Curriculum Council

EXAMINERS' REPORT ON 2003 TERTIARY ENTRANCE EXAMINATION

SUBJECT: PHYSICS

STATISTICS

Year	Number Who Sat	Non-Examination Candidates	Did Not Sit
2003	3154	45	209
2002	3001	29	181
2001	3131	55	162

The Examiners' Report is written by the Chief Examiner (or another Examiner on their behalf) to comment on matters relating to the Tertiary Entrance Examination in their subject. The opinions and recommendations expressed in this report are those of the Chief 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 may have 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 of 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 Syllabus Committee agreed that the paper contained a good range of questions and was an acceptable representation of the course. The marking of the paper was relatively straightforward. The format was similar to the previous year, differing only in the increase of numbers of questions in Parts B and C, from 7 and 1, to 8 and 2 respectively, but with no indication of students being unable to complete the paper due to time constraints. The mean 2003 raw exam score (59) was slightly greater than the 2002 mean (57), and the standard deviation of 2003 scores (16) was slightly lower than in 2002 (17). This suggests a relatively stable level of performance in comparison with previous years, but with a slight reduction in the number of extreme scores.

GENERAL COMMENTS

The disparity between scores on the optional sections (A and B) of Question 8 is problematic.
It is difficult to ensure that both questions are equal in difficulty, as intended but not evident in the means scores of 59% and 71%. Response frequencies of 1100 and 2000 respectively indicate that this difference was not due to small sample sizes. Alternative parts to cater for different contexts are not provided anywhere else on the paper and, in reality, it is possible for students to simply choose the question that looks easier, regardless of context. The practice of setting alternative questions based on context may need further consideration.

The policy of only testing year 12 work (and not year 11) was of concern to examiners when setting Section C questions on Comprehension and Interpretation. This forced a kind of artificial problem-setting situation for Question 1 of Part C, initially developed as a situation of a familiar home appliance (smoke detector). Much of the original question was removed when it was pointed out that electric forces and radioactivity are concepts included in year 11 work, and could not be examined, a difficult constraint in view of the fact charges moving in magnetic fields (year 12 work) are almost always accompanied by electric forces in practice. The examining panel has no practical suggestion about how to deal with this issue, but urge that it be addressed as soon as possible.

COMMENTS ON SPECIFIC QUESTIONS

SECTION A: *Short Answer*

Q1 Attempted 3153 Mean 59%

This question was intended to be an 'easy' one that would help students start the paper with confidence, but in fact it turned out to have the third lowest mean for this section. It highlighted some basic misconceptions in many students who did not identify the correct trajectory, and accepted the idea of a 'force due to the motion'.

Q2 Attempted 3087 Mean 81%

Lack of familiarity with the Earth's magnetic field arrangement in WA caused minor confusion in the interpretation of the word 'dip' and correct assignment of the angle 66˚. A number of students did not use an angle at all in their calculations.

Q3 Attempted 3153 Mean 90%

This question was almost universally answered correctly by students.

Q4 Attempted 3125 Mean 74%

This was a difficult question to mark due to the wide range of written explanations provided. A large number of students did not use the term 'plastic' in distinguishing the different behaviour of the materials, and used the term 'elastic' inappropriately. Diagrams generally were well drawn.

Q5 Attempted 3036 Mean 47%

This was a useful and revealing question that highlighted the understanding of the better students. It proved to be the most difficult question in this section. Many students did not use appropriate terminology such as centripetal force and gravitational force or could not express their ideas adequately. Surprisingly, a number of students thought that the Earth's magnetic field was somehow involved in gravitational orbits!

Q6 Attempted 3001 Mean 72%

Despite its simplicity, this question caused a great deal of misapplication of standing wave concepts (which were not relevant). Unfortunately, since the correct answer was one very familiar to most students (i.e. the speed of sound in air) many embarking on the wrong method nevertheless 'fiddled' their working to achieve the correct answer and so were not penalised. If the question had been reworded to ask for an unfamiliar quantity (e.g. find the handclapping frequency from the speed of sound) it may have been more discriminating.

Q7 Attempted 3145 Mean 61%

This was a multiple choice question that tested the students' ability to sort out the correct physics for a situation of common experience. A number of students opted for alternative A which may indicate that they were looking for a correct response and not an incorrect one.

Q8 Attempted 3125 Mean 61%

This question was familiar to many students, but marking was hampered by lack of universality in the assigning of harmonic number. The question refers to the third harmonic of a pipe closed at one end. Some students interpreted this to mean using n=3 in a standard pipe formula. However since the n=2 case does not appear in a closed pipe acoustic spectrum, some ambiguity was expected. A number of students did not realise that the node-antinode distance was a ¼ of the wavelength, and surprisingly many opted for an open pipe situation.

Q9 Attempted 2945 Mean 73%

This question asked students to derive a simple expression from 2 others. Very few students accomplished this with appropriate clarity and rigour, suggesting that this kind of skill is little covered (if at all) in most schools. It would be worth including similar derivation type questions in future papers to try to raise the skill levels of students throughout the state. Essentially this reflects the habit of most students to input numerical data far too early in problem solving, but this is also one that is seen at higher (tertiary) levels of physics education and represents a kind of physics maturity that takes time and effort to acquire. The majority of students recognised that the fundamental had a wavelength equivalent to 2L for a string.

Q10 Attempted 3114 Mean 86%

The majority of students had little trouble with this question, with the main errors being, inverting the ratio or wanting to add **units**.

Q11 Attempted 3100 Mean 71%

Perhaps this question was marked too easily - many answers achieved full marks without being properly complete. In particular the constancy of wavelength after diffraction was not clearly shown by many students, and many did not adequately label their diagrams. In general, diagrams were not well drawn by students, and this is a skill that needs improvement.

Q12 Attempted 3001 Mean 67%

This was a testing and useful question for gaining an insight into the student's physical mind. Perhaps the initial description contained too many elements to explain (very few students explained all the statements of phenomena). Many students gave a stock answer for resonance without addressing the particular circumstances described.

Q13 Attempted 3117 Mean 62%

This question tested both graphical interpretation and analysis where students needed to choose an appropriate set of assumptions in deriving the requested result. A number of students calculated the gradient but did not know how to use it to get the required answer. Many did not use the correct units.

Q14 Attempted 2945 Mean 54%

This question required students to know about electric forces. The relevant formula was supplied within the question to make this job easier, but many students seemed at a loss to separate electric from magnetic fields in parts of this question. The use of the word 'forces' rather than 'force' in part (a) was deliberate but lead to some rather subtle difficulties in the marking. Many students guessed an answer to part (b) without justifying it and a number said that **B** was perpendicular to **E** without reference to the velocity.

Q15 Attempted 2958 Mean 68%

This was a straightforward question but it highlighted a confusion between fluorescence and phosphorescence for a number of students. Many did not mention that the electron returns to the ground state in stages.

SECTION B: *Problem Solving*

Q1 Attempted 3133 Mean 58%

This question appeared to be a familiar transformer problem, but the inclusion of the concept of efficiency provoked a number of incorrect applications of the transformer equations, and showed up fundamental lack of understanding of the concept. An effort was made to allow for students to attempt later parts even if they couldn't do the earlier parts.

Q2 Attempted 3117 Mean 54%

A common difficulty for some students here was the recognition that the question involved a motor rather than the commonly studied AC generator. Also there was an ambiguity in the understanding of the expression 'coil parallel to the magnetic field' that could have easily been avoided by a more careful rewording.

Q3 Attempted 3051 Mean 35%

This question proved a stumbling block for a large number of students who failed to recognise it as a moments problem and attempted to answer in terms of forces only or to use energy conservation. Students had some idea that changing the direction of the force would result in less effort but were unable to explain why in most cases.

Q4 Attempted 3074 Mean 47%

This was a well-discriminating question. The fact that the string to the circulating aeroplane was not horizontal caused the greatest number of errors. The use of three vectors for this type of problem resulted in the great majority of students being unable to correctly solve parts (a) and (b). Most students successfully solved part (c) using answers from (a) and (b).

Q5 Attempted 3140 Mean 61%

Part (a) focused on causes, while part (b) addressed effects. Many students failed to grasp this and lead to difficulties in the marking. Almost no-one answered part (a) correctly (drag depends on diameter rather than surface area) but as this is not normally covered in detail in the syllabus, a more generous marking scheme was employed for this part. In section (c) many students did not choose the theoretical maximum range and chose the shot or soccer ball ranges in solving for the launch speed.

Q6 Attempted 3063 Mean 66%

This was a simple, familiar gravitational problem in an unfamiliar setting (masers around a black hole). A mixture of units (such as is ubiquitous in astronomy literature) lead to the common error of not converting km to m. This could have been avoided if '$2.4\text{x}10^{11}$ km' had been replaced by '$2.4\text{x}10^{14}$ m'. However at the time it had been left as a further test of the students ability to carefully read and manipulate real data.

Q7 Attempted 3103 Mean 66%

A useful question provoking the students to show their understanding of a simple quantised energy level scheme within a hypothetical atom. Most students could manage parts (a) and (b) correctly but many confused the processes of absorption and emission, calculating unwanted transitions and spectral lines.

Q8 Attempted 3114 Mean 67%

This question was the only one on the paper where students had a choice of contexts. While every effort was made to equalise the physics involved, it is likely that the bridge version (B) was somewhat easier than the arm version (A) of the problem. The most common omission was the reaction force at the pivot. Surprisingly, a number of students failed to identify all the forces in part (i) but then blithely included them to calculate part (ii).

SECTION C: *Comprehension and Interpretation*

Q1 Attempted 3106 Mean 40%

It was perhaps this question above all others in the paper that caused the greatest difficulties for students. In particular the revelation in part (c) that radioactive decay and the subsequent ionisation did not account for the commercially quoted currents was a great challenge for the better students. It is worth noting that all of the top papers considered for the exhibition prize DID get to the bottom of this issue - something that a number of the markers had difficulty with!

Q2 Attempted 3101 Mean 69%

Many students achieved full marks on this question even though a full understanding of the issues may have been lacking. Diagrams again were not well presented, with many answers failing to clearly indicate where the centre of mass was located. In d(ii) many students did not include the weight of the halteres in their calculations and were confused as to what mass they should use.

POINTS FOR THE SYLLABUS COMMITTEE TO CONSIDER

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

Although the opportunity for students to guess answers was limited, the ability to obtain full marks for a question by giving the correct answer even though the working is incorrect or non-existent should be removed. This could easily be addressed by changing the wording at the front of the paper.

Question 8 A/B brings up a philosophical discussion about why we need alternative parts to cater for different contexts. In truth, intelligent students should be able to transfer learning from one context to another. Do we really believe that students who have studied the human body context for structures and materials would not be able to attempt a question on bridges? Perhaps, it is about time that we dropped this idea of two separate parts – we don't do this anywhere else on the paper for any other questions and, in reality, students may simply choose the question that looks easier. It is also difficult to ensure that both questions are equal in difficulty. For instance the reaction force at the elbow was almost universally missed by students and yet many students identified the reaction force at the base of the post. Also, the direction of the force in the muscle was not well handled by students.

The policy of only testing year 12 work (and not year 11) seems pedagogically untenable due to the additive nature of basic physics knowledge and skill. This forced a kind of artificial problem setting that was problematic. For example it appears unreasonable to be testing a student's knowledge and skill in electrical power without being able to use something as fundamental as Ohm's Law directly in the TEE paper. This anomaly may have arisen from the practice of some colleges/schools of only teaching the year 12 syllabus. The examining panel trusts that the Physics Course of Study will address this issue.

Dr Ralph James
January 2004

2003 Examining Panel
Chief Examiner: Dr Ralph James
Deputy: Mrs Shelley Yeo
Third Member: Miss Megan Wride

Chief Marker: Mr William Biffin

SECTION A

1. (a)

ANSWER ____ B

(b) frictional force from air, plus weight

ANSWER ____ 4 & 5

2.

EMF $= Blv$
$= 5.80 \times 10^{-6} \times \sin 66^\circ \times 30.0 \times 85$
$= 1.35 \times 10^{-2}$ V

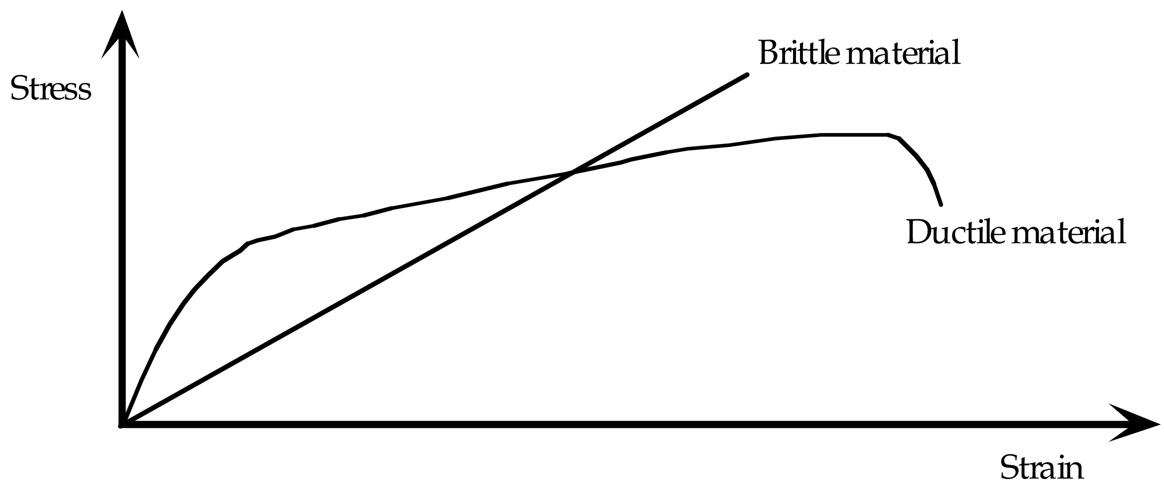
ANSWER ______ 1.4×10^{-2} V (14 mV)

3.

ANSWER_____ C

4.

A stress-strain graph reveals brittle materials to have no plastic region. Materials such as glasses, ceramics, and some steel break without exhibiting plastic behaviour.
Ductile materials on the other hand possess a definite plastic region. These materials include fishing wire, copper wire and mild steel. Graphically, these concepts are expressed in the graph below.



5. The centre of the orbit must be the centre of the force sustaining the orbit. The Newtonian gravitational force and centripetal force must be the same.

6. in moving 43 m path difference has changed by 1 wavelength. Since echo goes then returns actual path difference = 2 x 43 = 86 m

speed of sound = frequency x wavelength = 4 x 86 = 344 m/s

ANSWER _______ 3.4×10^2 m/s (2 sig figs)

7. (B) is incorrect hence LEAST reasonable

ANSWER ____ B

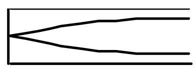
8.

For a stopped pipe one normally quotes

$$f_n = (2n - 1)f_1$$

where $$f_1 = \frac{c}{4\,L}$$

and n is a positive integer, sometimes referred to as the harmonic number



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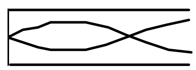

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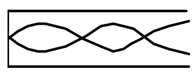

5

for the cases drawn above we have length: $L = n\frac{\lambda}{4}$

n = 3 case: $\Rightarrow \quad \lambda_3 = 2.0$ m

(a) node-antinode distance $= \frac{\lambda_3}{4} = \frac{L}{3} = 0.50$ m

ANSWER _____ 50 cm

(b) $f_3 = \frac{v}{\lambda_3} = \frac{3v}{4L} = 173$ Hz

ANSWER _____ 1.7×10^2 Hz

ALT: If the fundamental is treated separately to higher frequencies - ie the first frequency above the fundamental is called the "1st harmonic" as is sometimes done in text books, then we have alternate results. According to the above numbering scheme then, students may use either:

• the 3rd harmonic observed, being n=5 in the above diagram

• the 3rd higher harmonic observed, not counting the fundamental, being n=7

• NOTE: the "open only at one end" directive should allow students to rule out the even n solutions, so only partial marks should be awarded for incorrect assignment of n=4 or 6, etc.

n = 5 case: length: $L = 5\frac{\lambda}{4}$ ($\lambda = 1.2$ m)

(a) node-antinode distance $= \frac{\lambda}{4} = \frac{L}{5} = 0.30$ m

ANSWER _____ 30 cm

(b) $f = \frac{v}{\lambda} = \frac{5v}{4L} = 288$ Hz

ANSWER _____ 2.9×10^2 Hz

n = 7 case: length: $L = 7\frac{\lambda}{4}$ ($\lambda = 0.86$ m)

(a) node-antinode distance $= \frac{\lambda}{4} = \frac{L}{7} = 0.2143$ m

ANSWER _____ 21 cm

(b) $f = \frac{v}{\lambda} = \frac{7v}{4L} = 403.7$ Hz

ANSWER _____ 4.0×10^2 Hz

9. $v = f\lambda$ and $\lambda = 2L$ (2 mark)

$\therefore \quad f = \dfrac{v}{2L}$ (2 mark)

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10. $I[dB] = 10 \log_{10}\left(\dfrac{I}{I_o}\right)$ where $I_o = 10^{-12}$ W m^{-2}

Thus $\log_{10} I_A = \dfrac{22}{10} - 12 = -9.8$, $I_A = 10^{-9.8} = 1.58 \times 10^{-10}$ W m^{-2}

and $\log_{10} I_B = \dfrac{17}{10} - 12 = -10.3$, $I_B = 10^{-10.3} = 5.01 \times 10^{-11}$ W m^{-2}

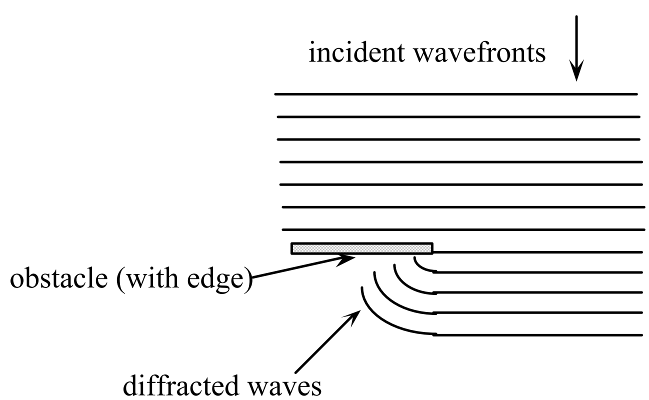
Hence: $\dfrac{I_B}{I_A} = \dfrac{10^{-10.3}}{10^{-9.8}} = 10^{-0.5} = 0.316$ ANSWER (2 sig.figs) = 0.32

OR: $\dfrac{I_B}{I_A} = \dfrac{I_B}{I_o}\dfrac{I_o}{I_A} = 10^{+1.7}\ 10^{-2.2} = 10^{-0.50} = 0.32$

(4 marks)

11.

DIFFRACTION: occurs when wavefronts encounter an obstacle with changes in transmission properties (in the simplest case - just a gap or edge).



REFRACTION: occurs when wavefronts pass through an interface (different v's) at a (non-zero) angle of incidence.

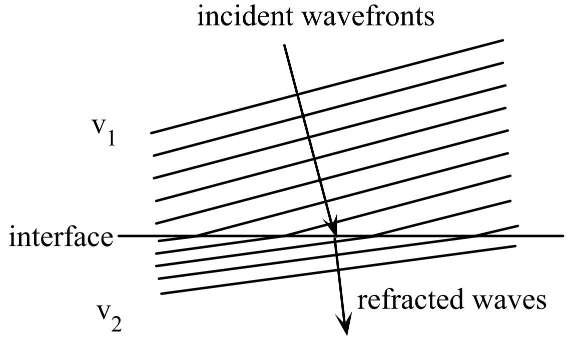


FIGURE: case where waves travel across interface into a medium with slower wave speed ($v_2 < v_1$).

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12. Natural frequency of vibrations (pendulum mode) (1 mark)

Forced oscillations (1 mark)

Vibrations at source (truck) are transmitted to object via medium (air/ground) as sound waves(?)

Resonance (2 marks)

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13. Line of best fit: slope $\frac{\Delta L}{\Delta m} \approx 1.04$ mm/g $= 1.04$ m/kg (2 marks)

Young's modulus: $E = \frac{\text{stress}}{\text{strain}} = \frac{\Delta mg}{A}\frac{L}{\Delta L} = \frac{gL}{A}\frac{\Delta m}{\Delta L}$

$= \frac{9.8 \times 79 \times 10^{-3}}{4.8 \times 10^{-7} \times 1.04} = 1.55 \times 10^{6}$ Pa (2 marks)

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14. (a) any E, but B needs to be perpendicular to v (2 mark)

(b) $F_e = eE = 1.6 \times 10^{-19} \times 110 = 1.8 \times 10^{-17}$ N

$F_m = evB = 1.6 \times 10^{-20}$ N

electric force is ≈ 1000x greater

ANSWER _____ electric field

(2 marks)

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15. metastable state

ultraviolet in => visible out (lower f, lower E)

minerology, medical tracers, watermarks (ID), fluorescent tubes for illumination

SECTION B

1. a) $P_{out} = VI = 0.335 \text{ x } 3.6 = 1.21 \text{ W}$

   b) $P_{in} = \frac{1}{0.75} P_{out} = 1.61 \text{ W}$

   c) $I_{in} = \frac{P_{in}}{V_{in}} = 6.7 \text{ mA}$

   d) eddy current losses in core
   resistance in coil windings
   vibration of transformer elements (transformers commonly emit an audible hum)

2. a) i) torque $= F \frac{w}{2} \sin(\text{angle}) = ILB \frac{w}{2} \sin(\text{angle}) = 0$

   ii) 0.0135 N m $1.4 \text{ x } 10^{-2}$ Nm

   iii) 0.0095 N m $9.5 \text{ x } 10^{-3}$ Nm

NOTE: there is a point of interpretation here as to how the student understands the phrase "coil parallel to the magnetic field".

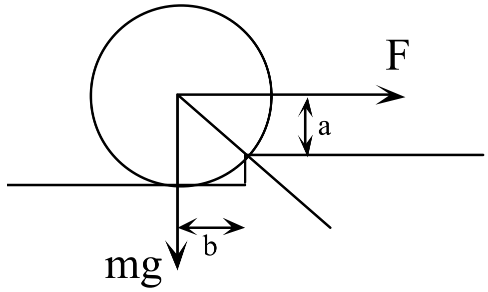
EITHER: coil direction is taken as the 'surface normal' or direction perpendicular to the plane of the coil. In this case the above results apply.

OR: coil alignment is taken as in the given diagram, ie surface normal is perpendicular to the B field. In this case answers (i) and (ii) will be reversed. Answer (iii) should be the same in either case.

   b) i) since torque varies from 0 to 0.0135 Nm, we have uneven propulsion

   ii) curved pole pieces -> reduce angle effect
   spread coil windings -> reduce angle effect

3. a) take moments about step edge:

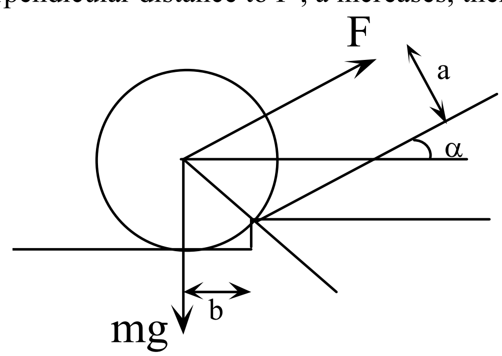


need net CW moment $= Fa - mgb > 0$

$$F > mg\frac{b}{a} = mg\frac{\sqrt{R^2 - a^2}}{a} = 290 = 2.9 \times 10^2 \text{ N}$$

b) As the wheel rises, a -> R, and the horizontal force required decreases.

c) At angle α , perpendicular distance to F , a increases, thereby decreasing required F.



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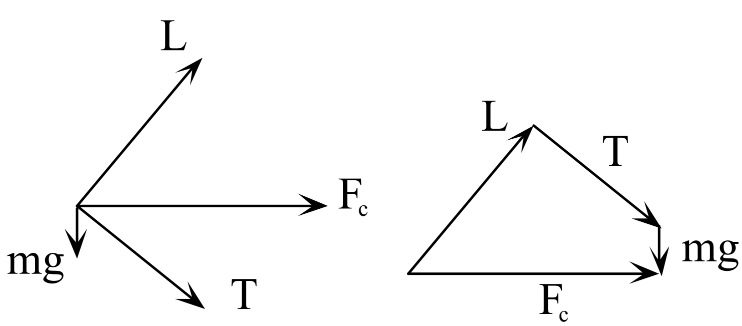
4. a) centipetal force is horizontal sum of lift and tension:

$F_c = L \sin 35^\circ + T \cos 35^\circ = 38.1$

ANSWER = 38 N



b) taking vertical components:

$mg = - L \cos 35^\circ + T \sin 35^\circ = -16$ N ANSWER = 1.6 kg

c) $F_c = \frac{mv^2}{r}$ so $v = \sqrt{\frac{rF_c}{m}} = \sqrt{\frac{15 \times 38}{1.6}} = 18.7$ m/s

ANSWER = 19 m/s

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5. a) drag increases with (Reynolds number which is proportional to) the effective size of the projectile. Hence shot is smaller => less drag

b) drag is proportional to area
effect of drag (change in momentum) is less in the case of greater mtm (same v)

c) Using no-drag case (40.7m)

$$\Delta x = v_x \Delta t \qquad \Delta y = -\frac{1}{2} g (\Delta t)^2 + v_y \Delta t$$

$$v_x = v_x = \frac{1}{\sqrt{2}} v$$

$$\Delta y = 0 \quad => \quad \Delta t = \frac{2v_y}{g}$$

$$\Delta x = v_x \frac{2v_y}{g} = \frac{v^2}{g}$$

so: $v = \sqrt{g\Delta x} = 20.0 = 20$ m/s

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6. a) $F = \frac{GmM}{r^2} = \frac{mv^2}{r} \quad => \quad \frac{GM}{r} = v^2$

$v = \frac{2\pi r}{T}$ so $M = \frac{4\pi^2 r^3}{GT^2} \approx 2.3 \times 10^{37}$ kg

ANSWER 2×10^{37} kg

b) $a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = 0.026 \text{ m s}^{-2}$

c) $g = \frac{GM}{R^2} = 1.5 \times 10^{21} \text{ m s}^{-2}$

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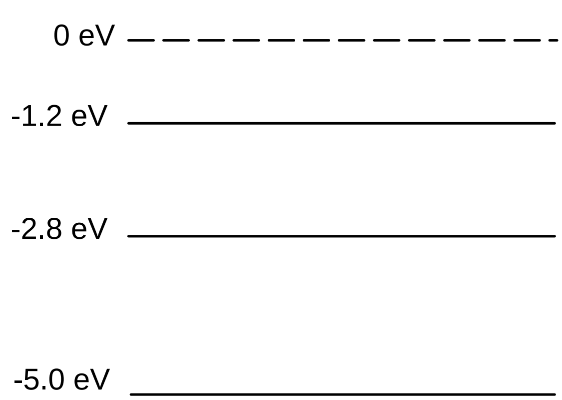
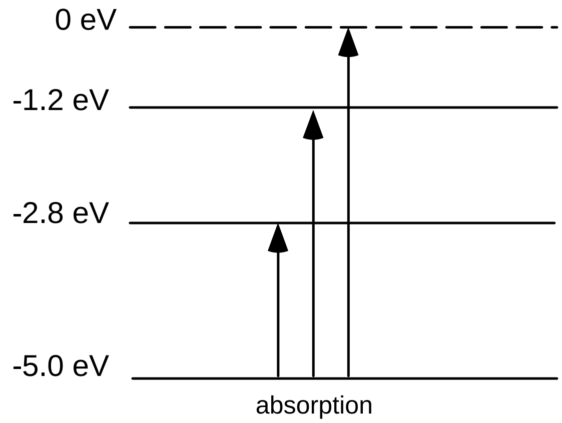
7. a)



b) $\Delta E = 5.0 \text{ eV} = 5.0 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-19}$ J

c) absorption spectrum

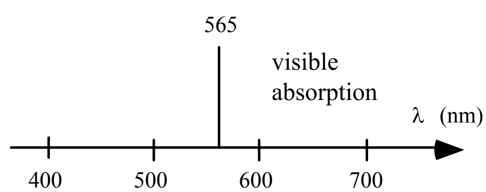


Planck's hypothesis: $\Delta E = hf = \dfrac{hc}{\lambda}$,

whence $\lambda = \dfrac{hc}{\Delta E} = \dfrac{6.63 \times 10^{-34} \,.\, 3 \times 10^{8}}{\Delta E \,.\, 1.6 \times 10^{-19}} = \dfrac{1.24 \times 10^{-6}}{\Delta E}$

ΔE = 2.2, 3.8 and 5.0 eV $\Rightarrow$ λ = **565, 327** and **249 nm**.

d) Visible spectrum: 400 nm < λ < 700 nm hence only 1 line:



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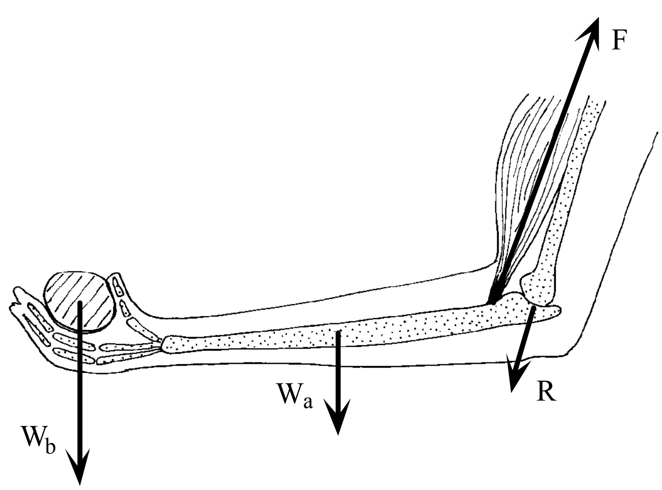
8. a) i)



W_b: weight of ball
W_a: weight of forearm
F: force in tendon
R: reaction force from upper arm

ii) moments about elbow joint:
balance => $x_a W_a + x_b W_b - F x_f = 0$

$$F = \frac{x_a W_a + x_b W_b}{x_f} = \frac{g}{x_f}\left(x_a M_a + x_b M_b\right)$$

given: $g = 9.80$, $M_b = 4.0$

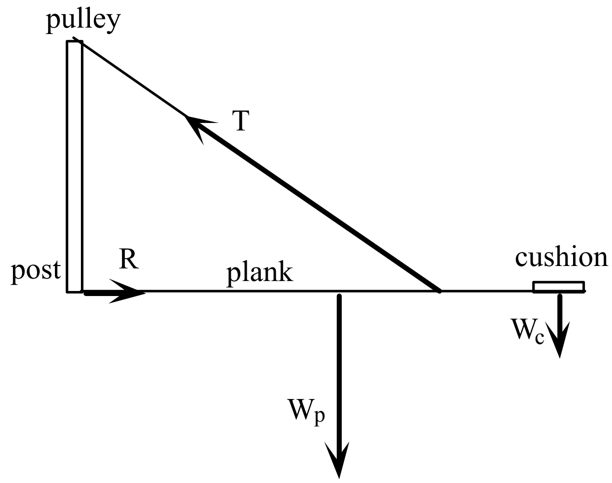
estimate: $x_a = 0.2$, $x_b = 0.5$, $x_f = 0.05$, $M_a = 1$

=> $F = 430$ N

range: $0.1 < x_a < 0.3$, $0.2 < x_b < 0.8$, $0.01 < x_f < 0.1$, $0.1 < M_a < 2$

=> $80 < F < 4000$ N

b) i)



W_p: weight of plank
W_c: weight of cushion
T: tension in cable
R: reaction force from post

ii) moments about base of post:

balance => $x_p W_p + x_c W_c - T x_t = 0$

$$T = \frac{x_p W_p + x_c W_c}{x_t} = \frac{g}{x_t}\left(x_p M_p + x_c M_c\right)$$

given: $g = 9.80$, $M_c = 2.5$, $M_p = 8.0$

estimate: $x_p = 0.6$, $x_c = 1.1$, $x_t = 0.5$

=> $F = 150$ N

range: $0.5 < x_p < 1.5$, $1 < x_c < 2$, $0.3 < x_t < 1$

=> $60 < F < 560$ N

SECTION C

1. a) inelastic collision of alpha particle with air molecule (O_2, N_2, CO_2, ...)

some of the KE of alpha particle is transferred to electron

creates free electron and positively charged ion

alpha ptcle slowed down (lost KE) - may cause further ionisations

b) A moving charge (alpha particle) in a B field is deflected by a magnetic force perpendicular to its motion (and B), hence this could interupt/reduce the detection current and lead to malfunction.

<<suitable diagram>>

c) power is needed for other components in sensing, amplifying and control circuits

d) operating power = 24 V x 45 μA = 1.1 mW

lifetime $= \dfrac{0.020 \times 10^{3}}{1.1 \times 10^{-3}} \approx 1.8 \times 10^{4}$ hours ≈ 2 years ⇒ change every year

e) $I_{15} = \left(\frac{1}{15}\right)^2 I_1$

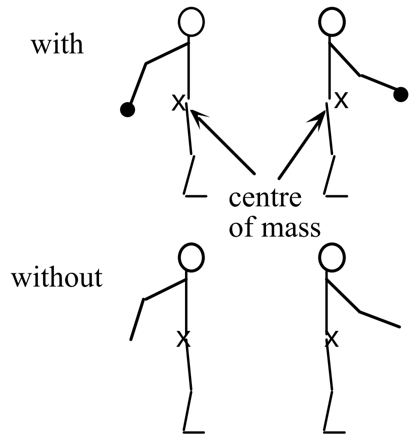
$10 \log I_{15} = 10 \log I_1 - 20 \log 15 = 80 - 23.5 = 56.5$ dB

ANSWER = 56 dB

2. a) • in para 2 "One key to understanding the improvement is the relationship between the jumpers' feet and their centre of mass." By changing the position in which the halteres are held prior to take-off and at the moment of landing the jumpers feet can extend further than an unloaded jumper.

• in *para 4*: "Minetti's explanation is that moderately loaded muscles can exert greater force than unloaded muscles, thus generating increased power. "

b)



c) likely mass $\approx$ 5 kg (weight $\approx$ 50N)

corresponds to maximum in fitted curve on graph

d) (i) stress $= \dfrac{\text{force}}{\text{area}}$, assuming area constant, only mass changes:

$$\frac{\Delta\text{stress}}{\text{stress}} = \frac{24}{76} = 0.32$$ 32% increase

or if all of each haltere is over each leg:

$$\frac{\Delta\text{stress}}{\text{stress}} = \frac{12}{76 \times 0.9} = 0.18$$ 18% increase

(ii) force required

$$F = mg + \frac{mv^2}{r} = 12 \times 9.8 + \frac{12 \times (6.2)^2}{0.75} = 0.74 \times 10^3 \text{ N (upwards)}$$

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