NZEST

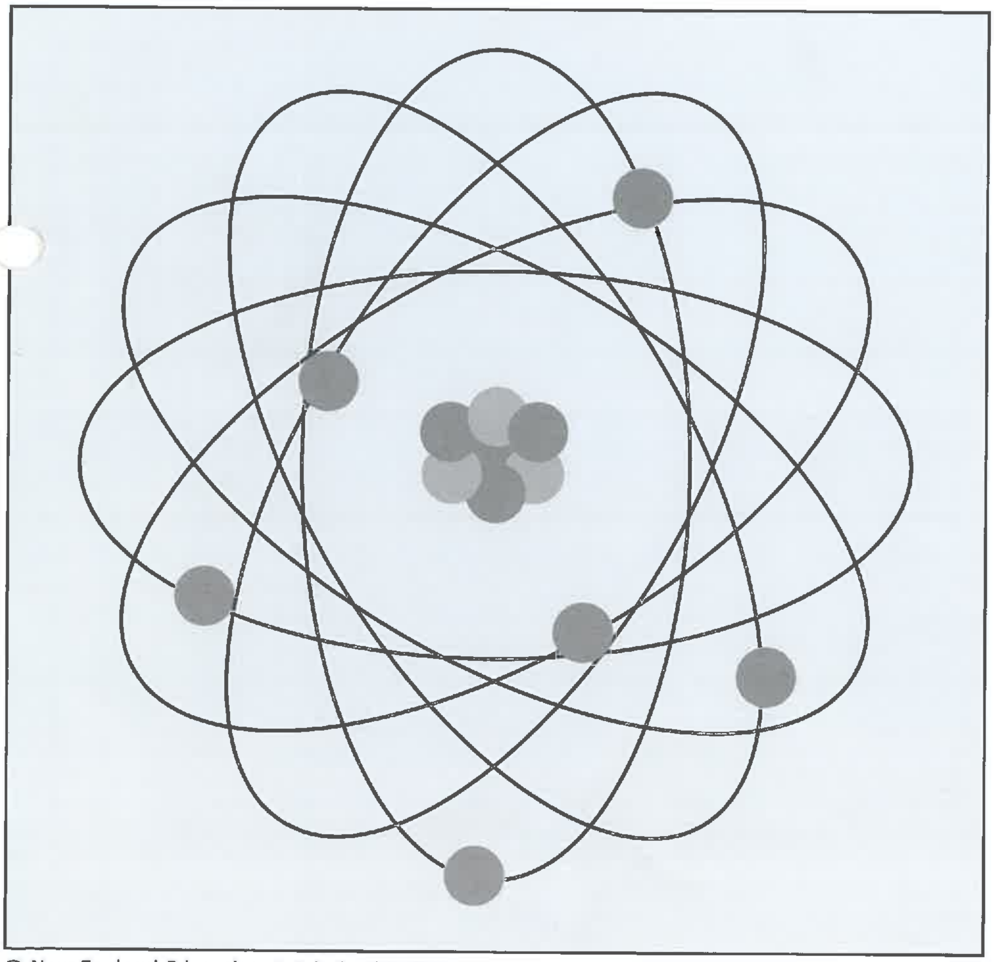
NEW ZEALAND EDUCATION & SCHOLARSHIP TRUST

ACADEMIC ACHIEVEMENT BY CHOICE

NZEST SCHOLARSHIP EXAMINATION

1997 EXAMINER'S REPORT AND SOLUTIONS

PHYSICS



1997 NZEST PHYSICS EXAMINER'S REPORT

Format

1. Exam statistics
2. Question statistics
3. Markers' comments
4. Examiner's comments
5. Teacher appraisal
6. Markers' requests
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1. Exam Statistics

Number of Students	:	596
Top Mark	:	89%
Upper Quartile	:	54%
Mean	:	44%
Lower Quartile	:	34%
Bottom Mark	:	4%

18 students were graded A+ mark > 75%
165 students were graded C- mark < 35%

2. Question Statistics

Question	Max possible	Mean	S.D.	Mean/Max	No. of attempts
1	14	9.0	2.8	.64	535
2	15	7.5	4.8	.50	535
3	18	8.2	3.9	.45	593
4	14	8.6	2.9	.61	571
5	17	8.3	4.3	.49	508
6	16	7.3	4.1	.45	568
7	17	8.9	4.5	.52	513
8	19	4.7	3.5	.25	517
9	20	6.5	3.8	.32	585
10	10	3.9	1.9	.39	531

3. Markers' Comments

Question 1

(a) (i) A generally reasonable performance; log-log graph most common but many v vs $n^{1/9}$ or v^9 vs n approaches (not all recognised the best fit should go through origin for these). Many stated log-log graph linear - ∴ case proved (without establishing the gradient). Most students insisted on keeping origin in graph - taught to do this?

(ii) Some problems with logs. Units usually missed for A. (1/2 mark off)

(iii) not all students quoted a whole no for rowers, or rounded down.

(b) (i) Usually handled OK.

(ii) Some students use $(F_{drag})_3 = P/v$; others can't establish B and quote $9B$.

(iii) Disappointing, many good students lost marks here.
Few correctly applied $F_{resultant} = ma$.

Common to state ' $a = F/m$ 'where F = any force, e.g. $(F_{drag})_{4.487 \text{ or } 3 \text{ m/s}}$ or F_{rower} at 3 m/s

Almost no force diagrams - perhaps the question should require one!

General:

1. A fair question and useful contextual example. Marked generously (e.g. any graph correctly labelled would earn 2/6 in a(i), Any F/m calculation earned 1/3 in b(iii). Mean mark was a respectable pass.
   However, depressing that only 5-10% of students had the central concept in (b) (iii): $(F_{rower} - F_{drag}) = M_{total}\, a$

2. Instructions to candidates should include statements re:

   (i) Sig figs - i.e. mark to 3 s.f. unless otherwise requested. Many students are trained to treat 6 m/s as 6 ± 0.5 m/s rather than something more accurate.

   (ii) Full marks will not be earned without showing working and explaining procedures.
   This makes it easier to penalise 'correct' answers that fall short of true scholarship standard.

Question 2

(a) (i) → (iv) "mechanically" done with heavy use of remembered formulae. Few students using first principles. Some ridiculous v values obtained with only one student offering self criticism in the form of "damn" when obtaining 475m/s for v_H!

Little sense shown of the physics (i.e. treat v_H & v_V separately), it was treated much more as a mathematical exercise.
Students either knew it or they didn't!

(b) (i) Some explicit acknowledgement of $\Sigma \underline{F} = 0$ looked for (e.g. $\underline{v}$ is const $\Rightarrow \underline{a} = 0$ or a closed vector Δ, etc.).

(ii) Two many students removed $\underline{v}$ then added remaining $\underline{D}$ & $\underline{S}$ not realising that $\underline{D}$ must be lineally opposed to $\underline{S}$. Pity the poor student who wrote "what is a keel?"

Also many discussed the torque effects of $\underline{S}$ & $\underline{K}$ and the possibility of boat capsizing. Whilst this would affect the boat's motion, the question wanted comment on the boats motion, assuming it could sail!

Question 3

Reasonably well answered question with a mode score of 10/18. Only 3 students did not attempt the question, 4 received full marks and 6 received zero. (total marks = 18, mean = 8.2, standard derivation = 3.9)

Part (i) Well done by most - 1 easy mark

Part (ii) Well done but most did not realise that '$v^2 = \omega^2 (A^2 - x^2)$' and hence $v_{max} = \omega A$. Not surprising, since this equation is not used in the Howison F7 text.

Part (iii) and (iv) Well done and most realised that 'P.E. lost = K.E. gained' and hence h could be worked out.
Consequential marking was very evident in both of these parts.

Part (v) Most difficult part of the question. Some ambiguity exists in interpreting the question although 3 marks is a lot for the obvious answer of $h/2$. Very few scored 3 marks and most candidates scored zero for this part.

Part (vi) Reasonably well done.

Part (vii) Some had difficulty in arriving at the correct equation for their graph.

Part (viii) Well done, most scored 2 marks for this part.

Part (ix) Next most difficult part with few candidates scoring 3 out of 3 for this part.

Note

A conscious effort not to award 1/2 marks was made

Consequential marking was very evident in this question

Rounding errors occur in parts (ii), (iii), (iv), (v) arising from (I).

A decision about significant figures should be made and stated on the front of the paper. e.g. 3 significant figures to be used throughout the exam, or 1 decimal place, etc.

Question 4

Question quite well answered : should have been well within capabilities of scholarship students.

(a) (i) The phrase "mathematical expressions" confused some candidates who tried to write equations. Perhaps "Write formulae for" would have been a clearer instruction. Many did not know $E_{krot} = mv^2/2$

(ii) Several candidates totalled the energy and equated it to zero.

(iii) Many did not get to the end of this because they did not realise to sub $v^2 = (r\omega)^2$ in the E_k not term

(iv) Poorly answered, though not difficult.

(v) I wish teachers would teach their students not to start with $E_K(linear) = 2E_k(rotational)$ but to derive the relationship and be delighted when it worked!

(b) Some students thought that your squiggly pattern indicating the polished floor were the marks made by the pens and they tried to explain them!

There were a reasonable number of correct drawings, but almost as many

and lots of sin/cos curves.

Another common error - they assumed the block was pivoted at the top. Explanations of the patterns were generally not good - especially SOL's.(?) We must sustain our effort to encourage physics students to be literate too.

General Comment:

Far too many loose sheets - how about a dedicated answer booklet (like Bursary)?

Question 5

1. I'm surprised to see how often students write units within an equation after making substitutions e.g. $12V - 4\Omega I, - 3\Omega I = O$ (Marked as correct)

2. Many students do not clearly see cause and effect with induced emf and current. e.g. " .. this induced current causes a voltage in the wire".

3. Many students could not calculate *energy = power x time*, and many used W as the unit for energy.

4. Questions using "Show that...." (like 5 (b) (ii)) are not good, because the student can work backwards to establish what the starting equation should have been.

5. An overwhelming proportion of answers to 5(a) (i), (ii) for most students are force - oriented, i.e. they talk about "the coil trying to oppose entry of the magnet". Only a small minority refer to an induced emf. due to flux-cutting.

6. Part 5 (b) (iv) is about School Certificate level, but earns higher marks than any other part of this question! ($W=I^2Rt$)

7. Part 5(a)(iv) contains misleading information. It refers to the "current" through the CRO. It should refer to the polarity of the emf. This gaffe seems to have led to numerous answers based on the coil's current creating poles which attract or repel the magnet.

8. A pity 5(a) (i) (ii) did not ask students to explain the period of time between the pulses, when no voltage was being induced.

Question 6

(a) A good searching question that provided some marks for 95% of candidates and the full 6 marks for the confident students who recognised that ranking in order did not necessarily mean 1st, 2nd, 3rd, but had to mean: 1st 2nd= ,in the first 2 cases. A small minority tried to apply the Doppler equations (with zero success!) and a small minority just tried three permutations of 1,2,3 (with limited success!); mean mark = 3.3

(b) On the whole very poorly done though at least the vast majority did recognise a basic interference pattern was required. The difficulty was in extending the concept of integral path differences to the space of a two-dimensional plane surrounding the transmitters. (Even if the examiner unwittingly gave a clue when referring to "in the same plane" that one student assumed to be an airplane carrying the detector!)

mean mark = 1.0

(c) A real polarising question with most candidates getting either 5,6 or 1,2. The trouble lay in the fact that to 90% of the candidates it was only a 3 mark question:

1. The fundamental modes matching
2. The sketch
3. The resonance without the process of elimination as expected by the examiner. Consequently, if candidates "saw" the answer, 3 lines gave 6 marks, but if not, many lines could not get more than 2 marks.

mean mark = 3.0

In overview, then, a question which did give top marks to the top students who demonstrated some superb solutions, but it also rewarded the grafters who had worked at the basics and could get information logically onto paper.

Question 7
Good basic question with marks for average students who weren't high fliers.

Not a good discriminator of top students (all the top students got 16-17 out of 17)
- could have been made a bit better if we had been a bit stricter over the award of the last two marks (i.e. require 2 reasons why the train was not realistic).

Odd that so many of them did this one last, since it was not hard, but most scored their marks in part (b).

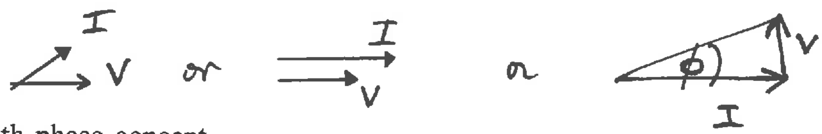
Question (a) (ii) should have read "Derive an equation for *B*". Too many had memorised the formula for radius and just re-arranged it, and we had no option but to give full marks for this.

Question (a) (iii) was a puzzle to mark : if the charges did not agree with the field direction, which was the one they started with? In the end we gave no marks for this case, but 1 mark if they gave either field or charge correctly and no answer for the others.

Units - many gave or played with units unnecessarily. e.g. 5.56×10^8A = 0.556GA and consequently lost marks unnecessarily.

Mag field direction (a) (i) badly done even by best students.

Question 8
(a) (i) Some tried



Difficulty with phase concept.

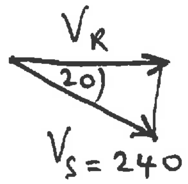
(ii) Often don't consider dimensions e.g. get $\tan\phi = V/I$

(iii) Some didn't sketch

(iv) Vast majority say 'decrease'. Didn't think about $1/\omega C$, just thought $C\uparrow \therefore \downarrow V_c$ gets bigger.

(b) (i) Almost everyone got it right.

(ii) Tried to do



but did not realise that current was no longer 2A

(iii) Often just wrote down the answer. Some explained that terms referred to reactances. Very few considered voltage logging current.

(iv) Mostly not derived clearly. Many got new X_c to be $1/(2\omega C)$. Few got 'lag' clear. Most did not see triangle clearly.

(v) Not bad. Almost all wrote down two simultaneous equations. Their algebra is terrible.

(c) (i) Very few know the equation. Not taught?

(ii) Sketch graph OK for shape but not labelled clearly.

(iii) No equation → no calculation.

In general: the question 'looked' hard and many (~ 60) did not attempt it or made a token stab at it. They mix up reactance phasors with voltage phasors. It has a sophistication that few of them can achieve, even if they know the basic ideas.

Question 9

Overall a searching question, with very few top marks.

(a) (i) A very large number failed to convert eV to J so λ often came out as close to 10^{-26} m!

(ii) Most students unaware of the zero E inside a closed conductor. Obviously the deletion of electric field work at 6th and 7th form is ill-equipping students in this area.

(iii) Most realised black absorbed well, but then became confused by photo-electron emission possibilities.

"Yes, because black absorbs all colours of light, so more energy will be taken in. Also it can then hide on the other side of the Earth in the dark so the Russians will have trouble shooting it down."

(b) (i) Generally well done, with some students confusing chemical activity with nuclear activity.

(ii) About half the students managed a reasonable attempt. A large proportion used the $\log_2$ method to good effect.

(iii) Mostly a consequential mark!

(c) (i) Usually well answered

(ii) Badly answered - very few knew the basics here, with most opting for an energy scenario.

"Bohr assumed the Earth was round, and the polar ice-caps wouldn't melt. If they did, it would be disastrous for the polar bears".

(iii) Many vague answers, with guarded references to escaping electrons. Many confused the negative electron charge with the binding energy.

(iv) Poorly answered - usually $13.6/1^2 = 13.6$eV!!

(v) A few good thinkers here. Most said it would be inverted or that an absorption spectrum may result.

All in all a good discriminator - only competent students scored 13+

Question 10

part #	Range of acceptable answers	.... A few exceptional answers!!! ...
1	800 km/h → mach 1; mach 1 marked wrong	10 ms^{-1}; 2.1 x 10^{-8} ms^{-1} ... cruising speed of Jumbo ...
2	40 MHz → 550 MHz	
3	1.5 m → 2.5 m	1 km ..... max height blood would rise ....
4	500 kg → 2500 kg	90 kg ... the mass of a car ...
5	5 cents → 20 cents	$350 ... cost of 1 kWh ...
6	9 m - 11 m	
7	500 Wm^{-2} → 1500 Wm^{-2}	
8	0.1 μm → 50 μm	7 mm ... track spacing on a CD...
9	500 μm → 600 μm 1 mark any visible λ or colour 1/2 mark	
10	1 kgm^{-3} → 2 kgm^{-3}	1 kg L^{-1} ... density of air ...
11	150° C → 200° C	550° 40° C ... temperature of oven ...
12	100 MHz → 235 MHz	20,000 MHz ... clock speed of Pentium ...
13	5000 MW → 10,000 MW	1600 W ... power capacity of National Grid ...
14	15 kHz → 21 kHz	
15	0.5 T → 2 T	5000 T ... max. B around electromagnet ...

- No marks were awarded for unitless solutions
- In the future with this type of question:
    1. Get students to write 1 to 15 down the left-hand column first ...
    2. Don't ask the students to reproduce roman numerals as many students made mistakes and lost marks.

4. Examiner's comments

Q1 (a) This is a log-log plot placed in a sporting context. This type of plot appears in Paul Howison's book on F7 physics. Fortuitously, the graph is made easier to plot because the number of rowers is in powers of 2. The index of (1/9) is unusual although it can be derived in a few lines with considerable knowledge of fluid mechanics.

(b) I decided to expand part (a) by looking at the motion while the skiff came up to its terminal speed. This then becomes the ' *F=ma* ' problem.

The constant power situation has some interesting offshoots which could be studied in class. Firstly 'constant power' in the automobile context corresponds to 'automatic transmission'. Secondly, the distance covered from rest under constant power is $\sim t^{3/2}$. This, is contrast to constant force: $d \sim t^2$ and constant speed: $d \sim t$. Of course, constant power implies high force at low speed, and *vice versa*. A relatively good constant force situation is a jet engine.

Q2 (a) A simple projectile problem based on a women's sport. Requires understanding of the constant acceleration equations.

(b) A recognition of the America's Cup victory. In fact, a physicist, on board, (Tom Schnackenburg) made a significant contribution to the victory. A major textbook in this field was written by another NZ physicist, Ross Garrett. Available in paperback, it is called 'The Symmetry of Sailing'. Cook's ship Endeavour had a measure of 'keel effect' which enabled it to sail only about 5° in to the wind - which is a serious limitation and the cause of anxiety in a strong on-shore wind. The limiting situation of an infinite keel would be established by placing a yacht on a railway carriage, say; the wheel / rails form a keel.

Q3 SHM - straightforward apart from part (v), which is a discriminator, and part (ix) which requires good verbal skills as well as insight.

Q4 (a) A question from Paul Howison's book. Parts (iv) and (v) are add-ons and were intended to be discriminatory.

(b) A variation on the 'tossing the spanner' in the air situation (in which case the CM follows a parabola). In the present case, the centre pen follows a straight line. A wonder to behold. The outer pen which follows a circular path about the CM has a partly retrograde motion but cusp-like waves for the path were accepted - anything that looked like a circle pulled apart. To make a convincing demo you could use two felt- tip pens in a 600 mm length of smooth, 100mm x 50 mm, radiata. Rubber bands, stretched over the pen tops and pinned into the wood, hold the pens down; a long run of shiny brown paper, 1m wide, captures the trajectories.

Q5 The 'equal area' query in (iii) is a discriminatory addition requiring insight into the induction law. Lenz's law gives the direction of the current in R in (iv). The problem with voltage is that the coil is a seat of emf so the current direction flows from -ve to +ve within it, a fact which tends to trip students at this level. The resistor would have been better placed across the coil (assuming the effect of the CRO in parallel was recognised as negligible); then the current could be much larger. Yes, forces of restraint are involved; small here though, like the current. Most of this question is from Paul Howison's book.

Q6 A waves question which stresses concepts. Some students moved quickly to the correct answer in (c) thereby gaining many marks and extra time.

Q7 The topic is electric and magnetic fields and their interaction with charge. Part (a) is conceptual; part (b) numeric.

Q8 (a) Standard AC theory with an interesting twist underscored in part (iv).

(b) More AC theory and requiring care. The equations in (iii) are (iv) were placed on the paper in a visually suggestive way such that the addition required might be obvious.

(c) If e^{-at} is a decay function, from one to zero limit, then $(1-e^{-at})$ is a growth function from zero to unit limit. (These two relations are worth knowing as are: all 'bump' functions are ~ $exp(-ax^2)$ and all waves are ~*sine waves*)
Intended to be, and was, a high level discriminator. Too high?

Q9 Last year's paper was justly criticised for lacking modern physics questions. The difficulty was, and is, to find material with enough character - in an area where there isn't much character at this level. The three parts chosen were deemed worthy of inclusion.

(a) The temperature oscillation of the black capsule could be life threatening, the black surface causing the capsule to heat in the sun's rays, and cool in shadow.

(b) This is based on data which I saw signposted in Kaitaia, Northland, by a company which produces wooden *objest d'art* from kauri stumps hauled out of ancient swamps. The University of Waikato did the analysis and dated the logs as ~ 50,000 years old.

(c) Standard Bohr-model material. The researchers *are* lookingfor a difference (miniscule, if any) in the spectra of the two types of hydrogen atom. A very hard experiment.

Q10 This was expected to draw criticism and did - some for and some against - but contact with the real world is important and in the present 'science+commerce' environment of 'transparently-obvious usefulness' these numbers are important. This is a question for those who raise their heads from the book and observe and wonder.

(ii) Too late in the day I discovered the range of frequencies was vast - too vast to make this question satisfactory, unfortunately. But we are now engulfed in an electronic communications revolution of which we must grasp a broad, as well as detailed, understanding.

(iii) Blood pressure was first measured in a horse using the neck vein. A glass tube, 2m high, is required, apparently. This question is for the many top physics students who will become doctors. A topic close to the heart of all teachers.

(iv) The NZ firm of Fisher and Paykel puts kWh labels on many kitchen appliances. e.g. a smallish fridge uses 660 kWh/year. So the yearly cost is quickly calculated. Something for the class to note. Another case of a solid (and increasing) number replacing gossip.

(v) Something quickly verified with a laser pointer and protractor. (You must be careful with these laser pointers - it is too easy to hit an eye.)

5. Appraisal by twelve senior physics teachers chosen by the NZEST executive

1.Was the Scholarship examination at the right level, ie sufficiently challenging, to extend the able student?

- Yes.
- Yes. Questions were within the syllabus but a hard enough challenge to extend students.
- Yes
- Definitely challenging; the marks ranged form 90% to very low. Certainly some of the candidates were incapable of answering basic questions and should not have entered the exam (they would be poor Bursary candidates)
- It is at a good level; maybe some questions were unrealistic (ie lift someone 4m above the ground).
- Fairly straightforward but question 2 is surely only an easy sixth form question?
- The majority of questions appeared on first glance to be logical with only a few, on their own, liable to extend the most able. The combination sets the challenge.
- Yes, there were enough application questions to test the higher skills and abilities. Top students would have difficulties but this is to separate the top.
- Yes, good standard for its purpose.
- There was enough material to challenge the most able student. The AC question was perhaps too difficult.
- Yes, I thought it was pitched at about the right level. Very achievable by good students so a good incentive to take part but more demanding than UB. I enjoyed question 10; thought it was a good question to test thinking in physics.
- Excellent questions - I especially liked question 10 as it tested their lateral thinking and ability to link physics with everyday occurences without seeming to be contrived.

2. Were there any questions considered to be inappropriate?

- No, except there were some reservations about Q10, although others liked it.
- No
- Q7: The syllabus does not require students to know about magnetic forces on currents or moving charges. Q8: (c)(i) students are asked to quote a formula that they are not required to know (see circular Q97/18S from NZQA 14/3/97). Q10: OK as it stands but I would not want to see this sort of thing become more than about 5% of the paper.
- The recall of an equation (Q8(c)) without real preparation in structuring the question was unfair.
- Q10
- Q2 is an easy form 6 question
- Q10 clearly has some aim to reward those with a good relevant general knowledge or feel for a real situationbut could skew results unfairly. 'How approximate' is required.
- Personally I thought Q10 an excellent idea but, O boy, did the kids complain! I believe top students should know this - but most do not know the name of the Governor General either. While I liked the idea of Q10 very much I was not convinced of its appropriateness.
- All questions appeared to be well focussed on the syllabus - good to see some atomic/nuclear physics.
- Only Q2 in my opinion. The material here is more directly related to F6 physics in terms of concepts. F7 students will not have covered this in 1997. Still a doable question for students but (not) covered specifically in their 1997 year.
- No

3. Was the coverage of the syllabus satisfactory?

- Yes
- No; electricity and electrostatics took up a big part. Mechanics, which is the largest topic in the prescription did not have many questions.
- Seems a heavy emphasis on mechanics
- Much better than the previous years' papers which have neglected modern physics
- Yes, better than last year.
- The balance was not as prescribed; waves at 10% was very low at the expense of mechanics and applied maths.
- Yes
- Yes
- Yes, a good balance of topics
- OK from the point of view that mechanics, electromagnetism and photons (et al) were all covered However the balance needs to be looked at more carefully. The UB prescription gives a specific weighting 35% mechanics, 20% waves, 30% electromagnetism, 15% photons et al.
- Lots of variety - covered the syllabus well.

4. Length of the paper - was the exam perceived to be too long? too short ? just right?

- Just right
- Extensive work of this kind will always find most students short of time.
- A bit long - but this is OK for a schol paper
- Good
- It was long but it really extended our top students.
- OK
- Appeared OK but students will be better judges
- Good students found it the right length
- Students thought it was long - I feel it needs to be
- Most students thought it was too long.
- Student feedback suggested this was OK

Not sure - I did not talk to the students afterwards

5. What could be done to improve this Scholarship examination paper?

- No real suggestions - overall a good paper
- Questions are alright; provide a list of formulae, as with Bursary
- Next year's setter must carefully read the new Bursary prescription. Some exams in recent years have not matched the prescription well enough. A challenging exam can be set within the prescription boundaries. I would like to see some questions based on modern devices, discoveries, etc Most questions were fairly traditional.
- I thought that the paper provided many excellent and discriminatory facets. Q6 being an admirable example of simple concepts requiring clear, logical explanations. Ten questions of this quality would be an ideal (and very difficult to achieve) solution.
- The traditional style of question is refreshing, though there is a bias towards the applied mathematician and tests of understanding of physical concepts could usefully replace the contextual maths of Q1 in particular.
- The paper is well thought out and appropriate. Cannot suggest improvements. To encourage others (lower ability) there could possibly be a 'skills section'. Bursary is no challenge for the top (students) so please do not make this exam too easy.
- 1. Use of language - speakers of other languages did not know what a 'keel' was, for example. 2. Precision in wording of questions. I can't find it now but there was one question where the word used to name something was changed to a synonym later in the question. Yes I am aware that this is a scholarship paper!
- Overall, I was very pleased with the paper.
- Balance of areas more tightly controlled. An issue of an NZEST physics prescription would, I think, be positive for teachers. especially if scholarship students are spread over more than one class. eg " NZEST exam will cover the NZQA UB prescription together with the inclusion of log-log graphs for interpreting data, and a question that tests general thinking in physics" I don't see any problem in going beyond the immediate demands of UB for our best students as long as it is transparent and clear to them and their teachers.
- Marks look well allocated for question length.
-

6. Requests from the markers with a response from the examiner

1. "If a graph page is used it should be included with the answer book"

   Agreed.

2. "The markers would prefer a formatted answer book"

   No. While a formatted answer book makes marking easier it tends to change the character of the exam as well as lower the standard. The format presumes the student cannot organise her/his thoughts in a coherent manner and does not offer good students the opportunity to demonstrate their ability to follow, and present, a chain of reasoning. This exam seeks to identify physics students with reasonably distant vision.

3. "Full marks will not be earned without showing and explaining procedures and arguments used to establish the result."

   Agreed. This should go on the front cover. This directive is to cope with students who simply state a number for an answer without displaying the required chain of reasoning.

4. "Work to 3 significant figures unless otherwise directed."

   Agreed. This should go on the front cover.

7. Acknowledgements

My sincere thanks to:

Paul Blomeley and Sean Cleary, who moderated the paper

Alex Binnie (St Kentigern's) and the marking panel of senior physics teachers

Sarah Taylor, Executive Officer, NZEST for her friendly and efficient management

Over the years, this is the fifth NZ Schol paper I have set. Having run dry, so to speak, I am happy to pass the task to another. I have been surprised and pleased by the number of teachers who have expressed their appreciation of this and previous papers.

A final thought: in the new world order of market forces I am left wondering by what mechanism the NZ market will respond to the fact that only 18 students obtained 75% or more - or maybe, this isn't important?

Dr Scott Whineray
Physics and Electronics
Massey University at Albany.

1997 MARK SCHEME

QUESTION 1

(a) (i) Plot log(v) versus log(n).

n	log(n)	log(v)
1	0.0	0.652
2	0.3	0.685
4	0.6	0.721
8	0.9	0.754

SEE GRAPH ON NEXT PAGE

The line is straight with slope = $\dfrac{\Delta\log(v)}{\Delta\log(n)} = \dfrac{0.102}{0.9} \approx \dfrac{1}{9}$

Yes, the prediction is confirmed. [6]

(ii) Use any point for A; n=1 is convenient: $v_1 = A.1^{\frac{1}{9}} = A$

∴ A = 4.487 m/s [1]

(iii) For v = 6 m/s we have $6 = 4.487\,n^{\frac{1}{9}}$. That is $\left(\dfrac{6.000}{4.487}\right)^9 = n$

∴ n = 13.6 → 14 rowers required. [2]

(b) (i) $400 = Fv = F\,.\,4.487$

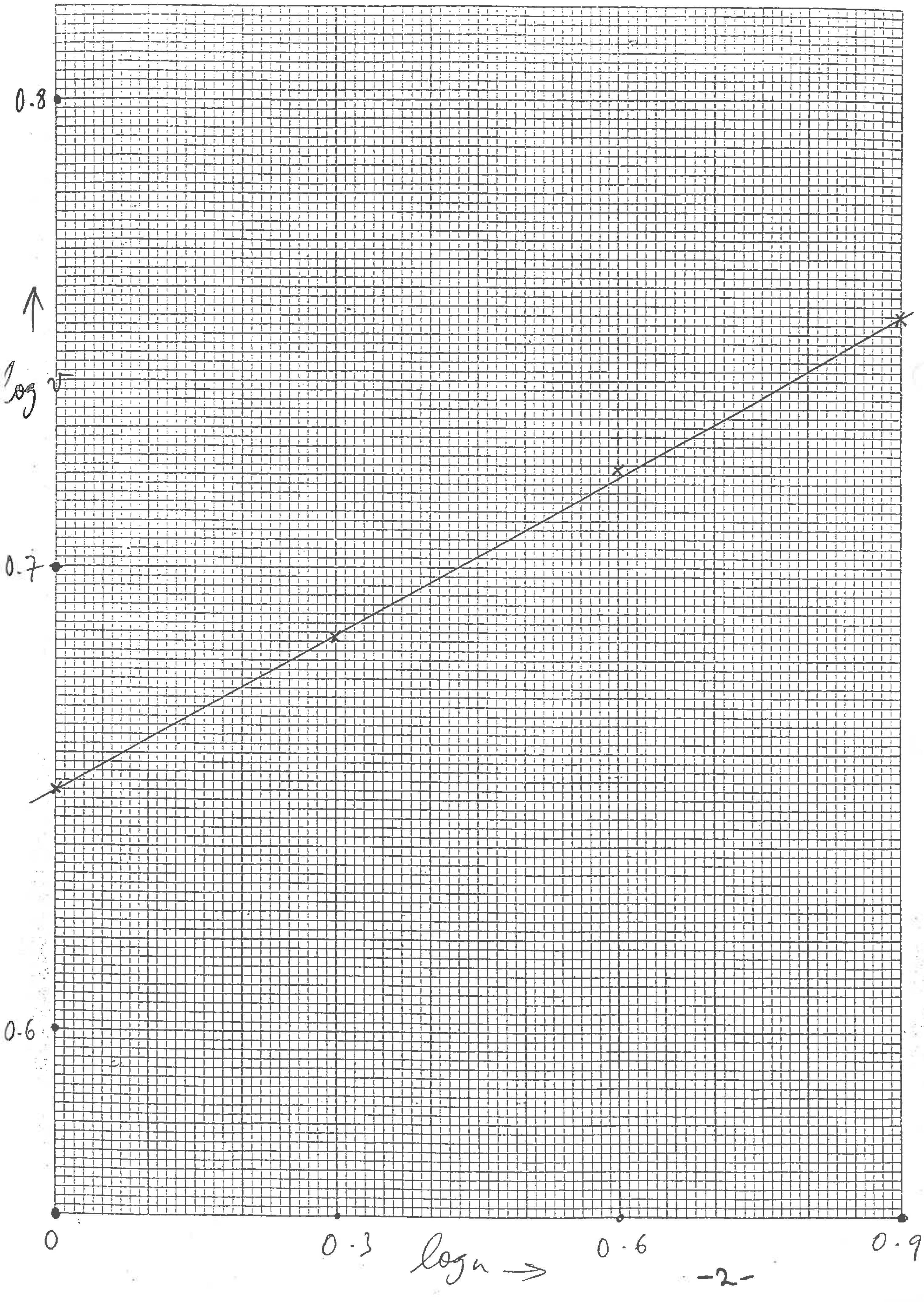
∴ $F = 89.1$ N [1]

(ii) $\dfrac{F_3}{F_{4.48}} = \dfrac{3^2}{4.487^2} \times 89.1 = 39.8$ N [1]

(iii) First calculate the rower's force at v = 3: $400 = F\,.\,3 \rightarrow F = 133.3$ N
Then use 'F=ma'

∴ $F - F_{drag} = m\,a$ or $133.3 - 39.8 = 110\,a$

Hence $a = 0.85$ m/s^2 [3]


0.8
0.7
0.6
log v
0
0.3
0.6
0.9
log u

QUESTION 2

(a) (i) Time of flight = twice the time up. Use $s = \frac{1}{2}gt^2$ with $s = 2$ and g =9.8 to get $t = 0.638$ s.

$\therefore$ time of flight = 2 x 0.638 = 1.277 s [3]

(ii) The horizontal velocity is related to the time of flight and the horizontal distance travelled through $x = vt$. $\therefore$ 29 = v x 1.277

$\therefore$ v = 22.7 m/s. [1]

(iii) To get the vertical velocity use:

$v^2 = u^2 + 2as \rightarrow 0 = u^2 - 2\,g\,2$

$\rightarrow u = \sqrt{4g} = 6.26\, m/s$ [3]

(iv) $tan\theta = 6.26 / 22.7 \rightarrow \theta = 15.4°$ [2]

(b) (i) For equilibrium, the force vectors sum to zero which means that $S \cos 25 = K$ and $S \cos 65 = D$

$\therefore S = 2000 / \cos 25 = 2207$ N and $D = 2207 / \cos 65 = 933$ N [4]

(ii) If there is no keel there is no force K (or K is small). Since D is a force which occurs in response to the motion S the boat must go where the wind pushes it, D acting only to limit the motion. [2]

QUESTION 3

(i) $T = 40 = 2\pi/\omega \quad \therefore \omega = \pi/20 = 0.157\ s^{-1}$ [1]

(ii) $v_{max} = \omega A = 0.157 \times 120 = 18.8$ m/s
The maximum velocity occurs at B. [2]

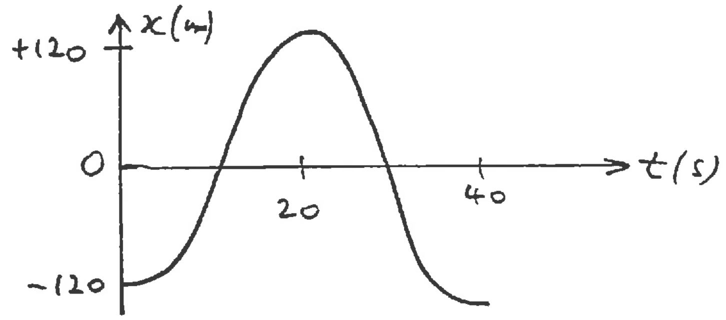
(iii) Use the max. velocity above to claculate the max. KE = total energy:
$(1/2)\, m v_{max}^2 = 3.55\ 10^5$ J [1]

(iv) Calculate the height that gives the max. KE above:
$V(x) = mgh = 355\ 000 = 3.55\ 10^5$ J

Therefore $h = 18.1$ m [1]

(v) $V(x) = (1/2)kx^2 = mgh$. The potential shape, usually provided by springs in the lab, is here manifest as gravitational potential.
So if x is halved h goes to a quarter; that is, a quarter of 18.1 m, or 4.52m [3]

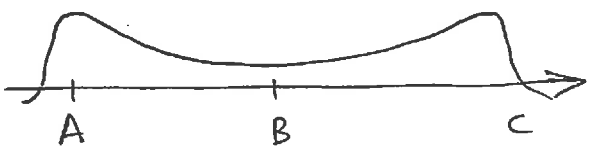
(vi)



[3]

(vii) This is an 'upside down' cosine wave form, hence $x = A\cos(\omega t)$ becomes $x = -120\cos(0.157\,t)$ [2]

(viii) No, it is not spread evenly. It is spread thinnest where the wagon spends the least time, that is, where it rolls fastest - which is in the middle, at B. At the ends, B and C, where the wagon slows to a stop, the sand trail thickens accordingly. [2]



(ix) The amplitude is the same since it starts from A and, because energy is conserved, it returns to A. However, the energy is less because much of the mass has been lost. That is, *Mgh* becomes *mgh*. [3]

QUESTION 4

(i)(1) mgh [1]

(2) $(1/2)mv^2$ [1]

(3) $(1/2)I\omega^2$ [1]

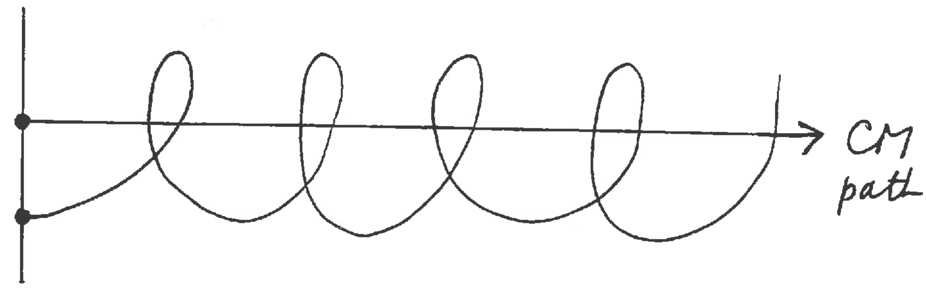
(ii) $mgh = (1/2)mv^2 + (1/2)I\omega^2$ [1]

(iii) Put $v = wr$, substitute for I and cancel m to get
$gh = v^2 / 2 + v^2 / 4 = 3v^2 / 4$
Therefore $v = \sqrt{4gh/3}$ [2]

(iv) $v_{top} = 2v$ while $v_{bottom} = 0$ [2]

(v) At any instant, KE(lin) = $(1/2)mv^2$ and KE(rot) = $(1/2)I\omega^2$
Substitute for I to get KE(rot) = $(1/2)x(1/2)mr^2x\omega^2$ = (1/2)KE(lin).
Hence, KE(lin) =2 KE(rot). [2]

(b) The block moves off with a mixture of linear and rotational motion.



The CM translates as a straight line while the block rotates with a constant angular speed about the CM. Eventually, friction brings the block to rest. [4]

QUESTION 5

(a) (i) The changing magnetic flux threading the coil when the magnet enters. [1]

(ii) Compared to the flux change at entry, the flux changes in the reverse sense when the magnet leaves the coil - so the 'scope signal reverses too. [2]

(iii) The instantaneous induced voltage is shown by the oscilloscope trace; this voltage is proportional to the rate of change of flux. The flux changes more rapidly when the magnet leaves the coil than when entering. Also, the flux change in each case is the same, which means that the peaks of induced voltage have the same area since

area $= \int Vdt = \int d\phi = \phi_{change}$ [2]

(iv) right to left [1]

(v) Eddy currents are induced in the tube wall adjacent to the falling magnet; these oppose the change and therefore oppose the motion creating them [2]

(b) (i) $12 - 4I_1 - 3I = 0$ [1]

(ii) $12 - 2(I-I_1) -5 -3I = 0$ which becomes $7 + 2I_1 = 5I$ [2]

(iii) $14 + 4I_1 = 10I$

$12 - 4I_1 = 3I$ from which we obtain $I = 2$ A and $I_1 = 1.5$ A [2]

(iv) In the 4Ω resistor the current is 1.5 A. Hence, the energy dissipated in 60 s is (I^2Rt): $1.5^2 \times 4 \times 60 = 540$ J [3]

(v) The 5V cell. [1]

QUESTION 6

(i) MGR 3 has the largest frequency change and hence the highest linear speed. The other two MGR's have the same, lower, linear speed.

→ MGR 3 has 2 units of lin. speed while MGR 2 and MGR 1 have 1 unit. [2]

(ii) MGR 1 has the shortest T ; only half the length of the others. Thus ω for MGR 1 is twice the other values:

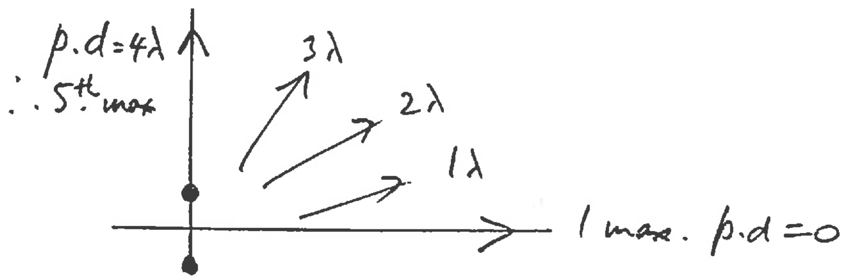
→ MGR 1 (2 units); MGR 2 and MGR 3 (1 unit). [2]

(iii) Use $v = \omega r$ to get $r = v/\omega$.

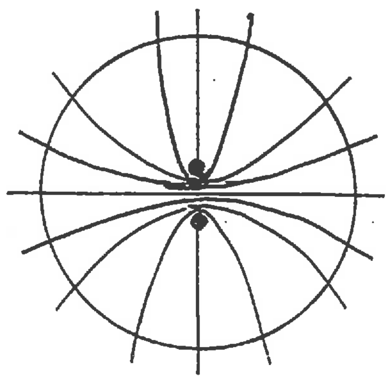
Hence for MGR 1 v/ω = 1/2 = 0.5 units
MGR 2 1/1 = 1 unit
MGR 3 2/1 = 2 units

→ Therefore MGR 3 has the largest r, then MGR 2 and then MGR 1. [2]

(b) With reference to the diagram, in the straight ahead direction - for which the path difference is 0 - there is a maximum.



In the sideways direction for which the path difference is 4λ there is another maximum. And for every wavelength difference in between these two directions there must be another max (at some angle). So there are three max. in between.



Adding around the circle gives a total of 16. [4]

(c) For the wire, oscillating in its fundamental mode, f = c/λ = c/2L

frequencies for tube 'a': $f_a = \frac{n_{odd}}{4}.\frac{c}{L}$. That is $\frac{c}{4L}, \frac{3c}{4L}, \frac{5c}{4L}$..etc NO MATCH

frequencies for tube 'b': $f_b = \frac{n_{odd}}{4}.\frac{c}{2L}$..................................NO MATCH

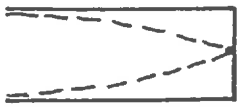
frequencies for tube 'c': $f_{c1} = \frac{c}{\lambda}$

where $\lambda = 2$ x (tube length) = $2L/2 = L$. Higher frequencies are integer multiples of this fundamental.

$\therefore\ f_{cn} = n\frac{c}{L} \Rightarrow \frac{c}{L}, \frac{2c}{L}, \frac{3c}{L},$.................................... NO MATCH

frequencies for tube 'd': $f_d = \frac{n_{odd}}{4}\frac{c}{L'} = \frac{n_{odd}}{4}\frac{c}{L/2} = \frac{n_{odd}\,c}{2L}$

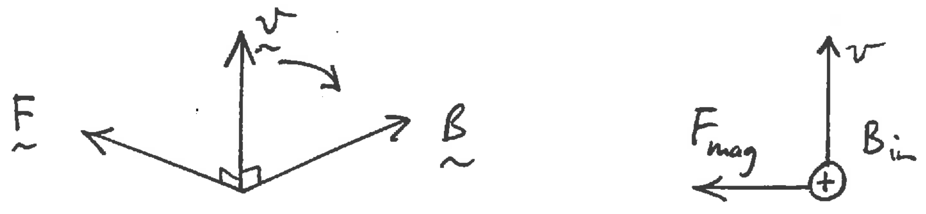
∴ tube 'd' has a resonant MATCH for n = 1 [6]



d

QUESTION 7

(a) (i) Of many rules the 'three perpendicular directions geometry' is as good as any.

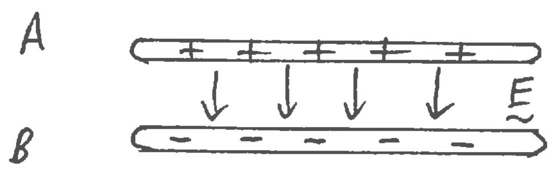


For this, the mantra is '***v*** turned to ***B*** advances a right hand screw'.

Hence, if *B* is into the page, a positive charge is bent as shown. But the charge here is negative so *B* must be out of the page. [1]

(ii) For circular motion the magnetic force provides the necessary centripetal force: $mv^2/r = Bqv$ Hence, $B = mv/qr$. [2]

(iii) To obtain a straight line path the magnetic force must be cancelled. This means that F_E points up for the upper straight-line section. Thus the charges must be negative on the inside plates (electrodes) as shown.



[2]

(iv) Equating forces we have $Eq = Bqv$ giving $v = E/B$ [2]

(b) (i) $F = BIL$ whence $10^4 = 10^{-5} \times I \times 1.8$ or $I = 5.56 \times 10^8$ A [2]

(ii) $R = \rho L/A$ or $R = 9 \times 10^{-8} \times 1000 / (40\ 10^{-4}) = 0.0225\ \Omega$ [2]

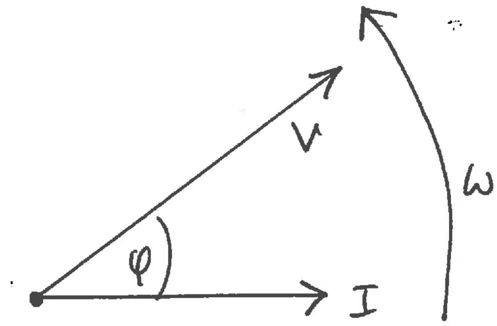
(iii) Each km of track dissipates energy as heat at the rate of $I^2R = 6.94 \times 10^{15}$ W where *R* is the resistance of one km of track. [2]

(iv) The rails repel each other (antiparallel currents) with a force per km of $F = (2x10^{-7}I^2L)/d = (2x10^{-7}x\,(5.56x10^8)^2\ x\ 10^3) / 1.8 = 3.43 \times 10^{13}$ N [2]

(v) The system is totally unrealistic. In the first place, there is not enough power generation capacity in NZ to drive just one axle; secondly, even if there were, the track would melt and simultaneously fly apart! [2]

QUESTION 8

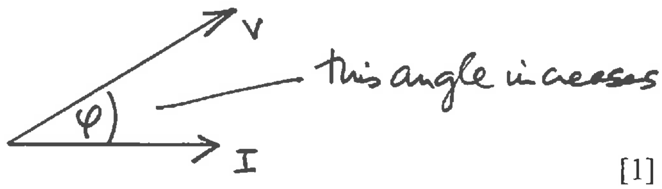
(a) (i)



[1]

(ii) $\tan \varphi = \dfrac{\omega L - \dfrac{1}{\omega C}}{R}$ [1]

(iii) The phase angle φ increases in the positive sense if L increases since, as the equation shows, $tan\varphi$ goes more positive.



[1]

(iv) The same result holds for C: If C increases the second term diminishes making the whole expression go more positive. [1]

(b) (i) Only L and C are in the circuit; the switch has shorted out R.
$\therefore V = I\,X$ where $V = 240$ V and $I = 2$ A; hence $X = 120\ \Omega$. [1]

(ii) $tan\varphi = X/R$ with $\varphi = 20$ degrees and $X = 120\ \Omega$. Hence $R = 329.7\ \Omega$. [1]

(iii) We are told in (ii) that the voltage lags the current; that tells us the capacitive reactance exceeds the inductive reactance. That is, $1/\omega C$ is greater than ωL so that the detailed answer to (i) is

$$\frac{1}{\omega C} - \omega L = 120.$$ [1]

(iv) The added capacitance has lowered the capacitive reactance to $1/2\omega C$ so the phase angle has moved more positive, from -20°to +10°.

Therefore, $tan\ \varphi = X'/R$ where $\varphi = 10$ degrees, $X' = \omega L - \dfrac{1}{2\omega C}$ and $R = 329.7\ \Omega$. Hence, $X' = 58.1\ \Omega$ [2]

(v) Combine this result with that from (i).

$$\frac{1}{\omega C} - \omega L = 120 \qquad \text{.............(A)}$$

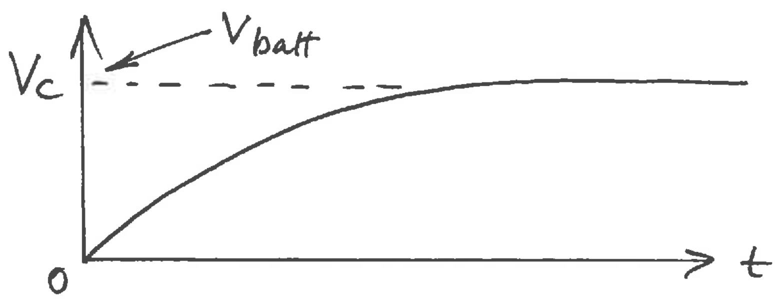
$$\omega L - \frac{1}{2\omega C} = 58.1 \qquad \text{.............(B)}$$

Written, one under the other, makes the next step clear:
Thus, (A) + (B) gives $1/2\omega C = 178.1$, that is,
$C = 1/(2 \times \omega \times 178) = 7.02\ 10^{-6} = 7.02\ \mu F$
Also, 2(B) + (A) = $\omega L = 236$. Hence $L = 236 / 400 = 0.591H$

[3]

(c) (i) $V_c = V_{batt} . (1 - e^{-t/RC})$ [2]

(ii)



[2]

(iii) $72 = 95 . (1 - e^{-0.5/RC})$.

That is $72/95 = 1 - 0.242 = (1 - e^{-0.5/RC})$

Hence $0.242 = e^{-0.5/RC}$

Take natural logs: $ln(0.242) = -1.42 = -0.5/RC$ Hence $RC = 0.352$

Thus $R = 2.35 \times 10^6\ \Omega$ since $C = 0.15 \times 10^{-6}$. [3]

QUESTION 9

(i) The least energy, E, required to eject an electron is 5.32 x 1.6 10^{-19} = 8.51 10^{-19} J. A photon of wavelength λ has energy $E = hc/\lambda$. Hence the longest wavelength which will eject an electron is

$$\lambda = \frac{6.63\times10^{-34}\times3\times10^{8}}{8.51\times10^{-19}} = 233\times10^{-9} = 233 \text{ nm.}$$ [3]

(ii) There is no electric field inside a metal container, charged or not. Therefore no dangerous electrical consequences will result from the photo-effect.

[1]

(iii) Photoemission will still occur, possibly of lesser extent. As well, a black surface absorbs radiation well and equally well radiates it - much better than a shiny surface. Thus the temperature of the capsule would rise higher in the sun's glare, and sink lower in Earth's shadow, than before. So it's a bad idea to paint it black. To keep an even temperature, a reflecting surface is required. [2]

(b) (i) The method assumes the C14 content of a living plant is kept constant by the combined effects of (1) 'breathing' atmospheric CO_2 (in which the C14 content is generated by cosmic ray collisions) and (2), the natural decay of the isotope. After death the C14 activity simply decays. A measure of the activity while living, and after death, is a measure of the decreased amount of C14 present and therefore the time since death. [2]

(ii) The activity per gram per minute is 0.0299 counts for the dead wood and 15.3 counts for the living sample.

Repeatedly dividing by two gives the number of half-lives thus:
15.3; 7.65; 3.82; 1.91; 0.956; 0.478; 0.239; 0.119; 0.059; 0.0299

That is 9 half-lives. [2]

(iii) 9 x 5730 ≈ 51 600 years. [1]

(c) (i) the principal quantum number [1]

(ii) the angular momentum is quantised: ang. mom = $L = \frac{nh}{2\pi}$ [2]

(iii) It is negative because the binding energy is defined to be zero when the electron and proton are widely separated, that is, at infinity. Since the atom is bound - which means it takes energy to effect a separation - the bound state must have lower energy than the energy of the infinitely separated pair. That is, the bound state has negative energy. [2]

(iv) $n = 3$ to $n = 2$. This is an energy change of $13.6\left(\frac{1}{4}-\frac{1}{9}\right) = 1.88$ eV.

[2]

(v) According to the Bohr model (and later sophisticated versions of same) NO change is expected since the Bohr model only requires opposite charges on the electron or the proton without worrying about which particle has which. (The physicists involved are looking for a difference - the slightest difference - because important theoretical issues are at stake.) [2]

Question 10

(1 mark each; 10 total; answers *in the vicinity* of the following are correct)

(i) 1000 km/h
(Actually near 920km/h)

(ii) 45 - 520 MHz
(Practicalities require the frequency range to be large: The signal from one locality often weakly penetrates into a neighbouring locality where, although too weak to be of use, it is sufficiently strong to be an 'interfering' nuisance. To overcome this problem, neighbouring transmitters use different frequencies. Another technique to separate the signals is to transmit, from the neighbouring aerials, using two polarisations differing by 90 degrees)

(iii) 140 mmHg
(This is equivalent to 2 m of water. A commonly measured parameter of the blood circuit, especially with the aged, the value can be higher and lower by about 50 mmHg.)

(iv) 1 - 1.5 tonne
(1000kg - 1500kg)

(v) 10 - 20 cents

(vi) 10 m

(vii) 1 kW/m^2 or 1000 W/m^2

(viii) 1.6 μm
(Easily and charmingly verified with a laser pointer, CD and a ruler)

(ix) λ = 550 nm; green
(The eye has evolved to readily detect this wavelength, a wavelength at which the solar intensity peaks.)

(x) 1 kg/m^3
(Actually 1.29 kg/m^3)

(xi) 200 °C
(more or less)

(xii) 133 - 233 MHz

(xiii) 7000 MW

(xiv) 20 kHz
(This value is for a child; it drops with age)

(xv) 1 T
(With special material and a thin air gap, the highest value is about 2T. A permanent magnet has much less than this, maybe a tenth, but new materials have impressive fields. Something to map with a Hall probe.)