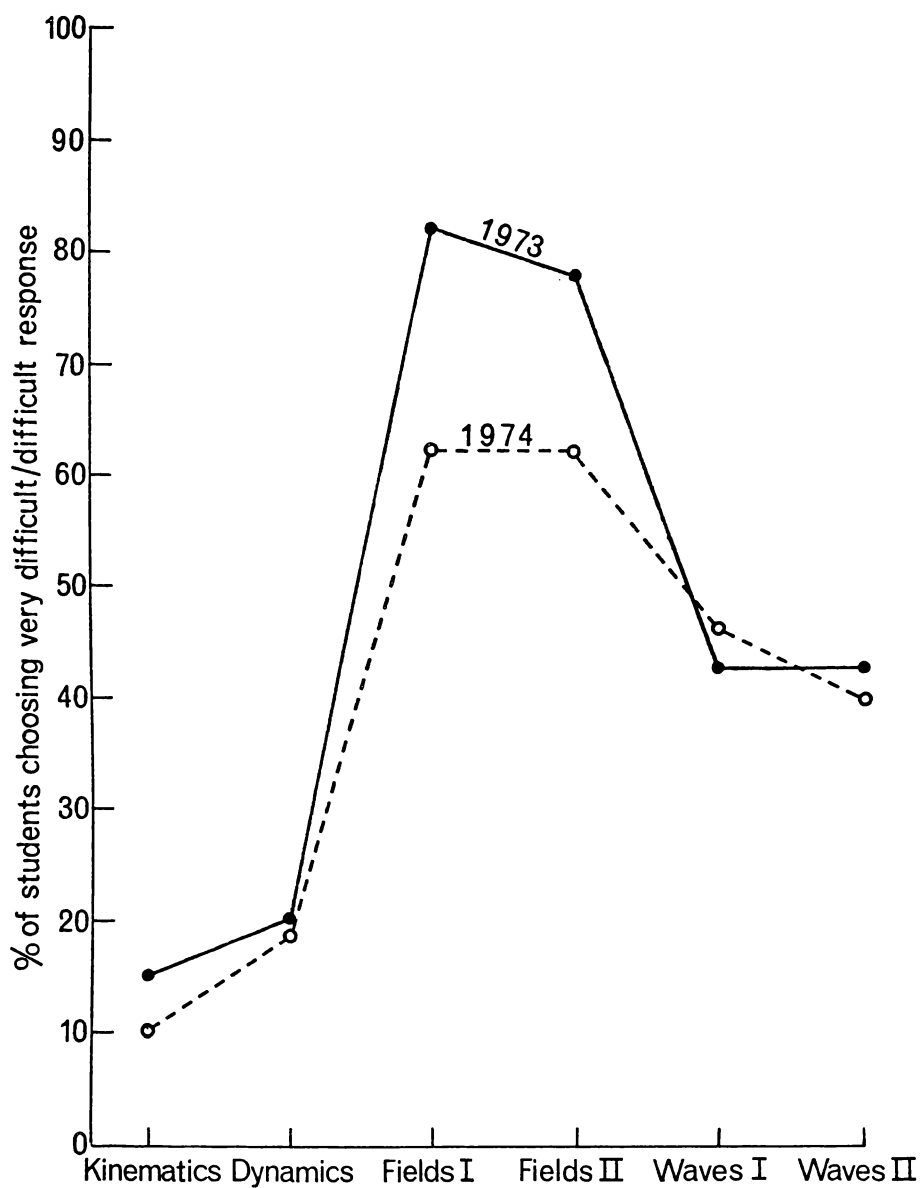


Fig 7.3 Student percentage response on the difficulty on average of the content of sections of the theoretical course. (Very difficult/difficult versus average/easy/very easy) (N =80 - 90)

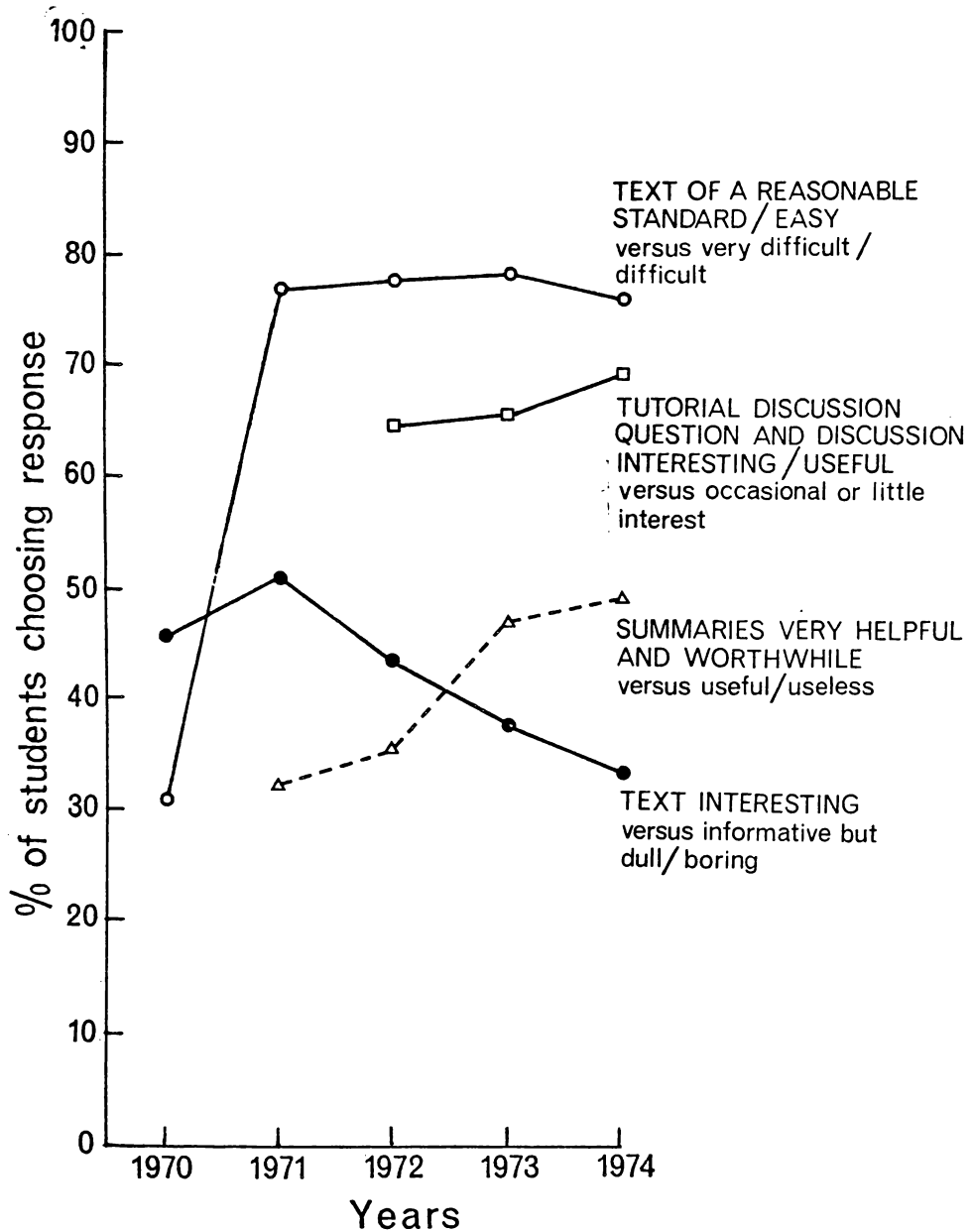


Fig 7.4 Monitoring student attitudes to aspects of the theoretical course (October) (N = 70 - 90)

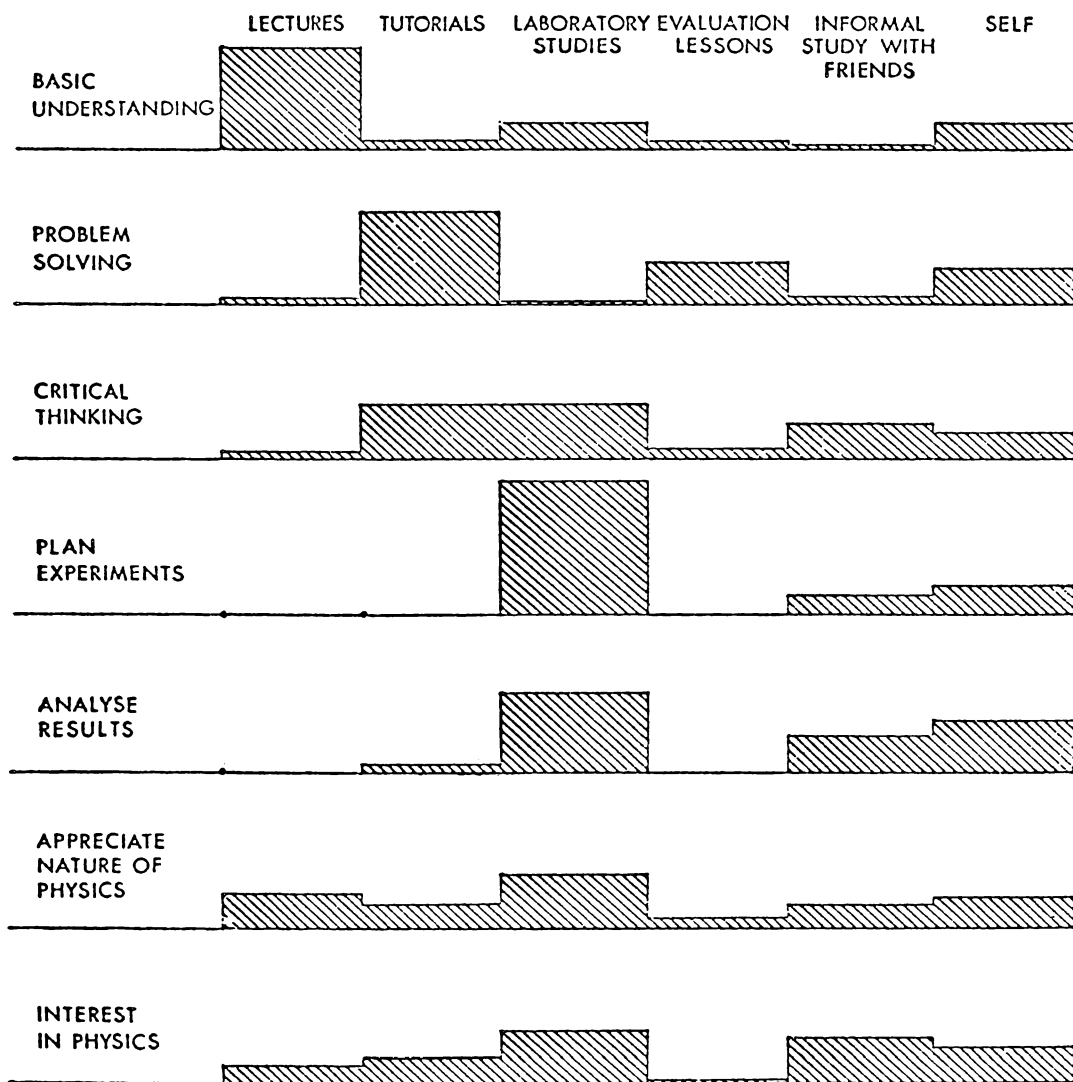


Fig 7.5 Student opinion on most effective learning environment in 1973 and 1974 (N = 170).

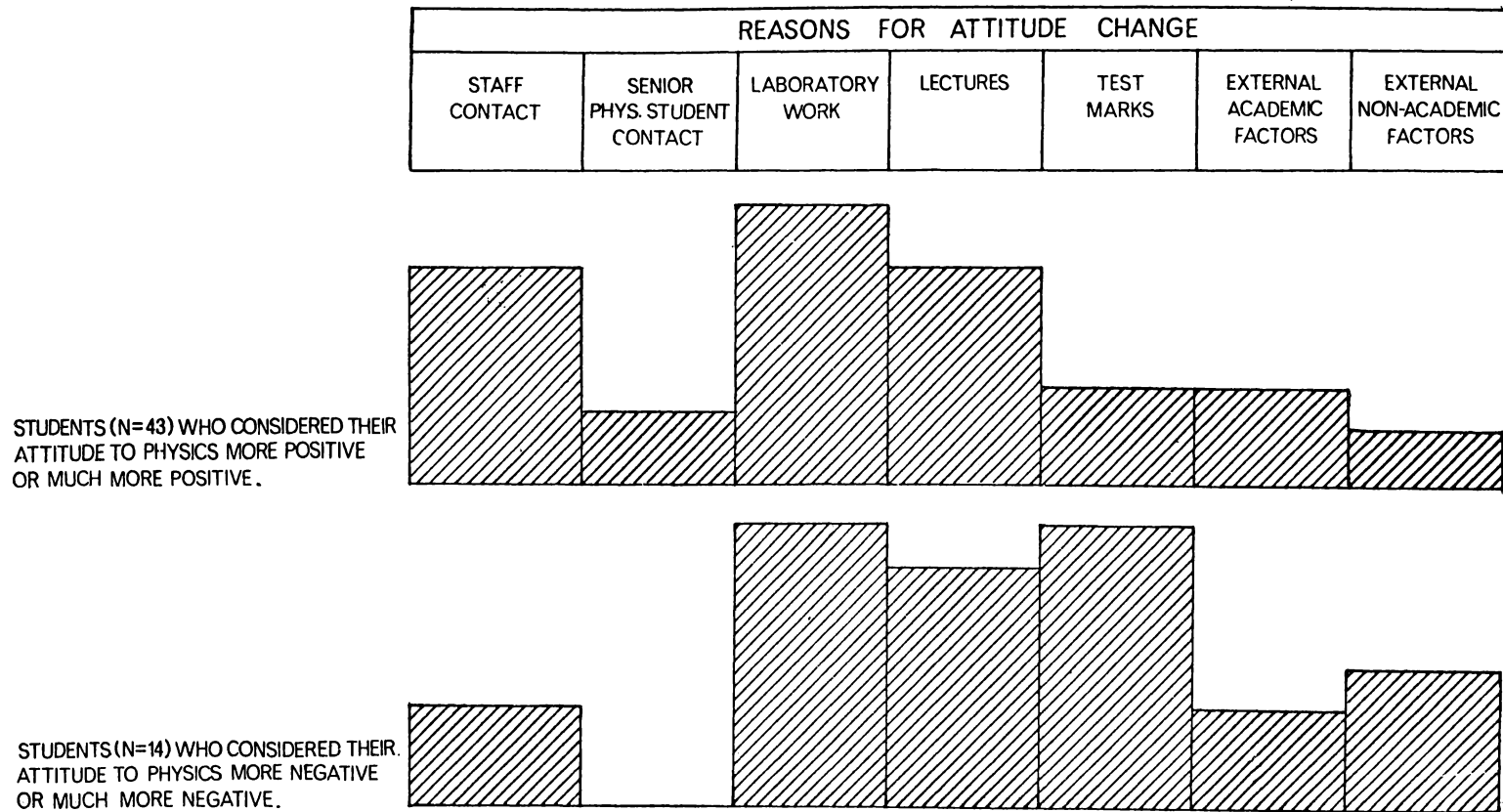


Fig 7.6 Relative student opinion on the reasons for their attitude change to Physics in 1972 (N=81)*

* 24 students considered their attitude to Physics had not changed

Table 7.6 Bipolar adjectives used to study attitudes towards experiments (7 point scale)

Enjoyable	-	Unenjoyable
Relevant	-	Irrelevant
Complicated	-	Straightforward
Clear instructions	-	Vague instructions
Unsatisfying	-	Satisfying
Important	-	Unimportant
Easy to write up	-	Difficult to write up
Open ended investigation	-	Closed investigation
Unpleasant	-	Pleasant
Worthless	-	Valuable
Lab work difficult	-	Lab work easy
Approximate results	-	Precise results
Interesting	-	Uninteresting
Useless	-	Useful
Many calculations	-	Few calculations
Adequate theory	-	Inadequate theory
Exciting	-	Dull
Uninformative	-	Informative
Short	-	Long
Theoretical	-	Technological
Mathematical	-	Non mathematical
Complex theory	-	Straightforward theory
Awful	-	Nice
Familiar theory	-	Unfamiliar theory
Varied	-	Monotonous
Adequate apparatus	-	Inadequate apparatus

The first adjective of each pair was the one given a high ranking for analysis purposes.

Table 7.7 Principal components analyses of semantic differential scales in 1973 (N = 265) and in 1974 (N = 240) with loadings ≥ 0.5 shown.

	I		II		III		IV		h ²		
	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	
Enjoyable	0.8	0.8							0.71	0.78	} Enjoyment
Pleasant	0.7	0.8							0.68	0.76	
Nice	0.8	0.8							0.72	0.74	
Exciting	0.8	0.9							0.71	0.80	
Varied	0.8	0.7							0.71	0.55	
Interesting	0.7	0.8							0.70	0.70	
Satisfying	0.6	0.7							0.62	0.63	
Informative	0.5		0.6	0.5					0.52	0.40	} Value
Relevant			0.8	0.8					0.65	0.66	
Important			0.8	0.8					0.72	0.65	
Valuable			0.7	0.8					0.60	0.64	
Useful			0.7	0.8					0.64	0.68	
Adequate Theory			0.5		0.5	0.5			0.49	0.30	} Laboratory Difficulty
Straightforward					0.7	0.8			0.57	0.60	
Lab work easy					0.7	0.7			0.61	0.60	
Clear Instructions					0.5	0.5			0.42	0.41	
Straightfwd Theory					0.6	0.7			0.56	0.58	
Write up easy					0.5	0.7			0.53	0.55	} Analysis Complexity
Few Calculations							0.7	0.8	0.58	0.61	
Non Mathematical							0.8	0.8	0.66	0.73	
Technological							0.6	0.5	0.44	0.29	} Low Communality Bipolar Adjectives
Short						0.5			0.38	0.38	
Precise									0.31	0.28	
Familiar					0.5	0.5			0.30	0.30	
Adequate									0.24	0.30	
Open					-0.6				0.44	0.14	

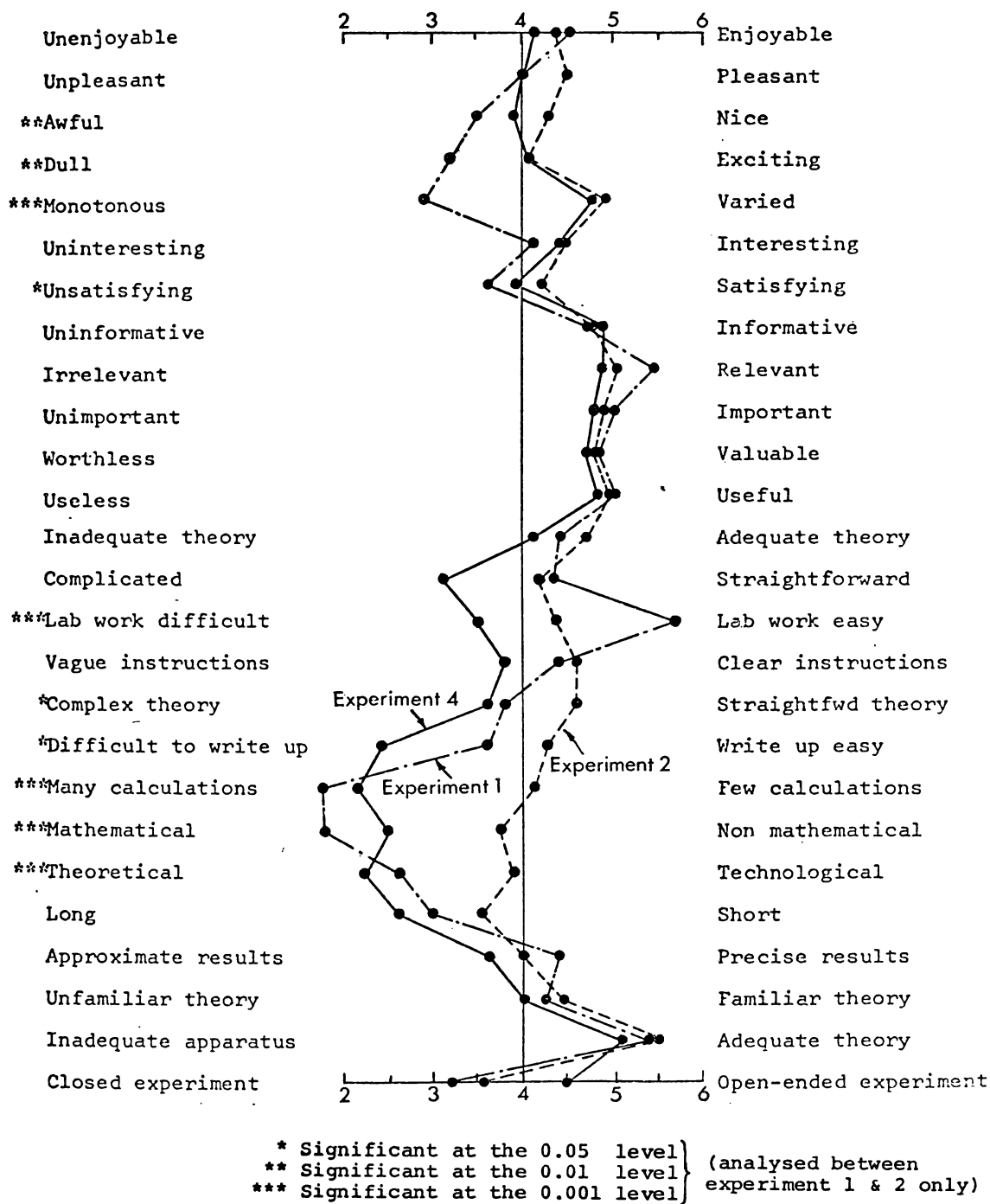


Fig 7.7 Experiment 1, 2 and 4 mean score profiles in 1973 (N = 53)

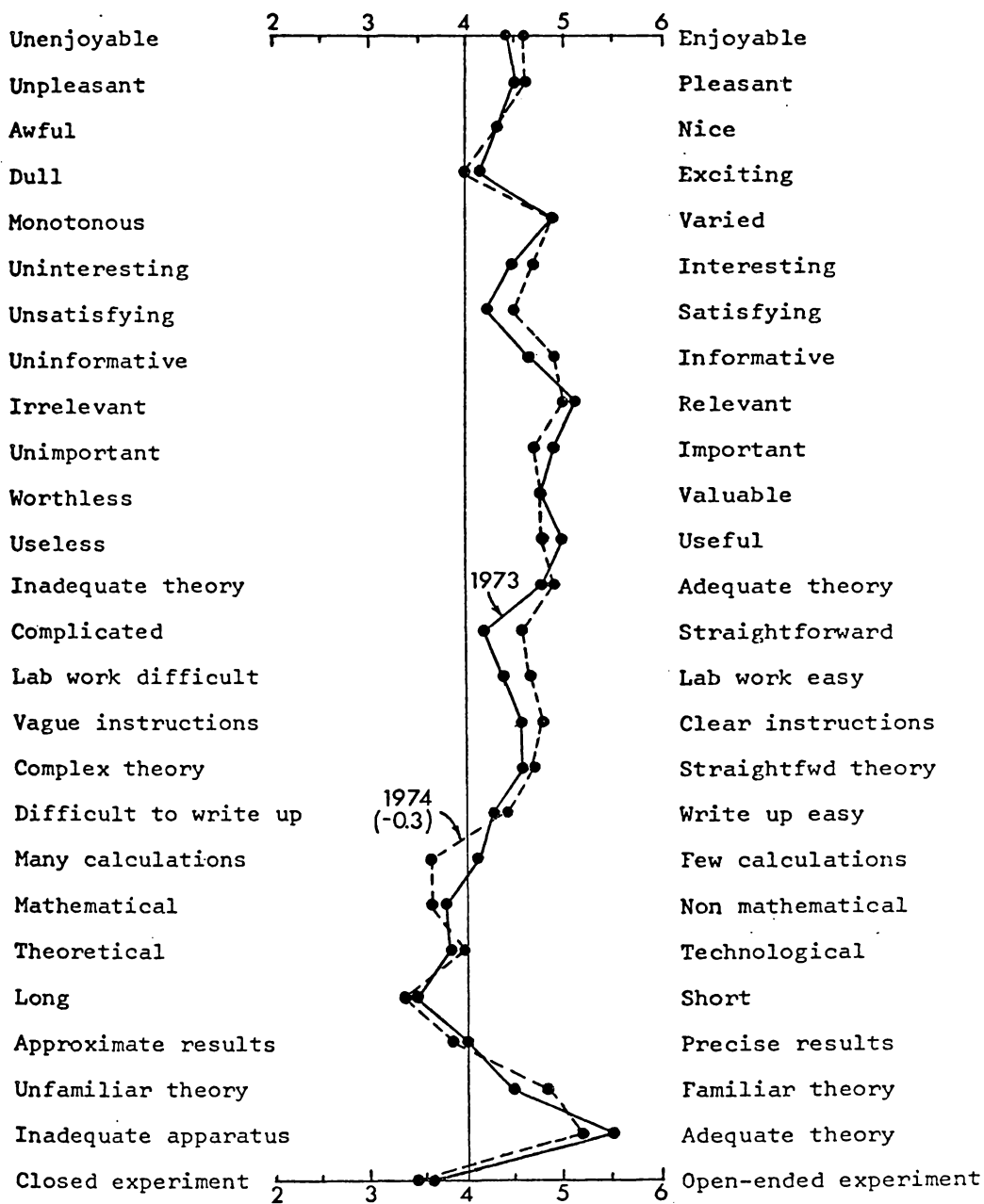


Fig 7.8 Experiment 2 profile in 1973 (N = 53) and in 1974 (N = 80)

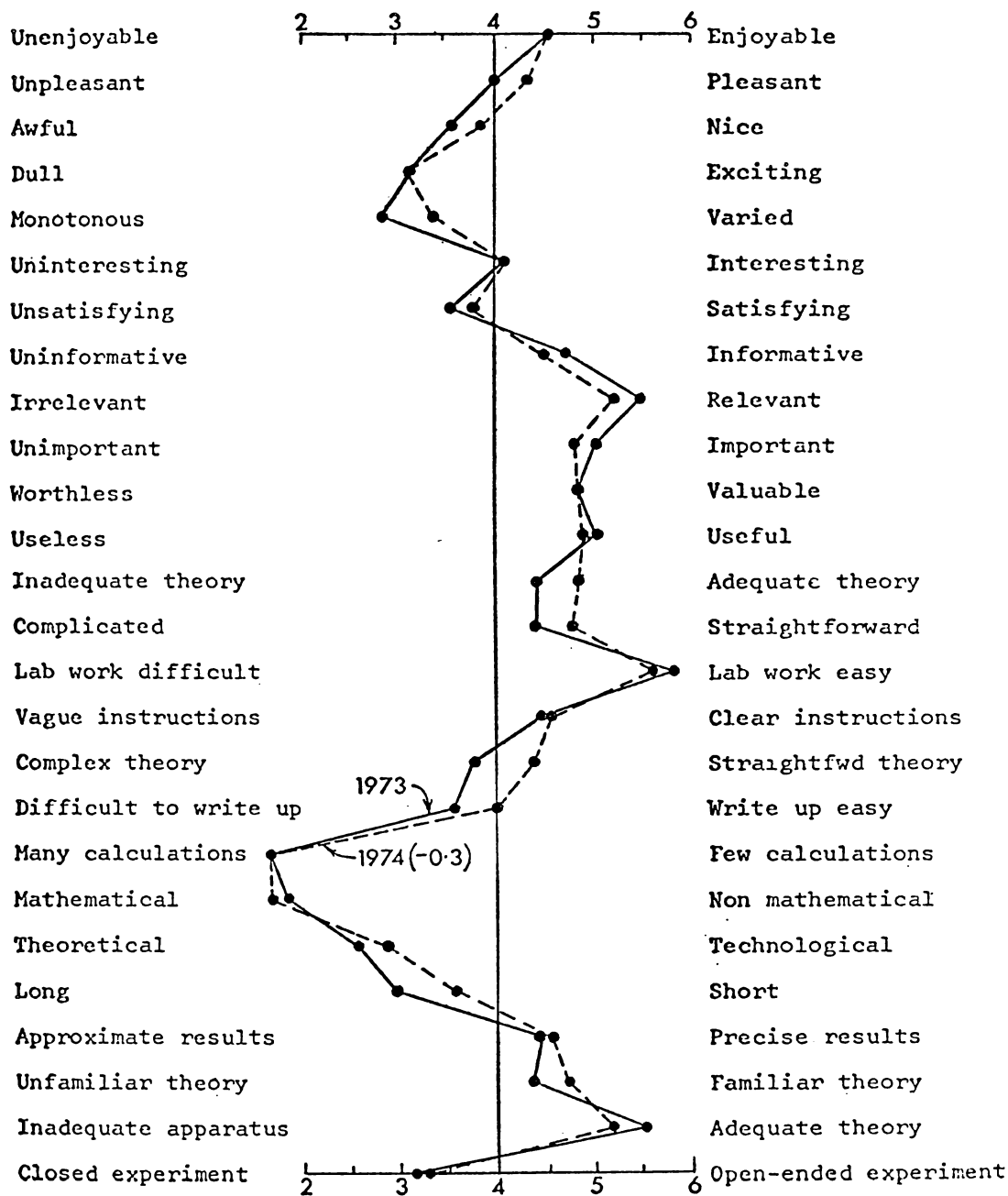


Fig 7.9 Experiment 1 profile in 1973 (N=53) and in 1974 (N=80)

Table 8.1 Principal components analysis of attitudes to Physics of seventh form, and first year university, physics students (N = 658), with factor loadings ≥ 0.5 shown.

Objective/ Question	Factor I	Factor II	Factor III	Factor IV	100h ²
V(C) 3				0.5	28
8				(0.2)	19
13				(0.3)	26
18				(0.4)	34
22				0.5	27
26				0.6	44
30				(0.4)	27
33			0.5	0.6	42
[35]				(0.0)	27
VI(A) [2]					11
5		0.7			53
7		0.7			52
11		0.7			58
16		0.7			55
19		0.7			53
24		0.5			29
27		0.6			45
31		0.7			61
VI(B) 4	0.7				54
9	0.7				44
12	0.7				57
15	0.7				52
20	0.6				42
23	0.6				47
28	0.7				62
34	0.6				34
[36]	0.7				46
VI(C) [1]	(0.3)		(0.1)		11
6	0.5		(0.4)		42
10	(0.3)		0.7		52
14	(0.2)		0.5		27
17	0.6		(-0.2)		39
21	(0.4)		0.5		43
25	0.6		(0.2)		45
29	(0.2)		0.5		32
32	0.5		(0.2)		29

Table 8.3 Principal components analyses of objective scores - output 1973 (N = 92) and 1974 (N = 74)
with factor loadings >0.5 shown.

Objective	Question Type	Factor								Percentage Mean		Percentage Standard Deviation		100h ²	
		I		II		III		IV		1973	1974	1973	1974	1973	1974
		1973	1974	1973	1974	1973	1974	1973	1974						
I (B)	M.C.	0.5	0.5	0.5						55	56	26	34	37	44
I (C)	M.C.	0.5	0.7							43	50	25	26	42	59
II (C)	M.C.	0.6	0.7							32	41	21	21	49	54
III (A)	M.C.	(0.3)	0.7			0.5				26	26	22	23	34	48
III (B)	M.C.	0.6	0.7							50	49	26	24	48	59
III (C)	M.C.	0.7	(0.3)					0.5		51	54	24	20	53	34
I (A)	M.C.			0.5	0.7					66	74	25	21	42	61
II (A)	M.C.			0.6	0.6					62	56	28	30	56	61
II (B)	M.C.		0.6	0.5	0.5	0.6				46	52	26	29	70	66
IV (E)	M.C.	0.5		0.5	0.5					57	59	28	30	52	55
VI (A)	Likert			0.7	0.7					71	70	14	14	58	57
VII (A)	M.C.			0.9	0.6					68	62	27	27	75	53
IV (A)	S.Q.					0.7	0.6			48	45	20	21	61	54
IV (B)	S.Q.					0.5	0.7			48	41	26	24	55	64
IV (C)	S.Q.					0.7	0.7			47	48	16	17	46	56
IV (D)	S.Q.					0.6	0.6			65	69	16	21	36	40
IV (F)	S.Q.					0.7	0.7			39	39	22	18	54	58
V (A/B)	S.Q./M.C.					0.6	(0.3)			63	52	18	17	46	20
V (C)	Likert							0.7	0.6	75	81	9	8	62	50
VI (B)	Likert							0.9	0.8	65	69	13	13	74	71
VI (C)	Likert							0.9	0.9	65	67	11	12	74	81

Table 8.4 Principal components analyses of objective scores - input 1973 (N = 101) and 1974 (N = 87)
factor loadings >0.5 shown.

Objective	Question Type	Factor								Percentage Mean		Percentage Standard Deviation		100h ²	
		I		II		III		IV		1973	1974	1973	1974	1973	1974
		1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
I (B) / (C)	M.C.	0.6	0.5							41	41	25	27	61	28
I (B)	M.C.	0.5	0.8							45	54	28	25	44	67
I (C)	M.C.	(0.4)	(0.2)		0.5					38	54	23	28	56	42
III (A)	M.C.	(0.3)	0.5	0.5						35	41	25	30	46	45
III (B)	M.C.	(0.4)	0.6							27	32	25	27	33	42
III (C)	M.C.	0.5	(0.2)			0.7				43	50	25	27	39	48
IV (E) *	M.C.	0.5	0.7							37	54	28	31	36	48
V (A/B) *	M.C.	0.6	0.6							49	58	25	18	50	44
VI (A) *	Likert	(0.4)	0.6							73	73	13	13	47	60
II (A)	M.C.		0.5	0.7	(0.2)					48	50	30	28	45	43
II (B)	M.C.			0.6	0.6					35	33	27	25	47	55
II (C) *	M.C.			0.5	0.6					28	33	25	26	27	42
IV (A) (i)	S.Q.					0.7	0.7			35	45	25	21	54	55
IV (A) (ii)	S.Q.					0.7	0.8			49	48	31	23	68	75
IV (B)	S.Q.					0.7	0.6			39	51	29	29	67	55
IV (C)	M.C.	0.6				(0.0)	0.6			33	41	23	25	36	52
IV (F)	S.Q.					0.8	0.6			45	50	32	29	71	41
V (C)	Likert							0.7	0.6	79	81	8	8	51	47
VI (B)	Likert							0.9	0.8	72	74	12	11	82	67
VI (C)	Likert							0.9	0.8	70	72	11	10	75	72

* Loading on a different factor from output tests

Table 8.5 Principal components analysis of objective scores
- 7 form output tests - October 1974 (N = 213) with
factor loadings ≥ 0.5 shown.

Objective	Question Type	Factor			Percentage Mean	Percentage Standard Deviation	100h ²
		I	II	III			
I (B/C)	M.C.	0.6			46	24	37
I (B)	M.C.	0.5			49	28	41
I (C)	M.C.	0.5			52	28	34
III (A)	M.C.	0.5			31	26	35
III (B)	M.C.	0.5			32	26	37
III (C)	M.C.	0.5			49	25	25
IV (E)	M.C.	0.6			54	34	42
V (A/B)	M.C.	0.5			52	22	25
VI (A)	Likert	(0.3)		0.5	68	15	32
II (A)	M.C.	0.6			48	28	41
II (B)	M.C.	0.7			39	26	43
II (C)	M.C.	0.6			33	25	33
IV (A) (i)	S.Q.		0.8		51	20	70
IV (A) (ii)	S.Q.		0.8		52	22	70
IV (B)	S.Q.		0.7		42	28	59
IV (C)	M.C.		(0.4)		38	26	16
IV (F)	S.Q.		0.6		45	32	44
V (C)	Likert			0.7	77	9	44
VI (B)	Likert			0.9	65	15	73
VI (C)	Likert			0.9	64	13	71

Table 9.1 Means of Attitude Scores in 1973 (N=92) and in 1974 (N=78)

Objective	Attitude Question	1973			1974		
		Input	Output	Diff (Out-In)	Input	Output	Diff (Out-In)
VC	3	4.14	3.74	-0.40	3.97	3.98	+0.01
	8	3.53	3.83	+0.30	3.98	4.10	+0.12
	13	3.96	3.95	-0.01	4.10	3.88	-0.22
	18	4.49	4.39	-0.10	4.50	4.43	-0.07
	22	3.93	3.88	-0.05	3.97	3.89	-0.08
	26	4.41	4.35	-0.06	4.41	4.51	+0.10
	30	3.38	3.39	+0.01	3.47	3.40	-0.07
	33	3.83	3.78	-0.05	3.91	4.00	+0.09
VC Subtotal		31.68	31.33	-0.35	32.33	32.22	-0.11
VIA	5	3.25	3.17	-0.08	3.30	3.16	-0.14
	7	3.61	3.48	-0.13	3.57	3.42	-0.15
	11	3.84	3.46	-0.38	3.72	3.25	-0.47
	16	3.97	3.75	-0.22	4.03	3.72	-0.31
	19	3.49	3.34	-0.15	3.53	3.50	-0.03
	24	3.64	3.75	+0.11	3.57	3.64	+0.07
	27	4.19	3.96	-0.23	4.03	3.91	-0.12
	31	3.75	3.41	-0.34	3.55	3.37	-0.18
VIA Subtotal		29.75	28.35	-1.40	29.33	27.99	-1.34
VB	4	3.51	3.27	-0.24	3.62	3.38	-0.24
	9	3.28	2.96	-0.32	3.47	3.15	-0.32
	12	3.29	2.78	-0.51*	3.47	2.91	-0.56*
	15	4.04	3.73	-0.31	4.29	3.86	-0.43
	20	3.44	3.25	-0.19	3.52	3.57	+0.05
	23	4.03	3.77	-0.26	4.11	3.66	-0.45
	28	3.56	3.06	-0.50*	3.70	3.25	-0.45*
	34	3.83	3.36	-0.47*	3.85	3.29	-0.56*
VB Subtotal		29.00	26.21	-2.79*	30.06	27.10	-2.96*
VIC	6	2.83	2.52	-0.31	3.14	2.86	-0.28
	10	3.85	3.98	+0.13	4.04	3.94	-0.10
	14	4.21	4.02	-0.19	4.22	3.95	-0.27
	17	3.52	3.18	-0.34	3.61	3.24	-0.37
	21	3.87	3.85	-0.02	4.06	3.96	-0.10
	25	2.51	2.20	-0.31	2.60	2.28	-0.32
	29	3.38	3.54	+0.16	3.60	3.46	-0.14
	32	3.97	3.24	-0.73*	3.83	3.03	-0.80*
VIC Subtotal		28.15	26.55	-1.60	29.11	26.73	-2.38*

* Significant difference ($p < 0.01$)

Table 9.2 Explicit attitude change to physics as a subject*

	Percentage Responses		
	1972 (N = 81)	1973 (N = 91)	1974 (N = 78)
Much more positive	3	8	5
More positive	49	38	44
Remained the same	30	38	35
More negative	16	14	13
Much more negative	1	2	2

* See Appendix L.6, Part C, Question 1.

Table 9.3 Attitude objective mean scores for input-output 1974 compared with an October 1974 sample in schools.

Objective	Attitude Mean Scores		
	Input Scores March 1974 (N=78) (Excludes 9 dropouts)	Output Scores October 1974 (N = 78)	Av 7 form Scores October 1974 (N = 214)
V(C)	32.3	32.2	30.8
VI(A)	29.3	28.0	27.1
VI(B)	30.1	27.1	25.9
VI(C)	29.1	26.7	25.4

Table 9.4 Correlation of student's stated attitude change with measured attitude change using Likert scales.

		Stated Attitude Change	
		1973 (N = 92)	1974 (N = 78)
Measured Attitude Change for Each Objective	V(C)	0.19	-0.04
	VI(A)	0.06	0.01
	VI(B)	0.32*	0.46*
	VI(C)	0.39	0.19

* Significant correlations at $p < 0.01$ level.

Table 9.5 Measured output attitude and student intention for the following year in 1973 (N = 92) and 1974 (N = 78).

	Percentage of Students in Each Group		Attitude Mean Scores							
			V(C)		VI(A)		VI(B)		VI(C)	
	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
More Physics	38	32	31.4	33.1	29.1	28.7	27.2	29.9	28.0	29.6
Specialists	23	35	33.2	32.0	30.1	29.4	28.1	27.6	26.2	26.1
No More Physics	39	33	30.0	31.5	26.3	25.8	24.0	23.8	25.2	24.5

Table 9.6 Retention rates (of students who had a 7 form year)
from first year physics to physics majors.

	Percentage of those enrolled in the course at the end of the first year		
	Waikato 1973	Waikato 1974	National Av*
Actually enrolled in the next year for sufficient physics courses to major in physics	15%	22%	10%
Actually enrolled in their final year in physics	14%	14%	5%

* Assessed from University statistics 1971-1974.

Table 9.7 Grouping of course objectives as determined experimentally from statistical analyses of output results (Table 8.3)

	Objective Number	Subjective Assessment Category	Course in which Objective Emphasized
A. Understandings of Theoretical Physics			
(i) Develop the ability to interpret information, particularly to interpret mathematical and graphical descriptions.	I (B)	P1*	101/102
(ii) Obtain an understanding of the facts, principles and theories of physics (as specified in the courses).	I (C)	P1	101/102
(iii) Develop an appreciation of some of the major themes and unifying concepts of physics (including the relationship between fundamental and derived laws).	III (C)	P3	101
(iv) Develop a critical attitude towards, and an ability to analyze, idealizations, approximations and assumptions in physical theories.	III (B)	P3	102
(v) Develop the ability to critically analyze problem situations and evaluate information.	III (A)	P3	101
(vi) Develop the ability to apply theory to relatively unfamiliar problem situations.	II (C)		101
B. Skills of Applied Physics			
(i) Develop the ability to extract information (from scientific literature).	I (A)		101/102
(ii) Develop the ability to manipulate and use the mathematical language of physics.	VII (A)	P2	101
(iii) Develop the ability to apply theoretical results to relatively familiar situations.	II (A)	P2	101
(iv) Develop the ability to apply theory, and mathematically analyze, problem situations.	II (B)	P2	101
(v) Develop the ability to analyze experimental data mathematically and graphically.	IV (E)		102
(vi) Develop the attitude that mathematics is a useful, convenient and precise language, and that the use of mathematics in physics is a satisfying activity.	VI (A)		101/102
C. Skills of Experimental Physics			
(i) Develop the ability to propose tentative ideas and working hypotheses, and make logical and testable predictions.	IV (A)	P4	102
(ii) Develop the ability to translate problems into experimental operations.	IV (B)	P4	102
(iii) Develop the ability to make useful and reliable observations.	IV (C)	P4	102
(iv) Develop the ability to keep adequately detailed and organized records of experimental work and to be able to extract information from these.	IV (D)	P5	102
(v) Develop the ability to draw valid conclusions from observations and data.	IV (F)	P5	102
(vi) Develop an awareness of the function and limitation of physical laws, and the relationship between experimental observation and theory.	V (A/B)		101/102
D. Appreciation of Physics			
(i) Develop an awareness of physics as a creative open ended and continuing development, both tentative and unfinished.	V (C)	P6	101/102
(ii) Develop the attitude that physics is an important, relevant and satisfying activity.	VI (B)	P6	102
(iii) Develop a commitment to actively searching for an understanding of physical phenomena and for theories by which they may be explained.	VI (C)	P6	102

* Refer section 5.4

Table 10.1 Correlations of Bursary Physics total mark with output results (excluding dropouts) in 1973 (N = 92) and in 1974 (N = 74).

		Bursary Physics Total	
		1973	1974
(i)	Final theoretical paper	0.78	0.77
(ii)	Final total theoretical course mark	0.83	0.80
(iii)	Final experimental paper	0.78	0.80
(iv)	Final total experimental course mark	0.77	0.78
(v)	University Grand Physics Total*	0.82	0.82

* (v) = (ii) + (iv)

Table 10.2 Input variables.

<u>Variable</u>	<u>Measure</u>	<u>Symbol</u>
<u>Background abilities</u>		
1. Spatial aptitude	Spatial relations test	} APT
2. Abstract reasoning aptitude	Abstract reasoning test	
3. Mathematical ability	School certificate mathematics	SCMATH
4. Literary ability	School certificate english	SCENG
5. Prior physics achievement	Bursary physics total	BPHS
6. Prior mathematical achievement	Bursary mathematics total	BMAT
<u>Background factors</u>		
1. Academic industry	Teacher's assessment	} MOTIV
2. Stability	Teacher's assessment	
3. Aim 73.101	Questionnaire (Appendix K)	} INAIM
4. Aim 73.102	Questionnaire (Appendix K)	
5. Parent education	Questionnaire (Appendix K)	PARENT
6. Sex	Female 1/Male 0	SEX
<u>Physics input attainment</u>		
1. Input theoretical factor	Input test subtotal	INPUT THEORETICAL
2. Input applied factor	Input test subtotal	INPUT APPLIED
3. Input experimental factor	Input test subtotal	INPUT EXPERIMENTAL
4. Input attitudinal factor	Input test subtotal	INPUT ATTITUDINAL
5. Bursary free format total	Examination subtotal	BURSARY FREE FORMAT
6. Bursary multiple choice total	Examination subtotal	BURSARY M.C.
<u>Physics content achievement (objectives I - III)</u>		
1. Input test mechanics score	Input test subtotal	INPUT MECHANICS
2. Input test fields total	Input test subtotal	INPUT FIELDS
3. Input test waves total	Input test subtotal	INPUT WAVES
4. Bursary mechanics total	Examination subtotal	BURSARY MECHANICS
5. Bursary fields total	Examination subtotal	BURSARY FIELDS
6. Bursary waves total	Examination subtotal	BURSARY WAVES

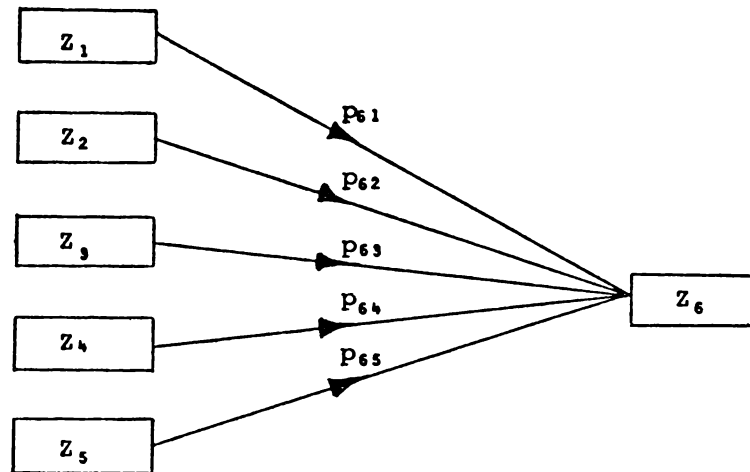


Fig 10.1 Hypothetical example where Z_6 is dependent on Z_1 to Z_5

Table 10.3 Comparison of beta weights and regression factor structure coefficients.

Variable	Normalized Beta Weights		Variable	Regression Factor Structure Coefficients	
	1973 (N=92)	1974 (N=74)		1973 (N=92)	1974 (N=74)
1	0.26*	0.09	1	0.73**	0.70**
2	0.08	0.16	2	0.27	0.53**
3	0.23	0.03	3	0.63**	0.50**
4	-0.02	0.05	4	-0.04	-0.01
5	-0.03	-0.08	5	0.05	-0.20
6	0.36*	0.50*	6	0.88**	0.90**
7	0.11	0.15*	7	0.47**	0.44**
Multiple R	0.74	0.73	Multiple R	0.74	0.73

* Significant Beta weights in the regression

** Significant simple correlations between variable and criterion

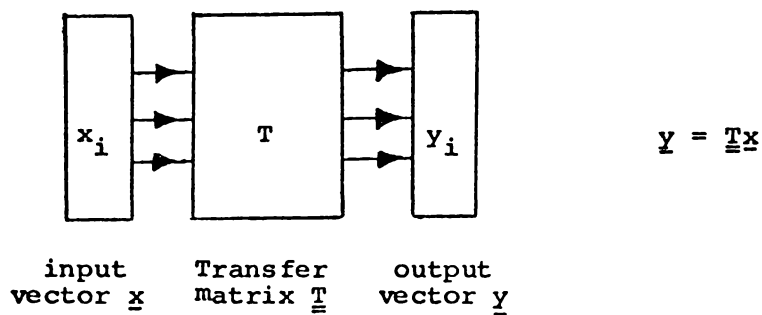


Fig 10.2(a) Simple input-output model (Type I)

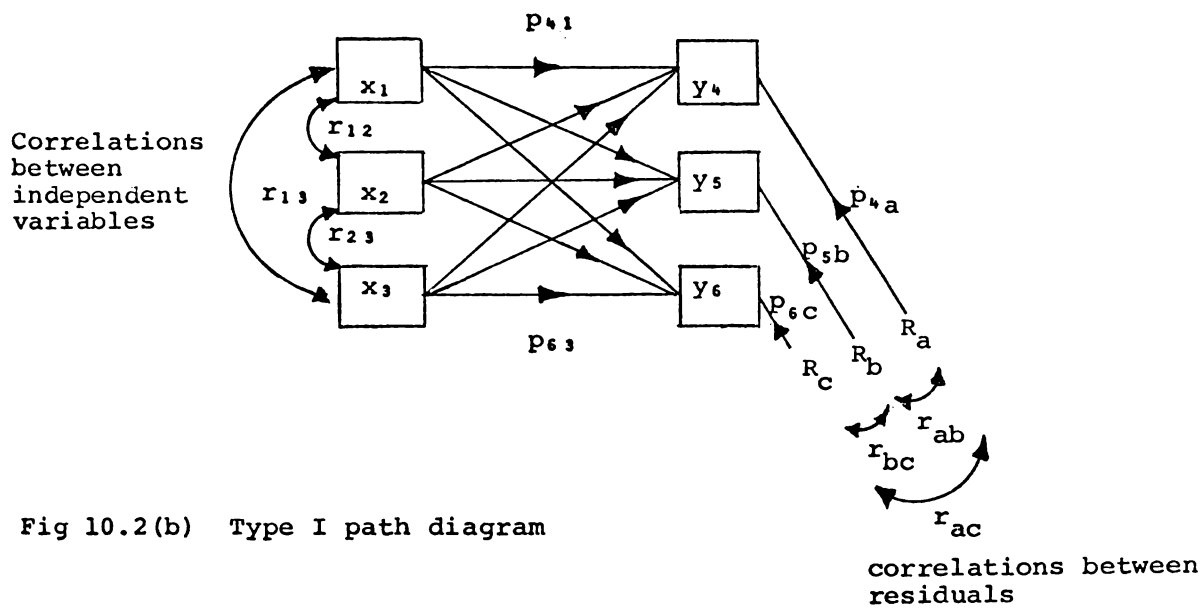


Fig 10.2(b) Type I path diagram

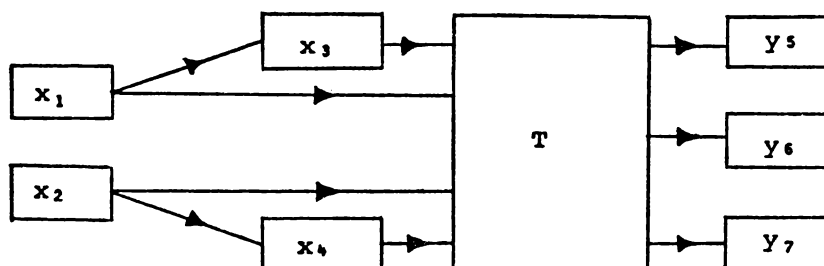


Fig 10.3(a) Multiple stage model (Type II)

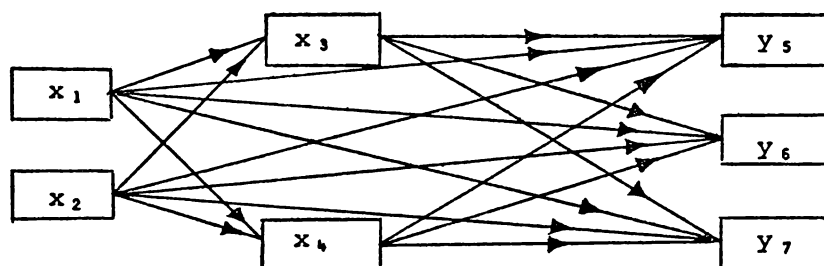


Fig 10.3(b) Type II path diagram

Table 11.1 Estimates of the coefficients of reliability for input and output totals using the Spearman-Brown formula.

<u>INPUT:</u>	
THEORETICAL	0.77
APPLIED	0.70
EXPERIMENTAL	0.84
ATTITUDINAL	0.85
 <u>OUTPUT:</u>	
THEORETICAL	0.75
APPLIED	0.80
EXPERIMENTAL	0.81
ATTITUDINAL	0.86

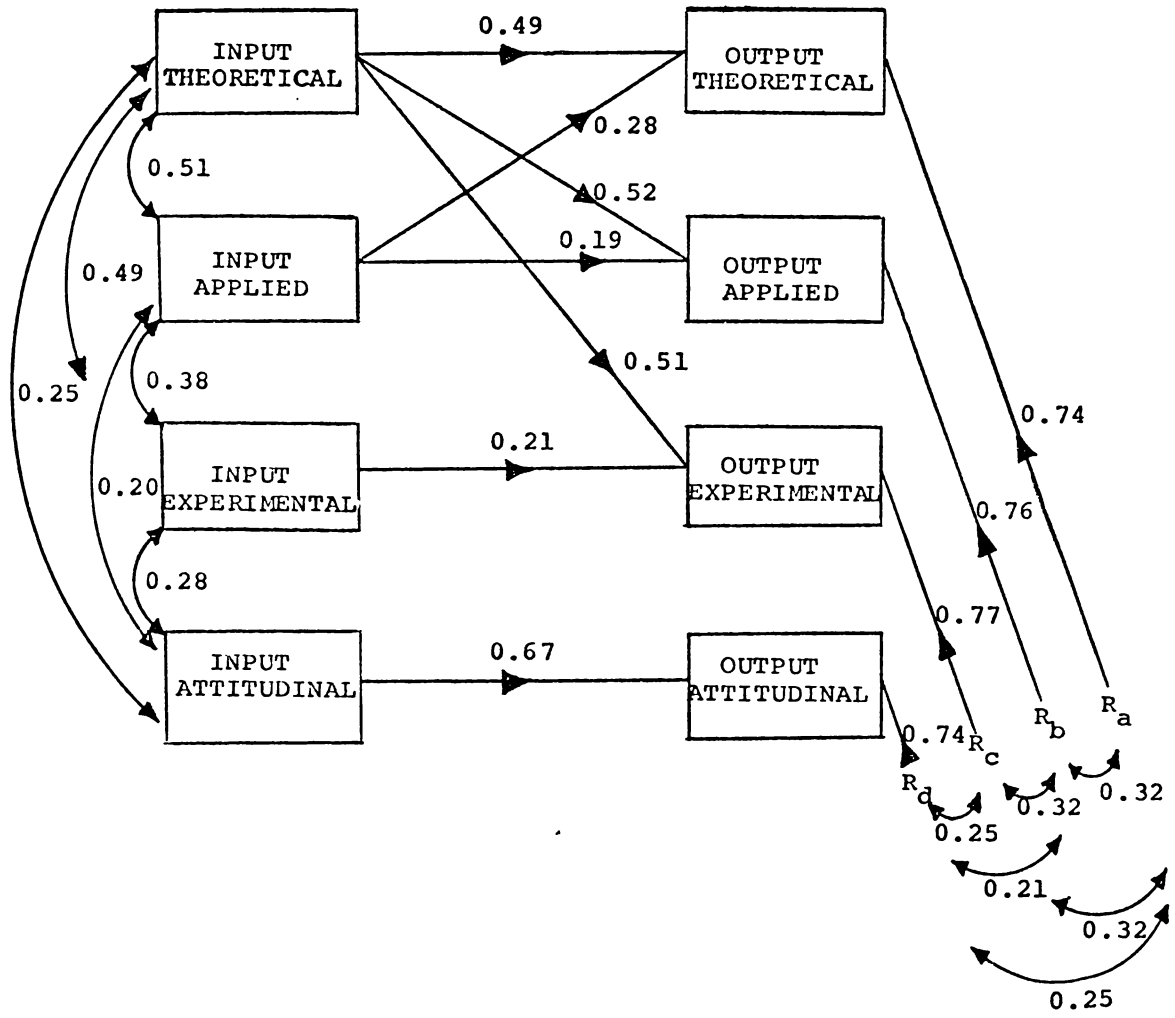


Fig 11.1 Model 1

Table 11.2 Model 1 correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 1 above diagonal assuming uncorrelated residuals.

	INPUT THEORETICAL	INPUT APPLIED	INPUT EXPERIMENTAL	INPUT ATTITUDINAL	OUTPUT THEORETICAL	OUTPUT APPLIED	OUTPUT EXPERIMENTAL	OUTPUT ATTITUDINAL
INPUT THEORETICAL	1.00	0.51	0.49	0.25	<u>0.63</u>	<u>0.62</u>	<u>0.61</u>	<u>0.17</u>
INPUT APPLIED	0.51	1.00	0.38	0.20	<u>0.53</u>	<u>0.46</u>	<u>0.34</u>	<u>0.13</u>
INPUT EXPERIMENTAL	0.49	0.38	1.00	0.28	<u>0.35</u>	<u>0.33</u>	<u>0.46</u>	<u>0.19</u>
INPUT ATTITUDINAL	0.25	0.20	0.28	1.00	<u>0.18</u>	<u>0.17</u>	<u>0.19</u>	<u>0.67</u>
OUTPUT THEORETICAL	0.63	0.53	0.40	0.24	1.00	<u>0.43</u>	<u>0.40</u>	<u>0.12</u>
OUTPUT APPLIED	0.62	0.46	0.27	0.20	0.61	1.00	<u>0.39</u>	<u>0.11</u>
OUTPUT EXPERIMENTAL	0.61	0.39	0.46	0.12	0.58	0.58	1.00	<u>0.13</u>
OUTPUT ATTITUDINAL	0.21	0.16	0.15	0.67	0.26	0.23	0.27	1.00

Table 11.3 Regression factor structure coefficients associated with Model 1 (N = 165)

	Regression Factor Structure Coefficients				Multiple R
	INPUT THEORETICAL	INPUT APPLIED	INPUT EXPERIMENTAL	INPUT ATTITUDINAL	
OUTPUT THEORETICAL	0.93	0.78	0.59	0.35	0.68
OUTPUT APPLIED	0.95	0.71	0.42	0.31	0.65
OUTPUT EXPERIMENTAL	0.95	0.61	0.72	0.19	0.64
OUTPUT ATTITUDINAL	0.31	0.24	0.22	1.00	0.67
PHYSICS GRAND TOTAL	0.94	0.68	0.60	0.25	0.76

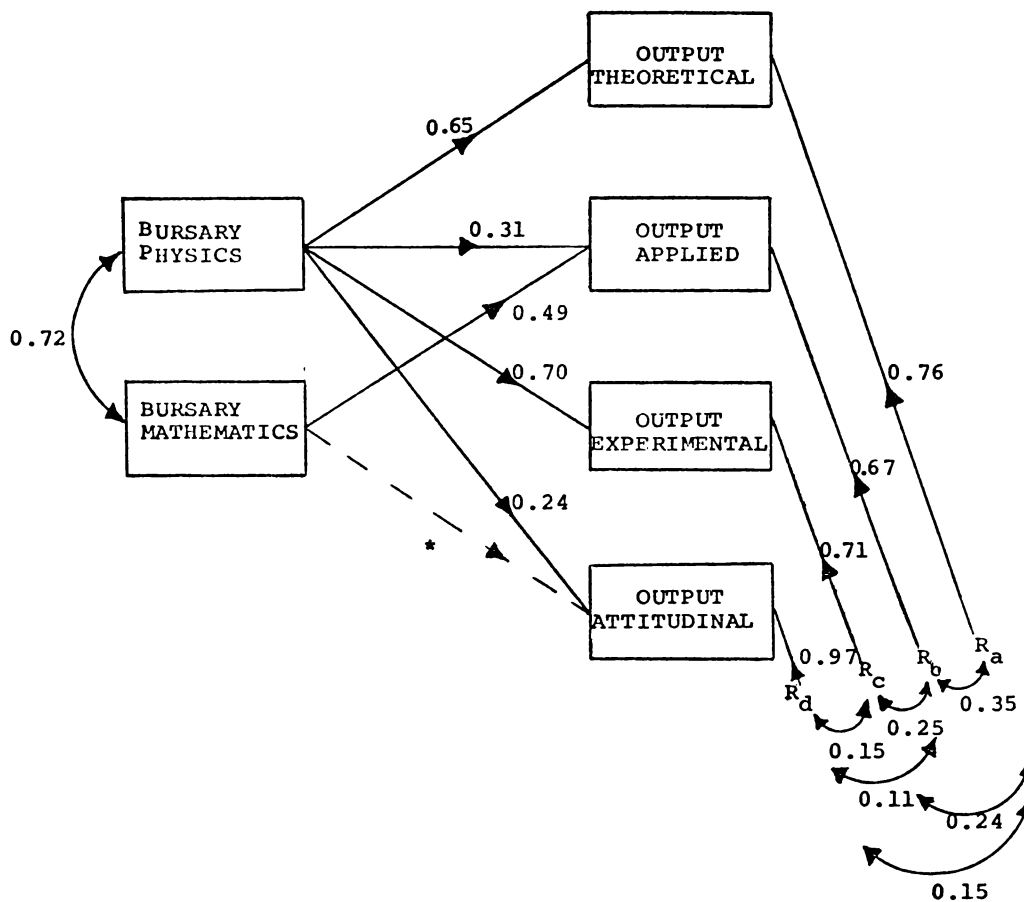


Fig 11.2 Model 2

*This negative but not statistically significant path coefficient (-0.13) is of interest as Fig 12.4 (model 8) reveals the same kind of relationship between physics, mathematics and attitudes.

Table 11.4 Model 2 correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 2 above diagonals assuming uncorrelated residuals.

	BURSARY PHYSICS	BURSARY MATHEMATICS	OUTPUT THEORETICAL	OUTPUT APPLIED	OUTPUT EXPERIMENTAL	OUTPUT ATTITUDINAL
BURSARY PHYSICS	1.00	0.72	0.65	0.66	0.70	0.24
BURSARY MATHEMATICS	0.72	1.00	<u>0.47</u>	0.71	<u>0.50</u>	<u>0.17</u>
OUTPUT THEORETICAL	0.65	0.47	1.00	<u>0.43</u>	<u>0.45</u>	<u>0.16</u>
OUTPUT APPLIED	0.66	0.71	0.61	1.00	<u>0.46</u>	<u>0.16</u>
OUTPUT EXPERIMENTAL	0.70	0.55	0.58	0.58	1.00	<u>0.17</u>
OUTPUT ATTITUDINAL	0.24	0.11	0.26	0.23	0.27	1.00

Table 11.5 Regression factor structure coefficients associated with Model 2 (N = 159).

	Regression Factor Structure Coefficients		Multiple R
	BURSARY PHYSICS	BURSARY MATHEMATICS	
OUTPUT THEORETICAL	0.99	0.72	0.65
OUTPUT APPLIED	0.89	0.96	0.74
OUTPUT EXPERIMENTAL	0.99	0.79	0.70
OUTPUT ATTITUDINAL	0.92	0.42	0.26
PHYSICS GRAND TOTAL	0.98	0.86	0.84

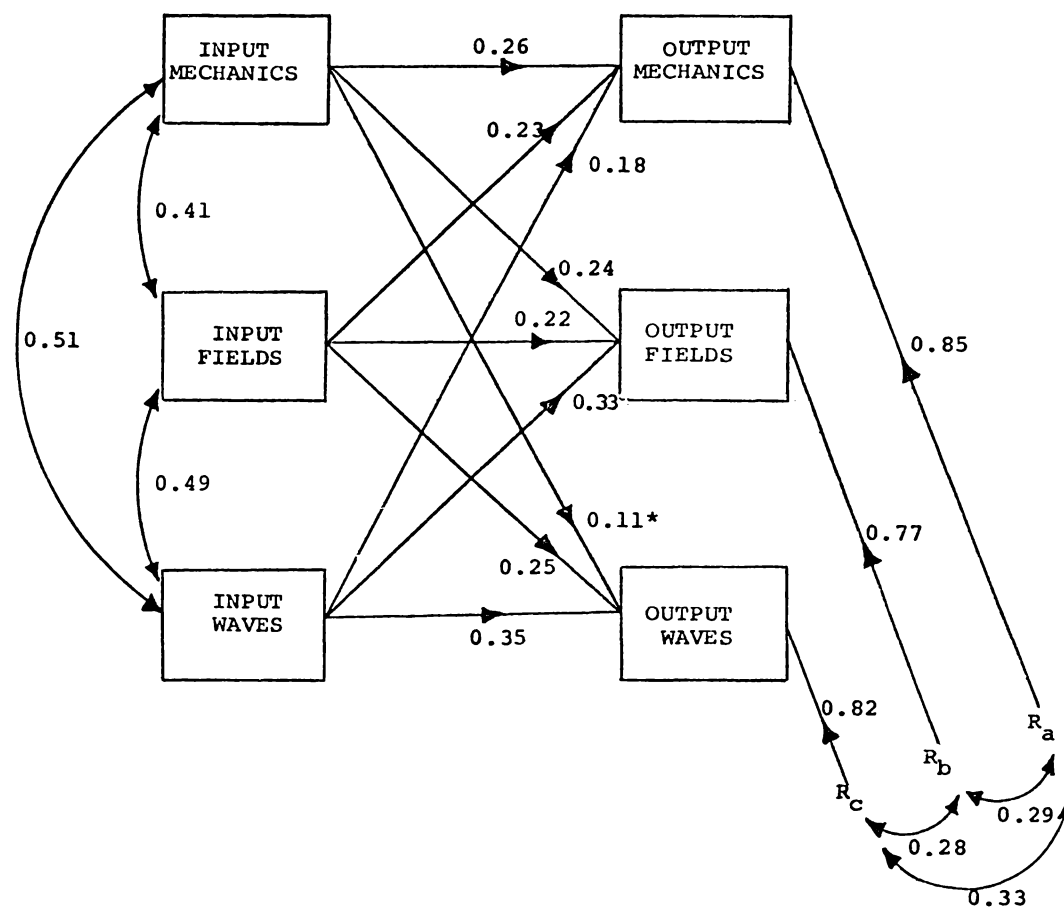


Fig 11.3 Model 3.

Table 11.6 Model 3 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 3 above diagonal assuming uncorrelated residuals.

	INPUT MECHANICS	INPUT FIELDS	INPUT WAVES	OUTPUT MECHANICS	OUTPUT FIELDS	OUTPUT WAVES
INPUT MECHANICS	1.00	0.41	0.51	0.44	0.50	0.38
INPUT FIELDS	0.41	1.00	0.49	0.42	0.48	0.46
INPUT WAVES	0.51	0.49	1.00	0.42	0.56	0.52
OUTPUT MECHANICS	0.44	0.42	0.42	1.00	<u>0.34</u>	<u>0.31</u>
OUTPUT FIELDS	0.50	0.48	0.56	0.53	1.00	<u>0.36</u>
OUTPUT WAVES	0.38	0.46	0.52	0.54	0.54	1.00

Table 11.7 Regression factor structure coefficients associated with Model 3 (N = 165).

	Regression Factor Structure Coefficients			Multiple
	INPUT MECHANICS	INPUT FIELDS	INPUT WAVES	R
OUTPUT MECHANICS	0.83	0.79	0.79	0.53
OUTPUT FIELDS	0.78	0.75	0.88	0.64
OUTPUT WAVES	0.67	0.81	0.91	0.57
PHYSICS GRAND TOTAL	0.76	0.78	0.88	0.73

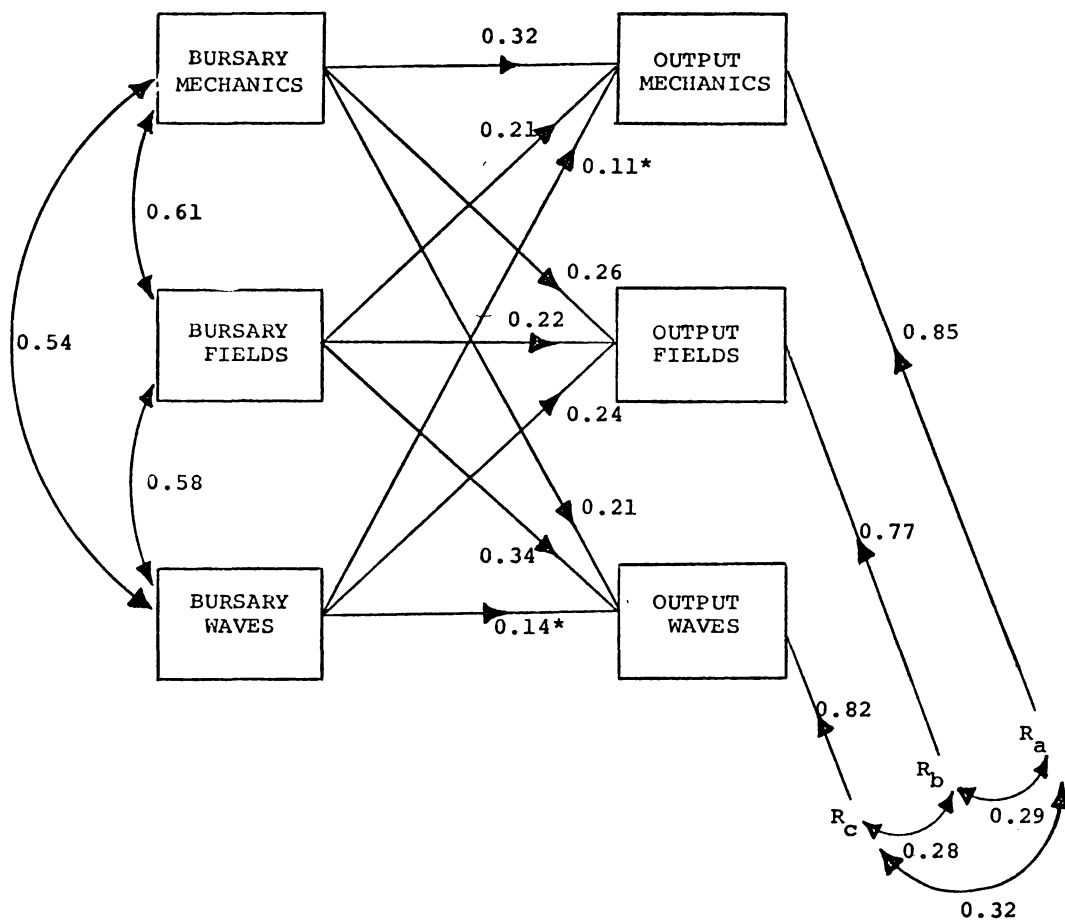


Fig 11.4 Model 4.

Table 11.8 Model 4 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 4 above diagonal assuming uncorrelated residuals.

	BURSARY MECHANICS	BURSARY FIELDS	BURSARY WAVES	OUTPUT MECHANICS	OUTPUT FIELDS	OUTPUT WAVES
BURSARY MECHANICS	1.00	0.61	0.54	0.51	0.53	0.48
BURSARY FIELDS	0.61	1.00	0.58	0.47	0.52	0.54
BURSARY WAVES	0.54	0.58	1.00	0.41	0.51	0.44
OUTPUT MECHANICS	0.51	0.47	0.41	1.00	<u>0.34</u>	<u>0.32</u>
OUTPUT FIELDS	0.53	0.52	0.51	0.53	1.00	<u>0.36</u>
OUTPUT WAVES	0.48	0.54	0.44	0.54	0.54	1.00

Table 11.9 Regression factor structure coefficients associated with Model 4 (N = 159).

	Regression Factor Structure Coefficients			Multiple
	BURSARY MECHANICS	BURSARY FIELDS	BURSARY WAVES	R
OUTPUT MECHANICS	0.92	0.85	0.75	0.55
OUTPUT FIELDS	0.87	0.85	0.83	0.61
OUTPUT WAVES	0.83	0.93	0.76	0.58
PHYSICS GRAND TOTAL	0.87	0.85	0.80	0.82

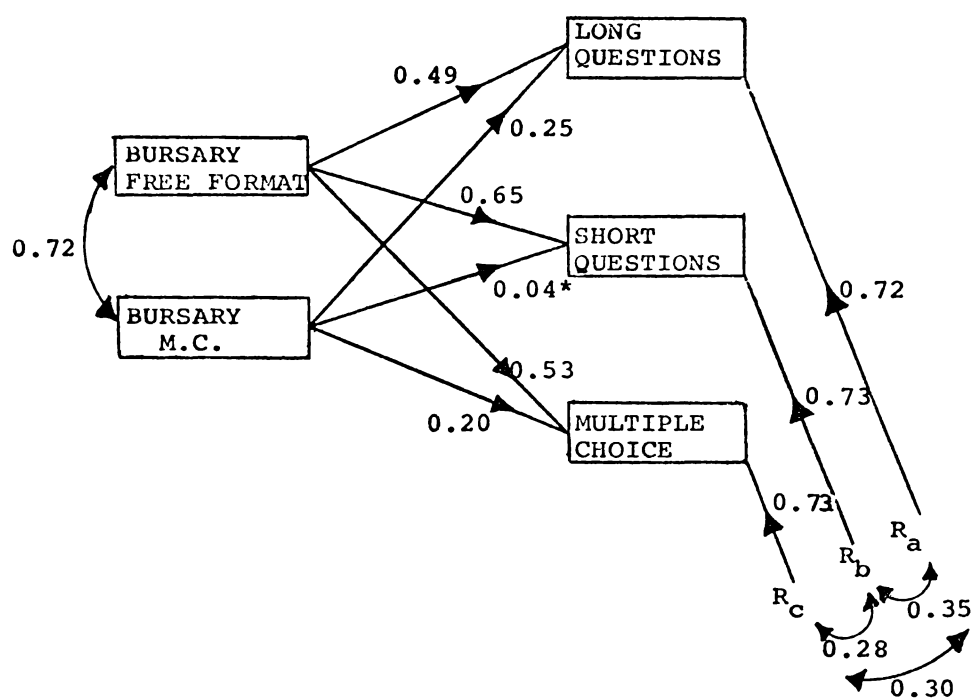


Fig 11.5 Model 5 (*path coefficients not significant at 5% level)

Table 11.10 Model 5 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 5 above diagonal assuming uncorrelated residuals.

	BURSARY FREE FORMAT	BURSARY M.C.	OUTPUT LONG	OUTPUT SHORT	OUTPUT M.C.
BURSARY FREE FORMAT	1.00	0.72	0.67	0.68	0.67
BURSARY M.C.	0.72	1.00	0.60	0.51	0.58
OUTPUT LONG	0.67	0.60	1.00	<u>0.46</u>	<u>0.48</u>
OUTPUT SHORT	0.68	0.51	0.65	1.00	<u>0.46</u>
OUTPUT M.C.	0.67	0.58	0.64	0.61	1.00

Table 11.11 Regression factor structure coefficients associated with Model 5 (N = 159).

	Regression Factor Structure Coefficients		Multiple R
	BURSARY FREE FORMAT	BURSARY MULTIPLE CHOICE	
OUTPUT LONG	0.97	0.87	0.69
OUTPUT SHORT	0.99	0.75	0.68
OUTPUT M.C.	0.99	0.85	0.68
PHYSICS GRAND TOTAL	0.98	0.81	0.84

Table 12.1 Lower limit estimates of the coefficients of reliability for variables in Chapter 12 estimated from correlation between subtotals and by the use of the Spearman-Brown formula.

BURSARY PHYSICS	0.90
BURSARY MATHS	(0.90)
S.C. ENGLISH	(0.75)
S.C. MATHS	(0.80)
APTITUDE (APT)	0.85
MOTIVATION (MOTIV)	0.80
PHYSICS GRAND TOTAL (PHYSICS G.T.)	0.95
INPUT AIM (INAIM)	0.90
INDUSTRY (IND)	0.90

[Brackets indicate a rough estimate only based, in part, on a knowledge of the correlations between the variables and other variables available.]

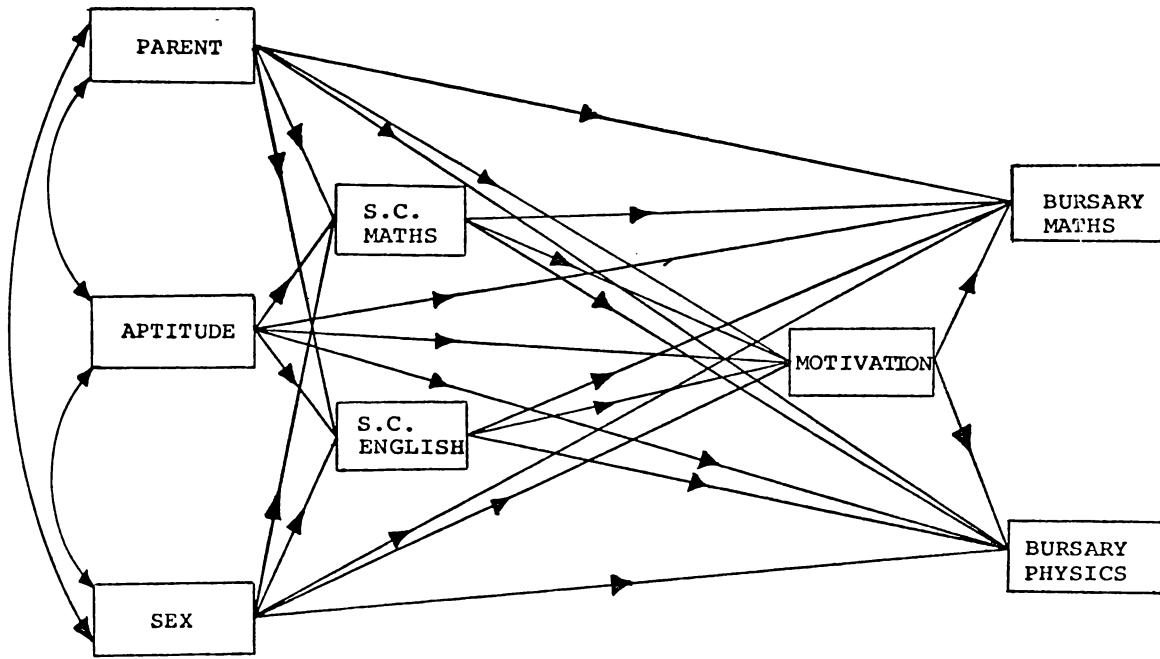
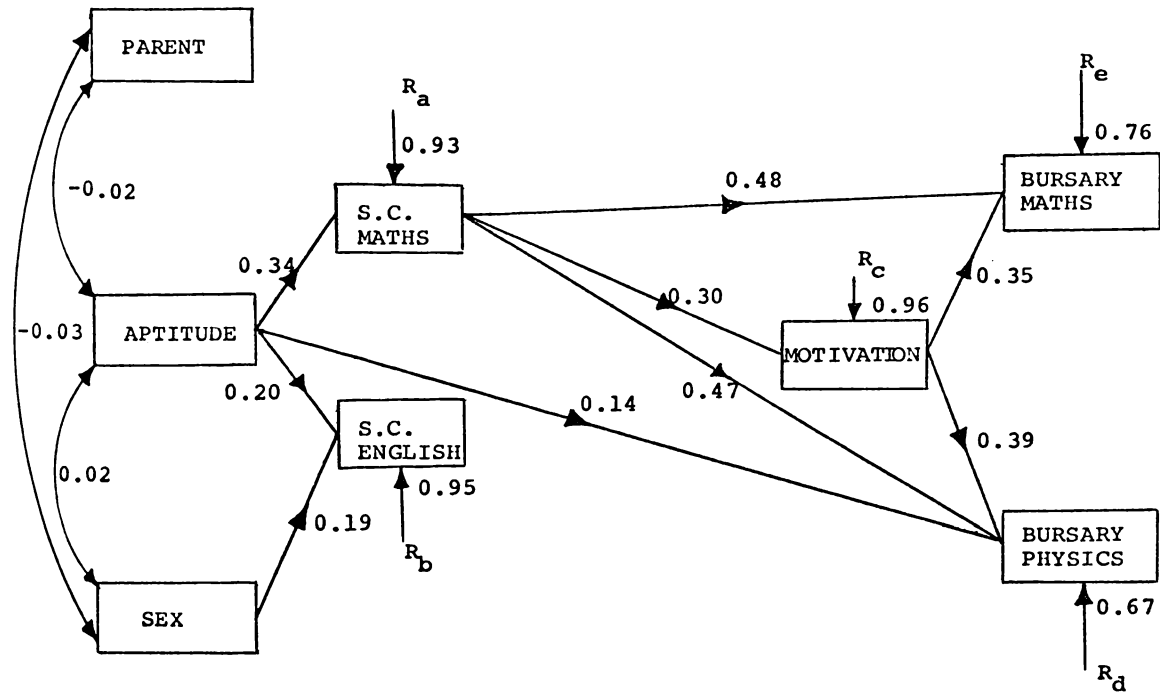


Fig 12.1(a) Path diagram for background variables



Non-zero correlation between residuals

- $r_{ba} = 0.35$
- $r_{bc} = 0.14$
- $r_{be} = 0.33$
- $r_{bd} = 0.39$
- $r_{de} = 0.49$

Fig 12.1(b) Model 6 (N = 159)

Table 12.2 Model 6 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 5 above diagonal assuming uncorrelated residuals. (N = 159)

	APTITUDE	PARENT	SEX	S.C. ENGLISH	S.C. MATHS	MOTIV	BURSARY PHYSICS	BURSARY MATHS
APTITUDE	1.00	-0.02	0.02	<u>0.20</u>	<u>0.34</u>	<u>0.10</u>	<u>0.34</u>	<u>0.20</u>
PARENT	-0.02	1.00	-0.03	<u>0.00</u>	<u>-0.01</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
SEX	+0.02	-0.03	1.00	<u>0.19</u>	<u>0.01</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
S.C. ENGLISH	0.20	-0.02	0.19	1.00	<u>0.07</u>	<u>0.02</u>	<u>0.07</u>	<u>0.04</u>
S.C. MATHS	0.34	-0.07	0.04	0.38	1.00	<u>0.30</u>	<u>0.59</u>	<u>0.59</u>
MOTIV	0.08	-0.01	0.09	0.15	0.30	1.00	<u>0.54</u>	<u>0.49</u>
BURSARY PHYSICS	0.33	0.00	-0.04	0.32	0.63	0.54	1.00	<u>0.47</u>
BURSARY MATHS	0.23	-0.01	0.10	0.28	0.58	0.49	0.72	1.00

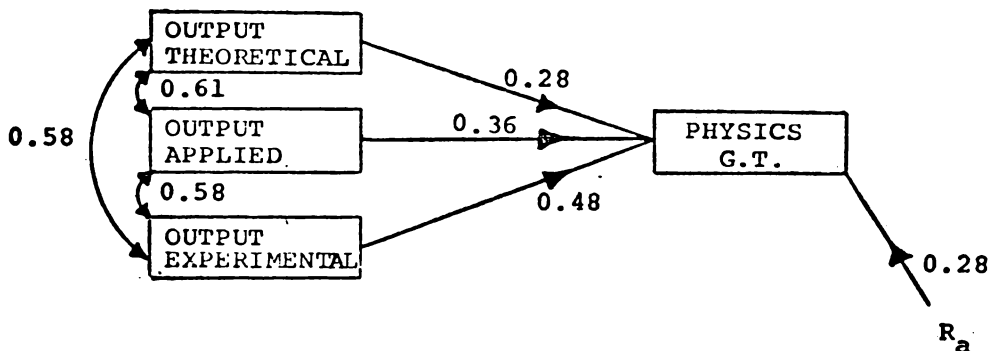


Fig 12.2 Model 7 (N = 165)

Table 12.3 Model 7 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 7 above diagonal. (N = 165).

	OUTPUT THEORETICAL	OUTPUT APPLIED	OUTPUT EXPERIMENTAL	PHYSICS GRAND TOTAL
OUTPUT THEORETICAL	1.00	1.61	0.58	0.78
OUTPUT APPLIED	0.61	1.00	0.58	0.81
OUTPUT EXPERIMENTAL	0.58	0.58	1.00	0.85
PHYSICS GRAND TOTAL	0.78	0.81	0.85	1.00

Table 12.4 Regression factor structure coefficients associated with Model 7 (N = 165).

	Regression Factor Structure Coefficients			Multiple R
	THEORETICAL	APPLIED	EXPERIMENTAL	
PHYSICS GRAND TOTAL	0.80	0.85	0.89	0.96

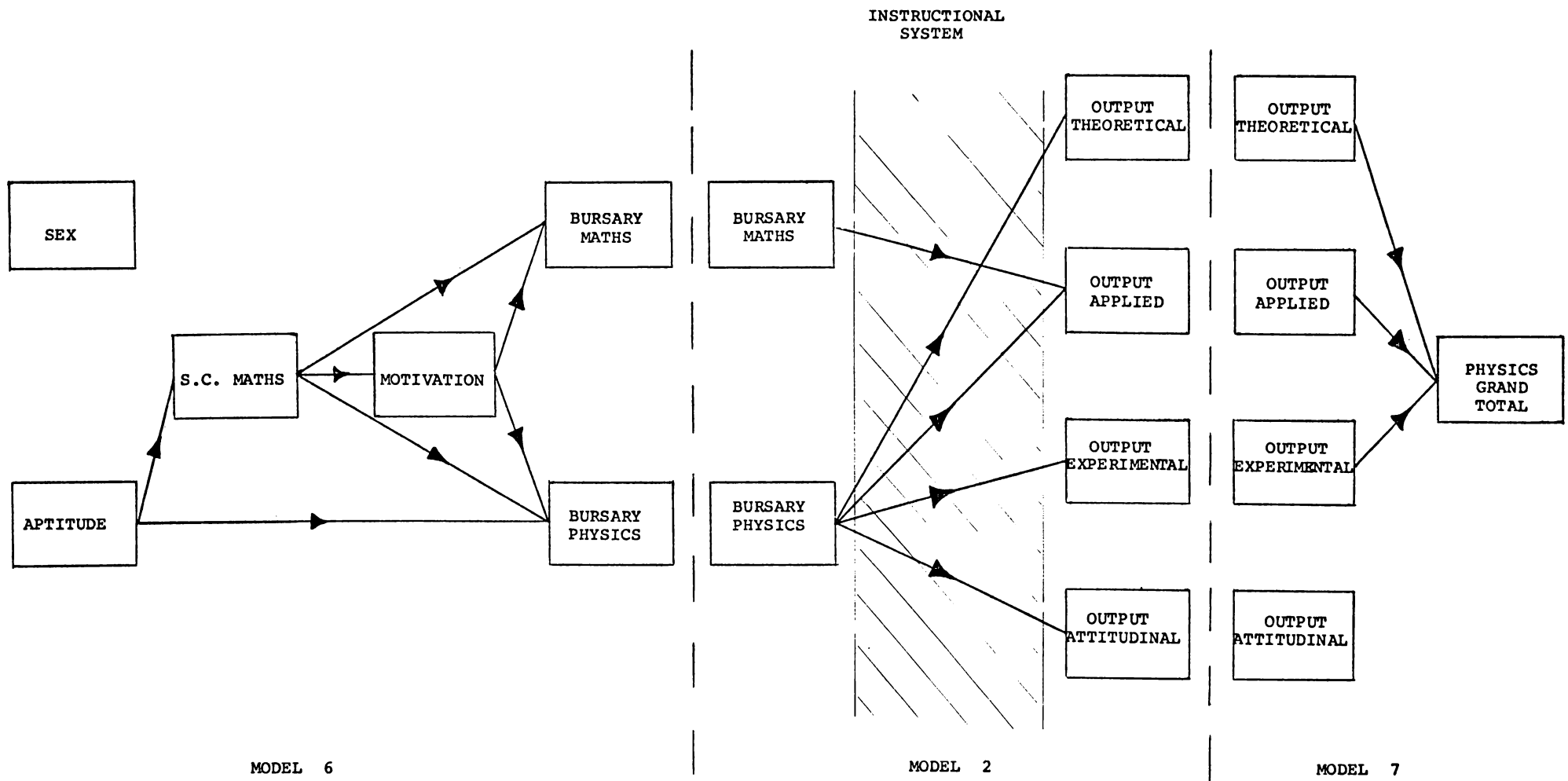
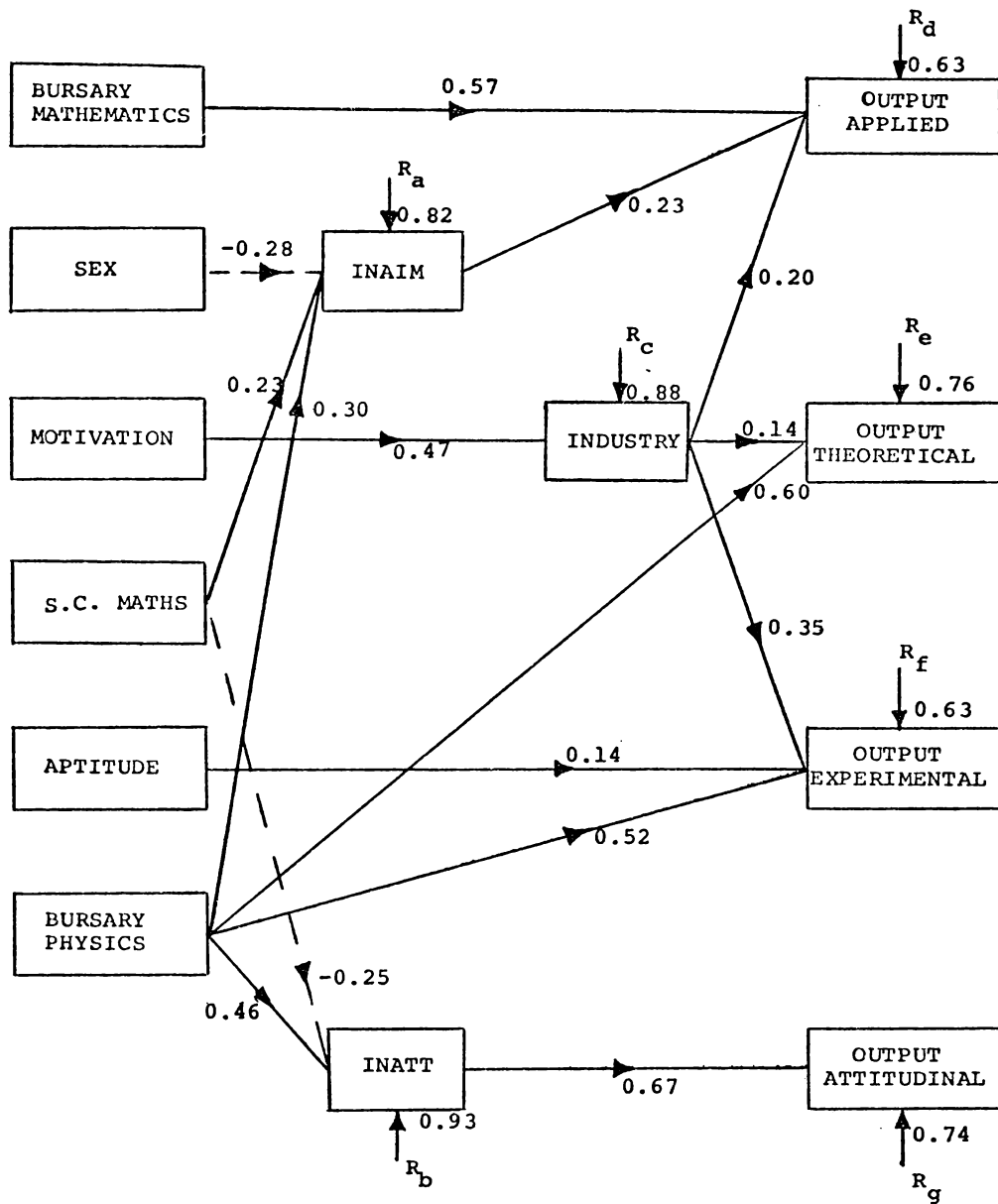


Fig 12.3 Combining models 6,2 and 7 - only important variables and significant paths shown.



$r_{ag} = 0.25$ $r_{de} = 0.46$
 $r_{df} = 0.30$ $r_{dg} = 0.21$
 $r_{ef} = 0.23$ $r_{eg} = 0.21$
 $r_{fg} = 0.30$

Fig 12.4 Model 8 (Broken lines denote significant, but negative path coefficients) (N = 159).

Table 12.5 Model 8 Correlation matrix; correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 8 above diagonal assuming uncorrelated residuals. (N = 159)

	BURSARY MATHS	SEX	MOTIV	S.C. MATHS	APT.	BURSARY PHYS.	AIM	INPUT ATT	IND	OUTPUT APP.	OUTPUT TH.	OUTPUT EXP.	OUTPUT ATT.
BURSARY MATHS	1.00	0.10	0.49	0.58	0.23	0.72	<u>0.32</u>	<u>0.18</u>	<u>0.23</u>	<u>0.69</u>	<u>0.45</u>	<u>0.48</u>	<u>0.12</u>
SEX	0.10	1.00	0.09	0.04	0.02	-0.04	<u>-0.29</u>	<u>-0.03</u>	<u>0.04</u>	<u>0.00</u>	<u>-0.02</u>	<u>-0.02</u>	<u>-0.02</u>
MOTIV	0.49	0.09	1.00	0.30	0.08	0.54	<u>0.20</u>	<u>0.17</u>	<u>0.47</u>	<u>0.43</u>	<u>0.39</u>	<u>0.45</u>	<u>0.11</u>
S.C. MATHS	0.58	0.04	0.30	1.00	0.34	0.63	<u>0.41</u>	<u>0.04</u>	<u>0.16</u>	<u>0.46</u>	<u>0.41</u>	<u>0.44</u>	<u>0.03</u>
APT.	0.23	0.02	0.08	0.34	1.00	0.33	<u>0.18</u>	<u>0.10</u>	<u>0.04</u>	<u>0.18</u>	<u>0.20</u>	<u>0.32</u>	<u>0.07</u>
BURSARY PHYSICS	0.72	-0.04	0.54	0.63	0.33	1.00	<u>0.46</u>	<u>0.30</u>	<u>0.26</u>	<u>0.57</u>	<u>0.64</u>	<u>0.66</u>	<u>0.20</u>
AIM	0.28	-0.29	0.24	0.41	0.18	0.46	1.00	<u>0.16</u>	<u>0.19</u>	<u>0.43</u>	<u>0.31</u>	<u>0.34</u>	<u>0.11</u>
INPUT ATT.	0.18	-0.10	0.15	0.04	0.05	0.30	0.28	1.00	<u>0.09</u>	<u>0.19</u>	<u>0.20</u>	<u>0.19</u>	<u>0.67</u>
IND.	0.38	0.12	0.47	0.27	0.00	0.38	0.23	0.01	1.00	<u>0.37</u>	<u>0.30</u>	<u>0.50</u>	<u>0.01</u>
OUTPUT APP.	0.71	-0.02	0.52	0.53	0.28	0.66	0.44	0.20	0.47	1.00	<u>0.39</u>	<u>0.46</u>	<u>0.13</u>
OUTPUT TH.	0.47	-0.12	0.31	0.45	0.19	0.65	0.32	0.24	0.37	0.61	1.00	<u>0.47</u>	<u>0.14</u>
OUTPUT EXP.	0.55	0.00	0.39	0.46	0.31	0.70	0.35	0.12	0.55	0.58	0.58	1.00	<u>0.13</u>
OUTPUT ATT.	0.11	-0.07	0.12	0.05	0.13	0.24	0.25	0.67	0.12	0.23	0.26	0.27	1.00

Table 13.1 Changes in student aims and factors affecting these changes in 1972 (N = 81).

	Percentage of Total Replies	Contributing Reason*					
		Staff/Student Contact	Physics Tests and Results from Tests	Laboratory Work	Changing Attitude to Physics	External Factors of an Academic Nature	External Factors of a Non-Academic Nature
Increase in Aim (over year)	11	50	80	30	30	30	0
Decrease in Aim (over year)	27	0	80	50	20	30	30
No Change in Aim (over year)	39	-	-	-	-	-	-
Fluctuating Aim but no Significant Overall Change	23	10	90	70	20	20	40

* Each number indicates the percentage of students with that particular aim change, who considered that reason a contributing one to their aim change (to nearest 10%).

Table 13.2 Students' expectation versus test results and students' change in aim in 1972 (N = 81).

	Percentage of Total Replies			Percentage of Students Within Each Group with Particular Aim Change
	Decreased Aim	No Significant Change in Aim	Increased Aim	
Students who considered marks from tests lower than expected	50	30	70	0
Students who considered marks from tests as expected	25	20	55	25
Students who considered marks from tests higher than expected	25	25	55	20

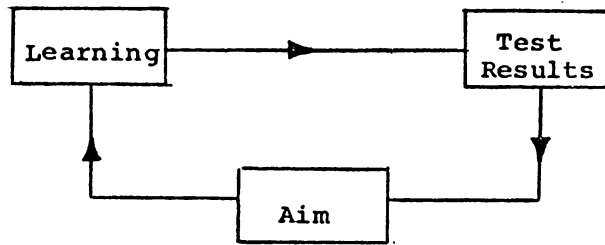


Fig 13.1(a) Feedback model of student attainment

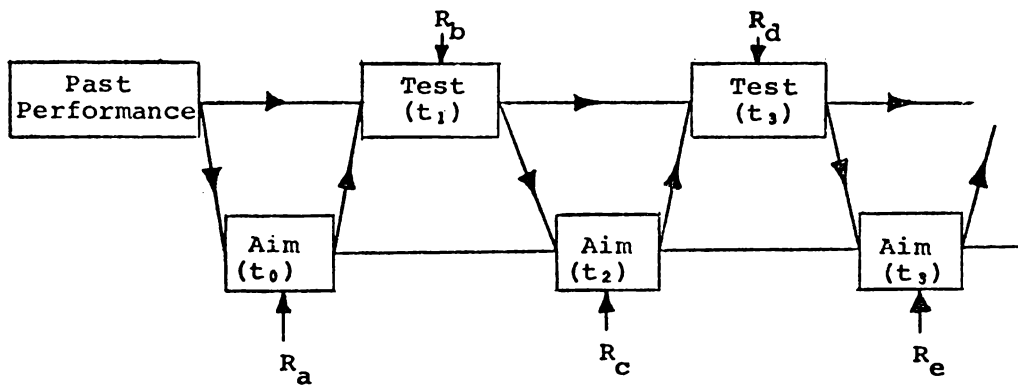


Fig 13.1(b) Respecified for path analysis

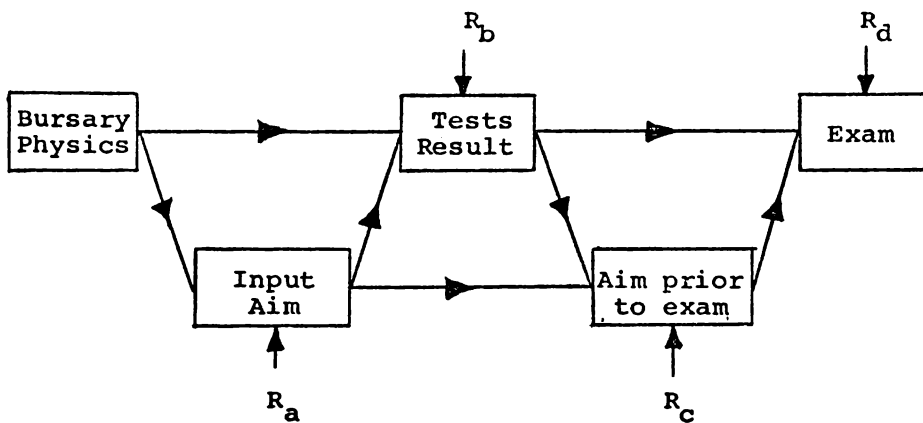


Fig 13.1(c) Simplified model with data available for testing

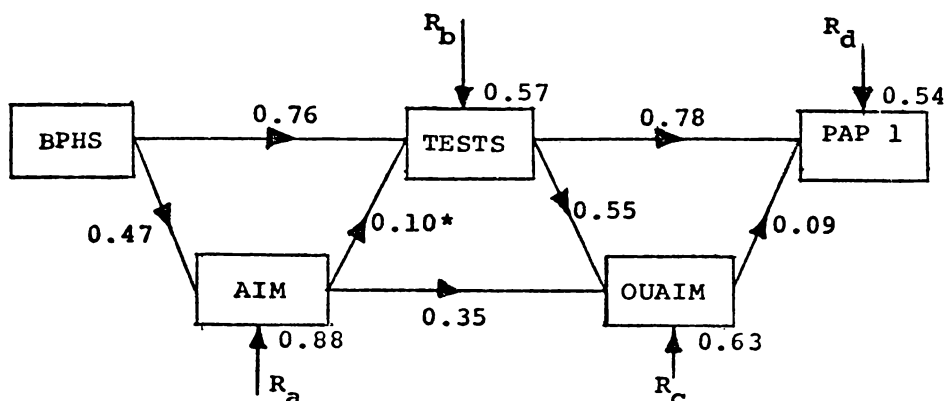
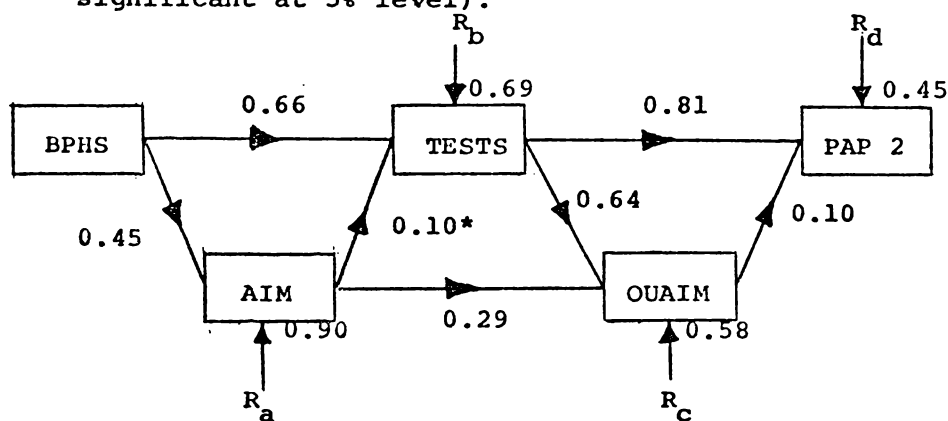


Fig 13.2(a) Model 9(a) Theoretical Course (* path coefficients not significant at 5% level).



*not significant at 5% level

Fig 13.2(b) Model 9(b) Experimental Course

Table 13.3 Model 9 Correlation matrix: Correlation values from observed data below diagonals, correlation values corresponding to Model 9 above diagonals (assuming uncorrelated residuals) (N = 165).

	BPHS	AIM	TESTS	OUAIM	PAP 1		BPHS	AIM	TESTS	OUAIM	PAP 2
BPHS	1.00	0.47	0.81	<u>0.62</u>	<u>0.69</u>	BPHS	1.00	0.45	0.71	<u>0.58</u>	<u>0.63</u>
AIM	0.47	1.00	0.46	0.60	<u>0.41</u>	AIM	0.45	1.00	0.40	0.55	<u>0.38</u>
TESTS	0.81	0.46	1.00	0.70	0.84	TESTS	0.71	0.40	1.00	0.76	0.89
OUAIM	0.65	0.60	0.70	1.00	0.66	OUAIM	0.65	0.55	0.76	1.00	0.72
PAP 1	0.78	0.40	0.80	0.66	1.00	PAP 2	0.79	0.41	0.89	0.72	1.00

Theoretical Course

Experimental Course

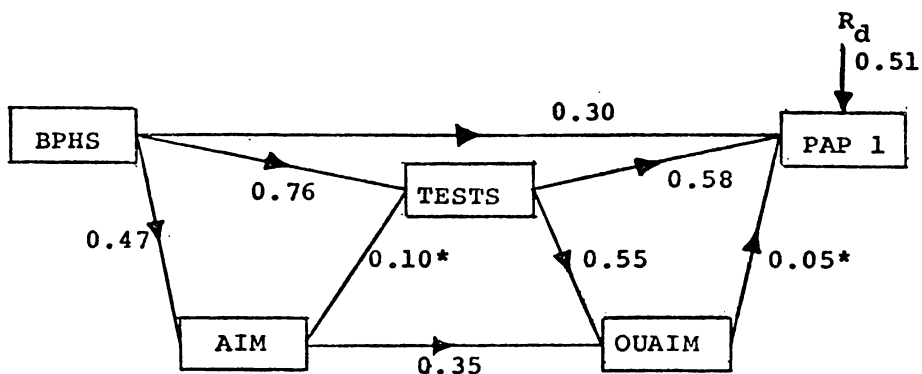


Fig 13.3(a) Model 10(a) Theoretical Course

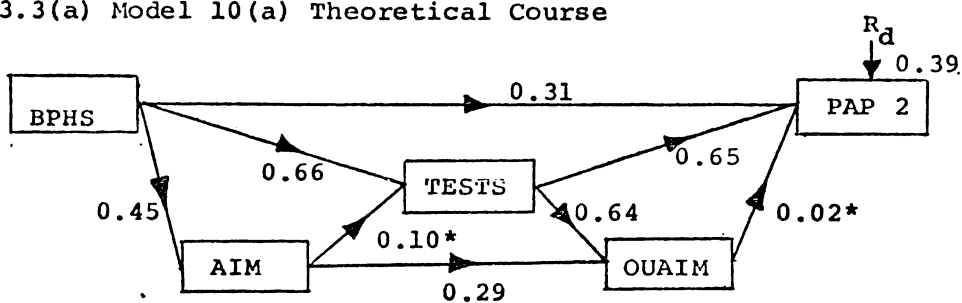


Fig 13.3(b) Model 10(b) Experimental Course

Table 13.4 Model 10 Correlation matrix; correlation values from observed data below diagonals, correlation values corresponding to Model above diagonals (assuming uncorrelated residuals).

	BPHS	AIM	TEST	OUAIM	PAP 1		BPHS	AIM	TEST	OUAIM	PAP 2
BPHS	1.00	0.47	0.81	<u>0.62</u>	<u>0.80</u>	BPHS	1.00	0.45	0.71	<u>0.58</u>	<u>0.78</u>
AIM	0.47	1.00	0.46	0.60	<u>0.41</u>	AIM	0.45	1.00	0.40	0.55	<u>0.38</u>
TEST	0.81	0.46	1.00	0.70	0.84	TEST	0.71	0.40	1.00	0.76	0.89
OUAIM	0.66	0.60	0.70	1.00	0.66	OUAIM	0.65	0.55	0.76	1.00	0.72
PAP 1	0.78	0.40	0.84	0.66	1.00	PAP 2	0.79	0.41	0.89	0.72	1.00

Theoretical Course

Experimental Course

Table 13.5 Principal components analyses of teacher's subjective assessments of first year physics students in 1973 (N = 101) and in 1974 (N = 87) with factor loadings ≥ 0.5 .

Objective/Criteria*	Factor				Mean 0-6 Scale		Standard Deviation		100h ²	
	I		II		1973	1974	1973	1974	1973	1974
	1973	1974	1973	1974						
Academic Ability (U1)	0.8	0.9			3.8	3.9	1.1	1.2	68	82
Academic Industry (U2)			0.8	0.9	4.0	4.0	1.2	1.4	72	82
Maturity/Stability (U3)			0.9	0.8	4.2	4.2	1.2	1.2	78	66
Comprehension of Physics (P1)	0.8	0.9			3.6	3.9	1.1	1.2	82	89
Ability to apply (P2)	0.9	0.9			3.5	4.0	1.1	1.1	82	85
Analyze and Evaluate (P3)	0.9	0.8			3.2	3.6	1.2	1.3	84	81
Conduct experimental work (P4)	0.6	0.5	0.5	0.6	3.7	3.9	1.1	1.2	61	64
Process experimental data (P5)	0.7	0.7	0.5	0.5	3.4	3.7	1.2	1.2	78	80
Attitude to physics (P6)	0.5		0.7	0.8	3.9	3.9	1.2	1.4	71	85
Rotated % variance accounted for by each factor.	46	45	30	34						

* see Appendix N

Table 13.6 Principal components analyses of lecturer's subjective assessments of first year physics students in 1973 (N = 101) and 1974 (N = 87) with factor loadings ≥ 0.5 .

Objective/Criteria*	Factor				Mean 0-6 Scale		Standard Deviation		100h ²	
	I		II		1973	1974	1973	1974	1973	1974
	1973	1974	1973	1974						
Academic Ability (U1)	0.9	0.9			3.8	3.6	1.4	1.3	83	80
Academic Industry (U2)			0.9	0.9	3.3	3.5	1.6	1.6	87	89
Maturity/Stability (U3)			0.9	0.8	3.5	3.3	1.5	1.2	83	79
Comprehension of Physics (P1)	0.8	0.9			3.4	3.5	1.5	1.4	92	92
Ability to apply (P2)	0.9	0.8		0.5	3.5	3.0	1.5	1.6	91	92
Analyze and Evaluate (P3)	0.9	0.9			3.1	2.9	1.5	1.7	92	91
Conduct exp. work (P4)	0.7	0.6	0.5	0.7	3.4	3.5	1.4	1.4	81	83
Process exp. data (P5)			0.9	0.9	3.3	3.4	1.5	1.7	88	91
Attitude to physics (P6)			0.8	0.8	3.4	3.5	1.4	1.5	82	85
Rotated % variance	45	41	39	45						

* see Appendix N

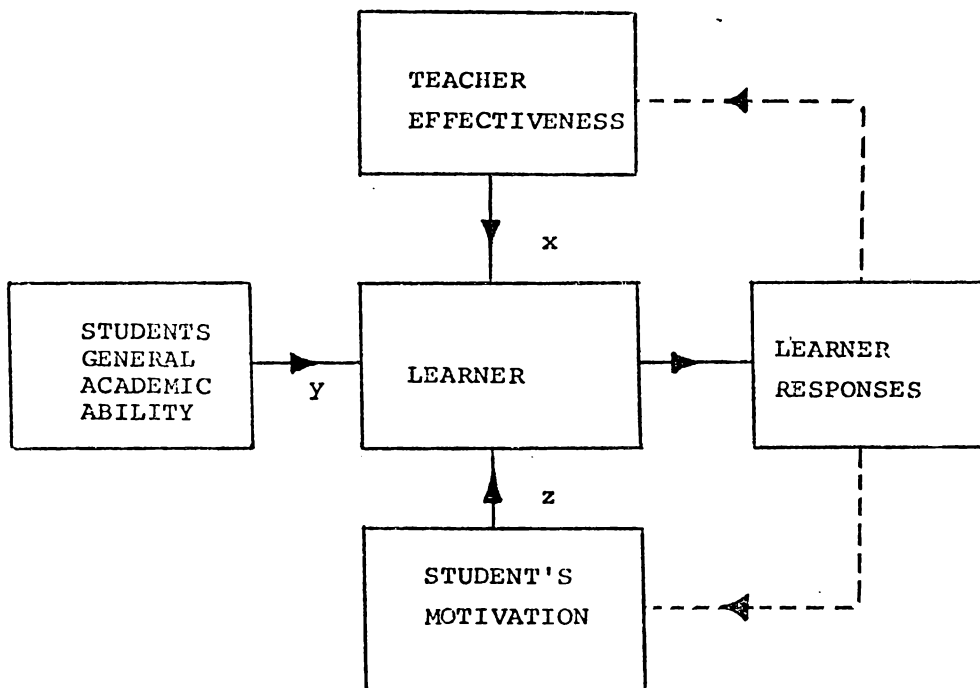


Fig 13.4 A simplified version of Fig 4.1 which relates to a teacher's (lecturer's) perception of student attainment.

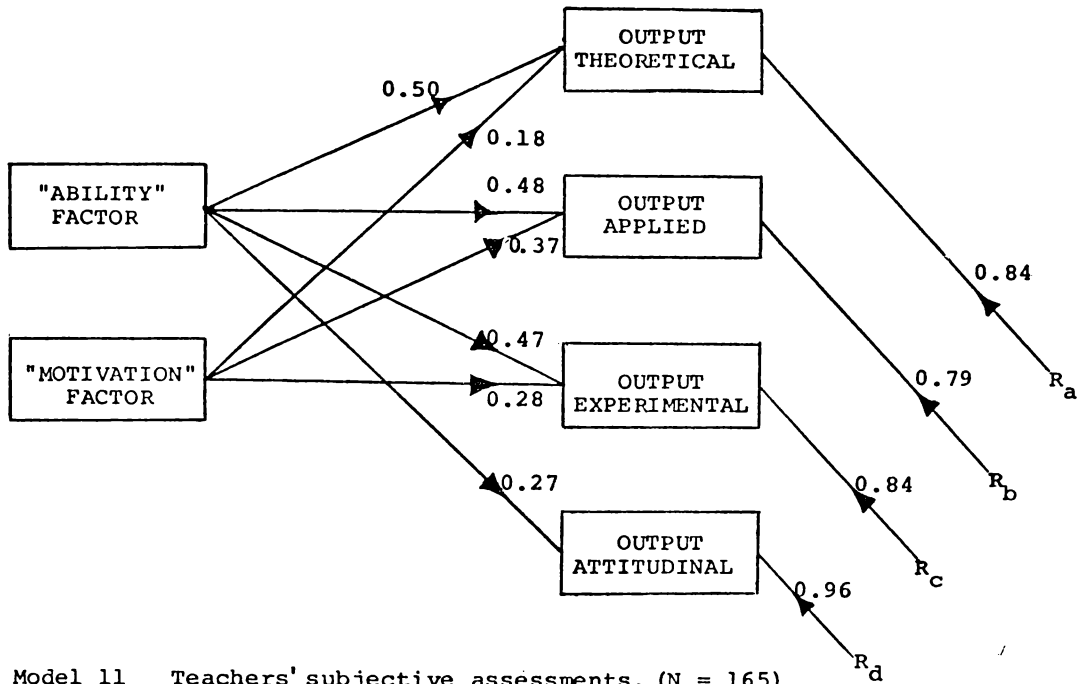


Fig 13.5 Model 11 Teachers' subjective assessments. (N = 165)

Table 13.7 Model 11 Correlation matrix: correlation coefficients from observed data below diagonal, correlation coefficients corresponding to Model 11 above diagonals assuming uncorrelated residuals.

	"ABILITY" FACTOR	"MOTIVATION" FACTOR	OUTPUT THEORETICAL	OUTPUT APPLIED	OUTPUT EXPERIMENTAL	OUTPUT ATTITUDINAL
"ABILITY" FACTOR	1.00	0.05	0.51	0.50	0.48	<u>0.27</u>
"MOTIVATION" FACTOR	0.05*	1.00	0.21	0.39	0.30	<u>0.01</u>
OUTPUT THEORETICAL	0.51	0.21	1.00	<u>0.31</u>	<u>0.29</u>	<u>0.13</u>
OUTPUT APPLIED	0.50	0.39	0.61	1.00	<u>0.34</u>	<u>0.13</u>
OUTPUT EXPERIMENTAL	0.48	0.30	0.58	0.58	1.00	<u>0.13</u>
OUTPUT ATTITUDINAL	0.28	0.12	0.26	0.23	0.27	1.00

* Orthogonal factors were estimated on total sample including dropouts.

Table 13.8 Regression factor structure coefficients associated with Model 11 (N = 165)

	Regression Factor Structure Coefficients		Multiple R
	"ABILITY" FACTOR	"MOTIVATION" FACTOR	
OUTPUT THEORETICAL	0.95	0.39	0.54
OUTPUT APPLIED	0.81	0.63	0.62
OUTPUT EXPERIMENTAL	0.87	0.55	0.55
OUTPUT ATTITUDINAL	0.97	0.41	0.29
PHYSICS GRAND TOTAL	0.85	0.54	0.67

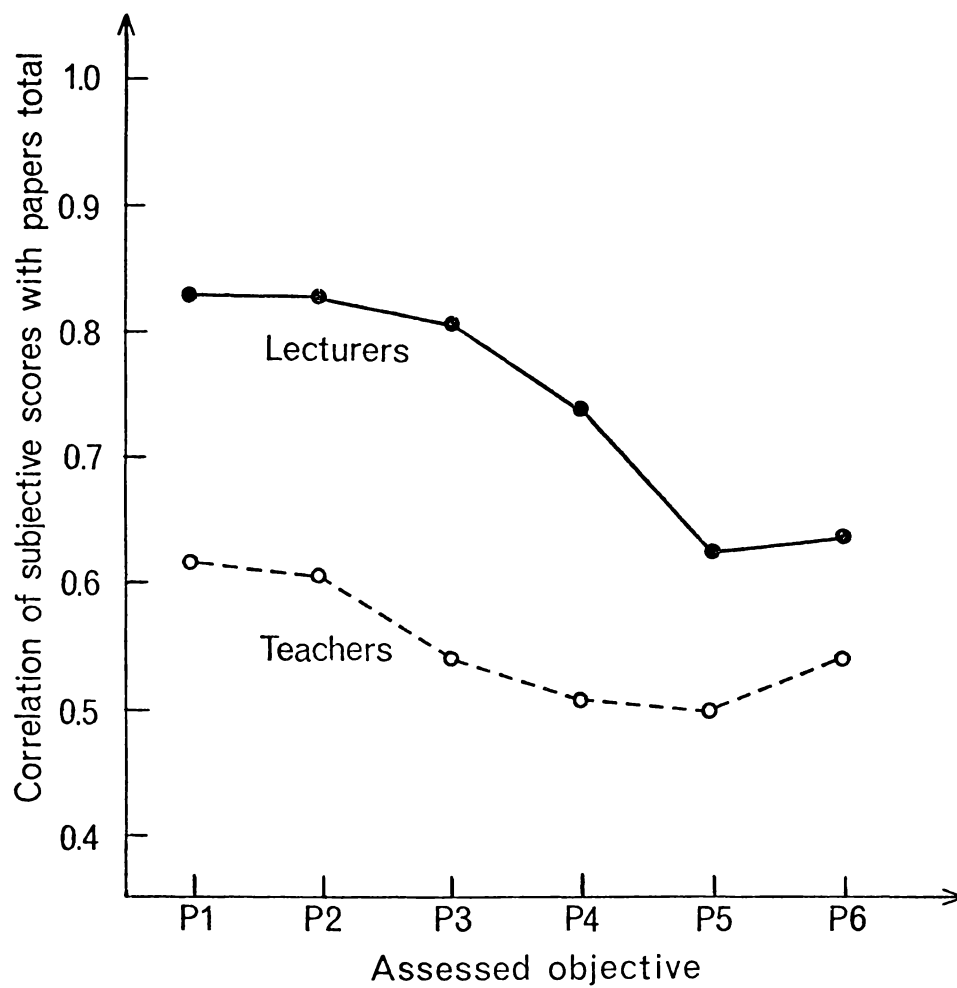


Fig 13.6 Mean correlations for 1973 and 1974 ($N = 165$) of subjective assessments with combined physics examination mark (papers only) at the end of the first year of University (excluding dropouts).

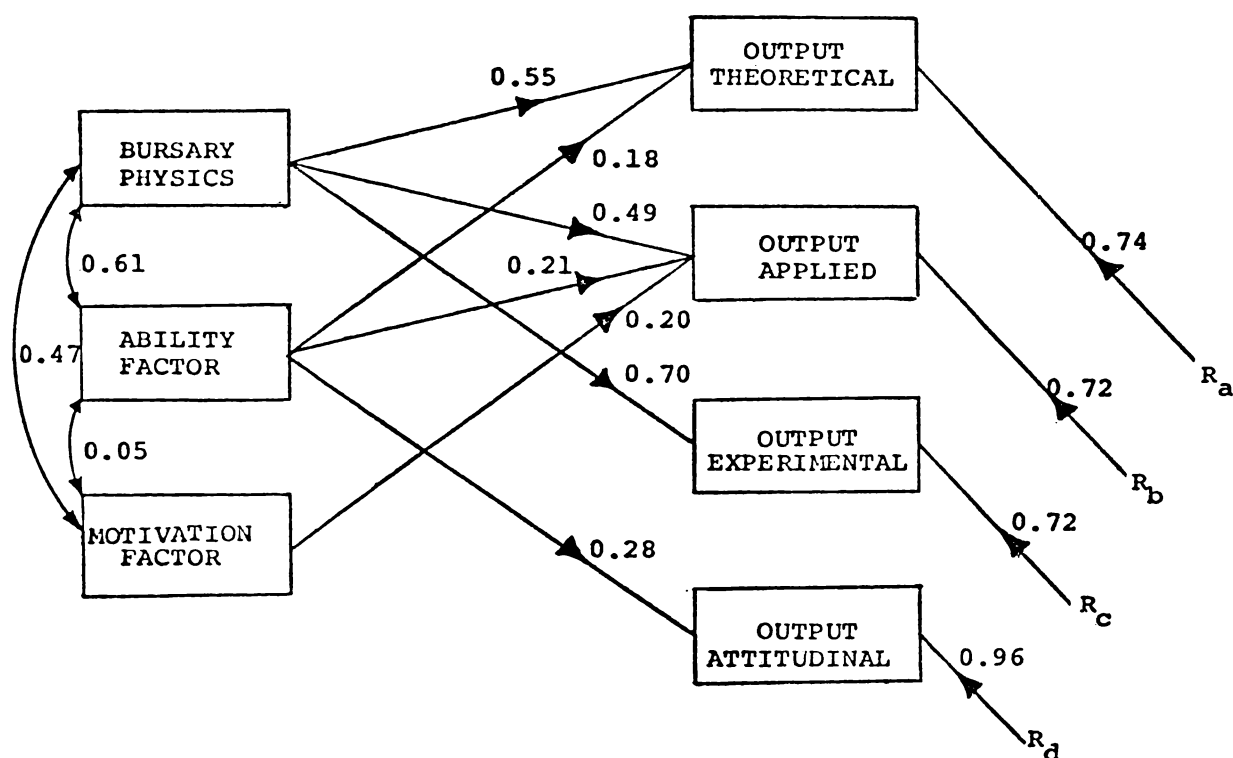


Fig 13.7 Model 12 Teachers' subjective assessment and Bursary Physics Total. (for correlation matrix refer Model 2 and Model 11).

Table 13.9 Regression factor structure coefficients associated with Model 12 (N = 159).

	Regression Factor Structure Coefficients			MULTIPLE
	BURSARY PHYSICS	ABILITY FACTOR	MOTIVATION FACTOR	R
OUTPUT THEORETICAL	0.97	0.76	0.31	0.67
OUTPUT APPLIED	0.94	0.72	0.56	0.70
OUTPUT EXPERIMENTAL	0.99	0.69	0.43	0.70
OUTPUT ATTITUDINAL	0.87	0.93	0.40	0.30
PHYSICS GRAND TOTAL	0.99	0.46	0.45	0.81

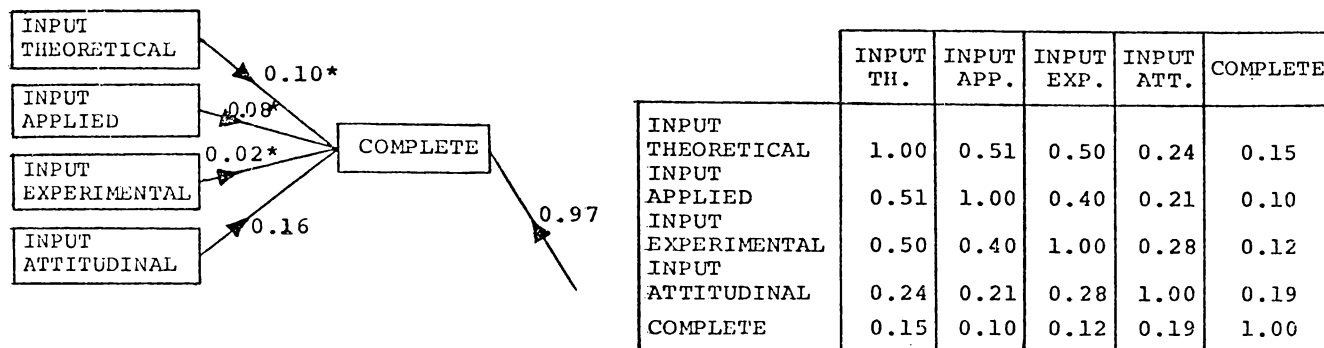


Fig 13.8(a) Model 1(a) (*Path coefficients not significant at 5% level) (N = 188)

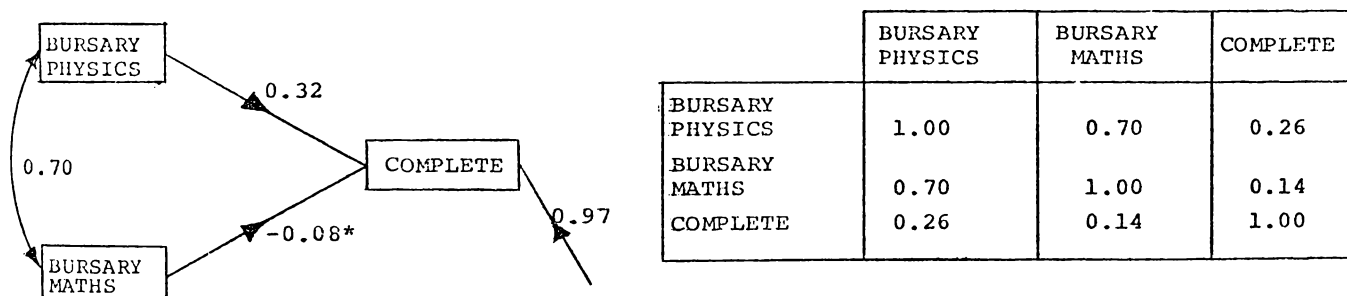


Fig 13.8(b) Model 2(a) (N = 182)

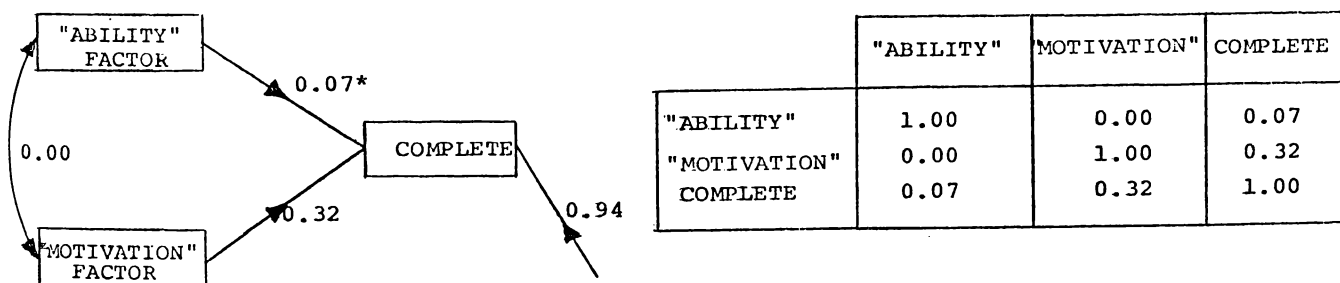


Fig 13.8(c) Model 11(a) Teachers' subjective factors (N = 188)

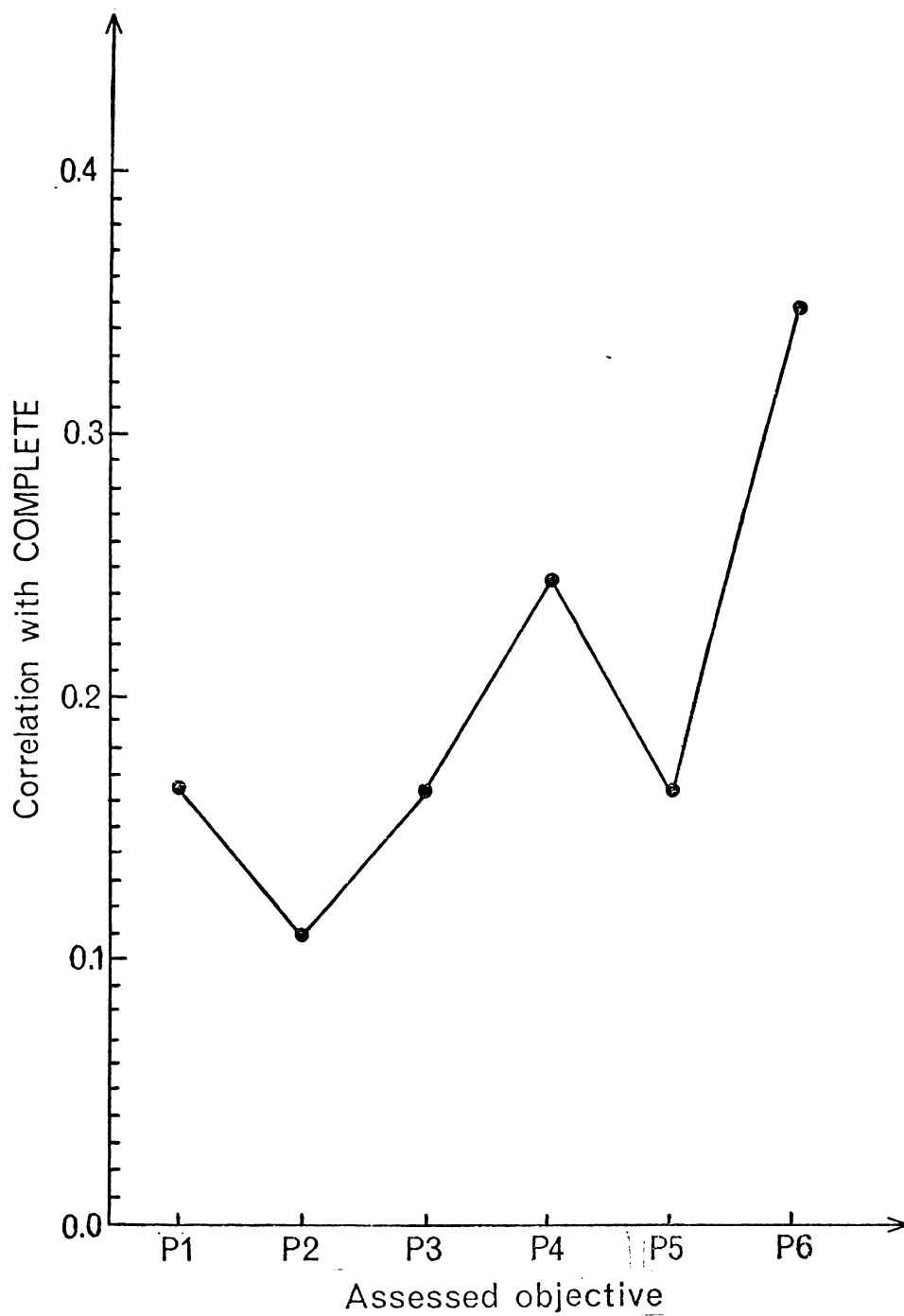


Fig 13.9 Correlation coefficients of the components of teachers' subjective assessment with COMPLETE (N = 188)

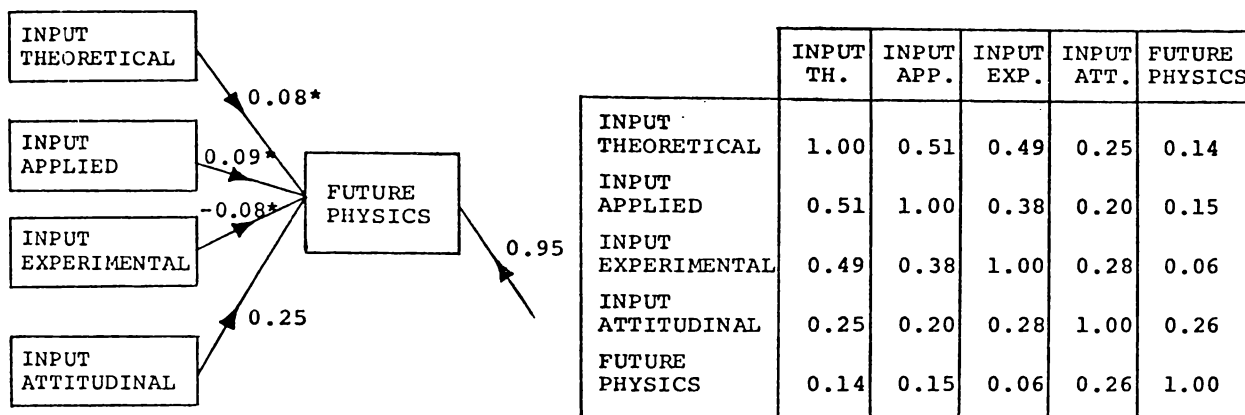


Fig 13.10(a) Model 1(b) (*Path coefficients not significant at 5% level) (N = 170)

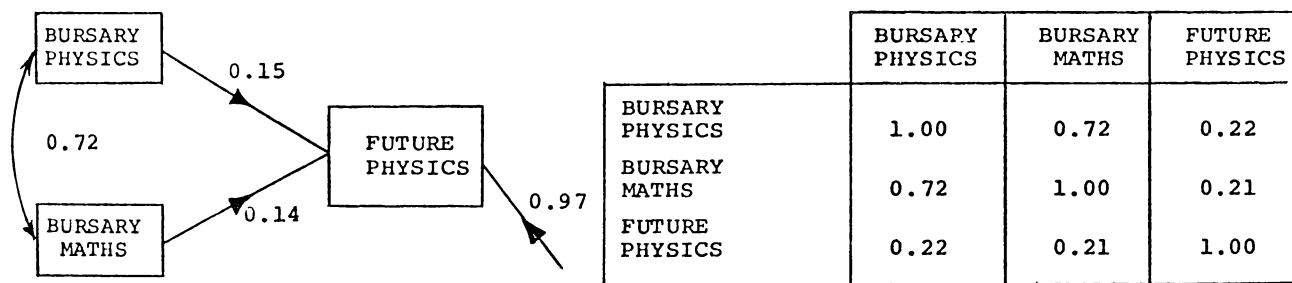


Fig 13.10(b) Model 2(b) (N = 165)

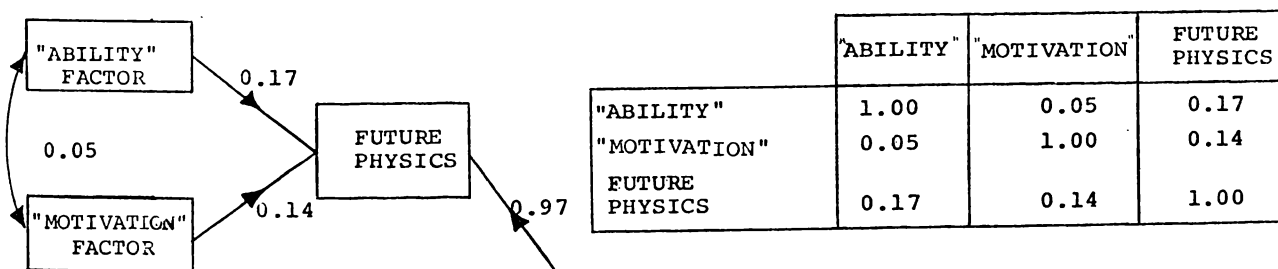


Fig 13.10(c) Model 11(b) Teachers' subjective assessment (N = 170)

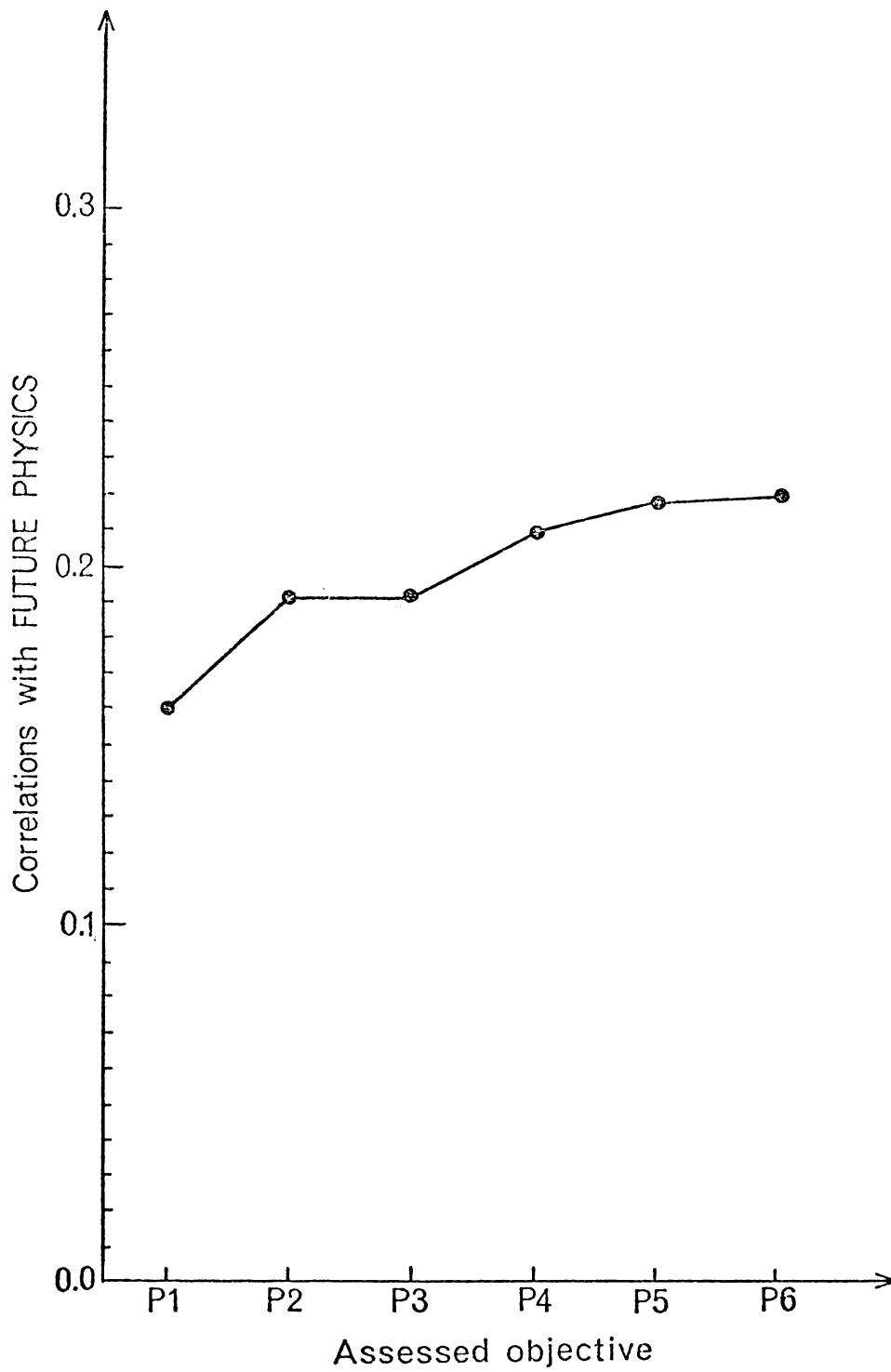


Fig 13.11 Correlation coefficients of the components of teachers' subjective assessment with FUTURE PHYSICS. (N = 170)

Table 14.1 Textbook design - Senior Advanced Physics.

Objective	Textbook design to achieve objective
I	(i) Short sectioned text with plenty of diagrams, each section followed by one or two test-yourself questions to act as a rough guide to basic understanding. (ii) Summaries at the end of each part of the book to co-ordinate ideas (part of objective III).
II	(i) Frequent and fully worked examples, students being encouraged to first find an answer themselves. (ii) Plenty of problems of suitable difficulty with answers supplied. (iii) An appendix on how to solve physics problems.*
III	(i) Discussion questions to extend capable students. (ii) Panel sections in the textbook providing additional material beyond the syllabus. (iii) Summaries including unifying ideas.
IV	Experimental work was explicitly not included in the text as it was available elsewhere. However an appendix on experimental work was provided.**

* Adapted from Pepper (1974)

** Adapted from Osborne (1974a)

Table 14.1 Graduates in schools (1971); graduate production (1967-1971); and stage II enrolments (1965) for New Zealand.*

	Graduates in Schools (1971)	Graduate Production (1967-1971)	Stage II Enrolments (1965)
Physics	163	308	149
Chemistry	359	897	354
Mathematics	496	1036	513
Biology	489	913	-

* For details see Osborne (1973)

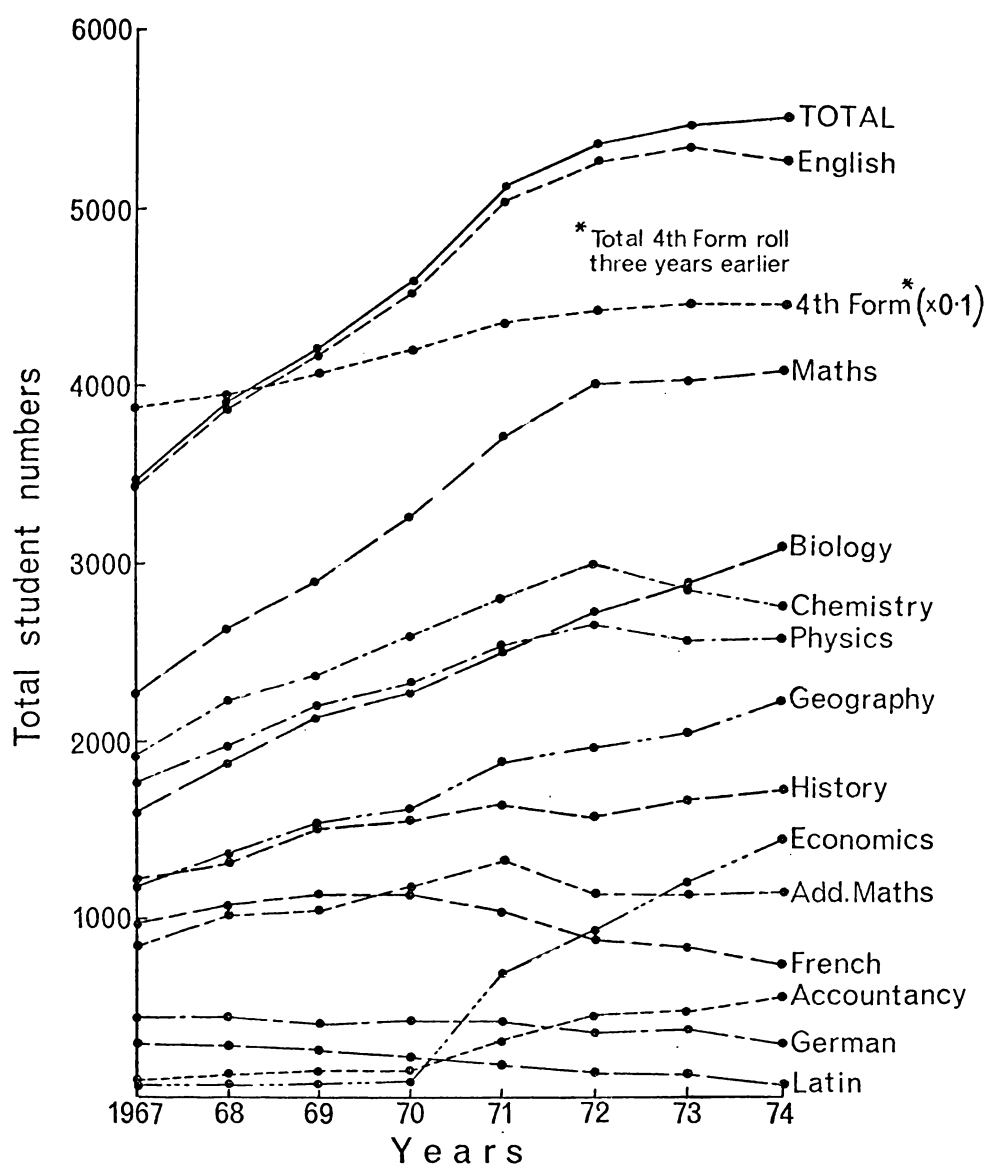


Fig 14.1 State secondary schools: seventh form roll (1st July returns).

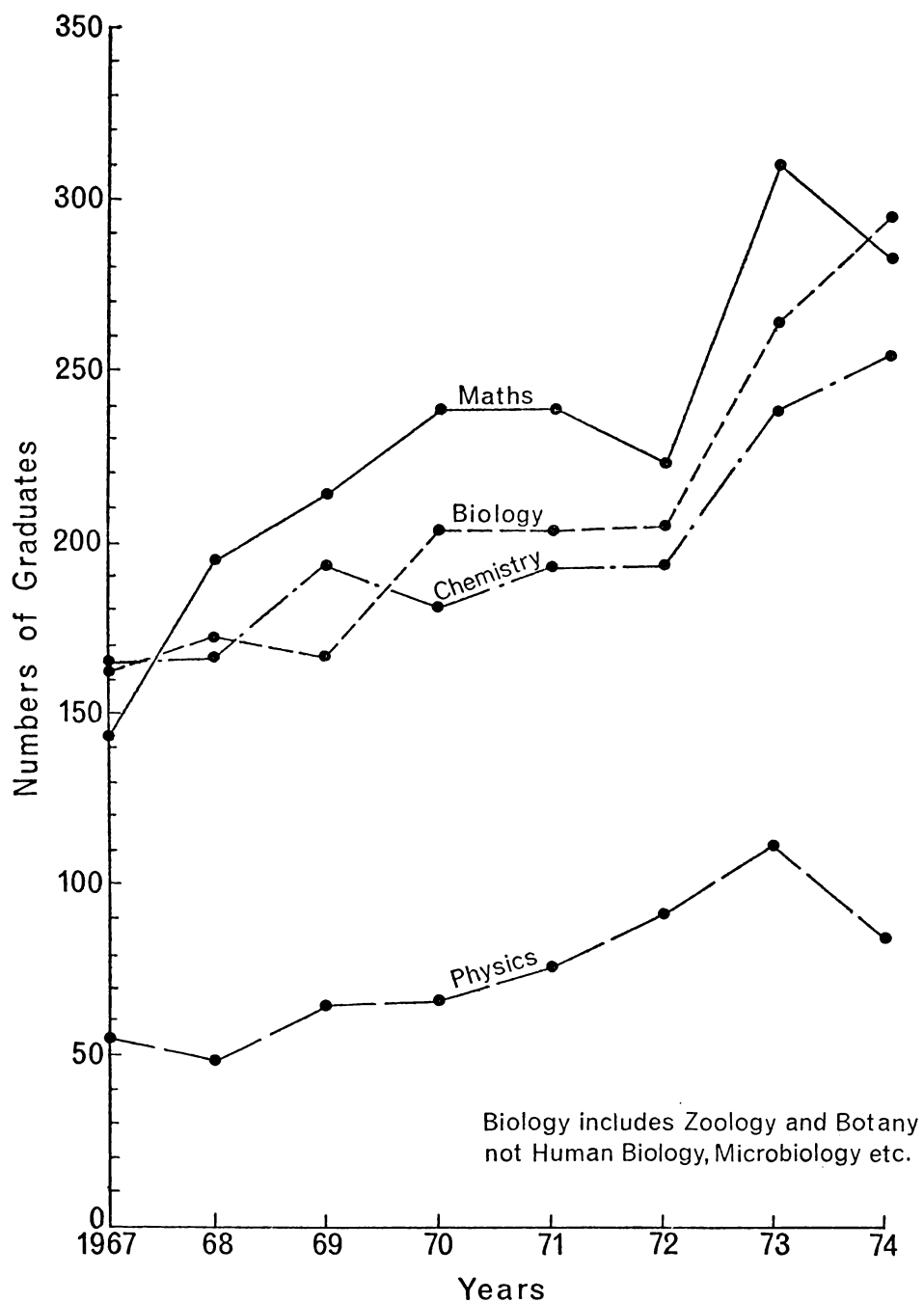


Fig 14.2 New Zealand science graduate production in secondary school teaching subjects 1967 - 1974

Table 15.1 Types of investigations in the evaluation and elucidation of instructional systems.

		EVALUATION			ELUCIDATION		
		CONTEXT	INPUT	PROCESS	PRODUCT	MODEL	
FORMAL AND OBJECTIVE INVESTIGATION	<u>Critical analysis of objectives</u> possible/desirable objectives.	<u>Critical analysis of instructional methods</u> summarized by empirical data if available.	<u>External evaluation</u> classroom interaction analysis.	<u>Measurement of product.</u> input-output measures.	<u>Mathematical or statistical model</u> (specific)	MATHEMATICAL	
SEMI FORMAL AND SEMI OBJECTIVE INVESTIGATION	<u>Teacher questionnaire</u> on importance of objectives	<u>Teacher questionnaire</u> does proposed instructional material appear useful	<u>Student questionnaire</u> instruction difficult easy informative?	<u>Teacher questionnaire</u> do students appear to be achieving goals?	<u>Verbal or graphical model</u> (generalized)		
INFORMAL AND SUBJECTIVE INVESTIGATION	<u>Teachers'/scientists' comments</u> about the course objectives or goals.	<u>Teachers'/students' comments</u> on proposed instructional methods.	<u>Informal comment</u> from students re instruction	<u>Student or society's subjective reaction</u> to value of product.	<u>Subjective perception of</u> of system	NON MATHEMATICAL	

APPENDIX A

BACKGROUND TO THE FIRST YEAR PHYSICS COURSES

A.1 The New Zealand education system

Students enter secondary school at approximately age 13 (third form) and at age 15 (fifth form) offer themselves for their first national examination (School Certificate) in four or five subjects. Approximately 50% of School Certificate candidates present "Science" as one of their subjects. Specialist courses are also offered in biology, physics and chemistry. However, the number of students in these subjects is steadily declining (less than 5% of S.C. candidates offered physics in 1975). Specialist studies start in earnest in the sixth form where no integrated science course is available. Approximately 30% of the sixth form students take physics (chemistry numbers are almost identical) and University Entrance is attained at the end of the sixth form year either by accreditation within the secondary school or by national examination. Most students wishing to pursue a science degree return to school for a seventh form year. To obtain financial support for university most seventh form students sit the Bursary examination in five subjects and some candidates sit a further examination in three of these subjects to complete the Scholarship examination. Approximately 45% of seventh form students took physics in 1972-1974.

The first year physics courses at most New Zealand universities attempt to provide not only a basis for a B.Sc. in physics, or a B.Sc. majoring in some other science, but also an "acceptable" education for students who are subsequently to enrol for a specialist degree (e.g., medicine, optometry, engineering, forestry) in the following year. These specialist degrees are likely to be at some other university.

A.2 The University of Waikato and the establishment of the first year physics courses, 1970

The University of Waikato was established in 1963, and in 1969 a School of Science was established within the university. Undergraduate students were enrolled for the first time in March 1970 for a three year, 22 course, B.Sc. degree, majoring in either Biological Science, Earth Science, Chemistry, Physics or Mathematics. The regulations for the degree were specified in the University of Waikato calendar (University of Waikato, 1970) and were substantially the same during the period of this research project. In the first year of study for the B.Sc. degree, students normally choose four subjects from Biological Science, Earth Science, Chemistry, Physics, Pure Mathematics or Applied Mathematics (vectorial mechanics, statistics and computing). In each of these subjects students usually enrol for the two complementary first year courses offered in each subject (although it is possible to enrol for only one course in a subject). The two first year courses in one subject were planned to be assessed independently, and together they were equivalent to a single first year unit then available (1970) at other New Zealand universities. Each of the 22 courses for the B.Sc. degree at Waikato consists of approximately 3-4 hours class contact per week with a total study time of 6 hours per week.

A.3 Initial implicit objectives (1970)

In establishing a new course stated differences, or similarities, with comparable courses (for example, at other universities) tend to indicate differences in implicit objectives. There has been a tendency in university physics courses for laboratory-based work, whether emphasizing experimental or practical skills or an understanding of basic principles, to be considered unimportant by students and often an appendage to a lecture course. This viewpoint arises because the effort a student puts into such work and the resulting educational attainments

often have had little bearing on the final grade (provided the "practical work" was "completed satisfactorily"). If certain objectives of physics teaching are considered to be more appropriately taught by experimental work and if such objectives are to be emphasized, then a change in the above situation is required. The division of "first year physics" into two separately assessed courses provided an ideal opportunity to do this.

In planning the first year programme:

- (i) It was decided to differentiate the two physics courses in terms of two aspects of physics—experimental physics and theoretical physics—rather than in terms of content, as was the policy in other subjects in the school. The theoretical course (73.101) was to be essentially expository in its approach while the experimental course (73.102) was to have a laboratory-based heuristic approach. The courses were designed to be complementary in that they would cover similar content. However, the experimental course was to be more an indepth study of particular concepts of physics and was to emphasize the relationships between these concepts and the real world. It was not to be a practical course emphasizing experimental skills, but oriented towards an understanding of basic physics, within the constraints of available experimental equipment, and other resources. On the other hand, the theoretical course was to be primarily a lecture series, designed to provide an overview of the major principles of classical physics described at a reasonably sophisticated mathematical level and to demonstrate the theoretical application of physical principles.
- (ii) The physics content of both courses was directed towards the basic principles of classical physics and towards the

appreciation of the unity of the subject as the study of the interaction of particles. This emphasis was seen as necessary for the education of any future physicist, and of more long-term value to the scientist or science-oriented specialist (medicine, optometry, engineering) than technological details.

- (iii) The courses were designed to emphasize comprehension and understanding. Rote learning and recall were to be de-emphasized as much as possible and the use of textbooks rather than lecture notes was to be encouraged.

A.4 Structural decisions made prior to the commencement of teaching

The following structural decisions were made prior to the commencement of teaching in 1970. These decisions were made keeping in mind

- (i) the total university setting explained above, and
- (ii) the educational emphases outlined in Appendix A.3.
 - (a) Staff-student contact. The theoretical course (course 73.101) was designed to have 3 one hour lectures per week and the experimental course (course 73.102) was designed to have a single 6 hour laboratory each fortnight. In addition, a tutorial of one hour per fortnight was scheduled to cover aspects of both courses (95% of students enrolled for both courses). Lectures were to be given simultaneously to all students enrolled in the theoretical course, each laboratory class was to contain up to 32 students (1 staff member plus one assistant), and each tutorial class was to contain about 16 students. Students in the laboratory were to work in pairs and to complete three sets of four experiments in the year. The student pair would be sequentially rotated about the four experiments in each set. Laboratory times were to be 3 hours one afternoon followed by 3 hours the following morning to provide overnight consideration of the experiment by the student.

(b) The textbook, "Fundamental University Physics" (Alonso and Finn, 1967) was chosen as the textbook to provide students with the basic theoretical knowledge required in the courses. This book was chosen as it provided an emphasis on the basic principles of classical physics and also provided an order of treatment which showed the unity of the subject. The lectures were envisaged primarily as providing support for understanding the concepts in, and the content of, the textbook. Graduates refer to published material not lecture notes and it was felt that first year students should be "weaned" from detailed lecture notes and directed towards learning from published material. Also in the laboratory it was decided students should be referred as much as possible to texts for background theory rather than have it provided in a laboratory guide.

(c) Assessment was seen as an integral part of the course structure in that students, particularly at university, are strongly motivated towards achieving "satisfactory grades". To emphasize the textbook rather than the lecture notes the tests and final examination in the theoretical course (73.101) were to be open textbook written examinations. The open book examination was also intended to reduce emphasis on recall and rote learning.

In the experimental course, the importance of understanding the theory on which an experiment was based and the minimal emphasis to be placed on practical skills suggested that the conventional assessment of laboratory books, or reports, was inappropriate. Instead open book written tests and examinations to which students could bring their laboratory accounts, laboratory guides, textbook and so on were considered a more satisfactory assessment procedure and one likely to provide the correct motivation for the course.

(d) Initially the tutorials were conceived as an opportunity for students in small groups of 16 with one staff member to ask questions relating to both courses. It was envisaged that the tutorials would emphasize problem-solving as well as helping students with underlying conceptual difficulties.¹

¹Although the tutorials were concerned with both courses many of the conceptual difficulties in the experimental course were overcome through student-staff discussion in the laboratory. The assessment procedures in that course freed staff from the routine marking of laboratory accounts and hence more time could be given to helping individual students.

APPENDIX B
PATH ANALYSIS

The method of path analysis applies to sets of relationships among variables which are assumed linear, additive and causal. In a predictive model it has no greater predictive power than multiple regression. However, in a structural model it provides a technique whereby the rationale for a set of regression equations can be made explicit. Basically, as Tatsuoka (1973) has stated, path analysis reflects a desire of the researcher to go beyond purely statistical relationships to the development and testing of models which hypothesize the structure of the relationships. Assertions made by tentative models may be refuted by observed data.

Introductory accounts of path analysis are provided by Duncan (1966), Land (1969) and Tatsuoka (1973), while the problems of using the technique have been discussed by Heise (1969). Briefly, path analysis involves selecting the variables, determining the order of variable causation, drawing the path model, and testing the model.

As a very simple example of the use of path analysis, consider three variables X_1 , X_2 and X_3 where X_3 is assumed to depend linearly on X_1 , X_2 and a residual term X_a i.e., $X_3 = a_{31}X_1 + a_{32}X_2 + a_{3a}X_a + a$.

Usually it is more convenient to treat the variables in standard form, each with mean zero and unit standard deviation. Hence

$$Z_3 = p_{31}Z_1 + p_{32}Z_2 + p_{3a}Z_a \quad \dots \dots \dots I$$

A path diagram of this model is given in Figure B.1 where p_{31} , p_{32} and p_{3a} are known as path coefficients or standardized path coefficients.

In path diagrams one-way arrows lead from each determining variable to each variable dependent on it. Unanalyzed correlations between

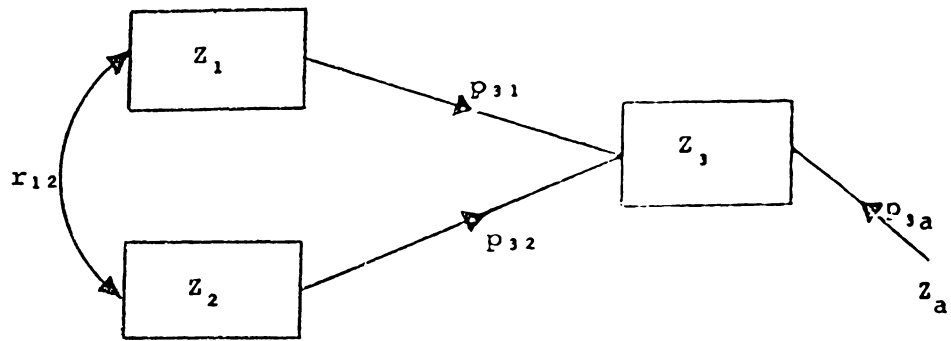


Fig B.1 A simple path diagram - one dependent variable Z_a

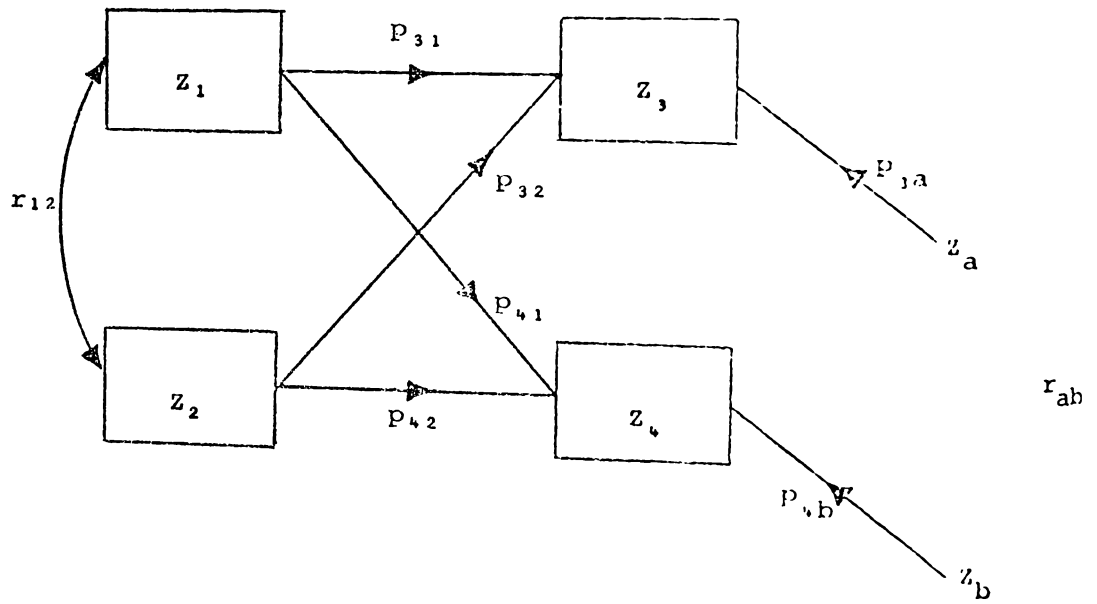


Fig B.2 A simple path diagram - two dependent variables.

variables not dependent on others in the system are shown by two-headed arrows and curved lines. Residuals are also represented by uni-directional arrows leading from the residual variable to the dependent variable (however, literal subscripts are attached to residual symbols to indicate that they are unmeasured). The quantities alongside the paths are symbolic or numerical values of the path, or correlation, coefficients of the postulated causal, or correlation, relationships respectively.

Assuming r_{12} represents the correlation coefficient between variable Z_1 and Z_2 in Figure B.1, then a system of structural equations can be derived from Figure B.1 and equation I. Namely,

$$r_{31} = p_{31} + p_{32}r_{12} \quad \dots \quad \text{II}$$

$$r_{32} = p_{32} + p_{31}r_{12} \quad \dots \quad \text{III}$$

$$r_{33} = 1 = p_{31}r_{31} + p_{32}r_{32} + p_{3a}^2 \quad \dots \quad \text{IV}$$

hence

$$p_{3a}^2 = 1 - (p_{31}^2 + p_{32}^2 + 2p_{31}p_{32}r_{12})$$

therefore

$$p_{3a} = \sqrt{1 - R^2}$$

where R is the multiple regression coefficient of Z_1, Z_2 on Z_3 and

$$p_{31} = \frac{r_{31} - r_{32}r_{12}}{1 - r_{12}^2} = \text{standardized partial regression coefficient} = \beta_{31}$$

Similarly $p_{32} = \beta_{32}$. An advantage of path analysis is that it helps in the interpretation of familiar statistical quantities.¹

¹(a) p_{3a} is the coefficient of alienation (see Guilford, 1965, p.376) and from path analysis can be interpreted as the path coefficient of a dummy variable (residual) having unit variance and zero mean representing all unmeasured variables which cause variation in Z_3 ;

(b) path analysis provides an interpretation of the correlation between any two variables as the sum of direct and indirect effects. The direct effect of Z_1 on Z_3 is estimated by the path coefficient p_{31} while the indirect effect is provided by the compound path $r_{12}p_{32} = r_{31} - p_{31}$.

Path coefficients can be determined numerically from the observed correlations either by direct solution of the equations or by obtaining the standardized regression coefficients, determined, for example, from the multiple regression of Z_1 and Z_2 on Z_3 . If all possible paths of one-way causation have been postulated there is a one-to-one correspondence of the coefficients of the structural equations of the path model with the estimated path coefficients. For path models of this type there are no conditions imposed on the model that can be used to test its adequacy. The model however may be adapted in the light of the observed data by removing all postulated paths except those found to be statistically significant (for example, as estimated by an F test) at a given criterion of significance (say, 5% for $N = 100 - 500$). On the other hand if all possible paths are not postulated in the hypothesized model, over-identification will arise and this allows a test of the fit of the model under assumed conditions. As a simple example, it might be postulated that p_{32} is zero in the path diagram Figure B.1, then the equations II and III reduce to $p_{31} = r_{31}$, $p_{32} = p_{31}r_{12}$. If these relationships hold for the computed coefficients then the model is not rejected. While Land (1969) considers that the structural equation (e.g., I to IV above) constitute the path model, in this thesis the path diagram including all numerical parameters is considered to constitute the model as all structured equations can be derived from such a diagram.

In Figure B.2 a second dependent variable, Z_4 , is also assumed to be dependent on Z_1 and Z_2 . Generalizing equations II to IV, the basic equation of path analysis is

$$r_{ij} = \sum_q p_{iq} r_{jq} \quad \dots \quad v$$

where q runs over all variables that lead directly to Z_i . Hence

$$r_{32} = p_{32} + p_{31}r_{12}$$

$$r_{42} = p_{42} + p_{41}r_{12}$$

$$r_{31} = p_{31} + p_{32}r_{21}$$

$$r_{41} = p_{41} + p_{42}r_{21}$$

$$p_{3a}^2 = 1 - p_{31}^2 - p_{32}^2 - 2p_{31}p_{32}r_{12}$$

$$p_{4b}^2 = 1 - p_{41}^2 - p_{42}^2 - 2p_{41}p_{42}r_{12}$$

Although the residuals (p_{3a} and p_{4b}) are unlikely to be zero, particularly in educational systems, it is still possible for the independent variables to account for the intercorrelations of the dependent variables and the aim of the researcher might well be to discover such independent variables. If the independent variables do not account for the correlations between dependent variables then the residuals will be correlated and from V

$$r_{34} = p_{31}r_{14} + p_{32}r_{24} + p_{3a}p_{4b}r_{ab}$$

hence the correlation r_{ab} between the unmeasured residuals can be determined from the observed data.

APPENDIX C

TYPICAL SUMMARY, SELF EVALUATION SHEETS AND TUTORIAL SHEETS

(for Alonso and Finn Physics, Chapter 8)

- C.1 Summary sheets for Chapter 8 issued in evaluation session for Chapter 8 (1974).
- C.2 Self evaluation questions and problems--used in evaluation session for Chapter 8 (1974).
- C.3 Tutorial sheet for Chapter 8 following above--issued in tutorials in Teaching week 7 (1974).

C.1 Summary sheetsUNIVERSITY OF WAIKATOPHYSICS 73.101Summary 6

(Alonso and Finn, Ch 8)

1. Impulse (I) (8.1)

$$\underline{I} = \int_{t_0}^t \underline{F} \cdot dt = \underline{p} - \underline{p}_0$$

where \underline{p} is the momentum at t \underline{p}_0 the momentum at t_0 .2. Work and Kinetic Energy

i) Work (W) (8.2)

$$W = \int_A^B \underline{F} \cdot \underline{dr} = \int_A^B F_T ds$$

where W = work done by the force \underline{F} moving a particle from A to B . F_T = component of \underline{F} along the path .

ii) Power (P) (8.3)

$$\begin{aligned} P &= \frac{dW}{dt} \\ &= \frac{d}{dt} (\underline{F} \cdot \underline{dr}) \\ &= \underline{F} \cdot \underline{v} \text{ if } \underline{F} \text{ is constant.} \end{aligned}$$

iii) Kinetic Energy (E_K) (8.5)

$$\begin{aligned} W &= \int_A^B F_T ds = \frac{1}{2} mv_B^2 - \frac{1}{2} mv_A^2 \\ E_K &= \frac{1}{2} mv^2 = \frac{p^2}{2m} \end{aligned}$$

3. Conservative Forcesi) A force \underline{F} is conservative if

$$\oint \underline{F} \cdot \underline{dr} = 0 \quad (8.8)$$

ii) Potential Energy (E_P) (8.8)

$$E_{P,B} - E_{P,A} = - \int_A^B \underline{F} \cdot \underline{dr}$$

iii) Conservation of Energy (8.10)

$$\text{Total Energy} = E = E_K + E_P = \text{CONST.}$$

IV) Force and Potential Energy (8.9)

$$F_x = -\frac{dE_P}{dx}$$

$$F_y = -\frac{dE_P}{dy}$$

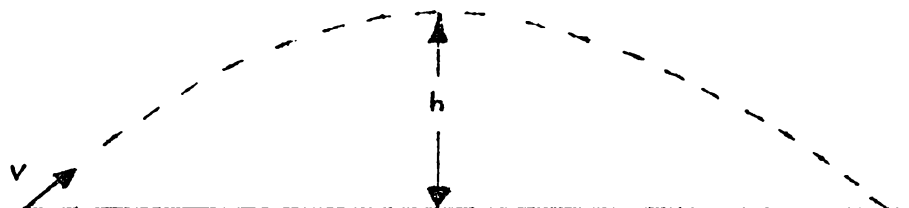
$$F_z = -\frac{dE_P}{dz}$$

4. Non Conservative Forces (8.12)

$\frac{d}{dt} (E_K + E_P) = \frac{dW'}{dt}$ where W' is the work done by non conservative forces.

C.2 Self-evaluation questions and problemsUNIVERSITY OF WAIKATOPHYSICS 73.101Problem Sheet 6

1. What is the power used by a 40 kg boy if he rides up a hill whose gradient is 4° on a 10 kg bicycle at 5 m s^{-1} . The frictional force is 20N.
- A. 27.5 watt
 B. 55 watt
 C. 175 watt
 D. 275 watt
 E. 550 watt
2. A small lead mass hanging from a string swings as a pendulum. The work being done on the bob by the tension in the string is
- A. greatest when the mass is rising most rapidly.
 B. greatest when the mass is passing through either end of its swing.
 C. greatest when the ball is at its lowest point.
 D. greatest when the ball has just passed the lowest point of the swing.
 E. zero.
- 3.



The initial horizontal component of velocity of the projectile in the above figure is

- A. $\sqrt{v^2 - 2gh}$
 B. $\sqrt{v^2 + 2gh}$
 C. $\sqrt{v^2 + gh}$
 D. v
 E. $\sqrt{v^2 - gh}$

4. A particle moves under a force described by the potential energy function $E_p(x) = -2x^2$. The force on the particle is given in vector form by
- A. $\underline{u}_x (4x)$
 - B. $\underline{u}_x (2x^2)$
 - C. $+\underline{u}_x (-4x)$
 - D. $-4x$
5. A body is falling through a viscous fluid starting from rest. When the body is travelling at its terminal velocity, show that the rate of dissipation of total energy is equal to $\frac{m^2 g^2}{K \eta}$.
6. A particle, mass m , moves in a vertical circle on a string. Show that the difference in tension in the string at the top and bottom of the string is equal to $6 mg$.

C.3 Tutorial sheetUNIVERSITY OF WAIKATOPHYSICS 73.101

Tutorial 7 - Chapter 8

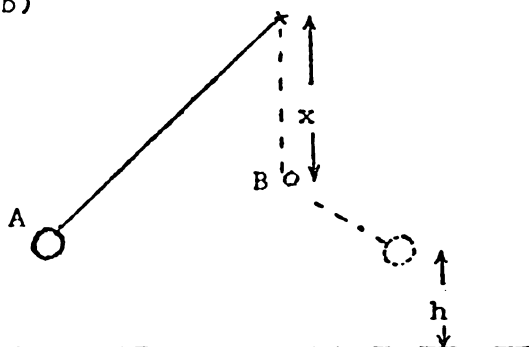
Week 8

Problems in Ch 8

- 8.6 100N
- 8.8 $1.04 \times 10^4 \text{W}$, $1.04 \times 10^5 \text{J}$
- 8.19 (Remember $\frac{k}{r^2} = \frac{mv^2}{r}$; $E_K = \frac{1}{2} mv^2$ and see Example 8.7 for E_p ; $E = E_p + E_K$)
- 8.25 Approx. 7cm (Read Example 8.3, and assume $x \ll 1\text{m}$)
- 8.35 (Stable $x=0$, Unstable $x=2$)
- 8.23 (Answer in book correct for $g = 9.8 \text{m s}^{-2}$)

Discussion Questions

1. When the bob of a simple pendulum is released at A, a nail catches the string at B. If the ball is always released from the same point, how does h vary as x is varied? (h is the max height reached by the bob)



2. A manufacturer makes the following claim about a new ball for children. "The super ball is so elastic that when dropped from rest onto a concrete floor it will rebound to 1.05 times its original height." Comment.
3. Potential energy is not uniquely defined, as its value at any point depends on the arbitrary assignment of zero potential energy. Is kinetic energy uniquely defined?
4. A stationary observer watches a 1 kg mass fall 0.6 m increasing its speed from 2 m s^{-1} to 4 m s^{-1} . The work done is $F \cdot d = 10 \times 0.6 = 6 \text{J}$ and the gain is $E_K = \frac{1}{2} mv'^2 - \frac{1}{2} mv^2 = 6 \text{J}$. An observer falling at 2 m s^{-1} (parachutist!) observes the physical situation and considers the speed increases from 0 m s^{-1} to 2 m s^{-1} , a kinetic energy increase of 2J. However, force and distance are invariant under a Galilean transformation, so the work done was 6J. Where is the extra energy?

APPENDIX D

EXTRACTS FROM EXPERIMENTAL PHYSICS

R.J. Osborne
University of Waikato, 1974

- D.1 Content of 73.102 from Experimental Physics, p.(iii).
- D.2 Introduction to 73.102 from Experimental Physics, p.1-2.
- D.3 A typical experiment with objectives annotated, Experiment 11
from Experimental Physics, p.117-125.
- D.4 Extract from self-evaluation questions from Experimental Physics,
p.169.
- D.5 Typical test and examination questions from Experimental Physics,
p.174.

D.1 Experimental Physics: List of ContentsEXPERIMENTAL PHYSICSIntroduction

1.	Experimental Physics	1
2.	Laboratory Notebooks	3
3.	Errors	13
4.	Graphical Analysis	18
<u>Set A Experiments - Measurement and Dynamics</u>		21
1.	Measurement and Probability	21
2.	Measurement and Laboratory Skills	29
3.	Frictionless Linear Dynamics	41
4.	Frictionless Dynamics	51
<u>Set B Experiments - Fields</u>		59
5.	Electron Dynamics in a Vacuum	59
6.	Forces and Potential Energy Relationships	69
7.	Electron Dynamics in a Conductor	77
8.	Magnetic Fields	88
<u>Set C Experiments - Waves</u>		99
9.	Interference	99
10.	Wave Geometry	109
11.	Polarization and Diffraction	117
12.	Light and Electron Waves	127
<u>Appendix</u>		139
1.	Gaussian Function and Integral Function	139
2.	Summary of Errors	140
3.	Theory	142
4.	The cathode ray oscilloscope	144
5.	Sign convention in optics	152
6.	Self evaluation questions	158
7.	Typical course evaluation questions	174

D.2 Experimental Physics: Introduction

INTRODUCTION

1) Experimental Physics (Course 73.102)

The course consists entirely of experimental work and the aim of the course is that you (as a student taking this course) should,

- i) obtain an understanding, and an ability to use in specific situations, some of the important principles and theories of physics.
- ii) come to know better the difficulties involved in relating experimental observations to physical laws, and to become more aware of the limitations of physical laws.
- iii) be able to propose simple tentative explanations for observed facts, and to not only make predictions from these explanations, but to plan experiments to test these predictions.
- iv) be able to record and analyze experimental results in graphical and mathematical forms and to make valid conclusions from observations and data.

In other words we wish to give you, by means of this course, an appreciation of physics and feel for the subject.

For specific examples of how the above aims relate to your laboratory work, consider the following:-

- i) To enable you to use theoretical ideas more effectively the aim of a number of experiments is for you to make predictions from theory and to test these predictions in the laboratory.
- ii) In judging whether a theory applies to a particular situation you will need to consider carefully the approximations and idealizations in a theory.
- iii) As part of planning experiments you will need to consider, for example, what measurements should be made to best test a theory or investigate a fact.
- iv) To make conclusions from data, you will need to carefully analyze your results to evaluate any discrepancy between theory and experiment.

Most of the principles and theories used in this course will be found in your textbook "Physics", Alonso and Finn, Addison-Wesley 1970, and it is therefore essential that you bring this book with you to the laboratory sessions. In many instances details of

experimental procedures and the analysis of the theory involved in a particular experiment will be left to you. This will require both study and thought, both before you come to the laboratory (in terms of what the experiment is about, referring to texts, film loops, etc) and while you are in the laboratory (in terms of the most suitable experimental set-up, etc). So that you might evaluate your understanding of any particular experiment and the theory related to it, a set of questions is provided in the appendix. Where any further theory, in addition to that required to understand an experiment, is expected to be understood as part of this course, specific reference to this will be made.

Tests and the end of year examination in this course will consist of theoretical papers which will involve questions relating to the course aims (for example see p.174). In particular, questions will relate to results obtained, conclusions drawn, knowledge of background theory, and the use of theory and apparatus in specific situations you will have met in this course and also in situations which may be novel to you. The examinations are open book exams to which you should bring this book, your laboratory notebook and your textbook. Details of your experimental procedures, your results, conclusions etc. should be fully recorded in your notebook as you will need to refer to these during the examination. (See page 3 for further details.)

Each experiment is designed for a six hour laboratory session. If you are well prepared before you come to the laboratory about 75% of the time available will be used in setting up your apparatus and obtaining results. The remaining 25% of the laboratory session time should be used in analysing and evaluating your results. If you have time you should proceed with the additional work at the end of the experiment. Although this work may be helpful, it will not be directly examined. While it is hoped that you will be able to learn, study and experiment without much help from the laboratory demonstrators, if you feel that you are making no progress with a particular aspect of an experiment do not hesitate to seek advice. Time in the laboratory is too valuable to waste.

In each experiment, normally one section is marked by an asterisk and often involves an open ended investigation. Emphasis should be given to a thorough investigation of all aspects of this section with careful consideration to the planning of your experiment and to the interpretation of your results.

We hope that you find the course both challenging and stimulating and that you gain satisfaction in searching for an understanding of physical phenomena.

D.3 Typical experiment—with objectives annotated

Objectives emphasized by the activities

Experiment 11: Polarisation and Diffraction11.0 Introduction

I (A) } γ ray, X-rays, Ultra-violet, Light, Infra red rays, Microwaves,
 I (B) } and Radio waves are all electromagnetic waves (Alonso and Finn,
 III (C) } Ch.24.8). They differ in wavelength, from γ rays (10^{-11} m) to radio
 waves (10^4 m), and in the way they are produced, used, and detected.

The properties of waves in general, and electro-magnetic waves in particular, can be studied very conveniently with microwaves which have a very suitable wavelength ($\lambda \approx 3$ cm) for work in the laboratory. Microwaves for example show all the phenomena characteristic of light but with the enormous advantage that fine scale effects, such as diffraction, (which are difficult to observe with light) become "gross" effects.

The source of microwaves is a klystron. This device consists of a resonant cavity in which bunches of electrons are made to oscillate. These oscillations result in the production of electro-
 I (C) magnetic radiation which have maximum intensity when the frequency is at the resonant frequency of the cavity.

The radiation from the klystron is emitted through a horn, which produces a reasonably well collimated beam. The waves are detected by a crystal diode mounted at the end of a second horn. The meter on the detector indicates, in arbitrary units, received beam intensity.

Set up the transmitter (oscillator) and receiver (detector) about 50 cm apart both in the upright position so that the klystron in the transmitter and the diode in the detector are both vertical. So that you may hear the detected signal the transmitted signal can be modulated.
 IV (B) Set the internal modulation of the power supply to 1000 Hz and adjust the reflector voltage for maximum microwave intensity. (The meter on the receiver should show almost maximum deflection when positioned at P in the diagram below.)

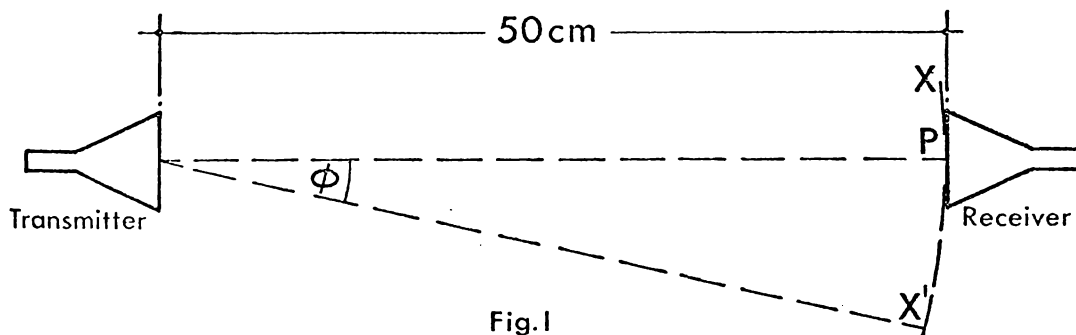


Fig.1

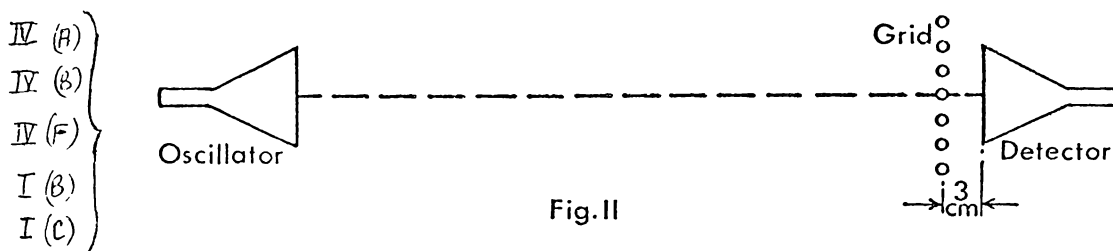
Notice the variation of beam intensity with angle of emission, ϕ . (No measurements need be recorded.)

PART AI(A)/I(c) 11.1 Polarisation (Alonso & Finn, Ch.23.6, 26)

The klystron produces a monochromatic wave which is plane polarised. The plane of polarisation, the plane in which the electric field oscillates, is vertical when the transmitter is operated in its usual (upright) position. The diode detector responds only to the component of the electric field in the vertical direction when the receiver is in its normal (upright) position.

- I (β) }
 I (c) }
 III (β) }
 IV (A-F) }
 V (β) }
- i) With the detector at P, investigate and explain the effect of rotating the transmitter horn about the line joining it and the detector horn. What relationship do you expect between received intensity and rotated angle? Attempt to experimentally verify your hypothesis by plotting a suitable graph of received intensity versus whatever function of rotated beam angle you consider will produce a linear relationship ($\sin \theta$, $\cos \theta$, $\cos^2 \theta$??). Why rotate the transmitter rather than the detector?

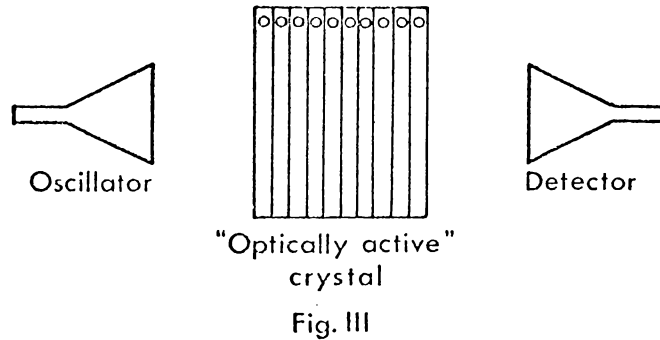
- ii) With the oscillator and detector set up at P with diode and klystron both vertical, place the screen of parallel wires about 3 cm in front of the receiver. Predict how the grid will affect the microwave beam when the wires are (a) vertical, (b) horizontal.



Rotate the grid about the line joining the oscillator and detector noting variation in beam intensity. Do you find the result to be as you predicted? Since the electrons can move only along the wires (assuming the wires are thin) they can respond only to that component of an incoming wave which is polarised with the electric field in that direction. The electrons oscillate in response to such a component and in doing so re-radiate. The result is that the radiation is almost entirely reflected.

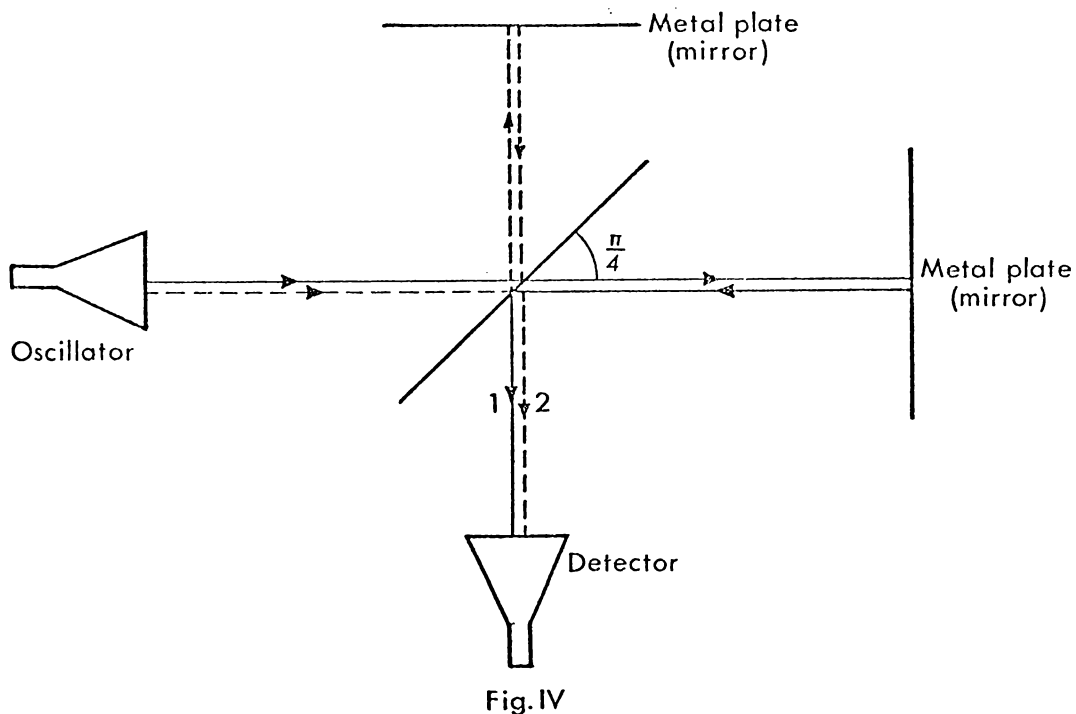
- I (β) }
 I (c) }
 IV (β) }
 IV (F) }
 VI (β) }
- iii) Rotate the oscillator 45° with respect to the line joining the oscillator and detector. With the grid wires horizontal compare the intensity of the transmitted wave when the diode is (a) vertical, (b) horizontal. Can you explain your results?
- I (β) }
 I (c) }
 IV (F) }
 VII (β) }
- iv) Rotate the oscillator through 90° from its vertical position so that the diode and klystron are mutually perpendicular. Rotate the grid slowly about a line joining transmitter and receiver. Can you explain your observations?

- I (a) }
 I (b) } v) The plane of polarisation of E/M waves may be rotated by a
 I (c) } substance which is "optically active". This is discussed in
 IV (b) } Alonso and Finn, Ch.26.10. "Optical active crystals" for the
 IV (c) } microwaves are provided. Determine, using the microwaves,
 IV (f) } whether each crystal is dextro rotatory or levo rotatory and
 estimate the angle θ through which the plane of polarisation
 is rotated by the crystal, per unit length.



11.2 Determination of the Wavelength of the Microwaves - the Michelson Interferometer (Alonso and Finn, p.95)

A microwave version of the Michelson Interferometer can be made with two metal reflectors and a partially reflecting hardboard sheet. Arrange these as in the figure below.



Move one of the mirrors forward slowly. The received signal at

the detector will pass through maxima and minima corresponding to constructive and destructive interference of beams 1 and 2, in the above figure.

IV (B) } Carefully align the apparatus for maximum contrast between maxima
 IV (C) } and minima. The distance between two adjacent positions of the mirror
 IV (E) } which produce maximum (or minimum) receiver intensity is, $\frac{\lambda}{2}$. Use the
 apparatus in the best way possible to obtain an accurate measurement
 of the wavelength of the microwaves. Estimate the error in your result.

I (B) } Alternatively, if the wavelength is known the distance the metal
 IV (B) } plate has been moved can be accurately determined. This principle
 is made use of in the optical Michelson Interferometer where small
 distances can be measured accurately in terms of the wavelength of light.

I (A) } The use of the interferometer in the Michelson-Morley experiment
 I (B) } is discussed in Alonso and Finn, Ch.6.8.

11.3 Diffraction

I (A) i) Fraunhofer Single Slit Diffraction (Ch.29.3)

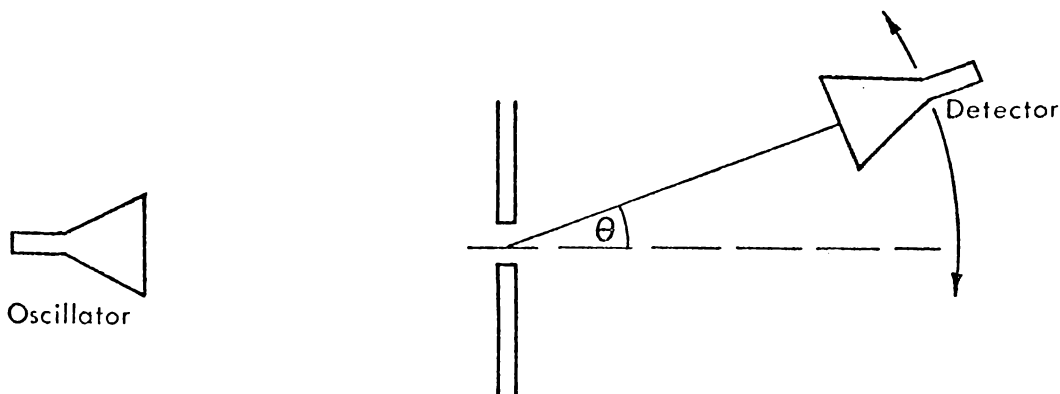


Fig.V

I (A) } Set up a single slit using two metal plates with a "slit"
 I (B) } between them (as in Fig V). If you are unfamiliar with the
 diffraction pattern from a single slit, study the film loop
 (M.12) on the subject and Alonso and Finn, Ch.29.3.

I (C) Use your value of the wavelength obtained in 8.2 and the
 theory of Ch.29.3 to predict a slit width which will produce a
 suitable diffraction pattern, i.e. one which includes some
 positions of zero intensity ($b > \lambda$).

I (B) } Notice the variation of intensity with angle θ . Determine
 I (C) } carefully the angular positions of zero intensity and compare with
 theoretical predictions.
 III (B) }
 IV (F) }
 IV (A) } ii) To investigate diffraction around an object set up the

circular metal disk as shown in Fig VI.

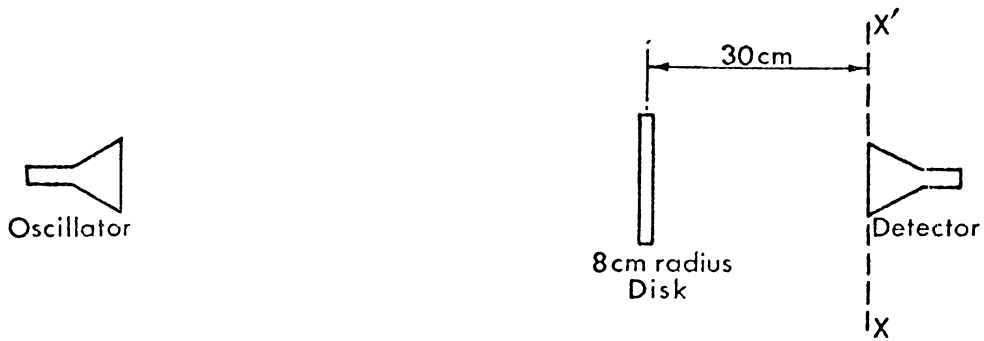


Fig. VI

- IV (b)
- IV (f)
- I (a)
- I (b)

Investigate the variation of the beam intensity with position along XX'. Do you find your results surprising particularly in the region directly behind the disk? Can you explain your results? (See Alonso and Finn, Fig 29.25)

Film Loop Reference: M.14 - Diffraction around objects

PART B

11.4 Standing Electromagnetic Waves

Read Alonso & Finn Ch. 28.5.

- I (a)
- I (b)
- I (c)
- IV (b)
- IV (f)
- V (b)

To study standing waves set up a metal plate and oscillator as shown in Alonso and Finn Fig. 28.22. To detect the standing wave it is essential to use the omnidirectional probe (connect it directly to the loudspeaker) rather than the horn detector. Why? Verify that the amplitude of the standing wave has maximum and minimum values at the points predicted by theory, near the plate.

11.5 Fresnel Half Period Zones

- I (a)
- I (b)

Study carefully Alonso and Finn, Ch.29.7

Set up the Fresnel half period zones about 1m in front of the oscillator, as shown in Fig VII . (If a probe detector is available use this to determine the intensity at point, P, rather than the horn detector.)

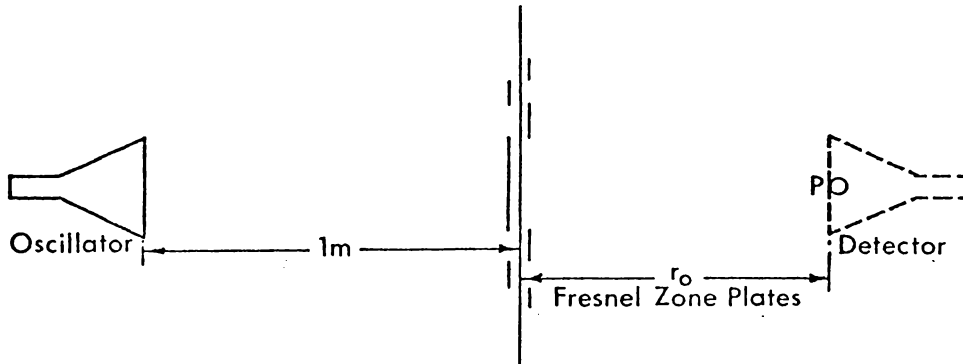


Fig. VII

IV (b) } With the centre zone only removed a maximum of intensity is
 E (a) } obtained at a distance $r_0 = \frac{a^2}{\lambda}$ behind the plates. With the
 detector positioned at this point remove in turn each of the
 remaining plates. Is the variation of the received intensity
 (qualitative only) as you might intuitively expect?

For example, notice the change in intensity when in addition
 to the removal of the central zone, (a) the second zone, or
 (b) the third zone is removed.

I (a) } With the help of Alonso and Finn try to explain these
 I (b) } effects. Try to predict whether the intensity will increase or
 I (c) } decrease when certain zones or combination of zones are removed.
 III (a) } Check your predictions experimentally. (As an understanding of
 V B } the idea of Fresnel zones only is required no qualitative results
 are required.)

*11.6 Bragg Scattering

Study carefully Alonso and Finn, Ch.29.9 which deals with
 Bragg Scattering of X-rays by crystals.

With microwaves we are able to set up an analogue of this experi-
 mental procedure using a "crystal" consisting of aluminium spheres
 mounted inside sheets of plastic foam (which are transparent to micro-
 waves). This analogue is possible as the ratio of crystal molecular
 distance to the wave-length of X-rays, corresponds to the ratio of the
 distance between aluminium spheres to the wavelength of microwaves.

Carefully set up the lenses, detector and oscillator as in Fig VIII
 to obtain a parallel beam over the turntable and maximum beam intensity
 at the detector.

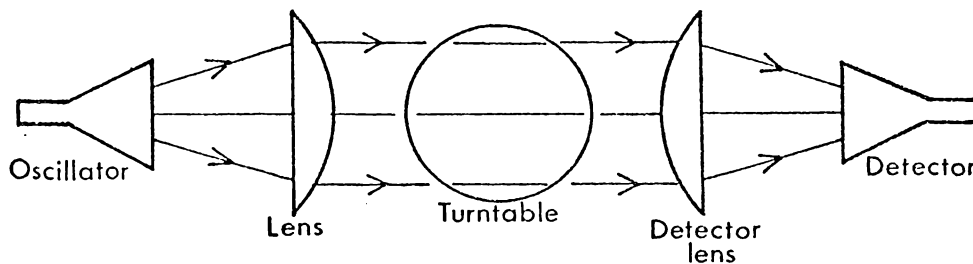


Fig. VIII

IV (b) } Place the "crystal" on the turntable so that the longest edges
 of the "crystal" are vertical. Rotate the crystal as slowly as
 possible using the motor. With the turntable rotating slowly,
 rotate the detector-lens system and use the loudspeaker to locate
 maximum intensity peaks in the reflected beam (see Fig IX).

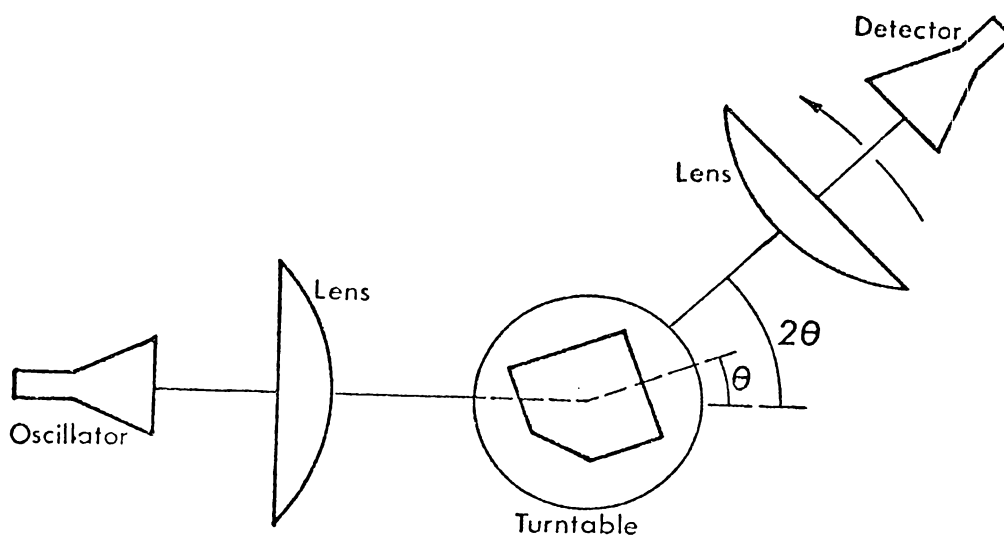


Fig. IX

I (b) } When the first position 2θ is found which gives maximum intensity
 I (c) } peaks, stop the motor and adjust by hand for true maximum intensity position. Use Bragg's equation to calculate the probable distance d between the planes of the spheres (assume $n = 1$ for the first maximum and notice carefully the plane in the crystal which is "producing" the reflected beam).

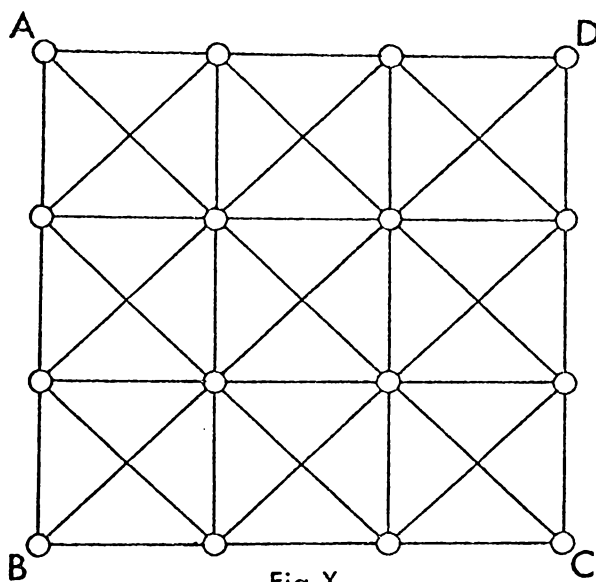


Fig. X

IV (a) } Assuming the spheres are regularly spaced as shown, use your first
 IV (b) } result to hypothesize on other positions of the crystal and detector
 V (a) } system which will give a strongly scattered beam. Check these
 V (b) } experimentally and hence try to confirm the position of, and distances
 VI (a) } between, spheres in the crystal. (Establish, for example, if the
 VI (b) } distance between planes parallel to AD is the same as the distance
 VII (a) } between planes parallel to AB.)

- IV(A) }
 IV(C) } To investigate the distance between "horizontal" planes in the
 IV(F) } crystal reposition the crystal so the "longest" edges are horizontal
 V(C) } and repeat the above analysis. Hence combining your results try
 to reach a conclusion regarding the three dimensional structure of
 the "crystal". (Introduce into the analysis as many crosschecks as
 possible.)

Film Loop Reference: M.6 - Bragg reflection of waves

11.7 Interference (Alonso and Finn, Ch.28.2)

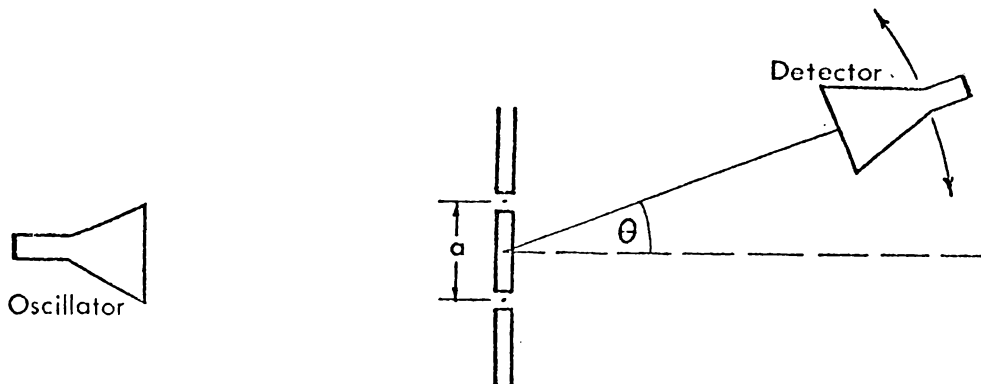


Fig.XI

- I(B) }
 I(C) } Set up a double slit as shown in the diagram. If you are
 III(B) } unfamiliar with double slit interference patterns, study the first
 part of film loop M.13. The position of the nth nodal line, is
 given by

$$\sin \theta = \frac{(n - \frac{1}{2})\lambda}{a} \quad \text{--- I}$$

- III(C) }
 IV(F) } Adjust the slit width to obtain a suitable interference pattern
 V(B) } i.e. one which includes at least one pair of nodal lines. Predict
 the position of the nodal lines using equation I. Are your predictions
 correct?

- I(A) } What effect should the slit width have on the interference pattern?
 I(B) } Refer Alonso and Finn, Ch.29.5.

I(C) }
 Film Loop Reference: M.10 - Interference of Waves
 M.13 - Multiple Slit Diffraction

Additional Work

11.8 Reflection

(i) Total Internal Reflection.

Set up the two horns as shown, so as to obtain total internal reflection from a prism face.

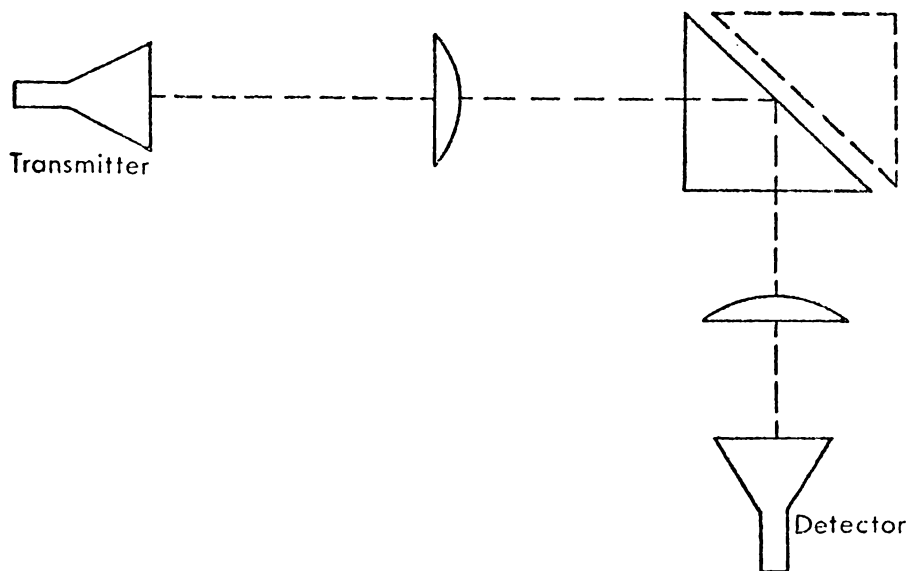


Fig. XII

Bring up a second prism, as shown by the dotted outline, with a face close to the prism face at which total internal reflection occurs. Measure the strength of the received signal as a function of separation between the two prisms. What is the intensity distance relationship when the distance is between zero and one wavelength?

This phenomena, sometimes called "frustrated internal reflection", is analogous to the quantum-mechanical effect known as the "tunnel effect", whereby a particle leaves a radioactive nucleus passing through a potential barrier.

How close would two glass prisms have to be for 50% transmission of light?

Film Loop Reference: M.5 - Barrier Penetration by Waves

ii) Lloyds Mirror

Set up a microwave analogue of Lloyd's Mirror and use it to determine the wavelength of the microwaves.

D.4 Example of self-evaluation questionsExperiment 11

- I(b) 1. What is meant by 'the microwaves are modulated by a 1000 Hz signal'?
- II(A) 2. A microwave transmitter and detector are both vertical (see Exp 8) and the received intensity is I_0 . If the detector is rotated through 45° about the transmitter-detector line what, according to theory, will be the received beam intensity?
- II(c) 3. In a single slit diffraction experiment a student is unable to locate any positions of minimum intensity. The slit width is 2 cm. Can you make any statement about the wavelength of the waves?
- II(F) 4. In a diffraction experiment a student locates the first minimum at 40° on one side of the central maxima, and at 50° on the other side of the central maxima. The width of the slit is 3 cm, what is the best estimate for the wavelength of the microwaves?
- II(A) 5. A mirror in an optical Michelson Interferometer is moved through 0.233 mm. 792 fringes (minima) are counted. What is the wavelength of the light?
6. In a 3 cm Bragg scattering experiment a 'crystal' was used where the distance between spheres was 4 cm. What values of θ would you expect for peak reflected intensity, from the planes parallel to
- II(B) i) AB
ii) BD (see figure in Section 11.6)
- II(B) 7. In a double slit interference pattern the distance between slits is 3 cm. If the wavelength of the microwaves is 1 cm at what angular positions would the nodal lines be found?
- II(B) 8. Describe how you might use the apparatus of Exp. 11 to find the Brewster Angle for microwaves incident on paraffin.

Objectives emphasized by the questions.

Typical Test and Examination Questions - questions may be long questions, short questions or multiple choice. These questions have been selected from the short question section of finals.

Understanding of Theory (see aim (i) page 1)

With regard to the photoelectric effect (Exp 12) what effect should the light intensity have on the energy of the emitted electrons, according to Einstein's theory of the photoelectric effect?

Experimental Work I (Planning Experiments) (see aim (iii) page 1)

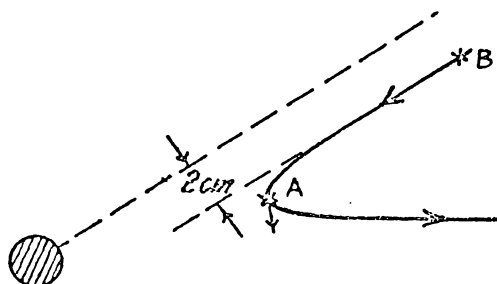
If two magnetic pucks could be designed for the air table so that they attracted each other and the inverse square law applied to their force distance relationship, satellite motion could be studied on the table by fixing one magnetic puck. Explain how you would attempt to verify Kepler's second and third laws. How could a log-log graph of suitably collected data be used to advantage in verifying the third law?

Experimental Work II (Results and Conclusions)(see aim (iv) page 1)

Draw a graph to display your results for power transferred to an external circuit (Exp 2.2) as the total resistance in the external circuit is varied. On your graph write down the theoretical relationship between internal resistance of the power supply, r , and the external resistance, R , for maximum power transfer. Compare your experimental results with theoretical predictions.

Application of Theory (see aim (i) page 1)

A magnetic puck is deflected by a fixed magnetic puck on an air table. The deflection is shown below.



The impact parameter is 2 cm, and the distance of closest approach to the centre of the puck is 6 cm. Assuming the pucks can be treated as point masses, the forces are central, and the original kinetic energy at B is 8×10^{-4} J and E_p is negligible, determine the potential energy in the system when the moving puck is at A.

Analysis of Assumptions and Approximations (see aim (ii) page 1)

In the theory of electron diffraction the assumption was made that

- i) the distance, L , from carbon to screen was constant,
- ii) θ was sufficiently small so that $\sin \theta = \theta$. Discuss each of these points stating whether you consider these assumptions were justifiable or not. Support your conclusions with your own experimental results.

APPENDIX E
OBJECTIVES AND TEACHING

Chapter 6.2 considered the different learning activities in the course and their relationship to the course objectives. This section, conversely, will consider each objective in turn and consider its relationship to the teaching and learning experiences in the course as a whole.

Objective I(A) Develop the ability to extract information (from scientific literature)

In the theoretical course the development of this ability cannot be considered in isolation from the assessment procedures. If all tests and final examinations are open textbook examinations (and some questions relate specifically to the ability of the student to extract textbook information), and if lectures are given primarily as a means by which students can better comprehend their textbook, then, hopefully, students will come to gain confidence and ability in the use of reasonably sophisticated published material.

Unlike most practical courses, the theoretical ideas and details required for experimental work were not detailed in the guide to the experimental course (Osborne, 1974a). Rather students were referred to their textbook or other reference books to be found in the laboratory. Therefore in this way also their ability at extracting information for themselves was hopefully developed.

Objective I(B) Develop the ability to interpret information, particularly to interpret mathematical and graphical descriptions

Both lectures and experimental work were directed towards the comprehension of ideas and the translation of the observation of physical phenomena into verbal, graphical and mathematical forms. (For example,

the motion of a damped pendulum can be described verbally. It can also be represented; graphically as a position-time graph, by a phaser of decreasing amplitude, or by a mathematical equation.) Lectures tended to emphasize the interpretation of mathematical descriptions, and to show how physical relationships could be concisely and unambiguously expressed in mathematical form. Certain experimental work enabled students to consider particular cases of mathematical relationships in depth, e.g., $F(x) = -\frac{dE_p}{dx}$ in Experiment 6.

Objective I(C) Obtain an understanding of the facts, principles and theories of physics (as specified in the courses)

This was the prime objective of both lectures and experimental work. Experimental work provided opportunities for students to understand specific concepts and to comprehend specific examples of principles and theories. The lectures, on the other hand, provided more opportunities for students to develop an understanding of the generality of the principles and of how relationships and laws could be derived from fundamental principles.

Objective II Application

Problem solving was emphasized by worked examples in lectures, and in the evaluation sessions, multiple choice and longer problems were attempted by students and then discussed by the lecturer. Problems were also specified for self study in lectures and in Experimental Physics; and further consideration of these was given in tutorials if students asked for assistance. To help students further a booklet on the techniques of problem solving was written specifically for the first year courses (Pepper, 1974). The distinction between the three objectives under Application tended to be more useful for testing than teaching.

Objective III(A) Develop the ability to critically analyze problem situations and evaluate information

While certain aspects of lectures, evaluation sessions and experimental work encouraged students to consider problems and information

critically, tutorial discussion questions were designed to specifically develop this objective. Beard (1971) and others suggest that discussion may well play an important part in the development of critical thinking. The most useful discussion questions were those that were sufficiently "straightforward" for all students to make a contribution to the discussion while sufficiently "complex" to provide a challenge for the best students (e.g., Discussion question 1, Appendix C.3.) Similar sessions to achieve this and other aims have been reported by Black (1974).

Objective III(B) Develop a critical attitude towards, and an ability to analyze, idealizations, approximations and assumptions in physical theories.

Some emphasis was given to this objective in lectures by pointing out the assumptions made when deriving a relationship. However, it became apparent that an over-emphasis on this objective in lectures tended to confuse the weaker students attempting to grasp the basic concepts. A teacher needs to over-simplify initially and then consider the finer details and complications later, as Frisch (1974) suggests. For this reason this objective was not categorized as simply "knowledge and comprehension". Compared with the theoretical course, a greater emphasis was given to this objective in the experimental course where students were often expected to compare theoretical predictions with experimental observations. This required a critical appreciation of the limitations inherent in the theoretically derived results. One of the early experiments in the experimental course (Osborne, 1974a, Experiment 1, Part B) deliberately encouraged students to develop a simple theory initially and then to reconsider the theory when it was found to be inadequate. (This was novel to many entrant students who seemed to have developed the idea that theories were always "correct" and their experimental results always "inadequate".)

Objective III(C) Develop an understanding, and appreciation, of some of the major themes and unifying concepts of physics (including the relationship between fundamental principles and derived laws)

Like Objective III(B), this objective is closely related in teaching to Objective I(C). (Objective III(B) is appropriately emphasized in the experimental course, while Objective III(C) is more appropriately emphasized in the theoretical course.) However, it was considered that the synthesis of the major themes and unifying concepts follows from a comprehension of the laws and principles. For example, students first comprehend Newton's three laws and the conservation of momentum and later become aware that, in a rather arbitrary way, two of these principles can be viewed as basic and the other two derived from them. Also it is necessary for a student to synthesize his own view of the structure of the subject and to build and rebuild this framework as he acquires new knowledge. Undoubtedly considerable guidance and assistance can be given in teaching to the synthesis of an acceptable framework. As a considerable amount of the content had been introduced at the seventh form level, greater emphasis was given in lectures to this overview than might normally be expected in a physics course. Further, the textbook (Alonso and Finn, 1970) presents a unified view of physics which is undoubtedly helpful in achieving this objective.

Objective IV(A) Develop the ability to propose tentative ideas, and working hypotheses, and make logical and testable predictions

Scientific inquiry is a cyclic process and Objective IV(A) is closely associated with making conclusions from experimental results (Objective IV(F)). Proposing a possible reason for a systematic discrepancy between a theoretical prediction and an experimental observation is one aspect of Objective IV(A) (for example, see Appendix D.3, Experiment 11.3(i)). Also students were expected to propose tentative ideas during experimental work (ibid, Experiment 11.6). Students were also encouraged to propose

tentative relationships between variables and then to test their hypotheses by graphical analysis (e.g., ibid, Experiment 11.1(i)). Undoubtedly the situations considered were very simple, but the students' limited store of requisite knowledge restricted the complexity of the exercises. To encourage the students to achieve this objective it is important to engender confidence.

Objective IV(B) Develop the ability to translate problems into experimental operations

To gain practice in achieving this objective students ideally should be given as little guidance in setting up the experimental situation as possible. However, there is a fine line between giving sufficient guidance for students to function adequately, and a "cookbook" approach to experimental work. In the experimental course the increased range of ability of a pair of students (normally paired on a basis of dissimilar backgrounds) enabled less guidance to be given than might have been required had students attempted the experiments individually. Also one of the demonstrator's main functions was to ensure that assistance was available when necessary. Much of the equipment was deliberately unlabelled and not set up in any way.

Objective IV(C) Develop the ability to make useful and reliable observations

This objective is closely associated with Objective IV(B) and again the question is, how much guidance is desirable? Presumably two alternative teaching strategies are possible;

- (i) to provide very specific details of precisely what measurements are to be made in the hope that students will learn by example (e.g., measure the distance moved by the mirror from a nodal point to the 21st nodal point. Repeat three times, average and hence determine the wavelength),
- (ii) to encourage students to struggle with the problem themselves. (e.g. "use the apparatus in the best way possible to obtain an

accurate measurement of the wavelength" (Appendix D.3, Experiment 11.2)).

The second approach was used wherever possible and students were encouraged to discuss their ideas with the demonstrators.

Objective IV(D) Develop the ability to keep adequately detailed and organized records of experimental work and to be able to extract information from these

As stated in detail in the introduction to Experimental Physics (Appendix D.2) students were encouraged to keep adequately detailed and organized records of experimental work and the information in these records were used by students in tests and examinations. Hence students were motivated by the necessity to keep useful records for subsequent reference rather than to meet some explicit standard required by a marker of that record. As in Objective IV(C), specific guidance and explicit requirements were replaced by a situation where a student was encouraged to develop his own style.

Objective IV(E) Develop the ability to analyze experimental data mathematically and graphically

Students were introduced to the technique of experimental data analysis gradually, as it was required by experiments. However, Experiment 1 specifically aimed to develop an understanding of an analysis of errors and a detailed introduction in Experimental Physics (Osborne, 1974a, p.5-19) was included for reference. It considered both error analysis, and graphical analysis (including log-log and semi-log graphs).

Objective IV(F) Develop the ability to draw valid conclusions from observations and data

While many experiments were primarily designed to enable students to comprehend physical phenomena and principles from first hand experience, students were also asked to find out how the experimental observations compared with idealized theoretical predictions. This encouraged students to consider possible mistakes, random error and systematic

errors involved in the experimental situation being considered.

Objective V Orientation

The orientation objectives are closely associated with Objectives III and IV. While these objectives have to be considered in the context of specific situations and require an appropriate knowledge of physics, Objective V emphasizes that from such examples students should become more aware of the nature of physics—an awareness that is somewhat independent of their more detailed knowledge of physics. The attitude of lecturers and tutors to their subject will undoubtedly result in a student appreciating how physicists view their subject. The emphases on Objective I(C) and III(C) in the theoretical course and also III(B), IV(C) and IV(F) in the experimental course were expected to lead to an increased awareness in students of the function and limitation of physical laws, of the relationship between experimental observation and theory, and of physics as creative, ongoing, tentative and unfinished.

Objective VI Attitudes

Because it was assumed that only the most mature student will differentiate significantly between his attitude toward a discipline and his attitude toward his experiences with the course activities in that subject, emphasis was placed on ensuring that at least the majority of students found "physics" reasonably satisfying. Further, one or two "interest" lectures covering non-examinable topics were included in the lecture programme. In addition, the learning aids room was expected to provide experiences designed to develop positive attitudes through a wide variety of film loops, short articles from journals, and so on. However, it seems likely that informal personal interactions with academic staff, research students and technical staff were at least of equal importance in the development of attitudes.

Objective VII(A) Develop the ability to manipulate, and use, the mathematical language of physics

Vector algebra, line integrals, surface integrals and so on were taught in lectures as required. Problems and tasks in the experimental course as well as in the evaluation sessions, encouraged the development of manipulative skills. Analysis of experiments and error tables, provided opportunities to develop arithmetic skills (manipulating numbers and assessing orders of magnitude).

As an example of the relationship between the objectives and an activity based programme, the perceived potential within the activities of Experiment 11 to develop particular objectives has been annotated alongside the activities (Appendix D.3) and alongside the self evaluation questions (Appendix D.4) for that experiment.

TYPICAL END-OF-YEAR SURVEY SHEET (1974)

UNIVERSITY OF WAIKATO

First Year Physics - End of Year Survey

PART A General (both courses 73.101 and 73.102)

1. Your background in Physics was
 A. None B. 6 form C. 7 form D. Attempted 73.101 (73.102) in 1973. Answer
2. A list of the possible ways in which you have learnt physics this year are
 A. lectures B. tutorials C. laboratory studies D. evaluation sessions
 E. informal study and discussion with friends F. self study.

Which of the above (or combination of the above) do you consider the most effective learning environment for the following aspects of physics:

- | | Answer |
|--|--------|
| (i) To obtain a basic understanding of the principles of physics | |
| (ii) To learn to solve problems | |
| (iii) To learn to think critically about physics | |
| (iv) To learn how to plan experiments | |
| (v) To learn how to analyse experimental results | |
| (vi) To develop an appreciation for the nature of physics | |
| (vii) To develop an interest in the study of physics | |

PART B 73.101 Theoretical Physics

Do you consider the work load (time to understand the text and to do problems) expected of you in this course (73.101)

1. More than any other course B. More than any other course, apart from 73.102
 C. Above average D. Average E. Less than average Answer
2. Did you find the pace of the lectures
 A. Too slow B. About right C. Occasionally too fast D. Too fast at all times Answer
3. Have you found the content of the lectures
 A. Very difficult B. Difficult C. Average D. Easy Answer
4. Do you consider the text of Alonso and Finn
 A. Very difficult to understand B. Difficult C. Of a reasonable standard D. Easy Answer
5. How would you describe the text
 A. Very interesting and helpful B. Informative and interesting C. Informative but dull
 D. Boring Answer
6. How do you rate the difficulty on average of the content of the following sections in the course 73.101

- Kinematics (RJO) Ch 1-6
- Dynamics (RJO) Ch 7-12
- Fields (ARP)
- Fields (BSL)
- Waves I (BSL/RJO) Ch 23, 24, 26.
- Waves II (RJO) Ch 27, 28, 29.

Very Difficult	Difficult	Average	Easy	Very Easy

7. Have you found the suggested problems in Alonso and Finn
 A. Impossible B. Difficult C. Of a suitable standard D. Easy Answer
8. Have you attempted
 A. Only a few of the problems suggested B. Most of the problems suggested
 C. All of the problems suggested D. More than the number of problems suggested Answer
9. If you have trouble with problems is it usually because
 A. You cannot understand the question B. You cannot see how to start the problem
 C. You cannot solve the equations you write down D. You spend considerable time trying to get agreement between your answer and the answer in the back of the book. Answer
10. Do you consider tutorials should be held
 A. More frequently B. As at present C. Less frequently D. Only in the third term Answer
11. Do you consider tutorials
 A. Usually helpful B. Useful only if you have questions to ask C. A waste of time Answer P T O

12. Do you find the discussion questions and the associated tutorial discussions
 A. Interesting, worthwhile and/or stimulating B. Reasonably interesting and useful
 C. Interesting occasionally D. Of little use, or interest E. A waste of time
 Answer
13. Do you find the evaluation lectures (Monday or Thursday)
 A. Extremely helpful B. Very helpful C. Useful D. Occasionally helpful
 E. A waste of time
 Answer
14. Do you consider the summaries of the chapters (Thursday)
 A. Very helpful and worthwhile B. Useful C. Occasionally useful D. Too brief
 E. Useless
 Answer
15. Do you find the multiple choice questions given in evaluation sessions
 A. Very helpful and worthwhile B. Useful C. Occasionally useful but usually too hard
 D. Occasionally useful but usually too easy E. Useless
 Answer

Have you any other constructive comments on 73.101, for example re lectures, evaluation sessions, tutorials?

73.102 - Experimental Physics

1. Do you consider the work load expected of you in this course (73.102)
 A. More than any other course B. More than any other course apart from 73.101
 C. Above average D. Average E. Less than average
 Answer
2. The experiments in this course were
- | | |
|-------|---|
| Exp 1 | Dart board and errors |
| 2 | D.C. circuits |
| 3 | Air track dynamics |
| 4 | Air table dynamics |
| 5 | Cathode ray tube |
| 6 | Air table and fields |
| 7 | Slow a.c. |
| 8 | Magnetic fields |
| 9 | Ultrasonic waves |
| 10 | Optics |
| 11 | Microwaves |
| 12 | Spectra, Photoelectric effect, Electron diffraction |

For each question below, do not list more than two experiments!

- | | | |
|-----|--|-----------|
| (a) | The longest experiment to do and write up was | Exp |
| (b) | The experiment which assumed the greatest background knowledge was | Exp |
| (c) | The most enjoyable and interesting experiment was | Exp |
| (d) | The most tedious and uninteresting experiment was | Exp |
| (e) | The most informative experiment in terms of physics learnt was | Exp |
| (f) | The least informative experiment in terms of physics learnt was | Exp |

Have you any other constructive comments on 73.102, for example re lab book, equipment (specific details here where possible), tests, etc.

APPENDIX G

FURTHER ASPECTS OF PROCESS EVALUATION

G.1 Theoretical course 73.101

During 1970 three lectures were provided each week. In addition to the difficulty of the textbook the course was undoubtedly too difficult and the work load expected of students too great (see Table G.1(a)). Because of this the content in 1971 was reduced somewhat and each third lecture replaced by an evaluation session which was concerned with reviewing preceding lectures, providing summaries, worked examples, demonstrations, and self evaluation questions. Student reaction to these evaluation sessions was favourable and has remained so subsequently¹ (Table G.1(b)). Reaction to the summaries and self evaluation questions provided in the evaluation session was equally positive and has remained so (Table G.1(c) and (d)). In 1972 printed discussion questions were given to students to promote tutorial discussion. By 1974 almost all tutorials during the year had an associated discussion sheet. Student reaction was again very positive (Table G.1(e)). One result of these changes to the course from 1970 to 1974 was that the work load was reduced in comparison with other courses (compare Table G.1(a) with Table G.1(f)).

G.2 Experimental Course 73.102

One advantage of students working in pairs in the laboratory (particularly when the members of each pair are chosen to have different background knowledge) is that the experimental guide does not have to be

¹The data of Table G.1 is supported by data from twice-yearly evaluation from 1970 to 1974, which for the sake of brevity and clarity is not shown in its entirety.

Table G.1 Student percentage responses in formal process evaluation of 73.101.

	Percentage Responses	
	June 1970 (N = 80)	Oct 1970 (N = 70)
(a) Do you consider the workload expected of you in this course (73.101) is		
A. more than any other course,	50	84
B. above average,	40	9
C. average,	8	7
D. less than average,	2	0
	Oct 1971 (N = 80)	Oct 1974 (N = 80)
(b) Do you find the evaluation session		
A. extremely helpful,	22	2
B. very helpful,	22	39
C. useful,	40	35
D. occasionally helpful,	13	20
E. a waste of time,	4	4
(c) Do you consider the summaries of the chapters		
A. very helpful and worthwhile,	32	48
B. useful,	52	38
C. occasionally useful,	11	9
D. too brief,	4	4
E. useless,	1	2
(d) Do you find the multiple choice questions		
A. very helpful and worthwhile,	26	35
B. useful,	61	50
C. occasionally useful but usually too hard,	6	11
D. occasionally useful but usually too easy,	5	4
E. useless	1	0
(e) Do you find the discussion questions and associated tutorial discussion		
A. interesting, worthwhile and/or stimulating,	-	16
B. reasonably interesting and useful,	-	53
C. interesting occasionally,	-	27
D. of little use or interest,	-	1
E. a waste of time.	-	2
(f) Do you consider the workload expected of you in this course (73.101) is		
A. more than any other course,	22	15
B. more than any other course apart from 73.102,	18	18
C. above average,	34	31
D. average,	25	36
E. less than average.	1	1

written down to the level of the student with the weaker background. Nevertheless the provision of sufficient but not excessive information for students in a guide is difficult, and feedback was obtained from students on this point (see Table G.2). The 1972 response was considered satisfactory.

The significant timetable difference between the experimental course and the laboratory work in other first year courses, was that laboratory sessions occurred fortnightly (3 hours one afternoon and 3 hours the next morning with the following week free) rather than 3 hours each week. In 1971 student responses showed a favourable reaction to the 6 hour laboratory sessions (Table G.3).

In 1971 self evaluation questions were introduced for each experiment. Feedback (Table G.4(a)) showed that students were using these questions, primarily for revision.

Prior to 1972 the total grade for the experimental course was derived solely from the results of the open book tests and the final examination. Since 1972 up to 5% of the maximum possible marks have been awarded for the completeness of the laboratory account as a nominal motivational procedure. In terms of the objectives of the course it was considered undesirable to raise this percentage, although student reaction (Table G.4(b)) showed that the students would personally have preferred a slightly greater percentage contribution.

One of the aims of the experimental course associated with Objective IV(D) was to encourage students to write directly into their laboratory notebooks rather than to write a final account at some subsequent time. "Notebooks" were not to be confused with subsequent reports, dissertations or papers that an experimentalist might write later from the notebook. (The open book tests and examination somewhat crudely simulated this second stage.) Considerable emphasis was given to this in Experimental Physics (Osborne, 1974a, p.3) where the

Table G.2 Student percentage response concerning the laboratory guide, 1971 and 1972

	Percentage Response	
	Oct 1971 (N = 80)	Oct 1972 (N = 90)
In a laboratory guide the amount of information supplied should be sufficient for you to understand what you are meant to do, leaving opportunity for independent study and investigation as to the exact theoretical and experimental details.		
Do you consider <u>Experimental Physics</u> is		
A. too detailed	0	0
B. on occasions too detailed	0	7
C. about right	59	61
D. occasionally insufficiently detailed	32	26
E. insufficiently detailed	10	5

Table G.3 Student attitude to the six hour laboratory timetable, 1971

	Percentage response to each statement				
	Strongly Agree	Agree	Un-decided	Dis-Agree	Strongly Disagree
6 hour lab sessions are useful as they allow a reasonably undisturbed length of time to study one topic in the lab.	12	64	13	9	2
6 hour lab sessions are useful in that familiarity with the apparatus is not lost overnight and this saves time next morning.	13	52	13	21	2
6 hour lab sessions are desirable as apparatus can be left set up overnight.	11	65	11	13	0
6 hour lab sessions are desirable as they provide an opportunity for undisturbed private study during alternate weeks.	28	45	21	7	0
6 hour sessions are undesirable as six hour experimental physics in twenty four hours is too much.	5	9	16	52	16
Afternoon/morning sessions are not worth while as the overnight break is insufficient time to think about what you are doing or to write up work done.	6	12	15	63	6
6 hour sessions are undesirable because the uneven loading of committed hours each week is disturbing	7	15	12	52	15

Table G.4 Student responses to aspects of formal process evaluation of 73.102.

		Percentage response to each question October 1971 (N = 80)		
		Yes	Sometimes	No
(a)	Do you use self evaluation questions to			
	A. learn about the experiment before doing it?	0	20	80
	B. check on your understanding after doing the experiment?	24	48	27
	C. check on your understanding before tests?	78	8	13
		Percentage response October 1972 (N = 90)		
(b)	What percentage of your assessment of this course do you consider should be allocated to your laboratory book (5% at present).			
	[Please appreciate in answering this question that this course is not a practical course but involves the understanding of theory and experiment with regard to a particular topic.]			
	A. 0%		2	
	B. 5%		36	
	C. 10%		45	
D. >10%		14		
(c)	Now that you have had some experience of laboratory work which of the following methods of recording laboratory results do you consider the best?			
	A. directly recorded into your final laboratory account,		26	
	B. recorded into a separate notebook,		42	
	C. recorded directly into your laboratory notebook but labelled "directly recorded results",		17	
	D. recorded in the back of your laboratory book.		14	

reasons for, and advantages of, such a procedure were detailed.

Students were individually encouraged by supervisors to write directly in their notebooks, and to add mathematical and graphical analyses and conclusions to the directly recorded results. However, students continued to rewrite their results in many cases and typical student opinion is indicated in Table G.4(c).

APPENDIX H
 SEMANTIC DIFFERENTIAL INSTRUMENT
 (Only Experiments 1 and 2 shown)

UNIVERSITY OF WAIKATO

Physics Education Analysis - 1973

Experimental Course Evaluation

The following is designed to investigate opinion on the first four experiments in the Experimental Course (73.102). In this analysis, please judge the experiments on what they meant to you.

Each sheet refers to one particular experiment and you are asked to judge this against a set of scales like the following

Exp.1 - Errors

Awful: ___:___:___:___:___:___:___: Nice

If you feel that the experiment is very closely associated with one end of the scale you might place your cross as follows:-

Microwave Experiment

Hard : ___:___:___:___:___:___: X : Easy

If you felt that the experiment was quite closely related to one side of the scale you might place a cross as shown

Ultrasonic Experiment

Precise : ___: X : ___:___:___:___:___: Imprecise

If you felt that the experiment seemed only slightly related to one side as opposed to the other, you might indicate as follows:

Water Wave Experiment

Complex : ___:___:___:___: X : ___:___: Simple

If you considered the scale completely irrelevant or both sides equally associated you would check the middle space on the scale.

Optics Experiment

Hot : ___:___:___: X : ___:___:___: Cold

Some scales may seem highly irrelevant. Do not let this worry you. Give the best judgement you can. There are no right or wrong answers.

Experiment 1 - Errors (Darts, Means and standard errors,
Measurement of g)

- Enjoyable : ___ : ___ : ___ : ___ : ___ : ___ : Unenjoyable
 Relevant : ___ : ___ : ___ : ___ : ___ : ___ : Irrelevant
 Complicated : ___ : ___ : ___ : ___ : ___ : ___ : Straightforward
 Clear instructions : ___ : ___ : ___ : ___ : ___ : ___ : Vague instructions
 Unsatisfying : ___ : ___ : ___ : ___ : ___ : ___ : Satisfying
 Important : ___ : ___ : ___ : ___ : ___ : ___ : Unimportant
 Easy to write up : ___ : ___ : ___ : ___ : ___ : ___ : Difficult to write up
 Open ended investigation : ___ : ___ : ___ : ___ : ___ : ___ : Closed investigation
 Unpleasant : ___ : ___ : ___ : ___ : ___ : ___ : Pleasant
 Worthless : ___ : ___ : ___ : ___ : ___ : ___ : Valuable
 Lab work difficult : ___ : ___ : ___ : ___ : ___ : ___ : Lab work easy
 Approximate results : ___ : ___ : ___ : ___ : ___ : ___ : Precise results
 Interesting : ___ : ___ : ___ : ___ : ___ : ___ : Uninteresting
 Useless : ___ : ___ : ___ : ___ : ___ : ___ : Useful
 Many calculations : ___ : ___ : ___ : ___ : ___ : ___ : Few calculations
 Adequate theory : ___ : ___ : ___ : ___ : ___ : ___ : Inadequate theory
 Exciting : ___ : ___ : ___ : ___ : ___ : ___ : Dull
 Uninformative : ___ : ___ : ___ : ___ : ___ : ___ : Informative
 Short : ___ : ___ : ___ : ___ : ___ : ___ : Long
 Theoretical : ___ : ___ : ___ : ___ : ___ : ___ : Technological
 Mathematical : ___ : ___ : ___ : ___ : ___ : ___ : Non mathematical
 Complex theory : ___ : ___ : ___ : ___ : ___ : ___ : Straightforward theory
 Awful : ___ : ___ : ___ : ___ : ___ : ___ : Nice
 Familiar theory : ___ : ___ : ___ : ___ : ___ : ___ : Unfamiliar theory
 Varied : ___ : ___ : ___ : ___ : ___ : ___ : Monotonous
 Adequate apparatus : ___ : ___ : ___ : ___ : ___ : ___ : Inadequate apparatus

*NOTE: Open ended - details of experiment, and what to do left to
 the student to decide
 closed - specified and detailed instructions, told
 exactly what to do.

Experiment 2 - Direct currents

Adequate apparatus : ___:___:___:___:___:___:___: Inadequate apparatus
 Varied : ___:___:___:___:___:___:___: Monotonous
 Familiar theory : ___:___:___:___:___:___:___: Unfamiliar theory
 Awful : ___:___:___:___:___:___:___: Nice
 Complex theory : ___:___:___:___:___:___:___: Straightforward theory
 Mathematical : ___:___:___:___:___:___:___: Non mathematical
 Theoretical : ___:___:___:___:___:___:___: Technological
 Short : ___:___:___:___:___:___:___: Long
 Uninformative : ___:___:___:___:___:___:___: Informative
 Exciting : ___:___:___:___:___:___:___: Dull
 Adequate theory: ___:___:___:___:___:___:___: Inadequate theory
 Many calculations : ___:___:___:___:___:___:___: Few calculations
 Useless : ___:___:___:___:___:___:___: Useful
 Interesting : ___:___:___:___:___:___:___: Uninteresting
 Approximate results : ___:___:___:___:___:___:___: Precise results
 Lab work difficult : ___:___:___:___:___:___:___: Lab work easy
 Worthless : ___:___:___:___:___:___:___: Valuable
 Unpleasant : ___:___:___:___:___:___:___: Pleasant
 Open ended investigation : ___:___:___:___:___:___:___: Closed investigation
 Easy to write up : ___:___:___:___:___:___:___: Difficult to write up
 Important : ___:___:___:___:___:___:___: Unimportant
 Unsatisfying : ___:___:___:___:___:___:___: Satisfying
 Clear instructions : ___:___:___:___:___:___:___: Vague instructions
 Complicated : ___:___:___:___:___:___:___: Straightforward
 Relevant : ___:___:___:___:___:___:___: Irrelevant
 Enjoyable : ___:___:___:___:___:___:___: Unenjoyable

APPENDIX I

SCHOLARSHIPS PHYSICS EXAMINATION
AND EXAMINER'S REPORT, 1973

- I.1 Entrance Scholarships Examination, 1973--Physics.
- I.2 Entrance Scholarship Physics (Examiner's Report).
- I.3 Further analysis of the Scholarships Physics Examination, 1973.

I.1 Scholarships Physics Examination, 1973

UNIVERSITIES ENTRANCE BOARD

ENTRANCE SCHOLARSHIPS EXAMINATION—1973

PHYSICS

[Time allowed: *Three* hours]

Ten minutes extra allowed for reading this paper.

INSTRUCTIONS:

- The paper consists of two compulsory sections: Section I and Section II.
 No choice is provided. Attempt all questions in both sections.
 Candidates are recommended to allocate their time in proportion to the marks allocated.
 Mathematical tables will be provided. Slide rules may be used.

SECTION I (65 marks)

1. This section contains five questions. Each question is worth 12 marks except question 5, which has five quite separate parts and is worth 17 marks.
2. Graph paper will be provided.
3. Tie your GRAPH PAPER securely to your answer book.

SECTION II (35 marks)

1. All answers are to be recorded on the special ANSWER SHEET provided.
2. Except where otherwise indicated you are required to select the *best* answer from several alternatives. Ambiguous answers will not be accepted.

If you consider b is correct shade thus

a	b	c	d	e

To change your choice from b to c rub out or cross b and shade c thus

a	b	c	d	e

3. Each question carries one mark.
4. Tie the ANSWER SHEET securely inside the front cover of your answer booklet.

Turn over

SECTION I (65 marks)

1. (a) An external force F_{EXT} , is applied to a rigid body, mass M , initially at rest. The force varies with time in magnitude but not in direction. Assuming the equations

$$F_{EXT} = \frac{dP}{dt} \text{ and } P = Mv_{CM} \text{ are true for a rigid body}$$

where v_{CM} is the velocity of the centre of mass, show that at time $t = T$,

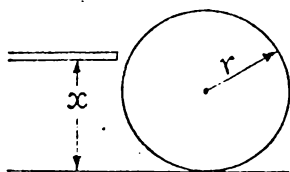
$$v_{CM} = \int_0^T \frac{F_{EXT} dt}{M} \text{ ----- equation A.} \tag{2 marks}$$

- (b) In the study of rotational dynamics of a rigid body, analogous expressions to those in 1 (a) exist for rotational motion about an axis through the centre of mass

$$\tau_{EXT} = \frac{dL}{dt} \quad \text{and} \quad L = I\omega$$

Explain the terms τ_{EXT} and L , and develop an expression analogous to equation A, for rotation about the centre of mass. (3 marks)

- (c) A stationary billiard ball, radius r , rests on a table where *friction can be assumed zero*. The ball is struck by a cue (rod) held horizontal at a distance x above the table, giving a horizontal impulse, R , to the ball.



[Assume that the impulse $R \approx \int F dt$ occurs in a very short time interval. Also assume that the rotational inertia of the ball about an axis through the centre of mass is $\frac{2}{5}Mr^2$.]

- (i) What is the subsequent velocity of the centre of mass, and the angular velocity (about the centre of mass), of the ball?
- (ii) From an analysis of the velocity of the lowest point on the ball, with respect to the “frictionless” table top, determine the impact height x for which the ball will roll along the table without sliding. (5 marks)
- (d) On an actual billiard table some friction may exist between the ball and the cloth surface of the table. The walls of the table are designed so that the place of contact between the wall and the ball is a height y above the table. Why is the loss of mechanical energy, when the ball strikes the wall, likely to be least if y is equal to the value determined for x in c (ii) above?



(2 marks)

Turn over

2. (a) Amperes Law, for magnetic fields produced by electric currents, can be stated symbolically as,

$$\oint B_{\parallel} dl = \mu_0 I_{TOTAL}$$

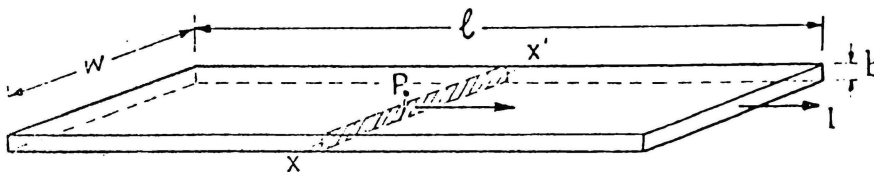
For a closed path in a region of magnetic field, explain the terms

$$\oint B_{\parallel} dl \quad \text{and} \quad I_{TOTAL}$$

(3 marks)

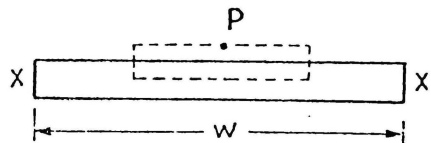
- (b) A long thin metal strip carries a large current, I , as shown.

The current density J is uniform throughout the metal (so $I = Jwb$) and is parallel to the length of the strip.



Determine the magnetic field due to the current at a point P above the centre of the plate and just above the surface of the conductor. State any assumptions that you make.

HINT: Consider a small rectangular path, perpendicular to the direction of J as shown.



(3 marks)

- (c) In (b), the potential difference, V , between the ends of the strip is known from experiment to be related to the current I by the rule, $V = \frac{\rho I}{bw}$ where ρ is a constant. Assume the "electron model" of current, according to which current density is given by $J = nev$. Use these relationships to show that this model requires the drift speed, v , to be proportional to the electric field, E , in the conductor, if n (the number of free electrons per unit volume) is assumed constant. In your explanation, make it clear how you relate E to V .

(3 marks)

(d) A physical model developed as an analogy to the electron drift model (a model of a model!) uses the gravitational field to simulate the electric field, and ball bearings to simulate the electrons. A large number of nails is placed in a sloping board, as shown in Fig. W. The balls fall from one row to the next, momentarily come to rest, and fall to the next row. The balls drift down the board more quickly when it is more tilted.

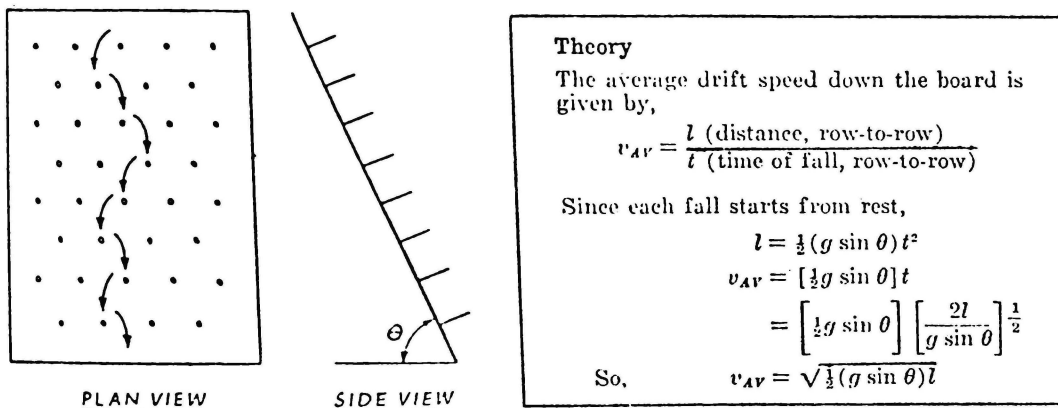


Fig. W

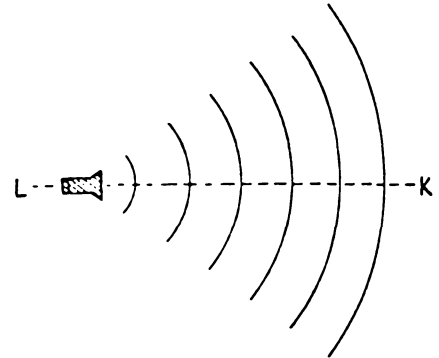
- (i) According to the theoretical development in the panel, what relation does this gravitational analogy predict between the electric field and the electron drift velocity in a conductor?
- (ii) In what physical way does this gravitational model fail to imitate the electron drift model (and therefore fail to predict the correct relationship between electric field and drift velocity)?

(3 marks)

Turn over

3. (a) A loudspeaker radiates sound waves, of frequency f_1 and speed v . At a distance r from the speaker along the line LK , the wave is described by the equation

$$y = \left(\frac{B}{r}\right) \sin 2\pi f_1 \left(\frac{r}{v} - t\right) \text{ for } r > 0.$$

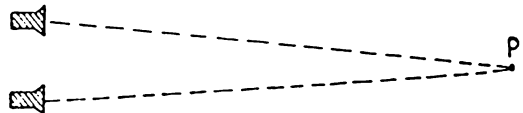


- (i) Suggest a physical quantity that y might represent.
 (ii) Suggest a reason for the inclusion of r in the amplitude $\left(\frac{B}{r}\right)$ factor in the equation above noticing that it does not appear in a similar way in the formula $y = A \sin 2\pi f \left(\frac{x}{v} - t\right)$ for a wave on a string.

(3 marks)

- (b) A second speaker is placed adjacent to the first speaker. The waves produced by this speaker are described by

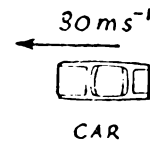
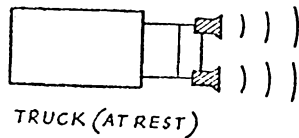
$$y = \left(\frac{B}{r}\right) \sin 2\pi f_2 \left(\frac{r}{v} - t\right)$$



Describe the resultant sound that would be heard by an observer at a point P equidistant from the two speakers if f_1 is slightly different from f_2 . (Include a sketch graph.)

(3 marks)

- (c) A stationary truck has a pair of horns mounted on the cab, and a car is approaching the truck at 30 ms^{-1} .

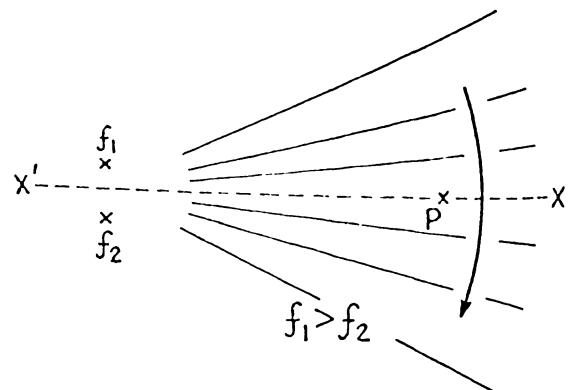


One horn is operating at 1000 Hz , the other at 1010 Hz . If the speed of sound is 330 ms^{-1} determine the beat frequency heard by the driver of the car.

(3 marks)

- (d) Consider the following statement about the situation described in (c).

“The sound from the two speakers result in a two source interference pattern which slowly rotates, as shown, from the higher frequency source to the lower frequency source. At *very large* distances from the sources the nodal lines are effectively straight lines which rotate like the spokes on a rotating wheel. The frequency at which nodal lines cross XX' is the frequency of the beats heard by P . The beat frequency will therefore be independent of the position P and hence independent of its velocity.”



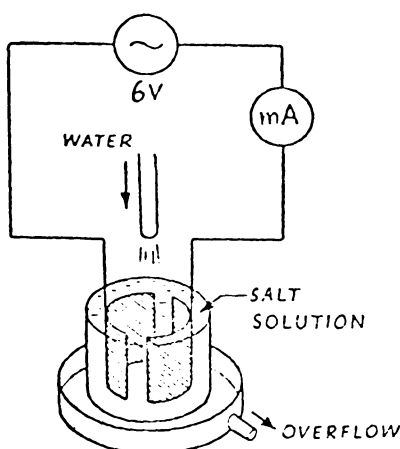
Criticize the above argument as, in practice, the beat frequency does depend on the velocity of P .

(3 marks)

7

4. (This question investigates your ability to analyse an experimental situation, and make conclusions from experimental results. The question does not assume that you have any previous knowledge about this experimental situation or associated theory.)

The following experiment was designed to study the relationship between the concentration of salt in water and the electrical conductivity of the solution. A 6 V, a.c. supply was connected to a 0–100 milliammeter, and two copper plates in a beaker of salt water, as shown in the diagram. The beaker was completely full with 1000 cm³ of salt water and the current was 100 mA. From time, $t = 0$, pure water was fed into the beaker at the constant rate of 10 cm³s⁻¹, where it mixed with the solution. The excess liquid overflowed. The tabulated variation of current with time is shown below.



I (mA)	t (s)
100	0
90	10
81	20
73	30
65	40
59	50
53	60
47	70
45	80
43	90
42	100

- (a) A simple model is that the total resistance of the salt solution, R , is inversely proportional to the concentration, C , hence $I = \frac{V}{R} = kC$ where k is a constant.

Now in each successive small interval of time, say 1 second, the concentration might be expected to become less by a constant factor f , so that the current would be expected to vary in the following manner.

$$\begin{array}{ll} \text{After 1 second} & I = I_{MAX}f \\ \text{2 seconds} & I = I_{MAX}f^2 \\ t \text{ seconds} & I = I_{MAX}f^t \end{array}$$

Plot a suitable graph of the data to find whether the expected relationship holds.

$$[\text{HINT: } \log I = (\log f)t + \log I_{MAX}]$$

Do the results confirm theoretical predictions?

(7 marks)

- (b) Determine a value for f from the first eight readings on the graph. What value do you expect for f considering the stated rate of flow of pure water into the beaker? (3 marks)
- (c) To ensure good mixing the salt solution was stirred continuously during the first 70 seconds but it was not stirred afterwards. Explain how this might account for the increasing discrepancy between experiment and theory after the first 80 seconds. (2 marks)

Turn over

5. (This question has five SEPARATE parts.)

(a) The following three formulae all have to do with energy.

$$E = hf$$

$$E = mc^2$$

$$\Delta E = mg \Delta x$$

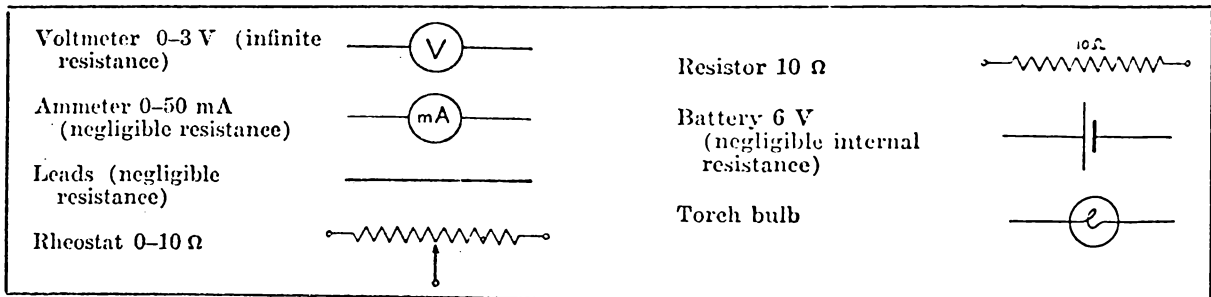
Although they were initially met in quite different topics in physics, perhaps applied to one situation they suggest new ideas.

Determine:

(i) the effective mass of a photon, frequency f .

(ii) the fractional change in frequency of a photon travelling a small vertical distance Δx in a uniform gravitational field. (3 marks)

(b) In a simple experiment to investigate the relationship between potential difference and current in a torch bulb (resistance between 200Ω and 600Ω), the following equipment is available.

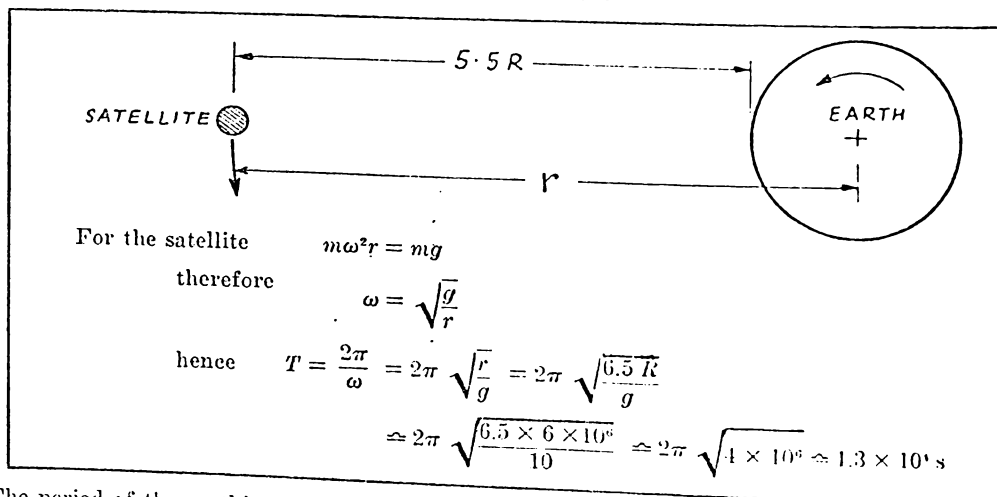


Draw a circuit diagram (symbols given) to show how you would set up the equipment to enable the potential across, and the current through, the torch bulb to be determined over the 0–3 V range.

(3 marks)

(c) Synchronous satellites have an orbital period equal to the period of the earth's rotation on its axis. They are positioned on the plane of the equator approximately $5.5 R$ above the earth's surface, where R is the radius of the earth ($R = 6 \times 10^6 \text{ m}$).

The following is an attempt to verify this information.



The period of the earth's rotation on its axis is actually $8.6 \times 10^4 \text{ s}$. Find the mistake in the working enclosed in the box, above, and state the correction which should be made. (3 marks)

(d) (This question investigates your ability to plan an experiment to test some proposed theory. You are not expected to be familiar with the theory.)

A physicist has a theory that when a mass m is suspended from a spring of mass m_s , and displaced from its equilibrium position, the period of the up and down motion is approximately given by

$$T = 2\pi \sqrt{\frac{m + \frac{m_s}{3}}{k}} \quad \text{where } k \text{ is the spring constant.}$$

To test the theory you are supplied with a spring, mass 1.2×10^{-2} kg, and *known* spring constant and a set of five 1.0×10^{-2} kg masses which can be suspended from the spring. Suggest what quantities you would measure (no details required) and the subsequent *graphical* analysis which you would make to verify the above equation.

(Draw a sketch graph to indicate what you would expect if your results verified the equation.)

(4 marks)

(e) The idea of phasor diagrams in a.c., can be extended to more complex circuits than the simple series circuit. For example, the phasor diagram Fig. 2 shows the relationships between the voltages across the various circuit components in the circuit Fig. 1.

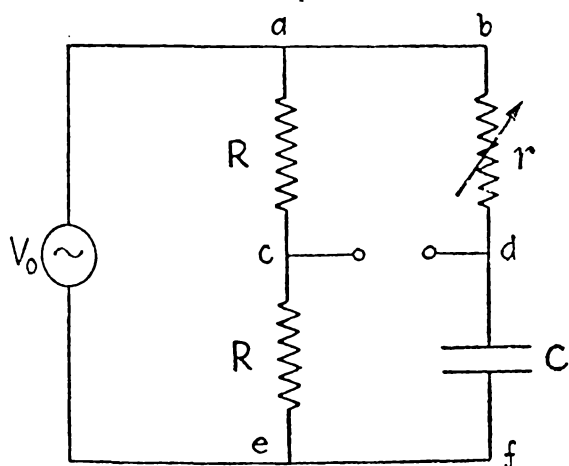


Fig. 1

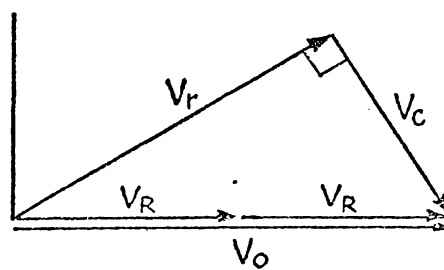


Fig. 2

(NOTE: The sum of the voltages V_r (across the resistor r), and V_c (across the capacitor C) must always be just the same as the total voltage, $V_R + V_R$, across the two identical resistors R . Also, as in a simple series circuit, the phase angle between V_c and V_r must always be 90° .)

- (i) The phasor marked V in Fig. 3 represents a potential difference. Between which points in Fig. 1 does the voltage occur?
- (ii) Show a similar phasor diagram for the case when r is reduced. Hence discuss how V varies in magnitude and phase as r varies.

(You may appreciate that such a variation could well be of practical use.)

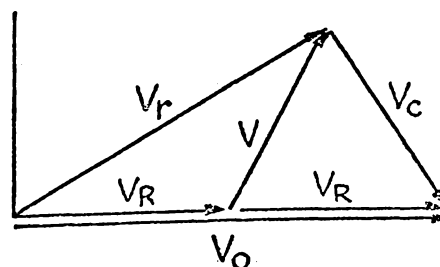


Fig. 3

(4 marks)

Turn over

SECTION II (35 marks)

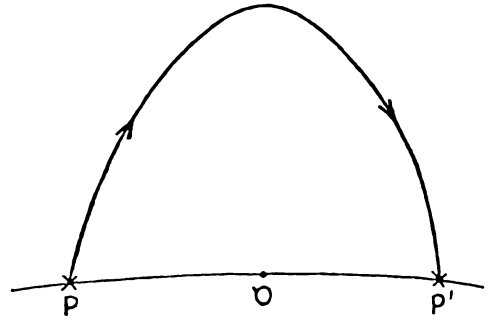
(Answers to be recorded on the *answer sheet* provided)

1. A projectile describes a path as shown on the surface of the moon.

O is the mid point between P and P' .

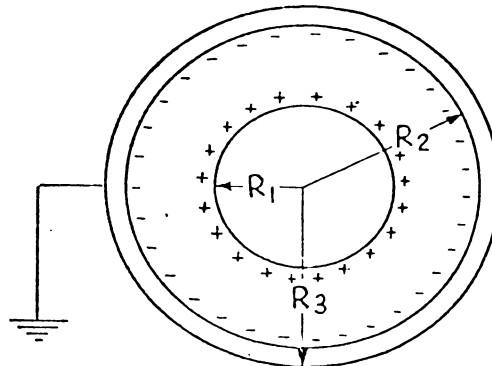
As the projectile moves along its path from P to P' , its angular momentum about the point O , will

- (a) remain constant.
- (b) first increase then decrease.
- (c) first decrease then increase.
- (d) decrease.
- (e) increase.



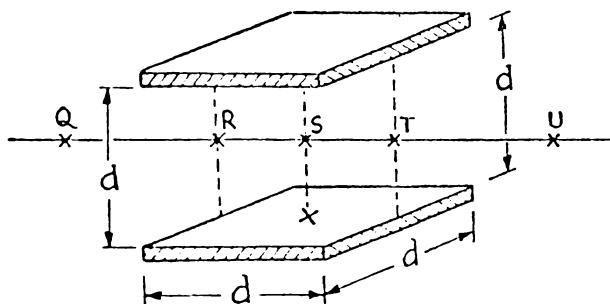
2. Two conducting concentric spheres with uniform surface charge densities are shown in the diagram. The total charge on R_1 is Q_1 . The outside sphere is connected to earth. If σ_1 is the density of the positive charges on the surface of the inner sphere and σ_2 the density of the negative charges on the inside surface of the outer sphere, then $\frac{\sigma_1}{\sigma_2}$ would equal

- (a) $\left(\frac{R_2}{R_1}\right)^2$
- (b) 1
- (c) $\left(\frac{R_1}{R_2}\right)^2$
- (d) Infinite
- (e) $\left(\frac{R_2}{R_1}\right)$

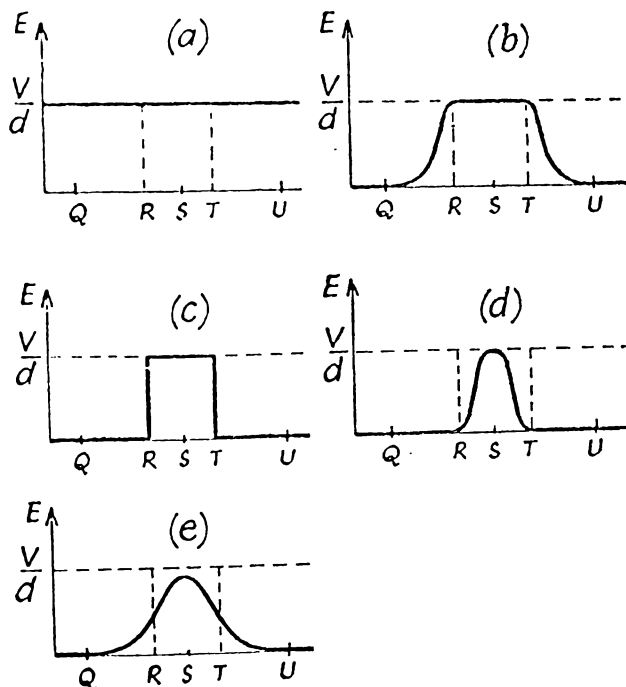


11

3. Two square parallel plates, of side length d , are a distance d apart. The electrical potential difference between the plates is V . S is midway between the centres of the plates and QU is a line through S parallel to one side of the plates.



The variation along QU of the magnitude of the electric field due to the charged plates, is best represented by which of the following graphs?



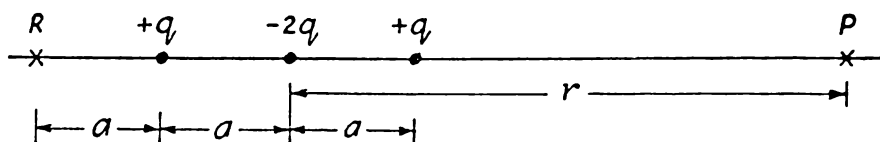
4. An isolated charged metal sheet has a charge density $\frac{\sigma}{2}$ coulomb m^{-2} on *each* surface. The magnitude of the electric field close to the metal sheet would be

(a) $\frac{\sigma}{4\epsilon_0}$ (b) $\frac{\sigma}{2\epsilon_0}$ (c) $\frac{\sigma}{\epsilon_0}$ (d) $\frac{2\sigma}{\epsilon_0}$ (e) $\frac{4\sigma}{\epsilon_0}$

Turn over

The following information and diagram refer to questions 5 and 6.

The distribution of three charges $+q$, $-2q$, and $+q$ shown in the diagram, is known as a linear electric quadrupole.



At P , a large distance from the charges, on a line through the charges, the electric potential is given by

$$V_P = \frac{qa^2}{2\pi\epsilon_0 r^3} \quad (r \gg a)$$

5. The magnitude of the electric field at P would be given by

- (a) $\frac{2qa^2}{\pi\epsilon_0 r^3}$ (b) $\frac{qa^2}{\pi\epsilon_0 r^2}$ (c) $\frac{qa^2}{4\pi\epsilon_0 r^2}$ (d) $\frac{3qa^2}{2\pi\epsilon_0 r^3}$ (e) $\frac{2qa^2}{\pi\epsilon_0 r^3}$

6. If point R is distant a from the closest charge, as shown, the potential at R would be

- (a) $\frac{q}{2\pi\epsilon_0 a}$ (b) $\frac{q}{4\pi\epsilon_0 a}$ (c) $\frac{q}{12\pi\epsilon_0 a}$ (d) $\frac{q}{16\pi\epsilon_0 a}$ (e) $\frac{q}{54\pi\epsilon_0 a}$

7. "The electric field at a position near a distribution of charges is given by the relationship $E = \frac{F}{q}$ where F is the force on a point test charge q ."

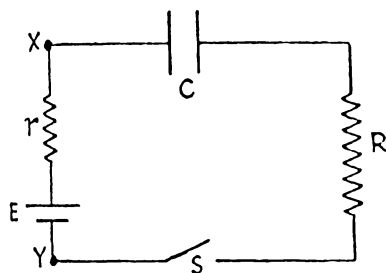
For this statement to be correct the magnitude of the test charge *must be* sufficiently small so that it does *not*

- (a) distort the electric field in any way.
 (b) distort the electric field near the test charge appreciably.
 (c) distort the electric field near the charges producing the field (even if the charges do not move).
 (d) move the charges producing the field.

13

The following information and diagram refer to questions 8, 9, and 10.

An uncharged capacitor (of capacitance C farad) is connected in series with a resistor (of resistance R ohm), and a battery (emf E volt and internal resistance r ohm) whose terminals are X and Y , as shown.



At a time t (second) after the switch S is closed, a charge of Q (coulomb) is on the plates of the capacitor, and the current in the circuit is $I = \left(\frac{dQ}{dt}\right)$.

8. Which of the following equations could be deduced by first using Kirchhoff's rule about potential differences around a closed circuit, and hence obtaining an expression for $\frac{dI}{dt}$.

(a) $R \frac{dI}{dt} + \frac{Q}{C} = 0$

(b) $R \frac{dI}{dt} + \frac{Q}{C} = E$

(c) $(R + r) \frac{dI}{dt} + IC = 0$

(d) $(R + r) \frac{dI}{dt} + \frac{Q}{C} = E$

(e) $(R + r) \frac{dI}{dt} + \frac{I}{C} = 0$

9. The voltage across the terminals XY of the battery, immediately after the switch is closed ($t = 0$) would be

(a) E (b) $E \left(\frac{R}{R+r}\right)$ (c) $E \left(\frac{R-r}{R}\right)$ (d) $E \left(\frac{R-1}{R}\right)$ (e) $E \left(\frac{R}{R+1}\right)$

10. If the capacitor is replaced by a perfect inductor (inductance L henry) the current in the circuit at any instant $t > 0$, is given by

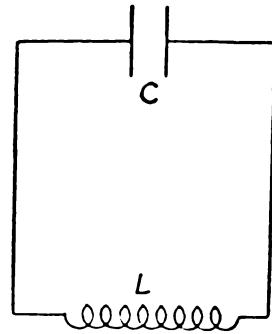
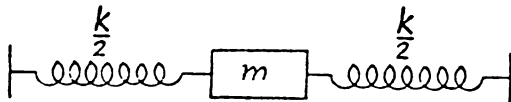
$$E = I(R + r) + L \frac{dI}{dt}$$

Draw a graph, on the axes given on your answer sheet to show qualitatively how the rate of change of current $\left(\frac{dI}{dt}\right)$ varies with current (I).

Turn over

The following information refers to questions 11 and 12.

In studying the oscillations of charge in an inductance-capacitance circuit a number of properties of the system are analogous to the oscillations of a mass between two springs. For example,



$$F = m \frac{dv}{dt}$$

$$v = \frac{dx}{dt}$$

$$V = L \frac{dI}{dt}$$

$$I = \frac{dQ}{dt}$$

$$m \frac{d^2x}{dt^2} = -kx$$

$$L \frac{d^2Q}{dt^2} = -\frac{Q}{C}$$

$$T = 2\pi \sqrt{\frac{m}{k}}$$

11. The above analogy suggests that the period of the oscillations of charge in the electrical circuit is

(a) $2\pi \sqrt{LC}$

(b) $2\pi \sqrt{\frac{L}{C}}$

(c) $2\pi \sqrt{\frac{1}{LC}}$

(d) $2\pi \sqrt{\frac{C}{L}}$

12. In the above analogy the kinetic energy of the mass is analogous to

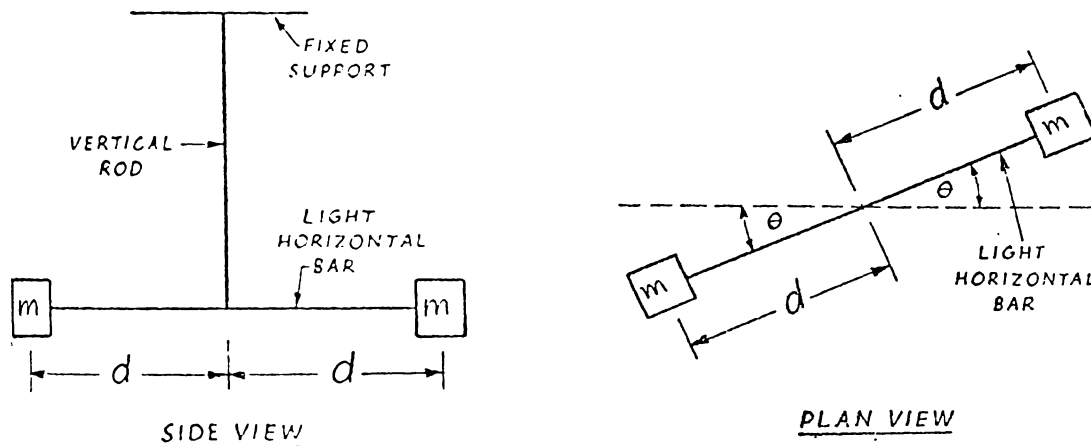
- (a) the kinetic energy of the electrons in the inductor.
 (b) the stored energy in the electric field of the capacitor.
 (c) the stored energy in the magnetic field of the inductor.
 (d) the total kinetic energy of the electrons in the circuit.

15

The following information and diagram refer to questions 13, 14 and 15.

A light horizontal bar has a mass m at either end and is suspended at its midpoint from a thin vertical rod. If the rod is turned through an angle θ in the horizontal plane, this twists the rod and the "restoring" torque it then exerts on the bar is $\tau = -c\theta$.

When the bar is released at some angle, it rotates to and fro about the vertical axis of the rod.



13. According to the rule relating torque and angular momentum, if I is the rotational inertia of the system about the vertical axis through O , which of the following equations represents the dynamic situation as the bar rotates to and fro.

(a) $I \frac{d^2\theta}{dt^2} = -c\theta$

(b) $I \left(\frac{d\theta}{dt} \right)^2 = -c\theta$

(c) $I\theta = -c \frac{d^2\theta}{dt^2}$

(d) $I \frac{d\theta}{dt} = -c\theta$

(e) $I\theta = -\frac{1}{c} \frac{d^2\theta}{dt^2}$

14. Since I depends on the masses m and the distance d , the period of oscillation of the horizontal bar could be written as,

(a) $\pi d \sqrt{\frac{8m}{c}}$

(b) $\frac{\pi}{d} \sqrt{\frac{2}{mc}}$

(c) $\pi d \sqrt{8mc}$

(d) $\frac{\pi}{d} \sqrt{\frac{2c}{m}}$

(e) $\frac{2\pi}{d} \sqrt{\frac{m}{c}}$

15. To determine the period in question 14, which of the following assumptions needs to be made?

I. The maximum value of θ is small ($\sin \theta \approx \theta$)

II. c is a constant.

III. $2m(d \cos \theta)^2$ is approximately equal to $2md^2$ (rotational inertia).

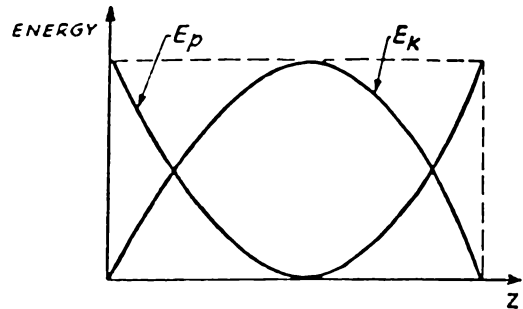
- (a) I only (b) II only (c) I and II only (d) I and III only (e) I, II and III

Turn over

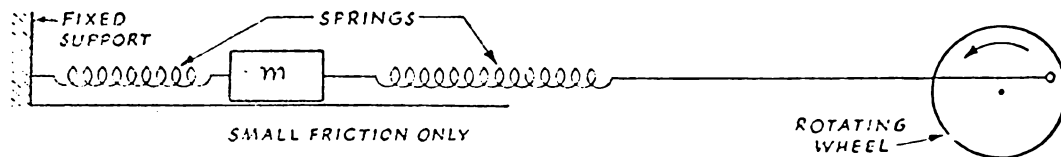
16. The following graph represents the variation of spring potential energy, E_p , and kinetic energy, E_k , of a mass oscillating on a spring in simple harmonic motion.

The axis labelled z could be

- (a) time only.
- (b) displacement only.
- (c) either time or displacement.
- (d) neither time nor displacement.



17. A mass m is supported by two springs. The end of one spring is attached via a long string to a rotating arm so that the string approximates simple harmonic motion and produces FORCED OSCILLATIONS in m .



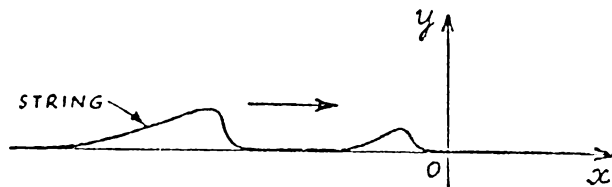
If the rotating arm is stationary, the natural period of the oscillating mass is 0.20 s. The rotating arm is then rotated at a period of 0.15 s.

After a long time the period of m is best described as being

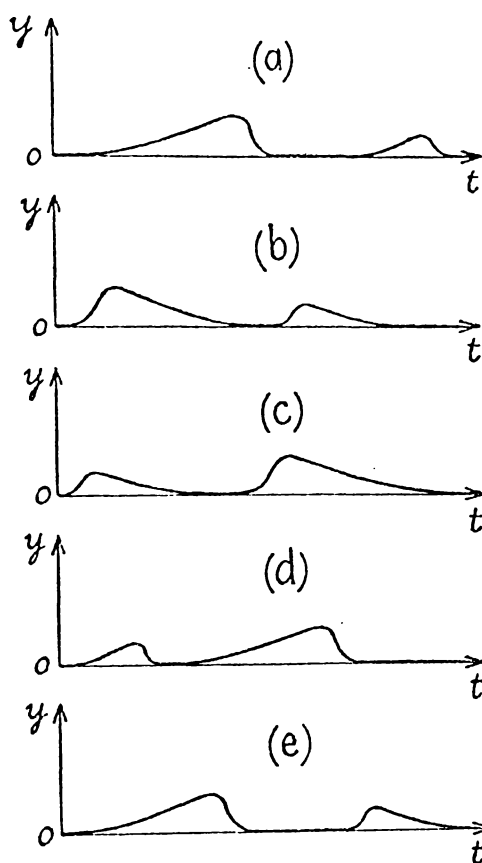
- (a) greater than 0.20 s
- (b) 0.20 s
- (c) between 0.20 s and 0.15 s
- (d) 0.15 s
- (e) less than 0.15 s

17

18. Two pulses move along a string as shown



The displacement time graph of a point O on the string would be given by



Turn over

19. A standing wave may be considered to be composed of two equal-amplitude waves travelling in opposite directions. If the average energy in each metre of the string from either one of these waves is E_0 , then what would be the average energy per metre in the resulting standing wave?

(a) zero (b) $\frac{1}{2}E_0$ (c) E_0 (d) $2E_0$ (e) $4E_0$

20. A metal rod of length one metre is held in a vertical position and dropped on a hard floor. As it rebounds the rod gives a definite frequency of sound which is about 2500 Hz. What would probably be the speed of compression waves in the rod?

(a) 5000 ms⁻¹ (b) 10,000 ms⁻¹ (c) 15,000 ms⁻¹ (d) 20,000 ms⁻¹ (e) 25,000 ms⁻¹

21. The principle of superposition is used widely in the study of wave motion. However, it is limited to the condition that the displacements are not too great. This limiting condition possibly applies to,

- I mechanical waves on strings, springs and liquid surfaces,
 II sound waves in gases, liquids and solids,
 III light waves and all other electromagnetic waves in free space.

Actually the limiting condition applies to

(a) I only (b) II only (c) III only (d) I and II only (e) I, II, and III

22. The following two waves travel along a string simultaneously

$$y_1 = A \sin \left(kx - \omega t + \frac{\pi}{2} \right)$$

$$y_2 = A \sin \left(\omega t - kx - \frac{\pi}{2} \right)$$

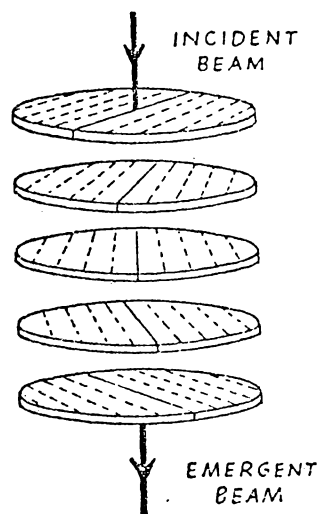
The resultant wave, assuming the principle of superposition, would be

- (a) a standing wave of maximum amplitude $2A$.
 (b) a travelling wave, velocity v , amplitude $2A$.
 (c) a travelling wave, velocity $2v$, amplitude A .
 (d) a standing wave of maximum amplitude A .
 (e) no wave at all.

23. N perfectly polarizing plates (plates that transmit all light whose polarization is correct) are stacked one on top of the other, and each succeeding plate has its polarizing axis at an angle $\theta = \frac{90^\circ}{N-1}$ clockwise with respect to the preceding plate. The last plate is therefore "crossed" with the first plate. The incident light on the top plate, as shown, is unpolarized.

If the number of plates is systematically changed

from two to eight ($\theta = \frac{90^\circ}{N-1}$ in each case), the intensity of the emergent beam



- systematically increases as N increases.
- systematically decreases as N increases.
- first decreases and then increases as N increases.
- remains constant but non zero as N increases.
- remains zero as N increases.

24. The stored energy in an inductor is $\frac{1}{2}LI^2$.

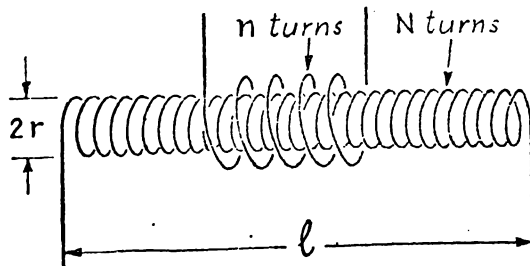
The magnetic field in a long thin solenoid is $B = \frac{\mu_0 NI}{l}$.

The inductance of a long thin solenoid is $L = \frac{\mu_0 N^2 \pi r^2}{l}$.

The above three equations suggest that the energy density in a magnetic field B is

- zero
- $\mu_0 B^2$
- B^2
- B
- $\frac{B^2}{2\mu_0}$

25. A short second coil of n turns is wound closely around a long thin solenoid length, l , radius r , and total number of turns N .



The mutual inductance of the pair of coils would be

- $\frac{\mu_0 N^2 \pi r^2}{l}$
- $\left(\frac{\mu_0 N n}{l}\right) \pi r^2$
- $\mu_0 n^2 \pi r^2$
- $\mu_0 N n$
- $\frac{\mu_0 N n}{l}$

Turn over

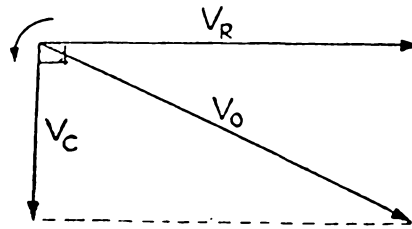
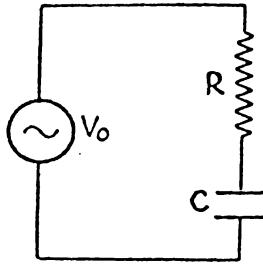
26. The relationship $V_{MAX} = \omega LI_{MAX}$ for the potential across the terminals of an inductor (where flux linkage $= N\phi = LI$ defines L) applies only,

- I for a sinusoidal current through an inductor,
- II assuming L is independent of time or current (i.e. a constant value),
- III assuming the resistance of the inductor is zero.

Of the above which conditions are necessary for $V_{MAX} = \omega LI_{MAX}$ to hold true?

- (a) I only (b) III only (c) I and II only (d) I and III only (e) I, II and III

27. The following phasor diagram represents the voltages in a resistor-capacitor series circuit, as shown.



Possible interpretations of V_0 , V_R , and V_C , on the phasor diagram, are that they represent,

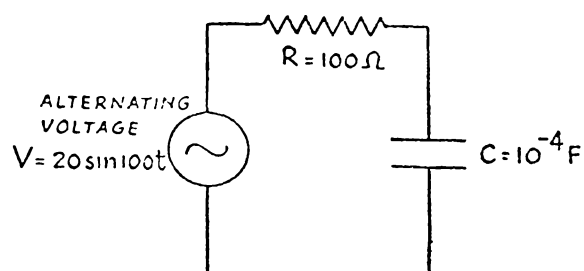
- I the R.M.S. voltages across the circuit components,
- II the peak voltages across the circuit components,
- III the instantaneous voltages across the circuit components.

Of these possible interpretations

- (a) I only is valid.
- (b) III only is valid.
- (c) I and II are both valid.
- (d) I and III are both valid.
- (e) I, II and III are all valid.

21

The following diagram refers to questions 28, 29, and 30.



28. The phase angle between the applied voltage and the current in the circuit would be equal to which of the following angles?

- (a) 0° (b) 37° (c) 45° (d) 60° (e) 90°

29. If the peak value of the current is I_0 the energy dissipated in the resistor per second is given by $\frac{1}{2}I_0^2R$. The energy dissipated in the capacitor per second is

- (a) $\frac{1}{2}I_0^2\omega C$ (b) $\frac{I_0^2}{2\omega C}$ (c) $\frac{I_0^2}{2\omega^2 C^2}$ (d) $\frac{I_0}{\omega C}$ (e) zero

30. In practice the resistance has, in addition, some slight series inductance.

The effect of this additional component will result in a current in the circuit which is,

- (a) slightly *less* than that predicted theoretically but *less* apparent at lower frequencies.
 (b) slightly *greater* than that predicted theoretically but *less* apparent at lower frequencies.
 (c) the same as that predicted theoretically for all frequencies.
 (d) slightly *less* than that predicted theoretically but *more* apparent at lower frequencies.
 (e) slightly *greater* than that predicted theoretically but *more* apparent at lower frequencies.

Turn over

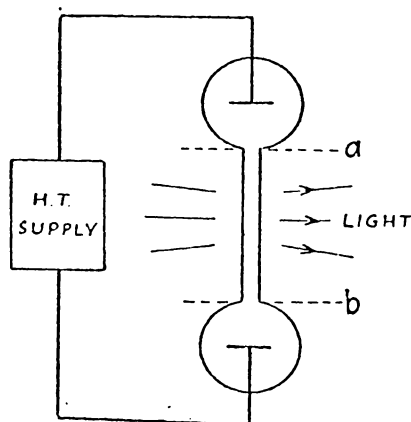
31. Consider the following statements about the photoelectric effect.

- I The photoelectric effect proves that light cannot be a wave motion.
- II The photoelectric effect suggests that a wave model of light is sometimes inadequate.
- III The photoelectric effect gives support to a particle model of light.
- IV The photoelectric effect proves that a light beam must always be considered as a stream of particles.

Of these statements

- (a) II and III are correct.
 - (b) I and IV are correct.
 - (c) II and IV are correct.
 - (d) I and III are correct.
 - (e) I only is correct.
32. A spectral lamp consists of two metal electrodes in a glass envelope. A small amount of hydrogen is introduced into the evacuated envelope. When the electrodes are connected to a high tension supply a small current flows in the circuit and light with a set of distinct wavelengths is emitted from the lamp even though the lamp remains relatively cool. These wavelengths are produced as the hydrogen atoms in the lamp can only exist in certain definite energy states.

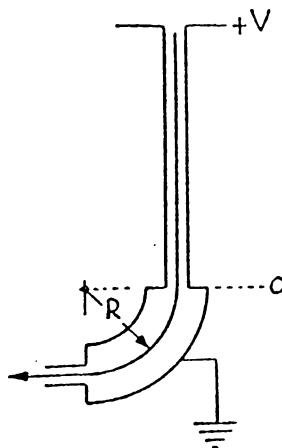
The *most likely way* in which a neutral hydrogen atom in the region *ab* would acquire a high-energy state would be



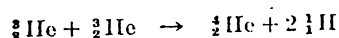
- (a) capturing a photon.
- (b) from the electric field between electrodes acting directly on the atom.
- (c) from random intermolecular collisions.
- (d) from the bombardment of the atom by electrons.
- (e) by the neutral atom colliding with the glass walls.

33. Bohr's theory of atomic structure is of wide significance even today in physics and chemistry because
- no more satisfactory model of atoms has yet been thought of.
 - his model has accounted for the spectra of a large number of elements other than hydrogen.
 - his quantization of angular momentum has been found to have wide generality.
 - the model of electrons moving in circular orbits explains why atoms link up to form molecules.
34. In a nuclear accelerator a particle with charge q and mass m is accelerated through a *potential difference* V . It then enters a magnetic field of a deflecting magnet of uniform magnetic field, B , and is deflected through 90° . The radius of the path in the magnetic field will be

- $B \sqrt{\frac{2mV}{q}}$
- $\frac{1}{B} \sqrt{\frac{2mV}{q}}$
- $\frac{Bq}{mV}$
- $\frac{mV}{Bq}$
- $\sqrt{\frac{mV}{Bq}}$



35. One of the nuclear reactions occurring in the fusion process in the sun is



If in this reaction the total rest mass of the system changes, which of the following conservation laws would be expected to hold true assuming no external forces act on the system?

- Conservation of Linear Momentum.
 - Conservation of Angular Momentum about any fixed point.
 - Conservation of Mass-Energy.
 - Conservation of Kinetic Energy.
 - Conservation of Charge.
- III only
 - III and V only
 - I, III and V only
 - I, II, III and V only
 - I, II, III, IV and V.

I.2 Examiner's Report—Scholarships Physics

ENTRANCE SCHOLARSHIP - PHYSICS

The paper was designed to give a three way coverage of:

- i) objectives of the prescription stated in the preamble and now further clarified in the Teachers' Guide Introduction (NOTE: All references to Teachers' Guide refer to C.D.U. Bulletin 48 Revised 1973.).
- ii) the topics in the prescription.
- iii) questioning techniques (long questions section I Q1-4, short questions Section I Q5 and multiple choice Section II).

As an indication of how the objectives detailed in the Teachers' Guide p iv were interpreted, some examples follow of questions which were an attempt to emphasize specific objectives.

	Section I	Section II
Objective A (Comprehension)	1(b); 2(a); 3(a)	11; 13; 18; 22; 32
Objective B (Application)	1(c); 2(b); 3(c)	1; 2; 14; 20; 28;34
Objective C (Higher skills)	1(d); 2(d); 3(d); 5(c)	3; 7; 15; 21; 26
Objective D (Experimental)	4(a); 4(b); 4(c); 5(b); 5(d)	-

Because of the variety of objectives and content, it is not expected that questions will necessarily correlate highly with each other, and therefore some caution is desirable when judging the usefulness of questions from statistical information e.g. means, correlations or discriminative indices. However, such information has been included for background reference.

Two general comments on the scripts.

i) While it may be justifiable for Scholarship candidates to study content areas not in the prescription, they should be clearly aware of the boundaries of the prescription. (See comment to Section I question 2(b).)

ii) A lack of basic comprehension of the physics expressed in mathematical language was evident, e.g. see comments on Section I question 2(a), 3(a); Section II question 8 and 10.

Detailed comments on specific questions follow.

SECTION I (65 marks)

Mean = 30.2 marks

Standard deviation = 10.6 marks

Question 1 (12 marks)

Mean = 6.5

Standard deviation = 2.6

Correlation with overall mark = 0.70

The introductory questions (a) and (b) were answered well by most candidates, many candidates reasoned out (c) (i) but had difficulty analyzing (c) (ii) correctly. In (d) few candidates understood that if the ball did not actually slip on the surface, negligible work would be done by the friction force as it did not move through a distance. Too many candidates seemed to consider any frictional force present as a form of energy.

Question 2 (12 marks)

Mean = 4.8

Standard deviation = 2.7

Correlation with overall mark = 0.77

(a) Candidates in general either had a clear appreciation of Ampere's law or were very confused. Confusion was evident between the line integral $\int Bdl$ and the surface integral $\int BdA$. The total current was often assumed to be the current due to all currents producing the magnetic field not just the current "threaded" by the path.

(b) If candidates had difficulty explaining Ampere's law they had even more difficulty applying it to the problem situation. Very few concluded that the magnetic field at the centre of the strip would be zero by symmetry but rather many incorrectly assumed that the field in the conductor was zero everywhere. Only the very best students seemed to be able to follow the argument through to the correct solution. There were a number of attempts at solving the problem using Biot Savart law. Such attempts seem to show a lack of awareness of the prescription content.

(d) Despite the clear emphasis in the prescription of a "model for the conduction of electricity in metals in terms of the motion of free electrons" few candidates had any real appreciation of the motion of free electrons. Many assumed the conduction electrons move with perfectly constant velocity through the metal.

Question 3 (12 marks)

Mean = 5.5

Standard deviation = 2.4

Correlation with overall mark = 0.69

(a) Like question 2(a), a lack of appreciation of the physical situation described by a mathematical equation was clearly evident. Taking the liberty of quoting candidates' answers, it was suggested that y represented the "length/spread/pitch/width/frequency/height of the sound waves" and even more exotic ideas were given, such as "the displacement of an observer/the distance between the waves" not to mention "y represents a microwave detector"! This point is laboured as it seems so important that pupils basically comprehend the physical reality behind the language being used, if any real learning is to occur.

(b) and (c) These questions were answered reasonably well. However, a number of candidates still do not appreciate that the sound actually heard is the mean frequency of the two sounds, and it is this sound that is varying in amplitude with a beat frequency of $f_1 - f_2$.

(d) Few candidates really appreciated that in this situation the nodal lines would be curved at even large distances due to time delay in propagation. Interestingly enough it was sometimes the apparently poorly prepared candidate who reasoned this out successfully, even though the candidate was unable to answer questions more closely related to bookwork.

Question 4 (12 marks)

Mean = 6.0

Standard Deviation = 3.2

Correlation with total mark = 0.61

Basically this question was answered satisfactorily. However, too many candidates were prepared to state that the results confirmed theoretical predictions without qualification, even though a significant departure from the linearity of the graph was apparent for $t > 80s$.

E.S. Physics-2

Question 5 (17 marks)

Mean = 7.6

Standard deviation = 3.5

Correlation with total mark = 0.73

(a) Mean = 1.9

This question was well answered by most candidates, although it was intended as an unfamiliar situation.

(b) Mean = 1.2

If this question is related in anyway to the ability of students to plan experiments then there are definitely some inadequacies in this area. Marking the 464 scripts gave a real opportunity to see the seemingly infinite variety of ways six circuit components can be joined together. Unfortunately the majority of the ways suggested were inadequate and were usually with complete disregard for the longevity of the components. Perhaps assignments of this type prior to an experimental session might provide the opportunity to develop this planning aspect of experimental work (refer Teachers' Guide p.(iv) D1.).

(c) Mean = 1.4

This question was answered reasonably well. The majority of students realizing that $g = 10 \text{ N kg}^{-1}$ was incorrect. Suggesting the specific correction proved slightly more difficult.

(d) Mean = 1.8

Suggestions of what graphical analysis would be useful to check the relationships

$$T^2 = \frac{4\pi^2}{k} m + \frac{4\pi^2 m s}{k}$$

were occasionally too simple (T versus m), but more often too sophisticated and incorrect ($\log T$ versus $\log m$). If the analysis is to verify such an equation where the exponents are known (T^2 and m), then a graph of these variables deserves first consideration.

(e) Mean = 1.4

Considering the deliberate unfamiliarity of the situation many candidates answered the question well, although the constant magnitude of V_{cd} was not always realized.

SECTION II (35 marks)

Mean = 15

Standard deviation = 5.3

Correlation with Section I = 0.66

An analysis of the questions in this section is given in Table I. The column T gives the *percentage* of all candidates ($N = 464$) who chose each alternative. The underlined alternative, the correct answer, therefore gives the *facility* of the question in terms of the percentage of all students who chose the correct answer.

Two groups were separated from all scripts, a higher group (H) consisting of the top 27% of the total mark for the paper, and a lower group (L) consisting of the bottom 27%. Again the choices

of each of these groups is given as percentages.

The Discrimination index is a measure of the questions ability to differentiate between candidates in the high and low groups.

$$\text{Discrimination Index} = \frac{\text{percentage correct in H} - \text{percentage correct in L}}{\text{percentage correct in L}}$$

The percentage discrimination index for each question can hence be obtained from the difference between the high and low percentages for the correct choice (underlined).

The Discrimination index provided in the last line is the index calculated using Section II only as the criteria for choosing high and low groups.

As mentioned last year, the discrimination index is susceptible to statistical fluctuations. This places reservations on the second significant figure.

The distribution of responses both by all candidates (T) and those in upper (H) and lower (L) groups, indicates common errors and confusions.

Detailed comments on individual questions follow.

1. The idea that the force on the particle was central to the moon's centre rather than to O, hence the torque with respect to O was non zero, was not appreciated by over half the candidates.

3. A critical attitude to the validity of relationships (Preamble 1) could perhaps be given more emphasis by scholarship candidates. The question proved difficult.

7. Provided the test charge does not move the charges producing the field, the value $\frac{F}{q}$ will correctly determine the field due to these other charges, at that point.

8 and 10. These questions proved difficult, showing some limitations in the abilities of candidates to understand and use the mathematical language of physics. Only 28% of candidates could recognize that the equation of question 10 was essentially of the form $y = mx + c$.

13, 14 and 15. This was an attempt to ask three questions all related to one specific situation at three levels of ability as set out in p.iv of the Teachers' Guide. (Q.13 Level A, Q.14 Level B and Q.15 Level C.) The variation in the difficulty of the questions suggests the attempt was reasonably successful.

16. This question proved difficult considering the emphasis given to this point in the Teachers' Guide p.48.

23. Another difficult question. The question is best answered graphically considering the component of the polarization passing through the next plate.

29. Although this question discriminated well, the facility level (34% correct) is surprisingly low.

30. This question proved difficult, it was hoped ideas of resonance would be related to this situation, and the idea that some inductance in the circuit would lead to an increase in the current.

35. The generality of the principles of conservation of momentum and angular momentum did not appear to be appreciated by a large number of candidates.

E.S. Physics-3

TABLE I

	1	2	3	4	5	6	7	8	9
	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L
A	57 46 57	47 68 30	3 1 5	19 15 21	20 18 15	22 12 23	33 23 35	1 0 2	34 28 38
B	10 10 14	18 8 23	55 47 54	51 64 45	8 5 11	22 6 36	25 38 15	3 1 6	45 59 40
C	30 42 26	19 15 26	13 6 20	24 18 23	21 14 33	36 66 17	15 16 22	6 6 8	15 7 14
D	1 2 1	4 3 6	6 9 6	5 2 8	43 61 28	16 11 16	27 22 26	60 44 61	2 1 2
E	1 1 0	11 5 12	23 38 14	1 0 2	6 1 9	3 4 4	-	28 49 19	3 4 3
DISC	0.23	0.43	0.32	0.23	0.30	0.48	0.07	0.32	0.29
	10*	11	12	13	14	15	16	17	18
	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L
A	28 55 10	71 88 54	10 9 14	76 92 57	40 73 23	6 3 8	22 24 26	9 6 11	12 2 22
B	71 45 89	14 5 25	11 6 16	5 2 11	5 2 7	24 43 13	18 27 13	9 10 9	3 1 6
C	1 0 1	11 6 14	50 65 35	4 2 8	7 3 7	47 38 49	57 48 58	30 22 38	79 94 62
D		3 1 6	29 21 34	12 4 18	9 7 10	8 2 14	2 1 2	41 57 29	3 2 5
E		-	- -	3 0 5	38 15 50	14 13 15	- - -	10 6 12	1 0 3
DISC	0.47	0.41	0.36	0.40	0.62	0.44	0.14	0.35	0.39

Q.10 A - correct B - incorrect C - no attempt

TABLE I contd..

	19	20	21	22	23	24	25	26	27
	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L
A	25 14 36	62 80 45	31 26 32	27 14 38	22 33 13	4 1 6	16 12 18	5 1 8	13 2 20
B	2 0 3	14 7 19	9 7 10	11 8 6	45 41 48	12 6 17	52 65 46	11 10 11	11 7 14
C	9 7 9	3 1 4	9 2 14	2 1 2	6 7 8	6 1 11	10 8 10	21 15 28	41 55 26
D	57 67 48	3 2 4	39 58 26	6 0 10	6 4 8	10 10 13	9 6 10	21 14 27	11 10 18
E	6 11 2	17 10 25	12 6 16	53 77 42	18 14 19	65 80 49	11 8 13	42 59 22	23 26 18
DISC	0.31	0.50	0.37	0.47	0.31	0.36	0.32	0.42	0.36
	28	29	30	31	32	33	34	35	
	T H L	T H L	T H L	T H L	T H L	T H L	T H L	T H L	
A	13 8 18	8 1 13	46 52 42	85 94 74	20 12 22	12 10 18	6 4 8	16 7 22	
B	13 6 18	44 30 55	19 27 11	3 2 5	16 12 19	27 15 37	28 52 12	36 32 38	
C	45 71 24	8 4 10	6 6 7	5 1 10	6 5 10	50 68 33	14 6 21	10 7 12	
D	8 5 10	4 3 6	19 9 26	5 2 7	55 70 45	8 6 8	34 29 36	28 51 14	
E	19 8 27	34 62 12	8 6 10	1 0 1	1 1 0	- - -	15 7 18	8 2 10	
DISC	0.49	0.61	0.21	0.35	0.38	0.41	0.41	0.37	

I.3 Further analysis of the Scholarships Physics Examination, 1973

As the author was involved in the detailing of the objectives of the seventh form course (CDU, 1973, p. iv-v) and was chief examiner for Scholarship Physics in 1972 and 1973, many of the ideas and perceptions about objectives and assessment procedures outlined in this thesis closely relate to the objectives and assessment procedures used with the Scholarship Physics candidates in 1972 and 1973. This is apparent to some extent in a comparison of the seventh form objectives with Table 5.1 and from the examiner's report on the 1973 examination (Appendix I.2). Objectives A to D in the examiner's report roughly correspond to the complexes of Objectives I to IV of Table 5.1 with some minor changes.

Principal components analyses of the marks on questions in the 1972 and 1973 examination papers showed that, as with the first year physics analyses, the score obtained on any question was a complex function of question type, position of the question on the paper, content covered and the objective assessed. Where structured questions were involved (Questions 1 to 4 in Part I of the Scholarship Physics paper, 1973) they tended to be more highly correlated even though the answers to one subquestion were not necessarily dependent on an earlier subquestion. For example, Table I.1 shows a component analysis of the subscores on the free-format question (Part 1) for the 1973 Scholarship Physics

paper.¹ As stated in the examiner's report, objectives were designated in terms of the examiner's intention in setting the questions. The four significant factors accounted for 50% of the variance.² However, these factors identified the way questions were grouped in terms of the position on the paper and of content areas covered rather than on different objectives. Table I.1 is of interest as it is also typical of results obtained from component analyses of tests and examinations of the first year courses in the cases where long questions involving structured questions were analyzed.

To obtain a closer comparison between attainments in the Scholarships examination and the results in Chapter 8, particular subtotals were extracted from the 1973 Scholarships paper. It was possible to obtain subscores of achievement on objectives closely related to many objectives of the first year courses. In addition, the achievement of each objective was normally measured by procedures similar to those used in Chapter 8. Four multiple-choice questions were used to obtain a relatively content free score for the attainment of the objectives corresponding to the first year objectives, I(B) to III(C) of Table 5.1. Further, some of the free format questions in the Scholarships examination paper were directed toward experimental objectives closely related to the experimental objectives of the first year courses. In this way subscores were extracted from the Scholarships Physics examination which were similar both in terms of assessment technique and objectives to the subscores analyzed with first year students in Chapter 8 (with regard to Objectives I to IV of Table 5.1).

¹An eigen value criterion of $\lambda > 1.0$ was taken in this analysis as larger numbers of students were involved giving greater stability to correlation values ($\lambda_1 = 5.8$, $\lambda_2 = 1.7$, $\lambda_3 = 1.4$ and $\lambda_4 = 1.2$).

²Typically the inclusion of subscores of multiple-choice questions into such component analyses was found not to introduce extra factors. Rather multiple-choice totals would load on factors already present.

Table I.1 Principal components analysis of the free format questions in the 1973 Scholarships Physics Examination 1973 (N=463) with factor loadings ≥ 0.5 shown.

Question Number	Objective Intended	Factor Loadings				Percentage Mean	Percentage Standard Deviation	100h ²
		I	II	III	IV			
1A	(A/B)	0.6				62	25	45
1B	A	0.7				81	24	45
1C	B	0.7				42	32	54
1D	C	0.5				31	33	35
2A	A	0.6				52	36	51
2B	B	0.6				31	29	49
2C	(A/B)	0.6				41	31	51
2D	C				0.5	33	25	38
3A	A				0.6	52	27	52
3B	(A/B)				0.5	51	27	47
3C	B				0.5	67	36	47
3D	C				0.6	12	19	46
4A	D		0.9			50	25	75
4B	D		0.7			31	31	62
4C	D		0.8			80	50	70
5A	(A/C)			0.5		62	24	40
5B	D			0.5		39	31	32
5C	C			0.6		46	39	47
5D	D			0.7		44	30	61
5E	(A/B/C)			0.7		35	28	51

A principal components analysis of the subscores from the Scholarships examination yielded the results of Table I.2 which is not dissimilar to aspects of the analyses in Chapter 8, particularly Table 8.5. However, the two significant factors account for only 40% of the variance.³ This low variance results, at least in part, from the narrow ability range of the Scholarship candidates who form only 15% of the total number of seventh form students.

Of wider interest from a seventh form examining point of view is the relationships between the components of achievement and other aspects of the educational system. In addition to details of a student's achievement on different questions in the 1973 Scholarships Physics examination, each student's marks in other subjects as well as his grand totals in Bursary and Scholarship were known.⁴ A reasonably reliable, if not perfectly valid, measure of achievement in each of the Objectives A to D of the seventh form syllabus was obtained from a combination of multiple-choice scores on each objective (Table I.2) with subscores on the same objective obtained from the free format questions (Table I.1). Only questions which could be unambiguously classified were included. (Bracketed objective subscores from Table I.1 were not included.) The means and standard deviations are provided in Table I.3 for these subscores, both for all candidates ($N = 463$) and for those whose total mark was at least one standard deviation above the mean ($N = 70$).⁵ Correlations of the total score on each objective with the Scholarship total derived from all eight papers sat showed

³An eigen value criterion $\lambda > 1.0$ was used ($\lambda_1 = 3.9$, $\lambda_2 = 1.6$).

⁴Bursary total is the total mark in five different subjects at the Bursary level. Scholarship total is the Bursary total plus the total mark in Scholarship papers in three subjects selected from those sat at Bursary level.

⁵A function of a Scholarship examination is to discriminate amongst such able candidates.

Table I.2 Principal components analysis of the objective subtotals in the 1973 Scholarships Physics examination 1973 (N = 463) with factor loadings >0.5 shown.

	Question Numbers	Objective Intended	Equivalent First Year Objective	Factor Loadings		Percentage Mean	Percentage Standard Deviation	100h ²
				I	II			
Part II	12,29,32	A	(Recall)	0.6		46	30	36
	10,11,18,27	A	I(B)	0.6		55	25	39
	8,13,17,22	A	I(C)	0.5		49	26	32
	4, 5, 9,28	B	II(A)	0.5		45	26	28
	6,14,25,34	B	II(B)	0.6		49	26	46
	1, 2,19,20	B	II(C)	0.6		49	25	36
	7,16,23,30	C	III(A)			22	21	9
	3,15,21,26	C	III(B)	0.6		32	26	38
	24,31,33,35	C	III(C)	0.6		59	26	37
Part I	4A	D	IV(E)		0.9	50	25	73
	4B	D	IV(E)		0.8	31	31	63
	4C	D	IV(A)		0.8	80	50	71
	5B	D	IV(B)			39	31	13
	5D	D	IV(C)		0.5	44	30	28

Table I.3 Means, standard deviations, and correlation coefficients for all candidates (N = 463) and for the best candidates (N = 70)

Objective	Maximum Possible Mark	Mean		Standard Deviation	
		All	Best	All	Best
A	20	11.1	15.8	3.4	1.9
B	23	10.4	17.2	4.3	2.4
C	23	7.8	12.5	3.4	2.8
D	19	8.9	13.2	4.1	2.7

Objective	Correlation Coefficients			
	Scholarships Grand Total		Bursary Grand Total	
	All	Best	All	Best
A	0.75	0.19	0.68	0.29
B	0.77	0.31	0.68	0.41
C	0.69	0.15	0.61	0.32
D	0.62	0.24	0.54	0.27

that the Objective B scores correlated most highly with the Scholarship total for not only all candidates but also for the subset of most able candidates.

It had been hoped that the Objective C questions involving higher skills may have more adequately discriminated amongst the students, particularly the most able. Two possible reasons why this did not occur are:

- (i) All the Scholarship candidates sat BURSARY PHYSICS (N = 463), of these all but one sat BURSARY MATHEMATICS. 344 candidates sat APPLIED MATHEMATICS while 447 sat BURSARY CHEMISTRY. The Scholarship grand total for the physics candidates is likely therefore to be dependent on mathematical ability. In fact the highest correlation between a Bursary score and the Scholarship grand total was for BURSARY APPLIED MATHEMATICS (0.87). As shown in Model 2, Chapter 11, Objective B (particularly related to Objectives II(A) and II(B) of Table 5.1) is dependent on mathematical ability.
- (ii) One of the problems of asking high level questions (Objective C) in an examination is that even in an examination where no choice is available, students can choose not to attempt a question. Particularly if a paper is long and students are rushed, a capable student will appreciate the difficulties of a question and pass over it in search for questions about which he is confident and from which he knows marks can be easily obtained. On the other hand, weaker candidates will attempt Objective C questions (particularly of an Objective III(A) of Table 5.1 type) either because they do not appreciate the subtlety of the question or because the question does not require recall information. This problem is clear from discussions with "capable" students

scoring low marks on Objective C questions and from the fact that unique factor loadings often appear on Objective III(A) (of Table 5.1) questions.⁶

In addition to the disappointingly low correlation of the Objective C scores to the Scholarship awarding mark, the low correlation of the experimental objective is of interest. At least two possible reasons for this result can be put forward;

- (i) there is a wide variety of experimental work undertaken in schools,
- (ii) there is a novelty about these "experimental" questions in that such questions are not found in the Bursary paper.

The above results indicate the possible interest in models of the national system particularly if different aspects of assessment are seen as assessing different objectives. It would be interesting to know, for example, what predictive validity in the long-term is associated with each of the objective scores (A to D) considered in this appendix and to monitor how these relationships change with changes in assessment methods, teaching techniques and the objectives themselves.

⁶For example, a principal components analysis of the multiple-choice subscores from Table I.2 yielded two factors. All loadings on factor 2 were less than 0.4 after a Varimax rotation except for Objective III(A) which was 0.9.

APPENDIX J

TYPICAL PRETEST INFORMATION (1971)

UNIVERSITY OF WAIKATO

Physics Education Analysis

Test Item **HF1**

Correct Answer **3**

	Subtest			Complete Test			Complete Test			Complete Test		
Test Name	IV(E)			B			E			F		
Number of Questions in Test	10			53			45			52		
Number of Students in Test	127			45			31			51		
Discrimination	0.64			0.42			0.50			0.57		
Facility	0.59			0.79			0.50			0.57		
	Total	Top	Lower	Total	Top	Lower	Total	Top	Lower	Total	Top	Lower
A	8	0	5	1	0	0	2	0	0	5	0	3
B	9	0	6	2	0	1	4	0	3	2	0	1
C	80	30	9	35	12	7	17	6	2	30	12	4
D	11	3	5	2	0	2	2	0	1	7	2	3
E	8	0	3	3	0	1	3	2	0	2	0	2

Applicability/relevance

Suggested Applicability

Input

A

Output

A very

Face validity

IV(E)

6

7

73.101

73.102

B adequate

Content Relevance

A

A

C if really necessary

HF1 The rate of flow of heat (R) through a metal bar depends on the radius of the bar (r), the length of the bar (l), and the difference in temperature between its ends. ($T_2 - T_1$).

A student investigates the rate of heat flow through a bar and obtains the following results:

R (joule s ⁻¹)	r(m)	l(m)	$T_2 - T_1$ (K)
4	2×10^{-2}	1.0	2
8	2×10^{-2}	1.0	4
12	2×10^{-2}	1.0	6
16	4×10^{-2}	1.0	2
36	6×10^{-2}	1.0	2
2	2×10^{-2}	2.0	2
1	2×10^{-2}	4.0	2

From these results we would conclude that R is proportional to,

A) $\frac{T_2 - T_1}{r^2}$

B) $\frac{r^2}{T_2 - T_1}$

C) $\frac{r^2(T_2 - T_1)}{l}$

D) $\frac{r(T_2 - T_1)}{l^2}$

E) $\frac{l(T_2 - T_1)}{r^2}$

Answer **C**.....

APPENDIX K

INPUT ASSESSMENT OF STUDENT ACHIEVEMENT

The following battery of tests were used with entrant students in March 1974. Except for minor changes to a few questions they are identical to the tests used in March 1973. The questions were also used in schools in October 1974 with slight adaptation to front pages and answer sheets and with the exclusion of the Aptitude Tests.

K.1 Objectives and multiple-choice summary statistics.

K.2 Part I Experimental Physics

K.3 Part IB Aptitude Tests

K.4 Part II Theoretical Physics

K.5 Part III Physics Questionnaire.

K.1 Objectives and multiple-choice summary statistics (input assessment)

(i) Cognitive items (all objectives except V(C) and VI)

Objective	Test Part	1973 Question Number	1974 Question Number	Content **	M.C. Facility (Discrimination) ***		
					March 1973 N=101	March 1974 N=87	Oct 1974 N=193 In Schools
I(B)	I	18	1	W	56(59)	68(36)	66(33)
	I	4	5	M	28(33)	43(59)	30(38)
	I	9	10	F	59(30)	59(27)	53(30)
	I	16	17	F	54(41)	57(50)	60(43)
I(C)	II	11	11	W	37(44)	43(32)	41(13)
	II	17	17	F	52(30)	59(64)	55(64)
	II	19	19	W	22(0)	70(23)*	61(36)
	II	25	25	M	28(-18)	52(23)*	54(36)
I(B)/I(C) Additional Items	B C C C	28(II)	24(I)	W	26(37)	34(41)	34(53)
		1	1	M	72(26)	68(-8)	77(8)
		9	2	F	39(63)	32(55)	33(47)
		4	4	W	44(52)	43(50)	40(26)
II(A)	II	7	7	M	54(26)	52(32)	37(40)
	II	10	10	F	65(41)	70(23)	61(43)
	II	18	18	W	54(19)	55(45)	42(53)
	II	20	20	W	35(48)	34(50)	42(62)
II(B)	II	2	9	M	61(41)	59(27)	59(26)
	II	15	15	F	28(41)	30(41)	38(45)
	II	16	16	M	26(30)	27(36)	34(42)
	II	21	21	F	37(22)	30(23)	27(43)
II(C)	II	5	5	F	13(19)	25(14)*	29(32)
	II	8	8	M	42(26)	55(45)	35(28)
	II	24	24	M	28(26)	34(32)	24(17)
	II	27	27	W	33(22)	48(41)	45(42)
III(A)	II	6	6	M	22(30)	30(59)	21(08)
	II	12	12	F	43(41)	50(36)	53(38)
	II	22	22	W	52(44)	59(64)	45(49)
	II	26	26	M	19(30)	43(50)	24(28)
III(B)	I	3	2	M	30(30)	43(68)	43(57)
	I	11	12	F	17(26)	41(18)	32(30)
	I	19	19	W	24(26)	30(41)	25(28)
	I	22	22	W	35(41)	32(45)	35(36)
III(C)	II	3	3	M	43(-3)	59(45)	53(26)
	II	13	13	F	61(26)	66(32)	65(28)
	II	14	14	F	56(30)	68(45)	58(25)
	II	23	23	W	15(11)	16(05)	26(23)
IV(A) (i)	I	5	6	GEN			
	I	13(a)	14(a)	GEN			
	(ii) I	6	7	GEN			
	I	13(b)	14(b)	GEN			
IV(B)	I	7	8	GEN			
	I	14	15	GEN			
IV(C)	I	10	11	F	44(22)	52(32)	43(15)
	I	12	13	GEN	41(44)	41(36)	42(45)
	I	17	18	GEN	33(22)	39(05)	19(23)
	I	23	23	GEN	17(11)	52(32)*	46(25)
IV(E)	I	1	3	GEN	46(11)	52(50)	64(53)
	I	2	4	GEN	44(67)	41(39)	50(55)
	I	20	20	GEN	46(48)	64(36)	57(75)
	I	21	21	GEN	15(22)	66(32)*	61(66)
IV(F)	I	8	9	GEN			
	I	15	16	GEN			
V(A)	III(B)	2	2	GEN	48(64)	59(44)	48(66)
	III(B)	3	3	GEN	50(76)	63(75)	50(70)
	III(B)	5	5	GEN	40(64)	52(47)	64(57)
	III(B)	6	6	GEN	46(68)	31(50)	32(53)
V(B)	III(B)	1	1	GEN	64(64)	70(53)	66(57)
	III(B)	4	4	GEN	68(40)	70(41)	73(43)
	III(B)	7	7	GEN	54(60)	58(66)	51(53)
	III(B)	8	8	GEN	24(48)	22(31)	21(42)

* Some questions were modified usually to improve face validity with respect to physics or the objective it was designed to measure.

** M - mechanics, F - fields, W - waves.

*** Discrimination index over all M.C. questions, except V(A) and V(B) questions for which discrimination was with respect to these objectives only.

(ii) Likert scale items, analyses of items see Chapter 7.3.

Objective	Test Part	Questions March 1973, March 1974, October 1974 (Schools)
V(C)	III(B)	3, 8, 13, 18, 22, 26, 30, 33, [35]
VI(A)	III(B)	[2], 5, 7, 11, 16, 19, 24, 27, 31
VI(B)	III(B)	4, 9, 12, 15, 20, 23, 28, 34, [36]
VI(C)	III(B)	[1], 6, 10, 14, 17, 21, 25, 29, 32

[] items not included in total score.

(iii) Content areas (objectives I - III only)

Content	Test Part	March 1973	March 1974, October 1974 (Schools)
Mechanics	I	3, 4	2, 5
	II	1, 2, 3, 6, 7, 8, 16, 24, 25, 26	1, 3, 6, 7, 8, 9, 16, 24, 25, 26
Fields	I	9, 11, 16	10, 12, 17
	II	5, 9, 10, 12, 13, 14, 15, 17, 21	2, 5, 10, 12, 13, 14, 15, 17, 21
Waves	I	18, 19, 22	1, 9, 22, 24
	II	4, 11, 18, 19, 20, 22, 23, 27, 28	4, 11, 18, 19, 20, 22, 23, 27

K.2 Part I Experimental PhysicsUNIVERSITY OF WAIKATO73.102 Experimental PhysicsINTRODUCTORY TEST

The following questions are designed to test your background knowledge of those aspects of physics particularly related to this course (PART A), and to gain some idea of your ability at tasks quite independent of your school background (PART B). The results of this test will not contribute in any way to your final assessment, rather they will be used to assign you to laboratory pairs, and assist us in helping you gain as much from this course as possible.

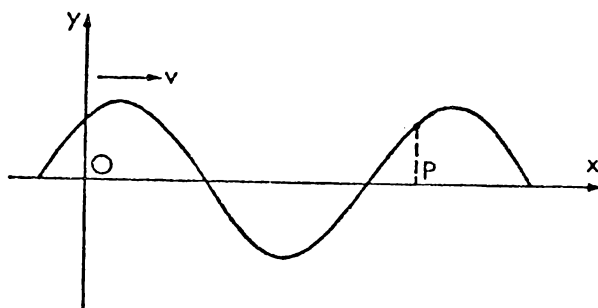
The results of these tests will not be published but your own result will be made available to you personally should you be interested.

PART A

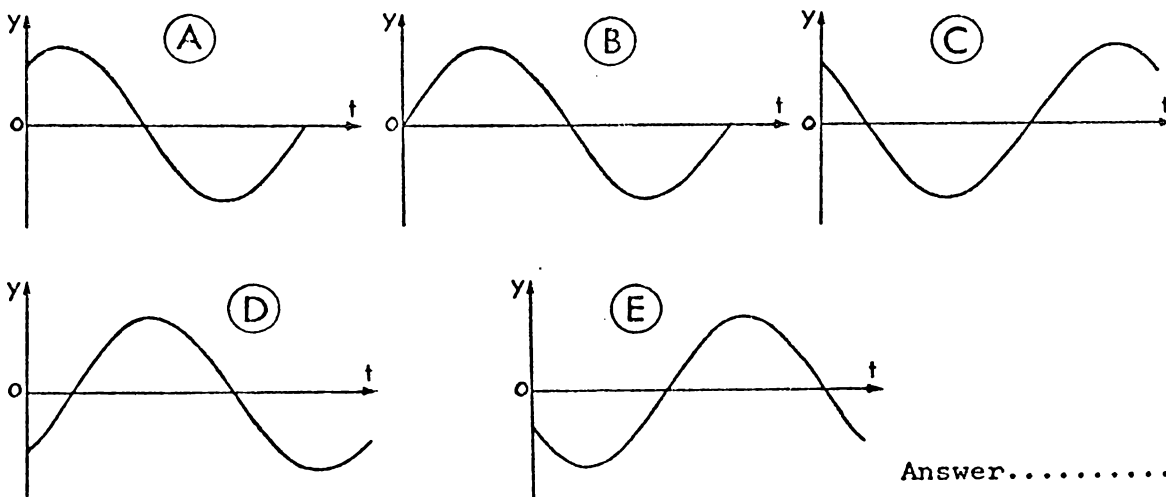
Obviously your performance in this test will be related to your background knowledge of physics and experimental work, however, many questions are designed so that they can be answered from a limited background of physics. We ask that whatever your background you answer each question to the best of your ability. If you are reduced to a random guess on any question please write DK (don't know).

Name.....

1. A transverse wave is moving in the positive x direction. The displacement of the medium is y and the diagram shows the position of the wave at time $t = 0$.



Of the following graphs, which one best represents the variation with time of the displacement of the point in the medium at P?



Answer.....

2. A pendulum, which consists of a small mass suspended on a string is released from rest. The initial angle of the pendulum is 80° to the vertical, and the length of the pendulum is 1 m. A student measures the period of motion of the pendulum as 2.20 s. Using the formula $T = 2\pi\sqrt{\frac{l}{g}}$ the period of the pendulum is calculated as 2.00s. (note: $g = \pi^2$)

The reason for the difference between the experimental and theoretical values is that,

- A. no account has been taken of the pendulum mass.
- B. a mistake has been made when calculating T from $T = 2\pi\sqrt{\frac{l}{g}}$.
- C. as $\frac{\pi^2}{g} = 1.007$, the assumption that $g = \pi^2$ is not warranted.
- D. experimental error has resulted in a value for the period which is too high.
- E. the formula $T = 2\pi\sqrt{\frac{l}{g}}$ does not really apply in the situation described.

Answer.....

This data refers to questions 3 and 4

Water is kept at a constant height in a tank. Water flows from the tank through a number of horizontal tubes of different lengths and cross-sectional areas. These tubes are all attached to the tank at the same level. The volume of water that flows from each of these tubes in 1 minute (the flow rate) is recorded in the following table:-

Length of tube L	Cross-sectional area of tube S	Flow rate V
10 cm	0.010 cm ²	90 cm ³ /min
20 "	0.010 "	45 "
30 "	0.010 "	30 "
30 "	0.020 "	120 "
30 "	0.030 "	270 "

3. Which of the following graphs would be the most useful in predicting the flow rates from tubes of various lengths, all of cross-sectional area 0.010 cm², and all at this same level in the tank?

- A. V against L B. V against $\frac{1}{L}$ C. V against L²
 D. V against $\frac{1}{L^2}$ E. V against $\frac{1}{L^3}$

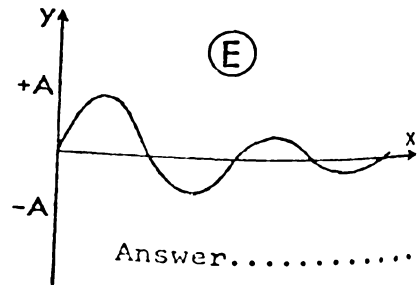
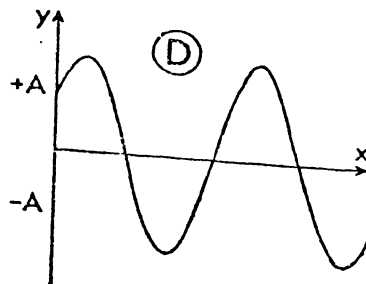
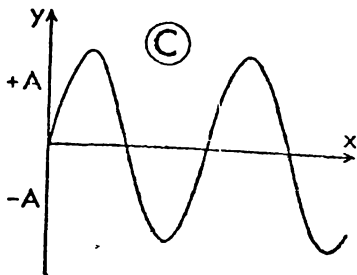
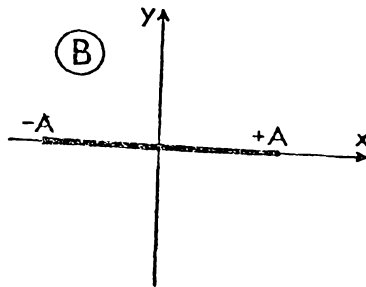
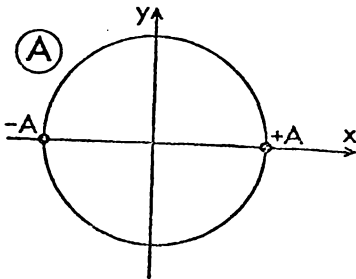
Answer.....

4. Which of the following graphs would be the most useful in predicting the flow rates from tubes of different cross-sectional areas all of length 30 cm, and all at this same level in the tank?

- A. V against S B. V against $\frac{1}{S}$ C. V against $\frac{1}{S^2}$
 D. V against S² E. V against S³

Answer.....

5. A particle moves along the x-axis and its position as a function of time is represented by $x = A \sin(\omega t + \phi)$. The path of the particle over a sufficiently long time interval will be best represented by which of the following diagrams?

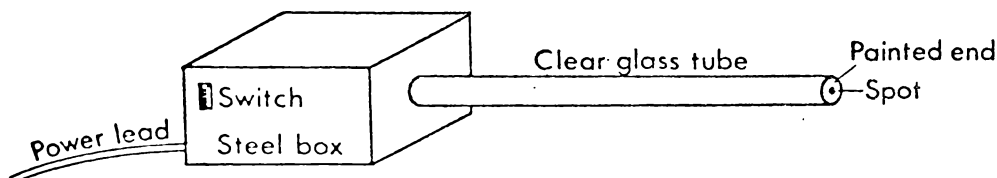


Answer.....

The following data refers to question 6 - 9

Read the complete set of questions 6 - 9 before attempting to answer any question.

A long thin tube of clear glass has one end enclosed in a small steel box. The other end is sealed and appears to have a coat of "paint" on it. Electrical power is supplied to the box by a lead which plugs into the main and a switch is provided on the side of the box.



When the switch is turned on a small spot appears on the end of the tube after a few minutes. Although no beam is visible it is assumed that an invisible ray, or beam, is passing down the tube and producing the visible spot on the paint surface.

6. A number of suggestions are put forward as to what the beam consists of. One suggestion is a beam of electrons. Give as many other suggestions as you can which are consistent with the known properties of the device.

Answer The beam could possibly consist of:

- (i)
- (ii)
- (iii)
- (iv)

7. How could you check the idea that the beam consists of electrons? (Outline of method only (no practical details).) Predict what would happen in your investigation if the beam is in fact electrons. (Very brief details one line only.)

(i) Method:.....

(ii) Prediction if beam electrons:.....

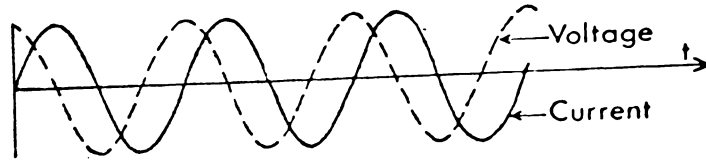
8. Give very brief practical details of how you would carry out the electron beam investigation.

.....

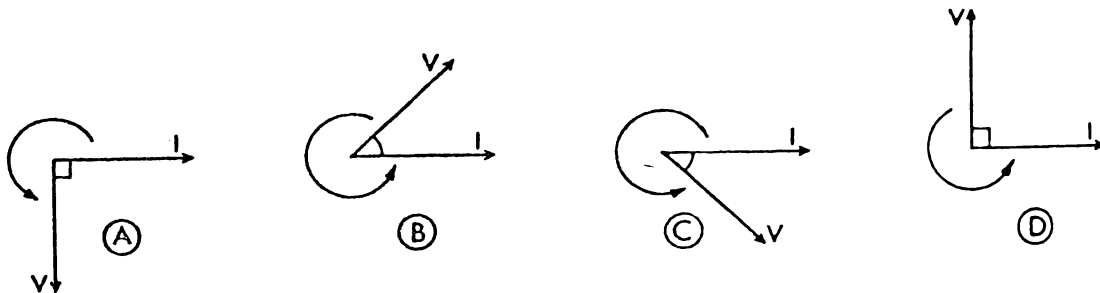
9. If your prediction was in fact true, would this prove the beam was electrons?

.....

10. The voltage across a component in an A.C. circuit and the current through the component are recorded simultaneously on a chart recorder.

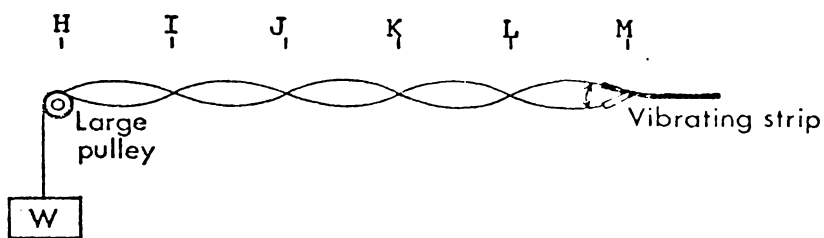


The phase relationship between the current and the voltage is best represented by which of the following rotating vector (phasor) diagrams.



Answer.....

11. An experimental set-up to investigate standing waves in a string consists of a weight, frictionless pulley, string and vibrating strip (as shown below). The frequency of the vibrator is 100 Hz, and the weight, W , is adjusted to produce standing waves, as shown. The wavelength of these waves is given by the distance $IK = JL = \text{etc.}$

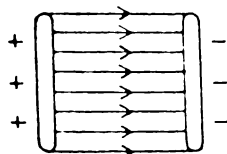


Experimentally, the most accurate value for the wavelength would be obtained from measurements of the distance,

- A. IL
- B. HL
- C. IM
- D. HM
- E. JK

Answer.....

12. "The electric field between two charged parallel plates is given by the equation $V = Ed$ where V is the potential between the plates and d is the distance between them. The electric field between the plates is shown in the figure".



The above description of the electric field between two charged parallel plates is actually,

- A. quite correct.
- B. always a good approximation.
- C. sometimes a good approximation.
- D. quite incorrect.

Answer.....

13. Two quantities are expected to vary according to the law $y = kx^n$ where k and n are unknown constants. It is decided to choose values of x and measure the dependent y values. The x values should be chosen so that:

- A. they are equally spaced.
- B. they are random values.
- C. the $\log x$ values are equally spaced.
- D. the y values are equally spaced.
- E. the values are concentrated near the origin.

Answer.....

The following data refers to questions 14, 15 and 16

(Questions 15 or 16 can be answered even if there is difficulty in answering the preceding question.)

In a scientific paper, an author states that he has invented some very small sources which give out a strange radiation of wavelength 5 cm, travelling at a speed of 1000m s^{-1} .

14. It is suggested that this claim is most dubious. Well known radiations might account for the effect, except that their properties are in some way inconsistent with the data given.

e.g. light - speed much greater and wavelength much smaller than given data.

Write down up to three types of radiation that you know of (waves or particles) and state in what way their properties are inconsistent (or consistent) with the data given.

<u>Type of radiation</u>	<u>Comparison of properties to given data</u>
i).....
ii).....
iii).....

15. A physicist reading the paper says "It all seems highly improbable, but I am going to get some of the lamps and check the author's statement." Providing suitable sources and detectors were available, suggest a simple method for checking the order of magnitude of the speed and wavelength of the radiation. (Brief outline only - diagrammatic explanation acceptable.)

(i) Wavelength.....
.....
.....
(ii) Speed
.....
.....

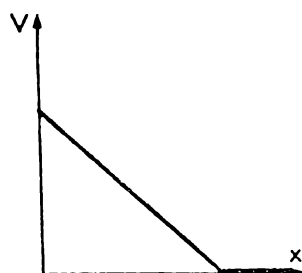
16. The physicist obtains some of the lamps and checks the wavelength and speed of the radiation produced by the lamps. He obtains the order of magnitude values stated below,

Wavelength = 10^{-7}m Speed = 10^8m s^{-1}

What conclusion about the nature of the radiation would you make now that this new data is available?

.....
.....
.....

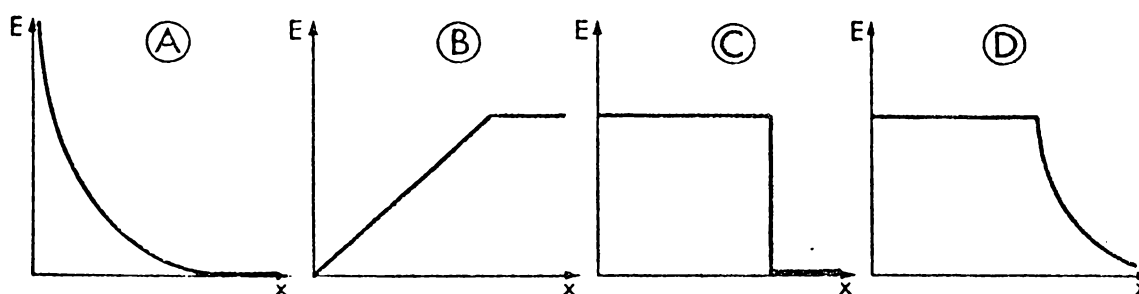
17. In a certain region of space, the electric potential V at a distance x from a plane is represented by the graph below.



The relationship between V and the electric field E is given by

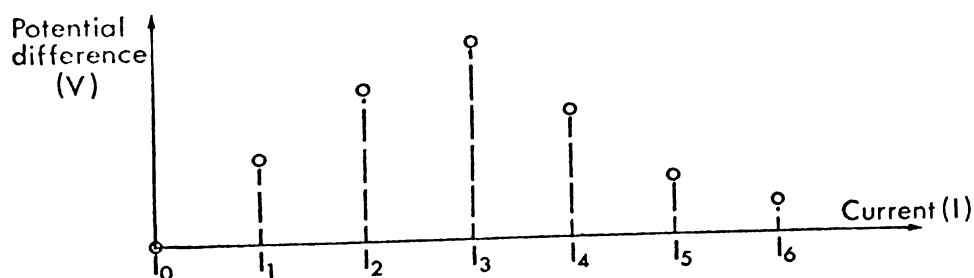
$$E = -\frac{dV}{dx}$$

The graph which best represents the corresponding values of the electric field E with distance x is



Answer.....

18. The potential difference versus current relationship for a thermistor is investigated over a certain current range. Initially seven readings are taken equally spaced over the current range. These results are plotted below.



It is decided that there are insufficient measurements to clarify the relationship between potential difference and current. If more readings are to be taken it would probably be desirable to choose additional values of the independent variable, I ,

- equally spaced between I_0 and I_6 .
- equally spaced between I_0 and I_3 .
- mainly concentrated near I_0 and I_6 .
- mainly concentrated near I_3 .
- chosen randomly within the range I_0 to I_6 .

Answer.....

19. The principle of superposition for waves only applies provided
- the wave motions are polarized in the same plane.
 - the medium is not distorted beyond its elastic limit.
 - the waves are travelling in the opposite directions.
 - the waves do not cancel each other completely by destructive interferences.
 - transverse wave motions are considered.

Answer.....

20. The rate of flow of heat (R) through a metal bar depends on the radius of the bar (r), the length of the bar (l), and the difference in temperature between its ends ($T_2 - T_1$).

In an investigation of the rate of heat flow through the bar the following results are obtained.

$R(\text{joule s}^{-1})$	$r(\text{m})$	$l(\text{m})$	$T_2 - T_1(\text{K})$
4	2×10^{-2}	1.0	2
8	2×10^{-2}	1.0	4
12	2×10^{-2}	1.0	6
16	4×10^{-2}	1.0	2
36	6×10^{-2}	1.0	2
2	2×10^{-2}	2.0	2
1	2×10^{-2}	4.0	2

These results suggest that R is proportional to,

- $\frac{r^2(T_2 - T_1)}{l}$
- $\frac{r^2 l}{T_2 - T_1}$
- $\frac{(T_2 - T_1)}{r^2 l}$
- $\frac{r(T_2 - T_1)}{l^2}$
- $\frac{l(T_2 - T_1)}{r^2}$

Answer.....

21. The potential difference across a resistor is to be calculated from the values of the resistance, R , of the resistor and the current, I , passing through it. ($V = RI$)

The values are, $R = 5.0 \pm 0.1$ ohm

$I = 2.0 \pm 0.1$ ampere

The potential difference, V , should be quoted as

$V = 10.0 \pm z$ volt, where z is the error or uncertainty. The correct value for z would be closest to which of the following values?

- 0.1 volt
- 0.2 volt
- 0.7 volt
- 0.9 volt
- 1.0 volt.

Answer.....

22. In developing his theory of the hydrogen atom, Bohr had to make a number of assumptions. To develop the formula $E_n = \frac{-chR}{n^2}$ theoretically (where E_n is the electron energy, and n is an integer) which of the following assumptions is not necessary?

- A. Coulomb's law applies.
- B. The electrons and the nucleus move about their common centre of mass.
- C. Angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$.
- D. Gravitational forces are negligible compared to electrical forces.
- E. The force on the electron is central.

Answer.....

23. A spring is extended by applying a force to one end. The other end is fixed. The following total length versus force data was obtained by a student who wishes to determine the spring constant, k .

Note: spring constant k is given by

$$k = \frac{\text{Force}}{\text{Length of spring extension}}$$

<u>Force (N)</u>	<u>Total length (m)</u>
0	0.10
2	0.26
4	0.40
6	0.75
8	0.71

If you had collected the above data you would next, probably

- A. calculate k directly from these results to be $\frac{8}{0.61} \text{ N m}^{-1}$.
- B. draw a graph and calculate k forthwith as the data seems reasonable.
- C. check some of the readings again, as the data is not self-consistent.
- D. check the first and the last reading only, as these readings will be used to determine k .

Answer.....

/contd...

24. The equation $y = 2A \sin kx \cos \omega t$ represents,

- A. a standing wave of frequency $\frac{\omega}{2\pi}$
- B. a single progressive wave of wavelength $\lambda = \frac{2\pi}{k}$
- C. a single wave progressing with velocity $\frac{\omega\lambda}{2\pi}$
- D. a standing wave of frequency $\frac{\lambda}{2\pi}$
- E. a single wave progressing with velocity $\frac{\omega}{k}$.

Answer.....

K.3 Part IB Aptitude Tests

P A R T B

NAME

(i) ABSTRACT

INSTRUCTIONS

In this test you will see rows of designs or figures like those on this page. Each row is a problem. You are to mark your answers as shown in the samples below.

Each row consists of four figures called Problem Figures and five called Answer Figures. The four Problem Figures make a series. You are to find out which one of the Answer Figures would be the next, or the fifth one in the series.

Example X.

PROBLEM FIGURES	ANSWER FIGURES	ANSWER
		(D)

Note that the lines in the Problem Figures are falling down. In the first square the line stands straight up, and as you go from square to square the line falls more and more to the right. In the fifth square the line would be lying flat. So the answer is D, which is indicated as your Answer by filling in the little space (D)

PROBLEM FIGURES	ANSWER FIGURES	ANSWER
		(B)

Study the position of the black dot. Note that it keeps moving around the square clockwise: upper left corner, upper right corner, lower right corner, lower left corner. In what position will it be seen next? It will come back to the upper left corner. Therefore, B is the answer, and you would mark your Answer (B)

Remember--You are to select the one figure from among the Answer Figures which belongs next in the series.

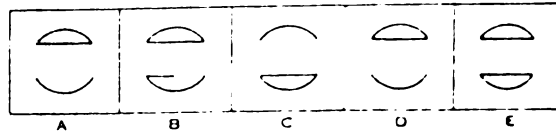
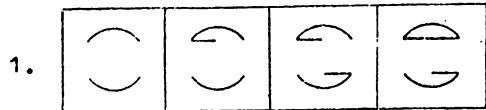
Work as rapidly and as accurately as you can. If you are not sure of an answer, mark the choice which is your best guess.

DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

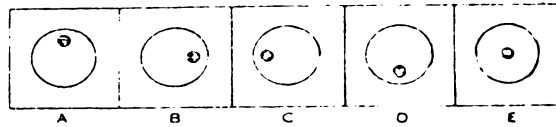
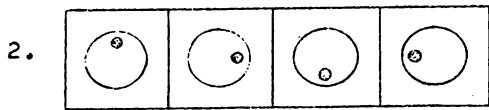
PROBLEM FIGURES

ANSWER FIGURES

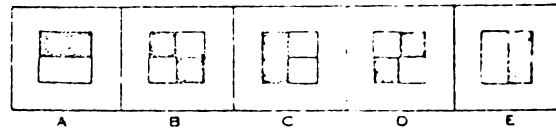
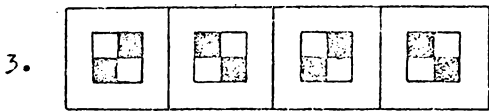
ANSWER



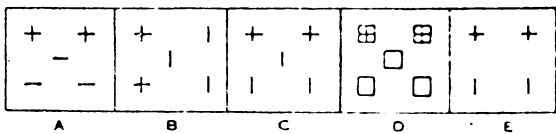
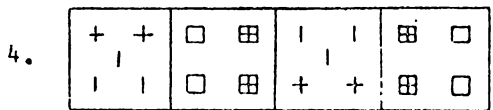
()



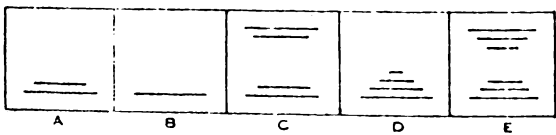
()



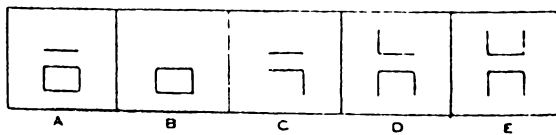
()



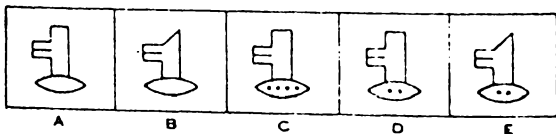
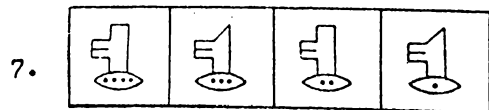
()



()



()



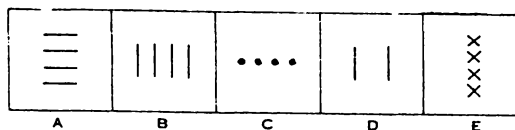
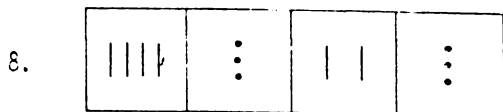
()

GO ON TO THE NEXT PAGE.

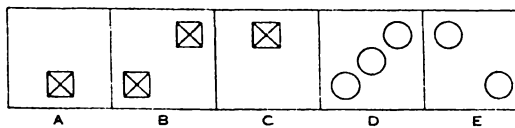
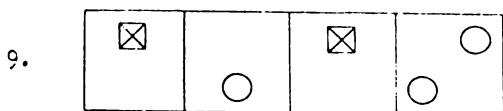
PROBLEM FIGURES

ANSWER FIGURES

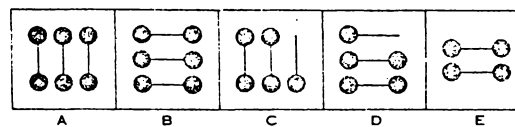
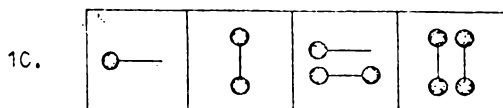
ANSWER



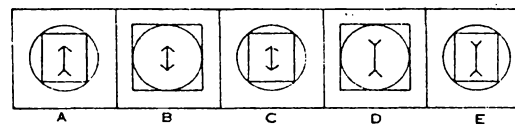
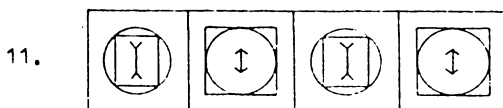
()



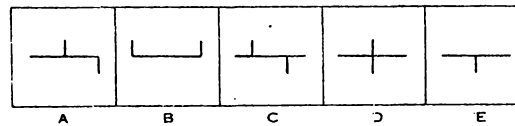
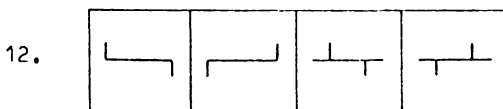
()



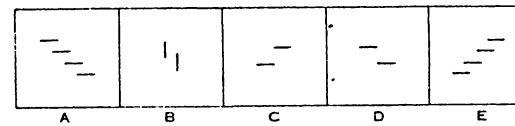
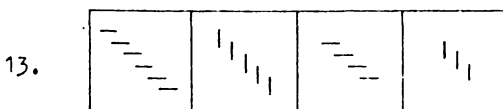
()



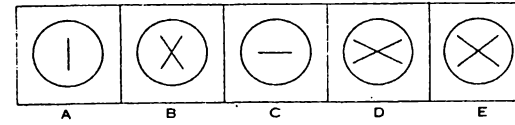
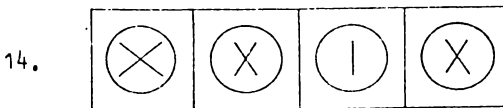
()



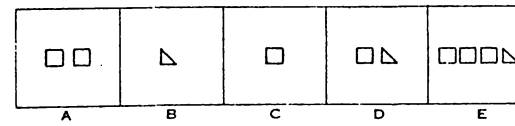
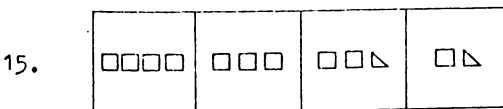
()



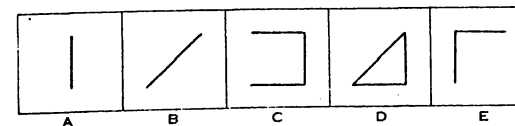
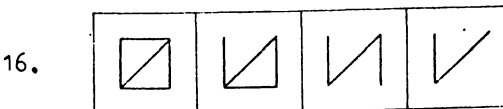
()



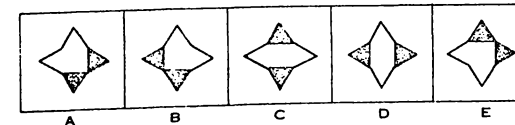
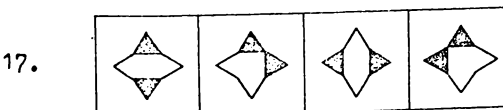
()



()



()



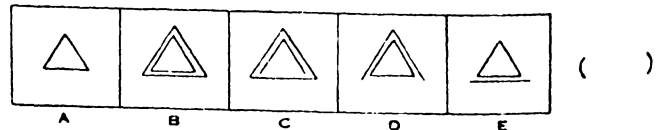
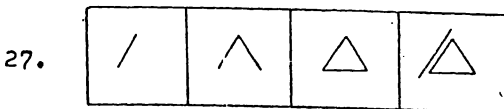
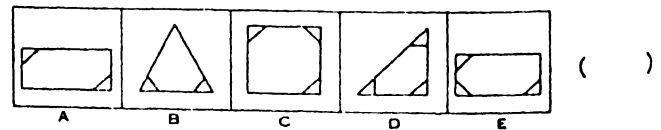
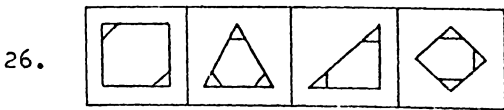
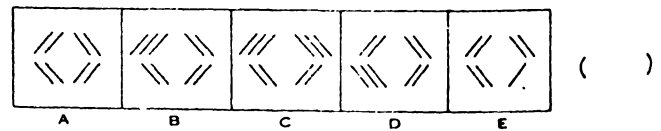
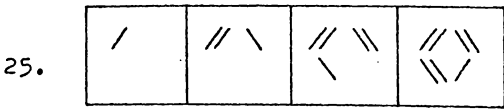
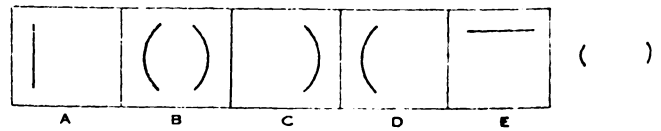
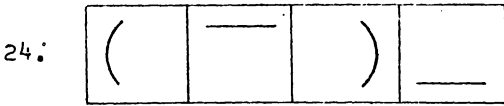
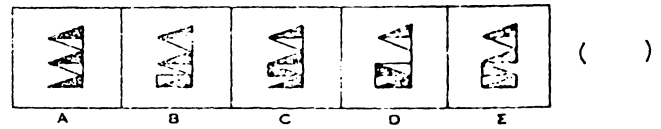
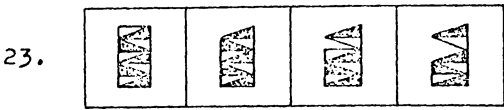
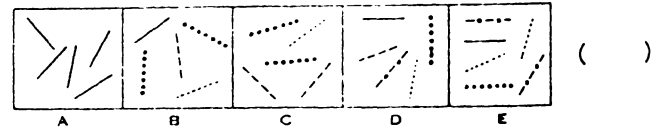
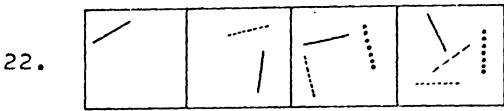
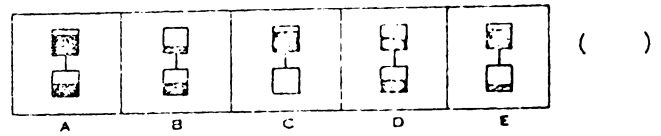
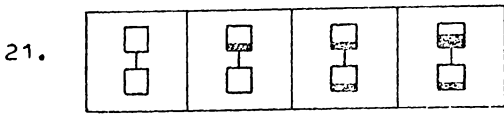
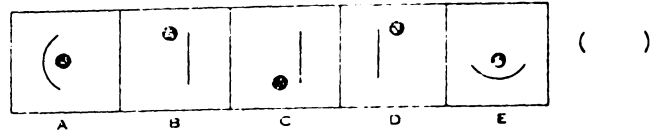
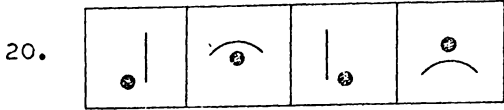
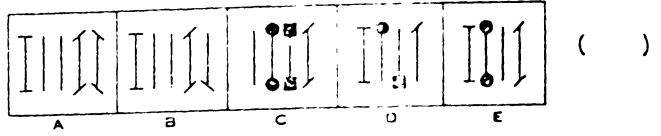
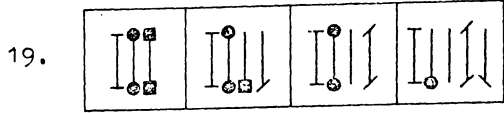
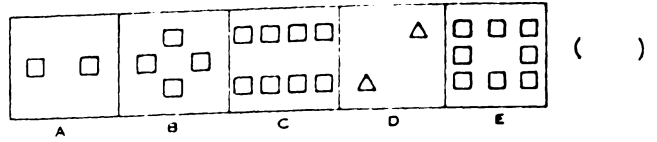
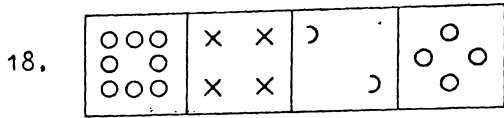
()

GO ON TO THE NEXT PAGE.

PROBLEM FIGURES

ANSWER FIGURES

ANSWER

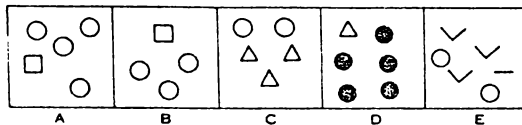
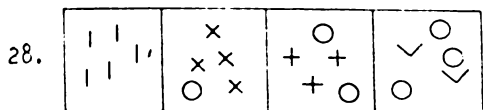


GO ON TO THE NEXT PAGE.

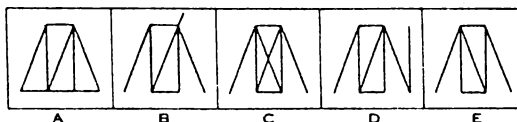
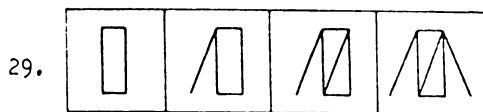
PROBLEM FIGURES

ANSWER FIGURES

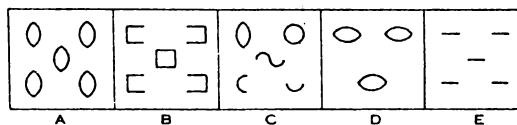
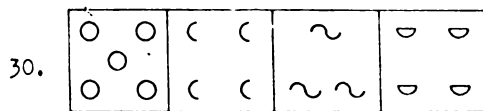
ANSWER



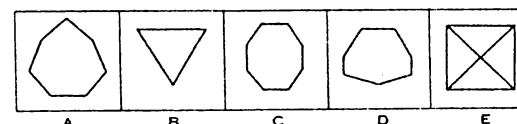
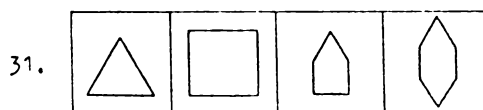
()



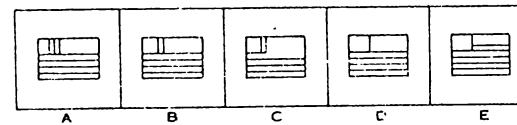
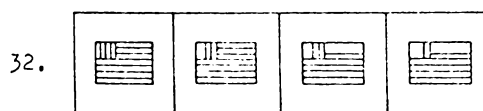
()



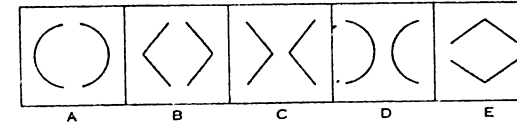
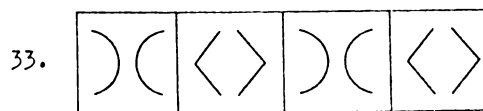
()



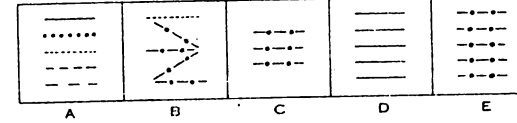
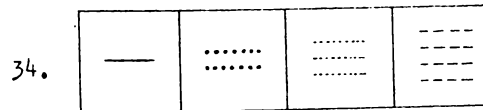
()



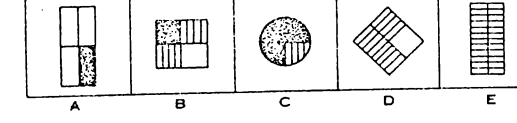
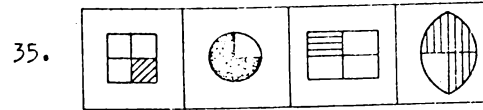
()



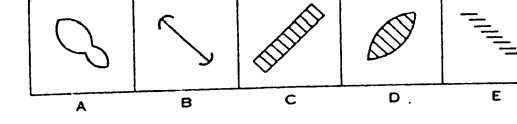
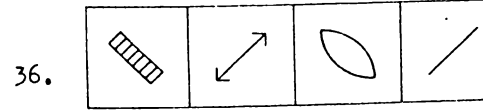
()



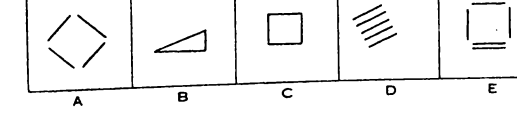
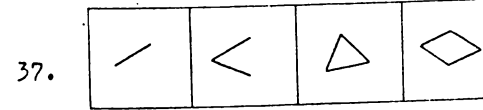
()



()



()



()

STOP. YOU MAY CHECK YOUR WORK ON THIS TEST. DO NOT TURN TO ANY OTHER TEST.

DO NOT TURN THE PAGE

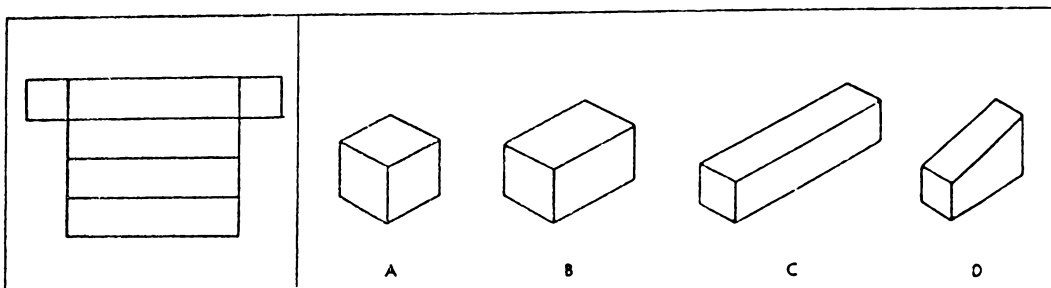
Wait for further instructions

(ii) SPACE

This test consists of 40 patterns which can be folded into figures. For each pattern, four figures are shown. You are to decide which one of these figures can be made from the pattern shown. The pattern always shows the outside of the figure. Here is an example:

Example X.

ANSWER



()

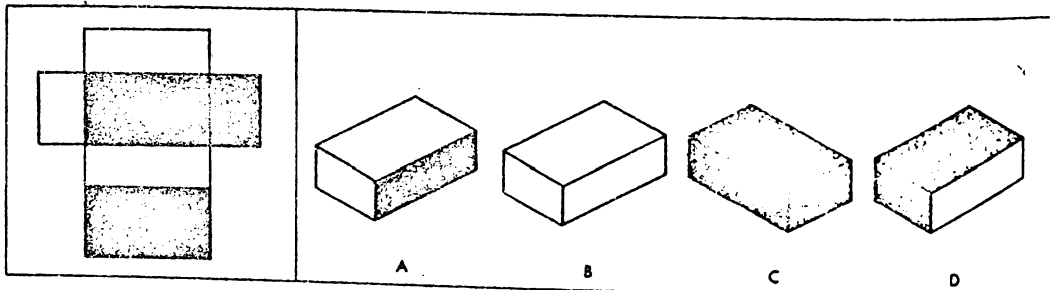
Which one of these four figures — A, B, C, D, — can be made from the pattern in Example X? A and B certainly cannot be made; they are not the right shape. C is correct both in shape and size. You cannot make D from this pattern. Therefore, C is the answer, and you would mark your Answer (C)

- In the test there will always be a row of four figures following each pattern.
- In every row there is only one correct figure.

Now look at the pattern for Example Y and the four choices for it. Note that when the pattern is folded, the figure must have three gray surfaces. Two of these will be large surfaces either of which could be the top or the bottom of a box. The other is a small surface which would be one end of the box.

Example Y.

ANSWER



()

Notice — all the figures made from this pattern are correct in **shape**, but the sides which you see are different. One of these figures can be made from this pattern while the others cannot. Look at the four choices:

- Figure A is wrong. The long, narrow side is not gray in the pattern and the large surface must be gray.
- Figure B is wrong. The large surface must be gray, although the gray end could be at the back.
- Figure C is wrong. The gray top and end are all right, but there is no long gray side in the pattern.
- Figure D is correct. A large gray surface can be shown as the top, and the end surface of gray can be shown facing towards you.

So, you see, all four surfaces are correct in shape, but only one shows the gray surfaces correctly. Therefore, **D** is the answer, and you would mark your Answer **(D)**

Remember that the surface you see in the pattern must always be the **outside** surface of the completed figure. In taking the test:

- Study each pattern.
- Decide which figure can be made from the pattern.

Work as rapidly and as accurately as you can. If you are not sure of an answer, mark the choice which is your best guess.

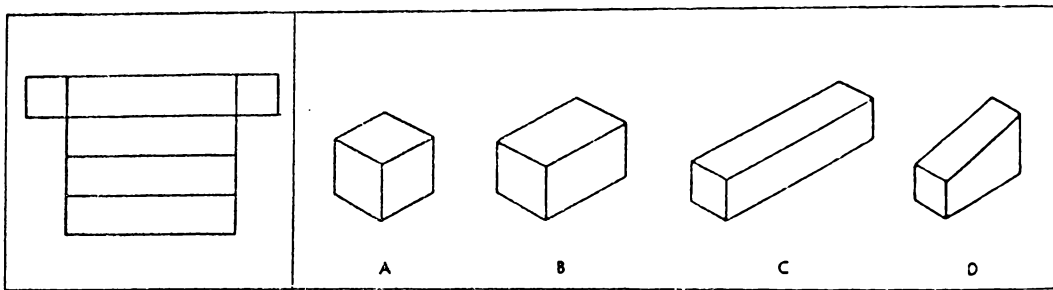
DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

(11) SPACE

This test consists of 40 patterns which can be folded into figures. For each pattern, four figures are shown. You are to decide which one of these figures can be made from the pattern shown. The pattern always shows the outside of the figure. Here is an example:

Example X.

ANSWER



Which one of these four figures — A, B, C, D, — can be made from the pattern in Example X? A and B certainly cannot be made; they are not the right shape. C is correct both in shape and size. You cannot make D from this pattern. Therefore, C is the answer, and you would mark your Answer (C)

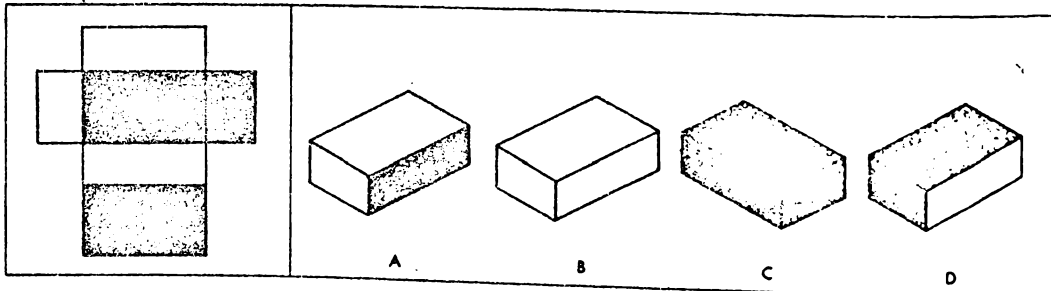
— In the test there will always be a row of four figures following each pattern.

— In every row there is only one correct figure.

Now look at the pattern for Example Y and the four choices for it. Note that when the pattern is folded, the figure must have three gray surfaces. Two of these will be large surfaces either of which could be the top or the bottom of a box. The other is a small surface which would be one end of the box.

Example Y.

ANSWER



Notice — all the figures made from this pattern are correct in **shape**, but the sides which you see are different. One of these figures can be made from this pattern while the others cannot. Look at the four choices:

- Figure A is wrong. The long, narrow side is not gray in the pattern and the large surface must be gray.
- Figure B is wrong. The large surface must be gray, although the gray end could be at the back.
- Figure C is wrong. The gray top and end are all right, but there is no long gray side in the pattern.
- Figure D is correct. A large gray surface can be shown as the top, and the end surface of gray can be shown facing towards you.

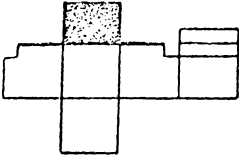
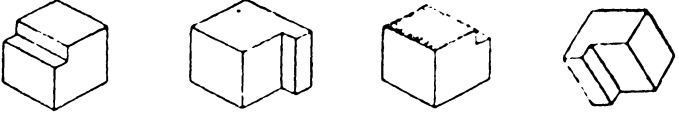
So, you see, all four surfaces are correct in shape, but only one shows the gray surfaces correctly. Therefore, **D** is the answer, and you would mark your Answer **(D)**

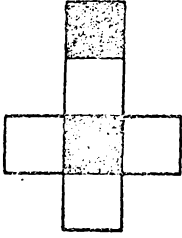
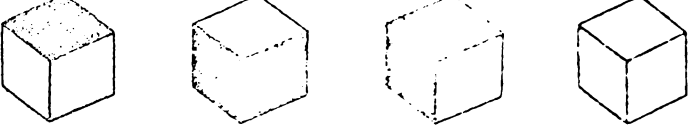
Remember that the surface you see in the pattern must always be the **outside** surface of the completed figure. In taking the test:

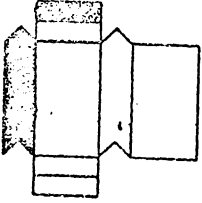
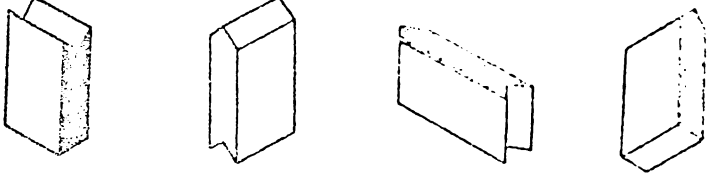
- Study each pattern.
- Decide which figure can be made from the pattern.

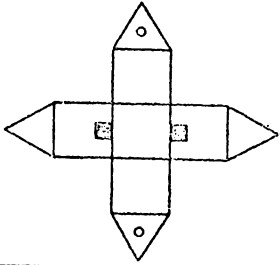
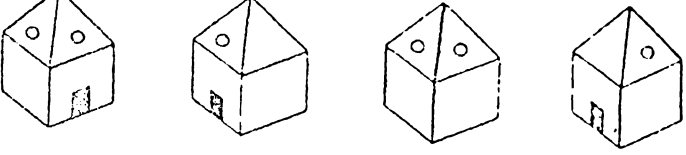
Work as rapidly and as accurately as you can. If you are not sure of an answer, mark the choice which is your best guess.

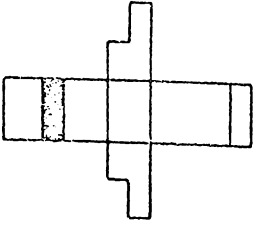
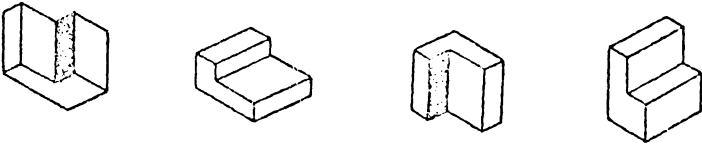
DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO DO SO.

1.   ()

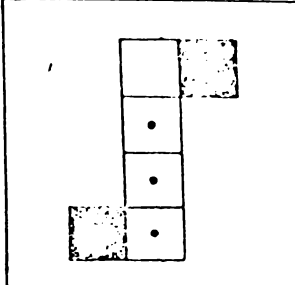
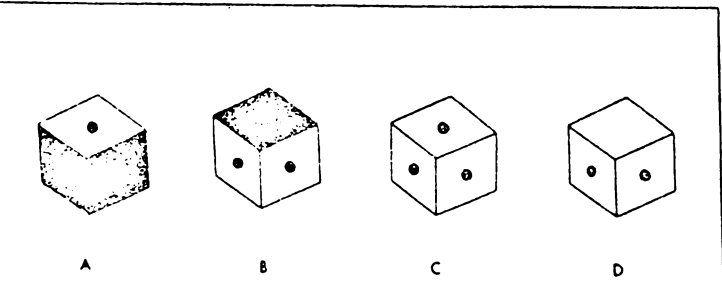
2.   ()

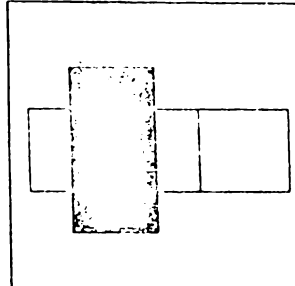
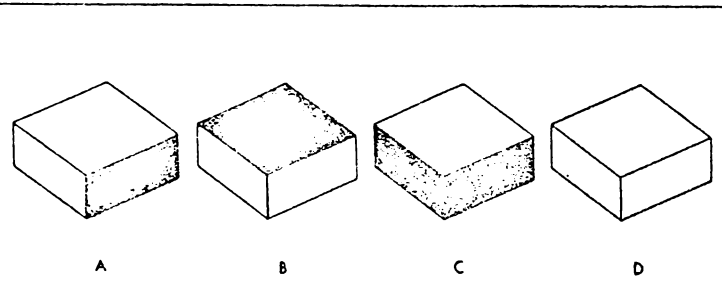
3.   ()

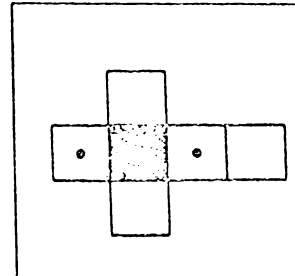
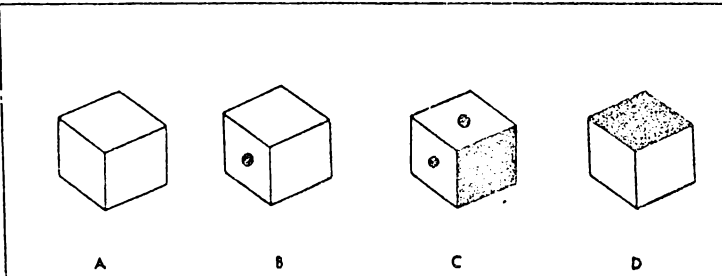
4.   ()

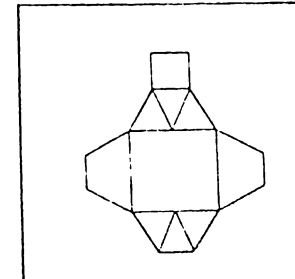
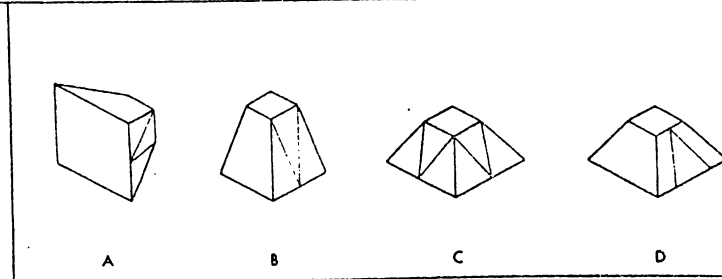
5.   ()

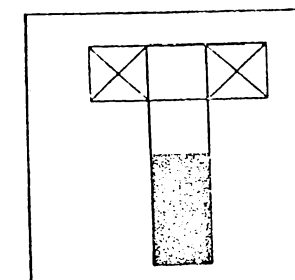
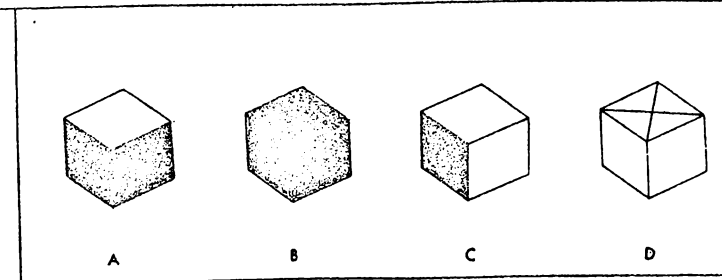
ANSWER

6.   ()

7.   ()

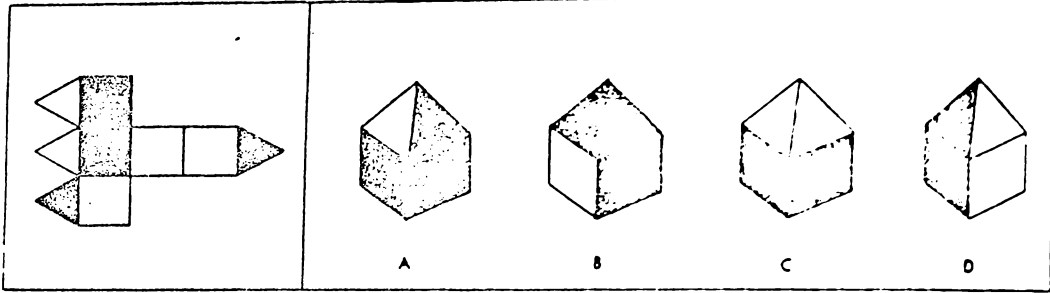
8.   ()

9.   ()

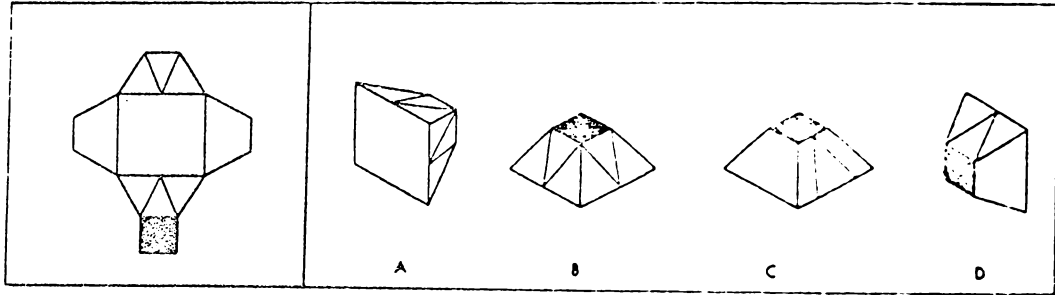
10.   ()

GO ON TO THE NEXT PAGE.

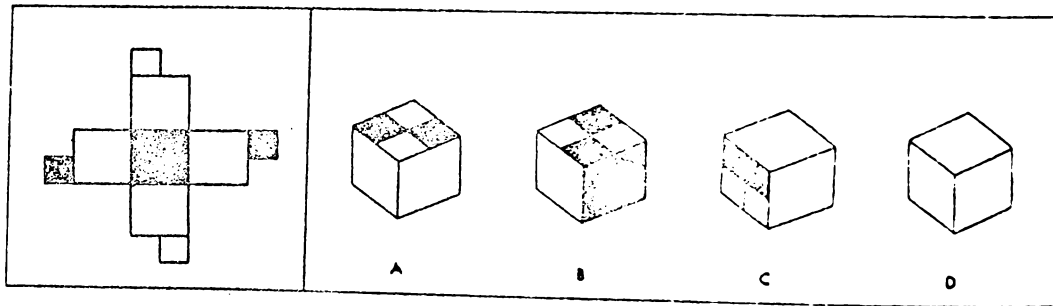
11.



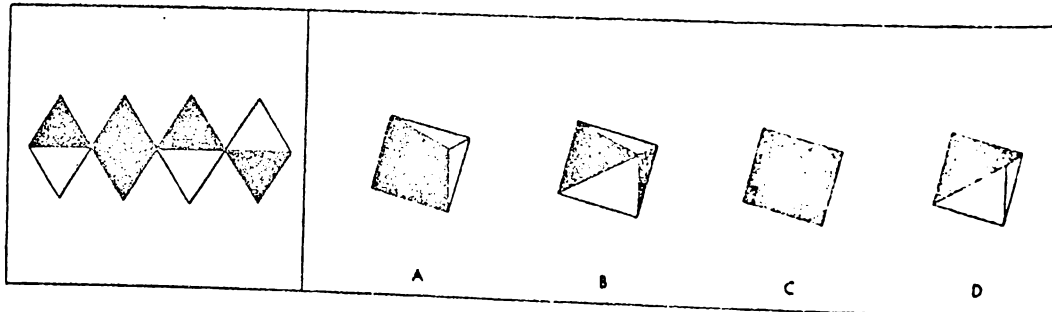
12.



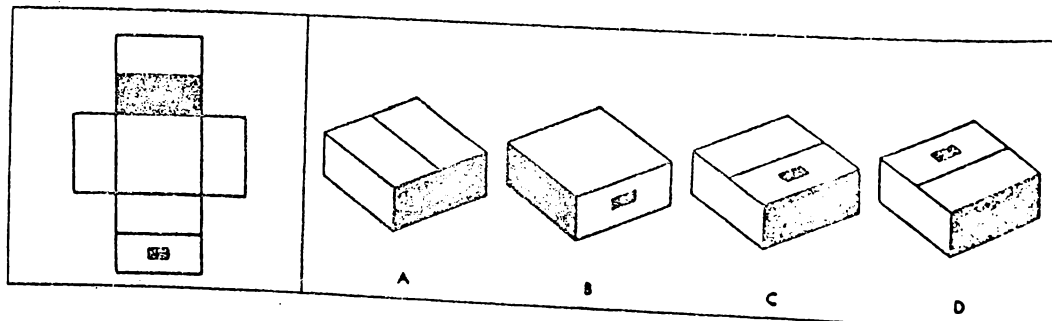
13.



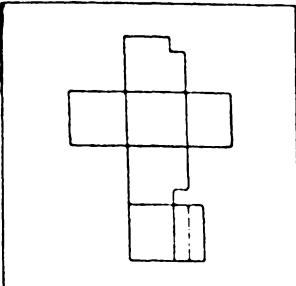
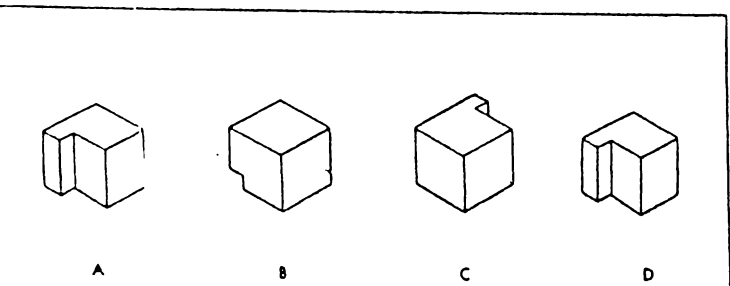
14.

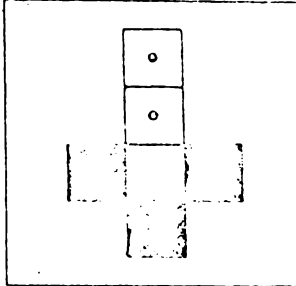
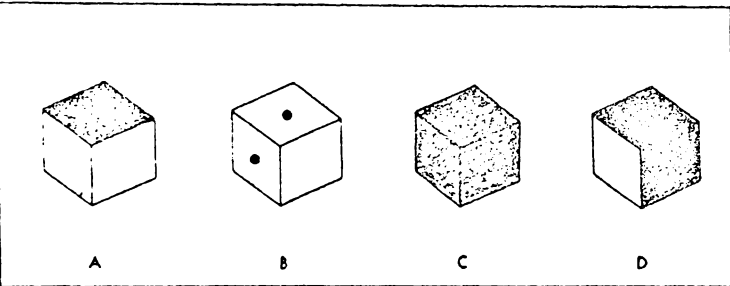


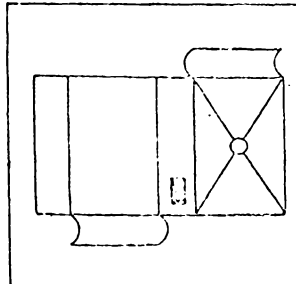
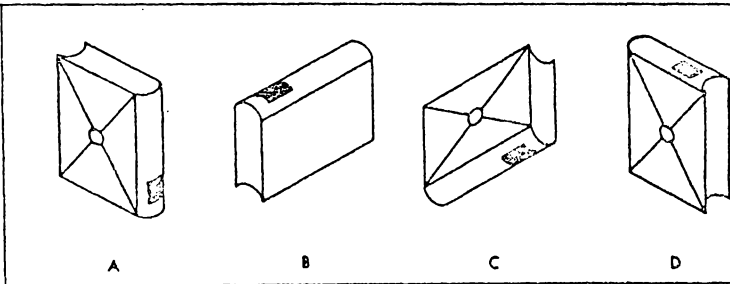
15.

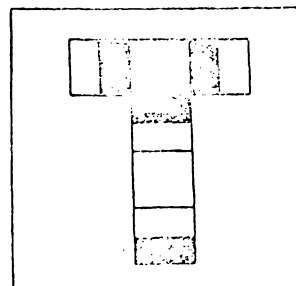
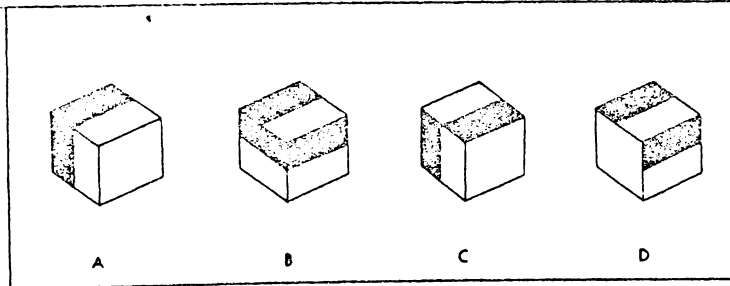


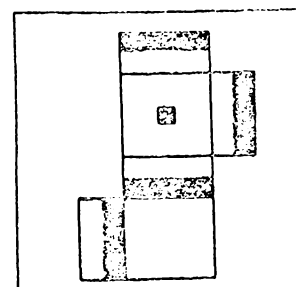
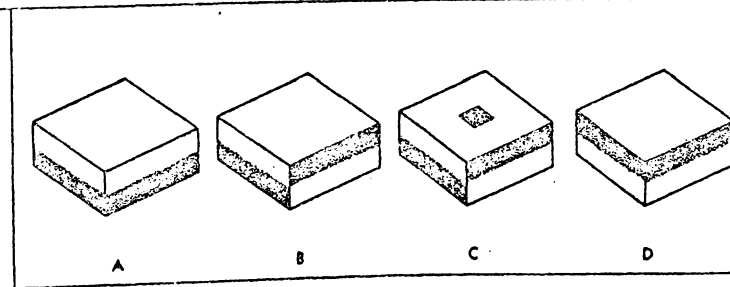
ANSWER

16.   ()

17.   ()

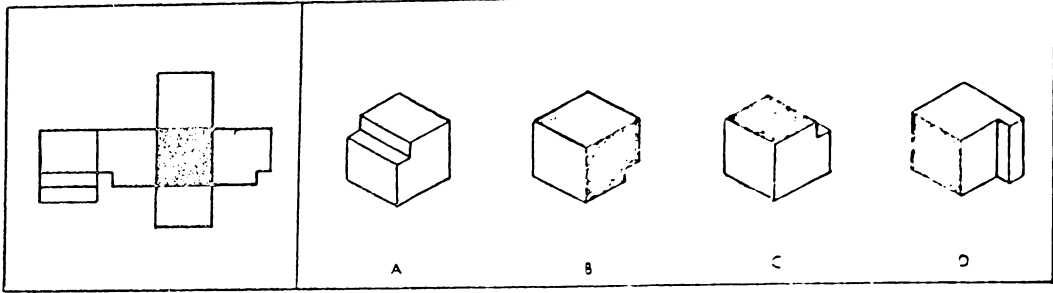
18.   ()

19.   ()

20.   ()

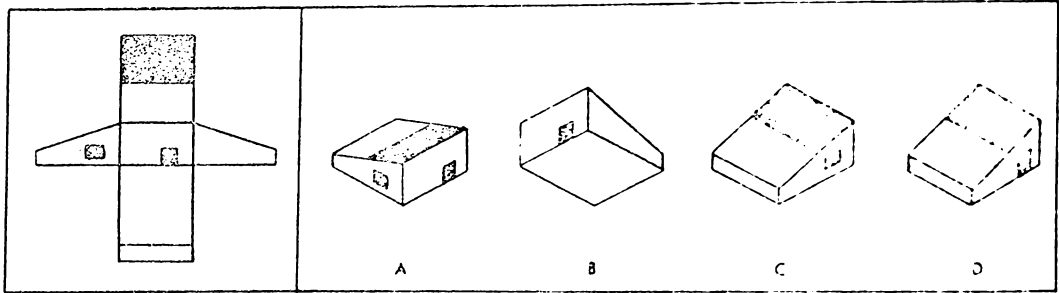
GO ON TO THE NEXT PAGE.

21.



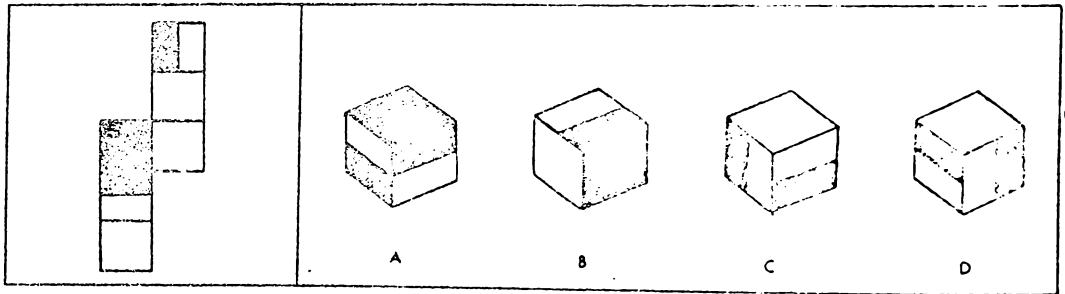
()

22.



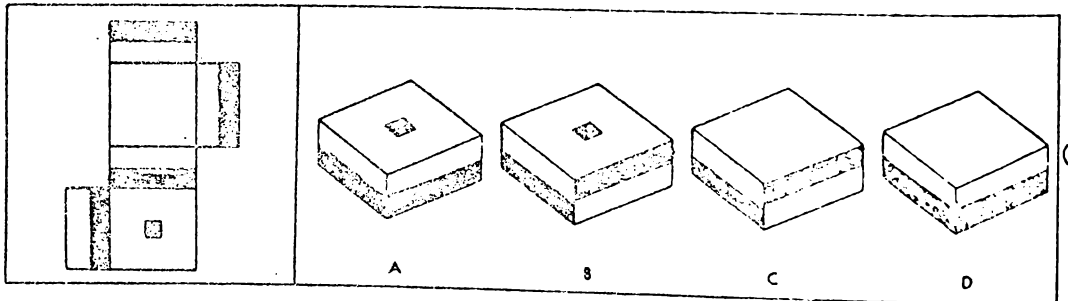
()

23.



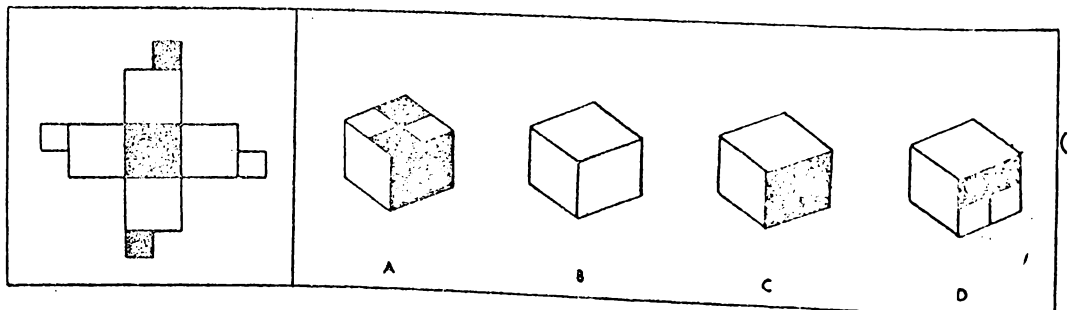
()

24.



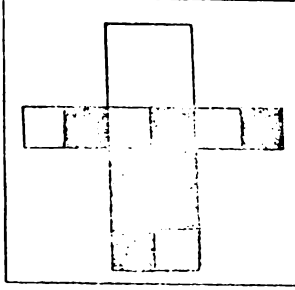
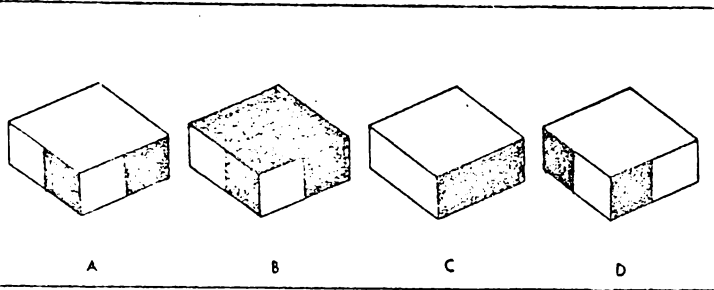
()

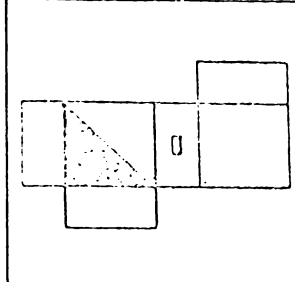
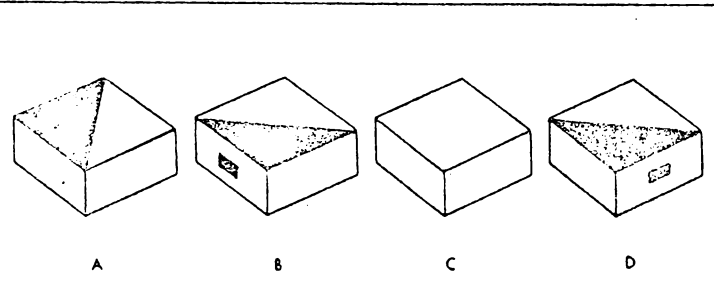
25.

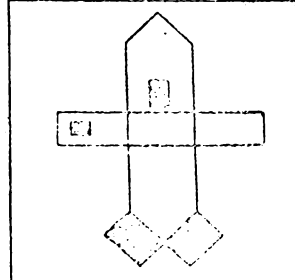
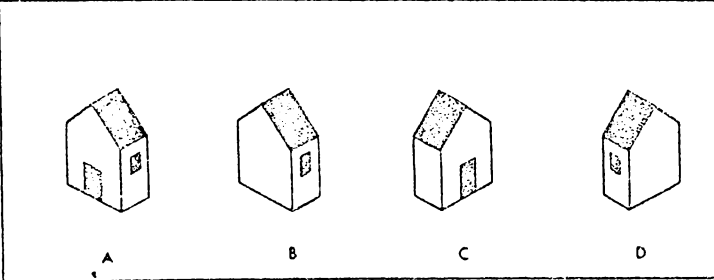


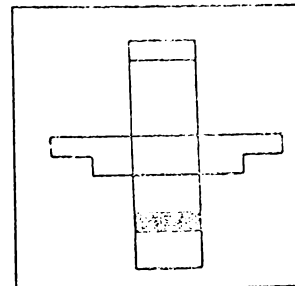
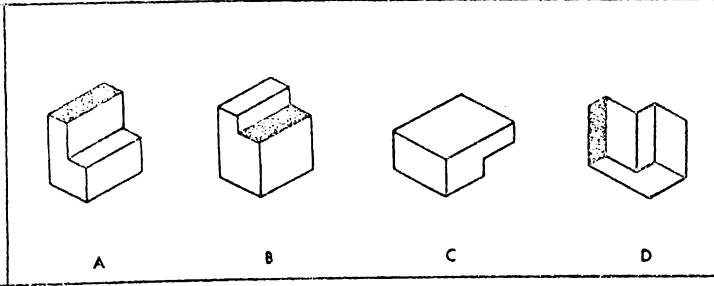
()

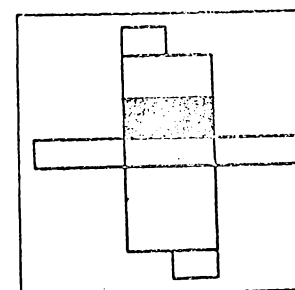
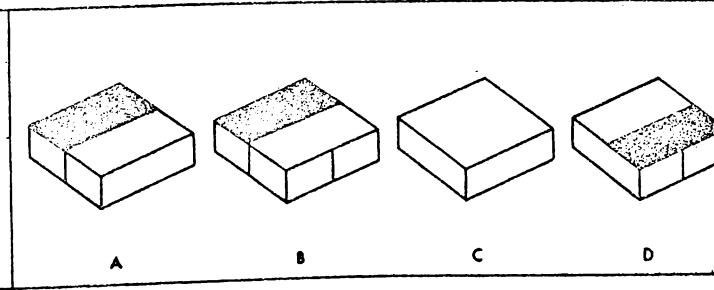
ANSWER

26.   ()

27.   ()

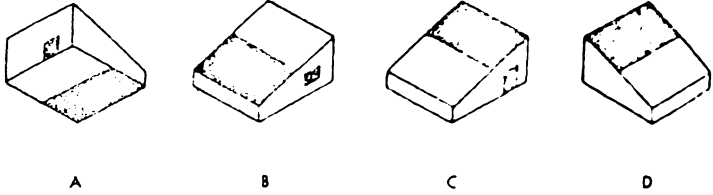
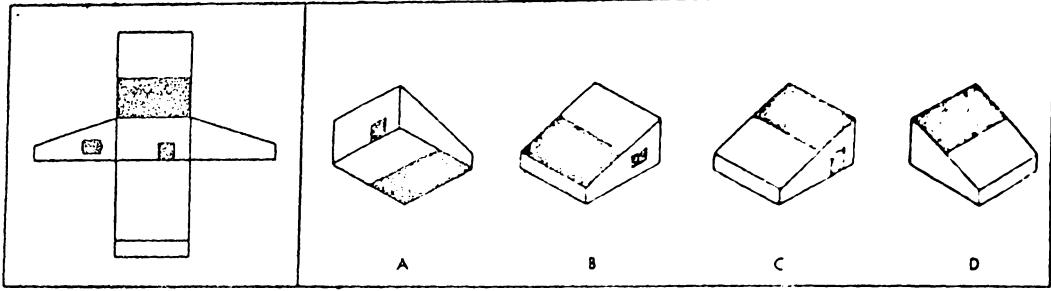
28.   ()

29.   ()

30.   ()

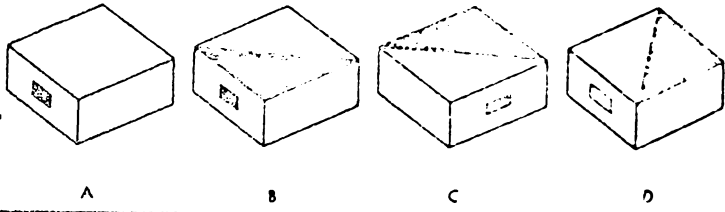
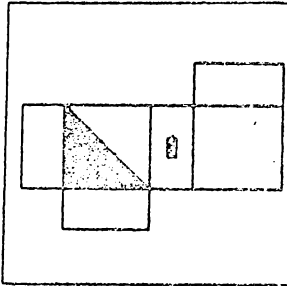
GO ON TO THE NEXT PAGE.

31.



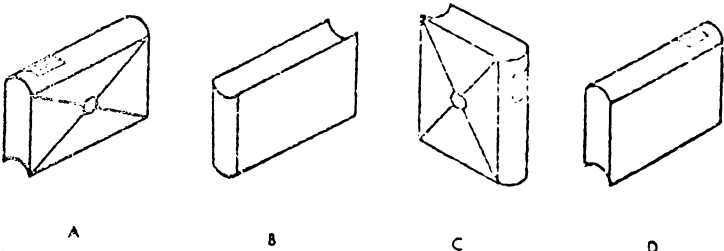
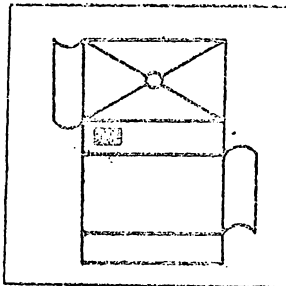
()

32.



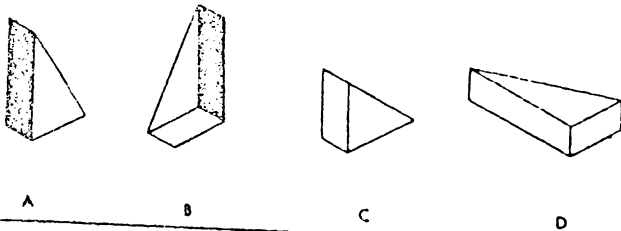
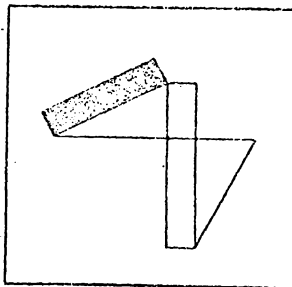
()

33.



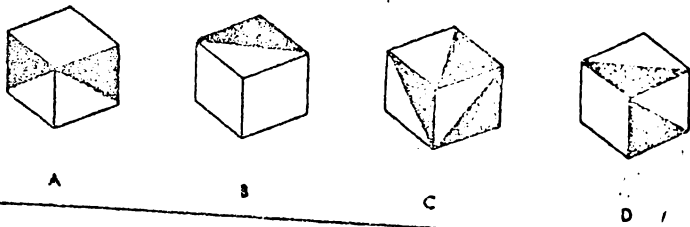
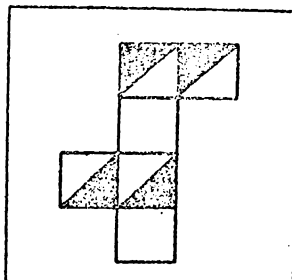
()

34.



()

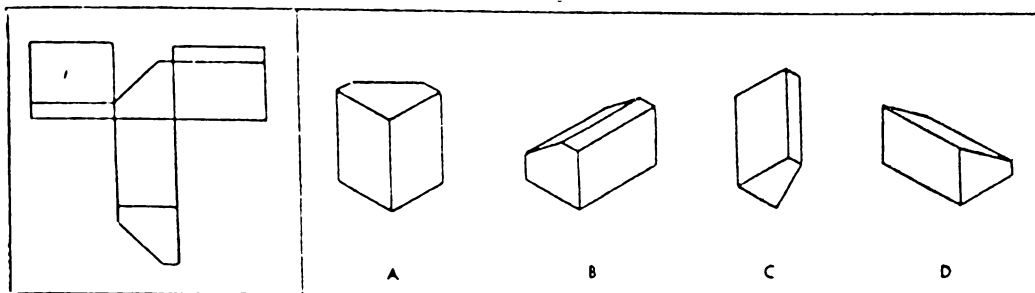
35.



()

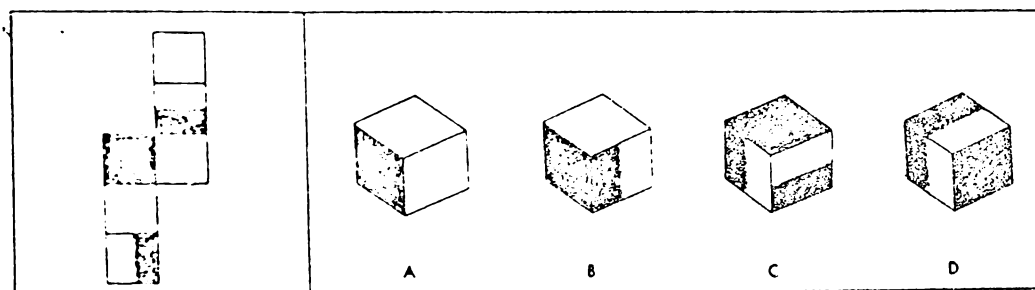
ANSWER

36.



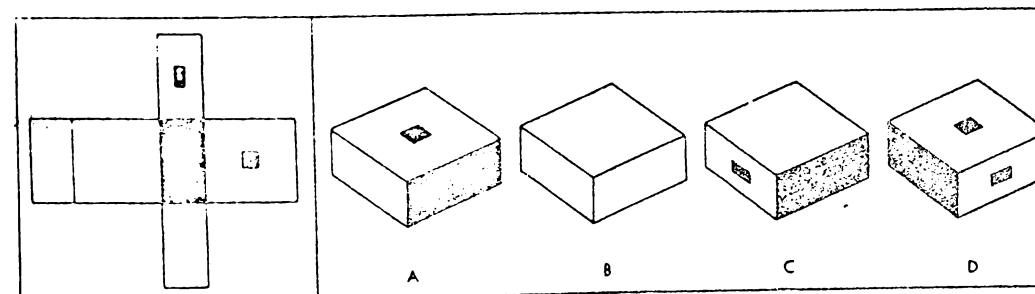
()

37.



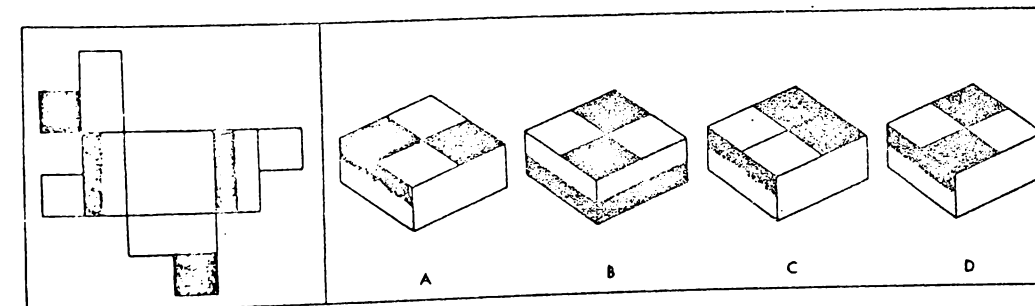
()

38.



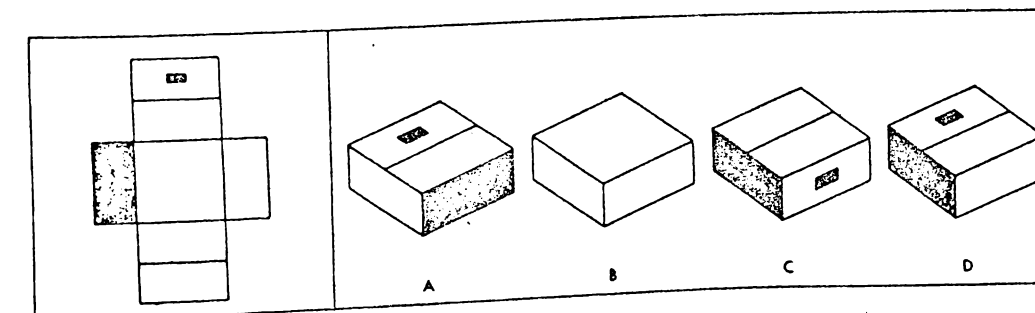
()

39.



()

40.



()

STOP. YOU MAY CHECK YOUR WORK ON THIS TEST. DO NOT TURN TO ANY OTHER TEST.

UNIVERSITY OF WAIKATO73.101 Physics Test 1Background Knowledge and Familiarization Test

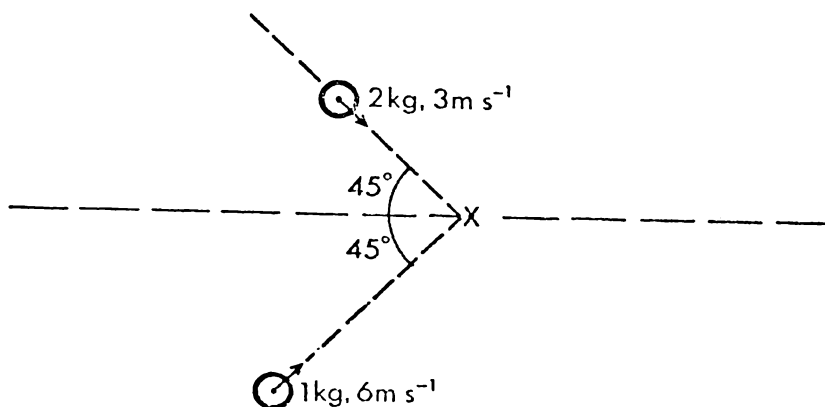
Name:

In answering the following questions reference can be made to the text "Physics" (by Alonso and Finn), however, as considerable time can be wasted looking up information (particularly if the book is unfamiliar to you), it is suggested you first attempt all questions without the aid of your textbook.

If necessary an intelligent guess as a last resort is considered warranted, however, particularly as this test does not count toward the final result, purely random guessing is discouraged. Leave the space blank if you have no idea whatever.

There are twenty-seven questions to attempt in 55 minutes. Few questions require detailed algebraic or numerical manipulation. Do not spend too long on any one question.

1. The diagram shows two masses, which collide at X and stick together. (Apart from the forces between the masses, no other forces are present).

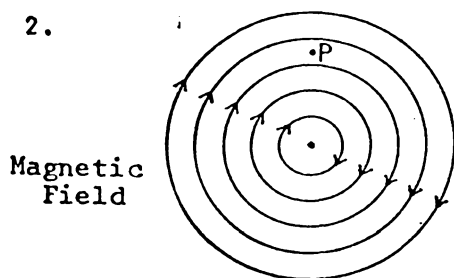


Which of the following statements about momentum is true for this collision?

- A. The sum of magnitudes of the momenta before collision is equal to the sum of the magnitudes of the momenta after the collision.
- B. The total momentum before the collision is equal to the total momentum after the collision.
- C. The total momentum after collision is less than the total momentum before the collision, because the collision is inelastic.
- D. Since the masses stick together it is impossible to make any conclusions about whether momentum is conserved or not.

Answer.....

2.



If the pattern shown represents a magnetic field what would happen to a stationary electron placed at point P?

- A. It would move upward in a straight path.
- B. It would move downward in a straight path.
- C. It would move counter clockwise in a circular path.
- D. It would move clockwise in a circular path.
- E. It would not move.

Answer.....

3. The relationship $F = ma$ (where F is the force on a particle with mass m and acceleration a) is very similar, at least in form, to $\tau = I\alpha$ (where τ is the torque on a particle, with moment of inertia I and angular acceleration α , all with respect to the same axis or point).

The similarity of these two formulae is,

- A. not surprising, as both formulae are based on Newton's second law.
- B. coincidental as they are independent in theory.
- C. purely coincidental as they apply to different situations.
- D. not surprising, as both formulae are really identical.
- E. not surprising, as both formulae follow from conservation of energy.

Answer.....

4. The energy of an electron according to the Bohr model of the hydrogen atom is given by

$E = \frac{-e^2}{8\pi\epsilon_0 r}$ where e is the electron charge and r is the radius of the electron's orbit.

This energy is the electron's,

- A. kinetic energy.
- B. electrostatic potential energy.
- C. kinetic plus electrostatic potential energy.
- D. rest-mass energy.
- E. nuclear plus electrostatic potential energy.

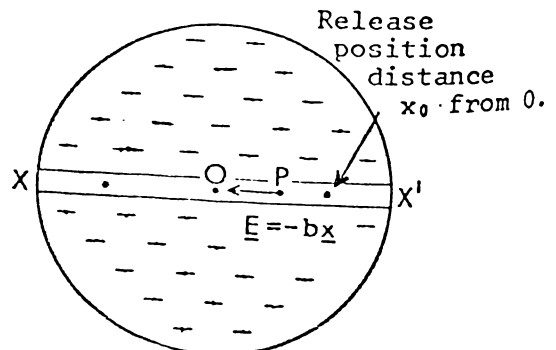
Answer.....

5. A sphere with uniform negative charge density throughout its volume has an electric field along a diameter XX' , as shown, given by $\underline{E} = -b\underline{x}$ where b is a constant and \underline{x} is the vector OP .

A proton (free to move along diameter XX') is released on the diameter, a distance x_0 from the centre. The proton next reaches a distance x_0 from the centre (diametrically opposite the release point) after a time T .

What is the dependence of T on x_0 ?

- A. T is independent of x_0 .
- B. T is proportional to x_0 .
- C. T is proportional to $\sqrt{x_0}$.
- D. T is proportional to x_0^2 .
- E. T is proportional to x_0^4 .



Answer.....

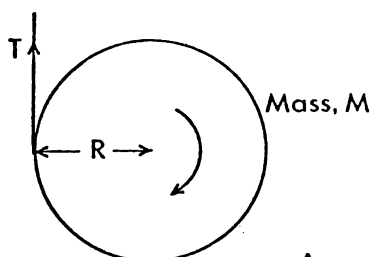
6. "The period of a simple pendulum, and the period of a mass hanging on the end of a spring, would be greater on the moon than on the earth". This statement is,
- correct, as the decreased force of gravity would affect the pendulum and spring system equally.
 - incorrect, as although the period of the pendulum would increase, the period of the mass on the spring would remain the same.
 - incorrect, as although the period of the pendulum would increase, the period of the mass on the spring would actually decrease.
 - incorrect, as although the period of the mass on the spring would increase, the period of the pendulum would remain the same.
 - incorrect, as although the period of the mass on the spring would increase, the period of the pendulum would actually decrease.

Answer.....

7. A flywheel rotates 200 rad in 4 seconds. If the initial angular velocity was 10 rad s^{-1} , the angular acceleration (assumed constant) during the 4 second period was,
- $+ 20 \text{ rad s}^{-2}$
 - $+ 10 \text{ rad s}^{-2}$
 - $- 10 \text{ rad s}^{-2}$
 - $- 20 \text{ rad s}^{-2}$
 - None of these

Answer.....

8. A cylinder, mass M and radius R , has a string wrapped around it. If it is let go it is found that if a certain tension T is applied to the string the cylinder will neither rise nor fall, as the string unwinds. The tension in the rope will be,
- $\frac{MRg}{2}$
 - $\frac{Mg}{2R}$
 - Mg
 - $2Mg$
 - None of these.

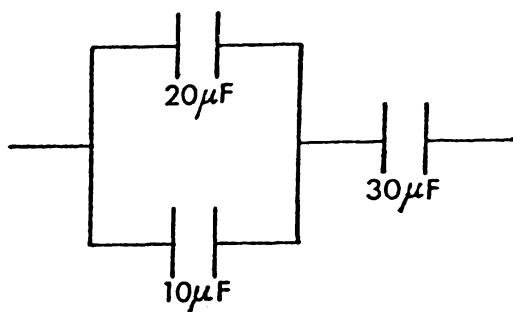


Answer.....

9. A satellite orbits the earth as close as possible to the earth's surface. Assuming the radius of the satellite's orbit is equal to the earth's radius R the period of the satellite will be,
- $2\pi\sqrt{\frac{g}{R}}$
 - \sqrt{gR}
 - $\frac{1}{2\pi}\sqrt{gR}$
 - $2\pi\sqrt{\frac{R}{g}}$

Answer.....

10.



The combined capacitance of the circuit shown will be,

- A. $36.6\mu\text{F}$
- B. $30\mu\text{F}$
- C. $15\mu\text{F}$
- D. $10\mu\text{F}$
- E. $5\mu\text{F}$.

Answer.....

11. When two waves of the same frequency and amplitude travel in opposite directions along a string a standing wave is produced. How does the amplitude of this standing wave vary with position along the string, and time?

- A. It is independent of both time and the position.
- B. It depends only on time.
- C. It depends only on position.
- D. It depends on both position and time.

Answer.....

12. "A charged particle moves in a uniform magnetic field B in a plane perpendicular to the magnetic field. The path of the particle is a circle radius R and in one revolution the particle moves a distance $2\pi R$. The force on the particle mass m is Bqv , where q is the charge of this particle. The work done by the magnetic field on the particle per revolution is $Bqv \times 2\pi R$."

This statement is incorrect because,

- A. the work done by the field is zero.
- B. the force on the particle is not Bqv .
- C. the particle will not move in a circle.
- D. the distance the particle moves per revolution is not $2\pi R$.
- E. more than one of the above criticisms is correct.

Answer.....

13. The energy stored in an electric field in a vacuum is given by the relationship $\text{Energy/unit volume} = \frac{1}{2} \epsilon_0 E^2$, where ϵ_0 is a constant and E is the electric field strength.

Would it be reasonable to assume that the energy density of a gravitational field is given by the relationship

$\text{Energy/unit volume} = \frac{1}{2} k g^2$, where k is a constant and g is the gravitational field strength?

- A. No, because electric and gravitational fields are quite different.
- B. No, because gravitational fields do not contain energy although they are similar to electric fields in some ways.
- C. No, because E and g are defined in quite different ways.
- D. Yes, because electric and gravitational fields are basically similar.
- E. Yes, because the energy density of a magnetic field is given by $\frac{1}{2\mu_0} B^2$.

Answer.....

14. A physics student states that there are too many laws to learn in physics and most of them can be derived from others. For example he says, "Gauss's Law and Coulomb's Law are both based on the same physical principle and we should only need to study one of these."

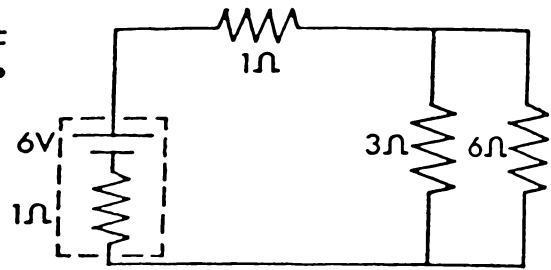
Which of the following replies shows the best understanding of physics?

- A. "They are based on the same principle, the inverse square law for electrostatics, but they are useful in different situations."
- B. "They are not based on the same physical principle, one is about forces and the other about fields, and they are therefore quite separate laws."
- C. "They are certainly not the same law. Coulomb's Law is an empirical (experimental) law while Gauss's Law is purely theory."
- D. "They are not the same law at all. Coulomb's Law applies to point charges but Gauss's Law applies to spheres and other large charged objects as well."

Answer.....

15 In the circuit shown the current through the 6Ω resistor will be,

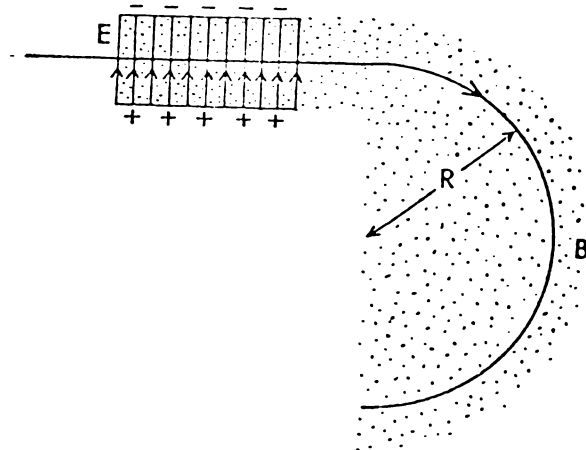
- A. 0.5 A
- B. 1 A
- C. 1.5 A
- D. 2 A
- E. None of these.



Answer.....

16. A particle, mass m , charge q , and velocity v , passes through an electric field, E , and magnetic field B , which are mutually perpendicular. The particle is undeflected by the combined fields. It then moves into a region where the electric field is zero. The radius of the particle in the magnetic field B will be,

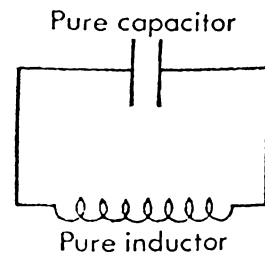
- A. $\frac{qm}{B^2}$
- B. $\frac{mE}{B^2q}$
- C. $\frac{mB^2}{Eq}$
- D. $\frac{mB}{E^2q}$
- E. $\frac{mBq}{E^2}$



Answer.....

17. A charged capacitor contains potential energy in the form of electrical potential energy. If the coil is connected to a perfect inductor, the capacitor will discharge through the inductor. At the instant when the capacitor is first fully discharged the electrical potential energy will have been mainly converted to,

- A. heat in the wire of the inductor.
- B. potential energy in the magnetic field around the inductor.
- C. potential energy in the electric field around the inductor.
- D. kinetic energy of the electrons in the inductor.



Answer.....

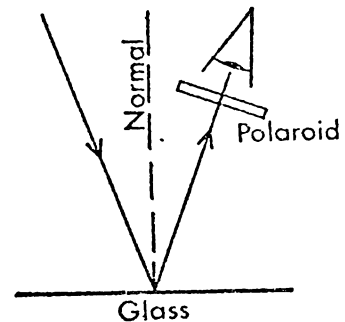
18. The speed of sound in air is 330 m s^{-1} . A person is moving toward a fire station at 30 m s^{-1} . The siren on the station is emitting a sound of frequency 330 Hz and there is no wind. The sound heard by the person will be,

- A. unobtainable from the information given
- B. 300 Hz
- C. 330 Hz
- D. 360 Hz
- E. 386 Hz.

Answer.....

19. Light is incident on a flat surface of glass, as shown. The reflected ray is viewed through a piece of polaroid which can be rotated about an axis in the direction of the beam. When this is done the observer is most likely to notice that the intensity of light,

- A. is zero for all positions.
 B. remains constant but is less than the incident intensity.
 C. remains constant and equal to the incident intensity.
 D. varies from a low value to a high value.



Answer.....

20. Ultraviolet light of frequency 10^{16} Hz is incident on a metal surface and electrons are ejected from the metal. The work function of the metal is 5×10^{-19} J and Planck's constant is 6.63×10^{-34} Js. The maximum kinetic energy of the ejected electrons is,

- A. zero B. 5×10^{-19} J C. 1.8×10^{-18} J
 D. 6.1×10^{-18} J E. 1.6×10^{-17} J.

Answer.....

21. A point charge $-q$ of mass m is released from rest a distance d_1 from a fixed point charge $+Q$. The charge $-q$ will reach a point distance d_2 from $+Q$ with speed,

- A. $\left[\frac{Qq}{4\pi\epsilon_0 m} (d_1 - d_2) \right]^{\frac{1}{2}}$ B. $\left[\frac{Qq}{2\pi\epsilon_0 m} \left(\frac{1}{d_2} - \frac{1}{d_1} \right) \right]^{\frac{1}{2}}$
 C. $\frac{Q}{4\pi\epsilon_0} (d_2 - d_1)^{\frac{1}{2}}$ D. $\left[\frac{Qq}{2\pi\epsilon_0 m} \cdot \frac{d_1 - d_2}{d_1^2} \right]^{\frac{1}{2}}$

Answer.....

22. Which of the following statements is incorrect?

- A. The concept of photons is necessary to explain the photoelectric effect.
 B. All photons travel at the same velocity in a vacuum.
 C. Photons have energies which depend on their wavelength.
 D. Photons behave in some situations like particles and in other situations like waves.
 E. Photons will only liberate electrons from a metal if they have a sufficiently long wavelength.

Answer.....

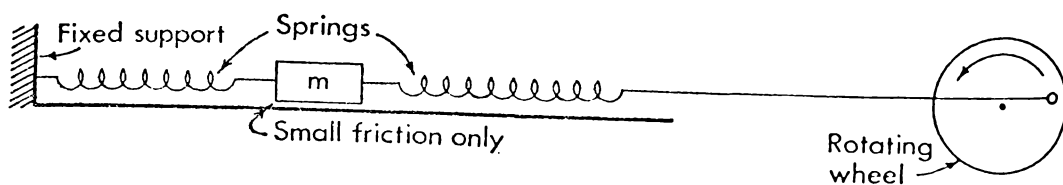
23. The Bohr theory of the hydrogen atom showed that the spectral lines emitted from a hydrogen atom could be explained if it was assumed that the angular momentum of an electron in a hydrogen atom was an integral multiple of $\frac{h}{2\pi}$. This assumption, can be justified in terms of,
- A. Newton's theory of gravitation.
 - B. Einstein's theory.
 - C. Millikan's theory of fundamental unity of charge.
 - D. the Kinetic theory.
 - E. the theory of particle-wave duality.

Answer.....

24. If the earth's mass were twice as great as it is, its period of revolution about the sun (assuming it stayed in the same orbit) would,
- A. increase 4 times.
 - B. increase 2 times.
 - C. decrease by a factor of 2.
 - D. decrease by a factor of 4.
 - E. remain the same.

Answer.....

25. A mass m is supported by two springs. The end of one spring is attached via a long string to a rotating arm so that the string approximates simple harmonic motion and produces FORCED OSCILLATIONS in m .



If the rotating arm is stationary, the natural period of the oscillating mass is 0.20 s. The rotating wheel is then rotated at a period of 0.15 s. If the wheel continues to rotate, then after a long time, the period of m is best described as being

- A. greater than 0.20 s.
- B. 0.20 s.
- C. 0.15 s.
- D. less than 0.15 s.

Answer.....

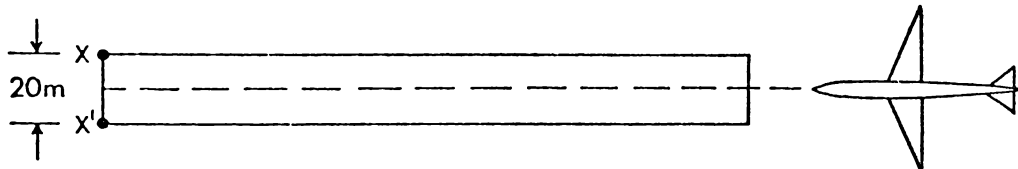
26. Is the following statement correct?

"The momentum and kinetic energy of a particle moving in uniform circular motion is continually changing."

- A. Yes, because the direction of the velocity is continually changing and hence the momentum and kinetic energy are continually changing.
- B. No, because the magnitude of the velocity is constant and hence the momentum and kinetic energy are both constant.
- C. Yes, because the direction of the velocity is continually changing and hence the momentum is continually changing.
- D. No, because the magnitude of the velocity is constant and hence the kinetic energy is constant.
- E. Yes, because the direction of the velocity is continually changing and hence the kinetic energy is continually changing.

Answer.....

27.



An airport (not drawn to scale!) is equipped with radio antennae X and X', 20m apart, which emit electromagnetic (radio) waves of wavelength 10 metres. There is a maximum signal along the runway. However, it is still possible for an aircraft some distance away to be flying in another straight line along which the radio signal is also a maximum. The smallest angle between such a line and the direction of the runway is approximately,

- A. 90°
- B. 45°
- C. 30°
- D. 20°
- E. 10°

Answer.....

PART B

The purpose of the following statements is to find your opinion about a number of things related to physics.

There are no "right" or "wrong" answers. What is wanted is an opinion which you should give as quickly and as accurately as you can.

Your opinions to the statements should be given by choosing one of the following and marking the appropriate square on the answer sheet provided.

- Mark Column - SA - if you strongly agree with the statement
A - if you agree with the statement
D - if you disagree with the statement
SD - if you strongly disagree with the statement
N - if you cannot decide whether you agree or disagree with the statement.

1. I sometimes think of a solution to a problem in physics when I am doing something quite unrelated to physics.
2. Calculus is not really much use to a physicist.
3. Physicists will never run out of new areas of investigation.
4. Physics fascinates me.
5. The use of mathematics in physics tends to make a relatively simple idea in physics seem much more complicated than it actually is.
6. I often study topics in physics outside the syllabus.
7. I find it very convenient to be able to express physical ideas as mathematical equations.
8. There is no place in physics for hunches and guesses.
9. I find the physics we study very relevant to my interests.
10. I consider it a waste of time finding out about the latest theories in geophysics, astrophysics or any other aspect of physics not directly related to my physics course.
11. If mathematical terms were not used in physics the subject would be much more enjoyable.
12. I find learning physics most enjoyable.
13. An imaginative and creative sort of person should become an artist or writer but certainly not a physicist.

	SA	A	N	D	SD
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					

- 3 -

	SA	A	N	D	SD
14. Nuclear physics is an uninteresting subject which, if I were free to choose, I would wish to know nothing about.	14.				
15. Physics is not really important to me.	15.				
16. I find it convenient to use mathematics in physics.	16.				
17. One important reason why I study mathematics is that I know it will be helpful in understanding physics.	17.				
18. Physics is basically a "finished and dead" subject.	18.				
19. Physics is bound to be more difficult if ideas are expressed in mathematical terms rather than words.	19.				
20. Physics is an important subject to me as I consider it such a fundamental science.	20.				
21. I am not interested in trying to apply my knowledge of physics to the understanding of things that I observe or read about during the vacation.	21.				
22. In general, physicists find that an answer to a problem usually produces at least one other question.	22.				
23. I find physics a most unsatisfying subject.	23.				
24. The precise relationship between physical quantities is much more obvious if the relationship is expressed as a mathematical equation.	24.				
25. I read a wide variety of physics books purely for interest.	25.				
26. There will be no interesting and worthwhile investigations left to do in physics by the year 2001.	26.				
27. I find mathematics of considerable help in solving problems in physics.	27.				
28. Physics is a very satisfying subject to study.	28.				
29. I hardly ever read the physical science articles in popular magazines, for example "Time" or the local newspaper.	29.				
30. Physicists find that their subject is very satisfying because it provides plenty of opportunity for creativity.	30.				
31. I find it hard to understand ideas in physics if these ideas are expressed as mathematical equations.	31.				

- 32. I never study physics except just before a test or exam.
- 33. Physicists have had some of their most cherished ideas shattered by discoveries in Physics.
- 34. The physics we study is not relevant to my particular interests.
- 35. Scientific processes lead to absolute truth.
- 36. Physics is one of the least important subjects I study.

	SA	A	N	D	SD
32.					
33.					
34.					
35.					
36.					

PART C

The following eight multiple choice questions investigate your understanding of the nature of physics rather than your understanding of the principles of physics. Even if your physics background is not strong and some of the ideas a little strange, sufficient information is provided within the question for you to make a reasonable attempt at it.

- 1. When new evidence that does not fit into a well established scientific theory appears, which one of the following do scientists do?
 - A. Discard the theory and produce a new one.
 - B. Modify the evidence in such a way that it does fit the theory.
 - C. Modify the theory in such a way that the evidence can fit it.
 - D. Design experiments to refute the new evidence.

Answer.....

- 2. If an astronomer is asked to explain why some stars vary in their apparent brightness, he will most likely give his explanation in terms of
 - A. the logical necessity for some stars at least to vary in brightness.
 - B. verified astronomical data.
 - C. precise mathematical formulae and equations.
 - D. accepted scientific laws and principles.
 - E. the theory of the expanding universe.

Answer.....

3. A long string is attached to a vibrating block which is moving in S.H.M. according to the mathematical equation $0.01 \sin 8t$. This produces a wave in the string which is described mathematically as

$$y = 0.01 \sin (8t - 120x) .$$

This describes a wave of constant amplitude, however, in fact, the amplitude of the wave actually decreases slightly as x , the distance from the block, increases. The mathematical equation above which is used to describe the wave in the string is best described as

- A. incorrect B. an assumption C. a generalisation
D. an idealisation E. an hypothesis.

Answer

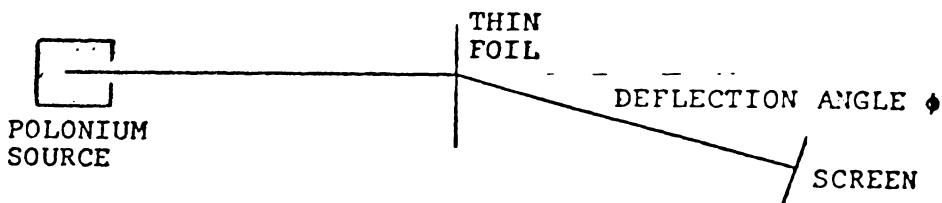
4. A research physicist working in the field of high energy dynamics, observes that in a nuclear particle interaction neither momentum nor total energy is conserved. He suspects a third particle must have been present, and he therefore assigns a given momentum and energy to the hypothetical particle, in an effort to make the final total energy and momentum conform to the conservation laws. Is such an action scientifically acceptable?

- A. Yes, provided that an investigation was then undertaken to try and detect the third particle.
B. No, because there is no reason for assuming that conservation of momentum or total energy will apply in this case.
C. No, because there is no reason whatever for assuming the undetected third particle exists.
D. Yes, because there is no reason to doubt the existence of the third particle.
E. No, because scientists do not make guesses involving hypothetical ideas.

Answer.....

The following data applies to questions 5 - 7

Ernest Rutherford at the beginning of this century made many measurements in the deflection of α -particles by thin foils. Rutherford worked with thin metal foils which he bombarded with α -particles from radio active polonium.



Rutherford, in his investigation, found that only one particle in 10,000 was deflected more than a few degrees even though the foil was 400 atoms thick.

- (i) Rutherford suggested that his results were explainable if the atom was considered primarily empty space with a small heavy positively charged nucleus at its centre.
- (ii) Assuming the nucleus was a point charge, and that Coulomb's Law applied in this situation, Rutherford's ideas about the nucleus resulted in a prediction that the number of particles per second, N , scattered through

any deflection, ϕ , would be proportional to $\frac{1}{\sin^2 \frac{\phi}{2}}$

5. In predicting the relationship $N \propto \frac{1}{\sin^2 \frac{\phi}{2}}$, Rutherford assumed that Coulomb's Law about forces between charges would apply at very small distances for which it had never been tested before. Was this assumption reasonable?
- A. Yes, such an assumption was perfectly justifiable as Coulomb's Law is a basic law of physics.
 - B. Yes, as Coulomb's Law does not explicitly state any limitations as to the distance between charges, Rutherford was completely justified in his assumption.
 - C. Yes, as it was not unreasonable to expect Coulomb's Law to hold at small distances and as there was no evidence to the contrary this assumption seemed justifiable.
 - D. Yes, Coulomb's Law is based on experimental evidence about forces between charges and therefore it must hold for any distance whatever between charges.

Answer.....

6. Rutherford was able to predict the number of particles scattered through any angle by assuming the nucleus was a point charge. This statement about the size of the nucleus is

- A. an idealisation. B. a generalisation.
 C. a prediction. D. an experimental observation.
 E. a definition.

Answer.....

7. Rutherford's initial ideas about the atom lead to a prediction which could be checked experimentally. Which of the following opinions about Rutherford's method of investigation shows the best understanding of scientific methods.

- A. Scientific ideas should not really be used to make predictions.
 B. Scientific ideas are most useful if they make predictions.
 C. Rutherford should have obtained all the experimental evidence possible before inventing any theory or ideas to explain his result.
 D. Rutherford proceeded in a rather unscientific manner in using his initial results to invent a model, or theory, of atomic structure.
 E. As Rutherford's initial ideas were based on experimental evidence, there was no need to experimentally check his prediction.

Answer

8. The visible spectral lines of hydrogen are given experimentally by the equation $\frac{1}{\lambda} = 1.09677 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right)$ ———— I where $n = 3, 4, 5$

A theory was developed by Bohr which predicted that the spectral lines of hydrogen are given by the equation

$$\frac{1}{\lambda} = 1.09737 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right) \text{ ———— II}$$

On comparing equation I and II it would appear that

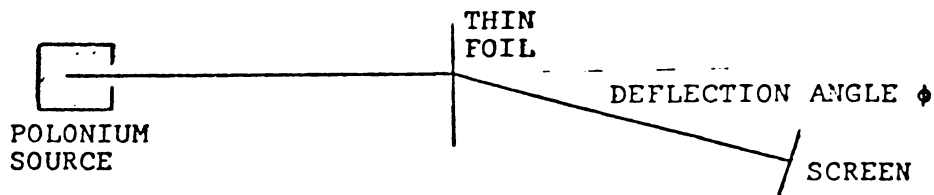
- A. there is complete agreement between experimental observation and theory.
 B. there is a slight discrepancy between theory and experiment but it is best ignored.
 C. an attempt should be made to modify the theory to fit the experimental results more closely.
 D. as the theory is so close to the experimental value it is obvious that the experimental results are slightly incorrect.

Answer.....

NAME

The following data applies to questions 5 - 7

Ernest Rutherford at the beginning of this century made many measurements in the deflection of α -particles by thin foils. Rutherford worked with thin metal foils which he bombarded with α -particles from radio active polonium.



Rutherford, in his investigation, found that only one particle in 10,000 was deflected more than a few degrees even though the foil was 400 atoms thick.

- (i) Rutherford suggested that his results were explainable if the atom was considered primarily empty space with a small heavy positively charged nucleus at its centre.
- (ii) Assuming the nucleus was a point charge, and that Coulomb's Law applied in this situation, Rutherford's ideas about the nucleus resulted in a prediction that the number of particles per second, N , scattered through any deflection, ϕ , would be proportional to $\frac{1}{\sin^2 \frac{\phi}{2}}$

5. In predicting the relationship $N \propto \frac{1}{\sin^2 \frac{\phi}{2}}$, Rutherford assumed that Coulomb's Law about forces between charges would apply at very small distances for which it had never been tested before. Was this assumption reasonable?

- A. Yes, such an assumption was perfectly justifiable as Coulomb's Law is a basic law of physics.
- B. Yes, as Coulomb's Law does not explicitly state any limitations as to the distance between charges, Rutherford was completely justified in his assumption.
- C. Yes, as it was not unreasonable to expect Coulomb's Law to hold at small distances and as there was no evidence to the contrary this assumption seemed justifiable.
- D. Yes, Coulomb's Law is based on experimental evidence about forces between charges and therefore it must hold for any distance whatever between charges.

Answer.....

6. Rutherford was able to predict the number of particles scattered through any angle by assuming the nucleus was a point charge. This statement about the size of the nucleus is
- A. an idealisation. B. a generalisation.
 C. a prediction. D. an experimental observation.
 E. a definition.

Answer.....

7. Rutherford's initial ideas about the atom lead to a prediction which could be checked experimentally. Which of the following opinions about Rutherford's method of investigation shows the best understanding of scientific methods.
- A. Scientific ideas should not really be used to make predictions.
 B. Scientific ideas are most useful if they make predictions.
 C. Rutherford should have obtained all the experimental evidence possible before inventing any theory or ideas to explain his result.
 D. Rutherford proceeded in a rather unscientific manner in using his initial results to invent a model, or theory, of atomic structure.
 E. As Rutherford's initial ideas were based on experimental evidence, there was no need to experimentally check his prediction.

Answer

8. The visible spectral lines of hydrogen are given experimentally by the equation $\frac{1}{\lambda} = 1.09677 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right)$ ———I
 where $n = 3, 4, 5$

A theory was developed by Bohr which predicted that the spectral lines of hydrogen are given by the equation

$$\frac{1}{\lambda} = 1.09737 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right) \text{ ———II}$$

On comparing equation I and II it would appear that

- A. there is complete agreement between experimental observation and theory.
 B. there is a slight discrepancy between theory and experiment but it is best ignored.
 C. an attempt should be made to modify the theory to fit the experimental results more closely.
 D. as the theory is so close to the experimental value it is obvious that the experimental results are slightly incorrect.

Answer.....

NAME

APPENDIX L

OUTPUT ASSESSMENT OF STUDENT ACHIEVEMENT

The following questionnaire and examination papers were used in the first year physics courses in 1973 and 1974.

- L.1 Objectives and multiple-choice summary statistics.
- L.2 The output questionnaire including attitudinal items, 1974.
- L.3 The theoretical examination 1973.
- L.4 The experimental examination 1973.
- L.5 The theoretical examination 1974.
- L.6 The experimental examination 1974.

L.1 Objectives and multiple-choice summary statistics (output assessment)

(i) Cognitive items

Objective	Examination	1973 Question Number	1974 Question Number	Content**	M.C. Facility (Discrimination)***	
					October 1973 (N = 92)	October 1974 (N = 74)
I(A)	101	C 8	C 7	M	75 (15)	83 (04)
	101	C12	C10	F	55 (57)	52 (35)
	101	C25	C23	W	45 (37)	71 (42) *
	102	C 9	C11	M	73 (40)	71 (35)
	102	C18	C23	W	67 (40)	73 (46)
I(B)	101	C18	C17	F	52 (70)	52 (27)
	101	C23	C25	W	53 (43)	63 (38)
	102	C 8	C10	M	62 (50)	69 (31)
	102	C19	C22	W	55 (17)	60 (50)
	102	C 3	C27	F	52 (43)	48 (50)
I(C)	101	C21	C19	F	52 (47)	52 (50)
	101	C26	C24	W	40 (27)	46 (31)
	102	C 7	C 8	M	48 (37)	56 (42)
	102	C10	C13	M	42 (30)	52 (65)
	102	C15	C16	F	55 (23)	52 (42)
II(A)	101	C 3	C 3	M	77 (33)	69 (46)
	101	C 4	C 4	M	87 (27)	42 (23) *
	101	C22	C20	F	50 (60)	60 (50)
	102	C22	C25	W	48 (70)	42 (38)
	102	C27	C30	W	53 (60)	52 (58)
II(B)	101	C13	C13	F	52 (37)	50 (54)
	101	C16	C21	F	52 (57)	44 (50)
	102	C11	C12	M	48 (43)	67 (42) *
	102	C20	C14	W	40 (27)	50 (62)
	102	C21	C24	W	38 (37)	46 (31)
II(C)	101	C 7	C 6	M	17 (-12)	52 (35) *
	101	C 9	C 8	M	38 (30)	42 (62)
	101	C24	C27	W	25 (37)	25 (4)
	102	C 4	C 7	F	30 (33)	25 (35)
	102	C14	C 9	F	53 (47)	62 (31)
III(A)	101	C10	C11	M	43 (27)	35 (31)
	101	C15	C15	F	13 (13)	21 (27)
	101	C17	C22	F	20 (40)	17 (27)
	101	C27	C26	W	23 (13)	29 (27)
	102	C24	C26	W	35 (50)	46 (54)
III(B)	101	C11	C12	M	28 (37)	37 (35)
		C26 (102)	C29 (101)	W	42 (37)	38 (8)
	102	C16	C19	M	57 (47)	67 (58)
	102	C17	C20	F	78 (23)	73 (38) *
	102	C28	C29	W	30 (33)	35 (31)
III(C)	101	C 5	C 9	M	42 (30)	33 (12)
	101	C14	C14	M	62 (10)	56 (-3)
	101	C20	C18	F	60 (47)	71 (42)
	101	C28	C28	W	25 (23)	27 (31)
	102	C 5	C 5	F	50 (53)	69 (23)
IV(A)	102	A 2(b)	B10	W		
	102	B 5	B 7	GEN		
	102	A 1(b)	B 5	M		
IV(B)	102	B 4	A 3(b)	W		
	102	A 2(c)	B11	F		
IV(C)	102	A 1(c)	A 1(a)	M/F		
	102	B 6	A 3(a)	W		
IV(D)	102	A 3(a)	A 1(b)	F		
	102	B11	B 6	F		
	102	A 2(a)	A 3(c)	W		

Objective	Examination	1973 Question Number	1974 Question Number	Content**	M.C. Facility (Discrimination)***	
					October 1973 (N = 92)	October 1974 (N = 74)
IV(E)	102	C29	C 1	GEN	63(27)	69(38)
	102	C30	C 2	GEN	48(37)	42(23)
	102	C23	C 6	GEN	68(43)	54(31)
	102	C12	C15	GEN	48(70)	52(88)
	102	C25	C28	GEN	67(33)	58(54)
IV(F)	102	B 8	A 2(b)	M		
	102	B10	B 9	F		
V(A)	101	C 6	C 5	M	57(33)	52(12)
	102	C29(101) B 9	C17(102) A 2(c)	F M	62(37)	40(4)
V(B)		C 6(101)	C30(102)	GEN	88(17)	35(15) *
	102	C30(101) B12	C18(102) B12	F GEN	55(30)	69(46)
VII(A)	101	C 2	C 1	GEN	65(57)	62(38)
	101	C 1	C 2	GEN	83(20)	75(50)
	102	C 2	C 3	GEN	50(53)	52(50) *
	102	C 1	C 4	GEN	87(27)	65(31)
	102	C13	C21	GEN	57(60)	38(46)

Objective	Test Part	Question 1973 - 1974
V(C)	Questionnaire B	3, 8, 13, 18, 22, 26, 30, 33, [35]
VI(A)	Questionnaire B	[2], 5, 7, 11, 16, 19, 24, 27, 31
VI(B)	Questionnaire B	4, 9, 12, 15, 20, 23, 28, 34, [36]
VI(C)	Questionnaire B	[1], 6, 10, 14, 17, 21, 25, 29, 32

[] items not included in total score

Content	Examination	Question Number 1973	Question Number 1974
Mechanics	101 Part C	3, 4, 5, 7, 8, 9, 10, 11, 14	3, 4, 6, 7, 8, 9, 11, 12, 14
	102 Part C	7, 8, 9, 10, 11, 16	8, 10, 11, 12, 13, 19
Fields	101 Part C	12, 13, 15, 16, 17, 18, 20, 21, 22	10, 13, 15, 17, 18, 19, 20, 21, 22
	102 Part C	3, 4, 5, 14, 15, 17	5, 7, 9, 16, 20, 27
Waves	101 Part C	23, 24, 25, 26, 27, 28	23, 24, 25, 26, 27, 28, 29
	102 Part C	18, 19, 20, 21, 22, 24, 26, 27, 28	14, 22, 23, 24, 25, 26, 29, 30

* Some modification made from 1973 to 1974 to align question more with teaching and objective.

** M - Mechanics, F - Fields, W - Waves.

*** Discrimination over all M.C. questions including V(A) and V(B) multiple choice.

Supplementary 73.101 questions.

Objective	Examination	1973 Question Number	1974 Question Number	Content
Section B - Short questions				
I (A)	101	B 10	B 10	W
I (B)	101	B 7	B 7	F
I (C)	101	B 6	B 6	M
II (A)	101	B 9	B 9	F
II (B)	101	B 4	B 4	M
II (C)	101	B 12	B 8	W
III (A)	101	B 5	B 5	M
III (B)	101	B 8	B 11	F
III (C)	101	B 11	B 12	W
Section A - Long questions				
I - III	101	A 1	A 1	M
I - III	101	A 2	A 2	F
I - III	101	A 3	A 3	W

L.2 The output questionnaire including attitudinal items, 1974UNIVERSITY OF WAIKATOFinal Personal Questionnaire

At the beginning of this year you were asked about your aim in taking courses 73.101 and 73.102, and about your attitude toward aspects of physics. For comparison, now at the end of the course, we would appreciate your honest answers to these same questions. All individual answers will be treated confidentially.

PART A

1. In MARCH you were asked where you were living during the term. As this may have changed, please specify which of the following categories of accommodation applied to you for the major part of the academic year.

Accommodation

- (i) Home (parents or married)
 (ii) Bryant Hall Accommodation during
 the term was
- (iii) Student Village
 (iv) Private board Accommodation during the
 vacations was mainly
- (v) Flatting

2. In MARCH you were asked what was your aim in terms of the final results for physics courses 73.101/73.102. The options were

- (i) to get something out of the course although I am not sure I will be able to pass
 (ii) to just gain a pass (C^- - C)
 (iii) to pass comfortably \sim (C^+)
 (iv) to pass with a good mark \sim (B)
 (v) to pass with very high marks \sim (A)

As far as you remember what was your aim in MARCH?

What do you really feel is your present aim?

73.101	73.102

PART B

The purpose of the following statements is to find your opinion about a number of things related to physics.

There are no "right" or "wrong" answers. What is wanted is an opinion which you should give as quickly and as accurately as you can.

Your opinions to the statements should be given by choosing one of the following and marking the appropriate square on the answer sheet provided.

- Mark Column - SA - if you strongly agree with the statement
A - if you agree with the statement
D - if you disagree with the statement
SD - if you strongly disagree with the statement
N - if you cannot decide whether you agree or disagree with the statement.

1. I sometimes think of a solution to a problem in physics when I am doing something quite unrelated to physics.
2. Calculus is not really much use to a physicist.
3. Physicists will never run out of new areas of investigation.
4. Physics fascinates me.
5. The use of mathematics in physics tends to make a relatively simple idea in physics seem much more complicated than it actually is.
6. I often study topics in physics outside the syllabus.
7. I find it very convenient to be able to express physical ideas as mathematical equations.
8. There is no place in physics for hunches and guesses.
9. I find the physics we study very relevant to my interests.
10. I consider it a waste of time finding out about the latest theories in geophysics, astrophysics or any other aspect of physics not directly related to my physics course.
11. If mathematical terms were not used in physics the subject would be much more enjoyable.
12. I find learning physics most enjoyable.
13. An imaginative and creative sort of person should become an artist or writer but certainly not a physicist.

	SA	A	N	D	SD
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					

- 3 -

	SA	A	N	D	SD
14. Nuclear physics is an uninteresting subject which, if I were free to choose, I would wish to know nothing about.					
15. Physics is not really important to me.					
16. I find it convenient to use mathematics in physics.					
17. One important reason why I study mathematics is that I know it will be helpful in understanding physics.					
18. Physics is basically a "finished and dead" subject.					
19. Physics is bound to be more difficult if ideas are expressed in mathematical terms rather than words.					
20. Physics is an important subject to me as I consider it such a fundamental science.					
21. I am not interested in trying to apply my knowledge of physics to the understanding of things that I observe or read about during the vacation.					
22. In general, physicists find that an answer to a problem usually produces at least one other question.					
23. I find physics a most unsatisfying subject.					
24. The precise relationship between physical quantities is much more obvious if the relationship is expressed as a mathematical equation.					
25. I read a wide variety of physics books purely for interest.					
26. There will be no interesting and worthwhile investigations left to do in physics by the year 2001.					
27. I find mathematics of considerable help in solving problems in physics.					
28. Physics is a very satisfying subject to study.					
29. I hardly ever read the physical science articles in popular magazines, for example "Time" or the local newspaper.					
30. Physicists find that their subject is very satisfying because it provides plenty of opportunity for creativity.					
31. I find it hard to understand ideas in physics if these ideas are expressed as mathematical equations.					

- 32. I never study physics except just before a test or exam.
- 33. Physicists have had some of their most cherished ideas shattered by discoveries in Physics
- 34. The physics we study is not relevant to my particular interests.
- 35. Scientific processes lead to absolute truth.
- 36. Physics is one of the least important subjects I study.

	SA	A	N	D	SD
32					
33					
34					
35					
36					

PART C

1. Since this time last year, would you consider your attitudes, towards physics as a subject (i.e. considering it as interesting, satisfying and useful as against boring, unsatisfying, and useless), have become

- (a) much more positive
- (b) more positive
- (c) remained the same
- (d) more negative
- (e) much more negative.

Answer.....

2. In general have your physics test marks been higher or lower than you anticipated in MARCH?

- (a) much higher than expected
- (b) higher than expected
- (c) more or less as expected
- (d) lower than expected
- (e) much lower than expected

Answer.....

3. In 1975 you will most probably

- (a) Major in physics or B.Sc.(Tech) in Physics.
- (b) Continue with some second year physics courses.
- (c) Transfer to a specialist degree - B.Arch, B.Eng.etc.
- (d) Continue with a B.Sc. without physics above 1st year.
- (e) Discontinue university study at least for the time being.

Answer.....

NAME:

L.3 The theoretical examination, 1973

UNIVERSITY OF WAIKATO

EXAMINATIONS 1973

73.101 PHYSICS

(Time allowed: *Three* hours)

This paper consists of three sections. Marks may be gained from all questions attempted.

Candidates may bring "Physics" by Alonso and Finn or "Fundamental University Physics", Vol. I and II, into the examination room.

The use of log tables, slide rules and drawing instruments is permitted.

THIS PAPER MUST BE HANDED IN, TIED TO ANSWER BOOKLET.

SECTION A

This section consists of THREE questions. Each question is worth 12 marks.

SECTION B

This section consists of NINE short questions. Each questions is worth 4 marks.

SECTION C

This section consists of THIRTY multiple choice questions and is worth 36 marks.

All answers to this section are to be recorded on the special answer sheet provided. Select the best answer from the alternatives provided.

(continued)

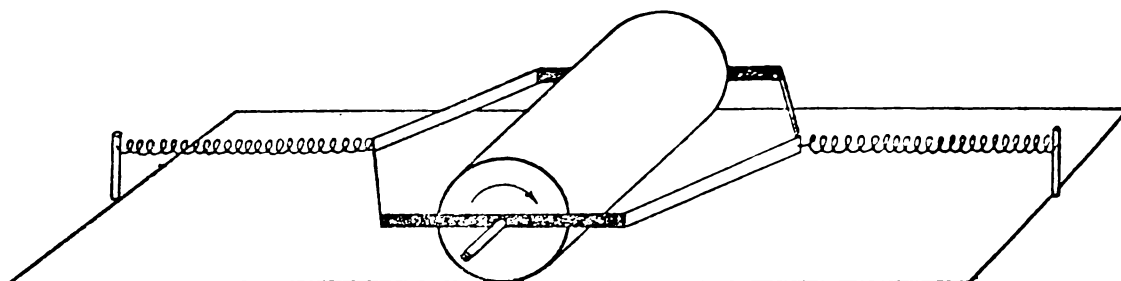
TURN OVER

continued

- 2 -

SECTION A

1. A solid cylinder of uniform mass density, has total mass M , and radius R and rests on a horizontal surface. It is attached to two opposing springs, as shown, via a light framework of negligible mass.



When the system is displaced a distance x from its equilibrium position the force on the cylinder is $-kx$, where k is a constant. The cylinder rolls and does not slip on the surface.

- (a) If the cylinder is rolling with a velocity of centre of mass, v , write down (in terms of v , M and R) an expression for
- (i) the angular velocity of the cylinder
 - (ii) the rotational kinetic energy of the cylinder
 - (iii) the total kinetic energy of the cylinder.
- [4 marks]
- (b) From a consideration of the total energy of the mass spring system, or otherwise, show the period of oscillation of the system will be 3π s, if $M = 3$ kg and $k = 2 \text{ N m}^{-1}$.
- [4 marks]
- (c) Discuss the assumptions made in the above about friction
- (i) between the axle and the frame
 - (ii) between the cylinder and the horizontal surface.

Is it reasonable to assume conservation of mechanical energy in this system? Why?

[4 marks]

2. (a) The Faraday-Henry Law is

$$V_E = \frac{-d\phi_B}{dt}$$

(Question 2 continued
next page)

continued

- 3 -

where

$$\phi_B = \int_S \underline{B} \cdot \underline{u}_N dS$$

$$V_E = \oint_L \underline{E} \cdot d\underline{\ell}$$

(i) Define and explain all terms in these three equations, including the meaning of the integral signs.

(ii) Is the integral

$$\int_S \underline{E} \cdot \underline{u}_N dS \quad \text{the same as} \quad \int_S \underline{B} \cdot d\underline{S} ? \quad \text{Explain.}$$

[6 marks]

(b) A current of I per turn flows in a long solenoid of n turns per unit length. A square loop of one turn only and of side b is placed inside the solenoid and so orientated that the normal to the plane of the loop makes an angle α with the axis of the solenoid.

(i) Obtain an expression for the flux passing through the loop, in terms of the above symbols.

[4 marks]

(ii) Show that the mutual inductance between the loop and the solenoid is $M = \mu_0 n b^2 \cos \alpha$.

[2 marks]

3. Under certain conditions, the speed of waves on water is given approximately by $v = \sqrt{gh}$, where h is the depth of the water, and hence the wave equation becomes

$$\frac{d^2 y}{dt^2} = (gh) \frac{d^2 y}{dx^2} \quad \text{where } y \text{ represents the surface}$$

displacement.

(a) (i) Write a solution for this equation for sinusoidal waves of wavelength λ , moving along the negative x direction.

(ii) Why are waves of this type referred to as "simple harmonic" waves?

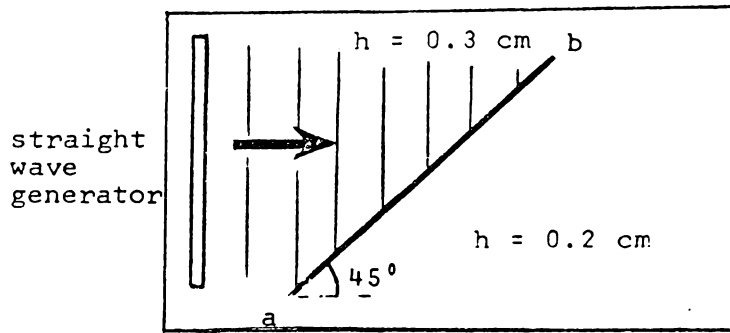
[[4 marks]

(b) Waves from a straight wave generator, in a ripple tank pass over a boundary ab between regions of depth 0.3 cm, and 0.2 cm as sketched.

(Questions 3 - continued
next page) TURN OVER

continued

- 4 -



Will the waves be refracted toward or away from the normal? Explain briefly. Determine the angle of refraction of the waves from the boundary.

[4 marks]

- (c) A more accurate expression for the velocity of water waves is

$$v = \sqrt{h \left[g + \left(\frac{2\pi}{\lambda} \right)^2 \frac{T}{\rho} \right]} \quad \text{for } h \ll \lambda$$

In a particular ripple tank

$$T = \text{surface tension} = 10^{-1} \text{ N m}^{-1}$$

$$\rho = \text{water density} = 10^3 \text{ kg m}^{-3}$$

$$\text{and } \lambda = 2\pi \times 10^{-2} \text{ m}$$

- (i) Is the expression $v = \sqrt{gh}$ an adequate approximation in this case?
- (ii) Will waves with a speed adequately represented

$$\text{by } v = \sqrt{gh}$$

and/or

$$v = \sqrt{h \left[g + \left(\frac{2\pi}{\lambda} \right)^2 \frac{T}{\rho} \right]} \text{ exhibit dispersion?}$$

Explain.

[4 marks]

(continued)

continued

- 5 -

SECTION B

4. A plank of weight 100 kgf and length 10 m is supported at its centre point. A weight of 20 kgf is placed at one end of the plank and a second weight is applied at a point 2 m on the opposite side of the support. If the magnitude of the second weight is adjusted to give equilibrium, determine the magnitude of the reaction on the support.
5. The acceleration of a particle in general curvilinear motion is known to be

$$\underline{a} = 3t \underline{u}_x + 2\underline{u}_y .$$

However, an observer claims that at $t = 2$ s the magnitude of the centripetal acceleration is 8 ms^{-2} . Give reasons why this claim cannot be correct.

6. A particle of mass m , experiences a force \underline{F} , and has a velocity \underline{v} . If F_T is the component of the force in the direction of \underline{v} , and F_N the component of the force perpendicular to \underline{v} , then

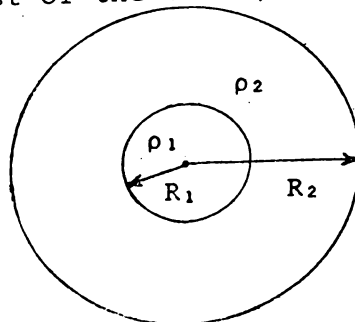
$$F_T = \frac{m_0}{(1 - \frac{v^2}{c^2})^{3/2}} \frac{dv}{dt} \quad \text{and} \quad F_N = \frac{m_0}{(1 - \frac{v^2}{c^2})^{3/2}} \frac{v^2}{R}$$

where R is the radius of curvature.

- (i) At what speeds do these relationships apply?
- (ii) What are the analogous relationships to these in Newtonian dynamics?
- (iii) What is one significant difference between the acceleration produced by \underline{F} , as predicted by Einstein, and by Newton?

[4 marks]

7. A geophysicist suspects that the earth has a core of radius R_1 , and density ρ_1 , DIFFERENT from the density ρ_2 of the rest of the earth, (total radius R_2).



(Question 7 - continued
next page) **TURN OVER**

continued

- 6 -

He can apply Gauss' Law to show theoretically that IF the core exists, the field can be expressed as a function of radius r by the equations

$$\underline{G} = \frac{-\gamma}{r^2} \frac{4}{3} \pi (R_1^3(\rho_1 - \rho_2) + r^3 \rho_2) \underline{u}_r \quad \text{for } R_1 < r < R_2$$

$$\underline{G} = \frac{-\gamma}{r^2} \frac{4}{3} \pi (R_1^3(\rho_1 - \rho_2) + R_2^3 \rho_2) \underline{u}_r \quad \text{for } r > R_2$$

These equations reduce to the following simple expressions when there is no distinguishable core

$$\underline{G} = -\gamma \frac{4}{3} \pi \rho r \underline{u}_r \quad \text{for } r < R_2$$

$$\underline{G} = -\frac{\gamma}{r^2} \frac{4}{3} \pi \rho R_2^3 \underline{u}_r \quad \text{for } r > R_2$$

By measuring the variation of G with r very accurately

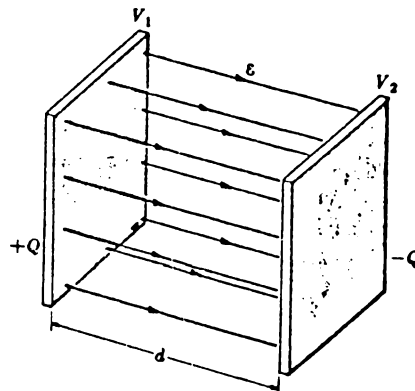
- (i) just below the surface, and
- (ii) just above the surface

can the geophysicist expect to be able to verify if there is a core, on the basis of the above equations? Explain.

[4 marks]

8. The following is a slightly modified extract from the text Alonso and Finn "Physics"; p.436, deriving the capacitance of a parallel plate capacitor.

"A typical capacitor is formed by two parallel plane conductors separated by a distance d , with the space between them filled by a dielectric (Fig. 19-28).



19.28 Parallel-plate capacitor.

(Question 8 - continued
next page)

continued

- 7 -

The electric field in the space between the conductors is uniform. If σ is the surface charge density, the potential difference between the plates is

$$V_1 - V_2 = Ed = \frac{\sigma d}{\epsilon}$$

If S is the area of the metal plates, we must have $Q = \sigma S$.

Therefore $C = \frac{\epsilon S}{d}$.

- (a) Which statements in this derivation are, in fact, approximations or assumptions?
 (b) Under what conditions might these assumptions be reasonable?

[4 marks]

9. A cyclotron has a radius of 1 m and a variable magnetic field of maximum value 1.8 T. The maximum attainable frequency for the accelerating field is $\frac{3}{\pi} \times 10^7$ Hz.

Determine the magnetic field required if protons are to be accelerated to maximum energy. What is the maximum energy that a proton may be accelerated to? (Take $e_p = 1.6 \times 10^{-19}$ C, $m_p = 1.6 \times 10^{-27}$ kg and give the proton energy in e.V.)

[4 marks]

10. Explain briefly how Heinrich Hertz in an experiment (sometimes known as the Hertz experiment), first obtained an experimental value for the velocity of propagation of electromagnetic waves.

[4 marks]

11. Two principles of physics which are related to wave motion are

- I The Principle of Superposition
 II Huygen's Principle.

Two phenomena observed with waves are interference and diffraction. In a very brief outline, indicate which principle, or principles (if any), are necessary to explain

- (i) interference
 (ii) diffraction.

Indicate by your answer whether you consider interference and diffraction to be basically identical, similar, or different.

[4 marks]

TURN OVER

continued

- 8 -

12. A space ship approaches the earth at high speed. It sends out radio signals to the control centre on Earth, using a frequency of 1.0000×10^6 Hz. The radio receiver at the control centre can detect signals only in the range $(1.0000 \pm 0.0100) \times 10^6$ Hz.
- (i) Why might communication between the incoming space ship and Earth be impossible?
 - (ii) Estimate the maximum allowable speed of the space ship if communication is to be maintained.
- [4 marks]

(continued)

continued

- 9 -

SECTION C

All answers are to be recorded on the special ANSWER SHEET provided.

1. Given the three vectors

$$\underline{A} = 7\underline{u}_x + 4\underline{u}_z$$

$$\underline{B} = -5\underline{u}_x + 7\underline{u}_z$$

$$\underline{C} = \underline{u}_x$$

then the product $\underline{C} \cdot (\underline{A} \times \underline{B})$ is

(A) 14 (B) $8\underline{u}_z$ (C) 6 (D) 0 (E) -12.

2. The cosine of the angle between the vector $4\underline{u}_x + 8\underline{u}_y + 8\underline{u}_z$ and the x-axis is

(A) 0.25 (B) 0.33 (C) 0.43 (D) 0.55

(E) 0.63.

3. The three forces $F_1 = 5\underline{u}_x + 4\underline{u}_y$ (N)

$$F_2 = -7\underline{u}_x + 2\underline{u}_y \quad (\text{N})$$

$$F_3 = 2\underline{u}_x - 2\underline{u}_y \quad (\text{N})$$

act concurrently at the point $3\underline{u}_x + 5\underline{u}_y$ (m). The torque with respect to the point $2\underline{u}_x + 5\underline{u}_y$ (m) is

(A) $2\underline{u}_z$ Nm (B) $4\underline{u}_z$ Nm (C) $10\underline{u}_y$ Nm

(D) $12\underline{u}_x$ Nm (E) $15\underline{u}_z$ Nm.

4. The angular displacement of a particle moving in a circle is given by $\theta = 3t^2 + t$. Its angular acceleration after 5 seconds is

(A) 30 rad s^{-2} (B) 20 rad s^{-2}

(C) 15 rad s^{-2} (D) 12 rad s^{-2} (E) 6 rad s^{-2} .

TURN OVER

5. Some of the basic principles of particle motion are

- I Conservation of Momentum
- II Newton's 1st Law
- III Newton's 2nd Law
- IV Newton's 3rd Law
- V Conservation of Angular Momentum

(where momentum is defined as $m\mathbf{v}$, and angular momentum as $\mathbf{r} \times m\mathbf{v}$).

Some of these principles can be considered fundamental, i.e. based on experimental evidence and definitions, and others can be derived from these fundamental ones.

A sufficient and complete set of fundamental principles to cover all the principles (I - V) would be,

- (A) I and III only
- (B) I and II only
- (C) II and V only
- (D) I only
- (E) V only.

6. Consider the following statement.

"Basic principles of mechanics, for example conservation of momentum, are never observed exactly in any experimental analysis in the laboratory. It is therefore rather unscientific to have such principles called basic principles."

Which of the following replies show a good understanding of the nature of physics?

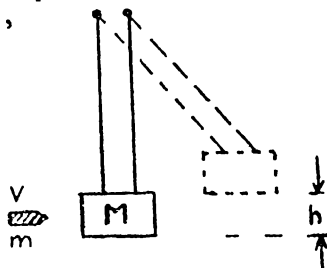
- I "The basic principles are just theory and therefore it does not matter what happens in reality."
 - II "The basic principles are not observed in the laboratory merely because of inaccurate measurements of physical quantities (e.g. mass and velocity for conservation of momentum)."
 - III "Principles of physics are idealizations and it is almost impossible to observe phenomena under ideal conditions."
- (A) I only
 - (B) II only
 - (C) III only
 - (D) I and II only
 - (E) I and III only.

continued

- 11 -

7. To determine the speed of a bullet, mass m , it is fired into a block, mass M , which forms a ballistic pendulum. The block rises to a height h , after the bullet is embedded in it. Assuming the mass of the bullet is not negligible compared to the mass of the block, the speed of the bullet can best be obtained from the equation,

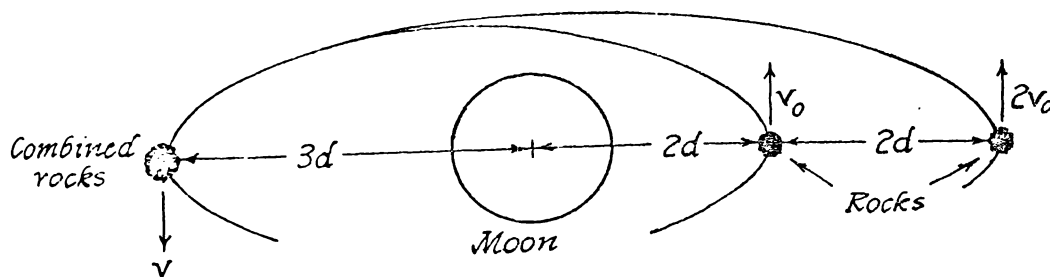
- (A) $\frac{(mv)^2}{2m} = Mgh$
 (B) $\frac{(mv)^2}{2M} = Mgh$
 (C) $\frac{1}{2}mv^2 = (M + m)gh$
 (D) $\frac{1}{2}mv^2 = (M + m)gh$
 (E) $\frac{(mv)^2}{2(M+m)} = (M + m)gh$



8. A cycloidal pendulum has a period which is,

- (A) dependent on the mass of the pendulum
 (B) independent of amplitude
 (C) independent of the pendulum length
 (D) independent of temperature variation
 (E) independent of the gravitational field g .

9. Two equal mass "moonlets" or rocks orbit the moon. They collide at P and combine, as shown in the subsequent diagram.

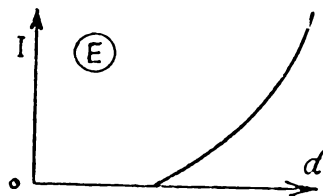
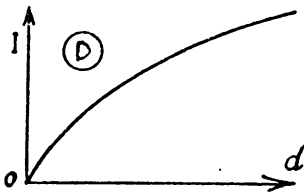
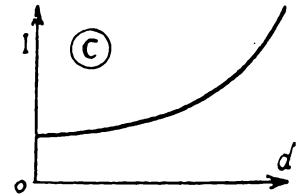
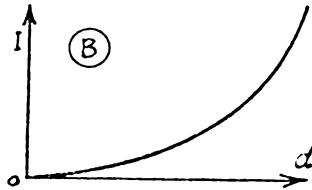
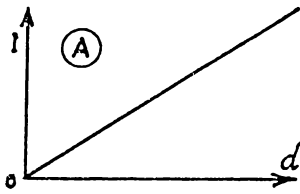
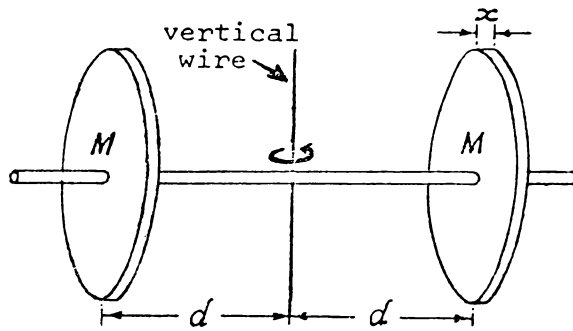


The value of v is

- (A) $\frac{1}{3} v_0$ (B) $\frac{2}{3} v_0$ (C) v_0 (D) $\frac{3v_0}{2}$
 (E) $\frac{5}{3} v_0$

TURN OVER

10. Which of the following graphs best represents the moment of inertia I , of two disks supported by a light horizontal rod rotated about its centre, versus the distance d . (The vertical wire is of negligible thickness, x can be assumed negligible, and the moment of inertia of the horizontal rod ignored.)



11. The relationship $P = 2\pi\sqrt{\frac{I}{k}}$ applies for the period of a torsional pendulum. This relationship only applies for

- I small angular displacements, θ , where $\sin\theta \approx \theta$
- II negligible friction
- III situations where the moment of inertia, I , is constant.

(Question 11 - continued next page)

continued

- 13 -

Of the above

- (A) I only is valid
- (B) III only is valid
- (C) I and II only are valid
- (D) II and III only are valid
- (E) all of the above are valid.

12. According to the text Alonso and Finn, the distance between the surface of the earth, and the centre of the moon (assumed constant) is

- (A) $1.74 \times 10^6 \text{ m}$
- (B) $2.53 \times 10^6 \text{ m}$
- (C) $3.72 \times 10^8 \text{ m}$
- (D) $3.78 \times 10^8 \text{ m}$
- (E) $3.82 \times 10^8 \text{ m}$

13. A body of mass m released from rest a distance $3R$ from the centre of the earth will reach the earth's surface with a speed

- (A) $\sqrt{\frac{4YM}{3R}}$
- (B) $\sqrt{\frac{Ym}{R^2}}$
- (C) $\frac{2Ym}{3R}$
- (D) $\sqrt{\frac{YM}{R}}$
- (E) $\sqrt{\frac{2YM}{R}}$

where M and R are respectively the mass and radius of the earth.

14. The gravitational force was found by Newton to be

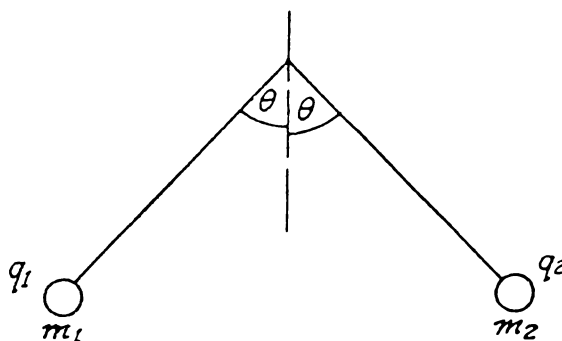
- (a) a central force, and
- (b) a force that varies as $\frac{1}{r^2}$ (an inverse square law force)

Newton was able to deduce both these facts from

- (A) Keplers second law only
- (B) the observation that all falling bodies have the same acceleration
- (C) Keplers third law only
- (D) the observation that planets moved in approximately circular orbits
- (E) Keplers second and third laws.

15. Two small electrically charged spheres, mass m_1 and m_2 and charges q_1 and q_2 respectively, are suspended by insulating threads of equal length and repel each other so that the threads make equal angles with the vertical.

(Question 15 - continued
next page) **TURN OVER**



Which of the following statements about the masses and the charges must be true.

- (A) $m_1 = m_2$ and $q_1 = q_2$
- (B) $m_1 = m_2$ but q_1 is not necessarily equal to q_2
- (C) $q_1 = q_2$ but m_1 is not necessarily equal to m_2
- (D) $\frac{m_1}{q_1} = \frac{m_2}{q_2}$

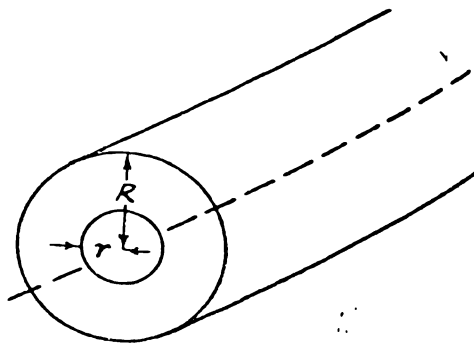
16. A long straight filamentary conductor produces a magnetic field at a radius d from its axis of B_0 . If the mean velocity of the electrons responsible for this field is v , the number of electrons, (charge e), per unit length of the conductor would be

- (A) $\frac{\mu_0 B d}{2\pi e v}$
- (B) $\frac{\mu_0 B d v}{2\pi e}$
- (C) $\frac{2\pi B d}{\mu_0 e v}$
- (D) $\frac{B d}{e v}$
- (E) $B d e v$

17. A current I is uniformly distributed over the cross-section of a cylindrical conductor of radius R .

According to Ampere's Law, the circulation of the magnetizing field ($\oint \underline{H} \cdot d\underline{\ell}$) around a circle, concentric with the axis of the conductor ($r < R$) is

- (A) $\frac{\mu_0 r I}{R^2}$
- (B) $\frac{r^2}{R^2} I$
- (C) $\frac{\mu_0 r}{2\pi R^2} I$
- (D) I
- (E) $\frac{\mu_0 I}{2\pi r}$



(continued)

continued

- 15 -

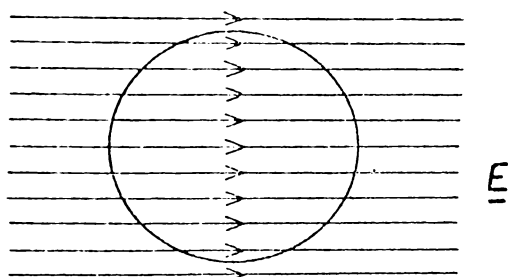
18. Gauss Law is written

$$\epsilon_0 \oint_S \underline{E} \cdot \underline{u}_N dS = \Sigma q$$

 \underline{E} in this equation is

- (A) the electric field, which is always the same at all points over the Gaussian surface.
- (B) the normal component of the electric field at the surface element dS , due to all charges.
- (C) the electric field at the surface element dS , due to all charges.
- (D) the normal component of the electric field at the surface element dS , due to all charges within the surface S .
- (E) the electric field, which is always the same at all points over the Gaussian surface due to charges within the surface.

19. $\oint_S \underline{E} \cdot \underline{u}_N dS$ is the flux of the electric field through a closed surface. A uniform electric field passes through a spherical surface as shown.



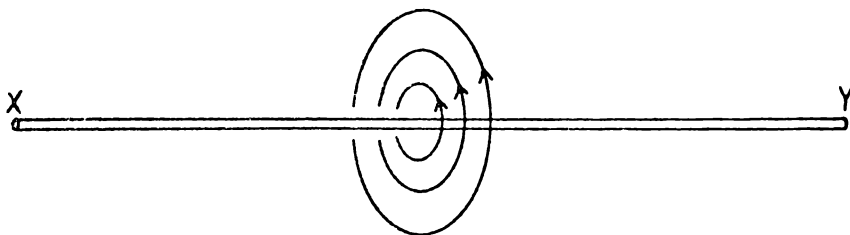
The flux of the electric field over the total surface of the sphere would be,

- (A) zero (B) $2\pi RE$ (C) $\pi R^2 E$ (D) $4\pi R^2 E$
- (E) $\frac{4}{3} \pi R^3 E$
20. Frequently the electric fields near
- (i) an isolated charged sphere
- (ii) a long line of charge
- and (iii) an infinitely large charged plate,
- can all be found easily using Gauss' Law. This is because Gauss' Law can be

(Question 20 - continued
next page) TURN OVER

- (A) applied to find the field near any distribution of charges provided the charges all have the same sign
- (B) easily applied to find the electric field near any relatively simple charge distribution
- (C) often applied to find the electric field near charge distributions which have symmetry properties
- (D) easily applied to find the electric field near any charge distribution
- (E) only apply to the three physical situations described in (i), (ii) and (iii).

21. The diagram shows a number of concentric field lines surrounding a tube of material.



(If the field lines represent a magnetic field, this field could have been caused by a steady electric current in the tube XY.)

If the field lines represent an electric field, which of the following could have caused the field?

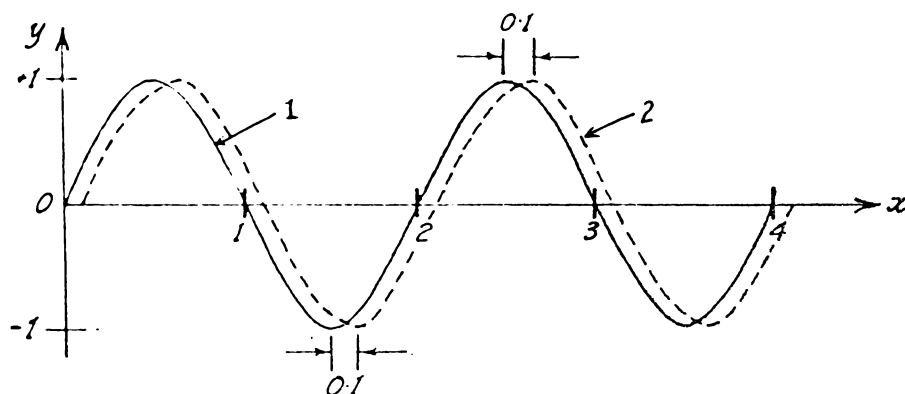
- (A) Tube XY carries a steady electric current
- (B) Tube XY contains a constant magnetic field parallel to XY
- (C) Tube XY contains a changing electric field parallel to XY
- (D) Tube XY has a positive electric charge distributed uniformly along its length
- (E) Tube XY contains a changing magnetic field parallel to XY.

(continued)

continued

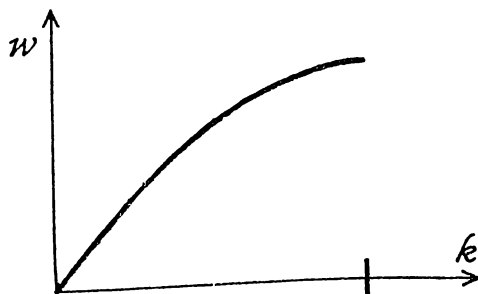
- 17 -

22. The energy stored in the magnetic field of an inductor is 1J. If the self-inductance of the circuit is 2×10^{-2} H, the current flowing in the circuit is
- (A) 2×10^{-2} A (B) 1A (C) 7A (D) 10A
(E) 50A
23. Two progressive S.H.M. wave trains, as shown, move with the same speed (2ms^{-1}) to the right.



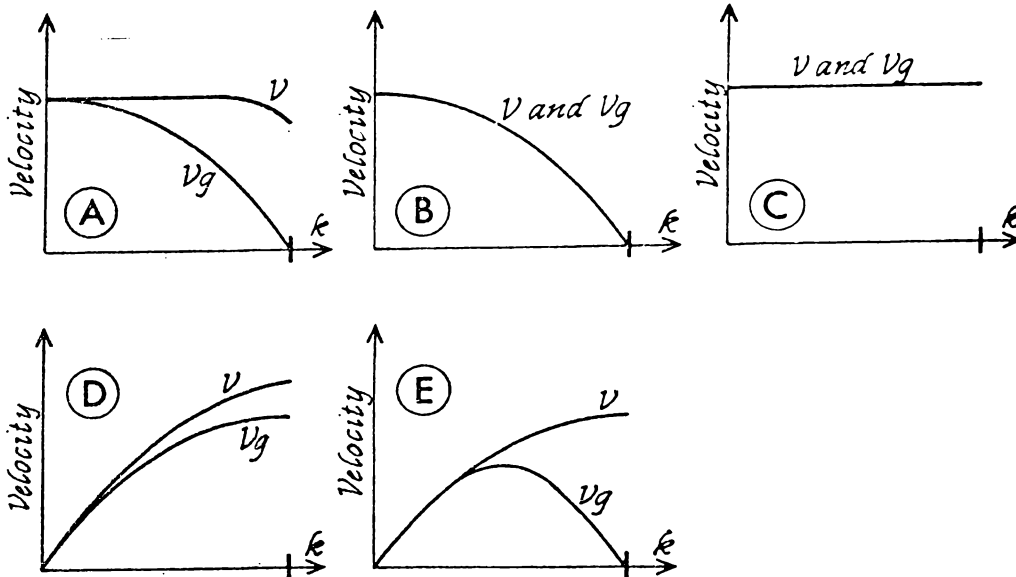
If the equation of wave train (1) is $y = \sin(\pi x - 2\pi t)$, the equation of the wave train (2) will be

- (A) $y = \sin \pi(x - 2t)$
 (B) $y = \sin \pi(x - 2t - 0.1)$
 (C) $y = \sin(\pi x - 0.1 - 2t)$
 (D) $y = \sin \pi(x - 2t + 0.1)$
 (E) $y = \sin(\pi x + 0.1 - 2t)$
24. The graph of angular frequency, ω , versus wave vector k , for sound waves travelling in a solid is of the form shown in the figure.



(Question 24 - continued
next page) TURN OVER

The corresponding graph of phase velocity v , and group velocity v_g , versus k , would be best shown by which of the following graphs.



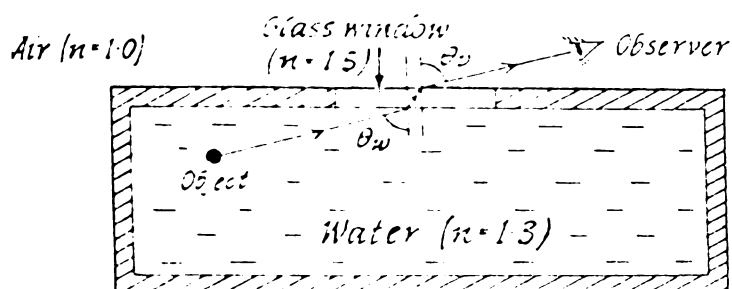
25. A beam of plane polarized light is incident on a sheet of dichroic material, and no light is transmitted. This is because the energy in the incident beam is
- (A) reflected back along the original direction.
 - (B) scattered out at right angles to the original direction.
 - (C) rotated into a plane perpendicular to the original plane.
 - (D) absorbed in the material as heat.
 - (E) transformed into the energy of the ejected photoelectrons.
26. Brewster's angle for glass is 56° . Plane polarized light is incident on a glass surface at this angle and the plane of polarization is rotated about the incident beam. The intensity of the reflected light
- (A) is always zero.
 - (B) varies between a minimum and a maximum value.
 - (C) remains constant.
 - (D) varies between zero and a maximum value.
 - (E) is sometimes greater than that of the incident beam.

(continued)

continued

- 19 -

27. A water tank has a glass window, as shown in the plan view below. An object in the tank is visible to an outside observer if light travels as indicated by the ray diagram.



Note

$$\sin 64^\circ = \frac{1.3}{1.5}$$

$$\sin 49^\circ = \frac{1}{1.3}$$

$$\sin 42^\circ = \frac{1}{1.5}$$

If it were possible for θ_w to have any value in the range -90° to $+90^\circ$, then the observer could see an object anywhere in the tank.

- (A) This is possible, but θ_v must vary between $+90^\circ$ and -90°
- (B) This is possible, but θ_v must vary between $+64^\circ$ and -64°
- (C) This is possible, but θ_v must vary between $+49^\circ$ and -49°
- (D) This is possible, but θ_v must vary between $+42^\circ$ and -42°
- (E) This is impossible.
28. In which of the following situations can the interaction of electromagnetic radiation with matter only be explained in terms of the photon concept.

- I Photoelectric effect
 II Radiation pressure
 III Optical Activity

- (A) I only
 (B) I and II only
 (C) I and III only
 (D) II and III only
 (E) I, II and III.

The following information refers to questions 29 and 30

In an experimental investigation of α particles deflected by a thin foil of gold, Rutherford found that only one particle in 10,000 was deflected more than a few degrees. In an attempt to explain the minimal deflection of α particles by a gold foil Rutherford proposed his model of the atom. Further, assuming the nucleus was a point charge, and

TURN OVER

Coulomb's Law could be used to determine the force between the nucleus and the α particle, a prediction was made that the number of particles with a scattering angle between ϕ and $\phi+d\phi$ was proportional to $\text{cosec}^4 \frac{\phi}{2}$.

29. In predicting the $\text{cosec}^4 \frac{\phi}{2}$ relationship, Rutherford assumed that Coulomb's Law ($F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$) would apply at very small distances for which it had never been tested before. Which of the following statements about Coulomb's Law would have been the basis for making this assumption?

- (A) Coulomb's Law is based on experimental evidence about forces between charges and therefore it must hold at any distance whatever between charges.
- (B) Coulomb's Law does not explicitly state any limitations on the distance between charges.
- (C) Coulomb's Law is a basic principle of physics hence must apply at all distances.
- (D) It was not unreasonable to expect Coulomb's Law to hold at small distances and there was no evidence to the contrary.

30. Rutherford's initial ideas about the atom lead to a prediction which could be checked experimentally. Which of the following opinions about Rutherford's method of investigation shows the best understanding of scientific methods.

- (A) Rutherford should have obtained all the experimental evidence possible before inventing any theory, or ideas, to explain his results.
- (B) Scientific ideas should not really be used to make predictions.
- (C) Rutherford proceeded in a rather unscientific manner in using his initial results to invent a model, or theory, of atomic structure.
- (D) Scientific ideas are most useful if they make predictions.
- (E) As Rutherford's initial ideas were based on experimental evidence, there was no need to experimentally check his prediction.

L.4 The experimental examination 1973

UNIVERSITY OF WAIKATO

EXAMINATIONS 1973

73.102 PHYSICS

(Time allowed: *Three hours*)

This paper consists of three sections. Marks may be gained from all questions attempted.

Candidates may bring any books into the examination room, and are expected to bring "Physics" by Alonso and Finn, "Experimental Physics", and laboratory notebooks.

The use of log tables, slide rules and drawing instruments is permitted.

Appropriate graph paper will be provided.

Laboratory Notebooks must be handed in at the end of the examination.

THIS PAPER MUST BE HANDED IN, TIED TO ANSWER BOOKLET.

SECTION A

This section consists of THREE questions. Each question is worth 12 marks.

SECTION B

This section consists of NINE short questions. Each question is worth 4 marks.

SECTION C

This section consists of THIRTY multiple choice questions and is worth 36 marks. In each case choose the best alternative from those provided.

(Up to FIVE marks will be awarded for the completeness of your laboratory notebook.)

NOTE: It is not anticipated that you will use all the graph paper supplied.

(continued)

TURN OVER

SECTION A

1. (a) A complex system of bumpers is designed to provide a barrier for the testing of cars crashing at high speeds. The compression, x , of the bumper system versus applied force, F , is given in the table below.

Applied Force $F(N)$	Compression $x(m)$
100	0.06
200	0.10
400	0.15
800	0.25
1600	0.40
3000	0.60
4500	0.80

It is suspected that the relationship between F and x is of the form $F = kx^n$.

By plotting a suitable graph show that the relationship between F and x is of the form $F = kx^n$ and, hence, determine k .

[4 marks]

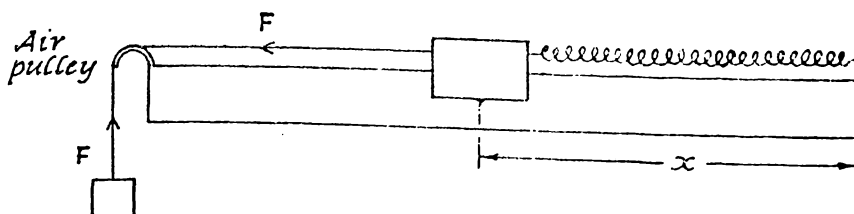
(b) An experiment is carried out to determine the suitability of an air track, photocell gate, electric clock system for the measurement of g using the relationship $v^2 = 2g \sin\theta x$, where v is the velocity of the glider after accelerating a distance x from rest.

Consistently with the particular apparatus used, a value of g of 7.0 m s^{-2} is obtained.

Give at least three possible reasons which might account for this large systematic error, and which you think should be investigated if the systematic error is to be eliminated. (Do not assume this apparatus is exactly the same as you used.) Mention very briefly why you consider your reasons would lead to a low value of g .

[4 marks]

(c) To determine the spring constant using a glider on an air track, a weight is supported by the spring over an air pulley. k is required to 5%. The following readings are obtained.



(Question 1(c) - continued
next page)

continued

- 3 -

F(N)	x(m)
0	0.1005
1×10^{-2}	0.1515
2×10^{-2}	0.2010
3×10^{-2}	0.2905
4×10^{-2}	0.3015
8×10^{-2}	0.5000
16×10^{-2}	0.9015

Criticize the data that has been collected.

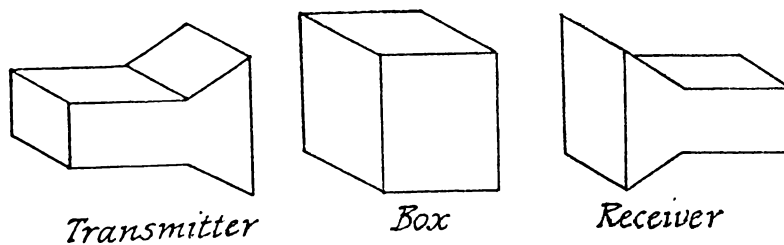
[4 marks]

2. (a) The wavelength of microwaves can be determined using a Michelson Interferometer. Explain briefly how, once your apparatus was set up (see Experimental Physics, p.119) you obtained your results. List all readings and explain how the wavelength λ , was determined from these results. Include, with your value for λ , your error analysis.

[4 marks]

- (b) A new microwave experiment is developed, where the problem is to determine the possible shape of metal objects (or a metal object) inside two different polystyrene boxes, by analyzing the intensity and polarization of microwaves transmitted through the boxes.

The following are some preliminary results, using the following apparatus.



(Question 2(b) - continued
next page) **TURN OVER**

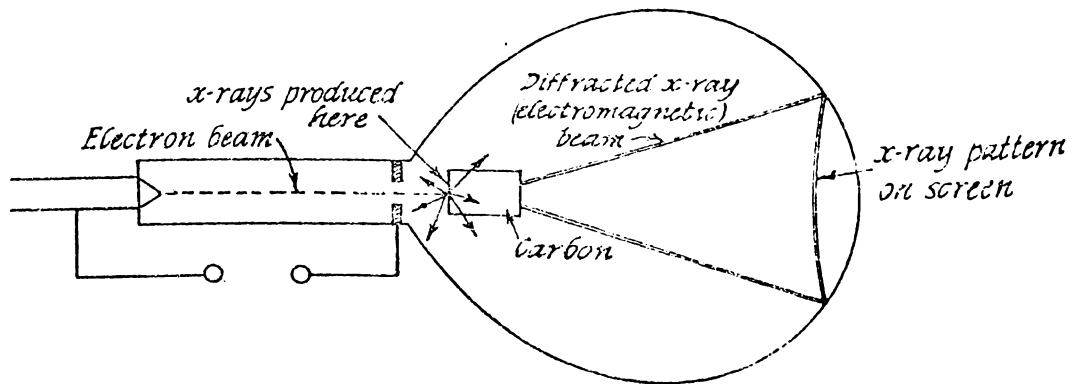
continued

<u>Results</u>	<u>Initial Polarization</u>	<u>Final Polarization</u>	
<u>Box A</u>	Vertical		} Polarization vector Rotated 45° (as shown) and <u>diminished in intensity</u>
	Horizontal		
<u>Box B</u>	Vertical		} Polarization vector Rotated 45° (as shown) with <u>minimal intensity change</u>
	Horizontal		

Suggest what might be in the boxes to produce these results. If the incident polarization vector is now orientated at an angle of 45° to the vertical, predict for each box the final direction of the polarization vector and comment on its final intensity.

[4 marks]

(c) A student studying "electron diffraction" does not believe electrons have an associated wavelength. Rather he considers that the pattern is due to X-ray diffraction, since X-rays would be produced when electrons collide with the crystal, and these X-rays would be diffracted by the crystal, as suggested in the diagram.



(Question 2(c) continued next page)

continued

- 5 -

His theory could be disproved because of the difference in behaviour of electrons and of electromagnetic waves in either electric or magnetic fields. Explain how you would, in practice, experimentally verify that the pattern on the screen is produced by electrons and not electromagnetic waves (suggest two procedures).

[4 marks]

3. (a) In the D.C. circuits experiment, the values for the resistances R_1 , R_2 and R_3 were experimentally obtained. From these results the combined resistances of the three resistors in (i) series and (ii) parallel were predicted. These "theoretical" values were checked experimentally.

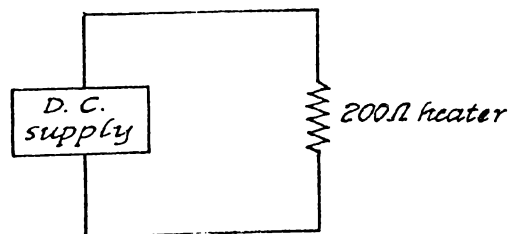
Copy and complete the following table giving your values for this experiment.

	Theoretical result	Experimental result
R_{TOTAL} series		
R_{TOTAL} parallel		

Give very approximate error estimates in each case, and hence conclude if your results confirm, or not, the theoretical equations for adding resistors in series and in parallel.

[4 marks]

- (b) It is required to provide maximum power output from a small heater of 200Ω when connected as in the figure, with a d.c. supply.



Several d.c. power supplies all of 10V e.m.f. are available, however they have a variety of internal resistances.

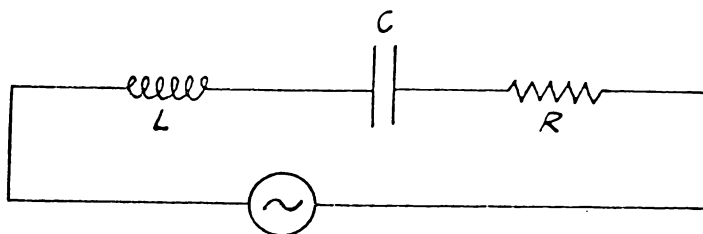
Supply A has 1Ω internal resistance while supplies B,C,D, and E have internal resistances of 50Ω , 100Ω , 200Ω and 400Ω respectively.

(Question 3(b) - continued
next page) TURN OVER

It is suggested that, as maximum power transfer occurs when the internal resistance of the supply is equal to the external resistance in the circuit, the "D" supply should be used to obtain maximum power transfer. Can you explain why this is not a reasonable suggestion?

[4 marks]

(c) An a.c. voltage $V = V_0 \sin \omega t$ is applied to an R-L-C series circuit, as shown.



The components are pure (e.g. the resistance of the inductor is negligible).

Sketch the rotating vector diagram to roughly represent the amplitude of the voltages across each component in the circuit V_L , V_C , V_R and V_0 . Include on this representation the rotating vector to represent the current I .

If $V_C = 700\text{V}$, $V_L = 300\text{V}$ and $V_R = 300\text{V}$, determine the amplitude of the applied voltage V_0 . Also determine the phase angle between the applied voltage and the current.

[4 marks]

(continued)

continued

- 7 -

SECTION B

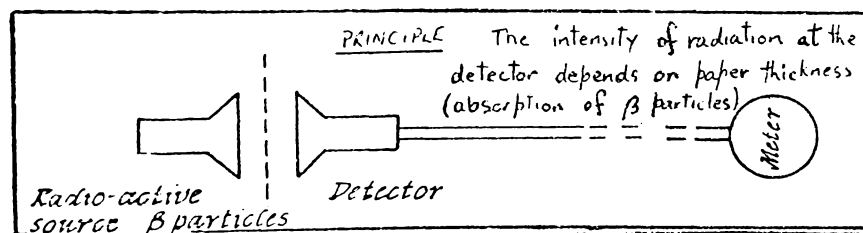
4. It is decided to measure the wavelength of sound, frequency 3000 Hz, by analysing the interference pattern produced by two adjacent, and synchronous sound sources (loudspeakers). In addition to the speakers, an oscillator, a microphone and a C.R.O. are available. The speed of sound is known to be about 330m s^{-1} , but the interference pattern is to be used to provide a precise measure of wavelength.

With a schematic diagram, show how you would set up the above apparatus. Determine suitable values for source-source, and source-detector distances (show working) and include these values on your diagram.

[4 marks]

5. A physicist working for a publishing firm is asked to suggest a continually repeatable method for measuring the thickness of single sheets of paper. The paper varies in thickness, not in density, and the method suggested must be adaptable to remote reading in a distant control room.

He suggests using a radioactive source and detector system, or a mechanical (remote control) micrometer device. His radioactivity suggestion is outlined in the diagram.



Suggest (from your knowledge of physical phenomena considered in experiments in this course (or otherwise)) two alternative methods for measuring the paper thickness that might be feasible and practicable, (one sentence only for each method explaining briefly the principle involved).

[4 marks]

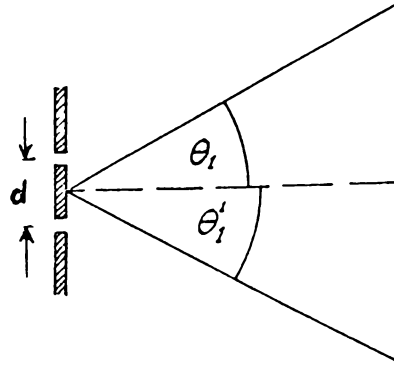
6. To determine the wavelength of microwaves, a two slit interference pattern is to be analysed using the relationship $\sin \theta = \frac{(n-\frac{1}{2})\lambda}{d}$ for the angular position of the nodal lines.

With the apparatus set up (and not subsequently altered) two students obtain results, for the position of the first nodal line, and the distance, d .

(Question 6 - continued
next page) **TURN OVER**

continued

- 8 -



Student I $\theta_1 = 32^\circ, 30^\circ, 27^\circ, 31^\circ, 30^\circ$

$d = 6.0 \pm 0.1 \text{ cm}$

Student II $\theta_1 = 32^\circ, 28^\circ$ $\theta'_1 = 23^\circ, 21^\circ$

$d = 6.0 \pm 0.5 \text{ cm.}$

State which student has the most useful set of results.
Explain briefly.

[4 marks]

7. An electron moves in a circular path in a magnetic field of 10^{-2} tesla.

The radius of the electron path is 0.50 m. Determine the total energy of the electron (to one significant figure).

[4 marks]

8. In Exp. 4, a photographic analysis was made of the collision of a magnetic puck with an equal mass stationary magnetic puck. Is the loss of energy in this experiment negligible compared to the other errors or uncertainties involved in this experiment and in the photographic analysis? Explain briefly and clearly, supporting your argument with numerical data where possible.

[4 marks]

9. One of the basic laws of physics is the conservation of momentum - "the total momentum of an isolated system of particles is constant".

With relation to the above basic law explain (one sentence) in what way it

- (i) is an idealization
- (ii) is a generalization
- (iii) is an experimental observation
- (iv) can be used as a basis for prediction.

[4 marks]

(continued)

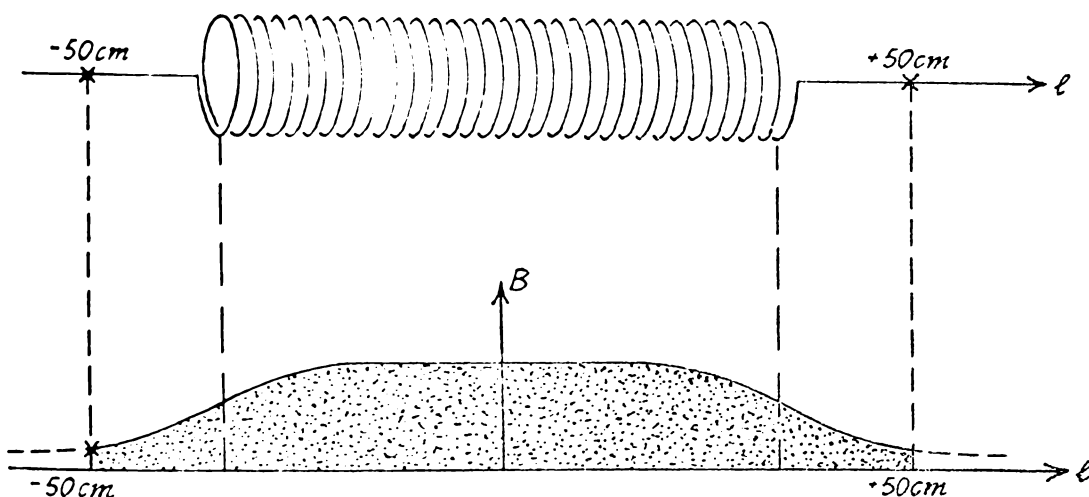
continued

- 9 -

10. A student is attempting to verify the Ampere Law relationship

$$\int_{-\infty}^{+\infty} \mathbf{B} \cdot d\mathbf{l} = \mu_0 NI$$

by measuring the magnetic field along the axis of a solenoid of 100 turns, carrying a current of 5.00A.



Using a Hall probe the field is measured from -50 cm to $+50 \text{ cm}$ as shown.

The area shaded on the graph ($\int B \cdot dl$) is determined to be

$$(5.4 \pm 0.3) \times 10^{-4} \text{ m kg C}^{-1} \text{ s}^{-1}$$

while $\mu_0 NI$ is equal to

$$(5.00 \pm 0.01) \times 10^{-4} \text{ m kg C}^{-1} \text{ s}^{-1}$$

What conclusion would you make from these results? Do you suspect a systematic error?

[4 marks]

11. State the values you obtained for the $\frac{e}{m}$ ratio of the electron using J.J. Thompson's method. Include the values for the electric and magnetic fields used for each analysis. When you compared your value of $\frac{e}{m}$ with that given by the text Alonso and Finn, what was your conclusion about the possibility of systematic error?

[4 marks]

TURN OVER

12. De Broglie in 1924, merely from consideration of the particle nature of light, and the relationship $\lambda = \frac{h}{p}$ for photons, suggested that particles (e.g. electrons) might have a wavelike nature with a wavelength given by $\lambda = \frac{h}{p}$.

As De Broglie, had no experimental evidence to support this proposal at that time, but merely invented the idea (probably because nature is strikingly symmetric in many other ways) it is suggested by a student that this was a most unscientific proposal.

In general would you consider a tentative proposal like De Broglie's to be unscientific? Very briefly give your reason (one or two sentences only).

[4 marks]

(continued)

continued

- 11 -

SECTION C

Answers to be recorded on the special ANSWER SHEET provided.

1. The following table shows a set of results obtained for measuring the period of a ball rolling on a spherical dish.

x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
1.9		
2.2		
2.5		
2.1		
2.3		

$\bar{x} = 2.2$

The error in the mean value, $\sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n(n-1)}}$ is approximately

- (A) $1 \times 10^{-1} \text{ s}$
- (B) $2 \times 10^{-1} \text{ s}$
- (C) $3 \times 10^{-1} \text{ s}$
- (D) $4 \times 10^{-1} \text{ s}$
- (E) $5 \times 10^{-1} \text{ s}$

2. The percentage error of a product is given by $\sqrt{P_A^2 + P_B^2}$, hence if the current through a resistor is $2.0 \pm 0.1 \text{ mA}$ and if the potential difference across the resistor is $1.00 \pm 0.05 \text{ V}$, then the resistance of the resistor ($\frac{V}{I}$) is best expressed as,

- (A) $(5 \pm 1) \times 10^2 \Omega$
- (B) $(5.0 \pm 0.5) \times 10^2 \Omega$
- (C) $(5.0 \pm 0.4) \times 10^2 \Omega$
- (D) $(5.0 \pm 0.2) \times 10^2 \Omega$
- (E) $(5.0 \pm 0.1) \times 10^2 \Omega$

3. A photovoltaic cell will generate a small current in a circuit as shown in Fig (a) when light is incident on it.

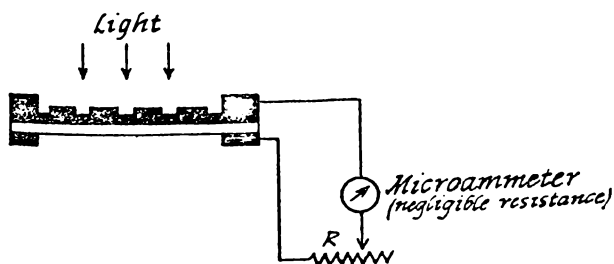


Fig.(a)

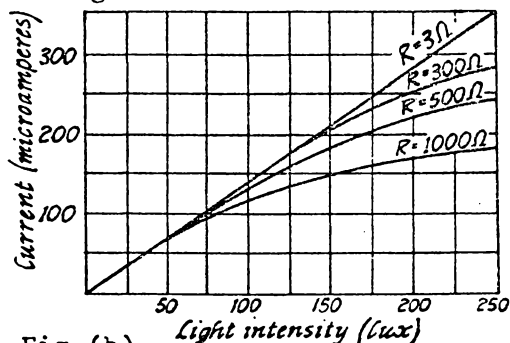


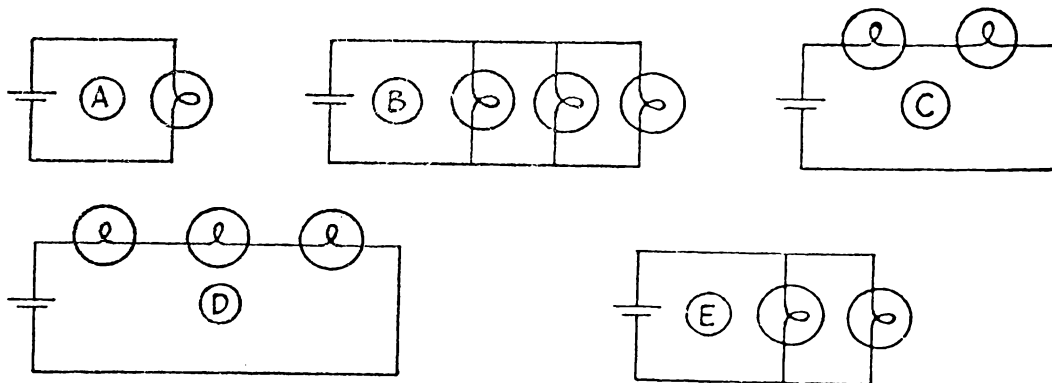
Fig.(b)
(Question 3 - continued next page) TURN OVER

Fig. (b) shows the current generated in this circuit at different light intensities and with different resistances R in the circuit. The light intensity is given in lux, a common unit for this quantity.

If the resistance of the "external" resistance R was reduced to zero, what current would you predict for a light intensity of 200 lux:

- (A) greater than $300\mu\text{A}$.
- (B) about $280\mu\text{A}$.
- (C) between 160 and $250\mu\text{A}$.
- (D) it is impossible to predict from the information given.

4. A battery of internal resistance, 3Ω , and three light bulbs (each of constant resistance 1.5Ω) can be connected together in various ways. If the light emitted from the bulbs is proportional to the power dissipated in the bulb, which of the following would give the total maximum output of light?



5. From a theoretical point of view, Kirchhoff's Laws for D.C. circuits are best described as
- (A) fundamental laws of physics, i.e. basic principles of physics.
 - (B) purely experimental laws, unrelated to any basic principles of physics.
 - (C) laws which can be derived from basic conservation laws.
 - (D) laws which can be derived from Ohms Law.
 - (E) laws which can be derived from Coulomb's Law.

continued

- 13 -

6. A prediction is made regarding the outcome of a novel experiment in physics. Possible reactions of the experimenter if the result is not as anticipated might be:

- I "Predictions should not be made before attempting an experiment."
- II "If the experiment is repeated a sufficient number of times, the anticipated result will be obtained."
- III "The observations will need to be checked, and the experiment possibly improved."
- IV "The prediction may need reconsideration."
- V "The equipment must be improved so that the anticipated result is obtained."

The scientifically acceptable reactions would be

- (A) I and III
- (B) I, III and IV
- (C) II and V
- (D) I, II and V
- (E) III and IV

7. Two magnets are attached to the adjacent ends of two gliders so that they attract rather than repel. One glider is placed in the centre of the track and is initially stationary. The second glider has an initial velocity of 2 m s^{-1} . The two gliders are of equal mass and on collision they naturally 'stick' together. What is their combined velocity after collision?

- (A) The final combined velocity will be 1 m s^{-1} , as conservation of momentum will apply.
- (B) As the magnets attract the initially stationary glider will be moving toward the other glider before collision so that the final combined velocity will be less than 1 m s^{-1} .
- (C) As the magnetic potential energy is lost on collision the final K.E. will be greater than that obtained by a putty collision and therefore the final velocity will be greater than 1 m s^{-1} .
- (D) The final combined velocity will depend on the velocity of the two gliders just before collision and this is not known.

TURN OVER

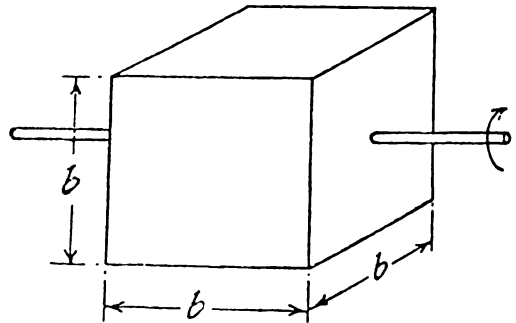
8. The mathematical relationship

$$\frac{d^2x}{dt^2} = -9.2 \times 10^{-4} \frac{dx}{dt} - 0.1x$$

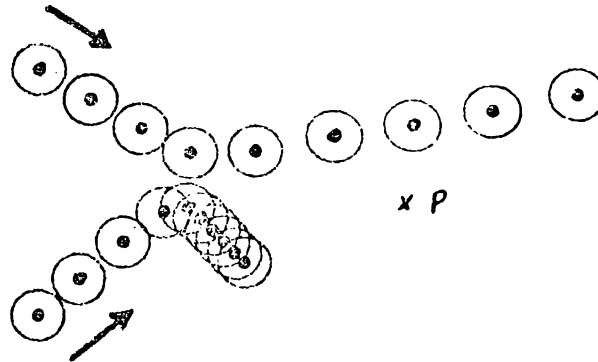
represents a particle moving in

- (A) simple harmonic motion
 - (B) damped motion under a constant force
 - (C) forced oscillations with damping
 - (D) forced oscillations without damping
 - (E) damped harmonic motion.
9. A solid cube mass M , edge length b , has a long thin rod driven through the centre of one face, and perpendicular to it, as shown. The rod is therefore an axis of symmetry of the cube. The moment of inertia of this cube about this rod will be

- (A) $\frac{Mb^2}{12}$
- (B) $\frac{Mb^2}{6}$
- (C) $\frac{Mb^2}{3}$
- (D) Mb^2
- (E) zero



- 10.



The above collision is analysed and linear momentum, translational kinetic energy, and angular momentum (about P), are all found to be conserved if magnetic pucks are used. If the magnetic pucks are now replaced by plastic pucks ($Q < 0$) which of the above quantities would you now expect to be conserved?

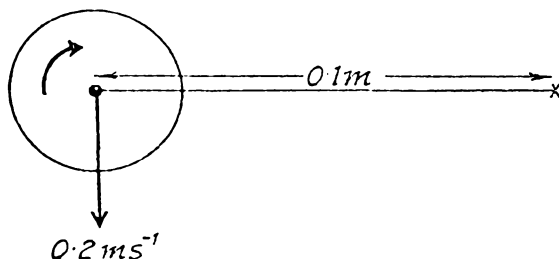
(Question 10 - continued
next page)

continued

- 15 -

- (A) Angular momentum (about P) only
 (B) Linear momentum only
 (C) Angular and linear momentum
 (D) Angular momentum, linear momentum, and translational kinetic energy
 (E) Angular momentum, linear momentum and total kinetic energy (rotational plus translational).

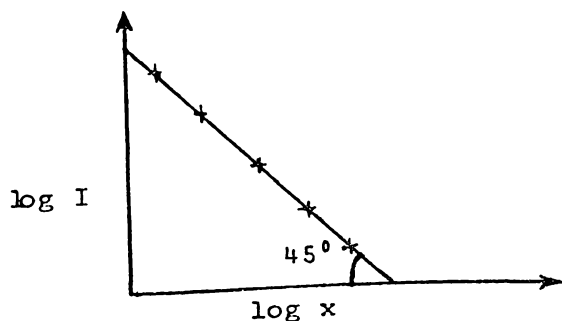
11. An isolated frictionless plastic puck has a mass of 0.1kg, a radius of 2×10^{-2} m, and is rotating at 4 rad s^{-1} as shown.



The centre of mass of the puck is moving at 0.2 m s^{-1} , and the moment of inertia of the puck is given by $\frac{1}{2}mr^2$.

The spin (internal angular momentum) of the puck is

- (A) $8 \times 10^{-1} \text{ kg m}^2 \text{ s}^{-1}$
 (B) $2 \times 10^{-2} \text{ kg m}^2 \text{ s}^{-1}$
 (C) $8 \times 10^{-3} \text{ kg m}^2 \text{ s}^{-1}$
 (D) $2 \times 10^{-4} \text{ kg m}^2 \text{ s}^{-1}$
 (E) $8 \times 10^{-5} \text{ kg m}^2 \text{ s}^{-1}$
12. A physicist attempts to find the intensity (I) versus distance (x) relationship for the variation of sound intensity directly in front, and relatively near a large loudspeaker. A log-log graph is plotted of the results, as shown. The consecutive "power of ten" intercepts are equally spaced on the two axes, and the straight line intercepts the x-axis at 45°



According to the above graphical results the relationship between I and x (assuming k and c are constants), over this range of values, is best summarized

(Question 12 - continued
 next page) TURN OVER

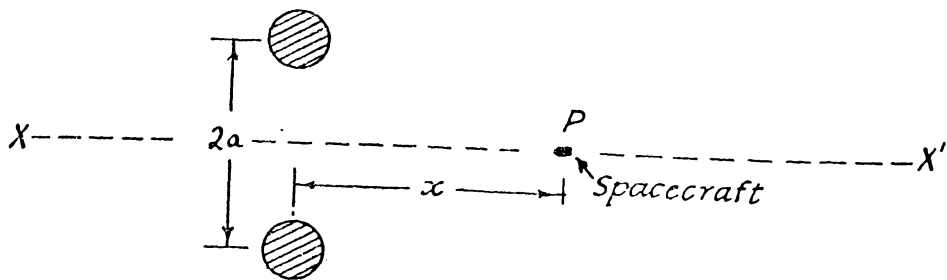
- (A) $I = -kx + c$
- (B) $I = -kx^2 + c$
- (C) $I = \frac{k}{x^2}$
- (D) $I = \frac{k}{x}$
- (E) $I = \frac{k}{x^2} + c.$

13. The force distance relationship between two magnets is given by

$$F(x) = 6 \times 10^{-2}x^{-1.5} \text{ N}$$

where x is the distance between the magnets in metres. As $F(x) = -\frac{dE_p}{dx}$, the magnetic potential energy between magnets (assuming $E_p = 0$ at infinity) is given by

- (A) $E_p(x) = 1.2 \times 10^{-1}x^{-0.5}$
 - (B) $E_p(x) = 2.4 \times 10^{-2}x^{-2.5}$
 - (C) $E_p(x) = 9 \times 10^{-2}x^{-0.5}$
 - (D) $E_p(x) = 9 \times 10^{-2}x^{-2.5}$
 - (E) $E_p(x) = 3 \times 10^{-2}x^{-0.5}$
14. A space craft, P, moves purely under the gravitational attraction of a double star along the path $X'X$ shown (no rockets). The two stars are a distance $2a$ apart. (The rotation of the two stars about their centre of mass in the time taken for the space craft to move from X' to X is negligible.)



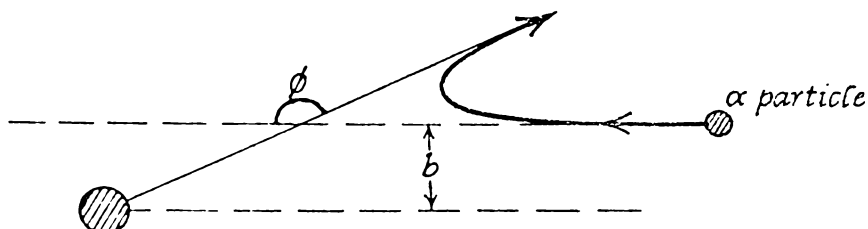
The position x at which the space craft P would experience a maximum acceleration along XX' would be when x is equal to

- (A) $\sqrt{2}a$
- (B) a
- (C) $\frac{a}{2}$
- (D) $\frac{a}{\sqrt{2}}$
- (E) zero.

continued

- 17 -

15. The following diagram represents the interaction of an alpha particle with a heavy gold nucleus. The diagram represents the collision from the frame of reference of the gold nucleus.



Assuming the gold nucleus is very much heavier than the α -particle the diagram is quite an incorrect representation of the collision. Possible reasons for this are:

- I the impact parameter is incorrectly defined
- II the scattering angle is incorrectly defined
- III angular momentum could not possibly have been conserved according to this diagram, but it is conserved in theory.

Of the above,

- (A) I and II only are valid.
- (B) I only is valid.
- (C) II only is valid.
- (D) III only is valid.
- (E) I, II, and III are valid.

16. Certain assumptions are made in deriving the period of a simple pendulum

$$P = 2\pi \sqrt{\frac{l}{g}}$$

Some of these assumptions might be;

- I the pendulum has a small amplitude motion,
- II the tension in the string is negligible,
- III the string obeys Hooke's Law ($F = -kx$),
- IV the damping of the pendulum is negligible.

The necessary assumptions are,

- (A) I and IV only.
- (B) I, II and IV only.
- (C) I, and III only.
- (D) I, II and III only.
- (E) I, III, and IV only.

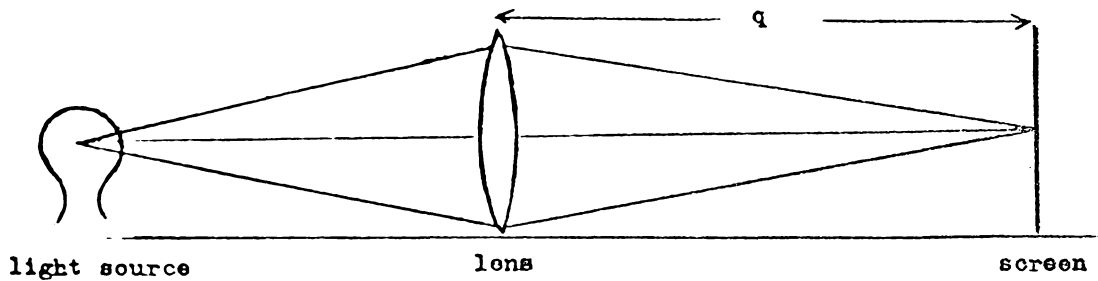
17. In developing the relationship for the deflection of an electron beam in a simple cathode ray tube,
 $D = \frac{L V_x l}{2Vd}$ which of the following was the most drastic assumption made?

(Question 17 - continued next page) TURN OVER

continued

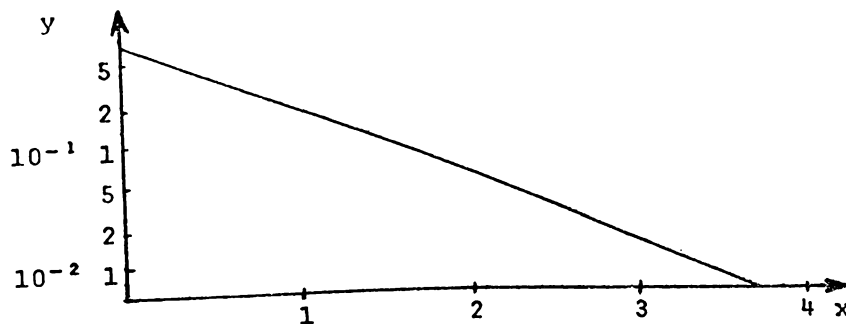
- 19 -

21. A light source, converging lens, and a screen are set upon an optical bench, as shown, and a clear image of magnification M , is obtained on the screen.



If the distance from lens to screen is q , the focal length of the lens is

- (A) $\frac{q}{1+M}$ (B) $\frac{Mq}{(1+M)}$ (C) $\frac{(1+M)q}{M}$
 (D) $\frac{(1+M)}{Mq}$ (E) $\frac{1+M}{q}$
22. A convex lens of focal length 0.2 m is placed in contact with a concave lens of focal length -0.4 m. The focal length of the combined lens would be
- (A) -0.2 m (B) -0.4 m (C) 0.1 m (D) +0.4 m
 (E) +2.5 m.
23. The relationship between two physical quantities, y and x , is investigated and the following graph plotted (note axes).



This graph suggests that, provided k and n are both positive

- (A) $y = kx^n$ (B) $y = \frac{k}{x^n}$ (C) $y = ke^{-nx}$
 (D) $y = ke^{nx}$ (E) $y = n-kx$.

TURN OVER

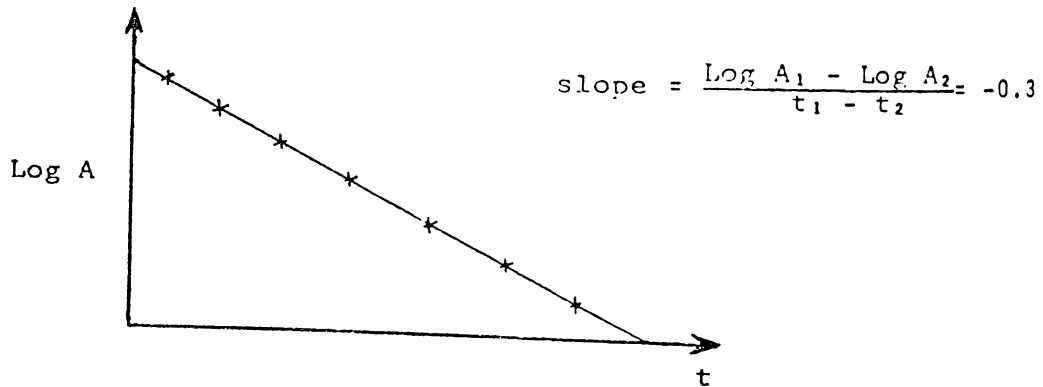
24. A lens is placed between a light source and a screen. The distance between source and screen is 4m and no position of the lens can be found so that a clear image of the light source is formed on the screen. Assuming the lens is a thin lens i.e. the focal length is long compared to the lens thickness, the fact that no clear image is obtainable suggests that possibly the lens is

- I concave (diverging) of focal length less than 1m.
- II convex (converging) of focal length less than 1m.
- III concave (diverging) of focal length greater than 1m.
- IV convex (converging) of focal length greater than 1m.

Of these suggestions the reasonable ones are

- (A) I, II, and III only
- (B) II and III only
- (C) I and III only
- (D) III and IV only
- (E) I, III and IV only.

25. The following graph represents a set of results plotted on semi-log graph paper. The maximum value of A at $t = 0$ is 0.5 m



The best expression for the relationship between A and t is

- (A) $A = 0.5e^{0.3t_m}$
- (B) $A = 0.5e^{-0.3t_m}$
- (C) $A = 0.3e^{+0.5t_m}$
- (D) $A = 0.3e^{-0.5t_m}$
- (E) $A = 0.3t^{-0.5}_m$

continued

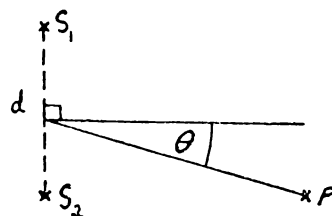
- 21 -

26. Interference patterns are produced by two in-phase periodic sources of waves, a distance d apart. If P is on a nodal line then

$$\sin\theta = \frac{(n-\frac{1}{2})\lambda}{d}$$

The relationship may only apply under certain conditions, for example

- | | |
|-----|---|
| I | S_1P is much greater than S_1S_2 |
| II | $\sin\theta = 0$ |
| III | d is very much greater than λ |



Of the above conditions,

- | | |
|-----|--------------------------------------|
| (A) | neither I, II, nor III is necessary. |
| (B) | I only is necessary. |
| (C) | II only is necessary. |
| (D) | II and III are both necessary. |
| (E) | I, II and III are all necessary. |
27. The work function of a metal is 3 e.V. Planck's constant is 6.63×10^{-34} Js and the electron charge is -1.6×10^{-19} C.

The threshold frequency of the above metal is

- | | |
|-----|-------------------------|
| (A) | 7.2×10^{14} Hz |
| (B) | 4.8×10^{14} Hz |
| (C) | 4.1×10^{14} Hz |
| (D) | 2.5×10^{14} Hz |
| (E) | 1.6×10^{13} Hz |
28. In studying the photoelectric effect, in Exp. 12, a 'reverse' current is found to result for large retarding potentials. Theoretically, this is not expected but it occurs because
- | | |
|-----|--|
| (A) | the filters do not pass a well defined wavelength of light. |
| (B) | the large photosensitive surface recaptures all the photoelectrons emitted from the surface. |
| (C) | the amplifier, and additional circuitry, produce a spurious reverse current for low output currents. |
| (D) | some ultraviolet light is emitted by the light source. |
| (E) | the collector emits photoelectrons which are collected by the large photosensitive surface. |

TURN OVER

The following information refers to questions 29 and 30

Spheres are allowed to fall vertically through a tank of water, and are timed between fixed points 1 m apart.

The time of fall for spheres of various radii and densities are given in the following table.

Density of sphere (ρ_s kg m^{-3})	Radius of sphere (m)	Time to fall 1m (s)
4×10^3	1.00×10^{-2}	9
4×10^3	0.75×10^{-2}	16
4×10^3	0.25×10^{-2}	144
7×10^3	0.25×10^{-2}	72
10×10^3	0.25×10^{-2}	48

Density of water = $\rho_0 = 1 \times 10^3 \text{kg m}^{-3}$

29. Which of the following graphs would be most useful in predicting the time to fall 1 metre for spheres all of fixed density $4 \times 10^3 \text{kg m}^{-3}$?

- (A) t versus r^2
 (B) t versus $\frac{1}{r}$
 (C) t versus $\frac{1}{r^2}$
 (D) t versus r^3
 (E) t versus $\frac{1}{r^3}$

30. Which of the following graphs would be a straight line graph?

- (A) t versus ρ_s
 (B) t versus $\frac{1}{\rho_s}$
 (C) t versus $\frac{1}{\rho_s + \rho_0}$
 (D) t versus $\rho_s - \rho_0$
 (E) t versus $\frac{1}{\rho_s - \rho_0}$

L.5 The theoretical examination 1974

UNIVERSITY OF WAIKATO

EXAMINATIONS 1974

73.101 PHYSICS - Theoretical Physics

(Time allowed: Three hours)

This paper consists of three sections. Marks may be gained from all questions attempted.

Candidates may bring "Physics" by Alonso and Finn or "Fundamental University Physics", Vol. I and II, into the examination room.

The use of log tables, slide rules and drawing instruments is permitted.

THIS PAPER MUST BE HANDED IN, TIED TO ANSWER BOOKLET.

SECTION A

This section consists of THREE questions. Each question is worth 12 marks.

SECTION B

This section consists of NINE short questions. Each question is worth 4 marks.

SECTION C

This section consists of THIRTY multiple choice questions and is worth 36 marks.

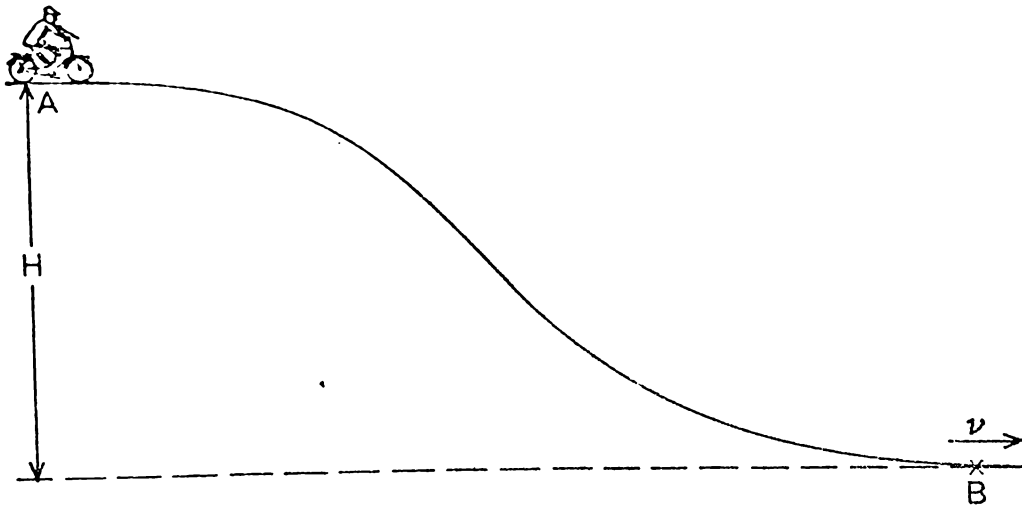
All answers to this section are to be recorded on the special answer sheet provided. Select the best answer from the alternatives provided.

SECTION A

1. (a) Explain what is meant by a conservative force. Give two examples of conservative forces and two examples of non conservative forces.

[4 marks]

- (b) A bicycle and rider have a total mass M . The two wheels can be treated as uniform density discs each of mass m and radius R . If the rider leaves the top of the hill, A, from rest, what will be the velocity of the rider at B assuming he does not pedal?



[4 marks]

- (c) Discuss the assumptions you have made in the above about

- (i) the frictional forces between the axle and the frame
- (ii) the total force provided by the slope on the bicycle.

Is it reasonable to assume conservation of mechanical energy in this system? Explain.

[4 marks]

TURN OVER

Continued

-2-

2. (a) The Faraday-Henry Law is

$$V_E = \frac{-d\phi_B}{dt}$$

where

$$\phi_B = \int_S \underline{B} \cdot \underline{u}_N dS$$

$$V_E = \oint_L \underline{E} \cdot d\underline{\ell}$$

- (i) Define and explain all terms in these three equations, including the meaning of the integral signs.
- (ii) Is the integral

$$\int_S \underline{B} \cdot \underline{u}_N dS \quad \text{the same as} \quad \int_S \underline{B} \cdot d\underline{S} \quad ? \quad \text{Explain.}$$

[6 marks]

(b) A current of I per turn flows in a long solenoid of n turns per unit length. A square loop of one turn only and of side b is placed inside the solenoid and so orientated that the normal to the plane of the loop makes an angle α with the axis of the solenoid.

- (i) Obtain an expression for the flux passing through the loop, in terms of the above symbols.

[4 marks]

- (ii) Show that the mutual inductance between the loop and the solenoid is $M = \mu_0 n b^2 \cos \alpha$.

[2 marks]

Continued

Continued

-3-

3. (a) A wave is represented by the equation

$$\xi = \frac{0.2}{r} \sin 2\pi(r-10t)$$

What is

- (i) the shape of the wavefront of the wave,
- (ii) the velocity of the wave (include direction),
- (iii) the wavelength of the wave,
- (iv) the frequency of the wave.

[4 marks]

- (b) A steel rod of length 1m is dropped vertically onto a concrete floor. It rebounds resonating at a number of different frequencies simultaneously. If Young's modulus for the rod is $2 \times 10^{11}\text{N m}^{-2}$, and the density of steel $8 \times 10^3\text{kg m}^{-3}$, determine the lowest frequency likely to be heard. (State any assumptions you make).

[4 marks]

- (c) A physics textbook states,

"In the case of electromagnetic radiation, shock waves result in what is known as Cerenkov radiation".

Critical of this statement, a reader comments:

To obtain a shock wave, the speed of the source must be greater than the wave speed. As electromagnetic waves travel at the speed of light, and according to relativity theory nothing travels faster than the speed of light, shock waves produced by electromagnetic waves cannot occur.

Discuss the comment given in the box. For example, is it reasonable or has some point been overlooked?

[4 marks]

TURN OVER

SECTION B

4. A boy and a man sit on a seesaw which consists of a plank of mass 50kg, and length 5m, which is supported at its centre point. The boy, mass 30kg, sits at the extreme end of the plank and the man sits on the opposite side of the support. To obtain equilibrium the man sits 1m from the support. Determine the magnitude of the reaction on the support. (Assume $g=10 \text{ N kg}^{-1}$).

[4 marks]

5. The acceleration of a particle in general curvilinear motion is known to be

$$\underline{a} = 5t \underline{u}_x + 5 \underline{u}_y$$

However, an observer claims that at $t = 1\text{s}$, the particle had a velocity of 3m s^{-1} and was moving in a circular path of radius 1m. Give reasons why this claim cannot be correct.

[4 marks]

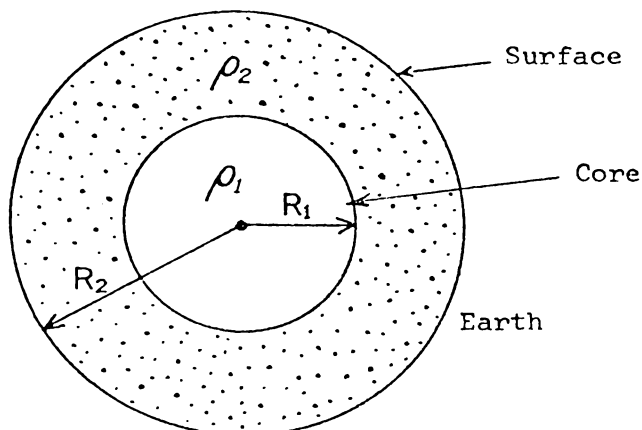
6. (i) Give a kinematic definition of simple harmonic motion.
- (ii) Explain clearly what is meant by angular simple harmonic motion, and state how the period of such a motion is related to the initial displacement.

[4 marks]

Continued

-5-

7. A geophysicist suspects that the earth has a core of radius R_1 and density ρ_1 , DIFFERENT from the density ρ_2 of the rest of the earth (total radius R_2).



- (i) Theoretically he can show, using Gauss' Rule, that if the core exists, the field within the earth ($R_1 < r < R_2$) can be expressed as a function of radius r by the equation

$$\underline{G} = \frac{-\gamma}{r^2} \frac{4}{3}\pi (R_1^3(\rho_1 - \rho_2) + r^3\rho_2)\underline{u}_r \quad \text{for } R_1 < r < R_2$$

If the core does not exist

$$\underline{G} = -\gamma \frac{4}{3}\pi \rho r \underline{u}_r \quad \text{for } r < R_2$$

On the basis of the above equations, can the geophysicist expect to be able to verify if there is a core, by very accurately measuring the variation of \underline{G} with \underline{r} just below the surface? Explain.

- (ii) Above the surface of the earth ($r > R_2$) Gauss' Law leads to

$$\underline{G} = \frac{-\gamma}{r^2} \frac{4}{3}\pi (R_1^3(\rho_1 - \rho_2) + R_2^3\rho_2)\underline{u}_r \quad \text{if the earth has a core}$$

and

$$\underline{G} = \frac{-\gamma}{r^2} \frac{4}{3}\pi \rho R_2^3 \underline{u}_r \quad \text{if the core does not exist.}$$

On the basis of these equations would it be possible to predict if the earth had a core by carefully measuring the variation of \underline{G} with \underline{r} just above the earth's surface? Explain.

[4 marks]
TURN OVER

8. A high speed space ship approaches the earth. It sends out radio signals to the control centre on earth using a frequency of 2.0000×10^6 Hz. The radio receiver at the control centre can only detect signals in the range $(2.0000 \pm 0.0010) \times 10^6$ Hz.

What is the maximum allowable speed of the space ship if communication with the earth is to be maintained? Explain clearly the reasons for your answer.

[4 marks]

9. The maximum attainable frequency for the accelerating field of a cyclotron is $\frac{6}{\pi} \times 10^7$ Hz. Determine the magnetic field required if protons are to be accelerated in the cyclotron. If the maximum radius of the cyclotron is 1m, determine the maximum energy that a proton can be accelerated to. (Take $e_p = 1.6 \times 10^{-19}$ C, $m_p = 1.6 \times 10^{-27}$ kg and give the proton energy in eV.)

[4 marks]

10. Explain briefly how Heinrich Hertz in an experiment (sometimes known as the Hertz experiment) first obtained an experimental value for the velocity of propagation of electromagnetic waves.

[4 marks]

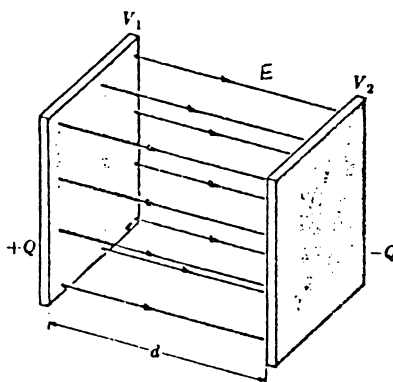
Continued

-7-

11. The following is a slightly modified extract from the text Alonso and Finn "Physics", p.436, deriving the capacitance of a parallel plate capacitor.

"A typical capacitor is formed by two parallel plane conductors separated by a distance d , with the space between them filled by a dielectric (Fig. 19-28).

19.28 Parallel-plate capacitor.



The electric field in the space between the conductors is uniform. If σ is the surface charge density, the potential difference between the plates is

$$V_1 - V_2 = Ed = \frac{\sigma d}{\epsilon}$$

If S is the area of the metal plates, we must have $Q = \sigma S$.
Therefore $C = \frac{\epsilon S}{d}$. "

(a) Which statements in this derivation are, in fact, approximations or assumptions?

(b) Under what conditions might these assumptions be reasonable?

[4 marks]

12. Two principles of physics which are related to wave motion are

- I Huygen's Principle
II The Principle of Superposition.

Two phenomena observed with waves are interference and diffraction. In a very brief outline, indicate which principle, or principles (if any), are necessary to explain

- (i) interference
(ii) diffraction.

Indicate by your answer whether you consider interference and diffraction to be basically identical, similar, or different.

[4 marks]

TURN OVER

SECTION C

All answers are to be recorded on the special ANSWER SHEET provided.

1. The cosine of the angle between the vector $8\mathbf{u}_x + 4\mathbf{u}_y + 8\mathbf{u}_z$ and the x-axis is
- A. 0.25 B. 0.43 C. 0.55 D. 0.67 E. 0.82

2. Given the three vectors

$$\underline{A} = \underline{u}_x$$

$$\underline{B} = -5\underline{u}_x + 2\underline{u}_z$$

$$\underline{C} = 7\underline{u}_x + 3\underline{u}_z$$

then the product $\underline{A} \cdot (\underline{B} \times \underline{C})$ is

- A. -8 B. 0 C. 6 D. $7\underline{u}_z$ E. +8

3. The three forces
- $$\underline{F}_1 = 5\underline{u}_x + 2\underline{u}_y \quad (\text{N})$$
- $$\underline{F}_2 = 2\underline{u}_x - 8\underline{u}_y \quad (\text{N})$$
- $$\underline{F}_3 = -2\underline{u}_x + 6\underline{u}_y \quad (\text{N})$$

act concurrently at the point $4\underline{u}_x + 7\underline{u}_y$ (m). The torque with respect to the point $4\underline{u}_x + 6\underline{u}_y$ (m) is

- A. $-5\underline{u}_z$ mN B. $2\underline{u}_z$ mN C. $4\underline{u}_x$ mN
- D. $12 \underline{u}_x$ mN E. $15\underline{u}_z$ mN

4. The angular acceleration of a disk about its axis is $\alpha = 8\text{ms}^{-2}$. If at $t=0$, $\omega=0$, the number of revolutions between $t = \sqrt{\pi}$, and $t = 4\sqrt{\pi}$ is

- A. 10 B. 20 C. 30 D. 60 E. 80

Continued

-9-

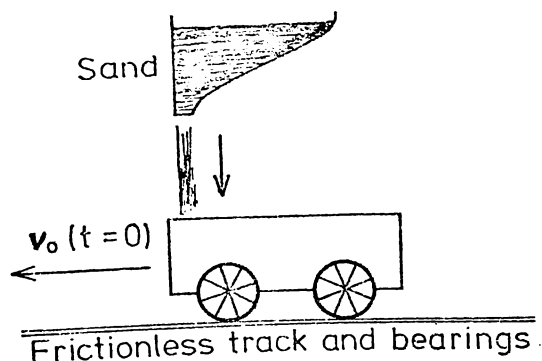
5. Consider the following statement.

"Basic principles of mechanics, for example conservation of momentum, are never observed exactly in any experimental analysis in the laboratory. It is therefore rather unscientific to have such principles called basic principles."

Which of the following replies show a good understanding of the nature of physics?

- I "The basic principles are just theory and therefore it does not matter what happens in reality."
 II "The basic principles are not observed in the laboratory merely because of inaccurate measurements of physical quantities (e.g. mass and velocity for conservation of momentum)."
 III "Principles of physics are idealisations and it is almost impossible to observe phenomena under ideal conditions."

- A. I and III only.
 B. I and II only
 C. I only
 D. II only
 E. III only.
6. An empty freight car of mass m_0 (kg) coasts along a horizontal frictionless track with velocity v_0 at time $t=0$. Sand is falling from a hopper above the car vertically with respect to the ground.

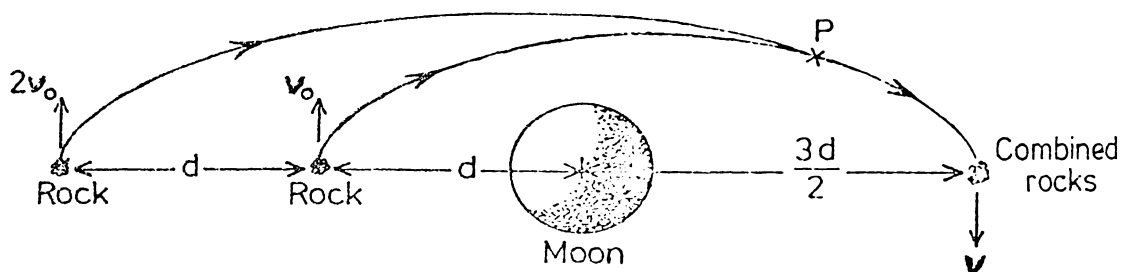


If the sand hits the floor of the car with velocity V , and the mass of sand in the car accumulates at the rate of λ (kg) per second, the speed of the car at time t will be

- A. v_0 B. $\sqrt{\frac{m_0 v_0^2}{m_0 + \lambda t}}$ C. $\frac{m_0 v_0 + \lambda t V}{m_0 + \lambda t}$
 D. $\sqrt{\frac{m_0 v_0^2 + \lambda t V^2}{m_0 + \lambda t}}$ E. $\frac{m_0 v_0}{m_0 + \lambda t}$

TURN OVER

7. A cycloidal pendulum has a period which is,
- dependent on the mass of the pendulum.
 - independent of the gravitational field g .
 - independent of temperature variation.
 - independent of the pendulum length.
 - independent of amplitude.
8. Two equal mass "moonlets" or rocks orbit the moon. They collide at P and combine, as shown in the subsequent diagram.



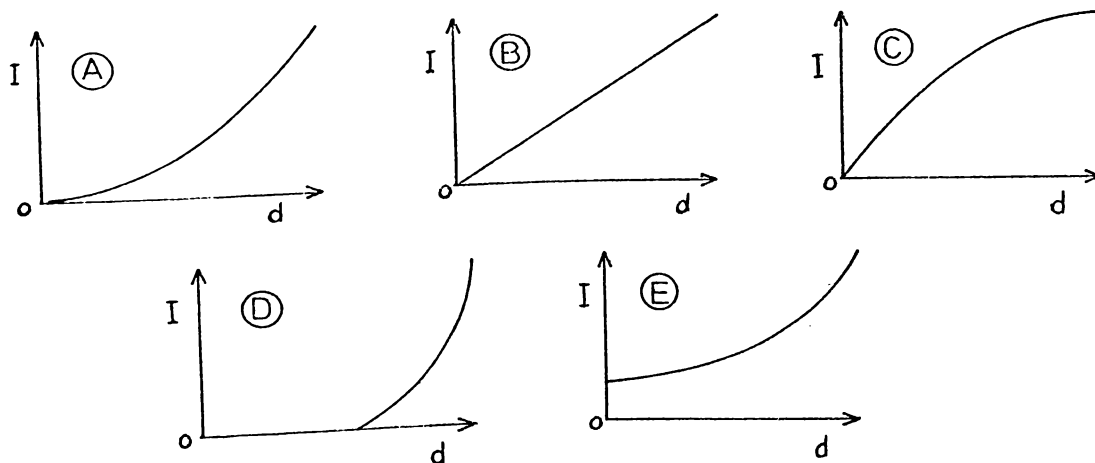
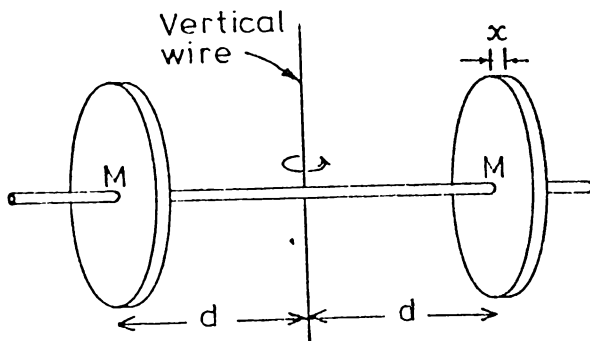
The value of v is

- A. $\frac{5}{3} v_0$ B. $\frac{3}{2} v_0$ C. v_0 D. $\frac{2}{3} v_0$ E. $\frac{1}{3} v_0$
9. Some of the basic principles of particle motion are
- Conservation of Momentum
 - Newton's 1st Law
 - Newton's 2nd Law
 - Newton's 3rd Law
 - Conservation of Angular Momentum
- (where momentum is defined as $m\underline{v}$, and angular momentum as $\underline{r} \times m\underline{v}$).
- Some of these principles can be considered fundamental, i.e. based on experimental evidence and definitions, and others can be derived from these fundamental ones.
- A sufficient and complete set of fundamental principles to cover all the principles (I - V) would be,
- I only
 - V only
 - I and III only
 - I and II only
 - II and V only

Continued

-11-

10. According to the text Alonso and Finn, the distance between the surface of the earth, and the centre of the moon (assumed constant) is
- A. $3.82 \times 10^8 \text{ m}$
 B. $3.78 \times 10^8 \text{ m}$
 C. $3.72 \times 10^8 \text{ m}$
 D. $2.53 \times 10^6 \text{ m}$
 E. $1.74 \times 10^6 \text{ m}$
11. Two discs are supported by a light horizontal rod which is free to rotate about its centre on a vertical wire. Which of the following graphs best represents the moment of inertia I of the system about the vertical wire, versus the distance d . (The vertical wire is of negligible thickness, x can be assumed negligible, and the moment of inertia of the horizontal rod ignored).



TURN OVER

12. The relationship $P = 2\pi\sqrt{\frac{I}{k}}$ applies for the period of a torsional pendulum. This relationship only applies for
- I situations where the moment of inertia, I , is constant
 - II negligible friction
 - III small angular displacements, θ , where $\sin\theta \approx \theta$.

Of the above,

- A. I only is valid.
 - B. I and II only are valid.
 - C. II and III only are valid.
 - D. III only is valid.
 - E. all of the above are valid.
13. A body of mass m released from rest a distance $3R$ from the centre of the earth will reach the earth's surface with a speed
- A. $\sqrt{\frac{2\gamma M}{R}}$
 - B. $\sqrt{\frac{\gamma M}{R}}$
 - C. $\frac{2\gamma Mm}{3R}$
 - D. $\sqrt{\frac{\gamma Mm}{R^2}}$
 - E. $\sqrt{\frac{4\gamma M}{3R}}$

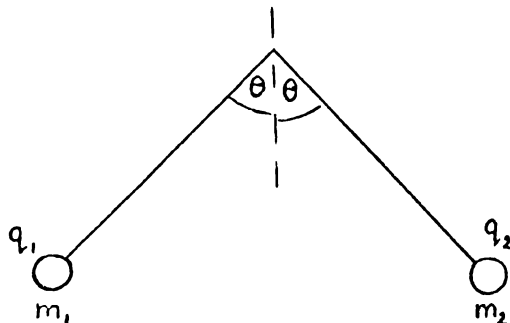
where M and R are respectively the mass and radius of the earth.

14. The gravitational force was found by Newton to be
- (a) a central force, and
 - (b) a force that varies as $\frac{1}{r^2}$ (an inverse square law force).
- Newton was able to deduce both these facts from
- A. Kepler's second and third laws.
 - B. the observation that planets moved in approximately circular orbits.
 - C. Kepler's third law only.
 - D. the observation that all falling bodies have the same acceleration.
 - E. Kepler's second law only.

Continued

-13-

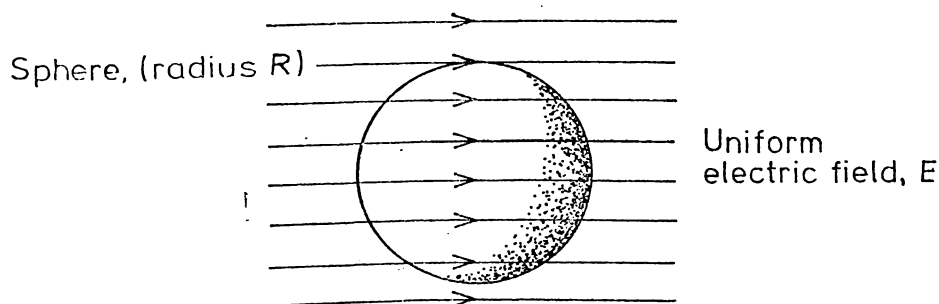
15. Two small electrically charged spheres, mass m_1 and m_2 and charges q_1 and q_2 respectively, are suspended by insulating threads of equal length and repel each other so that the threads make equal angles with the vertical.



Which of the following statements about the masses and the charges must be true.

- A. $m_1 = m_2$ and $q_1 = q_2$
- B. $m_1 = m_2$ but q_1 is not necessarily equal to q_2
- C. $q_1 = q_2$ but m_1 is not necessarily equal to m_2
- D. $\frac{m_1}{q_1} = \frac{m_2}{q_2}$
16. $\oint_S \underline{E} \cdot \underline{u}_N \, dS$ is the flux of the electric field through a

closed surface. A uniform electric field passes through a spherical surface as shown, of radius R .



The flux of the electric field over the total surface of the sphere would be,

- A. $\frac{4}{3} \pi R^3 E$ B. $4\pi R^2 E$ C. $\pi R^2 E$ D. $2\pi R E$
- E. zero.

TURN OVER

17. Gauss' Law is written

$$\epsilon_0 \oint_S \underline{E} \cdot \underline{u}_N dS = \Sigma q$$

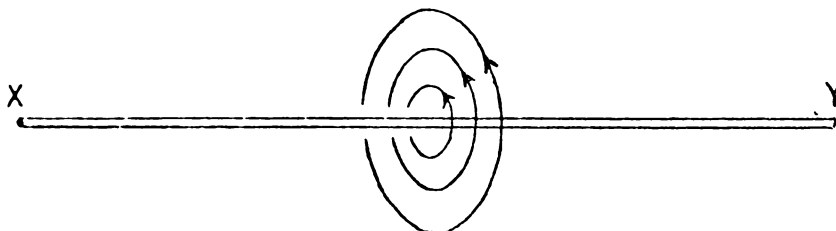
\underline{E} in this equation is

- A. the electric field, which is always the same at all points over the Gaussian surface due to charges within the surface.
 - B. the normal component of the electric field at the surface element dS , due to all charges within the surface S .
 - C. the electric field at the surface element dS , due to all charges.
 - D. the normal component of the electric field at the surface element dS , due to all charges.
 - E. the electric field, which is always the same at all points over the Gaussian surface.
18. Frequently the electric fields near
- (i) an isolated charged sphere
 - (ii) a long line of charge
 - and (iii) an infinitely large charged plate,
- can all be found easily using Gauss' Law. This is because Gauss' Law can be
- A. easily applied to find the electric field near any charge distribution.
 - B. easily applied to find the electric field near any relatively simple charge distribution.
 - C. applied to find the field near any distribution of charges provided the charges all have the same sign.
 - D. often applied to find the electric field near charge distributions which have symmetry properties.
 - E. only apply to the three physical situations described in (i), (ii) and (iii).

Continued

-15-

19. The diagram shows a number of concentric field lines surrounding a tube of material.



(If the field lines represent a magnetic field, this field could have been caused by a steady electric current in the tube XY.)

If the field lines represent an electric field, which of the following could have caused the field?

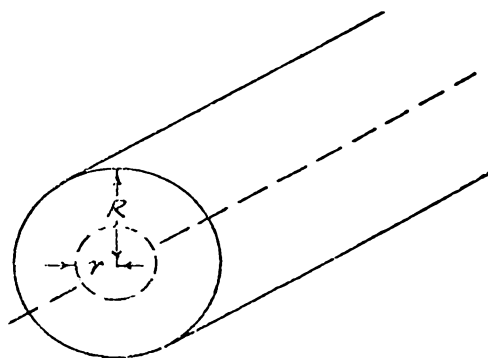
- A. Tube XY has a positive electric charge distributed uniformly along its length.
- B. Tube XY carries a steady electric current.
- C. Tube XY contains a constant magnetic field parallel to XY.
- D. Tube XY contains a changing magnetic field parallel to XY.
- E. Tube XY contains a changing electric field parallel to XY.
20. The energy stored in the magnetic field of an inductor is 2J. If the self-inductance of the circuit is 4×10^{-2} H, the current flowing in the circuit is
- A. 50A B. 10A C. 7A D. 1A
- E. 2×10^{-2} A
21. A long straight filamentary conductor produces a magnetic field at radius r from its axis of B . If the mean velocity of the electrons responsible for this field is v , the number of electrons, (charge e), per unit length of the conductor would be
- A. $Brev$ B. $\frac{Br}{ev}$ C. $\frac{2\pi Br}{\mu_0 ev}$ D. $\frac{\mu_0 Br}{2\pi ev}$
- E. $\frac{\mu_0 Brv}{2\pi e}$

TURN OVER

22. A current I is uniformly distributed over the cross-section of a cylindrical conductor of radius R .

By analogy with Ampere's Law, the circulation of the magnetising field $(\oint \underline{H} \cdot d\underline{\ell})$ around a circle, concentric with the axis of the conductor ($r < R$) is

- A. $\frac{\mu_0 I}{2\pi r}$
 B. I
 C. $\frac{\mu_0 r}{2\pi R^2} I$
 D. $\frac{r^2}{R^2} I$
 E. $\frac{\mu_0 r^2 I}{R^2}$

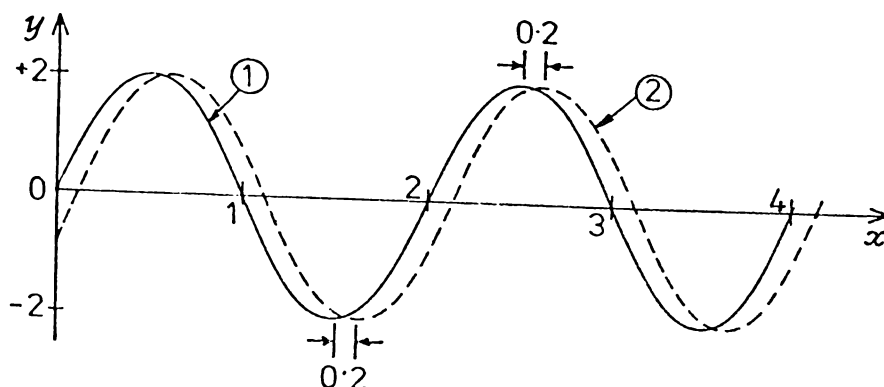


23. A beam of plane polarised light is incident on a sheet of dichroic material, and no light is transmitted. This is because the energy in the incident beam is
- A. absorbed in the material.
 B. transformed into the energy of the ejected photoelectrons.
 C. rotated into a plane perpendicular to the original plane.
 D. scattered out at right angles to the original direction.
 E. reflected back along the original direction.
24. Brewster's angle for glass is 56° . Plane polarised light is incident on a glass surface at this angle and the plane of polarisation is rotated about the incident beam. The intensity of the reflected light
- A. is sometimes greater than that of the incident beam.
 B. varies between zero and a maximum value.
 C. remains constant.
 D. varies between a minimum and a maximum value.
 E. is always zero.

Continued

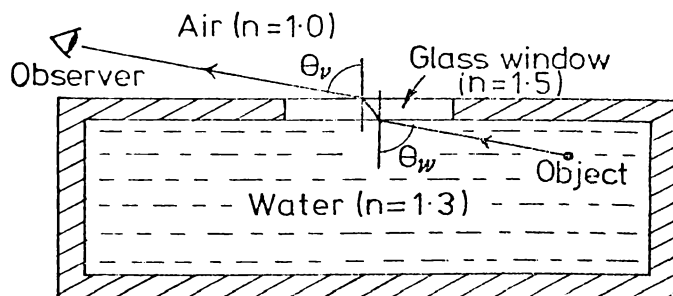
-17-

25. Two progressive SHM wave trains, as shown, move with the same speed (3ms^{-1}) to the right.



If the equation of wave train (1) is $y = 2\sin(\pi x - 3\pi t)$, the equation of the wave train (2) will be

- A. $y = 2\sin \pi(x - 3t)$
 B. $y = 2\sin(\pi x - 0.2 - 3t)$
 C. $y = 2\sin(\pi x + 0.2 - 3t)$
 D. $y = 2\sin \pi(x - 3t - 0.2)$
 E. $y = 2\sin \pi(x - 3t + 0.2)$
26. A water tank has a glass window, as shown in the plan view below. An object in the tank is visible to an outside observer if light travels as indicated by the ray diagram.



Note

$$\sin 64^\circ = \frac{1.3}{1.5}$$

$$\sin 49^\circ = \frac{1}{1.3}$$

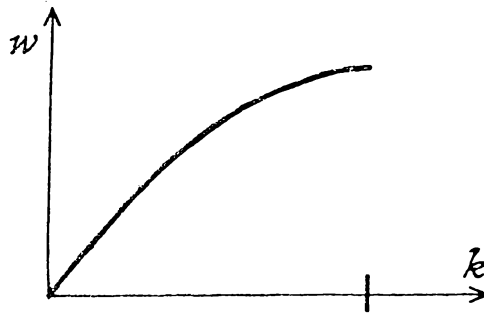
$$\sin 42^\circ = \frac{1}{1.5}$$

If it were possible for θ_w to have any value in the range -90° to $+90^\circ$, then the observer could see an object anywhere in the tank.

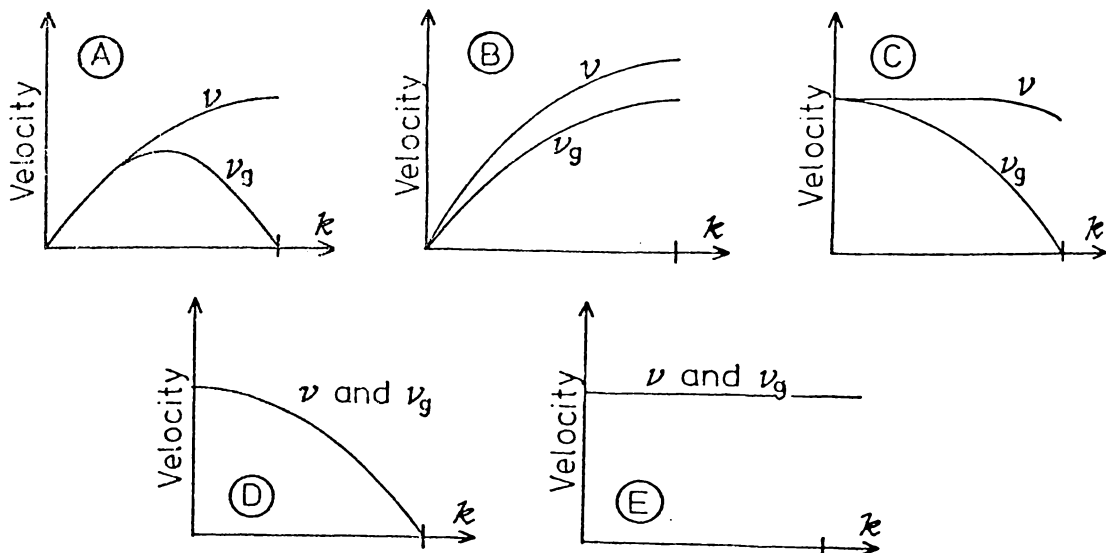
- A. This is impossible.
 B. This is possible, but θ_v must vary between $+42^\circ$ and -42° .
 C. This is possible, but θ_v must vary between $+49^\circ$ and -49° .
 D. This is possible, but θ_v must vary between $+64^\circ$ and -64° .
 E. This is possible, but θ_v must vary between $+90^\circ$ and -90° .

TURN OVER

27. The graph of angular frequency, ω , versus wave vector k , for sound waves travelling in a solid is of the form shown in the figure.



The corresponding graph of phase velocity v , and group velocity v_g , versus k , would be best shown by which of the following graphs.



28. In which of the following situations can the interaction of electromagnetic radiation with matter only be explained in terms of the photon concept.

- I Optical activity
- II Radiation pressure
- III Photoelectric effect

- A. III only
- B. I and II only
- C. I and III only
- D. II and III only
- E. I, II and III.

Continued

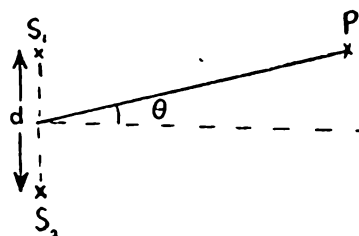
-19-

29. Interference patterns are produced by two in-phase periodic sources of waves a distance d apart. If P is on a nodal line then

$$\sin \theta = \frac{(n-\frac{1}{2})\lambda}{d}$$

The relationship may only apply under certain conditions, for example

- I d is very much greater than λ
- II $\sin \theta \approx \theta$
- III S_1P is much greater than S_1S_2



Of the above conditions,

- A. I, II and III are all necessary.
 - B. I and II are both necessary.
 - C. II only is necessary.
 - D. III only is necessary.
 - E. neither I, II, nor III is necessary.
30. The visible spectral lines of hydrogen have been confirmed to be given experimentally by $\frac{1}{\lambda} = 1.09677 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right)$ —I

A theory was developed by Bohr which predicted that the spectral lines of hydrogen are given by the equation

$$\frac{1}{\lambda} = 1.09737 \times 10^7 \left(\frac{1}{4} - \frac{1}{n^2} \right) \text{ —II}$$

On the basis of equations I and II it would appear that,

- A. there is complete agreement between experimental observation and theory.
- B. there is a slight discrepancy between experiment and theory but it best be ignored.
- C. an attempt should be made to modify the theory to fit the experimental results more closely.
- D. as the theory is so close to the experiment it is obvious that the experimental results are slightly incorrect.

L.6 The experimental examination 1974

UNIVERSITY OF WAIKATO

EXAMINATIONS 1974

73.102 PHYSICS - Experimental Physics

(Time allowed: *Three hours*)

This paper consists of three sections. Marks may be gained from all questions attempted.

Candidates may bring any books into the examination room, and are expected to bring "Physics" by Alonso and Finn, "Experimental Physics", and laboratory notebooks.

The use of log tables, slide rules and drawing instruments is permitted.

Appropriate graph paper will be provided.

Laboratory notebooks must be handed in at the end of the examination.

SECTION A

This section consists of THREE questions. Each question is worth 12 marks.

SECTION B

This section consists of NINE short questions. Each question is worth 4 marks.

SECTION C

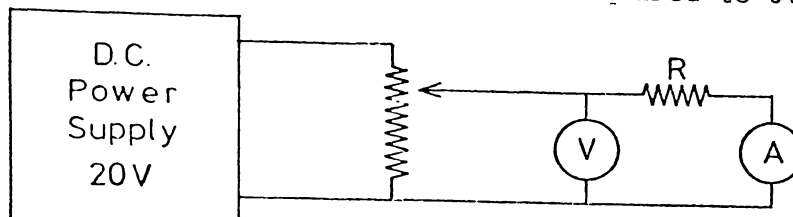
This section consists of THIRTY multiple choice questions and is worth 36 marks. In each case choose the best alternative from those provided.

(Up to five marks will be awarded for the completeness of your laboratory notebook).

NOTE: *It is not anticipated that you will use all the graph paper supplied.*

SECTION A

1. (a) To determine the resistance, R , of a resistor the following circuit is used. R is required to 5%.



The following readings are obtained.

V (Volt)	I (milliampere)
0	0.05
1	5.15
2	10.10
3	19.05
4	20.15
8	40.00
16	80.15

Criticise the data that has been collected.

[4 marks]

(b) In the D.C. circuits experiment, the values for the resistances R_1 , R_2 and R_3 were experimentally obtained. From these results the combined resistances of the three resistors in (i) series and (ii) parallel were predicted. These "theoretical" values were checked experimentally.

Copy and complete the following table giving your values for this experiment.

	Theoretical result	Experimental result
R_{TOTAL} series		
R_{TOTAL} parallel		

Give very approximate error estimates in each case, and hence conclude if your results confirm, or not, the theoretical equations for adding resistors in series and in parallel.

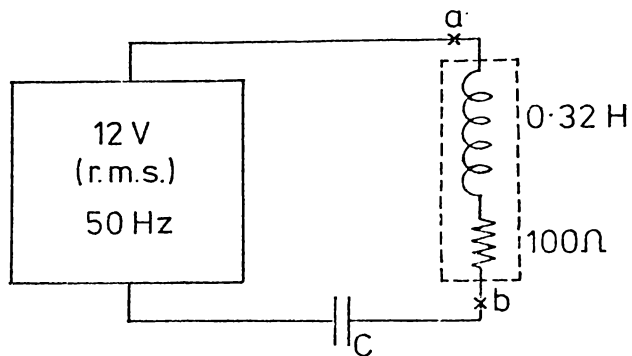
[4 marks]

(Question 1 - continued next page) TURN OVER

Continued

-2-

1. (c) A 50 Hz, 12 V (r.m.s.) ac supply is connected in series to an inductor, of resistance 100Ω and inductance 0.32H , and a capacitor.



If the r.m.s. current in the circuit is 120mA what is

- (i) the value of C ,
- (ii) the phase angle between the potential across ab and the current in the circuit.
(Assume $\pi^2 = 10$ and $0.32\pi = 1$).

[4 marks]

Continued

Continued

-3-

2. (a) An experimental buffer system is provided at the end of a railway track to stop trains (when necessary!). The compression, x , of the buffer system versus applied force, F , is given in the table below.

Applied Force $F(N)$	Compression $x(m)$
1.3×10^4	0.02
2.1×10^4	0.04
3.0×10^4	0.06
5.0×10^4	0.10
8.0×10^4	0.20
1.5×10^5	0.40
2.0×10^5	0.60

It is suspected that the relationship between F and x is of the form $F = kx^n$.

By plotting a suitable graph show that the relationship between F and x is of the form $F = kx^n$ and, hence, determine k .

[4 marks]

(b) In Exp. 4, a photographic analysis was made of the collision of a magnetic puck with an equal mass stationary magnetic puck. Is the loss of energy in this experiment negligible compared to the other errors or uncertainties involved in this experiment and in the photographic analysis? Explain briefly and clearly, supporting your argument with numerical data where possible.

[4 marks]

(c) One of the basic laws of physics is the conservation of momentum - "the total momentum of an isolated system of particles is constant".

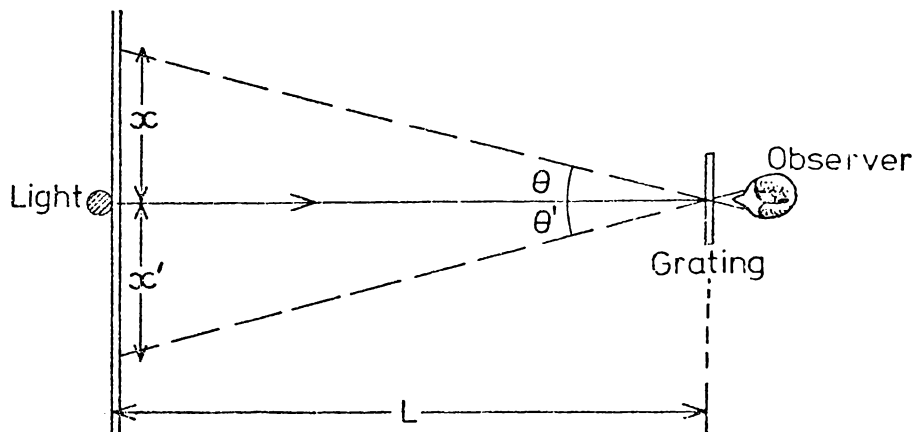
With relation to the above basic law explain (one sentence each) in what way it

- (i) is an experimental observation,
- (ii) is an idealisation,
- (iii) is a generalisation,
- (iv) can be used as a basis for prediction.

[4 marks]

TURN OVER

3. (a) To determine the number of lines in a new diffraction grating, a diffraction pattern for a known wavelength of light from a helium discharge tube, is to be analysed using the relationship $d \sin \theta = n\lambda$ for the angular position of the diffraction maxima.



With the basic apparatus set up (and not subsequently altered) two students obtain results, for the position of the first order strong yellow helium line (wavelength $\sim 5.876 \times 10^{-7}\text{m}$).

Student 1 $x = 26.1, 26.4, 26.2, 26.0, 26.3$
 $L = 2.000 \pm 0.005\text{m}$

Student 2 $x = 26.1, 26.3; x' = 24.3, 24.8$
 $L = 2.00 \pm 0.02\text{m}$

State which student has the most useful set of results. Explain.

[4 marks]

(b) It is decided to measure the wavelength of sound, frequency 3000 Hz, by analysing the interference pattern produced by two adjacent; and synchronous sound sources (loudspeakers). In addition to the speakers, an oscillator, a microphone and a C.R.O. are available. The speed of sound is known to be about 330 ms^{-1} , but the interference pattern is to be used to provide a precise measure of wavelength.

With a schematic diagram, show how you would set up the above apparatus. Determine suitable values for source-source, and source-detector, distances (show working) and include these values on your diagram.

[4 marks]

(c) The wavelength of microwaves can be determined using a Michelson Interferometer. Explain briefly how, once your apparatus was set up (see Experimental Physics, p.119) you obtained your results. List all readings and explain how the wavelength λ , was determined from these results. Include, with your value for λ , your error analysis.

[4 marks]

Continued

Continued

-5-

SECTION B

4. "Experimental Physics" gives two different relationships for the standard error, i.e.

$$\sigma = \sqrt{\frac{\sum n_i (x_i - \bar{x})^2}{N}}$$

and
$$\sigma = \sqrt{\frac{\sum n_i (x_i - \bar{x})^2}{n(n-1)}}$$

Explain clearly the basic difference in these two formulae by stating clearly the situation for which each one applies.

[4 marks]

5. An experiment is carried out to determine the suitability of an air track, photocell gate, electric clock system for the measurement of g using the relationship $v^2 = 2g \sin\theta x$, where v is the velocity of the glider after accelerating a distance x from rest.

Consistently, with the particular apparatus used, a value of g of 7.0 m s^{-2} is obtained.

Give at least three possible reasons which might account for this large systematic error, and which you think should be investigated if the systematic error is to be eliminated. (Do not assume this apparatus is exactly the same as you used). Mention very briefly why you consider your reasons would lead to a low value of g .

[4 marks]

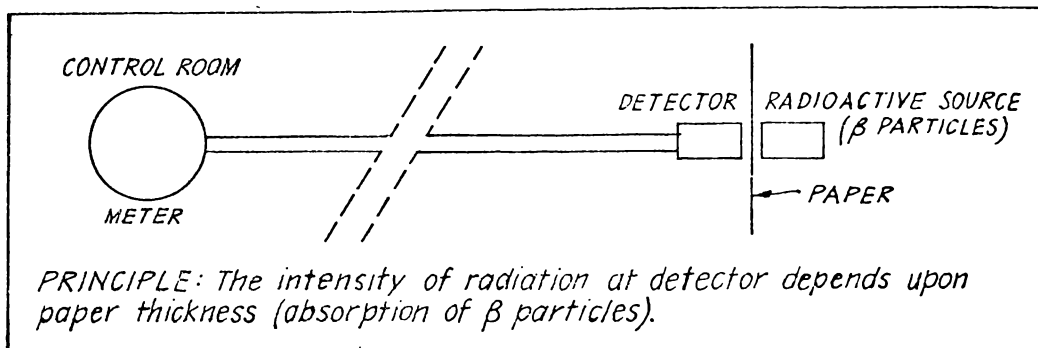
6. State the values you obtained for the $\frac{e}{m}$ ratio of the electron using J.J. Thompson's method. Include the values for the electric and magnetic fields used for each analysis. When you compared your value of $\frac{e}{m}$ with that given by the text Alonso and Finn, what was your conclusion about the possibility of systematic error?

[4 marks]

TURN OVER

7. A physicist working for a publishing firm is asked to suggest a continually repeatable method for measuring the thickness of single sheets of paper. The paper varies in thickness, not in density, and the method suggested must be adaptable to remote reading in a distant control room.

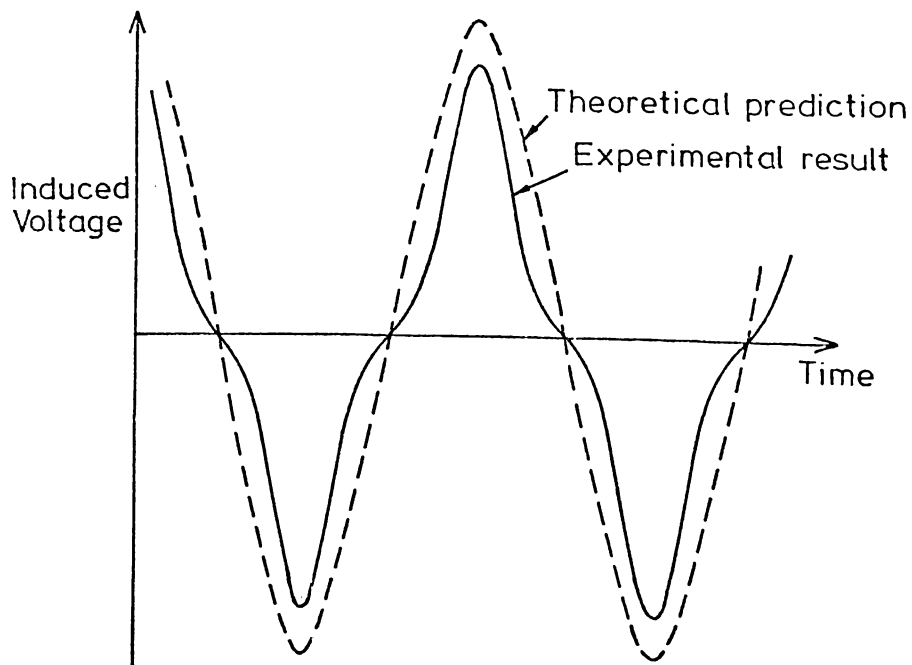
He suggests using a radioactive source and detector system, or a mechanical (remote control) micrometer device. His radioactivity suggestion is outlined in the diagram.



Suggest (from your knowledge of physical phenomena considered in experiments in this course (or otherwise)) two alternative methods for measuring the paper thickness that might be feasible and practicable, (one sentence only for each method, explaining briefly the principle involved - rough sketch if appropriate).

[4 marks]

8. The induced voltage produced by a coil rotating in the magnetic field of a horseshoe magnet is shown in the diagram (solid line).



According to theory the induced voltage can be shown to be sinusoidal with amplitude $BAN\omega$ (dotted line).

(i) What simplifying assumptions are made to theoretically predict the sinusoidal relationship?

(ii) By considering which of these assumptions may not be valid, attempt to account for the shape of the induced voltage-time graph obtained in practice.

[4 marks]

Continued

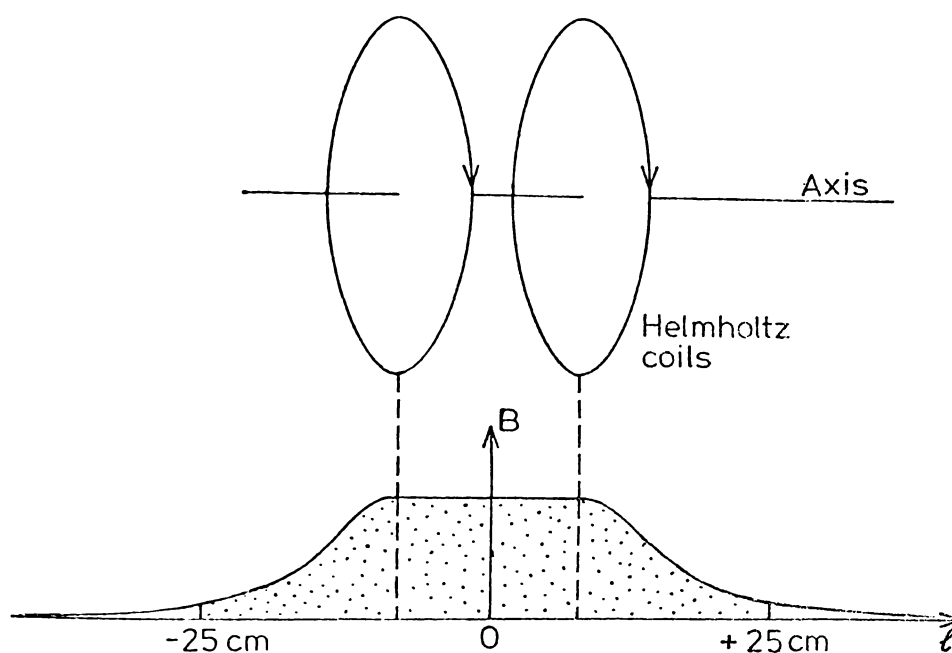
Continued

-7-

9. A student is attempting to verify the Ampere Law relationship

$$\oint \underline{B} \cdot d\underline{\ell} = \int_{-\infty}^{+\infty} \underline{B} \cdot d\underline{\ell} = \mu_0 NI$$

by measuring the magnetic field along the axis of a Helmholtz coil arrangement. Each coil has 50 turns, and carries a current of 4.00 A per turn.



Using a Hall probe the field is measured from -25cm to +25cm as shown. The area shaded on the graph

$(\int \underline{B} \cdot d\underline{\ell})$ is calculated to be

$$(4.40 \pm 0.01) \times 10^{-4} \text{ m kg C}^{-1} \text{ s}^{-1}$$

while $\mu_0 NI$ is calculated to be

$$(4.00 \pm 0.01) \times 10^{-4} \text{ m kg C}^{-1} \text{ s}^{-1}$$

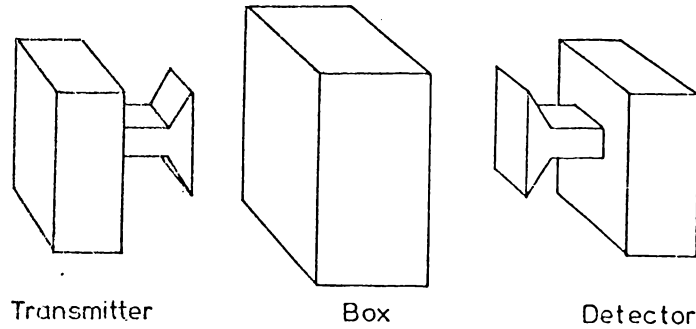
What conclusion would you make from these results? Do you suspect a systematic error?

[4 marks]

TURN OVER

10. A new microwave experiment is developed, where the problem is to determine the possible shape of metal objects (or a metal object) inside two different polystyrene boxes, by analysing the intensity and polarisation of microwaves transmitted through the boxes.

The diagram shows the apparatus used, and then some preliminary results follow.



<u>Results</u>		Initial Polarization	Final Polarization	
<u>Box A</u>	Horizontal			} Polarization vector Rotated 45° (as shown) with minimal intensity change
	Vertical			
<u>Box B</u>	Horizontal			} Polarization vector Rotated 45° (as shown) and <u>diminished</u> in intensity
	Vertical			

Suggest what might be in the boxes to produce these results. If the incident polarisation vector is now orientated at an angle of 45° to the vertical, predict for each box the final direction of the polarisation vector and comment on its final intensity.

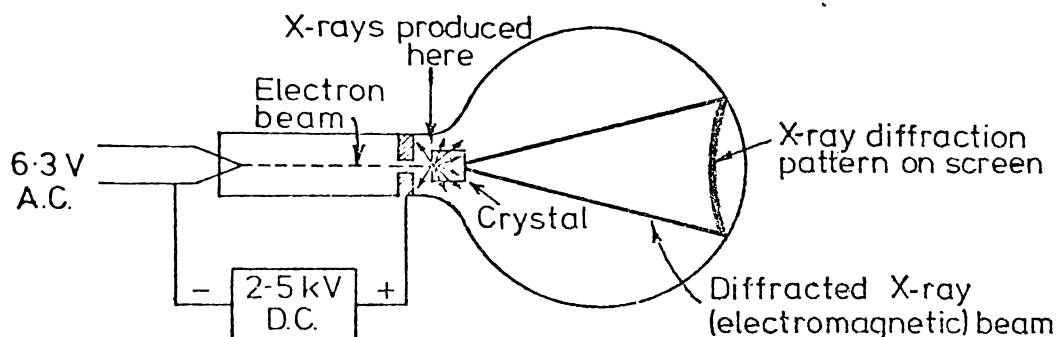
[4 marks]

Continued

Continued

-9-

11. A student studying "electron diffraction" does not believe electrons have an associated wavelength. Rather he considers that the pattern is due to X-ray diffraction, since X-rays would be produced when electrons collide with the crystal, and these X-rays would be diffracted by the crystal, as suggested in the diagram.



His theory could be disproved because of the difference in behaviour of electrons and of electromagnetic waves in either electric or magnetic fields. Explain how you would, in practice, experimentally verify that the pattern on the screen is produced by electrons and not electromagnetic waves (suggest two procedures).

[4 marks]

12. De Broglie in 1924, merely from consideration of the particle nature of light, and the relationship $\lambda = \frac{h}{p}$ for photons, suggested that particles (e.g. electrons) might have a wavelike nature with a wavelength given by $\lambda = \frac{h}{p}$.

As De Broglie had no experimental evidence to support this proposal at that time, but merely invented the idea (probably because nature is strikingly symmetric in many other ways) it is suggested by a student that this was a most unscientific proposal.

In general, would you consider a tentative proposal like De Broglie's to be unscientific? Very briefly, give your reason (one or two sentences only).

[4 marks]

TURN OVER

SECTION C

All answers are to be recorded on the special ANSWER SHEET provided.

The following information refers to questions 1 and 2

Spheres are allowed to fall vertically through a tank of water, and are timed between fixed points 1 m apart.

The time of fall for spheres of various radii and densities are given in the following table.

Density of sphere	Radius of sphere	Time to fall 1m
ρ_s (kg m^{-3})	r (m)	t (s)
4×10^3	1.00×10^{-2}	9
4×10^3	0.75×10^{-2}	16
4×10^3	0.25×10^{-2}	144
7×10^3	0.25×10^{-2}	72
10×10^3	0.25×10^{-2}	48
Density of water = $\rho_0 = 1 \times 10^3 \text{kg m}^{-3}$		

- Which of the following graphs would be most useful in predicting the time to fall 1 metre for spheres all of fixed density $4 \times 10^3 \text{kg m}^{-3}$?
 - t versus r^2
 - t versus $\frac{1}{r}$
 - t versus $\frac{1}{r^2}$
 - t versus r^3
 - t versus $\frac{1}{r^3}$
- Which of the following graphs would be a straight line graph?
 - t versus ρ_s
 - t versus $\frac{1}{\rho_s}$
 - t versus $\frac{1}{\rho_s + \rho_0}$
 - t versus $\rho_s - \rho_0$
 - t versus $\frac{1}{\rho_s - \rho_0}$

Continued

-11-

3. The percentage error of a quotient is given by $\sqrt{p_A^2 + p_B^2}$, where p_A and p_B represent individual percentage errors. Hence if the current through a resistor is 4.0 ± 0.2 mA and if the potential difference across the resistor is 0.20 ± 0.01 V, then the resistance of the resistor $\left(\frac{V}{I}\right)$ is best expressed as,

- A. $(5.0 \pm 0.1) \times 10^1 \Omega$
- B. $(5.0 \pm 0.2) \times 10^1 \Omega$
- C. $(5.0 \pm 0.4) \times 10^1 \Omega$
- D. $(5.0 \pm 0.5) \times 10^1 \Omega$
- E. $(5 \pm 1) \times 10^1 \Omega$

4. The following table shows a set of results obtained for measuring the focal length of a spherical mirror.

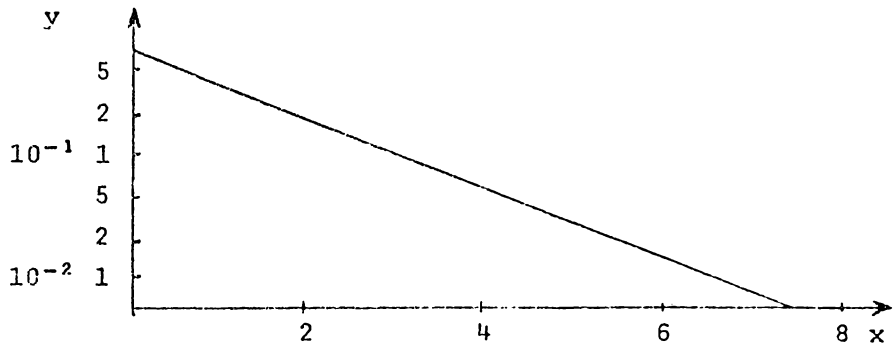
f_i	$f_i - \bar{f}$	$(f_i - \bar{f})^2$
20.5		
19.9		
19.5		
20.5		
19.8		

Assuming $\bar{f} = 20.0$, the error value of $\sqrt{\frac{\Sigma(f_i - \bar{f})^2}{n(n-1)}}$ is approximately,

- A. 1×10^{-1} s
 - B. 2×10^{-1} s
 - C. 3×10^{-1} s
 - D. 4×10^{-1} s
 - E. 6×10^{-1} s
5. From a theoretical point of view, Kirchhoff's Laws for D.C. circuits are best described as
- A. laws which can be derived from basic conservation laws.
 - B. purely experimental laws, unrelated to any basic principles of physics.
 - C. laws which can be derived from Ohms Law.
 - D. laws which can be derived from Coulomb's Law.
 - E. fundamental laws of physics, i.e. basic principles of physics.

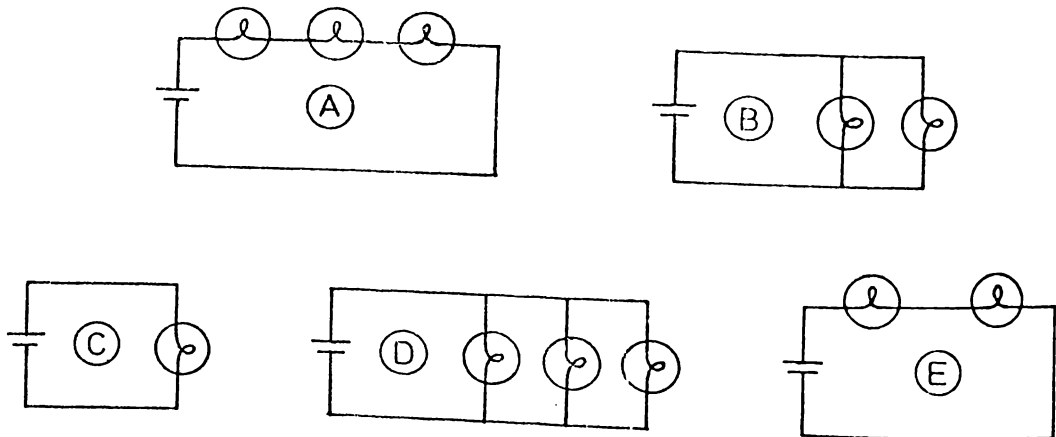
TURN OVER

6. The relationship between two physical quantities, y and x , is investigated and the following graph plotted (note axes).



This graph suggests that, provided k and n are both positive

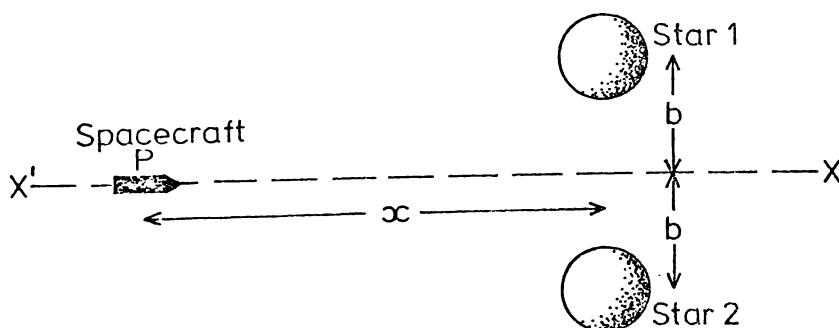
- A. $y = kx^n$ B. $y = \frac{k}{x^n}$ C. $y = ke^{nx}$
 D. $y = ke^{-nx}$ E. $y = n-kx$.
7. A battery of internal resistance, 3Ω , and three light bulbs (each of constant resistance 1.5Ω) can be connected together in various ways. If the light emitted from the bulbs is proportional to the power dissipated in the bulb, which of the following would give the maximum total output of light?



Continued

-13-

8. Two magnets are attached to the adjacent ends of two gliders so that they attract rather than repel. One glider is placed in the centre of the track and is initially stationary. The second glider has an initial velocity of 2 m s^{-1} . The two gliders are of equal mass, and on collision they naturally 'stick' together. What is their combined velocity after collision?
- A. The final combined velocity will be 1 m s^{-1} , as conservation of momentum will apply.
- B. As the magnetic potential energy is lost on collision the final K.E. will be greater than that obtained by a putty collision and therefore the final velocity will be greater than 1 m s^{-1} .
- C. The final combined velocity will depend on the velocity of the two gliders just before collision and this is not known.
- D. As the magnets attract the initially stationary glider will be moving towards the other glider before collision so that the final combined velocity will be less than 1 m s^{-1} .
9. A space craft, P, moves purely under the gravitational attraction of a double star along the path X'X shown (no rockets). The two stars are a distance $2b$ apart. (The rotation of the two stars about their centre of mass, in the time taken for the space craft to move from X' to X, is negligible).



The position x at which the space craft P would experience a maximum acceleration along XX' would be when x is equal to

- A. zero B. $\frac{b}{\sqrt{2}}$ C. $\frac{b}{2}$ D. b E. $\sqrt{2}b$

TURN OVER

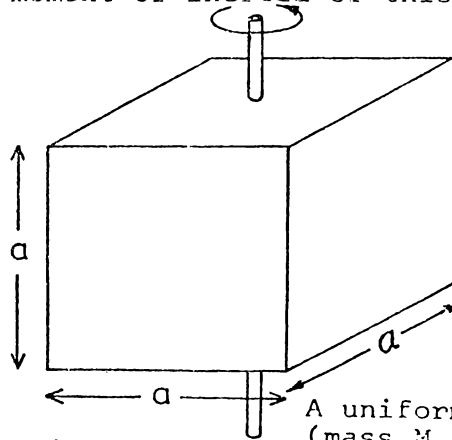
10. The mathematical relationship

$$\frac{d^2x}{dt^2} = -8.6 \times 10^{-3} \frac{dx}{dt} - 0.4x$$

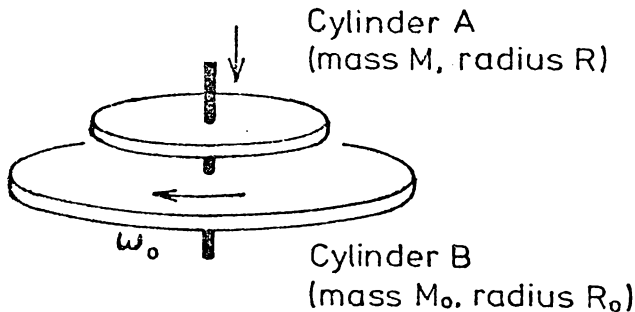
represents a particle moving in

- A. damped harmonic motion
 B. damped motion under a constant force
 C. forced oscillations with damping
 D. forced oscillations without damping
 E. simple harmonic motion.
11. A solid cube mass M , edge length a , has a long thin rod driven through the centre of one face, and perpendicular to it, as shown. The rod is therefore an axis of symmetry of the cube. The moment of inertia of this cube about this rod will be

- A. zero
 B. Ma^2
 C. $\frac{Ma^2}{3}$
 D. $\frac{Ma^2}{6}$
 E. $\frac{Ma^2}{12}$



- 12.



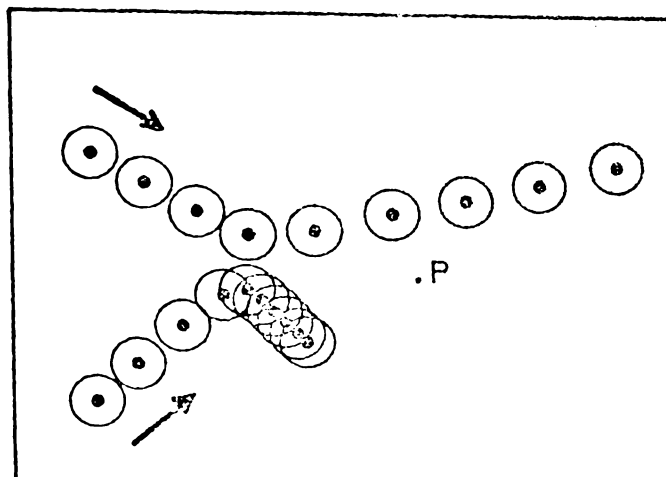
A uniform cylinder A (mass M , radius R) is dropped from rest onto a freely rotating uniform density cylinder, B (mass M_0 , radius R_0) which had initial angular velocity ω_0 . After A has dropped onto B, the combination rotates with angular velocity ω . The radius R of the dropped cylinder is equal to

- A. $\left[\frac{M_0 R_0^2 (\omega_0 - \omega)}{M\omega} \right]^{\frac{1}{2}}$ B. $\left[\frac{M_0 R_0^2 \omega_0}{M(\omega + \omega_0)} \right]^{\frac{1}{2}}$ C. $\frac{M_0 R_0 (\omega - \omega_0)}{M\omega}$
 D. $\frac{M_0 R_0 \omega_0}{M\omega}$ E. $\left[\frac{M R_0 \omega_0^2}{M\omega} \right]^{\frac{1}{2}}$

Continued

-15-

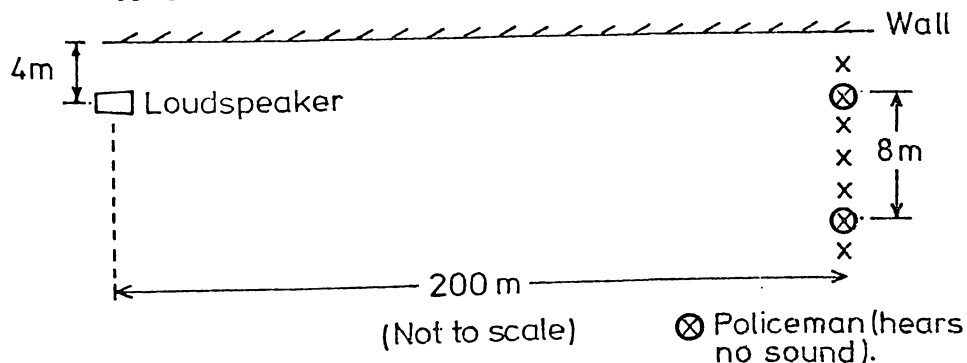
13.



The above collision is analysed and linear momentum, translational kinetic energy, and angular momentum (about P), are all found to be conserved if magnetic pucks are used. If the magnetic pucks are now replaced by plastic pucks ($Q < 0$) which of the above quantities would you now expect to be conserved?

- A. Angular momentum (about P) only.
- B. Linear momentum only.
- C. Angular and linear momentum.
- D. Angular momentum, linear momentum, and translational kinetic energy.
- E. Angular momentum, linear momentum and total kinetic energy (rotational plus translational).

14. A loudspeaker emits a sound of frequency f , near a solid wall. A line of policemen stand in a line at right angles to the wall as shown.

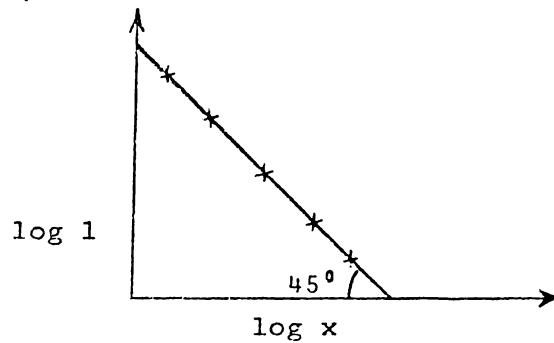


The policemen stand 2 m apart and (as shown) one policeman in four claims he is unable to hear the sound. The wavelength of the sound emitted by the speaker must be

- A. 4.0 m
- B. 2.0 m
- C. 0.32 m
- D. 0.16 m
- E. 0.04 m

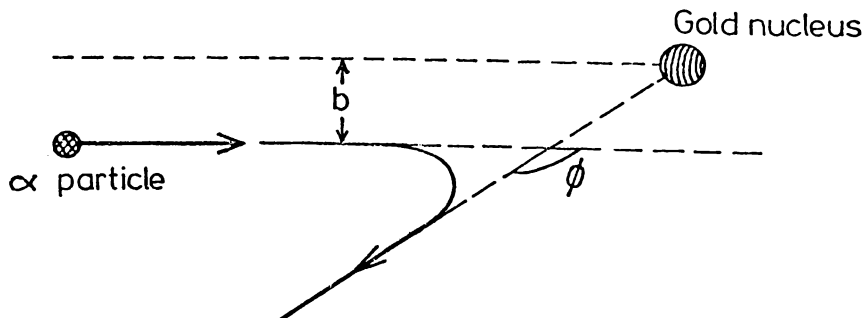
TURN OVER

15. A physicist attempts to find the intensity (I) versus distance (x) relationship for the variation of sound intensity directly in front of, and relatively near, a large loudspeaker. A log-log graph is plotted of the results, as shown. Consecutive "powers of ten" are equally spaced on the two axes, and the straight line intercepts the x-axis at 45° .



According to the above graphical results the relationship between I and x (assuming k and c are constants), over this range of values, is best summarised

- A. $I = \frac{k}{x^2} + c$
 B. $I = \frac{k}{x}$
 C. $I = \frac{k}{x^2}$
 D. $I = -kx^2 + c$
 E. $I = -kx + c$
16. The following diagram represents the interaction of an alpha particle with a heavy gold nucleus. The diagram represents the collision from the frame of reference of the gold nucleus.



(Question 16 - continued next page)

Continued

-17-

Assuming the gold nucleus is very much heavier than the α -particle, the diagram is quite an incorrect representation of the collision. Possible reasons for this are

- I the scattering angle is incorrectly defined,
- II the impact parameter is incorrectly defined,
- III angular momentum could not possibly have been conserved according to this diagram, but it is conserved in theory.

Of the above,

- A. I and II only are valid.
- B. I only is valid.
- C. II only is valid.
- D. III only is valid.
- E. I, II, and III are valid.

The following information refers to questions 17 and 18

In an experimental investigation of α particles deflected by a thin foil of gold, Rutherford found that only one particle in 10,000 was deflected more than a few degrees. In an attempt to explain the minimal deflection of α particles by a gold foil Rutherford proposed his model of the atom. Further, assuming the nucleus was a point charge, and Coulomb's Law could be used to determine the force between the nucleus and the α particle, a prediction was made that the number of particles with a scattering angle between ϕ and $\phi+d\phi$ was proportional to $\text{cosec}^2 \frac{\phi}{2}$.

17. In predicting the $\text{cosec}^2 \frac{\phi}{2}$ relationship, Rutherford assumed that Coulomb's Law ($F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$) would apply at very small distances for which it had never been tested before. Which of the following statements about Coulomb's Law would have been the basis for making this assumption?
- A. It was not unreasonable to expect Coulomb's Law to hold at small distances and there was no evidence to the contrary.
 - B. Coulomb's Law is based on experimental evidence about forces between charges and therefore it must hold at any distance whatever between charges.
 - C. Coulomb's Law does not explicitly state any limitations on the distance between charges.
 - D. Coulomb's Law is a basic principle of physics and hence must apply at all distances.

TURN OVER

18. Rutherford's initial ideas about the atom led to a prediction which could be checked experimentally. Which of the following opinions about Rutherford's method of investigation shows the best understanding of scientific methods.
- Scientific ideas should not really be used to make predictions.
 - Rutherford should have obtained all the experimental evidence possible before inventing any theory, or ideas, to explain his results.
 - Rutherford proceeded in a rather unscientific manner in using his initial results to invent a model, or theory, of atomic structure.
 - As Rutherford's initial ideas were based on experimental evidence, there was no need to experimentally check his prediction.
 - Scientific ideas are most useful if they make predictions.

19. Certain assumptions are made in deriving the period of a simple pendulum

$$P = 2\pi \sqrt{\frac{l}{g}}$$

Some of these assumptions might be:

- the tension in the string is negligible,
- the string obeys Hooke's Law ($F = -kx$),
- the damping of the pendulum is negligible,
- the pendulum has a small amplitude motion.

The necessary assumptions are,

- I, II and IV only.
 - I, III and IV only.
 - II and IV only.
 - II, III and IV only.
 - III and IV only.
20. In developing the relationship for the deflection of an electron beam in a simple cathode ray tube,
- $$D = \frac{L V_x l}{2Vd}$$
- , the unstated assumption has been made that the acceleration due to the gravitational field is negligible. This assumption is reasonable because
- the cathode ray tube is mounted vertically.
 - the gravitational field in a vacuum is zero.
 - the acceleration of the electron due to the gravitational field would be much less than 10 m s^{-2} .
 - the electric field produces accelerations very much greater than 10 m s^{-2} .

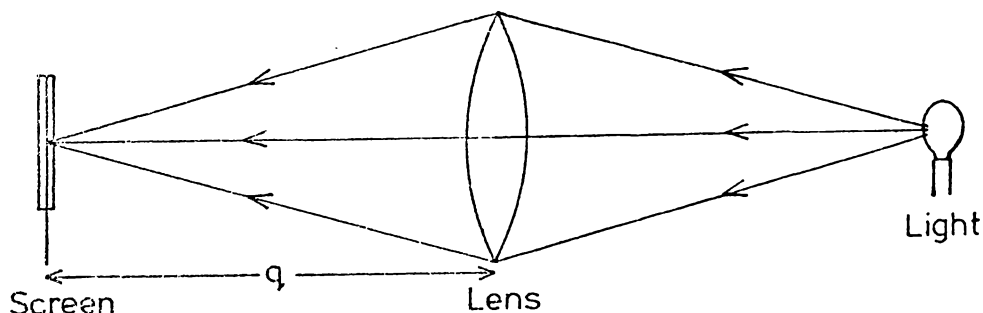
Continued

-19-

21. The force distance relationship between two magnets is given by $F(x) = 8 \times 10^{-3} x^{-1.5}$ N where x is the distance between the magnets in metres. As $F(x) = -\frac{dE_p}{dx}$, the magnetic potential energy between magnets (assuming $E_p = 0$ at infinity) is given by
- A. $E_p(x) = 4 \times 10^{-3} x^{-0.5}$
 B. $E_p(x) = 1.2 \times 10^{-2} x^{-2.5}$
 C. $E_p(x) = 1.2 \times 10^{-2} x^{-0.5}$
 D. $E_p(x) = 3.2 \times 10^{-3} x^{-2.5}$
 E. $E_p(x) = 1.6 \times 10^{-2} x^{-0.5}$
22. In Experimental Physics, p.106, a graph is provided of frequency and velocity of water waves at a given depth. Referring to this graph, what would be the most suitable depth of water so that there would be as little range of wave speed, over the entire frequency range 1 Hz to 100 Hz, as possible?
- A. 0.2 cm B. 0.4 cm C. 1 cm
 D. 2 cm E. very deep.
23. What category of electromagnetic waves has a wavelength of 8mm?
- A. Gamma rays.
 B. Red light.
 C. Infrared light.
 D. Microwaves.
 E. Radio waves.

TURN OVER

24. A light source, converging lens, and a screen are set upon an optical bench, as shown, and a clear image of magnification M , is obtained on the screen.



If the distance from lens to screen is q , the focal length of the lens is

- A. $\frac{Mq}{(1+M)}$ B. $\frac{q}{(1+M)}$ C. $\frac{(1+M)}{Mq}$ D. $\frac{(1+M)}{q}$ E. $\frac{(1+M)q}{M}$
25. A convex lens of focal length 0.2 m is placed in contact with a concave lens of focal length -0.4 m. The focal length of the combined lens would be
- A. 0.1 m B. +0.4 m C. +2.5 m D. -0.2 m E. -0.4 m.
26. A lens is placed between a light source and a screen. The distance between source and screen is 4m and no position of the lens can be found so that a clear image of the light source is formed on the screen. Assuming the lens is a thin lens, i.e. the focal length is long compared to the lens thickness, the fact that no clear image is obtainable suggests that possibly the lens is
- I concave (diverging) of focal length less than 1m.
 II convex (converging) of focal length less than 1m.
 III concave (diverging) of focal length greater than 1m.
 IV convex (converging) of focal length greater than 1m.
- Of these suggestions the reasonable ones are
- A. I and III only
 B. I, II, and III only
 C. I, III and IV only
 D. II and III only
 E. III and IV only.

Continued

-21-

27. A photovoltaic cell will generate a small current in a circuit as shown in Fig (a) when light is incident on it.

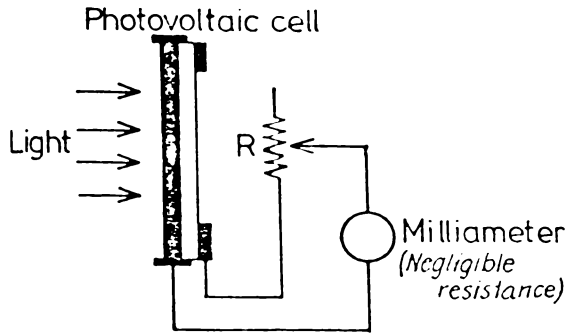


Fig (a)

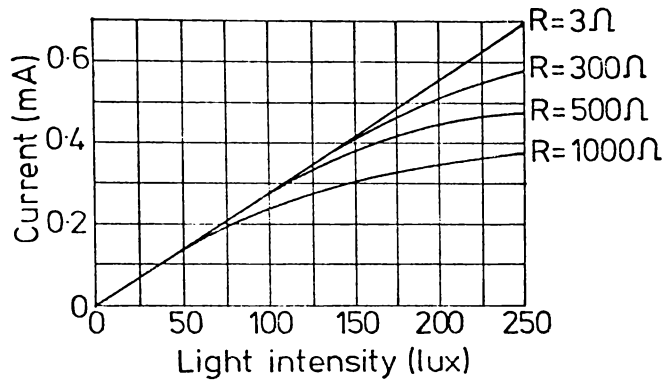
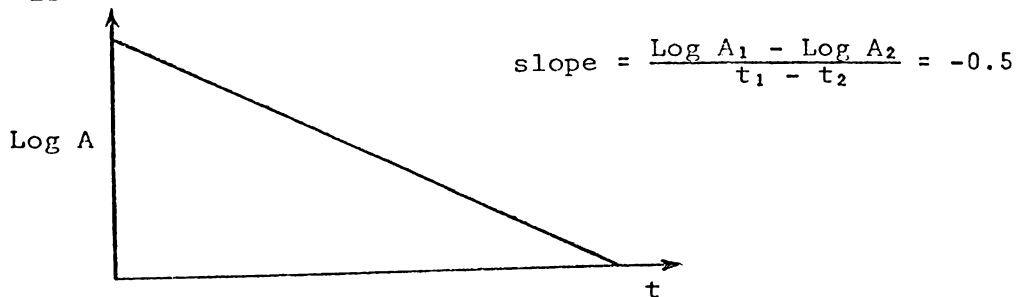


Fig. (b)

Fig. (b) shows the current generated in this circuit at different light intensities and with different resistances R in the circuit. The light intensity is given in lux, a common unit for this quantity.

If the resistance of the "external" resistance R was reduced to zero, what current would you predict for a light intensity of 200 lux?

- A. greater than 600μA.
 - B. about 560μA.
 - C. between 320 and 500μA.
 - D. it is impossible to predict from the information given.
28. The following graph represents a set of results plotted on semi-log graph paper. The maximum value of A (at t = 0) is 0.3 m.



The best expression for the relationship between A and t is

- A. $A = 0.5t^{-0.3}$ m.
- B. $A = 0.5e^{-0.3t}$ m.
- C. $A = 0.5e^{+0.3t}$ m.
- D. $A = 0.3e^{-0.5t}$ m.
- E. $A = 0.3e^{+0.5t}$ m.

TURN OVER

29. In studying the photoelectric effect, in Exp. 12, a 'reverse' current is found to result for large retarding potentials. Theoretically, this is not expected but it occurs because
- A. the filters do not pass a well defined wavelength of light.
 - B. the large photosensitive surface recaptures all the photoelectrons emitted from the surface.
 - C. the amplifier, and additional circuitry, produce a spurious reverse current for low output currents.
 - D. some ultraviolet light is emitted by the light source.
 - E. the collector emits photoelectrons which are collected by the large photosensitive surface.
30. The work function of a metal is 4 eV. Planck's constant is 6.63×10^{-34} Js and the electron charge is -1.6×10^{-19} C.

The threshold frequency of the above metal is

- A. 9.6×10^{14} Hz
- B. 6.4×10^{14} Hz
- C. 4.1×10^{14} Hz
- D. 2.5×10^{14} Hz
- E. 1.6×10^{14} Hz

APPENDIX M

FURTHER ASPECTS OF ATTITUDE MEASUREMENT

In a study associated with the work described in Section 8.3, Tennent (1972), as part of an undergraduate project in physics supervised by the author, investigated the use of the semantic differential technique (Osgood, 1957) as an alternative method of attitude measurement. He developed a semantic differential instrument and compared it with the Likert scale instrument of Section 8.3 by using both instruments with 147 undergraduate and seventh form students.¹

The semantic differential instrument analyzed the concepts of PHYSICS and the USE OF MATHEMATICS IN PHYSICS with respect to bipolar adjectives associated with Objectives V(C), VI(A) and VI(B) of the first year physics courses. A factor analysis yielded the factor loadings shown in Table M.1.²

Correlations between the totals obtained from each set of four semantic differential bipolar adjectives (Table M.1) and the totals obtained for each objective using the Likert items are shown in Table M.2. In the latter table the correlations which were expected to be high in terms of face validity are underlined, and the results provide some support for the validity of the Likert totals.

The analyses of Tables 8.1 and 8.2 suggested that:

- (i) Objective V(C) is not a unidimensional objective in that factor loadings for this objective in Tables 8.1 and 8.2 were not all on the same factor. This view is supported by

¹These students were not the students used in Tables 8.1 and 8.2.

²Four bipolar adjectives used in this analysis but not of consequence to the work of Chapter 7.3 have been omitted from the table.

Table M.1 Factor analysis* of Semantic Differential Scales in 1972
(N = 147)(7 form and undergraduate Physics students)

Concept	Bipolar Adjectives [and Possibly Related Objectives]	Factor Loadings ≥ 0.5				
		1	2	3	4	5
PHYSICS	[Objective V(C)]					
	Finalized - Tentative			0.6		
	Closed - Open			0.5		
	Stable-Changeable			0.6		
	Complete-Unfinished			0.6		
USE OF MATHS IN PHYSICS	[Objective VI(A)]					
	(i)					
	Bad-Good				0.6	
	Nice-Awful				0.6	
	Unsatisfying-Satisfying				0.7	
	Unpleasant-Pleasant				0.8	
	(ii)					
	Worthless-Valuable		0.6			
	Unimportant-Important		0.8			
	Useless-Useful		0.7			
	Irrelevant-Relevant		0.5			
	PHYSICS	[Objective VI(B)]				
(i)						
Dull-Sharp		0.7				
Pleasant-Unpleasant		0.7				
Satisfying-Unsatisfying		0.7				
Uninteresting-Interesting		0.8				
(ii)						
Inconvenient-Convenient		0.6				(0.4)
Irrelevant-Relevant		(0.4)				0.6
Unimportant-Important	(0.4)				0.6	
Worthless-Valuable	0.6				(0.4)	

* Factor analysis using multiple correlation coefficient in the diagonals of the correlation matrix.

Table M.2 Correlations between Likert Scales Subtotals and Semantic Differential Subtotals, Tennent (1972)
(N = 147)

		Likert Scales			
		V(C)	VI(A)	VI(B)	VI(C)
Semantic Differential Subtotals	V(C)s	<u>0.21</u>	0.09	-0.07	0.13
	VI(A) (i) s	0.20	<u>0.67</u>	0.44	0.22
	VI(A) (ii) s	0.36	<u>0.46</u>	0.36	0.23
	VI(B) (i) s	0.46	0.41	0.69	0.40
	VI(B) (ii) s	0.45	0.42	<u>0.58</u>	0.29

Expected high correlations underlined

the low correlation between the Likert score on this objective and the relevant Semantic Differential score ($r = 0.21$).³

- (ii) Objective VI(A) is unidimensional and quite distinct from the other objectives in that all Objective VI(A) items in Tables 8.1. and 8.2. loaded on a single factor. However, the Semantic Differential analysis suggests that the "useful" aspect and the "satisfaction" aspect of this objective (in Table 5.1) may be two distinct aspects of this objective.
- (iii) Objective VI(B) is unidimensional. Although the Semantic Differential analysis of Table M.2 indicates two aspects of the objective, the totals of VI(B) (i)s and VI(B) (ii)s were highly correlated ($r = 0.71$).⁴
- (iv) Objective VI(C) is not a unidimensional objective in that in Tables 8.1. and 8.2. the factor loadings on this objective were not all on the same factor. This objective was not considered appropriate for a semantic differential procedure and was not investigated fully by Tennent. However, it is interesting that the Likert total for Objective VI(C) correlated most highly with the Semantic Differential Total VI(B) (i)s.

³It is now appreciated that the semantic differential concept of PHYSICS with respect to the bipolar adjectives of V(C)s in Table M.2. was ambiguous. It could be viewed as "Physics I am taught" or "Physics of the Physicist".

⁴The correlation between VI(A) (i)s and VI(A) (ii)s was 0.53 in comparison.

APPENDIX N

SUBJECTIVE ASSESSMENT OF STUDENTS BY TEACHERS

- N.1 Letter to the headmaster
- N.2 Information for teachers on subjective assessment of former physics students
- N.3 Seventh form physics subjective assessment
- N.4 Seventh form physics teachers opinion survey

N.1 Letter to the headmaster

Dear

As part of an intensive research project in physics education, I am studying the progress of all University of Waikato first year physics students through their first year of study. For example, I wish to relate the students' background and school achievement, their external examinations results, and their university environment and progress, to their final achievement in physics at the end of this year (1973).

Naturally the information on examination results can be obtained directly from students, but this has been found unreliable where it applies to achievement a number of years prior to university matriculation. I would be most grateful if the S.C. marks of the students listed on the enclosed sheets could be supplied from your records.

In addition to the above it would be most relevant to our work to obtain from the students' 7 form physics teacher a subjective assessment of each student's ability and achievement. I consider a teacher usually acquires, over a year's teaching a reasonably good assessment of his pupils with respect to a number of academic and non-academic areas, and that this subjective assessment, in addition to external examination performance, may well improve the prediction of university success.

The information the 7 form teacher could supply would be held in strictest confidence, would not be made known to other university staff or to the students, and individual schools or pupils would in no way be identified in any research papers resulting from this study. Information supplied by schools would not be studied until after the university results are known in December.

I appreciate that this request will place an extra burden on your already busy physics teacher. However, I do feel that consideration of the different aspects of physics education as outlined in the following sheets, may be in itself a worthwhile exercise and that the study itself is very relevant to the present educational climate.

If you are unsure about any point, please contact me, or Professor P.S. Freyberg, Dean of Education, who is supervising this project. Thank you.

Yours sincerely,

R.J. Osborne
Senior Lecturer in Physics

Information for Teachers on Subjective Assessment of former Physics StudentsI The Assessment of Students

In an intensive study of first year physics at Waikato, an attempt is being made to study the abilities of students over a variety of physics educational objectives. In addition to the testing of student abilities at the beginning of 1973/74, it is considered that a student's former 7 form teacher could provide a useful subjective assessment of particular abilities. These could not only be used to check on the validity of the tests which have been devised, but in addition could well be useful predictors of university success in themselves.

I would be most appreciative if the requested information could be supplied by the former 7 form physics teacher of each student listed. In each case a number of abilities, interests, etc. are specified and a seven point scale provided, e.g.

Academic Ability HIGH: ___:___:___:___:___:___:___:LOW

In assessing the scale a cross should be placed at the point where you consider the student would be located if a reliable and valid test for the scale was available. As far as possible compare the student with other New Zealand 7 form Bursary candidates assuming the following national distribution

HIGH: 5% : 10% : 20% : 30% : 20% : 10% : 5% : LOW

II Classification of Interests and AbilitiesSuitability for Academic work in general

Academic ability - a student's general intellectual ability with regard to 7 form work in so far as it can be separated from his scholastic achievement, e.g. reasoning ability, ability to ask intelligent questions and provide thoughtful answers to questions.

Academic Industry - a student's academic industry in the 7 form, e.g. effort put into homework, study habits, attitude toward study, questioning of doubtful points, etc.

Maturity/Stability - this scale indicates a student's independence and stability of purpose. A student high on this scale would not be unduly influenced by other students or affected by change to a new environment, e.g. university. The scale is independent of academic ability or the level of purpose (e.g. low or high achievement aims).

Knowledge and Ability in Physics

Comprehension of the Concepts in 7 form Physics - an understanding of the basic ideas of physics as presented by direct teaching, or from textbooks. A student low on

this scale would have little useful knowledge of physics and probably a considerable number of misconceptions, e.g. understanding of centripetal force and acceleration, Gauss Law, Ampere's Law, etc.

Ability to apply physics to simple standard problems - a student's ability to apply theory to problem situations, e.g. an ability to do homework problems and to solve applications problems in tests and exams. (Although this ability is not independent of comprehension of physical ideas, some students show a particular facility for this aspect of physics despite some misconceptions about physics while alternatively some students comprehend the ideas but have difficulty applying them.)

Ability to critically analyse and evaluate ideas in physics - a student's ability to think critically, to realize the full implications of derivations, and to critically analyse apparently satisfactory statements in physics, e.g. a student's critical study of material presented to him, and the perceptive enquiry of points which are not clearly presented.

Ability to carry out experimental work - a student's ability in the laboratory, e.g. ability to set up an experiment, interpret instructions in terms of equipment provided, practical ability, etc.

Ability to process experimental data and draw conclusions - includes the analysis of graphs, interpretation of results, and drawing conclusions from the results. A measure of this scale would be the work in a student's laboratory notebook particularly as it relates to detailed analysis of results and conclusions.

Positive attitude to physics - a student's apparent satisfaction with school physics, e.g. a teacher's subjective impression as to whether the pupil found physics enjoyable and satisfying.

It is appreciated that it will be difficult to make reliable judgements on some of the above scales, particularly on a national basis, and in retrospect. However, it is the author's view that even teachers' subjective impressions of these different aspects of physics may, in spite of this, be useful indicators of further academic success.

If you feel you can participate in this exercise, I thank you for your time and assistance.

R. J. Osborne
March 1974

N.3 Seventh form physics subjective assessment7 FORM PHYSICS SUBJECTIVE ASSESSMENT*

School:.....Name of Pupil:.....

Teacher:.....

Suitability for University Work (as compared with an average
New Zealand 7 form pupil)

Academic Ability HIGH: ___:___:___:___:___:___:___:LOW

Academic Industry HIGH: ___:___:___:___:___:___:___:LOW

Maturity/Stability HIGH: ___:___:___:___:___:___:___:LOW

Ability in Physics (as compared with an average New Zealand 7
form pupil)

(In completing the following please attempt to base your subjective assessment on internal school study and not be influenced by the student's Bursary of Scholarship results.)

Comprehension of the
concepts in Physics HIGH: ___:___:___:___:___:___:___:LOWAbility to apply Physics
to simple standard
problems HIGH: ___:___:___:___:___:___:___:LOWAbility to critically
analyse and evaluate
ideas in Physics HIGH: ___:___:___:___:___:___:___:LOWAbility to carry out
laboratory work in
Physics HIGH: ___:___:___:___:___:___:___:LOWAbility to process experi-
mental data and make
conclusions in Physics HIGH: ___:___:___:___:___:___:___:LOWPositive attitude toward
Physics HIGH: ___:___:___:___:___:___:___:LOWRelationship between Bursary mark and Physics ability

Compared with other pupils' marks in the 1973 Bursary exam, do you consider the mark obtained by this student in the Bursary exam to be much higher or lower than you would have predicted. (NOTE: This is in comparison to other pupils and not to any absolute scale, i.e. ignoring the fact that all students may have achieved a higher mark than expected.)

MUCH HIGHER: ___:___:___:___:___:___:___: MUCH LOWER

*see information sheet for details of categories and distribution assessment.

N.4 Seventh form physics teachers opinion survey

7 Form Physics Teachers Opinion Survey

Optional and anonymous if you prefer (to be anonymous, please return under separate cover!)

This sheet has been included to provide physics teachers with an opportunity to state their view of the importance in teaching of the Physics objectives outlined in this study. Space is provided to qualify, if desired, any views, and to add other objectives which are considered important in physics teaching at this level, but which have not been included in this study.

What importance to you consider should be given to the following Physics objectives in teaching at (A) 7 form level (B) 1st year University level).

		Very Important	Important	Possibly Important	Not Important	Undesirable
Comprehension of basic concepts	(A)					
	(B)					
Problem Solving Ability	(A)					
	(B)					
Critical Evaluation of ideas	(A)					
	(B)					
Experimental Procedure Skills	(A)					
	(B)					
Processing of Experimental Data	(A)					
	(B)					
Attitude toward Physics	(A)					
	(B)					

Qualifying Remarks or other Objectives: (use back of sheet, if required).

BIBLIOGRAPHY

- Alexander, J.D., 1974. Nuffield Secondary Science: an Evaluation. London, Macmillan Educational.
- Alonso, M. & E.J. Finn, 1967. Fundamental University Physics vs.1 and 2. Reading, Mass., Addison & Wesley.
- Alonso, M. & E.J. Finn, 1970. Physics. Reading, Mass., Addison & Wesley.
- Amara, R., 1972. Toward a framework for national goals and policy research. IEEE Transactions on Systems, Man and Cybernetics v.SMC-2(5), p. 603-609.
- Anderson, G.J. & H.J. Walberg, 1968. Classroom climate and group learning. International Journal of Education Sciences v.2, p. 175-180.
- Apple, M.W., 1972. The adequacy of systems management procedures in education. The Journal of Educational Research v.66(1), Sept., p. 10-18.
- Armitage, P., C. Smith & P. Alper, 1969. Decision Models for Educational Planning. London, Allen Lane the Penguin Press.
- Atkin, J.M., 1968. Research styles in science education. Journal of Research in Science Teaching v.5(4), p. 338-345.
- Balzer, le Von, 1970. Review, appraisal and recommendations concerning research on classroom behavior in science. Paper presented at 43rd Annual Meeting of the National Association for Research in Science Teaching. Minneapolis, Minnesota, March 5-8 (personal copy).
- Barber, N.F. & R.J. Osborne (Eds.), 1974. Senior Advanced Physics. Auckland, Heinemann Educational.
- Barratt, J. & P. Blake, 1974. The teaching of reaction kinetics to first year undergraduates. Studies in Laboratory Innovation. London, Group for Research and Innovation in Higher Education, Nuffield Lodge.
- Beard, R.M., 1970. Teaching and Learning in Higher Education. London, Penguin Books Ltd.
- Beard, R.M. & D.A. Bligh, 1971. Research into Teaching Methods in Higher Education - Mainly in Universities. 3rd ed. London, Society for Research in Higher Education.
- Berkman, H.G., 1972. Urban systems in general systems theory. IEEE Transactions on Systems, Man and Cybernetics v.SMC-2(2), April, p 231-237.

- Bertalanffy, L. Von, 1968. General Systems Theory. New York, George Braziller.
- Black, P.J. et al., 1974. Skill sessions. Physics Education v.19(1), January, p. 18-22.
- Blalock, H.M., 1964. Causal Inferences in Non-experimental Research. Chapel Hill, University of North Carolina Press.
- Bloom, B.S. (Ed.), 1956. Taxonomy of Educational Objectives. The Classification of Educational Goals Handbook I - Cognitive Domain. New York, McKay.
- Bloom, B.S. et al. (Ed.), 1971. Handbook on Formative and Summative Evaluation of Student Learning. New York, McGraw-Hill.
- Bolte, J.R., 1966. Background factors and success in college physics. Journal of Research in Science Teaching v.4(2), p. 74-78.
- Bondi, H., 1975. Physics education and society. Physics Education v.10(7), Nov., p. 469-474.
- Bridgham, R.G. & W.W. Welch, 1969. Physics enrollments and grading practices. Journal of Research in Science Teaching v.4(1), p. 44-46.
- Campbell, N.H., 1972. Objectives in teaching. The Australian Journal of Education v.16(1), March, p. 1-11.
- Cattell, R.B. (Ed.), 1966a. Handbook of Multivariate Data Analysis. Chicago, Rand McNally.
- Cattell, R.B., 1966b. Multivariate behavioral research and the integrative challenge. Multivariate Behavioral Research v.1(1), p. 4-23.
- CDU, 1973. Curriculum Development Unit Bulletin Number 48. Wellington, Government Printer.
- Chestnut, H., 1967. Systems Engineering Methods. New York, John Wiley.
- Churchman, C.W., 1968. The Systems Approach. New York, Dell Publishing Co.
- Coleman, J.S., 1966. Equality of Educational Opportunity. Washington (D.C.), U.S. Office of Education.
- Cooley, W.W. & P.R. Lohnes, 1971. Multivariate Data Analysis. New York, John Wiley.
- Council of Europe, 1972. European Curriculum Studies No.6: Physics. Strasbourg, Council for Cultural Cooperation.
- Cox, R., 1972. The value of objective examinations. Nature v.237, June 30, p. 489-492.
- Cronbach, L.J., 1971. Test validity. In Thorndike (Ed.) Educational Measurement. 2d ed. Washington (D.C.), American Council in Education.

- Firestone, J.M. & D.W. McCormick, 1972. An exploration in systems analysis of domestic conflict. General Systems v.XVII, p. 79-107.
- Forrester, J.W., 1968. Principles of Systems. Cambridge, Mass., Wright Allen.
- Frazer, B.J., 1975. Curriculum evaluation - help or hindrance to teaching and innovation. The Australian Science Teachers Journal v.21(2), p. 45-51.
- Friedman, C.P. et al., 1975. The rise and fall of P.S.I. at M.I.T. Background paper presented to the IUPAP/UNESCO International Physics Conference. Edinburgh, July 29-August 6 (personal copy).
- Frisch, O.R., 1974. Presenting physics. Physics Bulletin - Institute of Physics v.25, Sept., p. 392-393.
- Gardner, P.L., 1972. Attitudes in Physics. Unpublished Ph.D. thesis. Monash. (Photostat extracts, University of Waikato library.)
- Gardner, P.L., 1973. Changes in attitude of PSSC physics students: a second look. Australian Science Teachers Journal v.19(1), March, p. 71-78.
- Gimmel, D.R., 1974. A path model for course achievement. The Journal of Experimental Education v.43(2), Winter, p. 1-7.
- Glass, G.V., 1972. The wisdom of scientific inquiry in education. Journal of Research in Science Teaching v.9(1), p. 3-18.
- Gresford, G.B., 1972. Systems approach to development. IEEE Transactions on Systems, Man and Cybernetics v.SMC-2(3), July, p. 311-316.
- Gronlund, N.E., 1970. Stating Behavioural Objectives for Classroom Instruction. London, Collier-Macmillan.
- Guilford, J.P., 1965. Fundamental Statistics in Psychology and Education. 4th ed. New York, McGraw-Hill.
- Guilford, J.P., 1971. The Analysis of Intelligence. New York, McGraw-Hill.
- Harlen, W., 1975. Science 5-13 A Formative Evaluation. London, Macmillan Educational.
- Hartley, H.J., 1968. Educational Planning - Programming - Budgeting - A Systems Approach. New Jersey, Prentice-Hall.
- Hartley, J., 1973. Aspects of programmed learning. Trends in Education No.32, October, p. 30-35.
- Hartley, J. & S. Marshall, 1974. On notes and note-taking. University Quarterly v.28, Spring, p. 225-235.
- Heise, D.R., 1969. Problems in path analysis and causal inference. In E.F. Borgatta (Ed.) Sociological Methodology. San Francisco, Jossey Bass.

- Higginbottom, I.G., 1975. Problems of Keller plans and mastery. Physics Education v.10, Sept., p. 461-462.
- Hogben, P., 1970. Are behavioural objectives really necessary? The Australian Journal of Education v.14(3), October, p. 330-336.
- Hyvärinen, L.P., 1968. Information Theory for Systems Engineers. New York, Springer-Verlag Berlin.
- Iberall, A.S., 1974. On a thermodynamic theory of history. General Systems v.XIX, p. 201-208.
- Immegart, G.L. & F.J. Pilecki, 1973. An Introduction to Systems for Educational Administration. Reading, Mass., Addison Wesley.
- Johnstone, A.H., 1974. Evaluation of chemistry syllabuses in Scotland. Studies in Science Education v.1, p. 21-50.
- Jonnada, R.K. & K.A. Fegley, 1974. Path analysis in systems science. IEEE Transactions on Systems, Man and Cybernetics v.SMC-4(5), Sept., p. 418-424.
- Kac, M., 1969. Some mathematical models in science. Science v.166(69) p. 695-699.
- Kaiser, H.F., 1958. The varimax criterion for analytical rotation in factor analysis. Psychometrika v.23(3), Sept., p. 187-200.
- Kalman, R.E., P.L. Falb & M.A. Arbib, 1969. Topics in Mathematical Systems Theory. New York, McGraw-Hill.
- Kane, R.B., 1969. Semantic differential factor structure with concepts and subjects from education. The Journal of Experimental Education v.37(3), Spring, p. 34-37.
- Katz, F.M. & C.N. Katz, 1968. Students "definitions" of the objectives of a university education. The Australian Journal of Higher Education v.3(2), Dec., p. 111-118.
- Keeves, J.P., 1972. Educational Environment and Student Achievement. Stockholm, Almqvist & Weksell.
- Keller, F.S., 1968. "Goodbye teacher . . ." Journal of Applied Behaviour Analysis v.1(1), p. 78-89.
- Kelly, P.J., 1971a. A reappraisal of examinations. Journal of Curriculum Studies v.3(2), Nov., p. 119-127.
- Kelly, P.J., 1971b. Evaluation studies of the Nuffield A-level biology trials. 1. Overall achievements of students. Journal of Biological Education v.5(6), Dec., p. 315-327.
- Kelly, P.J., 1972a. Evaluation studies of the Nuffield A-level biology trials. 3. Student characteristics and achievement. Journal of Biological Education v.6(2), April, p. 99-107.
- Kelly, P.J., 1972b. Evaluation studies of the Nuffield A-level biology trials. 4. School characteristics and achievement. Journal of Biological Education v.6(3), June, p. 197-202.

- Keuning, D., 1974. General systems theory. Methodology and Science v.7(3), p. 109-137.
- Klopfer, L.E., 1971. Evaluation of learning in science. In B.S. Bloom (Ed.) Handbook of Formative and Summative Evaluation of Student Learning. New York, McGraw-Hill.
- Klug, B., 1972. A Case for Profiles. London, National Union of Students.
- Krathwohl, D.R. et al., 1964. Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook 2 - Affective Domain. New York, McKay.
- Kropp, R.P. & H.W. Stoker, 1966. The construction and validation of tests of the cognitive processes as described in the taxonomy of educational objectives. Cooperative Research Project No.2117 February 1966. Office of Education, U.S. Department of Health, Education & Welfare.
- Land, K.C., 1969. Principles of path analysis. In E.F. Borgatta (Ed.) Sociological Methodology. San Francisco, Jossey Bass.
- Lerner, J.W., 1973. Systems analysis and special education. The Journal of Special Education v.7(1), p. 15-26.
- Likert, R., 1932. A technique for the measurement of attitudes. Archives of Psychology No.140. p. 1-55.
- Lord, F.M. & M.R. Novick, 1968. Statistical Theories of Mental Test Scores. Reading, Mass., Addison Wesley.
- Mackay, L.D., 1971a. Changes in cognitive objectives during two years of physics study in Victorian schools. Australian Science Teachers Journal v.17(3), Oct., p. 74-79.
- Mackay, L.D., 1971b. Changes in affective domain objectives during two years of physics study in Victorian schools. Australian Science Teachers Journal v.17(1), May, p. 67-71.
- Mansell, T., 1974. Project work in the final year of the physics course: Bristol University. Studies in Laboratory Innovation. London, Group for Research and Innovation in Higher Education, Nuffield Lodge.
- Mathews, J.C., 1974. A report on research into the Nuffield Advanced Chemistry course and examination. Unpublished. University of Lancaster. (Personal copy.)
- Merrill, M.D. (Ed.), 1971. Instructional Design: Readings. London, Prentice-Hall.
- Miller, G.W., 1970. Success, Failure and Wastage in Higher Education; an overview of the problem derived from research and theory. London, Harrap for University of London Institute of Education.
- Mueller, D.J., 1973. The mastery model and some alternative models of classroom instruction and evaluation; an analysis. Educational Technology v.13, May, p. 5-10.

- Nicholas, K.M., 1973. Report on the Secondary School Teachers' Fellowship in Physics for 1973. Hamilton, University of Waikato Council Minutes, Dec.
- Nicholas, K.M., 1974. 7th Form Physics Tests 1974. Wellington, Curriculum Development Unit, Department of Education.
- Nuthall, D.L., 1974. Schools Council Examinations Bulletin 28. London, Evans-Methuen Educational.
- Osborne, R.J., 1972. Travelling Waves. Wellington, Visual Production Unit, Department of Education.
- Osborne, R.J., 1973. The shortage of physics graduates in New Zealand secondary schools. New Zealand Journal of Educational Studies v.8(1), May, p. 25-38.
- Osborne, R.J., 1974a. Experimental Physics. Hamilton, University of Waikato.
- Osborne, R.J., 1974b. Examiner's report scholarship physics in Examiner's Report 1973. Wellington, Universities Entrance Board.
- Osgood, C.E. et al., 1957. The Measurement of Meaning. Illinois, University of Illinois Press.
- Parlett, M. & D. Hamilton, 1972. Evaluation as illumination: a new approach to the study of innovatory programmes. Occasional Paper 9 Centre for Research in the Educational Sciences. Edinburgh, University of Edinburgh.
- Pentony, P. & A.P.T. Loftus, 1970. On prediction of first year performance of science students from I.Q. and performance matriculation. Australian Journal of Higher Education v.4(1), Dec., p. 57-64.
- Pepper, A.R., 1974. Solving Physics Problems. Unpublished. Physics Department, University of Waikato.
- Pillenger, A.E.G. & J.G. Houston, 1974. The effect of verbal teaching style on the attainment of educational objectives in physics. British Journal of Educational Psychology v.44(2), June, p. 163-174.
- Rappaport, A., 1970. Modern systems theory - an outlook for coping with change. General Systems v.XV, p. 15-25.
- Rath, C. & G.J. Rath, 1973. Evaluation is a process: systems analysis in education. Educational Technology v.13, March, p. 60-62.
- Richards, C., 1974. The schools council - a critical examination. University Quarterly (Higher Education and Society) v.28(3), Summer, p. 323-336.
- Ritchie, W.R., 1970. Teaching physics in Scotland. Physics Education v.5(4), July, p. 193-198.
- Roebuck, M., 1972. Floundering among measurements in educational technology. Programmed Learning and Educational Technology v.9(2) p. 87-97.

- Runyan, H.M., 1971. Cybernetics of economic systems. IEEE Transactions on Systems, Man and Cybernetics v.SMC-1(1), Jan., p. 8-18.
- Schol, 1972. Universities Scholarships Examination Physics 1972. Wellington, Universities Entrance Board (Whitcoulls), 1973.
- Schol, 1973. Universities Scholarships Examination Physics 1973. Wellington, Universities Entrance Board (Whitcoulls), 1974.
- Shubick, M., 1967. Simulation of socio-economic systems. General Systems v.XII, p. 149-175.
- Stone, R., 1967. Mathematical Models in Educational Planning. Organisation for Economic Cooperation and Development OECD; Technical Report.
- Stowe, R.A., 1973. Research and the systems approach. AV Communications Review v.21(2), Summer, p. 165-175.
- Stufflebeam, D.L. et al., 1971. Educational Evaluation and Decision Making. Illinois, F.E. Peacock.
- Szabo, M., 1969. The Relationship of Intellectual, Personality and Biographical Variables to Success and its Prediction in an Independent Biology Course at College Level. Unpublished D.Phil. thesis. Purdue. (Microfilm - University of Waikato.)
- Tamura, H. & T. Yoshida, 1974. Modes of control and the limits of control capability for human beings. IEEE Transactions on Systems, Man and Cybernetics v.SMC-4(5), p. 482-487.
- Tatsuoka, M.M., 1973. Multivariate analysis in educational research. In F.N. Kerlinger (Ed.) Review of Research in Education I. Illinois, F.E. Peacock.
- Tennent, W., 1972. Attitudes in physics education. Applied Physics Project (73.307). Unpublished. Physics Department, University of Waikato.
- Thornstad, T., 1967. A Mathematical Model of the Norwegian Educational System in Mathematical Models in Educational Planning. Paris, OECD; Education and Development Technical Report.
- Truxal, J.G., 1972. Introductory Systems Engineering. New York, McGraw-Hill.
- Tuckman, B.W. & K.J. Edwards, 1971. A systems model for instructional design and management. Educational Technology v.11, Sept., p. 21-26.
- Tyler, R.W., 1968. Resources, models and theory in the improvement of science teaching. Journal of Research in Science Teaching v.5(1), p. 43-51.
- UGCH, 1970. University Grants Committee Handbook. Wellington, Whitcoulls.

- UGCH, 1971. University Grants Committee Handbook. Wellington, Whitcombe.
- Walberg, H.J., 1969a. Predicting class learning: an approach to the class as a social system. American Educational Research Journal v.6(4), p. 520-542.
- Walberg, H.J., 1969b. A portrait of the artist and scientist as young men. Exceptional Children v.36, Sept., p. 5-11.
- Walberg, H.J., 1970. A model for research in instruction. School Review v.78, Feb., p. 185-200.
- Weizsacker, von C.C., 1967. Training Policies under Conditions of Technical Progress: A Theoretical Treatment in Mathematic Models in Educational Planning. Paris, OECD; Education and Development Technical Report.
- Welch, W.W., 1972. Review of research 1968-1969 in secondary level science. Journal of Research in Science Teaching v.9(2), p. 97-127.
- Welch, W.W., 1973. Review of research and evaluation program of Harvard Project Physics. Journal of Research in Science Teaching v.10(4), p. 365-378.
- Welch, W.W. & H.J. Walberg, 1967. Are the attitudes of teachers related to declining percentage enrollments in physics? Science Education v.51(5), Dec., p. 436-442.
- Welch, W.W. & H.J. Walberg, 1972. A national experiment in curriculum evaluation. American Educational Research Journal v.9(3), Summer, p. 373-383.
- White, H.J. & S. Tauber, 1969. Systems Analysis. London, W.B.Saunders.
- Wight, A.R., 1972. Beyond behavioural objectives. Educational Technology v.12, July, p. 9-14.
- Wilson, J.W., 1971. Evaluation of learning in secondary school mathematics. In B.S. Bloom et al. (Eds.) Handbook of Formative and Summative Evaluation of Student Learning. New York, McGraw-Hill.
- Windecknecht, T.G. & H. D'Angelo, 1975. The stereotype approach to the modelling and simulation of an elementary school. IEEE Transactions on Systems, Man and Cybernetics v.SMC-5(2), March, p. 216-225.
- Woolnough, B.E., 1974. Current trends in school physics teaching. Physics Bulletin (Institute of Physics) v.25, Sept., p. 386-390.
- Wright, S., 1960a. Path coefficients and path regression: alternative or complementary concepts. Biometrics v.XVI, June, p. 189-202.
- Wright, S., 1960b. The treatment of reciprocal interaction, with or without lag, in path analysis. Biometrics v.XVI, Sept., p. 423-445.

Yee, A.H., 1972. The limits of scientific - economic - technological approaches and the search for perspective in education: the case of performance contracting. The Journal of Educational Research v.66(1), Sept., p. 19-29.