Class	Index Number	Name
22S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2023
Preliminary Examination

PHYSICS, Higher 2 **9749/03**

Paper 3 Longer Structured Questions **15th September 2023**
2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section **A**
Answer **all** questions.

Section **B**
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Section A	
1	/ 11
2	/ 5
3	/ 10
4	/ 10
5	/ 12
6	/ 12
Section B	
7	/ 20
8	/ 20
Total	/ 80

This document consists of **31** printed pages including this page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	$g = 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas	$W = p\,\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	T / K $= T$ / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$v = \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 n I$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{1/2}}$

Section A

Answer **all** questions in the spaces provided

1 **(a)** Fig. 1.1 shows a speed-time graph for a car moving in a straight line. The graph has been divided into 5 stages A, B, C, D and E.

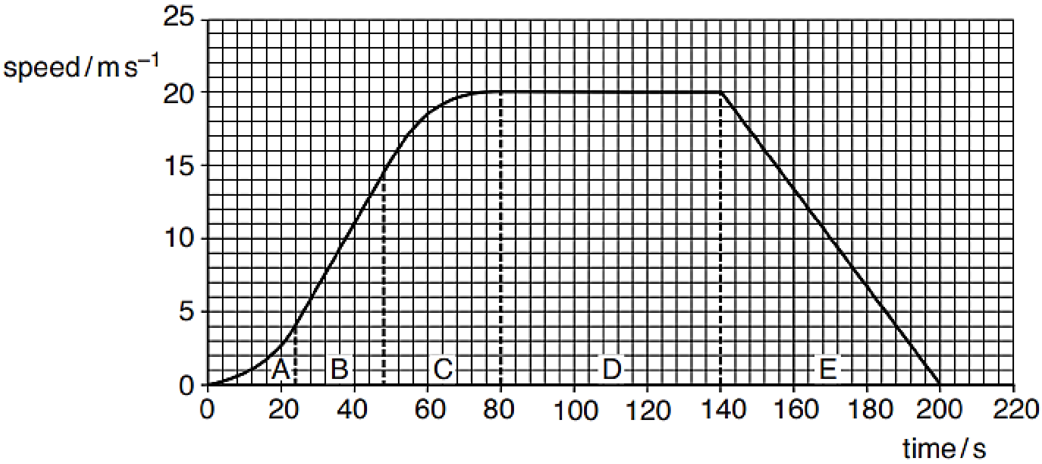


Fig. 1.1

(i) Using Fig. 1.1, estimate the distance that the car travels during the whole 200 s.

distance = ... m [2]

(ii) Estimate the uncertainty in your answer to **(a)(i)** and explain your reasoning

....

....

uncertainty = ... m [2]

(b) A golf ball is hit from point A on the ground and moves through the air to point B. The path of the ball is illustrated in Fig. 1.2.

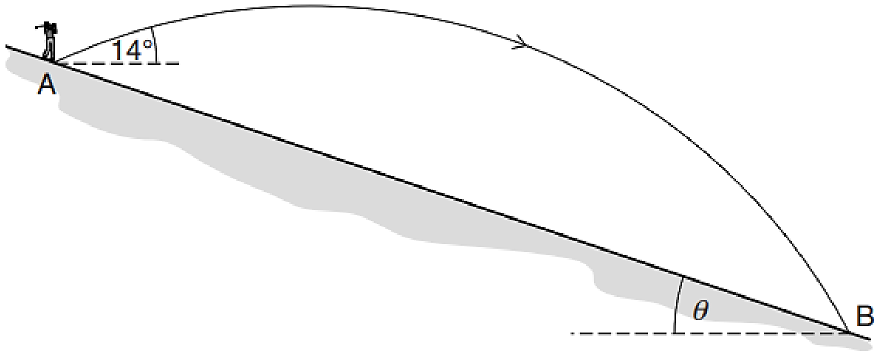


Fig. 1.2 (not to scale)

The ground slopes downhill with constant gradient. The ball has an initial velocity of 63 m s^{-1} at an angle of 14° to the horizontal. The ball hits the ground at B after 4.9 s.

(i) Determine the angle of the slope to the horizontal, θ.

angle θ = …………………………… ° [3]

(ii) In a real situation, air resistance provides a force on the ball in the opposite direction to its motion.

1. On. Fig. 1.2, sketch a likely path of the ball hit from A when air resistance is taken into account. [1]

2. Give reasons for the shape you have drawn in **(b)(ii)1.** for

the path of the ball at the start,

……………………..……………………………………………………………..

………………………..…………………………………………………………..

..……………………..…………………………………………………………

the position for the highest point,

……………………..……………………………………………………………..

………………………..…………………………………………………………..

………………………..…………………………………………………………..

the angle at which the ball hits the ground.

……………………..……………………………………………………………..

………………………..…………………………………………………………..

………………………..…………………………………………………………..
[3]

2 **(a)** In the circuit shown in Fig. 2.1, the cell has an e.m.f. of 10 V and negligible internal resistance. The resistances of R_1 and R_2 are such that both lamps **A** and **B** are operating at their rated voltage.

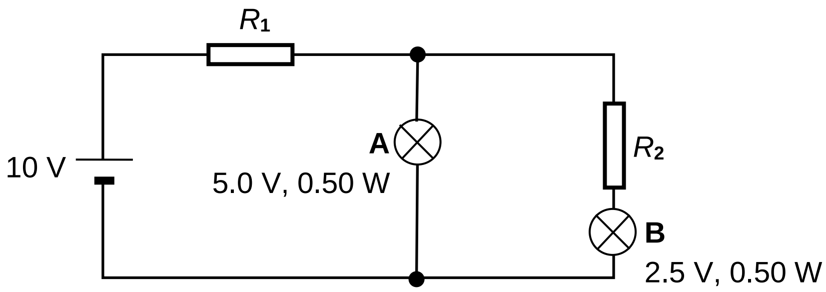


Fig. 2.1

Calculate the resistances of R_1 and R_2.

R_1 = ………………………….. Ω

R_2 = ………………………….. Ω [3]

(b) In the circuit shown in Fig. 2.2, the cell has an e.m.f. of 12 V and internal resistance of 10 Ω. It is connected in series with a 7 Ω resistor and R_3.

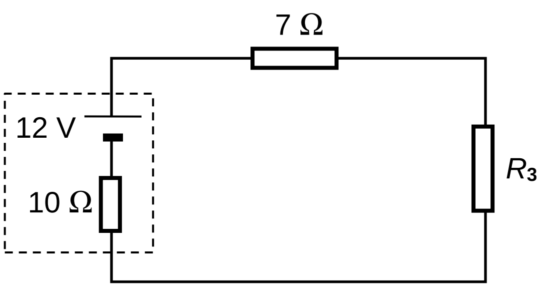
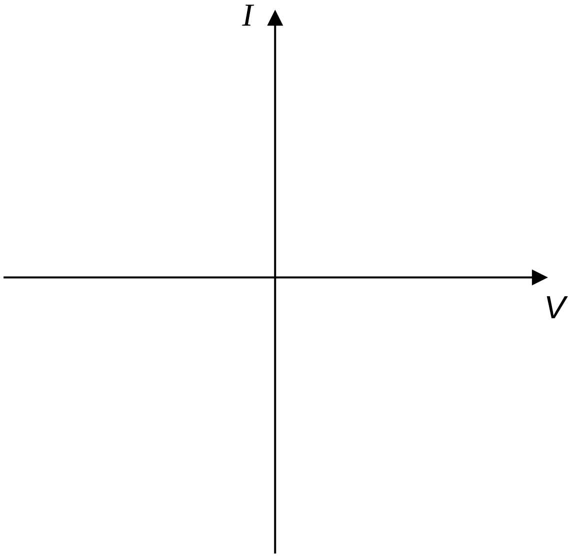


Fig. 2.2

State the resistance of R_3 such that there is maximum power delivered to R_3.

R_3 = ………………………….. Ω [1]

(c) Sketch the current – voltage (I – V) characteristics of an *ideal* semiconductor diode.



[1]

3 **(a)** State Coulomb's Law.

……

……

………………………………………………………………………………………………….. [1]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 3.1.

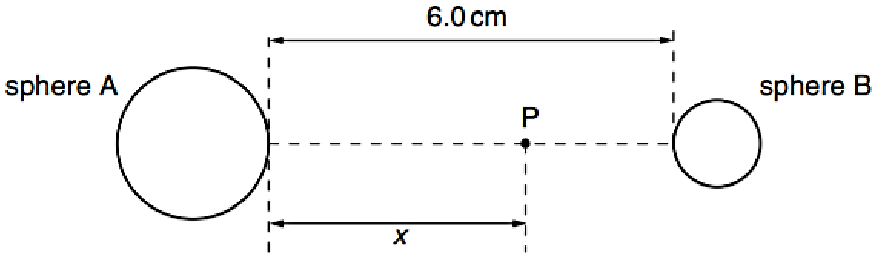


Fig. 3.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance *x* from the surface of sphere A.

The variation with distance *x* of the electric field *E* at point P is shown in Fig. 3.2.

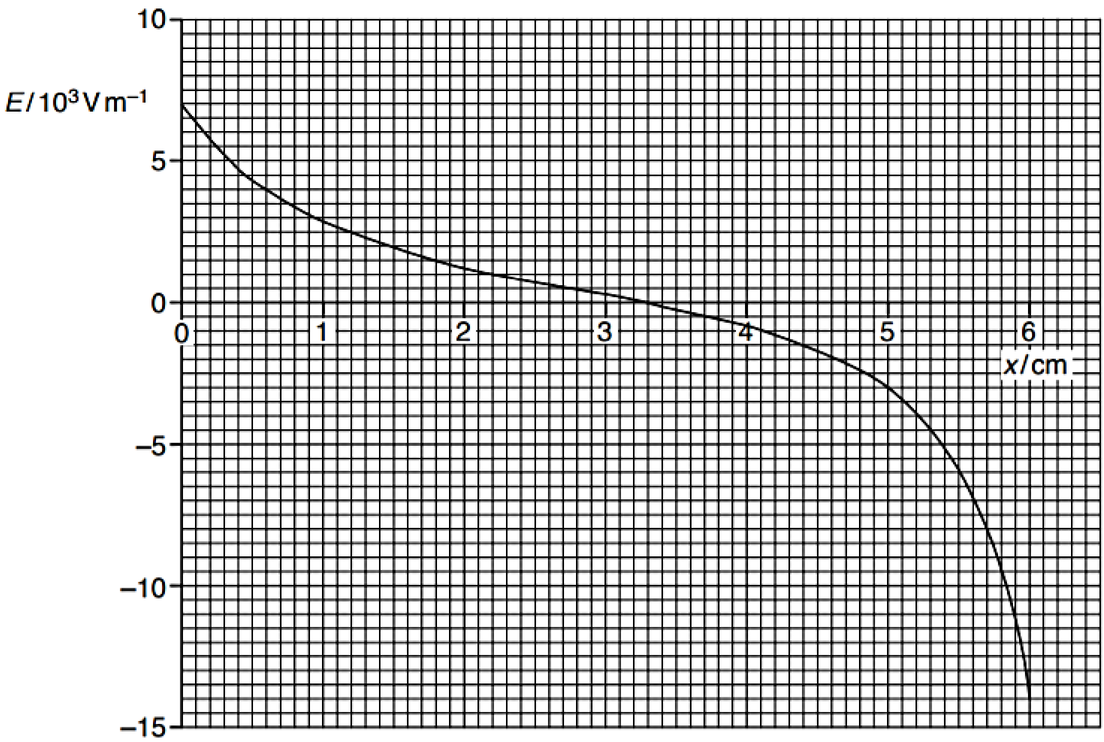


Fig. 3.2

A proton is at rest at point P when x = 5.0 cm.

Use data from Fig. 3.2 to estimate the speed of the proton at x = 3.3 cm.

speed = ………………………….. m s^{-1} [3]

(c) A charge of +5.0 μC is shot through a small hole at **A** into a region between two parallel metal plates separated by a distance d and connected to a d.c. voltage source. One metal plate is at a potential of +100 V, and the charge emerges from another hole at **B** as shown in Fig. 3.3 below.

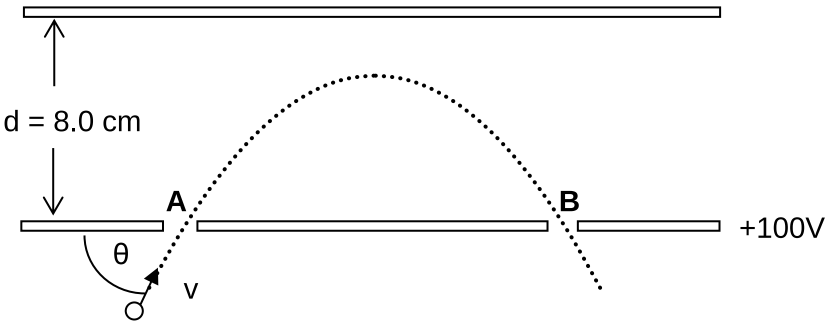


Fig. 3.3

(i) The electric field between the plates is found to be 2500 V m^{-1}.

Determine the potential of the other metal plate.

potential = ………………………….. V [2]

(ii) Sketch a possible trajectory of the charge on Fig. 3.4 when the upper plate is moved further away from the lower plate.

Label this trajectory **E**.

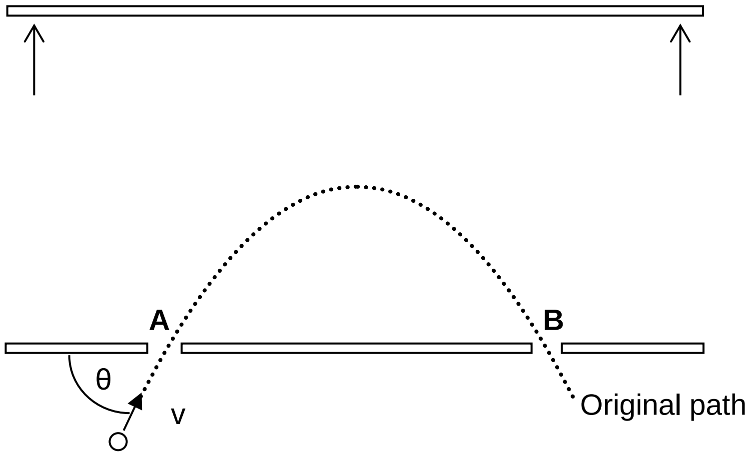


Fig 3.4

[1]

(d) Two identical spherical drops of water, each carrying a charge of +1.0 x 10^{-11} C and with electric potential of 500 V on its surface, combine to form a single spherical drop.

Determine the approximate potential on the surface of the new drop formed.

potential = ………………………….. V [3]

4 **(a)** Two charged particles X and Y travelling in the same direction, each with velocity *v*, enter a uniform magnetic field of flux density *B* in a vacuum. Particles X and Y have the same mass *m* but different charges q_X and q_Y respectively.

The paths of particles X and Y in the magnetic field are shown in Fig. 4.1. The radius of the semi-circular path of particle Y is double that of particle X.

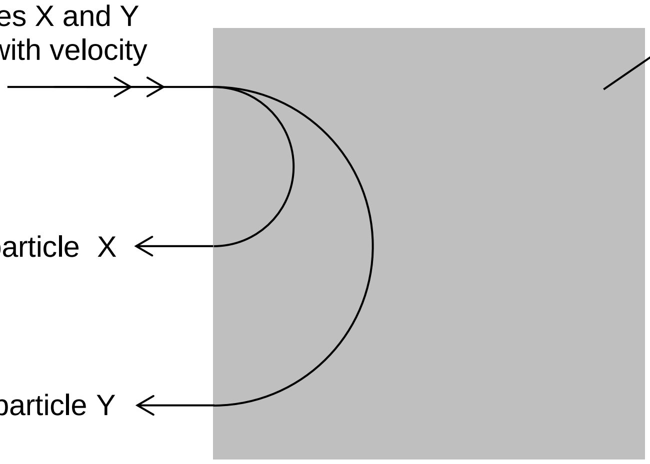


Fig. 4.1

(i) Explain why the paths of the charged particles are circular in the magnetic field.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(ii) State if the charge of the particles is positive or negative.

…………………………………………………………………………………………… [1]

(iii) Determine the ratio $\frac{q_x}{q_y}$.

$\frac{q_x}{q_y}$ = ………………………….. [2]

(b) Particle X with velocity *v* now enters another uniform magnetic field region having the same flux density *B* as before but with uncharged gas particles throughout. It moves in a path in the magnetic field as shown in Fig. 4.2.

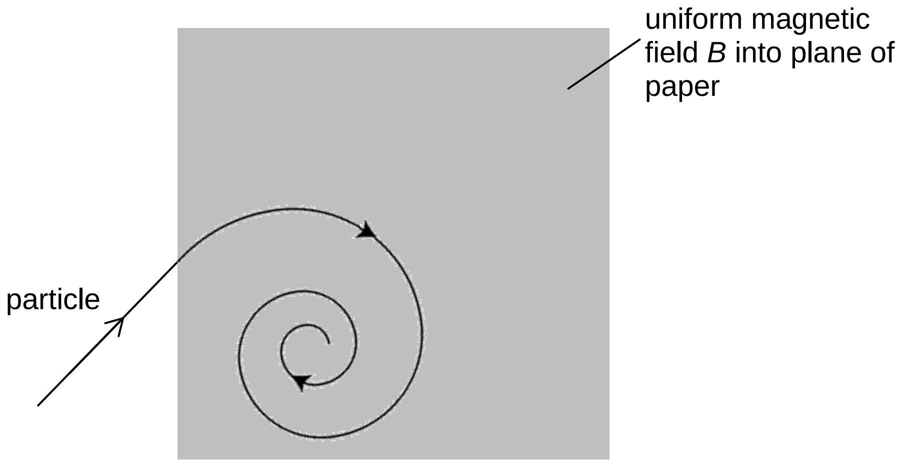


Fig. 4.2

(i) Explain, using any relevant equations, the path of particle X shown in Fig. 4.2.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………… [2]

(ii) **1.** Deduce an expression for the time *T* taken for one revolution of the path in terms of *m*, q_X and *B*.

T = ………………………….. [2]

2. The tau particle is an elementary particle that has the same charge as an electron but has a mass that is 3000 times that of an electron. It has a mean lifetime of 2.9×10^{-13} s.

State with a reason if particle X could be a tau particle if B = 1.0 T.

……………………………………………………………………………………….

……………………………………………………………………………………... [1]

5 **(a)** Fig. 5.1 shows a ground fault interrupter (GFI) - a device used in a.c. outlets where the risk of electric shock is high, e.g. bathrooms. The GFI consists of a sensing coil wound around an iron ring that surrounds the wires that transmit electricity to the appliance.

When the appliance functions normally, the net magnetic field in the iron ring is zero. However, when current flows through a person to the ground instead of flowing through the return wiring, the sensing coil activates a circuit breaker.

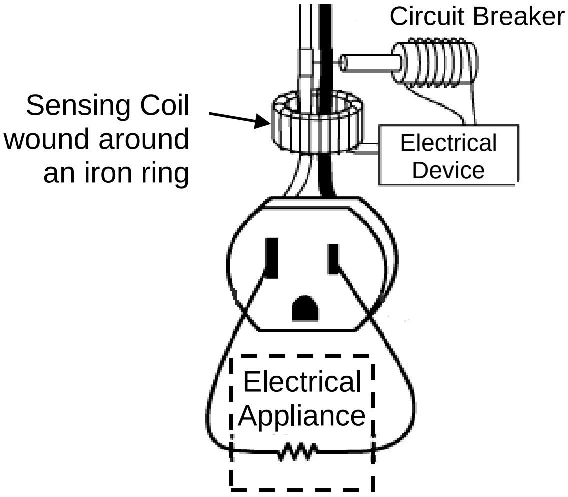


Fig. 5.1

(i) State the purpose of the iron ring.

…………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

(ii) Use Faraday's law to explain why the circuit breaker is triggered when a fault in the appliance causes the user to be electrocuted.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………… [3]

(iii) Suggest one way to increase the sensitivity of the sensing coil.

…………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

(b) The magnetic field shown in Fig. 5.2 below has a uniform magnitude of 25.0 mT directed into the paper. A long wire that forms a loop with an initial diameter of 2.00 cm is placed within the field.

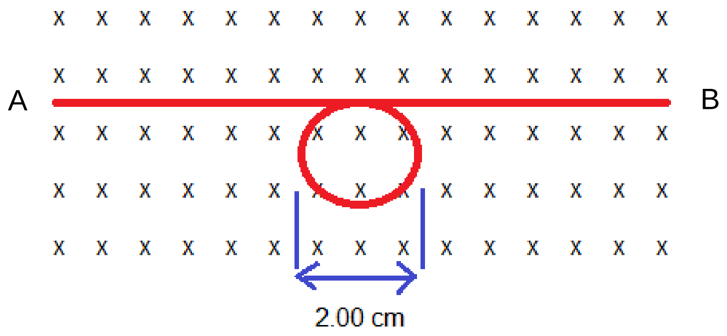


Fig. 5.2

The wire is quickly pulled taut and straightened such that there is no more loop in 50.0 ms.

(i) Determine the average voltage induced between endpoints A and B.

voltage = ………………………….. V [2]

(ii) State and explain whether the potential at A is higher or lower than the potential at B.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………... [2]

(c) An oscilloscope is used to measure the potential difference across a resistor in an a.c. circuit. The voltage waveform is shown in Fig. 5.3.

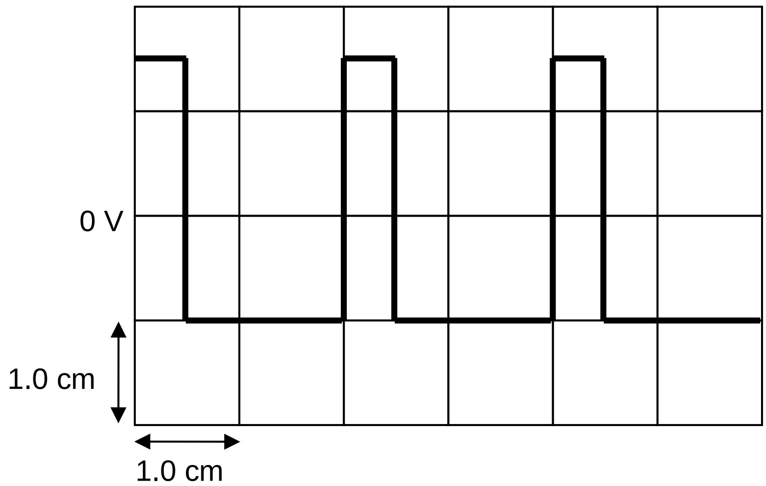


Fig. 5.3

(i) Determine the time base setting of the oscilloscope if the frequency of the waveform is 100 Hz.

time base = ………………………….. ms cm^{-1} [1]

(ii) Determine the root-mean-square value of the potential difference across the resistor if the Y-gain is set at 0.5 V cm^{-1}.

V_{rms} = ………………………….. V [2]

6 In a photoelectric experiment, a beam of radiation of wavelength 620 nm from a laser of intensity 400 W m^{-2} is used to irradiate a silver surface of area 100 mm^2 in an evacuated photocell as shown in Fig. 6.1. The experiment is then repeated with another radiation of the same intensity but of unknown wavelength.

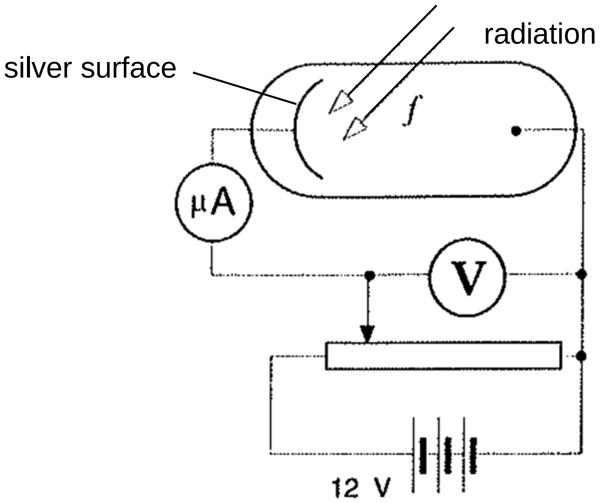


Fig. 6.1

Fig 6.2 shows the variation with voltage *V* across the electrodes of the photocurrent *I* for the two radiations used.

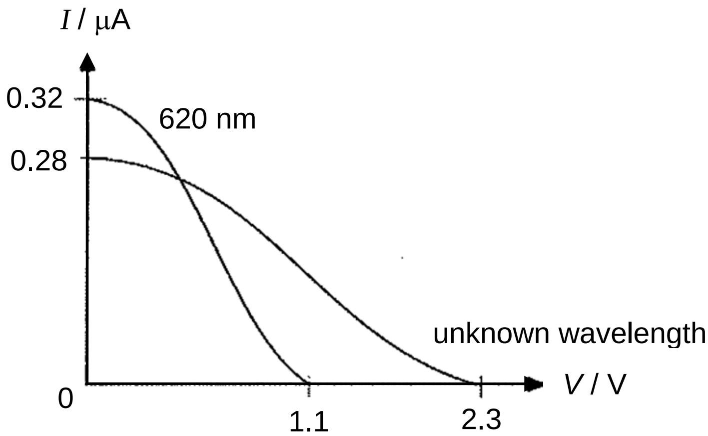


Fig. 6.2

(a) **(i)** Using Fig. 6.2, determine the wavelength of the unknown radiation.

wavelength = ………………………….. m [3]

(ii) Hence explain why this unknown radiation produces a lower saturation current as compared to the radiation with a wavelength of 620 nm.

……………………………………………………………………………………………...

……………………………………………………………………………………………...

……………………………………………………………………………………………...

…………………………………………………………………………………………. [2]

(b) In the Coolidge tube (also called a hot cathode tube), electrons are produced from a filament heated by an electric current as shown in Fig. 6.2. A large accelerating potential difference is set up between the filament and the target material. The electrons are accelerated from the filament and hit the target material to emit x-ray photons.

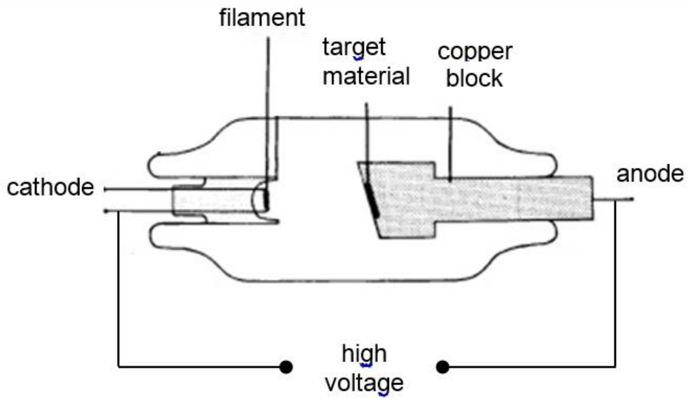


Fig. 6.2

A graph of intensity against frequency of the emitted radiation is plotted as shown in Fig 6.3.

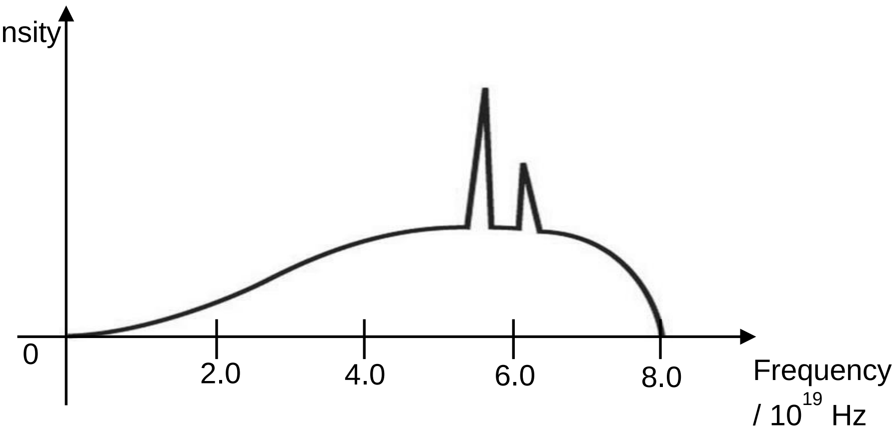


Fig. 6.3

(i) Explain why there is a maximum frequency as shown in Fig. 6.3

……………………………………………………………………………………………….

………………………………………………………………………………………… [1]

(ii) Determine the maximum energy of the X-ray photons emitted.

maximum energy = ………………………….. MeV [1]

(iii) Sketch on Fig. 6.3, a graph to show the intensity variation with frequency if the current in the filament increases. Label this graph P. [1]

(iv) Sketch on Fig. 6.3, a graph to show the intensity variation with frequency if the accelerating potential is reduced to one half of its original value. Label this graph Q. [1]

(c) Fig. 6.4 shows the lowest five energy levels for a hydrogen atom.

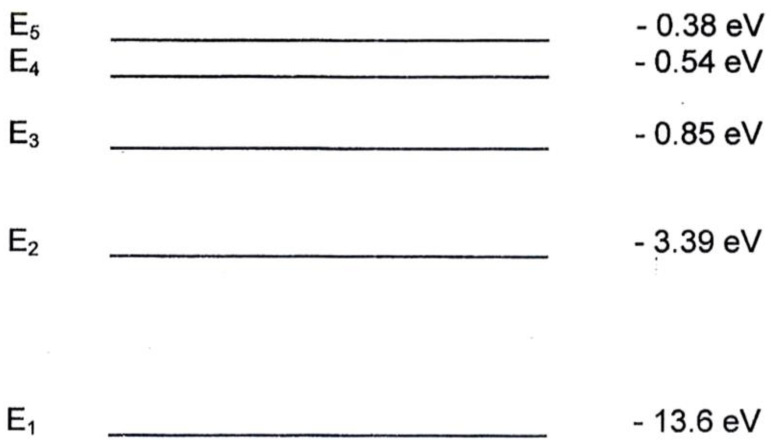


Fig. 6.4

Hydrogen atoms are contained in a low pressure vapour lamp. Electrons in the vapour are accelerated from rest by a potential difference *V* and subsequently bombard the hydrogen atoms. A line corresponding to a wavelength of 436 nm is observed in the line spectrum.

(i) Deduce the energy levels involved in the transition to produce this wavelength.

the transition is from ………….. to ………….. [2]

(ii) State and explain the minimum value of V used to give rise to the transition in **(i)**.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [1]

Section B

Answer **one** question from this section in the spaces provided.

7 **(a)** Two blocks, P and Q, of masses 0.50 kg and 1.00 kg respectively, are connected by a string that passes over a pulley as shown in Fig. 7.1. The spring constant is 200 N m^{-1}.

The pulley is light and frictionless, and the string is inextensible. The system is released from rest.

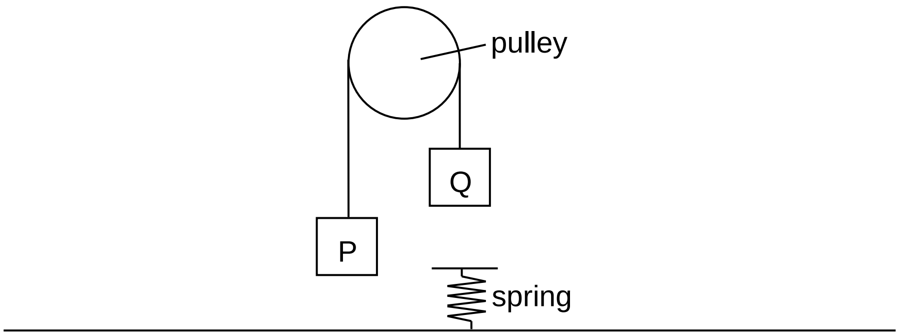


Fig. 7.1

Block Q falls vertically before it strikes a spring that is firmly attached to the floor.

(i) Determine the tension in the string just before block Q strikes the spring.

tension in the string = ……………………..……. N [3]

(ii) The acceleration of Block Q decreases after it touches the spring. Block Q comes to a permanent stop after some time and the spring is observed to be compressed.

Calculate the compression of the spring, *x*.

compression of spring, *x* = ……………….……. m [2]

(b) A bullet of mass 5.0 g is fired from a gun into a block of mass 0.500 kg, which is suspended by thin threads from fixed points. The bullet remains in the block, which swings upwards as to a maximum height of h as shown in Fig. 7.2.

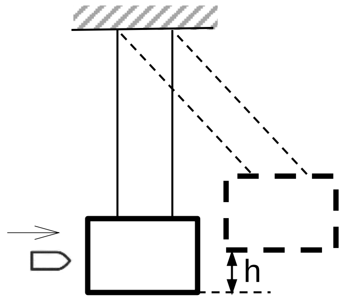


Fig. 7.2

(i) If the velocity of the bullet just before it strikes the block is 100 m s^{-1}, determine the maximum height h.

maximum height = ……………….……. m [2]

(ii) State the type of collision between the bullet and the block.

……………………………………………………………………………………. [1]

(c) Fig 7.3 below shows a ride that involves a train being launched by a mechanism that accelerates it to 89 km h^{-1} in 4.5 seconds. The train will then negotiate a 23.0 m diameter loop before ascending the open-end 45.0 m tall front track. The train then falls backwards under its own weight, going through the loop a second time, ascending the back vertical track and returning to its starting position at the station, brought to a halt through brakes in the station.

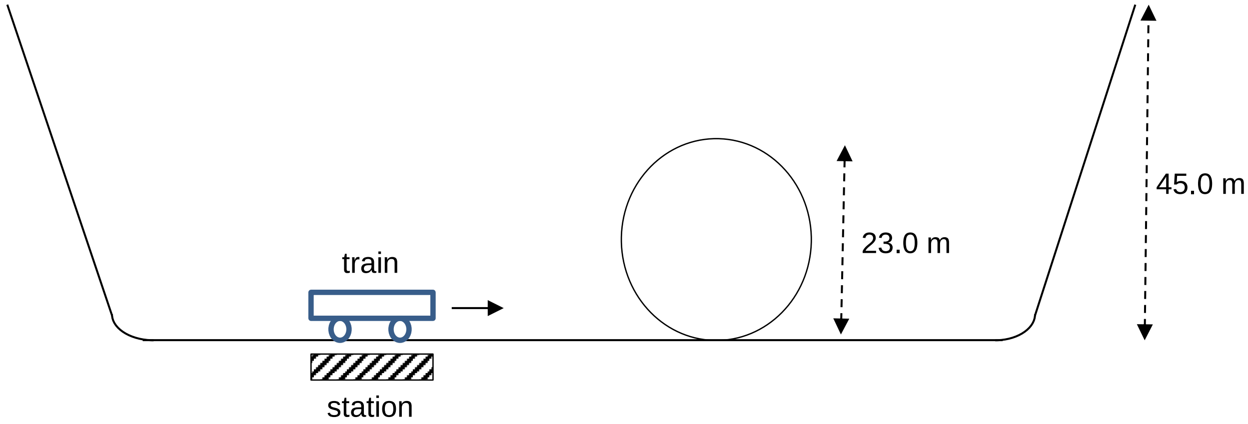


Fig. 7.3

In a typical operation, 28 riders in a single train with 7 cars have a combined mass of 6500 kg. Assume that the track is smooth.

(i) Determine the average power required by the mechanism to bring the train to 89 km h^{-1} in 4.5 s.

average power = ……………………..……. W [1]

(ii) Show that the train will not travel beyond the open-end part of the track after emerging from the loop.

[1]

(iii) Each rider is to be restrained by a lap bar. Should the lap bar's locking mechanism fail and unlock itself as the train negotiates the loop, determine if the rider will fall off the train. Show all calculations clearly.

....

.... [3]

(d) A boom can be used to assist a person to move heavy loads. A typical arrangement is shown below.

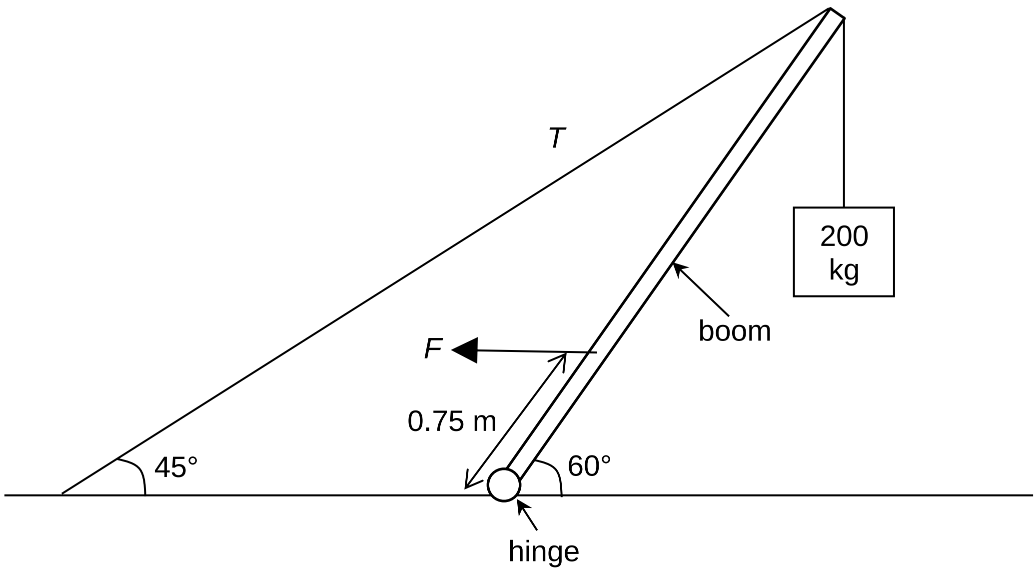


Fig. 7.4

The boom is angled at 60° to the horizontal, and a steel cable is attached to the top of the boom and the floor such that the cable makes an angle of 45° to the horizontal, as shown. The uniform boom has a mass of 45 kg and length 3 m.

A human operator exerts a force F = 120 N horizontally at a distance 0.75 m away from the hinge as measured along the boom. The system is in equilibrium.

(i) State the conditions for a body to be in static equilibrium.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………………………………………………………………………………….. [2]

(ii) Show that the tension *T* in the cable connecting from the top of the boom to the floor is 4.1 kN.

[2]

(iii) Determine the magnitude and direction of the force exerted by the hinge on the boom.

magnitude of force = …………………………….. N

direction of the force = ………………………………………………………… [3]

8 **(a)** A test-tube is partially loaded with small ball bearings such that it is able to float upright in water of density ρ as shown in Fig. 8.1. The bottom of the test-tube is a distance H below the water surface.

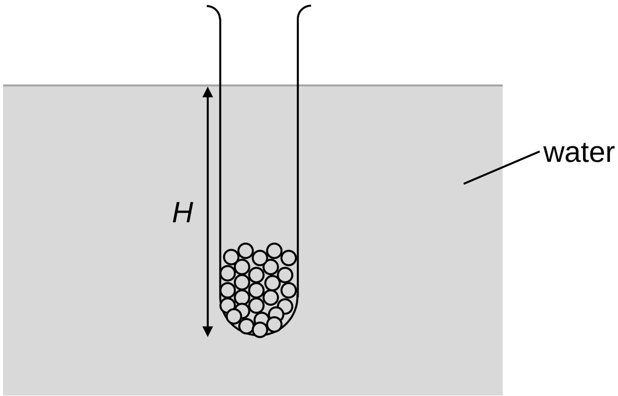


Fig. 8.1

Ignoring its rounded bottom, the test-tube may be regarded as a cylinder of cross sectional area A and mass m. The mass of the ball bearings added is M.

(i) On Fig. 8.2, draw the forces acting on the system of the test-tube and ball bearings when it is floating.

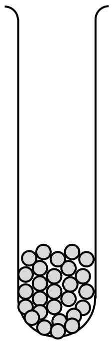


Fig. 8.2

[1]

(ii) The test-tube is displaced vertically downward by displacement *y* and then released.

Taking downward to be positive and ignoring any dissipative forces, show that the acceleration of the test-tube is given by

$$a = -\left(\frac{\rho A g}{M + m}\right) y$$

where *g* is the acceleration of free fall.

[3]

(iii) It is given that *H* = 0.062 m.

Show that the period of oscillation of the test-tube is 0.50 s.

[2]

(iv) Given that *M* = 0.012 kg, *m* = 0.025 kg and *y* = 1.0 cm, calculate the maximum vibrational kinetic energy of the oscillating system.

maximum kinetic energy = …………………… J [2]

(v) On Fig. 8.3, show the variation with time of the vibrational kinetic energy of the system.

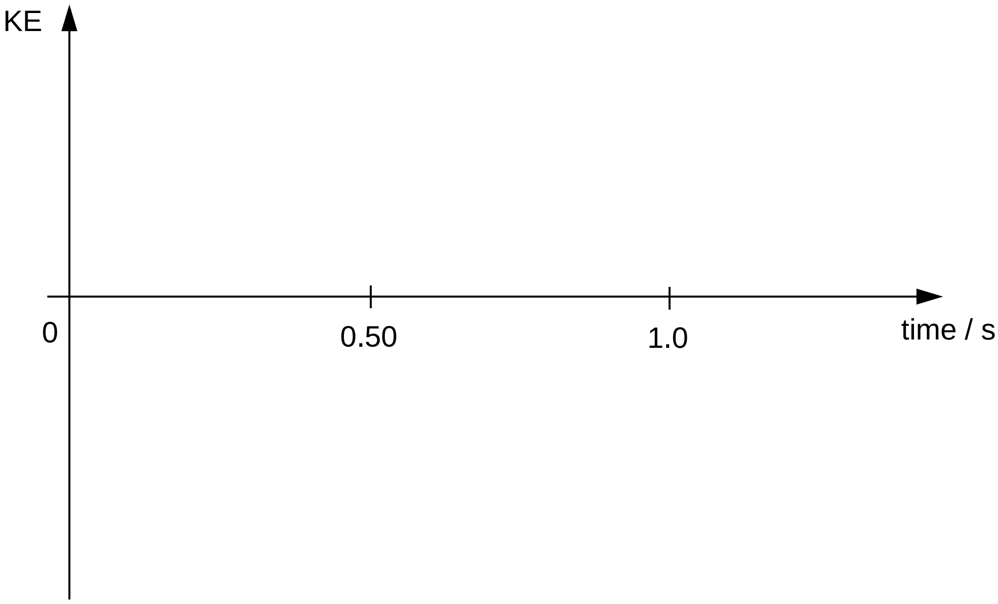


Fig. 8.3

[2]

(vi) In practice, it is observed that the variation with time *t* of the vertical displacement *y* of the test-tube is as shown in Fig. 8.4.

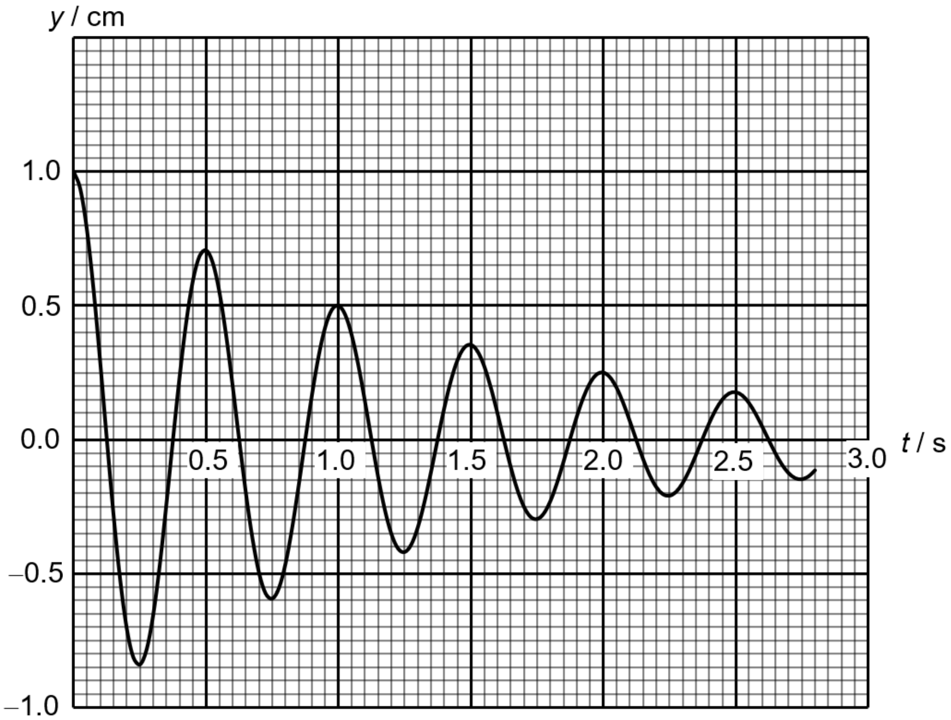


Fig. 8.4

Explain why the amplitude of the oscillations decreases gradually over time.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

………………………………………………………………………………………………. [2]

(vii) To sustain the oscillations of the test-tube, low-amplitude water waves of variable frequency are generated on the surface of the water.

1. On Fig. 8.5, show the variation with driving frequency of the amplitude of the test-tube.

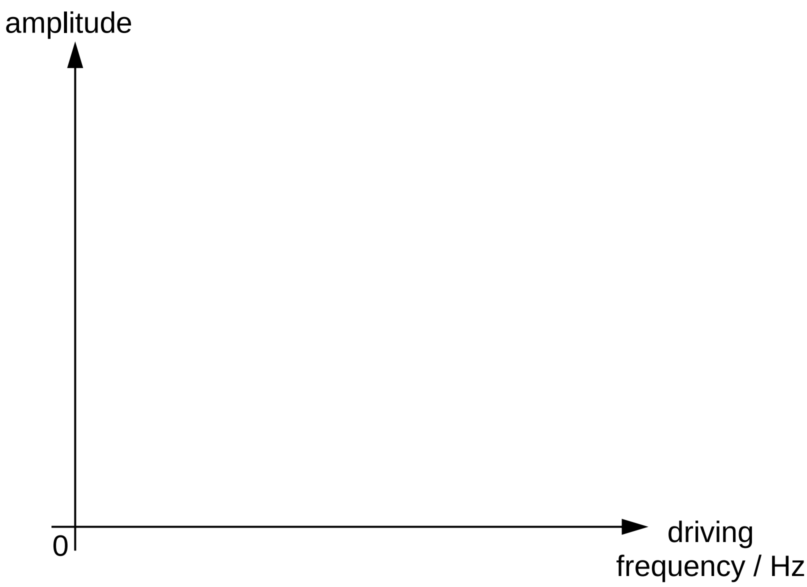


Fig. 8.5 [1]

2. When water waves of frequency 0.30 Hz are generated on the surface of the water, it is observed that the amplitude of the vertical oscillations of this test-tube is rather small.

Without changing the frequency of the water waves, suggest with reasoning how the amplitude of the oscillations of this test-tube may be increased.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

………………………………………………………………………………………… [2]

(b) Fig. 8.6 shows unpolarised light of intensity I_0 incident, at right angles, on a polarising filter F_1. A second polarising filter F_2 is identical to F_1. It is placed parallel to F1.

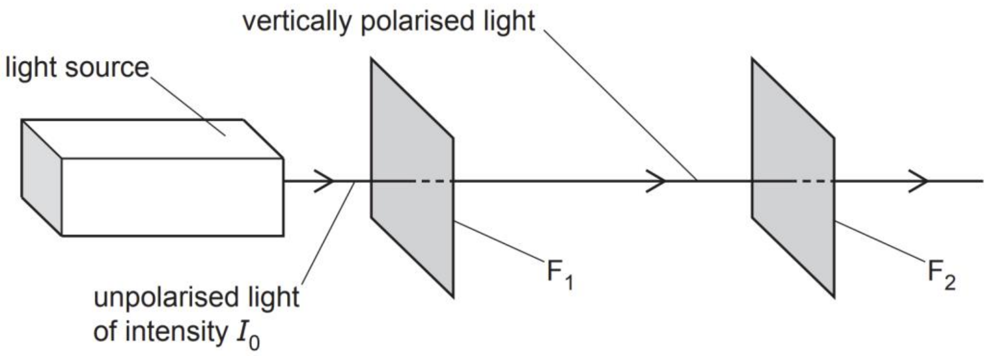


Fig. 8.6

The light that emerges from F_1 is completely vertically polarised and strikes F_2 at 90° to its surface.

When F_2 is in this position, the light that emerges from it is equal in intensity to the light that is incident on it.

(i) F_2 is now rotated about an axis perpendicular to its surface, as shown in Fig. 8.7.

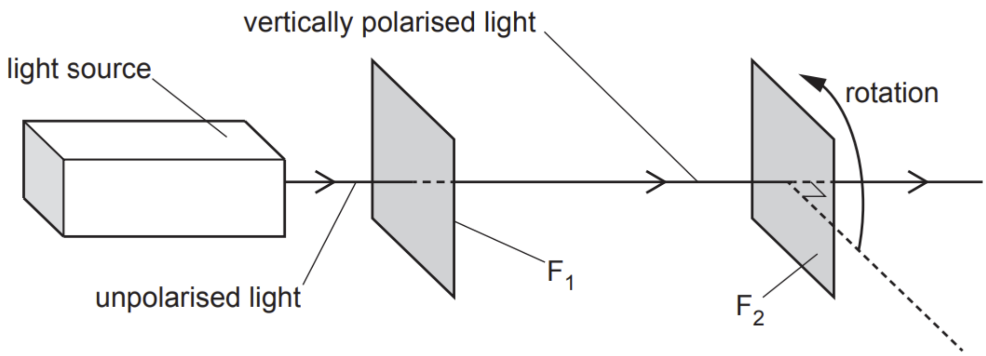


Fig. 8.7

On Fig. 8.8, sketch a graph to show how the intensity of the light emerging from F_2 varies with angle as F_2 is rotated through 360°

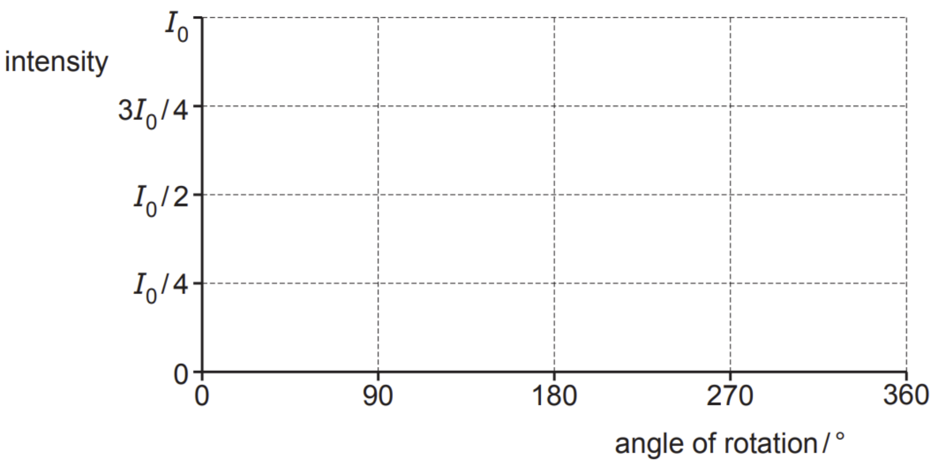


Fig. 8.8 [2]

(ii) F_2 is rotated until no light emerges from it.

Then, a third identical polarising filter F_3 is placed between F_1 and F_2. Fig. 8.9 shows that F_3 is parallel to both F_1 and F_2.

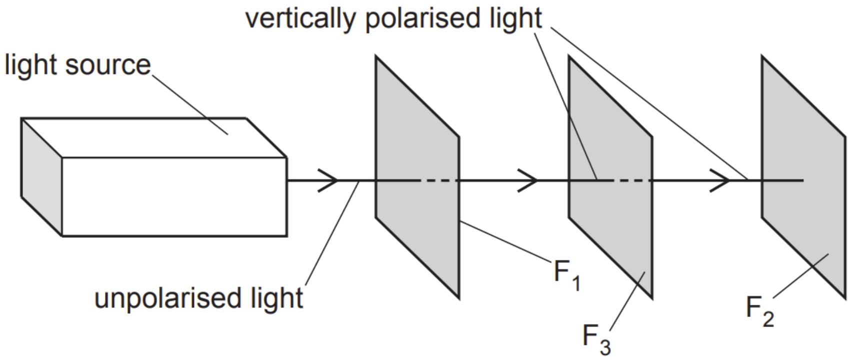


Fig. 8.9

The light that emerges from F_3 is equal in intensity to the light that is incident on it and still no light emerges from F_2.

F_3 is now rotated through 45° about an axis perpendicular to its surface.

Explain why some light now emerges from F_2.

…………………………………………………………………………………………………...

…………………………………………………………………………………………………...

………………………………………………………………………………………………. [2]

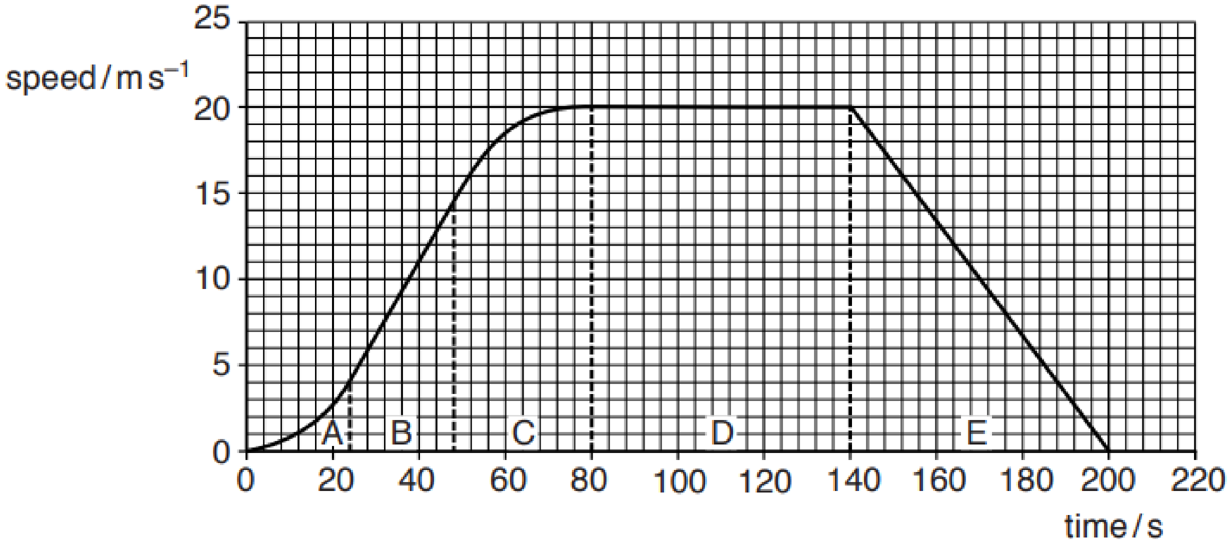
(iii) Calculate the intensity of light that emerges from F_2 when F_3 is fixed at 45°.

intensity = …………………….. I_0 [1]

End of Paper

Solution for 2021 SAJC H2 Physics Prelim Paper 3

1 (a) (i)



Distance = area of trapezium
= 20 (200 + 64) / 2
= 2640 m (accept 2580 m to 2700 m)

Accept other appropriate methods of estimation eg. counting squares.

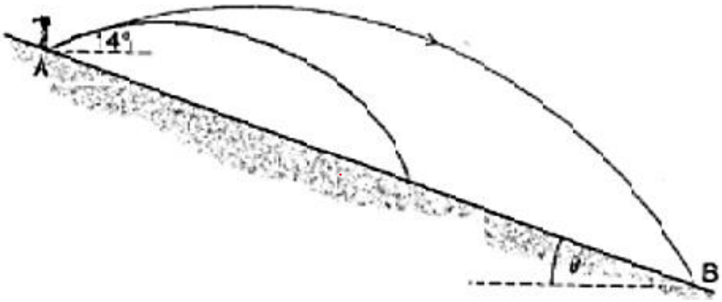
(ii) Accept uncertainty 10 m to 130 m

Reason for uncertainty: (any one)

- Estimating area using straight lines instead of curves
- Difficulty of counting squares

(b) **(i)** $s_x = u_x t$ = (63 cos 14) 4.9 = 299.5 m
$s_y = u_y t + ½ a t^2$ = (63 sin 14) 4.9 + 0.5 (-9.81) 4.9^2 = - 43.09 m
$\theta = \tan^{-1} (s_y / s_x)$ = 8.2° (to 2 sf)

(ii) **1.**



Features (all 3)
- At least 3 mm along original path **(but not too many mm)**
- New path under original path
- Max height is lower and earlier.

(ii) **2.** the path of the ball at the start, (any one)
- Path determined by movement of club / Same initial velocity
- Caused by same force in same direction
- Air resistance has acted for short time

the position for the highest point, (any one)
- Air resistance reduces upward velocity (and forward velocity)
- Air resistance opposes motion

the angle at which the ball hits the ground.
- Forward / horizontal velocity is (much) reduced

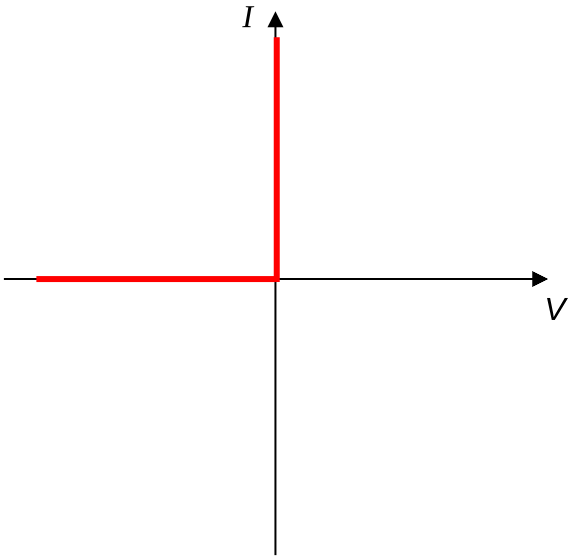
2 **(a)** Current passing A = 0.50 / 5.0 = 0.10 A
Current passing B = 0.50 / 2.5 = 0.20 A

p.d. across R_1 = 5.0 V
p.d. across R_2 = 2.5 V

R_1 = 5.0 / 0.30 = 16.7 Ω
R_2 = 2.5 / 0.20 = 12.5 Ω

(b) R_3 = 17 Ω

(c)



3 **(a)** The (mutual) electric force acting between two point charges is proportional to product of the charges and inversely proportional to the square of their separation.

(b) Evidence of correct estimation of ΔV by area under graph between 3.3 cm to 5 cm

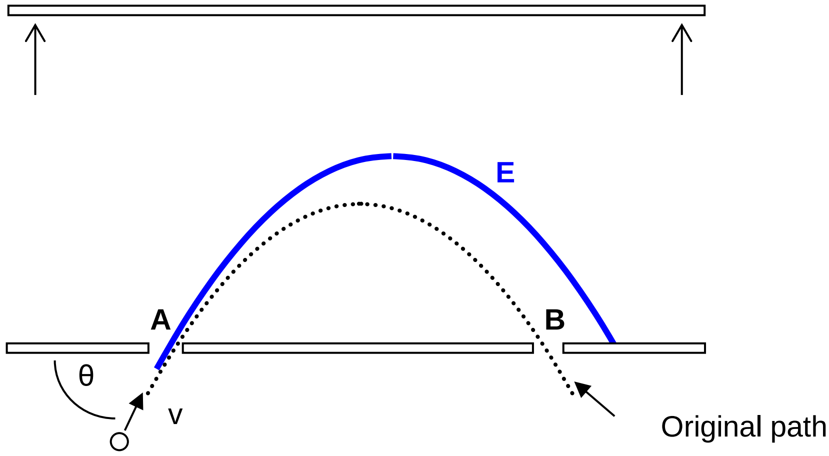
Estimated ΔV = 42 squares multiply by $(0.5 \times 10^3 \times 0.001)$ V per square
= 21 V

$$q\,\Delta V = \tfrac{1}{2} m v^2$$
$$(1.60 \times 10^{-19}) \times (21) = \tfrac{1}{2}(1.67 \times 10^{-27})\, v^2$$
$$v = 6.34 \times 10^4 \text{ m s}^{-1}$$

(c) **(i)** $E = \dfrac{V - 100}{d}$

$$V = Ed + 100$$
$$= (2500)(8.0 \times 10^{-2}) + 100$$
$$= 300 \text{ V}$$

(ii)



Mark awarded only if parabolic shape and,
higher vertical displacement
further horizontal displacement

(d) Volume, V, of each drop $\frac{4}{3}\pi r^3$, hence, $V \propto r^3$

After combining, the volume of new drop is 2V, hence,

$$V \propto r^3 \quad \Rightarrow \quad \left(\frac{r'}{r}\right)^3 = \frac{2V}{V} \quad \Rightarrow \quad r' = (2^{1/3})r$$

Potential, $V = \dfrac{Q}{4\pi\varepsilon_o r}$, hence,

$$V \propto \frac{Q}{r} \quad \Rightarrow \quad \frac{V'}{V} = \left(\frac{Q'}{Q}\right)\left(\frac{r}{r'}\right) = \left(\frac{2Q}{Q}\right)\left(\frac{r}{(2^{1/3})r}\right)$$

$$V' = \frac{2}{(2^{1/3})}(500) = 793.7 \text{ V}$$
$$= 794 \text{ V (3 sf)}$$

4 **(a)** **(i)** Using Fleming Left hand rule, the magnetic force will always be perpendicular to the direction of the charged particle's velocity and provides the centripetal force. Thus, it only changes the direction of velocity and not the speed. Therefore, the magnitude of the magnetic force will remain constant.

(ii) Negative.

(iii) Magnetic force provides the centripetal force,

$$\mathrm{Bqv} = \frac{\mathrm{mv}^2}{\mathrm{r}}$$

$$\mathrm{q} = \frac{\mathrm{mv}}{\mathrm{Br}}$$

$$\mathrm{q}\ \alpha\ \frac{1}{\mathrm{r}} \quad \Rightarrow \quad \frac{q_x}{q_y} = \frac{r_y}{r_x} = 2$$

(b) **(i)** As particle X collides with the gas particles, its magnitude of velocity v will gradually decrease. Since $r = \frac{mv}{Bq}$ and only v is decreasing with B, charge q and mass m constant, r, the radius of circular motion, will be decreasing as depicted by the spiral nature in the diagram.

(ii) **1.** $v = r\omega$, where $\omega = \frac{2\pi}{T}$ => $v = r\frac{2\pi}{T}$ => $T = 2\pi(\frac{r}{v})$

Hence, $T = 2\pi(\frac{m}{Bq})$ => $T = \frac{2\pi\, m}{B\, q_x}$

2. When $m = 3000(9.11\times10^{-31}) = 2.733 \times 10^{-27}$ kg, $B = 1.0$ T, $q = 1.6 \times 10^{-19}$ C, $T = \frac{2\pi\, m}{B\, q_x} = \frac{2\pi(2.733 \times 10^{-27})}{(1.0)(1.6 \times 10^{-19})} = 1.07 \times 10^{-7}$ s. It cannot be a tau particle as it does not live long enough to make the orbits shown in Fig. 4.2.

5 **(a)** **(i)** To channel / strengthen / increase / concentrate the magnetic field produced by the 2 wires through the sensing coil.

(ii) When there is a fault, the current in the 2 wires between the sensing coil will be unequal. The net magnetic flux through the sensing coil is no longer zero. (Since the current is alternating,) the changing magnetic flux will induce an emf, according to Faraday's law, and trigger the circuit breaker.

(iii) Increase the number of turns of the sensor coil.

(b) **(i)** Ave $\boldsymbol{\varepsilon}$ $= \dfrac{\Delta NBA}{\Delta t}$

$$= NB\frac{\Delta A}{\Delta t}$$

$$= 1 \times (25.0 \times 10^{-3}) \times \frac{\pi \times 0.0100^2}{50.0 \times 10^{-3}}$$

$$= 1.57 \times 10^{-4}\ \text{V}$$

(ii) According to Lenz's law, as the loop shrinks, the direction of the induced EMF is such that it will oppose the motion by causing an outward radial force on the loop. Hence, by Fleming's left hand rule, induced current will flow from A to B and hence, B is at a higher potential than A.

(c) **(i)** frequency = 100 Hz, period = 10 ms
Hence, as 2 cm represents 10 ms, the time base setting is 5 ms cm^{-1}

(ii) $V_{rms} = \sqrt{\langle V^2 \rangle} = \sqrt{\dfrac{0.75^2 \times 1 + (-0.5)^2 \times 3}{4}}$

$$= 0.573\ \text{V}$$

6 **(a)** **(i)** Photon energy = eV_s + work function

$$\frac{hc}{\lambda} = 1.60\times10^{-19}\times2.3+\phi----(1)$$

$$\frac{hc}{620\times10^{-9}} = 1.60\times10^{-19}\times1.1+\phi----(2)$$

$$(1)-(2): hc\left(\frac{1}{\lambda}-\frac{1}{620\times10^{-9}}\right)=1.60\times10^{-19}\times1.2$$

$$\lambda = 3.87\times10^{-7}m$$

(ii) For the same incident power, the rate of photon incident on the surface is proportional to the wavelength of the radiation. Since the unknown radiation has a shorter wavelength, the rate of photons incident on the silver surface is less and hence less photoelectrons are ejected, giving rise to a lower saturation current.

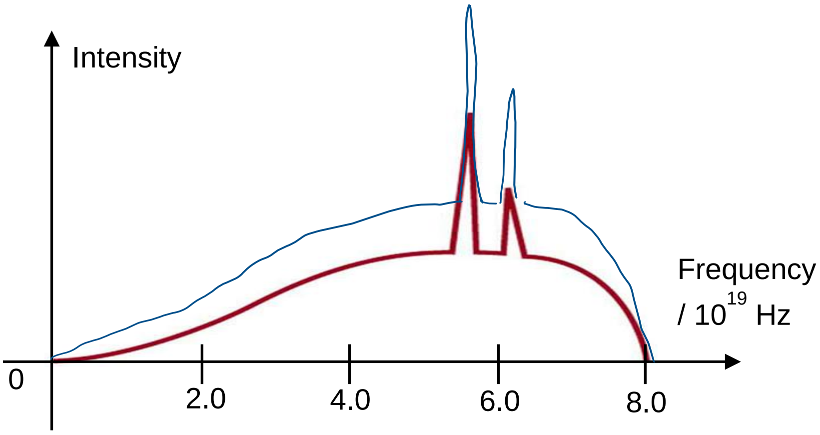
(b) **(i)** When an accelerated electron loses all its KE to the target atom, the KE lost is converted into an photon of maximum energy, hence maximum frequency.

(ii) $E = hf = (8.0\times10^{19})(6.63\times10^{-34})$

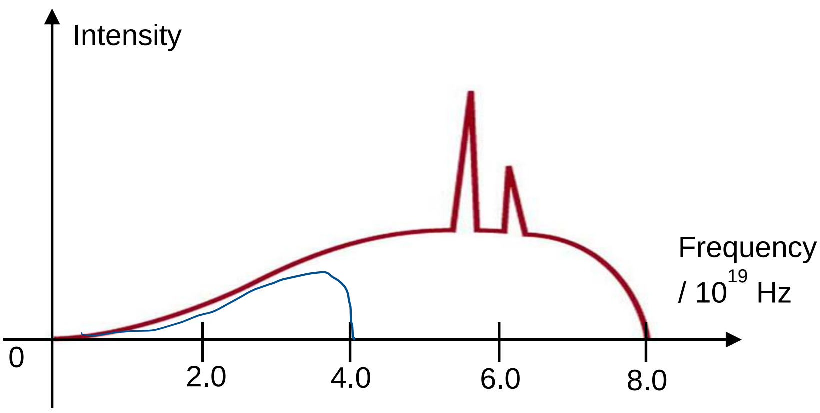
$= 5.304\times10^{-14}$ J

$= 0.332$ MeV

(iii) sketch a graph with similar shape above original graph with same cut-off frequency.



(iv) sketch a graph with similar shape below original graph without any characteristics lines with cut-off frequency at <u>4.0 X 10^{19} Hz</u>.



(c) **(i)** $$\frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{436\times10^{-9}} = 4.56\times10^{-19} = 2.85\ eV$$

Since $E_4 - E_2$ = 2.85 eV, the transition is from E_4 to E_2

(ii) The bombarding electron must have a minimum kinetic energy of (13.6 eV – 0.54 eV) 13.06 eV in order for the hydrogen atom to be excited from ground state E_1 to $E_{4.}$ Hence a transition from E_4 to E_2 can take place. So the minimum value is 13.06 V.

7 **(a)** **(i)** Consider each mass separately,

$T - W_P = m_P a$ ---(1)

$W_Q - T = m_Q a$ ---(2)

Solving the simultaneous equations (1) + (2),

(1.00)(9.81) – (0.50)(9.81) = (1.00 + 0.50)a

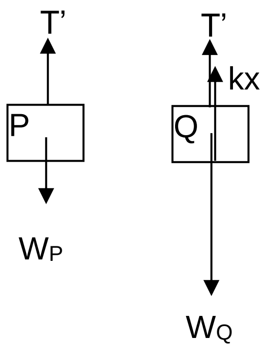
$a = 3.27 \text{ m s}^{-2}$

From equation (1) in 1(a)(i),

T = 0.50(9.81) + 0.50(3.27)

= 6.54 N (accept 3 or 4 s.f.)

(ii) After Block Q comes to a stop, the forces acting on P and Q are in equilibrium.



$T' = W_P$ ------------------ (3)

$T' + kx = W_Q$ ------------------ (4)

Substitute (3) into (4)

0.50(9.81) + 200x = 1.00(9.81)

x = 0.0245 m (3 s.f.)

(b) **(i)** By conservation of momentum,

Initial momentum of bullet = final momentum of bullet and block

$m_{bullet} \times 100 = (m_{bullet} + m_{block})v$

$v = 0.990 \text{ m s}^{-1}$

By conservation of energy,

Loss in k.e. of bullet and block = Gain in g.p.e of bullet and block

$\frac{1}{2} (m_{bullet} + m_{block})v^2 = (m_{bullet} + m_{block})gh$

$h = \frac{1}{2}(0.990)^2/(9.81) = 0.050 \text{ m}$

(ii) The collision is perfectly inelastic.

(c) **(i)** $a = \frac{v - u}{t} = \frac{24.72 - 0}{4.5} = 5.493 \text{ m s}^{-2}$

$P_{ave} = F(\frac{1}{2}v_{max}) = ma(\frac{1}{2}v_{max}) = (6500)(5.493)(\frac{1}{2})(24.72) = 441 \times 10^3 \text{ W}$

(ii) Loss in KE = Gain in GPE

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

$h = \frac{v^2}{2g} = \frac{24.72^2}{2(9.81)} = 31.2 \text{ m}$

Hence it will not go beyond the track which is 45.0 m tall.

(iii) Let the speed of the train at the top of the loop be v_{top},

$$\tfrac{1}{2}mv_{top}^2 = \tfrac{1}{2}mv^2 - mgh$$
$$v_{top} = 12.6 \text{ m s}^{-1}$$

To stay on the seat (and not fall off) at the top of the inner loop, N > 0.

$$N + mg = \frac{mv_{min}^2}{r},$$
$$N = \frac{mv_{min}^2}{r} - mg$$

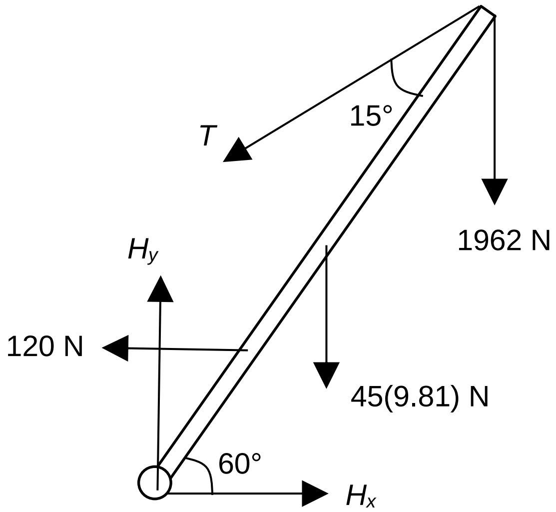
Hence, to not fall off, N > 0 and therefore $v_{min} > \sqrt{(rg)}$.

$$\sqrt{(rg)} = \sqrt{(11.5)(9.81)} = 10.6 \text{ m s}^{-1}$$

Since $v_{top} > 10.6 \text{ m s}^{-1}$, the rider will not fall off if the lap-bar mechanism fail.

(d) **(i)** Net force is zero in any direction.
Net moment is zero about any point.

(ii)



Evidence of angle between *T* and boom (in working) = 15°
Taking moments about the hinge,

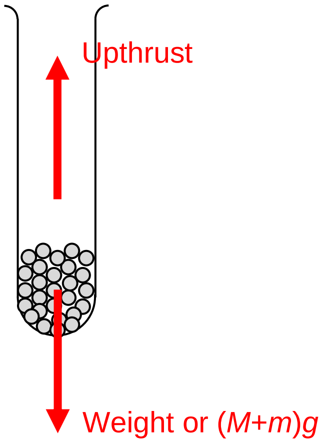
$$(T\sin 15°)(3) + (120\sin 60°)(0.75) = (45)(9.81)(1.5\cos 60°) + (1962)(3\cos 60°)$$
$$T = 4116 = 4.1 \text{ kN}$$

(iii) (Let H_y and H_x be the vertical and horizontal components of the force hinge acts on the boom)

$H_y = 1962 + 45(9.81) + T\cos 45° = 5314$ N
$H_x = 120 + T\sin 45° = 3030$ N

Therefore, magnitude of force hinge acts on boom = $\sqrt{5314^2 + 3030^2} = 6120$ N
Direction of the force = $\tan^{-1}(5314 / 3030) = 60.3°$ above horizontal

8 (a) (i)



Arrow should be equal in size (cannot be more than 1mm different in length)
Labelling should be fully spelled out for Upthrust.

(ii) at equilibrium, Weight = AHρg
at displacement *y*, Upthrust = A(H+y)ρg

Taking downward to be positive,

Weight – Upthrust = (M+m)a

AHρg – A(H+y)ρg = (M+m)a

$$a = -\left(\frac{\rho A g}{M+m}\right)y$$

(iii) Using W = AHρg, (M+m)g = AHρg

1 / H = Aρ / (M+m)

Hence, ω^2 = (g / H)

$(2\pi / T)^2$ = (9.81 / 0.062)

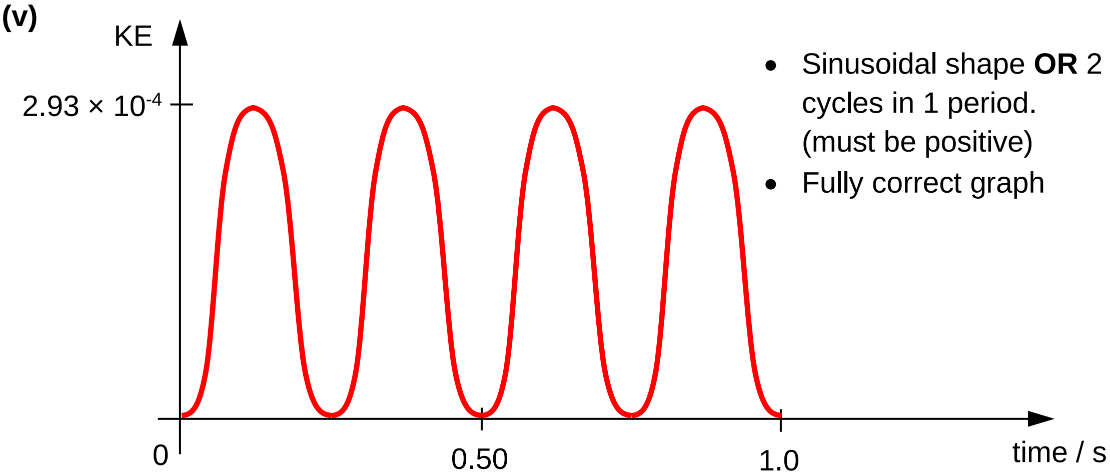
T = 0.50

(iv) Max KE = ½ (M+m)(y^2)(ω^2)

= ½ (0.012 + 0.025)(0.01^2)(9.81 / 0.062)

= 2.93 × 10^{-4} J

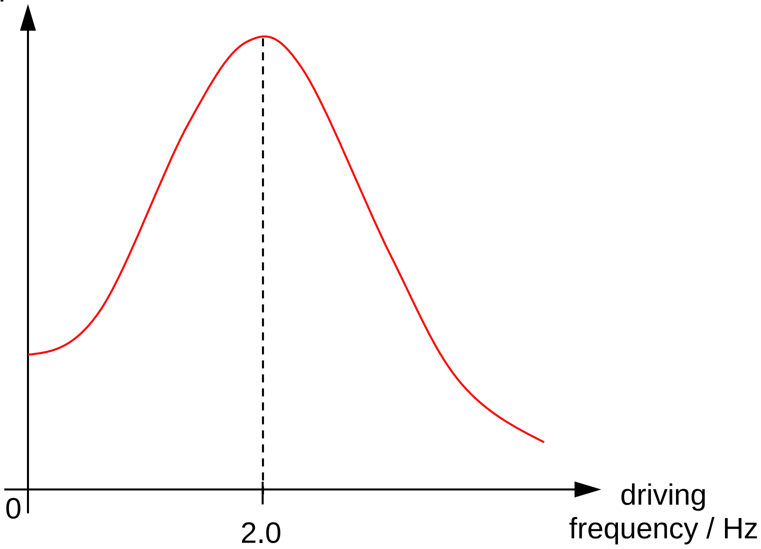
(v)



- Sinusoidal shape **OR** 2 cycles in 1 period. (must be positive)
- Fully correct graph

(vi) As the test-tube oscillates, it experiences drag force / viscous force / dissipative forces exerted by the water. This results in light damping and energy is gradually lost as heat.

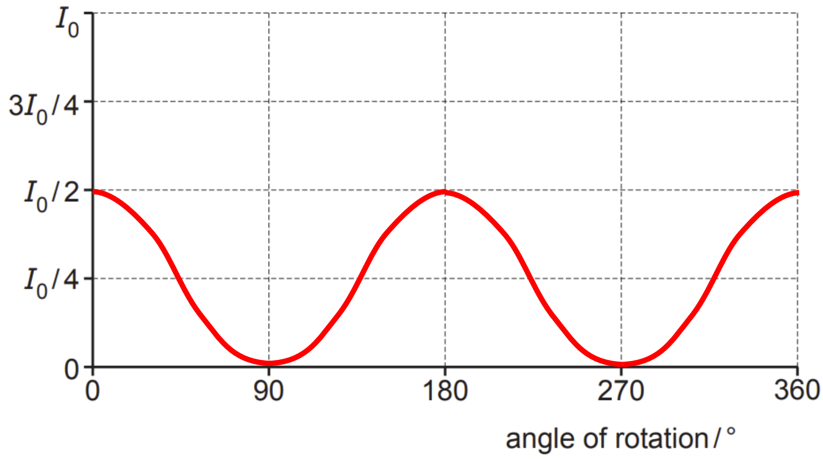
(vii) **1.**



Shape + labelling of resonant frequency

2. Add more ball bearings to the test tube.
This will decrease the natural frequency of the system and hence be closer to the driving frequency.

(b) **(i)**



1 mark for max intensity at 0.5 I_0
1 mark for correct shape (sine or cosine but 2 cycle)

(ii) plane of polarisation of light from F_1 is at 45° / not perpendicular to the plane of polarisation of F_3 (and some light emerges from F_3)

plane of polarisation of lights from F3 is at 45° / not perpendicular to the plane of polarisation of F_2

(iii) Intensity = (0.5 I_0)($\cos^2$ 45°)($\cos^2$ 45°) = 0.125 I_0