NAME ______________________ **CLASS** 2T

Catholic Junior College

JC2 Preliminary Examinations
Higher 2

PHYSICS 9749/01

Multiple Choice Questions

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write your name and tutorial group on this cover page.

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

There are a total of 30 Multiple Choice Questions in 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 Answer Sheet (OMR sheet) provided.

Read the instructions on the Answer Sheet very 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.
Calculators may be used.

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	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2 a s$
work done on / by a gas	W	=	$p \Delta V$
hydrostatic pressure	P	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

1 A student measured the mass and linear dimensions of a rectangular block in order to determine its density. The measurements are:

Height = (1.00 ± 0.01) cm
Length = (5.00 ± 0.01) cm
Breadth = (2.00 ± 0.01) cm
Mass = (80.0 ± 0.2) g

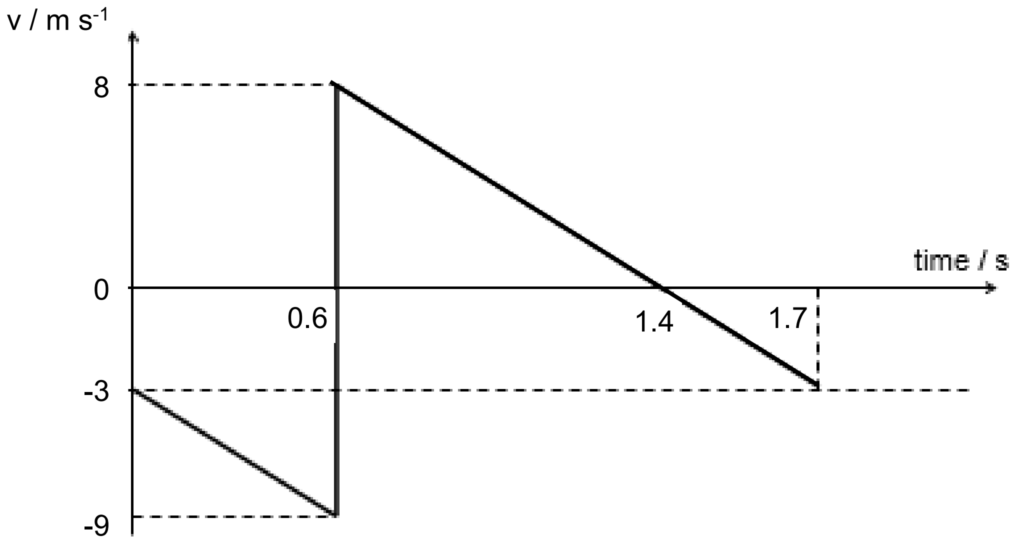
What is the uncertainty in the value of the density calculated?

A 0.01 g cm^{-3} **B** 0.02 g cm^{-3} **C** 0.1 g cm^{-3} **D** 0.2 g cm^{-3}

2 Express the *volt* in SI base units.

A kg m^2 s^{-3} A^{-1} **B** kg m s^{-2} A^{-1} **C** J C^{-1} **D** V

3 A student throws a rubber ball vertically downwards at a speed of 3.0 m s^{-1}. It hits the ground and rebounds vertically. The graph below shows the velocity-time graph for the first 1.7 s of the motion of the rubber ball



What is the displacement of the ball between the point at which it was first thrown and the highest point of the motion?

A zero **B** 0.4 m **C** 1.8 m **D** 3.6 m

4 An object is thrown vertically upwards in air in which the air resistance is not to be neglected.

If the times of flight for the upward motion t_u and the time of flight to return to the same level t_d are compared, then

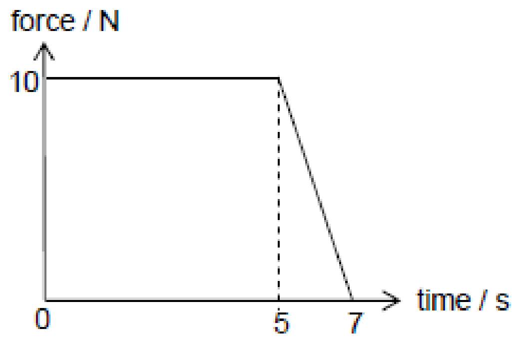
A $t_d > t_u$, because the object moves faster on its downward flight and therefore the air resistance is greater.

B $t_d = t_u$, because the effect of the air resistance is the same whether the object is moving upwards or downwards.

C $t_d < t_u$, because at any given speed the net force when the object is moving downwards is greater than the net force when it is moving upwards.

D $t_d > t_u$, because at a given speed the net force when the object is moving downwards is smaller than the net force when it is moving upwards.

5 A body of mass 2.0 kg is moving along a smooth horizontal surface to the right with a constant velocity of 18 m s^{-1} when a left force is applied on it for 7 s. The graph below shows how the applied force varies with time.



What is the final velocity of the body after 7 s?

A 12 m s^{-1} to the right

B 48 m s^{-1} to the right

C 12 m s^{-1} to the left

D 48 m s^{-1} to the left

6 A fast moving neutron with an initial velocity *u* has a head-on elastic collision with a stationary proton. After the collision, the velocity of the neutron is *v* and that of the proton is *w*.

Taking the masses of the neutron and proton to be equal, which of the following statements is **incorrect**?

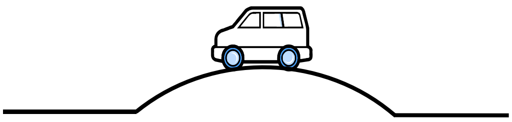
A Since collision is elastic, it shows that $u + v = w$.

B The proton and the neutron move off in opposite directions with equal speeds.

C By considering kinetic energies of the particles, it can be shown that $u^2 = v^2 + w^2$.

D The speed of the proton after the collision is the same as that of the neutron before the collision.

7 A car is travelling on a hump with a radius of curvature of 30 m as shown in figure below. The car loses contact with the hump at the highest point.



At what speed will the car be losing contact as it moves over the hump at the highest point?

A 15.7 m s^{-1} **B** 17.2 m s^{-1} **C** 22.2 m s^{-1} **D** 29.4 m s^{-1}

8 A proposed space laboratory is to create artificial gravity as shown in Fig. 8.a and Fig. 8.b below.

The space laboratory is rotated about an axis so that it simulates an acceleration due to gravity equal to that of the gravity due to Earth at the outer ring which has a radius R_1 of 2150 m.

What should be the approximate radius R_2 of the inner ring, so that it simulates the acceleration due to the gravity of Mars which is 3.72 m s^{-2} ?

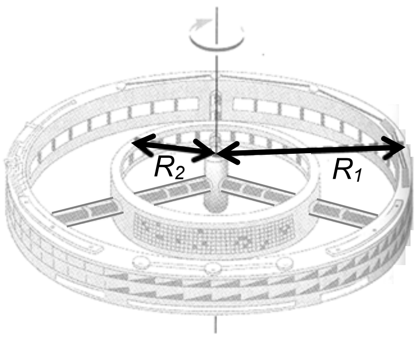


Fig. 8.a

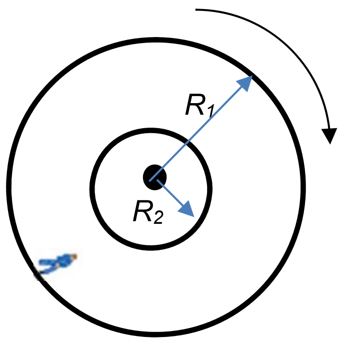
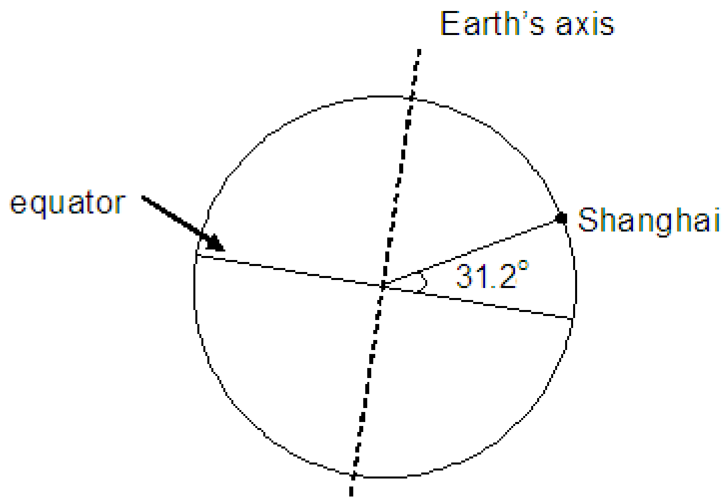


Fig. 8.b

A 700 m **B** 800 m **C** 900 m **D** 1000 m

9 A person is located near the city of Shanghai which has a latitude of 31.28° N.

Assuming that the Earth is a sphere of radius 6380 km, find the linear velocity of the person due to the rotation of the Earth about its axis.



A 240 m s^{-1} **B** 337 m s^{-1} **C** 397 m s^{-1} **D** 464 m s^{-1}

10 The density of a sample of helium gas at the pressure of 100 kPa is 0.180 kg m^{-3}. The root- mean- square speed of the helium molecules is

A 41 m s^{-1} **B** 561 m s^{-1} **C** 1290 m s^{-1} **D** 1685 m s^{-1}

11 A car tyre, initially at $28°C$, has been inflated to a pressure of 160 kPa as indicated by the pressure gauge. This means that the pressure in the tyre is 160 kPa above the atmospheric pressure of 100 kPa.

After driving on hot roads, the temperature of the air in the tyre is $65°C$.

What is the percentage increase in the pressure gauge reading?

A 10% **B** 20% **C** 200% **D** 270%

12 Fig. 12a shows the variation with displacement x of the velocity v of a body in simple harmonic motion. Fig. 12b shows the variation with time t of the net force F acting on the body.

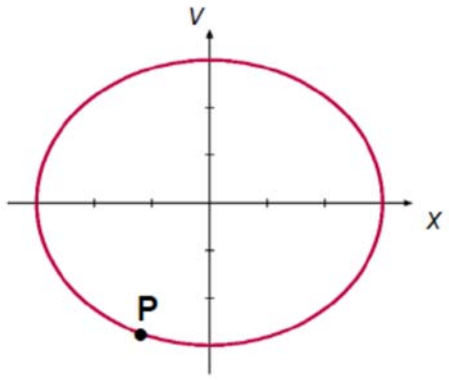


Fig. 12a

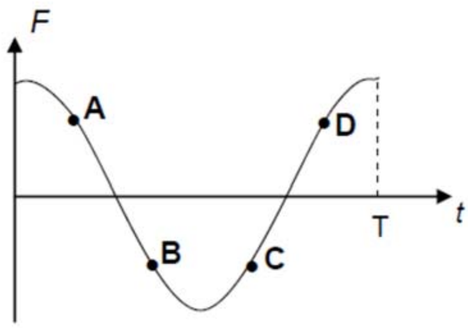


Fig. 12b

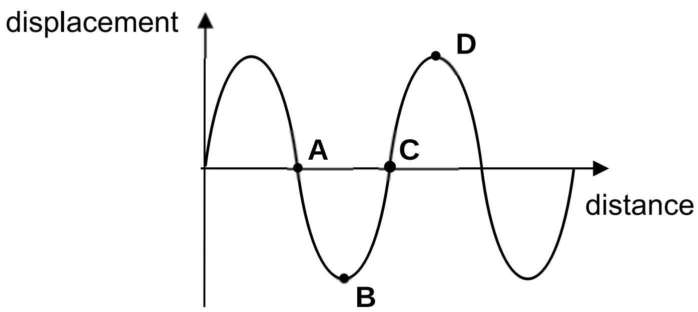
Which of the points on Fig. 12b corresponds to the state of motion represented by point P on Fig. 12a?

13 The phase difference between 2 points at a distance 60 cm apart along a progressive transverse wave is $\frac{\pi}{2}$ rad.

If the frequency of the wave is 200 Hz, what is the speed of the wave?

A 240 m s^{-1} **B** 480 m s^{-1} **C** 24000 m s^{-1} **D** 48000 m s^{-1}

14 A sound wave travelling towards the right through air causes the air molecules to be displaced from their original positions. The graph below shows the variation with distance of the displacement of the air molecules at a particular instant in time.



Taking the displacement towards the right as positive, at which point is the pressure maximum?

15 In a two-slit interference experiment, one slit transmits waves of twice the amplitude compared to the other slit.

If the maximum intensity of the interference pattern is I_o, what is the minimum intensity of the pattern?

A zero **B** $\frac{I_o}{2}$ **C** $\frac{I_o}{4}$ **D** $\frac{I_o}{9}$

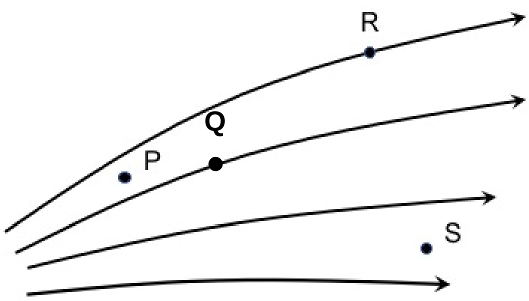
16 A space station orbits at a height of 335 km above the surface of the Earth. It carries two panels separated by a distance of 25 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the panels with a telescope that has an aperture diameter of 200 mm. Assume that the panels act as point sources of light for the observer.

Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
A	Yes	2.5×10^{-6}
B	Yes	7.5×10^{-5}
C	No	2.5×10^{-6}
D	No	7.5×10^{-5}

17 A region of electric field is represented by the electric field lines shown below. P, Q, R and S are 4 points in the field.



Which of the following statements is **incorrect**?

A The electric force on a charged particle is stronger when it is located at P than that at R.

B A positively charged particle released from rest at Q will travel along the electric field line which passes through Q.

C The electric potential energy of a negatively charged particle at S is higher than that at P.

D The electric field strength at Q is stronger than that at S.

18 A isolated metal sphere of radius 0.1 m is positively charged. A small charge was brought from a distant point to a point 0.5 m from the centre of the metal sphere. The work done against the electric field is *W*. At its final position, the electric force on the charge is *F*.

If the charge has been brought to a point 1.0 m from the centre of the metal sphere, what would have been the values for the work done against the electric field and the electric force on the charge at its final position?

	work done against electric field	force on charge at its final position
A	$\frac{W}{4}$	$\frac{F}{4}$
B	$\frac{W}{4}$	$\frac{F}{2}$
C	$\frac{W}{2}$	$\frac{F}{4}$
D	$\frac{W}{2}$	$\frac{F}{2}$

19 The electrical potential difference between two points in a wire carrying a current is

A the ratio of the power supplied to the current between the points.

B the force required to move a unit positive charge between the points.

C the ratio of the energy dissipated to the current between the points.

D the product of the square of the current and the resistance between two points.

20 An electrical source with internal resistance *r* is used to operate a lamp of resistance *R*.

What fraction of the total power is delivered to the lamp?

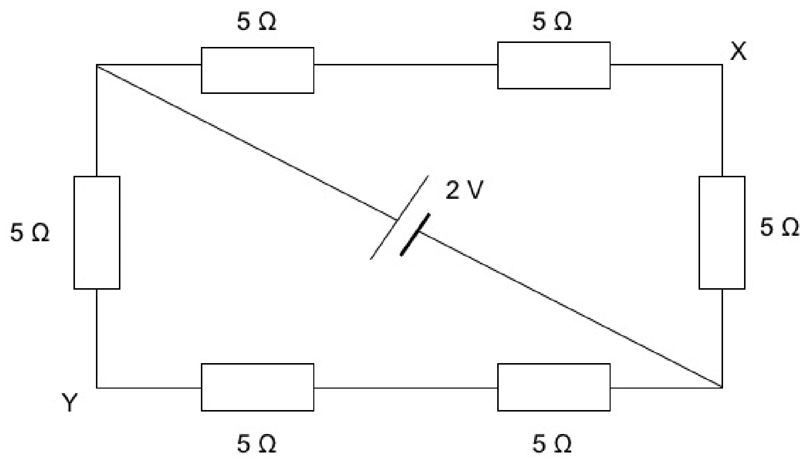
A $\frac{R+r}{R}$ **B** $\frac{R-r}{R}$ **C** $\frac{R}{R+r}$ **D** $\frac{R}{r}$

21 A high potential is applied between the electrodes of a hydrogen discharge tube so that the gas is ionised. Electrons then move towards the positive electrode and protons towards the negative electrode. In each second, 7×10^{18} electrons and 2×10^{18} protons pass a cross section of the tube.

The current flowing in the discharge tube is

A 0.32 A **B** 0.80 A **C** 1.12 A **D** 1.44 A

22 Six 5 Ω resistors are connected to a 2 V cell of negligible internal resistance, as shown in the figure below.

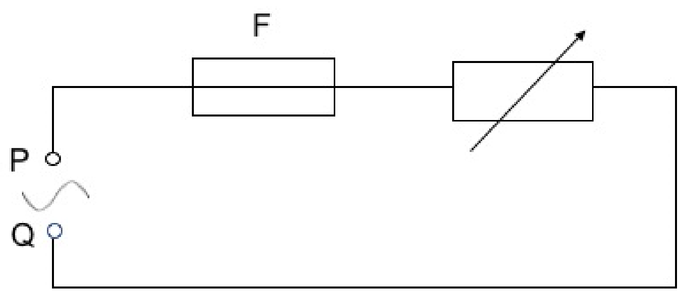


The potential difference between X and Y is

A 0 V **B** $\frac{2}{3}$ V **C** $\frac{8}{9}$ V **D** $\frac{4}{3}$ V

23 When an alternating power supply of 240 V r.m.s. is connected across PQ in the circuit shown below.

The fuse F breaks the circuit if the current in it just exceeds 13 A r.m.s.



When the alternating power supply is replaced with a 120 V d.c. source, an identical fuse breaks the circuit if the current just exceeds

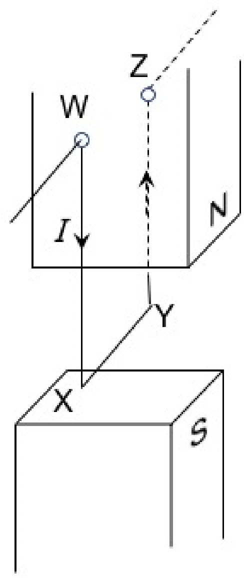
A $\frac{13}{2}$ A **B** $\frac{13}{\sqrt{2}}$ A **C** 13 A **D** 26 A

24 An alternating power supply of root-mean-square voltage 4.0 V is connected across a resistive load such that the average power dissipated across it is *P*.

What is the d.c. voltage applied across the same load which will give rise to an average power dissipation of 3*P* ?

A 6.9 V **B** 8.5 V **C** 12 V **D** 17 V

25 A piece of wire WXYZ is pivoted freely about a horizontal axis at points W and Z. Section XY of the wire is situated between the North (N) and South (S) poles of a horse-shoe magnet. WXYZ is connected to an electrical circuit.



What will happen to the wire, if any, when the circuit is just turned on and there is a constant current *I* in the wire as shown?

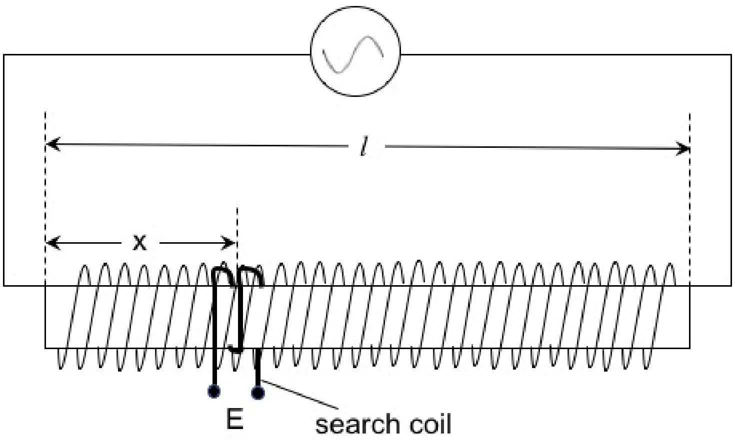
A swings to the left

B swings to the right

C swings from X to Y

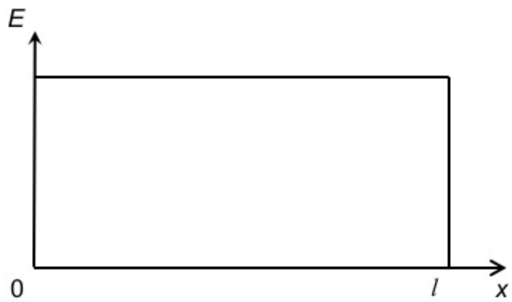
D remains at rest at its original position

26 In the diagram below, the solenoid of length l which is closely and uniformly wound, carries an alternating current of constant amplitude. A search coil (which is a coil consisting of a few turns of wires) is placed in different positions along the solenoid.

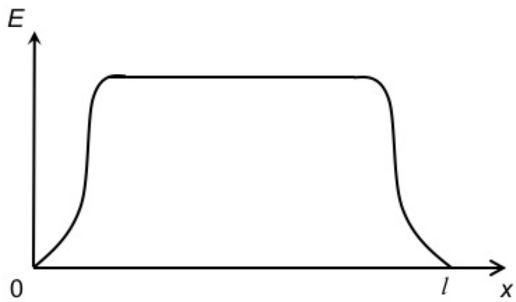


Which one of the following graphs most nearly shows how the amplitude of the e.m.f. E induced in the search coil varies with its position?

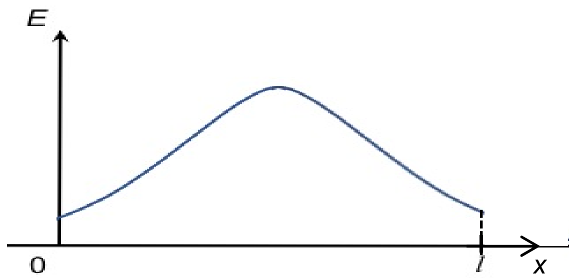
A



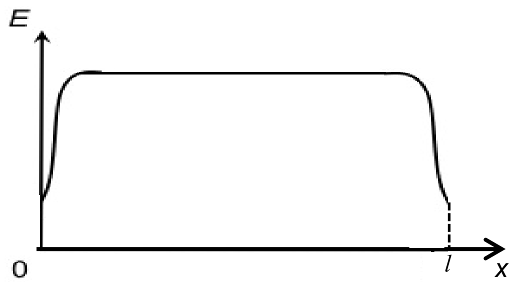
B



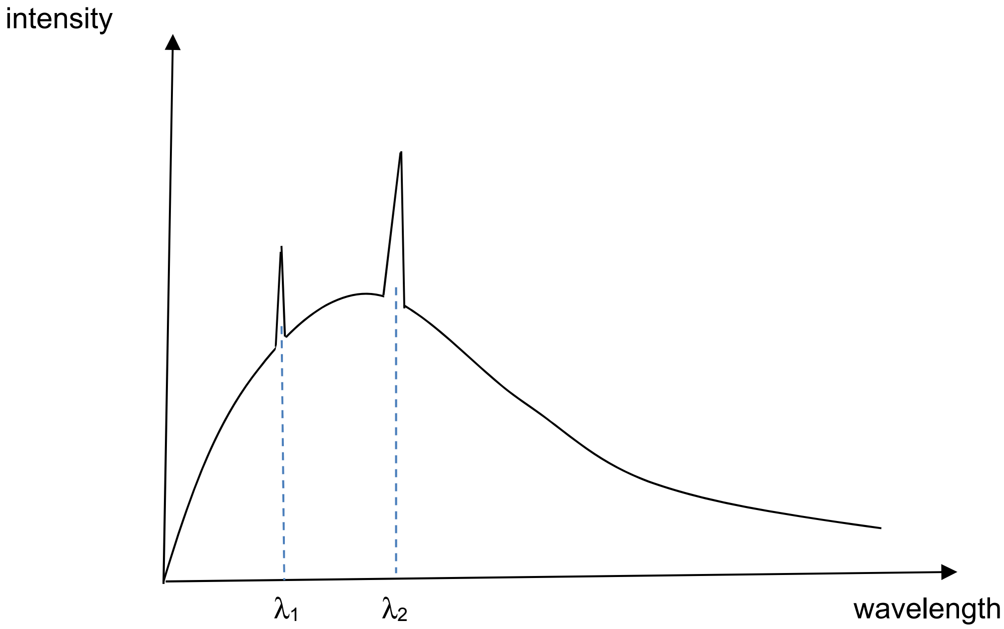
C



D



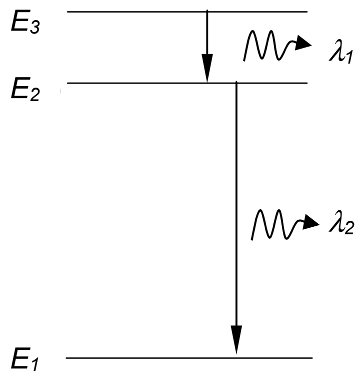
27 The diagram below shows a typical X-ray spectrum produced by an X-ray tube.



The operating voltage across the X-ray tube is increased. Which of the following gives the corresponding changes, if any, in λ_1 and λ_2?

	λ_1	λ_2
A	no change	no change
B	no change	decrease
C	decrease	no change
D	decrease	decrease

28 The diagram below shows a simplified representation of the three electron energy levels in an atom.



Cool vapour of this element at low pressure is bombarded with electrons accelerated from rest across a potential difference V. Two possible transitions which result in the emission of photons of wavelengths $\lambda_1 = 6.22 \times 10^{-7}$ m and $\lambda_2 = 1.78 \times 10^{-7}$ m are observed.

What is the minimum value of V for the above transitions to occur?

A 1.56 V **B** 2.80 V **C** 7.00 V **D** 9.00 V

29 A stationary uranium nucleus of mass 238 units disintegrates by the emission of an α-particle of mass 4 units.

The ratio $\dfrac{\text{kinetic energy of the } \alpha\text{ - particle}}{\text{kinetic energy of the recoiling daughter nucleus}}$ is

A $\dfrac{4}{234}$ **B** $\dfrac{4}{238}$ **C** $\dfrac{234}{4}$ **D** $\dfrac{238}{4}$

30 The half-life of a certain radioactive material is 3.0 s.

How long does it take for its activity to become 10 % of the original activity?

A 0.46 s **B** 5.4 s **C** 10 s **D** 15 s

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gravitational potential	ϕ	=	$-\frac{Gm}{r}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
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decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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	A	0.01 g cm^{-3}	**B**	0.02 g cm^{-3}	**C**	0.1 g cm^{-3}	**D**	0.2 g cm^{-3}

L2 **Solution: D**

$$\rho = \frac{M}{lbh} = \frac{80}{(5)(2)(1)} = 8$$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta h}{h}$$

$$\Delta\rho = \left[\frac{0.2}{80.0} + \frac{0.01}{5.00} + \frac{0.01}{2.00} + \frac{0.01}{1.00}\right](8)$$

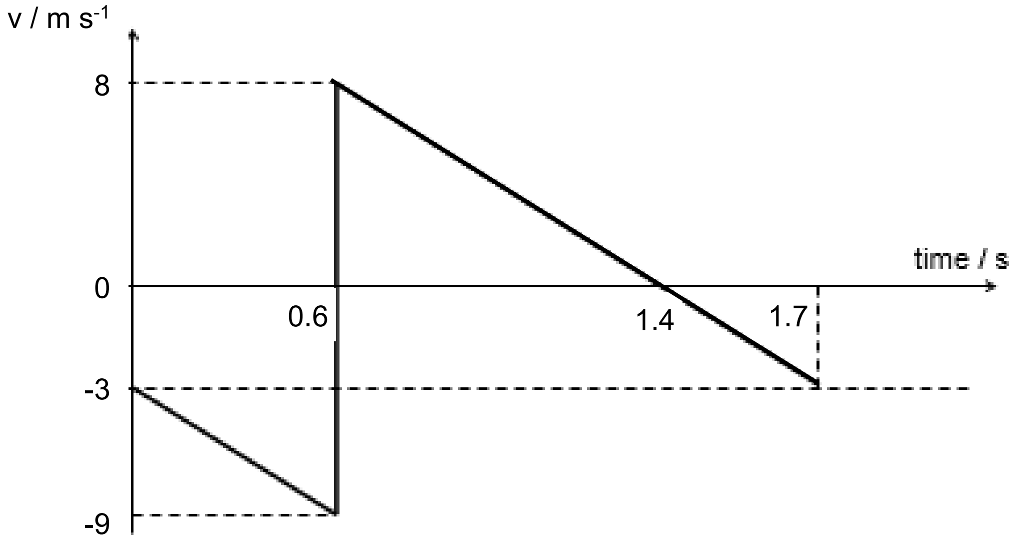
$$= 0.156$$

$$= 0.2 \text{ g cm}^{-3}$$

2	Express the *volt* in SI base units.							
	A	kg m^2 s^{-3} A^{-1}	**B**	kg m s^{-2} A^{-1}	**C**	J C^{-1}	**D**	V

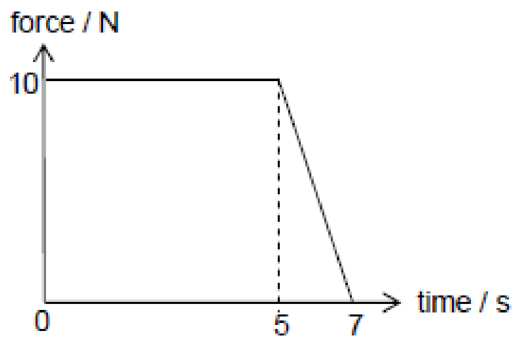
L2 **Solution: A**

$$[V] = \frac{[W]}{[Q]} = \frac{[F][s]}{[I][t]} = \frac{kgms^{-2}m}{As} = kgm^2s^{-3}A^{-1}$$

3	A student throws a rubber ball vertically downwards at a speed of 3.0 m s^{-1}. It hits the ground and rebounds vertically. The graph below shows the velocity-time graph for the first 1.7 s of the motion of the rubber ball  What is the displacement of the ball between the point at which it was first thrown and the highest point of the motion?							
	A	zero	**B**	0.4 m	**C**	1.8 m	**D**	3.6 m
L2	Solution: B Distance from initial point to the ground is = (0.6)(3) + ½ (6)(0.6) = 3.6 m Distance from ground to highest point = ½ (0.8)(8) = 3.2 m ➔ displacement is 3.6 – 3.2 = 0.4 m							

4	An object is thrown vertically upwards in air in which the air resistance is not to be neglected. If the times of flight for the upward motion t_u and the time of flight to return to the same level t_d are compared, then		
	A	$t_d > t_u$, because the object moves faster on its downward flight and therefore the air resistance is greater.	
	B	$t_d = t_u$, because the effect of the air resistance is the same whether the object is moving upwards or downwards.	
	C	$t_d < t_u$, because at any given speed the net force when the object is moving downwards is greater than the net force when it is moving upwards.	
	D	$t_d > t_u$, because at a given speed the net force when the object is moving downwards is smaller than the net force when it is moving upwards.	
L3	Solution: D Consider forces on the object when it moves upwards and it falls. The net force in the downward motion is smaller than that in the upwards direction. The average deceleration in the downward motion is lower than the average acceleration in the upward motion. Hence the time taken to rise is shorter than the time taken to fall.		

5 A body of mass 2.0 kg is moving along a smooth horizontal surface to the right with a constant velocity of 18 m s^{-1} when a left force is applied on it for 7 s. The graph below shows how the applied force varies with time.



What is the final velocity of the body after 7 s?

A	12 m s^{-1} to the right	
B	48 m s^{-1} to the right	
C	12 m s^{-1} to the left	
D	48 m s^{-1} to the left	

L3 Solution: C

The initial momentum of the body = (2.0) (18) = 36 Ns to the right

The change in momentum
= area under the graph
= (10)(5) + (0.5)(2)(10)
= 60 N s

The applied force is to the left hence the change in the momentum is to the left.

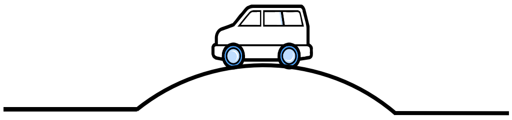
final momentum of the body
= initial momentum + change in momentum
= 36 + (– 60) = - 24 Ns to the right

final velocity = - 24 / 2.0 = - 12 m s^{-1} to the right

i.e. 12 m s^{-1} to the left

6	A fast moving neutron with an initial velocity *u* has a head-on elastic collision with a stationary proton. After the collision, the velocity of the neutron is *v* and that of the proton is *w*. Taking the masses of the neutron and proton to be equal, which of the following statements is **incorrect**?	
	A	Since collision is elastic, it shows that $u + v = w$.
	B	The proton and the neutron move off in opposite directions with equal speeds.
	C	By considering kinetic energies of the particles, it can be shown that $u^2 = v^2 + w^2$.
	D	The speed of the proton after the collision is the same as that of the neutron before the collision.
L2	**Solution: B** Relative velocity of approach = Relative velocity of separation Taking vectors to the right as positive. $u – 0 = w – v$ $u + v = w$ Option A is true. For elastic collision of the same mass, the velocities are exchanged. ➔ Option B is incorrect ➔ but option D is correct Option C is correct since the total K.E. before and after collision is the same for an elastic collision.	

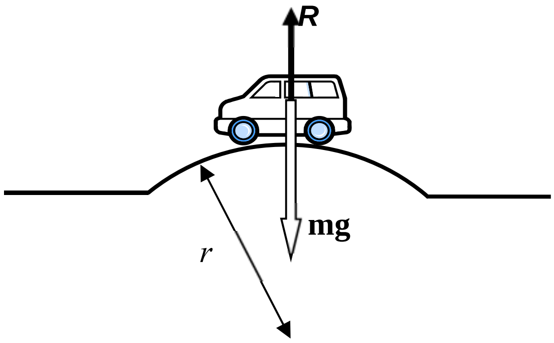
7 A car is travelling on a hump with a radius of curvature of 30 m as shown in figure below. The car loses contact with the hump at the highest point.



At what speed will the car be losing contact as it moves over the hump at the highest point?

A	15.7 m s^{-1}	**B**	17.2 m s^{-1}	**C**	22.2 m s^{-1}	**D**	29.4 m s^{-1}

L2 **Answer: B**



Net force towards centre of curve provides centripetal force

$mg - R = mv^2/r$ where R is the normal contact force on car by road

car loses contact with road $R = 0$

$\Rightarrow$ $v = \sqrt{rg} = 17.2$ m s^{-1}

8 A proposed space laboratory is to create artificial gravity as shown in Fig. 8.a and Fig. 8.b below.

The space laboratory is rotated about an axis so that it simulates an acceleration due to gravity equal to that of the gravity due to Earth at the outer ring which has a radius R_1 of 2150 m.

What should be the approximate radius R_2 of the inner ring, so that it simulates the acceleration due to the gravity of Mars which is 3.72 m s^{-2} ?

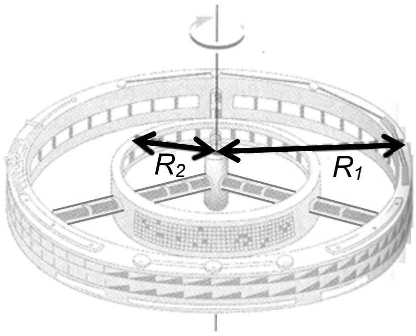


Fig. 8.a

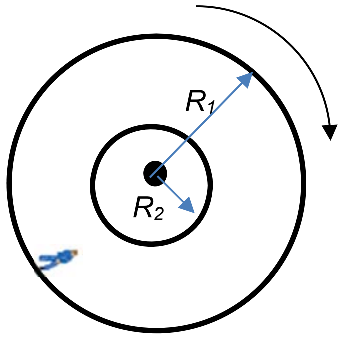


Fig. 8.b

A	700 m	**B**	800 m	**C**	900 m	**D**	1000 m

L3 Answer: B

To simulate gravity
➔ normal contact force N = mg; where g = acceleration due to gravity

Centripetal force is provided by the normal contact force
$F_c = N$

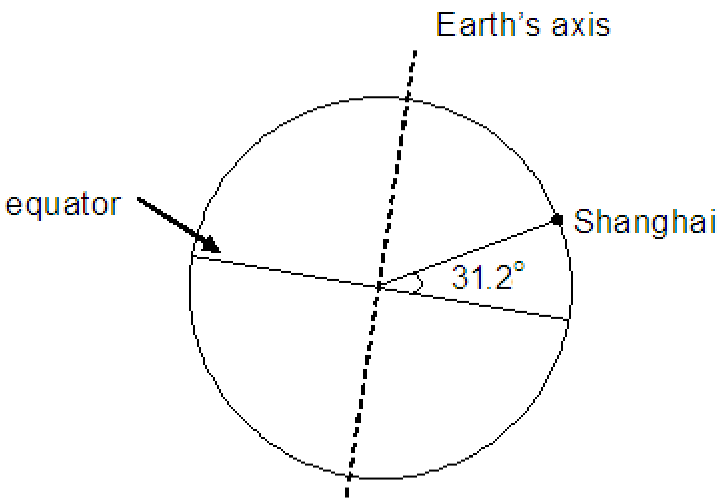
$F_c = ma_c = mr\omega^2 = mg$
$r\omega^2 = g$

$g \propto r$ since ω^2 is a constant

$$\frac{9.81}{2150} = \frac{3.72}{r}$$
$$r = 815\ m$$

9 A person is located near the city of Shanghai which has a latitude of 31.28° N.

Assuming that the Earth is a sphere of radius 6380 km, find the linear velocity of the person due to the rotation of the Earth about its axis.



A	240 m s^{-1}	**B**	337 m s^{-1}	**C**	397 m s^{-1}	**D**	464 m s^{-1}

L2 **Answer: C**

$$v = r\omega$$

$$v = (6.38 \times 10^6) \cos 31.2 \left(\frac{2\pi}{24 \times 60 \times 60}\right)$$

$$v = 397\ m\ s^{-1}$$

10 The density of a sample of helium gas at the pressure of 100 kPa is 0.180 kg m^{-3}. The root- mean- square speed of the helium molecules is

A	41 m s^{-1}	B	561 m s^{-1}	C	1290 m s^{-1}	D	1685 m s^{-1}

L2 **Answer: C**

$$P = \frac{1}{3}\frac{Nm}{V} v_{rms}^2$$

$$P = \frac{1}{3}\rho v_{rms}^2$$

$$100000 = \frac{1}{3}(0.180) v_{rms}^2$$

v_{rms} = 1290 m s^{-1}

11 A car tyre, initially at $28^{\circ}C$, has been inflated to a pressure of 160 kPa as indicated by the pressure gauge. This means that the pressure in the tyre is 160 kPa above the atmospheric pressure of 100 kPa.

After driving on hot roads, the temperature of the air in the tyre is $65^{\circ}C$.

What is the percentage increase in the pressure gauge reading?

A	10%	**B**	20%	**C**	200%	**D**	270%

L3 **Answer: B**

Taking n,R, V to be constant

Using the ideal gas equation,

$P_i = 160 + 100 = 260 \text{ kPa}$

$T_i = 273.15 + 28 = 301.15 \text{ K}$

$T_f = 273.15 + 65 = 338.15 \text{ K}$

$PV = nRT$

$\frac{P}{T} = \frac{nR}{V} = \text{constant}$

$\frac{P_i}{T_i} = \frac{P_f}{T_f}$

$\frac{260}{301.15} = \frac{P_f}{338.15}$

$P_f = 291.94 \text{ kPa}$

New reading of Pressure Gauge

$= 291.94 - 100 = 191.9 \text{ kPa}$

$\text{\%tage increase} = \frac{191.9 - 160}{160} x100\% = 20\%$

12	Fig. 12a shows the variation with displacement *x* of the velocity *v* of a body in simple harmonic motion. Fig. 12b shows the variation with time *t* of the net force *F* acting on the body.	

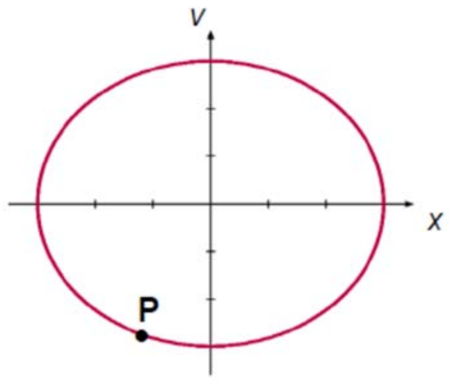


Fig. 12a

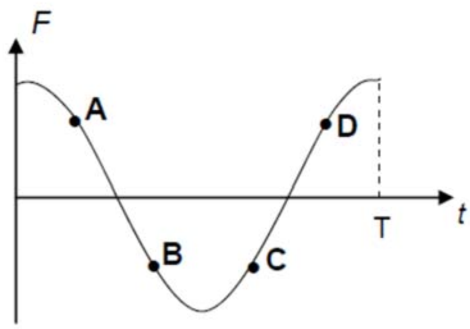


Fig. 12b

Which of the points on Fig. 12b corresponds to the state of motion represented by point P on Fig. 12a?

L3 **Answer: D**

At point P, the displacement is negative and velocity is negative.

For s.h.m. net force $F = ma = - m\omega^2 x$,
x is negative implies net F is positive (B and C not possible).

As the displacement is negative and the velocity is negative, the displacement will be more negative in the next instant.
Hence the force will increase positively.

13 The phase difference between 2 points at a distance 60 cm apart along a progressive transverse wave is $\frac{\pi}{2}$ rad.

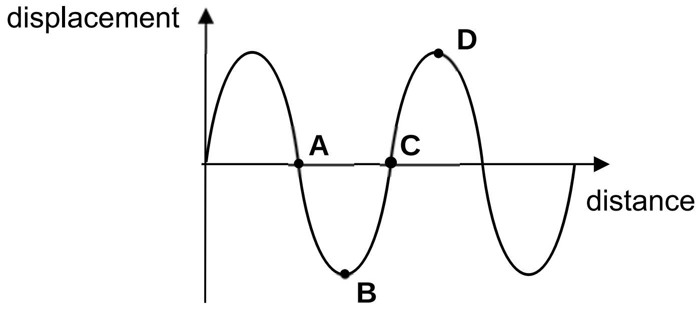
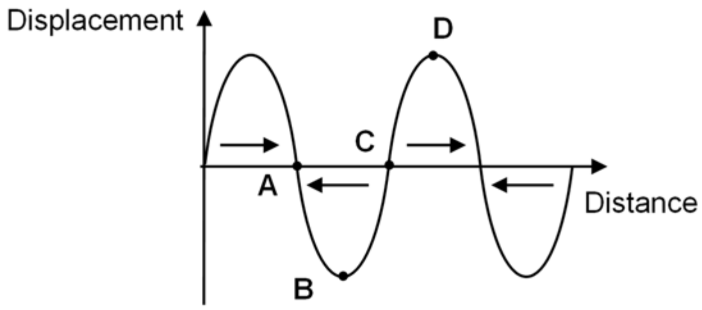
If the frequency of the wave is 200 Hz, what is the speed of the wave?

A	240 m s^{-1}	**B**	480 m s^{-1}	**C**	24000 m s^{-1}	**D**	48000 m s^{-1}

L2 **Answer: B**

Since phase difference of $\frac{\pi}{2}$ at distance 60 cm apart,

the wavelength = 60 x 4 = 240 cm = 2.40 m
speed = $f\lambda$ = 200 x 2.40 = 480 m s^{-1}

14	A sound wave travelling towards the right through air causes the air molecules to be displaced from their original positions. The graph below shows the variation with distance of the displacement of the air molecules at a particular instant in time.  Taking the displacement towards the right as positive, at which point is the pressure maximum?	
L2	**Answer: A** Since displacement towards the right is taken as positive, we can label the directions of displacement of air molecules as follows:  It can be seen from the figure that at point **A**, it is a region of compression as air molecules on the left side of **A** is displaced to the right and on the right side of **A**, they are displaced to the left. Hence **A** has the maximum pressure.	
15	In a two-slit interference experiment, one slit transmits waves of twice the amplitude compared to the other slit. If the maximum intensity of the interference pattern is I_o, what is the minimum intensity of the pattern?	

A	zero	**B**	$\frac{I_o}{2}$	**C**	$\frac{I_o}{4}$	**D**	$\frac{I_o}{9}$	

L2	**Answer: D** $I \propto A^2$ For maximum intensity, $I_o \propto (2A + A)^2$ For minimum intensity, $I \propto (2A - A)^2$ $\frac{I}{I_o} = \left(\frac{A}{3A}\right)^2$ $I = \frac{I_o}{9}$	

16 A space station orbits at a height of 335 km above the surface of the Earth. It carries two panels separated by a distance of 25 m. The panels reflect light of wavelength 500 nm towards an observer on the Earth's surface.

The observer views the panels with a telescope that has an aperture diameter of 200 mm. Assume that the panels act as point sources of light for the observer.

Which of the following is correct?

	Will the two images seen by the observer be resolved?	Angular separation of two sources as measured from aperture / rad
A	Yes	2.5×10^{-6}
B	Yes	7.5×10^{-5}
C	No	2.5×10^{-6}
D	No	7.5×10^{-5}

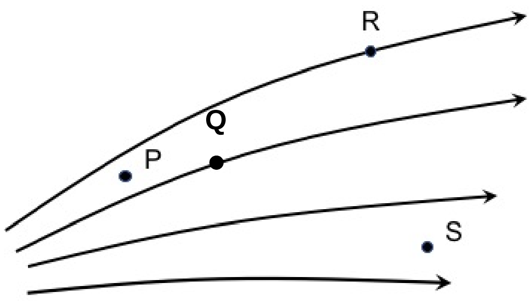
L2 **Answer: B**

$s = r\theta$

$$\theta = \frac{s}{r} = \frac{25}{335x10^3} = 7.46x10^{-5} = 7.5x10^{-5}\,rad$$

Min angle of resolution $\theta_m = \frac{\lambda}{b} = \frac{500x10^{-9}}{200x10^{-3}} = 2.5x10^{-6}\ rad$

Images seen are resolved since angular separation between two sources is larger than the min angle of resolution.

17	A region of electric field is represented by the electric field lines shown below. P, Q, R and S are 4 points in the field.  Which of the following statements is **incorrect**?	
	A The electric force on a charged particle is stronger when it is located at P than that at R.	
	B A positively charged particle released from rest at Q will travel along the electric field line which passes through Q.	
	C The electric potential energy of a negatively charged particle at S is higher than that at P.	
	D The electric field strength at Q is stronger than that at S.	
L2	**Answer: B** The force on the charged particle is along the tangent of the field at a point and hence it experiences an acceleration along the tangent of the field. This implies that the change in the velocity is in the direction of the acceleration but the instantaneous velocity is not along the field line. Hence the path of the charged particle is not along the field line.	

18 A isolated metal sphere of radius 0.1 m is positively charged. A small charge was brought from a distant point to a point 0.5 m from the centre of the metal sphere. The work done against the electric field is *W*. At its final position, the electric force on the charge is *F*.

If the charge has been brought to a point 1.0 m from the centre of the metal sphere, what would have been the values for the work done against the electric field and the electric force on the charge at its final position?

	work done against electric field	force on charge at its final position
A	$\frac{W}{4}$	$\frac{F}{4}$
B	$\frac{W}{4}$	$\frac{F}{2}$
C	$\frac{W}{2}$	$\frac{F}{4}$
D	$\frac{W}{2}$	$\frac{F}{2}$

L2 Answer: C

Treating the sphere as a point source,

At 0.5 m $F = \frac{kq_{sphere}q}{0.5^2}$

At 1.0 m $F_{new} = \frac{kq_{sphere}q}{1.0^2} = \frac{1}{4}\frac{kq_{sphere}q}{0.5^2} = \frac{1}{4}F$

At 0.5 m $W = U = \frac{kq_{sphere}q}{0.5}$

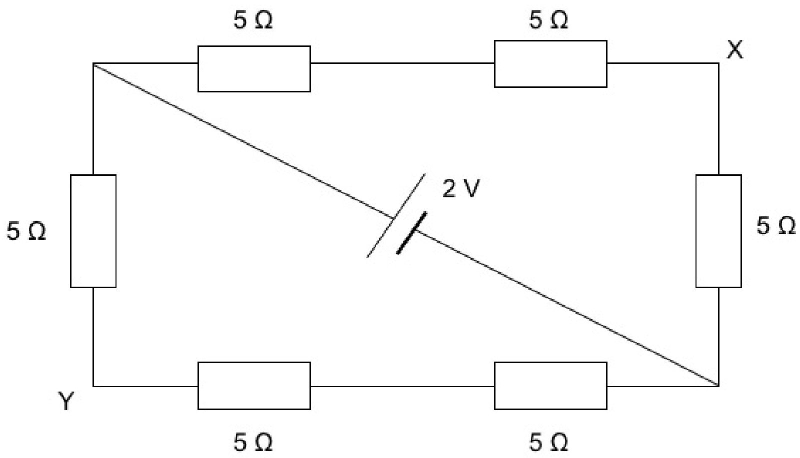
At 1.0 m $W_{new} = \frac{kq_{sphere}q}{1.0} = \frac{1}{2}\frac{kq_{sphere}q}{0.5} = \frac{1}{2}W$

19	The electrical potential difference between two points in a wire carrying a current is	
	A	the ratio of the power supplied to the current between the points.
	B	the force required to move a unit positive charge between the points.
	C	the ratio of the energy dissipated to the current between the points.
	D	the product of the square of the current and the resistance between two points.
L2	**Answer: A** $V = W/Q = P/I$ it can be expressed as the ratio of P to I.	

20	An electrical source with internal resistance r is used to operate a lamp of resistance R. What fraction of the total power is delivered to the lamp?							
	A	$\frac{R+r}{R}$	**B**	$\frac{R-r}{R}$	**C**	$\frac{R}{R+r}$	**D**	$\frac{R}{r}$
L2	**Answer: C** $\frac{P_L}{P_{tot}} = \frac{I^2R}{I^2R+I^2r}$ $= \frac{R}{R+r}$							

21	A high potential is applied between the electrodes of a hydrogen discharge tube so that the gas is ionised. Electrons then move towards the positive electrode and protons towards the negative electrode. In each second, 7×10^{18} electrons and 2×10^{18} protons pass a cross section of the tube. The current flowing in the discharge tube is							
	A	0.32 A	**B**	0.80 A	**C**	1.12 A	**D**	1.44 A
L2	**Answer: D** Since the electrons and protons are moving in opposite directions, the total current is the sum of the current due to both charges $I = \frac{N_e q_e}{t} + \frac{N_p q_p}{t}$ $= \left(\frac{7\times10^{18}}{1} + \frac{2\times10^{18}}{1}\right)\times(1.6\times10^{-19})$ $= 1.44$ A							

22 Six 5 Ω resistors are connected to a 2 V cell of negligible internal resistance, as shown in the figure below.

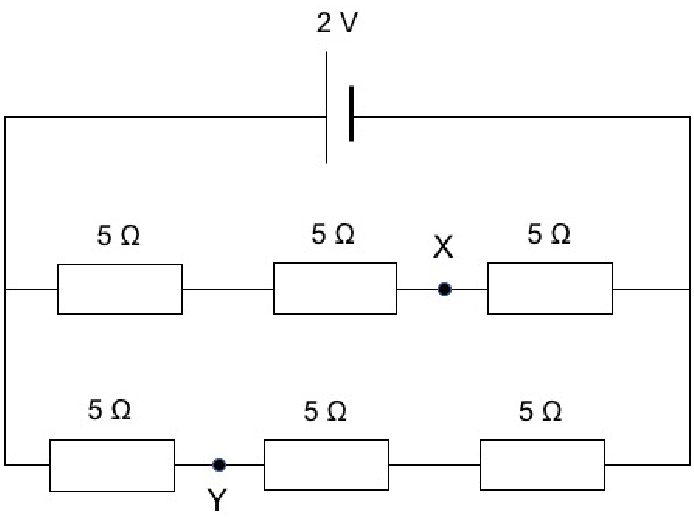


The potential difference between X and Y is

A	0 V	**B**	$\frac{2}{3}$ V	**C**	$\frac{8}{9}$ V	**D**	$\frac{4}{3}$ V

L2 **Answer: B**

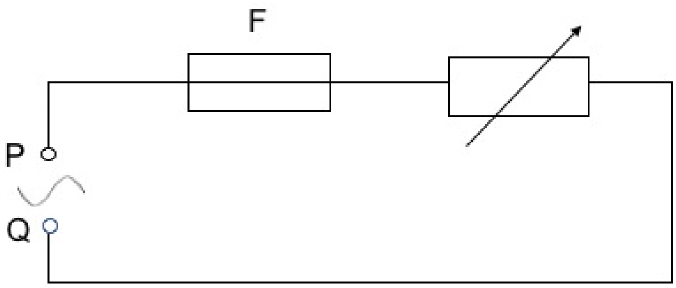
The diagram can be re-drawn as shown:



the resistors are all with the same resistance,
the potential drop across each resistor $=\frac{1}{3}(2)=\frac{2}{3}$ V

potential at X is $= \frac{2}{3}$ V.
potential at Y is $2 \times \frac{2}{3} = \frac{4}{3}$ V.

potential difference between XY is
$\frac{4}{3}-\frac{2}{3}=\frac{2}{3}$ V

23	When an alternating power supply of 240 V r.m.s. is connected across PQ in the circuit shown below. The fuse F breaks the circuit if the current in it just exceeds 13 A r.m.s.  When the alternating power supply is replaced with a 120 V d.c. source, an identical fuse breaks the circuit if the current just exceeds							
	A	$\frac{13}{2}$ A	**B**	$\frac{13}{\sqrt{2}}$ A	**C**	13 A	**D**	26 A
L2	**Answer: C** As the r.m.s current is the equivalent dc current for the same power dissipation in the same resistor, since the fuse breaks when the a.c. r.m.s. current is 13 A, this implies that the fuse will also break at d.c. current of 13 A.							

24	An alternating power supply of root-mean-square voltage 4.0 V is connected across a resistive load such that the average power dissipated across it is *P*. What is the d.c. voltage applied across the same load which will give rise to an average power dissipation of 3*P* ?							
	A	6.9 V	**B**	8.5 V	**C**	12 V	**D**	17 V

L2

Answer: A

For an alternating supply,

$\langle P \rangle = P$

$$P = \frac{V_{rms}^2}{R} \quad ......(1)$$

Across the same load, to have average power to be 3P,

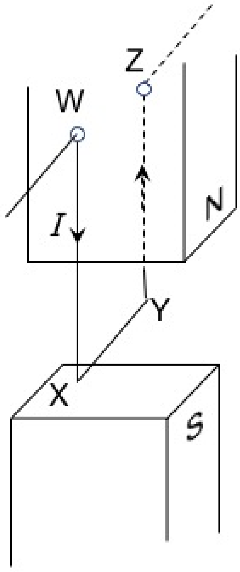
$$\langle P \rangle_{new} = \frac{V_{rms}^2{}_{new}}{R}$$

$$3P = \frac{V_{rms}^2{}_{new}}{R} \quad ...(2)$$

(1) / (2)

$$1/3 = \frac{\frac{V_{rms}^2}{R}}{\frac{V_{rms}^2{}_{new}}{R}}$$

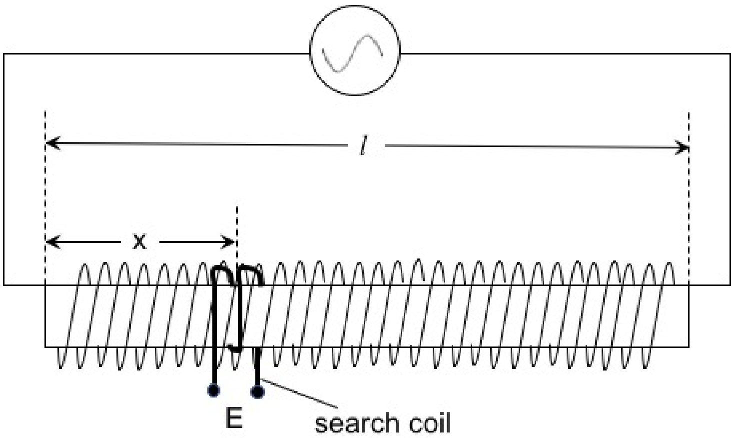
$$V_{rms,\ new} = \sqrt{3V_{rms}^2} = \sqrt{3(4)^2} = 6.9\text{ V}$$

25	A piece of wire WXYZ is pivoted freely about a horizontal axis at points W and Z. Section XY of the wire is situated between the North (N) and South (S) poles of a horse-shoe magnet. WXYZ is connected to an electrical circuit.  What will happen to the wire, if any, when the circuit is just turned on and there is a constant current *I* in the wire as shown?	

	A	swings to the left	
	B	swings to the right	
	C	swings from X to Y	
	D	remains at rest at its original position	

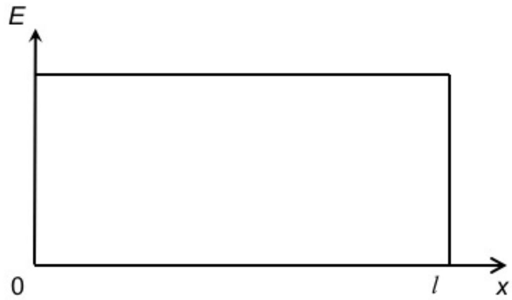
L1	**Answer: A** By Fleming's left hand rule, the force acting on the wire section XY will be towards the left.	

26 In the diagram below, the solenoid of length *l* which is closely and uniformly wound, carries an alternating current of constant amplitude. A search coil (which is a coil consisting of a few turns of wires) is placed in different positions along the solenoid.

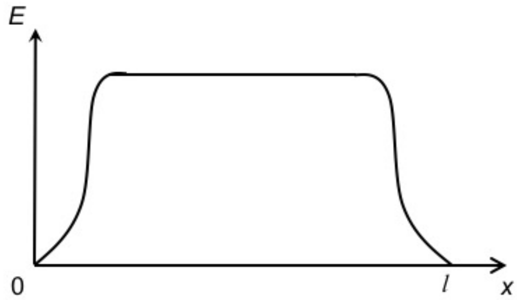


Which one of the following graphs most nearly shows how the amplitude of the e.m.f. *E* induced in the search coil varies with its position?

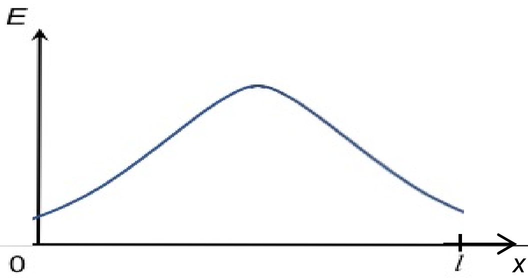
A



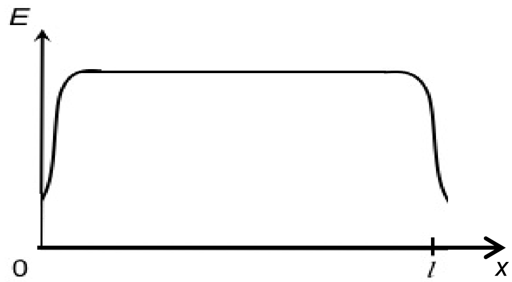
B



C



D



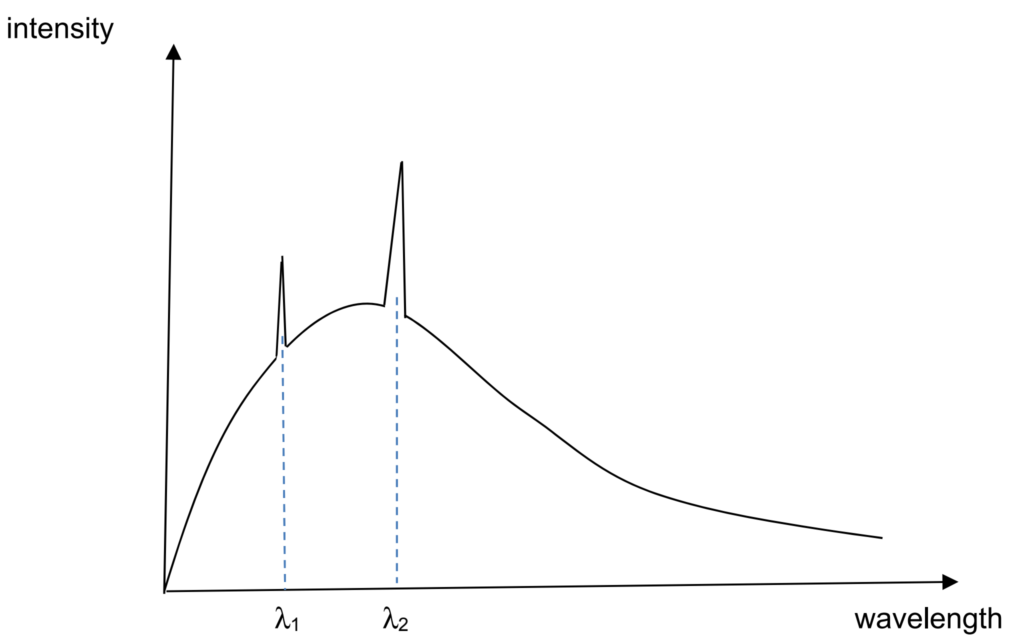
L3 **Answer: D**

As the current in the solenoid is alternating, the amplitude of the e.m.f. induced in the search coil is proportional to the max magnetic flux density which varies sinusoidally

The maximum magnetic flux density along the length of the solenoid is uniform since it is long. The maximum magnetic flux density near the ends decreases.

Hence maximum e.m.f. induced in the search coil is almost constant along the length of the solenoid and decreases at the ends.

27 The diagram below shows a typical X-ray spectrum produced by an X-ray tube.



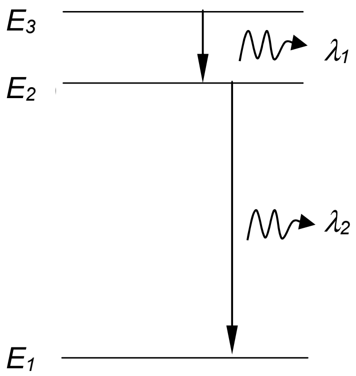
The operating voltage across the X-ray tube is increased. Which of the following gives the corresponding changes, if any, in λ_1 and λ_2?

	λ_1	λ_2
A	no change	no change
B	no change	decrease
C	decrease	no change
D	decrease	decrease

L2 **Answer: A**

λ_1 and λ_2 is only dependent on the target.

28 The diagram below shows a simplified representation of the three electron energy levels in an atom.



Cool vapour of this element at low pressure is bombarded with electrons accelerated from rest across a potential difference *V*. Two possible transitions which result in the emission of photons of wavelengths $\lambda_1 = 6.22 \times 10^{-7}$ m and $\lambda_2 = 1.78 \times 10^{-7}$ m are observed.

What is the minimum value of *V* for the above transitions to occur?

A	1.56 V	B	2.80 V	C	7.00 V	D	9.00 V

L2 **Ans: D**

Minimum energy of the electrons
$= hc/\lambda_1 + hc/\lambda_2$
$= 1.44 \times 10^{-18}$ J

Since E = qV
=> V = E/e
$= 1.44 \times 10^{-18} / 1.6 \times 10^{-19}$
= 9 V

29	A stationary uranium nucleus of mass 238 units disintegrates by the emission of an α-particle of mass 4 units. The ratio $\dfrac{\text{kinetic energy of the } \alpha \text{ - particle}}{\text{kinetic energy of the recoiling daughter nucleus}}$ is								
	A	$\dfrac{4}{234}$	**B**	$\dfrac{4}{238}$	**C**	$\dfrac{234}{4}$	**D**	$\dfrac{238}{4}$	
L3	Ans: C The reaction can be represented by $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ By principle of conservation of momentum, $(238 - 4)\ V_{th} = 4\ V_{\alpha}$ *where* V_{th} : velocity of the recoiling thorium nucleus and v_{α} : velocity of the α – particle $\Rightarrow \dfrac{V_{\alpha}}{V_{th}} = \dfrac{234}{4}$ Ratio of the kinetic energies is $\dfrac{\text{kinetic energy of the } \alpha - \text{particle}}{\text{kinetic energy of the recoiling thorium nucleus}} = \dfrac{4V_{\alpha}^2}{234V_{th}^2} = \dfrac{4}{234}\left(\dfrac{234}{4}\right)^2 = \dfrac{234}{4}$								

30	The half-life of a certain radioactive material is 3.0 s. How long does it take for its activity to become 10 % of the original activity?								
	A	0.46 s	**B**	5.4 s	**C**	10 s	**D**	15 s	
L2	Ans: C $\lambda = \ln 2 / t_{½} = \ln 2 / 3$ $A = A_o e^{-\lambda t}$ $\ln (A / A_o) = -\lambda t$ $\ln 0.1 = -(\ln 2 / 3)\ t$ t = 10 s								

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS 9749/02
Paper 2

2 hours

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 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 staples, paper clips, highlighters, glue or correction fluid.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/6			
Q2	/10			
Q3	/7			
Q4	/8			
Q5	/5			
Q6	/7			
Q7	/10			
Q8	/8			
Q9	/19			
TOTAL FOR PAPER 2	/ 80			

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	=	$u\,t + \frac{1}{2}a\,t^2$
	v^2	=	$u^2 + 2\,a\,s$
work done on / by a gas	W	=	$p\,\Delta V$
hydrostatic pressure	P	=	$\rho g h$
gravitational potential	ϕ	=	$-\dfrac{Gm}{r}$
temperature	T / K	=	$T / {}^\circ C + 273.15$
pressure of an ideal gas	p	=	$\dfrac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\dfrac{3}{2}kT$
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	=	$\dfrac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\dfrac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\dfrac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

1 A hydroelectric power station could make a significant contribution to energy requirements.
Fig. 1.1 shows a dam at the hydroelectric power station which traps water behind a dam. When the height of the water behind the dam reaches 10.0 m, the water is released and passed through the turbines.

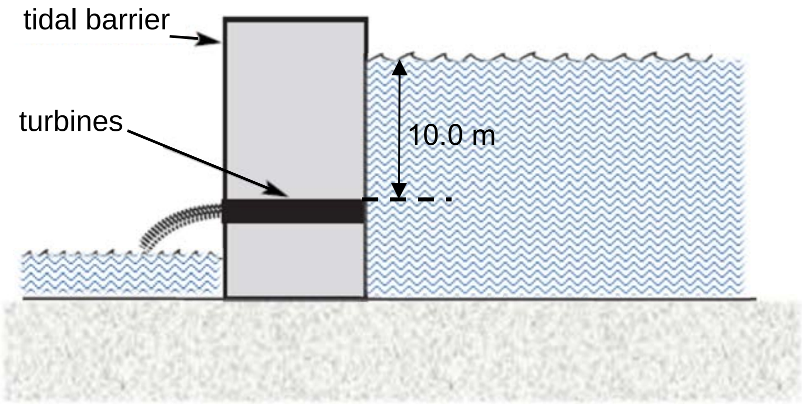


Fig. 1.1

(a) It takes 6.0 hours for a total mass of 1.32×10^{12} kg of water to flow through the turbines. The centre of mass of this amount of water is 5.0 m above the turbines.

Calculate the loss in the potential energy of the trapped water when it is released through the turbines completely. Assume that the density of the water is uniform.

loss in the potential energy = ………………………………..J [2]

(b) The potential energy calculated in part **(a)** is lost and the efficiency of the power station is 40 %.

Calculate the average power output of the power station over this time period of 6.0 hours.

average power output = ……………………………………W [3]

[Turn over

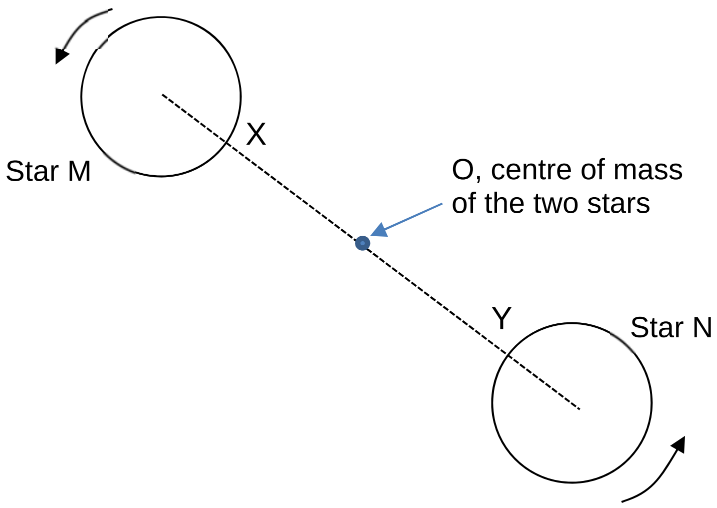
(c) Suggest how the output power of the hydroelectric power station can be controlled as the level of trapped water decreases.

……

……

…… **[1]**

2 In a binary star system, two stars, each of equal mass 3.5 x 10^{30} kg, rotate about their common centre of mass O which is equidistant from the centres of the stars. The separation between the two centres of the stars is 2.0 x 10^{11} m.



(a) Define gravitational potential at a point.

……

……

…… [1]

(b) Calculate the gravitational potential at O, the centre of mass of the binary star system.

gravitational potential = …………………………… J kg^{-1} [2]

(c) An asteroid passes through point O, at a speed v.

Determine the minimum speed of the asteroid if it is to escape from the gravitational pull of the binary star system.

minimum speed = ………………….. m s^{-1} [3]

(d) **(i)** On Fig. 2.1, sketch a graph showing the variation of gravitational potential along the line XY between the two stars. [2]

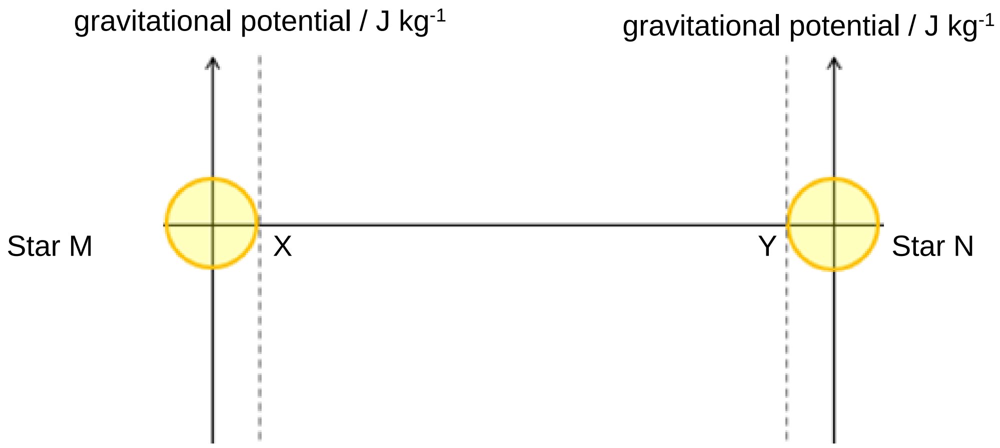


Fig. 2.1

(ii) Hence describe the variation in gravitational potential energy of an object moving from O towards star M.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

3 **(a)** Define *specific latent heat*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) A beaker containing a liquid is placed on a balance, as shown in Fig. 3.1.

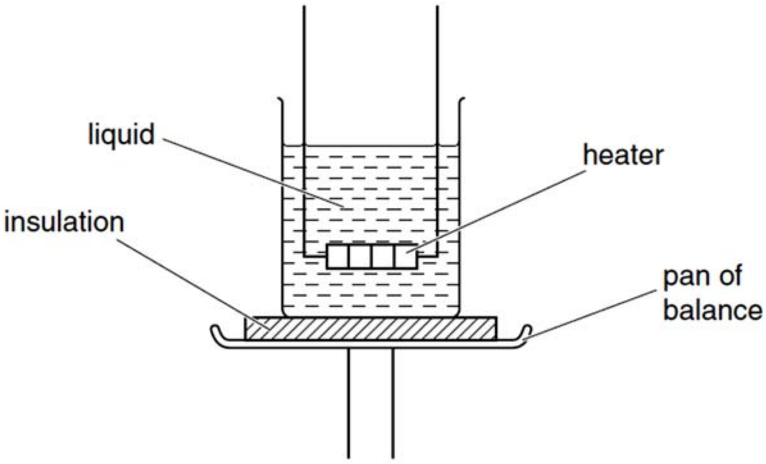


Fig. 3.1

A heater of power 120 W is immersed in the liquid. The heater is switched on and, when the liquid is boiling, balance readings *M* are taken at corresponding times *t*.

A graph of the variation with time *t* of the balance reading *M* is shown in Fig. 3.2.

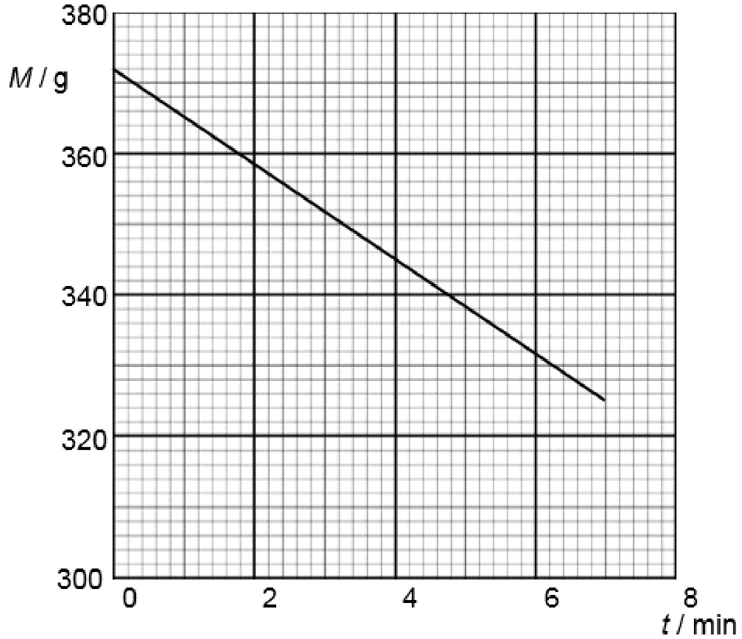


Fig. 3.2

(i) State the feature of Fig. 3.2 which suggests that the liquid is boiling at a steady rate.

…………………………………………………………………………………………………

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

(ii) Use data from Fig. 3.2 to determine a value for the specific latent heat of vaporisation l_v of the liquid. Explain your working.

l_v = ………………………………… J kg^{-1} [3]

(c) State, with a reason, whether the experimental value determined in **(b)(ii)** is likely to be an overestimate or an underestimate of the expected value for the specific latent heat of vaporisation of the liquid.

……………………………………………………………………………………………………

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

4 (a) Describe one condition necessary for observable two-source interference fringes to be formed.

……………………………………………………………………………………………………

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

(b) Two microwaves transmitters produce waves of the same frequency are placed at P and Q which are at a distance of 2*d* apart. Points Y and Z are equidistant from O. The line YXZ is perpendicular to OX, as shown in Fig. 4.1.

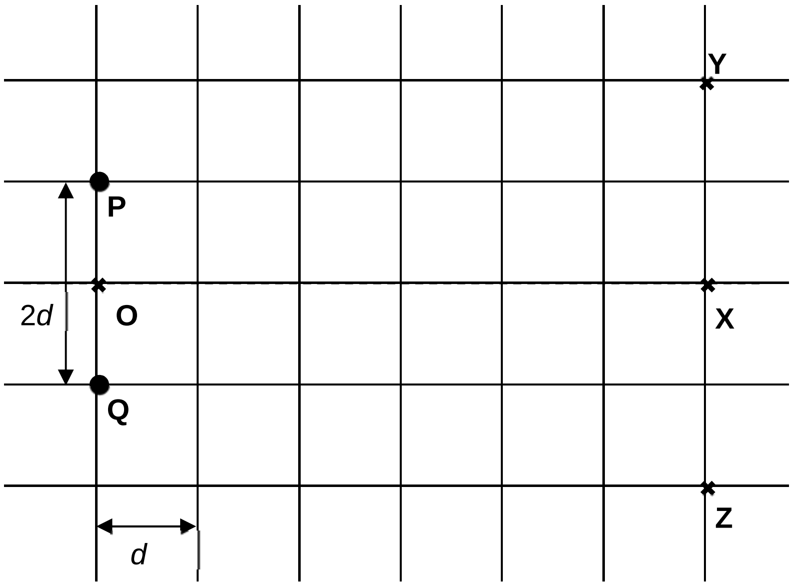


Fig. 4.1

[Turn over

(i) The waveforms of the microwaves from P and Q arriving at point Y vary with time as shown in Fig. 4.2.

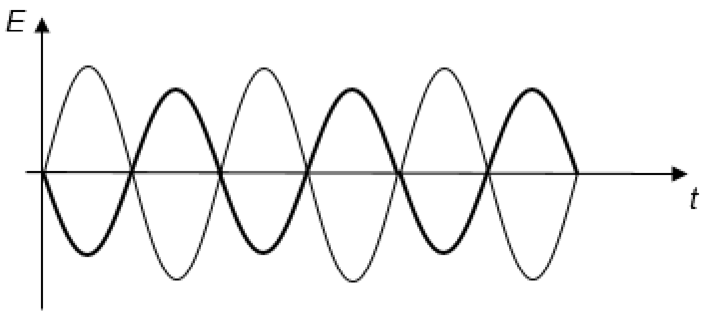


Fig. 4.2

1. State and explain if the waves arriving at Y are coherent.

…………………………………………………………………………………………….

…………………………………………………………………………………………….

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

2. Explain why a minimum intensity is detected at Y.

…………………………………………………………………………………………….

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

(ii) Show that the path difference of the waves arriving at point Y from P and Q is 0.625*d*.

[1]

(iii) As a detector is moved along a straight line from X to Y, it encountered three intensity maxima, including the maximum at X.

Determine the frequency of the wave in terms of *d*.

frequency = …………………Hz [3]

5 In a simple experiment to find the wavelength of monochromatic red light emitted by a laser, a fine beam of red laser light is incident on a diffraction grating as shown in Fig. 5.1. The diffraction grating has 300 lines per millimeter and it is arranged such that its plane is normal to the incident light.

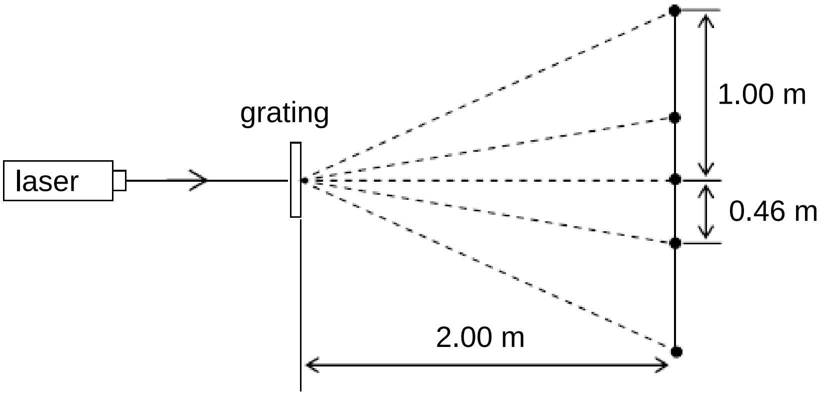


Fig. 5.1

Bright spots are observed at 0.46 m and 1.00 m from the central spot on a screen, which is 2.00 m from the grating.

(a) By considering the bright spot at 0.46 m from the central spot, calculate the wavelength of the laser light.

wavelength = …………………… m [3]

(b) Suggest and explain an experimental advantage of obtaining the wavelength of the laser light by using the second-order diffracted light rather than the first-order diffracted light.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

6 **(a)** Define *magnetic flux density*.

……..

……..

……. [2]

(b) Fig. 6.1 shows a long, straight, vertical wire WX, carrying a current of 9.0 A downwards. A second long, straight wire YZ is placed horizontally, and carries a current of 12.0 A in the direction shown.

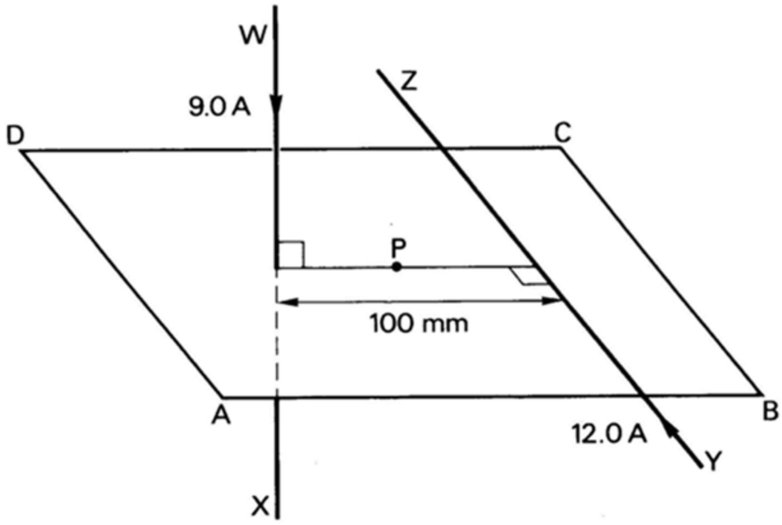


Fig. 6.1

ABCD is a horizontal, rectangular table-top. The wire YZ is parallel to the side BC of this table, and the wire WX passes through a small hole in the table. The perpendicular distance between the wires is 100 mm. P is the point 50 mm from YZ along the perpendicular between the wires.

(i) Determine the magnitude of the magnetic flux density at the point P due to WX only.

magnetic flux density = …………………….…. T [2]

(ii) Determine the magnitude of the net magnetic flux density at the point P.

net magnetic flux density at P = ………………. T [3]

7 A spring is attached to the middle of a horizontal wooden rod AB. A U-shaped metal wire ASTB is attached to the rod AB. The U-shaped wire is placed with side ST in a region of uniform magnetic flux pointing out of the page, as shown in Fig. 7.1.

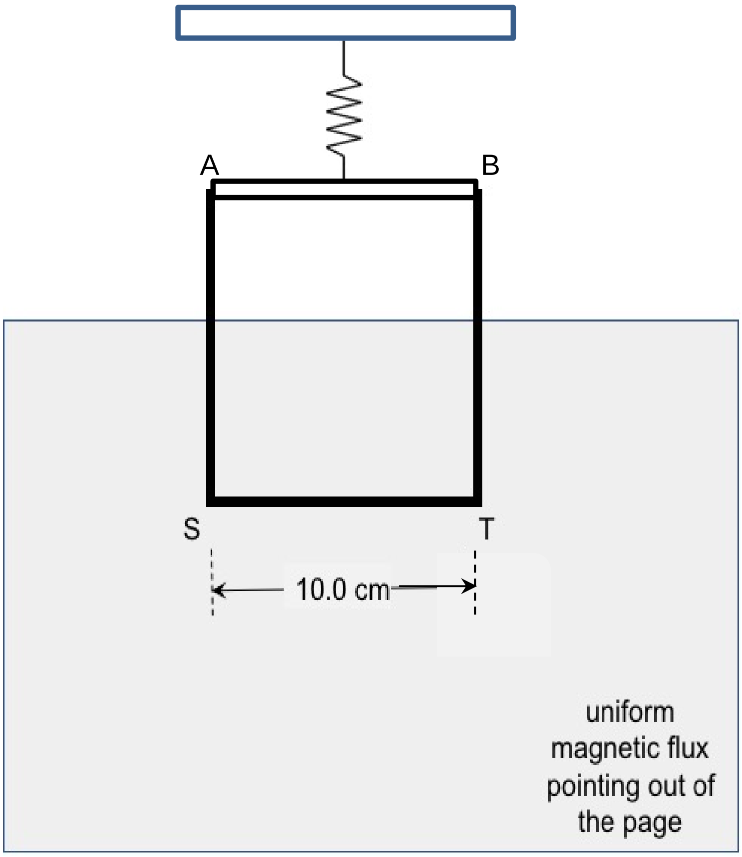


Fig. 7.1

The frame is then pulled down a distance of 1.0 cm and then released. The wire ST undergoes simple harmonic motion in the vertical direction.

(a) **(i)** Using Faraday's law of electromagnetic induction, explain why there is an induced e.m.f. in the wire ST while it is in motion.

....

....

....

....

.... [3]

(ii) Explain why the induced e.m.f. varies sinusoidally with time.

....

....

.... [2]

[Turn over

(b) The wooden rod AB is replaced by a metal rod. The frame is then set to oscillate as in **(a).**

(i) Sketch the time variation of the induced e.m.f. observed on Fig. 7.2. Explain your answer.

Fig. 7.2

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) Explain, how your graph in Fig. 7.2 will change, if any, when the metal rod AB and the wire ASTB are both fully inside the magnetic field.

…………………………………………………………………………………………………

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

8 **(a)** **(i)** State what is meant by the *photoelectric effect.*

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) Describe the principal features that are observed in the photoelectric effect that support the particulate nature of electromagnetic radiation.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(b) A low pressure sodium lamp produces an intensity of 0.20 W m^{-2} of yellow light of frequency 4.55×10^{14} Hz at a distance of 5.0 m from the lamp.

(i) Assuming that the lamp acts a point source, show that the intensity a distance 20 m from the lamp is 0.013 W m^{-2}.

[1]

(ii) Estimate the number of photons per second that would strike a piece of A4 size paper which is held 20 m perpendicular to the ray of light from the lamp.

number of photons per second = …………………… s^{-1} [3]

9 The bow is a powerful two-arm string machine used for archery. Fig. 9.1 shows the three types of bows, namely the Longbow, the Recurved and the Compound bow.

Fig. 9.1

Each bow consists of a limb and a handle as shown in Fig.9.2. The distance between the string and the bow handle at rest is known as the bracing distance. When a bow is drawn by the fingers of the archer, the string is not stretched but the shape of the bow is changed and bent and the string is displaced by a drawing distance. The shaft of the arrow is rested on the handle and the tail of the arrow is rested on the middle of the string.

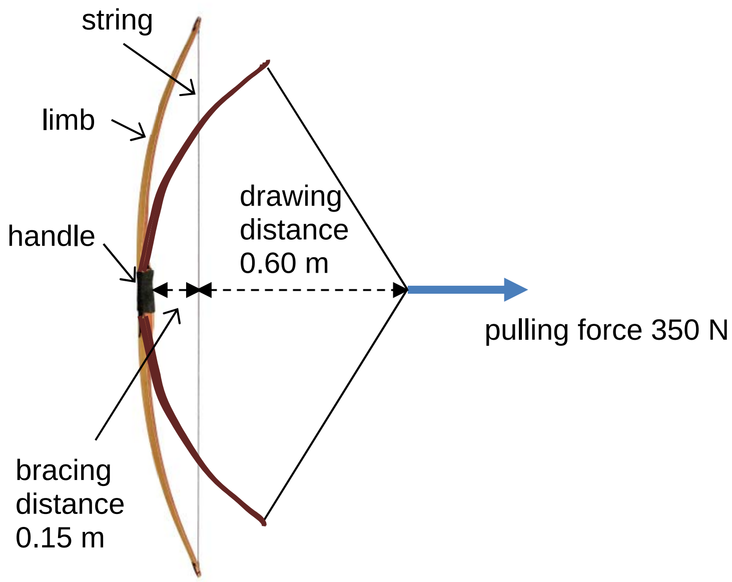


Fig. 9.2

In a Longbow, if we suppose that the bow is initially unstressed and the string is almost slack, then the archer starts to draw his arrow with a pulling force which is nearly zero and the pulling force increases with the drawing distance. The energy stored in the bow is equal to the work done in drawing back the string. In practice, a typical archer can draw an arrow back about 0.60 m and with a maximum force of about 350 N as shown in Fig. 9.3.

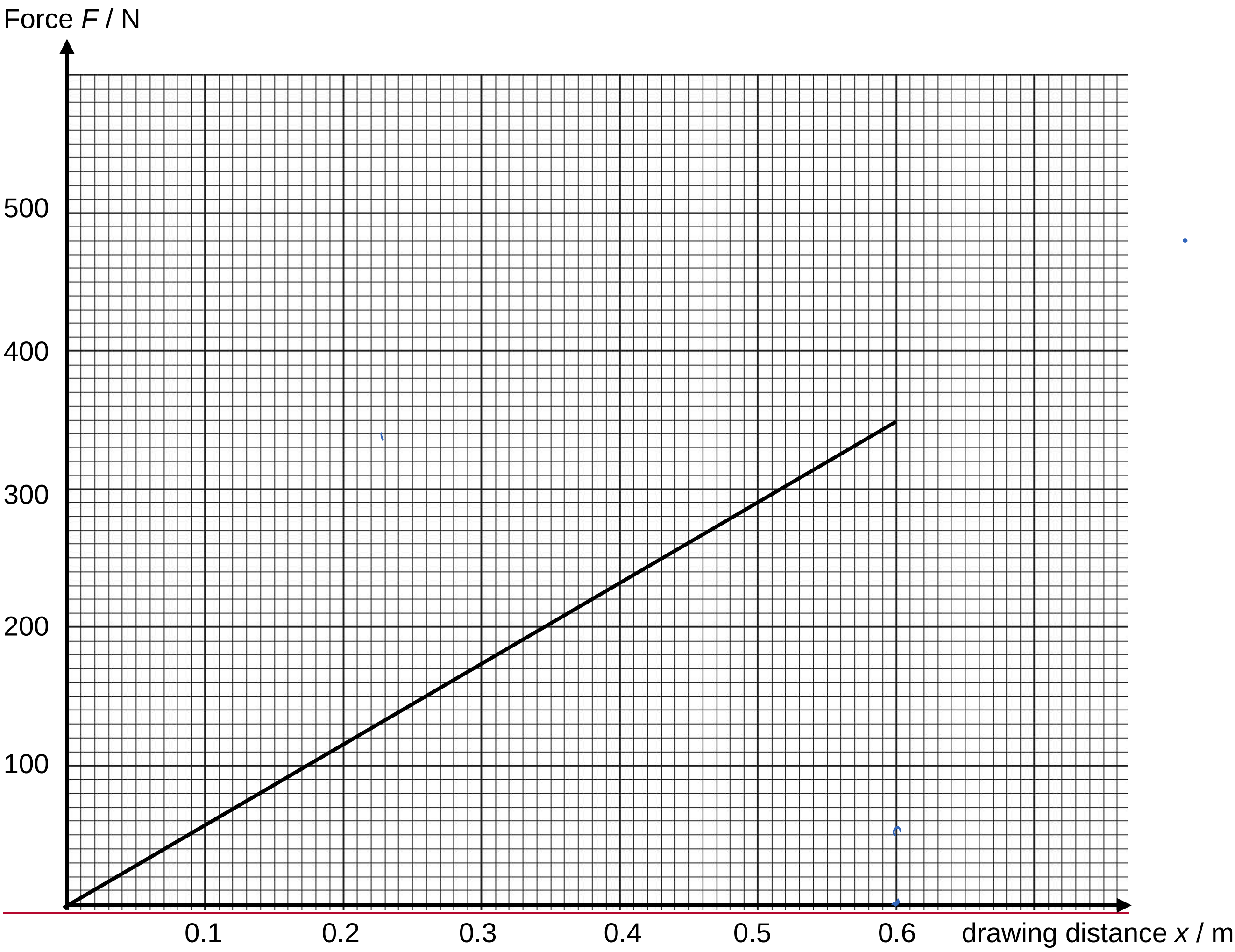


Fig. 9.3

The efficiency of the bow, η, can be defined as

$$\eta = \frac{\text{kinetic energy of the arrow}}{\text{elastic potential energy stored in the bow}}$$

When an arrow is shot, the force due to the tension in the string accelerates the arrow. A larger part of the energy stored in the bow is transferred to the arrow. Since this transferred energy is converted into the kinetic energy of the arrow ½ m v^2 (where v is the speed of the arrow as it leaves the bow), the increase in the length and therefore the mass of the arrow has two opposing effects: an increase in efficiency but a decrease in speed.

When a bow string is released, the string exerts a forward force on the arrow and causes it to accelerate forward. At the same time, there is a sudden compressive force along the length of the arrow, causing it to buckle. Hence the arrow will undergo **lateral vibrations** as it accelerates forward. Fig. 9.4 shows the top view of the arrow leaving bow (not to scale).

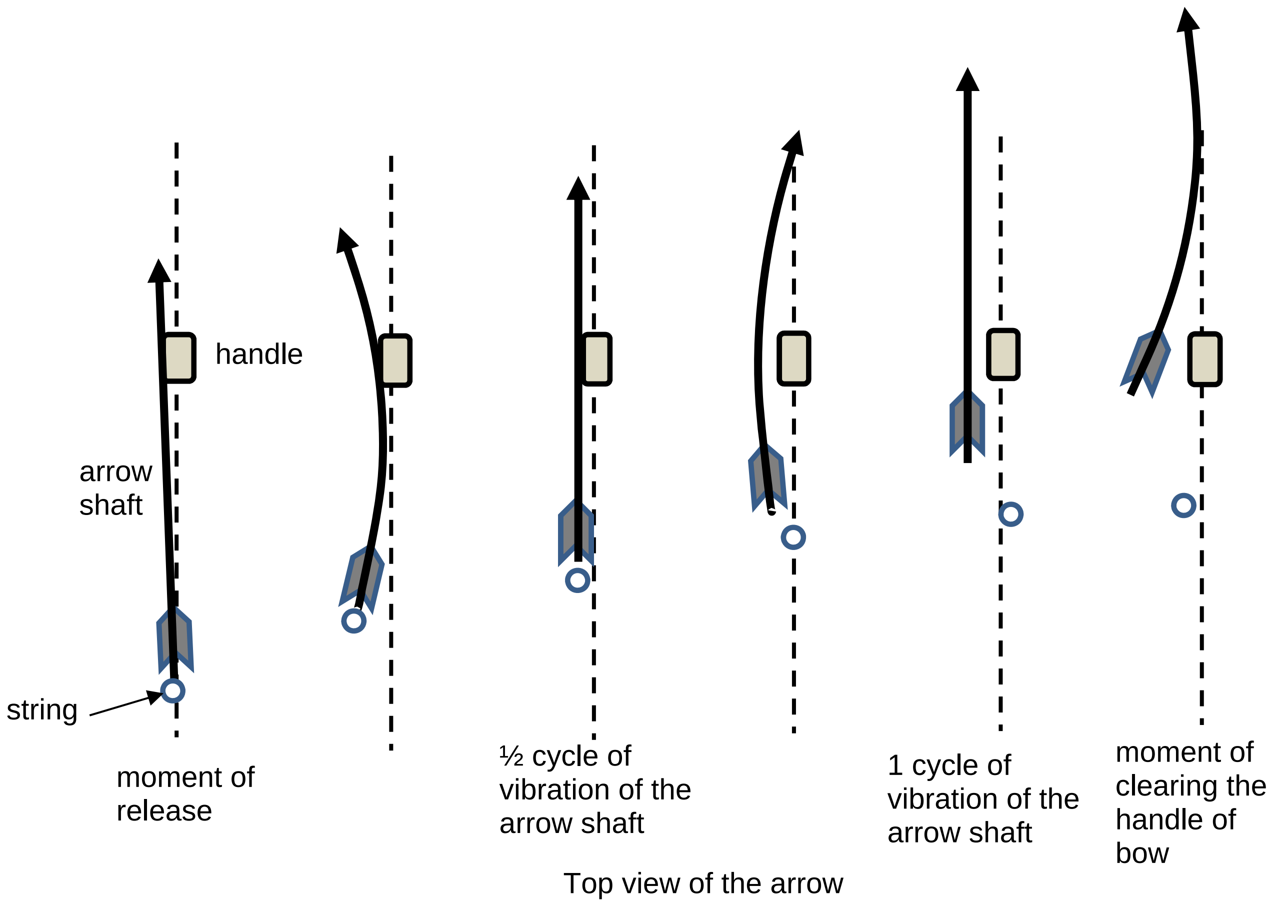


Fig. 9.4

Both the frequency and the amplitude of these vibrations must be matched to the bow if the arrow is to avoid hitting the side of the handle during its discharge. Ideally the arrow will make 1¼ vibrations from the moment of release until it finally clears the handle of the bow.

A Recurved bow is one in which the end of each limb curve away from the archer such that the limbs are braced with a bracing distance. The archer must start his pull with a non-zero force which is about 1/3 of the maximum force. When using a Recurved bow, the average force will be higher as compared to a Longbow without bracing.

In a Compound bow, which utilizes levers, the drawing force increases and decreases with the drawing distance as shown in Fig. 9.5.

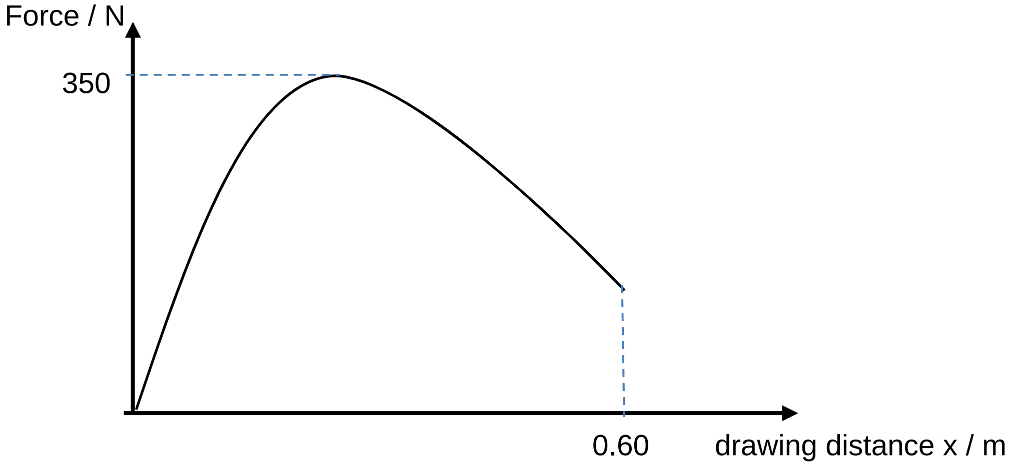


Fig. 9.5

(a) Explain what is meant by *lateral vibrations*.

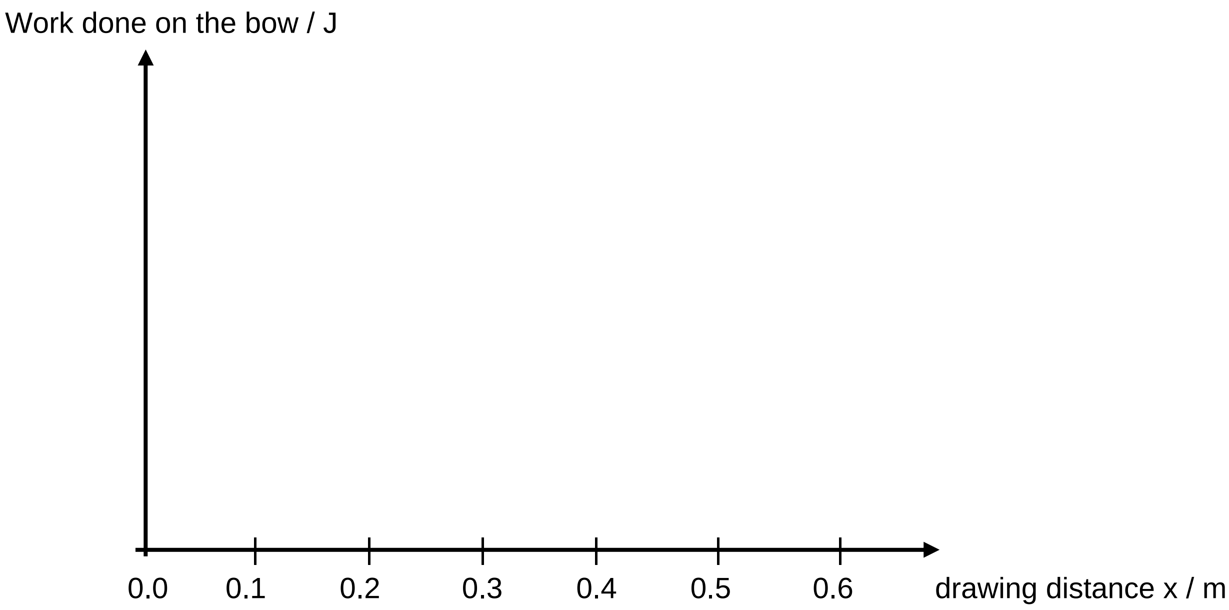
………..

……….. [1]

(b) Use the graph in Fig. 9.3 to calculate the energy stored in the Longbow when the maximum pulling force of 350 N is exerted on the string.

energy stored = ……………………………….…J [2]

(c) On Fig. 9.6, sketch a graph to show how the work done on the Longbow changes with the drawing distance of the string. Label the work done axis clearly.



[2]

Fig. 9.6

(d) It is thought that the efficiency η of the bow obeys a relation of the form

$$\eta = \frac{m}{m + k}$$

where m is the mass of the arrow and
k is a constant depending on the mass of the bow.

A student performed an experiment to investigate how η, the efficiency of the bow varies with m, the mass of the arrow. He obtained data which allows him to plot the graph of Fig. 9.7.

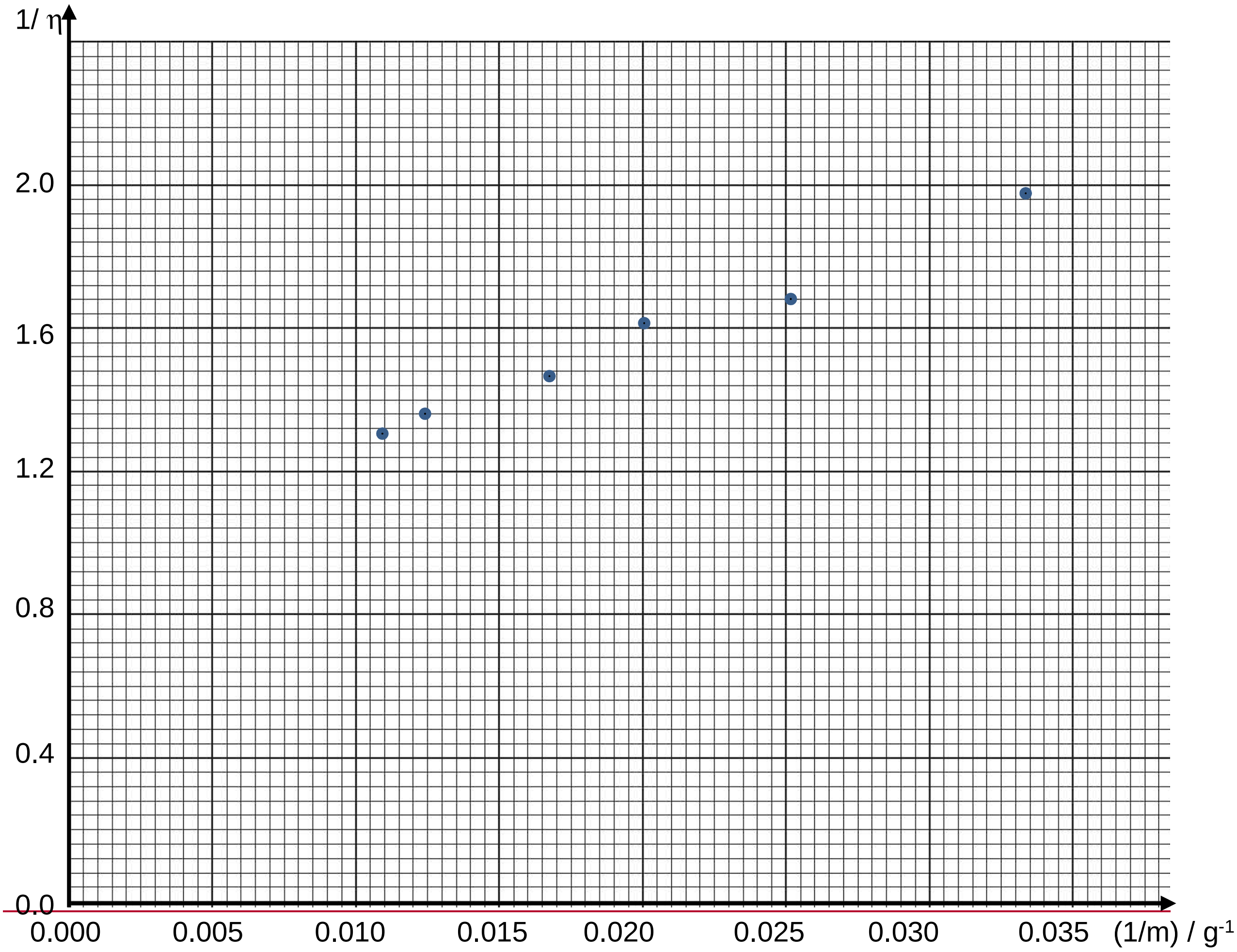


Fig. 9.7

(i) Draw the line of best fit for the points. [1]

(ii) Explain whether the relation in **(d)** is valid using the line drawn in Fig. 9.7.

……

……

……

……

…… [3]

(iii) Use the line drawn in Fig. 9.7 to determine the magnitude of the constant k in the expression in **(d)**.

k = ………………………………….. [2]

(iv) An arrow of mass 70 g is being shot from an initially unstressed Longbow drawn back as shown in Fig. 9.2. Use the graph in Fig. 9.7 and the definition of the efficiency to determine the speed of the arrow leaving the bow.

speed of the arrow = ………………………..m s^{-1} [3]

(e) Calculate the frequency of vibration for an arrow leaving the string at 50 m s^{-1}, from a bow of bracing distance of 0.15 m, and shot by an archer with a drawing distance 0.60 m, as shown in Fig. 9.2.

frequency of vibration = ………………………….. s^{-1} [2]

(f) **(i)** On Fig. 9.3, sketch the force-drawing distance graph for a Recurved bow which is already braced by 150 N. The maximum drawing force of 350 N is exerted on the string at the maximum drawing distance of 0.60 m. [1]

(ii) State and explain, in terms of the energy stored, why the Recurved bow is better than a Longbow.

………

……… [1]

(g) Refer to the force-drawing distance graph of a Compound bow as shown in Fig. 9.5. Suggest an advantage of a Compound bow as compared to the Longbow.

. ……

……… [1]

- END OF PAPER -

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	MARK SCHEME
CLASS	2T

PHYSICS — 9749/02
Paper 2

2 hours

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST
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Write in dark blue or black pen in the space provided. **[PILOT FRIXION ERASABLE PENS ARE NOT ALLOWED]**
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Do not use staples, paper clips, highlighters, glue or correction fluid.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/6			
Q2	/10			
Q3	/7			
Q4	/8			
Q5	/5			
Q6	/7			
Q7	/10			
Q8	/8			
Q9	/20			
TOTAL FOR PAPER 2	/ 80			

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			$\approx (1/(36\pi)) \times 10^{-9}$ 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	=	$u t + \frac{1}{2} a t^2$
	v^2	=	$u^2 + 2 a s$
work done on / by a gas	W	=	$p \Delta V$
hydrostatic pressure	P	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

1 A hydroelectric power station could make a significant contribution to energy requirements.
Fig. 1.1 shows a dam at the hydroelectric power station which traps water behind a dam. When the height of the water behind the dam reaches 10.0 m, the water is released and passed through the turbines.

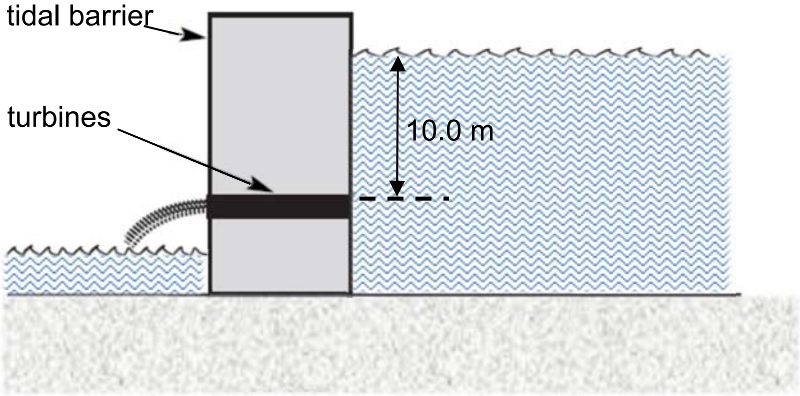


Fig. 1.1

(a) It takes 6.0 hours for a total mass of 1.32×10^{12} kg of water to flow through the turbines. The centre of mass of this amount of water is 5.0 m above the turbines.

Calculate the loss in the potential energy of the trapped water when it is released through the turbines completely. Assume that the density of the water is uniform.

loss in the potential energy = ………………………………..J **[2]**

Loss in potential energy
= mgh
= $1.32 \times 10^{12} \times 9.81 \times 5.0$ (since the average height of the water is 5.0 m)
= 6.5×10^{13} J

(b) The potential energy calculated in part (a) is lost over a time period of 6.0 hours and the efficiency of the power station is 40 %.

Calculate the average power output of the power station over this time period of 6.0 hours. **[3]**

Power from sea water
= gravitational energy lost / time
= $6.5 \times 10^{13} / 6.0 \times 3600$
= 3000×10^{6} W

Average power output = $3000 \times 10^{6} \times 0.40$
= 1200 MW

	(c)	Suggest how the output power of the hydroelectric power station can be controlled as the level of trapped water decreases.	

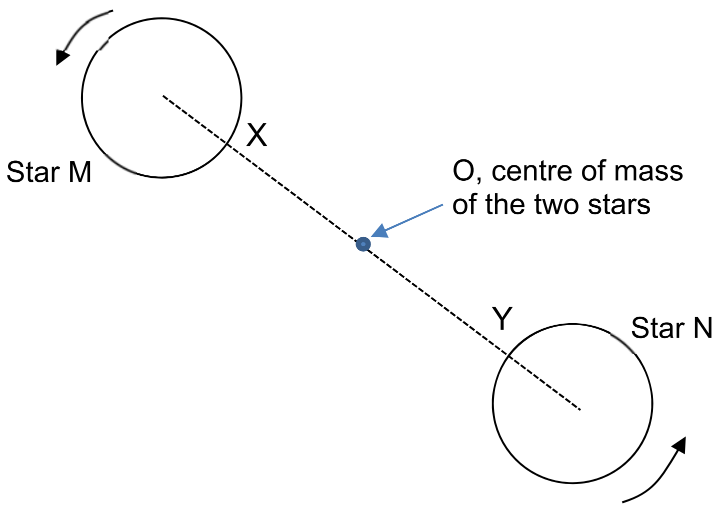
………………………………………………………………………………………………………

………………………………………………………………………………………………………

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

		There are valves within the dam that controls and regulates the flow of water into the turbines.	

2 In a binary star system, two stars, each of equal mass 3.5 x 10^{30} kg, rotate about their common centre of mass O which is equidistant from the centres of the stars. The separation between the two centres of the stars is 2.0 x 10^{11} m.



	(a)	Define gravitational potential at a point.	
		……………………………………………………………………………………… ……………………………………………………………………………………… ………………………………………………………………………………………	[1]
		The gravitational potential at a point is the work done per unit mass by an external agent in bringing a point mass from infinity to that point.	
	(b)	Calculate the gravitational potential at O, the centre of mass of the binary star system.	[2]
		Gravitational potential at the centre of mass O $= (-\frac{Gm}{0.5d}) + (-\frac{Gm}{0.5d})$	

$$= -\frac{4Gm}{d}$$

$$= -\frac{4(6.67\ x\ 10^{-11})(3.5\ x\ 10^{30})}{2.0\ x\ 10^{11}}$$

$$= -4.67\ x\ 10^{9} Jkg^{-1}$$

Where d is the separation between the two stars.

(c) An asteroid passes through point O, at a speed v. Determine the minimum speed of the asteroid if it is to escape from the gravitational pull of the binary star system.

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

By the principle of conservation of energy,

Loss in kinetic energy of the asteroid = Gain in gravitational potential energy of the asteroid as it completely leaves the gravitational pull of the binary star system

$$0 - \frac{1}{2}mv^2 = -\frac{4GMm}{d} - 0$$

$$v = \sqrt{\frac{8GM}{d}}$$

$$= \sqrt{\frac{8(6.67\ x\ 10^{-11})(3.5\ x\ 10^{30})}{2.0\ x\ 10^{11}}}$$

$$v = 9.66\ x\ 10^{4}\ ms^{-1}$$

(d) (i) On Fig.2.1, sketch a graph showing the variation of gravitational potential along the line XY between the two stars. [2]

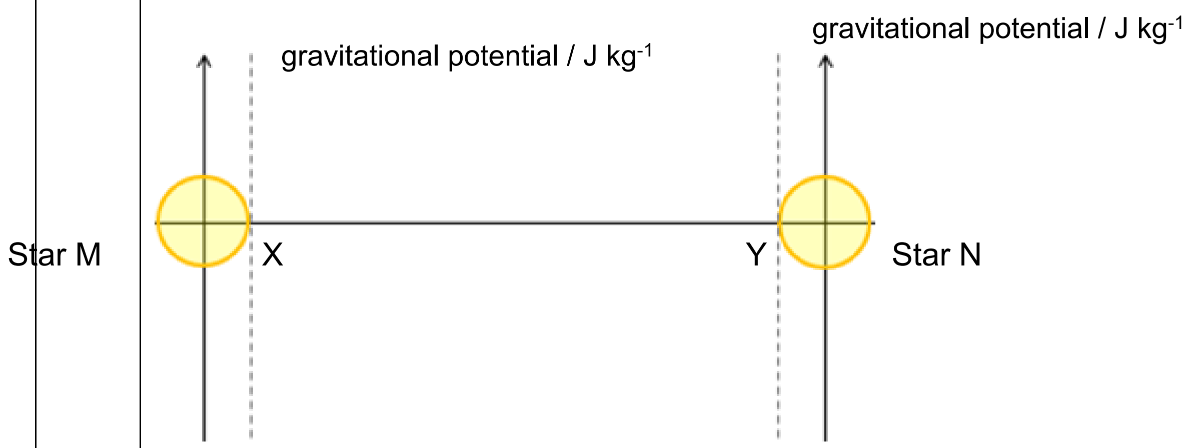
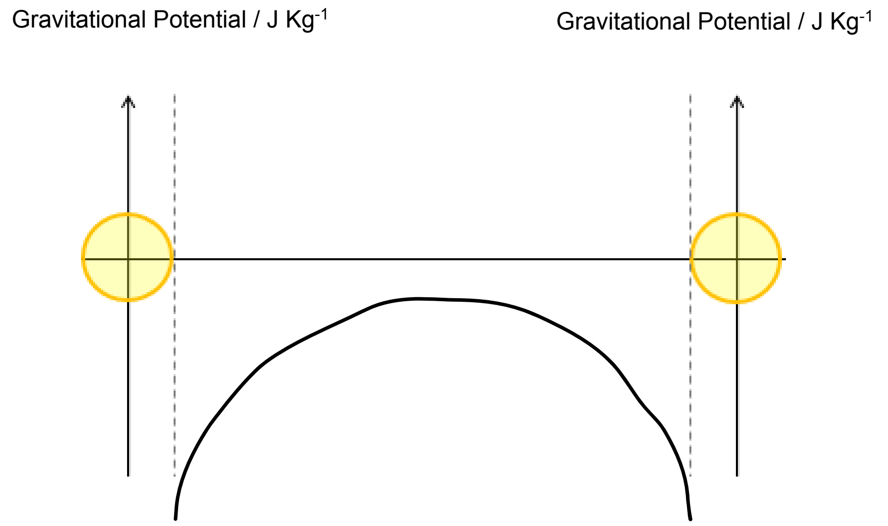


Fig. 2.1



		(ii)	Hence describe the variation in gravitational potential energy of an object moving from O towards star M.	
			…………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………	[2]
			The gravitational potential energy of the object will decrease as it moves towards one of the stars. As the object leaves the centre of mass, the gravitational potential decreases at an increasing rate and since the mass of the object is constant, the gravitational potential energy of the object decreases.	

3	**(a)**	Define *specific latent heat*.	
		…………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………	[1]
		Solution: is a value that is numerically equal to the thermal energy transferred when **unit mass** of a substance **changes state**, **without any change of temperature**.	

(b) A beaker containing a liquid is placed on a balance, as shown in Fig. 3.1.

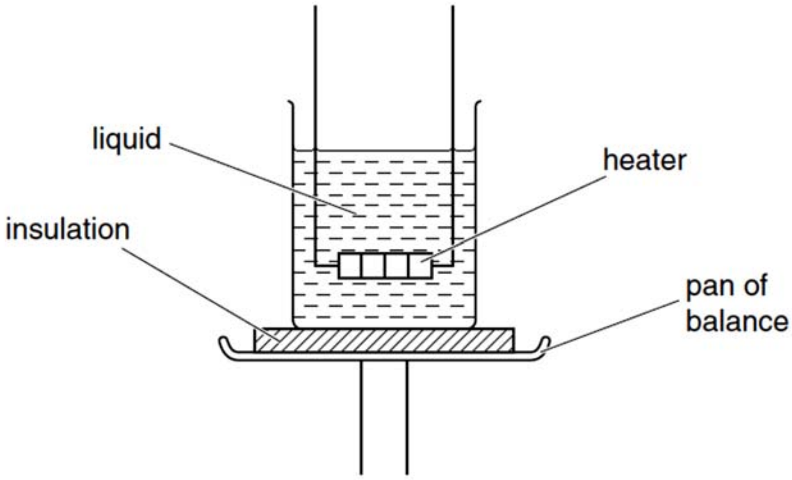


Fig. 3.1

A heater of power 120 W is immersed in the liquid. The heater is switched on and, when the liquid is boiling, balance readings *M* are taken at corresponding times *t*.

A graph of the variation with time *t* of the balance reading *M* is shown in Fig. 3.2.

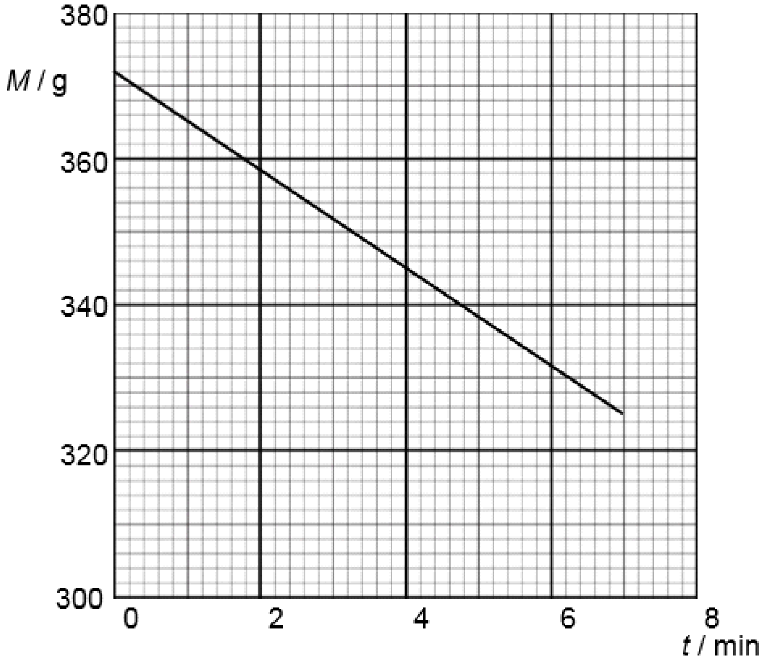


Fig. 3.2

(i) State the feature of Fig. 3.2 which suggests that the liquid is boiling at a steady rate.

....

.... [1]

Solution:

Straight line graph with **constant gradient**

(Note: total mass *M* decreases linearly with time which means that mass of liquid evaporated increases linearly with time)

		(ii)	Use data from Fig. 3.2 to determine a value for the specific latent heat of vaporisation l_v of the liquid. Explain your working.	
			l_v = ... J kg^{-1}	[3]
			Solution: *Q = Pt = ml$_v$ (where m is the mass that has evaporated)* $P = \frac{m}{t} l_v$ $\frac{m}{t} = -\frac{\Delta M}{t}$ *(Note: $\frac{\Delta M}{t}$ is a negative gradient of the graph in Fig 3.2 [where ΔM is the mass loss]* *Since gradient of graph =* $-\frac{\Delta M}{t}$ $P = (-\frac{\Delta M}{t})l_v$ or [power = - gradient × l_v] Determine gradient of graph *(or two points separated by at least 3.5 minutes)* $120 = l_v \times \frac{(372 - 325) \times 10^{-3}}{(7.0 - 0) \times 60}$ $l_v = 1.07 \times 10^6$ J kg^{-1} *(accept 2 s.f.) [will get a negative gradient but times negative will become positive]*	
	(c)	State, with a reason, whether the experimental value determined in **(b)(ii)** is likely to be an overestimate or an underestimate of the expected value for the specific latent heat of vaporisation of the liquid.		
		....		[2]
		Solution: some energy/ heat is lost to surroundings so value is an overestimate In calculating for l_v in part bii, heat lost was not taken into consideration $P = (-\frac{\Delta M}{t})l_v$ However, if heat lost is taken into consideration,		

$P = (-\frac{\Delta M}{t})l_v + Q$

l_v will be a smaller value.
Therefore, l_v found in bii is an overestimation.

4 (a) Describe one condition necessary for observable two-source interference fringes to be formed.

....

.... [1]

Solution:

The sources must be **coherent**; i.e. they must maintain a *constant phase difference* with respect to each other.
OR
The two wave sources must also emit waves of roughly the same amplitude.

(b) Two microwaves transmitters produce waves of the same frequency are placed at P and Q which are at a distance of 2*d* apart. Points Y and Z are equidistant from O. The line YXZ is perpendicular to OX, as shown in Fig. 4.1.

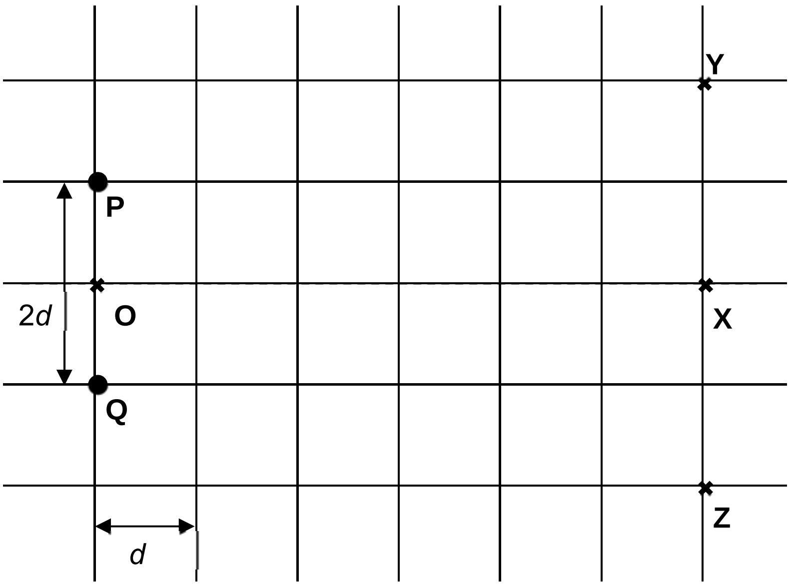


Fig. 4.1

(i) The waveforms of the microwaves from P and Q arriving at point Y vary with time as shown in Fig. 4.2.

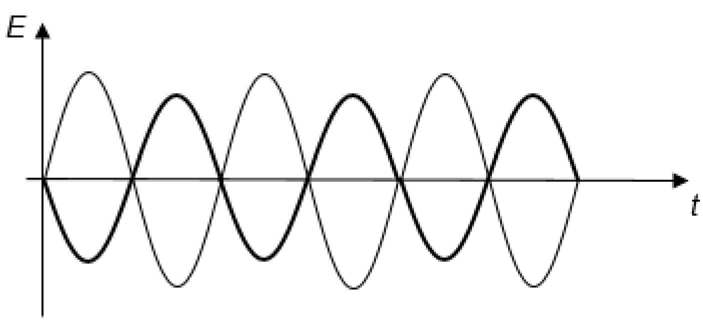


Fig. X.2

1. State and explain if the waves arriving at Y are coherent.

....

.... [2]

Solution:
They are coherent
as the phase difference between them is a constant value of π.

2. Explain why a minimum intensity is detected at Y.

....

.... [1]

Solution:

From the graph, the waves arrive at point Y in antiphase, and interfere destructively.

(ii) Show that the path difference of the waves arriving at point Y from P and Q is 0.625*d*.

[1]

Solution:

Path difference, = QY – PY = $\left(\sqrt{6^2+3^2}-\sqrt{6^2+1^2}\right) d$

= 0.625 d

(iii) As a detector is moved along a straight line from X to Y, it encountered three intensity maxima, including the maximum at X.

Determine the frequency of the wave in terms of *d*.

frequency = …………………Hz [3]

Solution:

3rd order minimum is formed at Y (can see from graph that the waves meet in antiphase, hence destructive interference occurs.)

Path difference = 0.625 d = 2.5 λ

$\lambda = 0.25\, d$

From $v = f\lambda$

$$f = \frac{v}{\lambda}$$

$$f = \frac{3.0 \times 10^8}{0.25d}$$

$$= \frac{1.2 \times 10^9}{d}\ \text{Hz}$$

5 In a simple experiment to find the wavelength of monochromatic red light emitted by a laser, a fine beam of red laser light is incident on a diffraction grating as shown in Fig.5.1. The diffraction grating has 300 lines per millimeter and it is set so that its plane is normal to the incident light.

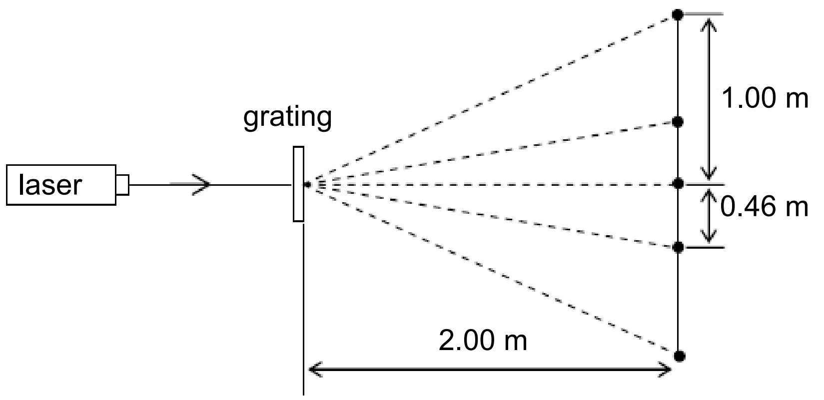


Fig. 5.1

Bright spots are observed at 0.46 m and 1.00 m from the central spot on a screen, which is 2.00 m from the grating.

(a) By considering the bright spot at 0.46 m from the central spot, calculate the wavelength of the laser light.

wavelength = ... m [3]

Solution:

The first order maximum is diffracted at an angle $\theta = \tan^{-1}(0.46/2.00) = 12.95^{\circ}$.

From $d \sin\theta = n\lambda$

where $d = 1/N = 1/300 \times 10^3$ and $n = 1$

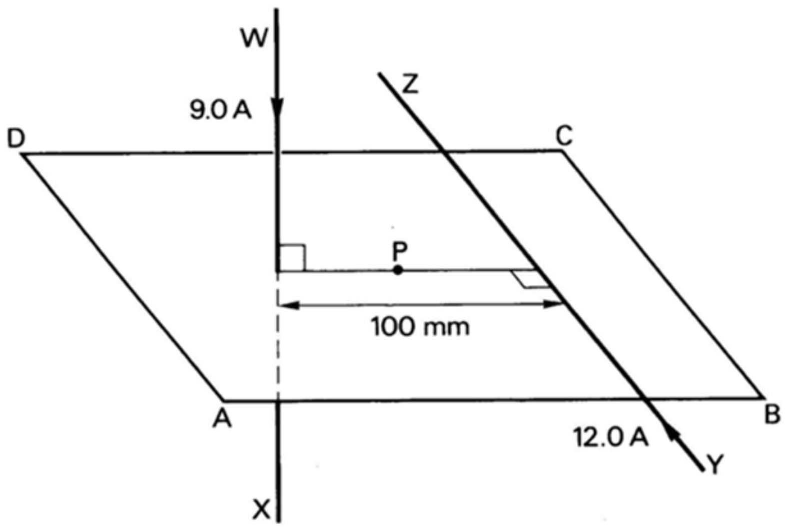
$$\frac{\sin 12.95}{300 \times 10^3} = 1 \times \lambda$$

$\Rightarrow \lambda = 7.47 \times 10^{-7}$ m

(b) Suggest and explain an experimental advantage of obtaining the wavelength of the laser light by using the second-order diffracted light rather than the first-order diffracted light.

....

			....	[2]
			Solution: Using the second-order diffracted light to measure the wavelength is more accurate. This is because the larger angle of diffraction can be measured experimentally with a lower percentage error for a given precision of the measuring instrument used.	B1 B1

6	**(a)**	Define *magnetic flux density*.		
		....		**[2]**
		Solution: It is the **force experienced per unit length of wire** carrying **per unit electric current** when placed inside a magnetic field, with the **conductor placed perpendicular to the magnetic field.**		
	(b)	Fig. 6.1 shows a long, straight, vertical wire WX, carrying a current of 9.0 A downwards. A second long, straight wire YZ is placed horizontally, and carries a current of 12.0 A in the direction shown.  **Fig. 6.1** ABCD is a horizontal, rectangular table-top: the wire YZ is parallel to the side BC of this table, and the wire WX passes through a small hole in the table. The perpendicular distance between the wires is 100 mm. P is the point 50 mm from YZ along the perpendicular between the wires.		
		(i)	Determine the magnitude of the magnetic flux density at the point P due to WX only.	
			magnetic flux density at P due to WX = ... T	**[2]**
			Solution:	

$$B_{WX,\,P} = \frac{\mu_0 I_{WX}}{2\pi r_p}$$
$$= \frac{(4\pi\times10^{-7})(9.0)}{2\pi(50\times10^{-3})}$$
$$= 3.6\times10^{-5}\ \text{T}$$

(ii) Determine the magnitude of the net magnetic flux density at the point P.

net magnetic flux density at P = ……………… T **[3]**

Solutions

$$B_{YZ,\,P} = \frac{\mu_0 I_{YZ}}{2\pi r_p}$$
$$= \frac{(4\pi\times10^{-7})(12.0)}{2\pi(50\times10^{-3})}$$
$$= 4.8\times10^{-5}\ \text{T}$$

$$B_{res} = \sqrt{B_{WX,\,P}^{\,2} + B_{YZ,\,P}^{\,2}}$$
$$= \sqrt{(3.6\times10^{-5})^2 + (4.8\times10^{-5})^2}$$
$$= 6.0\times10^{-5}\text{T}$$

7 A spring is attached to the middle of a horizontal wooden rod AB. A U-shaped metal wire ASTB is attached to the rod AB. The U-shaped wire is placed with side ST in a region of uniform magnetic flux pointing out of the page, as shown in Fig. 7.1

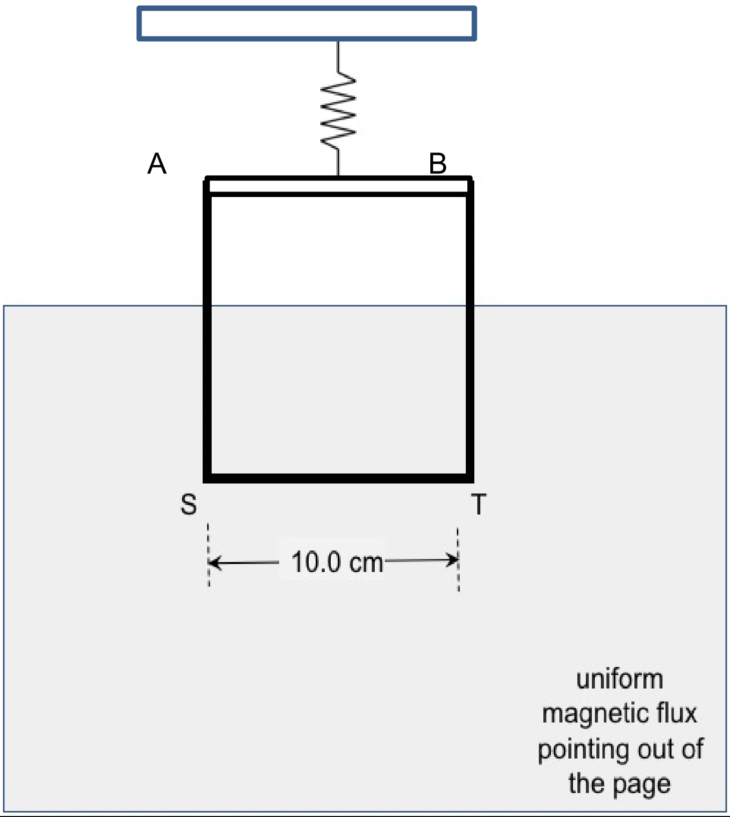


Fig. 7.1

The frame is then pulled down a distance of 1.0 cm and then released. The wire ST undergoes simple harmonic motion.

(a) **(i)** Using Faraday's law of electromagnetic induction, explain why there is an induced e.m.f. in the wire ST while it is in motion

....

....

....

....

.... [3]

As the frame is in motion, the wire ST cuts the magnetic field and there is a rate of change of magnetic flux linkage

The e.m.f. induced is proportional to the rate of change of flux linkage
Hence there is an induced e.m.f. in the wire ST.

(ii) Explain why the induced e.m.f. varies sinusoidally with time,

....

....

.... [2]

Solution:

As the frame oscillates, its velocity will vary in a sinusoidal manner.

Therefore, the rate of change of magnetic flux linkage will also change sinusoidally.

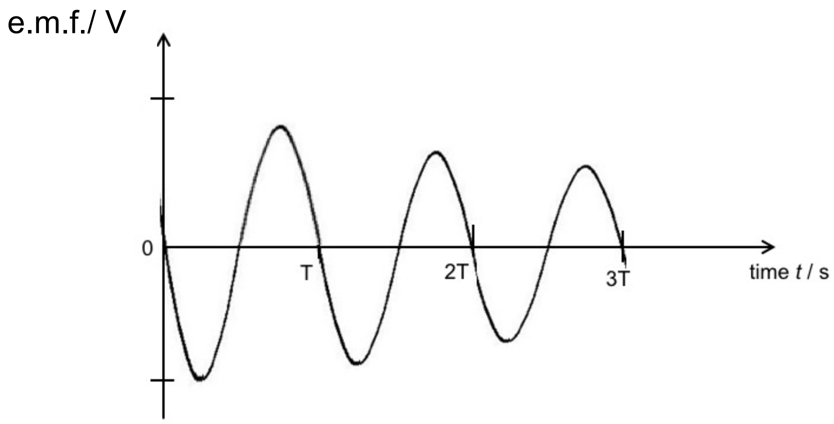
Since the emf across ST is proportional to the rate of change of magnetic flux linkage, it will also vary sinusoidally.

(b) The wooden rod AB is replaced by a metal rod. The frame is then set to oscillate as in (a).

(i) Sketch the time variation of the induced e.m.f. observed on Fig. 7.2. Explain your answer. [3]

Fig. 7.2

Solution:



1 mark: sinusoidal e.m.f with decreasing amplitude

The induced current results in a magnetic force on the metal wire ST which opposes the motion of the frame ASTB and hence the oscillation is damped.

This affects the maximum speed and hence induced e.m.f in the frame. Therefore, amplitude of e.m.f decreases.

(ii) Explain, how your graph in Fig. 7.2 will change, if any, when the metal rod AB and the wire ASTB are now inside the magnetic field.

....

....

.... [2]

Solution:

Case 1 (considering the whole loop)
The oscillation will be undamped and the amplitude will be unchanged because there is no e.m.f. induced in the frame and there will be no current in the loop and there is no

			electromagnetic damping. OR There is no change in the magnetic flux linkage, thus there is no emf induced. Thus, the graph is a straight horizontal line, cutting the emf = 0. *Case 2 (considering ST)* Net emf induced is zero, therefore no current within rod ST, thus, no damping force. The graph drawn in Fig 7.2 remains the same.	

8	**(a)**	**(i)**	State what is meant by the *photoelectric effect.*	
			....	[1]
			Photoelectric effect is a phenomenon in which electrons are emitted from the surface of a metal when it is irradiated with electromagnetic radiation of high enough frequency.	
		(ii)	Describe the principal features that are observed in the photoelectric effect that support the particulate nature of electromagnetic radiation.	
			....	[3]
			Experimental observations which support the particulate nature of em radiation are 1. There is a minimum frequency below which no photoelectric emission of electrons is possible, even with very intense radiation. 2. The maximum KE of the emitted electrons increases with the frequency of the radiation. The max KE does not depend on the intensity of the radiation. 3. Photoelectrons are emitted almost immediately when radiation was incident; no time lag was observed. 4. The rate of emission of photoelectrons is proportional to the intensity of the incident radiation. Max three marks.	
	(b)		A low pressure sodium lamp produces an intensity of 0.2 W m^{-2} of yellow light of frequency 4.55 x 10^{14} Hz at a distance of 5.0 m from the lamp.	
		(i)	Assuming that the lamp acts a point source, show that the intensity a distance 20 m from the lamp is 0.013 W m^{-2}.	

				[1]
			Solutions For a point source of constant power, intensity is inversely proportional to the distance from the source, i.e. $I \propto 1/r^2$ $I' / I = (1/r'^2) / (1/r^2) = (r/r')^2$ $I' / 0.20 = (5/20)^2$ $I' = 0.013$ W m^{-2}	
		(ii)	Estimate the number of photons per second that would strike a piece of A4 size paper which is held 20 m perpendicular to the light from the lamp. number of photons per second = …………………… s^{-1}	[3]
			Solutions Energy of each photon = hf $= 6.63 \times 10^{-34} \times 4.55 \times 10^{14}$ $= 3.02 \times 10^{-19}$ J Estimate area of writing paper = 0.15×0.30 m^2 Intensity = E / t A = Nhf / t A = (N/t) hf / A $0.013 = (N/t)\ 3.02 \times 10^{-19}$ J / 0.15×0.30 $N/t = 1.94 \times 10^{15}$	

9 The bow is a powerful two-arm string machine used for archery. Figure. 9.1 shows the three types of bows, namely the Longbow, the Recurved and the Compound bow.

Longbow | Recurved bow | Compound bow.

Fig. 9.1

Each bow consists of a limb, a handle and a as shown in Fig.9.2. The distance between the string and the bow handle at rest is known as the bracing distance. When a bow is drawn by the fingers of the archer, the string is not stretched but the shape of the bow is changed and bent and the string is displaced by a drawing distance. The shaft of the arrow is rested on the handle and the tail of the arrow is rested on the middle of the string.

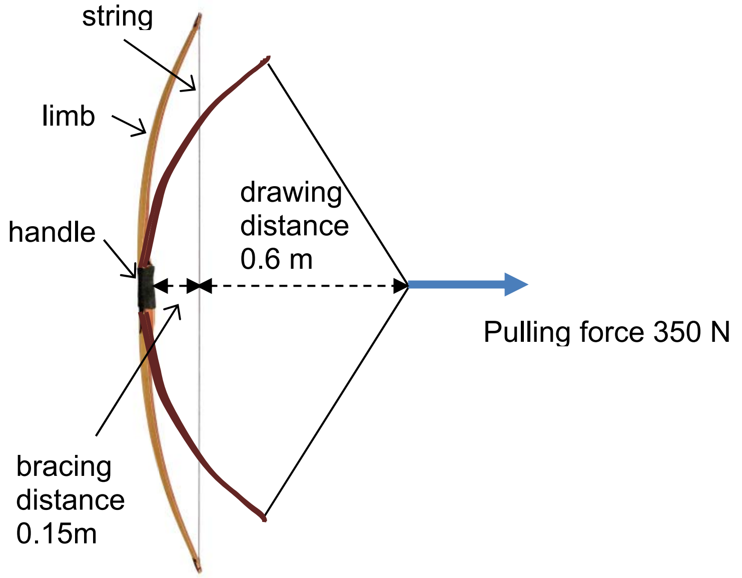


Fig. 9.2

In a Longbow, if we suppose that the bow is initially unstressed and the string is almost slack, then the archer starts to draw his arrow with a pulling force which is nearly zero and the pulling force increases with the drawing distance. The energy stored in the bow is equal to the work done in drawing back the string. In practice, a typical archer can draw an arrow back about 0.6 m and with a maximum force of about 350 N as shown in Fig. 9.3.

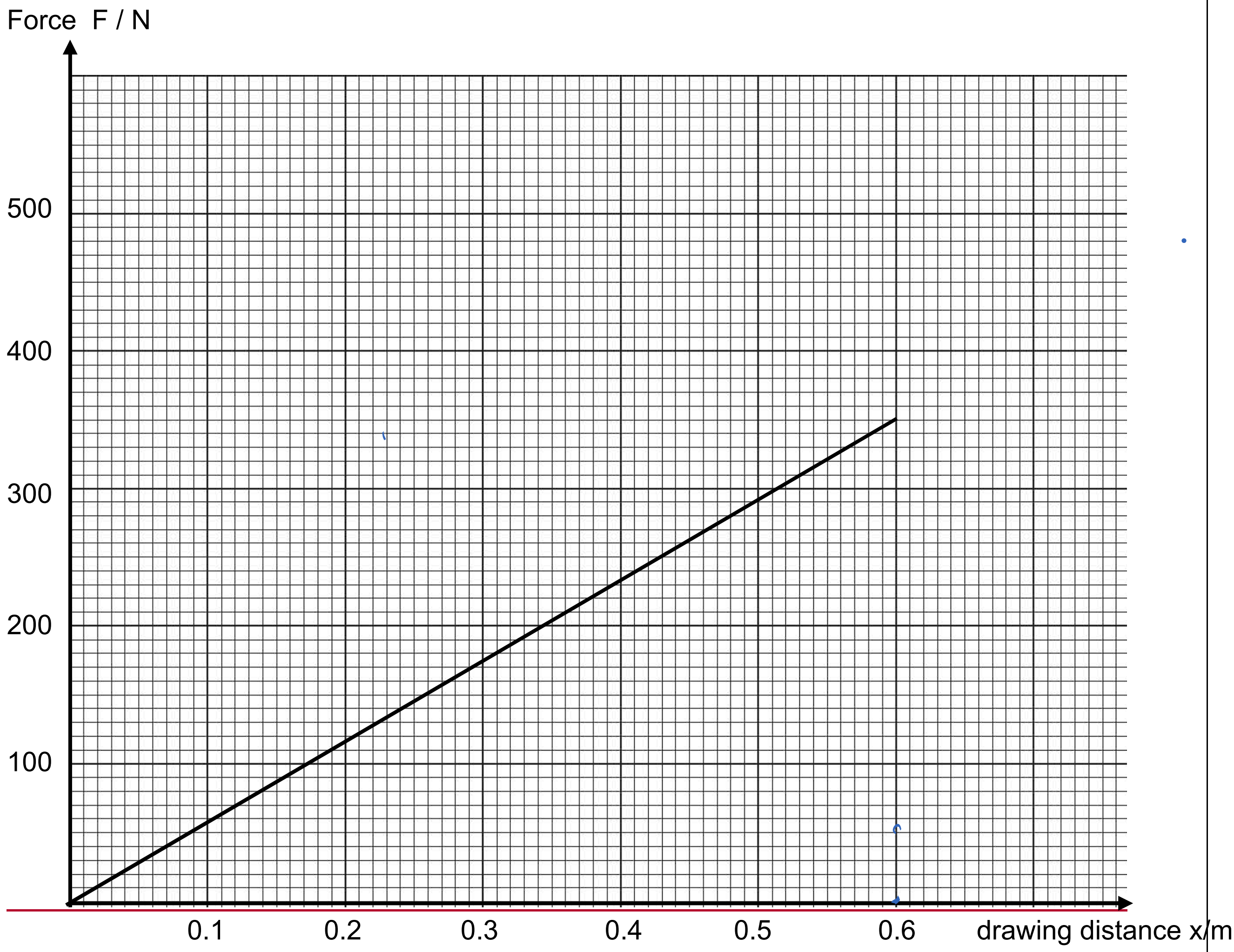


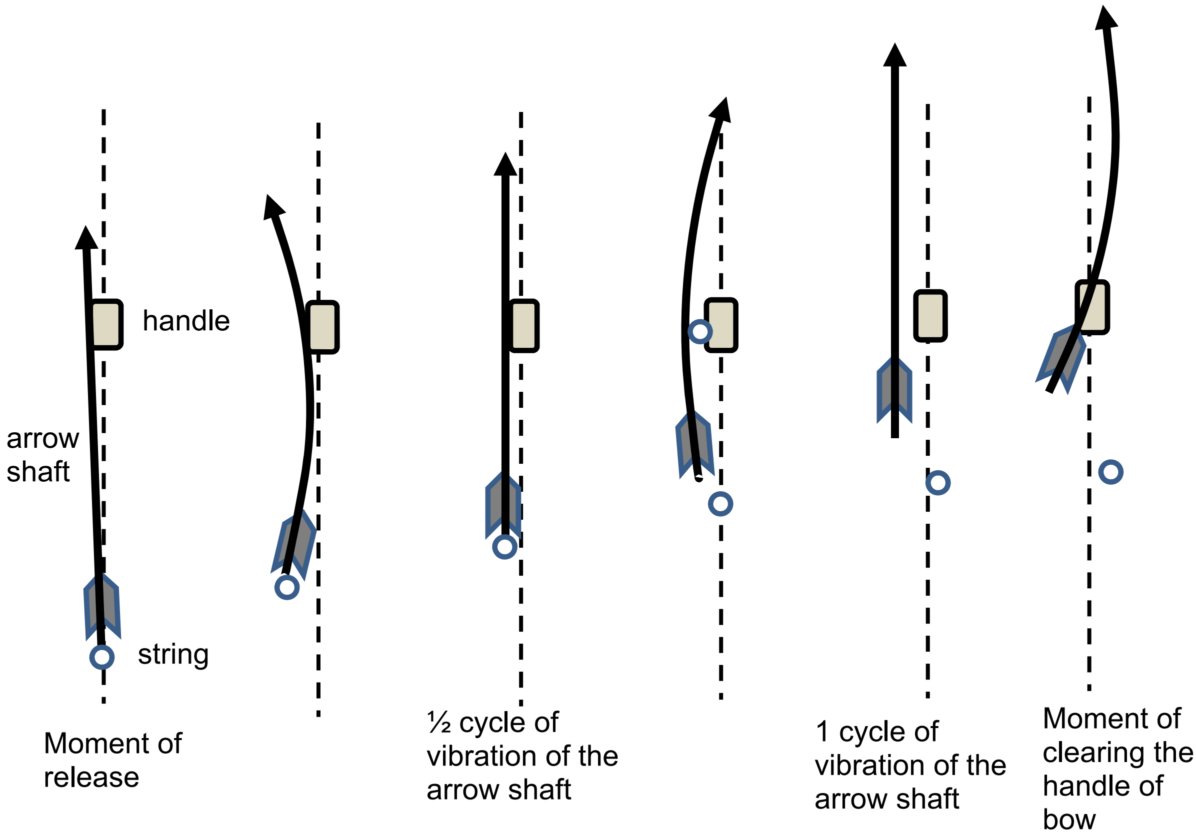
Fig. 9.3

The efficiency of the bow, η, can be defined as

$$\eta = \frac{\text{kinetic energy of the arrow}}{\text{elastic potential energy stored in the bow.}}$$

When an arrow is shot, the force due to the tension in the string accelerates the arrow. A larger part of the energy stored in the bow is transferred to the arrow. Since this transferred energy is converted into the kinetic energy of the arrow ½ mv^2 (where v is the speed of the arrow as it leaves the bow), the increase in the length and therefore the mass of the arrow has two opposing effects: an increase in efficiency but a decrease in speed.

When a bow string is released, the string exerts a forward force on the arrow and causes it to accelerate forward. At the same time, there is a sudden compressive force along the length of the arrow causes it to buckle. Hence the arrow will undergo **lateral vibrations** as it accelerates forwards. Fig. 9.4 shows the view from above the arrow leaving bow (not to scale)



Top view of the arrow

Fig. 9.4

Both the frequency and the amplitude of these vibrations must be matched to the bow if the arrow is to avoid hitting the side of the handle during its discharge. Ideally the arrow will make 1¼ vibrations from the moment of release until it finally clears the handle of the bow.

A Recurved bow is one in which the end of each limb curve away from the archer such that the limbs are braced with a bracing distance. The archer must start his pull with a non-zero force which is about 1/3 of the maximum force. When using a Recurved bow, the average force will be higher as compared to a Longbow without bracing.

In a Compound bow, which utilizes levers, the drawing force increases and decreases with the drawing distance as shown in Fig.9.5.

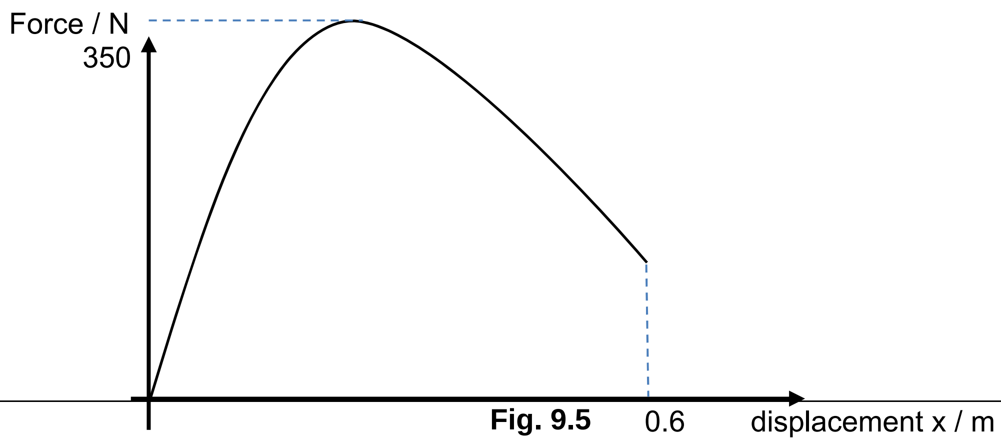


Fig. 9.5

(a) Explain what is meant by *lateral vibrations*.

....

.... [1]

Solution:
Periodic to and fro motion of a segment of the arrow from its position before release in a direction perpendicular to the motion of arrow/ limb of the bow/ left-right

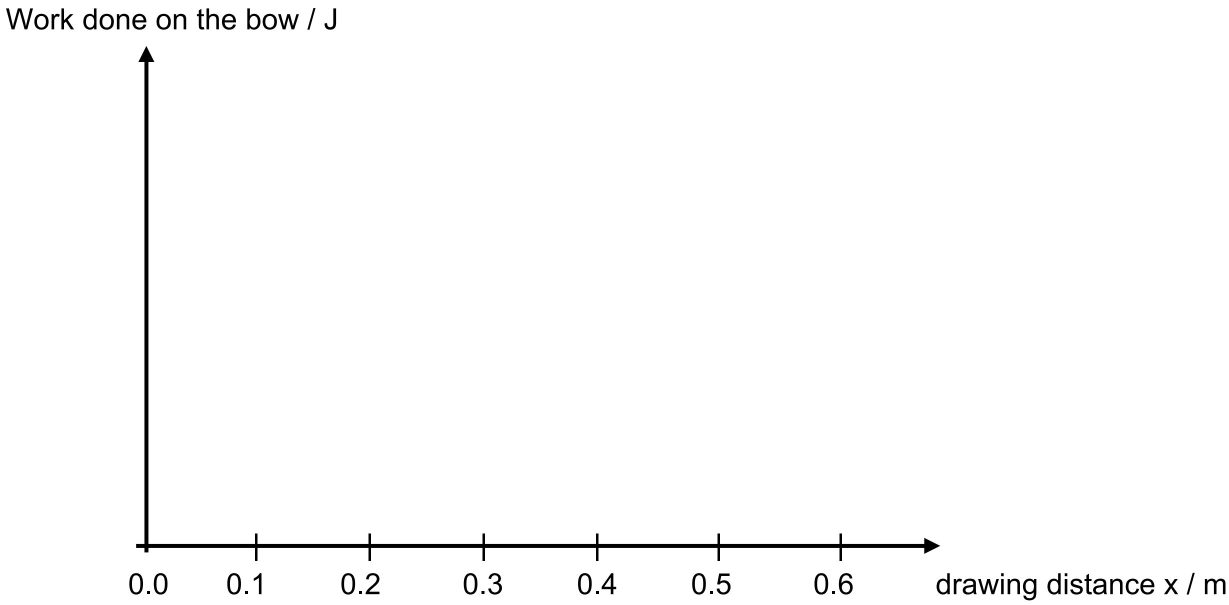
(b) Use the graph in Fig. 9.3 to calculate the energy stored in the Longbow when the maximum pulling force of 350 N is exerted on the string.

[2]

energy stored = ...J

Energy stored
= area under the force-displacement graph
= ½ (350)(0.6)
= 105 J

(c) On Fig. 9.6, sketch a graph to show how the work done on the Longbow changes with the drawing distance of the string. Label the work done axis clearly.



[2]

Fig. 9.6

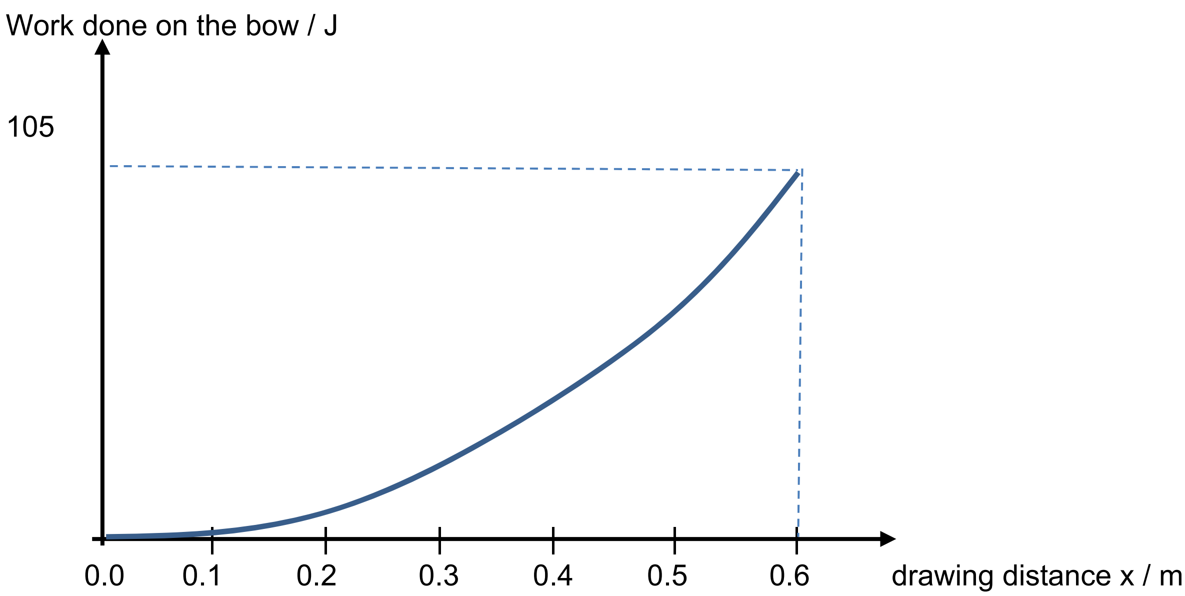


Fig. 9.6

Curve line from 0 J to 105 J when x changes from 0 to 0.6 m
Zero gradient at x = 0 and increasing gradient

(d) It is thought that the efficiency η of the bow obeys a relation of the form

$$\eta = \frac{m}{m + k}$$

where m is the mass of the arrow and
k is a constant depending on the mass of the bow.

A student performed an experiment to investigate how η, the efficiency of the bow varies with m, the mass of the arrow. He obtained data which allows him to plot the graph of Fig. 9.7.

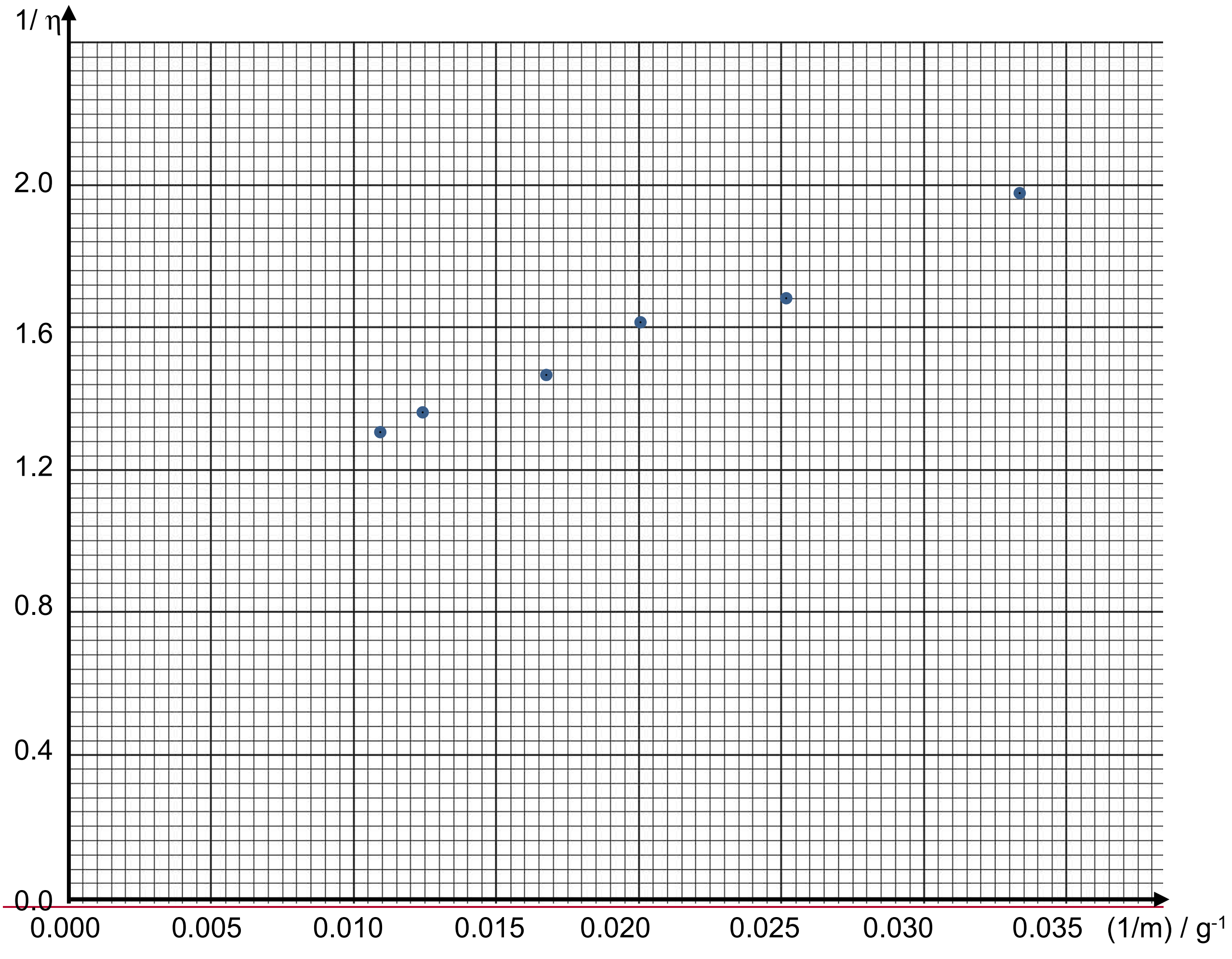
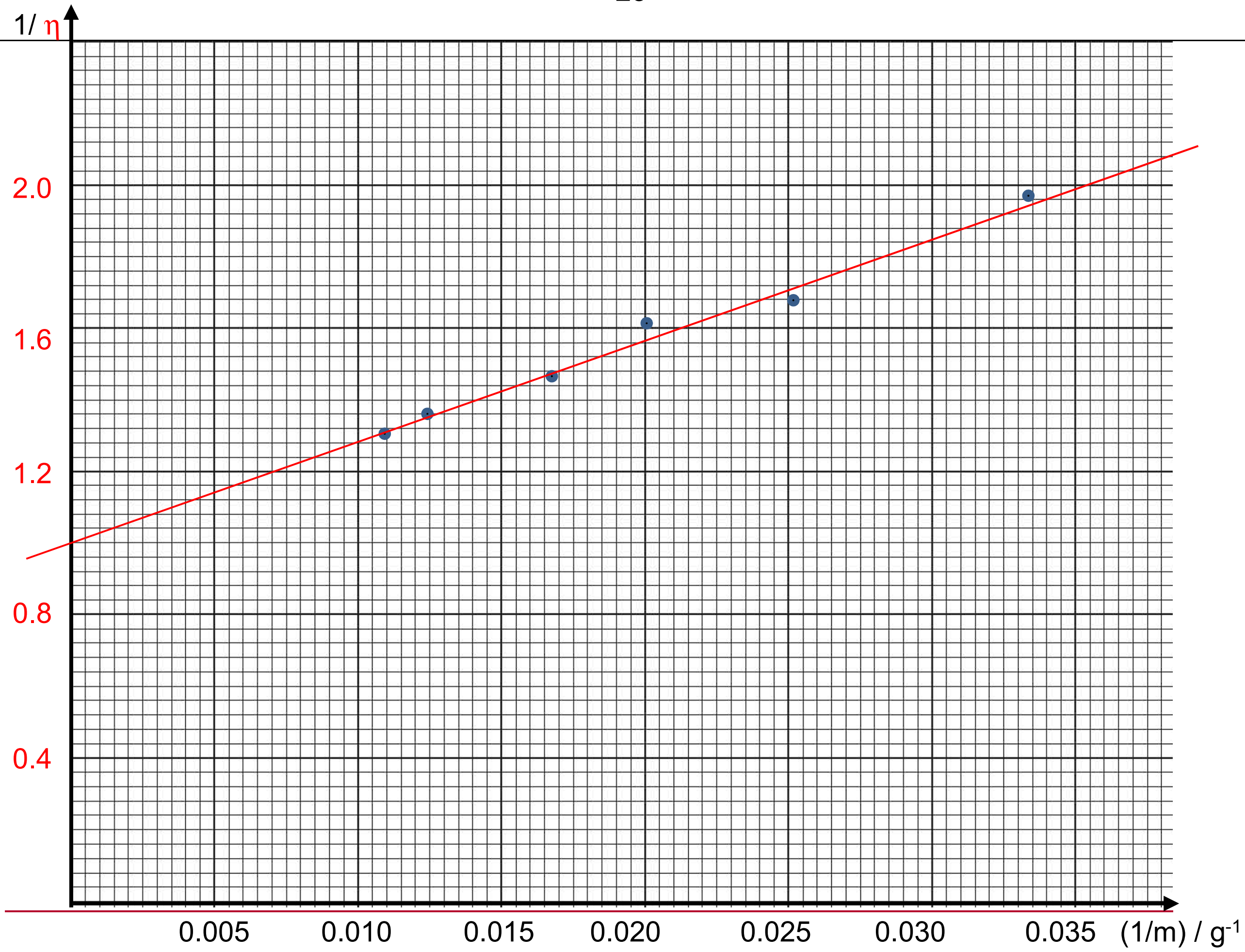


Fig. 9.7

(i) Draw the line of best fit for the points [1]



(ii) Explain whether the relation in **(d)** is valid using the line drawn in Fig. 9.7.

....

....

....

....

.... [3]

From η = m / (m + k)
1/η = (m + k)/ m = 1 + k/m

If the graph of 1/η against 1/m is a straight line with y-intercept equal to 1

Since the graph is a straight line with a y-intercept equal to 1, the relation is tested correct

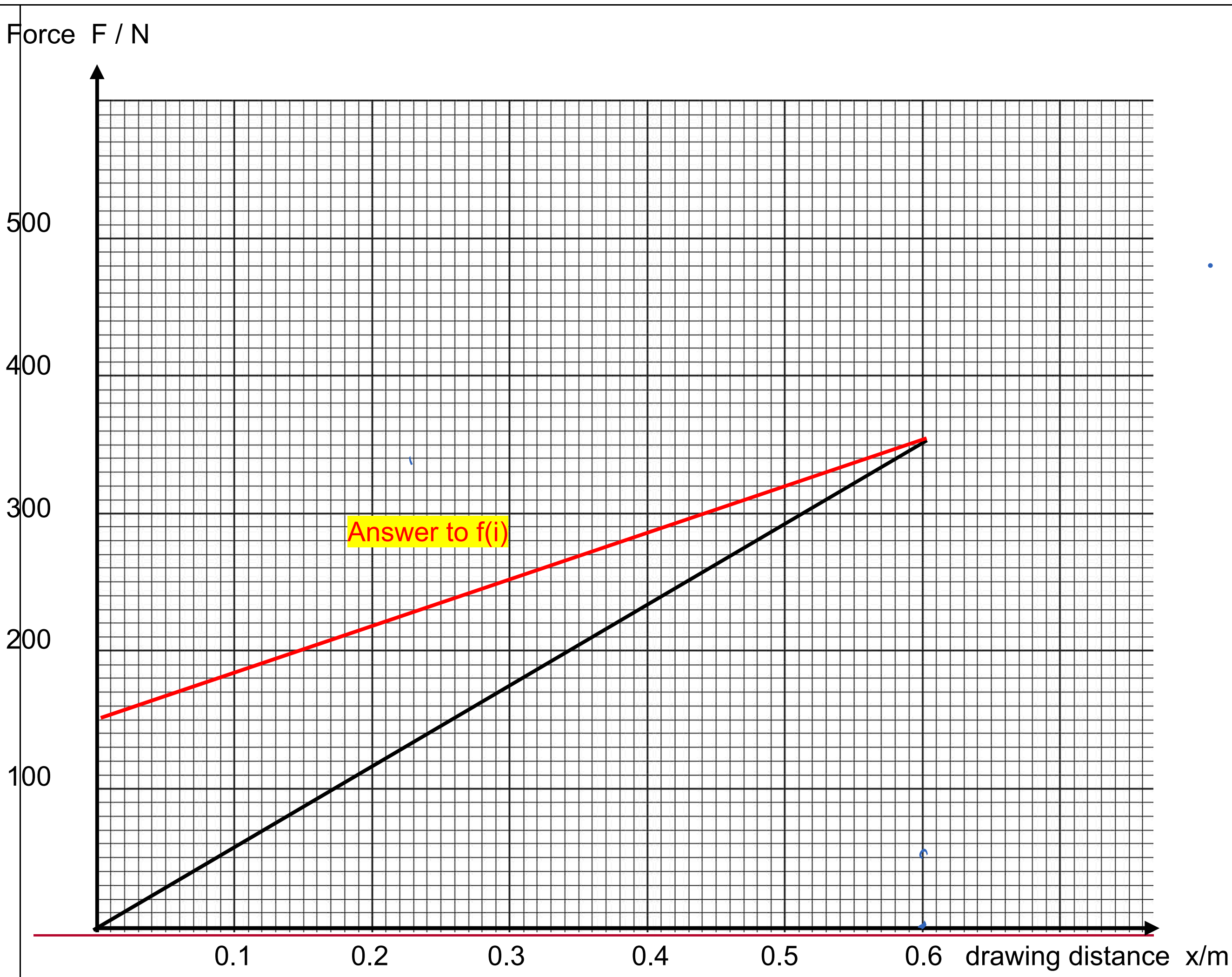
(iii) Use the line drawn in Fig. 9.7 to determine the magnitude of the constant k in the expression in (d).

[2]

k = gradient of the line
= 1.84 – 1.0 / 0.030 – 0 = 28 g

Calculate gradient correctly, read coordinate to ½ smallest grid

		(iv)	An arrow of mass 70 g is being shot from an initially unstressed Longbow drawn back as shown in Fig. 9.2. Use the graph in Fig. 9.7 and the definition of the efficiency to determine the speed of the arrow leaving the bow.	
			speed of the arrow = ………………………..m s^{-1}.	[3]
		Let m = 70 g , 1/m = 1/70 = 0.0143 From the graph 1/ η= 1.40 η = 0.714 η = KE/Energy stored = ½ m v^2 / E 0.714 = ½ (0.070)v^2 / 105 v = 46 m s^{-1}		
	(e)	Calculate the frequency of vibration for an arrow leaving the string at 50 m s^{-1}, from a bow of bracing distance of 0.15 m, and shot by an archer with a drawing distance 0.6 m, as shown in Fig. 9.2.		
		frequency of vibration = ………………………….. s^{-1}		[2]
		time to clear handle = (0.15 +0.60)/ 50 = 0.015 s 1 ¼ T = 0.0150 s T = 0.012 s f = 1/T = 1/0.0120 = 83 s^{-1}		
	(f)	**(i)**	On Fig. 9.3, sketch the force-drawing distance graph for a Recurved bow which is already braced to 150 N. The maximum drawing force of 350 N is exerted on the string at the maximum drawing displacement of 0.6 m.	[1]



Straight line from F = 150 N to F = 350 N

(ii) State and explain, in terms of the energy stored, why the Recurved bow is better than a Longbow.

……………………………………………………………………………………………………

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

Energy stored = ½ (350 + 150) x 0.6 = 150 N
This is greater than that of the Longbow. Hence the arrow can travel at greater speed and further.

(g) Refer to the force-displacement graph of a Compound bow as shown in Fig. 1.5. Suggest an advantage of a compound bow as compared to the Longbow.

……………………………………………………………………………………………………

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

As compared to the fully drawn Longbow at same max drawing force (350 N) at the drawing distance of 0.6 N

1. It can store more energy for a fully drawn bow.
2. It allows the archer to hold and aim a fully drawn bow without as much strain or fatigue since the drawing force at the fully drawn distance is smaller.

-- END OF PAPER –

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	2T

PHYSICS 9749/03
Paper 3

2 hours

Candidates answer on the Question Paper.

READ THESE INSTRUCTIONS FIRST
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Q1	/13			
Q2	/8			
Q3	/7			
Q4	/9			
Q5	/10			
Q6	/13			
Q7	/ 20			
Q8	/ 20			
TOTAL PAPER 3	/ 80			
TOTAL PAPER 1	/ 30			
TOTAL PAPER 2	/ 80			
TOTAL	/190			

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:

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	v^2	=	$u^2 + 2 a s$
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hydrostatic pressure	P	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
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	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided

1 A construction worker on the roof of a hemispherical dome releases a wrench at the highest point A with negligible speed as shown in Fig 1.1. The radius R of the dome is 30.0 m. The surface of the dome's roof is smooth. At a certain point B, the wrench just loses contact with the surface of the dome and falls with a projectile motion through the air, and finally hits the ground at point C.

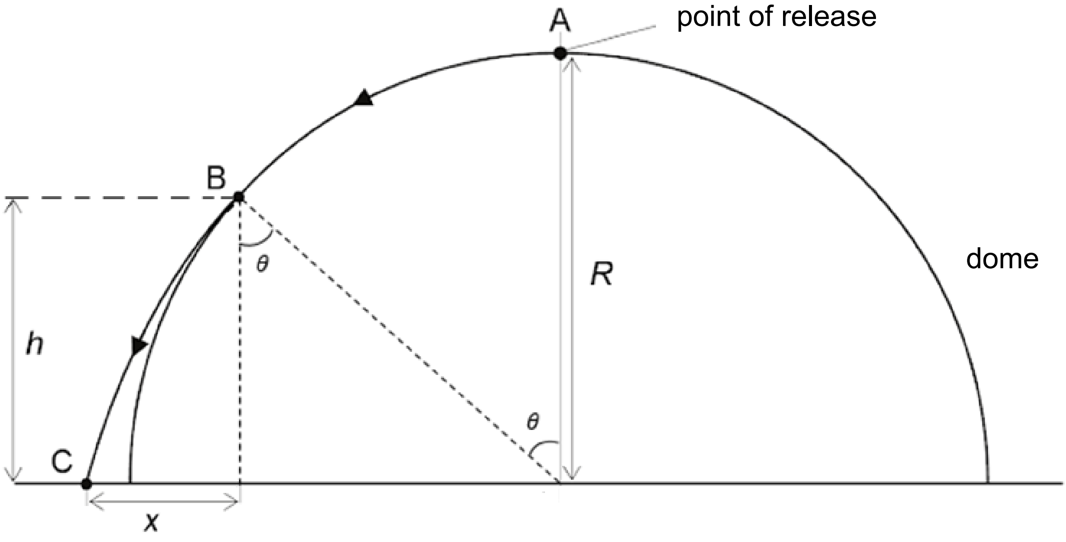

Fig 1.1

(a) (i) Explain why the centripetal acceleration of the wrench increases as it slides from A to B.

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

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

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

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

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

(ii) State the magnitude of the normal contact force on the wrench at point B.

normal contact force = …………………..N [1]

(b) By considering the forces contributing to the centripetal force on the wrench at point B, show that the vertical distance between B and C, h is

$$h = \frac{v^2}{g}$$

where v is the linear velocity of the wrench at point B and
g is the acceleration due to gravity.

[3]

(c) **(i)** At the point of losing contact with the surface of the dome, h is related to R by $h = \frac{2R}{3}$.

Use this relation and the relation in **(b)** to calculate for the wrench at the point of losing,

1. its speed and
2. its direction of motion with respect to the horizontal.

speed = ………………………….. m s^{-1}

direction from the horizontal = ………………………………………..° [2]

(ii) Using the equations of motion, determine the time taken for the wrench to fall from point B to C. Air resistance is assumed to be negligible.

time taken = …………………... s [3]

(iii) Hence determine *x*, the horizontal distance between points B and C.

horizontal distance, *x* = ………………………. m [2]

2 In a diesel engine, a fixed amount of gas undergoes a cycle of four stages. The cycle is shown in Fig. 2.1.

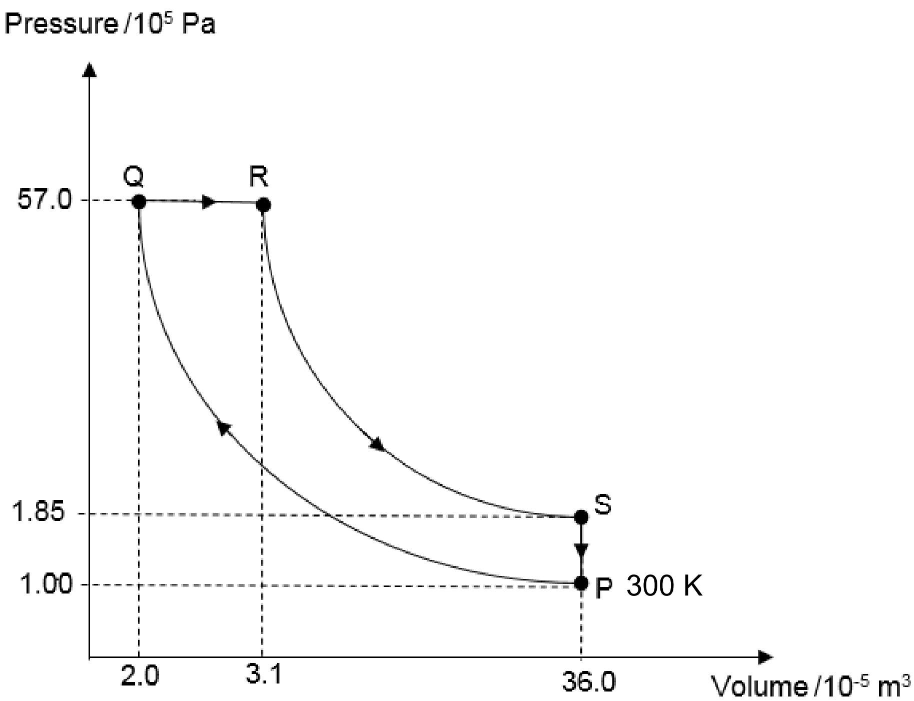

Fig. 2.1 (not to scale)

The four stages are

P → Q : compression with a rise in temperature and pressure,
Q → R : expansion at constant pressure while fuel is being burnt,
R → S : expansion with a drop in both temperature and pressure,
S → P : decrease in pressure at constant volume.

Some numerical values of temperature, pressure and volume are given on Fig. 2.1.

(a) Using Fig. 2.1, calculate the work done by the gas during the stages

(i) Q → R,

work done = ………………..J [1]

(ii) S → P.

work done = ………………..J [1]

(b) Using your answers in **(a)**, complete Fig. 2.2 for the four stages of the cycle.

Stage of cycle	heat supplied to gas /J	work done on gas /J	increase in internal energy of the system /J
P → Q	0	235	
Q → R	246		
R → S	0	–333	
S → P			

Fig. 2.2

[4]

(c) Assuming that the gas is ideal, calculate the temperature of the gas at point Q.

temperature = ………………… K [2]

3 The variation with displacement of the acceleration of an animal's eardrum is shown in Fig. 3.1.

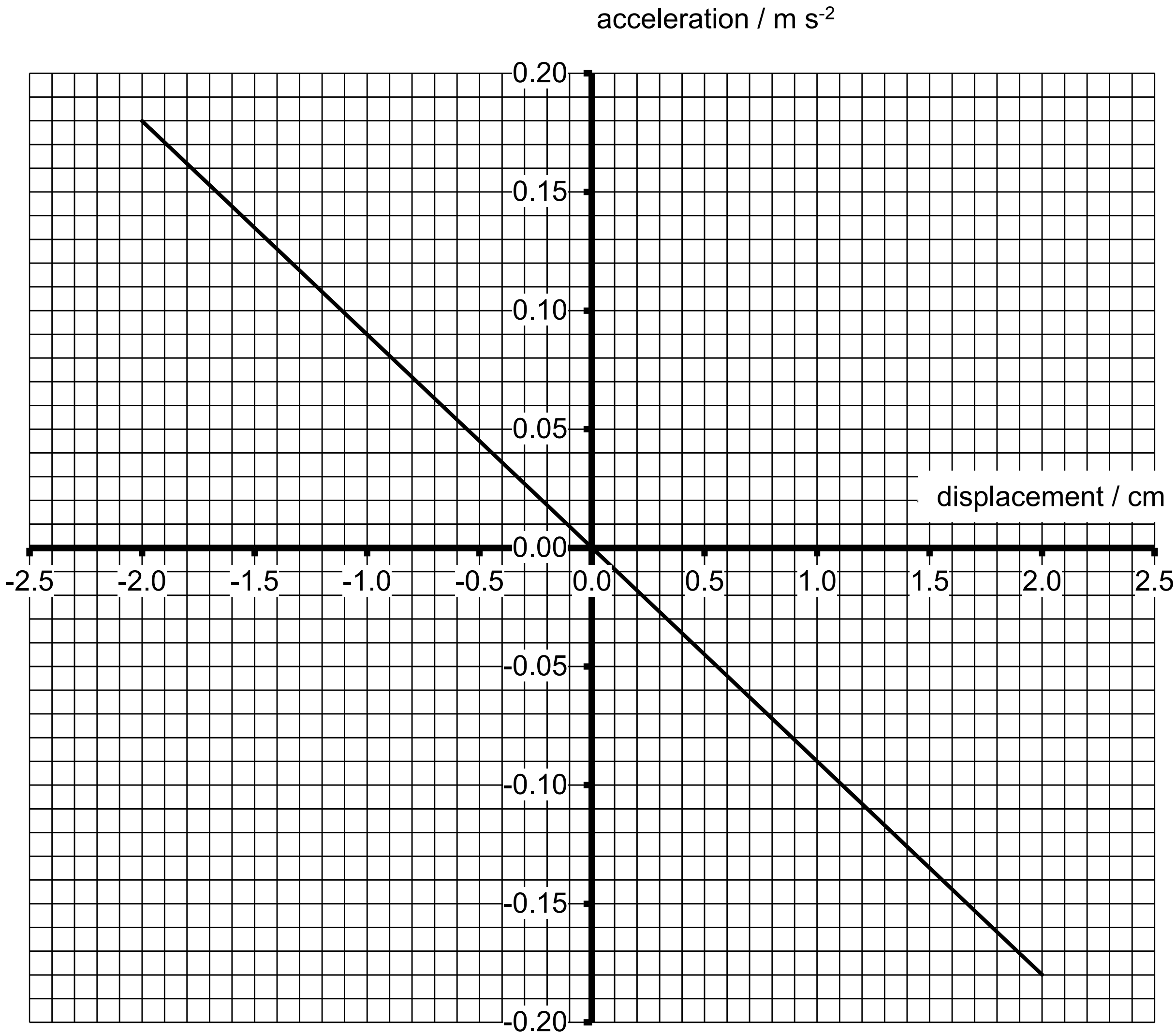

Fig. 3.1

(a) Explain how Fig. 3.1 shows that the motion of the eardrum is simple harmonic.

....

....

....

.... [2]

(b) The period of the oscillation is 2.10 s.

Calculate the time taken for the eardrum to travel a distance of 0.50 cm starting from its maximum displacement towards the equilibrium point.

time taken = ………………….. s [3]

(c) The mass of the eardrum is 100 g.

Show that the potential energy of the eardrum is 2.5×10^{-5} J when its displacement is 0.75 cm. [2]

4 A length of wire is held taut between two points M and P as shown in Fig. 4.1. A signal generator which produces an alternating current of variable frequency is passed through the wire and a pair of magnets is placed on either side of the wire.

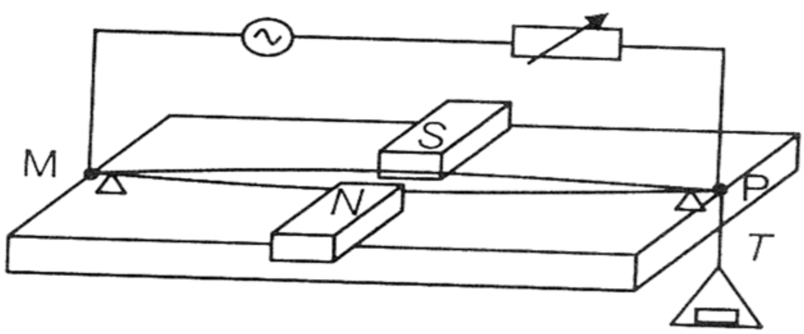

Fig. 4.1

The frequency of the alternating current is gradually increased from zero. A stationary wave is set up as shown in Fig. 4.1 when the frequency is 10 Hz.

(a) Explain how the stationary wave is formed on the wire when an alternating current is passed through it.

……

……

……

……

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

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

……………………………………………………………………………………………………….. [4]

(b) The distance between M and P is 0.60 m.

Calculate the wavelength of the stationary wave formed.

wavelength = …………………………..m [1]

(c) Determine the speed of the wave.

speed = ………………………. m s^{-1} [2]

(d) Sketch the stationary wave formed in the space below when the frequency of the alternating current is adjusted to 30 Hz.

[2]

[Turn over

5 **(a)** A particle of mass *m*, carrying a negative charge - q and travelling at speed *v*, enters a region of uniform magnetic field of flux density *B* directed at right angles to the motion of the particle as shown in Fig. 5.1.

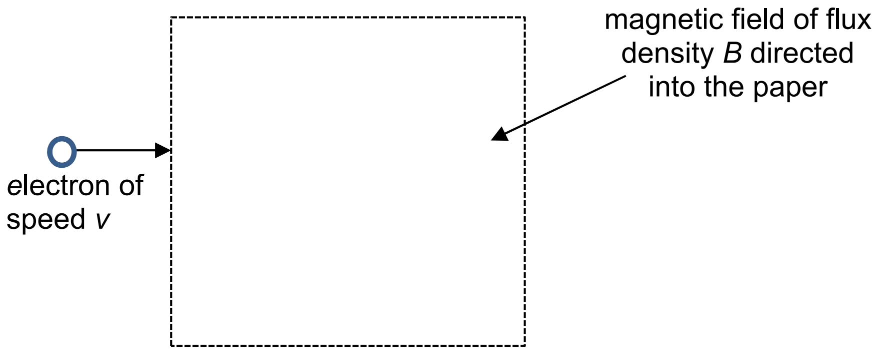

Fig. 5.1

(i) State the expression for the magnitude of the force *F* acting on the particle and the direction of the force.

F = ...

direction =..................................... [2]

(ii) Explain why the path of the electron is circular.

....

....

....

.... [3]

(b) The diagram in Fig. 5.2 shows a type of cathode ray tube containing a small quantity of gas. Electrons from a hot cathode emerge from a small hole in the conical shaped anode, and the path subsequently followed is made visible by the gas in the tube.

The accelerating voltage is 5.0 kV.

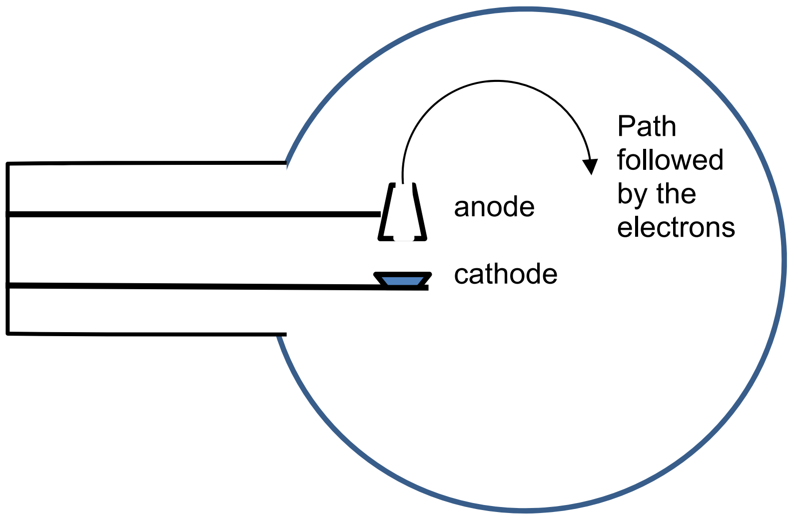

Fig. 5.2

(i) Calculate the speed of the electrons as they emerge from the anode.

speed = …………………..m s^{-1} [2]

(ii) The apparatus is situated in a uniform magnetic field acting into the plane of the paper.

1. Calculate the radius of the circular path for a flux density of 2.0×10^{-3} T.

radius = …………………… m [2]

2. Suggest how the gas in the tube might make the path of the electrons visible.

……………………………………………………………………………………………………

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

6 **(a)** In 1919, Rutherford performed the first nuclear reaction induced in a laboratory in which a stationary nitrogen nucleus $^{14}_{7}N$ bombarded with an α-particle of a certain energy, transmutes to an oxygen nucleus $^{17}_{8}O$ and a proton.

Data:
mass of $^{14}_{7}N$ = 13.9993 u;
mass of $^{17}_{8}O$ = 16.9947 u;
mass of a proton = 1.0073 u;
mass of an α-particle = 4.0015 u.

(i) Write an equation for this nuclear reaction, showing the mass numbers and the atomic numbers of the particles involved.

[2]

(ii) Calculate the minimum kinetic energy of the alpha particle for the reaction to make this reaction occur.

kinetic energy = …………………………..J [3]

(b) A radioactive isotope of thallium $^{207}_{81}Tl$ emits a *β*-particle and is thought to emit a gamma photon. The half-life of $^{207}_{81}Tl$ is 135 days.

(i) The radiation is allowed to pass though perpendicularly a vertical uniform magnetic field and the photographs of traces is obtained in a cloud chamber under certain conditions. Fig 6.1 show tracks produced by the beta-particles and gamma ray photons.

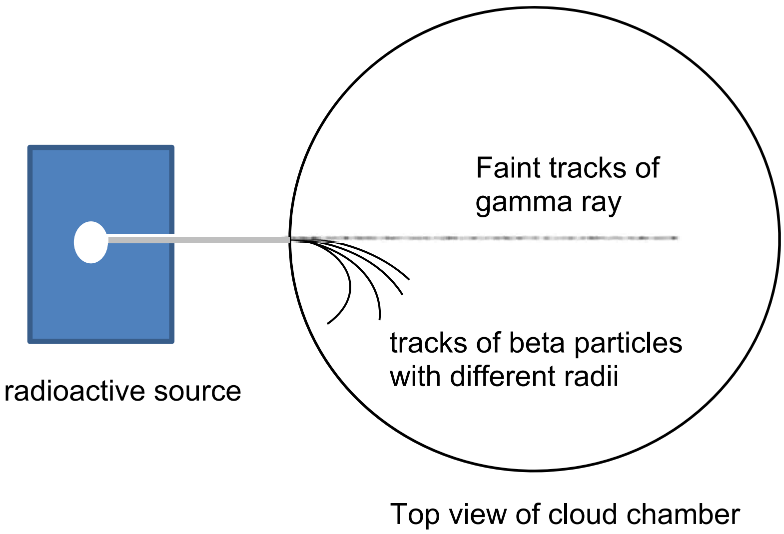

Fig. 6.1

Explain the features of the tracks.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) An isotope of thallium $^{207}_{81}\text{Tl}$ emits a β-particle with an average energy of 2.4 x 10^{-13} J.

Calculate

1. the total energy available from 1 g of thallium-207,

total energy = ……………….J [2]

2. the initial rate at which the β-particles are emitted from 1 g of the freshly prepared isotope,

initial rate of emission = …..………………..day^{-1} [2]

3. the initial power available from the beta particles emitted at the rate calculated in **b(ii)2**.

initial power = ………………. W [1]

[Turn over

Section B

Answer **One** question from this section

7 A uniform wooden rod of weight 50 N and length 1.0 m is gently lowered into water. The upper end of the rod is attached to a light string. When the rod is in equilibrium, the string is vertical and exactly half of the rod is underwater as shown in Fig. 7.1. The rod makes an angle θ with the surface of the water.

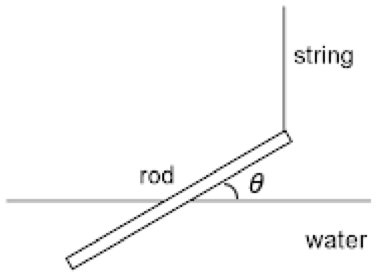

Fig. 7.1

(a) (i) Explain why the string is vertical.

....

.... [1]

(ii) On Fig. 7.1, draw the three forces tension *T*, upthrust *U* and the weight *W* acting on the rod. [2]

(iii) By considering moments about the centre of gravity of the rod, show that $T = 0.5\ U$.

[2]

(iv) Calculate the magnitude of *T*.

T = ………………..N [2]

(v) By balancing the forces, determine the density of the wooden rod. The density of water is 1.0×10^3 kg m^{-3}.

density of rod = ...kg m^{-3} [4]

(b) **(i)** State the principle of the conservation of momentum.

....

.... [1]

(ii) Object **A** of mass 1.2 kg collides head-on and elastically with object **B** of mass 0.60 kg moving with a speed 0.20 m s^{-1} towards it as shown in Fig. 7.2.

Fig. 7.2

After the collision, object **B** moves off with a speed of 0.10 m s^{-1} opposite to its initial motion.

Calculate the initial speed of object **A**.

initial speed of **A** = ... m s^{-1} [3]

(c) An 80 kg astronaut is at a distance of 30 m away from a space shuttle. He wishes to return to the space shuttle by means of a thruster. The thruster is attached to the body of the astronaut and it emits a stream of gas when it is turned on.

(i) State and explain the direction in which the gas has to be ejected for him to return to the space shuttle.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) The gas is ejected at a constant rate of 0.5 kg s^{-1} and at a speed of 20 m s^{-1} relative to the astronaut for a period of 1.0 s.

Calculate the speed of the astronaut at the end of 1.0 s.

speed = ……………..m s^{-1} [2]

8 **(a)** A cell of e.m.f. E and internal resistance r is connected in series to a resistor of resistance R.

(i) Define *electromotive force*.

.... [1]

(ii) Show, by considering energy conversion, that V the terminal potential difference of the cell is

$$V = E - Ir$$

where I is the current flowing in the cell.

[2]

(b) Fig. 8.1 shows a battery with e.m.f. E and an internal resistance r connected to a uniform nichrome resistance wire MN. J is a movable jockey which can slide along wire MN. The voltmeter and the ammeter are taken to be ideal.

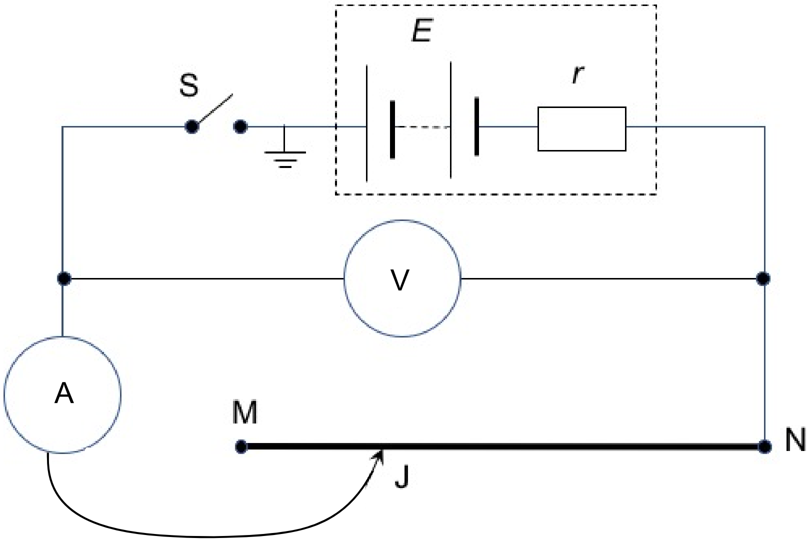

Fig. 8.1

The voltmeter readings V and ammeter readings I obtained for different lengths of JN are used to plot the graph in Fig. 8.2.

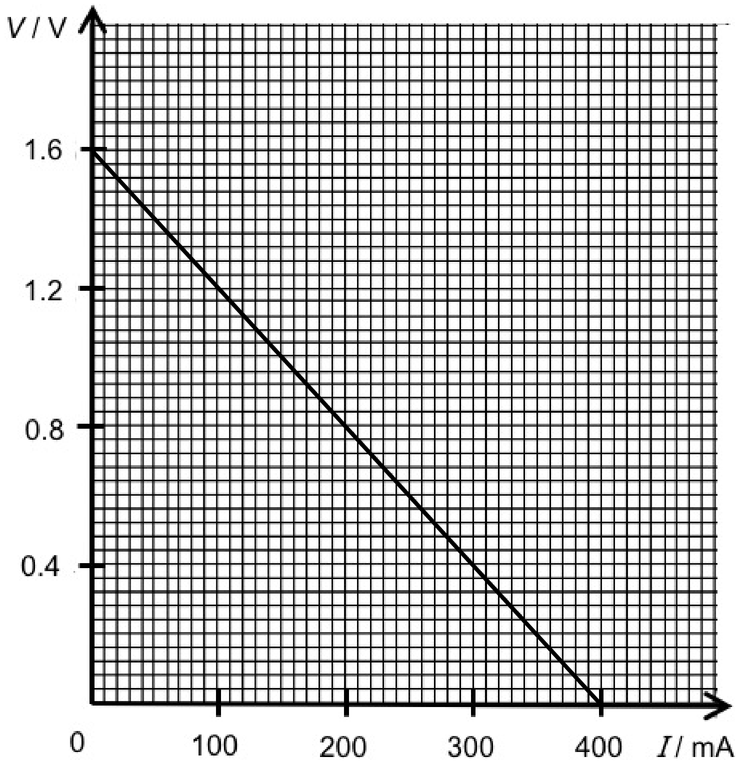

Fig. 8.2

(i) Deduce from Fig. 8.2 the e.m.f. *E* and the internal resistance *r* of the cell.

E = ……………….. V

r = ……………….. Ω [3]

(ii) J is placed at the position such that **maximum power** is delivered from the cell to the wire JN.

Determine the potential at J and N.

potential at J = ………….V

potential at N = …………V [3]

(iii) On Fig. 8.3 sketch the graph to show how electric potential varies with position along the wire JN. Label the vertical axis clearly. Explain your answer.

Fig. 8.3

....

....

....

.... [3]

(iv) Suggest, with a reason, why the position of the jockey J has to be shifted, when the battery has been used for a prolong period of time for maximum power transfer.

....

....

.... [1]

(c) (i) Explain what is meant by an *electric field*.

....

.... [1]

(ii) Draw the charge distribution and the electric field around the charged metal bodies for the following bodies

1. an isolated positively charged sphere A.

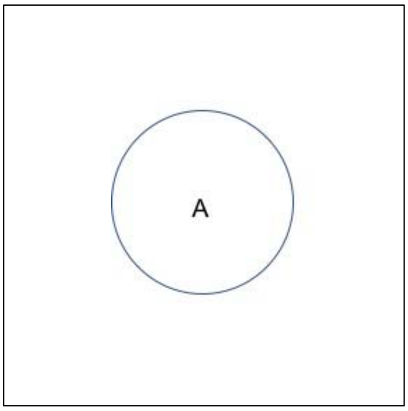

Fig. 8.1 [2]

2. When a neutral metal sphere B is brought close to the positively charged metal sphere A in **(c)(ii)1.**

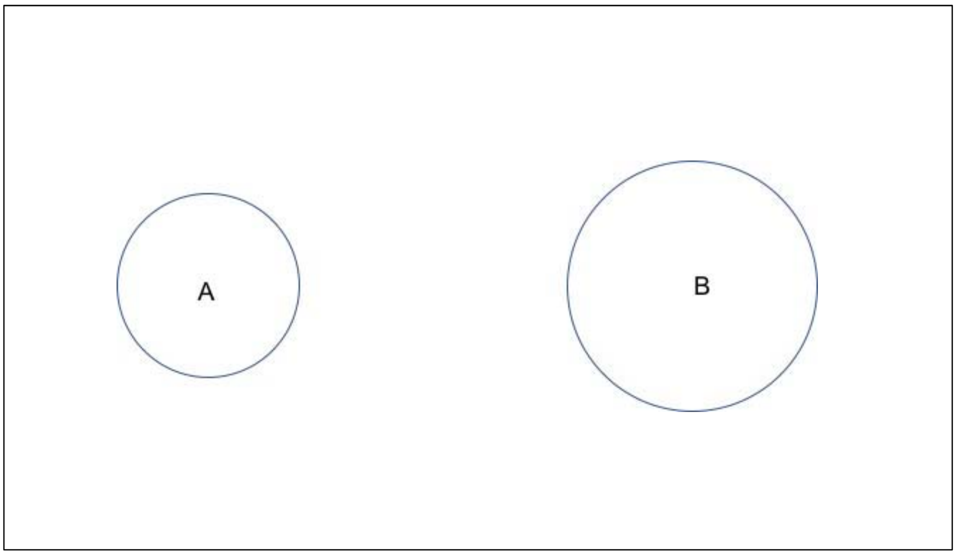

Fig. 8.2 [4]

- END OF PAPER -

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Catholic Junior College

JC2 Preliminary Examinations

Higher 2

CANDIDATE NAME: **MARK SCHEME**

CLASS: **2T**

PHYSICS

9749/03

Paper 3

2 hours

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Q7	/ 20			
Q8	/ 20			
TOTAL PAPER 3	/ 80			
TOTAL PAPER 1	/ 30			
TOTAL PAPER 2	/ 80			
TOTAL	/190			

This document consists of **25** printed pages and **1** blank page.

[Turn over

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pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
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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	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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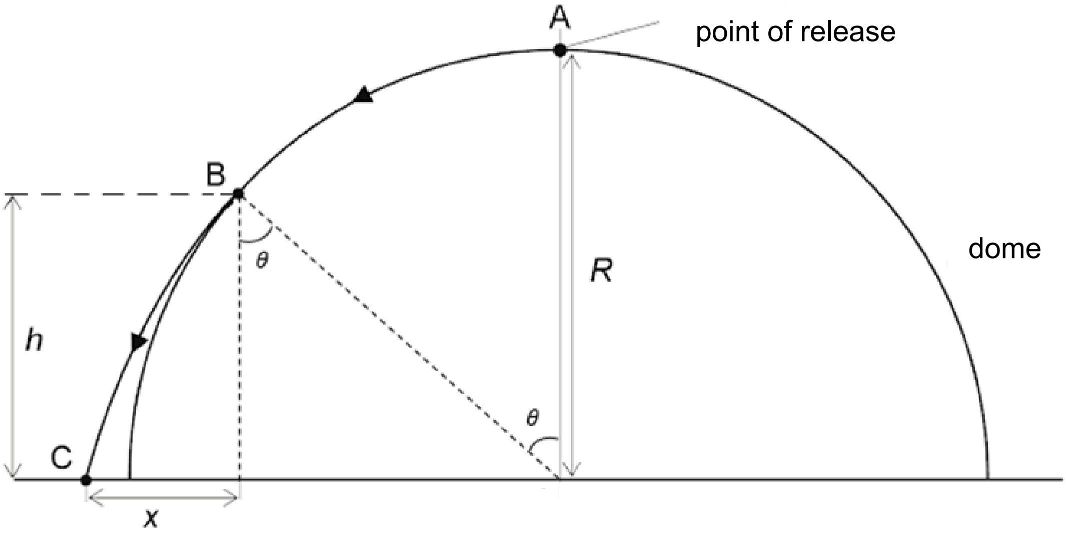


Fig 1.1

(a) (i) Explain why the centripetal acceleration of the wrench increases as it slides from A to B.

....

....

....

....

....

.... [2]

As the wrench falls, it loses gravitational potential energy but it gains kinetic energy. Kinetic energy = ½ mass x square of speed, therefore its speed increases.

Centripetal acceleration is directly proportional to the square of the velocity and inversely proportional to the radius of the circular path, which in this case is the radius of the dome, and is constant.

Therefore, the centripetal acceleration of the wrench increases as it slides from A to B.

(ii) State the magnitude of the normal contact force on the wrench at point B.

normal contact force = ...N [1]

			N = 0	
	(b)	By considering the forces contributing to the centripetal force on the wrench at point B, show that the vertical distance between B and C, h is $$h = \frac{v^2}{g}$$ where v is the linear velocity of the wrench at point B and g is the acceleration due to gravity.		[3]
			Since N = 0 when wrench loses contact with the surface, $$mg\cos\theta = \frac{mv^2}{r}$$ $$mg\left(\frac{h}{R}\right) = \frac{mv^2}{R}$$ $$h = \frac{v^2}{g}$$	
(c)	**(i)**		At the point of losing contact with the surface of the dome, h is related to R by $h = \frac{2R}{3}$. Use this relation and the relation in **(b)** to calculate for the wrench at the point of losing, **1.** its speed and **2.** its direction of motion with respect to the horizontal.	
			speed = ………………………. m s^{-1} direction from the horizontal = ……………………………………….°	[2]
			$v^2 = hg$ $v^2 = \frac{2}{3}(30.0)(9.81)$ $v = 14.0\ m\ s^{-1}$ We also have, $\cos\theta = \frac{h}{R}$ $\cos\theta = \frac{\frac{2}{3}R}{R} = \frac{2}{3}$ $\theta = 48.2°$	
	(ii)		Using the equations of motion, determine the time taken for the wrench to fall from point B to C. Air resistance is assumed to be negligible.	
			time taken = ………………….. s	[3]

Considering vertical components and taking vectors downwards as positive,

$$s_y = u_y t + \frac{1}{2} g t^2$$

$$h = \frac{2}{3} R = (v \sin\theta) t + \frac{1}{2}(9.81) t^2$$

$$h = \frac{2}{3} R = (14.0 \sin(48.2)) t + \frac{1}{2}(9.81) t^2$$

$$\frac{2}{3}(30.0) = (14.0 \sin(48.2)) t + \frac{1}{2}(9.81) t^2$$

$$20.0 = (10.44) t + \frac{1}{2}(9.81) t^2$$

$$t = 1.22 \text{ s}$$

(iii) Hence determine *x*, the horizontal distance between points B and C.

horizontal distance, *x* = ………………………… m [2]

$$s_x = u_x t + \frac{1}{2} a_x t^2$$

$$s_x = v \cos\theta (t)$$

$$s_x = 14\left(\frac{2}{3}\right)(1.22)$$

$$x = 11.4 \text{ m}$$

2 In a diesel engine, a fixed amount of gas undergoes a cycle of four stages. The cycle is shown in Fig. 2.1.

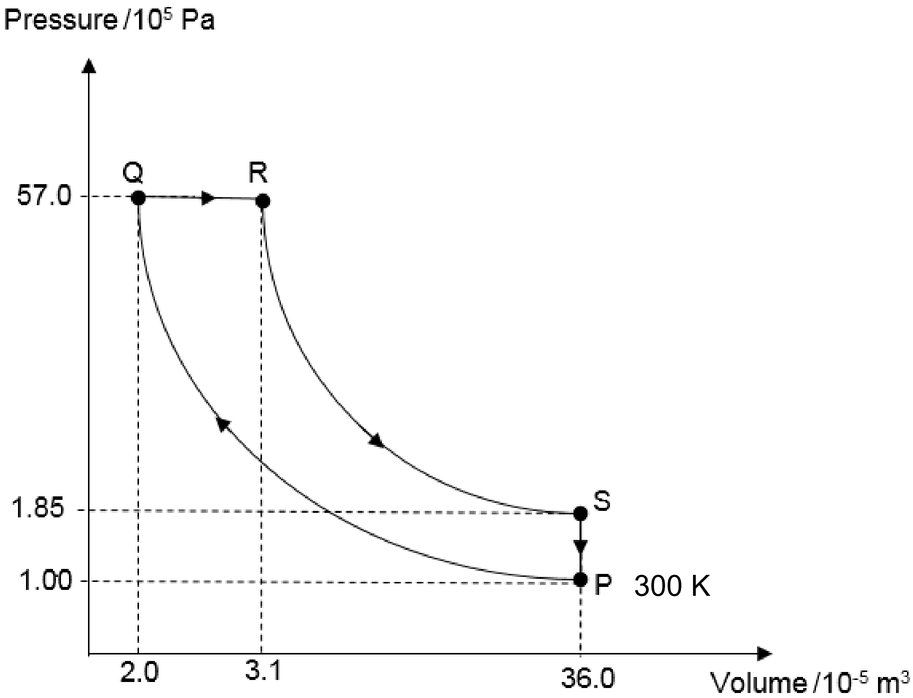


Fig.2.1 (not to scale)

The four stages are

P → Q : compression with a rise in temperature and pressure,
Q → R : expansion at constant pressure while fuel is being burnt,
R → S : expansion with a drop in both temperature and pressure,
S → P : decrease in pressure at constant volume.

Some numerical values of temperature, pressure and volume are given on Fig. 2.1.

(a) Using Fig. 2.1, calculate the work done by the gas during the stages

(i) Q → R,

work done = ……………….J [1]

Solution:

$W = p\,\Delta V = 57.0 \times 10^5 \text{ Pa} \times (3.1 - 2.0) \times 10^{-5} \text{ m}^{-3}$
$= 62.7 \text{ J}$

(ii) S → P.

work done = ……………….J [1]

Solution:
W = **0** J

(b) Using your answers in **(a)**, complete Fig. 2.2 for the four stages of the cycle.

Stage of cycle	heat supplied to gas /J	work done on gas /J	increase in internal energy of the system /J
P → Q	0	235	
Q → R	246		
R → S	0	–333	
S → P			

[4]

Fig. 2.2

Solution:

Stage of cycle	heat supplied to gas /J	work done on gas /J	increase in internal energy of the system /J
P → Q	0	235	**ΔU = Q + W = 0 + 235 = 235 [A]**
Q → R	246	**–62.7 [B] Since it is work done ON gas, put a negative sign.**	**ΔU = Q + W = 246 – 62.7 = 183 [A]**
R → S	0	–333	**ΔU = Q + W = 0 – 333 = – 333 [A]**
S → P	**ΔU = Q + W -85 = Q Q = –85 [A]**	**No change in vol→ no work done 0 [C]**	**ΔU = 0 235 + 183 – 333 + $\Delta U_{S\to P}$ = 0 $\Delta U_{S\to P}$ = –85 [D]**

[A] (application of first law equation – mark by merit),
[B] (insertion of negative sign),
[C] (identifying work done is 0),
[D] (ΔU = 0)

	(c)		Assuming that the gas is ideal, calculate the temperature of the gas at point Q.	
			temperature = ………………… K	[2]
			Solution: $\frac{P_P V_P}{T_P} = \frac{P_Q V_Q}{T_Q}$ $T_Q = \frac{P_Q V_Q T_P}{P_P V_P} = \frac{(57.0\times10^5)(2.0\times10^{-5})(300)}{(1.00\times10^5)(36.0\times10^{-5})}$ $= 950\ K$	

3 The variation with displacement of the acceleration of an animal's eardrum is shown in Fig. 3.1.

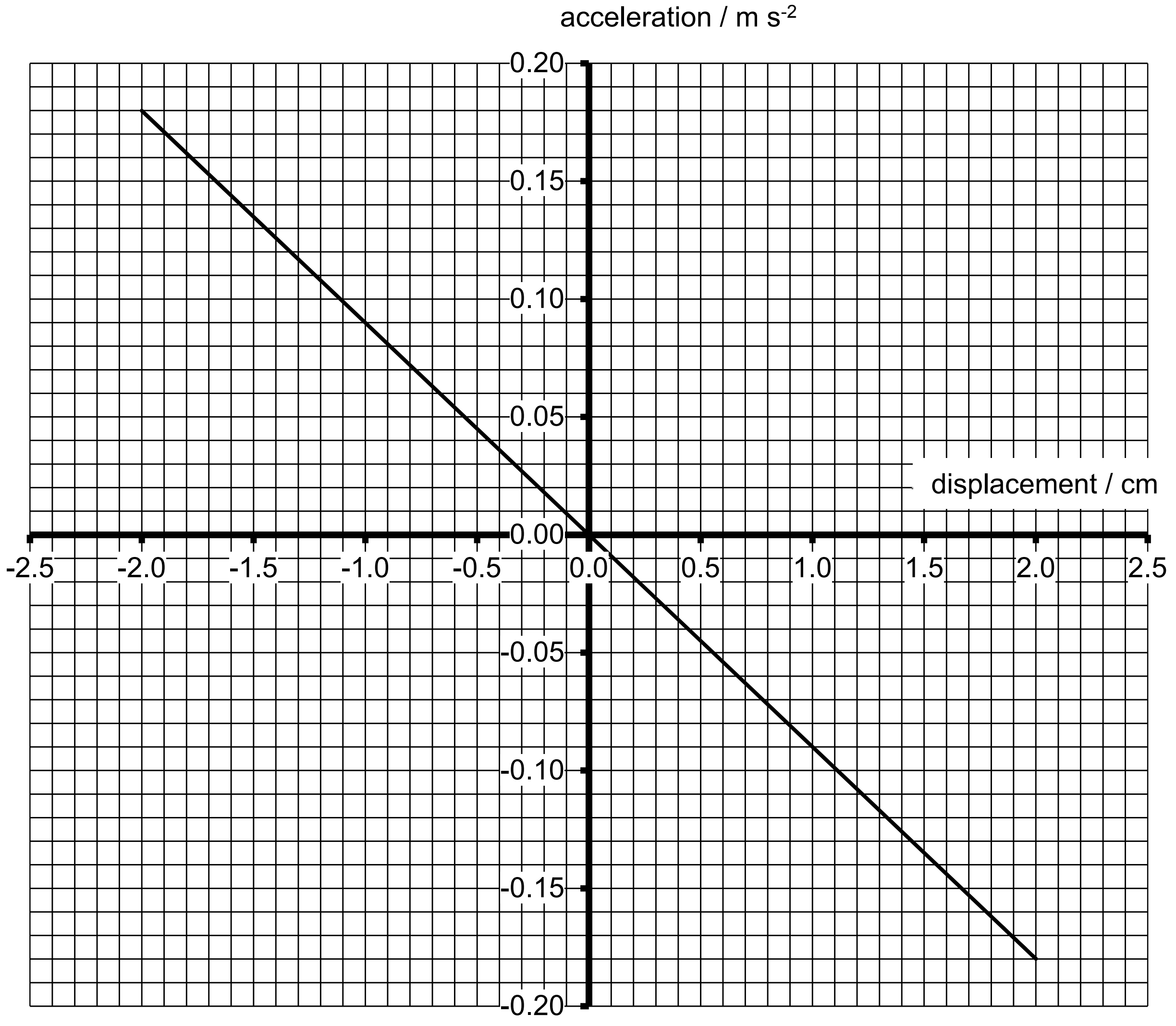


Fig. 3.1

(a) Explain how Fig. 3.1 shows that the motion of the eardrum is simple harmonic.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

		....	[2]
		Solution: The graph is a **straight line passing through the origin** which shows that the acceleration is directly proportional to the displacement. The straight line has a **negative gradient** which shows that direction of acceleration is always opposite to the direction of displacement.	**B1** **B1**
	(b)	The period of the oscillation is 2.10 s. Calculate the time taken for the eardrum to travel a distance of 0.50 cm starting from its maximum displacement towards the equilibrium point.	
		time taken = ... s	[3]
		Solution: When the eardrum travels a distance of 0.50 cm from max displacement, its displacement will be 1.50 cm from equilibrium position. $x = x_0 \cos(\omega t)$ $1.50 = 2.00 \cos(\frac{2\pi}{2.10} t)$ $t = 0.242$ s	
	(c)	The mass of the eardrum is 100 g. Show that the potential energy of the eardrum is 2.5×10^{-5} J when its displacement is 0.75 cm.	[2]
		Solution: Total energy = Maximum kinetic energy $= \frac{1}{2} m v_{max}^2 = \frac{1}{2} m \omega^2 x_0^2$	

Potential energy $= \text{Total energy} - \text{Kinetic energy}$

$$= \frac{1}{2}m\omega^2 x_0^2 - \frac{1}{2}m\omega^2 (x_0^2 - x^2)$$

$$= \frac{1}{2}m\omega^2 x^2$$

$$= \frac{1}{2} \times 0.100 \times (\frac{2\pi}{2.10})^2 \times (0.75 \times 10^{-2})^2$$

$$= 2.5 \times 10^{-5}\ J$$

4 A length of wire is held taut between two points M and P as shown in Fig. 4.1. A signal generator which produces an alternating current of variable frequency is passed through the wire and a pair of magnets is placed on either side of the wire.

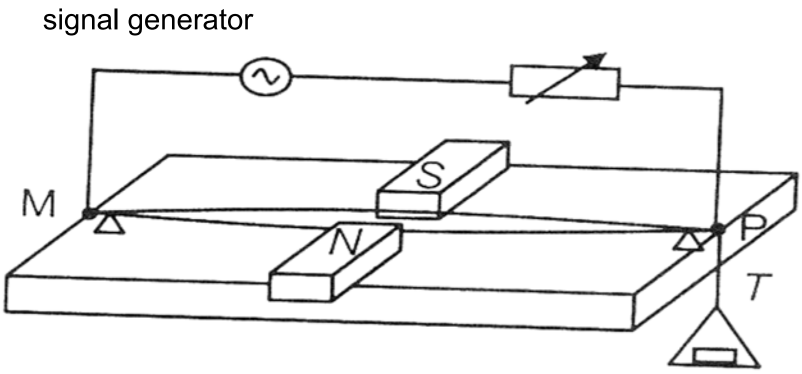


Fig. 4.1

The frequency of the alternating current is gradually increased from zero. A stationary wave is set up as shown in Fig. 4.1 when the frequency is 10 Hz.

(a) Explain how the stationary wave is formed on the wire when an alternating current is passed through it.

....

....

....

....

....

....

.... [4]

L3 Solution:

The current carrying wire **experiences a magnetic force in the vertical plane** as given by Fleming's Left Hand Rule.

Since the current is alternating and changes direction, the **direction of force alternates and causes the wire to vibrate.**

			The vibration will cause **progressive waves travelling towards P & M and the reflected waves will superpose.** Resonance occurs and a stationary wave will be formed when the **frequency of the periodic magnetic force (due to the sinusoidal current) matches the natural frequency of the stationary waves in the string.**	
	(b)	The distance between M and P is 0.60 m. Calculate the wavelength of the stationary wave formed.		
			wavelength = ……………………………m	[1]
			Solution: $0.6 = \frac{\lambda}{2}$ $\lambda = 1.20$ m	
	(c)	Determine the speed of the wave.		
			speed = ……………………… m s^{-1}	[2]
			Solution: $v = f\lambda = (10)1.20$ $= 12.0$ m s^{-1}	
	(d)	Sketch the stationary wave formed in the space below when the frequency of the alternating current is adjusted to 30 Hz.		
				[2]
			Solution: Correctly drawn stationary wave with 3 antinodes and 4 nodes, with 2 of the nodes at M and P. (Three loops with nodes at the ends with equal distance between adjacent nodes) Reason: Same tension, speed is the same Determine new wavelength when freq is increased to 30 Hz. $\lambda = \frac{v}{f} = \frac{12}{30} = 0.4\ m$ Number of wavelengths formed = 0.6/0.4 = 1.5 There will be 3 loops formed.	

5 (a) A particle of mass m, carrying a negative charge $-q$ and travelling at speed v, enters a region of uniform magnetic field of flux density B directed at right angles to the motion of the particle as shown in Fig. 5.1.

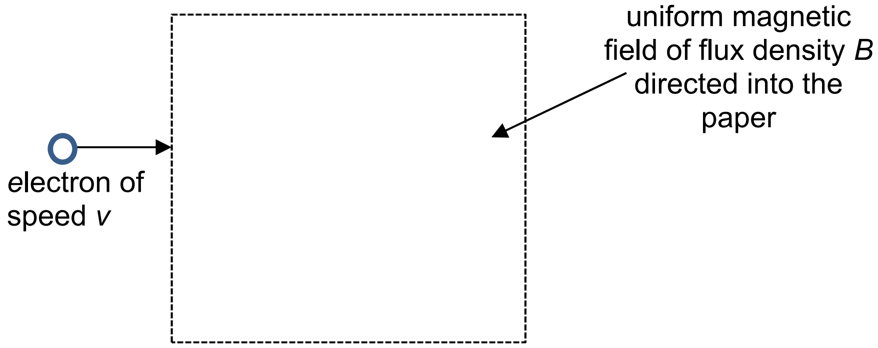


Fig. 5.1

(i) State the expression for the magnitude of the force F acting on the particle and the direction of the force.

F = ...

Direction = ... [2]

$F = Bqv$

And

Direction downwards

(ii) Explain why the path of the electron is circular.

....

....

....

.... [3]

Magnetic force is perpendicular to the motion hence the kinetic energy of the particle is unchanged.

Since K.E. is proportional to the square of the speed and mass.

Hence its speed and the magnetic force it experiences is unchanged

Since F = Bqv, the magnetic force is constant.

Hence the path is circular

(b) The diagram in Fig. 5.2 shows a type of cathode ray tube containing a small quantity of gas. Electrons from a hot cathode emerge from a small hole in the conical shaped anode, and the path subsequently followed is made visible by the gas in the tube.

The accelerating voltage is 5.0 kV.

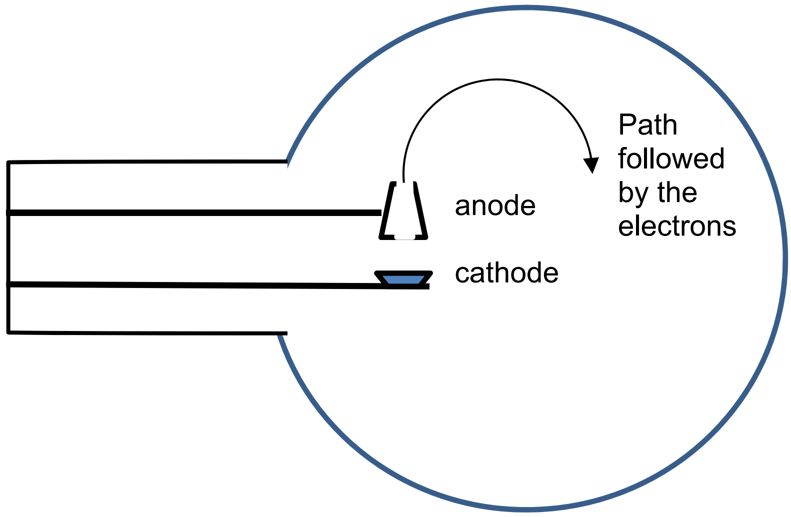


Fig. 5.2

(i) Calculate the speed of the electrons as they emerge from the anode.

speed = ………………….m s^{-1} [2]

Work done on electron = gain in K.E

$qV = \frac{1}{2} m v^2$

$v = \sqrt{2q\ V\ /\ m}$

$= \sqrt{2\ (1.6 \times 10^{-19})\ (5000) /\ 9.11 \times 10^{-31}} = 4.19 \times 10^7$ m s^{-1}

(ii) The apparatus is situated in a uniform magnetic field acting into the plane of the paper.

1. Calculate the radius of the circular path for a flux density of 2.0×10^{-3} T.

radius = …………………… m [2]

The magnetic force provides the centripetal force

$Bqv = mv^2/r$

$r = mv / Bq$

$= 9.11 \times 10^{-31} \times 4.19 \times 10^7 / 2.0 \times 10^{-3} \times 1.6 \times 10^{-19}$

$= 0.12$ m

2. Suggest how the gas in the tube might make the path of the electrons visible.

……………………………………………………………………………………………………

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

Condensation of the vapour/alcohol in the tube occurs and this forms a visible track along the trails of the charged particles (β-particles or α-particles or gamma ray photons). When the charged particles collide electrostatically with the gas atoms, they are ionized and the ions cause condensation of the vapour.

6 **(a)** In 1919, Rutherford performed the first nuclear reaction induced in a laboratory in which a stationary nitrogen nucleus $^{14}_{7}N$ bombarded with an α-particle of a certain energy, transmutes to an oxygen nucleus $^{17}_{8}O$ and a proton.

Data:
mass of $^{14}_{7}N$ = 13.9993 u;
mass of $^{17}_{8}O$ = 16.9947 u;
mass of a proton = 1.0073 u;
mass of an α-particle = 4.0015 u.

(i) Write an equation for this nuclear reaction, showing the mass numbers and the atomic numbers of the particles involved.

[2]

$^{14}{}_{7}N + {}^{4}{}_{2}He \rightarrow {}^{17}{}_{8}O + {}^{1}{}_{1}H$.

Symbol, mass number and atomic number of alpha particle
Symbol, mass number and atomic number of proton
Correct representation of nuclear equation

(ii) Calculate the minimum kinetic energy of the alpha particle for the reaction to make this reaction occur.

kinetic energy = ……………………………J [3]

Solutions
Sum of the masses of $^{14}{}_{7}N$ and an α-particle
= 13.9993 u + 4.0015 u
= 18.0008 u
Sum of the masses of $^{17}{}_{8}O$ and proton
= 16.9947 u + 1.0073 u
= 18.0020 u

increase in mass
= 18.0020 u - 18.0008 u
= 0.0012 u

The minimum energy is to be supplied to the reactants in the form of kinetic energy of the α-particle

The kinetic energy of the alpha particle
= mass increase x c^2
= 0.0012 u x c^2
= $0.0012 \times 1.66 \times 10^{-27} \times (3 \times 10^{8})^{2}$
= 1.79×10^{-13} J

(b) A radioactive isotope of thallium $^{207}_{81}Tl$ emits a β-particle and is thought to emit a gamma photon. The half-life of $^{207}_{81}Tl$ is 135 days.

(i) The radiation is allowed to pass though perpendicularly a vertical uniform magnetic field and the photographs of traces is obtained in a cloud chamber under certain conditions. Fig 6.1 show tracks produced by the beta-particles and gamma ray photons.

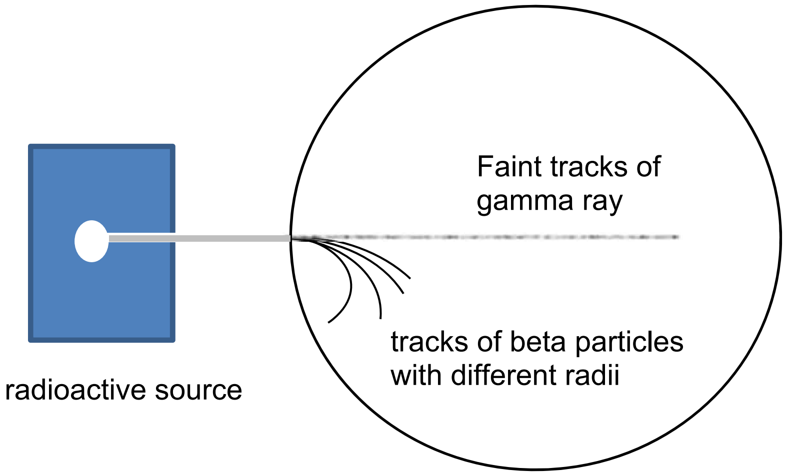


Fig. 6.1

Explain the features of the tracks.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

Circular paths of small radii show that beta particles are present and that beta particles are charged.

Circular paths of different radii show that the beta particles have different speed and hence different kinetic energy.

The faint straight line path shows the presence of gamma ray photons which have no charge and not deflected by the magnetic field. The faint path shows that the gamma ray photon has much less ionization ability as compared to the beta particles.

Max 3 marks

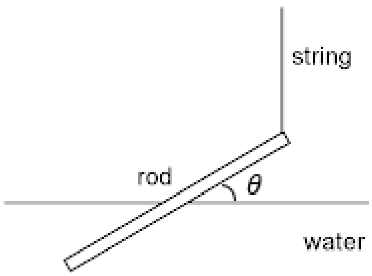
(ii) An isotope of thallium $^{207}_{81}Tl$ emits a β-particle with an average energy of 2.4×10^{-13} J.

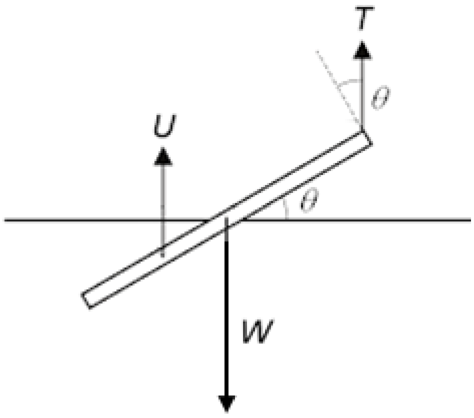
Calculate

			1. the total energy available from 1 g of thallium-207,	
			total energy = ………………J	[2]
			Solutions Energy available from 1 g of thallium-207 = number of thallium-207 atoms x 2.4 x 10^{-13} = (1/207) x 6.02 x 10^{23} x 2.4 x 10^{-13} = 6.98 x 10^{8} J	
			2. the initial rate at which the β-particles are emitted from 1 g of the freshly prepared isotope,	
			initial rate of emission = …..………………..day^{-1}	[2]
			Solution: Initial rate of β-particle emission = activity of thallium = decay constant x number of thallium nuclei = (In 2 / half-life) x number of thallium nuclei = (In 2 /135) x (1/207) x 6.02 x 10^{23} = 1.493 x 10^{19} = 1.5 x 10^{19} day^{-1}	
			3. the initial power available from the beta particles emitted at the rate calculated in **b(ii)2**.	
			initial power =………………. W	[1]
			Solutions Initial power = initial rate x energy of a β-particle = 1.493 x 10^{19} / (24 x 60 x 60) x 2.4 x 10^{-13} = 41.5 W	

Section B

Answer **One** question from this section

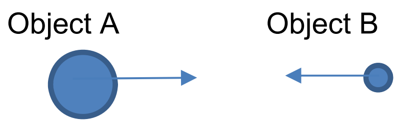
7	A uniform wooden rod of weight 50 N and length 1.0 m is gently lowered into water. The upper end of the rod is attached to a light string. When the rod is in equilibrium, the string is vertical and exactly half of the rod is underwater as shown in Fig. 7.1. The rod makes an angle θ with the surface of the water.  **Fig. 7.1**			
	(a)	**(i)**	Explain why the string is vertical.	
			……………………………………………………………………………………… ………………………………………………………………………………………	[1]
		(ii)	On Fig. 7.1, draw the three forces tension T, upthrust U and the weight W acting on the rod.	[2]



Where

W is the weight of the rod and T is the tension on the string
U is the upthrust on the rod

		(iii)	By considering moments about the centre of gravity of the rod, show that $T = 0.5\,U$.	[2]
			Taking moments about the centre of gravity of the rod, $$U\cos\theta\left(\frac{0.5}{2}\right)=T\cos\theta\,(0.5)$$ $$0.5\,U=T$$	
		(iv)	Calculate the magnitude of T.	[2]
			T = ……………….N	
			Balancing vertical forces, $$T + U = W$$ Using, $$0.5\,U = T$$ We have, $$T + 2T = W$$ $$T = 16.7\ N$$	
		(v)	By balancing the forces, determine the density of the wooden rod. The density of water is 1.0×10^3 kg m^{-3}.	
			density of rod = ……………………..kg m^{-3}	[4]
			Balancing vertical forces,	

			$T + U = W$ $0.5\,U + U = W$ $U = \frac{2}{3}W$ $U = V_f \rho_f g$	B1
			Since volume of the rod, V_r is equal to the twice the volume of the fluid displaced, $2V_f$	B1
			$U = 0.5 V_r \rho_f g$ $\frac{2U}{\rho_f g} = V_r$ We have, $W = V_r \rho_r g$ $W = \frac{2U}{\rho_f g}\rho_r g$ $W = \frac{4W}{3\rho_f g}\rho_r g$ $\rho_r = \frac{3(1000)}{4} = 750\ kg\ m^{-3}$	
	(b)	**(i)**	State the principle of the conservation of momentum.	
			....	[1]
			The total linear momentum of a system will remain constant if no net external force acts on it.	A1
		(ii)	Object **A** of mass 1.2 kg collides head-on and elastically with object **B** of mass 0.60 kg moving with a speed 0.20 m s^{-1} towards it as shown in Fig. 7.2.  **Fig. 7.2** After the collision, object **B** moves off with a speed of 0.10 m s^{-1} opposite to its initial motion.	
			Calculate the initial speed of object **A**.	
			initial speed of **A** = ... m s^{-1}	[3]
			Taking vectors to the right as positive.	

Using conservation of linear momentum

$1.2u+0.6(-0.2)=1.2v+0.6(0.1)$

$1.2u=1.2v+0.18$----(1)

Using relative speed of approach = relative speed of separation:

$u+0.2=0.1-v$-----(2)

Solving (1) and (2)

u = 0.025 m s^{-1}

(c) A 80 kg astronaut is at a distance of 30 m from a space shuttle. He wishes to return to the space shuttle by means of a thruster. The thruster is attached to the body of the astronaut and it emits a stream of gas when it is turned on.

(i) State and explain the direction in which the gas has to be ejected for him to return to the space shuttle.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

When the gas is ejected from the thruster, it gains a momentum. As a consequence, based on the conservation of momentum, the astronaut gains an equal and opposite momentum.

Hence the gas is to be ejected in the opposite direction to that in the direction of the space shuttle.

OR

The thruster exerts a force onto the gas.

By Newton's third law, the gas exerts an equal and opposite force on the thruster and the astronaut.

To allow the astronaut to move towards the space shuttle, the gas is to be ejected in the opposite direction to that in the direction of the space shuttle.

(ii) The gas is ejected at a constant rate of 0.5 kg s^{-1} and at a speed of 20 m s^{-1} relative to the astronaut for a period of 1.0 s.

Calculate the speed of the astronaut at the end of 1.0 s.

speed = ……………..m s^{-1} [2]

Based on the conservation of momentum,

$m\Delta u = M\Delta v$

$(0.5)(1)(20 - 0) = 80 (v - 0)$

v = 0.125 m s^{-1}

OR

			Magnitude of momentum of gas $F\Delta t = \Delta p$ $\frac{dp}{dt}\Delta t = m\Delta v$ $(0.5)(20)(1.0) = 80(v-0)$ $v = 0.125\ m\ s^{-1}$	

8	**(a)**	A cell of electromotive force E and internal resistance r is connected to a resistor of resistance R.		
		(i)	Define *electromotive force*.	
			....	[1]
			It is the energy transferred per unit charge from some form into electrical energy when charge is moved round a complete circuit. Alternate solution: The energy delivered by the cell per unit charge flow.	
		(ii)	Show, by considering energy conversion, that V the terminal potential difference of the cell is $V = E - Ir$ where I is the current flowing in the cell.	
				[2]
			Energy supplied by the cell = energy dissipated in the external and internal resistance Energy supplied by the cell per unit charge = energy dissipated in the external and internal e.m.f. of cell per unit charge = p.d across the external circuit + p.d across the internal resistance of the cell $E = V + V_r$ $E = V + Ir$ $V = E - Ir$	
	(b)		Fig. 8.1 shows a battery with e.m.f. E and an internal resistance r connected to a uniform nichrome resistance wire MN. J is a movable jockey which can slide along wire MN. The voltmeter and the ammeter are taken to be ideal.	

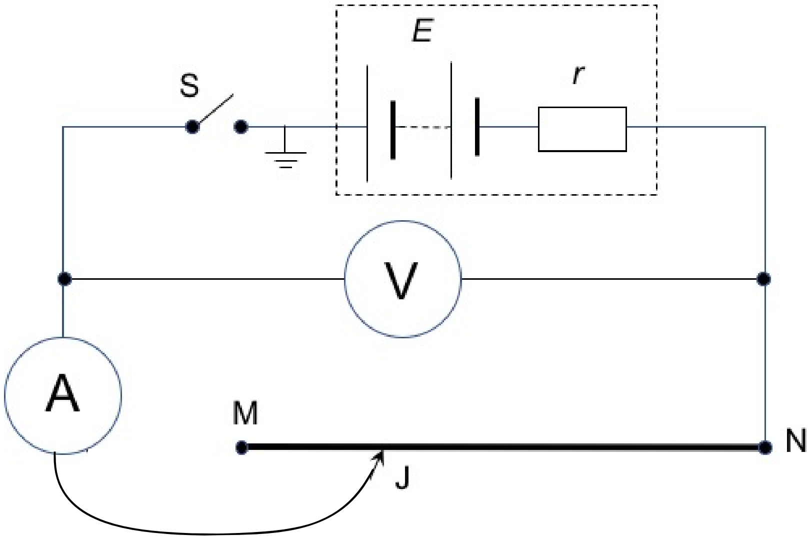


Fig. 8.1

The voltmeter readings V and ammeter readings I obtained for different lengths of JN are used to plot the graph in Fig. 8.2.

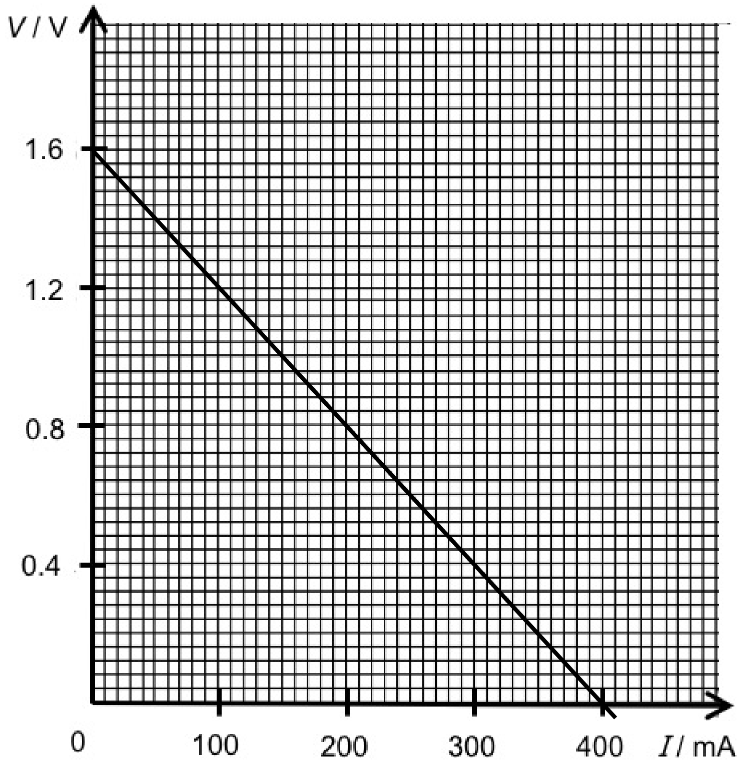


Fig. 8.2

(i) Deduce from Fig. 8.2 the e.m.f. E and the internal resistance r of the cell.

E = ………………. V

r = ………………. Ω [3]

Solution:

$V = E - Ir$

At (300, 0.4),

$0.4 = E - (300\times10^{-3})r$ - - - (1)

At (100, 1.2),

$1.2 = E - (100\times10^{-3})r$ - - - (2)

(2) – (1):

$$0.8 = (200\times10^{-3})r$$
$$r = 4\ \Omega$$

Sub into (2):

$$1.2 = E - (100\times10^{-3})(4)$$
$$E = 1.6\ \text{V}$$

(ii) J is placed at the position such that maximum power is delivered from the cell to the wire JN.

Determine the potential at J and N.

potential at J = ...V

potential at N = ...V [3]

Solution:

The emf is 1.6 V as calculated in b(i).

For maximum power to be delivered to JN, the resistance of JN must be the same as that of the internal resistance.

Hence the potential difference across the internal resistance must be the same as that across JN. Since JN is the only external resistor in the circuit, the potential difference must be 0.8 V (which is 50% of the emf), as it is a series connection.

Since J is connected to earth, potential at J is **0 V** and since pd drops from J to N, N is at a lower potential of **-0.8 V**. (allow for ecf)

(iii) On Fig. 8.3, sketch the graph to show how electric potential varies with position along the wire JN. Label the vertical axis clearly. Explain your answer.

[3]

Fig. 8.3

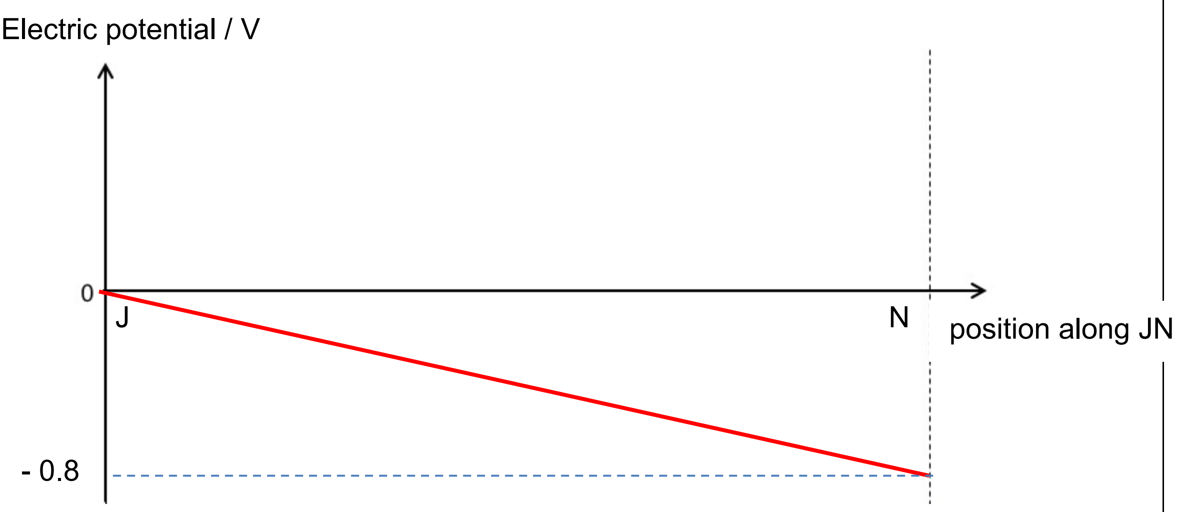


Fig. 8.3

straight line graph starting with 0 V at J and ending at – 8 V at N

Reasons:
Current along JN is constant
Potential drops along wire JN is equal to current x resistance of wire
Resistance of wire is proportional to the length since wire is uniform

Potential difference drop is proportional to length of wire measured from J, therefore graph is linear.

(iv) Suggest, with a reason, why the position of the jockey J has to be shifted, when the battery has been used for a prolong period of time for maximum power transfer.

....

....

....

.... [1]

Solution:

As the battery is used, its e.m.f. is reduced but its internal resistance will be increased.

For maximum power transfer, the external resistance should be larger now since it is equal to that of the internal resistance of the battery, hence the wire JN will be longer , so that jockey J has to be shifter to the left.

(c) **(i)** Explain what is meant by an *electric field*.

....

.... [1]

Solution:

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

(ii) Draw the charge distribution and the electric field around the charged metal bodies for the following bodies

1. an isolated positively charged sphere A.

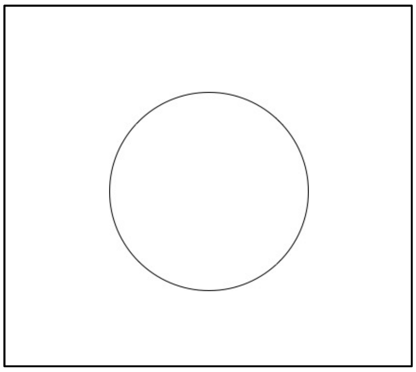
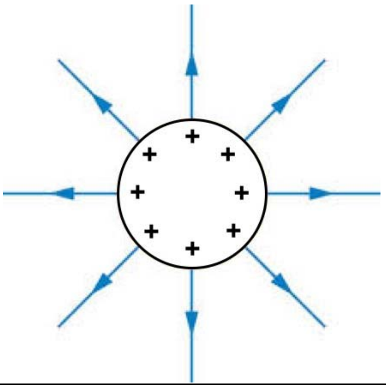


Fig. 8.1 [2]

Solution:



approximately equal distribution of positive charges
electric field pattern must correspond to the position of the charges, correct directional arrows indicated

2. When a neutral metal sphere B is brought close to the positively charged metal sphere A in **(c)(ii)1.**

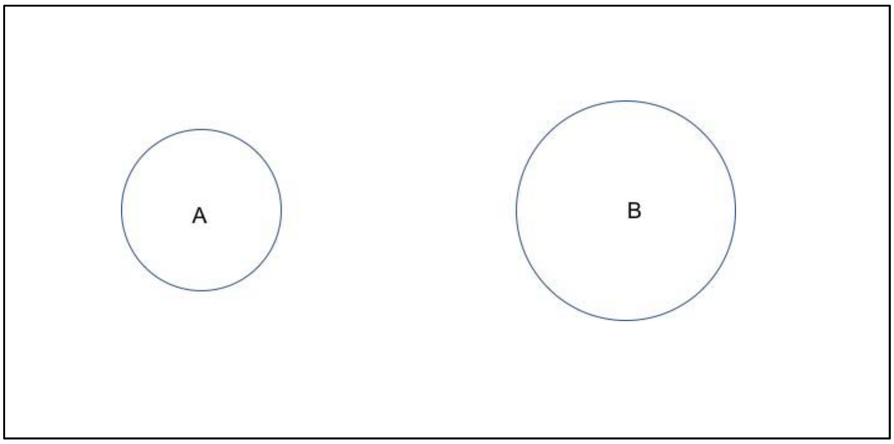
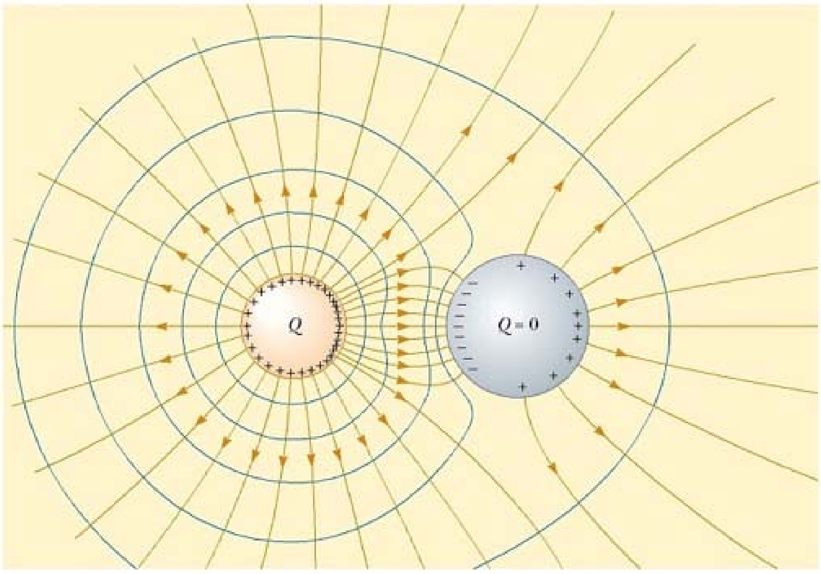


Fig. 8.2 [4]

Solution:



This solution also shows the equipotential lines.

closer distribution of positive charges on A facing B
equal number of positive charges and negative charges on B, at the correct sides
correct direction of electric field lines for A and B
correct shape of the electric field pattern

Note: equipotential lines are not required