

TERTIARY ENTRANCE EXAMINATION, 1992

QUESTION/ANSWER BOOKLET

PHYSICS

Please place one of your student identification labels in this box

SEA STUDENT NUMBER – In figures

In words _____

_____

TIME ALLOWED FOR THIS PAPER (FOR SECTIONS A & B)

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

TO BE PROVIDED BY THE SUPERVISOR

This Question/Answer Booklet comprising 39 pages (Section A - 30 questions, Section B - 8 questions)
Physical Constants (inside front cover of this Question/Answer Booklet)

TO BE PROVIDED BY THE CANDIDATE

Standard Items: Pens, pencils, eraser or correction fluid, ruler

Special Items: A calculator satisfying the conditions set by the Secondary Education Authority, compass, protractor and set square.

IMPORTANT NOTE TO CANDIDATES

No other items may be taken into the examination room.

It is your responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you hand it to the supervisor BEFORE reading any further.

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INSTRUCTIONS TO CANDIDATES

This paper consists of **TWO (2)** sections

In SECTION A, answer **ALL** thirty questions, and **write your answers in the spaces provided below or next to each question.** This section is worth 48% of the marks for the examination. Each of these questions is of equal value.

In SECTION B, answer **ALL** eight questions, and write your answers in the spaces provided beneath each question in the Question/Answer Booklet provided. This section is worth 52% of the marks for the examination.

Note that (where appropriate) answers should be given numerically and that they should be evaluated and not left in fractional or radical form. Give all answers to three significant figures unless otherwise instructed.

A calculator satisfying the conditions set by the Secondary Education Authority may be used to evaluate numerical answers.

Despite an incorrect final result, credit may be obtained for method and working, provided these are clearly and legibly set out.

At the commencement of this examination, attach your STUDENT IDENTIFICATION label to the front cover of this Question/Answer Booklet. Write your SEA Student Number in the spaces provided in the Question/Answer Booklet.

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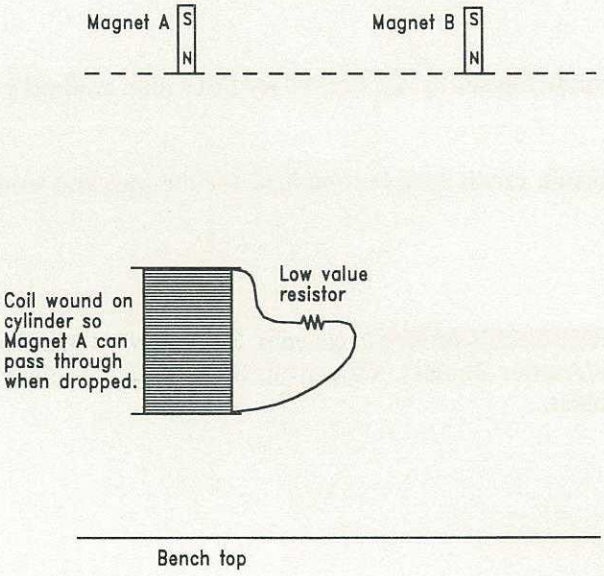
SECTION A

MARKS ALLOTTED : 48

Attempt all thirty 30 questions in this section. All questions are worth equal marks. **Answers are to be written in the spaces below or next to the question.**

Evaluate answers numerically where possible. Credit will be given for working, if shown.

1. Magnets A and B are dropped at the same instant from equal heights above a bench top as shown. Magnet A falls through a coil that is connected to a low value resistor.



(a) Describe any differences, if any, between the **time taken** for the two magnets to fall.

Magnet A will take longer to fall

(b) If there is a difference in time explain why.

The induced current in the coil will be in such a direction as to exert a force that opposes the fall of the magnet. Thus the acceleration experienced by A will be slightly less than B, so the time taken to fall is greater.

SEE PAGE 5

2. A small battery driven cart in a factory starts from rest and accelerates for 25·0 s, by which time it has gained $5{\cdot}00 \times 10^3$ J of kinetic energy.

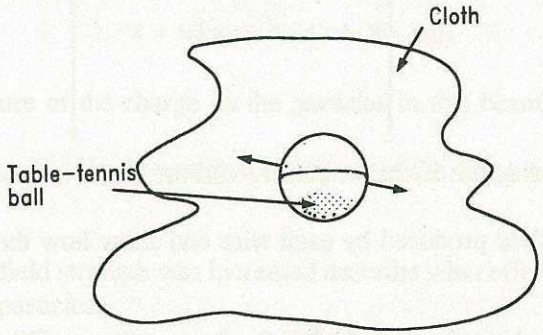
(a) What is the power of this cart assuming it is 100% efficient?

$$P = \frac{\Delta E_k}{t}$$
$$= \frac{5{\cdot}00 \times 10^3}{25{\cdot}0}$$
$$= 2{\cdot}00 \times 10^2 \text{ W}$$

(b) What current was drawn from the 12·0 V battery?

$$P = VI$$
$$\Rightarrow I = \frac{2{\cdot}00 \times 10^2}{12{\cdot}0}$$
$$= 16{\cdot}67 \text{ A}$$
$$\therefore I = 16{\cdot}7 \text{ A}$$

3. A table-tennis ball can be charged positively by rubbing it against a piece of cloth.



Fully describe this charging process. To gain full marks answers must explain what happens to charges on both the ball and the cloth.

Electrons transfer from the ball to the cloth due to friction. Thus the cloth will have an excess of e^{-}'s (and be negative) while the ball will have a deficiency of e^{-}'s (and will be positive). The magnitude of the charge on each will be the same.

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4. Two equally charged positive spheres repel each other with a force of 0·150 N when they are 30·0 mm apart. Calculate the charge on each sphere.

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{d^2}$$

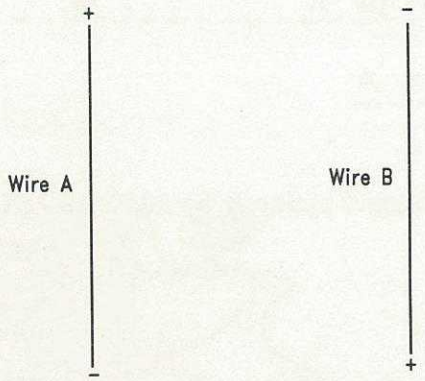
$$\Rightarrow q = \sqrt{(0.150)\, 4\pi (8.85\times10^{-12})(3.00\times10^{-2})^2}$$

$$= 1.225\times10^{-7}\ \text{C}.$$

$$\therefore q = 1.22\times10^{-7}\ \text{C}.$$

5. Two parallel wires carry equal currents in opposite directions as shown in the diagram below.

Side view



A plan view of this diagram is drawn below. On the plan view draw

(a) the magnetic field produced by each wire and show how the magnetic fields interact with each other.

(b) two arrows to show the direction of the force acting on Wire A and on Wire B.

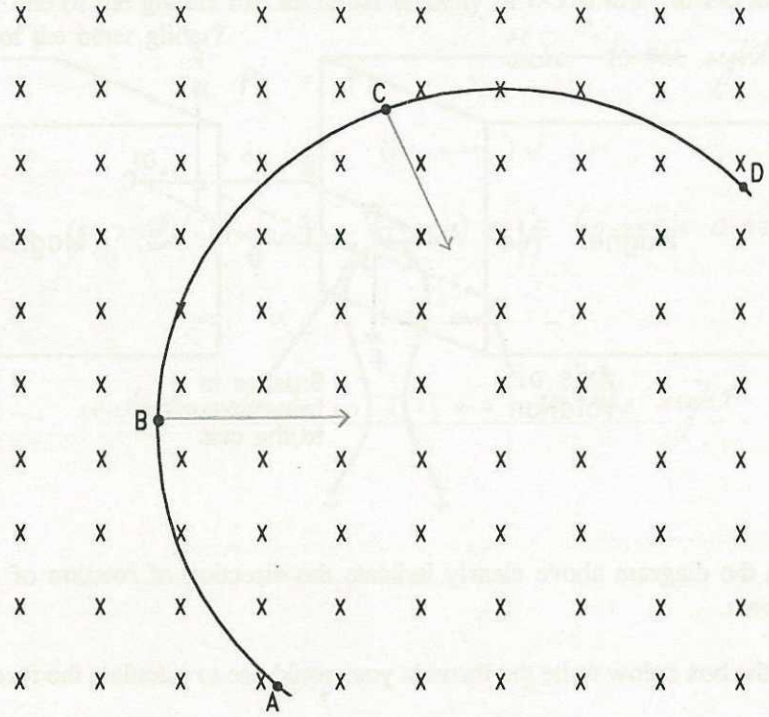
Plan view

X Current into page

· Current out of page

SEE PAGE 7

6. The circular arc ABCD is part of the path of a beam of charged particles as they move from A to D through the magnetic field that is directed perpendicular to and into the page.



X = Magnetic field into the page

(a) What is the nature of the charge on the particles in this beam? +VE

(b) Draw arrows **on the diagram above** to represent the force on the particles at B and at C respectively.

(c) If the magnetic field strength was increased describe what effect this would have on the path of the charged particles.

radius would decrease

(d) Does the force on the particles due to the magnetic field increase the kinetic energy of the particles? Explain your answer.

No since it is always at right angles to the direction of travel of the particles and thus does not change its velocity.

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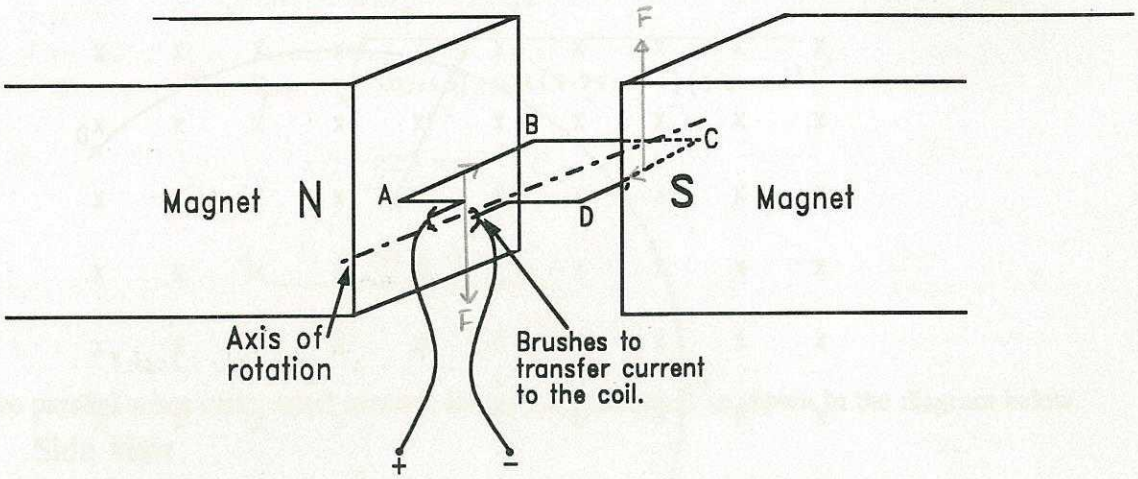
7. The diagram below shows the basic principle of a simple direct current electric motor. The coil ABCD is free to rotate around the axis shown.



(a) On the diagram above clearly indicate the direction of rotation of the coil at the instant shown.

(b) In the box below write the formula you would use to calculate the force on the segment AB.

$F = I \ell B$

(c) List three ways of **increasing** the power of a simple direct current electric motor similar to the one shown above.

1. More coils

2. Larger current

3. Stronger magnetic field.

SEE PAGE 9

8. Two objects, called gliders, each of mass 0·255 kg are moving on a frictionless air track when they collide and couple (join) together. After the collision their combined velocity is 0·370 m s^{-1} to the right. If one of the gliders had an initial velocity of 0·370 m s^{-1} to the left what was the initial velocity of the other glider?

Take "to the right as +ve".

$$P_i = P_f$$

$$\Rightarrow \quad m_1u_1 + m_2u_2 = (m_1+m_2)v.$$

$$\Rightarrow \quad (0.255)(-0.370) + (0.255)u_2 = (0.255+0.255)(0.370)$$

$$\Rightarrow \quad u_2 = 1.11 \text{ ms}^{-1}$$

$\therefore$ initial velocity is 1·11 ms^{-1} to the right.

9. An arrow of mass 0·150 kg is fired from a bow with a velocity of 60·0 m s^{-1}. If the bowstring is in contact with the arrow for 55·0 ms what is the average force exerted by the bowstring.

$$I = Ft = m\Delta v = \Delta p$$

$$\Rightarrow \quad F = \frac{(0.150)(60.0)}{(5.50\times10^{-2})}$$

$$= 1.636\times10^{2} \text{ N}$$

$\therefore$ $F = 1.64\times10^{2}$ N in the direction of the arrow's movement

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10. A bicycle and rider have a combined mass of 93·0 kg. The centre of gravity acts through a point that is exactly one third of the distance between the back wheel and the front wheel. What is the **force** exerted on the ground by each wheel at the point of contact with the ground.

$\Sigma F = 0 \Rightarrow F_1 + F_2 = 9.114 \times 10^2$ N

$\Rightarrow F_2 = 9.114 \times 10^2 - F_1$

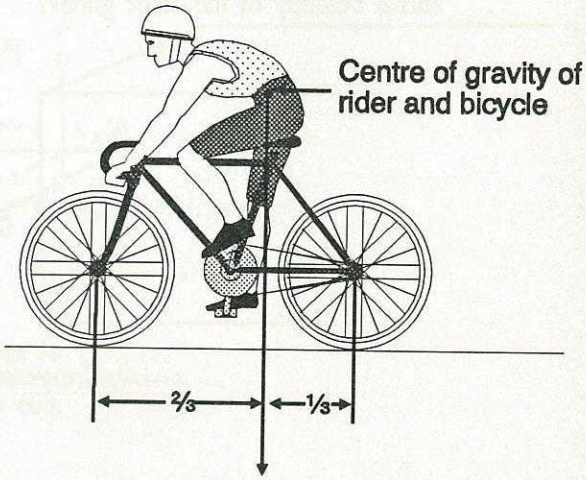
$\Sigma CM = \Sigma ACM \Rightarrow F_1 \times \frac{2}{3} = (9.114 \times 10^2 - F_1) \times \frac{1}{3}$

$\Rightarrow 3F_1 = 9.114 \times 10^2$

$\Rightarrow F_1 = 3.038 \times 10^2$ N

$\Rightarrow F_2 = 6.076 \times 10^2$ N

$\therefore$ $F_1 = 3.04 \times 10^2$ N and $F_2 = 6.08 \times 10^2$ N.



11. If an artificial satellite was to be put in a circular orbit around the moon with a period of exactly one Earth day, what would be the radius of orbit of the satellite?

$F_g = F_c$

$\Rightarrow \frac{GM_1M_2}{r^2} = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2}$

$\Rightarrow r = \sqrt[3]{\frac{(6.67 \times 10^{-11})(7.36 \times 10^{22})(8.64 \times 10^4)^2}{4\pi^2}}$.

$= 9.7549 \times 10^6$ m

$\therefore r = 9.75 \times 10^6$ m

12. When a sewing machine is being used on a slow speed setting it will often vibrate quite significantly, but when it is being used to sew at a normal or fast speed setting it operates very smoothly. Name the phenomenon that causes this and explain why it happens.

Name of phenomenon: RESONANCE

Explanation:

The frequency of movement of the needle exactly matches the natural frequency of the casing of the machine and its supports. This causes the vibrations to be amplified.

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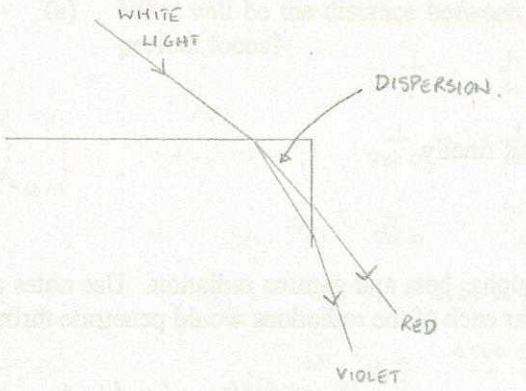
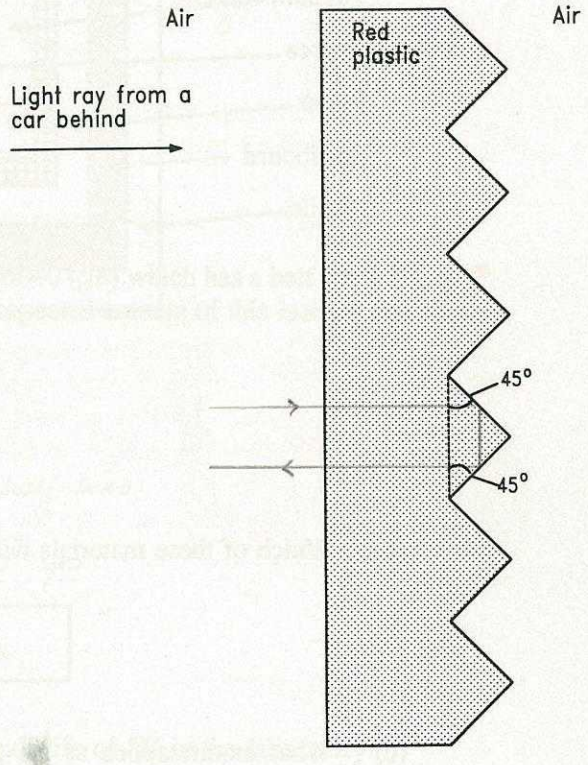
13. Explain, using a diagram, why you can sometimes see coloured fringes when white light shines onto the edges of objects made from transparent materials such as glass or plastic.



The white light undergoes dispersion since each coloured light has a slightly different speed within the material (i.e. the angle of refraction is different for each colour).

14. The diagram on the right shows the cross-section of a reflector like those used on the back of bicycles and cars. It is shaped like this so that light from a following car is totally internally reflected.



(a) Show on the diagram the path of the ray of light into and out of the red plastic reflector.

(b) What is the minimum value of the refractive index of the plastic that could be used to make such reflectors?

$$\frac{n_2}{n_1} = \frac{1}{\sin \alpha_c}$$

$$\Rightarrow \frac{n_2}{1.00} = \frac{1}{\sin 45.0^\circ}$$

$$\Rightarrow n_2 = 1.414$$

$$\therefore n_{plastic} = 1.41$$

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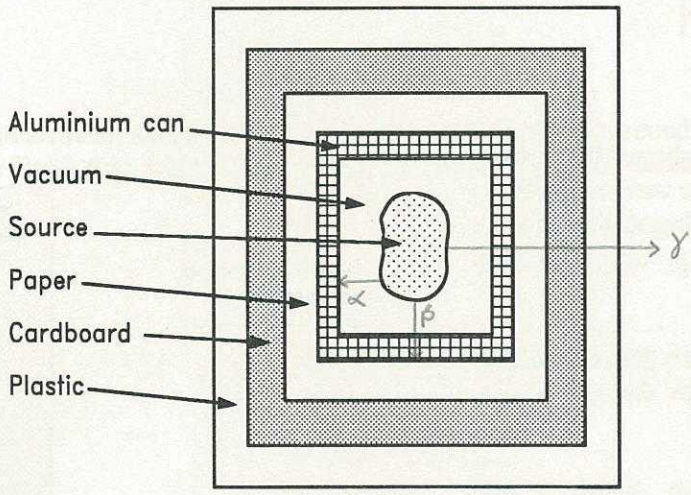
15. A low level radioactive sample is packaged for transport through the mail in the following way:

- the radioactive material is placed inside a sealed aluminium can (similar to a soft drink can) from which air is removed
- the can is then wrapped in paper
- it is then placed inside a cardboard box and finally
- the cardboard box is wrapped in plastic.

(a) Assume that the radioactive sample emits alpha, beta and gamma radiation. Use notes and labels on the diagram below to show how far each of the radiations would penetrate through the packaging materials.



β particles should be stopped by the aluminium (if it is thick enough : 1-3 mm)

γ rays would easily escape.

α particles would be stopped by the aluminium.

(b) Which of these materials will absorb most of the radiation?

ALUMINIUM

(c) What modifications to the packaging arrangement would be required if the radioactive sample was primarily a high activity gamma emitter?

The inner layer(s) should be lead.

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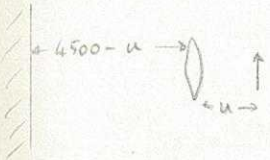
16. A simple slide projector uses a thin convex lens with a focal length of 80·0 mm. The projector is normally set up to focus slides onto a screen 4·50 m away.

(a) What will be the distance between the slide and the lens when the image of the slide is in perfect focus?



$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\Rightarrow \frac{1}{80{\cdot}0} = \frac{1}{u} + \frac{1}{4500-u}$$

$$\Rightarrow \frac{1}{80{\cdot}0} = \frac{4500-u+u}{4500u-u^2}$$

$$\Rightarrow u^2 - 4500u + 3{\cdot}60\times10^5 = 0$$

$$\Rightarrow u = \frac{4500 \pm \sqrt{(4500)^2 - 4(3{\cdot}60\times10^5)}}{2}$$

$= 9{\cdot}758\times10^6$ or $81{\cdot}48$ mm

$\therefore u = 81{\cdot}5$ mm

(b) State whether the image produced is real or virtual. Justify your answer.

Real since the image can be shown on the screen.
ie the light rays converge to form a real image.

17. A geologist measures the amount of the isotope potassium-40 ($^{40}_{19}K$) which has a half life $1{\cdot}28 \times 10^9$ years, in a rock and finds it contains one eighth of the expected amount of this isotope that would be present in a newly formed rock.

(a) Calculate the age of the rock.

$$\frac{1}{8} = \frac{1}{2^n}$$

$\Rightarrow n = 3$ half lives

$\therefore$ age $= 3{\cdot}84\times10^9$ yrs.

(b) Explain why it may be difficult to measure the half life of $^{40}_{19}K$ in the laboratory.

With such a large half life, any significant change in the amount of $^{40}_{19}K$ present would take a long time.

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18. Sunlight reaches the surface of the earth with an intensity of 1 350 W m^{-2}. Assuming the average wavelength of the photons is 555 nm, how many photons per square metre per second does this represent.

Energy of 1 photon:

$E = h\nu = \frac{hc}{\lambda}$

$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{5.55\times10^{-7}}$

$= 3.584\times10^{-19}$ J.

Power per m^2 of each photon:

$P = \frac{E}{t}$

$= 3.584\times10^{-19}$ W.

Power per m^2 of sunlight:

$P = 1.350\times10^{3}$ W

$\therefore$ number of photons $= \frac{1.350\times10^{3}}{3.584\times10^{-19}}$

$= 3.767\times10^{21}$

$\therefore$ number $= 3.77\times10^{21}$ each second.

19. A simple model for electronic conduction in a metallic conductor proposes that the electrical conductivity σ is given by

$$\sigma = \frac{e^2 nT}{2m}$$

where e is the charge on an electron
m is the mass of an electron
T is the average time between collisions of free electrons and fixed metal atoms and
n is the number of conducting electrons per cubic metre.

Use this information to show that the unit for electrical conductivity is $(\Omega\ m)^{-1}$.

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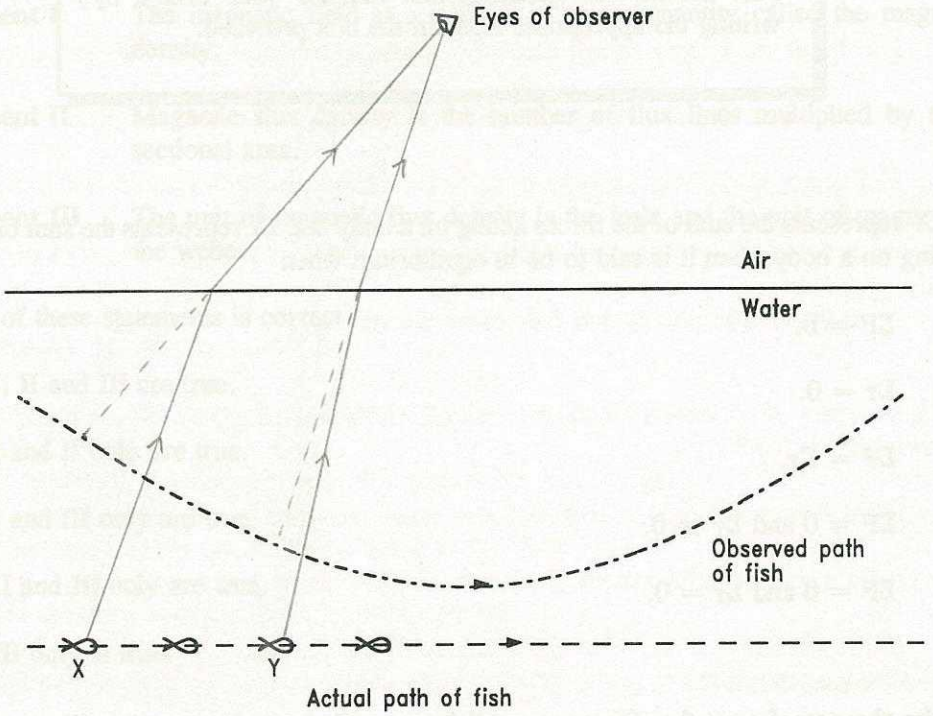
20. A person watching a fish swimming parallel to the surface of an aquarium that is below her observes that it appears to be moving along the path shown below.



(a) On the diagram above sketch two rays from the fish to the eye, one when the fish is at position X and the other when it is at position Y.

(b) Explain the observation with reference to the diagram as appropriate.

The angle of refraction for the ray from X is greater than that for the one from Y. This gives the appearance to the observer that X is closer to the surface than Y.

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For the next ten questions, choose which of the alternatives **best** answer the questions and indicate your choice by writing the appropriate letter in the box provided.

21. If ΣF represents the sum of the forces acting on a body and $\Sigma\tau$ represents the sum of the moments acting on a body, then it is said to be in equilibrium when

A. $\Sigma F = 0$.

B. $\Sigma\tau = 0$.

C. $\Sigma F = \Sigma\tau$.

D. $\Sigma F = 0$ and $\Sigma\tau \neq 0$.

E. $\Sigma F = 0$ and $\Sigma\tau = 0$.

E

22. In the absence of any other forces, a small force applied to a large mass will

A. not be able to change its momentum.

B. give it a fixed momentum.

C. cause its momentum to change for as long as it is applied.

D. give it a change in momentum initially which will then reduce to zero.

E. only change its shape.

C

23. P, Q and R are three point charges which carry +8q C, -q C and +2q C respectively. These charges are in a straight line and Q is between P and R. The distance PQ = x and the distance QR = y.

The resultant electrostatic force on Q is zero provided

A. x = y.

B. 2x = y.

C. x = 2y.

D. 4x = y.

E. x = 4y.

C

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24. Consider the following three statements that relate to magnetic fields:

Statement I The magnetic field at a point is a vector quantity called the magnetic flux density.

Statement II Magnetic flux density is the number of flux lines multiplied by the cross-sectional area.

Statement III The unit of magnetic flux density is the tesla and the unit of magnetic flux is the weber.

Which of these statements is correct

A. I, II and III are true.

B. I and II only are true.

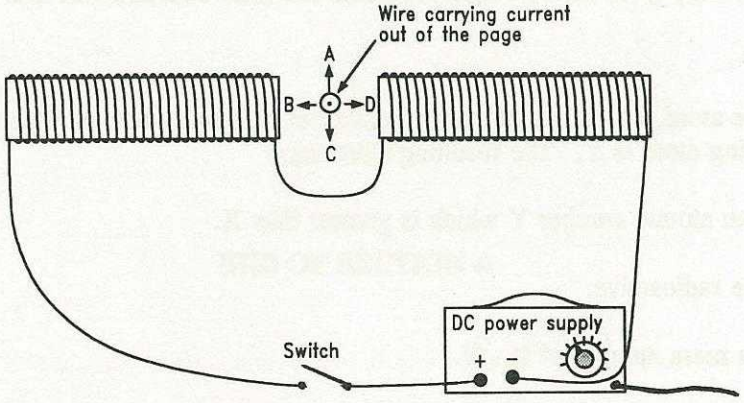
C. I and III only are true.

D. II and III only are true.

E. III only is true.

C

25. Two coils of wire are wound onto soft iron cylinders as shown. The coils are connected in series. Between the coils is a wire carrying a current out of the page.



When the switch S is closed so current flows through the coils the wire that is between the coils will

A. move in the direction A.

B. move in the direction B.

C. move in the direction C.

D. move in the direction D.

E. not move.

A

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26. The electrons in a cathode ray oscilloscope are accelerated from the cathode to the screen by a potential difference of 1·50 kV. If this potential difference is increased to 6·00 kV, the electrons will arrive at the screen with

A. four times the kinetic energy and four times the velocity.

B. four times the kinetic energy and sixteen times the velocity.

C. four times the kinetic energy and twice the velocity.

D. twice the kinetic energy and twice the velocity.

E. twice the kinetic energy and four times the velocity.

C

27. A clean surface of potassium metal will emit electrons when exposed to blue light. Which of the following is correct?

A. Light from a red light source will also cause electrons to be emitted from potassium.

B. If light of a different colour is used the work function will be different.

C. If the intensity of the blue light increases the maximum kinetic energy of the ejected electrons increases.

D. If the intensity of the blue light increases the number of electrons ejected per second increases.

E. If the intensity of the blue light increases the work function will also increase.

D

28. A radioactive atom, which has an atomic number of X, emits a beta particle. The atomic number of the resulting atom is Y. The resulting atom must

A. have an atomic number Y which is greater than X.

B. also be radioactive.

C. have a mass number of X - Y.

D. be an isotope of the initial atom.

E. have more neutrons than protons.

A

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29. The "Binding Energy per Nucleon" for a specific nucleus is

A. the total energy inside that nucleus.

B. the energy released when this nucleus is formed.

C. an indication of the energy needed to add a neutron to the nucleus.

D. an indication of the energy needed to add a proton to the nucleus.

E. a measure of the nuclear stability of the nucleus.

E

30. Line emission spectra are caused by

A. absorption of energy from atoms in a gas.

B. transfers of electrons between different atoms in a hot gas.

C. electrons in very hot solids releasing in the form of light.

D. the destruction of electrons by heat energy.

E. photons being emitted as electrons change energy levels within the same atom of a hot gas.

E

END OF SECTION A

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SECTION B

MARKS ALLOTTED : 52

Attempt ALL questions from this section. Credit will be obtained for method and reasoning only if these are clearly shown. Answers should be evaluated numerically.

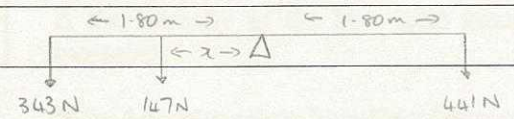
[6 marks]

1. A seesaw consists of a plank of wood which has a mass of 25·0 kg and is 3·60 m long. It is pivoted at the centre. Two children, one of mass 35·0 kg and the other of mass 45·0 kg sit on the extreme ends.

   (a) Where would a small third child of mass 15·0 kg need to sit to just balance the seesaw?
   [2 marks]

   (b) If the small child insisted on sitting at the end with the older and heavier of the two children, what adjustment to the position of the pivot point would be required for the plank to just balance?
   [4 marks]

(a)



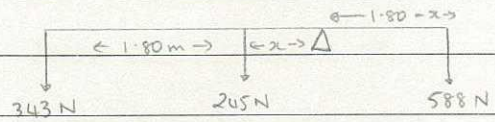
$\Sigma CM = \Sigma ACM$

$\Rightarrow (441)(1.80) = (147)x + (343)(1.80)$

$\Rightarrow x = 1.20\ m.$

∴ the child must sit 0·60 m from the same end as the 35·0 kg child

(b)



$\Sigma CM = \Sigma ACM$

$\Rightarrow (588)(1.80 - x) = (245)(x) + (343)(1.80 + x)$

$1058.4 - 588x = 245x + 617.4 + 343x$

$\Rightarrow x = 0.375\ m$

∴ the pivot is 1·42 m from the "heavy end".

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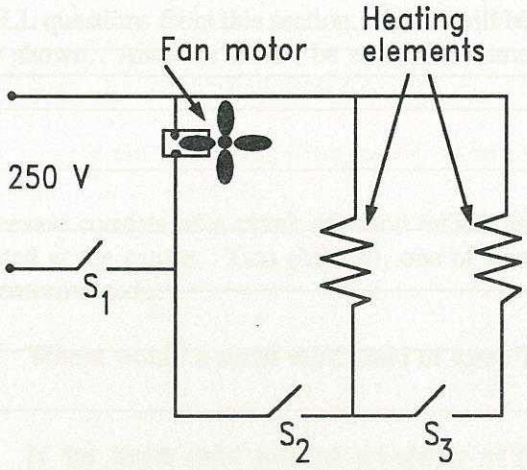
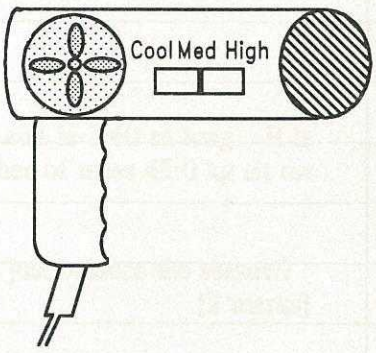
[7 marks]

2. The diagram below is a circuit for a hair drier like the one shown.





Each of the heating elements generates $5 \cdot 50 \times 10^2$ W and the fan motor requires $15 \cdot 0$ W to operate.

(a) The switch system on this type of hair drier is usually arranged so S_1 must be on before S_2 and then S_3 can be switched on. Also, if S_1 is switched off then S_2 and S_3 are also switched off. Explain why this is necessary. [1 mark]

(b) Calculate the cost of drying a person's hair if the drier is required to operate on the hottest ('high') setting for $5 \cdot 00$ minutes and if power costs $12 \cdot 3$ cents per kilowatt hour. [3 marks]

(c) Determine the ratio of the current flow through the motor to the current flow through each of the elements when the drier is operating on 'high'. [3 marks]

(a) Otherwise, the heaters would come on as soon as the plug is put in and turned on, but the fan wouldn't come on. Thus the dryer would overheat and cause a fire.

(b) $P = 1 \cdot 115 \times 10^3$ W. $E = Pt$

$= 1 \cdot 115$ kW $= (1 \cdot 115)(0 \cdot 08333)$

$= 9 \cdot 292 \times 10^{-2}$ kWh

$\therefore$ cost $= (9 \cdot 292 \times 10^{-2})(12 \cdot 3)$

$= 1 \cdot 143$ cents.

ie cost $= 1 \cdot 14$ d

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(c)

$$I_{FAN} = \frac{P}{V}$$

$$= \frac{15.0}{2.50 \times 10^{2}}$$

$$= 6.00 \times 10^{-2} \text{ A}$$

$$I_{HEATER} = \frac{P}{V}$$

$$= \frac{5.50 \times 10^{2}}{2.50 \times 10^{2}}$$

$$= 2.20 \text{ A}$$

$$\frac{I_{FAN}}{I_{HEATER}} = \frac{6.00 \times 10^{-2}}{2.20}$$

$$= 2.727 \times 10^{-2}$$

$\therefore$ ratio $= 2.73 \times 10^{-2}$

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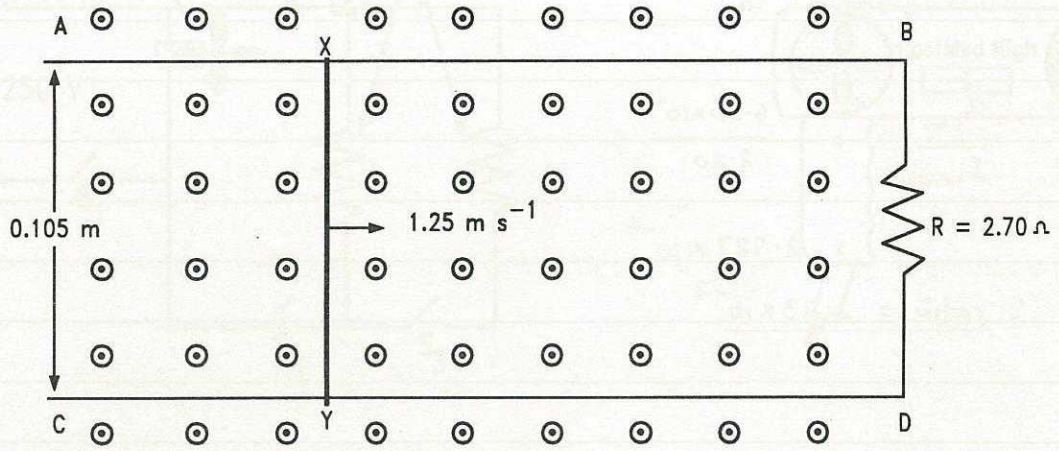
[6 marks]

3. Two parallel wires AB and CD are placed so that they are separated by a distance of 0·105 m and are perpendicular to a magnetic field of $2{\cdot}50 \times 10^{-3}$ T out of the page as shown in the diagram below.



A third wire XY is free to slide along AB and CD.

(a) Calculate the emf induced across XY if the wire slides to the right at 1·25 m s^{-1}. [3 marks]

(b) Use this to determine the power generated in the 2·70 Ω resistor. [2 marks]

(c) In which direction does the current flow? [1 mark]

(a) $EMF = Blv$

$= (2{\cdot}50 \times 10^{-3})(0{\cdot}105)(1{\cdot}25)$

$= 3{\cdot}281 \times 10^{-4}$ V

$\therefore EMF = 3{\cdot}28 \times 10^{-4}$ V

(b) $P = \frac{V^2}{R}$

$= \frac{(3{\cdot}28 \times 10^{-4})^2}{2{\cdot}70}$

$= 3{\cdot}984 \times 10^{-8}$ W

$\therefore P = 3{\cdot}98 \times 10^{-8}$ W

(c) XY

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[6 marks]

4. Deep space probes such as the two Voyager probes are powered by "thermionic" devices which convert the heat from radioactive decay directly into electrical energy. The typical radioisotope used is $^{238}_{94}$Pu which decays via alpha emission to $^{234}_{92}$U.

$^{238}_{94}$Pu = 238·0495 u $^{234}_{92}$U = 234·0409 u

(a) Write a balanced nuclear equation describing this decay. [1 mark]

(b) If all the energy comes from the alpha decay, calculate the maximum power output of thermionic device in which the $^{238}_{94}$Pu is decaying at a rate of $1{\cdot}9 \times 10^{15}$ atoms per second. [4 marks]

(c) Suggest why the thermionic generator is located on the end of a long arm as far away as possible from the main electronics payload of the space probe. [1 mark]

(a) $^{238}_{94}Pu \rightarrow {}^{234}_{92}U + {}^{4}_{2}He$

(b) m (reactant) = 238·0495 u

m (products) = 234·0409 u + 4·0026 u

= 238·0435 u

∴ lost mass = 0·0060 u

$= 9{\cdot}966 \times 10^{-30}$ kg

Mass lost per second = $(9{\cdot}966 \times 10^{-30})(1{\cdot}9 \times 10^{15})$

$= 1{\cdot}894 \times 10^{-14}$ kg

$P = \frac{E}{t} = \frac{mc^2}{t}$

$= \frac{(1{\cdot}894 \times 10^{-14})(3{\cdot}00 \times 10^{8})}{1{\cdot}00}$

$= 1{\cdot}705 \times 10^{3}$ W

∴ $P = 1{\cdot}70 \times 10^{3}$ W

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(c) The α particles emitted can damage sensitive electrical equipment.

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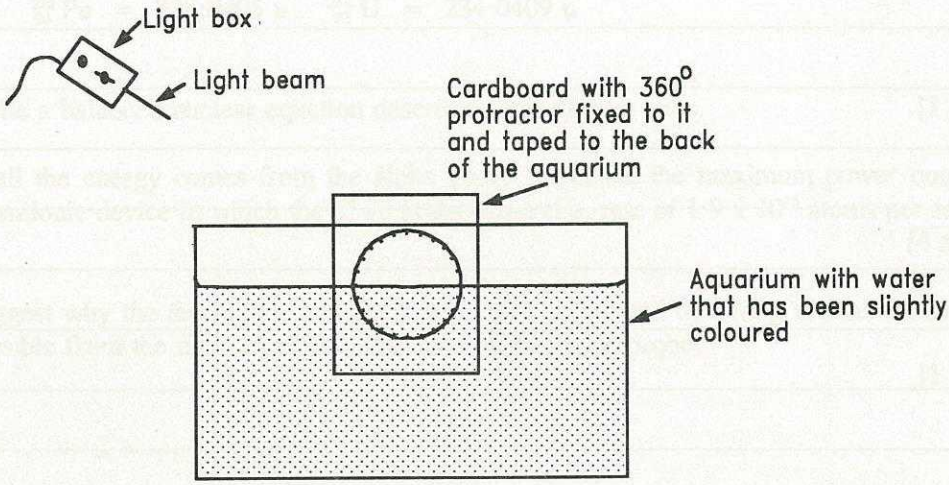
[7 marks]

5. You are a member of a group of students who set up the following arrangement to determine the relationship between the angle of incidence and the angle of refraction for a beam of light passing from air to water.



You obtained the following set of results:

	0·174	0·342	0·500	0·643	0·766	0·866	0·940	0·985
angle of incidence	10·0°	20·0°	30·0°	40·0°	50·0°	60·0°	70·0°	80·0°
angle of refraction	7·8°	15·5°	22·5°	29·0°	35·0°	40·5°	45·5°	50·0°
	0·136	0·269	0·383	0·485	0·574	0·649	0·713	0·766

(a) Use the above set of results and an appropriate graph to show whether these measurements are consistent with the known law of refraction. Note that it may be necessary to reprocess the above results to demonstrate this relationship. [3 marks]

(b) Use the data from the graph to calculate the refractive index of the water. [2 marks]

(c) Describe qualitatively how the graph would change if ethyl alcohol (refractive index 1·36) had been used instead of water. [1 mark]

(d) Carefully describe how each reading would need to be taken to ensure errors are minimised. [1 mark]

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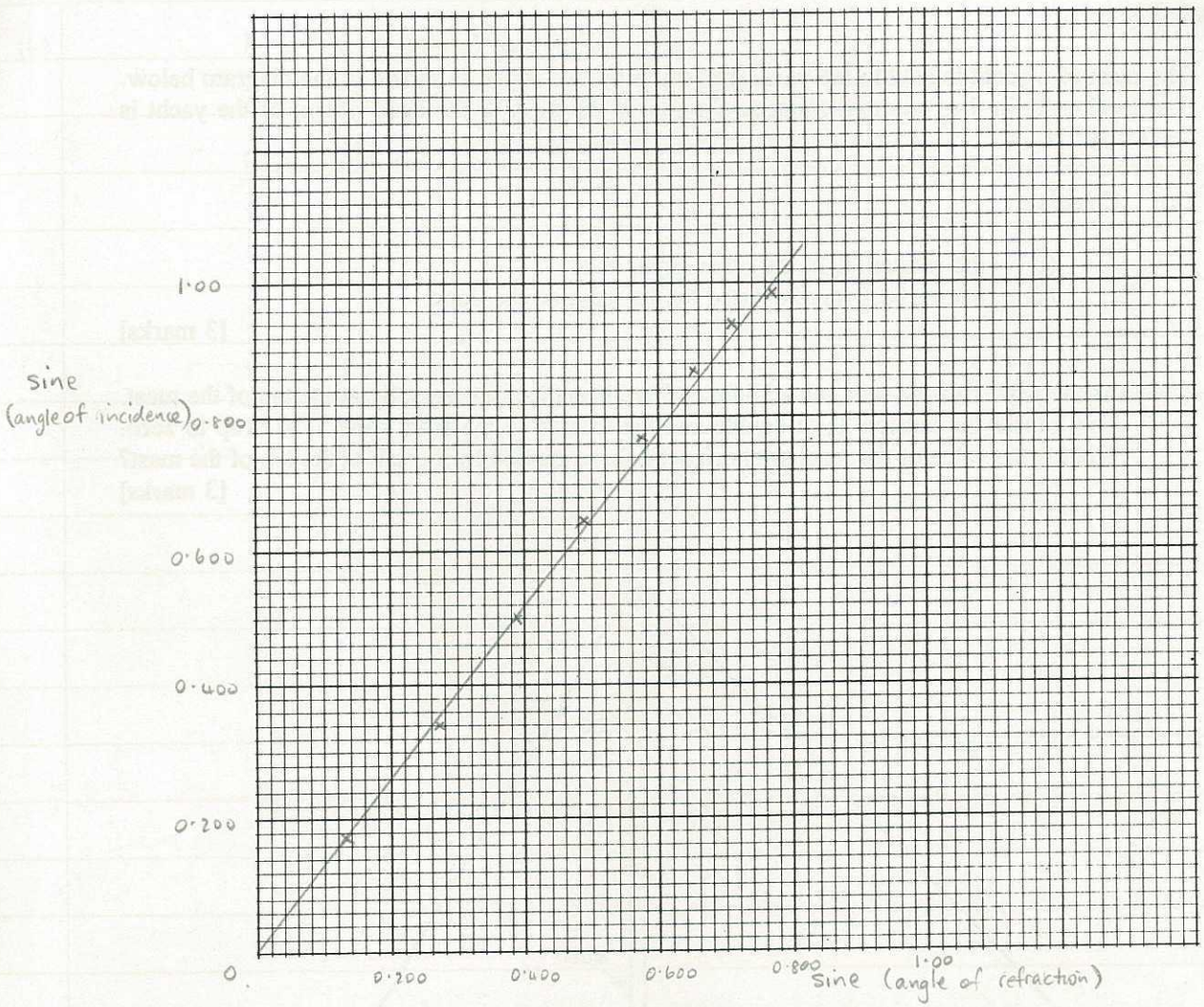

(b) $n_{N} = \text{slope} = \frac{1.00}{0.77}$

$= 1.3$

(c) The slope would be greater.

(d) Same person must make the measurements with his/her eyes level with the top of the water and directly in front of the scale.

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[6 marks]

6. The mast of a yacht is held in the vertical position by two ropes as shown in the diagram below. The tension T_b in the rope that connects the top of the mast to the back (stern) of the yacht is $7{\cdot}80 \times 10^3$ N.

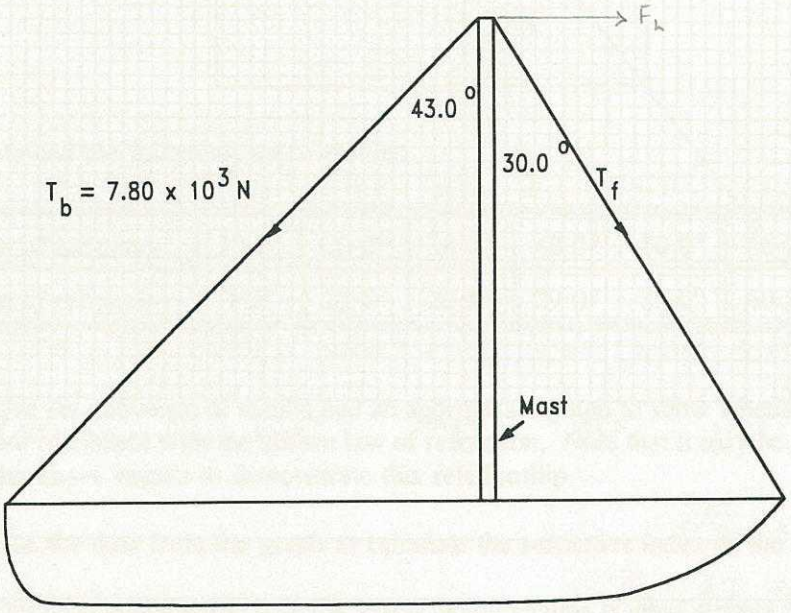
(a) Calculate

(i) the tension T_f in the other rope, and
(ii) the vertical force exerted by the mast on the deck.

[3 marks]

(b) As the wind fills the sails, an additional force is applied horizontally at the top of the mast. This causes the tension T_b to double and the tension in the front rope T_f to drop to zero. What is the value of the resultant horizontal force applied by the sail at the top of the mast?

[3 marks]



(a) (i) $\Sigma F_h = 0$

$\Rightarrow 7{\cdot}80 \times 10^3 \cos 47{\cdot}0^\circ = T_f \cos 60{\cdot}0^\circ$

$\Rightarrow T_f = 1{\cdot}064 \times 10^4$ N

$\therefore T_f = 1{\cdot}06 \times 10^4$ N

(ii) $\Sigma F_v = 0$

$\Rightarrow F_v = 7{\cdot}80 \times 10^3 \cos 43{\cdot}0^\circ + 1{\cdot}06 \times 10^4 \cos 30{\cdot}0^\circ$

$= 1{\cdot}492 \times 10^4$ N

$\therefore F_v = 1{\cdot}49 \times 10^4$ N downwards

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(b) $F_h = 2(7.80 \times 10^3) \cos 47.0^\circ$

$= 1.064 \times 10^4$ N.

$\therefore F_h = 1.06 \times 10^4$ N

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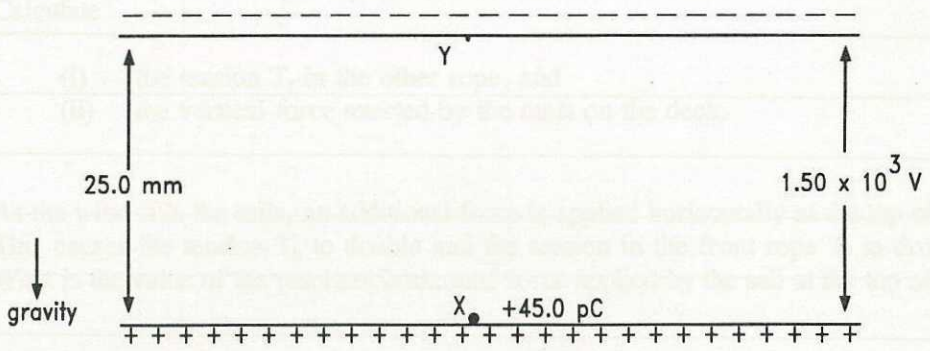
[7 marks]

7. Two parallel metal plates are placed 25·0 mm apart in a vacuum with a potential difference of $1{\cdot}50 \times 10^3$ V between them. A small insulating sphere of mass $5{\cdot}00 \times 10^{-8}$ kg carries a net charge of +45·0 pC and is held on the lower plate as shown in the diagram below.



When the sphere is released it moves from X to Y.

(a) Calculate the electric force acting on the sphere as it moves from X to Y.

[2 marks]

(b) Compare the electric force with the weight force acting on the sphere.

[1 mark]

(c) At what speed will the sphere be travelling when it reaches Y.

[2 marks]

(d) Show that energy is conserved as the sphere moves from X to Y.

[2 marks]

(a) $F_E = \frac{Vq}{d}$

$= \frac{(1{\cdot}50\times10^{3})(4{\cdot}50\times10^{-11})}{(2{\cdot}50\times10^{-2})}$

$= 2{\cdot}70\times10^{-6}$ N up.

(b) $F_W = mg$

$= (5{\cdot}00\times10^{-8})(9{\cdot}80)$

$= 4{\cdot}90\times10^{-7}$ N.

$\frac{F_E}{F_W} = \frac{2{\cdot}70\times10^{-6}}{4{\cdot}90\times10^{-7}}$

$= 5{\cdot}51$

$\therefore F_E = 5{\cdot}51 F_W$

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(c) $\Sigma F = ma = F_E - F_W$

$\Rightarrow a = \dfrac{(2.70\times10^{-6} - 4.90\times10^{-7})}{5.00\times10^{-8}}$

$= 44.2\ ms^{-2}$

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

$= 0 + 2(44.2)(2.50\times10^{-2})$

$\Rightarrow v = 1.487\ ms^{-1}$

$\therefore v = 1.49\ ms^{-1}$ towards the negative plate.

(d) Energy expended by the field: $E_T = Vq$

$= (1.50\times10^{3})(4.50\times10^{-11})$

$= 6.750\times10^{-8}\ J.$

In moving from X to Y: $E_T = E_p + E_K$

$= mgh + \frac{1}{2}mv^2$

$= (5.00\times10^{-8})(9.80)(2.50\times10^{-2}) + \frac{1}{2}(5.00\times10^{-8})(1.487)^2$

$= 6.753\times10^{-8}\ J.$

$\therefore$ energy has been conserved.

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[7 marks]

8. A disc with diameter of $3{\cdot}00 \times 10^2$ mm is rotating in a horizontal plane at 33·3 r.p.m. (revolutions per minute). A beetle starts at the centre and crawls outwards along a diameter at a velocity of $0{\cdot}0150$ m s^{-1}.

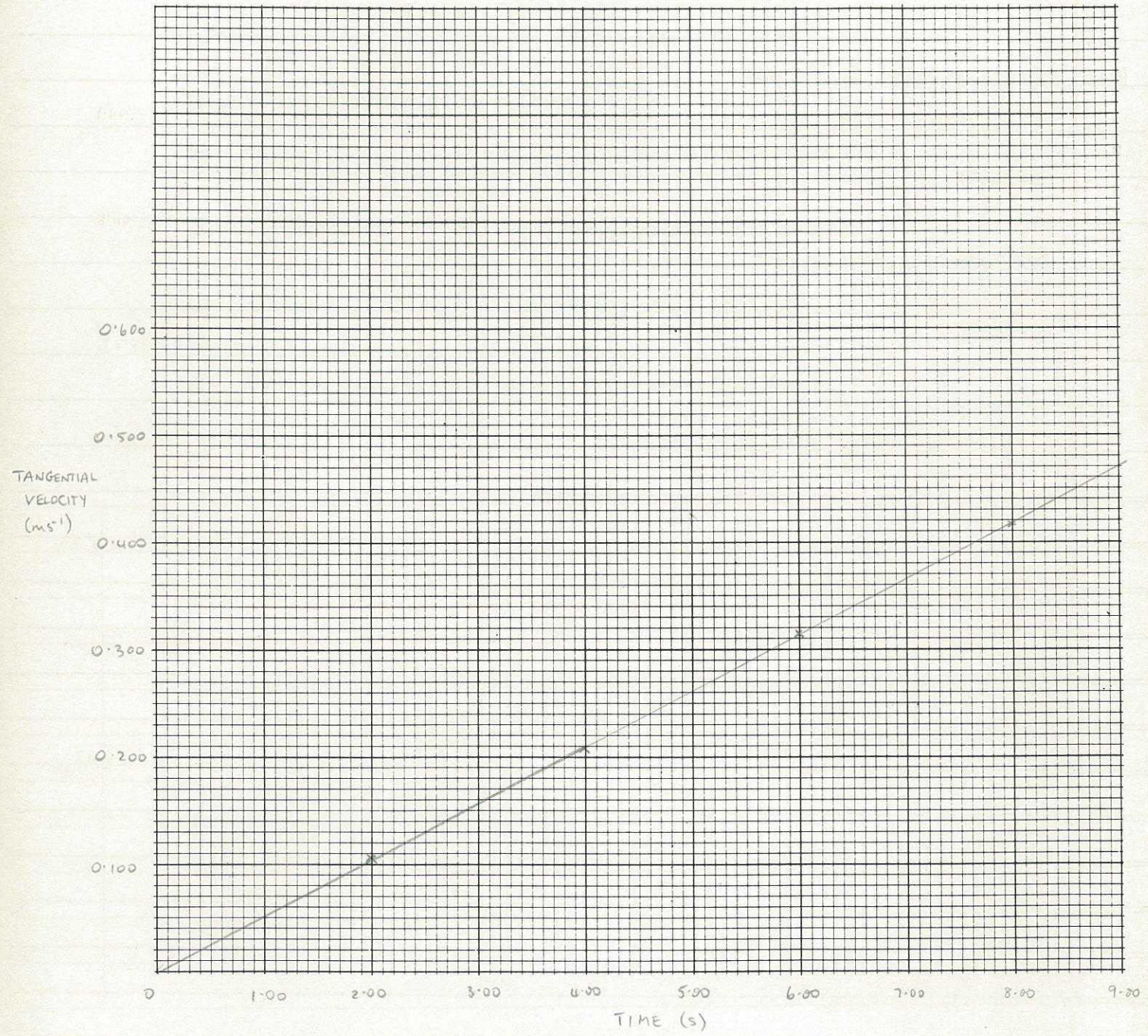
(a) Draw an accurate graph showing how the beetle's tangential velocity varies with time as it crawls from the centre towards the perimeter.

[3 marks]

(b) If the maximum force that friction can supply between the beetle's feet and the disc is $6{\cdot}00 \times 10^{-4}$ N and the beetle has a mass of 0·450 g, what radius will the beetle reach before slipping off the disc?

[4 marks]

$T = \frac{60}{33{\cdot}3} = 1{\cdot}802\,s.$ $\quad v = \frac{2\pi r}{T} = \frac{2\pi (0{\cdot}01500)}{1{\cdot}802}\, t$



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(b)

$$F_c = F_{FR} = \frac{mv^2}{r}$$

$$= \frac{4\pi^2 mr}{T^2}$$

$$\Rightarrow r = \frac{F_{FR} T^2}{4\pi^2 m}$$

$$= \frac{(6.00 \times 10^{-4})(1.802)^2}{4\pi^2 (4.50 \times 10^{-4})}$$

$$= 1.097 \times 10^{-1} \text{ m}.$$

$$\therefore r = 0.110 \text{ m}.$$

END OF QUESTIONS

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