EXAMINERS' REPORT ON 2006 TERTIARY ENTRANCE EXAMINATION

SUBJECT: PHYSICS

STATISTICS

Year	Number Who Sat	Non-Examination Candidates	Did Not Sit
2006	2778	22	159
2005	3021	29	170
2004	2975	33	208

This Examiner's report is written by the Chief Marker in collaboration with the Chief Examiner to comment on matters relating to the Physics Tertiary Entrance Examination. The opinions and recommendations expressed in this report are those of the Chief marker and Examiner and not necessarily representative of, or endorsed by, the Curriculum Council.

The Marking Guide provided at the end of this report was prepared for markers and has been substantially amplified by discussions held in the pre-marking meeting. It is not intended as a set of model answers, and is not exhaustive as regards alternative answers. Some of the answers are less than perfect, but represent a standard response that the examiners deemed sufficient to earn full marks. Teachers who use this guide should do so with its original purpose in mind.

SUMMARY/ABSTRACT

The markers felt that the paper gave good, clear instructions to the students and provided ample discrimination, with the early part of most questions in section B being accessible to all students. A variety of question styles was used. The marking of the paper was mostly straightforward with markers finding it easier to mark than the 2005 paper.

The format of the paper was the same as last year except that there were only seven questions in Section B, as opposed to eight in 2005. The majority of the students appeared to complete the paper in the time allowed.

The 2006 mean raw exam score of 55.48 was slightly more than that in 2005 (52.2), and the standard deviation of 16.47 was slightly less than that of 2005 (17.2). This suggests a slightly easier paper than last year with a slightly narrower spread of marks. This was reflected in the reduced maximum mark of 92% in 2006 compared with 96% in 2005.

Significant figures were again an issue with many students using an inappropriate number. This seems to be getting worse. Students are penalised on this in all questions that require an estimate.

GENERAL COMMENTS

Firstly, thanks must go to the examining panel for their dedication in producing a paper that was well received by students, teachers and markers. The major criticisms were:

1. that there was not enough space left below some questions to adequately cater for the different size writing styles or for a more complete answer. This seems to be an ongoing problem.
2. that there was no extra paper in the booklet if students needed more space or had to redo a question.

These two points were criticisms of last year's layout.

The design of the paper this year was consistent with the format used in 2005. The 2005 paper was considered a little too hard and it was intended that the level of difficulty be reduced for this paper. This was achieved but some questions proved more difficult than expected. Conceptual problems were encountered in: maximum emf calculations, application of torque in dynamic situations, application of circular motion involving friction. The two other major areas for concern were the continued poor use of diagrams (These are often essential in order to clarify understanding or provide correct working.), and the ability to derive a given equation.

1. There was a deliberate attempt to vary the question types and thus the way in which information was presented to students and also in the way in which students were required to answer the question. A brief description of the types of question formats for Part A is given in the section titled "**Breakdown of Paper**".

2. Part A contained three items in which a multiple choice question was used, but for which the student was also asked to explain their choice of answer.

3. As in 2005, there was no choice of alternate-context questions, but instead questions 1 in Part A and 6(d) in Part B offered students the choice of answering in relation to specific contexts.

4. In parts B and C, most questions had an initial short, low value part-question to assist all students in starting the question and to focus their attention on the stimulus material provided. This was done in order to reduce the likelihood of them misinterpreting the question.

5. There was a deliberate attempt to include questions or part-questions that specifically tested students' conceptual physics understanding.

6. As in 2005, a question on experimental design and the analysis of data was included in Part C rather than Part B or Part A. This question also accommodated students who preferred to formulate a solution using manual graphing as well as those who preferred to use a graphics calculator. This question also provided a numerical value that students might use should they have been unable to complete the earlier parts of the question.

Breakdown of Paper

This breakdown is not always easy to ascertain because many questions, particularly in Parts B and C, cover several areas and/or contexts.

1. The approximate mark allocation for different answer types is given below. The figures are percentages.

	Section A	Section B	Section C	Total
Numerical answers	13	28.5	10.5	52
Written answers	11.5	15	5	31.5
Graphical or diagrammatic	4	5.5	4.5	14
Multiple choice answers	1.5	1	--	2.5
	30	50	20	100

2. On setting the paper, the breakdown by area of study in comparison with the syllabus requirements is given below. Figures for the 2004 paper are also provided. The figures are percentages.

Topic	**Syllabus requirement**	**2006 paper**	**2005 paper**	**2004 paper**
Sound Waves	15-20	18	18.5	15
Electric power	20-30	21	21	30
Movement	20-30	27.5	20	23
Structures and Materials	15-25	16.5	21	20
Atomic Physics	10-20	17	19.5	12

3. Breakdown by parts of the paper was:

	Section A	Section B	Section C	Total
Sound Waves	4	5.5	8.5	18
Electric power	5	8.5	7.5	21
Movement	8	15.5	4	27.5
Structures and Materials	10	6.5	--	16.5
Atomic Physics	3	14	--	17

The following illustrates the range of ways in which students were required to provide answers:

Section A: Short Answers

1. Respond to a contextual written question requiring relatively straight-forward answer.
2. Calculate a relatively simple answer based on interpreting a fairly complex real-world context situation.
3. Interpret a diagram, choose a multiple choice answer and explain the choice.
4. Interpret two diagrams and provide a written response. Complex situation but relatively simple answer required.
5. Translate information from description and a diagram to a vector diagram and perform a calculation.
6. Choose a multiple choice answer and explain the choice using calculations or explanations.
7. Interpret written information and diagram and formulate a written response.
8. Estimate distances or angles from a photograph and calculate an answer.
9. Explain an observation with a related calculation from given data.
10. Interpret diagram and calculate an answer for which a 'formula' was not readily available.
11. Draw a diagram to illustrate a concept and explain the application.
12. Transform data and use this in a simple calculation.
13. Draw an accurate diagram to illustrate understanding of a complex application.
14. Interpret written information and diagram, choose a multiple choice answer and explain the choice.
15. Interpret two diagrams and provide a mixed calculation/written response. Complex situation and application of physics concepts.

Section B: Problem Solving

This again contained a set of questions that provided the students with a variety of methods in which to respond (descriptive, graphically, mathematically) and this should be retained for future years.

Section C: Comprehension and Interpretation

This also followed last year's format in that one question was based on an experimental situation with data analysis and interpretation. This question also involved drawing vector diagrams, an explanation of the physics principles involved and a derivation of a given equation. The second question involved the comprehension of a complex physics article and the interpretation of graphical data. Students had to read graphs, do simple calculations, draw interpretive diagrams and extract information. These questions provided a good mix of skills.

COMMENTS ON SPECIFIC QUESTIONS.

These comments are offered by the Chief Marker after consultation with selected individual markers and the Chief Examiner. Total number of candidates was 2778.

SECTION A: ***Short Answer***

Q1 Attempted 2736 Mean 76%

This was a good, easy start to the paper. Students understood beats very well with less clarity shown for diffraction. Many students discussed how beats occur but not the conditions necessary, with a number not providing an example which was clearly asked for. Some did both diffraction and beats. These latter two points indicate that not all students read the question thoroughly enough.

Q2 Attempted 2723 Mean 83%

This question was done well with the concept of open pipes well understood. Very few used closed pipe formulae with the major error being an incorrect value for the speed of sound. Weaker students used the speed of light.

Q3 Attempted 2765 Mean 46%

This proved to be a difficult question. Students understood that moments were involved but applied them poorly to this practical situation. Many students confused the length of the screwdriver as the distance involved in the formula $\tau = r \times F$. This indicates little practical knowledge of how a screwdriver works. Often the choice of P or Q did not match the reasons given.

Q4 Attempted 2697 Mean 50%

Students who made the analogy with an arch gave a very good response usually only leaving off a minor point. Those that did not, generally gave poor responses with very few getting above one or two marks.

Q5 Attempted 2615 Mean 46%

This was done poorly for what should have been a simple vectors problem. Most calculated the angle correctly but did not draw a proper vector diagram. The majority of students used $\boldsymbol{F = T\cos\theta}$ rather than $\boldsymbol{F = 2T\cos\theta}$ due to the lack of a proper vector diagram.

Q6 Attempted 2768 Mean 72%

This was a very straightforward question which proved to be one of the easiest questions in section A. Most students who calculated the acceleration of gravity at the distance of Everest gained full marks. Weaker students were under the misconception that gravity was the same everywhere on Earth and did not change with height.

Q7 Attempted 2752 Mean 42%

Many students were confused by this question referring to the centre of mass and stability but missing the point that toppling was due to an unbalanced torque. Very few mentioned that the larger force applied at M would overcome friction and result in sliding.

Q8 Attempted 1985 Mean 37%

This had the lowest attempt rate on the paper and the majority who attempted the question had very little idea. This was in fact the simple idea that the angular arc produced by the starlight was a proportion of 24 hours. Those who saw this usually received full marks. Very few took accurate measurements.

Q9 Attempted 2744 Mean 46%

Students answered this question very poorly. The information given was not used correctly and very few correctly applied transformer and efficiency formulae.

Q10 Attempted 2728 Mean 60%

This was answered well with the main error being that students did not draw vectors on the circular motion diagram and as a result, did not combine the forces together correctly to find the reaction force. A disappointing number of students simply calculated the centripetal force.

Q11 Attempted 2629 Mean 66%

The process of fluorescence was generally well understood but the diagrams that were drawn did not illustrate the process clearly with often many lines drawn or only one. Many students who gave good explanations did not justify their reasoning with appropriate equations.

Q12 Attempted 2746 Mean 81%

This proved to be the second easiest question on the paper. The main error was in calculating the cross-sectional area. Of those who made mistakes, the main one was using the diameter instead of the radius. Weaker students used $A=2\pi r$ when calculating cross-sectional area.

Q13 Attempted 2737 Mean 43%

Students' ability to draw accurate and neat diagrams was not very good with many having field lines meet or cross. Quite a few students did not realise the iron would become magnetised. Those that did, either did not draw the field at large distances, or did not show the short range field.

Q14 Attempted 2712 Mean 52%

This was a simple but discriminating question. Many students got the right hand palm rule concept but did not reverse it for negative charges. A surprising number of students did not mention the electric field.

Q15 Attempted 2727 Mean 24%

This was supposed to be a difficult question and proved to be even harder than expected. Most students chose the circular path (b), with the idea that with a large velocity and small radius you generate a large force, not realising that this is the force needed which must be supplied by friction. Very few stated that there is a limiting frictional force beyond which the car slides. Those that chose the straight breaking path (a) tended to justify this by talking about rollover, perhaps a reflection on the comprehension article from a previous TEE paper, and missed the point about friction. Very few chose a mathematical solution but the better students that did, gave excellent answers.

SECTION B: *Problem Solving*

Q1 Attempted 2773 Mean 68%

This was intended to be a fairly straightforward question which it proved to be. The major problem here was that many students do not know how to calculate areas of spheres or hemispheres. The meaning of pitch and ultrasonic was well explained and calculations involving $v=f\lambda$ were well done. Weaker students used the speed of light instead of sound and could not calculate intensity properly.

Q2 Attempted 2736 Mean 73%

Generally this question was handled well and proved to be the easiest question in Section B. Students showed an excellent grasp of centripetal force and acceleration and the rearrangement of these formulae. The major errors in this question were caused by poor conversion of units, particularly ng to kg. Most students realised that the greatest speed and force occurred at the greatest distance if the frequency is constant.

Q3 Attempted 2772 Mean 62%

Students demonstrated a good understanding of equilibrium and the principle of moments. Surprisingly, conservation of forces was not well applied with a number of students not using this to find the second force. In part (c) students identified the sections of the board under tension and compression extremely well but explained the reason why the board bends poorly. Many did not address the second part of the question regarding why it hardly bends at all; **not addressing all of a question was somewhat of a trend in the paper**. Properties of materials were not explained well with many using terms incorrectly. It was apparent that many students do not fully understand the correct terms and their associated properties.

Q4 Attempted 2761 Mean 49%

Electromagnetic principles usually cause students some difficulty and this was evident in this question. Most students included some of the factors that contribute to torque but not all. Weaker students included irrelevant factors and did not appreciate that current is the variable most easily controlled. Although the majority of students chose graph B many students chose A which involved a negative torque and therefore, should have been discounted as an option. Graph C is not a complete revolution. Part (c) involved a number of calculations. Most students gained some marks with the most common error being the equating of power to kinetic energy. This is a fundamental error in basic physics which is of some concern. Answers to part (d) were not clearly stated and, although, most students understood that energy was being stored in the batteries, many thought that it was being used directly in the motor to save energy! Safety factor was the common answer for mechanical breaks but very few realised that the electromagnetic breaking ability reduced with speed. Part (e) was supposed to be a more challenging question and this proved to be the case as it was one of the most badly handled questions on the paper. In hindsight, there were perhaps too many factors to estimate, namely, the diameter of the buses wheel connected to the motor, the size of the motor, the shape of the motor and the number of turns. Only a handful of students gained full marks and this would have been even less if only maximum emf could attract full marks. Generally, the better answers involved a quarter turn method which is an average emf not maximum. The stock answer simply used E = Blv with the numbers plugged in from the question. This is related to the maximum but there seemed little understanding demonstrated of this fact. The better students did estimate the size of the wheels to determine a frequency for the motor but many forgot to estimate the number of turns. One major problem with this question is that reasonable estimates seem to give a very unrealistic value for the emf which caused some students to doubt their working. There seems to be general lack of understanding between average emf and maximum emf in a generator.

Q5 Attempted 2730 Mean 69%

This question was well answered by the majority of students with the majority of errors related to clarity of explanations rather than misunderstandings. In part (a) students related energy to frequency but many did not go on to relate wavelength to penetrating power. Although intensity is an important property related to the probability that a cell will be ionised, this was not stated by the students. In part (b) the calculation was done well, with only a few forgetting to convert electron-volts to joules, but a surprising number could not read the chart, given in the data sheet, correctly to identify the region of the electromagnetic spectrum to which the value obtained belonged. In part (c) many students did not realise that the excess energy was turned into kinetic energy of the electron. Although quantisation of energy levels and photon energy were well understood, few students put both of these factors down to explain why only photons of specific energies are absorbed. Some students, despite showing that microwaves had insufficient energies to damage cells, still said they would cause cancer.

Q6 Attempted 2705 Mean 60%

The main difficulty that this question posed for the students was in the drawing of clear magnetic field diagrams. Few clearly showed a uniform field in the triangles and even less showed a progressively increasing field strength in the rectangular region, although many stated this in their answer. The simple calculation in part (b) was well handled. Contexts given were generally valid but descriptions often lacked clarity.

Q7 Attempted 2750 Mean 61%

Part (a) was generally well done but many students did not set their working out in a clear and logical manner. Part (b) was a very straightforward calculation but a surprising number of students did not use an initial vertical velocity of zero when applying $s = ut + 0.5\ a\ t^2$. Part (c) required some careful consideration of the graphs and the conditions necessary. Many did not choose the correct angle as they did not realise the range should be just over 80m.

SECTION C: *Comprehension and Interpretation*

Q1 Attempted 2760 Mean 40%

This proved to be one of the more difficult questions on the paper. It highlighted some weaknesses in student skills. These being the ability to draw clear vector diagrams which include all the forces. Many students forgot to include the normal force or included components or added forces such as friction which was specifically stated to be zero. Very few explained why the rod reached a constant velocity with any clarity. A large number of students talked about friction which, although used as an example in the article, was irrelevant for this question. Part (b) was the second hardest question on the paper and demonstrates a clear weakness for most physics students to construct a logical derivation of an equation. This is an important skill that should be reinforced. Part (c) demonstrated that many students do not know how to use their graphics calculator to determine lines of best fit. Typical errors include; transposing of variables; failure to define variables used in equations; incorrectly reading the screen (missing the exponential power of the constant). Hand drawn graphs were generally well done, so students choosing this option, had an advantage but with the disadvantage that it was more time consuming. Interpretation of the gradient, units for variables and applying these to the theoretical equation were all poorly done. Many just used values from the table in part (d) and, often incorrectly, which gained no marks. Less than 5% of students realise that a gradient has units that are given by the ratio of the units on the two axes.

Q2 Attempted 2656 Mean 48%

This was a very difficult comprehension piece but many students did well in interpreting the information given. The diagram in part (a) was poorly drawn across the board with most students unable to represent their interpretations diagrammatically. Although the second part of this question involved putting values into the appropriate equation students made errors by not using S.I. units or putting down too many significant figures. Part (b) involved using $v = 2\pi r/T$ and most students used this but did not always choose appropriate values from the text. The second part which involved explaining where the most damage would occur was not well done with many regurgitating the paragraph from the text about the serious damage done to the surface. Good students used the value from the first part to explain that the most damage is done to the extremities of the blade. In part (c) values from the graph were often not accurately estimated and many thought that the time of collapse was the total time from when it was created. Many students stated that a shock wave stuns or kills the prey but failed to recognise the significance of the pressure change.

ISSUES FOR THE SYLLABUS COMMITTEE TO CONSIDER

No major difficulties were faced. However some areas of concern may be highlighted.

- As stated last year, students continue to have trouble distinguishing between average and maximum values for generated emfs, in particular the significance of rms values. Given the common occurrence of this term some thought should be given to including this in the syllabus.

- The issue of **significant figures** seems to be worsening. Students do not appreciate the importance of significant figures and the information they convey about the accuracy of the data or the final value calculated. Many gave a completely inappropriate number of significant figures to estimate questions and there is still this desire to quote answers to two decimal places. This shows little understanding as the number of decimal places changes depending on the prefix chosen for the unit.

- The use of graphics calculators in data analysis also needs to be addressed. Students are not using them correctly and questions involving them to determine lines of best fit have traditionally been answered poorly. Drawing graphs and interpreting data from them is a different skill to using a graphics calculator and interpreting the information presented. There should be a clear direction as to the skills that need to be learned.

William R Biffin
December 2006

2006 Examining Panel
Chief Examiner: Dr Shelley Yeo
Deputy : Dr Dmitry Fursa
Third Member: Wayne Keady

Chief Marker: Mr Bill Biffin

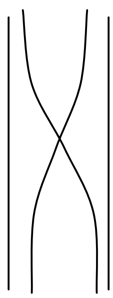
PHYSICS 2006 MARKING GUIDE

SECTION A: Short Answers **(60 Marks)**

1.

Beats	Diffraction	
Example:	Example:	[2 marks]
Conditions: Two waves with similar frequencies interact.	Conditions: Wave fronts passing a barrier or through a gap with width similar to wavelength.	[2 marks]

2.



For lowest frequency: $L = n \lambda / 2$ where $n = 1$

$\lambda = 2 \times 3 = 6$ m [2 marks]

$$f = \frac{v}{\lambda} = \frac{346}{6} = 58 \text{ Hz} \quad \text{(or 60 Hz)}$$ [2 marks]

(closed pipe: max 3 marks if done correctly.)

(no working = zero)

3. Q is best [1 mark]

…because there is a greater torque for same applied force (diagram)

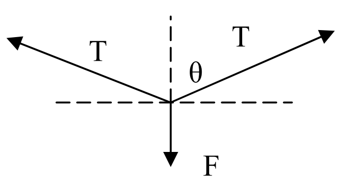
Torque is proportional to the radius of the handle (not length), $\tau = r \times F$ [3 marks]

4. Water exerts pressure (hence a force) on the dam wall.

The dam wall in A is under compression. The dam wall in B is under tension. [2 marks]

Brick/concrete has high compressive strength, but a low tensile strength, which may result in cracks (weakening the whole structure—leading to collapse) [2 marks]

5.



$\theta = \tan^{-1}(6/0.5) = 85.2°$ (or compliment 4.76°) [1 mark]

$F = 2\, T \cos\theta$ [2 marks]

$$T = \frac{800}{2\cos 85.2} = 4.82 \times 10^{3}\ N \quad = 4800\text{N}$$ [1 mark]

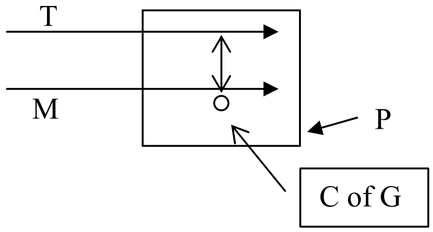
6. Answer = A [1 mark]

Explanation can be verbal and/or mathematical

g at any point depends on the square of the distance from that point to the centre of the earth (**g is proportional to $1/r^2$**). [1 mark]

The height of Mt Everest (about 9000m) is very much less than the radius of the earth. The two distances are about 6409000 m and 6400000 m, and so g will be not very different from what it is at the earth's surface. (**g** $_{\text{Everest}}$ = 99.7% **g** $_{\text{sea level}}$) [2 marks]

7.



T acts further from the pivot point ,P, than does M. [1 mark]

T will tend to produce a larger torque (causing the chair to rotate about its leg) as it is further from the pivot. [2 marks]

Whereas M will provide enough force to overcome friction but not enough torque to counter the torque from C of G. [1 marks]

8. The earth rotates once in 24 hours, so a complete 360° star trail will represent 24 hours (15° represents 1 hour). [2 marks]
Any of the arcs shown cover approximately 25°-27°, which represent a time of about 100-108 minutes. Hence shutter was open about 100-110 minutes. [2 marks]
Since only an estimate may use values from **20° to 30°** to give times of **80 to 120** minutes

9 a) $P_{in} = P_{out}$
so $V_1I_1 = V_2I_2$ hence as voltage is changed, current must also be changed. [2 marks]

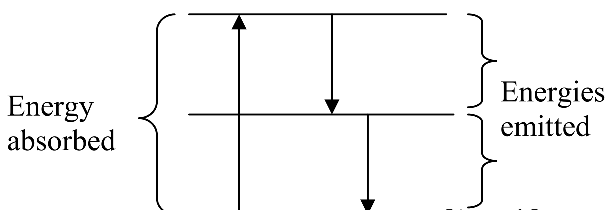
9 b) $P_{out} = 0.90 \text{ x } P_{in}$
$50 = 0.90\ (240)\ I_{in}$
Hence $I_{in} = 0.23$ A. [2 marks]

10 a) $F = mg = 1.25 \text{ x} 10^3 \text{ x } 9.8 = 1.22 \text{ x } 10^4$ N [1 mark]

10 b) $$F = mg - \frac{mv^2}{r} = 1.25\times10^3(9.8) - \frac{1.25\times10^3(20)^2}{80} = 6.00\times10^3\ N$$ [3 marks]

1 1 1

11



[1 mark]

Wavelength is longer [1 mark]

Energy of emitted photons is less than energy of absorbed photon. [1 mark]

Since $v = f\lambda$ and $E = hf$
If E is less, f is less and λ is larger (i.e. wavelength is longer). [1 mark]

12 Area = $\pi r^2 = \pi(1 \text{ x} 10^{-3})^2 = 3.14 \text{ x } 10^{-6}$ m^2 l = 30 x10^{-2} m [1 mark]

$$Y = \frac{F/A}{l/\Delta l}$$

[3 marks]

$$\Delta l = \frac{Fl}{YA} = \frac{250(30\times10^{-2})}{(5.04\times10^{9})(3.14\times10^{-6})} = 4.74\times10^{-3}\ \text{m}$$

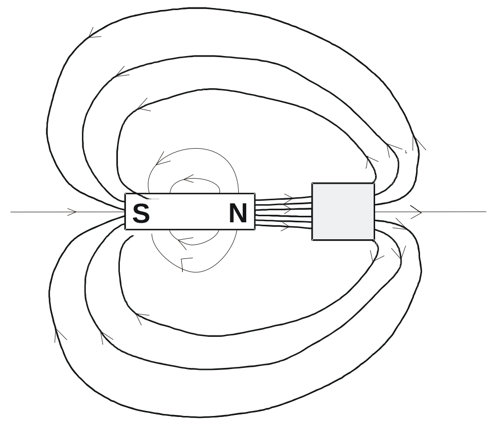
1 1 1

13

2 soft iron becomes magnet
(flux concentrated through iron)

2 overall shape - near field + large
scale field

field lines touching subtract one mark



[4 marks]

14 Answer A [1 mark]
Electric field is towards the right so force on electrons due to electric field is to the left. [1 mark]
Magnetic field is to the right, so force on moving charge due to magnetic filed is upwards.
(right hand palm rule) [2 marks]
The resultant force will direct the beam towards quadrant A.

15 Answer A [1 mark]
The force that prevents the car hitting the wall will be the force (or component of it) that acts perpendicularly away from the wall.

For situation (a), this force is provided by braking the car. 1

For situation (b), this force is provided by centripetal force only (or more correctly, the component of this force acting perpendicularly away from the wall). Initially, this component is zero, but is increases to the full centripetal force when the car is parallel to the wall. 1

Hence, the centripetal force needed for situation (b) would have to be much greater than the braking force for situation (a) for it to have an equal effect in preventing the car from hitting the barrier. 1

OR **Calculation** might involve using:

(a) loss KE = $F_b.s$ $F_b = m v^2 / 2s$ 1

(b) $F_f = m v^2 / s$ 1

Thus $F_b = F_f / 2$ This suggests that the braking force need only be half the centripetal force.
[3 marks]
1

SECTION B: Problem Solving **(100 Marks)**

Question 1	[**10 marks**]

1(a) High pitch is a high frequency sound [1 mark]
Ultrasonic means that the pitch is so high that it can't be heard by humans [1 mark]

1(b) $v = \lambda f$ $346 = \lambda\,(18 \times 10^3)$ [2 marks]
$\lambda = 0.019$ m (1.9 cm) [1 mark]

1(c) P = E x t Assume area = $2\pi r^2$ a hemisphere 2
but may use sphere $4\pi r^2$ (1mark only)

$$Intensity\ at\ 3m = \frac{P}{A} = \frac{5}{2\pi 3^2} = 8.84x10^{-2}\ Wm^{-2}$$ 1

$$2\ 'mosquitos' = 0.177\,Wm^{-2}$$ 1 [4 marks]

$$dB = 10\log\frac{0.177}{10^{-12}} = 112dB$$

(109dB for a sphere) [2 marks]

Question 2	[**13 marks**]

2(a) 4500 rpm = 4500/60 Hz = 75 Hz 1 r = 0.10 m 1 [2 marks]

$$v = \frac{s}{t} = \frac{2\pi r}{t} = 2\pi(0.10)75 = 47.1\,ms^{-1}$$ [2 marks]

1 1

2(b)
$$a = \frac{v^2}{r} = \frac{(47.1)^2}{0.1} = 2.22 \times 10^4\ ms^{-2}$$ [3 marks]

1 1 1

2(c)
F_{max} = 8 mN = 8 $\times 10^{-3}$ N 1 m = 89 ng = 89 $\times 10^{-9}$ g = 89 $\times 10^{-12}$ kg 1 [2 marks]

$$g = \frac{F}{m} = \frac{8 \times 10^{-3}}{89 \times 10^{-12}} = 8.99 \times 10^7\ ms^{-2}$$ 1 [1 marks]

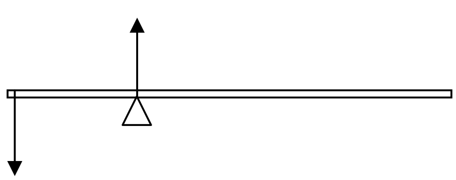
$$v = \sqrt{rg} = \sqrt{0.1(8.99 \times 10^7)} = 3000\ ms^{-1}$$ 1 [1 marks]

$$f = \frac{v}{2\pi r} = \frac{3000}{2\pi(0.1)} = 4.77 \times 10^3\ Hz = 2.86x10^5\,rpm$$ [2 marks]

1 1

Question 3	[**16 marks**]

3(a)



[2 marks]

3(b)

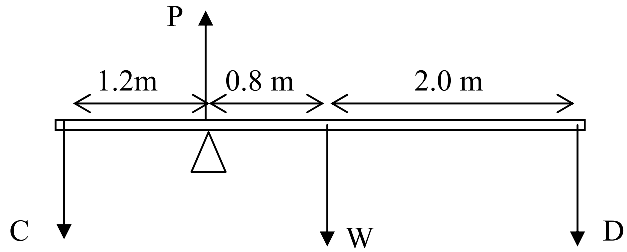


diagram with correct distances [1 mark]

Board is in equilibrium therefore Σ CWM = Σ ACWM 1

Taking moments about P:

$$W(0.8) + D(2.8) = C(1.2)$$

$$(120)(9.8)(0.8) + (62.5)(9.8)(2.8) = (C(1.2) \quad 1$$

$$C = 2.21 \times 10^4 \text{ N} \quad 1$$

[3 marks]

$$\Sigma F_{up} = \Sigma F_{down}$$

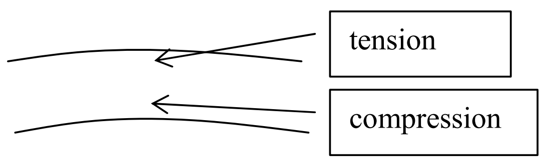
$$P = C + W + D \quad 1$$

$$= 2.21 \times 10^4 + (120 (9.8) + 62.5 (9.8)$$

$$= 4.00 \times 10^3 \text{ N} \quad 1$$

[2 marks]

3(ci)



[1 mark]

[1 mark]

3(cii) When standing, the force acting on the end of the board equals the weight of the diver [1 mark]

When the falling diver lands on the end of the board, the board must exert extra force to decelerate the diver to rest (W = Fs). This force is related to the restoring force in the deformed board.

The board is deformed as it absorbs the KE of the falling diver. The KE is converted to PE in the board. [2 marks]

3(ciii) Factors that might be considered include:

- Breaking stress of material (should be high enough so board does not break)
- Young's Modulus—not too high (board won't bend enough) nor too small (boards will bend too much).
- Density of board (would affect the overall weight and hence force on P and C)

[3 marks]

Question 4	[**17 marks**]

4(ai) torque = 2r (I l B) N = 2 NIAB hence size of motor (radius and length of armature) or area
current (I)
magnetic field strength (B)
number of turns (N) [2 marks]

4(aii) only current (I) [1 mark]

4(b) Answer B 2 Answer C 1 [2 marks]

4(c) Power output $= 0.68 \times 200 \times 10^3$ W $= 136 \times 10^3$ W 1 [1 mark]

$$p = \frac{KE\ gained}{t} = \frac{mv^2}{2t} = \ 544\ kJ \quad 1$$

$$v_{\max} = \sqrt{\frac{2Pt}{m}} = \sqrt{\frac{2(136\times10^3)4}{4.4\times10^3}} = 15.7\ ms^{-1}$$

1 1 [3 marks]

4(di) Without regenerative braking, all of the KE of the bus is lost to heat each time it brakes. The heat is dissipated. With regenerative braking, at least some of this KE is re-captured in the form of chemical (potential) energy and is then available for later re-conversion to KE. [2 marks]

4(dii) Rapid/emergency braking might be required. **(low speeds insufficient force)** [1 mark]

4(e) Three assumptions are needed—number of turns (N), shape of armature (r) and diameter of wheel.
60 km/h = 16.7 ms^{-1} Estimate N = 100 turns, rectangular coil length 0.8m and d_{wheel} = 1m
[1 mark]

frequency of motor = frequency of wheel since there is no gearing.

$$v = \frac{2\pi r}{t} = 2\pi rf \quad \therefore\ f = \frac{v}{2\pi r} = \frac{16.7}{2\pi 0.5} = 5.3Hz$$ [2 marks]

V_{max} = 2NBlv = 2πBANf = 2πx2.0x0.7x0.8x100x5.3 = 3.7kV [2 marks]
(This is far too high as it cannot exceed the applied voltage: the field given is unusually high and the motor dimensions are very big)
or Quarter turn method: (This only gives an approximate average and therefore is not a maximum)

$$t = \frac{T}{4} = \frac{s}{4v} = \frac{2\pi r}{4v} = \frac{2\pi(0.5)}{4(16.7)} = 0.047s$$ [2 marks]

$$V_{avg} = \frac{-N\Delta\Phi}{\Delta t} = \frac{NBA}{t} = \frac{100(2.0)(0.7x0.8)}{0.047} = 2.4\ kV$$ [2 marks]

Question 5	**[12 marks]**

5(ai) properties = frequency and intensity (or sufficient **energy** and small enough **wavelength** to be able to penetrate tissues without being absorbed) [2 marks]
5(aii) Yes, they are very high energy and have a small enough wavelength to penetrate the body [1 mark]

5(bi) $\mathrm{E} = \mathrm{hf} = \frac{\mathrm{hc}}{\lambda}$ 1 [1 mark]

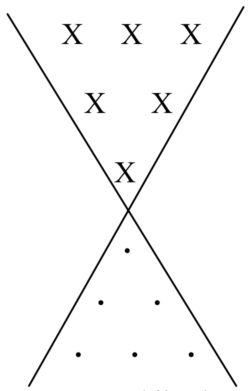
$$\lambda = \frac{\mathrm{hc}}{\mathrm{E}} = \frac{(6.63\times10^{-34})(3\times10^8)}{32(1.6\times10^{-19})} = 3.89\times10^{-8}\,\mathrm{m} \quad \approx 4\times10^{-8}\,\mathrm{m} = 40\mathrm{nm}$$ 1 1 [2 marks]

5(bii) ultraviolet 1 [1 mark]

5(ci) Electrons only absorb energy when they are promoted to a higher energy state. Therefore they will only absorb photon energy that is equivalent to the difference between energy states (levels). Since photon energies are quantised only those of specific energy will be absorbed. [2 marks]
5(cii) The energy appears as KE of the ejected electron (and eventually dissipated as heat in tissues). [1 mark]
5(ciii) Unlikely as microwaves can't cause ionisation of atoms in the tissues—energy per photon is too low. [2 marks]

Question 6 [**16 marks**]

6(ai)



Dots at the bottom, crosses at the top [2 marks]

Equally spaced [1 mark]

6(aii) Forces act while electron moves in field
Force is perpendicular to the velocity causing it to move in arc in plane of paper
The longer the distance in the field, the more curve (displacement from original path), and therefore outer electrons deviate more than those nearer the middle. [3 marks]

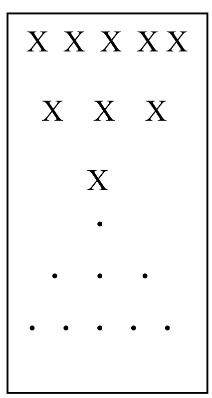
6(b)

$$F = qvB$$

$$B = \frac{F}{qv}$$ [2 mark]

$$= \frac{4.59 \times 10^{-4}}{(1.6 \times 10^{-19})(2.05 \times 10^{6})} = 0.14 \text{ T}$$ [2 marks]

6(c)



Dots at the bottom, crosses at the top [1 mark]

Fields stronger at the outer parts [2 marks]

6(d) Contexts

Sunlight & starlight e.g. Formation of auroras as charged particle enter the earth's magnetic field (brief description)	Medical applications e.g. Cyclotrons CRTs using magnetic fields (brief description)	Domestic/industrial applications e.g. CRTs using magnetic fields Mass spectrometer (brief description)	[1 marks] [2 mark]

Question 7	[**15 marks**]

7(a) $v_H = 40\cos 60^o$ $v_V = 40\sin 60^o$ [Students may use $h = \dfrac{v_0^{\,2}\sin^2\theta}{2g}$]

$$v^2 = u^2 + 2as$$

$$s = h = \frac{v^2 - u^2}{2g} = \frac{0 - (40\sin 60^o)^2}{2\times(-9.8)} = 61.2m \quad (\text{max } \textit{height above nozzle})$$ [2 marks]

$$v = u + at$$

$$\therefore t = \frac{v-u}{g} = \frac{0 - 40\sin 60^o}{-9.8} = 3.53s$$

[Students may use $R = \dfrac{v_0 \sin 2\theta}{g}$]

$$v = \frac{s}{t}$$

$$s = R = v_H t = 40\cos 60^o \times 2 \times 3.53 = 141m \quad (\textit{range})$$

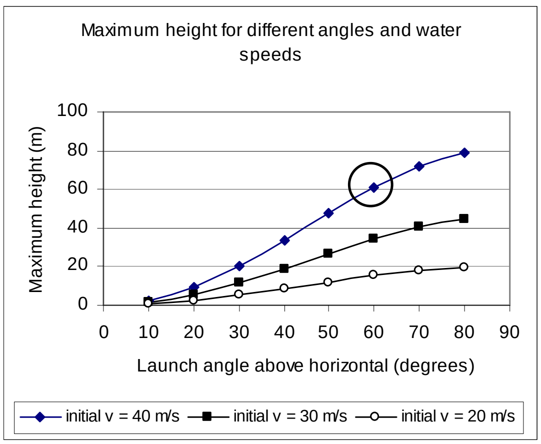
Assume height of nozzle negligible [2 marks]

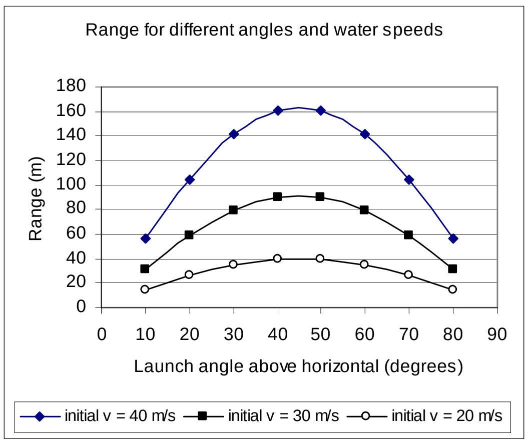
7(b) $s_H = 150\text{m}$ $v_H = 22\ \text{ms}^{-1}$

Horizontal: $v = \dfrac{s}{t}$ hence $t = \dfrac{s_H}{v_H} = \dfrac{150}{22} = 6.82\text{s}$ [2 marks]

Vertical: $s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(9.8)(6.82)^2 = 228\text{m}$ (= minimum height) [3 marks]

7(ci)





[2 marks]

7(cii) Best angle = 60° Best velocity = 30 ms^{-1} [2 marks]

Explanation may include any of the following:

Maximum height should be around 35m

Launch speed = 20 ms^{-1} won't reach required height

Launch speed = 30 ms^{-1} but angles ≤ 50° and ≥ 60° won't reach required height

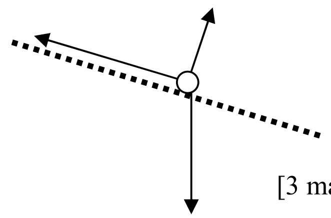
Launch speed = 40 ms^{-1} at angle of 70-80° is possible but reaches too great a height

[2 marks]

SECTION C: Comprehension and Interpretation **(40 Marks)**

Question 1 [**20 marks**]

1(ai) Weight (mg) or gravitational force exerted by Earth
Force acting up and parallel to plane—as a result of induced current moving through magnetic field
Reaction force exerted by rails (normal reaction)



[3 marks]

1(aii) Force up the plane increases with speed of the rod down the plane.
When this force equals the component of weight acting down the plane, it travels at constant velocity [2 marks]

1(b) Weight W = mg Induced emf V = lvB
Force on current F = ILB V = IR [2 marks]

At constant velocity: $F_{mag} = F_{g\ parallel}$

$$F = mg\sin\alpha$$

$$IlB = mg\sin\alpha$$

$$\left(\frac{V}{R}\right)lB = mg\sin\alpha$$

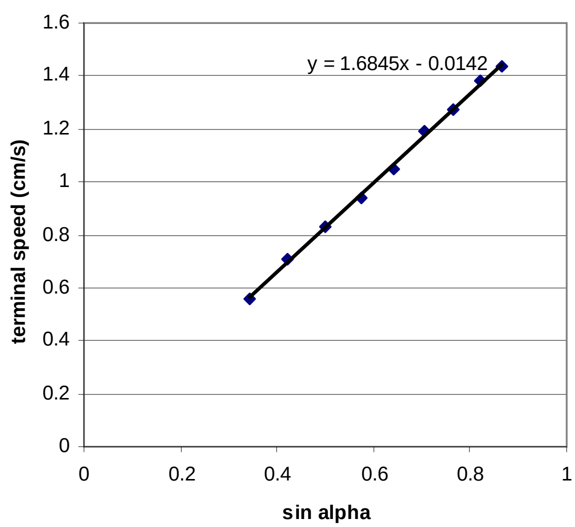
[3 marks]

$$\left(\frac{lvB}{R}\right)lB = mg\sin\alpha$$

$$v_{ts} = \frac{(mg\sin\alpha)R}{l^2B^2}$$

1(c)

Angle (α)	Terminal speed (cm/s)	sin α
20	0.56	0.34
25	0.71	0.42
30	0.83	0.50
35	0.94	0.57
40	1.05	0.64
45	1.19	0.71
50	1.27	0.77
55	1.38	0.82
60	1.44	0.87



1(ci) $v_{ts} = 1.68 \sin\alpha - 0.014$

Suggest Graphical method: 4 marks for sin α (in table) and graph.
Graphics calculator: 4 marks for sin α and line of best fit/regression line. [4 marks]

1(cii) gradient = 1.68 cm s^{-1} or 0.0168 m s^{-1} [2 marks]

1(d) $v_{ts} = \left(\dfrac{mgR}{l^2B^2}\right)\sin\alpha$ hence gradient $= \dfrac{mgR}{l^2B^2}$ [2 mark]

$$0.0168 = \frac{mgR}{l^2B^2}$$

$$B = \sqrt{\frac{mgR}{l^2(0.0168)}} = \sqrt{\frac{(44\times10^{-3})(9.8)(1.4\times10^{-4})}{(0.20)^2(0.0168)}} = 0.30\ \text{T}$$ [2 marks]

Students who use 1.68 should get 0.030 T

Students who use 1.57 should get 0.031 T

Question 2	[**20 marks**]

2(ai) Diagram should show an oscillating bubble and formation of spherical pressure waves (rarefactions and compressions) [para 2] [3 marks]

2(aii)

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3\gamma P_0}{\rho R_0{}^2}}$$ [1 mark]

$$= \frac{1}{2\pi}\sqrt{\frac{3(1.4)(100\times10^3)}{(1\times10^3)(3\times10^{-3})^2}}$$

$$= 1088$$ [3 marks]

$$\approx 1100\ \text{Hz}$$

2(bi) $f = \dfrac{300}{60} = 5\ \text{Hz}$ $v = 14\ \text{ms}^{-1}$ [1 mark]

$$v = \frac{2\pi r}{T} = 2\pi rf$$

$r = \dfrac{v}{2\pi f} = \dfrac{14}{2\pi(5)} = 0.45\ \text{m}$ i.e. 0.45 m along blade from centre. [3 marks]

2(bii) The tips of the blades or where water speed (relative to blade) is greatest [2 marks]

2(ci) From the figure 1: radius ≈ 3.5 mm [2 marks]
2(cii) From either figure: time ≈ 0.3 ms [2 marks]
2(ciii) Figure 2 shows a high-pressure pulse, over 50kPa change in pressure, produced during the time that the bubble collapses. This small shock wave/pressure pulse can stun small creatures. [3 marks]

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