NAME ______________________________ CLASS 2T ________

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

PHYSICS 9749/01

Paper 1: Multiple Choice

18 September 2020
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.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions** in this paper.
For each question there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet (OMR sheet).

Read the instructions on the Answer Sheet carefully.

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

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	=	$R_1 + R_2 + ...$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + ...$
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 Which of the following is not a reasonable estimate?

A The power of an electric iron is 1 kW.
B The weight of a man on the moon is 100 N.
C The momentum of a tennis ball served by a professional tennis player is 4 N s.
D The kinetic energy of a double-decker bus moving at a constant speed on an expressway is 50 kJ.

2 Four students **A**, **B**, **C** and **D** measured the potential difference across an electric component. Each student obtained five sets of data for the potential difference.

If the actual potential difference is 1.65×10^{-2} V, which student's measurement was accurate but not precise?

	potential difference / 10^{-2} V					mean / 10^{-2} V
A	1.61	1.65	1.65	1.58	1.61	1.62
B	1.66	1.68	1.63	1.64	1.65	1.65
C	1.65	1.64	1.65	1.65	1.66	1.65
D	1.69	1.70	1.69	1.70	1.69	1.69

3 A boat moves at velocity of 4 m s^{-1} due south in still water across a lake. It then experiences a current flowing towards the west. The velocity of the boat changes to 7 m s^{-1}.

What is the change in the velocity of the boat due to the current?

A 3 m s^{-1} due west
B 3 m s^{-1} due west of south
C 6 m s^{-1} due west
D 6 m s^{-1} due west of south

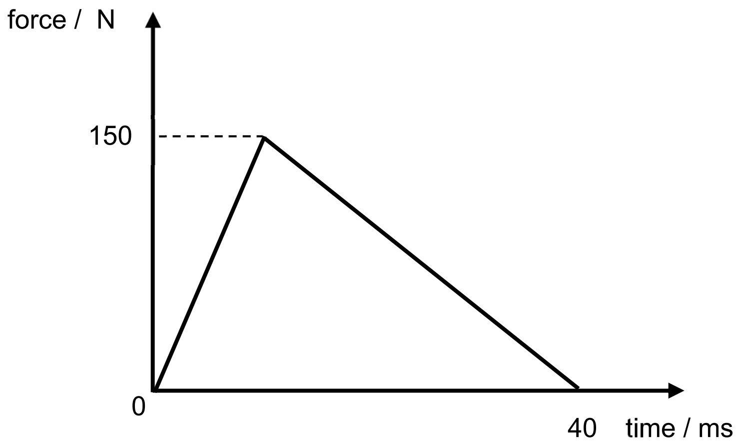
4 Two cars are initially side-by-side and at rest. They then accelerate in the same direction along the same straight line at different uniform rates. After 4.0 s, one of the cars is 12 m ahead of the other.

If they continue to accelerate at the same rate, how far apart will they be 6.0 s after they started?

A 15 m **B** 18 m **C** 22 m **D** 27 m

5 A tennis ball of mass 0.060 kg is moving normally towards a racket with an initial velocity of 5.0 m s^{-1} and rebounds in the opposite direction.

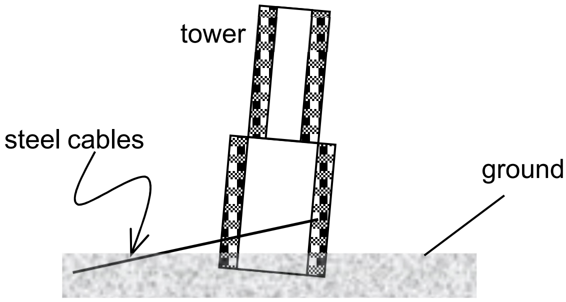
The force of the racket exerted on the tennis ball varies with time as shown.



What is the final velocity of the ball when it leaves the racket?

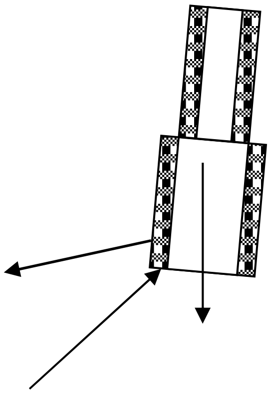
A 45 m s^{-1} **B** 50 m s^{-1} **C** 55 m s^{-1} **D** 95 m s^{-1}

6 A tower is pulled by a bundle of steel cables anchored to the ground, as shown by the simplified sketch below.

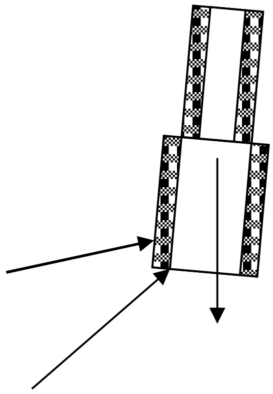


The tower is acted upon by three forces. Which diagram shows the position and direction of each of the forces when the tower is in equilibrium?

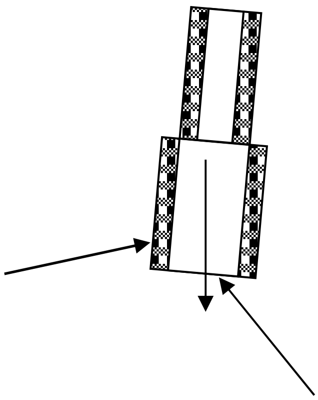
A



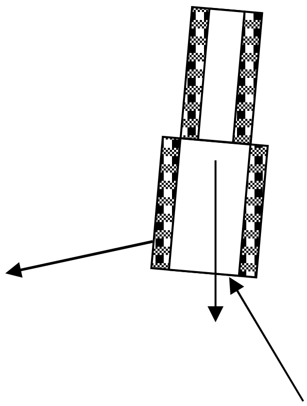
B



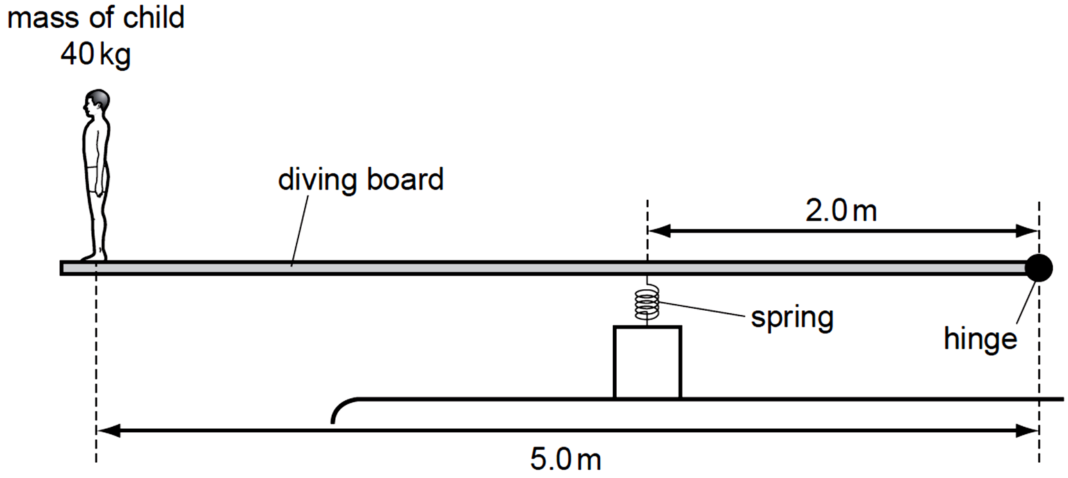
C



D



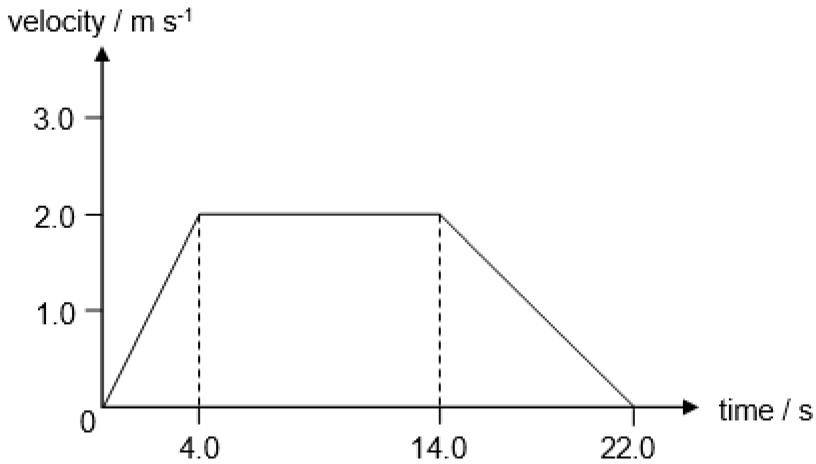
7 A diving board of length 5.0 m is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.



What is the compression of the spring caused by the child standing on the end of the board?

A 1.0 cm **B** 1.6 cm **C** 9.8 cm **D** 16 cm

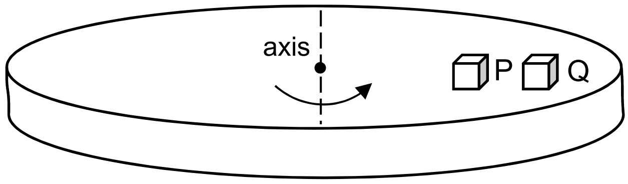
8 The diagram shows the velocity-time graph of a 500 kg elevator during its upward motion.



What is the maximum power generated by the engine of the elevator?

A 7810 W **B** 9310 W **C** 9810 W **D** 10300 W

9 Two identical objects, P and Q, are placed on a flat rough circular disc. Q is at a further distance from the centre of the disc compared to P.



The disc starts spinning from rest about its central axis with increasing speed. At a certain speed, one of the objects starts to slide off the disc.

Q slides off the disc first because

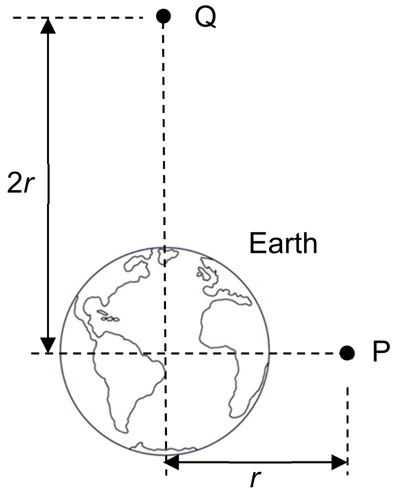
A the friction experienced by P and Q are always equal.

B it moves with a larger angular velocity compared to P.

C it requires greater friction to keep it in its position compared to P.

D the friction experienced by P is larger than Q before one of the objects slide off the disc.

10 P and Q are two points above Earth's surface at distances r and $2r$ respectively from the centre of the Earth.



The gravitational potential at P is –800 kJ kg^{-1}. What is the gain in gravitational potential energy of a 2 kg mass when it is moved from P to Q?

A - 400 kJ **B** - 200 kJ **C** 400 kJ **D** 800 kJ

11 Planet X has a density of ρ and radius of R. The gravitational acceleration at its surface is a. What is the gravitational acceleration at the surface of Planet Y which has a density of 2ρ and radius of $2R$?

A 0.5 a **B** a **C** 2 a **D** 4 a

12 A particle of mass 5.0×10^{-3} kg performing simple harmonic motion of amplitude 150 mm takes 47 s to make 50 oscillations.

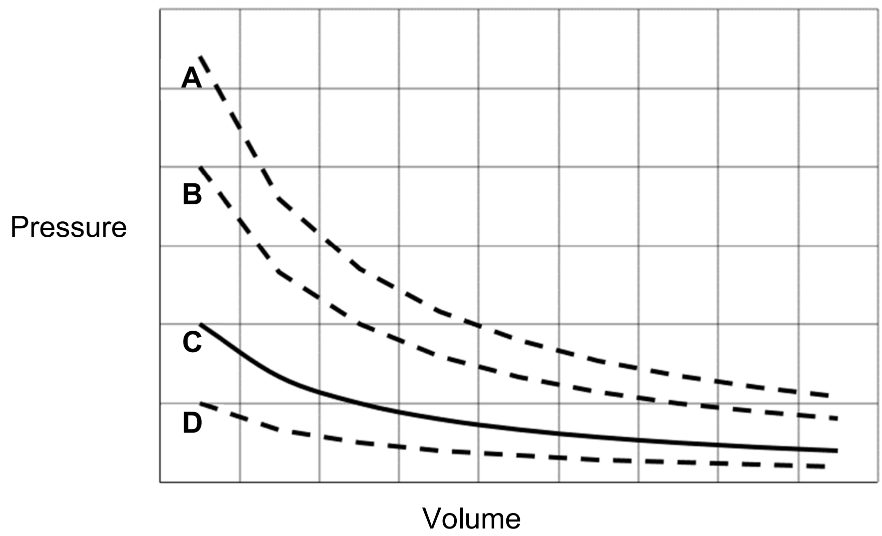
What is the maximum kinetic energy of the particle?

A 2.0×10^{-3} J **B** 2.5×10^{-3} J **C** 3.9×10^{-3} J **D** 5.0×10^{-3} J

13 Which of the following statements is true for a stationary sound wave?

A The pressure at a displacement node is always very high.
B The pressure at a displacement antinode is always very high.
C The pressure at a displacement node fluctuates between high to low.
D A stationary wave can be formed by two waves with the same amplitude and frequency, travelling at the same direction towards a point.

14 In the figure below, graph **C** shows how the pressure of a fixed mass of an ideal gas varies with its volume at a constant temperature.



If a similar ideal gas with double the mass is used and the experiment is conducted at the original constant temperature, which curve (**A**, **B**, **C** or **D**) gives the variation of the gas pressure with its volume?

15 An ideal gas undergoes a cyclic process in three stages:

(1) Expansion at constant pressure,
(2) Decrease in pressure at constant volume,
(3) Compression at constant temperature.

Which of the following must be true?

A There is net heat released by the gas during the cycle.

B The net work done on the gas during the cycle is positive.

C The net work done by the gas during the cycle is equal to the net heat transferred to the gas.

D The change in internal energy of the gas is equal to the work done during the constant pressure stage minus the work done during the constant temperature stage.

16 A beam of plane-polarised light of intensity I falls normally onto a thin sheet of polaroid.

If the transmitted beam has an intensity of $\frac{3}{4}I$, what is the angle between the plane of polarisation of the incident beam and the polarising axis of the polaroid?

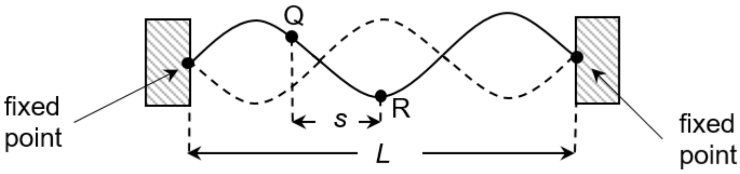
A 30° **B** 41° **C** 45° **D** 60°

17 A hemispherical bowl of radius 200 mm is completely filled with water at rest. If its side is tapped gently, a circular water wave pulse can be produced on the surface of the water which travels inwards with a speed of 250 mm s^{-1}.

What is the radius of the pulse and its direction of travel one second after the pulse is produced?

A zero, stationary
B 50 mm, inwards
C 50 mm, outwards
D 100 mm, outwards

18 A stationary wave is formed on a stretched string of length L between two points as shown below.



Particles Q and R on the string are separated by distance s. The total energy of Q and of R are E_Q and E_R respectively.

Which of the following gives the correct phase difference between Q and R, and the relationship between E_Q and E_R?

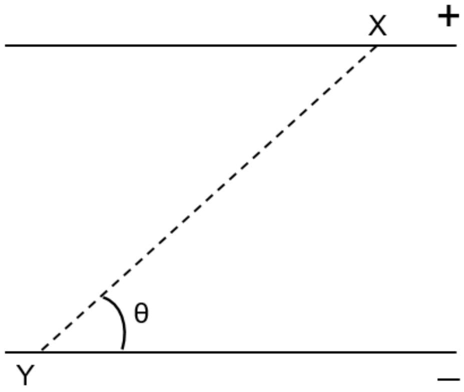
	phase difference / rad	total energy
A	$\frac{2s}{L}\pi$	$E_Q = E_R$
B	$\frac{2s}{L}\pi$	$E_Q < E_R$
C	π	$E_Q = E_R$
D	π	$E_Q < E_R$

19 Light of wavelength λ is incident normally on a diffraction grating of slit spacing five times the wavelength of the light.

What is the angle of diffraction of the second order maximum?

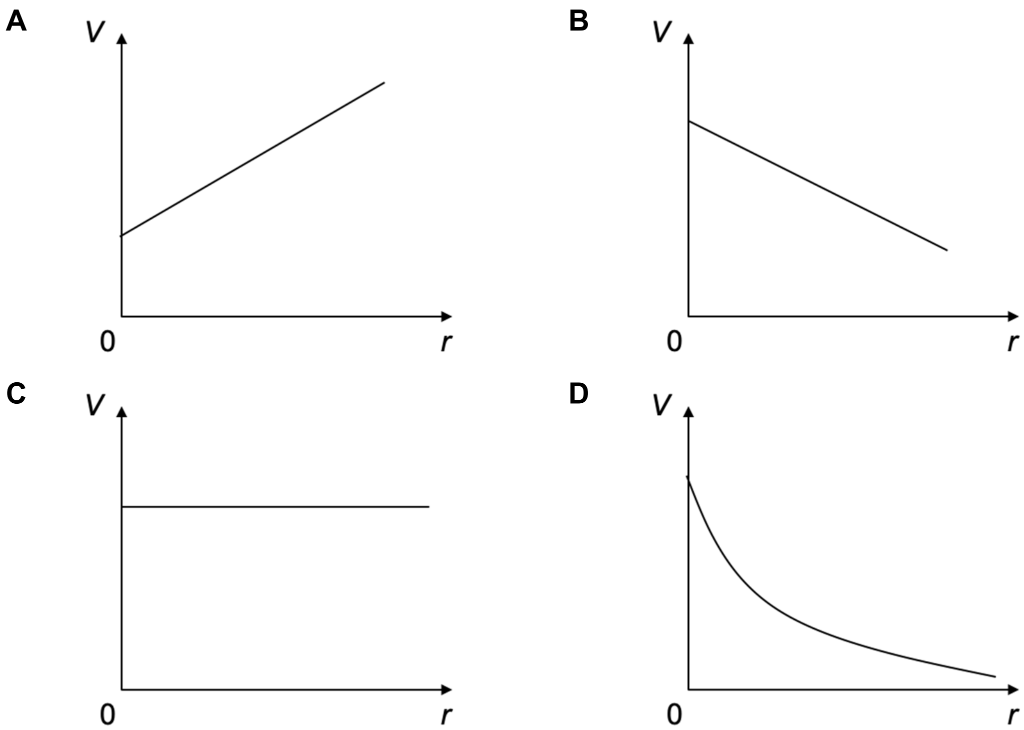
A 12° **B** 24° **C** 37° **D** 45°

20 The figure below shows two horizontal parallel metal plates. The upper plate is maintained at a higher potential relative to the lower plate.



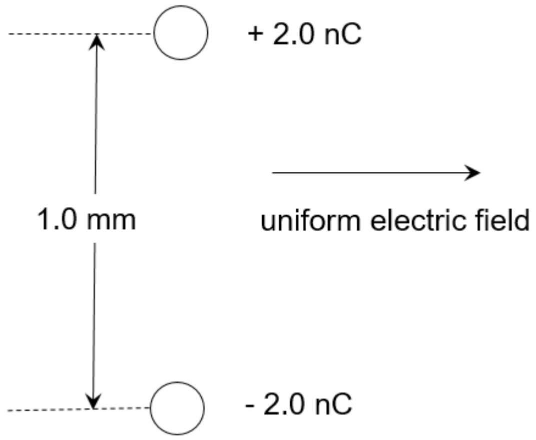
Line XY is inclined at an angle θ to the metal plates.

Which of the following graphs best shows the variation of electric potential V with distance r from X along the line XY?



21 Two charges are fixed at a distance of 1.0 mm apart as shown below.

A uniform electric field with field strength 4.0 N C^{-1} is applied in the direction from left to right.



Which statement describes the net force and torque experienced by the pair of charges?

A No net force and no torque.
B No net force and the torque is 8.0×10^{-12} N m in the clockwise direction.
C A net force of 3.6×10^{-14} N acts and the torque is 4.0×10^{-12} N m in the clockwise direction.
D A net force of 3.6×10^{-14} N acts and the torque is 8.0×10^{-12} N m in the clockwise direction.

22 A battery causes a current of 3 A to flow through a metal wire of diameter 2.0 mm. The number density of the free electrons in the metal wire is 8.5×10^{28} m^{-3}.

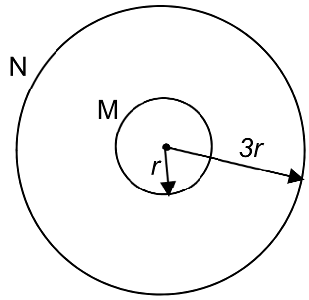
What is the average speed of the electrons drifting along the wire?

A 2.0×10^{-11} m s^{-1} **B** 2.0×10^{-5} m s^{-1} **C** 7.0×10^{-11} m s^{-1} **D** 7.0×10^{-5} m s^{-1}

23 A heater of resistance 5.0 Ω dissipates 125 W of power when current flows through it. The amount of energy converted to heat when 0.4 C of charge passes through it is

A 2 J **B** 10 J **C** 50 J **D** 625 J

24 A flat circular coil M is mounted co-axially inside another flat circular coil N. N has three times the radius of M.



The two coils are connected in series to the same power supply. At the centre of the two coils, the magnetic field created by M is opposite in direction to the magnetic field created by N.

What is the ratio of the number of turns of coil M to the number of turns of coil N to create zero magnetic flux density at the centre?

A 1 : 3 **B** 2 : 3 **C** 3 : 1 **D** 3 : 2

25 In a velocity selection, positively charged particles $+q$ enter an electric field of strength E and a magnetic field of flux density B that are applied perpendicularly to each other in the same region. Particles which are travelling at speed v are undeflected by the cross-fields.

Which of the following is necessarily true?

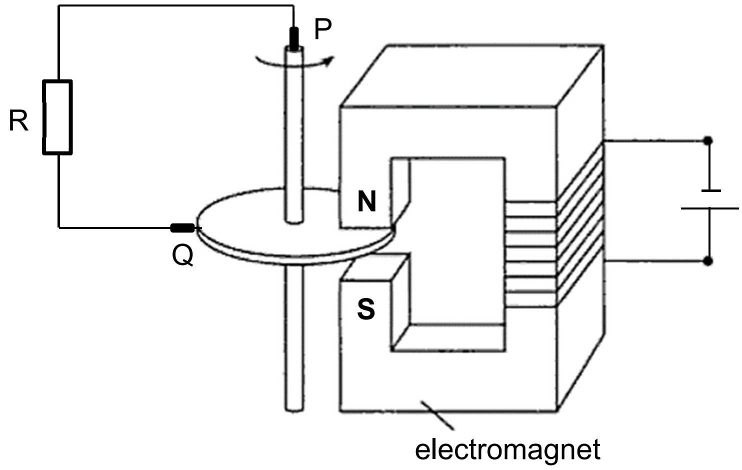
A To select particles of charge $-q$ with speed v, there is a need to reverse the direction of either E or B.

B To select charged particles with speed $2v$, with the magnitude of B unchanged, the magnitude of E needs to be doubled.

C For particles of charge $-q$, there is a need to reverse the directions of both E and B in order to select the particles with speed v.

D If the magnitude of charge doubles, the magnitudes of the electric field strength and magnetic flux density cannot remain as E and B to select the particles with speed v.

26 A copper disc spins freely between the poles of an electromagnet at a constant speed. P and Q are two metallic brushes making contact with the axle and the edge of the disc as shown in the diagram. A resistor R is connected across P and Q.



Which of the following statements is correct?

A A current flows from P through R to Q, and P is at a higher potential then Q.

B A current flows from Q through R to P, and Q is at a higher potential then P.

C A current flows from P to Q in the disc, and P is at a higher potential then Q.

D A current flows from Q to P in the disc, and Q is at a higher potential then P.

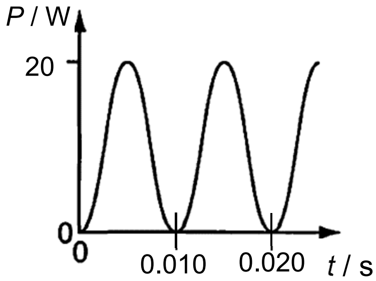
27 A sinusoidal alternating current I / A varies with time t / s according to the equation

$$I = 2.0 \sin (100\pi t)$$

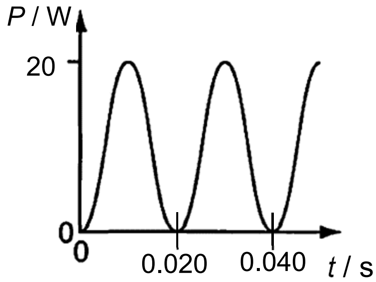
This current is allowed to pass through a resistor of resistance 5.0 Ω.

Which of the following shows how the power P / W dissipated in the resistor varies with t / s?

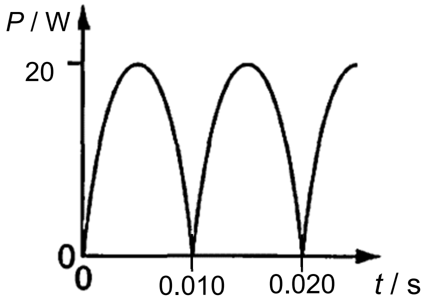
A



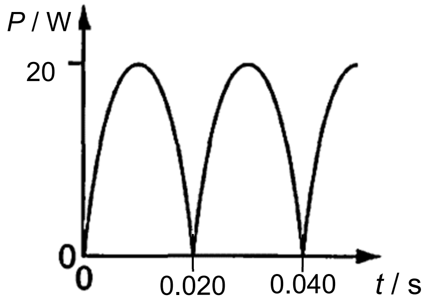
B



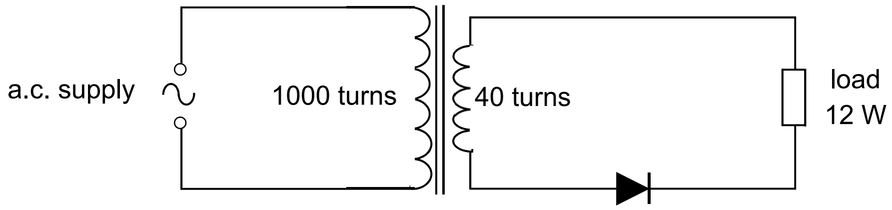
C



D



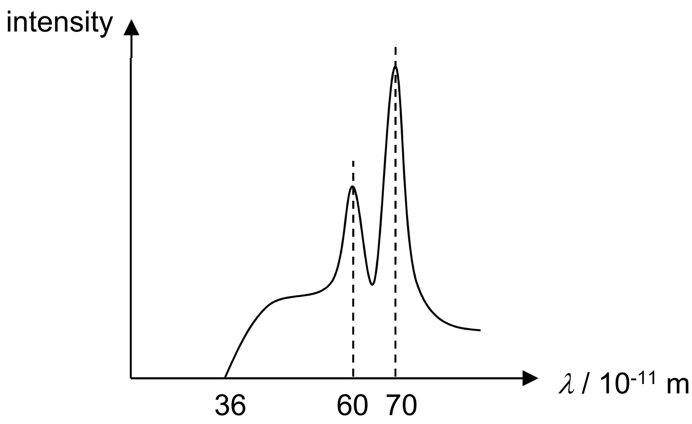
28 The primary coil of an ideal transformer has 1000 turns and is connected to a sinusoidal a.c. supply. The secondary coil has 40 turns and is connected to an ideal diode and a load.



If the root-mean-square (r.m.s) voltage across the load is 6.5 V and the mean power dissipated in the load is 12 W, what is the r.m.s current in the primary coil?

A 0.026 A **B** 0.074 A **C** 0.10 A **D** 0.15 A

29 The x-ray spectrum of a metal target is shown in the figure below.



Which of the following statements is correct?

A The smallest wavelength detected, 36 x 10^{-11} m, is dependent on the target material.

B The graph shows that electrons with a range of kinetic energies are used to bombard the target.

C The locations of the peaks can be used to identify the element that the target material is made of.

D The position of the peaks allow us to calculate the energy of the electrons used to bombard the target.

30 A photon of wavelength 555.00 nm, measured to an accuracy of 0.01 nm.

What is the minimum uncertainty in the location of the photon?

A 6.6×10^{-23} m **B** 1.0×10^{-11} m **C** 3.1×10^{-2} m **D** 3.0×10^{-1} m

-- END OF PAPER 1 --

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME

CLASS 2T

PHYSICS — 9749/02

Paper 2: Structured Questions

27 August 2020

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

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 use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 9			
Q2	/ 8			
Q3	/ 11			
Q4	/ 10			
Q5	/ 12			
Q6	/ 9			
Q7	/ 21			
PAPER 2	/ 80			

This document consists of **19** printed pages and **one** blank page.

[Turn over

PHYSICS DATA:

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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}
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	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	=	$\frac{Q}{4\pi\varepsilon_o r}$
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magnetic flux density due to a long straight wire	B	=	$\frac{\mu_o I}{2\pi d}$
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radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 (a) A ball is kicked from horizontal ground towards a vertical wall, as shown in Fig. 1.1.

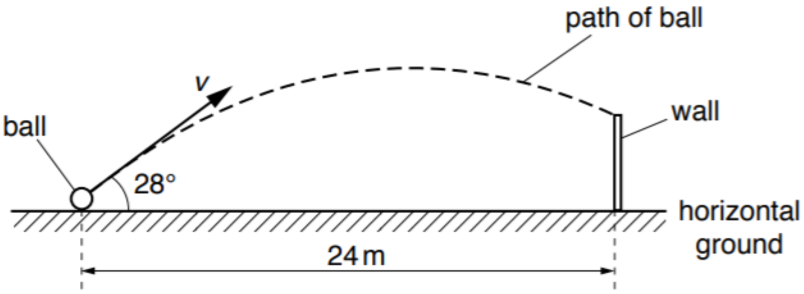

Fig. 1.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity *v* at an angle of 28° above the horizontal. The ball hits the wall after a time of 1.50 s. Air resistance is negligible.

(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ... m s^{-1} [1]

(ii) Show that the initial vertical component v_Y of the velocity of the ball is 8.5 m s^{-1}.

[1]

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

time = ... s [2]

[Turn Over

(iv) The ball is kicked at time t = 0. Assume that the vertical component v_Y of the velocity of the ball is positive in the upwards direction. On Fig. 1.2, sketch the variation with time t of v_Y for the time until the ball hits the wall. **Label this graph Q**.

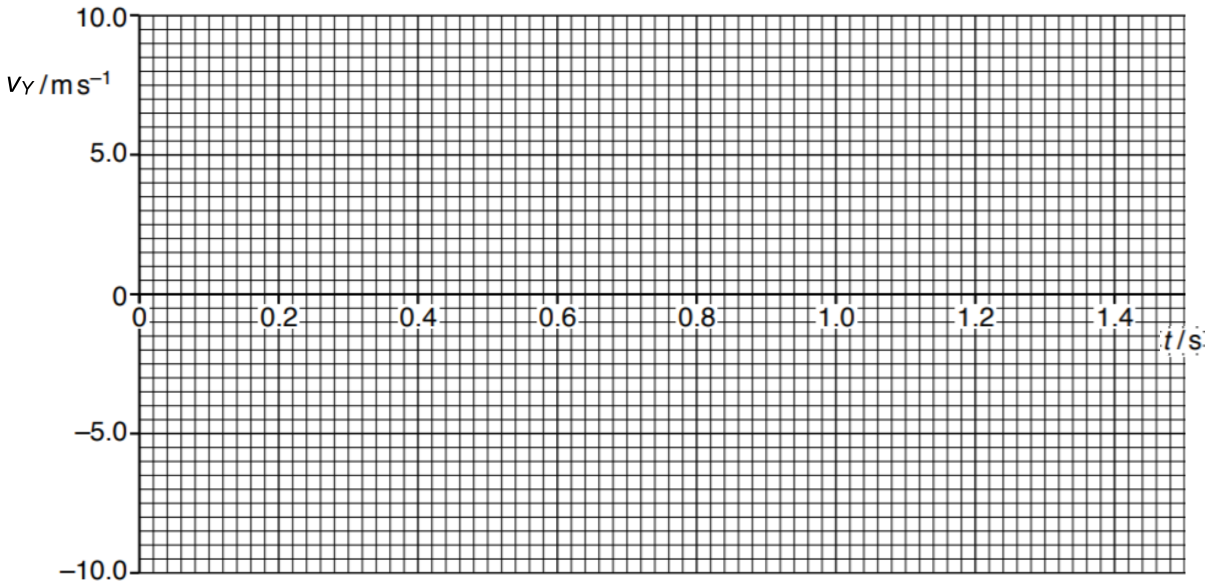

Fig. 1.2 [1]

(v) Use your graph in Fig. 1.2 to estimate the height of the wall.

height of wall = ... m [2]

(b) On Fig. 1.2, sketch a possible v_Y against t graph if air resistance acts on the ball. Assume the ball does not reach the ground before 1.50s. **Label this graph R**. [2]

2 (a) Explain the origin of upthrust acting on a body in a fluid.

....

....

....

....

....

.... [2]

(b) In order to lift a submerged load of 600 kg from a seabed, a lifting bag made of an elastic material of negligible mass is filled with air and attached to the load, as shown in Fig. 2.1. The density of seawater is 1050 kg m^{-3} and the lifting bag contains 0.700 m^3 of air of density 1.27 kg m^{-3} such that the load ascends with a constant speed.

The volume of the load is negligible compared to the volume of the lifting bag.

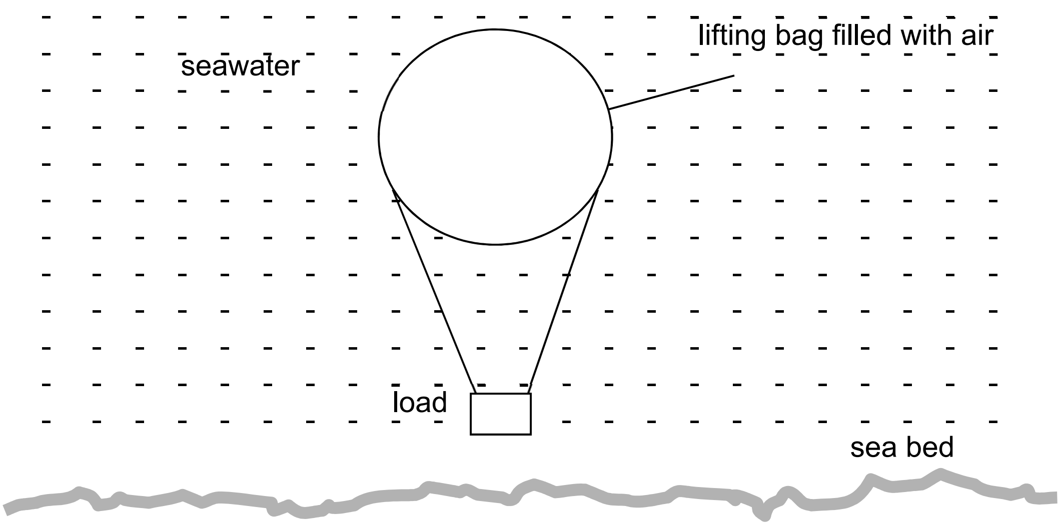

Fig. 2.1 (not to scale)

(i) Calculate the upthrust on the lifting bag when its volume is 0.700 m^3.

upthrust = ... N [2]

(ii) Calculate the total drag force on the bag and load.

total drag force = ... N [2]

[Turn Over

(iii) Explain why in practice, to maintain a constant speed of ascent, air has to be released continuously from the lifting bag. Temperature change during the ascent is negligible.

....

....

....

....

....

.... [2]

3 **(a)** State the *principle of superposition*.

....

....

....

....

.... [2]

(b) Interference effects are produced on a viewing screen as a result of interference of the direct waves from a 500 nm electromagnetic wave source S and reflected waves from the mirror as shown in Fig. 3.1.

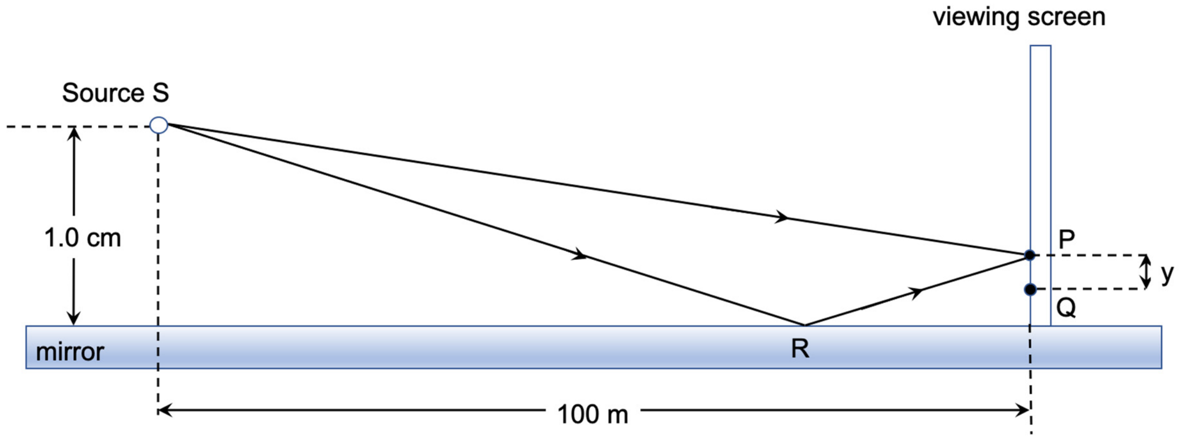

Fig. 3.1 (not to scale)

Points P and Q are at minimum intensity and there is only one point between P and Q which is at a maximum intensity.

S is placed 100 m to the left of the screen and 1.0 cm above the mirror.

(i) Explain why P is at a minimum intensity.

…….

…….

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

(ii) Calculate the distance y. Explain your working.

y = …………………………………… mm [3]

(iii) Describe and explain the changes observed at point P, if any, as a result of the following changes made independently to the experiment.

1. Source S is gradually shifted vertically further away from the mirror.

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

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

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

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

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

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

2. The mirror is replaced by a black cardboard.

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

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

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

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

4 **(a)** **(i)** State what is meant by the *internal energy* of a system.

....

....

.... [1]

(ii) Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.

....

....

....

....

....

....

.... [3]

(iii) A box, filled with an ideal gas, is rapidly accelerated horizontally from rest.

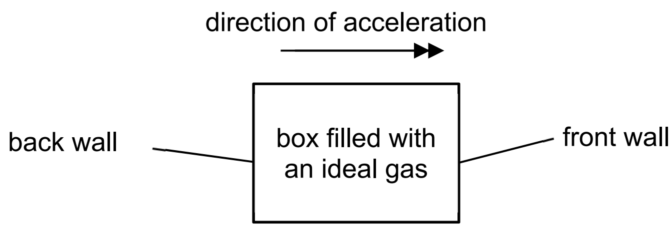

Fig. 4.1

Suggest, with a reason, how the internal energy of the gas would vary from the back wall to the front wall of the box during the acceleration.

....

....

....

....

.... [2]

(b) A cylinder of volume 1.8×10^4 cm^3 contains helium gas at pressure 6.4×10^6 Pa and temperature 25 °C. The root-mean-square speed of the helium gas atoms is 336 m s^{-1}. Helium gas may be considered to be an ideal monatomic gas.

(i) Calculate the number of helium atoms in the cylinder.

number = ... [2]

(ii) Calculate the density of helium atoms in the cylinder.

density = ... kg m^{-3} [2]

5 (a) Twin core cable, consisting of a 'live' wire and a 'neutral' wire, is commonly used for wiring applications. Current is supplied via the 'live' wire from an electrical power source to the appliance. Current then flows via the 'neutral' wire back to the electrical power source.

The twin core cable shown in Fig. 5.1 consists of two thin wires whose centres are 5.0 mm apart. Each wire carries a current of 0.25 A.

Permeability of the insulating material, $\mu = 1.3 \times 10^{-6}$ H m^{-1}.

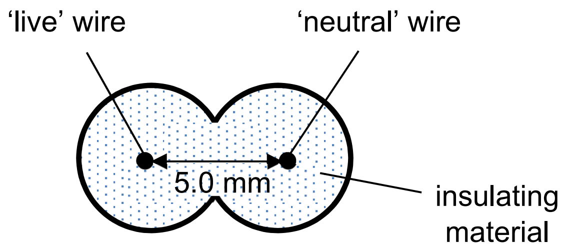

Fig. 5.1

(i) State whether the force between the wires is attractive or repulsive.

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

(ii) Calculate the magnitude of the force per unit length on each wire.

force per unit length = ……………………………………… N m^{-1} [3]

(b) A railgun is a device typically designed as a weapon that uses electromagnetic force to launch high speed projectiles. A simplified model of a railgun is shown in Fig. 5.2. Fig. 5.2 shows the top view of a pair of smooth horizontal metal rails connected across a 2.0 V battery of negligible internal resistance. The metal rails have negligible resistance. A copper rod XY of resistance 3.04 mΩ is resting on the rails. The rails and the rod lie in a horizontal plane and a uniform vertical magnetic field of flux density 24 mT is applied out of the page.

When the switch is closed, a magnetic force acts on XY which causes it to start moving towards the right. At time *t* s after the switch is closed, XY has a velocity *v* m s^{-1}.

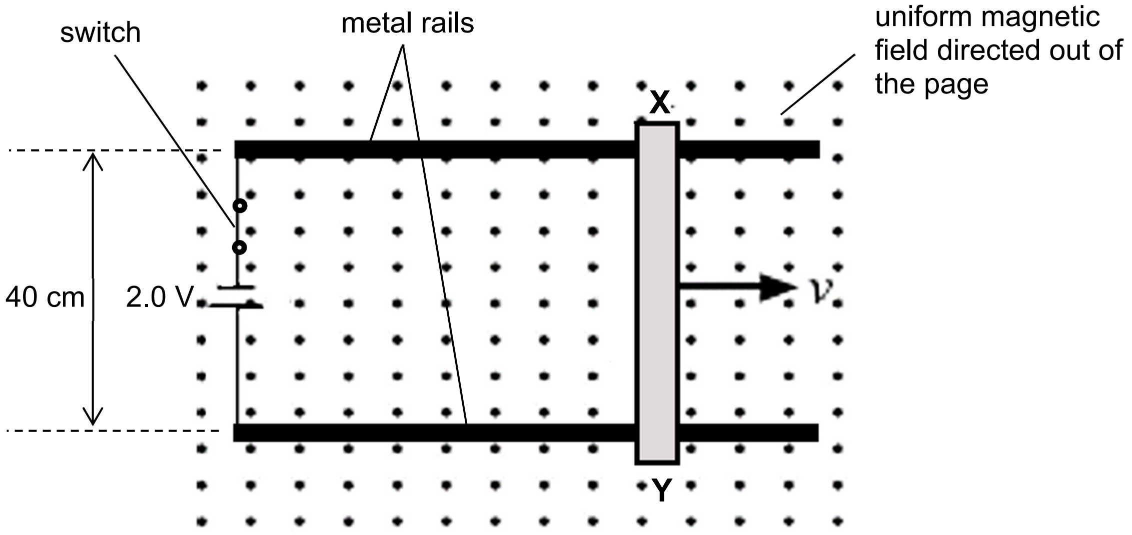

Fig. 5.2

(i) As the rod moves to the right, there is an induced e.m.f across rod XY. Use Lenz's law to explain why the **induced** electric potential at X is lower compared to Y.

……

……

……

……

……

……

……

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

(ii) Show that the current, in amperes, in the closed circuit at time *t* is given by (660 - 3.2*v*).

[2]

(iii) Show that after some time rod XY will slide with constant velocity. Determine this velocity.

Explain your working.

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

6 A photocell is connected in a series circuit with a variable d.c. power supply and a sensitive ammeter as shown in Fig. 6.1.

The photocell is illuminated with electromagnetic radiation of wavelength 264 nm and power 3.8 mW and photoelectrons are emitted. The potential difference *V* between the collector C and emitter E in the photocell is adjusted and the photocurrent I is measured. Fig. 6.2 below shows the graph of I against *V*.

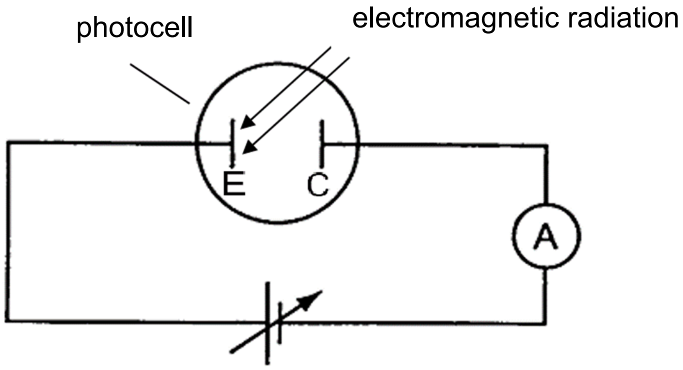

Fig. 6.1

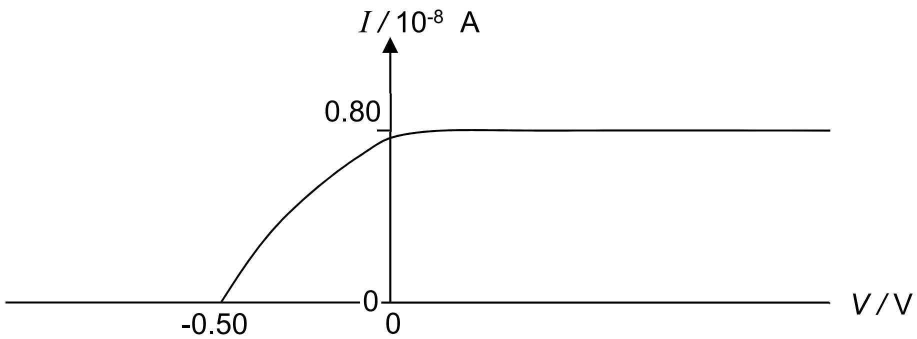

Fig. 6.2

(a) Explain why the photocurrent does not continue to increase for positive values of *V*.

....

....

....

.... [1]

(b) **(i)** Determine the energy of a photon of the incident electromagnetic radiation.

energy = ... J [1]

[Turn Over

(ii) Calculate the rate at which the photons are incident on the emitter.

rate of photon incidence = ….…………………………………… s^{-1} [2]

(iii) Show that the maximum rate of photoelectron emission is 5.0×10^{10} s^{-1}.

[1]

(iv) Suggest a reason for the difference between **(b)(ii)** and your answer in **(b)(iii)**.

……

……

……

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

(c) **(i)** Calculate the work function energy of the emitter.

work function energy = ………………………………………… J [1]

(ii) The emitter is replaced with another emitter of **half** the work function energy. On Fig. 6.2, sketch a graph to show the new variation with *V* of *I*. [2]

7 A solar cell is a device which converts light energy directly into electrical energy. Under the influence of light, a terminal potential difference (p.d.) is generated across the solar cell. This process is explained as follows.

A solar cell consists of three main layers: an N-type material layer, a Junction layer, and a P-type material layer.

There is an electric field across the Junction layer as shown in Fig. 7.1. When photons are incident on the solar cell, electron-hole pairs are generated in the Junction layer. Holes are positively charged carriers with charge +*e*. The electrons and holes move in opposite directions under the influence of the electric field, which sets up a terminal p.d. across the solar cell.

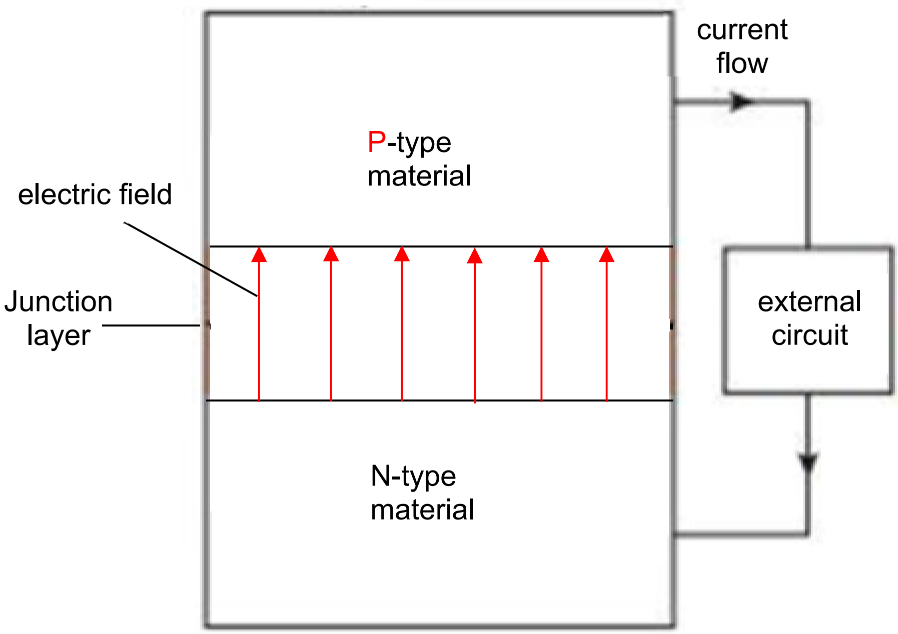

Fig. 7.1

Electron-hole pairs will be generated in the solar cell provided that the incident photon has an energy greater than a certain value known as the band gap energy of the material used.

The magnitude of the p.d. developed across the terminals of the solar cell depends on the intensity of light incident onto the solar cell.

The variation of the potential difference V across the cell with current I can be investigated using the circuit shown in Fig. 7.2.

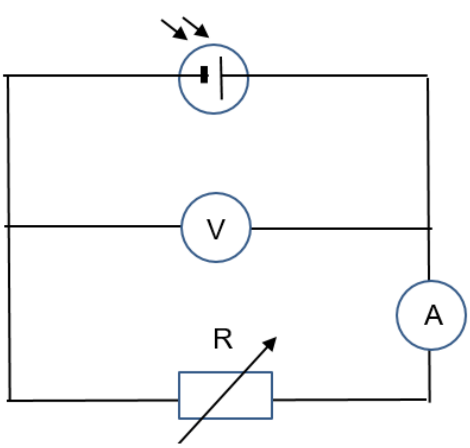

Fig. 7.2

R is a variable resistor with a maximum resistance of 7.0 Ω. The voltmeter has infinite resistance and the resistance of the ammeter is negligible.

Fig. 7.3 shows the variation of I with V for a particular cell of surface area 4.0×10^{-4} m^2 when illuminated normally with light intensity 1100 W m^{-2}.

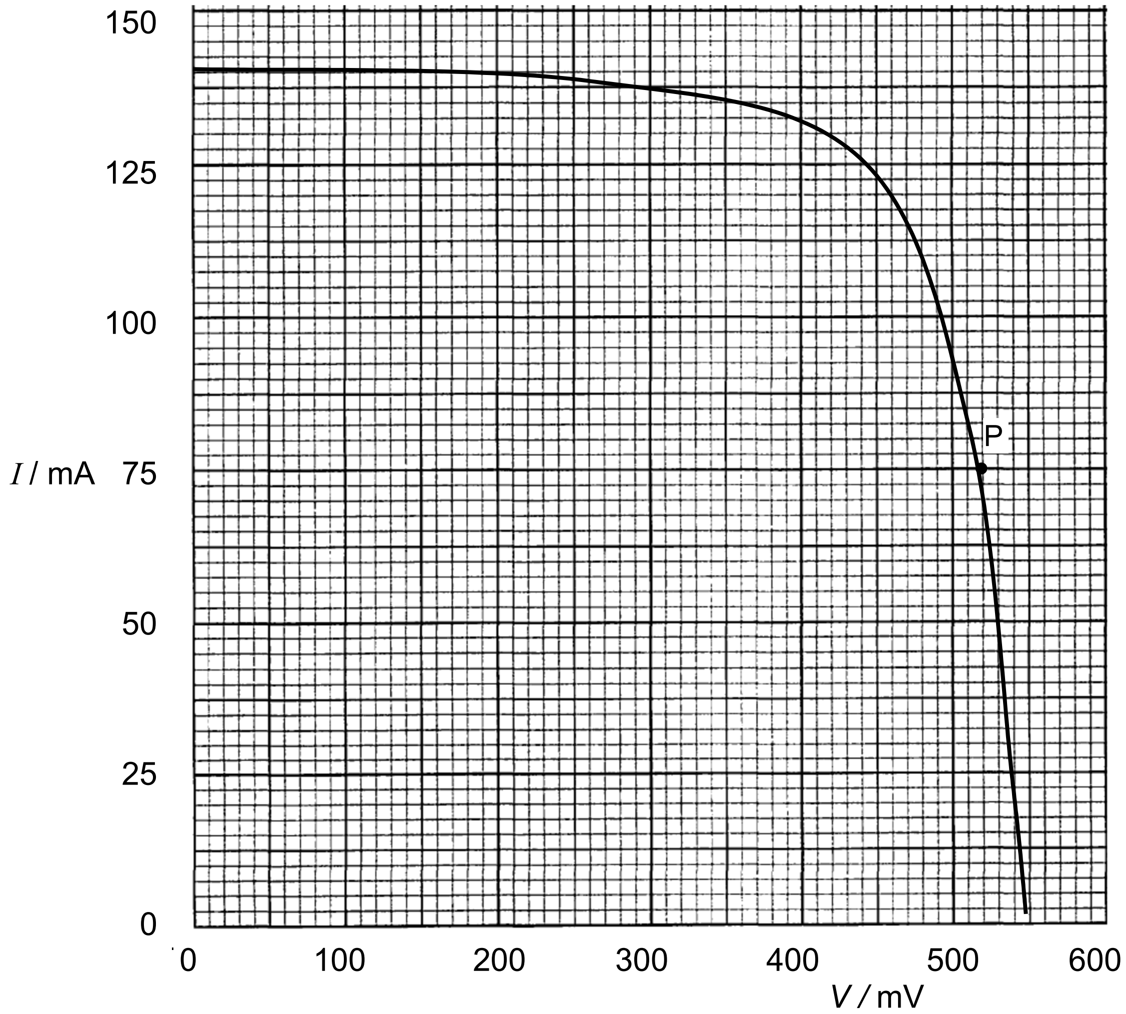

Fig. 7.3

(a) **(i)** State why a p.d. is set up across the solar cell only for a limited range of frequencies of photons.

……

……

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

(ii) Explain why the p.d. across the solar cell increases with the intensity of the incident light.

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

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

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

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

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

(b) **(i)** Explain how the graph shows that the e.m.f. of the solar cell is 550 mV.

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

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

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

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

(ii) Explain why the experiment data needed to be extrapolated to obtain the trend from P to the point when V = 550 mV.

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

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

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

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

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

(c) **(i)** From Fig. 7.3, determine the power dissipation in the load resistor for point P.

power dissipation = ………………………………………… W [2]

(ii) On Fig. 7.3, shade an area that represents the power dissipation calculate in **(c)(i).** [1]

[Turn Over

(iii) From Fig. 7.3, estimate the maximum power dissipation in the load resistor. Show your working.

maximum power = ………………………………….. W [2]

(iv) On Fig. 7.4, sketch the graph of power output P_o of the cell against V. Label and include a suitable scale on the vertical axis.

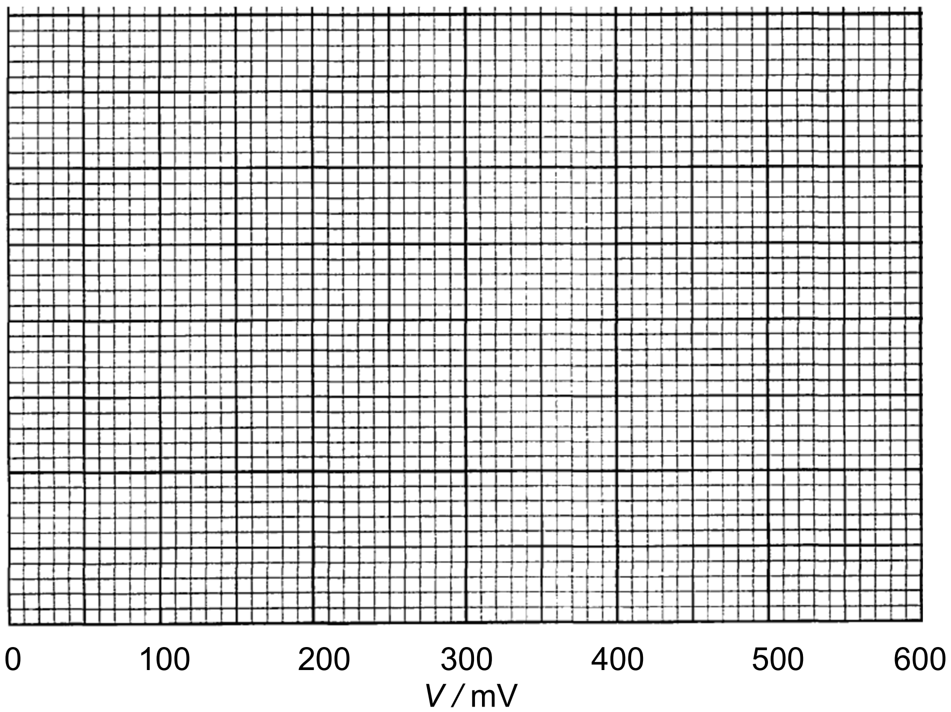

Fig. 7.4 [2]

(d) Calculate the maximum efficiency of conversion of light energy into electrical energy.

maximum efficiency = ……………………………………… [2]

(e) A number of solar cells are connected to a load resistor L as shown in Fig. 7.5.

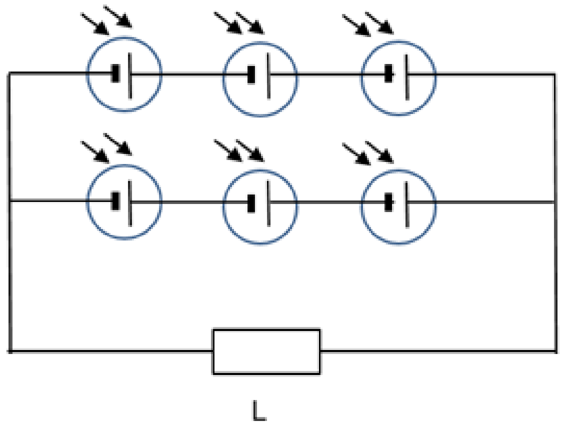

Fig. 7.5

The resistance of L has been adjusted so that each cell gives the maximum power estimated in **(c)(iii)**.

Calculate

(i) the potential difference across L,

potential difference = ... V [1]

(ii) the current through L.

current = ... A [1]

(f) Suppose each cell is operating at maximum power estimated in **(c)(iii)**. Draw a suitable network of cells so that the cells may be used to provide an output power of approximately 5 kW at 30 V.

[3]

-- END OF PAPER 2 --

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Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	
CLASS	**2T**

PHYSICS

9749/03

Paper 3: Longer Structured Questions

14 September 2020

2 hours

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

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.

Section A: Answer **all** questions.

Section B: Answer **one** question only. **Circle** the question number attempted in Section B.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
SECTION A				
Q1	/ 8			
Q2	/ 7			
Q3	/ 10			
Q4	/ 11			
Q5	/ 12			
Q6	/ 5			
Q7	/ 7			
SECTION B				
Q8	/ 20			
Q9	/ 20			
PAPER 3	/ 80			
PAPER 2	/ 80			
PAPER 1	/ 30			
TOTAL FOR THEORY	/ 190			

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

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	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Fig. 1.1 shows block A of mass 1.5 kg held against a spring with a force F. The spring is compressed by 2.0 cm.

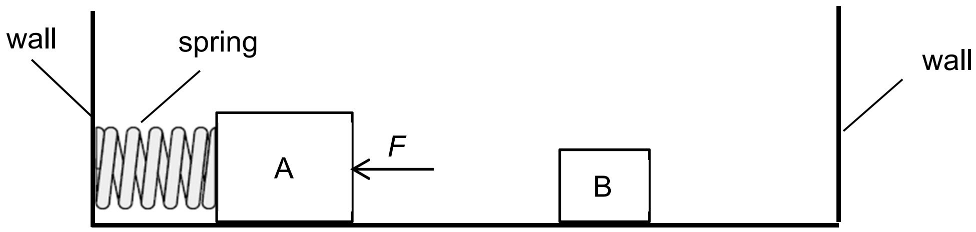


Fig. 1.1

The force F is then removed and the block A accelerates to the right before losing contact with the spring with a speed of 0.50 m s^{-1} as shown in Fig. 1.2. Block A collides elastically head-on with block B. The mass of block B is 0.50 kg.

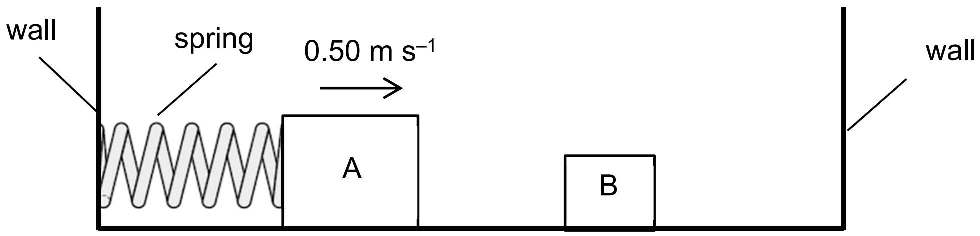


Fig. 1.2

Air resistance and frictional forces are negligible.

(a) Determine the speed of block B after the collision with block A.

final speed of block B = ………………………………… m s^{-1} [3]

[Turn Over

(b) Fig 1.3 shows the variation with time of the force acting on block A during the collision with block B.

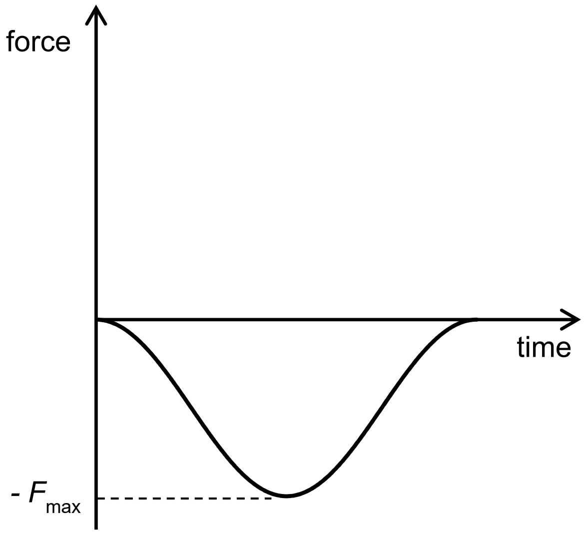


Fig. 1.3

(i) Sketch on Fig. 1.3, the corresponding graph to show how the force on block B varies with time during the collision between block A and block B. [1]

(ii) Explain how your graph shows that the total momentum of the blocks remains unchanged during the collision.

....

....

....

.... [2]

(c) Block B hits the wall elastically, rebounds and collides with block A. Block A then moves and compresses the spring. State, with a reason, whether the maximum compression of the spring will be greater than, less than or equal to 2.0 cm.

....

....

....

.... [2]

2 A block of mass 2*m* initially rests on a track at the bottom of the circular, vertical loop of radius *r* as shown in Fig. 2.1. A bullet of mass *m* strikes the block horizontally and remains embedded in the block as the block and bullet circle the loop. Assume frictional force of the loop is negligible.

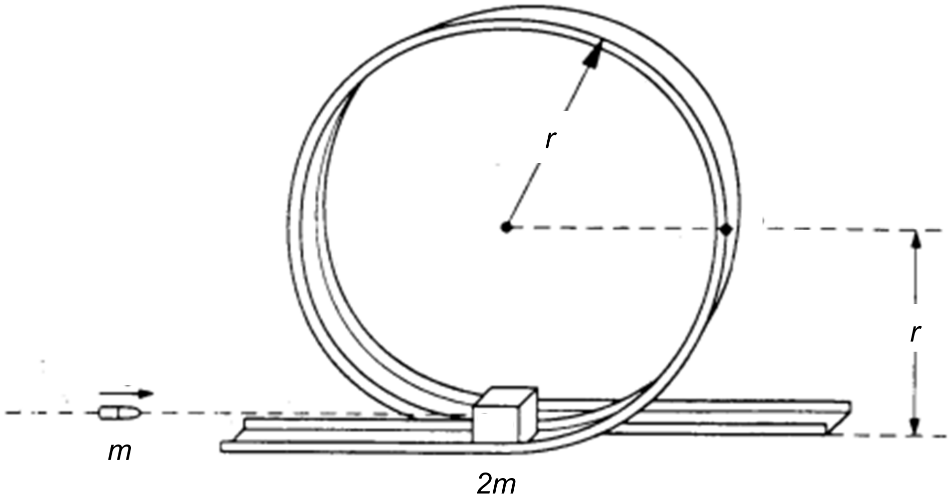


Fig. 2.1

(a) Show that the minimum speed of the block at the top of the loop such that it just completes the vertical circular motion without falling off the loop is given by

$$\sqrt{gr}$$

where *g* is the acceleration due to gravity.

[3]

(b) Derive an expression for the minimum speed of the bullet in order for the block to just complete the vertical circular motion without falling off the loop.

Explain your working.

[4]

3 (a) A ball is held between two fixed points A and B by means of two stretched springs as shown in Fig. 3.1.

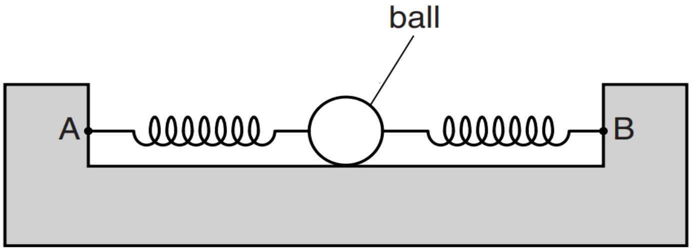


Fig. 3.1

The ball is free to oscillate horizontally on the smooth horizontal table. The variation of the acceleration *a* of the ball with its displacement *x* from its equilibrium position is shown in Fig. 3.2.

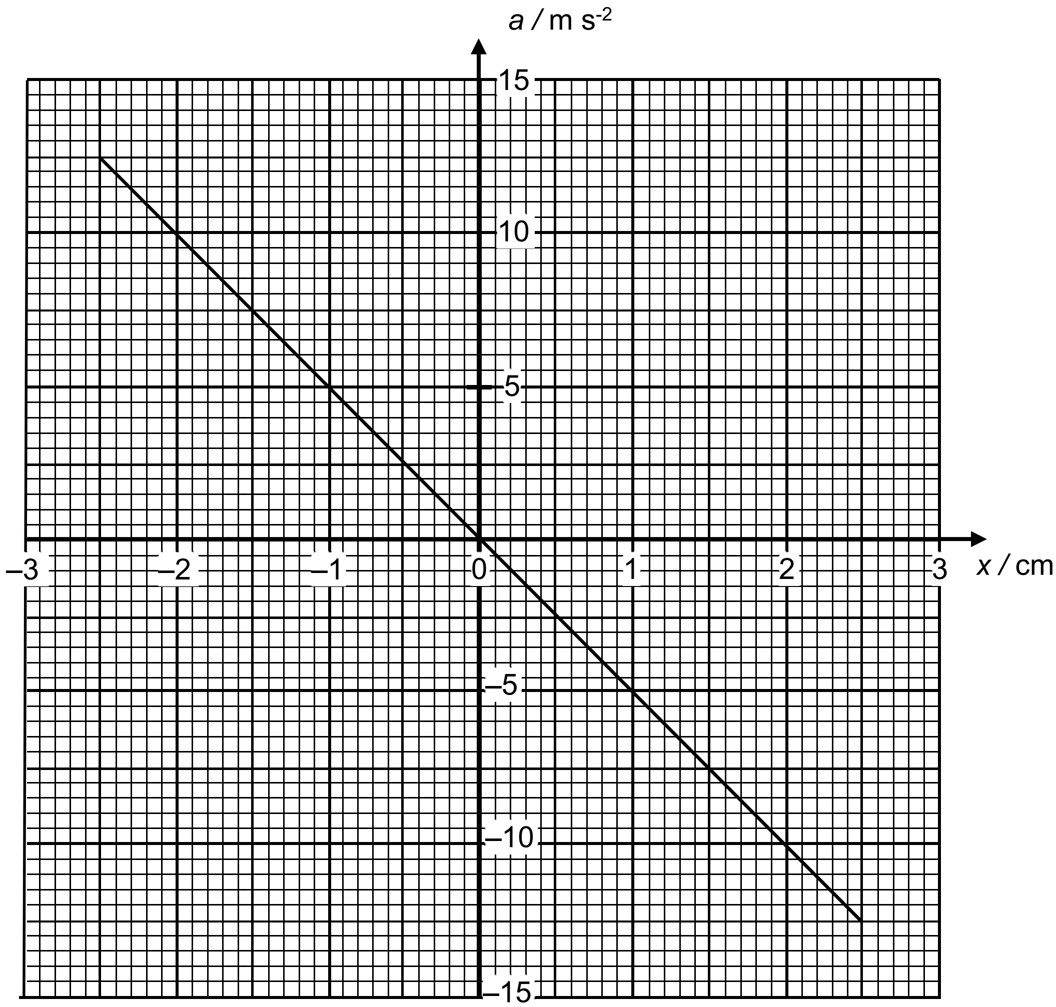


Fig. 3.2

(i) State and explain the features of Fig. 3.2 which indicate that the moving ball is exhibiting simple harmonic motion.

....

....

....

.... [2]

[Turn Over

(ii) On Fig. 3.3, sketch the variation of the velocity *v* of the ball with *x*. Include the values of the horizontal and vertical intercepts of the graph.

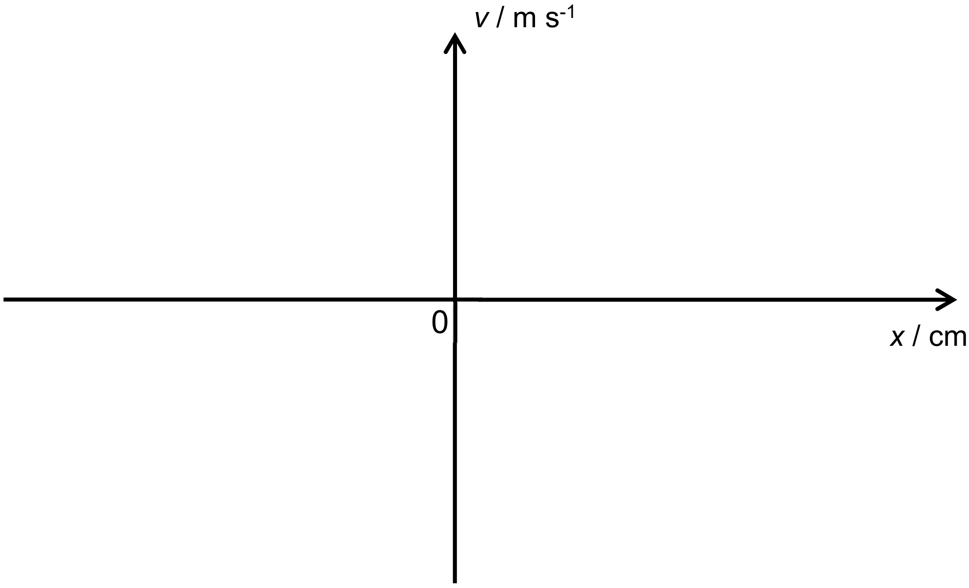


Fig. 3.3 [3]

(b) A ball is attached to the apparatus illustrated in Fig. 3.4 in order to investigate its vertical oscillations on a spring. The amplitude of the vibrations produced by the oscillator is constant.

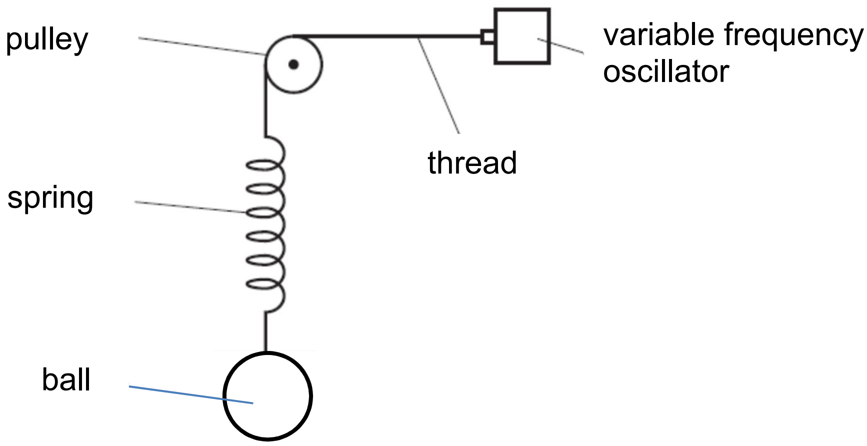


Fig. 3.4

The variation of the amplitude of the oscillations of the ball with the frequency f of the oscillator is shown in Fig. 3.5. The oscillations are assumed to be simple harmonic.

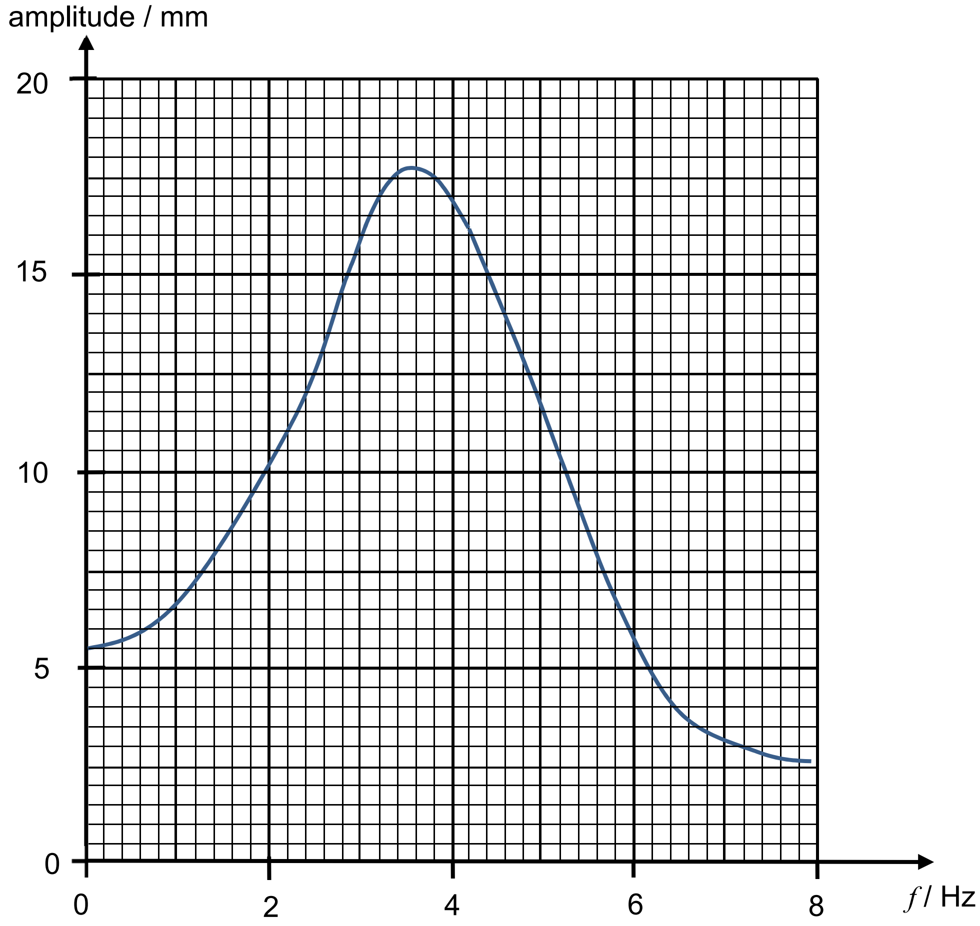


Fig. 3.5

(i) State the natural frequency of the oscillations.

natural frequency = ... Hz [1]

(ii) Explain why Fig. 3.5 shows that the oscillations are damped.

....

....

....

.... [1]

(iii) On Fig. 3.5, sketch a possible variation of the amplitude of the oscillations of the ball with f if the oscillations are damped with a greater resistive force. [3]

4 **(a)** A Keck telescope at Mauna Kea, Hawaii, is the world's largest optical telescope and has a diameter of 10 m and is set to detect waves of wavelength 600 nm. The distance, in metres, from the aperture to the viewing screen is *L*.

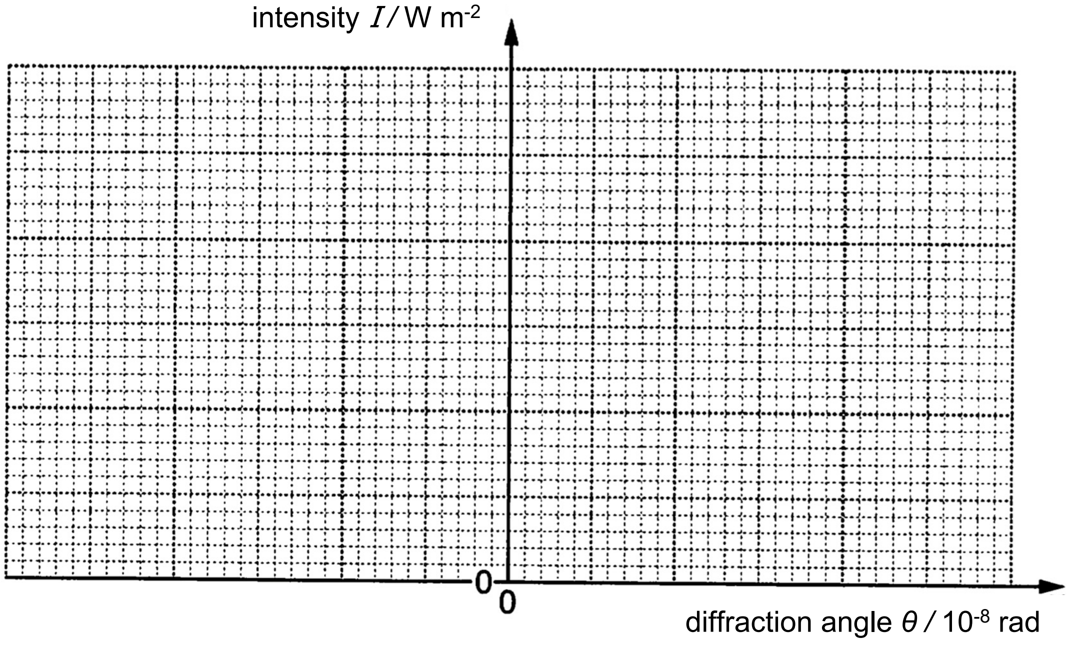
(i) Calculate the diffraction angle θ_{min} at which the first minimum of the diffraction pattern is observed on the viewing screen.

θ_{min} = ... rad [2]

(ii) Determine, in terms of *L*, the width of the central bright fringe of the diffraction pattern observed on the viewing screen.

width = ... m [2]

(iii) On Fig. 4.1, sketch a graph to show the variation with diffraction angle θ from the central maximum of the intensity I of the light on the viewing screen. Include the angles for the first minima.



[3]

Fig. 4.1

(b) A radio telescope at Arecibo, Puerto Rico, has a diameter of 305 m and is designed to detect radio waves of wavelength 0.75 m.

(i) State two physical quantities that determine the resolving power of the telescope.

quantity 1 : ……………………………………

quantity 2 : …………………………………… [2]

(ii) Explain quantitatively whether the Keck telescope used in the detection of light waves has a higher or lower resolving power compared to the radio telescope used in the detection of radio waves at Arecibo.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

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

5 (a) Define *potential difference* between two points in a circuit.

……

……

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

(b) A thermistor and a variable resistor are connected in a potential divider circuit as shown in Fig. 5.1.

The battery has an e.m.f. of E, the thermistor has a resistance R_T and the variable resistor has a resistance R_V.

This circuit is used to activate an alarm system whenever the ambient temperature rises to a certain value. The alarm bell will sound if the potential difference across it increases beyond the pre-set value.

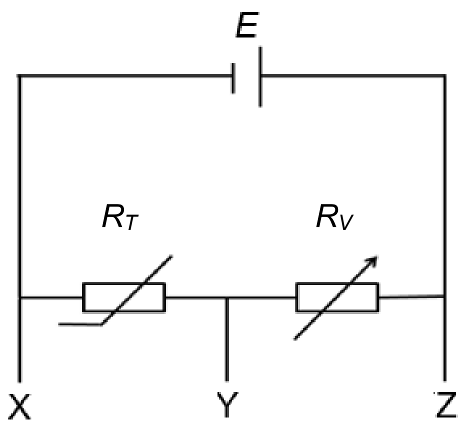


Fig. 5.1

(i) State an expression for the potential difference across the variable resistor in terms of E, R_T and R_V. [1]

(ii) State and explain across which two terminals, XY or YZ, the alarm bell should be connected to the circuit in Fig. 5.1.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) State and explain the purpose of the variable resistor in the circuit.

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

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

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

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

(c) Fig. 5.2 shows a potentiometer circuit consisting of a 100 cm length of wire AB and a driver cell E_1 of e.m.f. 2.0 V and of negligible internal resistance.

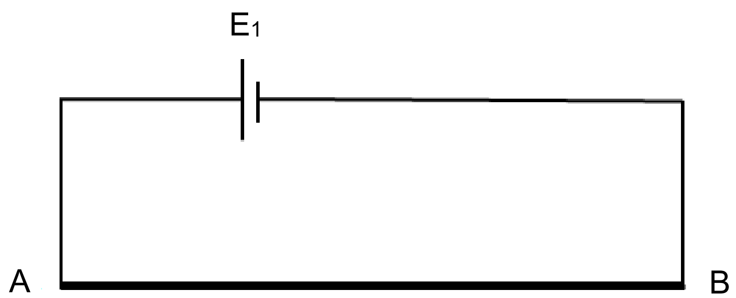


Fig. 5.2

(i) State the value of the potential gradient along AB.

potential gradient = …………………………….. V cm^{-1} [1]

(ii) A circuit consisting of a cell E_2 and a variable resistor R is now connected to the potentiometer as shown in Fig. 5.3.

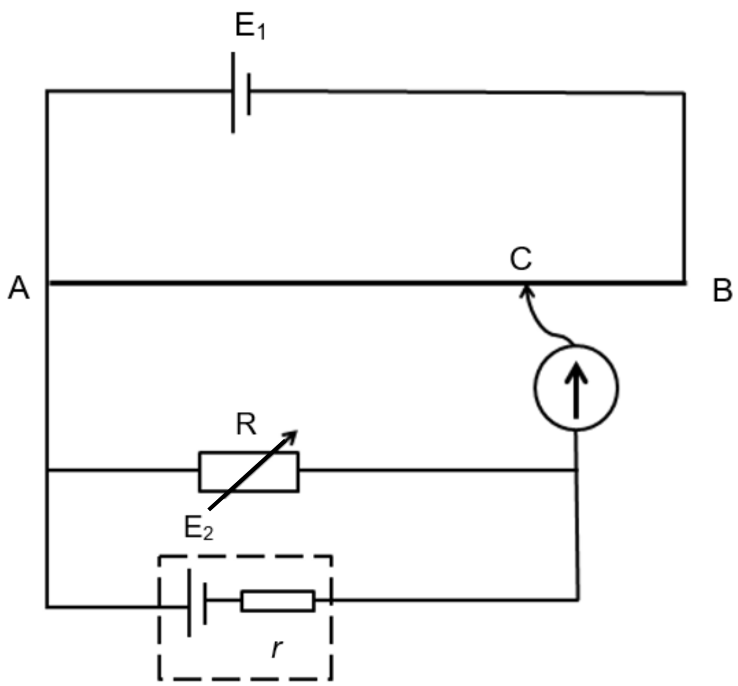


Fig. 5.3

The resistance of R is set to 10.0 Ω and the sliding contact C is adjusted until there is no current flowing in the galvanometer. The length AC is found to be 60.0 cm.

The resistance of R is now set to 3.0 Ω and the experiment is repeated. The length AC is now 54.0 cm.

Calculate the e.m.f. and internal resistance *r* of cell E_2.

e.m.f. of cell E_2 = ... V

internal resistance of cell E_2 = ... Ω [5]

6 (a) A coil with 500 turns is placed in a uniform magnetic field of flux density 5.0×10^{-2} T. The area of the coil perpendicular to the field is 2.5×10^{-2} m^2, as shown in Fig. 6.1.

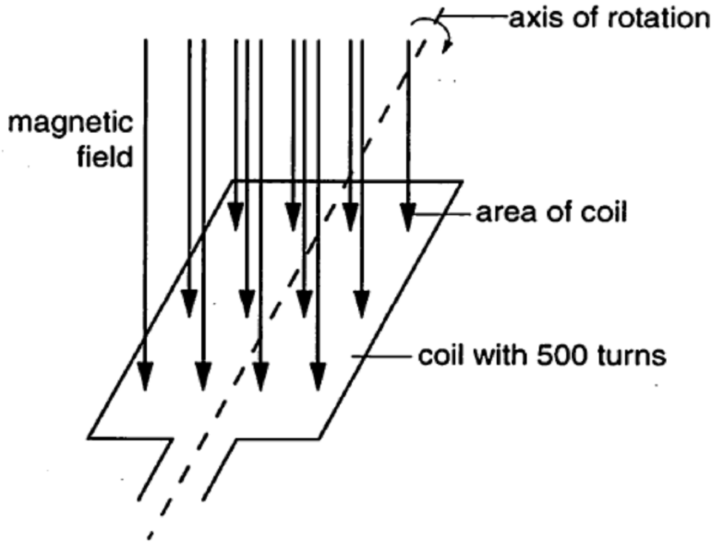


Fig. 6.1

Calculate the magnetic flux linkage of the coil. Give an appropriate unit.

magnetic flux linkage = ……………………………… unit: …………………… [1]

(b) The coil in **(a)** is rotated at a constant angular velocity about the axis in Fig. 6.1. The flux linkage Φ of the coil varies with time t, as shown in Fig. 6.2.

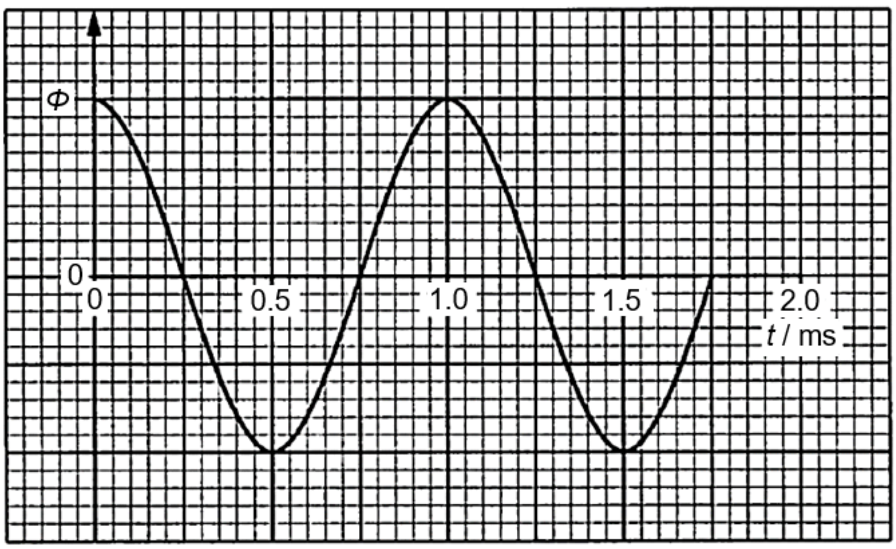


Fig. 6.2

(i) Calculate the maximum induced electromotive force (e.m.f.).

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

(ii) Calculate the root-mean-square value of the induced e.m.f.

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

(iii) Explain why the flux linkage changes *sinusoidally* as the coil is rotated.

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

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

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

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

7 Fig. 7.1 shows some of the energy levels of an helium atom.

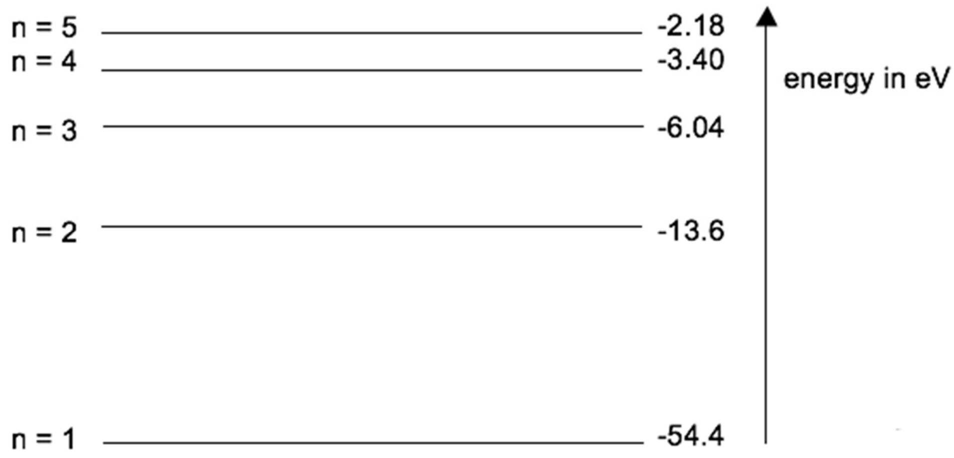


Fig. 7.1

An electron with kinetic energy of 50.0 eV collides with a helium atom in its ground state and the helium atom is excited.

(a) **(i)** In Fig. 7.1, use arrows to show the possible energy transitions when the excited helium atom de-excites. [2]

(ii) Calculate the shortest wavelength of the radiation that is emitted from the transitions in **(a)(i).**

shortest wavelength = …………………………………….. m [2]

(b) When a beam of white light is passed through a cold helium gas, an absorption spectrum of coloured background with dark lines is observed.

Use Fig. 7.1 to explain quantitatively why one of the dark lines correspond to a wavelength of 471 nm.

....

....

....

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....

.... [3]

Section B

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

8 **(a)** Two ions S and T, each of negative charge –*q*, are held stationary at a distance of 2.0 cm from each other as shown in Fig. 8.1. P_1 is the midpoint between S and T.

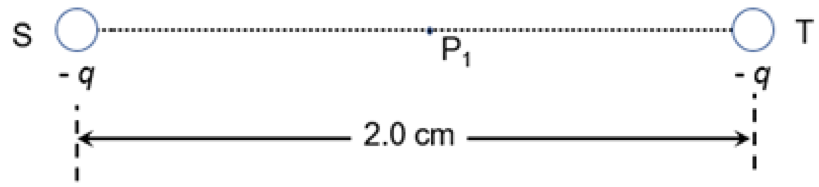

Fig. 8.1

State what it means by

(i) the *electric field strength* at P_1,

....

....

....

.... [1]

(ii) the *electric potential* at P_1.

....

....

....

.... [1]

(b) The value of q is known to be 1.6×10^{-19} C. A third ion R of positive charge $+q$ is introduced into the system at a distance of 4.0 cm from ions S and T as shown in Fig. 8.2. All three ions are held stationary.

P_2 is the midpoint between R and T.

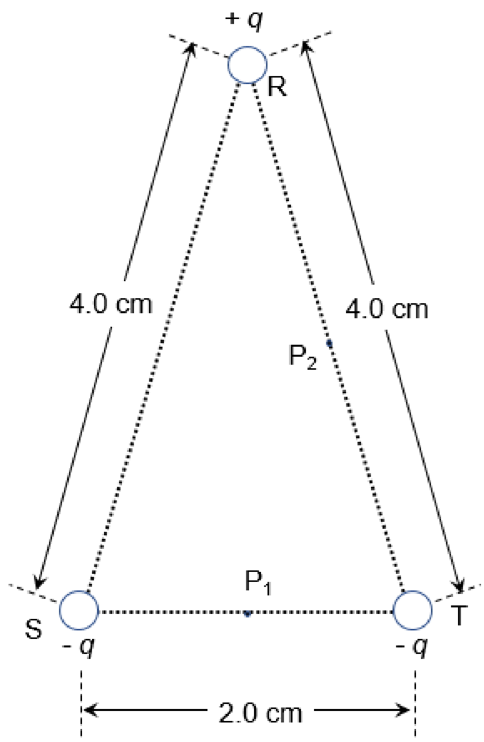

Fig. 8.2

(i) Calculate the amount of work done required to assemble R.

work done = ………………………..…………… J [3]

(ii) Without calculations, explain whether the work done required is more or less if R were to be placed at P_2 instead.

……

……

……

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

(iii) With reference to the direction of the electric field strength along RP_1, describe the variation of electric potential along the line joining ion R to the point P_1.

……

……

……

…… [2]

(c) (i) Show that the magnitude of the electric field strength that R experiences for the ion assembly in Fig. 8.2 is given by 1.74×10^{-6} N C^{-1}.

[4]

(ii) R is subsequently released.

Hence, calculate

1. the magnitude and state the direction of the resultant force on R just as it is released,

force = ………………………………… N

direction : ………………………………………………… [3]

[Turn Over

2. the magnitude of the initial acceleration of R if it has a mass of 2.58×10^{-26} kg.

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

(d) Suggest with a reason, the subsequent motion of R after passing through the line joining S and T.

………

………

………

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

9 **(a)** Distinguish between *gravitational field strength* and *acceleration of free fall*.

………

………

………

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

(b) Assuming Earth to be a sphere, explain with the help of free body diagrams, the difference in the weight of a person measured on an electronic balance at the poles and at the equator.

………

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………

………

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………

…………………………………………………………………………………………………… [5]

[Turn Over

(c) Assuming Earth to be a sphere of radius 6.4×10^6 m, calculate the mass of Earth.

mass of Earth = ………………………………………. kg [2]

(d) Calculate the radius of the orbit of a geostationary satellite.

radius = ………………………………….. m [3]

(e) **(i)** A space mission is to launch a space shuttle from Earth. The space shuttle comprise of a land rover to be delivered to the moon.

Using the answer in part **(c)**, calculate the distance from the centre of Earth where the resultant gravitational field strength due to the Earth and the Moon is zero.

The mass of the Moon is 7.4×10^{22} kg and distance between centres of the Earth and the Moon is 3.8×10^8 m.

distance from centre of Earth = ……………………………………… m [3]

(ii) On Fig. 9.1, sketch the variation of gravitational potential ϕ between the surface of Earth and the surface of the moon.

Include the value obtained in **(e)(i)**.

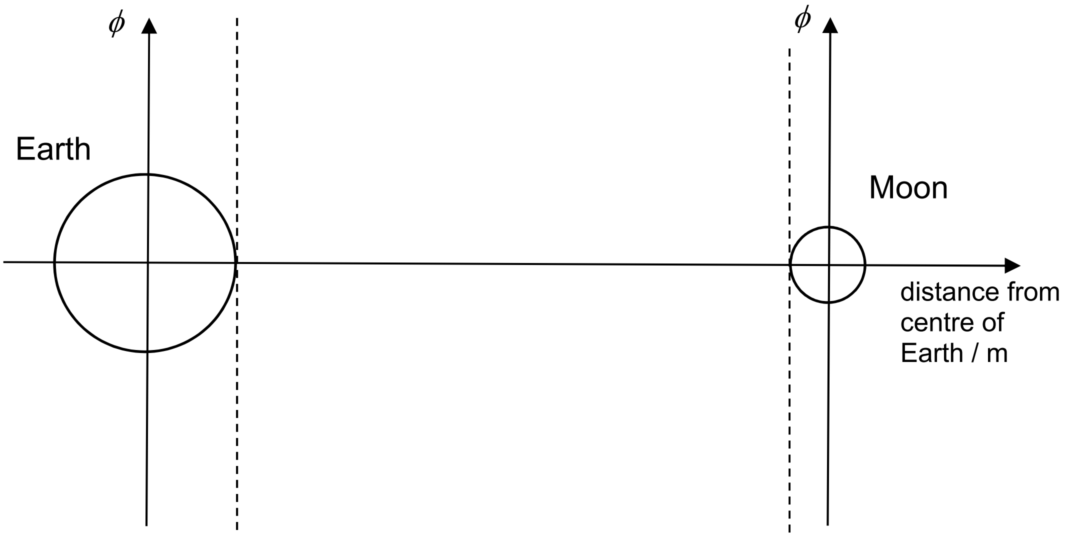

Fig. 9.1 [2]

(iii) Calculate the minimum launch speed of the space shuttle from Earth such that the space shuttle will be able to reach the surface of the moon.

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

-- END OF PAPER 3 --

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NAME ______________________ **CLASS** 2T

Catholic Junior College

JC2 Preliminary Examinations

Higher 2

PHYSICS

9749/01

Paper 1: Multiple Choice

18 September 2020

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.
Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all 30 questions** in this paper.
For each question there are four possible answers, **A, B, C** and **D**. Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet (OMR sheet).

Read the instructions on the Answer Sheet carefully.

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

MARK SCHEME

This document consists of **27** printed pages and **one** blank page.

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	Which of the following is not a reasonable estimate?
	A The power of an electric iron is 1 kW.
	B The weight of a man on the Moon is 100 N.
	C The momentum of a tennis ball served by a professional tennis player is 4 N s.
	D The kinetic energy of a double-decker bus moving at a constant speed on an expressway is 50 kJ.
	Answer: D
	Usual electric iron power is between 1000 – 1800 W. Reasonable. On moon, g is approximately 1.6 m s^{-2}. W = 100 N on moon translates to m is approximately 63 kg. Reasonable. Tennis ball m is approximately 60 g. p = 4 N s translates to v is approximately 67 m s^{-1} is approximately 240 km h^{-1}. Reasonable. Bus m is approximately 10000 kg, KE is approximately 50 kJ translates to v is approximately 3.2 m s^{-1} is approximately 11 km h^{-1}. Not reasonable.

2 Four students **A**, **B**, **C** and **D** measured the potential difference across an electric component. Each student obtained five sets of data for the potential difference.

If the actual potential difference is 1.65 × 10^{-2} V, which student's measurement was accurate but not precise?

	Potential difference / 10^{-2} V					Mean / 10^{-2} V
A	1.61	1.65	1.65	1.58	1.61	1.62
B	1.66	1.68	1.63	1.64	1.65	1.65
C	1.65	1.64	1.65	1.65	1.66	1.65
D	1.69	1.70	1.69	1.70	1.69	1.69

Answer: B

Student A's results: mean value = 1.62 x 10^{-2} V, spread = 0.07 x 10^{-2} V
Student B's results: mean value = 1.65 x 10^{-2} V, spread = 0.05 x 10^{-2} V
Student C's results: mean value = 1.65 x 10^{-2} V, spread = 0.02 x 10^{-2} V
Student D's results: mean value = 1.69 x 10^{-2} V, spread = 0.01 x 10^{-2} V

The actual potential difference is 1.65 × 10^{-2} V

Hence, student B's results are accurate (low systematic errors, mean value close to actual value) but not precise (high random errors, large spread).

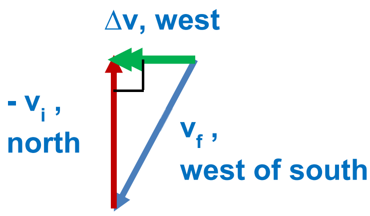
3	A boat moves at velocity of 4 m s^{-1} due south in still water across a lake. It then experiences a current flowing towards the west. The velocity of the boat changes to 7 m s^{-1}. What is the change in the velocity of the boat due to the current?	
	A	3 m s^{-1} due west
	B	3 m s^{-1} due west of south
	C	6 m s^{-1} due west
	D	6 m s^{-1} due west of south

Answer: C

Boat's final velocity must be due west of south.

Direction of change in velocity must be that of the current's direction, i.e. due west.

$\Delta v = v_f - v_i = v_f + (-v_i)$ west

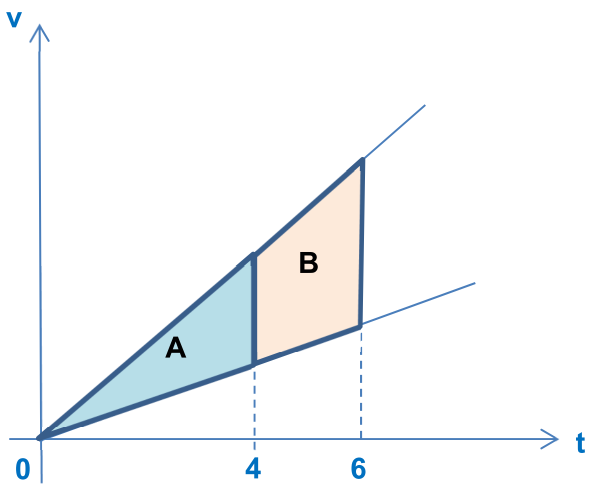


Magnitude of change in velocity, $|\Delta v| = \sqrt{|v_f^2| - |v_i^2|} = \sqrt{7^2 - 4^2}$ = 6 m s^{-1}

4	Two cars are initially side-by-side and at rest. They then accelerate in the same direction along the same straight line at different uniform rates. After 4.0 s, one of the cars is 12 m ahead of the other. If they continue to accelerate at the same rate, how far apart will they be 6.0 s after they started?							
	A	15 m	**B**	18 m	**C**	22 m	**D**	27 m

Answer: D

Method 1 (graphical method)



Distance apart at 4 s = Shaded area A = 12 m

Distance apart at 6 s = Shaded areas A and B

By similar triangles,

$$\frac{Area\ A}{Area\ A + Area\ B} = \left(\frac{4}{6}\right)^2$$

$$\frac{12}{Area\ A + Area\ B} = \left(\frac{4}{6}\right)^2$$

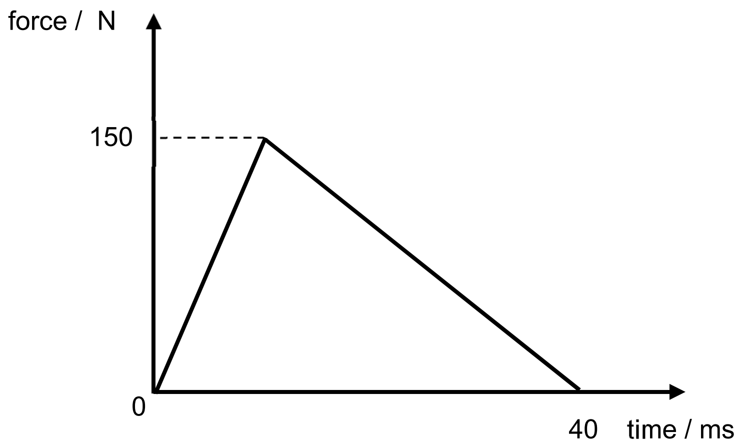
$$Area\ A + Area\ B = 12\left(\frac{6}{4}\right)^2 = 27\ m$$

Method 2 (using kinematics equations)

Using $S = ut + \frac{1}{2}at^2$
Since they both start from rest, u = 0.
At t = 4 s, $S_1 - S_2 = \frac{1}{2} a_1 (4)^2 - \frac{1}{2} a_2 (4)^2 = 12$ m
Hence $a_1 - a_2 = 24/16$
At t = 6s, $S_1 - S_2 = \frac{1}{2} a_1 (6)^2 - \frac{1}{2} a_2 (6)^2 = \frac{1}{2} (6)^2 (a_1 - a_2) = 27$ m

5 A tennis ball of mass 0.060 kg is moving normally towards a racket with an initial velocity of 5.0 m s^{-1} and rebounds in the opposite direction.

The force of the racket exerted on the tennis ball varies with time as shown.



What is the final velocity of the ball when it leaves the racket?

A	45 m s^{-1}	**B**	50 m s^{-1}	**C**	55 m s^{-1}	**D**	95 m s^{-1}

Answer: A

Take final velocity direction as positive direction.

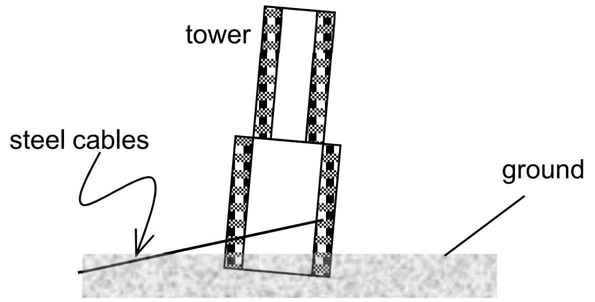
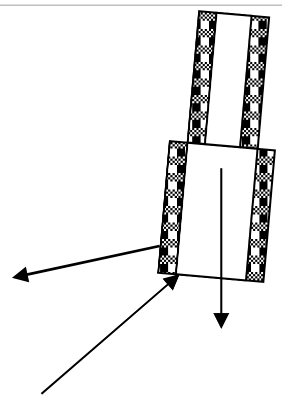
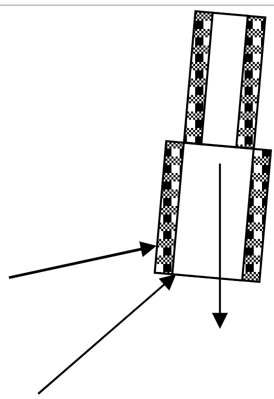
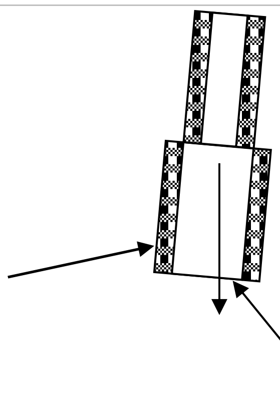
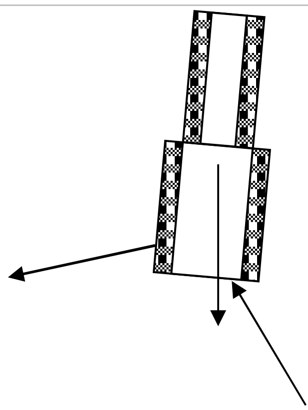
Area under the force-time graph represents the impulse on the tennis ball.

$$F\Delta t = \Delta p$$

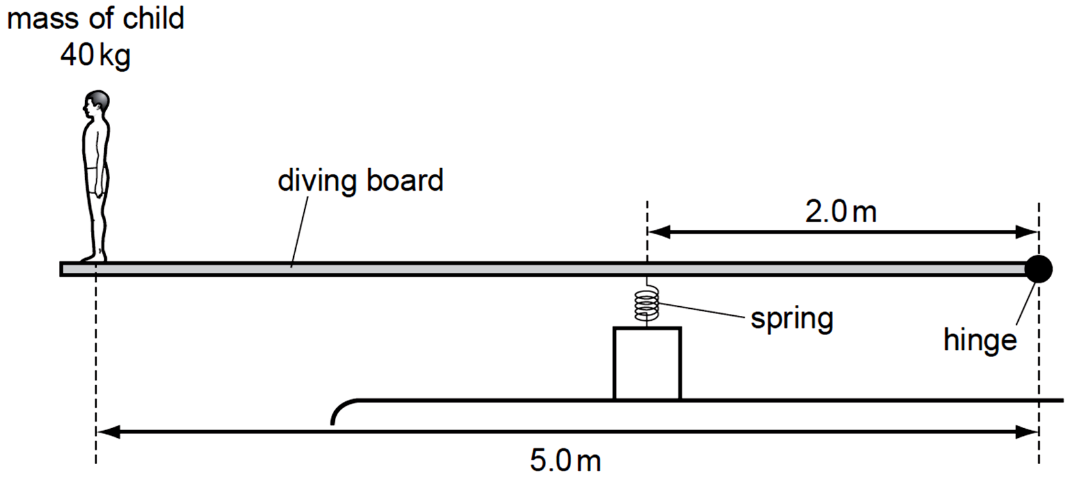
$$\frac{1}{2}(0.040)(150) = m\Delta v$$

$$3 = 0.060\,(\,v_f - (-5.0))$$

$$v_f = 45\ ms^{-1}$$

6	A tower is pulled by a bundle of steel cables anchored to the ground, as shown by the simplified sketch below.  The tower is acted upon by three forces. Which diagram could show the position and direction of each of the forces when the tower is in equilibrium?			
	A		**B**	
	C		**D**	
	Answer: A If 3 coplanar and non-parallel forces act on a body which is in equilibrium, the lines of action of all 3 forces must pass through a common point. C and D are eliminated. Option B is incorrect as the steel cable is in tension not compression and there is a net force to the right and therefore the tower would not be in equilibrium.			

7	A diving board of length 5.0 m is hinged at one end and supported 2.0 m from this end by a spring of spring constant 10 kN m^{-1}. A child of mass 40 kg stands at the far end of the board.



What is the compression of the spring caused by the child standing on the end of the board?

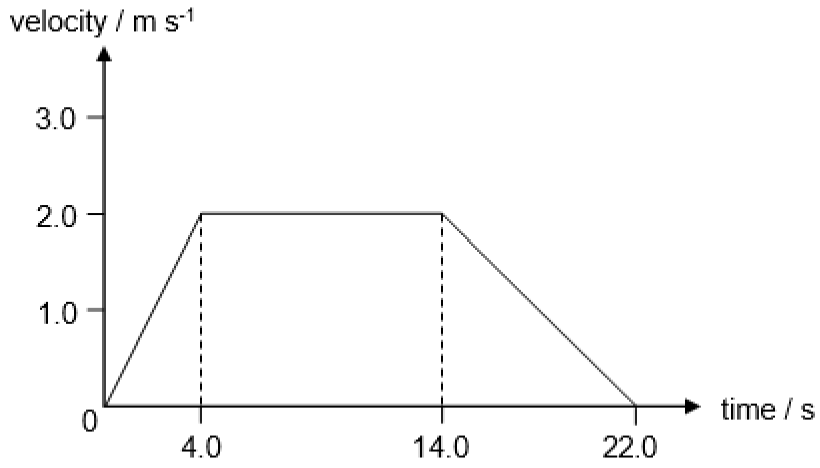
A	1.0 cm	**B**	1.6 cm	**C**	9.8 cm	**D**	16 cm

Answer: C

Taking moments about hinge,
Sum of anticlockwise moments = Sum of clockwise moments
5.0(40 x 9.81) = 2.0 F
5.0(40 x 9.81) = 2.0 (10 000)x
x = 0.0981 m = 9.81 cm = 9.8 cm

where F = kx

8 The diagram shows the velocity-time graph of a 500 kg elevator during its upward motion.



What is the maximum power generated by the engine of the elevator?

A	7810 W	**B**	9310 W	**C**	9810 W	**D**	10300 W

Answer: D

Let T be the upward pull by the elevator cable on the elevator.

Power = Tv
P is max when product Tv is max.

T is max when elevator's **acceleration is upwards**, i.e. from t = 0 s to 4.0 s.

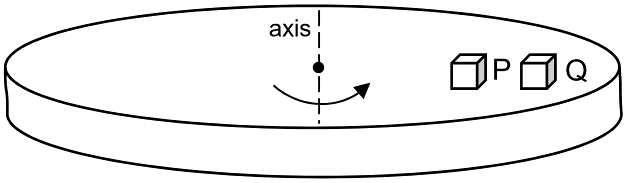
Maximum power generated ***just*** **before** *t* = 4.0 s, **when speed is max**.

$$T - mg = ma$$

$$T = ma + mg = 500\left(\frac{2.0}{4.0} + 9.81\right)$$

$$P_{max} = Tv = 500\left(\frac{2.0}{4.0} + 9.81\right)(2.0) = 10310 = 10300 \text{ W}$$

9	Two identical objects, P and Q, are placed on a flat rough circular disc. Q is at a further distance from the centre of the disc compared to P.



The disc starts spinning from rest about its central axis with increasing speed. At a certain speed, one of the objects starts to slide off the disc.

Q slides off the disc first because

A	the friction experienced by P and Q are always equal.
B	it moves with a larger angular velocity compared to P.
C	it requires greater friction to keep it in its position compared to P.
D	the friction experienced by P is larger than Q before one of the objects slide off the disc.

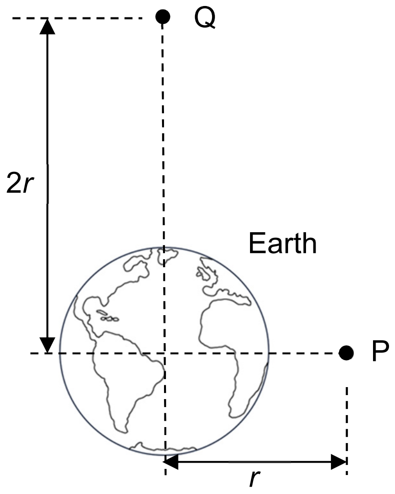
Answer: C

$F_c = mr\omega^2$

Both objects have the same mass and same angular velocity, but the centripetal force required for Q's circular motion is larger due to larger radius.

When the centripetal force required exceeds the maximum static friction available, Q starts to slide.

10 P and Q are two points above Earth's surface at distances r and $2r$ respectively from the centre of the Earth.



The gravitational potential at P is –800 kJ kg^{-1}. What is the gain in gravitational potential energy of a 2 kg mass when it is moved from P to Q?

A	- 400 kJ	**B**	- 200 kJ	**C**	400 kJ	**D**	800 kJ

Answer: D

Since the distance from earth changes from r to 2r, the gravitational potential at Q is –400 kJ kg^{-1}.

Gain in gravitational potential energy
= final GPE – initial GPE
= 2.00 (-400 – (-800))
= 800 kJ

11 Planet X has a density of ρ and radius of R. The gravitational acceleration at its surface is a. What is the gravitational acceleration at the surface of Planet Y which has a density of 2ρ and radius of $2R$?

A	0.5 a	**B**	a	**C**	2 a	**D**	4 a

Answer: D

$$a = \frac{GM}{R^2} = \frac{G\rho V}{R^2} = \frac{G\rho(\frac{4}{3}\pi R^3)}{R^2} = \frac{4G\rho R\pi}{3}$$

$$a \propto \rho R$$

Since ρ and R is doubled, a' is 4 a.

12	A particle of mass 5.0 × 10^{-3} kg performing simple harmonic motion of amplitude 150 mm takes 47 s to make 50 oscillations. What is the maximum kinetic energy of the particle?

A	2.0 × 10^{-3} J	**B**	2.5 × 10^{-3} J	**C**	3.9 × 10^{-3} J	**D**	5.0 × 10^{-3} J

Answer: B

Frequency = 50/47 Hz

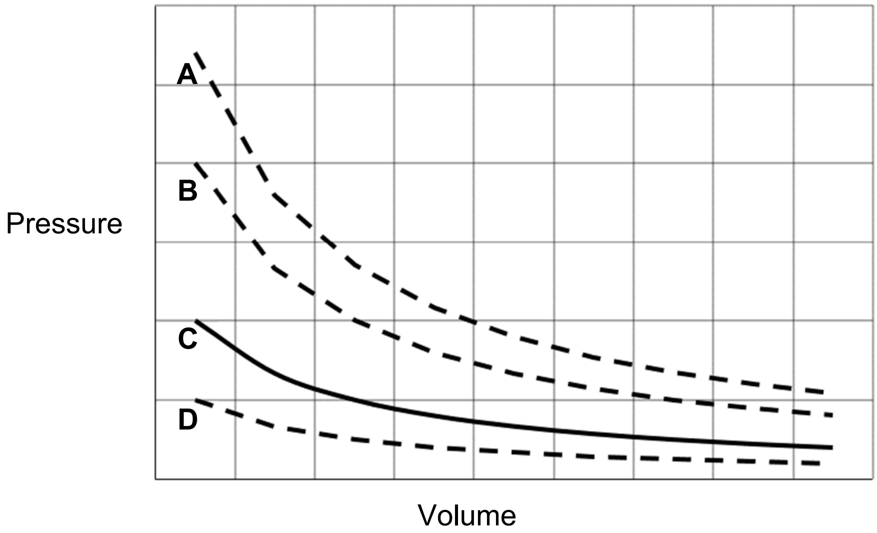
$KE_{max} = \frac{1}{2}m(\omega x_0)^2 = \frac{1}{2}m(2\pi f x_0)^2$
$= (0.5)(5.0 \times 10^{-3})(2\pi\,(50/47)(150 \times 10^{-3}))^2$
$= 2.5 \times 10^{-3}$ J

13		Which of the following statements is true for a stationary sound wave?
	A	The pressure at a displacement node is always very high.
	B	The pressure at a displacement antinode is always very high.
	C	The pressure at a displacement node fluctuates between high to low.
	D	A stationary wave can be formed by two waves with the same amplitude and frequency, travelling at the same direction towards a point.

Answer: C

Displacement node is the location of pressure antinode for sound wave. By definition, pressure antinode is the location where the pressure fluctuate from the highest to the lowest.

14	In the figure below, graph **C** shows how the pressure of a fixed mass of an ideal gas varies with its volume at a constant temperature.



If a similar ideal gas with double the mass is used and the experiment is conducted at the original constant temperature, which curve (**A**, **B**, **C** or **D**) gives the variation of the gas pressure with its volume?

Answer: B

pV = nRT

When mass is doubled for the same gas, n is doubled.

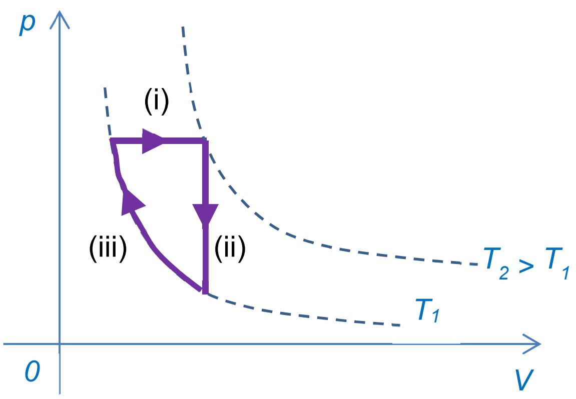
At the same T, product pV remains constant, but is doubled for the 2nd gas.

- ➔ **For the same V, p is doubled.**

15	An ideal gas undergoes a cyclic process in three stages: (1) Expansion at constant pressure, (2) Decrease in pressure at constant volume, (3) Compression at constant temperature. Which of the following must be true?	
	A	There is net heat released by the gas during the cycle.
	B	The net work done on the gas during the cycle is positive.
	C	The net work done by the gas during the cycle is equal to the net heat transferred to the gas.
	D	The change in internal energy of the gas is equal to the work done during the constant pressure stage minus the work done during the constant temperature stage.

Answer: C

Represent the cyclic process on a p-V diagram:



From the p-V diagram there is NET work done BY gas during the cycle, so net W is negative → Eliminate option B.

Since net work done is non-zero, Option D would imply that ΔU is non-zero but in fact per cycle ΔU is zero.

Per cycle, ΔU = 0
→ Eliminate option D.

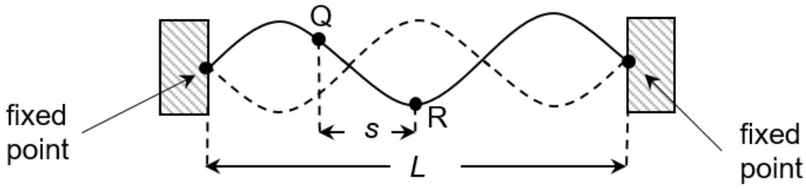
By ΔU = Q + W, 0 = Q + (negative value), so net Q is positive which implies that there is net heat transferred TO the gas during the cycle
→ Eliminate option A.

Conversely, option C is correct.

16	A beam of plane-polarised light of intensity I falls normally onto a thin sheet of polaroid. If the transmitted beam has an intensity of $\frac{3}{4}I$, what is the angle between the plane of polarisation of the incident beam and the polarising axis of the polaroid?						
	A	30°	**B**	41°	**C**	45°	**D** 60°
	L2	**Answer: A** Using Malus' Law, $I_{transmitted} = I_0 \cos^2\theta$ $\frac{3}{4}I = I\cos^2\theta$ $\cos^2\theta = \frac{3}{4}$ $\cos\theta = \frac{\sqrt{3}}{2}$ $\theta = 30°$					

17	A hemispherical bowl of radius 200 mm is completely filled with water at rest. If its side is tapped gently, a circular water wave pulse can be produced on the surface of the water which travels inwards with a speed of 250 mm s^{-1}. What is the radius of the pulse and its direction of travel one second after the pulse is produced?	
	A	zero, stationary
	B	50 mm, inwards
	C	50 mm, outwards
	D	100 mm, outwards
	L2	**Answer: C** After 1 second, the wave would have travelled a total distance of 250 mm. However, since the radius of the bowl is 200 mm, there will be a reflection of the wave at the centre of the bowl when the wave has travelled 200 mm. The wave would have then travelled outward for 50 mm. Thus, the radius of the circle will be 50 mm.

18 A stationary wave is formed on a stretched string of length L between two points as shown below.



Particles Q and R on the string are separated by distance s. The total energy of Q and of R are E_Q and E_R respectively.

Which of the following gives the correct phase difference between Q and R, and the relationship between E_Q and E_R?

	phase difference / rad	total energy
A	$\frac{2s}{L}\pi$	$E_Q = E_R$
B	$\frac{2s}{L}\pi$	$E_Q < E_R$
C	π	$E_Q = E_R$
D	π	$E_Q < E_R$

Answer: D

Since Q and R are in adjacent segments of the same stationary wave, they are π radians apart.

As Q has a smaller amplitude compared to R, it has a smaller total energy.

19 Light of wavelength λ is incident normally on a diffraction grating of slit spacing five times the wavelength of the light.

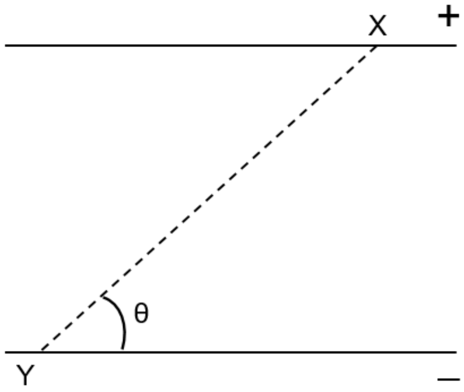
What is the angle of diffraction of the second order maximum?

A	12°	**B**	24°	**C**	37°	**D**	45°

Answer: B

$$d\sin\theta = n\lambda$$
$$\sin\theta = \frac{n\lambda}{d}$$
$$= \frac{2\lambda}{5\lambda}$$
$$= \frac{2}{5}$$
$$\theta = 24°$$

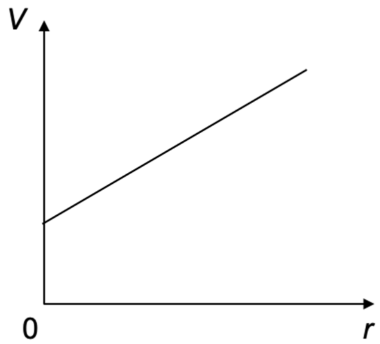
20 The figure below shows two horizontal parallel metal plates. The upper plate is maintained at a higher potential relative to the lower plate.



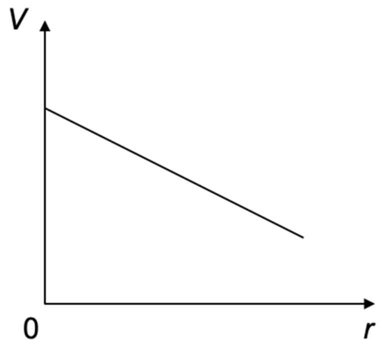
Line XY is inclined at an angle θ to the metal plates.

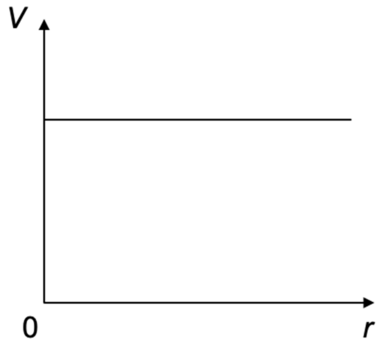
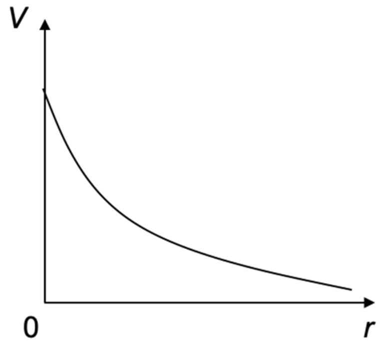
Which of the following graphs best shows the variation of electric potential V with distance r from X along the line XY?

A



B



	C		D	

Answer: B

Since *θ* and *E* are constant, *V* has a linear relationship to *r*, eliminating options C and D. *E* is the electric field strength between the plates.

Furthermore, X is at a higher potential compared to Y. Therefore, option A is not correct.

Mathematical proof

Point P on XY is defined to be at a perpendicular distance rsinθ from the upper plate.

$$E_P = \frac{\Delta V_{X \to P}}{r\sin\theta}$$
$$\Delta V_{X \to P} = E_P(r\sin\theta)$$
$$= r(E_P\sin\theta)$$

Therefore, the graph's equation is given by

$$V = V_P$$
$$= V_X - \Delta V_{X \to P}$$
$$= V_X - r(E_P\sin\theta)$$

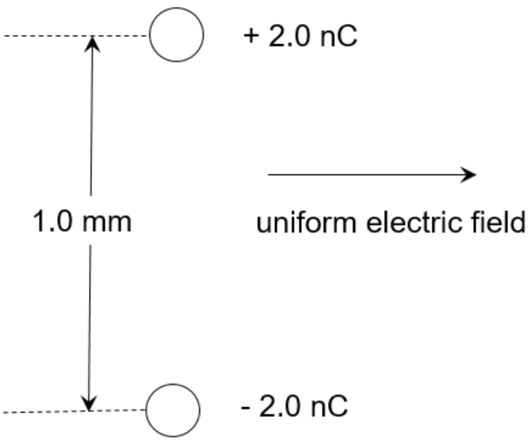
Since E_P is the same at all points in a uniform field and sin*θ* is a constant, the equation above can be simplified to

$$V = V_X - kr$$

where *k* and V_X are constants.

21 Two charges are fixed at a distance of 1.0 mm apart as shown below.

A uniform electric field with field strength 4.0 N C^{-1} is applied in the direction from left to right.

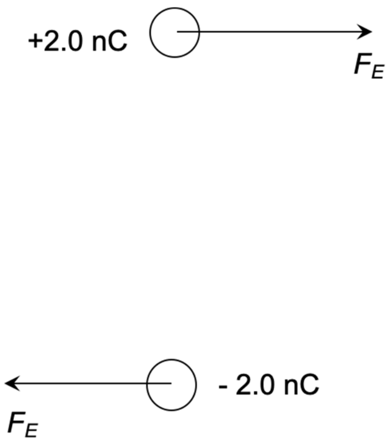


Which statement describes the net force and torque experienced by the pair of charges?

A	No net force and no torque acts.
B	No net force acts and the torque is 8.0×10^{-12} N m in the clockwise direction.
C	A net force of 3.6 x 10^{-14} N acts and the torque is 4.0×10^{-12} N m in the clockwise direction
D	A net force of 3.6 x 10^{-14} N acts and the torque is 8.0×10^{-12} N m in the clockwise direction

Answer: B

An electric dipole context where the two charges are connected by an electric force of attraction



torque = qEd
$= (2.0\times10^{-9})(4.0)(1.0\times10^{-3})$
$= 8.0\times10^{-12}$ N m

22	A battery causes a current of 3 A to flow through a metal wire of diameter 2.0 mm. The number density of the free electrons in the metal wire is 8.5 x10^{28} m^{-3}. What is the average speed of the electrons drifting along the wire?

A	2.0 x 10^{-11} m s^{-1}	**B**	2.0 x 10^{-5} m s^{-1}	**C**	7.0 x 10^{-11} m s^{-1}	**D**	7.0 x 10^{-5} m s^{-1}

Answer: D

I = nAvq
3 = (8.5 x 10^{28})(π x 0.0010^2)v (1.60 x 10^{-19})
v = 7.0 x 10^{-5} m s^{-1}

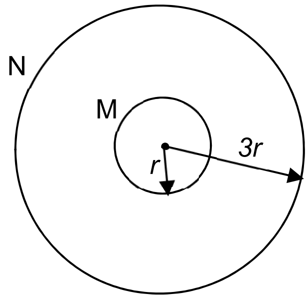
23	A heater of resistance 5.0 Ω dissipates 125 W of power when current flows through it. The amount of energy converted to heat when 0.4 C of charge passes through it is

A	2 J	**B**	10 J	**C**	50 J	**D**	625 J

Answer: B

$$P = \frac{V^2}{R} \implies V^2 = 125 \times 5 \implies p.d\ across\ heater, V = \sqrt{625} = 25\ V$$

$$Since\ V = \frac{W}{Q} \implies Amount\ of\ energy\ conveted\ to\ heat, W = VQ = 25 \times 0.4 = 10\ J$$

24	A flat circular coil M is mounted co-axially inside another flat circular coil N. N has three times the radius of M.  The two coils are connected in series to the same power supply. At the centre of the two coils, the magnetic field created by M is opposite in direction to the magnetic field created by N. What is the ratio of the number of turns of coil M to the number of turns of coil N to create zero magnetic flux density at the centre?

	A	1 : 3	**B**	2 : 3	**C**	3 : 1	**D**	3 : 2

Answer: A

For flat circular coil, at its CENTRE: $B = \frac{\mu_o N I}{2R}$

For resultant flux density at the centre to zero for both coils,
B_N and B_M at the centre must be equal in magnitude.
In series implies same magnitude of current I flows in both coils.

$$B_N = B_M$$

$$\frac{\mu_o N_N I}{2(3r)} = \frac{\mu_o N_M I}{2(r)}$$

$$\frac{N_N}{3} = \frac{N_M}{1}$$

$$\frac{N_M}{N_N} = \frac{1}{3}$$

25	In a velocity selection, positively charged particles +*q* enter an electric field of strength *E* and a magnetic field of flux density *B* that are applied perpendicularly to each other in the same region. Particles which are travelling at speed *v* are undeflected by the cross-fields. Which of the following is necessarily true?	
	A	To select particles of charge –*q* with speed *v*, there is a need to reverse the direction of either *E* or *B*.
	B	To select charged particles with speed 2*v*, with the magnitude of *B* unchanged, the magnitude of *E* needs to be doubled.
	C	For particles of charge -*q*, there is a need to reverse the directions of both *E* and *B* in order to select the particles with speed *v*.
	D	If the magnitude of charge doubles, the magnitudes of the electric field strength and magnetic flux density cannot remain as *E* and *B* to select the particles with speed *v*.

Answer: B

For the charged particles to be undeflected by the crossed-fields,
$F_E = F_B$
$qE = Bqv$
$v = E/B$

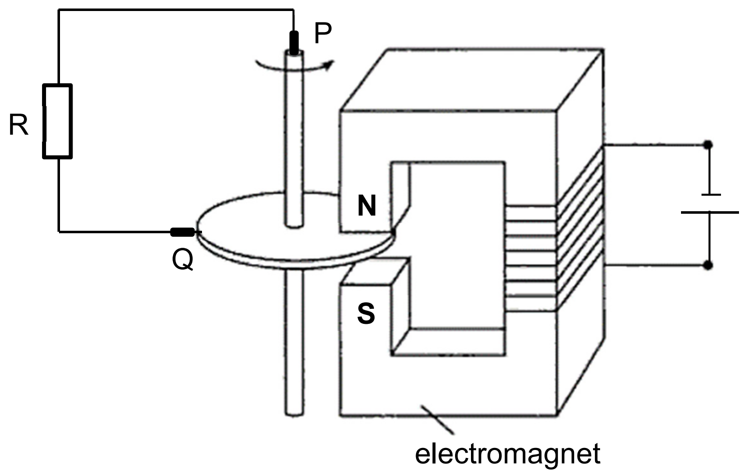
Option A – False. If the charge is of opposite polarity, with no change made at all to E and B, the direction of both forces reverse, equilibrium of forces to select those with speed v is still achieved.

Option B – True. Since v = E/B.

Option C – False. Because with directions of E and B maintained, particles of speed v can still be selected.

Option D – False. If q doubles, F_E and F_B increase by the same factor. q has no effect on the selected speed.

26	A copper disc spins freely between the poles of an electromagnet at a constant speed. P and Q are two metallic brushes making contact with the axle and the edge of the disc as shown in the diagram. A resistor R is connected across P and Q.



Which of the following statements is correct?

A	A current flows from P through R to Q, and P is at a higher potential then Q.
B	A current flows from Q through R to P, and Q is at a higher potential then P.
C	A current flows from P to Q in the disc, and P is at a higher potential then Q.
D	A current flows from Q to P in the disc, and Q is at a higher potential then P.

Answer: A

Using Fleming's RH Rule, induced current flows from the edge of the disc to the axle, i.e. Q to P.
Current then flows through the external circuit from P through R to Q and returns back to the disc.

Magnetic force causes the free electrons in the disc to drift towards the edge, so the edge becomes more negatively charged compared to the axle which becomes more electron deficient. Hence P is higher potential than Q.
[Recall also that current flows from higher to lower potential in the external circuit, but from lower to higher potential within a source of e.m.f.]

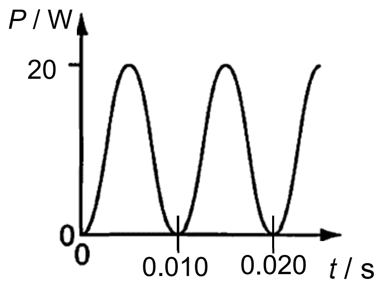
27 A sinusoidal alternating current I / A varies with time t / s according to the equation

$$I = 2.0 \sin (100\pi t)$$

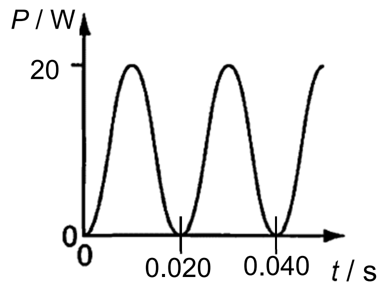
This current is allowed to pass through a resistor of resistance 5.0 Ω.

Which of the following shows how the power P / W dissipated in the resistor varies with t / s?

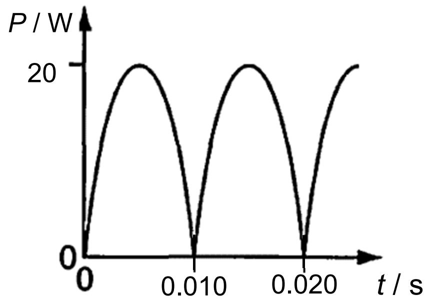
A



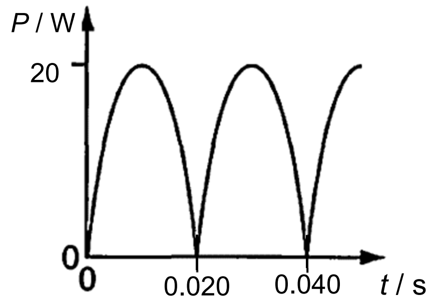
B



C



D



Answer: A

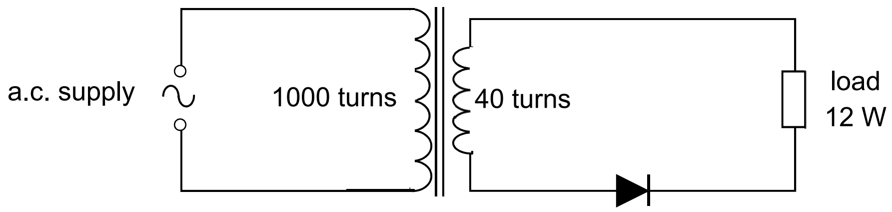
From the equation, compare with the general equation: $I = I_o \sin (\omega t)$
$I_o = 2.0$ A and $\omega = 100\pi$

$P_o = I_o^2 R = (2.0^2)(5.0) = 20$ W

$T = 2\pi/\omega = 2\pi/100\pi = 0.020$ s

P-t graph is a sine-*squared* function.

28 The primary coil of an ideal transformer has 1000 turns and is connected to a sinusoidal a.c. supply. The secondary coil has 40 turns and is connected to an ideal diode and a load.



If the root-mean-square (r.m.s) voltage across the load is 6.5 V and the mean power dissipated in the load is 12 W, what is the r.m.s current in the primary coil?

A	0.026 A	**B**	0.074 A	**C**	0.10 A	**D**	0.15 A

Answer: C

On the secondary side, at the load, $I_{L\,rms} = \frac{\langle P \rangle}{V_{L\,rms}} = \frac{12}{6.5} = 1.8462\ A$

Since the <u>current at the load</u> is <u>Half-wave rectified</u>, it can be shown that

$$I_{L\,rms} = \sqrt{\frac{{I_{L\,peak}}^2}{4}} = \frac{I_{L\,peak}}{2} \quad \Longrightarrow \quad I_{L\,peak} = 2 \times .1.8462 = 3.6923\ A$$

On the <u>secondary side</u> <u>before the diode</u>, the current is <u>Full-wave sinusoidal A.C.</u>,

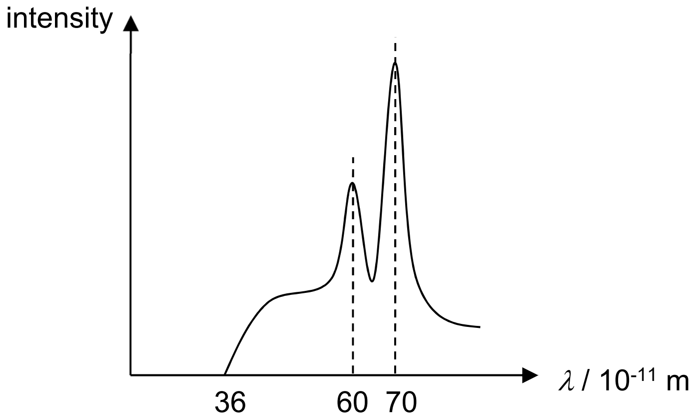
$$I_{S\,rms} = \frac{I_{s\,peak}}{\sqrt{2}} = \frac{3.6923}{\sqrt{2}} \quad \Longrightarrow \quad 2.6109\ A$$

Therefore using

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

$$I_p = \frac{40}{1000} \times 2.6108 = 0.10443 = 0.10\ A$$

29 The x-ray spectrum of a metal target is shown in the figure below.



Which of the following statements is correct?

A	The smallest wavelength detected, 36×10^{-11} m, is dependent on the target material.
B	The graph shows that electrons with a range of kinetic energies are used to bombard the target.
C	The locations of the peaks can be used to identify the element that the target material is made of.
D	The position of the peaks allow us to calculate the energy of the electrons used to bombard the target.

Answer: C

Option A is not correct because minimum wavelength (cut-off wavelength) depends on the maximum energy of the incident electrons and independent of the target material.

Option B is not correct because since the X-ray spectra will always contain bremsstrahlung radiation whether the electrons bombarding the metal target has a single energy or have a range of energies.

Option D is not correct because the position (wavelength) corresponding to the characteristic peaks is dependent only on the kind of target and not on the energy of the incoming electrons.

30	A photon of wavelength 555.00 nm, measured to an accuracy of 0.01 nm. What is the minimum uncertainty in the location of the photon?							
	A	6.6×10^{-23} m	**B**	1.0×10^{-11} m	**C**	3.1×10^{-2} m	**D**	3.0×10^{-1} m

Answer: C

De Broglie Wavelength,

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

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

$$\Delta p = \frac{\Delta \lambda}{\lambda} p = \frac{0.01}{555.00}\left(\frac{6.63\ x\ 10^{-34}}{555.00\ x\ 10^{-9}}\right) = 2.1524\ x\ 10^{-32}\ N\ m$$

Heisenberg Uncertainty Principle,

$$\Delta p \Delta x \gtrsim h$$
$$2.1524\ x\ 10^{-32}\ \Delta x \gtrsim 6.63\ x\ 10^{-34}$$
$$\Delta x \gtrsim 3.1\ x\ 10^{-2}\ m$$

-- END OF PAPER 1 –

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME: **MARK SCHEME**

CLASS: **2T**

PHYSICS
9749/02

Paper 2: Structured Questions

27 August 2020

2 hours

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

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 use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
Q1	/ 9			
Q2	/ 8			
Q3	/ 11			
Q4	/ 10			
Q5	/ 12			
Q6	/ 9			
Q7	/ 21			
PAPER 2	/ 80			

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

[Turn over

PHYSICS DATA:

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

PHYSICS FORMULAE:

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on / by a gas	W	=	$p\Delta V$
hydrostatic pressure	P	=	ρgh
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	=	$\frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** A ball is kicked from horizontal ground towards a vertical wall, as shown in Fig. 1.1.

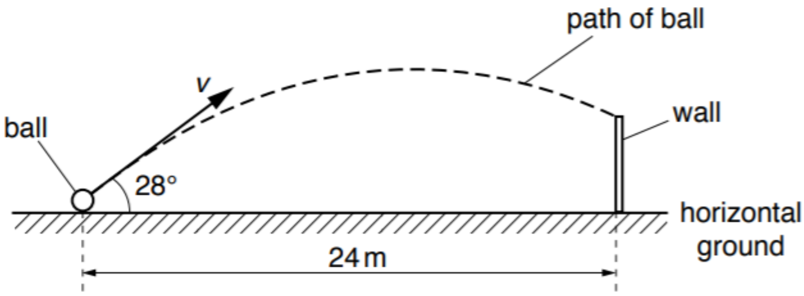


Fig. 1.1 (not to scale)

The horizontal distance between the initial position of the ball and the base of the wall is 24 m. The ball is kicked with an initial velocity v at an angle of 28° above the horizontal. The ball hits the wall after a time of 1.50 s. Air resistance is negligible.

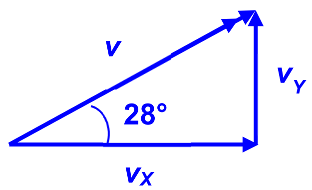
(i) Calculate the initial horizontal component v_X of the velocity of the ball.

v_X = ... m s^{-1} [1]

$$v_X = \frac{s_X}{t} = \frac{24}{1.50} = 16 \text{ m s}^{-1}$$ **1**

(ii) Show that the initial vertical component v_Y of the velocity of the ball is 8.5 m s^{-1}.

[1]



tan 28° = v_Y / v_X

v_Y = v_X tan 28° = (16) tan 28° = 8.5 m s^{-1} (shown) **1**

OR

v_X = v cos 28° --- (1)
v_Y = v sin 28° --- (2)

(2)/(1): tan 28° = v_Y / v_X
v_Y = v_X tan 28° = (16) tan 28° = 8.5 m s^{-1} (shown) **(1)**

(iii) Calculate the time taken for the ball to reach its maximum height above the ground.

time = ... s [2]

Use $v_{Y,\,final} = v_{Y,\,initial} + a_Y t$ --- (1)

Take vectors upwards as positive.

At maximum height, $v_{Y,\,final} = 0$

Free fall, so $a_Y = -9.81 \text{ m s}^{-2}$

$v_{Y,\,initial} = v_Y$ from (a)(ii) = $+8.5 \text{ m s}^{-1}$

Sub into (1): $0 = 8.5 + (-9.81)t$ 1

$t = 8.5 / 9.81 = 0.86646 = 0.87$ s (2 s.f.) 1

(iv) The ball is kicked at time $t = 0$. Assume that the vertical component v_Y of the velocity of the ball is positive in the upwards direction. On Fig. 1.2, sketch the variation with time t of v_Y for the time until the ball hits the wall. **Label this graph Q**.

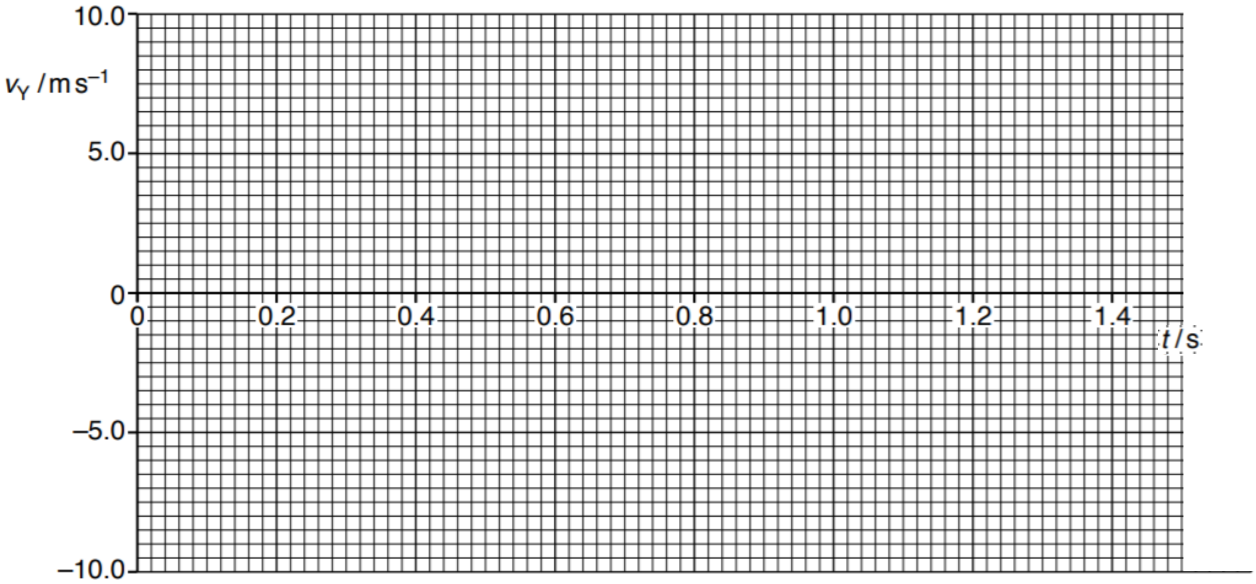
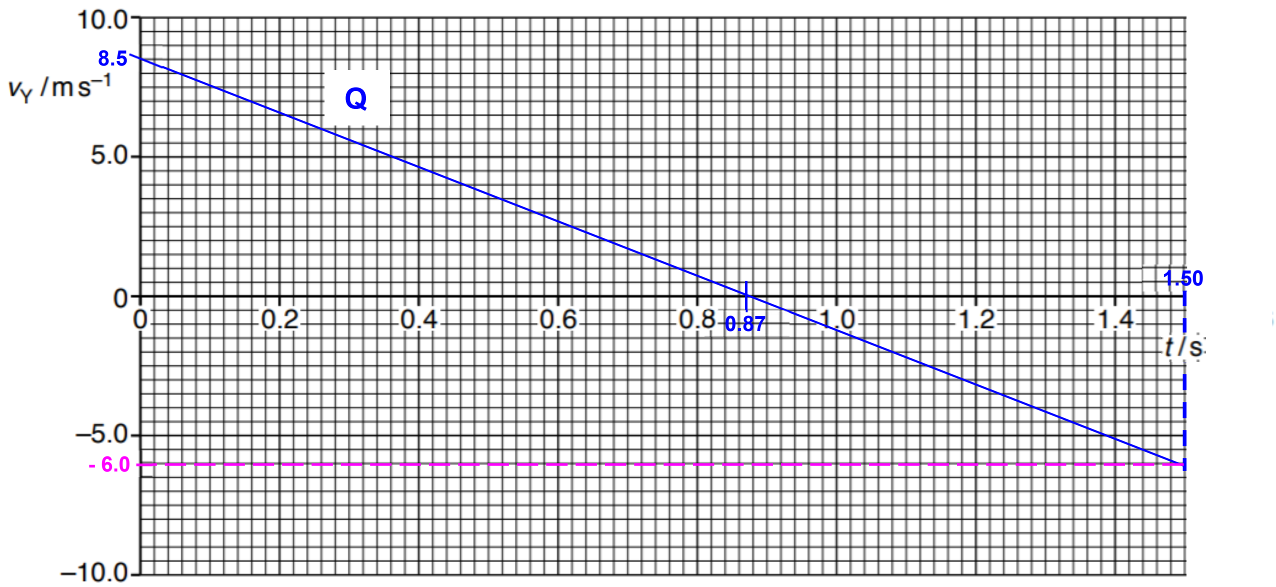


Fig. 1.2 [1]

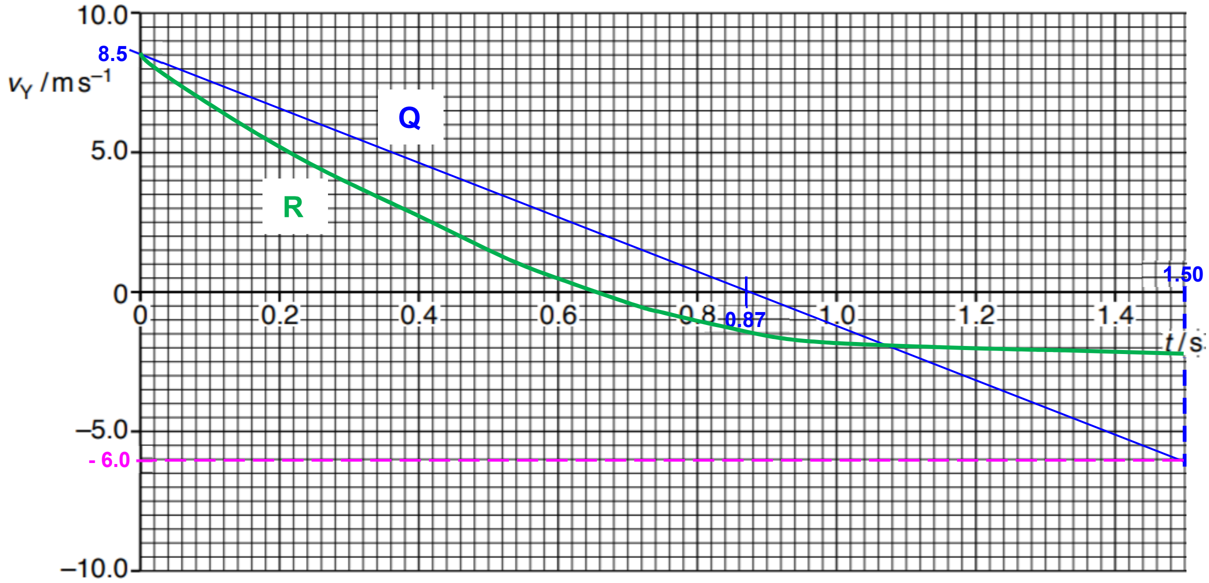
Solution:



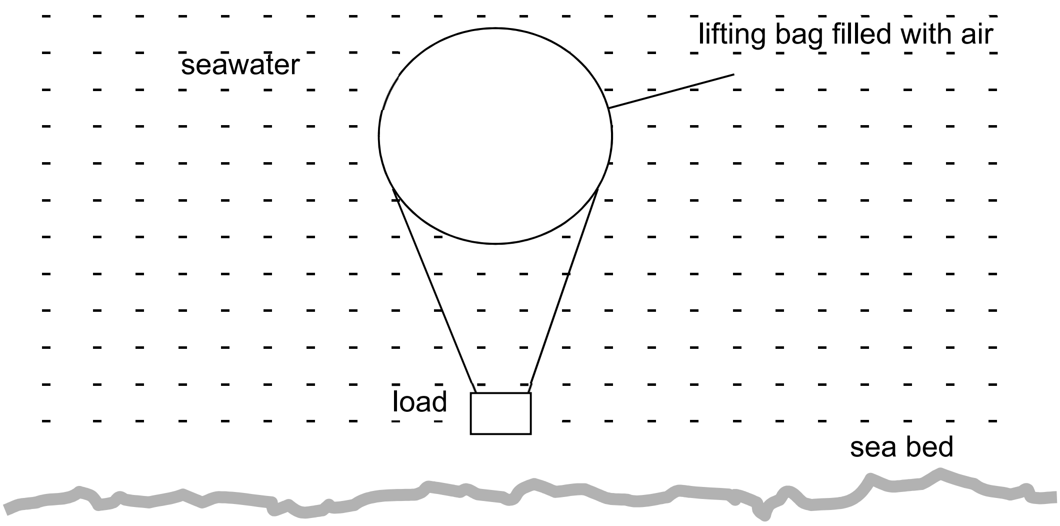
- **Straight line** from **(0, +8.5)** and crosses t-axis at **(0.87, 0).** 1

		(v)	Use your graph in Fig. 1.2 to estimate the height of the wall.	
			height of wall = ... m	[2]
			Height of wall = Net change in displacement of the ball **= Total area bounded by the graph and t-axis** **= ½ (0.87)(8.5) – ½ (6.0)(1.50-0.87)** **= 1.9075 = 1.9 m (2 s.f.)**	**M1** **A1**
	(b)	On Fig. 1.2, sketch a possible v_Y against t graph if air resistance acts on the ball. Assume the ball does not reach the ground before 1.50s. **Label this graph R.**		[2]

Solution:



- Reaches max height earlier, so $v_y = 0$ at earlier t ($t < 0.87$ s)
- Before max height, greater magnitude of acceleration, so steeper gradient (more negative)
- At v_y=0, gradients of both graphs are equal.
- After max height, smaller magnitude of acceleration, so gentler gradient (less negative but not zero).
- Net area under graph should be estimated less than net area under original graph, since ball hits wall at a lower height.
- Area under graph before max. height reached is greater than or equal to area under graph after max height reached (since ball either hit the wall at its base, or some distance above its base). **1** **1**

2	(a)	Explain the origin of upthrust acting on a body in a fluid.		
		....		
		....		[2]
		Fluid pressure increases (directly proportional) with depth in the fluid. This **pressure differences** results in a **net upward force** exerted **by the fluid on the body**, which is known as upthrust.		1 1
	(b)	In order to lift a submerged load of 600 kg from a seabed, a lifting bag made of an elastic material of negligible mass is filled with air and attached to the load, as shown in Fig. 2.1. The density of seawater is 1050 kg m^{-3} and the lifting bag contains 0.700 m^3 of air of density 1.27 kg m^{-3} such that the load ascends with a constant speed. The volume of the load is negligible compared to the volume of the lifting bag.  **Fig. 2.1 (not to scale)**		
		(i)	Calculate the upthrust on the lifting bag when its volume is 0.700 m^3.	
			Upthrust = Weight of seawater displaced = density × volume × g = 1050 x 0.700 x 9.81 = 7210.35 = 7210 N	 1 1
			upthrust = ... N	[2]

		(ii)	Calculate the total drag force on the bag and load.	[2]
			$U = mg + F_D$ $F_D = 7210.35 - 600 \times 9.81$ $= 1.32 \times 10^3$ N	 **1** **1**
			total drag force = …………………. N	[2]
		(iii)	Explain why in practice, to maintain a constant speed of ascent, air has to be released continuously from the lifting bag. Temperature change during the ascent is negligible.	
			…………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………	
			……………………………………………………………………………………………	[2]
			Net force must remain equal to zero. Since the drag force and weight constant, upthrust must be constant and hence the volume of the lifting bag must be constant. As fluid pressure decreases as the bag ascends, the volume of air in the bag increases. Therefore, air has to be let out so as to maintain constant volume of the bag.	 **1** **1**

3 (a) State the *principle of superposition*.

....

....

....

....

.... [2]

Solution:

The principle of superposition states that when two or more waves of the same nature meet at a point, **1**

the resultant displacement is the vector sum of the individual displacements due to each wave at that point. **1**

(b) Interference effects are produced on a viewing screen as a result of interference of the direct waves from a 500 nm electromagnetic wave source S and reflected waves from the mirror as shown in Fig. 3.1.

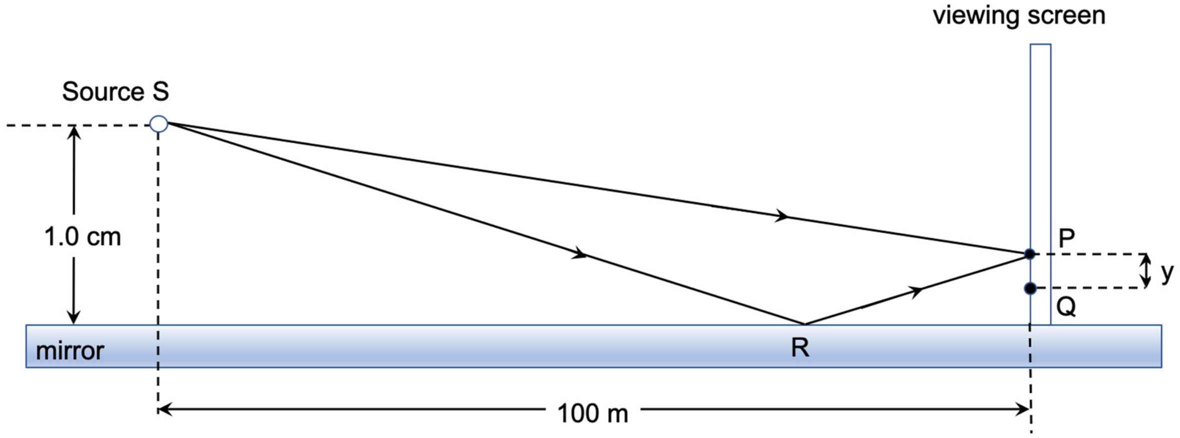


Fig. 3.1 (not to scale)

Points P and Q are at minimum intensity and there is only one point between P and Q which is at a maximum intensity.

S is placed 100 m to the left of the screen and 1.0 cm above the mirror.

(i) Explain why P is at a minimum intensity.

....

....

....

.... [1]

1

Solution:

The direct and reflected waves arrive at P in antiphase, undergoing destructive interference.

(ii) Calculate the distance *y*. Explain your working.

y = …………………… mm [3]

y = fringe separation

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

$$y = \frac{(500\times10^{-9})(100)}{2\times(1.0\times10^{-2})}$$ 1

$$= 2.5\times10^{-3}\,\text{m} = 2.5\,\text{mm}$$ 1

1

(iii) Describe and explain the changes observed at point P, if any, as a result of the following changes made independently to the experiment.

1. Source S is gradually shifted vertically further away from the mirror.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

As S is shifted away gradually, the PATH difference between the direct wave and the reflected wave arriving at P will increase continuously. **1**

This causes the PHASE difference between the waves at P to change continuously from 180° to 0°, back to 180° and so on. **1**

Thus alternating instances of constructive and destructive interferences will occur at P.

As a result, alternating instances of brightening and dimming of the light intensity will be observed at P. **1**

			2.	The mirror is replaced by a black cardboard.	
				……………………………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………	
				………………………………………………………………………………………………	[2]
				Solution: The black cardboard is a very poor reflector of light (OR absorbs most of the light wave incident on it rather than reflect the wave).	**1**
				Thus interference between waves are no longer observable. P which was initially experience destructive interference will now appear brighter.	**1**
				[OR Thus the reflected wave will have significantly lower amplitude compared to the direct wave arriving at P. At P, destructive interference results in an intensity that is very similar to the intensity due to one wave only, so P appears brighter than before.]	

4	**(a)**	**(i)**	State what is meant by the *internal energy* of a system.	
			……………………………………………………………………………………………… ………………………………………………………………………………………………	
			………………………………………………………………………………………………	[1]
			Solution: sum of the random kinetic and potential energies of the individual atoms/molecules/particles of the system	**1**
		(ii)	Explain why, for an ideal gas, the change in internal energy is directly proportional to the change in thermodynamic temperature of the gas.	
			……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………	
			………………………………………………………………………………………………	[3]
			In an ideal gas, no intermolecular forces so potential energy between atoms/molecules equal to zero. Thus internal energy is solely due to kinetic energy of the atoms/molecules.	**1**

(Mean) kinetic energy of atoms/molecules is proportional to the (thermodynamic) temperature of the gas. **1**

Therefore the *change in* internal energy is proportional to the *change in* thermodynamic temperature of the gas. **1**

(iii) A box, filled with an ideal gas, is rapidly accelerated horizontally from rest.

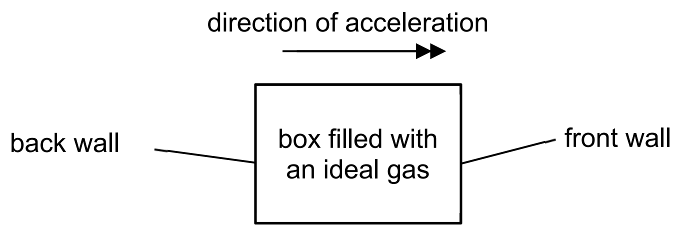


Fig. 4.1

Suggest, with a reason, how the internal energy of the gas would vary from the back wall to the front wall of the box during the acceleration.

....

....

....

....

.... [2]

Solution:

Region of sudden compression at the BACK → work done on gas → gain energy;
Region of sudden expansion at the FRONT → work done by gas→ lose energy **1**

(Assuming adiabatic process), the internal energy decreases from back towards the front. **1**

(b) A cylinder of volume 1.8×10^4 cm^3 contains helium gas at pressure 6.4×10^6 Pa and temperature 25°C. The root-mean-square speed of the helium gas atoms is 336 m s^{-1}. Helium gas may be considered to be an ideal monatomic gas.

(i) Calculate the number of helium atoms in the cylinder.

number = ... [2]

Solution:

$pV = NkT$
$(6.4 \times 10^6)(1.8 \times 10^4 \times 10^{-6}) = N (1.38 \times 10^{-23})(25 + 273.15)$ **1**
$N = 2.7999 \times 10^{25} = 2.8 \times 10^{25}$ **1**

OR

pV = nRT **(1)**
$(6.4 \times 10^6)(1.8 \times 10^4 \times 10^{-6}) = n\,(8.31)(25 + 273.15)$
n = 46.496

$N = n \times N_A$
$= 46.496 \times (6.02 \times 10^{23})$ **(1)**
$= 2.7991 \times 10^{25} = 2.8 \times 10^{25}$

(ii) Calculate the density of helium atoms in the cylinder.

density = ……………………….kg m^{-3} [2]

Solution:

$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle = \frac{1}{3}\rho\langle c^2\rangle$ where $\sqrt{\langle c^2\rangle} = 336$

$(6.4 \times 10^6) = \frac{1}{3}\rho\,(336^2)$ **1**

$\rho = 170.07 = 170$ kg m^{-3} **1**

5 **(a)** Twin core cable, consisting of a 'live' wire and a 'neutral' wire, is commonly used for wiring applications. Current is supplied via the 'live' wire from an electrical power source to the appliance. Current then flows via the 'neutral' wire back to the electrical power source.

The twin core cable shown in Fig 5.1 consists of two thin wires whose centres are 5.0 mm apart. Each wire carries a current of 0.25 A.

Permeability of the insulating material, $\mu = 1.3 \times 10^{-6}$ H m^{-1}.

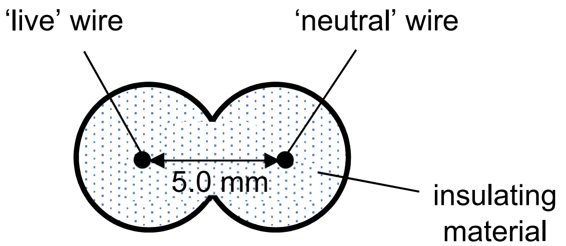


Fig 5.1

(i) State whether the force between the wires is attractive or repulsive.

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

Solution:

Repulsion **1**

(ii) Calculate the magnitude of the force per unit length on each wire.

force per unit length = ……………………….N m^{-1} [3]

Solution:

The magnetic flux density at one wire due to the other wire is,

$B = \frac{\mu I}{2\pi d}$

$= \frac{1.3\times10^{-6}\times0.25}{2\pi\times5\times10^{-3}}$ T 1

Force on each wire = BIL

Force per unit length = BI

$= \frac{1.3\times10^{-6}\times0.25}{2\pi\times5\times10^{-3}} \times 0.25$ 1

= 2.5863 x 10^{-6} = 2.6 x 10^{-6} N m^{-1} (2 s.f.) 1

(b) A railgun is a device typically designed as a weapon that uses electromagnetic force to launch high speed projectiles. A simplified model of a railgun is shown in Fig. 5.2. Fig. 5.2 shows the top view of a pair of smooth horizontal metal rails connected across a 2.0 V battery of negligible internal resistance. The metal rails have negligible resistance. A copper rod XY of resistance 3.04 mΩ is resting on the rails. The rails and the rod lie in a horizontal plane and a uniform vertical magnetic field of flux density 24 mT is applied out of the page.

When the switch is closed, a magnetic force acts on XY which causes it to start moving towards the right. At time *t* s after the switch is closed, XY has a velocity *v* m s^{-1}.

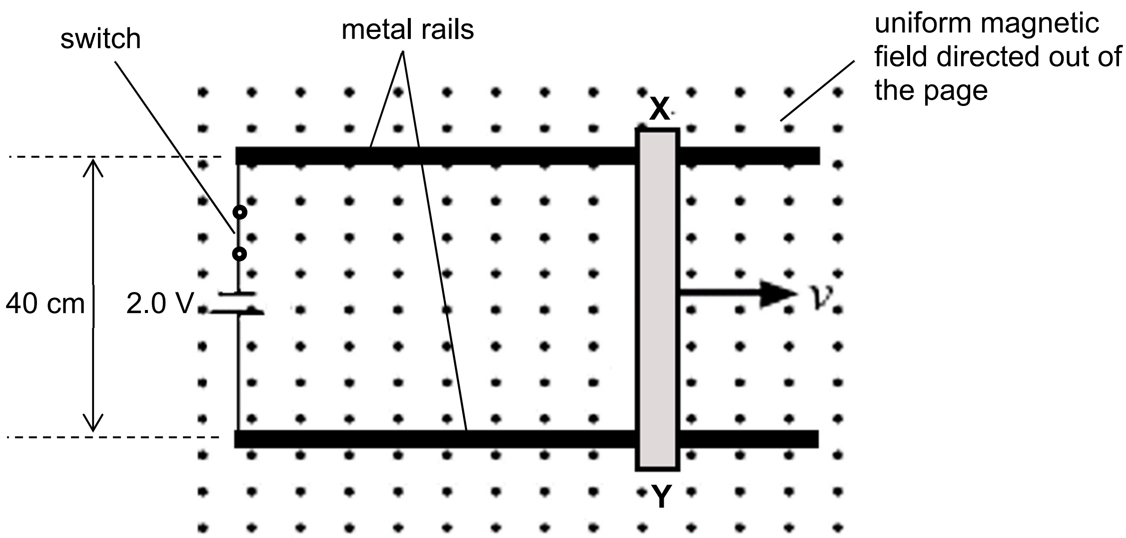


Fig. 5.2

		(i)	As the rod moves to the right, there is an induced e.m.f across rod XY. Use Lenz's law to explain why the **induced** electric potential at X is lower compared to Y.	
			…………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… …………………………………………………………………………………… ……………………………………………………………………………………	
			……………………………………………………………………………………	[2]
			Solution: As rod XY moves, it continuously sweeps an area perpendicular to the uniform magnetic field. This causes the rod to experience an increasing magnetic flux linkage through the area swept. [OR As the rod moves, the magnetic flux linkage through the area enclosed by the closed circuit, consisting of the battery and rod increases.) By Lenz's law, the induced e.m.f. in XY will attempt to drive a current in XY that will flow in a direction that induces a magnetic field directed opposite (i.e. into the page) to the original uniform magnetic field to reduce this increase in magnetic flux linkage. This causes X to be at a lower potential than Y.	**1** **1**
		(ii)	Show that the current, in amperes, in the closed circuit at time *t* is given by (660 - 3.2*v*).	
				[2]
			Solution: Net e.m.f = 2.0 – back induced e.m.f = 2.0 - BLv = 2.0 - $(24 \times 10^{-3})(40 \times 10^{-2})$v Current in closed circuit = Net e.m.f / circuit resistance = $[2.0 - (24 \times 10^{-3})(40 \times 10^{-2})v] / (3.04 \times 10^{-3})$ = 657.89 – 3.1579 v = 660 – 3.2v	**1** **1**

		(iii)	Show that after some time rod XY will slide with constant velocity. Determine this velocity. Explain your working.	
			velocity = ……………………….m s^{-1}	[4]
			Suggested solution 1: The current in the closed circuit is equal to (660 – 3.2v), as the rod speeds up, v increases and therefore current decreases. Eventually, when the current reduces to zero. Thus the net force provided by the magnetic force (F) acting on the rod XY also reduces to zero. Acceleration ceases, and the rod XY continues moving with constant velocity. I_{net} = 660 – 3.2v = 0 v = $210\ m\ s^{-1}$ **Suggested solution 2:** Initially, a net current flows anticlockwise, given by $I_{net} = \frac{E - BLv}{R}$ = 660 – 3.2v ----- (1) Where E is the battery's e.m.f., B is the magnetic flux density, L is length of the rod XY, and R is the circuit resistance. At the instant when speed of rod XY is v, Magnetic force on rod XY acting to the right, F = B I_{net} L $= \frac{E - BLv}{R} BL$ As the rod XY speeds up, v increases, causing induced current ($I_{induced}$) to increase, while the current driven by the battery ($I_{battery}$) remains constant. Thus the net current (I_{net}) flowing anticlockwise through the closed circuit decreases with time. [See equation (1).] Eventually, when the induced e.m.f. (BLv) increases to a value equal to the e.m.f. of the battery (E), I_{net} reduces to zero. Thus the net force provided by the magnetic force (F) acting on the rod XY also reduces to zero. Acceleration ceases, and the rod XY continues moving with constant velocity. Therefore, at maximum speed, E = BLv $\therefore v = \frac{E}{BL} = \frac{2}{(24 \times 10^{-3})(40 \times 10^{-2})} = 208.33 = 210\ m\ s^{-1}$	 **1** **1** **1** **1**

6 A photocell is connected in a series circuit with a variable d.c. power supply and a sensitive ammeter as shown in Fig. 6.1.

The photocell is illuminated with electromagnetic radiation of wavelength 264 nm and power 3.8 mW and photoelectrons are emitted. The potential difference V between the collector C and emitter E in the photocell is adjusted and the photocurrent I is measured. Fig. 6.2 below shows the graph of I against V.

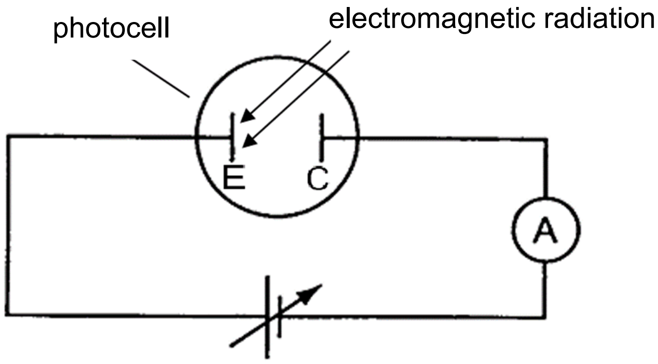


Fig. 6.1

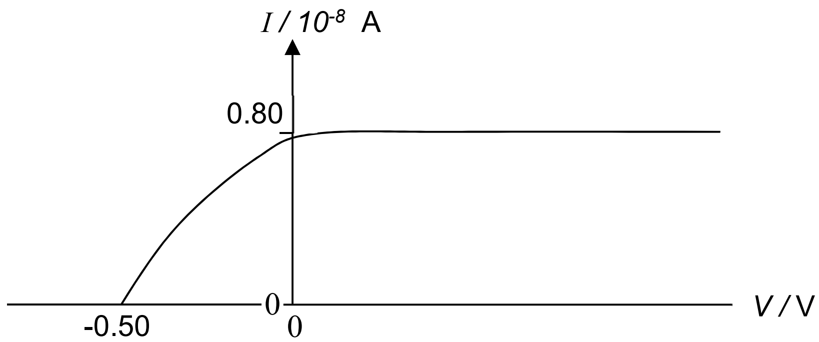


Fig. 6.2

(a) Explain why the photocurrent does not continue to increase for positive values of V.

....

....

....

.... [1]

Solution:

The rate of electron ejection from the emitter arriving at the collector is fixed because it is proportional to the rate of photon incidence which is fixed when electromagnetic radiation is at a fixed intensity and fixed wavelength. **1**

	(b)	**(i)**	Determine the energy of a photon of the incident electromagnetic radiation.	
			energy = ... J	[1]
			Solution: $Energy\ of\ a\ photon = \frac{hc}{\lambda}$ $= \frac{6.63 \text{ x } 10^{-34}(3.00 \text{ x } 10^{8})}{(264 \text{ x } 10^{-9})}$ $= 7.5341 \text{ x } 10^{-19}\ \text{J}$ $= 7.53 \text{ x } 10^{-19}\ \text{J}$	**1**
		(ii)	Calculate the rate at which the photons are incident on the emitter.	[2]
			$Rate\ of\ photon\ incidence = \frac{\text{incident power}}{energy\ of\ photon}$ $= \frac{3.8 \text{ x } 10^{-3}}{7.5341 \text{ x } 10^{-19}}$ $= 5.0437 \text{ x } 10^{15}\ s^{-1}$ $= 5.0 \text{ x } 10^{15}\ s^{-1}$	**M1** **A1**
			rate of photon incidence = ... s^{-1}	[2]
			Solution: $Rate\ of\ photon\ incidence = \frac{\text{incident power}}{energy\ of\ photon}$ $= \frac{3.8 \text{ x } 10^{-3}}{7.5341 \text{ x } 10^{-19}}$ $= 5.0437 \text{ x } 10^{15}\ s^{-1}$ $= 5.0 \text{ x } 10^{15}\ s^{-1}$	

(iii) Show that the maximum rate of photoelectron emission is 5.0×10^{10} s^{-1}. [1]

Solution:

$$Rate\ of\ photoelectron\ emission = \frac{\text{photoelectric saturation current}}{charge\ of\ electron}$$

$$= \frac{0.80 \times 10^{-8}}{1.60 \times 10^{-19}}$$

$$= 5.0 \times 10^{10}\ s^{-1}$$

(iv) Suggest a reason for the difference between **(b)(ii)** and your answer in **(b)(iii)**.

....

....

....

.... [1]

A fraction of the incident photons are reflected by the emitter and do not cause photoelectric effect, hence the number of emitted photoelectrons is smaller than the number of incident photons. **1**

(c) **(i)** Calculate the work function energy of the emitter.

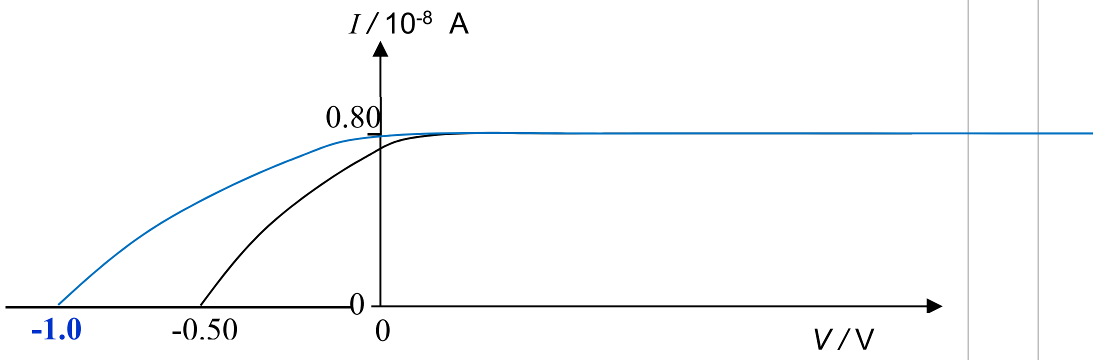
work function energy = ... J [1]

Solution:
Using photoelectric equation,

$$E_{photon} = \phi + eV_s$$

$$7.5341 \times 10^{-19} = \phi + (1.60 \times 10^{-19})(0.50)$$

$$\phi = 6.7 \times 10^{-19}\ J$$ **1**

		(ii)	The emitter is replaced with another emitter of **half** the work function energy. On Fig. 6.2, sketch a graph to show the new variation with V of I.	[2]
			 1 mark: correct graph with a more negative horizontal intercept 1 mark: precision of horizontal intercept (doubled),labelling the new horizontal intercept at -1.0 V	

7 A solar cell is a device which converts light energy directly into electrical energy. Under the influence of light, a terminal potential difference (p.d.) is generated across the solar cell. This process is explained as follows.

A solar cell consists of three main layers: an N-type material layer, a Junction layer, and a P-type material layer.

There is an electric field across the Junction layer as shown in Fig. 7.1. When photons are incident on the solar cell, electron-hole pairs are generated in the Junction layer. Holes are positively charged carriers with charge $+e$. The electrons and holes move in opposite directions under the influence of the electric field, which sets up a terminal p.d. across the solar cell.

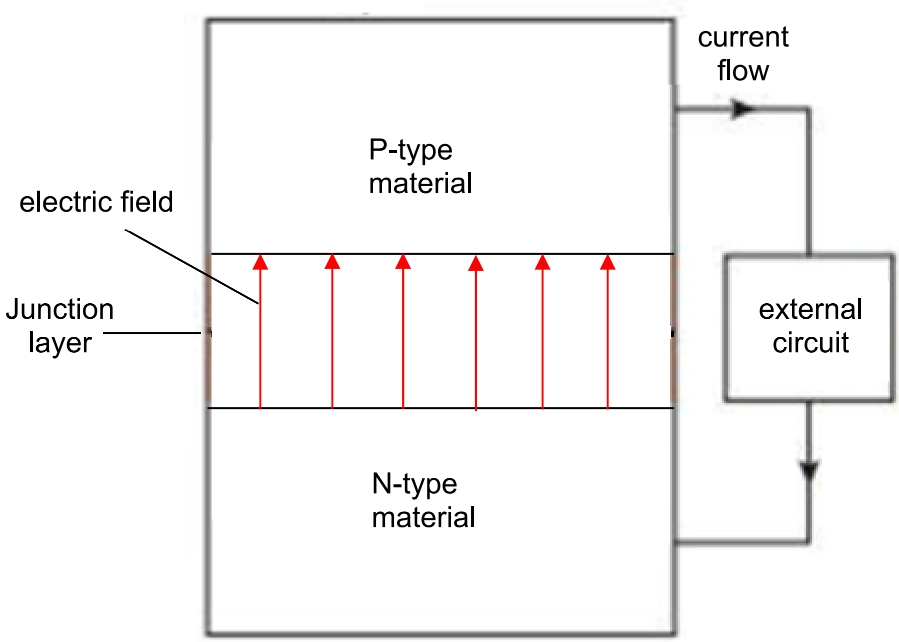


Fig. 7.1

Electron-hole pairs will be generated in the solar cell provided that the incident photon has an energy greater than a certain value known as the band gap energy of the material used.

The magnitude of the p.d. developed across the terminals of the solar cell depends on the intensity of light incident onto the solar cell.

The variation of the potential difference V across the cell with current I can be investigated using the circuit shown in Fig. 7.2

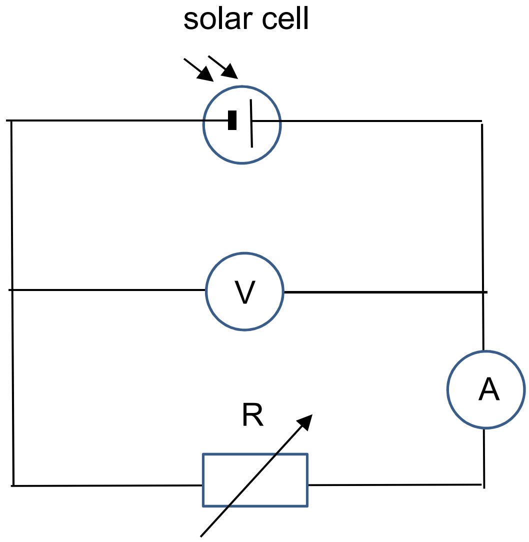


Fig. 7.2

R is a variable resistor with a maximum resistance of 7.0 Ω. The voltmeter has infinite resistance and the resistance of the ammeter is negligible.

Fig 7.3 shows the variation of I with V for a particular cell of surface area 4.0×10^{-4} m^2 when illuminated normally with light intensity 1100 W m^{-2}.

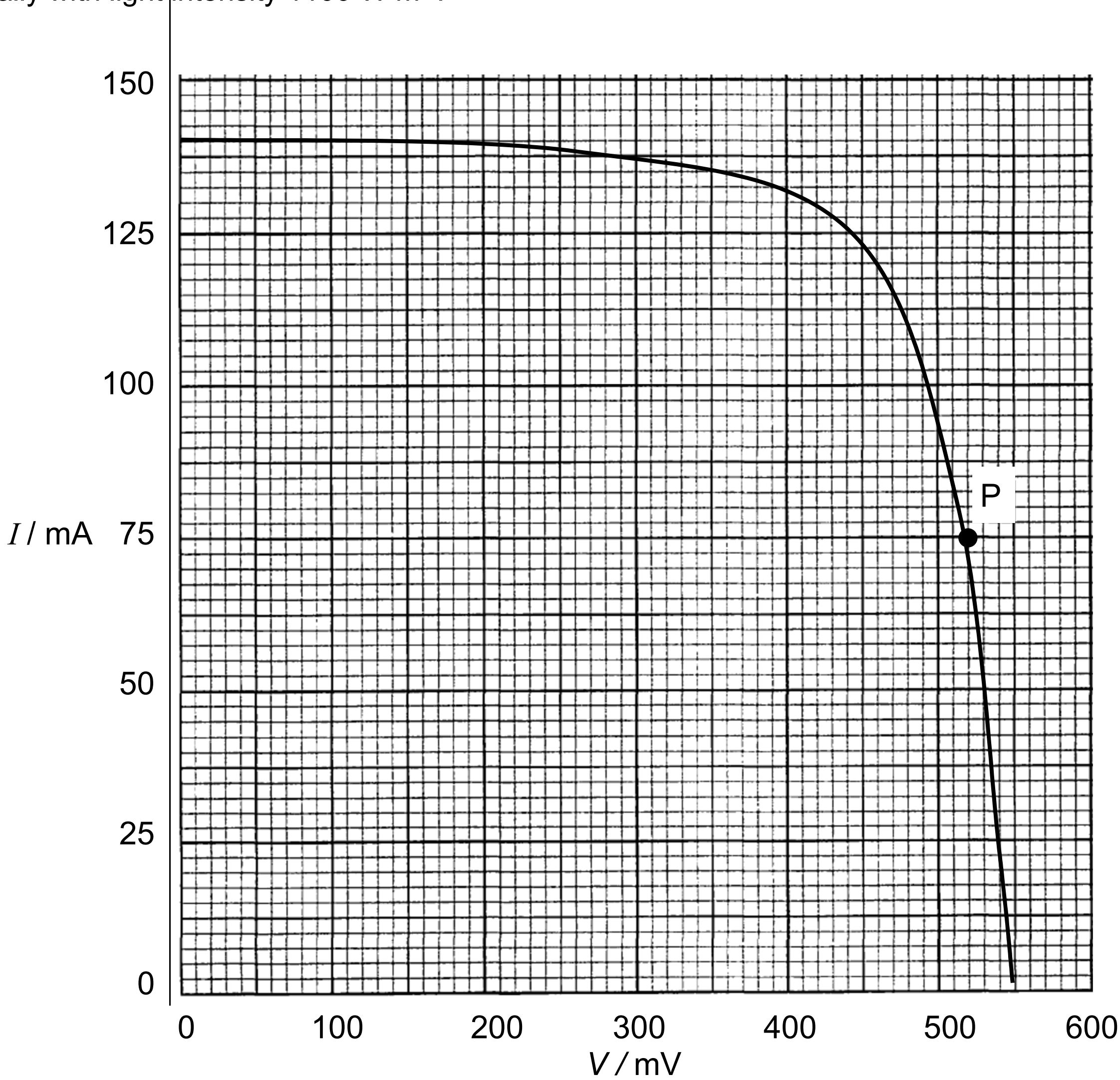


Fig 7.3

(a) (i) State why a p.d. is set up across the solar cell only for a limited range of frequencies of photons.

....

....

.... [1]

Solution:

Because the electron-hole pairs are created only when the energy of a photon is greater than the band gap energy of the material of the solar cell, and the energy of a photon is proportional to the frequency of the incident light. **1**

1 mark is given to relate the given information (that energy of photon must be greater than the band gap energy of the material) to the knowledge that energy of a photon equals to hf.

(ii) Explain why the p.d. across the solar cell increases with the intensity of the incident light.

....

....

....

....

.... [2]

Solution:

When intensity is increased at a fixed frequency the number of photons incident per unit time is proportional to the intensity. 1

Since each electron-hole pair created is the result of absorbing one photon, hence more electron-hole pairs will be created per unit time. 1

(b) (i) Explain how the graph shows that the e.m.f. of the solar cell is 550 mV.

....

....

.... [1]

Solution:

The value corresponds to an open circuit when the current is zero and the terminal p.d. is equal in value to e.m.f. 1

(ii) Explain why the experiment data needed to be extrapolated to obtain the trend from P to the point when V = 550 mV.

……

……

……

……

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

Solution:

At point P
I = 75 mA
V = 520 mV
The resistance at P = 520 V / 75 mA = 6.9 Ω 1

From P to the point when V = 550 mV, the resistance is larger than 6.9 Ω, between 6.9 Ω to infinite resistance (as seen from the ratio V/I). 1
However the variable resistor R only has a maximum resistance of 7.0 Ω. Thus experiment data cannot be obtained for this range of values of V. 1

(c) **(i)** From Fig. 7.3, determine the power dissipation in the load resistor for point P.

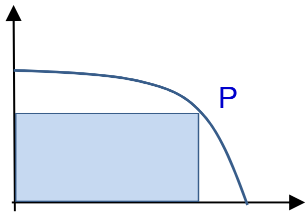
power dissipation = ……………..….W [2]

I = 75.00 mA
V = 520 mV

P = IV = 75 mA x 520 mV 1
= 3.90 x 10^{-2} mW 1

(ii) On Fig. 7.3, shade an area that represents the power dissipation calculate in **c(i).** [1]

Solution:



1

(iii) From Fig. 7.3, estimate the maximum power dissipation in the load resistor. Show your working.

maximum power = …………………..W [2]

When V = 460 mV and I = 120 mA,
Power = 120 mA x 460 mV = 55.2 mW
When V = 470 mV and I = 117.5 mA,
Power = 55.225 mW
When V = 480 mV and I = 110 mA,
Power = 52.8 mW 1

Hence Maximum Power ≈ 55 mW

Accept range of Power 55 mW to 60 mW 1

(iv) On Fig. 7.4 sketch the graph of power output P_o, of the cell against V. Label and include a suitable scale on the vertical axis.

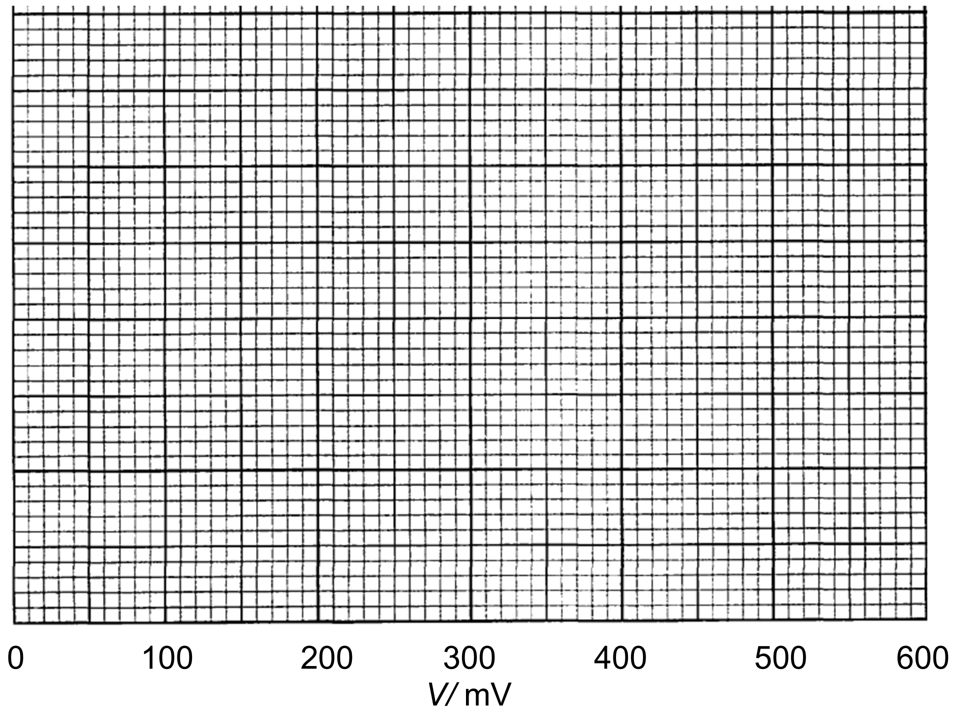
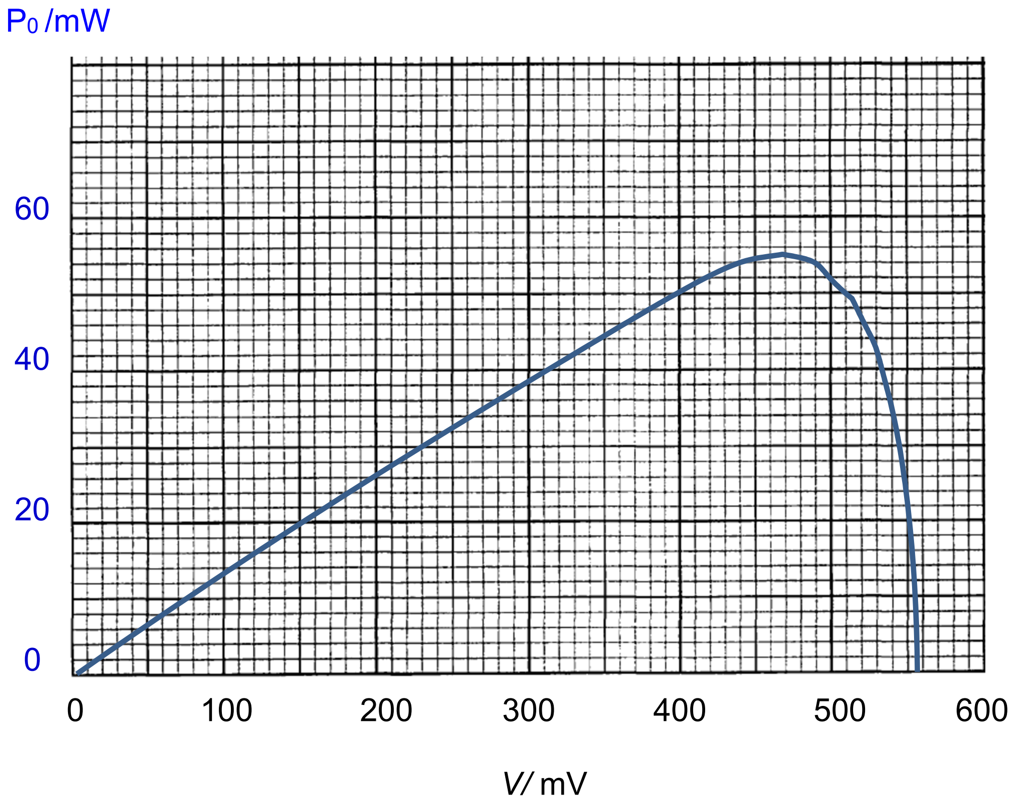


Fig. 7.4 [2]

Solution:



P_0 increases and decreases

P_0 = 0 at V = 0, and V is max at 550 mV, and P_0 = 55 mW at V = 470 mV 1

(estimated from area of 'rectangle' under the I-V graph)

P_0 increases almost linearly for V < 200 mV 1

(because P_o = IV, so when I is approximately constant, P_o is approximately proportional to V → linear variation)

(d) Calculate the maximum efficiency of conversion of light energy into electrical energy.

maximum efficiency = ……………………… [2]

From (c)(iii), Maximum power output = 55 mW

Power input (from incident light energy) = intensity x area = 1100 x 4 x 10^{-4} = 440 mW 1

efficiency = 55/ 440 = 0.125 or 12.5 % 1

(e) A number of solar cells are connected to a load resistor L as shown in Fig. 7.5.

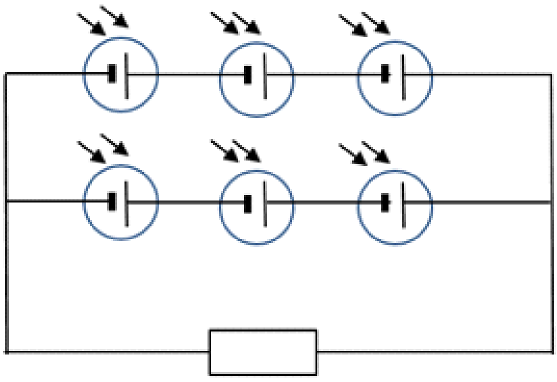


Fig. 7.5

The resistance of L has been adjusted so that each cell gives the maximum power estimated in **(c)(iii)**.

Calculate

(i) the potential difference across L,

potential difference = ………………V [1]

Solution:

V = 3 x 470 mV = 1.41 V **1**

(ii) the current through L.

current = ………………A [1]

Solution:

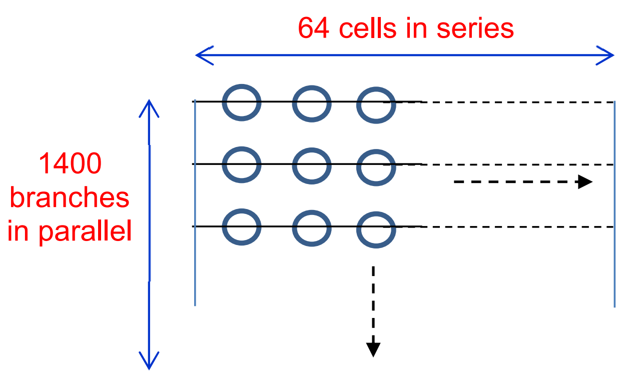
I = 2 x 117.5 mA = 0.235 A **1**

(f) Suppose each cell is operating at maximum power estimated in **(c)(iii)**. Draw a suitable network of cells so that the cells may be used to provide an output power of approximately 5 kW at 30 V.

[3]

Solution:

A network of cells in series and parallel connections



1 Mark – Correct number of cells in series
1 Mark – Correct number of cells in parallel
1 Mark – Diagram - Label the number of cells in series per branch and number of branches (Circuit symbol in branches not required)

At max power, **each cell** has a **p.d. of 47 mV** and **current of 117.5 mA**

Number of cells **in series** = 30 / **0.470** = 63.8 = 64 cells
Number of cells **required** = 5 kW / **55 mW** = 90900 cells
Number of **parallel circuits** = 90900 / 64 = 1400

-- END OF PAPER 2 --

Catholic Junior College
JC2 Preliminary Examinations
Higher 2

CANDIDATE NAME	MARK SCHEME
CLASS	2T

PHYSICS — 9749/03

Paper 3: Longer Structured Questions

14 September 2020

2 hours

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

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.

Section A: Answer **all** questions.

Section B: Answer **one** question only. **Circle** the question number attempted in Section B.

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

FOR EXAMINER'S USE		DIFFICULTY		
		L1	L2	L3
SECTION A				
Q1	/ 8			
Q2	/ 7			
Q3	/ 10			
Q4	/ 11			
Q5	/ 12			
Q6	/ 5			
Q7	/ 7			
SECTION B				
Q8	/ 20			
Q9	/ 20			
PAPER 3	/ 80			
PAPER 2	/ 80			
PAPER 1	/ 30			
TOTAL FOR THEORY	/ 190			

This document consists of **36** printed pages and **zero** blank page.

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	=	$\dfrac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_o nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 Fig. 1.1 shows block A of mass 1.5 kg held against a spring with a force F. The spring is compressed by 2.0 cm.

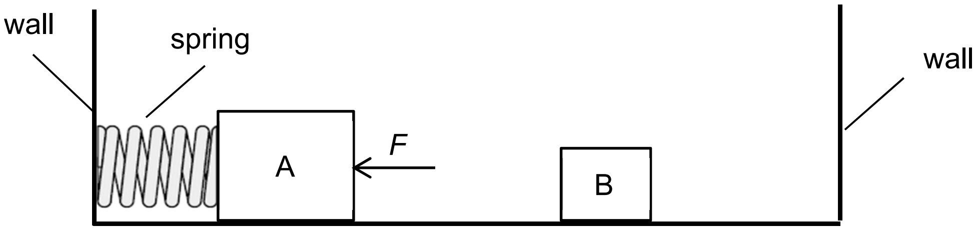


Fig. 1.1

The force F is then removed and the block A accelerates to the right before losing contact with the spring with a speed of 0.50 m s^{-1} as shown in Fig. 1.2. Block A collides elastically head-on with block B. The mass of block B is 0.50 kg.

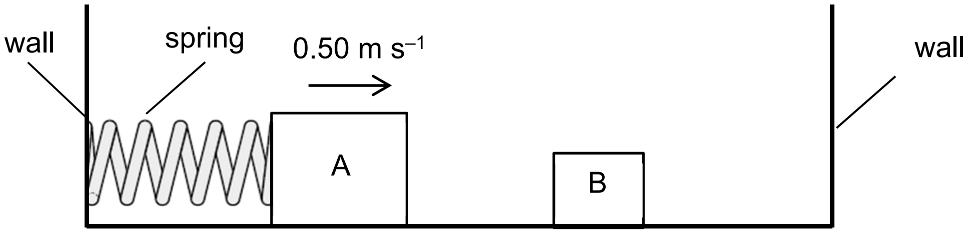


Fig. 1.2

Air resistance and frictional forces are negligible.

(a) Determine the speed of block B after the collision with block A.

final speed of block B = ………………… m s^{-1} [3]

Solution:

Take vectors to the right as positive.
By Conservation of Momentum,

$$m_A u + 0 = m_A v_1 + m_B v_2$$

$$1.5(0.50) = (1.5)v_1 + (0.50)v_2 \qquad (1)$$ 1

$$0.75 = 1.5v_1 + 0.50v_2$$

For head-on, elastic collision,
Relative speed of approach = Relative speed of separation

$$u - 0 = v_2 - v_1$$

$$0.5 = v_2 - v_1 \qquad (2)$$

$$v_1 = v_2 - 0.5$$ 1

Sub (2) into (1)

$$0.75 = 1.5(v_2 - 0.5) + 0.50v_2$$

$$v_2 = 0.75 \text{ m s}^{-1}$$ 1

(b) Fig 1.3 shows the variation with time of the force acting on block A during the collision with block B.

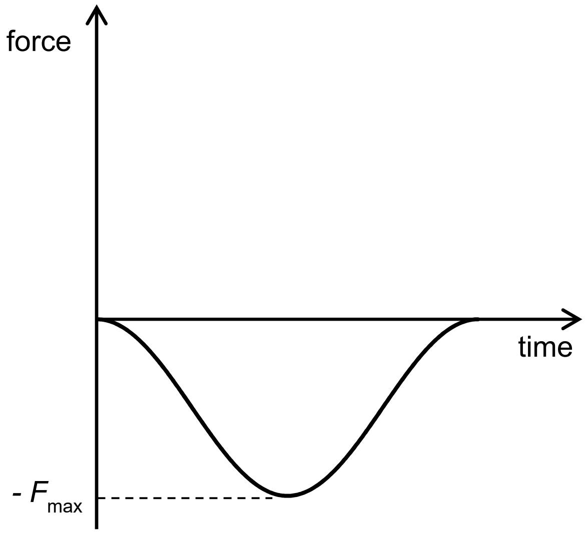
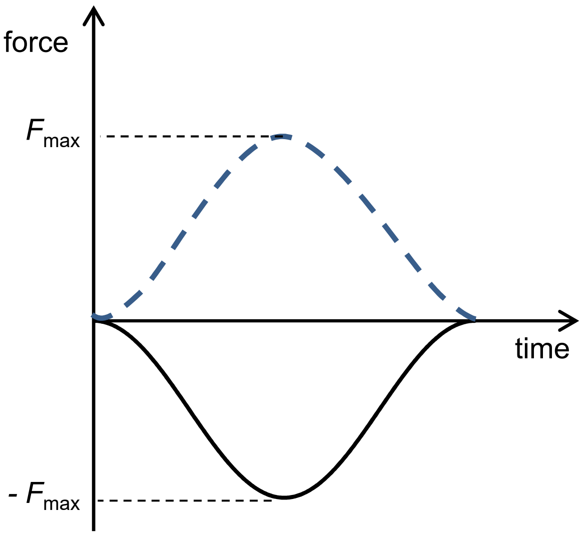


Fig. 1.3

(i) Sketch on Fig. 1.3, the corresponding graph to show how the force on block B varies with time during the collision between block A and block B.

[1]

Solution:

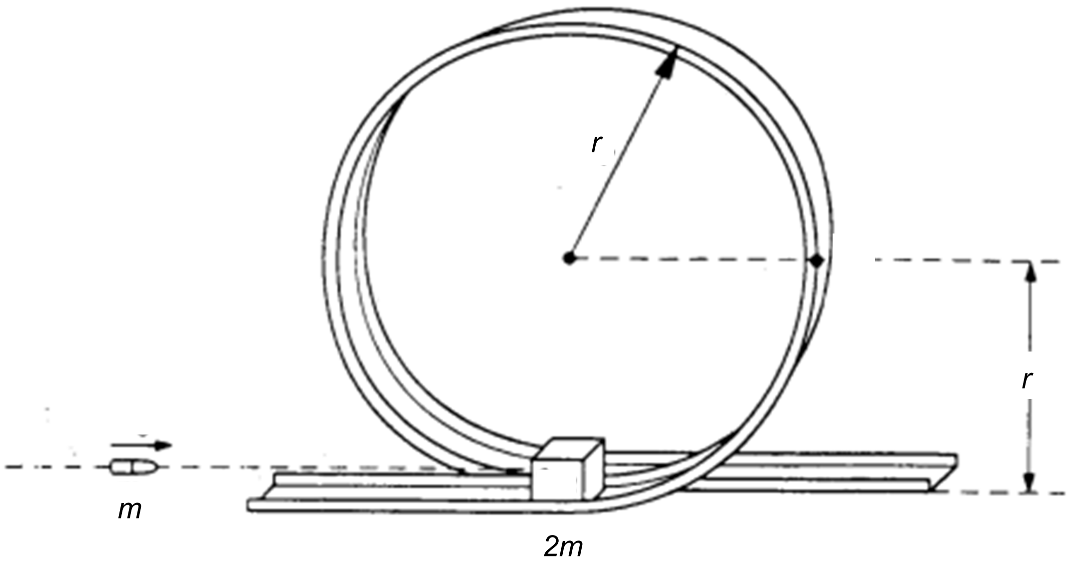


1

Marking points:

- Equal in magnitude and opposite in direction at every instant in time

		(ii)	Explain how your graph shows that the total momentum of the blocks remains unchanged during the collision.	
			....	
			....	[2]
			Solution: Area under the force-time graph represents the change in momentum of a body. The area under the graphs of A and B are equal in magnitude but opposite in direction. This implies that the change in momentum of one block is equal and opposite to the change in momentum of the other so that total momentum is conserved.	 1 1
	(c)	Block B hits the wall elastically, rebounds and collides with block A. Block A then moves and compresses the spring. State, with a reason, whether the maximum compression of the spring will be greater than, less than, or equal to 2.0 cm.		
		....		
		....		[2]
		Solution: Even though total kinetic energy is conserved, the kinetic energy of A is now less than initially as some of its kinetic energy has been transferred to B. By conservation of energy, energy transferred to the spring will therefore be less and the compression of the spring will be less than 2.0 cm.		 1 1

2	A block of mass 2*m* initially rests on a track at the bottom of the circular, vertical loop of radius *r* as shown in Fig. 2.1. A bullet of mass *m* strikes the block horizontally and remains embedded in the block as the block and bullet circle the loop. Assume frictional force of the loop is negligible.  **Fig. 2.1**			
	(a)	**(i)**	Show that the minimum speed of the block at the top of the loop such that it just completes the vertical circular motion without falling off the loop is given by $\sqrt{gr}$ where *g* is the acceleration due to gravity.	[3]
			Solution: At the **Top** of the loop, the **vector sum** of the **Weight of the block (with bullet embedded) *[3mg]*** and the **Normal contacf force *[N]* exerted by the loop on the block <u>provide for</u> the Centripetal force required** $\left[\frac{(3m)v^2}{r}\right]$.	1
			Thus, $3mg + N = \frac{(3m)v^2}{r}$ **where *v* is the speed at the top** $N = \frac{(3m)v^2}{r} - 3mg$	1
			For the block **to JUST complete** the vertical circular motion without falling off the loop **at the Top**, ***N* ≥ *0*.** $\Longrightarrow \frac{(3m)v^2}{r} - 3mg \geq 0$ $\Longrightarrow v \geq \sqrt{rg}$ Minimum velocity at the top of the loop, $v_{min,top} = \sqrt{rg}$	1

		(ii)	Derive an expression for the minimum speed of the bullet in order for the block to just complete the vertical circular motion without falling off the loop. Explain your working.	[4]
			Solution: Since the track is frictionless, the loss in the kinetic energy of the block and bullet is converted into their gain in gravitational potential energy.	1
			Therefore, $\frac{1}{2}(3m)\, v_{min,top}{}^2 - \frac{1}{2}(3m)v_{bottom}{}^2 = (3m)g(2r)$ $\frac{1}{2}(3m)\left(\sqrt{rg}\right)^2 - \frac{1}{2}(3m)v_{bottom}{}^2 = (3m)g(2r)$ $v_{bottom} = \sqrt{5rg}$	1
			where v_{bottom} is the speed at the **bottom** of the loop Applying principle of conservation of linear momentum, taking vectors to the right as positive, Total initial momentum of bullet = Total momentum of block with embedded bullet JUST AFTER the collision	1
			$mv_{bullet} = 3m\sqrt{5rg}$ $v_{bullet} = 3\sqrt{5rg}$	1

3 **(a)** A ball is held between two fixed points A and B by means of two stretched springs as shown in Fig. 3.1.

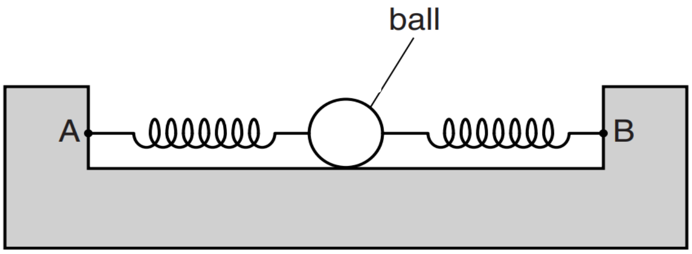


Fig. 3.1

The ball is free to oscillate horizontally on the smooth horizontal table. The variation of the acceleration *a* of the ball with its displacement *x* from its equilibrium position is shown in Fig. 3.2.

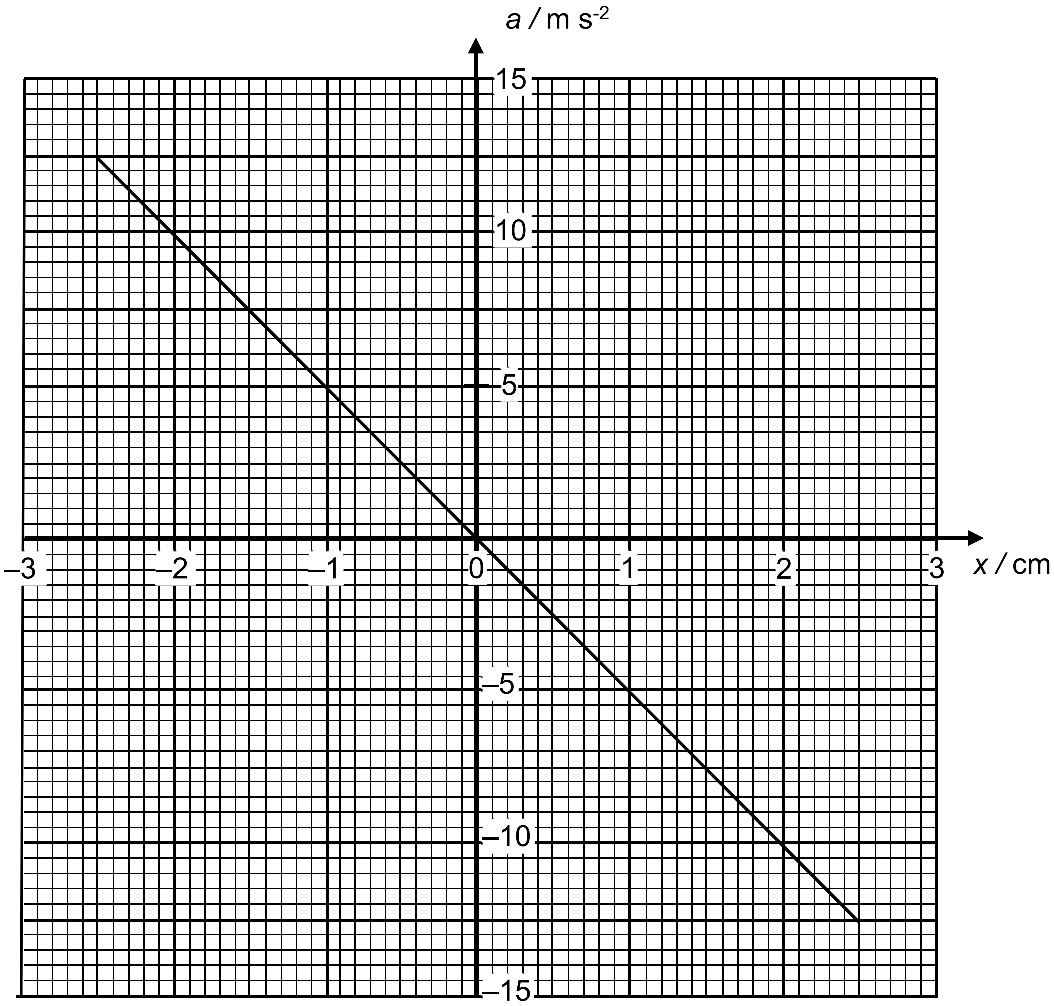


Fig. 3.2

(i) State and explain the features of Fig. 3.2 which indicate that the moving ball is exhibiting simple harmonic motion.

....

....

....

.... [2]

Solution:

The graph is a straight line that passes through the origin, this indicates that the acceleration is directly proportional to the displacement from the equilibrium position. **1**

The gradient of the graph is negative, which indicate that the acceleration and the displacement are always in opposite directions (or the acceleration is always directed to a fixed equilibrium position). **1**

(ii) On Fig. 3.3, sketch the variation of the velocity *v* of the ball with *x*. Include the values of the horizontal and vertical intercepts of the graph.

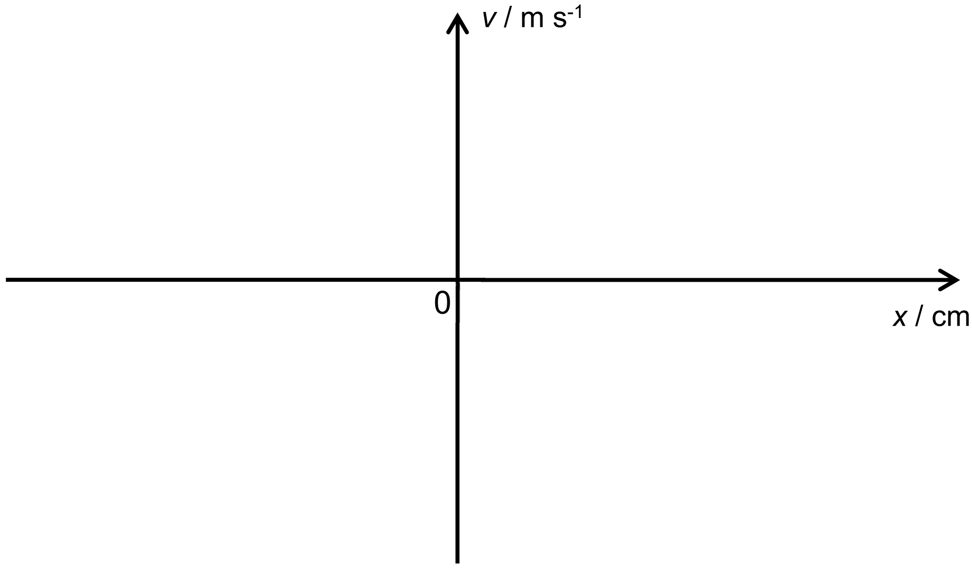
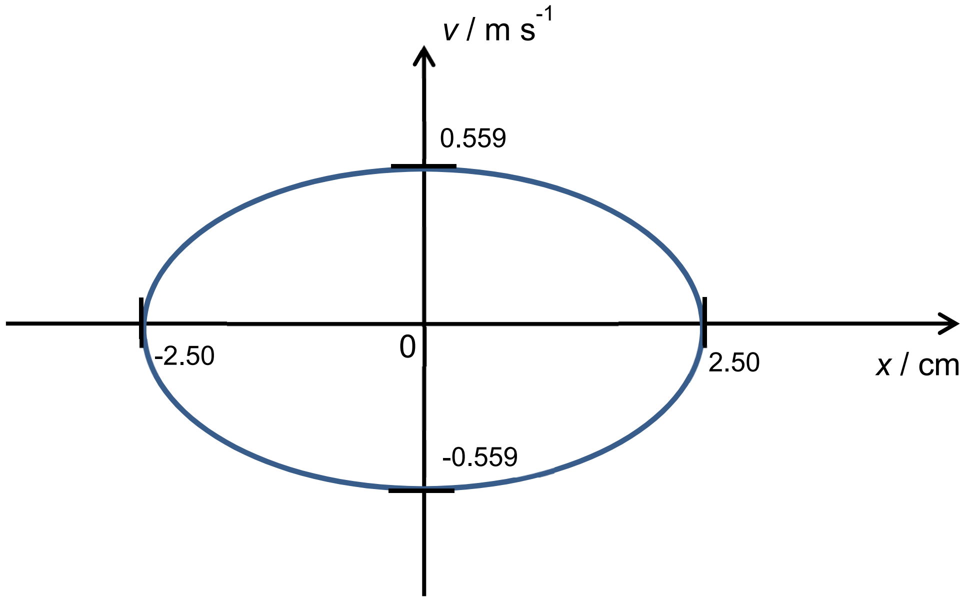


Fig. 3.3

[3]

Solution:



Mark scheme:

- **Shape of graph [ellipse]** **1**
- **From Fig. 3.2, x_o = 2.50 cm = 0.0250 m**
  ➔ Labelled horizontal intercepts at ±2.50 cm **1**
- **From Fig. 3.2, a_o = 12.5 m s^{-2}, $a_o = \omega^2 x_o$ → ω^2 = 12.5 / 0.0250 = 500 s^{-2} ,**
- **$v_o = x_o \omega$ = 0.559 m s^{-1}**
  ➔ Labelled vertical intercepts at ± 0.559 m s^{-1} **1**

(b) The ball is attached to the apparatus illustrated in Fig. 3.4 in order to investigate its vertical oscillations on a spring. The amplitude of the vibrations produced by the oscillator is constant.

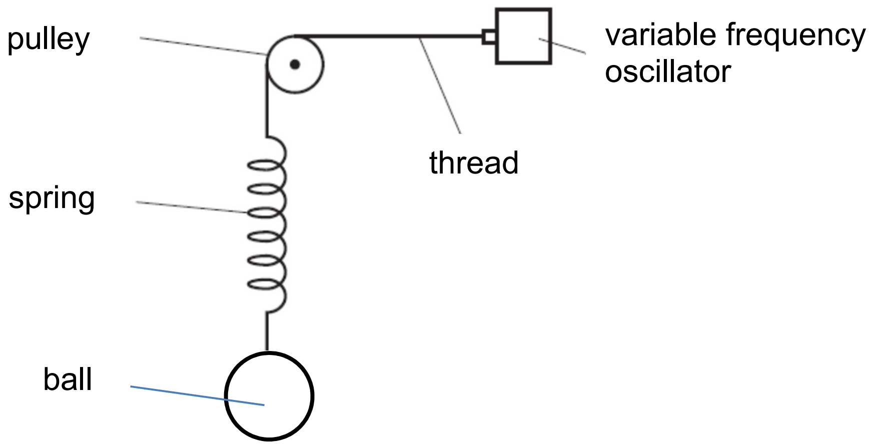


Fig. 3.4

The variation of the amplitude of the oscillations of the ball with the frequency f of the oscillator is shown in Fig. 3.5. The oscillations are assumed to be simple harmonic.

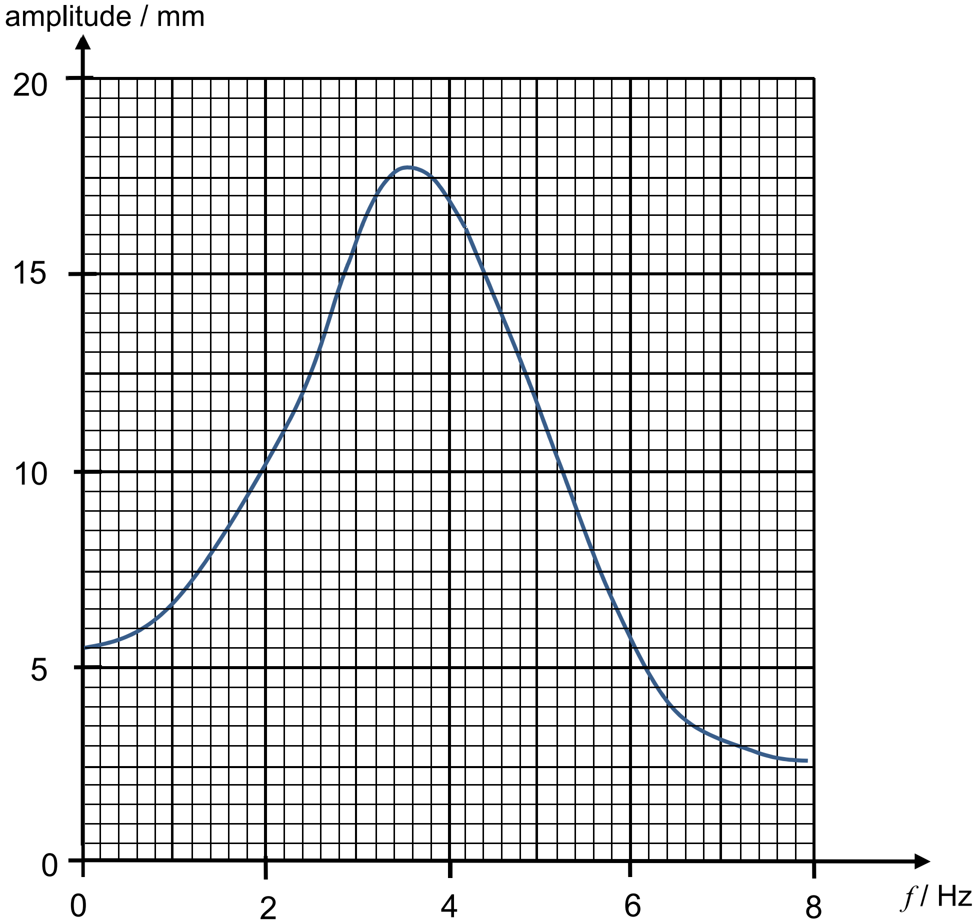


Fig. 3.5

		(i)	State the natural frequency of the oscillations.	
			natural frequency = ... Hz	[1]
			Solution: 3.5 Hz	**1**
		(ii)	Explain why Fig. 3.5 shows that the oscillations are damped.	
			....	[1]
			Solution: The graph of Fig. 3.5 shows that the resonance occurs at 3.5 Hz with a finite amplitude showing the system is damped. (Without damping the resonance amplitude would be infinite.)	**1**
		(iii)	On Fig. 3.5, sketch a possible variation of the amplitude of the oscillations of the ball with f if the oscillations are damped with a greater resistive force.	[3]

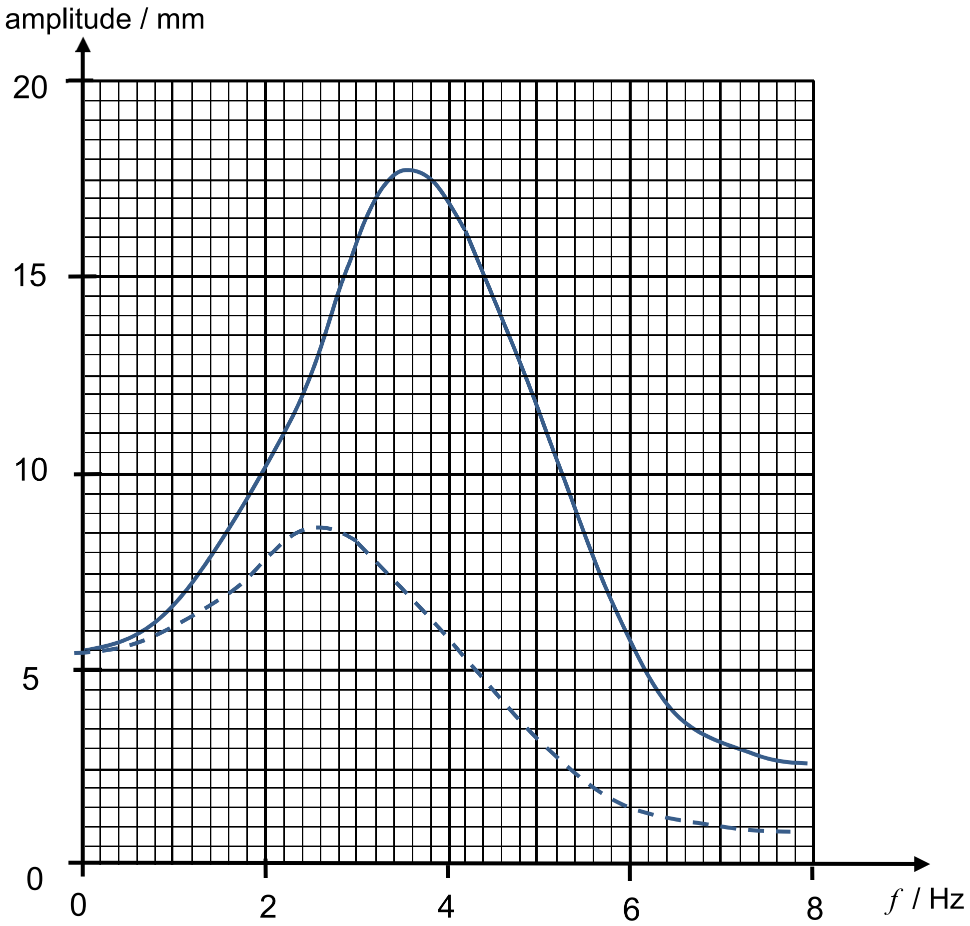
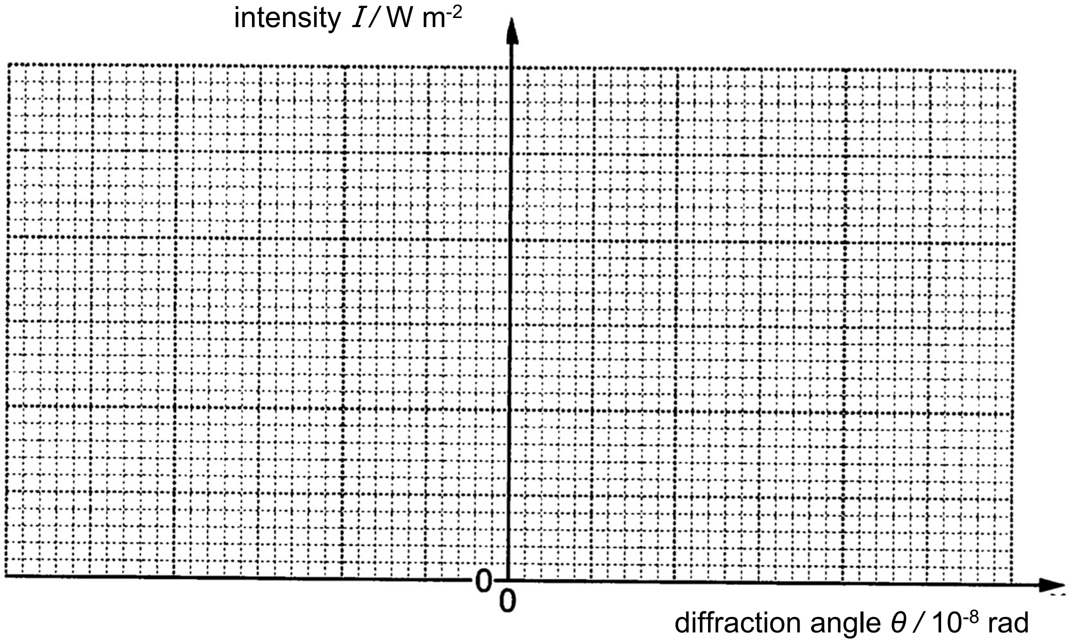


Fig. 3.5

		• Lower resonance frequency → 'peak' shifted to lower f • Lower amplitude at ALL frequencies (except at f = 0) • Amp unchanged at f = 0 → same vertical-intercept	1 1 1

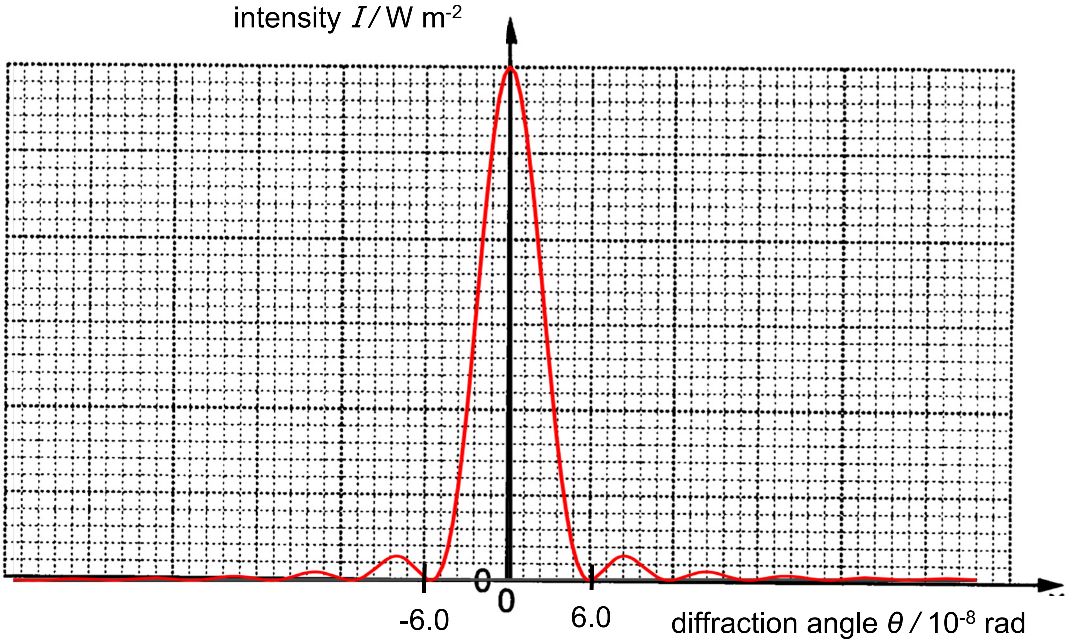
4	**(a)**		A Keck telescope at Mauna Kea, Hawaii, is the world's largest optical telescope and has a diameter of 10 m and is set to detect waves of wavelength 600 nm. The distance, in metres, from the aperture to the viewing screen is *L*.	
		(i)	Calculate the diffraction angle θ_{min} at which the first minimum of the diffraction pattern is observed on the viewing screen.	
			θ_{min} = ………………… rad	[2]
			Solution: $\sin\theta_{min} = m\frac{\lambda}{b}$ $\sin\theta_{min} = (1)\frac{600\times10^{-9}}{10}$ $\theta_{min} = 6.0\times10^{-8}$ rad	1 1
		(ii)	Determine, in terms of *L*, the width of the central bright fringe of the diffraction pattern observed on the viewing screen.	
			width = ………………… m	[2]
			Solution: $\tan\theta_{min} = \frac{y}{L}$ $\tan 6.0\times10^{-8} = \frac{y}{L}$ $y = (6.0\times10^{-8})L$ Width = 2y = $2(6.0\times10^{-8})L = 1.2\,L\times10^{-7}$ m	 1 1

(iii) On Fig. 4.1, sketch a graph to show the variation with diffraction angle θ from the central maximum of the intensity I of the light on the viewing screen. Include the angles for the first minima.



[3]

Fig. 4.1



1 mark:
Smooth diffraction pattern curve, with 2 maxima on either side. 5 maxima in total when central maxima is included. Show to 3rd minima [3 maxima are insufficient to show a 'trend'!]

1 mark:
Exact values of intensity axis labelling with values are not required, however the value for the 1st minima should be included.

1 mark:

(Other details)

- Width of central fringe must be **twice** that of the other maxima fringes.
- Minima must touch zero intensity.
- Maxima intensity must reduce on either side as it gets further from central maxima fringe. (Intensity of central maxima must be shown to be **significantly higher** than the higher order maxima.)

(b) A radio telescope at Arecibo, Puerto Rico, has a diameter of 305 m and is designed to detect radio waves of wavelength 0.75 m.

(i) State two physical quantities that determine the resolving power of the telescope.

quantity 1 : ……………………………………………

quantity 2 : …………………………………………… [2]

Solution:

quantity 1: size/diameter of the aperture **1**
quantity 2: wavelength of the electromagnetic wave **1**

(ii) Explain quantitatively whether the Keck telescope used in the detection of light waves has a higher or lower resolving power compared to the radio telescope used in the detection of radio waves at Arecibo.

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

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

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

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

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

Solution:

Keck Telescope:

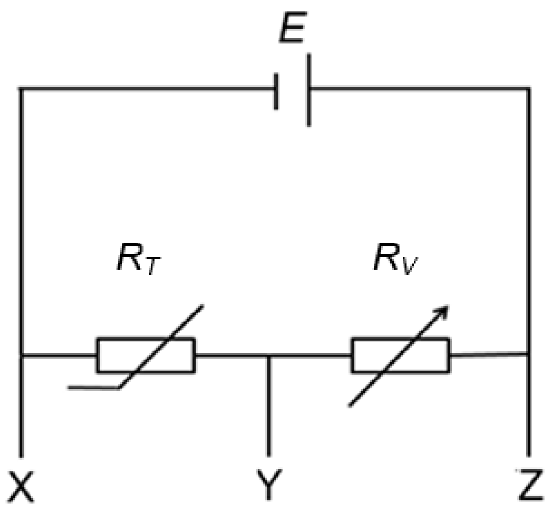
$$\theta_{min} \approx \frac{\lambda}{b}$$
$$= \frac{600\times10^{-9}}{10}$$
$$= 6.0\times10^{-8} \text{ rad}$$

(No marks awarded if candidates substitute wavelength as 0.75 m)
The Keck telescope as stated in (a) is set to detect waves of wavelength 600 nm

Radio Telescope:

$$\theta_{min} \approx \frac{\lambda}{b}$$
$$= \frac{0.75}{305}$$
$$= 3.0\times10^{-3} \text{ rad}$$

			Since the minimum angle for the radio telescope is much larger than that of the Keck telescope, it indicates that the Keck telescope is able to observe objects as separate images even though the objects are much closer to each other, whereas the radio telescope would not be able to pick up the distinction of the objects due to its larger limiting angle. Thus, the Keck telescope has a higher resolving power.	**1** **1**

5	**(a)**	Define *potential difference between two points in a circuit.*	
		…………………………………………………………………………………… ……………………………………………………………………………………	
		……………………………………………………………………………………	[1]
		Solution: It is the amount of electrical energy converted to other forms of energy per unit charge flowing between those two points in a circuit.	1
	(b)	A thermistor and a variable resistor are connected in a potential divider circuit as shown in Fig. 5.1. The battery has an e.m.f. of E, the thermistor has a resistance R_T and the variable resistor has a resistance R_V. This circuit is used to activate an alarm system whenever the ambient temperature rises to a certain value. The alarm bell will sound if the potential difference across it increases beyond the pre-set value.	
			
		Fig. 5.1	

State an expression for the potential difference across the variable resistor in terms of *E*, R_T and R_V.

[1]

Solution:

Let the current in the circuit be I

e.m.f. of cell E = I (R_T + R) ➔ I = E / (R_T + R_V)

p.d. across variable resistor = I R_V = E [R_V / (R_T + R_V)] 1

OR

By potential divider principle,

p.d. across variable resistor = E [R_V / (R_T + R_V)]

(i) State and explain across which two terminals, XY or YZ, how the alarm bell should be connected to the circuit in Fig. 5.1.

……

……

……

…… [2]

Solution:

As the temperature increases, the resistance of the thermistor R_T decreases As R_T decreases, the potential difference across the variable resistor increases since p.d. across variable resistor = I R_V = E R_V / (R_T + R_V) where E and R_v are constants. 1

Hence if the alarm bell is to be triggered when the p.d. across it goes beyond a particular value, the alarm should be connected across YZ (variable resistor). 1

(ii) State and explain the purpose of the variable resistor in the circuit.

……

……

……

…… [2]

Solution:

The variable resistor controls the temperature at which the alarm to be triggered. 1

The p.d. across the resistor depends on the resistance of the variable as well as that of the thermistor. By changing its resistance, it allows the p.d. across it to reach the triggering value at other temperatures when the thermistor reaches a different temperature. 1

(c) Fig. 5.2 shows a potentiometer circuit consisting of a 100 cm length of wire AB and a driver cell E_1 of e.m.f 2.0 V and of negligible internal resistance.

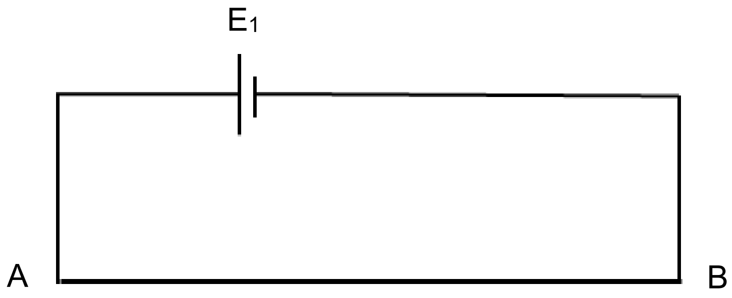


Fig. 5.2

(i) State the value of the potential gradient along AB.

potential gradient = ………….. V cm^{-1} [1]

Solution:

Potential gradient = 2.0 / 100 = 0.020 V cm^{-1} 1

(ii) A circuit consisting of a cell E_2 and a variable resistor R is now connected to the potentiometer as shown in Fig. 5.3.

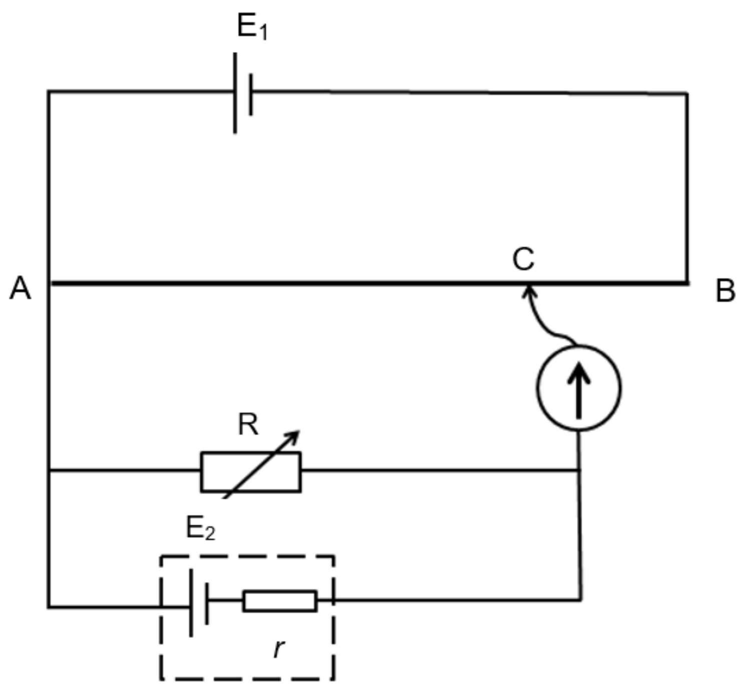


Fig. 5.3

	(d)	The resistance of R is set to 10.0 Ω and the sliding contact C is adjusted until there is no current flowing in the galvanometer. The length AC is found to be 60.0 cm. The resistance of R is now set to 3.0 Ω and the experiment is repeated. The length AC is now 54.0 cm.	
		Calculate the e.m.f. and internal resistance *r* of cell E_2.	
		e.m.f. of cell E_2 = ……………………..V internal resistance of cell E_2 = …………………. Ω	[5]
		Solution: p.d. across AB = e.m.f. of E_1 = 2.0 V When resistance of R = 10.0, balance length = 60.0 cm p.d. across AC = potential gradient x 60.0 = 0.020 x 60.0 = 1.2 V p.d. across R = E_2 x 10.0 / (10.0 + r) At balance length, p.d. across R = p.d. across AC E_2 x 10.0 / (10.0 + r) = 1.2 ………..(1) When resistance of R = 3.0, balance length = 54.0 cm p.d. across AC = potential gradient x 54.0 = 0.020 x 54.0 = 1.08 V p.d. across R = E_2 x 3.0 / (3.0 + r) At balance length, p.d. across R = p.d. across AC E_2 x 3.0 / (3.0 + r) = 1.08 ………..(2) (1) / (2) (10.0 /3.0) x [(3.0 + r) / (10.0 + r)] = 1.2 / 1.08 r = 0.5 Ω subtitute r = into (1) E_2 = 1.26 V	 1 1 1 1 1

6	**(a)**	A coil with 500 turns is placed in a uniform magnetic field of flux density 5.0 x 10^{-2} T. The area of the coil perpendicular to the field is 2.5 x 10^{-2} m^2, as shown in Fig. 6.1.	

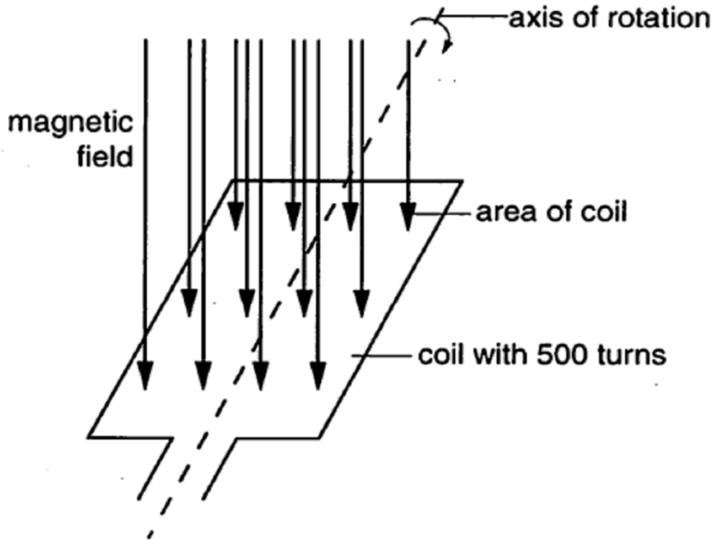


Fig. 6.1

Calculate the magnetic flux linkage of the coil. Give an appropriate unit.

magnetic flux linkage = ……………… unit: ………… [1]

Solution:

$\Phi = NBA\cos\theta = (500)(5.0\times10^{-2})(2.5\times10^{-2})\cos0°$

$= 0.625 = 0.63$ *Wb*

where θ: angle between the normal to the plane of the coil and the magnetic field.

OR

$\Phi = NBA\sin\alpha = (500)(5.0\times10^{-2})(2.5\times10^{-2})\sin90°$

$= 0.625 = 0.63$ *Wb*

where α: angle between the plane of the coil and the magnetic field. **1**

1 mark for both correct answer & units.

(b) The coil in **(a)** is rotated at a constant angular velocity about the axis in Fig. 6.1. The flux linkage *Φ* of the coil varies with time *t*, as shown in Fig. 6.2.

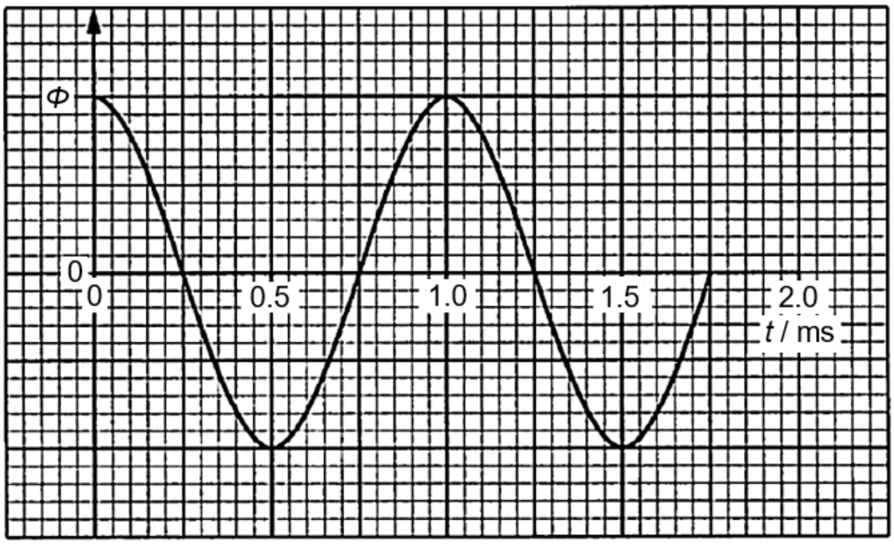


Fig. 6.2

(i) Calculate the maximum induced electromotive force (e.m.f.).

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

Solution:

From graph,

$\Phi = \Phi_o \cos(\omega t)$

$E = -d\Phi/dt = -\omega\Phi_o \sin(\omega t) = -(2\pi/T)\Phi_o \sin(2\pi/T)t$

$= -\left(\frac{2\pi}{1.0x10^{-3}}\right)(0.625)\sin\left[\left(\frac{2\pi}{1.0x10^{-3}}\right)t\right]$

Hence **Maximum induced e.m.f.,**

$\mathbf{E_o = \omega\Phi_o = \left(\frac{2\pi}{1.0\,x\,10^{-3}}\right)(0.625)}$ **1**

= 3927.0 = 3900 V (2 s.f.) **1**

		(ii)	Calculate the root-mean-square value of the induced e.m.f.	
			root-mean-square e.m.f. = ……………………….V	[1]
			Solution: Since sinusoidal AC, $E_{rms} = E_o / \sqrt{2} = 3927.0 / \sqrt{2} = 2776.8 = 2800$ V	**1**
		(iii)	Explain why the flux linkage changes *sinusoidally* as the coil is rotated.	
			………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………	
			………………………………………………………………………………………………	[1]
			Solution: The effective area of the coil perpendicular to the magnetic field to vary sinusoidally with time. OR The magnetic flux density perpendicular to the plane of the coil vary sinusoidally with time.	**1** **(1)**

7 Fig. 7.1 shows some of the energy levels of an helium atom.

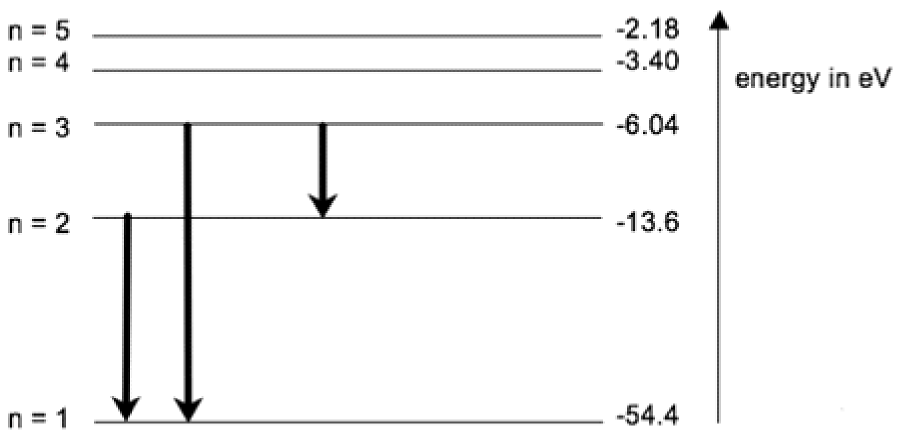
Fig. 7.1

An electron with kinetic energy of 50.0 eV collides with a helium atom in its ground state and the helium atom is excited.

(a) **(i)** In Fig. 7.1, use arrows to show the possible energy transitions when the excited helium atom de-excites. [2]

Solution:

Highest possible level that the electron can excite to is -6.04 eV, n = 3



2 marks - all 3 transitions
1 mark – any 2 transitions
0 mark – 0 or 1 transition

(ii) Calculate the shortest wavelength of the radiation that is emitted from the transitions in **(a)(i).**

Solution:

Loss of electron excitation energy ΔE = Energy of emitted photon E_{photon}

$$\Delta E = \frac{hc}{\lambda}$$

Largest ΔE (i.e. from n=3 to n=1) produces photon of shortest wavelength λ.

$$[-6.04-(-54.4)](1.6\ x\ 10^{-19}) = \frac{(6.63\ x\ 10^{-34})(3.0\ x\ 10^{8})}{\lambda}$$ 1

$$\lambda = 2.57\ x\ 10^{-8}\ m$$ 1

shortest wavelength = ………………………….. m [2]

(b) When a beam of white light is passed through a cold helium gas, an absorption spectrum of coloured background with dark lines is observed.

Use Fig. 7.1 to explain quantitatively why one of the dark lines correspond to a wavelength of 471 nm.

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

Solution:

Photon of wavelength 471 nm has energy of $\frac{(6.63\ x\ 10^{-34})(3.00\ x\ 10^{8})}{471\ x\ 10^{-9}} = 2.64\ eV$

Electrons absorb photons of energy 2.64 eV to make a transition from *n* = 3 to *n* = 4. 1

On de-excitation, photons of energy 2.64 eV, i.e. wavelength 471 nm are emitted. 1

But photons emitted are in **all** directions, not just along the initial direction, hence dark line is observed as compared to other regions whose wavelengths are not absorbed. 1

Section B

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

8 (a) Two ions S and T, each of negative charge $-q$, are held stationary at a distance of 2.0 cm from each other as shown in Fig. 8.1. P_1 is the midpoint between S and T.

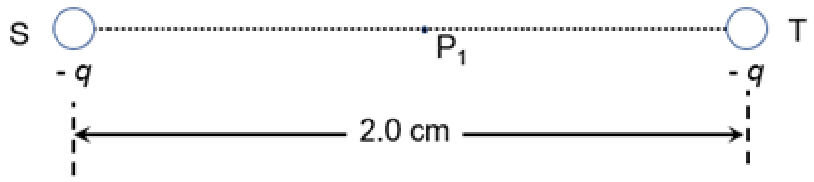


Fig. 8.1

State what it means by

(i) the *electric field strength* at P_1,

....

....

....

.... [1]

Solution:

It is the electric force per unit positive charge acting on a stationary test charge placed at P_1 due to the charges placed at S and T. **1**

(ii) the *electric potential* at P_1.

....

....

....

.... [1]

Solution:

It is the work done per unit positive charge by an external agent in moving a point charge from infinity to P_1. **1**

(b) The value of q is known to be 1.6 x 10^{-19} C. A third ion R of positive charge $+q$ is introduced into the system at a distance of 4.0 cm from ions S and T as shown in Fig. 8.2. All three ions are held stationary.

P_2 is the midpoint between R and T.

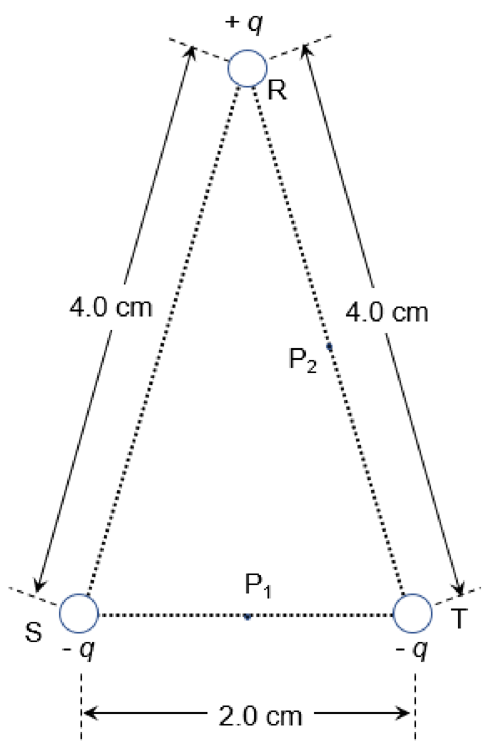


Fig. 8.2

(i) Calculate the amount of work done required to assemble R.

work done = ……………………… J [3]

Solution:

work done by external agent

$= q_R V_{R,net}$

$= q_R (V_{RT} + V_{RS})$

$= q_R \left(\frac{q_S}{4\pi\varepsilon_0 r_{RS}} + \frac{q_S}{4\pi\varepsilon_0 r_{RT}} \right)$

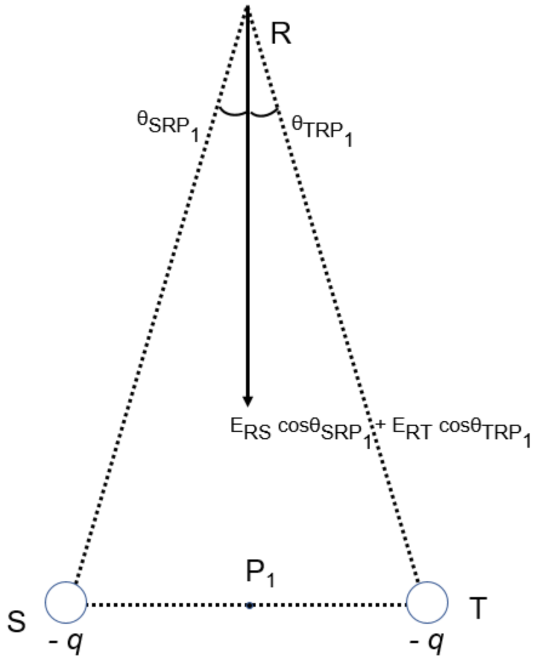
$= \frac{q_R}{4\pi\varepsilon_0 r_{RT}} (q_S + q_T)$ since $r_{RS} = r_{RT}$

$= \frac{+q}{4\pi\varepsilon_0 r_{RT}} ((-q) + (-q))$ **1**

$= \frac{(1.6\times10^{-19})^2}{4\pi(8.85\times10^{-12})(4.0\times10^{-2})}(-2)$ **1**

$= -1.2\times10^{-26}$ J **1**

		(ii)	Without calculations, explain whether the work done required is more or less if R was placed at P_2 instead.	
			....	
			....	
			....	
			....	[2]
			Solution: The resultant electric potential due to S and T at point P_2 is more negative than at R's original position. Therefore an external agent needs to do more work in moving R from infinity to P_2.	1 1
		(iii)	With reference to the direction of the electric field strength along RP_1, describe the variation of electric potential along the line joining ion R to the point P_1.	
			....	
			....	
			....	
			....	[2]
			Solution: The resultant field strength is directed downwards everywhere along the line joining R and P_1 and potential decreases in the direction of the field strength. ($E= -dV/dr$) The resultant potential along the line joining R and P_1 decreases.	1 1
	(c)	(i)	Show that the magnitude of the electric field strength that R experiences for the ion assembly in Fig. 8.2 is given by 1.74×10^{-6} NC^{-1}.	
			Solution: $E_{RT} = \dfrac{q_T}{4\pi\varepsilon_0 r_{RT}^2}$ $E_{RS} = \dfrac{q_S}{4\pi\varepsilon_0 r_{RS}^2}$ $E = E_{RS}\cos\theta_{SRP_1} + E_{RT}\cos\theta_{TRP_1}$ $= \dfrac{q_S}{4\pi\varepsilon_0 r_{RS}^2}\cos\theta_{SRP_1} + \dfrac{q_T}{4\pi\varepsilon_0 r_{RT}^2}\cos\theta_{TRP_1}$	 1 1



Since RST is an isosceles triangle,

$$r_{SR} = r_{RT} \text{ and } \cos\theta_{SRP_1} = \cos\theta_{TRP_1}$$

$$\cos\theta_{TRP_1} = \frac{r_{RP_1}}{r_{RT}}$$ 1

$$= \frac{\sqrt{r_{RT}^2 - r_{P_1T}^2}}{r_{RT}}$$

$$= \frac{\sqrt{4^2-1^2}}{4}$$

$$= \frac{\sqrt{15}}{4}$$

$$E = \frac{q_S}{4\pi\varepsilon_0 r_{RS}^2}\cos\theta_{SRP_1} + \frac{q_T}{4\pi\varepsilon_0 r_{RT}^2}\cos\theta_{TRP_1}$$

$$= 2\frac{q}{4\pi\varepsilon_0 r_{RT}^2}\cos\theta_{TRP_1}$$

$$= 2\frac{q}{4\pi\varepsilon_0 (4.0\times10^{-2})^2}\left(\frac{\sqrt{15}}{4}\right)$$

$$= 303\frac{q}{\pi\varepsilon_0}$$

$$= 303\frac{1.6\times10^{-19}}{\pi(8.85\times10^{-12})}$$ 1

$$= 1.74\times10^{-6}\ \text{NC}^{-1}$$

[4]

(ii) R is subsequently released.

Hence, calculate

1. the magnitude and state the direction of the resultant force on R just as it is released,

force = ………………… N

direction : ……………………… [3]

Solution:

$$F = q_R E$$
$$F = (1.6 \times 10^{-19})(1.74 \times 10^{-6})$$ 1

$$F = 2.784 \times 10^{-25}\ \text{N}$$ 1
$$F = 2.78 \times 10^{-25}\ \text{N}$$

Direction: Vertically downwards OR Towards P_1 1

2. the magnitude of the initial acceleration of R if it has a mass of 2.58×10^{-26} kg.

acceleration = ………………… m s^{-2} [2]

Solution:

$$F = m_R a$$
$$a = \frac{F}{m_R}$$
$$a = \frac{2.784 \times 10^{-25}}{2.58 \times 10^{-26}}$$ 1

$$= 10.8\ \text{m s}^{-2}$$ 1

(d) Suggest with a reason, the subsequent motion of R after passing through the line joining S and T.

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

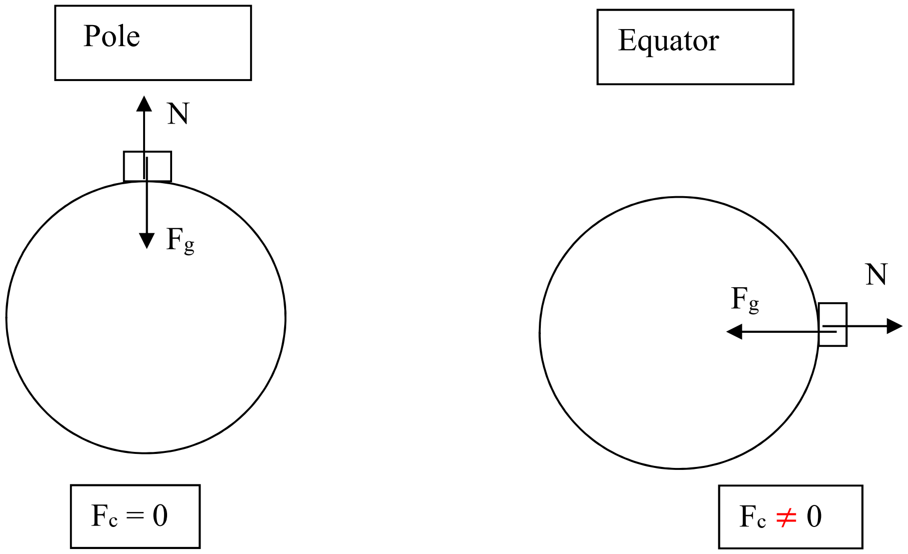
……………………………………………………………………………………………………

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

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

			Solution: • R will always experience a net force towards line joining S and T • Therefore R will oscillate to and fro about the line joining S and T. (1 mark) R will slow down because it experiences a force upwards. OR When R is released, it will accelerate towards P_1. Since all charges radiate when they accelerate, R will emit photons during its motion. Due to the conservation of momenta of R and the emitted photon, R will deviate from a straight path during photon emission.	 **1** **1** **(1)** **(1)**

9	(a)	Distinguish between *gravitational field strength* and *acceleration of free fall*.	
		……	
		……	
		……	
		……	[2]
		Solution: Gravitational field strength is the gravitational force per unit mass acting on a small mass at a point in a gravitational field. While acceleration of free fall is the change in velocity per unit time (i.e. acceleration) produced by gravitational force alone acting on a mass.	**1** **1**
	(b)	Assuming Earth to be a sphere, explain with the help of free body diagrams, the difference in the weight of a person measured on an electronic balance at the poles and at the equator.	
		……	
		……	
		……	
		……	
		……	
		……	
		……	
		……	
		……	
		……	[5]



Free Body diagrams with forces identified, and length of vectors at poles are equal, while at the equator F_g vector is longer than N vector.

N: Normal contact force exerted by electronic scale on person
F_g: Gravitational force exerted by Earth on person

1 mark for FBDs awarded if the following are shown:

- *Forces are identified and named*
- *At Poles : correct N and F_g (length and direction)(N and F_g vectors are equal in length)* 1
- *At Equator : correct N and F_g (length and direction)(F_g vector is longer than N vector)* 1

Electronic balance reads the apparent weight of the person which is given by the magnitude of N.

At a pole, person does not undergo circular motion, hence centripetal force F_c equals zero. Thus N equals in magnitude to F_g. 1

At the equator, person undergoes circular motion, hence F_c is non-zero. Thus N is less than F_g. 1

Since the Earth is assumed to be a perfect sphere, its radius at the poles and equator are equal, hence F_g at both locations are equal. This implies that N at the poles is greater than N at the equator, and hence the apparent weight of the person is lesser at the equator. 1

	(c)	Assuming Earth to be a sphere of radius 6.4 x 10^6 m, calculate the mass of Earth.	
		mass of Earth = ……………………… kg	[2]

Solution:

$g = G\,M/r^2$

$g_{\text{at Earth's surface}} = G\,M_E/r_E^2$ — 1

$M_E = g_{\text{at Earth's surface}}\,r_E^2 / G$

$M_E = 9.81(6.4\text{x}10^6)^2 / 6.67\ \text{x}10^{-11} = 6.02425\ \text{x}10^{24} = 6.0\ \text{x}10^{24}$ kg — 1

	(d)	Calculate the radius of the orbit of a geostationary satellite.	
		radius = ………………….. m	[3]

Solution:

Gravitational force (F_g) exerted by Earth on satellite provides for the centripetal force (F_c) required for the satellite's circular motion. — **1**

$F_g = F_c$

$$\frac{GMm}{r^2} = mr\omega^2 \qquad \textit{where } m\text{: mass of satellite}$$

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

$$T^2 = \frac{4\pi^2 r^3}{GM}$$ — **1**

For geostationary orbit, T = 24 h
From (c), $M = 6.02425\ \text{x}10^{24} kg$

$$(24\ x\ 60\ x\ 60)^2 = \frac{4\pi^2 r^3}{(6.67\ x\ 10^{-11})(6.02425\ \text{x}10^{24})}$$

$$r = 4.2\ x\ 10^7\ m$$ — **1**

(e) **(i)** A space mission is to launch a space shuttle from Earth. The space shuttle comprise of a land rover to be delivered to the moon.

Using the answer in part **(c)**, calculate the distance from the centre of Earth where the resultant gravitational field strength due to the Earth and the Moon is zero.

The mass of the Moon is 7.4×10^{22} kg and distance between centres of the Earth and the Moon is 3.8×10^{8} m.

distance from centre of Earth = ……………………… m [3]

Solution:

At the null point, $g_{resultant} = 0$ **1**

i.e. $g_E = g_M$

$GM_E/r_E^2 = GM_M/r_M^2$

where r_E is the distance from centre of Earth to null point;

r_M is the distance from centre of the moon to null point

1

$6.02425 \times 10^{24} / r_E^{\,2} = 7.4 \times 10^{22} / (3.8 \times 10^{8} - r_E)^2$

$r_E = 3.4209 \times 10^{8} = 3.4 \times 10^{8}$ m **1**

		(ii)	On Fig. 9.1, sketch the variation of gravitational potential ϕ between the surface of Earth and the surface of the moon. Include the value obtained in **(e)(i)**.	

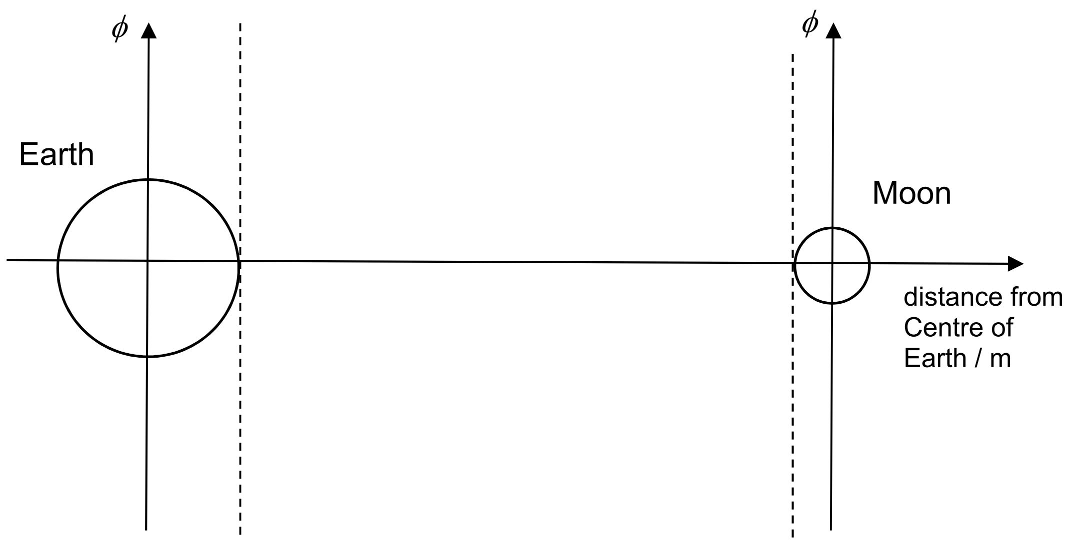


Fig. 9.1

[2]

Solution:

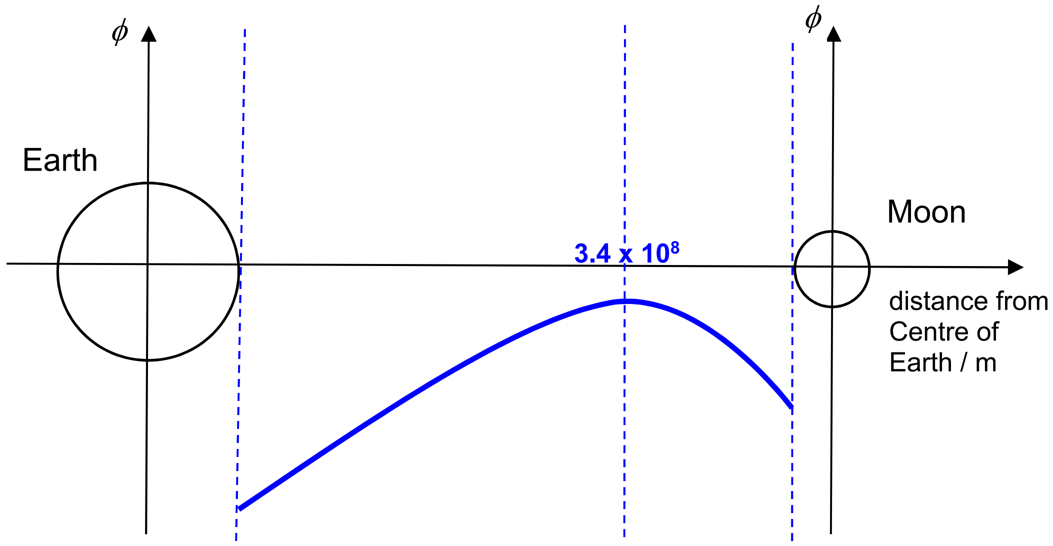


Fig. 9.1

- Maximum point at null point with position labelled **1**
- Potential at Earth's surface is more negative than potential at Moon's surface AND asymmetric curve of appropriate shape **1**

		(iii)	Calculate the minimum launch speed of the space shuttle from Earth such that the space shuttle will be able to reach the surface of the moon.	
			minimum launch speed = …………………… m s^{-1}	[3]

Solution:

By the Conservation of Energy,
Total Initial Energy $_{\text{Earth surface}}$ = Total Final Energy $_{\text{null point}}$

$$KE_{Earth} + GPE_{Earth} = KE_{null} + GPE_{null}$$

$$\frac{1}{2}mv_{object}^{2} + \left(-G\frac{mM_{Earth}}{r_{\text{Earth's centre to Earth's surface}}} - G\frac{mM_{Moon}}{r_{\text{Moon's centre to Earth's surface}}}\right) = 0 + \left(-G\frac{mM_{Earth}}{r_{\text{Earth's centre to Null pt.}}} - G\frac{mM_{Moon}}{r_{\text{Moon's centre to Null pt.}}}\right)$$ **1**

$$\frac{1}{2}v_{object}^{2} + \left(-G\frac{6.02425\times10^{24}}{6.4\times10^{6}} - G\frac{6.0\times10^{22}}{(3.8\times10^{8} - 6.4\times10^{6})}\right) = 0 + \left(-G\frac{6.02425\times10^{24}}{3.4209\times10^{8}} - G\frac{6.0\times10^{22}}{(3.8\times10^{8} - 3.4209\times10^{8})}\right)$$ **1**

$$v_{object}^{2} = 2G\left(9.4129\times10^{17} + 1.6060\times10^{14} - 1.7610\times10^{16} - 1.5827\times10^{15}\right) = 1.2304\times10^{8}$$

$$v_{object} = 1.1092\times10^{4} = 1.1\times10^{4}$$ **1**

-- END OF PAPER 3 –