NAME ______________________ CLASS 2T

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

PHYSICS 9749/1

Paper 1: Multiple Choice Questions — **16 September 2022**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST
Write your name and tutorial group on this cover page.

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write and shade your name, NRIC / FIN number and HT group on the Answer Sheet (OMR sheet), unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet (OMR sheet).

Read the instructions on the Answer Sheet carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15
A	A	B	C	A	C	A	A	C	B	D	D	D	B	B

Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30
A	B	B	C	A	A	A	B	B	A	D	A	B	B	D

Suggested Solutions

This document consists of **24** printed pages and **zero** blank page.

[Turn over

More papers at www.testpapersfree.com

PHYSICS DATA:

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
			$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_P	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} mol^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

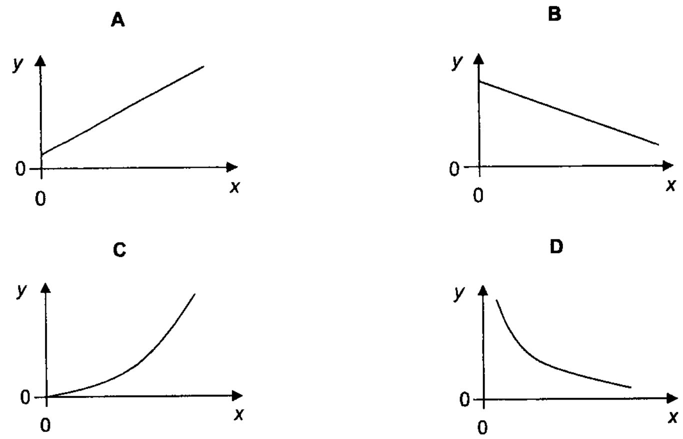
PHYSICS FORMULAE:

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	$P = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/^\circ C + 273.15$
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.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm \omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

BP-229

1 In an experiment, the perpendicular distance of a point from a long straight conductor carrying a constant current is measured and the perpendicular distance is used to calculate the magnetic flux density due to the long straight current-carrying conductor at that point. The experiment is repeated for a few points.

Which graph shows how the percentage uncertainty in the magnetic flux density of the long straight current-carrying conductor, y, varies with the percentage uncertainty in the perpendicular distance from the conductor, x?



Answer: A

The magnetic flux density due to a long straight current-carrying conductor is

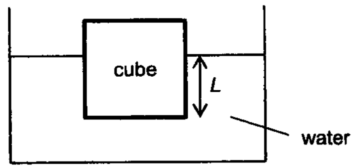
$$B = \frac{\mu_0 I}{2\pi r}$$

Therefore, the percentage uncertainty of the calculated magnetic flux density is

$$\frac{\Delta B}{B} = \frac{\Delta r}{r} + \frac{\Delta I}{I}$$

Therefore, the graph of $\frac{\Delta B}{B}$ against $\frac{\Delta r}{r}$ is a straight line graph with positive gradient and y-intercept $\frac{\Delta I}{I}$

2 A cube of side 5.0 cm is floating on a tank of water as shown in the figure below. The density of the cube is 450 kg m^{-3} and the density of water is 1000 kg m^{-3}.



What is the submerged depth L of the cube?

A	2.3 cm	B	2.8 cm	C	4.0 cm	D	4.5 cm

Answer: A

By the principle of floatation,
Weight of object = Weight of fluid displaced

$$V_c \rho_c g = V_w \rho_w g$$
$$V_c \rho_c = A L \rho_w,$$
$$L = \frac{V_c \rho_c}{A \rho_w} = \frac{0.050^3 \times 450}{0.050^2 \times 1000} = 0.023 \text{ m}$$

3 Water is ejected from the nozzle of a hose at a speed of 2.0 m s^{-1}. The density of water is 1000 kg m^{-3} and the diameter of the nozzle is 0.50 cm.

What is the force exerted on the nozzle by the ejected water?

A	0.039 N	B	0.079 N	C	0.31 N	D	7.9 N

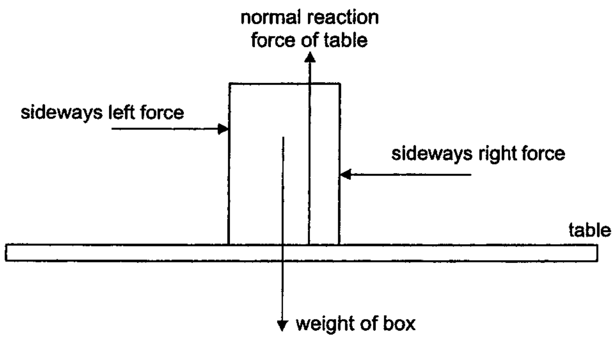
Answer: B

Force **on water** = mass per unit time x change in velocity
= (volume per unit time x density) x change in velocity
= (V/t)(ρ)Δv
=(πr^2)(v)(ρ)(v)
=π(0.0025^2)(2.0)(1000)(2.0) = 0.079 N

Magnitude of force **on nozzle** by water = Magnitude of force **on water** by nozzle = 0.079 N
(Newton's 3rd law of motion)

More papers at www.testpapersfree.com

4 A box resting on a table has two vertical and two horizontal forces acting on it as shown in the diagram below. The box is in equilibrium.

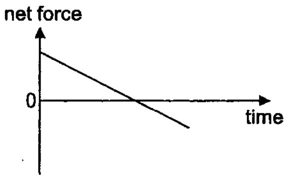


Which statement about the forces is **not** correct?

A	The sideways left force is equal and opposite to the sideways right force on the box.
B	The resultant of all the four forces is zero.
C	The torque provided by the vertical forces is equal to the torque provided by the horizontal forces.
D	The normal reactional force from the table is equal and opposite to the weight of the box.

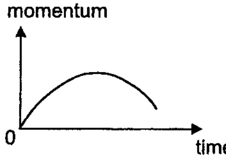
Answer: C
The torque provided by the vertical forces is not only equal to the torque provided by the horizontal forces but also in opposite directions

5 A vehicle starts from rest and a net force acts on it. The figure below shows how the net force varies with time.

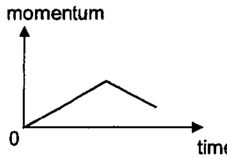


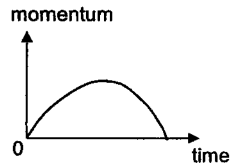
Which graph shows how the momentum of the vehicle varies with time?

A

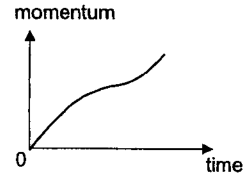


B





C

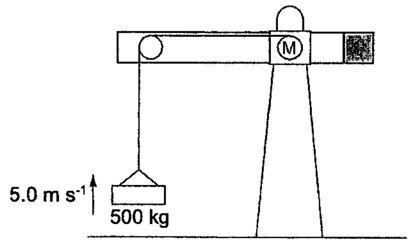


D

Answer: A

F = dp/dt = gradient of p-t graph
As force increases linearly, gradient of p-t graph increases. As forcce decreases linearly, gradient of p-t graph decreases B is incorrect
When F is negative, the momentum will decrease. D is incorrect
Area under F-t graph is the change in momentum. Hence the increase in momentum in part 1 is greater than that decrease in part 2 B is incorrect

6 The motor M in a crane is used to lift a load of 500 kg vertically upwards at a constant speed of 5.0 m s^{-1}. During the lifting of the load, energy is supplied to motor M at a constant rate of 3.0×10^4 J s^{-1}.



Which of the following statement is **not** correct?

A	The efficiency of motor M is 82%.
B	The kinetic energy of the load is 6.3 kJ.
C	The work done on the load by gravity is positive during the lifting of the load.
D	The rate of gravitational potential energy gained by the load is about 2.5×10^4 W.

Answer: C

Rate of gravitational potential energy gained,
$= Fv = mgv = 500 \times 9.81 \times 5.0 = 24525 = 2.5 \times 10^4$W (D is correct)

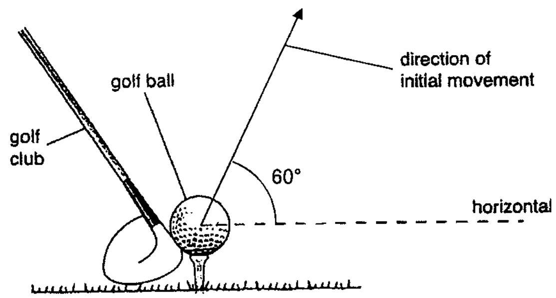
Efficiency of the motor $= \frac{\text{Power output}}{\text{Power input}} \times 100\% = \frac{24525}{3.0\times10^4} \times 100\% = 82\%$ (A is correct)

The kinetic energy of the load,
$\frac{1}{2}mv^2 = \frac{1}{2} \times 500 \times 5.0^2 = 6.3$ kJ (B is correct)

The gravitational force acts downwards on the load while the load's displacement is upwards. As such, the work done by gravity (gravitational force) is negative during the lifting of the load. (C is incorrect)

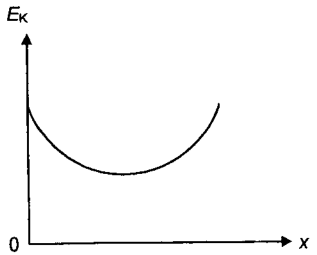
More papers at www.testpapersfree.com

7 A golf ball, on level ground, is hit and starts to move at an angle of 60° to the horizontal.

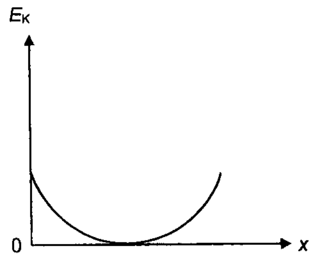


Which graph best represents the variation with horizontal distance x of the kinetic energy E_K of the golf ball? Ignore any effects of air resistance.

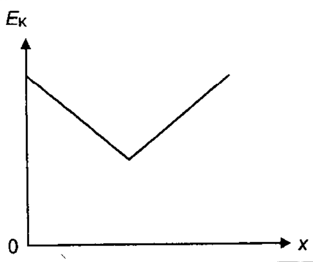
A



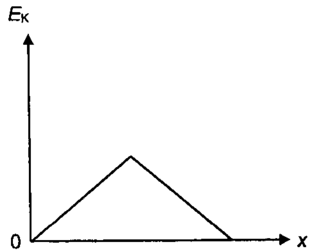
B



C



D



Answer: A

The kinetic energy of the golf ball at the highest point is non-zero. Hence option B is wrong.

The golf ball has the lowest kinetic energy at the highest point. Hence option D is wrong.

The vertical displacement s_y of the golf ball is of the parabolic equation $s_y = u_y t + \frac{1}{2} a_y t^2$ where u_y is the initial vertical velocity, a_y the vertical acceleration of the golf ball and t the time taken for the flight of golf ball. Since $s_x = u_x t$,

$t = \frac{s_x}{u_x} = \frac{x}{u_x}$ where s_x is the horizontal displacement, u_x the initial horizontal velocity of golf ball.

Therefore $s_y = u_y\left(\frac{x}{u_x}\right) - \frac{1}{2}g\left(\frac{x}{u_x}\right)^2 = -\left(\frac{g}{2u_x^2}\right)x^2 + \left(\frac{u_y}{u_x}\right)x$.

Since gravitational potential energy of golf ball of mass m is given as mgs_y, the graph for gravitational potential energy of the golf ball will be a negative parabolic curve.
By principle of conservation of energy, KE = TE − GPE, the graph for the kinetic energy of the golf ball will be a positive parabolic curve.

8 A body of mass m moves in a horizontal circle of radius r at constant angular speed ω.

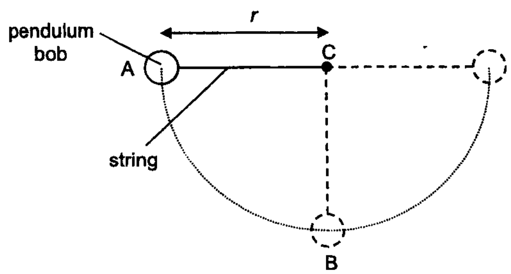
What is the work done on the body by the centripetal force in one revolution?

A	zero	B	$mr^2\omega^2$	C	$2mr^3\omega$	D	$4mr^2\omega^3$

Answer: A

Since the centripetal force always acts perpendicularly to the displacement moved by the body, there is zero work done on the body by the centripetal force.

9 A pendulum bob of mass 0.100 kg is supported by a string and swung along a circular path of radius r about the fixed point C. The bob is momentarily at rest at point A, with the string horizontal and just taut.



What is the tension in the string when the bob is at point B which is vertically below point C?

A	0.981 N	B	1.96 N	C	2.94 N	D	3.92 N

Answer: C

Given that at point A the string is horizontal & just taut → T = 0 at point A

Since Weight acts vertically, it cannot provide for the centripetal force at point A.

So at point A, centripetal force = 0 → speed at point A must be zero.

By principle of conservation of energy,
Gain in KE from A to B = Loss in GPE from A to B

$\left(\frac{1}{2}mv^2\right)_{\text{point B}} - 0 = mgr$

More papers at www.testpapersfree.com

At point B, $v^2 = 2gr$ ---- (1)

At point B, the resultant force will be towards the centre of the vertical circle is

$$T - mg = \frac{mv^2}{r}$$

$$T = \frac{mv^2}{r} + mg \text{ ----(2)}$$

Sub (1) into (2):

$$T = \frac{m(2rg)}{r} + mg = 3mg = 3(0.100)(9.81) = 2.943 = 2.94 \text{ N}$$

10	At a point on the surface of a uniform sphere of diameter d, the gravitational field strength due to the sphere is X. What would be the gravitational field strength on the surface of a uniform sphere of the same density but of diameter $3d$?						
A	$2X$	**B**	$3X$	**C**	$5X$	**D**	$8X$

Answer: B

$M = \textbf{density x volume} = \rho\left(\frac{4}{3}\pi R^3\right)$ where M is the mass, ρ the density and R the radius of sphere.

Gravitational field strength at the <u>surface</u>, $g = \frac{GM}{R^2} = \frac{G4\pi R^3\rho}{3R^2} = \frac{G4\pi R\rho}{3} = \frac{G4\pi d\rho}{6}$ where d is the diameter of sphere.

Since g is directly proportional to d, the gravitational field strength due to the sphere of diameter $3d$ will be $3X$.

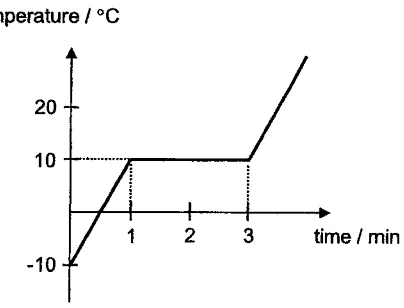
11	Which of the following statement about a geostationary satellite around Earth is true?	
	A	Its linear speed is equal to the speed of a point on the Earth's equator.
	B	It experiences zero net force as it orbits around Earth.
	C	It moves from East to West.
	D	It must remain directly above the equator.

Answer: D

Option A is wrong as the satellite's linear speed is proportional to the distance away from the centre of the earth ($v = r\omega$). Hence the speed of the satellite can never be the same as the speed on the equator.
Option B is wrong as the satellite is experiencing centripetal acceleration, and thus net force as it orbits around Earth.
Option C is wrong as it moves from West to East.
Option D is correct as the geostationary satellite must be at a fixed distance directly above the Earth's equator.

More papers at www.testpapersfree.com

12 A student heats a 500 g solid sample at an initial temperature of -10°C. The rate of heat absorbed by the sample is constant at 200 W. The graph below shows how the temperature of the sample varies with time.



What is the specific latent heat of fusion of the solid sample?

A	12 kJ kg^{-1}	**B**	18 kJ kg^{-1}	**C**	36 kJ kg^{-1}	**D**	48 kJ kg^{-1}

Answer: D

Energy supplied $E = Pt$ where P is the power supplied in time t.
By conservation of energy, $E = Pt = mL$ where m is the mass and L the specific latent heat of solid.

$$200(2\times 60) = 0.500L$$

L = 48000 J kg^{-1}
= 48 kJ kg^{-1}

13	The density of argon gas at a pressure of 1.00×10^5 Pa is 1.60 kg m^{-3}. What is the root-mean-square speed of the argon molecules?						
A	216 m s^{-1}	**B**	250 m s^{-1}	**C**	306 m s^{-1}	**D**	433 m s^{-1}

Answer: D

$pV = \frac{1}{3}Nm\langle c^2\rangle$ where p is the pressure, V the volume, N the number of molecules, m the mass and $\langle c^2\rangle$ the mean square speed of molecules.

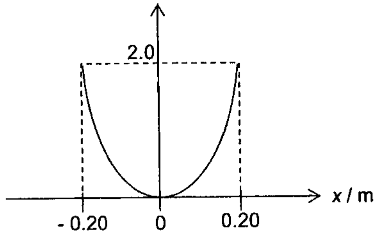
Therefore, $p = \frac{1}{3}\rho\langle c^2\rangle$ where ρ is the density of molecules.

$$\langle c^2\rangle = \frac{3p}{\rho}$$

$$\sqrt{\langle c^2\rangle} = \sqrt{\frac{3p}{\rho}} = \sqrt{\frac{3(1.00\times 10^5)}{1.60}} = 433 \text{ m s}^{-1}$$

14 A particle of mass 5.0 kg is moving in simple harmonic motion.

The variation of the potential energy U with the displacement from the equilibrium position x is as shown in the figure below.



What is the period of oscillation of the particle?

A	0.89 s	B	1.4 s	C	2.2 s	D	2.8 s

Answer: B

For SHM,

$$Max\ U = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}m\left(\frac{2\pi}{T}\right)^2 x_0^2$$

$$T = \sqrt{\frac{1}{2U}m(2\pi)^2 x_0^2} = \sqrt{\frac{2m}{U}}\pi x_0 = \sqrt{\frac{2(5.0)}{2.0}}\pi(0.20) = \frac{\pi}{\sqrt{5}} = 1.4\ s$$

15 A sound wave propagates from left to right through a gas.

Fig. 15(a) shows the positions of some gas molecules at a particular instant of time.
Fig. 15(b) shows the variation with time t of the displacement s of one of these particles.

The distance between particles P and Q is 0.26 m.

Fig. 15(a)

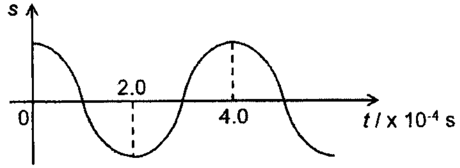


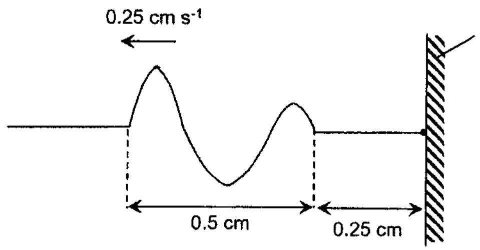
Fig. 15(b)

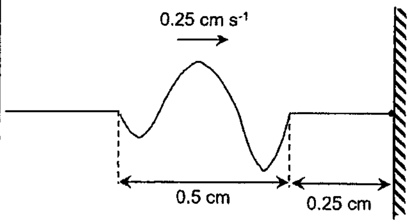
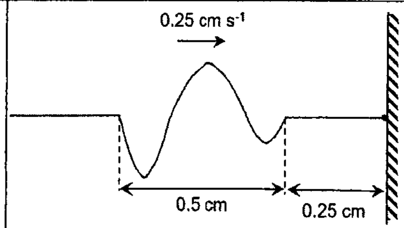
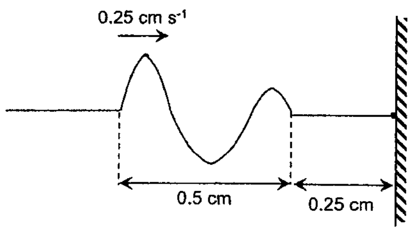
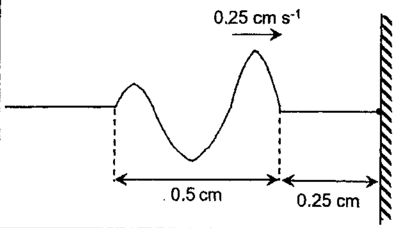
What is the speed of sound in this gas?

A	300 m s^{-1}	B	330 m s^{-1}	C	380 m s^{-1}	D	660 m s^{-1}

Answer: B

$$v = f\lambda = \left(\frac{1}{T}\right)\lambda = \left(\frac{1}{4.0\times10^{-4}}\right)\left(\frac{0.26}{2}\right) = 325 = 330\ m\,s^{-1}$$

16	A rope is rigidly fixed to a wall. A wave pulse of length 0.5 cm moves at a constant speed of 0.25 cm s^{-1} along the rope towards the wall and is reflected back. The figure below shows the waveform at time t = 4 s.  Which of the following correctly shows the waveform at t = 0 s?

A	B
	
C	**D**
	

Answer: A

<u>Checking position of the wave pulse:</u>

0.5 cm / 0.25 cm s^{-1} = 2 s
In 2 s, the wave pulse moves a distance equal to one wavelength.

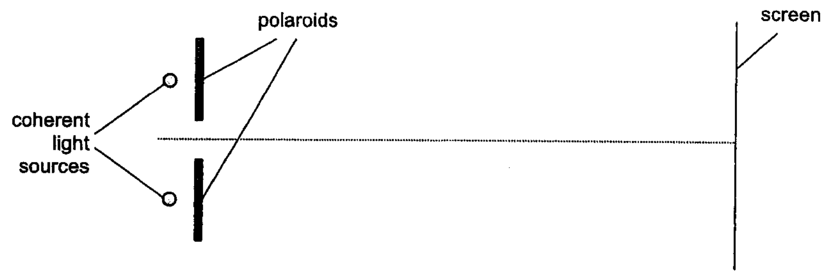
From options A, B, C, D, which shows the wave pulse at t = 0 s, it means that at t = 2 s, half of the wave pulse would have been reflected, and at t = 4 s, it would have been at the position shown.

<u>Determining the shape of the incident waveform:</u>

Since the wave pulse is **reflected at a fixed end**, the reflected pulse will have a **180° change in phase**. Hence answer is A.

17 Light is polarised when it passes through a sheet of material known as polaroid.

Two sources producing coherent light waves are placed at an equal distance away from an observation screen. Each source was covered with a polaroid.



Initially, both polaroids had their transmission axes in the same direction. The intensity of the central maximum fringe formed from the interference of the two light waves was measured to be I.

One of the polaroids is rotated by 60°.

What is the new intensity of the central maximum fringe?

A	$\frac{1}{2}I$	B	$\frac{9}{16}I$	C	$\frac{3}{2}I$	D	$\frac{9}{4}I$

Answer: B

Initially, the intensity of the central maximum fringe is I.

$$I = k(A_1 + A_2)^2 = k(2A)^2 = 4kA^2$$

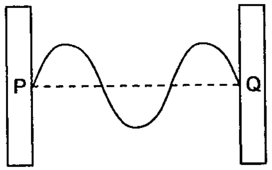
After the rotation of the polaroid,

$$I_{new} = k(A_1 + A_2)^2 = k(A + A\cos 60)^2 = k\left(\frac{3A}{2}\right)^2 = \frac{9}{4}kA^2 = \frac{9}{16}(4kA^2) = \frac{9}{16}I$$

BP~235

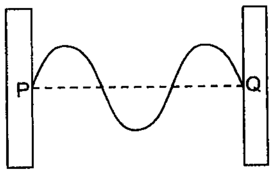
More papers at www.testpapersfree.com

18 The diagram shows a stationary wave of frequency 50 Hz formed between two points P and Q at a time t = 0.

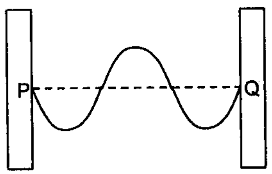


Which of the diagrams correctly shows a possible position of the string at a time t = 0.010 s?

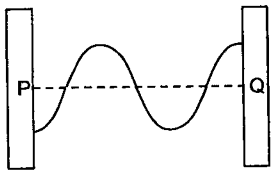
A



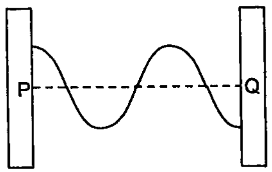
B



C



D



Answer: B

f = 50 Hz ➔ T = 1/50= 0.020 s. t = 0.010 s = ½ T

19 In a spectrometer experiment, light of wavelength 400 nm is incident normally on a diffraction grating having 400 lines per millimeters.

What is the angle of diffraction of the third order diffracted beam?

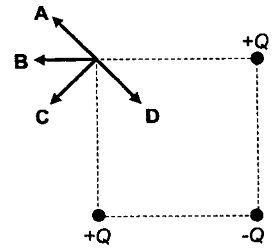
A	13.9°	**B**	18.7°	**C**	28.7°	**D**	56.1°

Answer: C

$d\sin\theta = n\lambda$
$\sin\theta = n\lambda/d$ $1/d = 400 \times 10^3$
$\sin\theta = 3(400\text{ nm})(400 \times 10^3) \rightarrow \theta = 28.7°$

20 Three point charges, each of magnitude Q, are placed at the three corners of a square as shown in the diagram.

What is the direction of the resultant electric field at the fourth corner?



Answer: A

Due to symmetry, the net electric field at the fourth corner must be along the diagonal of the square in direction A or D.

Let E_1 and E_2 be the electric field strength due to each of the charge of +Q.
Resultant of E_1 and E_2 is

$$E_{net\ of+Q} = \frac{Q}{4\pi\varepsilon_0 r^2}\sqrt{2}$$

Let E_3 be the electric field strength due to charge of –Q.

$$E_3 = \frac{Q}{4\pi\varepsilon_0 (r\sqrt{2})^2} = \frac{Q}{8\pi\varepsilon_0 r^2}$$

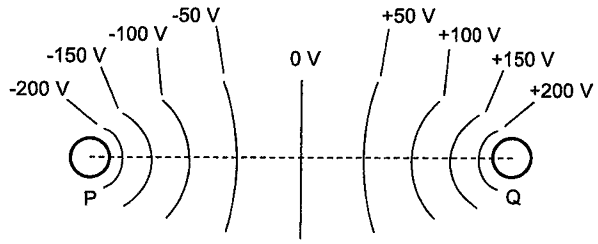
Therefore the net electric field strength due to all 3 charges is

$E_{net\ of+Q} - E_3 = \frac{Q\sqrt{2}}{4\pi\varepsilon_0 r^2} - \frac{Q}{8\pi\varepsilon_0 r^2} = \frac{Q}{8\pi\varepsilon_0 r^2}(2\sqrt{2}-1)$ **which is in the direction A**

More papers at www.testpapersfree.com

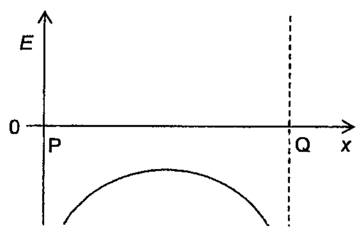
21 A charged object is placed at point P and another charged object is placed at point Q.

The diagram shows a number of solid lines along which the electric potential has a constant value.

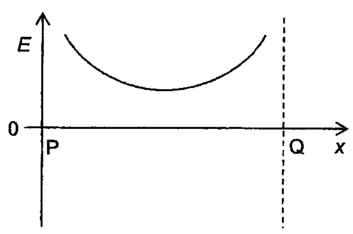


Taking vectors to the right as positive, which graph shows the variation with distance x along the line PQ of the electric field strength E?

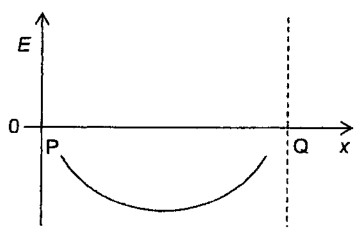
A



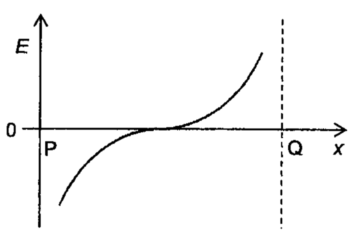
B



C



D



Answer: A

$$E = -\frac{dV}{dx}$$

Since the **electric potential V decreases all the way from Q to P**, and the **potential gradient is non-zero everywhere along PQ**,
the electric field along line PQ is **non-zero** everywhere along PQ (hence answer **cannot be D**) and,

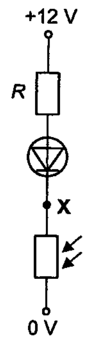
the direction of the electric field at every point along PQ is **leftwards**, which by the sign convention is the negative direction, hence ***E* is negative everywhere along PQ** (hence **answer can only be A or C**).

Also, **where the potential gradient is greater, *E* is greater in magnitude.** As shown in the equipotential map, **nearer P and nearer Q where the equipotential lines get closer, i.e. Δx decreases while ΔV unchanged, magnitude of E should be greater.** Hence **answer must be A.**

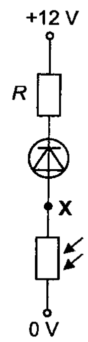
22 In bright light, a light-dependent resistor (LDR) has a resistance of R. It is connected in series with an ideal diode and a fixed resistor of resistance R. An ideal diode has zero resistance in the forward direction and infinite resistance in the reverse direction.

In which arrangement will the potential at **X** increase when the circuit is moved to a darker environment?

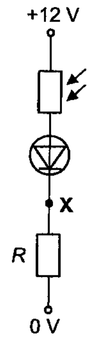
A



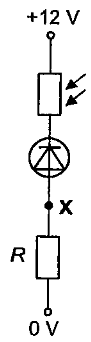
B



C



D



Answer: A

Diodes in options B and D are in reverse biased connection (like an open circuit where the diode is).

- → No current flows → zero p.d. across the resistance → potential at X = 0 V in both bright and dark conditions, i.e. no change in potential at X for options B and D.
- → Eliminate options B and D.

Diodes in options A and C are in forward biased connection (like zero resistance where the diode is).

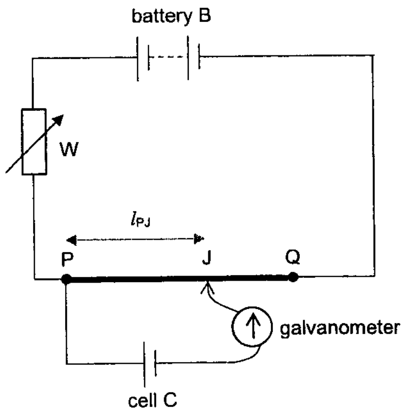
- → Current flows → non-zero p.d. across the resistance.

Since LDR's resistance increases when moved into the dark, by Potential Divider Principle, the p.d. across the LDR will increase.

Hence in option A potential at X will increase, while in option C potential at X will decrease.

More papers at www.testpapersfree.com

23 A battery B, a variable resistor W and a uniform resistance wire PQ are connected in series. A cell C and a galvanometer are connected to the wire PQ with a contact J as shown.



The contact J is moved along wire PQ until the galvanometer reads zero. The distance of J from P, l_{PJ} is then measured.

Which of the following changes will increase the measured distance l_{PJ}?

A	Removing W from the circuit.
B	Adjusting W to a higher resistance.
C	Connecting a resistor parallel to the galvanometer.
D	Replacing wire PQ with another wire of similar length and resistivity but smaller diameter.

Answer: B

Regardless, the p.d. across PJ (V_{PJ}) remains unchanged and equal to the e.m.f. of cell C.

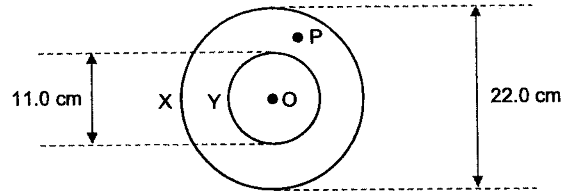
Option A: Removing W increases the p.d. across PQ, hence increases the p.d. per unit length of PQ. Thus for the same V_{PJ}, balance length will decrease.

Option B: Adjusting W to a higher resistance decreases the p.d. across PQ, hence decreases the p.d. per unit length of PQ. Thus for the same V_{PJ}, balance length will increase.

Option C: No effect on the balance length.

Option D: If the wire has a smaller cross-sectional area, its resistance increases. With W unchanged in resistance, the p.d. across PQ increases, hence increases the p.d. per unit length of PQ. Thus for the same V_{PJ}, balance length will decrease.

24 X and Y are two coaxial flat circular coils lying on a table. Coil X has 120 turns and a diameter of 22.0 cm. Coil Y has 80 turns and a diameter of 11.0 cm. O and P are two points on the table, and O is at the centre of the two coils.



Initially, there is a constant current of 1.2 A in coil X and no current in coil Y.

A current of 1.2 A is now passed through coil Y, which increases the magnitude of the magnetic flux density at P.

What is the final magnitude of the resultant magnetic flux density at O?

A	0.14 mT	**B**	0.27 mT	**C**	0.96 mT	**D**	1.9 mT

Answer: B

Since the magnitude of flux density at P increases, it implies that the currents in X and Y flow in opposite directions.
Thus the flux densities due to X and Y are in <u>opposite</u> directions at O.

Recall that for a flat circular coil, at its CENTRE, B is given by $\frac{\mu_o N I}{2r}$.

B due to X at O = $\frac{\mu_o N I}{2r} = \frac{(4\pi \times 10^{-7})(120)(1.2)}{2(0.220 \div 2)}$ = 8.22526×10^{-4} T
B due to Y at O = $\frac{\mu_o N I}{2r} = \frac{(4\pi \times 10^{-7})(80)(1.2)}{2(0.110 \div 2)}$ = 1.09670×10^{-3} T

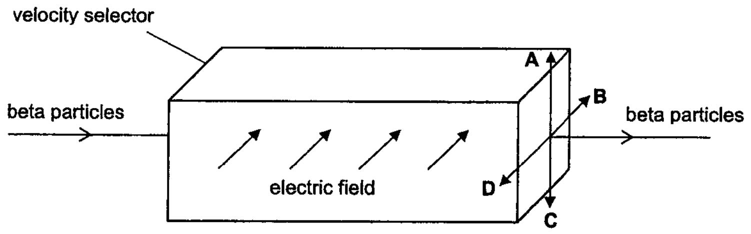
Magnitude of Resultant B at O = $(1.09670 \times 10^{-3}) - (8.22526 \times 10^{-4}) = 2.7418 \times 10^{-4}$ T = 0.27 mT

More papers at www.testpapersfree.com

25 A beam of beta particles enters a velocity selector. An electric field is applied in a horizontal direction, perpendicular to the beam of beta particles, as shown in the diagram below.

A magnetic field is applied perpendicular to the beam such that beta particles of a particular speed leave the selector undeflected.

In which direction is the magnetic field?



Answer: A

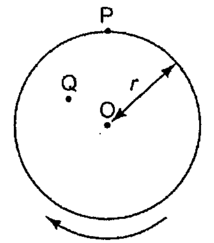
Beta particles are negatively charged.

Electric force acts out of the page, opposite to the electric field.

To remain undeflected, he magnetic force must be equal in magnitude and opposite direction to the electric force, so it must act into the page.

By FLHR, magnetic field acts upwards.

26 A copper disc of radius r rotates about its centre O at a constant speed. It is placed in a uniform magnetic field perpendicular to its surface. P is a point on the rim of the disc, while Q is a point at distance $\frac{r}{2}$ from O.



A steady electromotive force (e.m.f.) E is generated between points O and P.

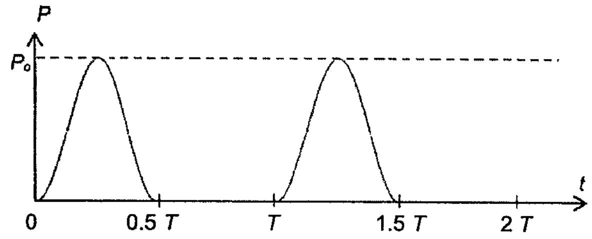
What is the e.m.f. generated between points P and Q?

A	zero	B	¼ E	C	½ E	D	¾ E

Answer: D

Between O and P, $e.m.f. = B(\pi r^2)f = E$
Between O and Q, $e.m.f. = B(\pi (r/2)^2)f = \frac{1}{4}E$
Between P and Q, $E - \frac{1}{4}E = \frac{3}{4}E$

27 A half-wave rectified sinusoidal alternating current flows through a light bulb. The graph shows the variation of the power dissipated in the light bulb with time t, where T is the period of the current.



What is the average power consumption of the light bulb?

A	0.25 P_o	B	0.40 P_o	C	0.50 P_o	D	0.70 P_o

Answer: A

Distribute area under graph across the entire period

For full sinusoidal a.c., the average power consumption is 0.50 P_o.

But this is half-wave rectified sinusoidal a.c. the average power consumption is 0.5 (0.50 P_o) = 0.25 P_o

28 To observe diffraction rings by a carbon film, a beam of electrons is accelerated from rest across a potential difference of V so that the de Broglie wavelength of the electrons is 0.10 nm.

What is the value of V?

A	90 V	B	150 V	C	270 V	D	330 V

Answer: B

de Broglie wavelength, $\lambda = \frac{h}{p}$

$p = \frac{h}{\lambda}$

KE = $\frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{\left(\frac{h}{\lambda}\right)^2}{2m} = \frac{h^2}{2m\lambda^2}$

Loss in EPE = Gain in KE

$eV = \frac{h^2}{2m\lambda^2}$

$(1.60 \times 10^{-19})V = \frac{(6.63 \times 10^{-34})^2}{2(9.11 \times 10^{-31})(0.10 \times 10^{-9})^2}$

$V = 150.79 = 150\, V\ (2\ sig. fig.)$

29 At time t, a sample of a radioactive substance contains N atoms of a particular nuclide. At time $(t + \Delta t)$, where Δt is a short period of time, the number of atoms of the nuclide is $(N - \Delta N)$.

Which expression is equal to the decay constant of the nuclide?

A	$\frac{N\Delta N}{\Delta t}$	B	$\frac{\Delta N}{N\Delta t}$	C	$\frac{\Delta N}{\Delta t}$	D	$\frac{\Delta N}{N}$

Answer: B

$Activity\ A = \lambda N$

For a short time interval,

$Activity\ A = \frac{\Delta N}{\Delta t}$

Hence

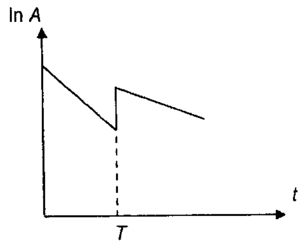
$\frac{\Delta N}{\Delta t} = \lambda N$

$\lambda = \frac{\Delta N}{N\Delta t}$

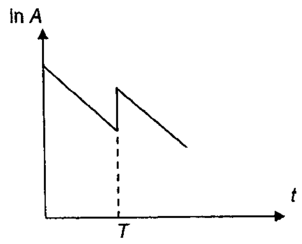
30 At time $t = 0$, some radioactive gas is injected into a sealed vessel. At time T, a different radioactive gas with a half-life very much shorter than the first is injected into the same vessel.

Which one of the following graphs best represents how activity A varies with t?

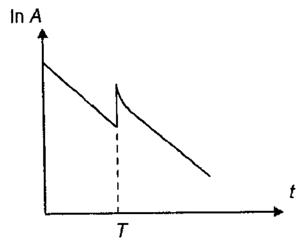
A



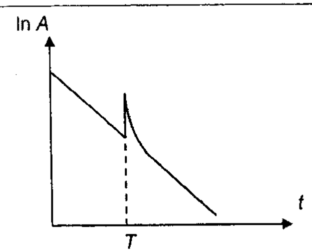
B



C



D

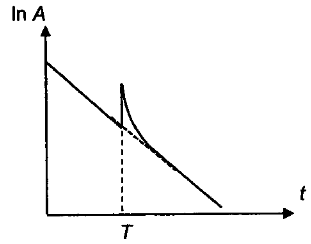


Answer: D

$A = A_0 e^{-\lambda t}$

$\ln A = \ln A_0 - \lambda t$

The curved part comes about because of two difference decay constants. Since the added gas has a much shorter half-life, the gradient of the graph should eventually return to the original gradient, and "continue" from where the original "left off".



-- END OF PAPER 1 –

-- BLANK PAGE --

More papers at www.testpapersfree.com

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS — 9749/2

Paper 2: Structured Questions

25 August 2022

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

Answer all questions in Paper 2.

Suggested Solutions

For Examiner's Use		Difficulty L1	L2	L3
Q1	/ 11			
Q2	/ 8			
Q3	/ 11			
Q4	/ 9			
Q5	/ 7			
Q6	/ 5			
Q7	/ 7			
Q8	/ 22			
Paper 2	/ 80			

This document consists of **25** printed pages and **0** blank page.

[Turn over

More papers at www.testpapersfree.com

PHYSICS DATA:

speed of light in free space	c	$= 3.00 \times 10^8$ m s^{-1}
permeability of free space	μ_0	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	$= 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ 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	$= 1.38 \times 10^{-23}$ mol^{-1}
gravitational constant	G	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
acceleration of free fall	g	$= 9.81$ m s^{-2}

PHYSICS 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	$P = \rho gh$
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.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

BP~241

BP-242

Answer **all** questions from this paper.

1 A cliff train cabin is used to carry passengers up a slope as shown in Fig.1.1.

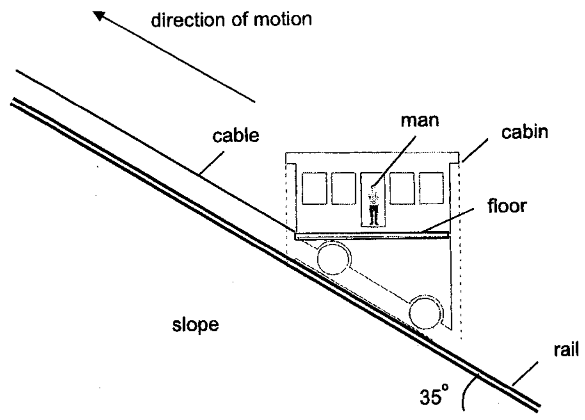


Fig. 1.1

The cable attached to the cabin pulls the cabin up the slope along the rail line which is inclined at 35° to the horizontal.

Initially, the cabin starts from rest and accelerates at 1.0 m s^{-2} for a time of 3.0 s. The cabin then moves at constant speed of 3.0 m s^{-1} for 100 s. Finally, the cabin decelerates to rest in 3.0 s.

The floor of the cabin is horizontal all the times. A man of mass 95 kg is standing upright on the floor of the cabin.

(a) Calculate the vertical height moved by the man during the initial acceleration of the cabin.

height = ... m [3]

Distance moved **along the rail line**,

$s = (0)(3.0) + \frac{1}{2}(1.0)(3.0)^2 = 4.5\ m$ — 1

Vertical height moved,

$h = s\sin(35°)$ — 1

$h = (4.5)(\sin 35°) = 2.58109 = \mathbf{2.6\ m}$ — 1

(b) (i) Calculate the normal reaction force acting on the man from the floor of the cabin when the cabin is moving at constant speed.

normal reaction = ... N [1]

N = W = mg = 95 × 9.81 = 931.95 = **930 *N*** — 1

(ii) Explain your working in **(i)**.

....

.... [1]

At constant speed, there is no acceleration, hence there is <u>no net</u> force acting on the <u>man</u>. — 1

There are two forces acting on the man: his weight and the normal reaction force of the floor on the man.
Since the weight acts vertically down, the normal reaction force must be equal in magnitude and opposite in direction to the weight to produce a zero net force.

(c) Forces act on the man by the floor of the cabin.

(i) State the forces for the man as the cabin accelerates.

.... [1]

Frictional force and **normal contact force** by the floor, and, man's **weight.** — 1

(ii) Explain how these forces produce the acceleration of the man.

....

.... [2]

The **vector sum** of the frictional force, the normal contact force and the man's weight is **non-zero** — 1
and **acts along the direction of the motion of the cabin.** — 1

OR

Normal contact force is greater than man's weight, causing a resultant force vertically upwards. — 1

The **resultant** of the **horizontal leftwards acting frictional force and the resultant vertical force acts along the direction of the motion** of the cabin to produce acceleration. — 1

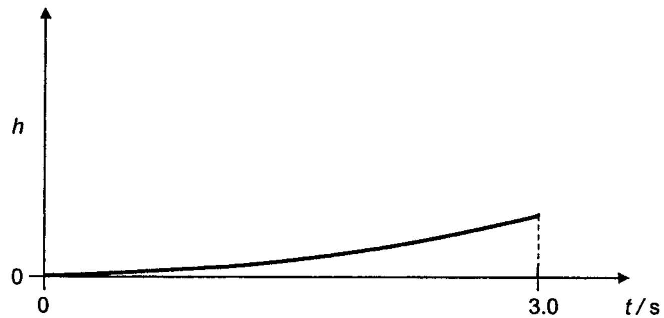
More papers at www.testpapersfree.com

(d) The vertical height h of the man varies with time t. On the axes below, show qualitatively the variation with time t of height h for the motion of the man during

(i) the acceleration,

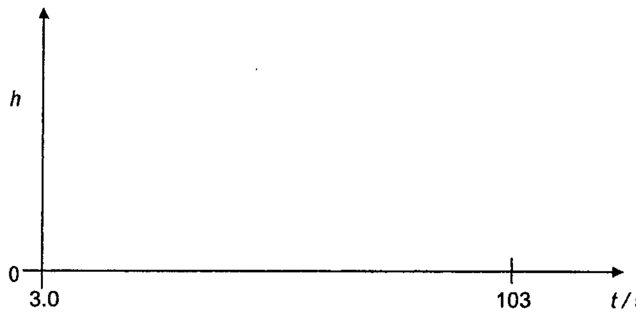
[1]

Solution:



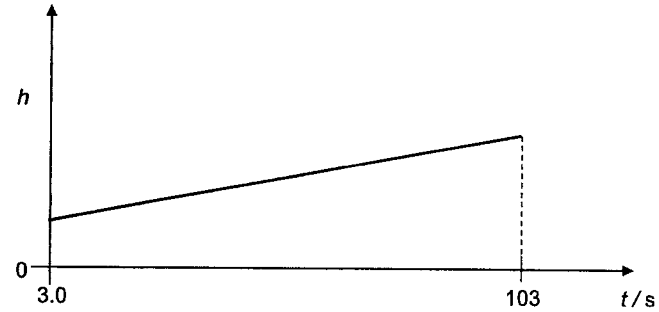
1

(ii) the constant speed,



[1]

Solution:

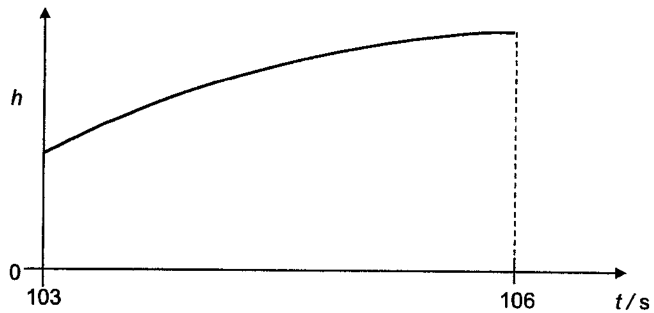


1

(iii) the deceleration.

[1]

Solution:



1

BP~243

2 A stationary electron is in a uniform field of force.

(a) Describe the direction of the force on the electron relative to the direction of the field if the field is

(i) a gravitational field,

.... [1]

same direction of the field. 1

(ii) an electric field,

.... [1]

opposite direction to the field. 1

(iii) a magnetic field.

.... [1]

no force acts. 1

(b) Describe and explain the path the electron will take when it moves at right angles to each field.

....

....

....

....

....

....

....

....

.... [5]

For gravitational field and electric field, the electron will move in a **parabolic path**, 1
as the ***net* force (or acceleration) is *always* of *constant* direction and *constant* magnitude throughout the motion** despite the direction of the electron's velocity. 1

For magnetic field, when the electron moves at right angle to the magnetic field, it **experiences a magnetic force that is *always* acting *perpendicular* to the velocity** of the electron. 1

This **changes the direction of the velocity of the electron continuously, but not the magnitude of velocity.** 1

This **constant speed will keep the magnetic force and hence the centripetal force constant in magnitude**, causing the electron to move in a **circular path of constant radius**. 1

3 (a) (i) Explain what is meant by an *ideal gas*.

....

.... [2]

An ideal gas is one that obeys the ideal gas equation $pV = nRT$ 1

at all values of temperature (T), pressure (p) and volume (V), where n is the number of moles of gas and R is the molar gas constant. 1

(ii) Use the kinetic theory of gases to explain why when the volume of an ideal gas decreases at constant temperature, the pressure of the gas increases.

....

....

....

....

....

....

.... [4]

When temperature is constant, the root-mean-square speed of the gas atoms is constant. 1

Therefore, **when volume decreases,** the distance travelled by the atoms between successive collisions with a wall of the container decreases, leading to **a higher frequency of collisions between the gas atoms and the wall of the container.** 1

A higher frequency of collisions leads to greater total rate of change of momentum of all the molecules hitting a wall at any instant in time 1

and **thus larger force on the container**, thus a higher pressure. 1

More papers at www.testpapersfree.com

(b) A fixed amount of an ideal gas undergoes a cycle of changes A→B→C→A as shown in Fig. 3.1.

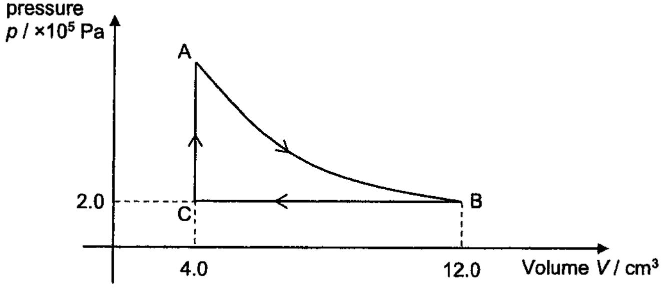


Fig. 3.1

(i) Determine the work done on the ideal gas during the process B→C.

work done on gas = ... J [2]

$W = -p\Delta V$

$W = -(2.0\times10^5)(4.0-12.0)(10^{-6})$ — 1

$W = 1.6\text{ J}$ — 1

(ii) Explain why there is a net thermal energy absorbed by the ideal gas when it undergoes a cycle of changes A→B→C→A.

....

....

....

....

....

....

.... [3]

Per cycle, total work done **by** gas is **greater** than **total** work done **on** the gas, thus there is a **net** work done **by** gas. — 1

Per cycle, there is **no net** change in the internal energy of the ideal gas. — 1

— 1

Thus, by the First Law of Thermodynamics, $\Delta U = Q + W$, with a **net** work done **by** the gas, there needs to be a **net** thermal energy **supplied to** the gas so that there is **no net change in** the internal energy.

4 The variation with potential difference V of current I in a resistor X is shown in Fig. 4.1.

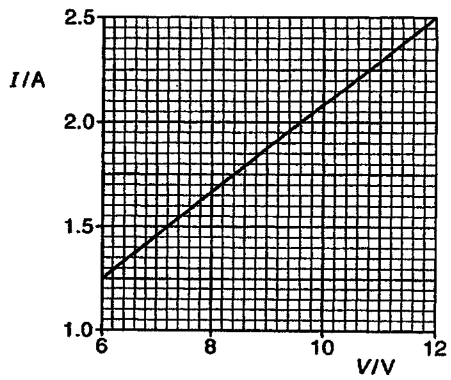


Fig. 4.1

(a) Use Fig. 4.1 to show that the resistance of X remains constant.

[2]

Method:

- *calculate the RATIO of the V-coordinate to the I-coordinate.*
- *Compare the ratios from the different points. Show that the ratios are constant.*

At (6.0 V, 1.25 A), $R = \frac{V}{I} = \frac{6.0}{1.25} = 4.8\ \Omega$ — 1

At (12 V, 2.5 A), $R = \frac{V}{I} = \frac{12}{2.5} = 4.8\ \Omega$

Since the ratio $\frac{V}{I}$ remains constant at 4.8 Ω, resistance of X remains constant. — 1

Method 2:

- Calculate gradient with either 2 points that are far apart on the graph OR at least 3 different points along the graph. — 1
- Use the gradient and straight line equation to calculate y-intercept and show that it is equal to zero. — 1

(b) In an attempt to obtain the graph of Fig. 4.1 for resistor X, a student sets up a circuit as shown in Fig. 4.2.

More papers at www.testpapersfree.com

BP~245

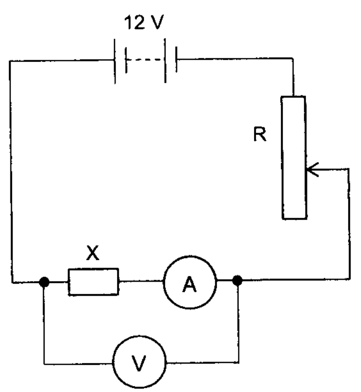


Fig. 4.2

The battery has an e.m.f. of 12 V and negligible internal resistance. The resistor R has a resistance that can be varied between 0.0 Ω and 2.0 Ω. The voltmeter and ammeter are both ideal.

State and explain why the circuit shown in Fig. 4.2 is inappropriate for obtaining data from V = 6 V to V = 12 V for the graph in Fig. 4.1.

....

....

....

....

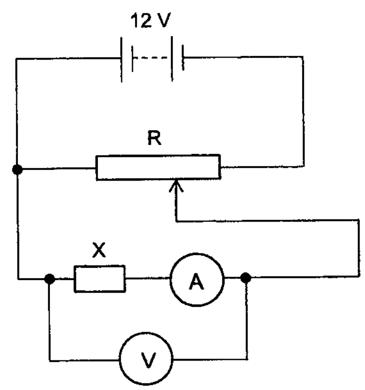
.... [2]

When R is set to its minimum of 0 Ω, a maximum potential difference (p.d.) of 12 V can be applied across X. Hence voltmeter and ammeter readings up to V = 12 V are obtainable. **1**

However, when R is set to its maximum of 2.0 Ω, since X has resistance of 4.8 Ω which is greater than 2.0 Ω, the p.d. across X will be greater than 6 V ($\frac{4.8}{4.8+2.0} x12 = 8.5\,V$). It would thus be impossible to obtain voltmeter and ammeter readings in the range of V = 6 V to V = 8.5 V in Fig. 4.1. **1**

(c) In the space below, draw a circuit diagram using the same components as shown in Fig. 4.2 from which the graph of Fig. 4.1 may be determined. [1]

Solution:



1

(d) Calculate the difference in the power dissipated in resistor X when V is increased from 7.2 V to 9.6 V.

difference in power = ... W [2]

Solution:

$Difference\ in\ power = I_1V_1 - I_2V_2$ **1**

$= (2.0)(9.6) - (1.5)(7.2)$

$= 8.4\,W$ **1**

(e) Suppose the battery has an internal resistance of 0.50 Ω, and R in Fig. 4.2 is adjusted to 0 Ω.

Calculate the terminal potential difference across the battery.

terminal potential difference = ... V [2]

By potential divider principle,

$terminal\ p.d. = p.d.\ across\ X = \frac{4.8}{4.8 + 0.5}\ x\ 12\,V$ **1**

= 10.868 V = **11 V** **1**

5 (a) When white light is incident on a single slit, a diffraction pattern is formed on a screen.

The central fringe of the diffraction pattern is coloured at the edges and has a white central region. Explain this observation.

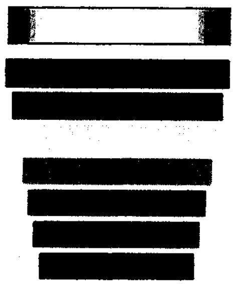
....

....

.... [2]

White light consists of <u>all</u> colours of visible light, which is of a <u>continuous range of wavelengths</u>. The <u>longer the wavelength</u>, the <u>greater the degree of diffraction</u>, <u>producing a central fringe of larger width</u>. 1

In the central region where <u>all</u> colours <u>overlap</u>, it is white. 1
At the edges where not all colours are present, they are coloured.



OR

White light consists of visible light of a continuous range of wavelengths. **Visible light of every wavelength meet with zero path difference at the centre, (thus meet in phase and undergo constructive interference,) thus all the overlapping colours produces a white region.**

At the edges, there are destructive interference of some light but not for others as the extent of diffraction increases with the wavelength. Hence the edges would not be white but be of the mixed colour of wavelengths that have non-zero intensity.

(b) (i) Explain what is meant by the *Rayleigh criterion* for the resolution of the images of two objects.

....

....

.... [2]

Two objects will be ***just* seen as separate / *just* distinguishable** when 1
the **first minimum** in the **diffraction pattern** of one image **coincides with** the **central maximum of the other**. 1

(ii) The Griffith Observatory in Los Angeles includes an astronomical refracting telescope (Griffith telescope) with an objective lens of diameter 0.305 m.

Calculate the wavelength of light for which the Griffith telescope has a minimum angular resolution of 1.8×10^{-6} rad.

wavelength = ... m [1]

From Rayleigh Criterion,

$\theta_{min} \approx \frac{\lambda}{b}$

$1.8 \times 10^{-6} \approx \frac{\lambda}{0.305}$

$\lambda \approx 5.49 \times 10^{-7} = \mathbf{5.5 \times 10^{-7}\ m}$ 1

(iii) The asteroid Apophis has a diameter of 325 m. It has been calculated that in the year 2029, its distance of closest approach to the Earth's surface will be 3.0×10^4 km.

Supporting your answer with calculations, explain whether the Griffith telescope can resolve Apophis.

....

.... [2]

Angular size of asteroid, $\theta \approx \frac{325}{3.0 \times 10^4 \times 10^3}$ 1
$= \mathbf{1.0833 \times 10^{-5} = 1.1 \times 10^{-5} rad}$

As $1.1 \times 10^{-5} rad$ is greater than $1.8 \times 10^{-6}\ rad$, the angular size of the asteroid exceeds the minimum angular resolution of the Griffith telescope, thus the telescope can resolve the asteroid. 1

More papers at www.testpapersfree.com

BP~247

6 In an X-ray tube, electrons are produced from a filament heated by an electric current as shown in Fig. 6.1. 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.

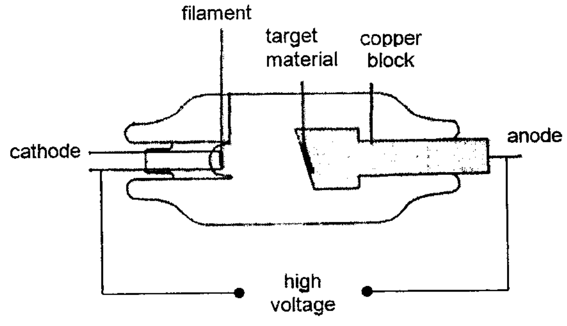


Fig. 6.1

A graph of intensity against wavelength of the emitted radiation is plotted as shown in Fig. 6.2 when the X-ray tube is operated at a voltage of 50 kV.

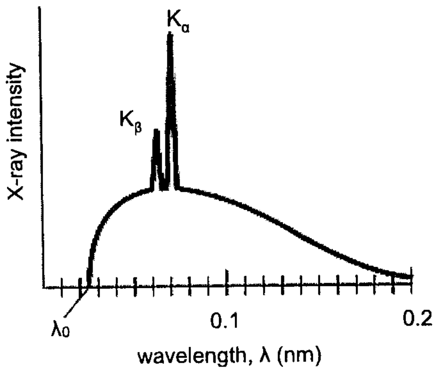


Fig. 6.2

(a) Explain why there is a minimum wavelength λ_0 for the emitted X-rays.

....

.... [2]

When an **accelerated electron from the cathode loses <u>all</u> of its kinetic energy (KE) in a <u>single</u> head-on collision with the target atom at the anode,** 1

the **KE lost is converted into an <u>x-ray photon</u> of <u>maximum energy</u>, <u>hence</u> minimum wavelength**. 1

(b) Show that λ_0 equals to 0.024 nm.

[1]

From (a),
Loss in EPE as electron moves from cathode to anode = Maximum KE gained just before it hits the anode = Maximum energy of photon emitted

So,
$\boldsymbol{eV_0 = hc/\lambda_0}$
$\boldsymbol{\Rightarrow \lambda_0 = hc/eV_0}$
$\boldsymbol{\Rightarrow \lambda_0 = (6.63 \times 10^{-34})(3.00 \times 10^{8}) / (1.60 \times 10^{-19})(50 \times 10^{3})}$ 1
$\Rightarrow \lambda_0 = 2.48625 \times 10^{-11} = 0.0248625 \times 10^{-9}$ m $\approx$ 0.024 nm

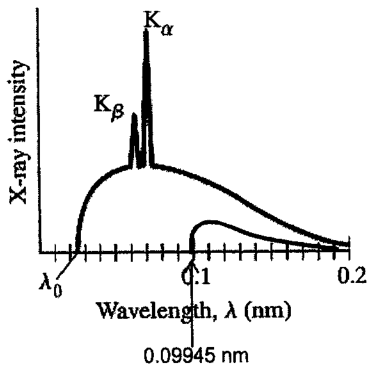
(c) Sketch on Fig. 6.2 a graph to show the intensity variation with wavelength if the accelerating potential difference is reduced to one-quarter of its original value. [2]

<u>Graph of **similar shape**, **below** the original graph (intensity lowered at all wavelengths).</u> 1

$\lambda_0 = hc/eV_0$
Since h,c,e are constants, thus **λ_0 is inversely proportional to V_0.**

Thus **if V_0 is one-quartered, <u>λ_0 will be increased by 4 times!</u>**

<u>New λ_0 = 4 x 0.0248625 nm = 0.09945 nm ≈ 0.1 nm AND without any characteristic lines.</u> 1



7 An induced nuclear fission reaction may be represented by the equation

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n$$

The variation with nucleon number *A* of the binding energy per nucleon B_E is illustrated in Fig. 7.1.

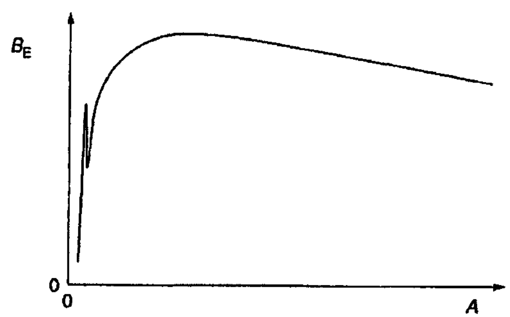


Fig. 7.1

(a) State an approximate value, in MeV, for the maximum binding energy per nucleon.

maximum binding energy per nucleon = ... MeV [1]

L1 Maximum binding energy per nucleon = **8.8 MeV (or 9 MeV)** (for Fe-56) 1

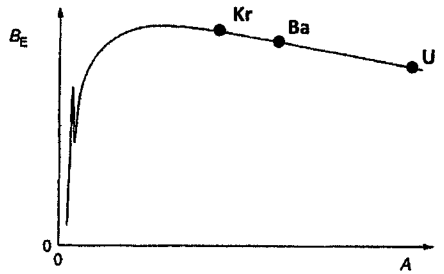
(b) On Fig. 7.1, mark approximate positions for the nuclei of

(i) uranium-235 (label the position U),

(ii) barium-141 (label the position Ba),

(iii) Krypton-92 (label the position Kr). [3]

Solution:



Mark scheme:
1 mark – In the ascending order, Kr, Ba and U 1
1 mark – All markings on the right-hand side of the peak (A = 56) 1
1 mark – Relative positions 1

(c) By reference to binding energy per nucleon, explain why energy is released in this fission reaction.

....

....

....

....

....

....

....

.... [3]

In the fission reaction, the **product** nuclides (Kr and Ba) have a **greater binding energy per nucleon** than the reactants (U and n, where n has zero binding energy). 1

Since the total number of nucleons is unchanged in the reaction, the **total binding energy** of the products is greater than that of the reactants. 1

This means that the **total energy released in the formation of Kr and Ba is more than the total energy absorbed during the disintegration of U**. Hence there is a *net* release in energy. 1

More papers at www.testpapersfree.com

8 Read the passage below and answer the questions that follow.

Torque from a Vehicle Engine

An internal combustion engine used on a vehicle operates over a limited rotational speed which can be controlled by the driver. As the driver increases the depression on the accelerator pedal, the input power to the engine will increase to a maximum when the throttle is fully opened. The power delivered to the wheels of the vehicle will also reach a maximum value.

The output torque of the engine is transmitted to the forward driving force on the vehicle's wheels. The transmission of the output torque of the engine is done through a gearbox which consists of several gear ratios capable of providing the required driving force to suit the different driving speeds and accelerations.

The gear ratio is the ratio of the rotational speed of the vehicle's engine to the rotational speed of the vehicle's wheel. A high gear ratio is required at low vehicle's speeds to provide a higher torque.

A vehicle starts to move off with the highest gear ratio, namely gear 1. As the vehicle's speed increases, the gear ratio changes from gear 1 to gear 4, with gear 4 being the lowest gear ratio. The lowest gear ratio is to provide for the maximum speed achievable. Thus, the forward driving force on the vehicle's wheels will change with the speed of the vehicle for different gears.

As the vehicle moves, it encounters a total resistive force that opposes its motion.

Fig. 8.1 shows how the speed of the vehicle affects the available force F at the wheels for different gears and the total resistive force on a 1200 kg vehicle when the input power to the engine is maintained at the maximum value. The available force is the maximum forward driving force that can be transmitted to the wheels.

To stop the vehicle quickly from a certain speed, the driver steps on the brake pedal to produce a braking force on the wheels, and at the same time, the power of the engine is removed completely. The maximum braking force of the car is 9300 N.

When a vehicle moves up an inclined slope, it encounters a climbing resistance that depends on the gradient of the slope. The gradient of the slope is defined as the ratio of the increase in height to the horizontal distance moved in percentage value.

The chart in Fig. 8.2 shows how the climbing resistance is affected by the gradient of the slope.

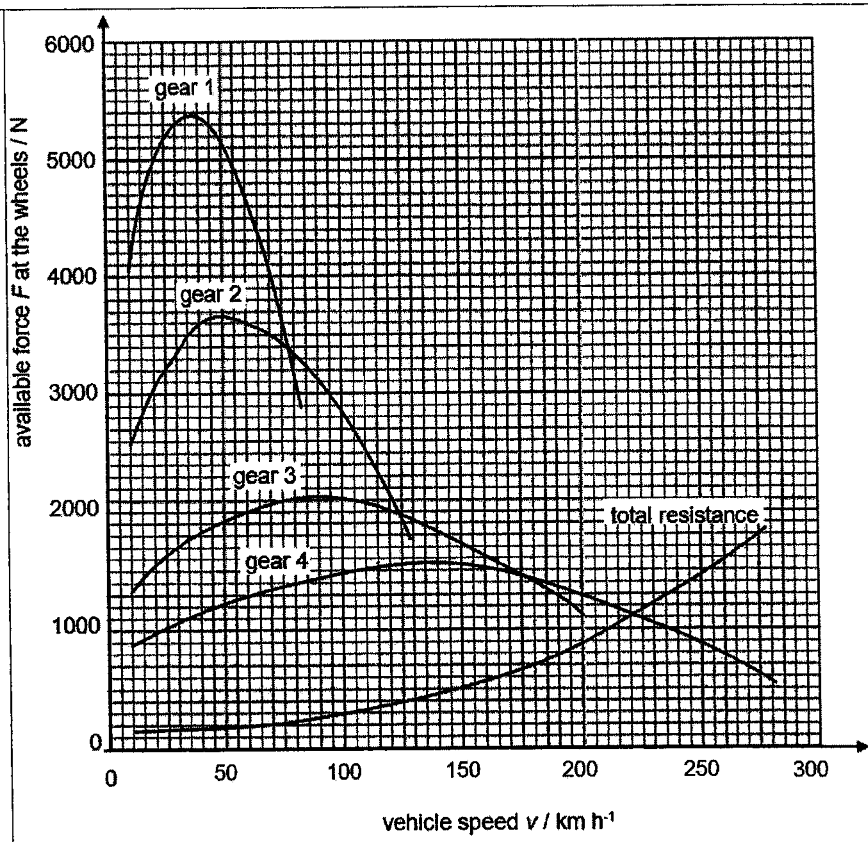


Fig. 8.1

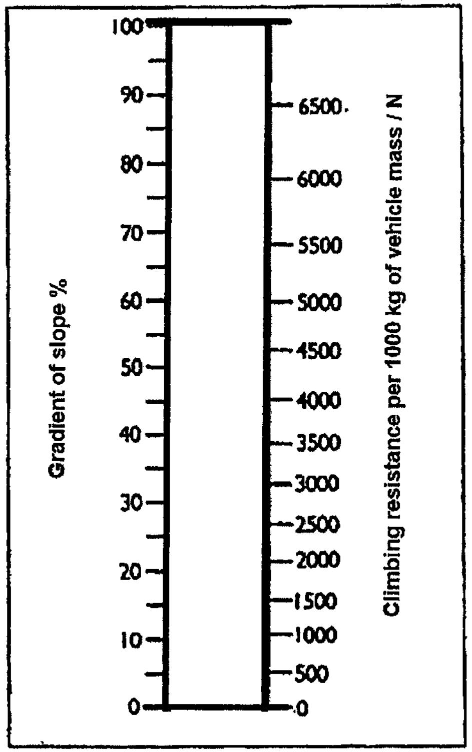


Fig. 8.2

(a) Explain why gear 1, is used to accelerate the vehicle from rest.

....

.... [1]

At low speed, the driver wishes to **increase speed at the fastest rate (or increase speed in the shortest possible time)** and hence the driving force should be largest and this is possible with gear 1. **1**

(b) Explain what is meant by the term *available force* at the wheels.

....

.... [1]

The **maximum** forward driving force on the wheels when the engine is given the full power. **1**

(c) The vehicle is travelling at 100 km h^{-1} on a horizontal road and gear 3 is engaged by a driver.

(i) State the available force at the wheels and the resistive force.

available force = ...N

resistive force = ...N [2]

Available driving force = 2100 N **1**

Resistive force = 300 N **1**

(ii) Calculate the maximum acceleration.

maximum acceleration = ...m s^{-2} [2]

$F_{net} = ma$

2100 - 300 = 1200 *a* **1**

a = 1800 / 1200 = 1.5 m s^{-2} **1**

(iii) Explain why gear 3 is the optimum gear for maximum power output at a speed of 100 km h^{-1}.

....

.... [1]

At gear 3, the **available force remains relatively constant when speed decreases slightly below 100 km h^{-1}.** **1**

(iv) The driver wishes to overtake another vehicle which is also travelling at 100 km h^{-1}. Explain whether he needs to change gear.

....

.... [2]

Yes. The driver needs to change to gear 2 to get a higher available force. **1**
This is because the net forward force will be higher and he can move with a larger acceleration. **1**

OR

No. At a constant speed of 100 km h^{-1}, he just needs to overcome the resistive force of about 300 N. Thus he does not need a maximum force (available force of 2100 N). [1]
He just needs to depress the accelerator more to increase the driving force up to a maximum of 2100 N. [1]

(Award credits based on good application of physics)

More papers at www.testpapersfree.com

(d) (i) Starting from the definition of work done, show that the power output of the vehicle is given by the expression

power output = driving force x speed

[2]

From definition of work done:
work done by driving force W
*= **average** driving force F x displacement s moved **in the** direction of F* — 1

From definition of power:
power output P
= work done per unit time — 1
= Fs / t   where *t* is the time taken to do work of *Fs*
= F (s/t)
= driving force F x speed s/t

(ii) Explain why for a given power delivered to the engine, the available force at the wheels for gear 3 is smaller than that for gear 2.

....

....

....

.... [2]

The **vehicle speed is larger when gear 3** is used. — 1

Since power output = driving force x speed — 1
For a given power output, at higher speed, the available (driving) force is smaller.

(e) State the maximum possible speed of the vehicle.

maximum possible speed = ... km h^{-1} [1]

220 km h^{-1} — 1

At this speed, the maximum driving force = total resistance force. So the net force is zero.

Above 220 km h^{-1}, the net force is opposing the motion and the vehicle will slow down.

(f) The vehicle is moving up a slope inclined at 20° to the horizontal.

(i) Show that the gradient of the slope, in percentage, is 36%.

[1]

gradient = (increase in height / horizontal distance moved) x 100%
= tan θ x 100%
= tan 20° x 100% — 1
= 36.4% = 36%

(ii) Use Fig. 8.2 to determine the climbing resistance on the car.

climbing resistance = ...N [2]

From chart, when gradient of slope is 36%, — 1
climbing resistance **per 1000 kg** = 3250 N

So **for 1200 kg**, climbing resistance = 1200/1000 x 3250 = 3900 N — 1

(iii) Using the answer to **(f)(ii)** and **Fig. 8.1**, estimate and explain the maximum speed at which the vehicle can move up the slope.

....

.... [2]

To overcome the climbing resistance of 3900 N, the difference between available force and the total resistance must be more than 3900 N. — 1

Referring to Fig. 8.1, **gear 1 must be used**.
The maximum speed is about **72.5 km h^{-1}**. — 1

(g) The vehicle is travelling up the slope with a speed of 40 km h^{-1}. The driver intends to stop the car by applying the maximum braking force.

Estimate the distance moved along the slope before the car stop.

More papers at www.testpapersfree.com

		distance moved = ...m	[3]
		Let the distance be d and the braking force be *B*. Total retarding force = *B* (from text) + climbing resistance + total resistance (from Fig. 8.1) = 9300 + 3900 + 150 = 13350 N Assuming the total resistance is also constant throughout *d*, then loss in K.E. = work done against the total retarding force $\frac{1}{2}(1200)(20\,000/3600)^2 = 13350 \times d$ *d* = 1.39 m	1 1 1

-- END OF PAPER 2 --

-- BLANK PAGE --

More papers at www.testpapersfree.com

More papers at www.testpapersfree.com

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS 9749/3

Paper 3: Longer Structured Questions

12 September 2022

2 hours

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen in the space provided. [PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use highlighters, glue or correction fluid.

Answer **ALL** questions in **Section A**.

Answer **ONE** out of two questions in **Section B**.
Circle on the cover page the question number attempted in Section B.

Suggested Solutions

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
SECTION A				
Q1	/ 8			
Q2	/ 9			
Q3	/ 8			
Q4	/ 9			
Q5	/ 9			
Q6	/ 9			
Q7	/ 8			
SECTION B				
Q8	/ 20			
Q9	/ 20			
PAPER 3	/ 80			
PAPER 2	/ 80			
PAPER 1	/ 30			
PAPER 4	/ 55			
TOTAL (WEIGHTED)	%			

This document consists of **32** printed pages and **zero** blank page.

[Turn over

More papers at www.testpapersfree.com

PHYSICS DATA:

speed of light in free space	c	= 3.00×10^{8} m s^{-1}
permeability of free space	μ_0	= $4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	= 8.85×10^{-12} F m^{-1}
		$\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	= 1.60×10^{-19} C
the Planck constant	h	= 6.63×10^{-34} J s
unified atomic mass constant	u	= 1.66×10^{-27} kg
rest mass of electron	m_e	= 9.11×10^{-31} kg
rest mass of proton	m_p	= 1.67×10^{-27} kg
molar gas constant	R	= 8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	= 6.02×10^{23} mol^{-1}
the Boltzmann constant	k	= 1.38×10^{-23} mol^{-1}
gravitational constant	G	= 6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g	= 9.81 m s^{-2}

PHYSICS 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	$P = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/K = T/^{\circ}C + 273.15$
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.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin \omega t$
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	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

BP - 255

Section A

Answer **all** questions from this section.

1 Fig. 1.1 shows a hinged beam of length 60.0 cm held horizontally against a wall by a cord XY.

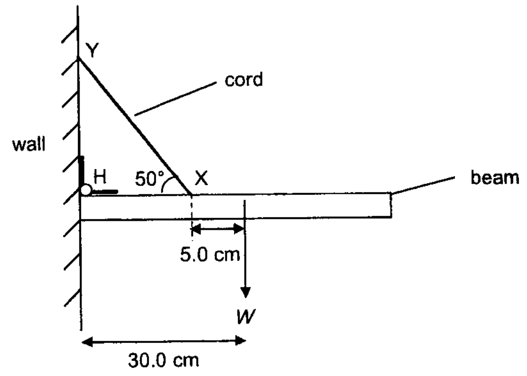


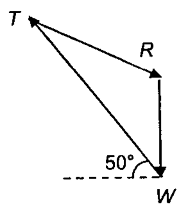
Fig. 1.1

The forces acting on the beam are its weight W, the force T exerted by the cord, and the force R exerted by the hinge H.

(a) In the space provided below, sketch a labelled vector triangle of the forces acting on the beam.

[2]

Solution:



- Correct labelling of forces and arrows point in the same direction (closed polygon). **1**
- R must be diagonally down not up, i.e. must have both a rightward & downward component. **1**

(b) The weight of the uniform beam is 40.0 N and the mass of the cord is negligible

Calculate the magnitude of

(i) the tension T,

T = ... N [2]

By principle of moments,
taking moments about the hinge H,
Sum of clockwise moment = sum of anti-clockwise moment

$40.0 \times 0.300 = T \sin 50^{0} \times 0.250$ **1**

$T = 62.7$ N **1**

(ii) the force R.

R = ... N [2]

Applying the cosine rule for the vector triangle,

$R^2 = T^2 + W^2 - 2TW \cos 40^0$

$R^2 = 62.7^2 + 40.0^2 - (2 \times 62.7 \times 40.0 \times \cos 40^0)$ **1**

$R = 41.1$ N **1**

Method 2:
Setting up 2 equations for Vertical & Horizontal Equilibrium, and then solving these 2 equations simultaneously.

(c) A brick is placed on the beam at X without the cord snapping. Subsequently, when the brick is shifted further away from the hinge along the beam, the cord snaps.

Explain why the cord snaps.

....

....

....

.... [2]

The total clockwise moments about the hinge H is larger than the total anti-clockwise moment that can be provided by the tension in the cord. **1**

Hence the cord snaps as the tension T has exceeded its breaking strength. **1**

2 (a) State the principle of *conservation of linear momentum*.

[1]

The total linear momentum of a system will remain constant if no net external force acts on it. **1**

(b) In a nuclear reactor, carbon atoms are used to slow down neutrons. A fast neutron collides head-on with a stationary carbon atom.

(i) Show that the impulse acted on the neutron is proportional to the final velocity of the carbon atom in such a collision. [2]

By conservation of momentum,

$$m_n u_n + m_C u_C = m_n v_n + m_C v_C$$
$$m_n v_n - m_n u_n = m_C u_C - m_C v_C$$
$$\text{impulse on neutron}, \Delta p_n = 0 - m_C v_C \quad 1$$

Since the mass of the carbon atom is constant, 1

$$\Delta p_n \propto v_C$$

OR

By conservation of momentum,
Total initial momentum of neutron and carbon atom
= Total final momentum of neutron and carbon atom
Change in momentum of the neutron
= - Change in momentum of the carbon atom

From definition of impulse,
Impulse on the neutron = Change in momentum of the neutron

Thus,
Impulse on the neutron = - Change in momentum of the carbon atom
= - (mass of carbon atom) x (final velocity of carbon atom – initial velocity of carbon atom)
= - (mass of carbon atom) x (final velocity of carbon atom) , since carbon atom was initially stationary

Since the mass of the carbon atom remains constant,

Impulse on the neutron is proportional to the final velocity of the carbon atom.

(ii) In the collision between a neutron and a carbon atom, a neutron of mass 1.0*m* with initial velocity *u* collides elastically head-on with a stationary carbon atom of mass 12*m*. The final velocities of the neutron and the carbon atom are *v* and *V* respectively.

By considering the relative speeds between the neutron and carbon atom before and after their collision, show that the fraction of the kinetic energy that is retained by the neutron after such a collision is 0.72. [3]

$$\frac{KE\ retained}{initial\ KE} = \frac{KE_{f,n}}{KE_{i,n}} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}mu^2} = \frac{v^2}{u^2} \quad ---(1) \quad 1$$

Using Relative speed of approach = Relative speed of separation 1

$$u - 0 = V - v$$
$$V = v + u$$

And Conservation of momentum,

$$m_n u_n + m_C u_C = m_n v_n + m_C v_C$$
$$mu + 0 = mv + 12mV$$
$$u = v + 12V$$

Therefore,

$$u = v + 12(v + u) \quad 1$$
$$v = -\frac{11}{13}u \quad ---(2)$$

Sub (2) into (1):

$$\frac{KE\ retained}{initial\ KE} = \frac{\left(-\frac{11}{13}u\right)^2}{u^2} = 0.72$$

(c) **(i)** Explain why nuclei which are much more massive than carbon atoms are ineffective in slowing down neutrons in the nuclear reactor.

....

....

.... [2]

Method 1: **From working in (b)**

$$\frac{KE\ retained}{initial\ KE} = \frac{m_{particle} - m_n}{m_{particle} + m_n}$$

When $m_{particle} \gg m_n$, ratio $\frac{KE\ retained}{initial\ KE} \approx \frac{m_{particle}}{m_{particle}} = 1$ which is the maximum. 1

Thus, when very massive particles are used ($m_{particle} \gg m_n$), the **kinetic energy retained by the neutron will be very large.** 1

Derivation in detail (optional):
Using Relative speed of approach = Relative speed of separation [1]

$$V = v + u$$

And Conservation of momentum, [1]

$$m_n u + 0 = m_n v + m_{particle} V$$
$$u = v + \frac{m_{particle}}{m_n} V$$

Therefore,

$$u = v + \frac{m_{particle}}{m_n}(v + u)$$
$$v = -\frac{m_{particle} - m_n}{m_{particle} + m_n} u \quad ---(2)$$

Sub (2) into (1):

BP-257

More papers at www.testpapersfree.com

$$\frac{KE\ retained}{initial\ KE} = \frac{\left(-\frac{m_{particle} - m_n}{m_{particle} + m_n}u\right)^2}{u^2} = \frac{m_{particle} - m_n}{m_{particle} + m_n}$$

<u>Method 2:</u> **<u>From conservation of momentum</u>**
When very massive particles are used, **by the principle of conservation of momentum, the neutrons will retain most of the magnitude of its initial momentum after collision,**

traveling in the opposite direction to its initial momentum.

(ii) Explain why particles of similar mass to neutrons such as hydrogen nuclei are not suitable for slowing down neutrons in the nuclear reactor.

....

.... [1]

<u>Method 1: From working in (b)</u>

$$\frac{KE\ retained}{initial\ KE} = \frac{m_{particle} - m_n}{m_{particle} + m_n}$$

When $m_{particle} = m_n$, ratio $\frac{KE\ retained}{initial\ KE} = 0$.

Thus, when particles of similar mass to neutrons are used ($m_{particle} = m_n$), the **neutrons will stop moving completely which is not the aim** (we want the neutrons to move more slowly but not to stop moving otherwise they cannot collide with the fissile isotope). **1**

<u>Method 2: From conservation of momentum</u>
By the principle of conservation of momentum, when a neutron collides with an <u>initially stationary</u> particle of similar mass (e.g. hydrogen atom), **the neutrons will stop moving completely after the collision which is not the aim** (we want the neutrons to move more slowly but not to stop moving otherwise they cannot collide with the fissile isotope).

3 A light helical spring is suspended vertically from a fixed point as shown in Fig. 3.1.

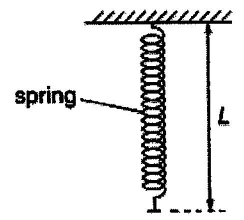


Fig. 3.1

A mass of weight 5.0 N is suspended from the spring of unstretched length 4.0 cm and then released from rest. The mass oscillates vertically.

The variation with resultant force *F* on the mass when *L* is between 4.0 cm and 8.0 cm is shown in Fig. 3.2 below.

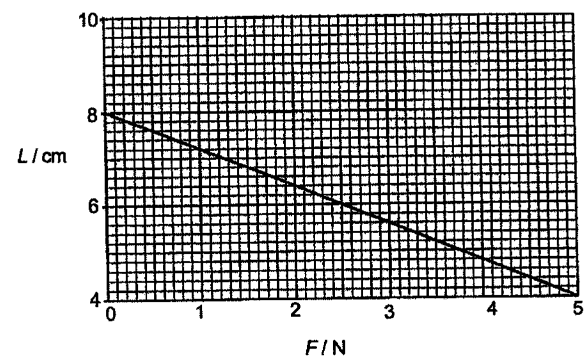


Fig. 3.2

(a) Explain why, as shown in Fig. 3.2, the resultant force on the mass increases as the length of the spring decreases from *L* = 8.0 cm to *L* = 4.0 cm.

....

.... [2]

Fig. 3.2 shows the part of the motion when the mass is **at and above** the equilibrium position.
Also, for the mass to **oscillate,** the upward spring force F_s must be **lesser than** the weight W when the mass is above the equilibrium position.

As spring length *L* decreases, the extension *x* of the spring decreases, hence spring force F_s decreases. **1**

Since weight *W* remains constant throughout the motion, the **magnitude of the resultant force *F* acting downwards increases (since F = W – F_s).** **1**

(Hence Fig. 3.2 has a negative gradient.)

More papers at www.testpapersfree.com

(b) Calculate the force constant of the spring.

force constant = ... N m^{-1} [3]

At equilibrium position (where resultant force F = 0),

From Fig. 3.2 → L = 8.0 cm

Since the unstretched spring length = 4.0 cm,

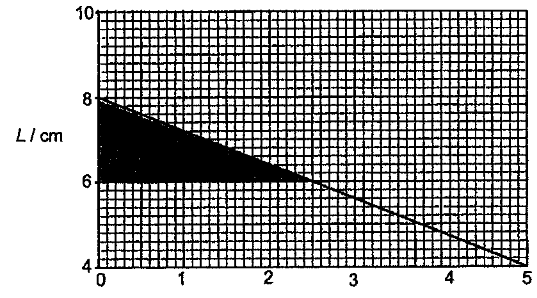
Extension x of the spring at the equilibrium position = 8.0 – 4.0 cm = 4.0 cm 1

Consider equilibrium of forces:

$$F_s = W$$
$$kx = W \quad 1$$
$$k = \frac{W}{x}$$
$$= \frac{5.0}{4.0 \times 10^{-2}} \quad 1$$
$$= 125\ N\,m^{-1}$$

(c) On Fig. 3.2, shade clearly the area of the graph that represents net work done on the mass when the mass has travelled from L = 8.0 cm to L = 6.0 cm. [1]

Solution: 1



For info:

$$WD_{net} = Area\ bounded\ by\ the\ graph\ and\ the\ L - axis$$

Net work done on the mass = $\int F\ ds$
where s is the displacement moved/change in displacement, hence corresponds to the **change in** L.

(d) Describe the energy changes in the spring-mass system when the mass moves from L = 8.0 cm to L = 6.0 cm.

.... [2]

The **kinetic energy of the mass decreases and the elastic potential energy of the spring also decreases,** 1
these energies convert into the increase in the gravitational potential energy of the mass. 1

4 (a) A revolving aluminium disc has small magnets equally spaced around its rim as shown in Fig. 4.1. The magnets are all aligned in the same direction with the north poles on the same side of the disc. The disc rotates at a constant angular velocity.

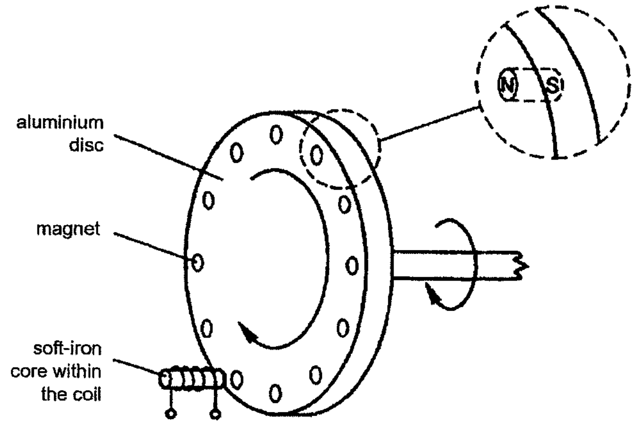


Fig. 4.1

A coil, wound on a soft-iron core, is fixed such that the north poles of the magnets pass close by the end of the coil without touching it. The terminals of the coil are connected to a detector which monitors the e.m.f. induced in the coil.

(i) As one magnet passes the coil, use the laws of electromagnetic induction to explain

1. why there is an induced e.m.f. in the coil.

....

....

....

....

....

....

....

.... [2]

The magnetic flux density experienced by the coil increases and decreases when one magnet approaches and leaves the coil respectively. 1

There is a rate of change of magnetic flux linkage experienced by the coil, and by Faraday's Law, there is an induced e.m.f. in the coil. 1

More papers at www.testpapersfree.com

2. why there is a reversal in the direction of the induced e.m.f.

....

....

....

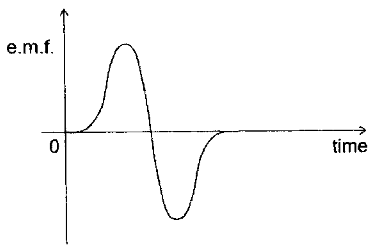
.... [1]

By Lenz's law, the **direction of the induced e.m.f in the time interval when the <u>magnetic flux linkage</u> <u>increases</u> <u>will be negative to that</u> in the time interval when the magnetic flux linkage <u>decreases</u>.** **1**

(ii) On Fig. 4.2, sketch a graph to show the variation with time of the e.m.f. induced in the coil as one magnet passes the coil.

Fig. 4.2 [1]

Solution:



1

1 mark for
- General shape (accept other similar variation but not linear e.g. do not accept saw-tooth, do not accept plateau)
- Start from e.m.f. = 0 (accept if graph did not start from t = 0)

(b) Fig. 4.3 and Fig. 4.4 show two views of a rectangular coil of height h and width d rotating with an angular speed ω about a vertical axis in a horizontal magnetic field of flux density B. At a certain instance of time t, the normal to the plane of the coil makes an angle of ωt with the magnetic field.

There are N turns in the coil.

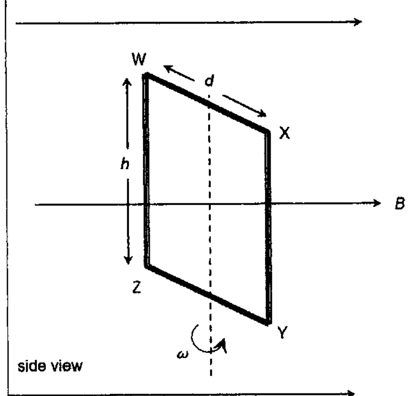


Fig. 4.3

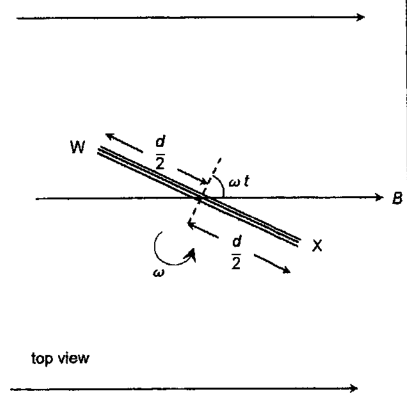


Fig. 4.4

(i) At time t = 0, the plane of the coil is perpendicular to the magnetic field.

Show that the magnitude of the induced e.m.f. E in the coil is given by

<u>$E = NBdh\omega \sin(\omega t)$</u>

[2]

Method 1

$$E = -\frac{d\Phi}{dt}$$ **1**

$$= -\frac{d(N\phi)}{dt}$$
$$= -N\frac{d(BA\cos\omega t)}{dt}$$
$$= -NBA\frac{d(\cos\omega t)}{dt}$$ **1**
$$= NBdh\omega \sin\omega t$$

Method 2

The linear speed v of the sides XY and ZW as they execute circular motion about the vertical axis is given by

$$v = r\omega = \left(\frac{d}{2}\right)\omega$$

Hence, the e.m.f. induced in each of the sides XY and ZW is given by

$$E = NB_{\perp v}lv = N(B\sin\omega t)lv = NBlv\sin\omega t$$ **[1]**

More papers at www.testpapersfree.com

$$= NBh\left(\frac{d}{2}\right)\omega \sin \omega t$$

Since the orientation of the induced e.m.f in XY and ZW are such that they are in the same direction,

$$E = E_{XY} + E_{ZW}$$ [1]

$$= 2\left[NBh\left(\frac{d}{2}\right)\omega \sin \omega t\right]$$ [0]

$$= NBdh\omega \sin \omega t$$

(ii) The coil has dimension 30 cm by 24 cm and has 15 turns and the uniform magnetic field has flux density of 0.018 T.

The coil rotates with a frequency of 25 Hz.

Determine, for the coil,

1. the maximum e.m.f. induced,

maximum e.m.f. induced = ... V [2]

Max . e.m.f. induced, E_0
= $NBdh\omega$
= $NBdh(2\pi f)$ — 1
= $15(0.018)(24 \times 10^{-2})(30 \times 10^{-2})(2\pi(25))$
= 3.053628 = 3.1 V — 1

2. the root-mean-square value of the e.m.f. induced.

root-mean-square e.m.f. induced = ... V [1]

$$E_{RMS} = \frac{E_0}{\sqrt{2}} = \frac{3.053628}{\sqrt{2}} = 2.1592 = 2.2\ V$$ 1

5 (a) Fig. 5.1 shows two small loudspeakers, L_1 and L_2, separated by 15 cm. A microphone is moved along a line XY parallel to the line joining the two loudspeakers and at a perpendicular distance of 1.2 m away.

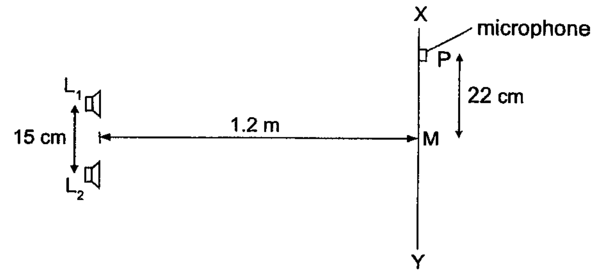


Fig. 5.1

The centre of the interference pattern formed along XY is at point M. When the microphone is moved from M to P by a distance of 22 cm, it detects three intensity maxima including the ones at M and P.

Given that the speed of sound in air is 330 m s^{-1}, determine the approximate frequency at which the speakers were driven. Express your answer to 2 significant figures.

frequency = ... Hz [3]

Method 1

three intensity maxima detected from M to P including the ones at M and P — 1
➔ 2 fringe separations = 22 cm
➔ fringe separation, x = 11 cm

Two-source interference fringe separation,

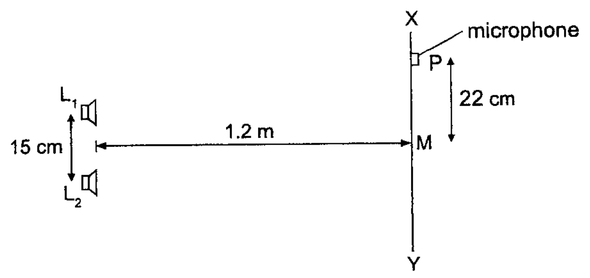
$$x = \frac{\lambda D}{a}$$

$$11\text{x}10^{-2} = \frac{\lambda(1.2)}{15\text{x}10^{-2}}$$ 1

$\therefore\ \lambda = 0.01375$ m

$$\therefore\ f = \frac{v}{\lambda} = \frac{330}{0.01375} = 2.4 \times 10^4\ \text{Hz}$$ 1

Method 2



Finding the path difference,

Path of L_1P = $\sqrt{1.2^2 + (0.22-0.075)^2} = 1.209$ **m**

Path of L_2P = $\sqrt{1.2^2 + (0.22+0.075)^2} = 1.236$ **m**

Path difference = 1.236 – 1.209 = 0.027 m = 2λ

$\therefore \lambda = 0.0135$ m (Note that it is a different outcome from the Young Double Slit experiment. It is expected as the Young's Double Slit equation is an approximation to the fringe separation.

$\therefore f = \frac{v}{\lambda} = \frac{330}{0.0135} = 2.4 \times 10^4$ Hz

(b) Fig. 5.2 shows a microwave transmitter T and a microwave receiver R placed at the same angle θ to the normal of a horizontal board A, which partially reflects and transmits microwaves. A similar horizontal board B is placed a distance d below board A, such that a high intensity signal is detected by receiver R. A metal sheet is placed between T and R to prevent microwaves from reaching R directly from T.

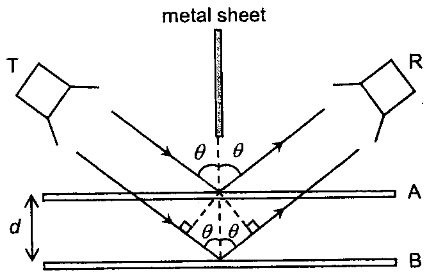


Fig. 5.2

The path difference between the two waves reflected off boards A and B is given by

$$2d \cos \theta$$

When a high intensity signal is detected by R,

$$2d \cos \theta = m\lambda$$

where m is a positive integer and refers to the order of constructive interference (m = 1, 2, 3, …) and λ is the wavelength of the microwaves.

(i) State the phase difference, in radians, between the reflected microwaves from A and B at a point where a high intensity signal is detected.

phase difference = ... rad [1]

0 rad (or 2π rad, 4π rad, etc.), as a high intensity signal or constructive interference is detected. 1

(ii) When distance d is increased by lowering board B, alternating low and high intensity signals are detected by receiver R. Explain these observations.

....

....

.... [3]

As board B is lowered, the **path difference** between the two reflected waves **continuously increases**. 1

This causes the **phase difference** between the **two waves at R** to **continuously alternate between being in phase and antiphase**. 1

The **high intensity signals are due to constructive interference** between the reflected waves **whenever they meet in phase at R**. 1
The **low intensity signals are due to destructive interference** between the reflected waves **whenever they meet in antiphase at R**.

(iii) Transmitter T and receiver R are now placed side-by-side and facing the boards normally, meaning that θ = 0°.

As board B is moved 140 mm downwards at a constant speed, receiver R goes from the initial high intensity signal through nine high intensity signals and then to a final high intensity signal.

Determine the wavelength of these microwaves.

wavelength = ... m [2]

Since θ = 0°, the expression for path difference in terms of d now becomes:
$2d \cos 0° = 2d$

Distance moved by board B (d) x 2 = Change in path difference = 10 λ 1
Thus,
$2d = 10\lambda$
140 mm x 2 = 10 λ
λ = 28 mm
= 0.028 m 1

More papers at www.testpapersfree.com

6 In a photoelectric experiment, an ultraviolet (UV) light source of constant intensity and single frequency is used. Two metal plates X and Y are contained in an evacuated glass container and are connected to a circuit as shown in Fig. 6.1. The UV source is placed at a distance away from X and Y.

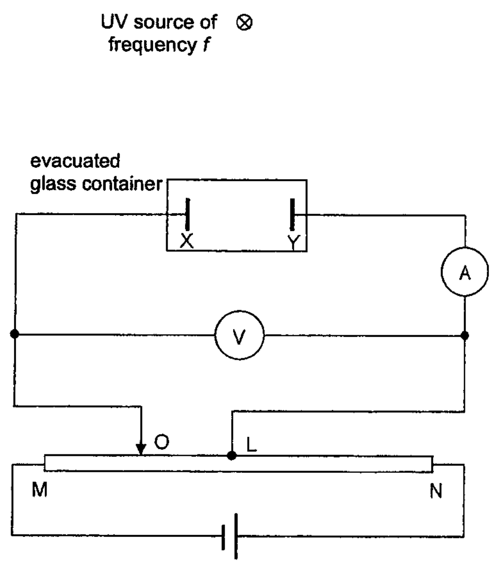


Fig. 6.1

The graph shown in Fig. 6.2 depicts the relationship between the voltmeter reading and the ammeter reading when metal plate X is the photoelectric emitter. No photoelectrons are emitted from Y.

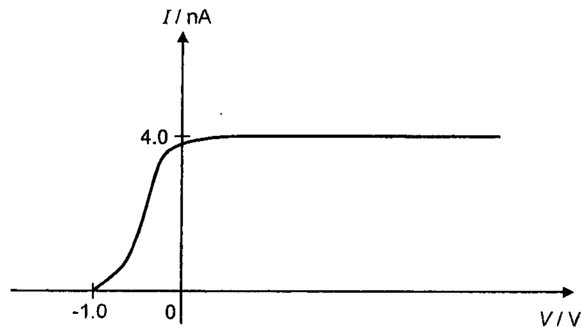


Fig. 6.2

(a) Explain why the current remains constant for positive values of V.

....

....

....

....

.... [3]

The **current measured is proportional to the rate of electrons reaching Y.**	1
The rate of <u>electron</u> ejection from X arriving at Y is fixed because it is proportional to the rate of <u>photon</u> incidence on X which is fixed when electromagnetic radiation is at a fixed intensity and fixed frequency.	1
For positive values of *V*, the electrons experience an accelerating force towards Y. Thus, ALL the electrons ejected from X will be collected at Y regardless of the applied potential difference. Therefore, the current will also be constant at a maximum value.	1

(b) Metal plate X is made of zinc with a work function of 3.8 eV. Using information from Fig. 6.2, determine the wavelength of the UV source.

wavelength = ... m [2]

Applying the photoelectric equation,
Photon Energy = Work function of metal surface + Maximum K.E. of emitted electrons

$$\frac{hc}{\lambda} = \phi + eV_s$$

$$\lambda = \frac{hc}{\phi + eV_s} \quad \textbf{1}$$

$$= \frac{6.63\times10^{-34}(3.00\times10^{8})}{3.8(1.60\times10^{-19}) + 1.60\times10^{-19}(1.0)}$$

$$= 2.59\times10^{-7}\ \text{m} \quad \textbf{1}$$

(c) Sketch, on Fig. 6.2, the graph when the experiment was repeated with UV light source of the same frequency but with intensity one-quartered. [2]

LHS of graph:
Same frequency photons incident and same work function energy of the metal
- ➔ Maximum K.E. of electrons ejected unchanged
- ➔ **Stopping potential unchanged**

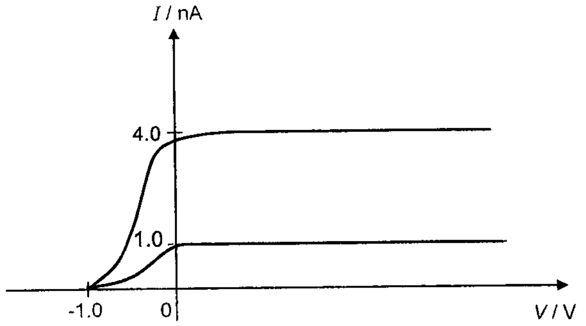
RHS of graph:

$$Intensity\ of\ radiation = \frac{P}{A} = \frac{E}{tA} = \frac{Nhf}{tA}$$

$$\frac{N}{t} = Intensity\ of\ radiation \times \frac{A}{hf}$$

Same frequency f and Intensity one-quartered
- ➔ No. of photons incident per unit time, $\frac{N}{t}$ will be one-quarter the original.
- ➔ Since each electron ejected is the result of absorbing one photon, the photoelectric current is proportional to $\frac{N}{t}$. Thus, **maximum photoelectric current will be <u>one-quarter</u> the original.**

BP-263



1
1

(d) The UV light source was replaced with another light source of higher frequency. The graph in Fig. 6.3 was obtained when the experiment was conducted using the higher frequency light source.

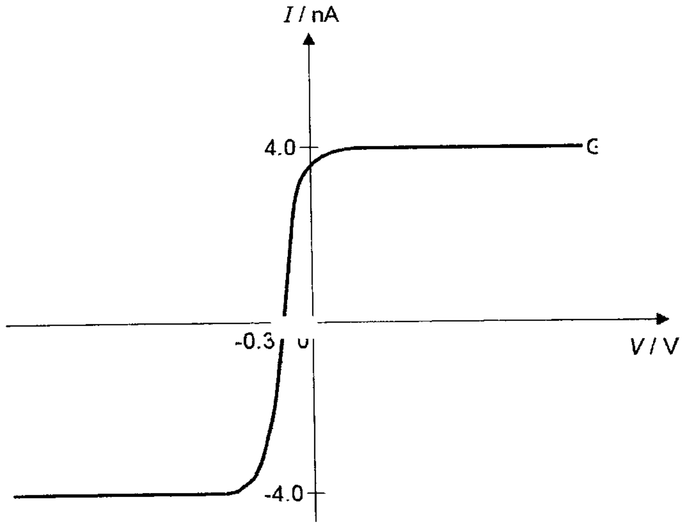


Fig. 6.3

Explain which metal plate, X or Y, has a greater work function energy.

....

.... [2]

Fig. 6.3 shows that photoelectron emission occurs in <u>both</u> metal plates X and Y when light source of higher frequency is used. Energy per photon is proportional to its frequency, and for an electron to be ejected from a metal surface the photon energy must be greater or equal to the work function energy of the metal surface. 1

Since Y emits electrons only with the higher frequency light source but X emits electrons with both the lower and higher frequency light source, Y must have <u>the greater work function energy</u>. 1

7 (a) State experimental evidence to suggest that the process of radioactive decay is

(i) random;

....

.... [1]

The **<u>points on a count rate against time graph</u> <u>scatter about the (exponential) line of best fit</u>.** 1

OR

<u>Measured count rate fluctuates</u> from instant to instant in time.

(ii) spontaneous.

....

.... [1]

The <u>rate of decrease of the measured count rate</u> is <u>unaffected by external stimuli and changes in physical conditions</u>. 1

OR

<u>Repeated experiments</u> under <u>different physical conditions</u> result in <u>no change</u> in the <u>rate of decrease of the measured count rate</u>.

(b) Uranium-238 decays into lead-206 by several stages. Lead-206 is a stable isotope. The overall decay can be represented by the following equation:

$$^{238}_{92}U \rightarrow ^{206}_{82}Pb + \text{decay products}$$

It is suggested that **all** of the decay products are alpha particles.

Use the equation to show that this cannot be correct.

[2]

Proof by Contradiction:

Suppose all the decay products are alpha particles and total number of alpha particles produced is x.

$$^{238}_{92}U \rightarrow ^{206}_{82}Pb + x\,^{4}_{2}He$$

For nucleon number to be conserved: $238 = 206 - 4x \Rightarrow x = 8$ 1

For proton number to be conserved: $92 = 82 - 2x \Rightarrow x = 5$

Need 8 alpha particles to balance the total number of nucleons, but 5 alpha particles to balance the total number of protons in the equation. Hence, it is not possible for all

More papers at www.testpapersfree.com

decay products to be alpha particles. **1**

OR

alpha-particle: ${}^{4}_{2}He \Rightarrow$ ratio of nucleon no. to proton no. = 2:1

Total number of nucleons in the decay products, A = 236 – 206 = 32
Total number of protons in the decay products, B = 92 – 82 = 10

ratio A:B = 32:10 $\neq$ 2:1
Therefore not all the decay products are alpha particles.

OR

alpha-particle: ${}^{4}_{2}He \Rightarrow$ 2 protons and 2 neutrons

Total number of protons in the decay products = 92 – 82 = 10
Total number of neutrons in the decay products = (238-92) – (206-82) = 22

Since an alpha-particle has equal number of protons and neutrons, but the total number of protons and neutrons are different in the decay products, hence not all the decay products are alpha-particles.

(c) Technetium-99, ${}^{99}_{43}Tc$, decays to ruthenium-99, ${}^{99}_{44}Ru$.

The half-life of technetium-99 is 4.00 x 10^6 years. Ruthenium-99 is a stable nuclide.

(i) Write down the nuclear equation representing this decay. State also the name(s) of the products other than ruthenium-99 that is/are formed.

Equation: ....

Name(s) of additional product(s): .... [2]

$${}^{99}_{43}Tc \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}e$$ **1**

Beta-particle AND antineutrino/neutrino. **1**

•

(ii) On the axes of Fig. 7.1, sketch a graph to show how the ratio

$$R = \frac{\text{number of ruthenium-99 nuclei}}{\text{number of technetium-99 nuclei}}$$

will change in a sample with time t.

Take t = 0 to be the instant of creation of ruthenium-99.

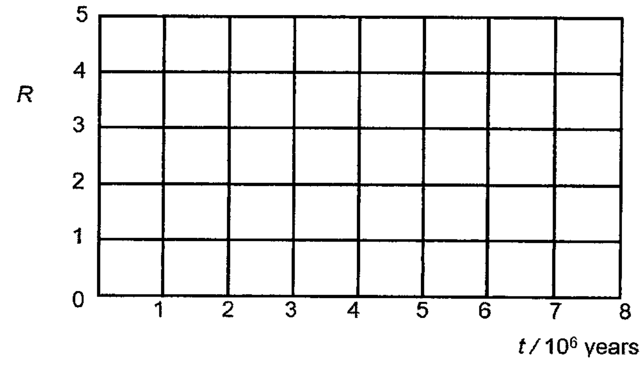
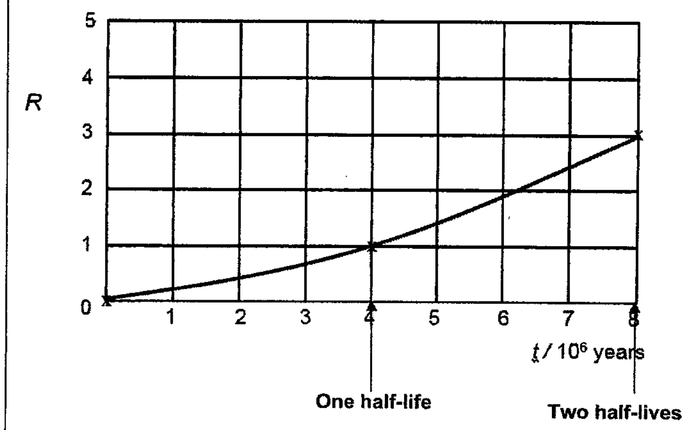


Fig. 7.1 [2]

Ru should be increasing, Tc decreasing with time.
Ru:Tc
0 : N at t=0
N/2 : N/2 after one half-life
3N/4 : N/4 after two half-lives
7N/8 : N/8 after three half-lives
etc…

Therefore,
R = 0 at t=0 → plot (0,0)
R = 1 at t=4x10^6 years → plot (4,1)
R = 3 at t=8x10^6 years → plot (8,3)

Since N is an exponential function with time, the ratio R will also be an exponential function. So graph of R is an exponential curve.



1
1

BP~265

Section B

Answer **one** question from this section.

8 (a) Explain what is meant by an *electric field*.

.... [1]

It is the **region of space** where a **charged particle experiences an electric force.** 1

(b) The charges on an isolated metal sphere are uniformly distributed on its surface. Fig.8.1 shows a positively charged metal sphere A.

On Fig.8.1, draw the charge distribution on the sphere and the electric field around it.

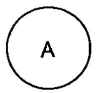
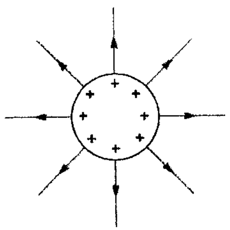


Fig. 8.1 [1]

Solution:



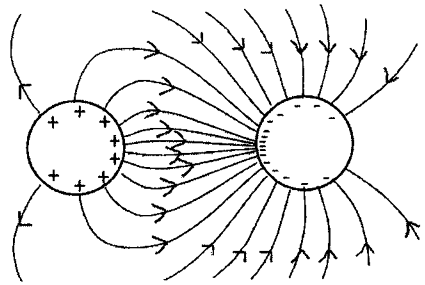
- equal spacing of charge on the surface of sphere, **and,** 1
- radial field acting outwards
- field lines drawn perpendicular to the surface of the metal sphere

(c) A negatively charged metal sphere B is brought close to the positively charged metal sphere A as shown in Fig.8.2. The charge on metal sphere B is twice that of the charge on metal sphere A.

On Fig. 8.2, draw the charge distribution on the spheres and the electric field around the spheres.

Fig. 8.2 [3]

Solution:



Mark scheme:

- Distribution of charges: correct distribution, charges drawn on the surfaces, twice the number of '-' on B compared to the number of '+' on A. 1
- Field pattern: correct shape & variation of density of field lines, number of field lines around B twice that around A. 1
- Direction of field lines, including field lines drawn perpendicular to the surface of each metal sphere. 1

OR

- Distribution of charges: correct distribution, charges drawn on the surfaces, twice the number of '-' on B compared to the number of '+' on A. [1]
- Field pattern & Direction of field lines [1]
- Details: number of line around each sphere, lines drawn perpendicular to the surface of the spheres. [1]

More papers at www.testpapersfree.com

(d) Point P is at a distance x from the centre of sphere A along the line joining the centres of the two spheres as shown in Fig.8.3. The radius of A and B is 15 mm and the distance between the centres of the spheres is 80 mm.

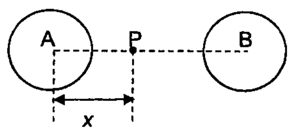


Fig. 8.3

The variation with x of the electric potential V at P is shown in Fig. 8.4.

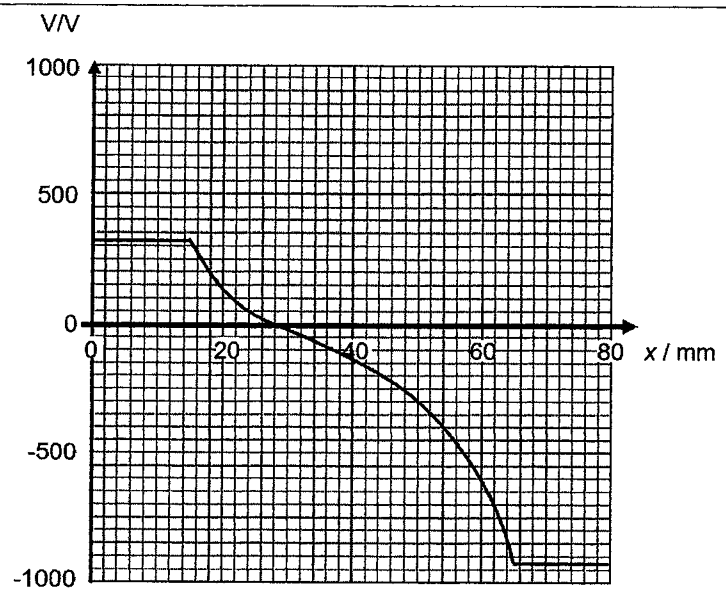


Fig. 8.4

(i) Determine the magnitude of the electric field strength at P where x = 40 mm.

magnitude of the electric field strength = ... V m^{-1} [2]

|E| = |dV / dx| — 1
= gradient of V-x graph at x = 40 mm
= 350 – (-600) / 80 x 10^{-3}
= 1.19 x 10^{4} V m^{-1} — 1

(ii) An electron is initially at rest at point P where x = 40 mm.

1. Describe and explain the motion of the electron as it travels 20 mm along the line joining the centres of the spheres.

....

.... [3]

$a = \frac{F_{net}}{m} = \frac{F_E}{m} = \frac{eE}{m}$
where $E = -\frac{dV}{dx}$

Gradient of the V-x graph is proportional to the electric field strength which is proportional to acceleration. — 1

When gradient decreases from 40 mm to 28 mm, acceleration decreases.
➔ **The electron moves to the left towards A, speeds up at a decreasing rate.** — 1

When gradient increases from 28 mm to 20 mm, acceleration increases.
➔ **The electron continues moving to the left towards A, speeds up at an increasing rate.** — 1

2. Determine the speed of the electron when it has travelled 20 mm along the line joining the centres of the spheres.

speed of electron = ...m s^{-1} [3]

moving 20 mm towards A, the electron moves from x = 40 mm to x = 20 mm,
increase in potential, **ΔV** = 125 –(-150) = 275 V
[Also accept V_{40mm} between -125 V to -150 V; V_{20mm} between 125 V to 150 V] — 1
decrease in potential **energy**, **ΔU = q.ΔV** = 1.60 x 10^{-19} x 275 = 4.40 x 10^{-17} J

By conservation of energy,
increase in KE = decrease in electric potential energy
final KE – initial KE = ΔU — 1
½ m v^2 – 0 = 4.40 x 10^{-17}
½ (9.11 x 10^{-31}) v^2 = 4.40 x 10^{-17}
v = 9.83 x 10^{6} m s^{-1} — 1

More papers at www.testpapersfree.com

(e) An electron is projected along the line XY into a region of uniform electric field between two charged parallel plates of length 20.0 cm separated by 8.0 cm, as shown in the Fig 8.5. The potential difference between the two plates is 200 V. Between the plates, the electron travels along a curved path and exit the region between the plates at point Q which is 3.0 cm from the line XY.

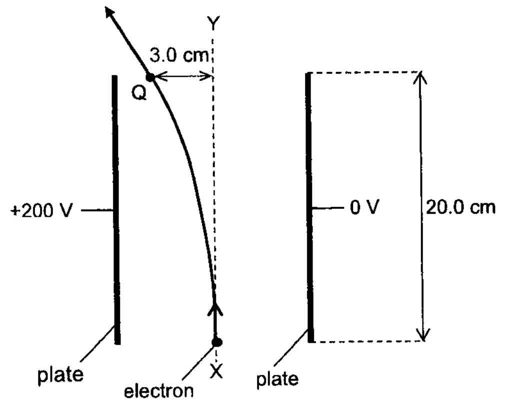


Fig. 8.5

(i) Calculate the electric field strength between the two plates.

electric field strength = ... V m^{-1} [1]

E = V /d = 200 / 0.080 = 2500 V m^{-1} **1**

(ii) Calculate the initial speed of the electron projected into the electric field.

speed = ... m s^{-1} [4]

consider motion perpendicular to XY
Electic force F = qE = 1.60 x 10^{-19} x 2500
accleration = F / m = 1.60 x 10^{-19} x 2500 / 9.11 x 10^{-31} = 4.396 x 10^{14} **1**

Using s = ut + ½ a t^2
0.030 = 0 + ½ (4.396 x 10^{14})t^2 ....(2) **1**
t = 1.168 x 10^{-8} s

consider motion along XY
Using s = ut + ½ a t^2
0.200 = u(1.168 x 10^{-8}) +0 **1**
u = 1.712 x 10^7= 1.7x 10^7 m s^{-1} **1**

(iii) A proton is now projected into the same electric field and with the same velocity as that of the electron.

Explain why the deflection of the proton is much lesser compared to the deflection of the electron.

....

.... [2]

A proton has the same magnitude of charge as the electron, hence it will experience the same magnitude of electric force as that on the electron. **1**

A proton has a mass about 1800 times that of the electron (or much more massive than that of the electron), hence it will experience an acceleration 1800 times less than that on the electron (or much smaller acceleration). **1**

Time spent between the plates is the same for both the proton and electron, hence the deflection will be much lesser and the path is much less curved.

9 (a) A satellite orbits the Earth of mass *M* in a circular path of radius *r*.

(i) Show that the period *T* of the satellite is given by the expression

$$T^2 = \frac{4\pi^2}{GM} r^3$$

[3]

Gravitational force F_G provides the centripetal force F_C. **1**

$F_C = F_G$

$mr\omega^2 = \frac{GMm}{r^2}$ **1**

$mr\left(\frac{2\pi}{T}\right)^2 = \frac{GMm}{r^2}$ **1**

$T^2 = \frac{4\pi^2}{GM} r^3$

(ii) A satellite is orbiting the Earth above the equator with a period of 28 hours. The mass of the Earth is 5.98 × 10^{24} kg.

1. Calculate the radius of the satellite's orbit.

radius = ... m [2]

Using $T^2 = \frac{4\pi^2}{GM} r^3$

$r = \sqrt[3]{\frac{GM}{4\pi^2}(T^2)}$

$= \sqrt[3]{\frac{(6.67\times10^{-11})(5.98\times10^{24})}{4\pi^2}(28\times60\times60)^2}$ **1**

$= 4.68 \times 10^7$ m **1**

2. The mass of the satellite is m.

For the satellite in orbit, show that its kinetic energy E_K is given by

$$E_K = \frac{GMm}{2r}$$

[2]

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$ 1

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

$$= \frac{GMm}{2r}$$

3. Hence, determine the kinetic energy of the satellite if it has a mass of 1200 kg.

kinetic energy = ... J [1]

$$E_K = \frac{GMm}{2r} = \frac{(6.67\times10^{-11})(5.98\times10^{24})(1200)}{2(4.68\times10^{7})}$$

$= 5.11 \times 10^9$ J 1

4. The satellite is then moved into a new orbit, gaining 1.14×10^9 J of gravitational potential energy in the process.

Calculate the satellite's loss in kinetic energy.

loss in kinetic energy = ... J [3]

Given:

Gain in gravitational potential energy $= -\frac{GMm}{r_2} - \left(-\frac{GMm}{r_1}\right) = 1.14\times10^9$ J 1

where r_1 and r_2 are the radii of the old and new orbit respectively.

Loss in kinetic energy = $KE_i - KE_f$

$$= \frac{GMm}{2r_1} - \left(\frac{GMm}{2r_2}\right)$$ 1

$$= \frac{1}{2}\left(\frac{GMm}{r_1} - \frac{GMm}{r_2}\right)$$

$$= \frac{1}{2}(1.14\times10^9)$$

$= 5.70 \times 10^8$ J. 1

(b) A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 9.2.

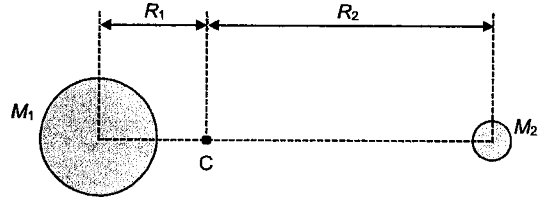


Fig. 9.2

The star of mass M_1 has a circular orbit of radius R_1, and the star of mass M_2 has a circular orbit of radius R_2. Rotating about point C, both stars have the same angular speed of 4.98×10^{-8} rad s^{-1}.

(i) Explain why the centripetal force acting on the two stars are equal in magnitude.

....

....

....

.... [2]

The **gravitational force on each star exerted by the other star provides the centripetal force required** for each star's circular motion. 1

By Newton's 3rd law, the gravitational force that each star exerts on the other star are equal in magnitude and opposite in direction. 1

(ii) Calculate the period of orbit of each star.

period = ... years [2]

$$\omega = \frac{2\pi}{T}$$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{4.98\times10^{-8}}$$ 1

$= 1.2617 \times 10^8$ s

$= 4.00$ years 1

(iii) Show that the ratio of the masses of the stars is given by the expression

$$\frac{M_1}{M_2} = \frac{R_2}{R_1}$$

[1]

More papers at www.testpapersfree.com

BP~269

Centripetal force experienced by both stars are equal, hence

$M_1R_1\omega^2 = M_2R_2\omega^2$ **1**

Hence, $\frac{M_1}{M_2} = \frac{R_2}{R_1}$

(iv) Given that $\frac{M_1}{M_2} = 3.0$ and the separation between the stars is 3.2 × 10^{11} m, calculate the radius R_1.

R_1 = ... m [2]

$\frac{M_1}{M_2} = \frac{R_2}{R_1} = 3.0$

$R_1 = \frac{1}{3.0}(R_2)$

Therefore,

$R_1 = \frac{1}{4} \times (3.2 \times 10^{11})$ **1**

$= 8.0 \times 10^{10}$ m **1**

(v) A planet orbits around the star of mass M_1 in the binary star system.

Suggest why the orbit of the planet is not circular.

....

....

....

.... [2]

When the planet and star of mass M_2 are on opposite sides of star of mass M_1, resultant force acting on the planet is large. **1**

When the planet and star of mass M_2 are on the same side of star of mass M_1, resultant force acting on the planet can be possibly be lower in magnitude. **1**

Hence, the orbit of the planet will not be a perfect circle.

e.g.
The star M_2 also exerts a gravitational force on the planet. **As the planet orbits the star M_1, the resultant gravitational force due to both stars M_1 and M_2 will not remain constant as the relative positions between the stars and planet change during orbit. It will be the least when the planet is in between the two stars and greatest when M_1 is in between the planet and M_2.**

Since the resultant gravitational force on the planet provides the centripetal force for its orbit, the centripetal force is not constant and thus the orbit will not be circular.

-- END OF PAPER 3 --

-- BLANK PAGE --

More papers at www.testpapersfree.com

NAME: ____________ CLASS: ________ INDEX: ________

CATHOLIC JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS
Higher 2

PHYSICS

Paper 4: Practical

9749/04
19 AUG 2022
2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST
Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
You may use an HB or 2B pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **ALL** questions.

Write your answers in the spaces provided on the question paper.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

Shift
Laboratory

At the end of the assessment, fasten all your work securely together.
The number of marks is given in brackets [ ] at end of each question or part question.

For Examiner's Use	
1	/ 11
2	/ 14
3	/ 20
4	/ 12
Total	/ 55

This document consists of **12** printed pages and **0** blank page.

[Turn over

More papers at www.testpapersfree.com

1 In this experiment, you will investigate the potential difference across a current-carrying wire.

You have been provided with three wires A, B and C attached onto the respective cards.

(a) Wire A has a diameter *D*.

(i) Without detaching the wire from the card, measure and record *D*.

D = ... [1]

Solution:
D_1 = 0.16 mm
D_2 = 0.16 mm
D = 0.16 mm

1 mark for
- Value for *D* in the range 0.14 mm to 0.16 mm.
- Precision to 0.01 mm.
- Units included.
- Repeated readings.

(b) Set up the circuit shown in Fig. 1.1.

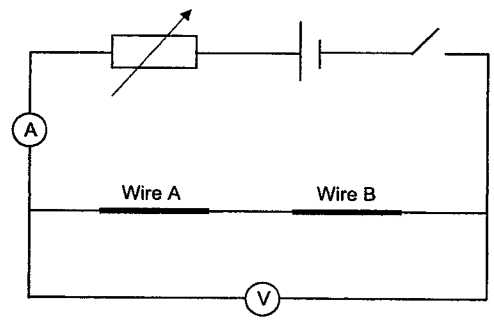


Fig. 1.1

Adjust the rheostat to approximately the middle of its range.

Close the switch.

(i) Record the ammeter reading.

ammeter reading = [1]

BP-271

Solution:

Ammeter reading = 63.8 mA

1 mark for
- Value in the range 50.0 mA to 100.0 mA.
- Ammeter setting: 0 – 200 mA. Hence precision is to 0.1 mA.
- Units included.

(ii) Record the voltmeter reading.

V = ... [1]

Solution:

Voltmeter reading = 0.529 V

1 mark for
- Value in the range 0.400 V to 1.000 V.
- Voltmeter setting: 0 – 2 V. Hence precision is to 0.001 V.
- Units included.

Open the switch.

(c) **(i)** Wire B has a diameter d.

Measure and record d.

d = ... [1]

Solution:

$d_1 = 0.19$ mm
$d_2 = 0.19$ mm
$d = 0.19$ mm

1 mark for
- Value for d in the range 0.18 to 0.20 mm. (Value of $d > D$ and $d < 1$ mm.)
- Precision to 0.01 mm.
- Units included.
- Repeated readings.

(ii) The diameter D of Wire A and the diameter d of Wire B are related by G, through

$$G = \frac{D^2 + d^2}{D^2 d^2}$$

Calculate G for Wire A and Wire B.

G = ... [1]

Solution:

$$G = \frac{0.16^2 + 0.19^2}{0.16^2\ 0.19^2} = 66.8 = 67\ \text{mm}^{-2}$$

1 mark for
- Correct calculation of G using candidate's values of D and d.
- Correct units.

(d) Replace Wire B with Wire C.

Close the switch.

Adjust the rheostat so that the ammeter reading is as close as possible to the reading in **(b)**,

Record the voltmeter reading V.

V = ... [1]

Solution:

0.399 V

1 mark for reading: Second value of V less than first value of V in **(b)(ii)**.

(e) Wire C has a diameter d_C.

(i) Measure and record d_C.

d_C = ...

Solution:

$d_1 = 0.27$ mm
$d_2 = 0.27$ mm
$d_C = 0.27$ mm

(ii) Use the expression in **(c)(ii)** to calculate G for Wire A and Wire C.

G = ... [1]

Solution:

$$G = \frac{0.16^2 + 0.27^2}{0.16^2\ 0.27^2} = 52.8 = 53\ \text{mm}^{-2}$$

1 mark for
- Correct calculation of G using candidate's values of D and d_C.
- Correct units. Allow ECF.

More papers at www.testpapersfree.com

(f) It is suggested that the relationship V and G is

$$V = kG$$

where k is a constant.

Using your data, calculate two values of k.

first value of k = ...

second value of k = ... [1]

Solution:

$$k_1 = \frac{V}{G} = \frac{0.529}{67} = 7.9 \times 10^{-3}\ \text{V mm}^2$$

$$k_2 = \frac{V}{G} = \frac{0.399}{53} = 7.5 \times 10^{-3}\ \text{V mm}^2$$

1 mark for

- Correct calculations.
- Appropriate units.

(g) It is suggested that the percentage uncertainty in the values of k is 4%, which is determined from the percentage uncertainty of V and G, as well as other experimental factors.

Using this uncertainty, explain whether your results support the relationship in **(f)**. [1]

Solution:

Percentage difference $\frac{7.90 - 7.53 \times 10^{-3}}{7.53 \times 10^{-3}} \times 100 = 5\%$

As the percentage difference of the two k values of 5% exceeds the percentage uncertainty of k of 4%, it means that the two values of k are not within experimental uncertainty. Therefore, my results do not support the relationship in **(f)**.

1 mark for

- Calculation of percentage difference between candidate's two k values.
- Comparison of percentage difference with the experimental uncertainty of 4%, leading to a consistent conclusion.

Total [9]

2 In this experiment you will investigate the equilibrium position of a half-metre rule supported by a spring.

(a) Attach the spring tied to the string and the 20 cm length of string to the half-metre rule as shown in Fig. 2.1.

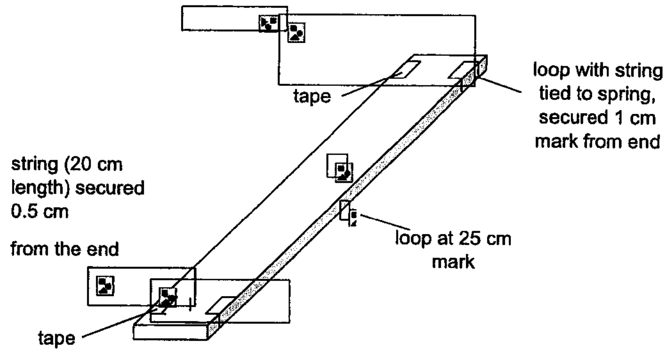


Fig. 2.1

Assemble the apparatus as shown in Fig. 2.2, using a mass of 300 g.

Ensure that the mass hanger and masses are not touching the bench.

The upper string must be parallel to the bench.

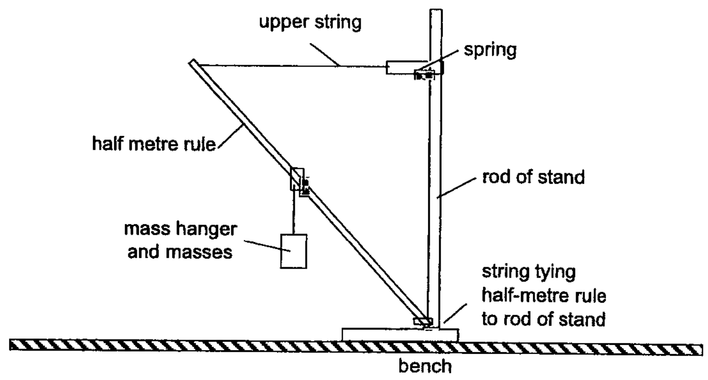


Fig. 2.2

More papers at www.testpapersfree.com

BP~273

(b) Fig. 2.3 shows the measurements you will take.

Point **A** is where the line of the upper string meets the half-metre rule.

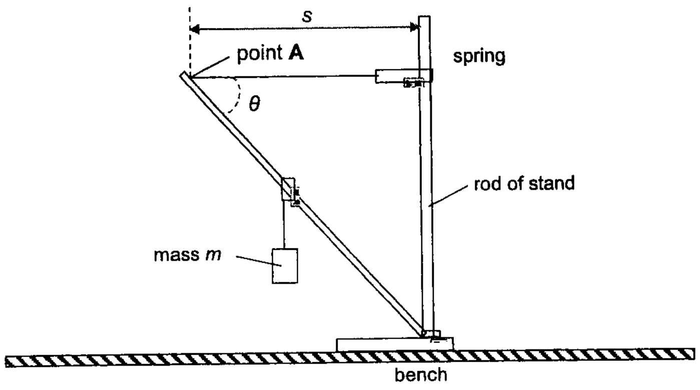


Fig. 2.3

(i) *M* is the mass of the half-metre rule as written on the card on the bench.

State your *M* value.

M = ...

Solution:
63 g

(ii) Record the total mass *m* of the mass hanger and masses.

m = ...

Solution:
300 g

(iii) Measure and record the distance *s* between the rod of the stand and **A**, as shown in Fig. 2.3.

s = ... [1]

Solution:
36.8 cm

1 mark for
- Precision to 0.1 cm
- Units included

(iv) Measure and record the angle *θ*, as shown in Fig. 2.3.

θ = ... [1]

Solution:
41 °

1 mark for
- Precision to 1°
- Unit included

(c) Change the value of *m* and repeat **(b)(ii)**, **(b)(iii)**, and **(b)(iv)** to obtain further sets of values of *m*, *s*, and *θ*. [6]

Solution:

m/g	s_1 /cm	s_1 /cm	s_{ave} /cm	θ_1 /°	θ_2 /°	θ_{ave} /°	(m + M)/g	tan (θ/°)	$\frac{(m+M)}{\tan\theta}$ /g
50	30.2	30.2	30.2	51	51	51	113	1.23	91.9
100	31.1	31.1	31.1	50	50	50	163	1.19	137
150	32.2	32.2	32.2	48	48	48	213	1.11	191
200	33.3	33.3	33.3	47	47	47	263	1.07	246
250	34.8	34.8	34.8	44	44	44	313	0.966	324
300	36.8	36.8	36.8	41	41	41	363	0.869	418
350	39.3	39.3	39.3	38	38	38	413	0.781	529
0 d.p.	**1 d.p.**	**1 d.p.**	**1 d.p.**	**0 d.p.**	**0 d.p.**	**0 d.p.**	**Follow least d.p. of m & M**	**3 s.f. (Follow Special Rule for trigo.)**	**Follow least s.f. of (m+M) & tan θ**

1 mark – at least 6 sets of data without assistance without assistance
1 mark – correct data trend, i.e. as m increases, s increases and θ decreases.
1 mark – repeat readings for both s and θ
1 mark – appropriate column headings, quantity and unit separated, i.e. slash
1 mark – all raw readings have the appropriate precision, i.e. m to 50 g, s to 0.1 cm and θ to 1°
1 mark – calculated values to correct d.p. or s.f. + all values calculated correctly, allowing maximum 2 slips

More papers at www.testpapersfree.com

(d) It is suggested that *m*, *s* and *θ* are related by the expression

$$\frac{m + M}{\tan\theta} = Ps - Q$$

where *P* and *Q* are constants.

Plot a suitable graph to determine the values of *P* and *Q*.

P = ...

Q = ... [6]

Solution:

Plot a graph of $\frac{(m+M)}{\tan\theta}$ against s. A straight line graph of gradient P and y-intercept -Q is expected.

Gradient = …….. = 48.571 g cm^{-1}
P = Gradient = 48.6 g cm^{-1}

Y-intercept = ….. = -1373.7 g
-Q = Y-intercept
Q = 1370 g

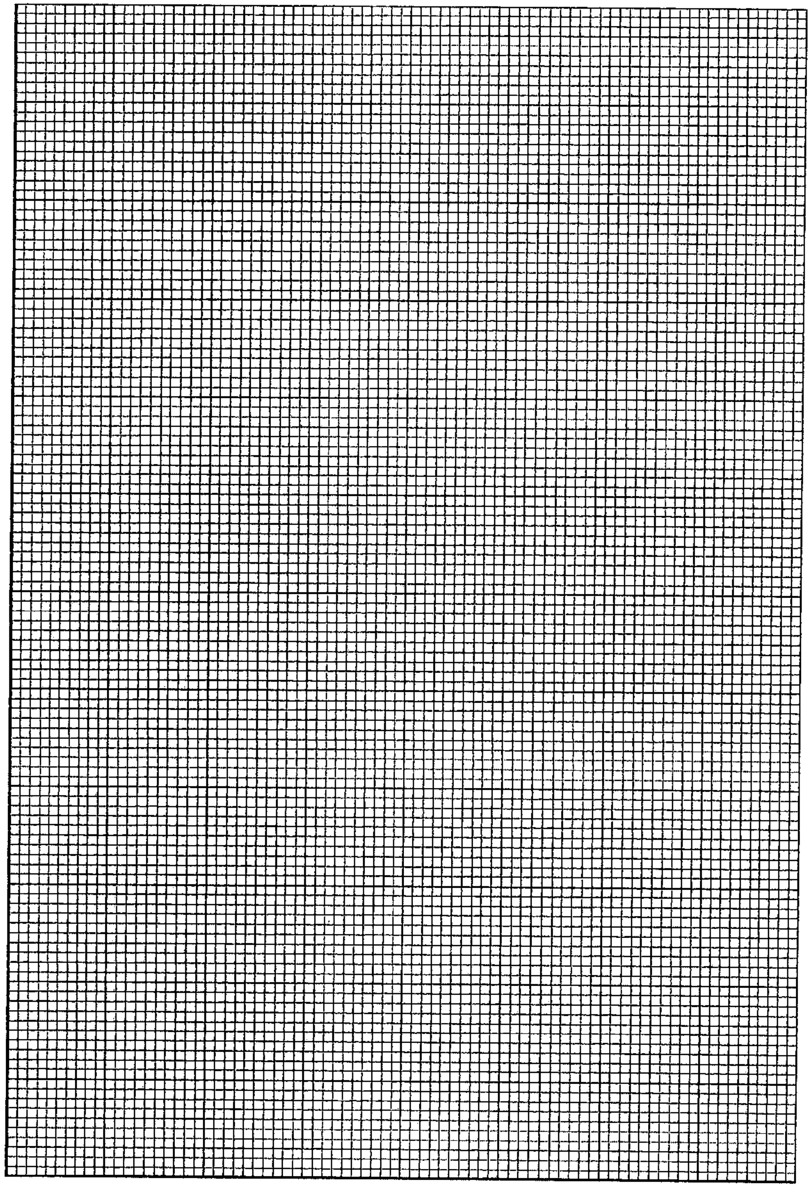
3 marks: Graph
- Axes labelled with Units + Good scale (no odd scales, and graph size at least half the graph grid)
- All points plotted + plotted accurately to half smallest division
- Best-fit straight line drawn

1 mark: Gradient calculation
- Correct gradient formula
- Used 2 coordinates far apart on the best-fit line (separated by at least half the length of the line drawn)
- Read off coordinates accurately to half the smallest division

1 mark: y-intercept
- Correct formula used, or, if able to read off the graph, read off accurately to half the smallest division.
- Read off coordinates from the best-fit line accurately to half the smallest division

1 mark: Determination of P & Q with Units
- Equate gradient to P
- Equate y-intercept to -Q
- Final answer of P & Q to appropriate sig. fig. & units

Total [14]



More papers at www.testpapersfree.com

3 In this experiment, you will investigate the motion of chains of paper clips.

You are provided with two chains of fifteen paper clips with two spheres of modelling clay.

(a) Measure and record the length L of one paper clip as shown in Fig. 3.1.

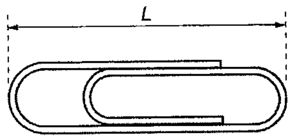


Fig. 3.1

L = ... [1]

Solution:

L = 2.8 cm

1 mark for
- Value for L in the range 2.6 cm to 3.0 cm
- Precision to 0.1 cm
- Units included

(b) Set up the apparatus as shown in Fig. 3.2.

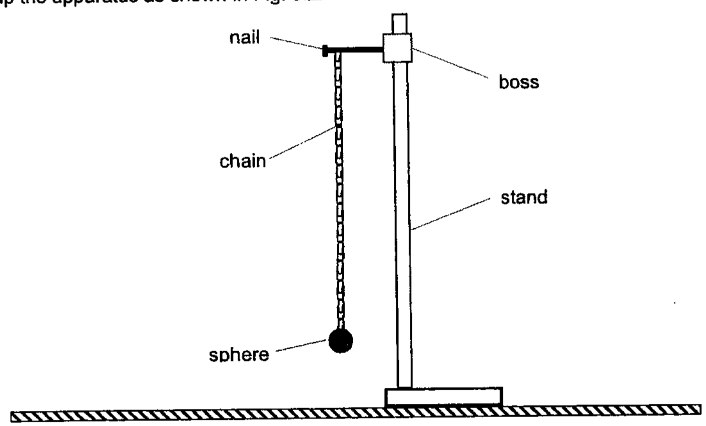


Fig. 3.2

Suspend the chain from the nail. The number n of the paper clips below the nail should be 15.

Move the sphere of modelling clay towards you a distance of approximately 5 cm. Release the sphere. The chain will oscillate.

(i) Determine the period T of the oscillations.

T = ... [1]

Solution:

For 20 oscillations, total time
t_1 = 24.9 s
t_2 = 24.7 s
t = 24.8 s

T = 24.8 / 20 = 1.24 s

1 mark for
- t greater than 20 s
- Repeated readings of t
- Precision of t to 0.1 s
- Recording of number of oscillations shown
- Correct calculation of T, and correct s.f. for T (3 s.f.)
- Units included for t and T

(ii) Estimate the percentage uncertainty in your value of T.

percentage uncertainty of T = ... [1]

Solution:

ΔT = 0.03 s

$$\frac{\Delta T}{T} \times 100\% = \frac{0.03}{1.24} \times 100\% = 2\%$$

1 mark for:
- Reasonable estimate of absolute uncertainty of T (accept Δt = 0.2 s to 0.6 s, or equivalently, ΔT = 0.01 s to 0.03 s since T = t/N)
- Final answer to appropriate sig. fig.

More papers at www.testpapersfree.com

(iii) The period of a simple pendulum is

$$T_P = 2\pi\sqrt{\frac{l}{g}}$$

where l is the length of the pendulum.

Taking g = 9.81 m s^{-2}, calculate a value for period of the chain in **(b)(i)**.

T_P = ______________________ [1]

Solution:

$$T_P = 2\pi\sqrt{\frac{15\times0.028}{9.81}} = 1.3 \text{ s}$$

1 mark for:
- Correctly determine total length of the chains as well as correct calculation of T_P.
- Units included

(iv) Justify the number of significant figures that you have given for your value of T_P in **(b)(iii)**.

[1]

Solution:

1 mark –
T_P is presented to 2 significant figures (s.f.) as the least number of s.f. among l and g used in its calculation is 2 s.f..

(v) It is suggested that the oscillation of the chain in **(b)(i)** is different from the oscillation of a simple pendulum.

State whether your results in **(b)(i)** and **(b)(iii)** support the suggestion.

Justify your conclusion by referring to your values in **(b)(ii)**.

[1]

Solution:

$$\left|\frac{Actual\ period - Theoretical\ period}{Theoretical\ period}\right| x\ 100\% = \left|\frac{1.24 - 1.3}{1.3}\right| x\ 100\% = 5\%$$

The percentage difference between the period values in **(b)(i)** and **(b)(iii)** is about 5% which is more than the estimated percentage uncertainty in T (2%, calculated in (b)(ii)). This suggests that the chain does not oscillate like a simple pendulum.

1 mark for:
- Comparison of percentage difference in the period values of (b)(i) and (b)(iii) with the percentage uncertainty in (b)(ii), and
- leading to a logical conclusion.

(c) Set up two chain pendulums side by side as shown in Fig. 3.3.

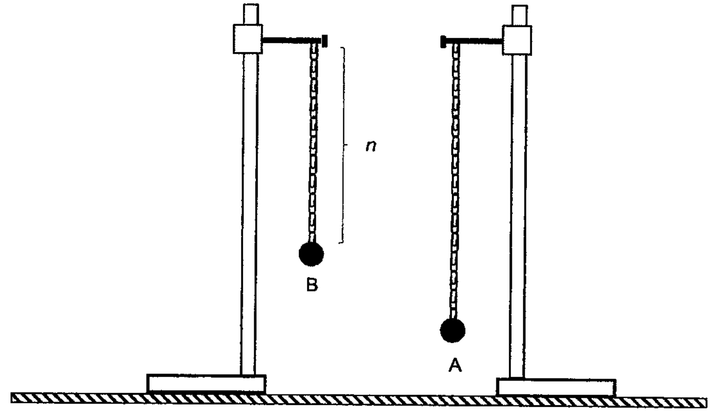


Fig. 3.3

Set chain A with 15 paper clips.

Set chain B with n paper clips such that n = 7.

Record n

n = ______________________

Solution:
7

(d) Set both pendulums into motion with small oscillations.

Start the stopwatch when the two pendulums are lined up in phase.

Measure the time t taken before the next occasion when the two pendulums are in phase again.

t = ______________________ [1]

Solution:

t_1 = 2.8 s
t_2 = 2.8 s
t = 2.8 s

1 mark for
- Value for t in the range 2 s to 3 s
- Repeated readings
- Precision to 0.1 s
- Units included

More papers at www.testpapersfree.com

(e) Increase the value of n and repeat **(d)** to obtain further sets of values of t until $n \leq 14$. [3]

Solution:

n	t_1 /s	t_1 /s	t_{ave} /s
14	59.6	60.0	59.8
13	17.9	17.8	17.9
12	10.4	10.6	10.5
11	7.9	7.9	7.9
10	5.4	5.5	5.5
9	4.3	4.3	4.3
8	3.2	3.1	3.2
7	2.8	2.8	2.8

1 mark – correct trend: as n decreases t decreases,
1 mark – at least 8 sets of data for a curve, and for the range of n not smaller than 7.
1 mark – column headings with units, and correct calculation of data

(f) (i) Plot t against n on Fig. 3.4. The graph obtained should be a curve. [3]

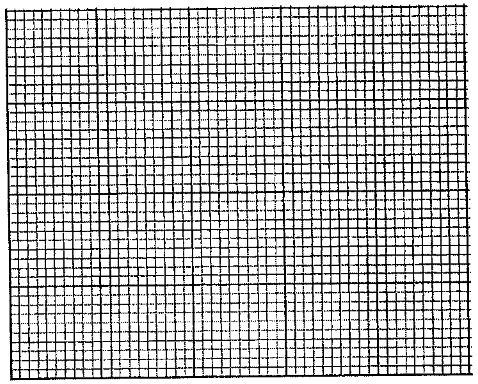


Fig. 3.4

1 mark – Good scale (No odd scale. Size of graph covers at least half the given graph grid)
1 mark – All points plotted, and plotted accurate to ½ smallest division
1 mark – curve drawn as line of best fit.

(ii) Explain why the graph in Fig. 3.4 should not have a value at $n = 15$. [2]

Solution:

When $n = 15$, the lengths of both pendulums A and B are the same.

Therefore, their periods are the same and always in phase. Hence, they do not go out of phase then come back in phase, suggesting that there is no such time t at $n = 15$.

OR accept other reasonable explanations based on students' observation.
e.g. As n increases, the time taken becomes increasingly longer and longer. At n = 15 it will take a very long time such that oscillations of the pendulums die off.

1 mark – Make meaning of $n = 15$ to the experiment
1 mark – Appropriate reasoning, by theory or by students' observation to having no t value at $n = 15$.

(g) (i) Theory suggests that

$$t = A\frac{\sqrt{Cn}}{\sqrt{C}-\sqrt{n}}$$

where A and C are constants.

State the graph to plot to obtain a straight line to determine values for constants A and C, assuming that the theory is correct. [1]

Solution:

$$t = A\frac{\sqrt{Cn}}{\sqrt{C}-\sqrt{n}}$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{\sqrt{C}-\sqrt{n}}{\sqrt{Cn}}\right)$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{1}{\sqrt{n}}-\frac{1}{\sqrt{C}}\right)$$

$$\frac{1}{t} = \frac{1}{A}\left(\frac{1}{\sqrt{n}}\right)-\frac{1}{A\sqrt{C}}$$

Plot a graph of $\frac{1}{t}$ as y-axis against $\frac{1}{\sqrt{n}}$ as the x-axis.

1 mark for:

- Correct linearization.

More papers at www.testpapersfree.com

(ii) State expressions for the gradient and y-intercept of the straight line. [1]

Solution:
Gradient expression:
$\frac{1}{A}$
y-intercept expression:
$-\frac{1}{A\sqrt{C}}$

1 mark for:
- Correct gradient and y-intercept expressions. Allow ECF from (g)(i).

(h) The physics of the oscillations of a hanging chain without the spherical modelling clay as shown in Fig. 3.5 is studied by Daniel Bernoulli in 1732, which led to the introduction to Bessel Functions.

Fig. 3.5

It was theorized that the period T of the oscillations depends on the mass per unit length, which is known as the linear mass density ρ of the chain.

Explain how you would investigate the relationship between the period T of the chain and the linear mass density of the chain.

Your account should include:

- your experimental procedure
- control of variables
- how you would determine the linear mass density ρ of the chain
- how you would use your results to that deduce the relationship of T and ρ.

[4]

Solution:
1. Set up the chain as shown in Fig. 3.5.
2. Measure the mass m of the chain using a weighing balance and the length L of the chain using a metre rule.
3. Calculate the line mass density of the chain by using the equation $\rho = m / L$
4. Displace the loose end of the chain slight and let it oscillate.
5. Measure the period of the oscillations using a stopwatch as performed in step (b)(i)
6. Method to vary m but keep L constant: Repeat steps 2 to 5 by adding more paper clips to the chain, each time adding one more paper clip per loop. (OR adding plasticine uniformly along the length of the chain.) This would keep the length L of the chain constant. Repeat the experiment until 6 sets of measurements were obtained for ρ and T.
7. Assume that the relationship between T and ρ is $T = k\rho^n$
8. Plot a graph of lg T against lg ρ, with n as the gradient and lg k as the y-intercept.
9. Calculate the gradient and the y-intercept to obtain the values for k and n, thus getting the relationship between T and ρ

1 mark – Method to determine ρ
1 mark – Method to vary mass but keeping L constant
2 marks – Analysis: using a graphical approach to deduce the relationship between T and ρ, such as proposing an appropriate equation relating them.

Total [21]

More papers at www.testpapersfree.com

4 Gases can absorb light of certain wavelengths as observed in the absorption line spectra.

A substance that consists of atoms and molecules may dissolve in water to form a solution which is also observed to absorb light of certain wavelengths.

The amount of light of a particular wavelength after passing through such a solution depends on the concentration *c* of the substance in water. The concentration *c* is defined as the mass of substance dissolved in per unit volume of water.

The intensity I detected from a light source of a particular wavelength after the absorption by the solution is given by the equation

$$I = kc^n L^m$$

where *k*, *n* and *m* are constants. *L* is the path length that the light takes to pass through the solution.

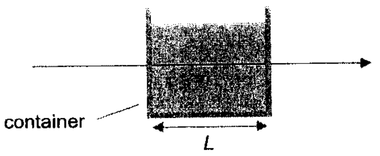


Fig. 4.1

Design an experiment to determine the values of *n* and *m*.

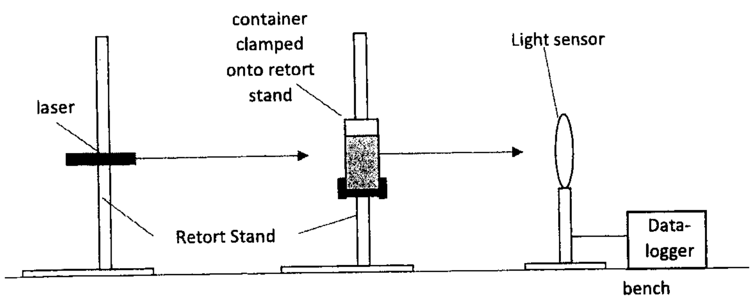
You are provided with containers of different sizes and a monochromatic laser light source. You also provided with the substance to be dissolved in water and the solution absorbs the laser light provided.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how the concentration of the solution and the path lengths are measured
(d) the control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

[11]

Diagram:



D1 – Well labelled diagram

Feasibility of setup

<u>1st part: Keeping the path length *L* constant, varying the concentration *c*</u>
Independent variable (IV): concentration *c*
Dependent variable (DV): light intensity I
Controlled variables (CV): path length *L*, ambient light intensity
Procedure:

1. Set up the experiment as shown in the diagram above.
2. Take one container and measure the path length *L* using the inner claws of a vernier caliper.
3. Measure 50 cm^3 of water using a measuring cylinder.
4. Measure 10 g of the substance using a weighing balance.
5. Dissolve the 10 g of substance into the 50 cm^3 water. Calculate concentration *c* of the solution using mass of substance divided by the volume of water, i.e. 10 g / 50 cm^3 = 0.20 g cm^{-3}. Pour the solution into the container.
6. Place the container in the path of the laser light.
7. Measure and record the light intensity I of the laser light after passing through the solution using a photometer or a light sensor connected to a datalogger.
8. Repeat steps 1 to 8 using different concentration *c* of the solution, by weighing different mass of the substance in step 4 with the same amount of water in step 3, for at least 6 sets of readings. Use the same container to keep *L* constant.
9. Plot a graph of lg I against lg *c*.
10. Calculate the gradient of the graph. The gradient of the graph gives the value of *n*.

IV1 - method of measuring c

VIV1 – Method of varying c while keeping L constant

A1 – Graphical solution

<u>2nd part: Keeping concentration *c* constant, vary *L*</u>
Independent variable (IV): path length *L*
Dependent variable (DV): light intensity I
Controlled variables (CV): concentration c, ambient light intensity

P1 – Two experiments with two sets of IV,DV,CV.

Procedure:

1. **Repeat** step 1 to step 8 of the experiment in part 1, but **each time with a different container to vary the path length *L*, for at least 6 sets** of readings.
2. Add in the **same mass of the same substance and volume of water to get the same concentration *c* of solution**.
3. Plot a graph of lg I against lg *L*.
4. Calculate the gradient of the graph. The gradient of the graph gives the value of *m*.

IV2 – Method of measuring *L*
VIV2 – Method of varying *L* while keeping c constant
A2 – Graphical solution

Additional Details:

1. Perform a preliminary experiment to determine the amount of substance required and how much water to add such that all substance dissolves in the water. Adjust the concentrations such that an observable trend can be obtained in the actual experiment.
2. (Steps taken to align the laser light)
   a. Measure the height from the surface of the bench to the laser light to check that the laser light is parallel.

AD1

More papers at www.testpapersfree.com

b. When placing the container on the platform, verify that the platform is horizontal by using a spirit level.

c. Rotate the container such that the light intensity measured by the light sensor is the maximum. This ensures that the laser light enters at right angle to the surface of the container.

3. (Steps taken to account for ambient light intensity)
   a. Perform experiment in a dark room / dark box so as to minimize the ambient light intensity from entering the light sensor.
   b. Take the ambient light intensity reading with the light sensor connected to the datalogger in the setup as shown in the figure but without switching on the laser light. Subtract this ambient intensity from the I readings in the above experiments.

Safety:

1. Wear goggles to prevent accidental looking into the laser light.
2. Prepared cloths in case of spills.
3. Wear gloves when handling the substance to prevent touching unknown chemicals with our bare hands.

(Generic safety precautions that are not specific to the nature of the experiment will not be accepted.)

S1 – Any relevant safety precaution

More papers at www.testpapersfree.com

More papers at www.testpapersfree.com