



**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 2**

NAME

CG

INDEX NO.

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**PHYSICS**

**9749/01**

**Preliminary Examination**  
**Paper 1 Multiple Choice**

**21<sup>st</sup> Sep 2018**  
**1 hour**

Additional Materials: OMS.

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**READ THIS INSTRUCTIONS FIRST**

Write your name, civics group and index number in the spaces at the top of this page.

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There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

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

<b>For Examiners' Use</b>	
<b>MCQ</b>	/ 30

## DATA AND FORMULAE

**Data**

speed of light in free space	$c$	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0$	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0$	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$ $= \frac{1}{36\pi} \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e$	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h$	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u$	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e$	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R$	$= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k$	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G$	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g$	$= 9.81 \text{ m s}^{-2}$

## DATA AND FORMULAE

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2} at^2$$

work done on/by a gas

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

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -\frac{GM}{r}$$

temperature

$$T/K = T/^{\circ}\text{C} + 273.15$$

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

$$I = Anqv$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

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magnetic flux density due to a long straight wire

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

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radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

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

**Answer all questions.**

- 1 The rate of heat flow,  $R$ , can be found using the equation

$$R = k A \frac{(T_2 - T_1)}{L}$$

where  $k$  is the thermal conductivity,  $A$  is the total cross sectional area of the conducting surface, and  $L$  is the thickness of conducting surface separating the 2 temperatures  $T_1$  and  $T_2$ .

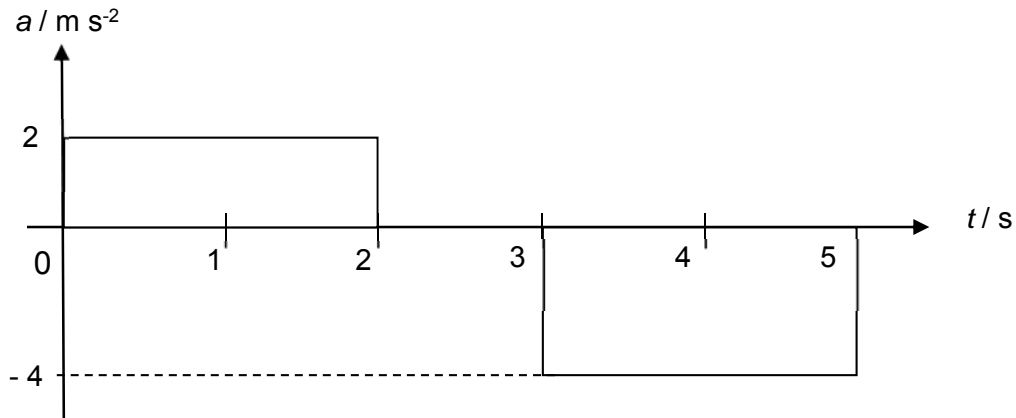
What is the SI base units for  $k$ ?

- A**  $\text{kg m s}^{-3} \text{K}^{-1}$       **B**  $\text{kg m s}^{-2} \text{K}^{-1}$       **C**  $\text{kg m s}^{-3}$       **D**  $\text{kg s}^{-2} \text{K}^{-1}$
- 2 With reference to Question 1, a student collected the following measurements to determine the rate of heat flow  $R$  of the object
- $L = (0.35 \pm 0.05) \text{ mm}$   
 $T_1 = (32.0 \pm 0.5) ^\circ\text{C}$   
 $T_2 = (4.0 \pm 0.5) ^\circ\text{C}$

What is the fractional uncertainty in  $R$ ?

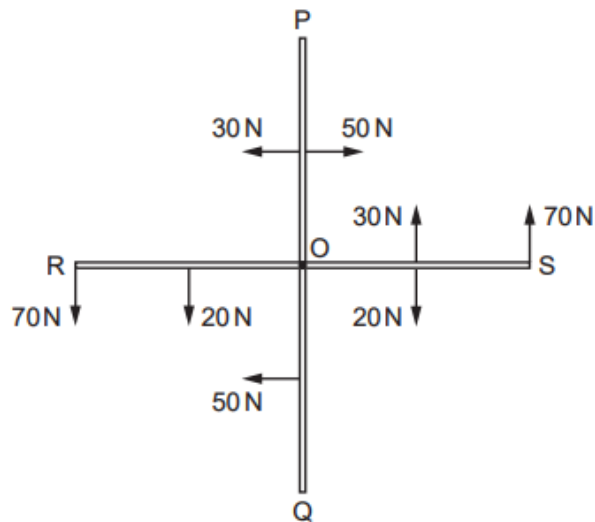
- A** 0.11      **B** 0.14      **C** 0.16      **D** 0.18
- 3 A value for the acceleration of free fall on Earth is given as  $(10 \pm 2) \text{ m s}^{-2}$ .
- Which statement is correct?
- A** The value is accurate but not precise.  
**B** The value is both precise and accurate.  
**C** The value is neither precise nor accurate.  
**D** The value is precise but not accurate.

- 4 The graph below represents the variation with time  $t$  of the acceleration  $a$  of a car starting from rest.



What is the total displacement of the car from the starting point at the end of 5 s?

- A -4 m                      B 4 m                      C 8 m                      D 12 m
- 5 A rigid cross-shaped structure having four arms PO, SO, QO and RO, each 1.80 m long, is pivoted at O. Forces act on the ends of the arms and on the midpoints of the arms as shown.



What is the net moment about O?

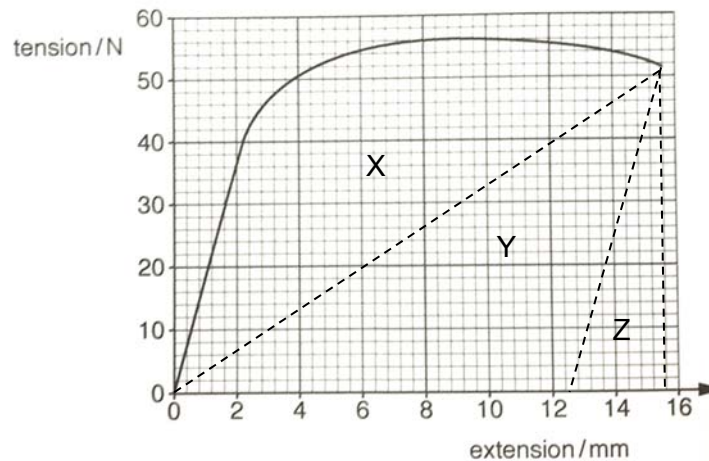
- A 54 N m                      B 108 N m                      C 216 N m                      D 432 N m
- 6 Forces 5 N, 12 N and 13 N act at a point which is in equilibrium.
- What is the angle between the 5 N and 13 N force?
- A  $23^\circ$                       B  $67^\circ$                       C  $90^\circ$                       D  $113^\circ$

- 7 A cube of sides 10 cm has a density of  $7.8 \text{ g cm}^{-3}$ . It floats vertically with one-eighth of its side exposed above the liquid surface.

What is the density of the liquid?

- A  $6.8 \text{ g cm}^{-3}$       B  $8.9 \text{ g cm}^{-3}$       C  $11.6 \text{ g cm}^{-3}$       D  $62.4 \text{ g cm}^{-3}$

- 8 The tension in a sample of wire varies with extension as shown in the diagram below.

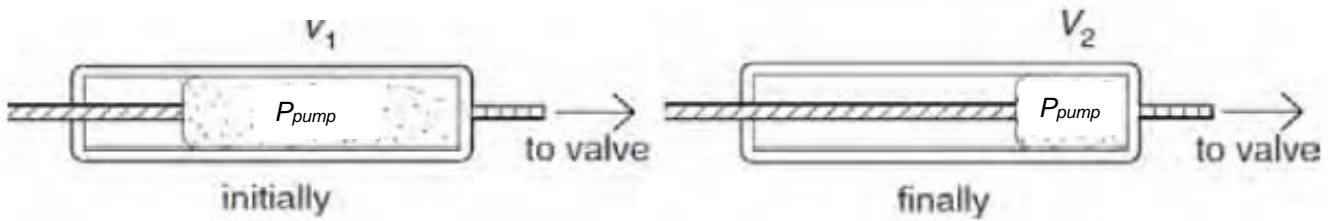


The graph shows that the wire undergoes two types of deformation as it is extended to 15.6 mm. In the region where Hooke's law applies, the deformation is elastic and the wire will lose this deformation when the tension is released. In the region where Hooke's law does not apply, the deformation is plastic and the wire retains this deformation when the tension is released.

Which area represents the elastic potential energy that is stored in the wire when it is extended to 15.6 mm?

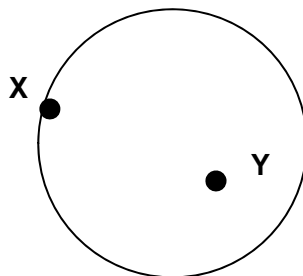
- A Area Z  
 B Area X + Area Y  
 C Area Y + Area Z  
 D Area X + Area Y + Area Z

- 9 Air in a bicycle pump is forced through a valve at a constant pressure  $P_{pump}$ , to supply air to a tyre which is initially at a pressure  $P_{tyre}$ . In one stroke of the pump, the volume of air in the pump chamber is reduced from  $V_1$  to  $V_2$ .



What is the work done on this air in one stroke of pump ?

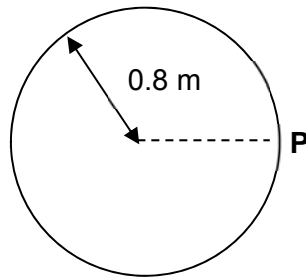
- A  $P_{pump} V_1$       B  $P_{pump} (V_2 - V_1)$       C  $P_{tyre} V_1$       D  $P_{tyre} (V_2 - V_1)$
- 10 Which one of the following statements is true about gravitational potential energy, electric potential energy and elastic potential energy?
- A Gravitational force and elastic force always points in the direction of decreasing potential energy but whether electric force will point towards increasing or decreasing potential energy depends on whether it is a positive or negative charge.
- B Zero gravitational potential energy and zero electric potential energy is the smallest possible potential energy in a given system of 2 masses and 2 negative charges respectively.
- C The magnitude of the potential energy can be found using the gradient of the force-displacement graph.
- D These potential energies are energies stored in the body due to its position or the arrangement of its component parts.
- 11 Sand is sprinkled on a turntable on points X and Y. The turntable is rotating with increasing speed.



Which one of the following comparing sand at points X and Y is true?

	angular speed	linear speed	which will fly off first?
A	$X = Y$	$X > Y$	X
B	$X = Y$	$X > Y$	Y
C	$X > Y$	$X = Y$	Y
D	$X > Y$	$X > Y$	Y

- 12 A model car moves in a circular path of radius 0.8 m at an angular speed of  $0.5\pi \text{ rad s}^{-1}$ .



What is its displacement from point P, 4 s after passing P?

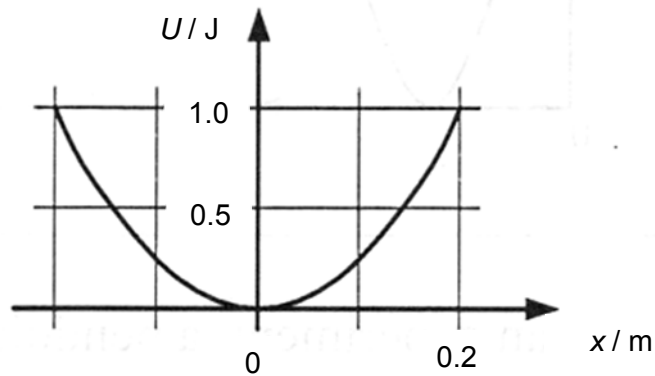
- A** zero      **B** 1.6 m      **C**  $0.8\pi \text{ m}$       **D**  $1.6\pi \text{ m}$
- 13 Which of the following is a correct description of a geostationary orbit?  
The mass of Earth is  $6.0 \times 10^{24} \text{ kg}$ .
- A** The moon is an example of a geostationary satellite of Earth.  
**B** A geostationary satellite has an orbital circumference of  $2.7 \times 10^8 \text{ m}$ .  
**C** A geostationary satellite moves from North pole to South pole then back to North pole in 24 hours.  
**D** A geostationary satellite experiences zero net force as it orbits around Earth.
- 14 Which of the following statements about the internal energy of a monatomic ideal gas is correct?
- A** It will increase when heat is supplied to the gas.  
**B** It is proportional to the root-mean-square speed of the gas.  
**C** It increases when the temperature of the gas increases.  
**D** It is dependent on the potential energy of the gas.
- 15 In a mixture of two monatomic ideal gaseous X and Y, the molecules of Y have thrice the mass of those of X. The mixture is in thermal equilibrium and the molecules of Y have a mean translational kinetic energy of  $E_K$ .

What is the mean translational kinetic energy of the molecules of X?

- A**  $\frac{1}{3} E_K$       **B**  $\frac{1}{2} E_K$       **C**  $E_K$       **D**  $3 E_K$

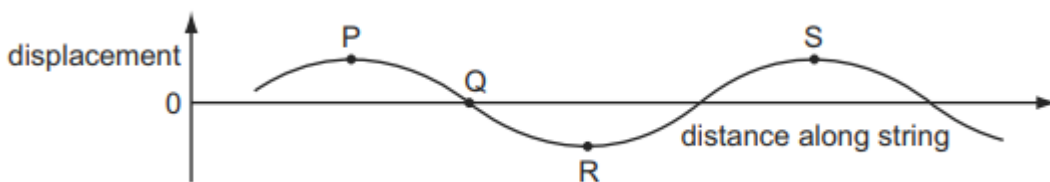


- 16 The given graph shows the variation with displacement  $x$  of the potential energy  $U$  of a particle of mass 4 kg moving in simple harmonic motion.



Which of the following is the period of oscillation of the mass?

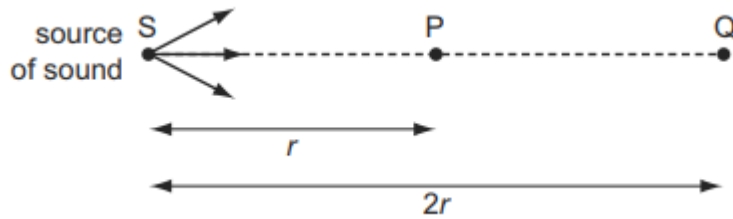
- A 0.3 s                      B 0.9 s                      C 1.1 s                      D 1.8 s
- 17 The string shows the shape at a particular instant of part of a progressive wave travelling along a string.



Which statement about the motion of the points along the string is correct?

- A The speed at point P is maximum.  
 B The displacement at point Q is always zero.  
 C The energy at point R is entirely kinetic.  
 D The acceleration at point S is maximum.

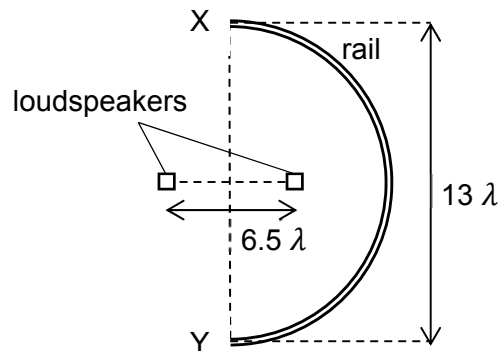
- 18 A point source of sound is placed at point S.



The air molecules at P, a distance  $r$  from S, oscillate with an amplitude of  $8.0 \mu\text{m}$ . Point Q is situated at a distance  $2r$  from S.

What is the amplitude of oscillation of air molecules at point Q?

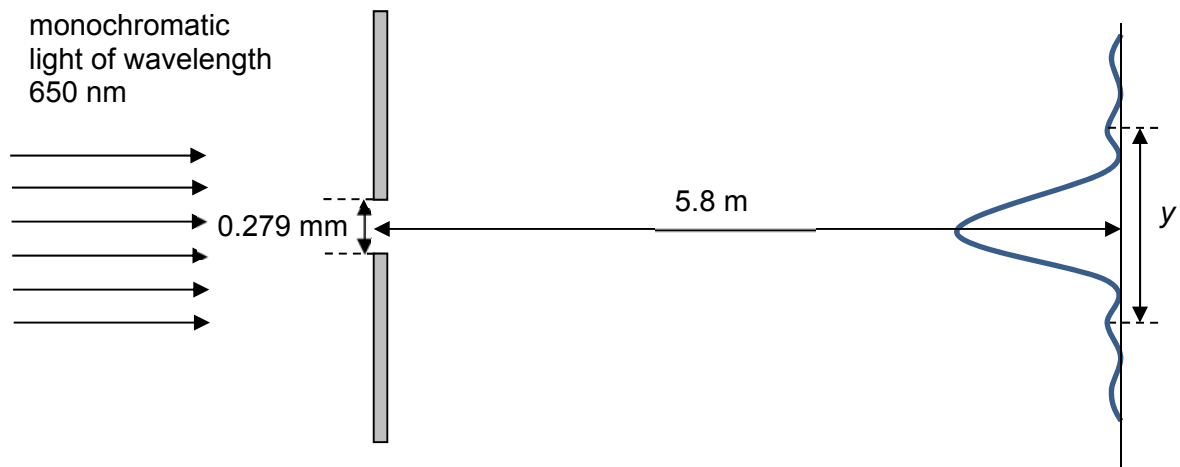
- A 1.4  $\mu\text{m}$       B 2.0  $\mu\text{m}$       C 2.8  $\mu\text{m}$       D 4.0  $\mu\text{m}$
- 19 Two loudspeakers are emitting sound of wavelength  $\lambda$  in all directions. They are in phase with each other and are placed a distance  $6.5 \lambda$  apart in the middle of a semicircular rail of diameter  $13 \lambda$ , as shown below. Moveable microphones along the rail are used to detect the sound intensity along the rail. The midpoint of the line joining the 2 speakers coincides with the centre of line XY.



How many minima will the microphones detect?

- A 7      B 12      C 13      D 14

- 20 A laser light of wavelength 650 nm is passed normally through a narrow slit. A screen is placed parallel to the slit 5.8 m away from the slit. An interference pattern is formed on the screen. The width of the slit is 0.279 mm. The distance  $y$  is the distance between the two first maximas.

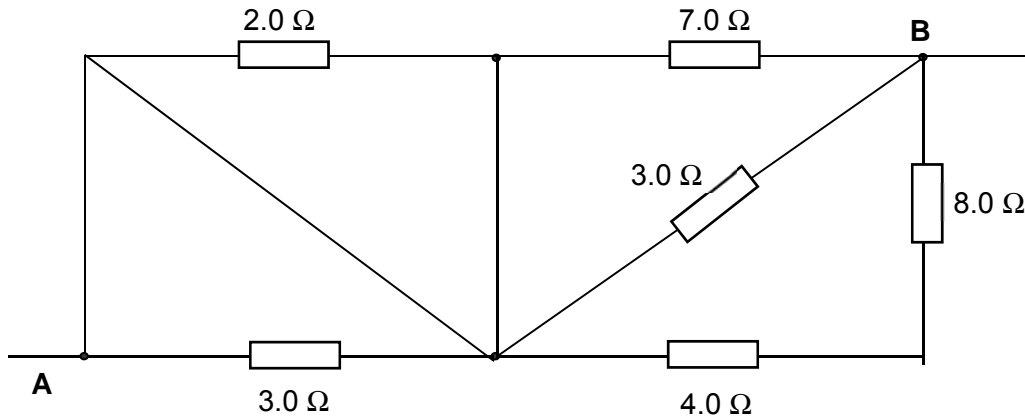


What is the value of  $y$ ?

- A** 13.5 mm      **B** 27.0 mm      **C** 40.5 mm      **D** 54.0 mm
- 21 A negatively-charged sphere P is balanced halfway between two horizontal plates when a potential difference  $V$  is applied between the plates.
- Which statement is correct?
- A** Increasing  $V$  increases both the electric and the gravitational potential energy of the sphere.
- B** Increasing  $V$  decreases the electric potential energy and increases the gravitational potential energy of the sphere.
- C** Decreasing  $V$  decreases both the electric and the gravitational potential energy of the sphere.
- D** Decreasing  $V$  increases both the electric and gravitational potential energy of the sphere.
- 22 A 8.0 A current passes through a cylindrical copper wire with a diameter of 8.0 mm. The density of copper is  $8960 \text{ kg m}^{-3}$  and the mass of a single copper atom is  $1 \times 10^{-25} \text{ kg}$ .
- Assuming that there is one conduction electron for each copper atom, what is the drift velocity of the electrons in the wire?

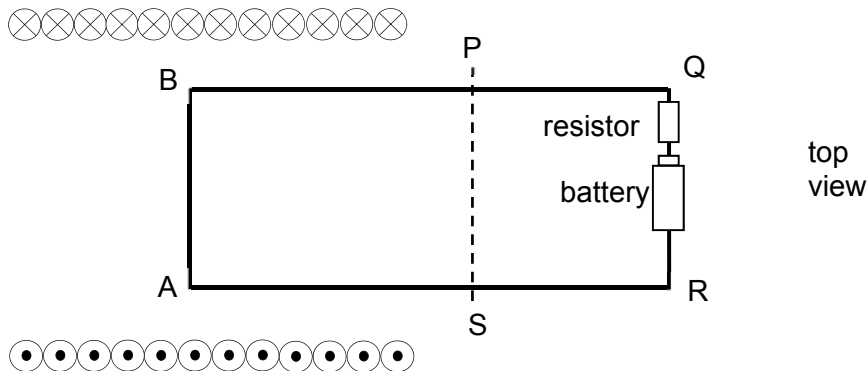
- A**  $2.8 \times 10^{-6} \text{ m s}^{-1}$       **B**  $3.4 \times 10^{-6} \text{ m s}^{-1}$       **C**  $1.1 \times 10^{-5} \text{ m s}^{-1}$       **D**  $5.8 \times 10^{-5} \text{ m s}^{-1}$

- 23 Six resistors are connected in a circuit as shown below.



What is the effective resistance of the circuit between terminals AB?

- A 1.2  $\Omega$                       B 1.8  $\Omega$                       C 3.0  $\Omega$                       D 3.4  $\Omega$
- 24 The figure below shows the top view of a current balance where the rigid rectangular wire loop ABQR pivoted at PS is in equilibrium. It is connected in series with an ideal 2.0 V battery and a 0.025  $\Omega$  resistor of a total mass of 300 g. Part of the wire loop is placed inside a solenoid. The mass of the loop can be taken to be negligible and the wire has no resistance.



The length of the side AB is 6.0 cm and  $SR = \frac{2}{5} BR$ .

What is the magnitude of the magnetic flux density in the solenoid?

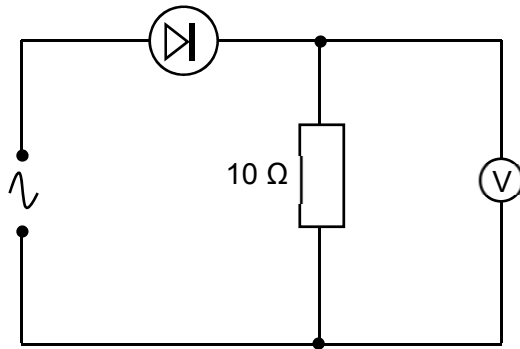
- A 0.37 T                      B 0.41 T                      C 3.7 T                      D 4.1 T

- 25 When a light bulb is connected across an a.c. source of peak voltage 150 V, the mean power dissipated is 13 W. Two such light bulbs are now connected in series to the electrical mains of 240 V r.m.s.

What is the peak voltage across each light bulb and the total power dissipated in the light bulbs?

	peak voltage across each light bulb / V	total power dissipated in the light bulbs / W
<b>A</b>	120	17
<b>B</b>	170	33
<b>C</b>	120	67
<b>D</b>	170	17

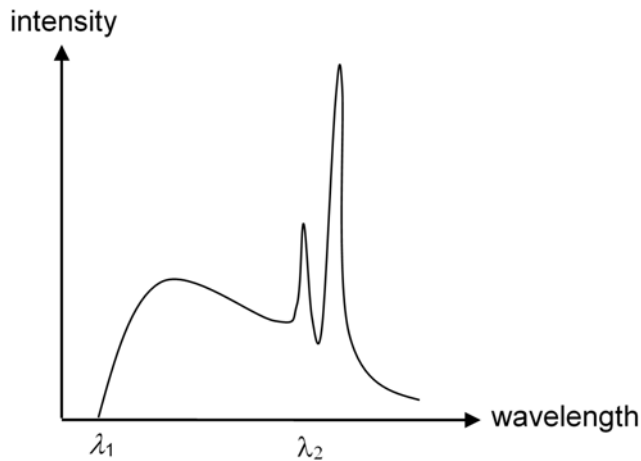
- 26 A voltmeter reads 80 V when measuring the potential difference across a load of  $10\ \Omega$  connected to a sinusoidal power source with frequency 888 Hz.



What is the peak power dissipated by the load when the frequency is  $1/3$  of its original?

- A** 640 W      **B** 850 W      **C** 1280 W      **D** 2560 W

- 27 The graph below shows the variation of X-ray intensity with wavelength emitted from an X-ray tube.



What are the factors that will affect  $\lambda_1$  and  $\lambda_2$ ?

	$\lambda_1$	$\lambda_2$
<b>A</b>	target metal	target metal
<b>B</b>	target metal	accelerating voltage
<b>C</b>	accelerating voltage	target metal
<b>D</b>	accelerating voltage	accelerating voltage

- 28 The momentum of an alpha particle is measured with an uncertainty of 2.0%.

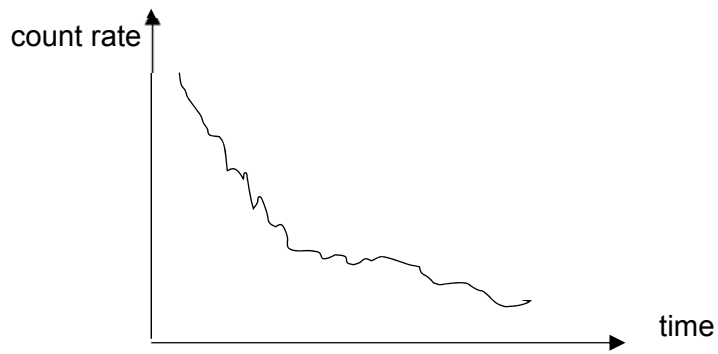
Given that it has a kinetic energy of 1.00 MeV, what is the minimum uncertainty in its position?

- A**  $2.1 \times 10^{-19}$  m    **B**  $7.2 \times 10^{-13}$     **C**  $1.6 \times 10^{-12}$     **D**  $7.2 \times 10^{-10}$

- 29 Which of the following is a correct description of mass defect?

- A** The difference between the mass of the nucleus of the products and reactants in a nuclear reaction.
- B** It is the difference between the total mass of the neutrons and the mass of the nucleus.
- C** It is equal to the energy gained when individual nucleons comes together to form a nucleus.
- D** It is the binding energy of a nucleus divided by square of the speed of light.

- 30 The graph below shows the variation of count rate from a particular radioactive sample with time.



What does the jagged feature of the graph indicate?

- A It indicates the presence of background radiation.
- B It indicates that the decay obeys radioactive decay law.
- C It indicates the spontaneous nature of the radioactive decay.
- D It indicates the random nature of the radioactive decay.

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**Higher 2**

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**SOLUTIONS**

**PHYSICS**

**9749/01**

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velocity of particle in s.h.m.

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electric current

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resistors in series

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decay constant

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## Answer all questions.

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$$R = k A \frac{(T_2 - T_1)}{L}$$

where  $k$  is the thermal conductivity,  $A$  is the total cross sectional area of the conducting surface, and  $L$  is the thickness of conducting surface separating the 2 temperatures  $T_1$  and  $T_2$ .

What is the SI base units for  $k$ ?

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<p style="text-align: center;"><math>[k] = \left[ \frac{R L}{A (T_2 - T_1)} \right]</math></p> <p><b>Ans: A</b></p> $= \frac{\text{W m}}{\text{m}^2 \text{K}}$ $= \text{W m}^{-1} \text{K}^{-1} = \text{J s}^{-1} \text{m}^{-1} \text{K}^{-1} = \text{kg m s}^{-3} \text{K}^{-1}$
---

- 2 With reference to Question 1, a student collected the following measurements to determine the rate of heat flow  $R$  of the object

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What is the fractional uncertainty in  $R$ ?

- A 0.11      B 0.14      C 0.16      D 0.18

<p><b>Ans: D</b></p> $\frac{\Delta R}{R} = \frac{\Delta L}{L} + \left  \frac{\Delta(T_2 - T_1)}{(T_2 - T_1)} \right $ $= \frac{0.05}{0.35} + \left  \frac{\Delta T_2 + \Delta T_1}{(T_2 - T_1)} \right $ $= \frac{0.05}{0.35} + \left  \frac{0.5 + 0.5}{(4.0 - 32.0)} \right  = 0.18$
---

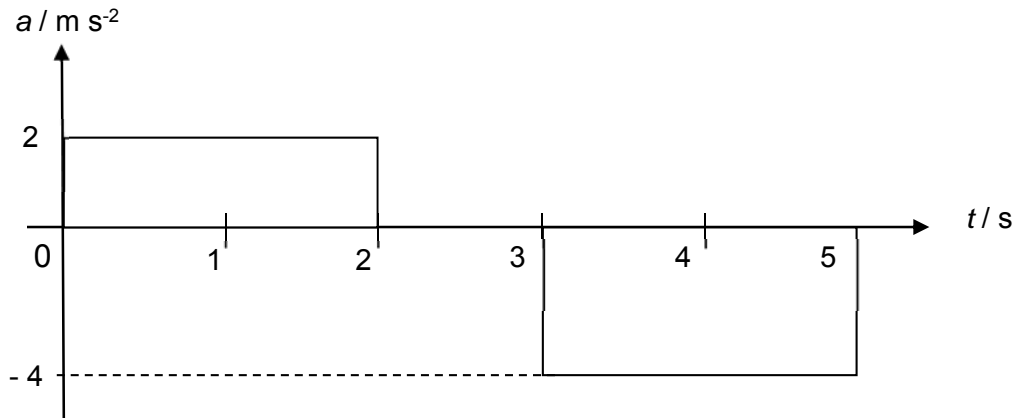
- 3 A value for the acceleration of free fall on Earth is given as  $(10 \pm 2) \text{ m s}^{-2}$ .

Which statement is correct?

- A The value is accurate but not precise.  
 B The value is both precise and accurate.  
 C The value is neither precise nor accurate.  
 D The value is precise but not accurate.

<b>Ans: A</b> value is not precise but still accurate to 1 sf
---

- 4 The graph below represents the variation with time  $t$  of the acceleration  $a$  of a car starting from rest.

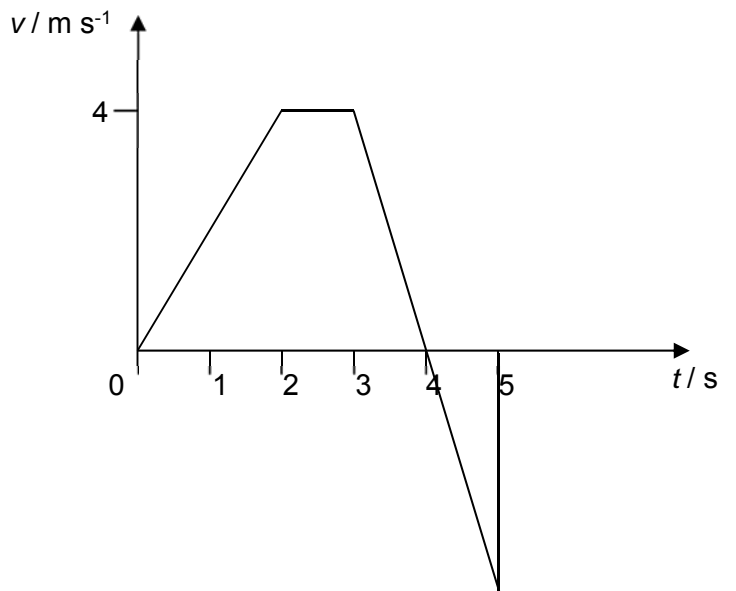


What is the total displacement of the car from the starting point at the end of 5 s?

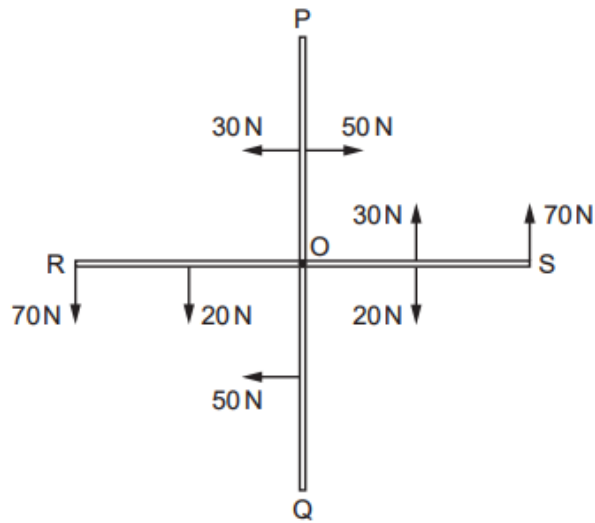
- A** -4 m                      **B** 4 m                      **C** 8 m                      **D** 12 m

**Ans: C**

change in displacement  
 = Area under the v-t graph  
 =  $\frac{1}{2}(1+4)(4) - \frac{1}{2}(1)(4)$   
 = 8 m



- 5 A rigid cross-shaped structure having four arms PO, SO, QO and RO, each 1.80 m long, is pivoted at O. Forces act on the ends of the arms and on the midpoints of the arms as shown.



What is the net moment about O?

- A 54 N m      B 108 N m      C 216 N m      D 432 N m

**Ans: C**

$$\text{sacw} = (20+30+30) \times 0.9 + (70+70) \times 1.8 = 324 \text{ N m}$$

$$\text{scw} = (20+50+50) \times 0.9 = 108 \text{ N m}$$

$$\text{Net moments} = 216 \text{ N m}$$

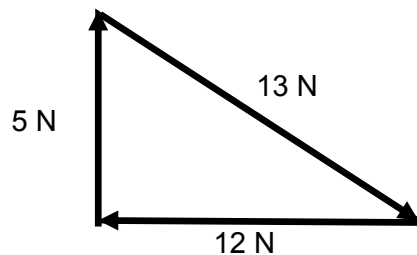
- 6 Forces 5 N, 12 N and 13 N act at a point which is in equilibrium.

What is the angle between the 5 N and 13 N force?

- A  $23^\circ$       B  $67^\circ$       C  $90^\circ$       D  $113^\circ$

**Ans: D**

$$\begin{aligned} \text{Angle} &= 180 - \tan^{-1}(12/5) \\ &= 180 - 67 \\ &= 113 \end{aligned}$$



- 7 A cube of sides 10 cm has a density of  $7.8 \text{ g cm}^{-3}$ . It floats vertically with one-eighth of its side exposed above the liquid surface.

What is the density of the liquid?

- A  $6.8 \text{ g cm}^{-3}$       B  $8.9 \text{ g cm}^{-3}$       C  $11.6 \text{ g cm}^{-3}$       D  $62.4 \text{ g cm}^{-3}$

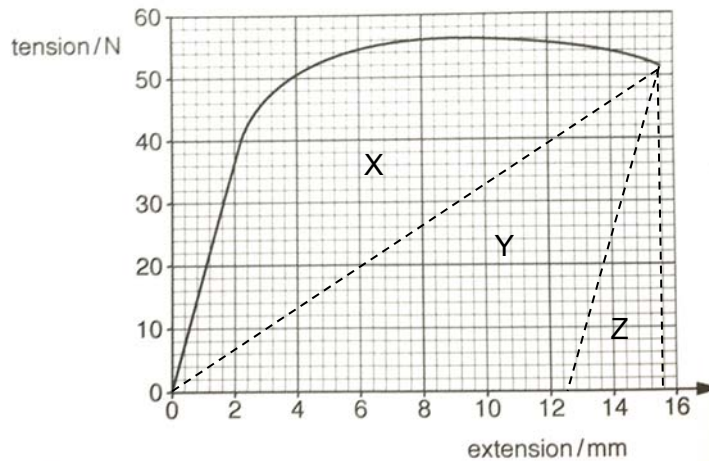
**Ans: B**

As object is floating, Weight of object = Upthrust

$$\rho_b V_b g = \rho_l V_{\text{submerged}} g$$

$$\rho_l = \frac{\rho_b V_b}{V_{\text{submerged}}} = \frac{(7.8)(l^3)}{\left(l^2 \times \frac{7}{8}l\right)} = 8.9 \text{ g cm}^{-3}$$

- 8 The tension in a sample of wire varies with extension as shown in the diagram below.



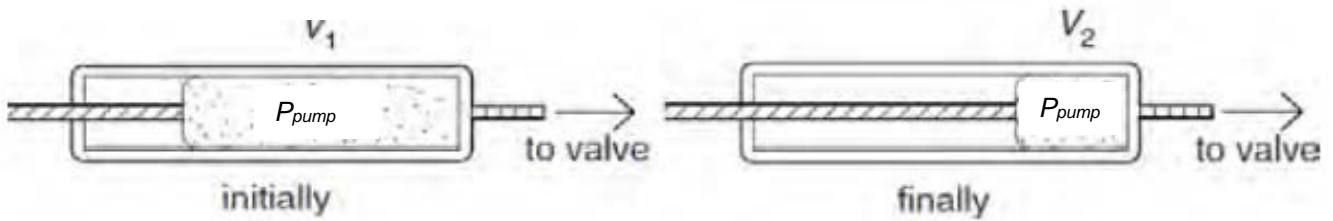
The graph shows that the wire undergoes two types of deformation as it is extended to 15.6 mm. In the region where Hooke's law applies, the deformation is elastic and the wire will lose this deformation when the tension is released. In the region where Hooke's law does not apply, the deformation is plastic and the wire retains this deformation when the tension is released.

Which area represents the elastic potential energy that is stored in the wire when it is extended to 15.6 mm?

- A Area Z  
 B Area X + Area Y  
 C Area Y + Area Z  
 D Area X + Area Y + Area Z

**Ans : A**

- 9 Air in a bicycle pump is forced through a valve at a constant pressure  $P_{pump}$ , to supply air to a tyre which is initially at a pressure  $P_{tyre}$ . In one stroke of the pump, the volume of air in the pump chamber is reduced from  $V_1$  to  $V_2$ .



What is the work done on this air in one stroke of pump ?

- A  $P_{pump} V_1$   
 B  $P_{pump} (V_2 - V_1)$   
 C  $P_{tyre} V_1$   
 D  $P_{tyre} (V_2 - V_1)$

Ans : B

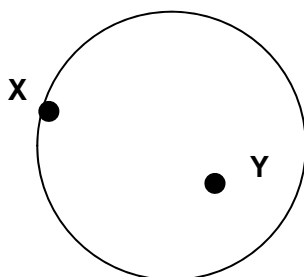
- 10 Which one of the following statements is true about gravitational potential energy, electric potential energy and elastic potential energy?

- A Gravitational force and elastic force always points in the direction of decreasing potential energy but whether electric force will point towards increasing or decreasing potential energy depends on whether it is a positive or negative charge.  
 B Zero gravitational potential energy and zero electric potential energy is the smallest possible potential energy in a given system of 2 masses and 2 negative charges respectively.  
 C The magnitude of the potential energy can be found using the gradient of the force-displacement graph.  
 D These potential energies are energies stored in the body due to its position or the arrangement of its component parts.

Ans : D  
 By definition of potential energy.



- 11 Sand is sprinkled on a turntable on points X and Y. The turntable is rotating with increasing speed.



Which one of the following comparing sand at points X and Y is true?

	angular speed	linear speed	which will fly off first?
<b>A</b>	$X = Y$	$X > Y$	X
<b>B</b>	$X = Y$	$X > Y$	Y
<b>C</b>	$X > Y$	$X = Y$	Y
<b>D</b>	$X > Y$	$X > Y$	Y

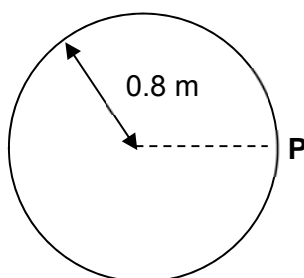
**Ans: A**

$\omega$  on the same turntable is the same for both points.

$v = r\omega$ , since  $r_x > r_y$ , therefore  $v_x > v_y$

Centripetal force  $F = mr\omega^2$  required for Sand at X is higher, so the sand at X will have a tendency to fly off 1<sup>st</sup> as the frictional force is unable to provide the higher centripetal force.

- 12 A model car moves in a circular path of radius 0.8 m at an angular speed of  $0.5\pi \text{ rad s}^{-1}$ .



What is its displacement from point P, 4 s after passing P?

- A** zero      **B** 1.6 m      **C**  $0.8\pi \text{ m}$       **D**  $1.6\pi \text{ m}$

**Ans: A**

$v = r\omega = 0.8 \times \pi/2 = 0.4\pi$ ,

$s = vt = 0.4\pi \times 4 = 1.6\pi$

Circumference of circle =  $2\pi(0.8) = 1.6\pi$

Therefore, displacement = 0

13 Which of the following is a correct description of a geostationary orbit?

The mass of Earth is  $6.0 \times 10^{24}$  kg.

- A The moon is an example of a geostationary satellite of Earth.
- B A geostationary satellite has an orbital circumference of  $2.7 \times 10^8$  m.
- C A geostationary satellite moves from North pole to South pole then back to North pole in 24 hours.
- D A geostationary satellite experiences zero net force as it orbits around Earth.

**Ans: B**

14 Which of the following statements about the internal energy of a monatomic ideal gas is correct?

- A It will increase when heat is supplied to the gas.
- B It is proportional to the root-mean-square speed of the gas.
- C It increases when the temperature of the gas increases.
- D It is dependent on the potential energy of the gas.

**Ans: C**

Since for an ideal gas, internal energy is purely kinetic energy, internal energy is proportional to the temperature of the gas.

15 In a mixture of two monatomic ideal gaseous X and Y, the molecules of Y have thrice the mass of those of X. The mixture is in thermal equilibrium and the molecules of Y have a mean translational kinetic energy of  $E_K$ .

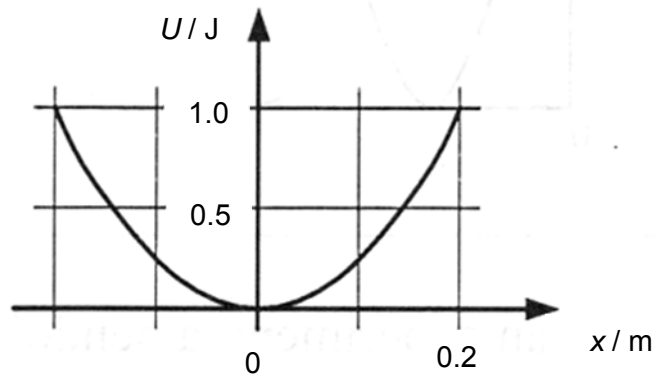
What is the mean translational kinetic energy of the molecules of X?

- A  $1/3 E_K$
- B  $1/2 E_K$
- C  $E_K$
- D  $3 E_K$

$T_X = T_Y$   
 $\langle KE \rangle_X = \langle KE \rangle_Y$   
 since  $T \propto \langle KE \rangle$

**Ans: C**

- 16 The given graph shows the variation with displacement  $x$  of the potential energy  $U$  of a particle of mass 4 kg moving in simple harmonic motion.



Which of the following is the period of oscillation of the mass?

- A 0.3 s                      B 0.9 s                      C 1.1 s                      D 1.8 s

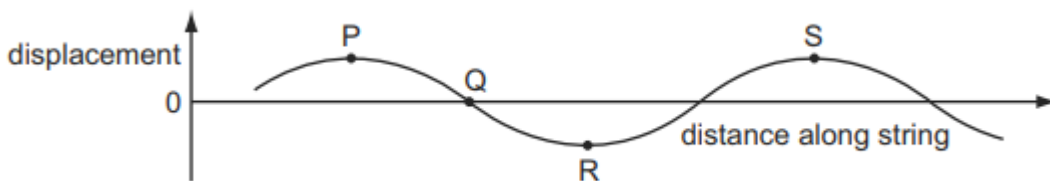
$$TE = KE_{\max} = \frac{1}{2}mv_o^2 = \frac{1}{2}m(\omega x_o)^2 = \frac{1}{2}m\frac{4\pi^2}{T^2}x_o^2$$

$$1 = \frac{1}{2}(4)\frac{4\pi^2}{T^2}(0.2)^2$$

$$T = \frac{2\pi\sqrt{2}}{5} \text{ s}$$

**Ans: D**

- 17 The string shows the shape at a particular instant of part of a progressive wave travelling along a string.



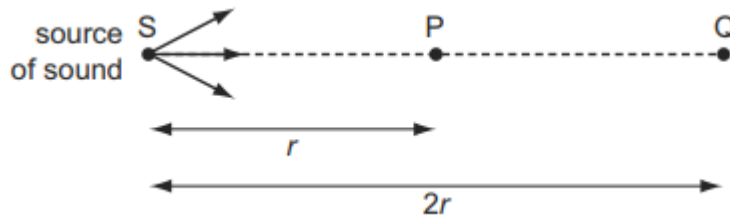
Which statement about the motion of the points along the string is correct?

- A The speed at point P is maximum.  
 B The displacement at point Q is always zero.  
 C The energy at point R is entirely kinetic.  
 D The acceleration at point S is maximum.

**Ans: D**

At Point S, the displacement of the particle is maximum. Hence, by using  $a = -\omega^2x$ , the acceleration will also be at a maximum.

- 18 A point source of sound is placed at point S.



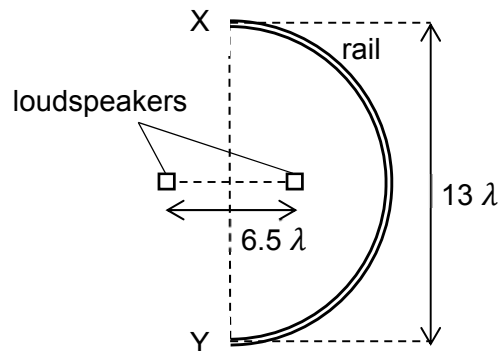
**Ans: D**

Amplitude is inversely proportional to the distance from the source.

The air molecules at P, a distance  $r$  from S, oscillate with an amplitude of  $8.0 \mu\text{m}$ . Point Q is situated at a distance  $2r$  from S.

What is the amplitude of oscillation of air molecules at point Q?

- A**  $1.4 \mu\text{m}$       **B**  $2.0 \mu\text{m}$       **C**  $2.8 \mu\text{m}$       **D**  $4.0 \mu\text{m}$
- 19 Two loudspeakers are emitting sound of wavelength  $\lambda$  in all directions. They are in phase with each other and are placed a distance  $6.5 \lambda$  apart in the middle of a semicircular rail of diameter  $13 \lambda$ , as shown below. Moveable microphones along the rail are used to detect the sound intensity along the rail. The midpoint of the line joining the 2 speakers coincides with the centre of line XY.



How many minima will the microphones detect?

- A** 7      **B** 12      **C** 13      **D** 14

**Ans : C**

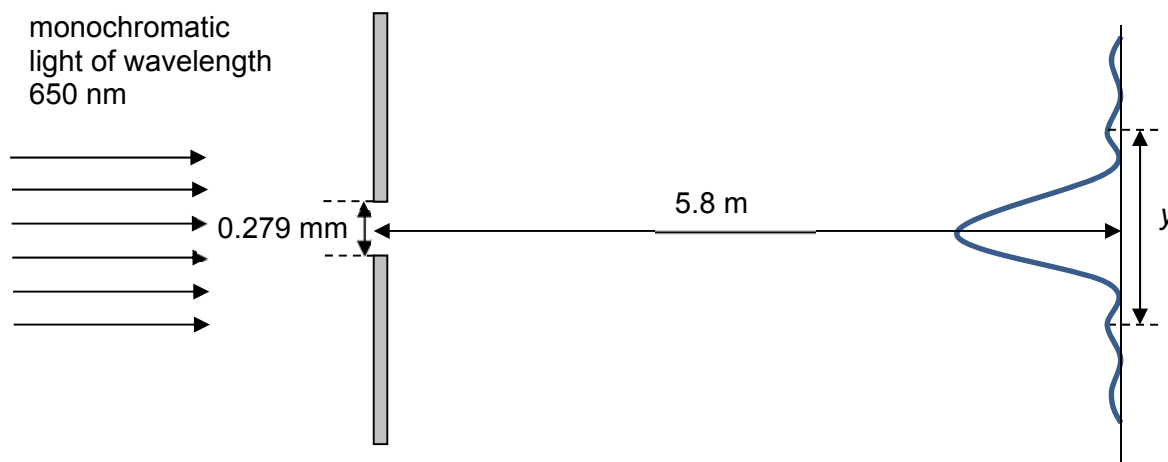
At the centre of the rail, the path difference is  $6.5 \lambda$ .

At the start and end of the rail, the path difference is  $0 \lambda$ .

Hence, the magnitude of path difference increases from 0 to  $6.5 \lambda$  and then decreases to 0

Since waves are in phase, minima will be detected at locations where path differences are  $(n+1/2)\lambda$  and this occurs at path differences =  $0.5 \lambda$ ,  $1.5 \lambda$ ,  $2.5 \lambda$ ,  $3.5 \lambda$ ,  $4.5 \lambda$ ,  $5.5 \lambda$ ,  $6.5 \lambda$ .

- 20 A laser light of wavelength 650 nm is passed normally through a narrow slit. A screen is placed parallel to the slit 5.8 m away from the slit. An interference pattern is formed on the screen. The width of the slit is 0.279 mm. The distance  $y$  is the distance between the two first maximas.



What is the value of  $y$ ?

- A 13.5 mm      B 27.0 mm      C 40.5 mm      D 54.0 mm

**Ans: C**

Since  $\sin\theta = \lambda/b$

$\theta = 0.1333^\circ$

Distance from central maxima to first minima = 13.5 mm

$y = 27 + 13.5 = 40.5$  mm

(since width of subsequent maxima is half the width of central maxima)

- 21 A negatively-charged sphere P is balanced halfway between two horizontal plates when a potential difference  $V$  is applied between the plates.

Which statement is correct?

- A Increasing  $V$  increases both the electric and the gravitational potential energy of the sphere.
- B Increasing  $V$  decreases the electric potential energy and increases the gravitational potential energy of the sphere.
- C Decreasing  $V$  decreases both the electric and the gravitational potential energy of the sphere.
- D Decreasing  $V$  increases both the electric and gravitational potential energy of the sphere.

**Ans: B**

When the potential difference is increased, the sphere will experience a greater upward electric force. Therefore, the electric force is bigger than the weight of the sphere. Net force will be upwards and hence sphere will accelerate upwards, and thus experiencing a decreasing EPE and increasing GPE.

(Answer will be the same even when the sphere is positive charged)

- 22 A 8.0 A current passes through a cylindrical copper wire with a diameter of 8.0 mm. The density of copper is  $8960 \text{ kg m}^{-3}$  and the mass of a single copper atom is  $1 \times 10^{-25} \text{ kg}$ .

Assuming that there is one conduction electron for each copper atom, what is the drift velocity of the electrons in the wire?

- A  $2.8 \times 10^{-6} \text{ m s}^{-1}$    B  $3.4 \times 10^{-6} \text{ m s}^{-1}$    C  $1.1 \times 10^{-5} \text{ m s}^{-1}$    D  $5.8 \times 10^{-5} \text{ m s}^{-1}$

**Ans: C**

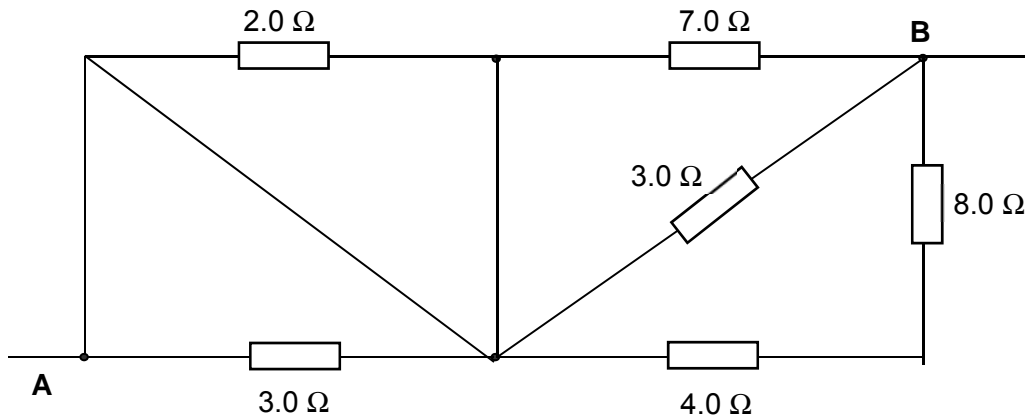
$$I = nAvq$$

$$v = \frac{I}{nAq} = \frac{8.0}{8960 / (1 \times 10^{-25}) \times \pi (4.0 \times 10^{-3})^2 \times 1.6 \times 10^{-19}} = 1.1 \times 10^{-5} \text{ m s}^{-1}$$

Distractors:

$2.8 \times 10^{-6}$ : Never convert diameter to radius.

- 23 Six resistors are connected in a circuit as shown below.



What is the effective resistance of the circuit between terminals AB?

- A 1.2 Ω   B 1.8 Ω   C 3.0 Ω   D 3.4 Ω

**Ans: B**

Distractors:

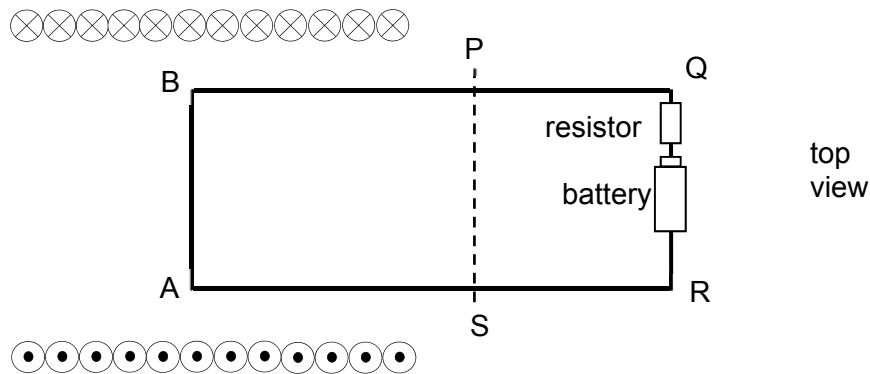
A:  $7 // 3 // 8 // 4$

Options C and D both consider the 2.0 and 3.0 resistor.

C:  $2 // 3 + 7 // 3 // 12$

D:  $9 // [3 + 3 // (8 \text{ and } 4)]$

- 24 The figure below shows the top view of a current balance where the rigid rectangular wire loop ABQR pivoted at PS is in equilibrium. It is connected in series with an ideal 2.0 V battery and a  $0.025 \Omega$  resistor of a total mass of 300 g. Part of the wire loop is placed inside a solenoid. The mass of the loop can be taken to be negligible and the wire has no resistance.



The length of the side AB is 6.0 cm and  $SR = \frac{2}{5} AS$ .

What is the magnitude of the magnetic flux density in the solenoid?

- A** 0.37 T      **B** 0.41 T      **C** 3.7 T      **D** 4.1 T

**Ans: B**

By principle of moments,

$$F_B \times AS = mg \times SR$$

$$B \times \frac{2}{0.025} \times 0.060 \times 3L = 0.300 \times 9.81 \times 2L$$

$$B = 0.41 \text{ T}$$

Distractors:

Never convert units – 4.1 T

Use wrong distance –  $AS = 5L$  and  $SR = 3L$  – 0.37 T

Use wrong distance and never convert units = 3.7 T

- 25 When a light bulb is connected across an a.c. source of peak voltage 150 V, the mean power dissipated is 13 W. Two such light bulbs are now connected in series to the electrical mains of 240 V r.m.s.

What is the peak voltage across each light bulb and the total power dissipated in the light bulbs?

	peak voltage across each light bulb / V	total power dissipated in the light bulbs / W
<b>A</b>	120	17
<b>B</b>	170	33
<b>C</b>	120	67
<b>D</b>	170	17

**Ans: B**

$$V_{rms} = \frac{150}{\sqrt{2}}$$

$$P = \frac{V_{rms}^2}{R} \Rightarrow R = 865\Omega$$

$$R_{total} = 865 \times 2$$

$$P_{total} = \frac{240^2}{865 \times 2} = 33$$

$$V_0 \text{ across each bulb} = 120\sqrt{2} = 170$$

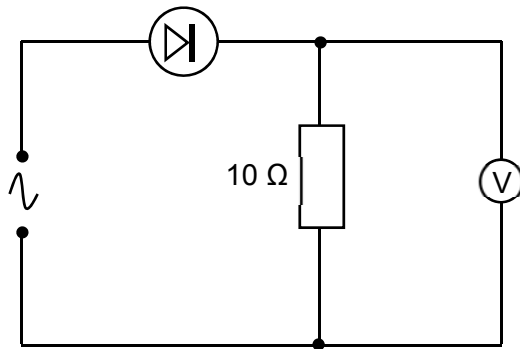
Distractors:

For 17 W, take peak voltage as  $V_{r.m.s.}$

For 67 W, assume only one bulb connected to 240 V rms source.



- 26 A voltmeter reads 80 V when measuring the potential difference across a load of  $10\ \Omega$  connected to a sinusoidal power source with frequency 888 Hz.



What is the peak power dissipated by the load when the frequency is  $1/3$  of its original?

- A 640 W                      B 850 W                      C 1280 W                      D 2560 W

**Ans: D**

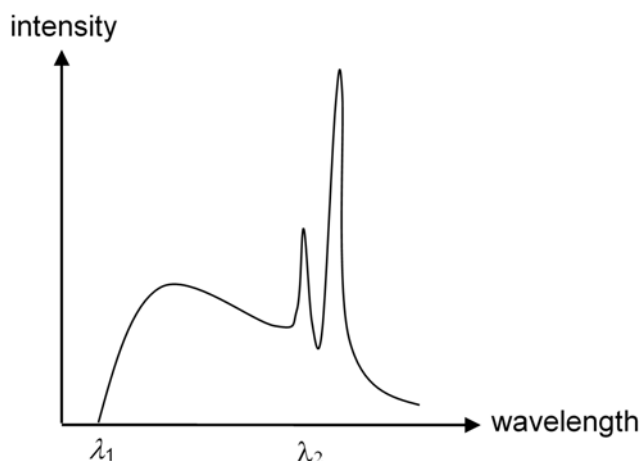
$$(V_{rms} \times 2)^2 / R = (80 \times 2)^2 / 10 = 2560$$

A:  $V_{rms}^2 / R$

B:  $(V_{rms} \times 2)^2 / 3R$

C:  $(V_{rms} \sqrt{2})^2 / R$

- 27 The graph below shows the variation of X-ray intensity with wavelength emitted from an X-ray tube.



What are the factors that will affect  $\lambda_1$  and  $\lambda_2$ ?

	$\lambda_1$	$\lambda_2$
<b>A</b>	target metal	target metal
<b>B</b>	target metal	accelerating voltage
<b>C</b>	accelerating voltage	target metal
<b>D</b>	accelerating voltage	accelerating voltage

**Ans: C**

- 28 The momentum of an alpha particle is measured with an uncertainty of 2.0%.

Given that it has a kinetic energy of 1.00 MeV, what is the minimum uncertainty in its position?

- A**  $2.1 \times 10^{-19}$  m    **B**  $7.2 \times 10^{-13}$     **C**  $1.6 \times 10^{-12}$     **D**  $7.2 \times 10^{-10}$

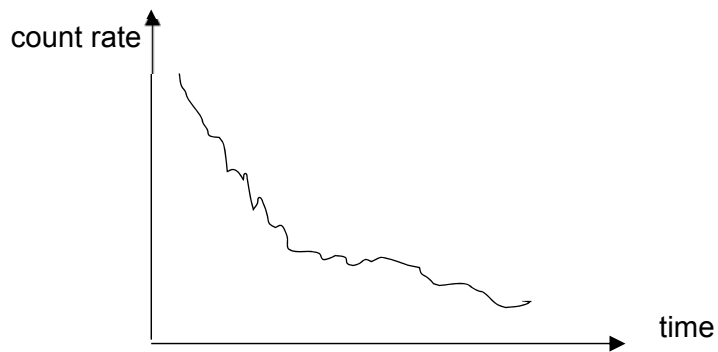
**Ans: B**

- 29 Which of the following is a correct description of mass defect?

- A** The difference between the mass of the nucleus of the products and reactants in a nuclear reaction.
- B** It is the difference between the total mass of the neutrons and the mass of the nucleus.
- C** It is equal to the energy gained when individual nucleons comes together to form a nucleus.
- D** It is the binding energy of a nucleus divided by square of the speed of light.

**Ans: D**

- 30 The graph below shows the variation of count rate from a particular radioactive sample with time.



What does the jagged feature of the graph indicate?

- A It indicates the presence of background radiation.
- B It indicates that the decay obeys radioactive decay law.
- C It indicates the spontaneous nature of the radioactive decay.
- D It indicates the random nature of the radioactive decay.

**Ans: D**



**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 2**

NAME

CG

INDEX NO.

**PHYSICS**

**9749/02**

**Preliminary Examination**  
**Paper 2 Structured Questions**

**14<sup>th</sup> September 2018**  
**2 hours**

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

**READ THIS INSTRUCTIONS FIRST**

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.  
You may use HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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

<b>For Examiners' Use</b>	
<b>Q1</b>	/ 10
<b>Q2</b>	/ 7
<b>Q3</b>	/ 14
<b>Q4</b>	/ 8
<b>Q5</b>	/ 8
<b>Q6</b>	/ 14
<b>Q7</b>	/ 19
<b>Total marks</b>	/ 80

## DATA AND FORMULAE

## Data

speed of light in free space	$c$	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0$	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0$	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$ $= \frac{1}{36\pi} \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e$	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h$	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u$	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e$	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R$	$= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k$	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G$	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g$	$= 9.81 \text{ m s}^{-2}$

## DATA AND FORMULAE

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2} at^2$$

work done on/by a gas

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

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -\frac{GM}{r}$$

temperature

$$T / K = T / ^\circ C + 273.15$$

pressure of an ideal gas

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

mean translational kinetic energy of an ideal gas molecule

$$E = \frac{3}{2} kT$$

displacement of particle in s.h.m.

$$x = x_0 \sin \omega t$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

electric current

$$I = Anqv$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r^2}$$

alternating current/ voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

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

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

1 A raindrop falls vertically from rest.

(a) Assume that air resistance is negligible.

On Fig. 1.1, sketch a graph to show the variation with time  $t$  of the velocity  $v$  of the raindrop for the first 1.0 s of the motion. [1]

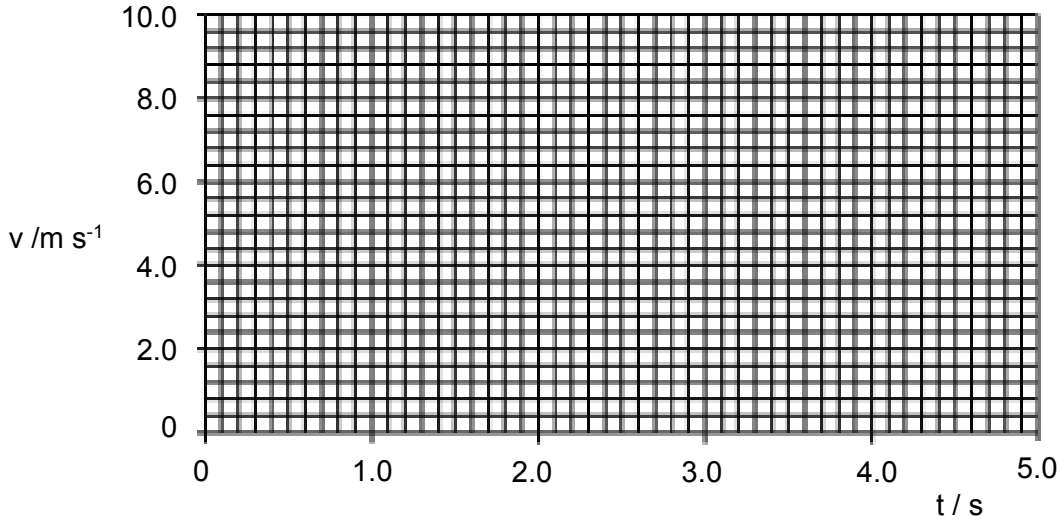


Fig. 1.1

(b) In practice, air resistance  $D$  on the raindrop is not negligible.

$D$  is given by the expression

$$D = k v^2$$

where  $k$  is a constant and  $v$  is the speed.

(i) The raindrop has mass  $1.38 \times 10^{-5}$  kg and  $k$  is  $2.76 \times 10^{-6}$  N m<sup>-2</sup> s<sup>2</sup>.

Calculate the terminal velocity of the raindrop.

terminal velocity = ..... m s<sup>-1</sup> [2]

(ii) The raindrop reaches terminal velocity at  $t = 3.0$  s.

On Fig. 1.1, sketch the variation with time  $t$  of velocity  $v$  for the raindrop. The sketch should include the first 5.0 seconds of the motion. [2]

- (c) A raindrop falls on a roof and rebounds off with a velocity of  $5.5 \text{ m s}^{-1}$  at an angle  $60^\circ$  with respect to the horizontal as shown in Fig. 1.2.

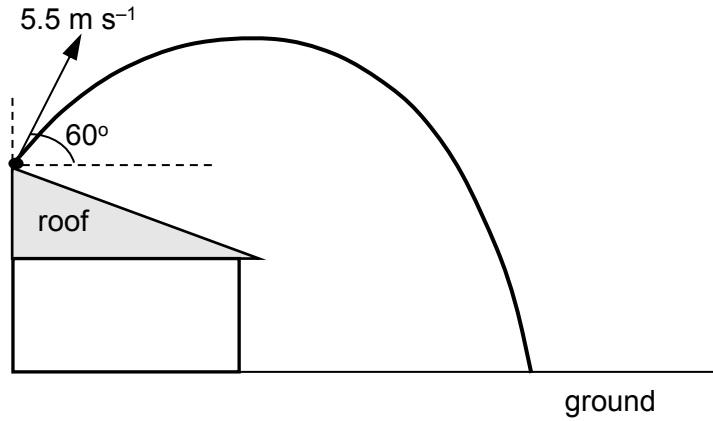


Fig. 1.2

Assume air resistance is negligible. The maximum horizontal distance travelled by the raindrop is 3.8 m.

- (i) Calculate the time taken for the raindrop to hit the ground.

time = ..... s [1]

- (ii) Determine the speed of the raindrop as it hits the ground.

speed = .....  $\text{m s}^{-1}$  [2]

- (iii) Discuss quantitatively whether the assumption that air resistance is negligible is justified by considering the vertical component of the initial velocity of the raindrop.

The raindrop has the same mass and dimension as in (b)(i).

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



- 2 A uniform rectangular card is suspended from a wooden rod. The card is held at one of its ends as shown in Fig. 2.1. The force by the hand on the card acts horizontally to the right.

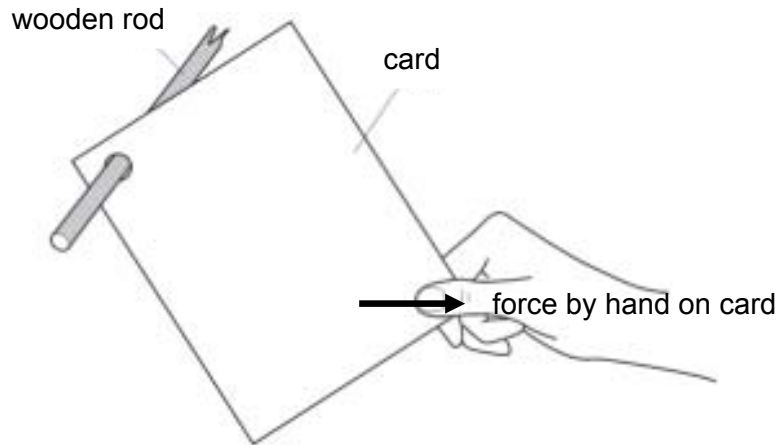


Fig. 2.1

- (a) On Fig. 2.1,

(i) mark with an 'X' the position of the centre of gravity of the card. [1]

(ii) draw an arrow labelled with  $W$  to represent the weight of the card. [1]

- (b) State the conditions for the card to be in equilibrium.

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

- (c) Draw an arrow labelled with  $R$  on Fig. 2.1 to represent the force exerted by the wooden rod on the card.

Show your construction clearly. [2]

- (d) The card is now released. It swings on the wooden rod and eventually comes to a rest.

By reference to the completed diagram in Fig. 2.1, describe the final position in which the card comes to a rest.

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

- 3 (a) An object is placed on a smooth horizontal surface and is connected to a light spring, as shown in Fig. 3.1.

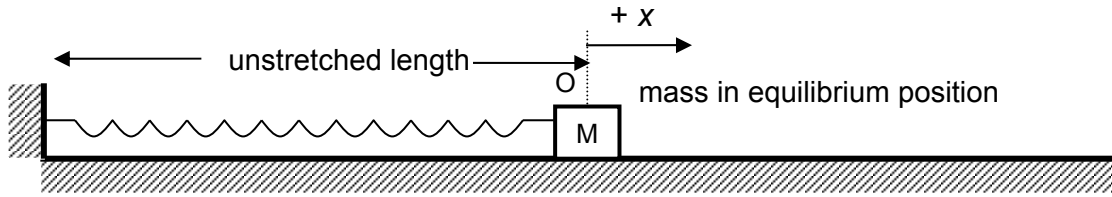


Fig. 3.1

The object is displaced to the right by 0.60 m and then released. Fig. 3.2 shows the variation with displacement  $x$  of acceleration  $a$  of the object.

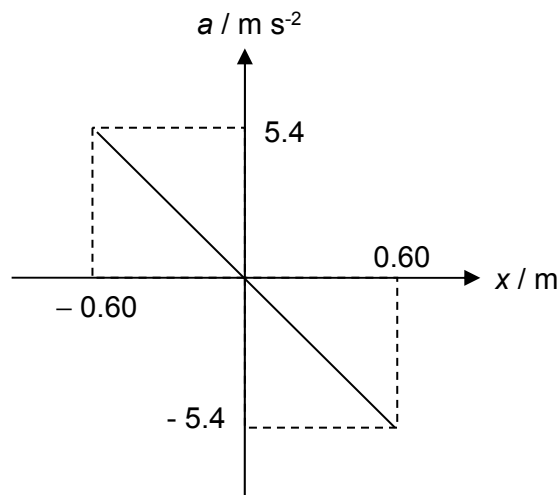


Fig. 3.2

- (i) Use two features of the graph in Fig 3.2 to explain why the motion of the object is simple harmonic.

.....

.....

.....

.....

..... [2]

- (ii) Calculate  
1. the angular frequency,

angular frequency = ..... rad s<sup>-1</sup> [1]

2. maximum speed of the object.

maximum speed = ..... m s<sup>-1</sup> [1]

- (iii) Sketch on Fig. 3.3 the variation with time of the kinetic energy of the object for one complete oscillation. The mass of the object is 0.0020 kg.

Assume that the object just passes by the equilibrium position at time = 0 s. [2]

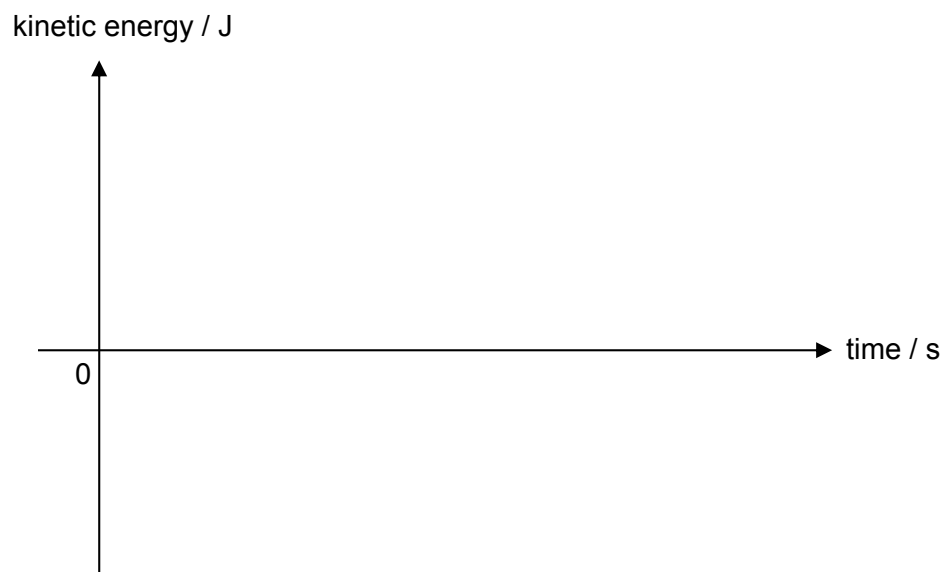


Fig. 3.3

- (iv) Calculate the shortest time taken for the object to move from a point 0.30 m to the left of the equilibrium point to a point 0.30 m to the right of the equilibrium point.

time = ..... s [3]

- (b) A car component of mass 0.0460 kg rattles at a resonant frequency of 35.5 Hz. Fig. 3.4 shows how the amplitude of the vertical oscillation varies with frequency.

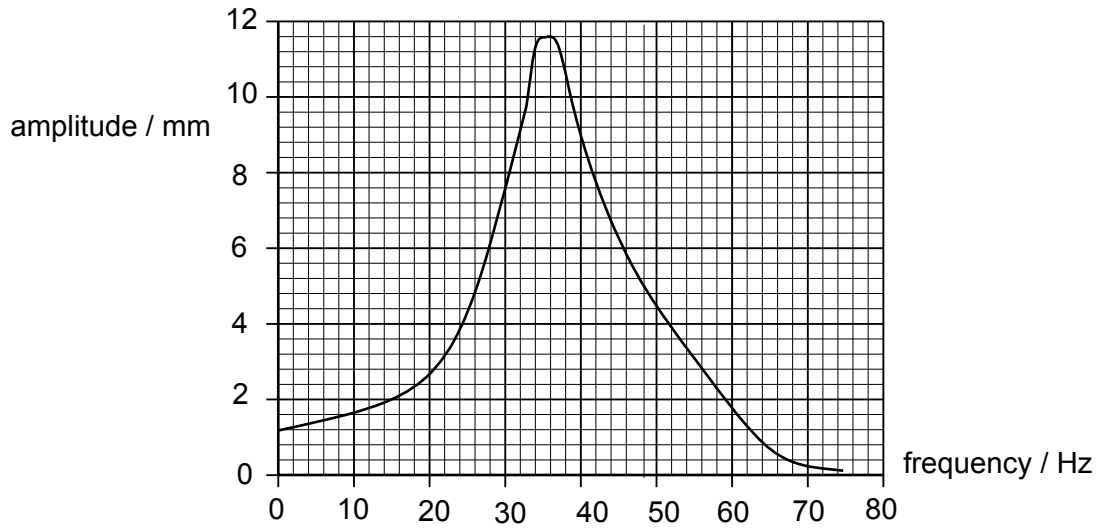


Fig. 3.4

- (i) When oscillating at the resonant frequency, calculate

1. the angular frequency of the oscillation,

angular frequency = ..... rad s<sup>-1</sup> [1]

2. the total energy stored in the oscillation of the component.

energy = ..... J [2]

- (ii) Draw on Fig 3.4 to show how the amplitude of the oscillation varies with frequency if the component is supported on a rubber mounting. [2]

- 4 (a) Fig.4.1 shows a string stretched between two fixed points P and Q.

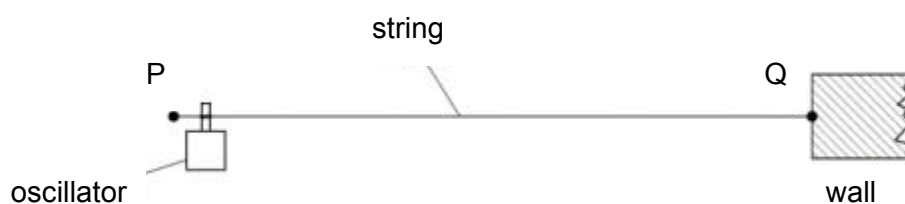


Fig. 4.1

An oscillator is attached near end P of the string. End Q is fixed to a wall. The oscillator has a frequency of 50.0 Hz.

The stationary wave produced on PQ at an instant time  $t$  is shown in Fig. 4.2. Each point on the string is at its maximum displacement.

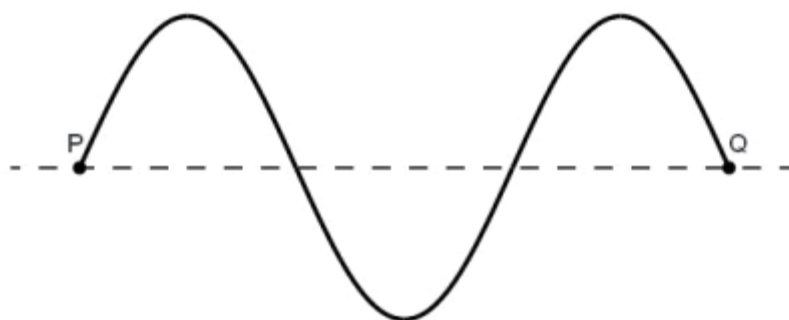


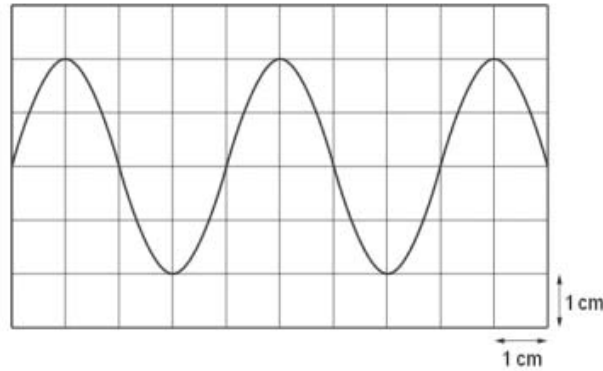
Fig. 4.2

- (i) On Fig. 4.2, label all the nodes with the letter **N** and the antinodes with the letter **A** along the dotted line PQ. [1]
- (ii) On Fig 4.2, draw the stationary wave at  $(t + 5.0 \text{ ms})$ . [1]



- (ii) The trace on the CRO in Fig. 4.4 shows the variation of signal with time at an antinode.

The time-base setting on the CRO is  $0.10 \text{ ms cm}^{-1}$ .



**Fig. 4.4**

The microphone is then moved by 3.3 cm and the trace on the CRO now records zero amplitude.

1. Determine the frequency of the sound.

frequency = ..... Hz [1]

2. Calculate the speed of sound.

speed = .....  $\text{m s}^{-1}$  [2]

- 5 (a) For a particular gas, the emission and absorption spectra are obtained for the visible light spectrum.

Discuss one similarity and one difference between the discrete lines of the absorption and emission spectra of this gas.

.....

.....

.....

.....

..... [2]

- (b) Fig. 5.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	energy of photon / eV
486	2.56
656	
1880	0.66

Fig. 5.1

- (i) Complete Fig. 5.1 by calculating the energy of the photon with wavelength 656 nm. [1]
- (ii) Fig. 5.2 is a partially completed diagram to show energy levels of a hydrogen atom.



Fig. 5.2

On Fig. 5.2, draw an additional labelled energy level which will account for the emission of the photons in Fig. 5.1. [1]



(c) Three of the energy levels of a lithium atom are shown in Fig. 5.3.

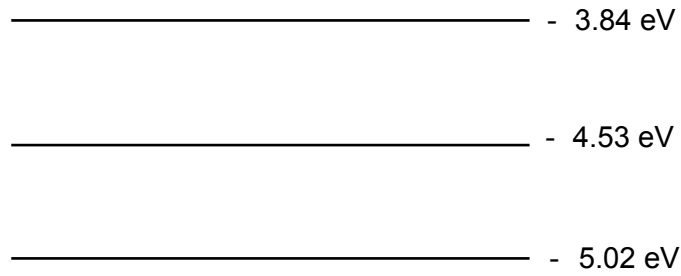


Fig. 5.3

One way to study the energy levels of an atom is to bombard the atom with electrons and measure the kinetic energies of the bombarding electrons before and after the collision. If a lithium atom which is originally in the – 5.02 eV level is bombarded with an electron of kinetic energy 0.92 eV, the scattered electron can have only two possible kinetic energies.

States these two kinetic energy values, and state what happens to the lithium atom in each case.

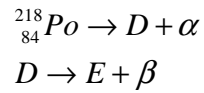
1<sup>st</sup> possible kinetic energy value: ..... eV [1]

..... [1]

2<sup>nd</sup> possible kinetic energy value: ..... eV [1]

..... [1]

- 6 (a) A stationary nucleus of a radioactive nuclide,  ${}_{84}^{218}\text{Po}$ , underwent a chain of decays by the emission of an  $\alpha$  and  $\beta$ -particles. The decay is represented by the two equations:



where D and E are the nuclides formed after the decay.

- (i) State the nuclear notation for E. [1]

.....*E*  
.....

- (ii) Determine the ratio of the kinetic energy of the  $\alpha$ -particle to the total kinetic energy of D and  $\alpha$ -particle.

ratio = ..... [3]

(iii) In reality, the  $\beta$ -particles have a range of kinetic energies, instead of a fixed value. Explain why this is so.

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

(iv) A sample of  $^{218}_{84}\text{Po}$  is placed on a weighing balance and a reading of 4.05 g is obtained. After 243 s, the reading drops to 4.02 g.

1. Determine the number of particles  $^{218}_{84}\text{Po}$  in the initial sample.

number of particles = ..... [1]

2. Show that the total number of particles D and E after 243 s is  $4.52 \times 10^{21}$ . [1]

3. Determine the half life of  $^{218}_{84}\text{Po}$ .

half life = ..... s [2]

- (b) For many unstable parent nuclei, the daughter nuclei is itself radioactive. This may give rise to a radioactive series where there may be ten or more different radioactive daughter products.

A radioactive parent nucleus X has a radioactive daughter nucleus Y and, in turn, this daughter produces a further stable daughter Z. The variation with time  $t$  of the percentage number  $P$  of the different nuclei X, Y and Z in a radioactive sample is illustrated in Fig. 6.1

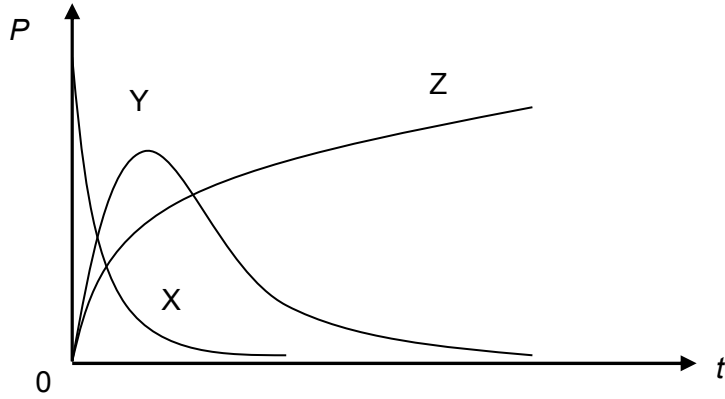


Fig 6.1

- (i) X has a half life of 5 hours. The count rate at  $t = 0$  and  $t = 5$  hours were measured. Suggest three possible reasons why the count rate is not exactly halved after 5 hours.

1. ....  
.....
  2. ....  
.....
  3. ....  
.....
- .....[3]

- (ii) Explain why graph of Y increases to a maximum and then decreases.
- .....  
 .....  
 .....  
 .....
- .....[2]

- 7 Many devices are designed to create a spray of tiny droplets. The effectiveness of these devices usually depends on droplet size. One example is an agriculture pesticide spray in which a few large droplets do not coat the leaves of plants as well as many small droplets. Another example is a fuel injection system for an engine.

Measuring the size of droplets present in a spray is difficult to do by direct means but instruments called droplet sizers can be purchased which make droplet sizing a fast routine operation.

The principle of operation of one such sizer is shown in Fig. 7.1, in which light from a helium/neon laser is passed through a spray of droplets of uniform diameter and forms a circular diffraction ring of radius  $x$ . The diameter  $d$  of the droplets is related to  $x$  by the equation

$$d = k \frac{\lambda}{x}$$

In this equation  $\lambda$ , the wavelength of the light, is  $6.33 \times 10^{-7}$  m.  $k$  is a constant equal to 0.474 m, and  $d$  and  $x$  are both in metres.

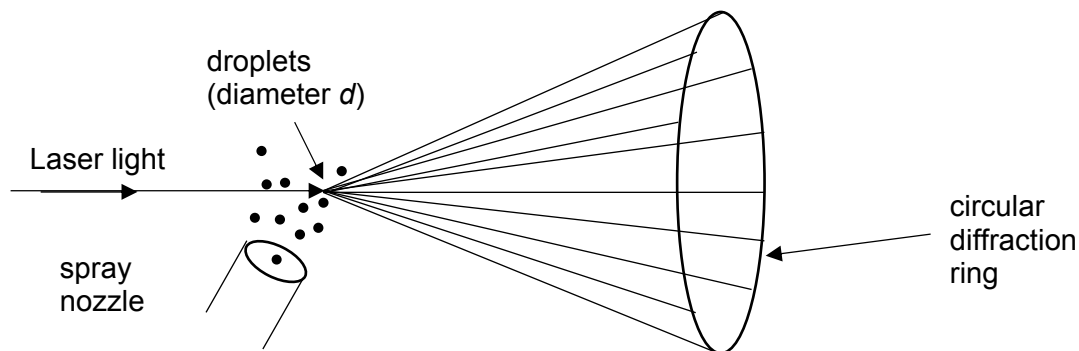


Fig. 7.1

In practice, a spray will consist of droplets of different sizes, so many rings of diffracted light will be caused. The diffraction pattern in Fig. 7.2a is projected on a flat surface containing many light sensitive detectors. The output from the detectors can be analysed by a computer and be shown in the form of a graph in Fig. 7.2b.

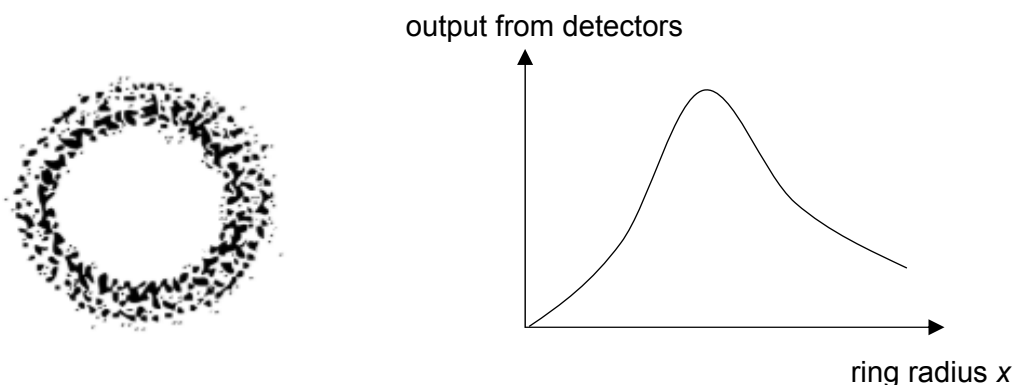


Fig. 7.2a

Fig. 7.2b

- (a) Suggest two devices, other than those mentioned in the first paragraph of the passage, where droplet size is important.

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

- (b) Outline a direct method for measuring droplet diameter.  
 Apparatus available includes: high speed camera, stroboscope, stopwatch, rulers.

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

- (c) Give two reasons why direct methods are likely to be difficult for measuring droplets of small diameter.

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

- (d) Calculate the value of  $x$  for a droplet of diameter

- (i)  $10\ \mu\text{m}$

$x = \dots\dots\dots\ \text{m}$  [1]

- (ii)  $200\ \mu\text{m}$

$x = \dots\dots\dots\ \text{m}$  [1]

(e) State whether a small value of  $x$  corresponds to large or to small droplets.

..... [1]

(f) Suggest, with reference to the equation given, how the radius of the circular diffraction ring can be increased for the same diameter of water droplets.

..... [1]

(g) Sketch on the axes in Fig. 7.3 curves to show the general shape of graphs that would be obtained if

(i) droplets with a wide range of diameters were used. Label as (i). [1]

(ii) very small droplets with a narrow range of diameters were used. Label as (ii) [1]

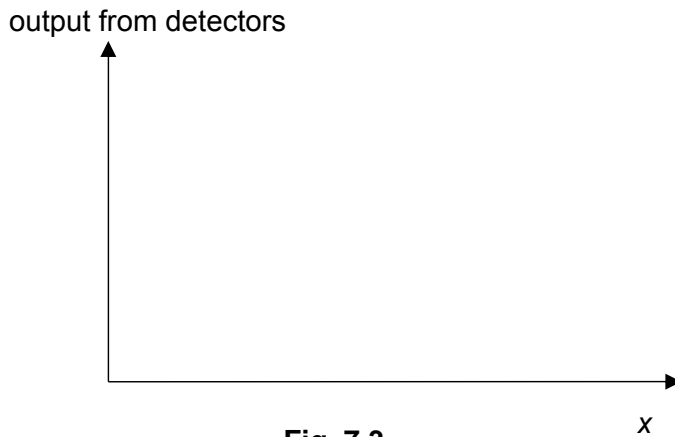


Fig. 7.3

- (h) In practice, a cloud of spray droplets moves through the laser beam as shown at intervals in Fig. 7.4. The output from the detectors varies with time in the way shown in Fig. 7.5.

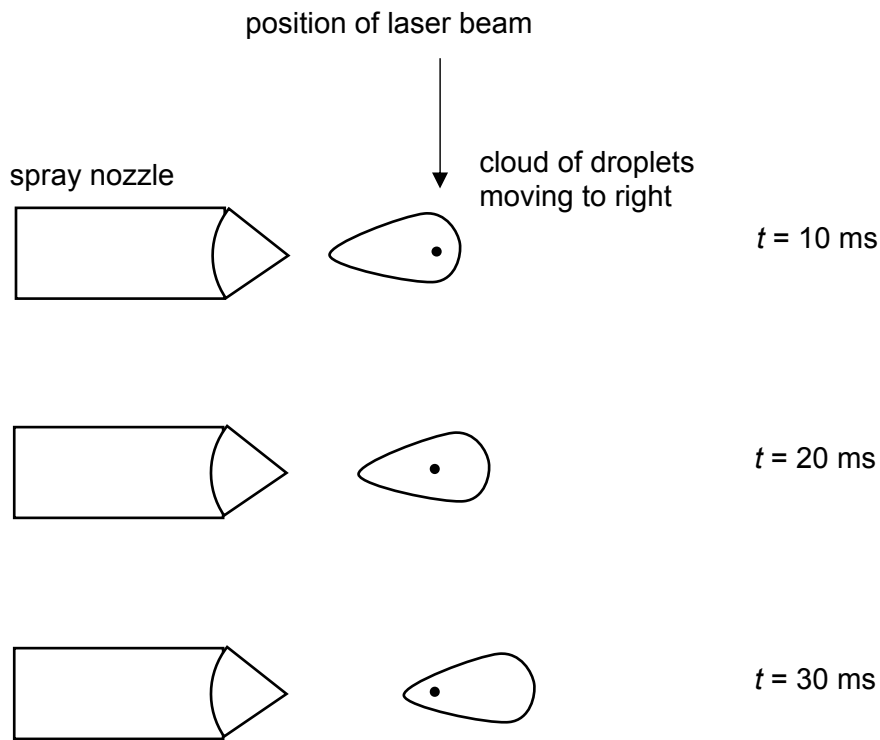


Fig. 7.4

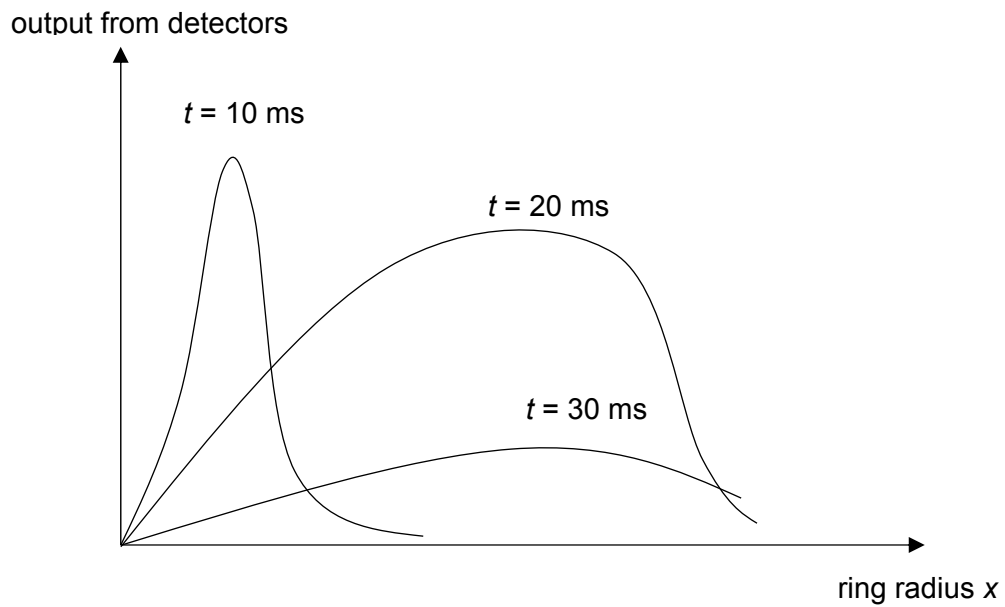


Fig. 7.5





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**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 2**

NAME

CG

INDEX NO.

**PHYSICS**

**9749/02**

**Preliminary Examination**  
**Paper 2 Structured Questions**

**14<sup>th</sup> September 2018**  
**2 hours**

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

**READ THIS INSTRUCTIONS FIRST**

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.  
You may use HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions.

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

<b>For Examiners' Use</b>	
<b>Q1</b>	/ 10
<b>Q2</b>	/ 7
<b>Q3</b>	/ 14
<b>Q4</b>	/ 8
<b>Q5</b>	/ 8
<b>Q6</b>	/ 14
<b>Q7</b>	/ 19
<b>Total marks</b>	/ 80

## DATA AND FORMULAE

## Data

speed of light in free space	$c$	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0$	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0$	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$ $= \frac{1}{36\pi} \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e$	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h$	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u$	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e$	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R$	$= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k$	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G$	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g$	$= 9.81 \text{ m s}^{-2}$

## DATA AND FORMULAE

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2} at^2$$

work done on/by a gas

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

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -\frac{GM}{r}$$

temperature

$$T / K = T / ^\circ C + 273.15$$

pressure of an ideal gas

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

mean translational kinetic energy of an ideal gas molecule

$$E = \frac{3}{2} kT$$

displacement of particle in s.h.m.

$$x = x_0 \sin \omega t$$

velocity of particle in s.h.m.

$$v = v_0 \cos \omega t$$

$$= \pm \omega \sqrt{x_0^2 - x^2}$$

electric current

$$I = Anqv$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/ voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

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

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

1 A raindrop falls vertically from rest.

(a) Assume that air resistance is negligible.

On Fig. 1.1, sketch a graph to show the variation with time  $t$  of the velocity  $v$  of the raindrop for the first 1.0 s of the motion. [1]

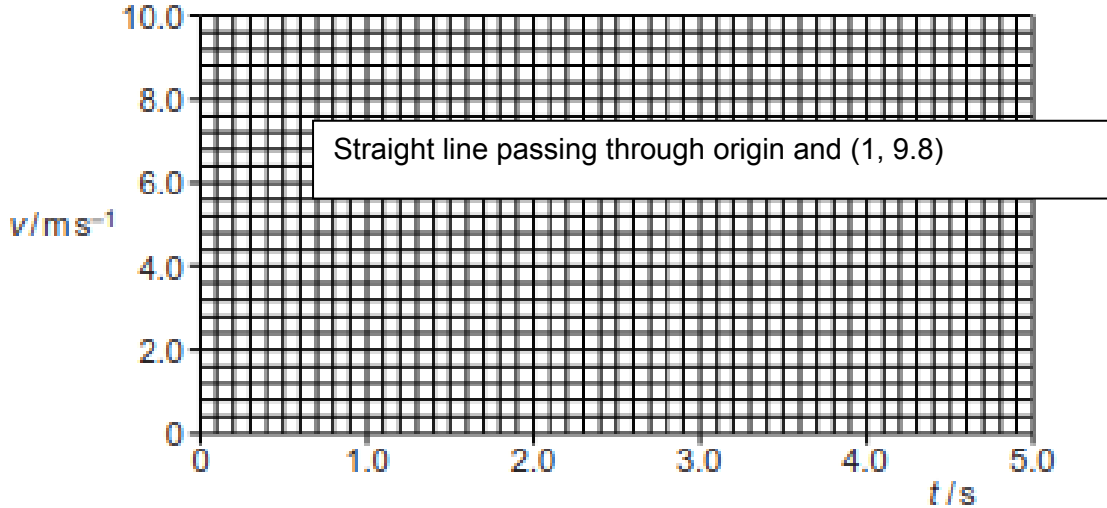


Fig. 1.1

(b) In practice, air resistance  $D$  on raindrops is not negligible.

$D$  is given by the expression

$$D = k v^2$$

where  $k$  is a constant and  $v$  is the speed

(i) The raindrop has mass  $1.38 \times 10^{-5}$  kg and  $k$  is  $2.76 \times 10^{-6}$  N m<sup>-2</sup> s<sup>2</sup>.

Calculate the terminal velocity of the raindrop.

At terminal velocity, acceleration is zero. By Newton's Law, $F_{net} = 0$ Weight = $D$ (+ upthrust) $1.38 \times 10^{-5} \times 9.81 = \frac{1}{2} (0.63 \times 1.2 \times 7.3 \times 10^{-6}) v^2$ $v = 7.0 \text{ m s}^{-1}$	[1] [1]
--	------------

terminal velocity = ..... m s<sup>-1</sup> [2]

(ii) The raindrop reaches terminal velocity at  $t = 3.0$  s.

On Fig. 1.1, sketch the variation with time  $t$  of velocity  $v$  for the raindrop. The sketch should include the first 5.0 seconds of the motion. [2]

Same initial gradient Curve passing through origin and tends towards a horizontal line should reach terminal velocity at 3 seconds	[1] and [1]
--	-------------------

- (c) A raindrop falls on a roof and rebounds off with a velocity of  $5.5 \text{ m s}^{-1}$  at an angle  $60^\circ$  with respect to the horizontal as shown in Fig. 1.2.

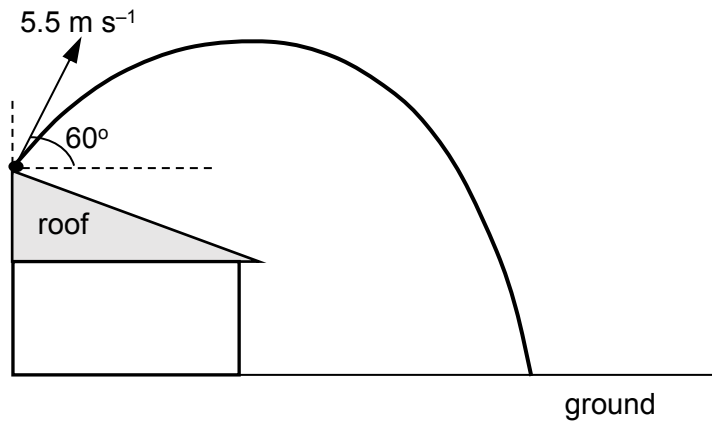


Fig. 1.2

Assume air resistance is negligible. The maximum horizontal distance travelled by the raindrop is 3.8 m.

- (i) Calculate the time taken for the raindrop to hit the ground.

$$\begin{aligned} S_x &= u_x t \\ 3.8 &= (5.5 \cos 60^\circ) t \\ t &= 1.38 \text{ s} \end{aligned}$$

time = ..... s [1]

- (ii) Determine the speed of the raindrop as it hits the ground.

$$\begin{aligned} v_x &= u_x = 5.5 \cos 60^\circ = 2.75 \text{ m s}^{-1} \\ v_y &= (-5.5 \sin 60^\circ) + (9.81)(1.38) = 8.77 \text{ m s}^{-1} \quad [\text{M1}] \\ v &= \sqrt{2.75^2 + 8.77^2} = 9.19 \text{ m s}^{-1} \quad [\text{A1}] \end{aligned}$$

speed = .....m s<sup>-1</sup> [2]

- (iii) Discuss quantitatively whether the assumption that air resistance is negligible is justified by considering the vertical component of the initial velocity of the raindrop.

The raindrop has the same mass and dimension as in (b)(i).

$$\text{Drag force} = 2.76 \times 10^{-6} (5.5 \sin 60) ^2 = 6.26 \times 10^{-5} \text{ N} [1]$$

this is 0.4 times of the weight of raindrop [1]  
so assumption is not justified

.....[2]



- 2 A uniform rectangular card is suspended from a wooden rod. The card is held at one of its ends as shown in Fig. 2.1. The force by the hand on the card acts horizontally to the right.

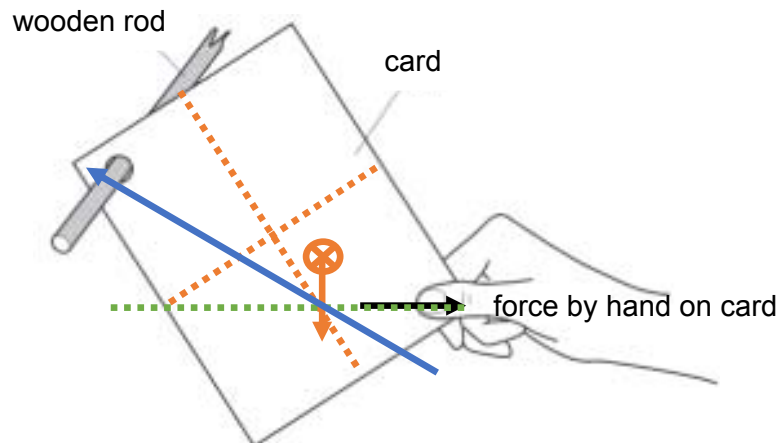


Fig. 2.1

- (a) On Fig. 2.1,

- (i) mark with an 'X' the position of the centre of gravity of the card. [1]

Accept answers that off-centre (below and towards the right) [1]

- (ii) draw an arrow labelled with  $W$  to represent the weight of the card. [1]

arrow points downwards starting from X [1]

- (b) State the conditions for the card to be in equilibrium.

.. Net force is zero [B1] .....  
 .. Net torque is zero [B1] or the sum of clockwise moments about any point is equal  
 .. to the sum of anticlockwise moments about that same point or the lines of action  
 of the 3 forces (weight, force by hand on card and force by rod on card) passes  
 through a common point [2]

- (c) Draw an arrow labelled with  $R$  on Fig. 2.1 to represent the force exerted by the wooden rod on the card.

Show your construction clearly. [2]

Concurrent forces, 3 forces passes through same point. [B1]  
 Correct direction of arrow [B1]

- (d) The card is now released. It swings on the wooden rod and eventually comes to a rest.

By reference to the completed diagram in Fig. 2.1, describe the final position in which the card comes to a rest.

Position of X directly below point of contact of card with rod/ line of action of  $W$   
 passing through the point of contact of card with rod [1] .....  
 Such that there is no resultant moment .....  
 Correct diagrams are accepted as part of the working. [1]

- 3 (a) An object is placed on a smooth horizontal surface and is connected to a light spring, as shown in Fig. 3.1.

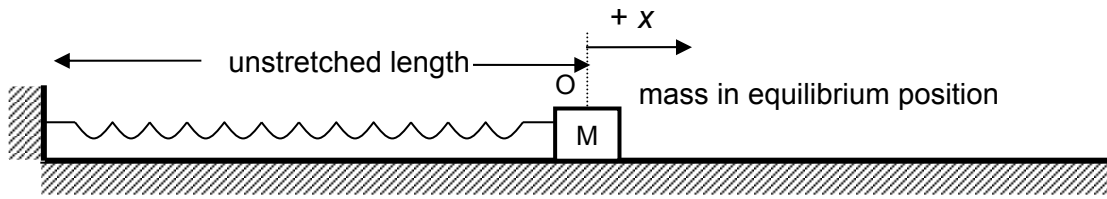


Fig. 3.1

The object is displaced to the right by 0.60 m and then released. Fig. 3.2 shows the variation with displacement  $x$  of acceleration  $a$  of the object.

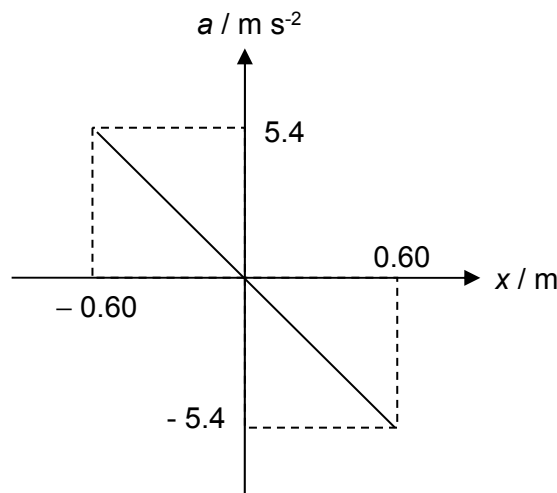


Fig. 3.2

- (i) Use two features of the graph in Fig 3.2 to explain why the motion of the object is simple harmonic.

... Negative gradient shows that the acceleration and displacement in opposite directions.	[1]
... Straight line through the origin shows that acceleration is proportional to displacement from equilibrium	[1]

[2]

- (ii) Calculate  
1. the angular frequency,

$ a_0  =  \omega^2 x_0 $ $5.4 = \omega^2 (0.6)$ $\omega = 3.0 \text{ rad s}^{-1}$
---

angular frequency = ..... rad s<sup>-1</sup> [1]

2. maximum speed of the object.

Since $v_0 = \omega x_0$ $v_0 = 3 (0.6) = 1.8 \text{ m s}^{-1}$	[1]
--	-----

maximum speed = .....  $\text{m s}^{-1}$  [1]

- (iii) Sketch on Fig. 3.3 the variation with time of the kinetic energy of the object for one complete oscillation. The mass of the object is 0.0020 kg.

Assume that the object just passes by the equilibrium position at time = 0 s. [2]

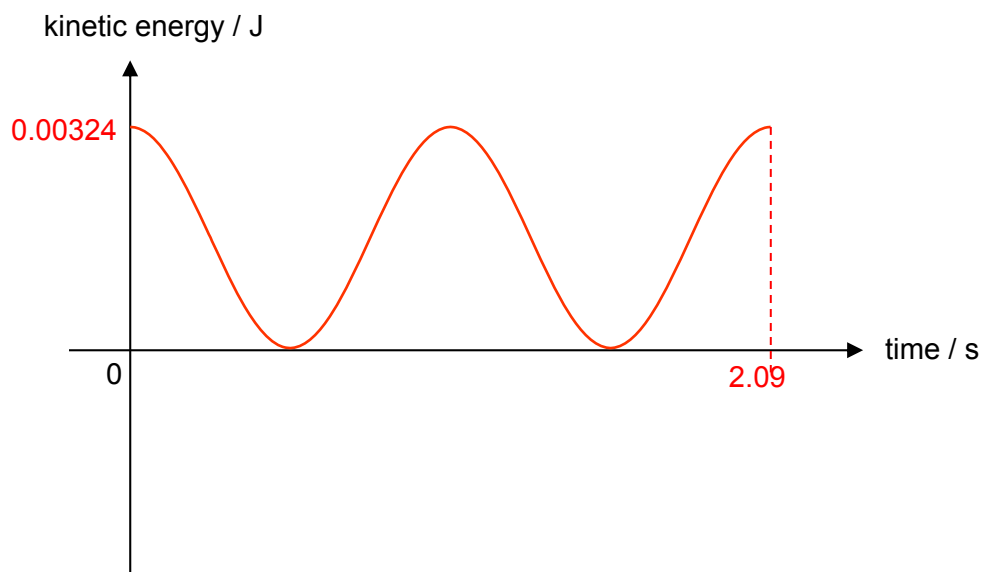


Fig. 3.3

- (iv) Calculate the shortest time taken for the object to move from a point 0.30 m to the left of the equilibrium point to a point 0.30 m to the right of the equilibrium point.

At $x = -0.30 \text{ m}$ , $0.3 = 0.6 \sin (3t_1)$	[1]
$t_1 = 0.174 \text{ s}$	[1]
Time taken = $0.174 \times 2 = 0.349 \text{ s}$	[1]

time = ..... s [3]

- (b) A car component of mass 0.0460 kg rattles at a resonant frequency of 35.5 Hz. Fig. 3.4 shows how the amplitude of the vertical oscillation varies with frequency.

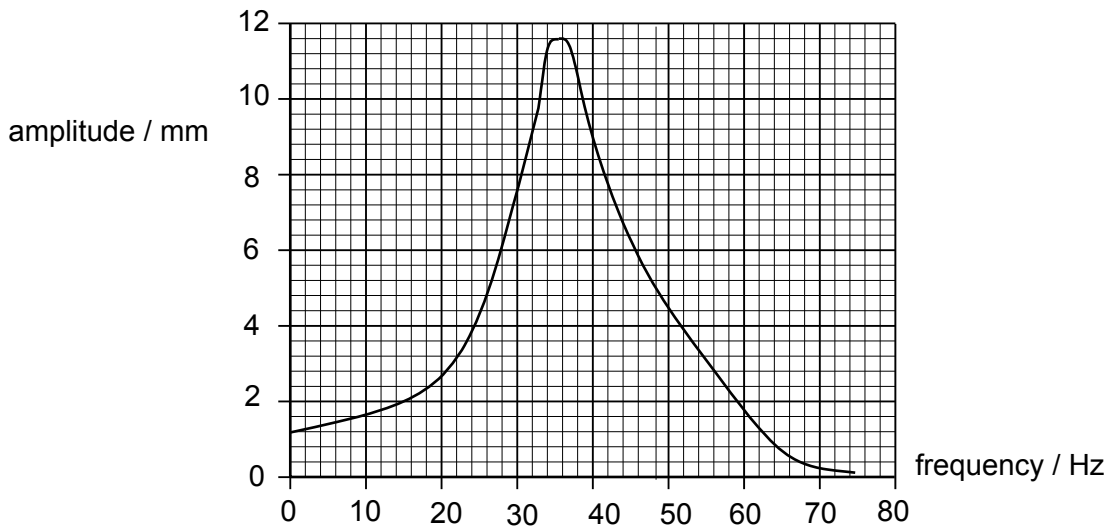


Fig. 3.4

- (i) When oscillating at the resonant frequency, calculate

1. the angular frequency of the oscillation,

$$\omega = 2\pi f = 2\pi \times 35.5 = 223 \text{ rad s}^{-1}$$

angular frequency = ..... rad s<sup>-1</sup> [1]

2. the total energy stored in the oscillation of the component.

$$\begin{aligned} \text{total energy} &= \frac{1}{2} m (\omega)^2 (x_0)^2 \\ &= \frac{1}{2} \times 0.046 \times 0.0116^2 \times 223^2 && [1] \\ &= 0.154 \text{ J} && [1] \end{aligned}$$

energy = ..... J [2]

- (ii) Draw on Fig 3.4 to show how the amplitude of the oscillation varies with frequency if the component is supported on a rubber mounting. [2]

maximum amplitude at lower frequency [1]  
same starting point and lower graph within original shape [1]

- 4 (a) Fig.4.1 shows a string stretched between two fixed points P and Q.

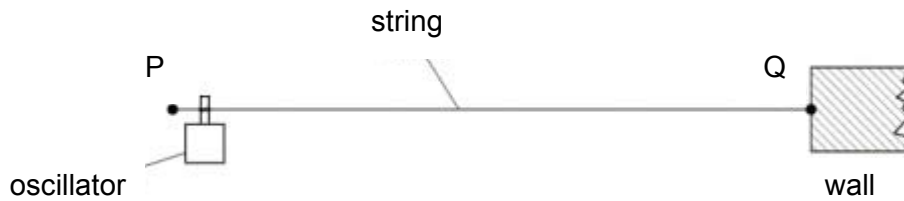


Fig. 4.1

An oscillator is attached near end P of the string. End Q is fixed to a wall. The oscillator has a frequency of 50.0 Hz.

The stationary wave produced on PQ at an instant time  $t$  is shown in Fig. 4.2. Each point on the string is at its maximum displacement.

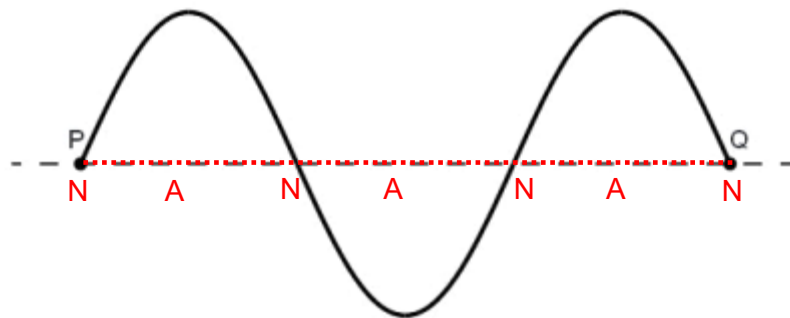


Fig. 4.2

- (i) On Fig. 4.2, label all the nodes with the letter **N** and the antinodes with the letter **A** along the dotted line PQ. [1]
- (ii) On Fig 4.2, draw the stationary wave at  $(t + 5.0 \text{ ms})$ . [1]

Since  $T = 1/f = 1/50 = 20 \text{ ms}$ ,  
5 ms is  $\frac{1}{4}$  of a period.

Correct diagram

[1]

- (b) Sound waves is directed from a loudspeaker towards a metal plate. A microphone, connected to a cathode ray oscilloscope (CRO), is placed in between the loudspeaker and the metal plate as shown in Fig. 4.3.

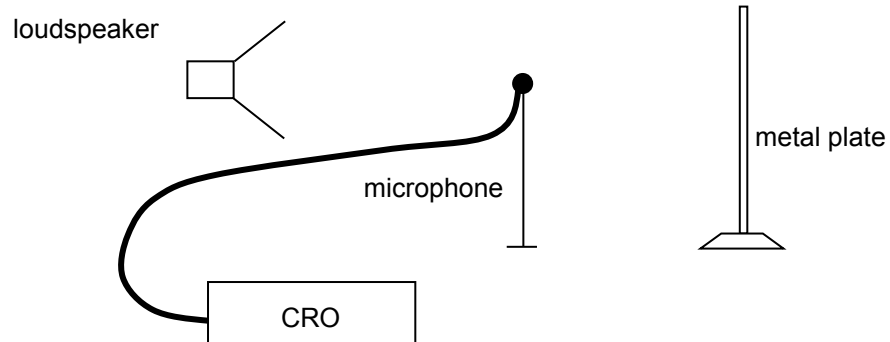


Fig. 4.3

- (i) Explain how stationary waves are formed in between the loudspeaker and the metal phase.

As the sound waves reflects off the metal plate, the incident and reflected waves have the same amplitude, wavelength and frequency [B1] move in opposite direction and overlap/superpose/meet [B1].

When they experience constructive interference, they form regions of high intensity and when they experience destructive interference, they forms regions of low intensity. [B1]

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

- (ii) The trace on the CRO in Fig. 4.4 shows the variation of signal with time at an antinode.

The time-base setting on the CRO is  $0.10 \text{ ms cm}^{-1}$ .

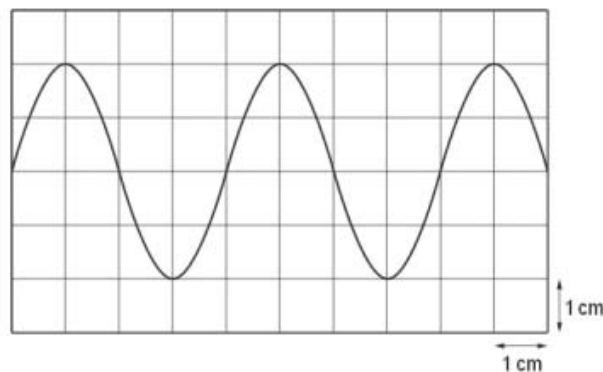


Fig. 4.4

The microphone is then moved by 3.3 cm and the trace on the CRO now records zero amplitude.

1. Determine the frequency of the sound.

$$\text{Frequency} = 1/\text{period} = 1 / 4 \times 10^{-3} = 2500 \text{ Hz} \quad [\text{A1}]$$

frequency = ..... Hz [1]

2. Calculate the speed of sound.

Distance between node and antinode =  $\frac{1}{4}$  wavelength.

$$\text{Wavelength} = 4 \times 3.3 = 13.2 \text{ m} \quad [\text{M1}]$$

$$v = f\lambda = 2500 \times 13.2 = 330 \text{ m s}^{-1} \quad [\text{A1}]$$

speed = ..... m s<sup>-1</sup> [2]

- 5 (a) For a particular gas, the emission and absorption spectra are obtained for the visible light spectrum.

Discuss one similarity and one difference between the discrete lines of the absorption and emission spectra of this gas.

..... {Similarity} The discrete lines of both absorption and emission spectrum .....  
 ..... occur at same frequencies [1], but {Difference} the absorption has dark .....  
 ..... lines against a continuous spectrum whereas the emission spectrum has .....  
 ..... coloured lines against a black background [1]. .....  
 ..... [2]

- (b) Fig. 5.1 gives information on three lines observed in the emission spectrum of hydrogen atoms.

wavelength / nm	energy of photon / eV
486	2.56
656	1.90
1880	0.66

Fig. 5.1

- (i) Complete Fig. 5.1 by calculating the energy of the photon with wavelength 656 nm. [1]
- (ii) Fig. 5.2 is a partially completed diagram to show energy levels of a hydrogen atom.

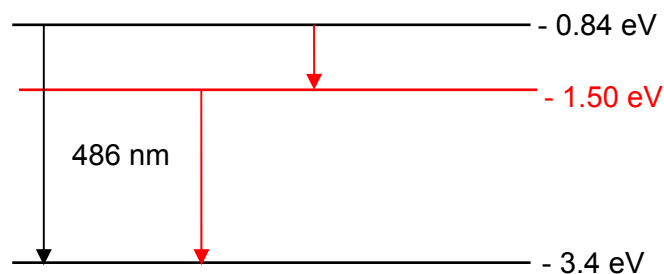
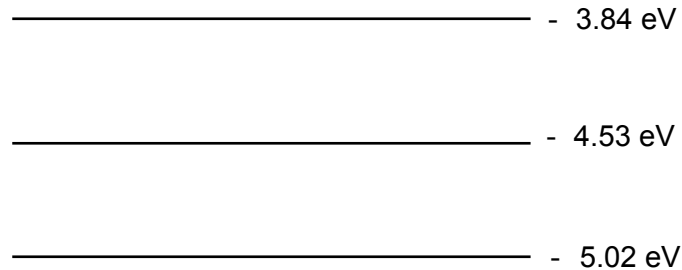


Fig. 5.2

On Fig. 5.2, draw an additional labelled energy level which will account for the emission of the photons in Fig. 5.1. [1]



- (c) Three of the energy levels of a lithium atom are shown in Fig. 5.3.



**Fig. 5.3**

One way to study the energy levels of an atom is to bombard the atom with electrons and measure the kinetic energies of the bombarding electrons before and after the collision. If a lithium atom which is originally in the  $-5.02$  eV level is bombarded with an electron of kinetic energy  $0.92$  eV, the scattered electron can have only two possible kinetic energies.

States these two kinetic energy values, and state what happens to the lithium atom in each case.

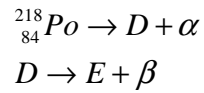
1<sup>st</sup> possible kinetic energy value: ..... eV [1]

0.92 eV [1]  
Nothing happens to the lithium atom (ie. it stays in the -5.02 eV level) [1] ..... [1]

2<sup>nd</sup> possible kinetic energy value: ..... eV [1]

$0.92 - (5.02 - 4.53) = 0.43$  eV [1]  
Atom will be excited to the -4.53 eV level [1] ..... [1]

- 6 (a) A stationary nucleus of a radioactive nuclide,  ${}^{218}_{84}\text{Po}$ , underwent a chain of decays by the emission of an  $\alpha$  and  $\beta$ -particles. The decay is represented by the two equations:

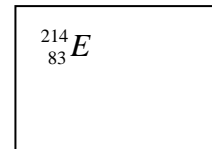


where D and E are the nuclides formed after the decay.

- (i) State the nuclear notation for E.

[1]

.....*E*  
.....



- (ii) Determine the ratio of the kinetic energy of the  $\alpha$ -particle to the total kinetic energy of D and  $\alpha$ -particle.

By conservation of linear momentum,

$$0 = p_D + p_\alpha$$

$$|p_D| = |p_\alpha| \quad [\text{M1}]$$

KE of  $\alpha$ -particle

total KE

$$\frac{\frac{p_\alpha^2}{m_\alpha}}{\frac{p_\alpha^2}{m_\alpha} + \frac{p_D^2}{m_D}} \quad [\text{M1}]$$

$$= \frac{\frac{1}{m_\alpha}}{\frac{1}{m_\alpha} + \frac{1}{m_D}}$$

$$= \frac{\frac{1}{4u}}{\frac{1}{4u} + \frac{1}{214u}}$$

$$= 0.982 \quad [\text{A1}]$$

ratio = ..... [3]

- (iii) In reality, the  $\beta$ -particles have a range of kinetic energies, instead of a fixed value. Explain why this is so.

Because there are neutrinos emitted together with the beta particles and kinetic energy is shared between the beta particles and neutrino. [A1]

.....[1]

- (iv) A sample of  ${}^{218}_{84}\text{Po}$  is placed on a weighing balance and a reading of 4.05 g is obtained. After 243 s, the reading drops to 4.02 g.

1. Determine the number of particles  ${}^{218}_{84}\text{Po}$  in the initial sample.

$$\text{No. of } {}^{218}_{84}\text{Po particles } N_{218} = \frac{4.05 \times 10^{-3}}{218u} = 1.12 \times 10^{22} \quad [\text{A1}]$$

number of particles = ..... [1]

2. Show that the total number of particles D and E after 243 s is  $4.52 \times 10^{21}$ . [1]

$$\begin{aligned} \text{Total mass after time } t &= (N_{\text{Po}} - N_{\text{D+E}})m_{\text{Po}} + (N_{\text{D+E}})m_{\text{D}} \\ (1.119 \times 10^{22} - N_{\text{D+E}})218u + (N_{\text{D+E}})214u &= 4.02 \times 10^{-3} \quad [\text{M1}] \\ (1.119 \times 10^{22} - N_{\text{D+E}})218u + (N_{\text{D+E}})214u &= 4.02 \times 10^{-3} \\ 4.05 \times 10^{-3} - 4.02 \times 10^{-3} &= (N_{\text{D+E}})4u \\ N_{\text{D+E}} &= 4.518 \times 10^{21} \end{aligned}$$

3. Determine the half life of  ${}^{218}_{84}\text{Po}$ .

$$\begin{aligned} N &= N_0 \left(\frac{1}{2}\right)^{\frac{t}{t_{\frac{1}{2}}}} \\ (1.12 \times 10^{22} - 4.52 \times 10^{21}) &= 1.12 \times 10^{22} \left(\frac{1}{2}\right)^{\frac{243}{t_{\frac{1}{2}}}} \quad [\text{M1}] \\ t_{\frac{1}{2}} &= 326 \text{ s} \quad [\text{A1}] \end{aligned}$$

half life = ..... s [2]

- (b) For many unstable parent nuclei, the daughter nuclei is itself radioactive. This may give rise to a radioactive series where there may be ten or more different radioactive daughter products.

A radioactive parent nucleus X has a radioactive daughter nucleus Y and, in turn, this daughter produces a further stable daughter Z. The variation with time  $t$  of the percentage number  $P$  of the different nuclei X, Y and Z in a radioactive sample is illustrated in Fig. 6.1

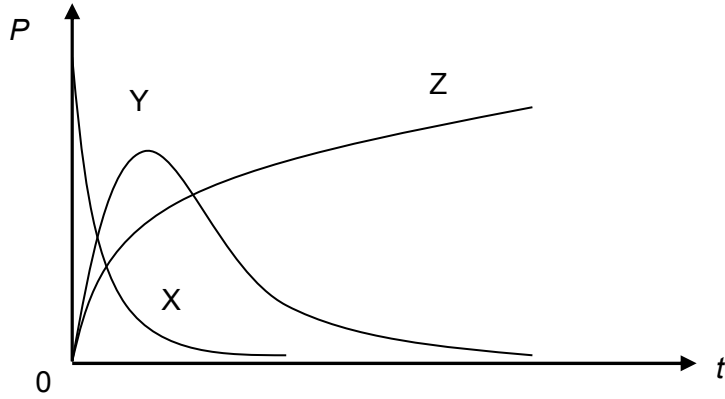


Fig 6.1

- (i) X has a half life of 5 hours. The count rate at  $t = 0$  and  $t = 5$  hours were measured. Suggest three possible reasons why the count rate is not exactly halved after 5 hours.

1. ....

2. 

1. Existence of background count. [B1] 2. Product Y is also giving off radiation that adds to count rate. [B1] 3. Random nature of radioactive decay. [B1]
--

 ....

3. ....

.....[3]

- (ii) Explain why graph of Y increases to a maximum and then decreases.

It happens because initially, there are more number of X than Y and hence, Y is being formed faster than it is decaying. [B1] As number of X decreases, there will be a point where Y decays faster than it is being formed. Hence, this will lead to a decrease in number of Y. [B1]
---

.....[2]

- 7 Many devices are designed to create a spray of tiny droplets. The effectiveness of these devices usually depends on droplet size. One example is an agriculture pesticide spray in which a few large droplets do not coat the leaves of plants as well as many small droplets. Another example is a fuel injection system for an engine.

Measuring the size of droplets present in a spray is difficult to do by direct means but instruments called droplet sizers can be purchased which make droplet sizing a fast routine operation.

The principle of operation of one such sizer is shown in Fig. 7.1, in which light from a helium/neon laser is passed through a spray of droplets of uniform diameter and forms a circular diffraction ring of radius  $x$ . The diameter  $d$  of the droplets is related to  $x$  by the equation

$$d = k \frac{\lambda}{x}$$

In this equation  $\lambda$ , the wavelength of the light, is  $6.33 \times 10^{-7}$  m.  $k$  is a constant equal to 0.474 m, and  $d$  and  $x$  are both in metres.

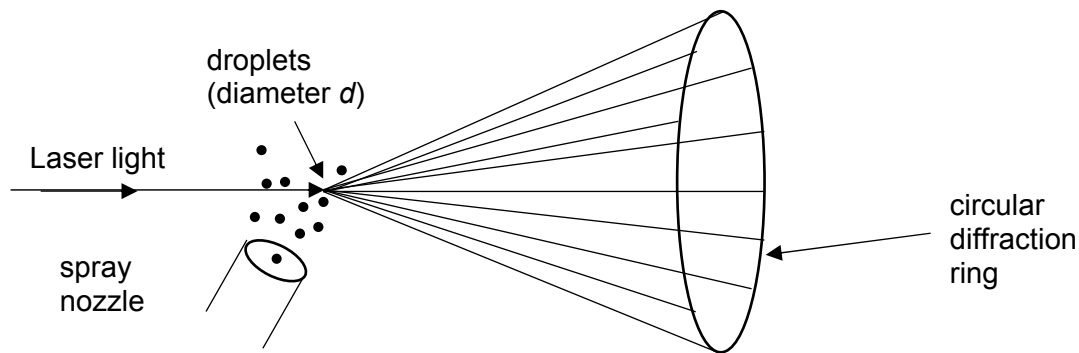


Fig. 7.1

In practice, a spray will consist of droplets of different sizes, so many rings of diffracted light will be caused. The diffraction pattern in Fig. 7.2a is projected on a flat surface containing many light sensitive detectors. The output from the detectors can be analysed by a computer and be shown in the form of a graph in Fig. 7.2b.

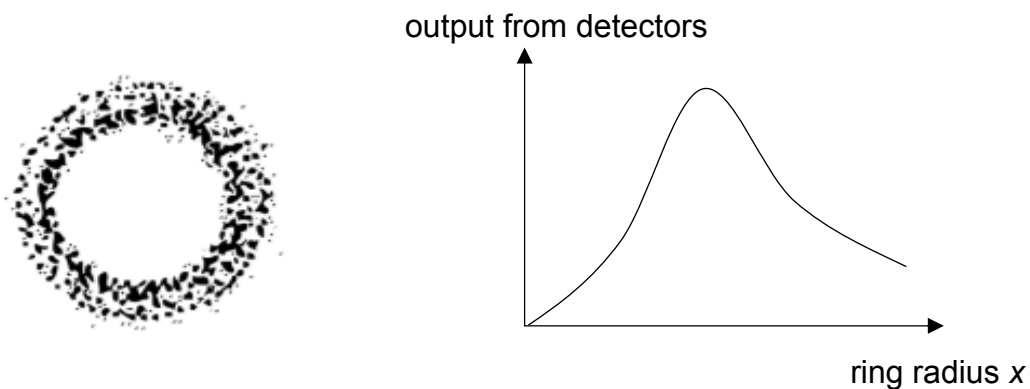


Fig. 7.2a

Fig. 7.2b

- (a) Suggest two devices, other than those mentioned in the first paragraph of the passage, where droplet size is important.

Spray paint [B1], Hair spray [B1]

[2]

- (b) Outline a direct method for measuring droplet diameter.  
Apparatus available includes: high speed camera, stroboscope, stopwatch, rulers.

Use high speed camera to capture still image of droplets. [1]  
Have a backdrop of grid squares in the background to estimate size of each droplet. [1]  
Use an object of known diameter at same distance from background to compare with size of droplet and thus use scaling to determine droplet diameter. [1]

[3]

- (c) Give two reasons why direct methods are likely to be difficult for measuring droplets of small diameter.

1. Measurement devices may lack sufficient precision for measurement. [B1]
2. The droplets may be too packed to give a distinct image [B1]

[2]

- (d) Calculate the value of  $x$  for a droplet of diameter

- (i)  $10\ \mu\text{m}$

$$d = k \frac{\lambda}{x}$$

$$x = k \frac{\lambda}{d} = 0.474 \left( \frac{6.33 \times 10^{-7}}{10 \times 10^{-6}} \right) = 0.0300\ \text{m} \quad [\text{A1}]$$

$x = \dots\dots\dots\ \text{m} \quad [1]$

- (ii)  $200\ \mu\text{m}$

$$d = k \frac{\lambda}{x}$$

$$x = k \frac{\lambda}{d} = 0.474 \left( \frac{6.33 \times 10^{-7}}{200 \times 10^{-6}} \right) = 0.00150\ \text{m} \quad [\text{A1}]$$

$x = \dots\dots\dots\ \text{m} \quad [1]$

- (e) State whether a small value of  $x$  corresponds to large or to small droplets.

Small  $x$  corresponds with large droplets [1]

[1]

- (f) Suggest, with reference to the equation given, how the radius of the circular diffraction ring can be increased for the same diameter of water droplets.

Increase wavelength of laser light. [1]

[1]

- (g) Sketch on the axes in Fig. 7.3 curves to show the general shape of graphs that would be obtained if

- (i) droplets with a wide range of diameter were used. Label as (i). [1]

- (ii) very small droplets with a narrow range of diameters were used. Label as (ii). [1]

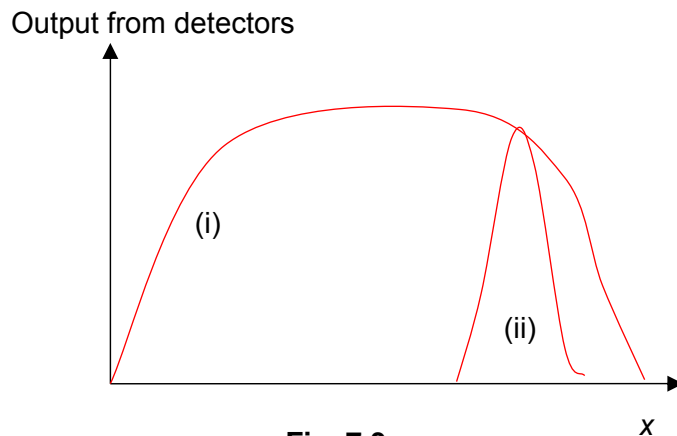


Fig. 7.3

- (h) In practice, a cloud of spray droplets moves through the laser beam as shown at intervals in Fig. 7.4. The output from the detectors varies with time in the way shown in Fig. 7.5.

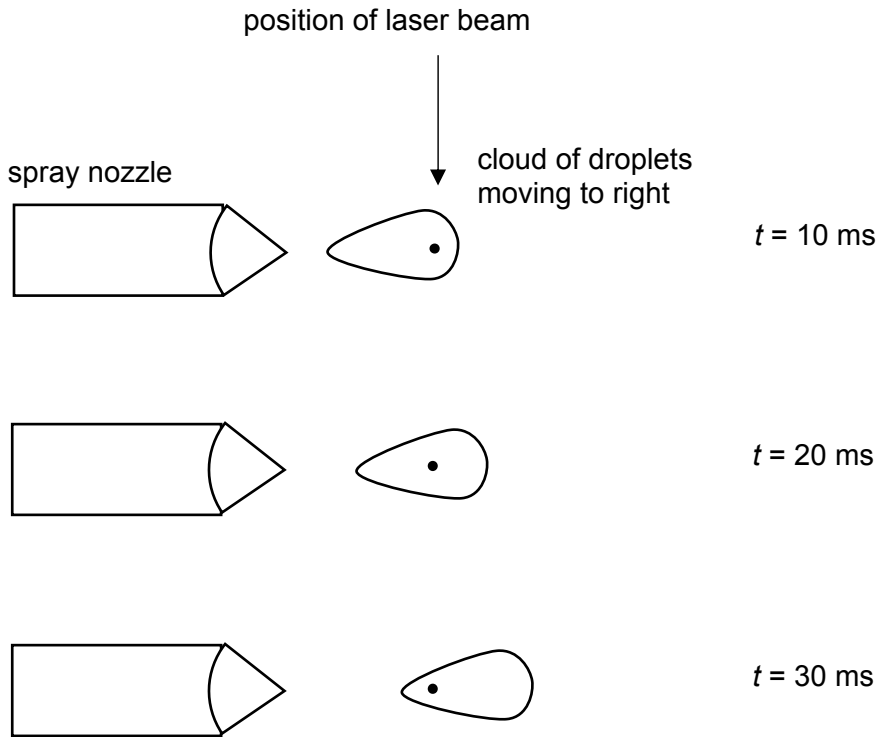


Fig. 7.4

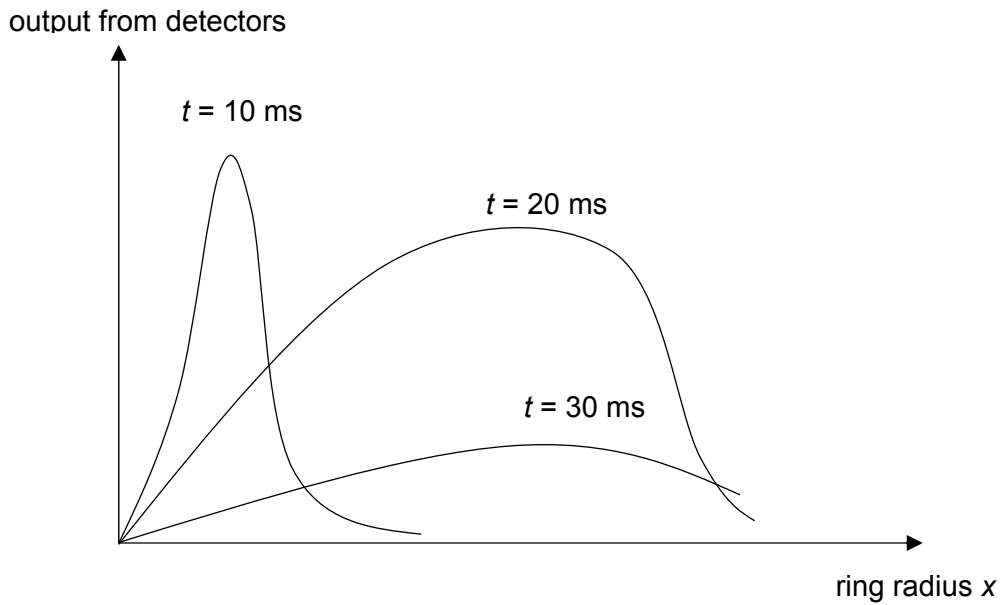
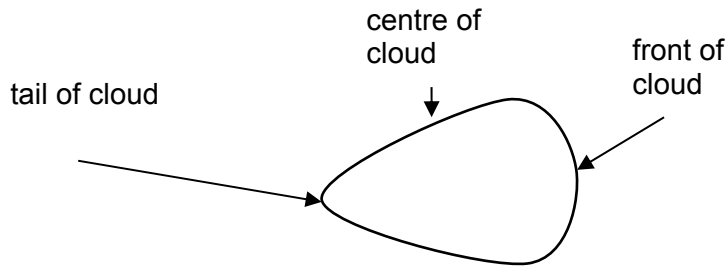


Fig. 7.5



With reference to Fig. 7.6, describe the distribution of droplets in the cloud according to their size and concentration (i.e. amount of droplets)..



**Fig. 7.6**

At the front tip of the cloud,  
Droplets are of uniform sizes and with a large diameter. [1] fewer droplets as compared to centre [1]

At the centre of cloud,  
Droplets are of a range of sizes [1] and are large number of droplets as compared to front and tail of cloud. [1]

At tail of cloud, detected with a range of different diameters. [1] fewer droplets as compared to centre [1]

Concentration – amount of water droplets  
Size – diameter + range of diameters

[6]

**END OF PAPER**

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**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 2**

NAME

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INDEX NO.

**PHYSICS**

**9749/03**

**Preliminary Examination**  
**Paper 3 Longer Structured Questions**

**20<sup>th</sup> September 2018**  
**2 hours**

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

**READ THIS INSTRUCTIONS FIRST**

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.  
You may use HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions in Section A, and **one** of the two questions in Section B.

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

<b>For Examiners' Use</b>	
<b>Q1</b>	/ 8
<b>Q2</b>	/ 7
<b>Q3</b>	/ 10
<b>Q4</b>	/ 8
<b>Q5</b>	/ 10
<b>Q6</b>	/ 10
<b>Q7</b>	/ 7
<b>Q8</b>	/ 20
<b>Q9</b>	/ 20
<b>Total marks</b>	/ 80

## DATA AND FORMULAE

**Data**

speed of light in free space	$c$	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0$	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0$	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$ $= \frac{1}{36\pi} \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e$	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h$	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u$	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e$	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R$	$= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k$	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G$	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g$	$= 9.81 \text{ m s}^{-2}$

## DATA AND FORMULAE

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2}at^2$$

work done on/by a gas

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

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -\frac{GM}{r}$$

temperature

$$T/K = T/^{\circ}\text{C} + 273.15$$

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

$$I = Anqv$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/ voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

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

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

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

**Section A**

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

1 (a) Define *impulse*.

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

(b) In a car test, a car with a dummy driver and passenger, moving at a speed of  $6.9 \text{ m s}^{-1}$ , collides head-on into a wall. The mass of the car is 1250 kg, the mass of the driver is 85 kg and the mass of the front passenger is 65 kg. The average deceleration of the car as it comes to a stop is  $48 \text{ m s}^{-2}$ . Both passenger and driver have their seat belts tightly fastened.

For the impact,

(i) determine the magnitude of the average force exerted on the car and its occupants.

average force = ..... N [1]

(ii) determine the magnitude of the impulse caused by the force.

impulse = ..... N s [2]

(iii) Hence, calculate the time taken for the car to come to a stop.

time = ..... s [2]

(iv) Assuming that the average deceleration remains the same, state and explain how your answer in (b) (iii) will change (if any) when the total mass of car and occupants is doubled.

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



- 2 A fixed mass of an ideal monatomic gas undergoes a cycle **ABCA** of changes, as shown in Fig. 2.1.

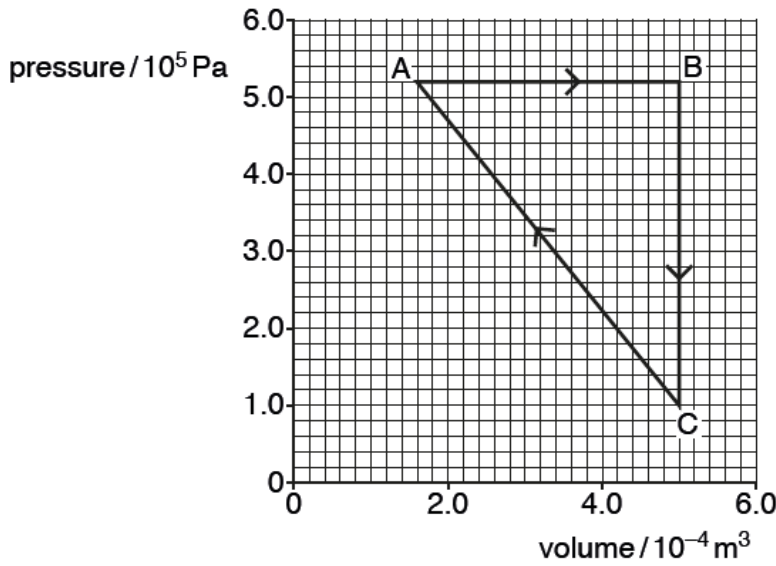


Fig. 2.1

- (a) During the change from **B** to **C**, the internal energy of the gas decreases by 315 J.

By considering molecular energy, state and explain qualitatively the change, if any, in the temperature of the gas.

.....

.....

.....

..... [2]

- (b) During the change from **A** to **B**, the energy supplied to the gas by heating is 442 J.

Fig. 2.2 is a table of energy changes during one cycle. Complete Fig. 2.2.

section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A to B	442		
B to C			-315
C to A			

Fig. 2.2

[3]

- (c) Calculate the root-mean-square speed of the gas atoms at point **B** if the root-mean-square speed at point **A** is  $350 \text{ m s}^{-1}$ .

root-mean-square speed = .....  $\text{m s}^{-1}$  [2]

- 3 (a) As seen in Fig 3.1, a monochromatic light of wavelength 580 nm is used to produce an interference pattern on screen AB. The separation between the slits is 0.41 mm and the perpendicular distance between the double slit and the screen is  $D$ . Point Y is at a distance  $x = 2$  mm from point O and it is the position of the first dark fringe. The intensities of the light passing through the two slits are the same.

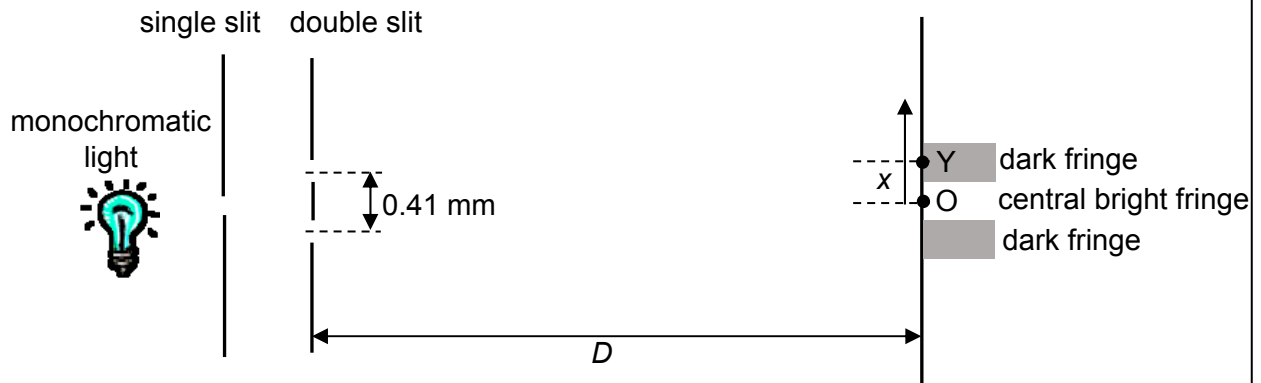


Fig 3.1

- (i) Calculate the path difference between the 2 waves arriving at point Y from the slits.

distance = ..... nm [1]

- (ii) Calculate the distance  $D$ .

$D =$  ..... m [2]

- (iii) The width of both slits is reduced by the same amount without altering their separation. The original variation with distance  $x$  from point O of the intensity is as shown in Fig. 3.2. Sketch the new variation of intensity on Fig. 3.2. [3]

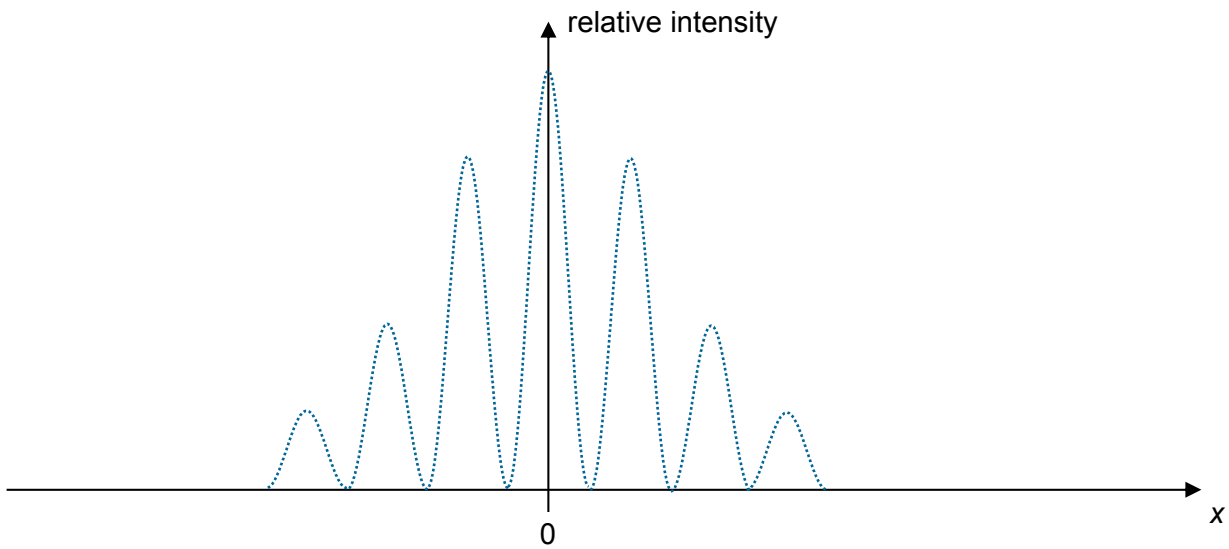


Fig. 3.2

- (b) A diffraction grating is used to measure the wavelengths of light. The angle  $\theta$  of the second order maximum is measured for each wavelength. The variation with wavelength  $\lambda$  of  $\sin \theta$  is shown in Fig 3.3.

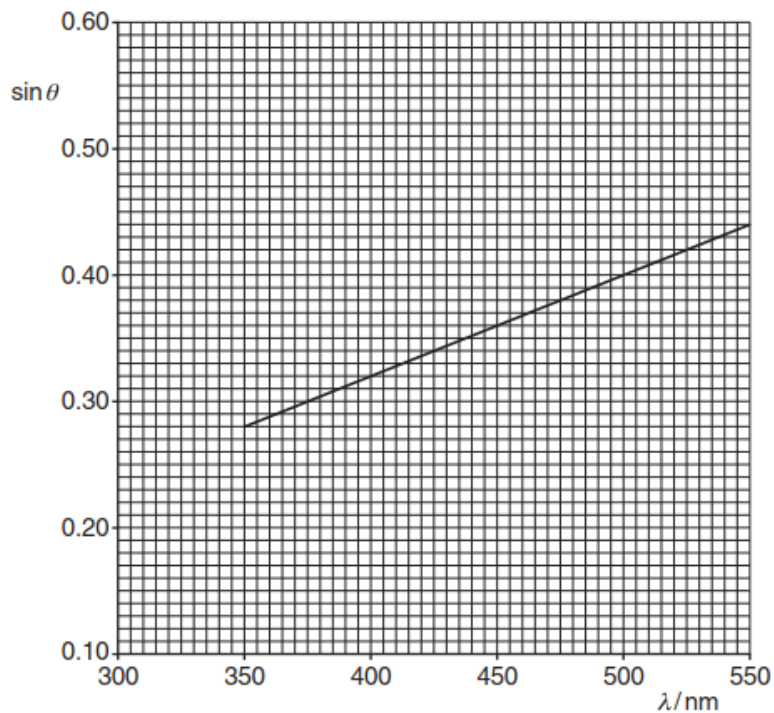


Fig. 3.3

- (i) Calculate the slit separation  $d$  of the diffraction grating.

$$d = \dots\dots\dots\text{m [3]}$$

- (ii) On Fig. 3.3, sketch a line to show the results that would be obtained for the first order maxima. [1]

4 (a) Define *electric potential* at a point.

.....

.....

..... [2]

(b) Two charged solid spheres A and B are situated in a vacuum. Their centres are separated by a distance of 30.0 cm, as shown in Fig. 4.1. The diagram is not drawn to scale.

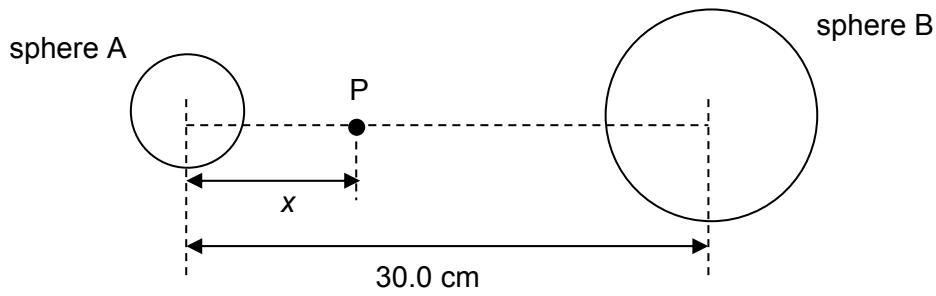


Fig. 4.1

The variation with distance  $x$  of the electric potential  $V_A$  and  $V_B$  due to sphere A and B independently is shown in Fig. 4.2.

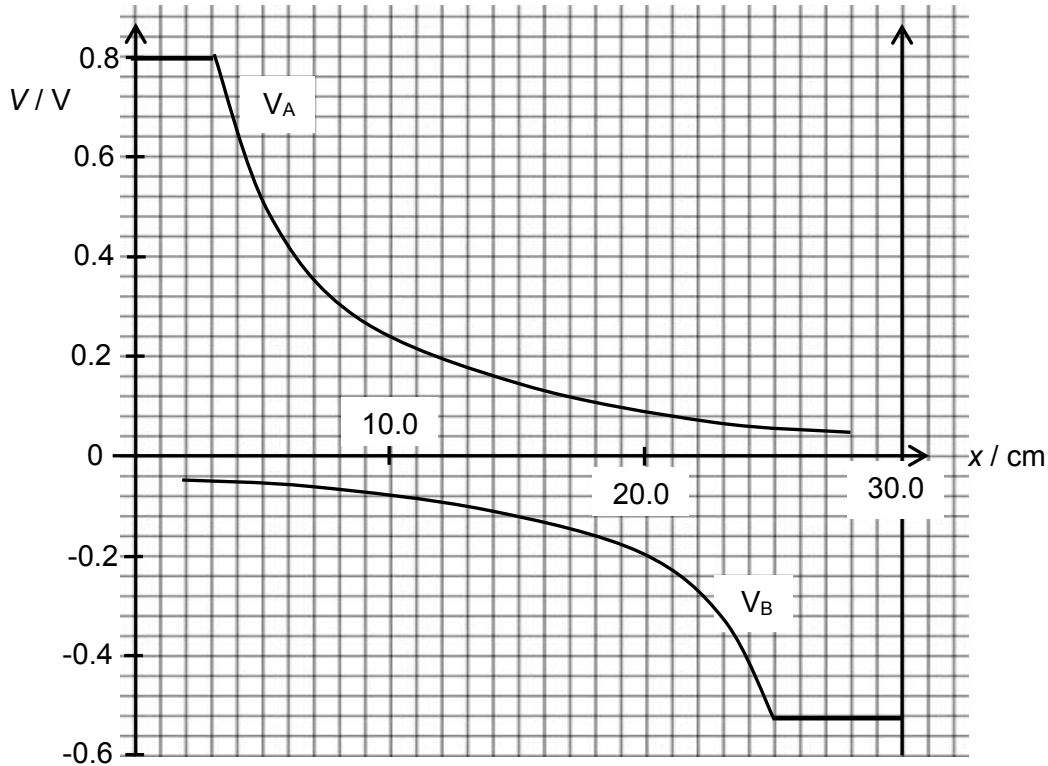


Fig. 4.2

(i) Using Fig. 4.2, state the radius of both spheres.

radius of sphere A = ..... cm

radius of sphere B = ..... cm [1]

(ii) State and explain the signs of both spheres.

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

(iii) Point P is at a distance  $x = 10.0$  cm.  
An alpha particle has kinetic energy  $E_K$  when at infinity.

Use Fig. 4.2 to determine the minimum value of  $E_K$  such that the alpha particle may travel from infinity to point P.

$E_K = \dots\dots\dots$  J [3]

- 5 An ideal transformer is connected to a sinusoidal a.c. supply, as shown in Fig. 5.1. The primary coil has a r.m.s. current of 0.85 A.

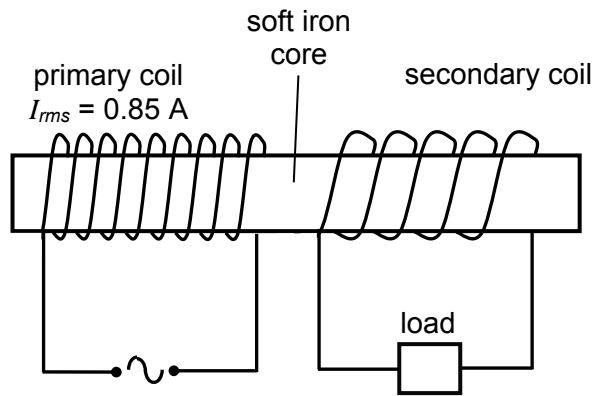


Fig. 5.1

- (a) Use the laws of electromagnetic induction to explain how a potential difference can be developed across the secondary coil.

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

- (b) (i) The primary coil contains 9 turns per cm, calculate the maximum magnetic field strength at its centre.

maximum magnetic field strength = ..... T [2]



- (ii) The ratio of the number of turns in the primary to secondary coil is 16 : 1.  
Calculate the peak current in the load.

peak current = ..... A [2]

- (iii) The variation with time  $t$  of current  $I_p$  in the primary coil is shown in Fig. 5.2.  
On Fig. 5.3, sketch the variation with time  $t$  of current  $I_s$  in the secondary coil. [1]

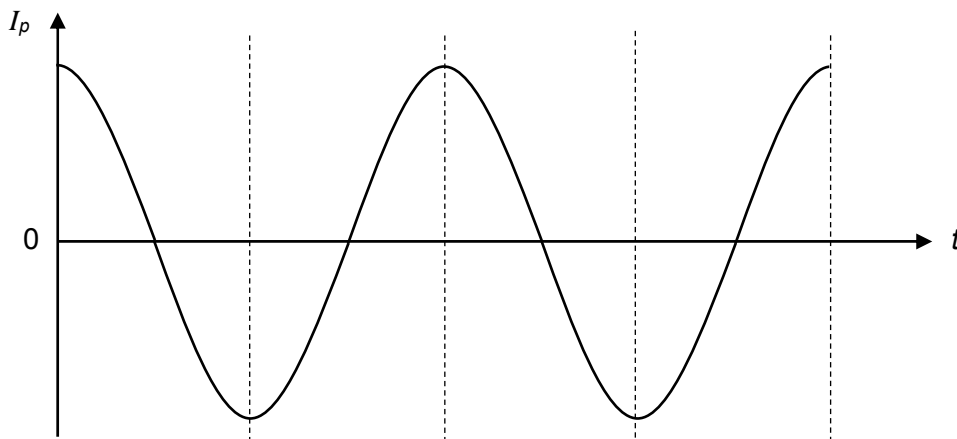


Fig. 5.2

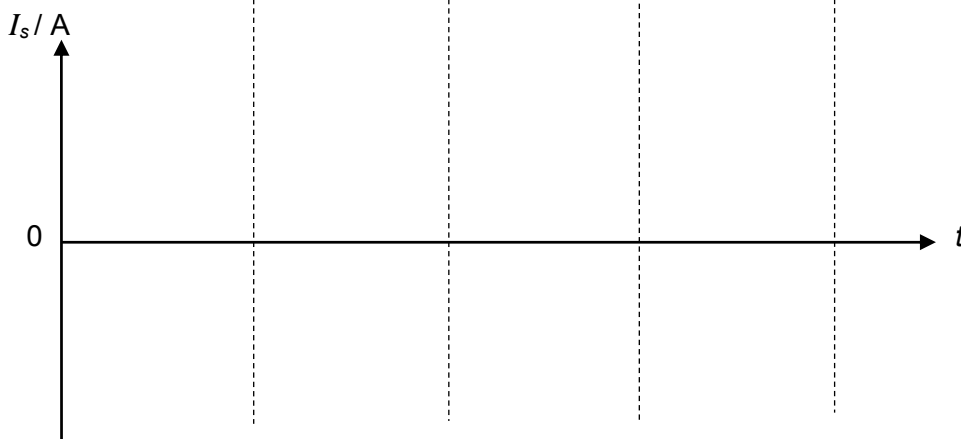


Fig. 5.3

- (iv) State and explain how the answer to **b (iii)** will change if the iron core is removed from the transformer.

.....

.....

..... [2]

- 6 Ultraviolet radiation of wavelength 122 nm is used to illuminate the cathode in the vacuum tube as shown in Fig. 6.1.

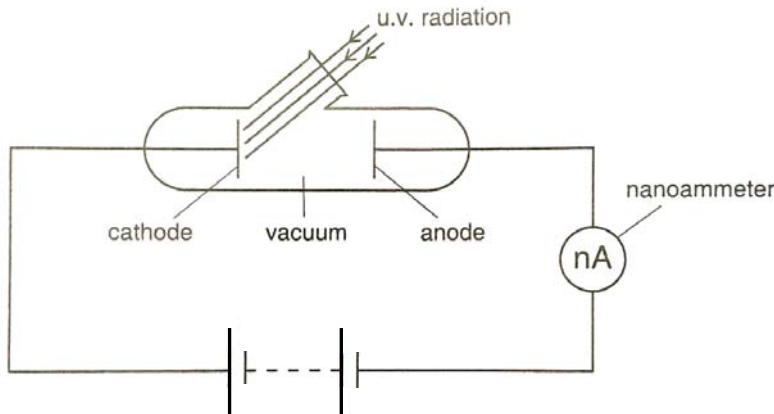


Fig. 6.1

- (a) Photoelectrons are emitted from the cathode and collected at the anode. With the anode made negative and the cathode positive, some photoelectrons can still reach the anode, and by varying the battery's e.m.f, a graph of current against e.m.f. can be plotted as shown in Fig. 6.2.

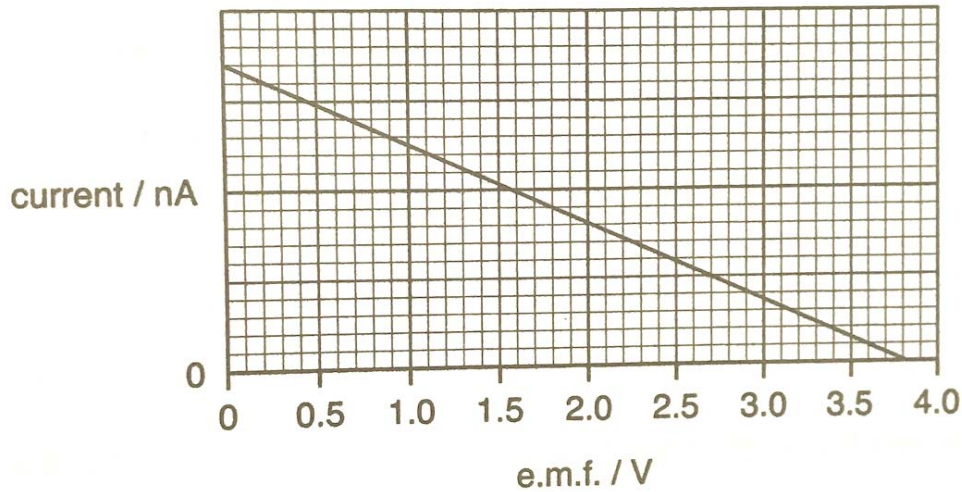


Fig. 6.2

- (i) Explain why some photoelectrons are still able to reach the negative anode.

.....

.....

.....

..... [1]

- (ii) Calculate the maximum speed the photoelectrons can have when they leave the cathode.

maximum speed = .....  $\text{m s}^{-1}$  [2]

- (iii) Calculate the work function of the metal used in the cathode.

work function = ..... J [2]

- (b) The photocurrent  $I$  for different potential difference  $V$  between the cathode and the anode was measured. The experiment was then repeated using ultraviolet radiation of the same wavelength but of different intensity.

The series of graphs of  $I$  against  $V$  are shown in Fig. 6.3.

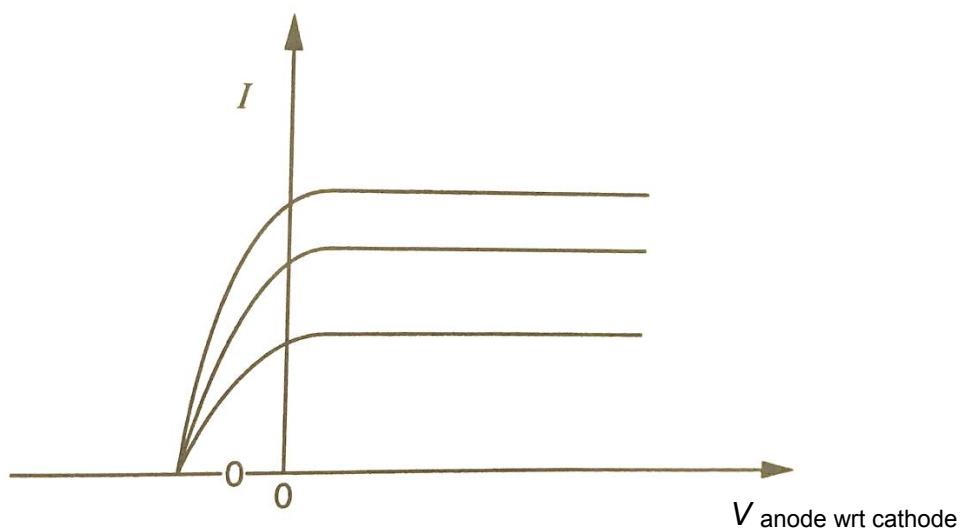


Fig. 6.3

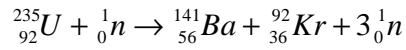
(i) State and explain which feature of this graph could not be explained using the wave theory of light.

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

(ii) Explain why the maximum kinetic energy of photoelectrons is independent of intensity whereas the photoelectric current is proportional to intensity of the light.

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

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



(a) Sketch the variation with nucleon number of the binding energy per nucleon in Fig 7.1. [2]

binding energy per nucleon / MeV



Fig 7.1

(b) Hence, explain why Uranium – 235 is more likely to undergo fission than fusion.

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

- (c) The masses of the various nuclides are as listed below:

nuclide	mass / $u$
Uranium - 235	235.04393
Barium – 141	140.91441
Krypton - 92	91.92616
neutron	1.00867

Determine the energy released in the reaction.

energy released = ..... J [2]

**Section B**

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

8 (a) (i) Define *gravitational field strength*.

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

(ii) Derive, from Newton's Law of Gravitation and (a)(i), the equation for the gravitational field strength of a point mass of mass  $M_1$ , placed in a gravitational field generated by a mass  $M_2$  and at a distance of  $r$  from  $M_1$ . [2]

(b) Information related to the Earth and the Moon is given below:

$$\frac{\text{Radius of Earth}}{\text{Radius of Moon}} = 3.7$$

$$\frac{\text{Mass of Earth}}{\text{Mass of Moon}} = 81$$

The center-to-center distance of the Moon from the Earth is  $3.84 \times 10^8$  m and the gravitational field strength due to the Earth at its surface is  $9.8 \text{ N kg}^{-1}$ .

(i) Using these data, calculate the gravitational field strength due to the Moon at its surface.

gravitational field strength = .....  $\text{N kg}^{-1}$  [3]

- (ii) There is a point on the line between the Earth and the Moon at which their combined gravitational field strength is zero.

Calculate the distance between this point and the centre of the Earth.

distance = ..... m [2]

- (iii) The Moon orbits around the Earth with a period of 27.3 days.

1. Calculate the angular speed of the Moon.

angular speed = ..... rad s<sup>-1</sup> [1]

2. Calculate the mass of the Earth.

mass = ..... kg [2]

3. Determine the gravitational force between the Earth and the Moon.

gravitational force = ..... N [2]



4. Tidal action on the Earth's surface causes the radius of the orbit of the Moon to increase by 4.0 cm each year. Using your answer in **(b)(iii)(3)**, determine the change, in one year, of the gravitational potential energy of the Moon.

change in potential energy = ..... J [2]

- (c) (i)** Explain, by considering the respective field forces, why gravitational potential energy is negative whereas electric potential energy can be positive or negative.

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

- (ii)** The Earth may be assumed to be an isolated sphere of radius  $6.4 \times 10^3$  km with its mass of  $6.0 \times 10^{24}$  kg concentrated at its centre. A 2.0 kg mass is projected vertically from the surface of the Earth so that it reaches a maximum altitude of  $1.3 \times 10^4$  km.

Calculate, for this mass,

1. the change in gravitational potential energy

change in gravitational potential energy = ..... J [2]

2. the speed of projection from the Earth's surface, assuming air resistance is negligible.

speed = .....  $\text{m s}^{-1}$  [2]

- 9 (a) By reference to energy transfers, distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

e.m.f. ....

.....

p.d. ....

..... [2]

- (b) A circuit is set up as shown in Fig. 9.1.

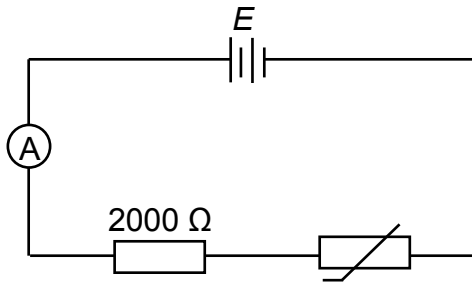


Fig. 9.1

The battery source of emf  $E$  is found to provide  $2.4 \times 10^5$  J of electrical energy to the  $2000 \Omega$  resistor and thermistor when a charge of  $2.2 \times 10^4$  C passes through the ammeter. At room temperature, the thermistor has a resistance of  $1800 \Omega$ .

- (i) Sketch on Fig. 9.2 the variation with temperature  $\theta$  of resistance  $R$  in a thermistor. [1]

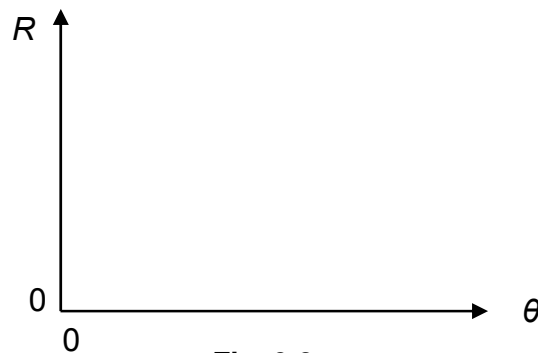


Fig. 9.2

- (ii) For the thermistor at room temperature,

1. show that  $E$  is 11 V.

[1]

2. determine the time taken for a charge of  $2.2 \times 10^4$  C to pass through the ammeter.

time = ..... s [2]

3. show that the fraction of power dissipated in the thermistor is 0.47. [1]

- (c) A uniform resistance wire PQ of length 1.2 m is subsequently connected across the resistor and thermistor, as shown in Fig. 9.3. A sensitive voltmeter is connected between point Y and a moveable contact M on the wire.

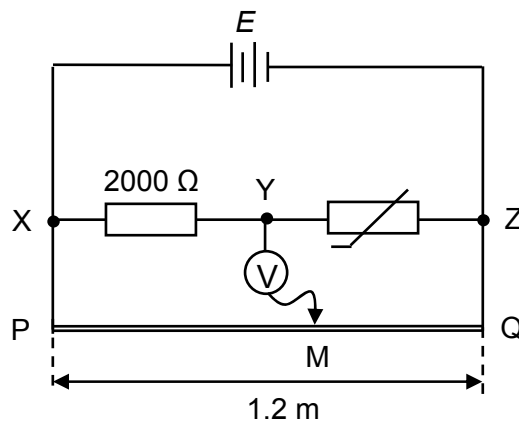


Fig. 9.3

- (i) At room temperature, the contact M is moved along PQ until the voltmeter shows zero reading.

Calculate the length of wire between M and Q.

length of wire = ..... m [2]

(ii) State and explain the effect, if any, on the length of the wire between M and Q for the voltmeter to remain at zero deflection if each of the following changes takes place independently.

1. The thermistor is warmed slightly.

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

2. A uniform wire with a bigger cross sectional area is used to replace PQ.

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

- (d) The circuit shown in Fig. 9.4 is used to compare potential differences.

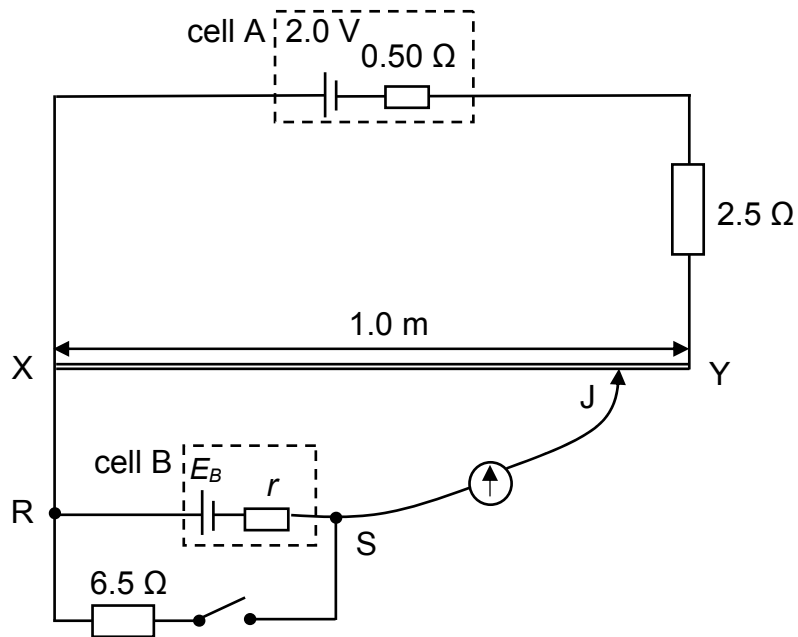


Fig. 9.4

The uniform resistance wire XY has length 1.0 m and resistance 8.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. Cell B has e.m.f.  $E_B$  and internal resistance  $r$ .

- (i) The switch is opened. The galvanometer shows no deflection when the moveable contact J is adjusted so that the length XJ is 0.90 m.

Show that the e.m.f.  $E_B$  of cell B is 1.3 V.

[2]

(ii) The switch is now closed.

1. For the galvanometer to show no deflection, contact J has to be adjusted so that length XJ is 0.75 m.

Determine the internal resistance  $r$  of cell B.

$r = \dots\dots\dots \Omega$  [3]

2. A resistor is connected in parallel with the  $6.5 \Omega$  resistor.

Deduce how the balanced length XJ would be affected.

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

**END OF PAPER**









**SERANGOON JUNIOR COLLEGE**  
**General Certificate of Education Advanced Level**  
**Higher 2**

NAME

CG

INDEX NO.

**PHYSICS**

**9749/03**

**Preliminary Examination**  
**Paper 3 Longer Structured Questions**

**20<sup>th</sup> September 2018**  
**2 hours**

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

**READ THIS INSTRUCTIONS FIRST**

Write your name, civics group and index number in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.  
You may use HB pencil for any diagrams or graphs.  
Do not use staples, paper clips, glue or correction fluid.

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

Answer **all** questions in Section A, and **one** of the two questions in Section B.

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

<b>For Examiners' Use</b>	
<b>Q1</b>	/ 8
<b>Q2</b>	/ 7
<b>Q3</b>	/ 10
<b>Q4</b>	/ 8
<b>Q5</b>	/ 10
<b>Q6</b>	/ 10
<b>Q7</b>	/ 7
<b>Q8</b>	/ 20
<b>Q9</b>	/ 20
<b>Total marks</b>	/ 80

## DATA AND FORMULAE

## Data

speed of light in free space	$c$	$= 3.00 \times 10^8 \text{ m s}^{-1}$
permeability of free space	$\mu_0$	$= 4\pi \times 10^{-7} \text{ H m}^{-1}$
permittivity of free space	$\epsilon_0$	$= 8.85 \times 10^{-12} \text{ F m}^{-1}$ $= \frac{1}{36\pi} \times 10^{-9} \text{ F m}^{-1}$
elementary charge	$e$	$= 1.60 \times 10^{-19} \text{ C}$
the Planck constant	$h$	$= 6.63 \times 10^{-34} \text{ J s}$
unified atomic mass constant	$u$	$= 1.66 \times 10^{-27} \text{ kg}$
rest mass of electron	$m_e$	$= 9.11 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.67 \times 10^{-27} \text{ kg}$
molar gas constant	$R$	$= 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
the Avogadro constant	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
the Boltzmann constant	$k$	$= 1.38 \times 10^{-23} \text{ J K}^{-1}$
gravitational constant	$G$	$= 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
acceleration of free fall	$g$	$= 9.81 \text{ m s}^{-2}$

## DATA AND FORMULAE

## Formulae

uniformly accelerated motion

$$s = ut + \frac{1}{2}at^2$$

work done on/by a gas

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

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential

$$\phi = -\frac{GM}{r}$$

temperature

$$T/K = T/^{\circ}\text{C} + 273.15$$

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

$$I = Anqv$$

resistors in series

$$R = R_1 + R_2 + \dots$$

resistors in parallel

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

electric potential

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/ voltage

$$x = x_0 \sin \omega t$$

magnetic flux density due to a long straight wire

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

magnetic flux density due to a flat circular coil

$$B = \frac{\mu_0 NI}{2r}$$

magnetic flux density due to a long solenoid

$$B = \mu_0 nI$$

radioactive decay

$$x = x_0 \exp(-\lambda t)$$

decay constant

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

## Section A

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

- 1 (a) Define *impulse*.

Product of (average) force and the time that the (average) force acts on the body [1] (or time of impact) .....

..... [1]

- (b) In a car test, a car with a dummy driver and passenger, moving at a speed of  $6.9 \text{ m s}^{-1}$ , collides head-on into a wall. The mass of the car is 1250 kg, the mass of the driver is 85 kg and the mass of the front passenger is 65 kg. The average deceleration of the car as it comes to a stop is  $48 \text{ m s}^{-2}$ . Both passenger and driver have their seat belts tightly fastened.

For the impact,

- (i) determine the magnitude of the average force exerted on the car and its occupants.

$$\text{average force} = ma = (1250+85+65) (48) = 67200 \text{ N}$$

average force = ..... N [1]

- (ii) determine the magnitude of the impulse caused by the force.

$$\begin{aligned} \text{Impulse} &= \text{change in momentum} \\ &= mv - mu \\ &= 0 - (1250+85+65) (6.9) \quad [1] \\ &= -9660 \text{ Ns} \\ \text{Ans: } &9660 \quad [1] \end{aligned}$$

impulse = ..... N s [2]

- (iii) Hence, calculate the time taken for the car to come to a stop.

$$\begin{aligned} \text{By Impulse - momentum theorem,} \\ Ft &= mv - mu \\ t &= 9660/67200 \quad [1] \\ &= 0.144 \text{ s} \quad [1] \end{aligned}$$

time = ..... s [2]

- (iv) Assuming that the average deceleration remains the same, state and explain how your answer in (b)iii) will change (if any) when the total mass of car and occupants has doubled.

No change [A1].  
Since the change in velocity and the deceleration remains unchanged ( $a = \Delta v/\Delta t$ ) [M1]  
Or since the impulse (the change in momentum) and the average force both doubled, the time taken remains unchanged [M1]

..... [2]

- 2 A fixed mass of an ideal monatomic gas undergoes a cycle **ABCA** of changes, as shown in Fig. 2.1.

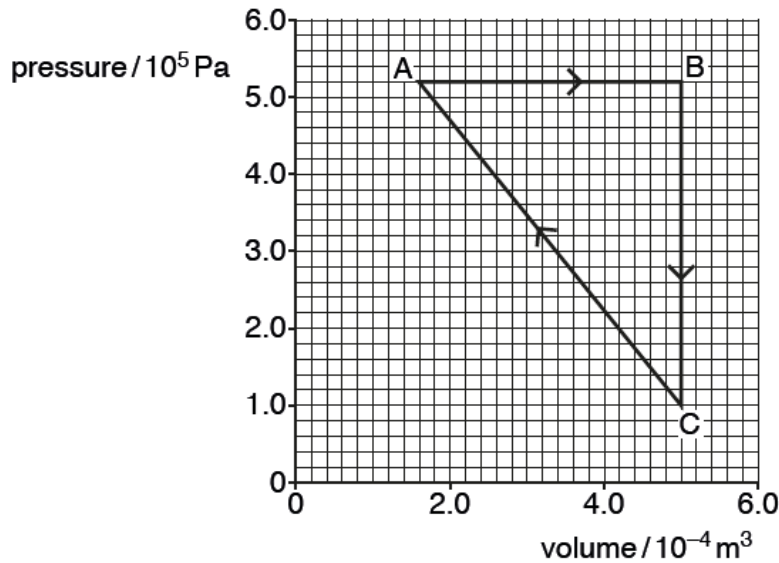


Fig. 2.1

- (a) During the change from **B** to **C**, the internal energy of the gas decreases by 315 J.

By considering molecular energy, state and explain qualitatively the change, if any, in the temperature of the gas.

..... There is negligible potential energy PE. As such, a decrease in internal energy is equivalent to a decrease in kinetic energy. [B1] .....

..... Since KE is proportional to thermodynamic T, a decrease in kinetic energy will lead to a decrease in the temperature of the gas. [B1] .....

..... [2]

- (b) During the change from **A** to **B**, the energy supplied to the gas by heating is 442 J.

Fig. 2.2 is a table of energy changes during one cycle. Complete Fig. 2.2.

section of cycle	heat supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
A to B	442	-177	265
B to C	-315	0	-315
C to A	-55	105	50

Fig. 2.2

[3]

Since  $\Delta U = 0$  for the entire cycle **ABCA**,  
 $\Delta U$  (for process C to A) =  $315 - 265.2 = 49.8$

Work done on gas (from C to A) = area under graph  
 $= (5 - 1.6) \times 10^{-4} \times (5.2 + 1) / 2$   
 $= 105.4 \text{ J}$

By First Law of Thermodynamics,  
 $\Delta U = Q + W$   
 $\Delta Q = 49.8 - 105.4$   
 $\Delta Q = -55.6 \text{ J}$

All W correct – 1 mark  
 Last column correct (add up to 0) – 1 mark  
 First Law correct – 1 mark

- (c) Calculate the root-mean-square speed of the gas atoms at point **B** if the root-mean-square speed at point **A** is  $350 \text{ m s}^{-1}$ .

Since  $\frac{1}{2} \langle c^2 \rangle = \frac{3}{2} kT$

$\sqrt{\langle c^2 \rangle}$  proportional to  $\sqrt{T}$  or  $\sqrt{P}$  when P is constant

$$\frac{\sqrt{\langle c^2 \rangle}}{350} = \sqrt{\frac{5}{1.6}}$$

$$\sqrt{\langle c^2 \rangle} = 619 \text{ m s}^{-1}$$

root-mean-square speed = .....  $\text{m s}^{-1}$  [2]

- 3 (a) As seen in Fig 3.1, a monochromatic light of wavelength 580 nm is used to produce an interference pattern on screen AB. The separation between the slits is 0.41 mm and the perpendicular distance between the double slit and the screen is  $D$ . Point Y is at a distance  $x = 2$  mm from point O and it is the position of the first dark fringe. The intensity of the light passing through the two slits is the same.

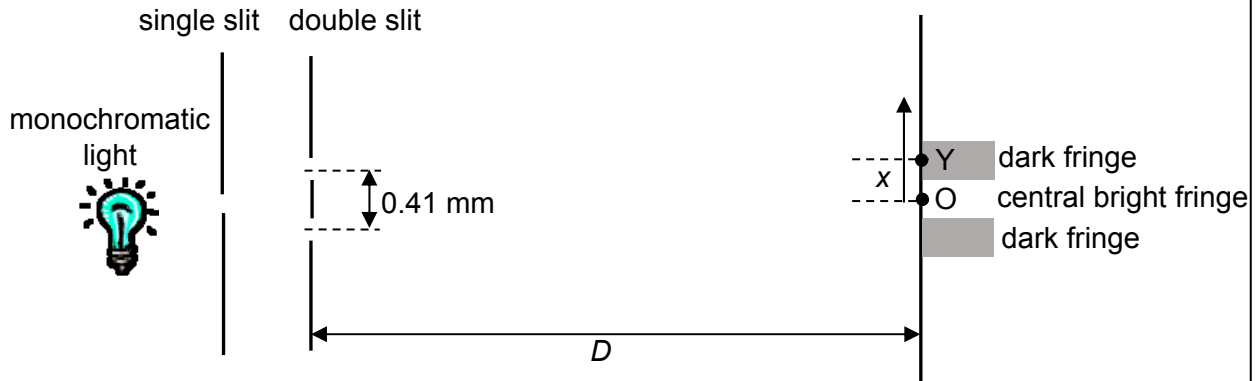


Fig 3.1

- (i) Calculate the path difference between the 2 waves arriving at point Y from the slits.

Path difference = $\lambda/2 = 580 / 2 = 290$ nm
--

distance = ..... nm [1]

- (ii) Calculate the distance  $D$ .

By using $x = \lambda D/a$
$D = 0.41 \times 10^{-3} (2 \times 2 \times 10^{-3}) / 580 \times 10^{-9}$ [M1]
$= 2.8$ m [A1]

$D =$  ..... m [2]

- (ii) The width of both slits is reduced by the same amount without altering their separation. The original variation with distance  $x$  from point O of the intensity is as shown in Fig. 3.2. Sketch the new variation of intensity on Fig. 3.2. [3]

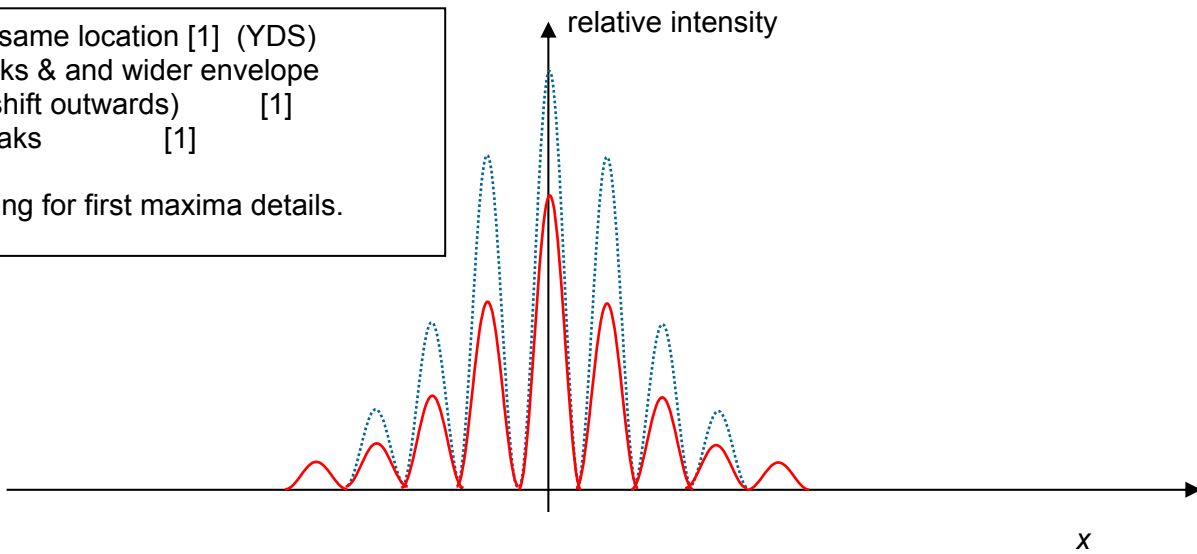


Fig. 3.2



- (b) A diffraction grating is used to measure the wavelengths of light. The angle  $\theta$  of the second order maximum is measured for each wavelength. The variation with wavelength  $\lambda$  of  $\sin \theta$  is shown in Fig 3.3.

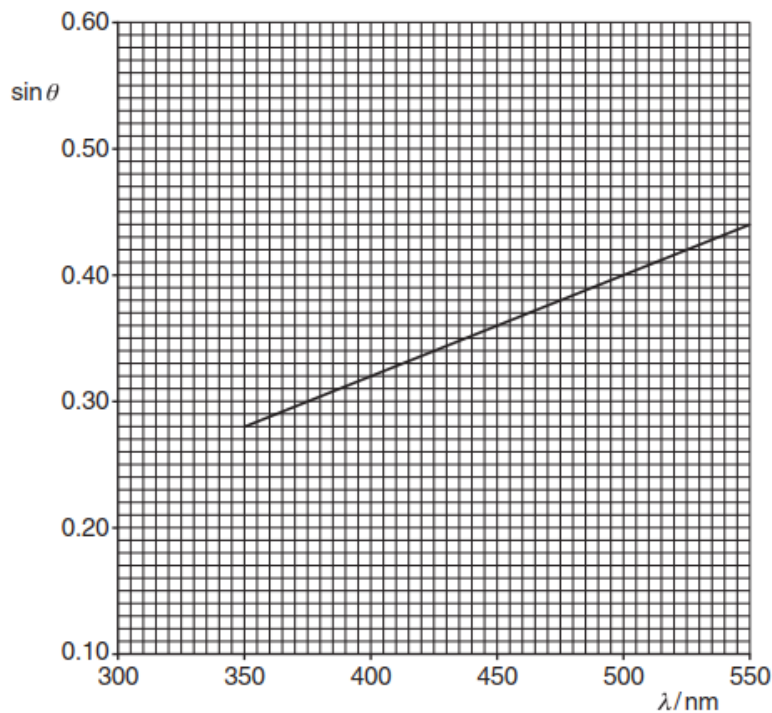


Fig. 3.3

- (i) Calculate the slit separation  $d$  of the diffraction grating.

Gradient = $8.0 \times 10^5$	[B1]
------------------------------	------

$d = n / \text{gradient} = 2 / 8.0 \times 10^5$	[M1]
$= 2.5 \times 10^{-6} \text{ m}$	[A1]

$d = \dots\dots\dots \text{m}$  [3]

- (ii) On Fig. 3.3, sketch a line to show the results that would be obtained for the first order maxima. [1]

straight line drawn with lower gradient ( $\frac{1}{2}$ ) and all new y coordinates are $\frac{1}{2}$ of the original y values
--

4 (a) Define *electric potential* at a point.

..... work done per unit positive charge by an external force [B1] in moving a  
 ..... small test charge from infinity to that point in the electric field [B1] (without a

..... change in its kinetic energy).  
 .....

[2]

(b) Two charged solid spheres A and B are situated in a vacuum. Their centres are separated by a distance of 30.0 cm, as shown in Fig. 4.1. The diagram is not drawn to scale.

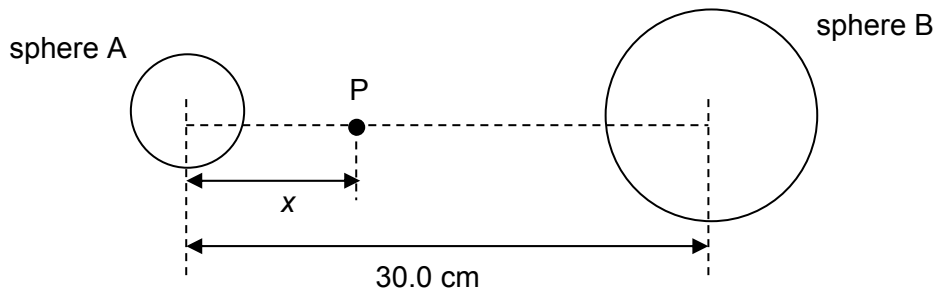


Fig. 4.1

The variation with distance  $x$  of the electric potential  $V_A$  and  $V_B$  due to sphere A and B independently is shown in Fig. 4.2.

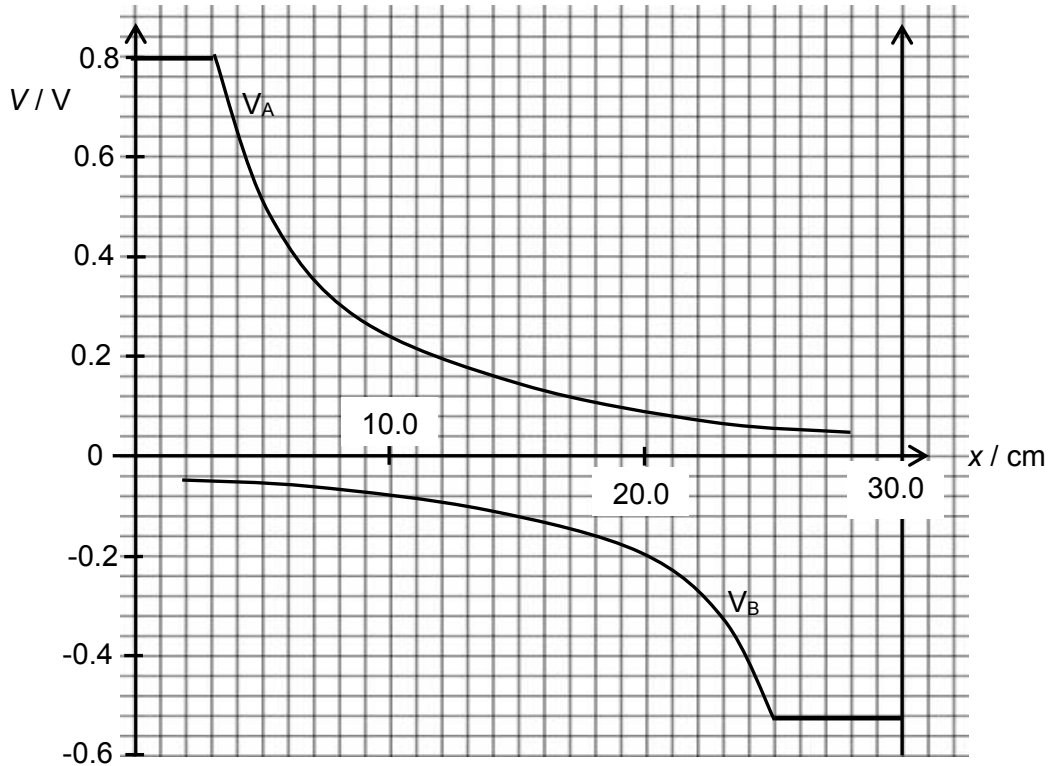


Fig. 4.2

(i) Using Fig. 4.2, state the radius of both spheres.

Sphere A: 3.0 cm  
Sphere B: 5.0 cm

radius of sphere A = ..... cm

radius of sphere B = ..... cm [1]

(ii) State and explain the signs of both spheres.

..... Since the potential of sphere A is positive and that of sphere B is  
..... negative, sphere A is positively charged while sphere B is negatively  
..... charged.  
..... 1 mark – opposite charges  
..... (Cannot accept using gradient to determine direction of E field since  
..... no indication of which direction of x is positive.) [2]

(iii) Point P is at a distance  $x = 10.0$  cm.  
An alpha particle has kinetic energy  $E_K$  when at infinity.

Use Fig. 4.2 to determine the minimum value of  $E_K$  such that the alpha particle may travel from infinity to point P.

Resultant potential (10 cm from sphere A) =  $0.24 + (-0.08) = 0.16$  V [B1]  
By COE,  
Loss in KE = Gain in EPE  
 $E_K - 0 = 0.16 (2 \times 1.6 \times 10^{-19}) - 0$  [M1 –  $2q, q\Delta V, COE$ ]  
 $E_K = 5.12 \times 10^{-20}$  J [A1]  
If B1 correct and M1 wrong, 1 mark.  
If B1 wrong and M1 correct, 1 mark.

$E_K =$  ..... J [3]

- 5 An ideal transformer is connected to a sinusoidal a.c. supply, as shown in Fig. 5.1. The primary coil has a r.m.s. current of 0.85 A.

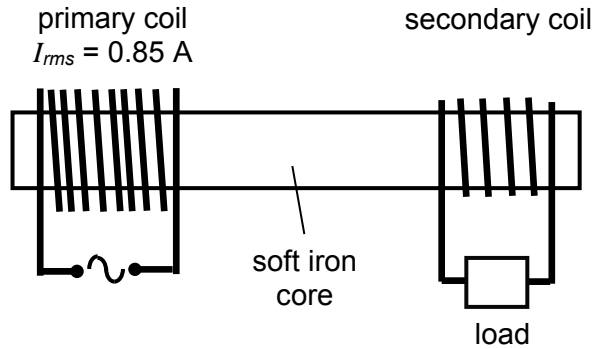


Fig. 5.1

- (a) Use the laws of electromagnetic induction to explain how a potential difference can be developed across the secondary coil.

Alternating current in the primary coil results in an alternating magnetic field strength generated. [M1]  
 Magnetic field strength generated by primary coil linked to secondary coil (via the soft iron core).  
 Secondary coil experiences alternating magnetic flux linkage due to alternating magnetic field strength [M1]. By Faraday's law, an e.m.f. will be induced across the secondary coil. [A1]  
 Without 1<sup>st</sup> M1, max 1 mark.

..... [3]

- (b) (i) The primary coil contains 9 turns per cm, calculate the maximum magnetic field strength at its centre.

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times 9 \times 100 \times 0.85\sqrt{2} = 1.36 \times 10^{-3} \text{ T} \quad [2]$$

maximum magnetic field strength = ..... T [2]

- (ii) The ratio of the number of turns in the primary to secondary coil is 16 : 1.  
Calculate the peak current in the load.

$$\frac{I_s}{I_p} = \frac{N_p}{N_s} = 16$$

$$I_s = 16 \times 0.85\sqrt{2} \quad \text{[M1]}$$

$$= 19.2 \text{ A} \quad \text{[A1]}$$

peak current = ..... A [2]

- (iii) The variation with time  $t$  of current  $I_p$  in the primary coil is shown in Fig. 5.2.  
On Fig. 5.3, sketch the variation with time  $t$  of current  $I_s$  in the secondary coil. [1]

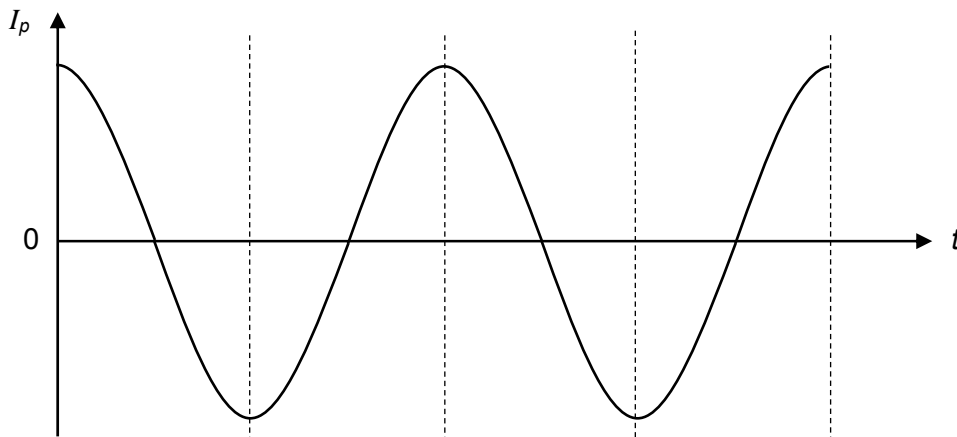


Fig. 5.2

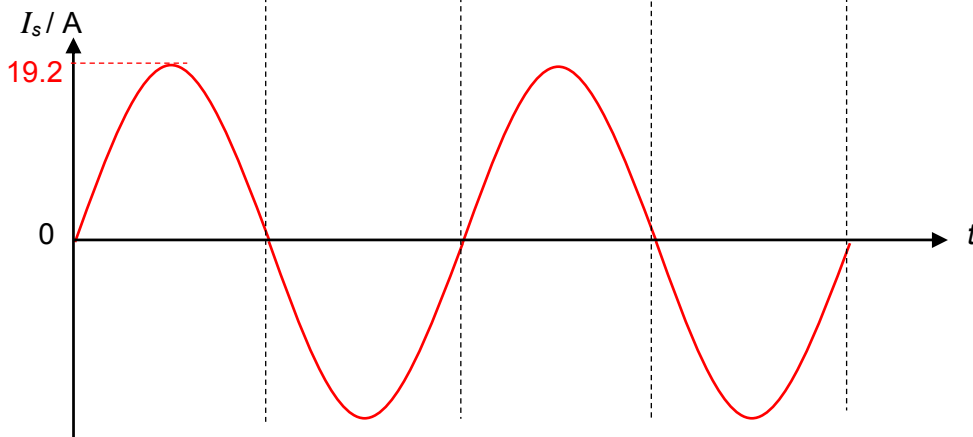


Fig. 5.3

- (iv) State and explain how the answer to b (iii) will change if the iron core is removed from the transformer.

Magnetic flux linking secondary coil will decrease. [M1] .....

Hence rate of change of flux linkage will decrease. (By Faraday's law, induced e.m.f. and) hence magnitude of induced current will decrease. [A1] .....

..... [2]

- 6 Ultraviolet radiation of wavelength 122 nm is used to illuminate the cathode in the vacuum tube as shown in Fig. 6.1.

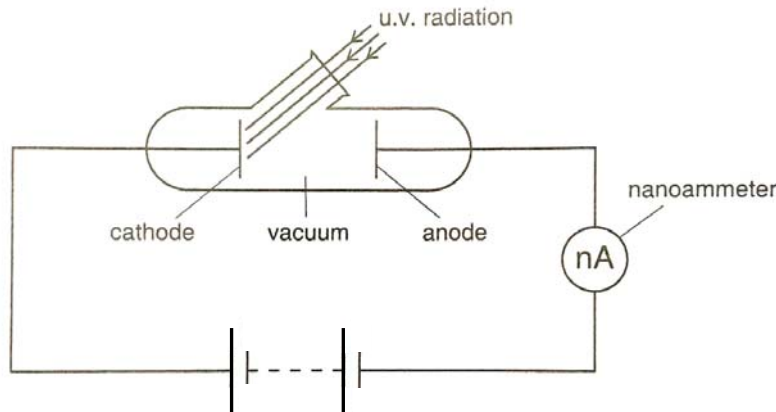


Fig. 6.1

- (a) Photoelectrons are emitted from the cathode and collected at the anode. With the anode made negative and the cathode positive, some photoelectrons can still reach the anode, and by varying the battery's e.m.f, a graph of current against e.m.f. can be plotted as shown in Fig. 6.2.

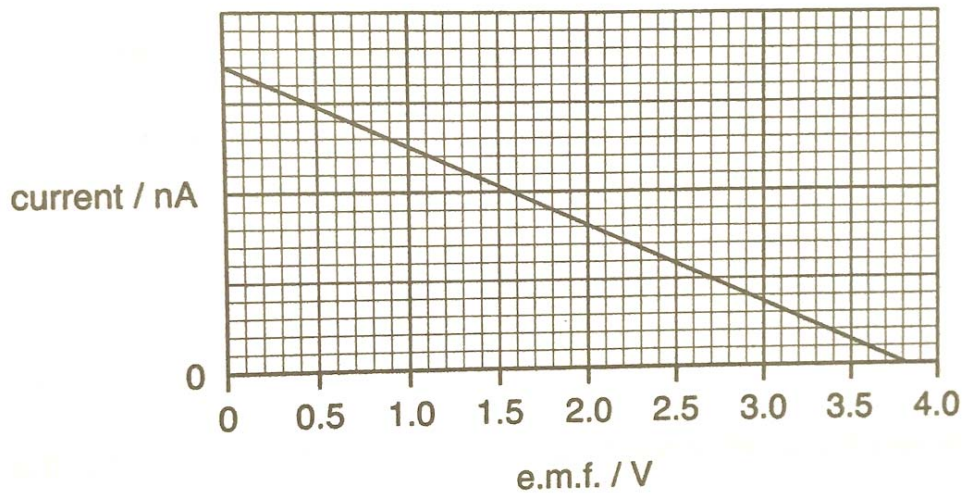


Fig. 6.2

- (i) Explain why some photoelectrons are still able to reach the negative anode.

..... Photoelectrons emitted have kinetic energies ranging from zero to a .....  
 ..... maximum values. Those photoelectrons that **have enough energy to** .....  
 ..... **do work against the electric field** will be able to reach the anode. ....  
 .....  
 ..... [1]

- (ii) Calculate the maximum speed the photoelectrons can have when they leave the cathode.

Loss in KE = Gain in EPE

$$\frac{1}{2} m v_{\max}^2 = e V_s$$

$$\frac{1}{2} (9.11 \times 10^{-31}) V_{\max}^2 = (1.6 \times 10^{-19})(3.8) \quad [1]$$

$$V_{\max} = 1.16 \times 10^6 \text{ m s}^{-1} \quad [1]$$

maximum speed = ..... m s<sup>-1</sup> [2]

- (iii) Calculate the work function of the metal used in the cathode.

$$hf = \phi + eV_s$$

$$\phi = (6.63 \times 10^{-34})(3 \times 10^8)/(122 \times 10^{-9}) - 1.6 \times 10^{-19} (3.8) \quad [1]$$

$$= 1.02 \times 10^{-18} \text{ J} \quad [1]$$

work function = ..... J [2]

- (b) The photocurrent  $I$  for different potential difference  $V$  between the cathode and the anode was measured. The experiment was then repeated using ultraviolet radiation of the same wavelength but of different intensity.

The series of graphs of  $I$  against  $V$  are shown in Fig. 6.3.

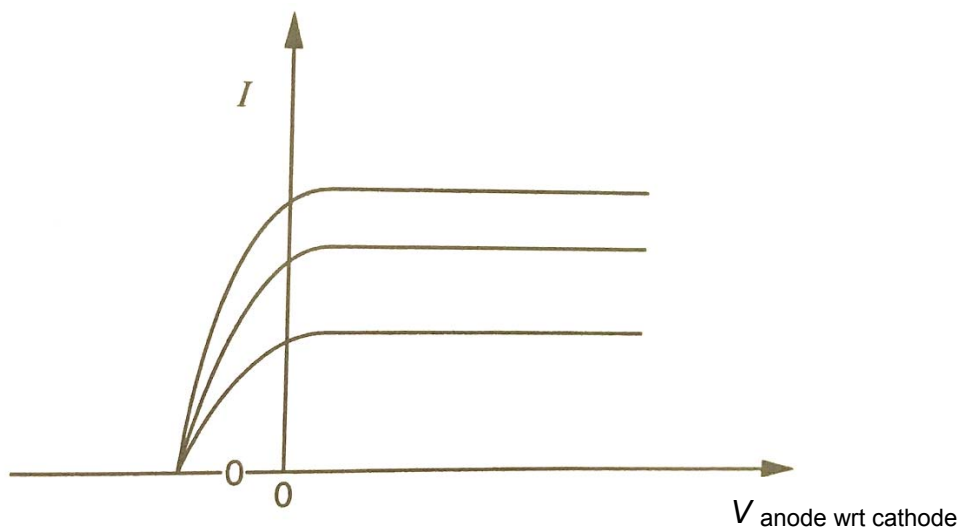


Fig. 6.3

(i) State and explain which feature of this graph could not be explained using the wave theory of light.

The stopping potential is independent of the intensity of the radiation [1].  
According to wave theory, the higher the intensity, the more energy the light would possess which would cause the **photoelectrons emitted to have higher kinetic energy**, and hence **a higher stopping potential to bring them to rest** [1].

[2]

(ii) Explain why the maximum kinetic energy of photoelectrons is independent of intensity whereas the photoelectric current is proportional to intensity of the light.

When electromagnetic radiation is irradiated on the metal surface, the energy is delivered in packets known as photons. The energy of each photon energy is  $hf$  (where  $h$  is Planck's constant and  $f$  is the frequency of radiation.) [B1]

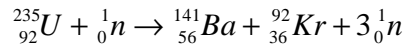
Photons interact with the electrons on a 1-to-1 basis such that the maximum kinetic energy of the emitted photoelectron,  $KE_{max} = hf - \phi$  is dependent only on the frequency of the radiation and  $\phi$ , the work function of the metal. [B1]

For light of a constant frequency, intensity is directly proportional to the rate of incidence of photons which is in turn directly proportional to the rate of photoelectrons emitted, and hence the photoelectric current. [B1]

[3]



7 An induced nuclear fission reaction maybe represented by the equation



(a) Sketch the variation with nucleon number of the binding energy per nucleon. [2]

binding energy per nucleon / MeV

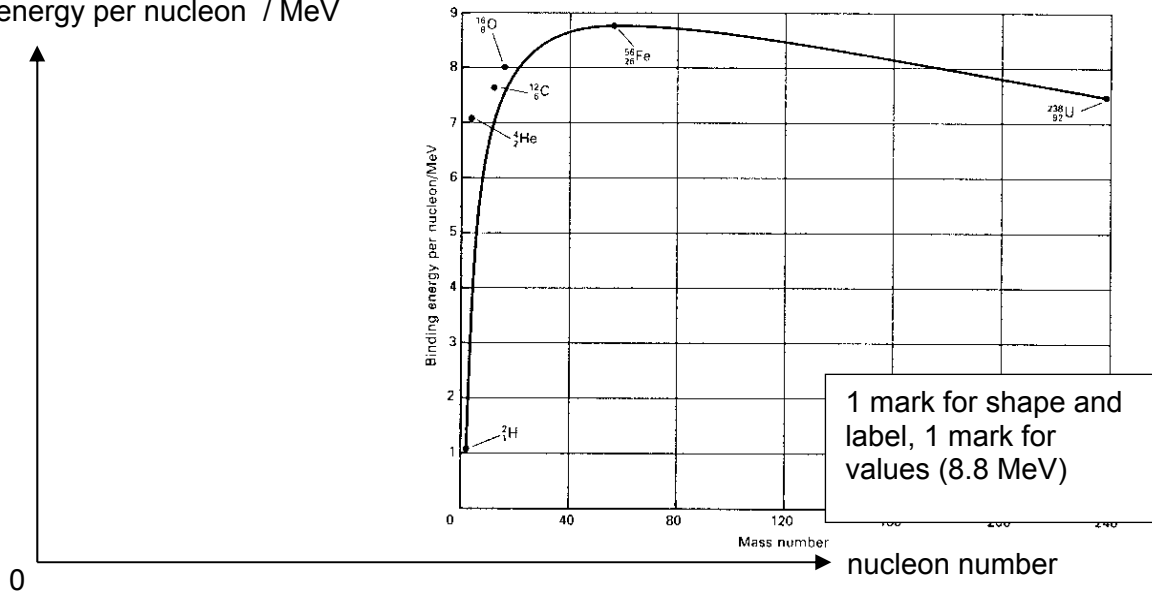


Fig. 7.1

(b) Hence, explain why Uranium – 235 is more likely to undergo fission than fusion.

Uranium-235 is on the right hand side of graph, beyond Fe-56. ....

BE is the BE per nucleon multiply by the number of nucleons. [B1] ....

Fission involves breaking a larger nucleus into smaller nuclei [B1]. ....

Fission will involve products with higher BE per nucleon, hence more stable products and more likely to occur. [B1] or Fission implies increase of total BE and hence release of energy, hence more likely to occur. [B1] ....

..[3]

(c) The masses of the various nuclides are as listed below:

nuclide	mass / $u$
Uranium - 235	235.04393
Barium - 141	140.91441
Krypton - 92	91.92616
neutron	1.00867

Determine the energy released in the reaction.

$$\begin{aligned} \text{Energy released} &= \text{mass of reactants} - \text{mass of products} \\ &= (235.04393 + 1.00867) - [140.91441 + 91.92616 + 3(1.00867)]uc^2 \quad [\text{M1}] \\ &= 0.18602uc^2 \\ &= 2.78 \times 10^{-11} \text{ J} \quad [\text{A1}] \end{aligned}$$

energy released = ..... J [2]

**Section B**

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

**8 (a)(i)** Define *gravitational field strength*.

..... The gravitational field strength at a point is the gravitational force exerted .....  
 ..... per unit mass when a small test mass is placed at that point in a .....  
 ..... gravitational field. ....

..... [1]

**(ii)** Derive, from Newton's Law of Gravitation and **(a)(i)** above, the equation for the gravitational field strength of a point mass of mass  $M_1$ , placed in a gravitational field generated by a mass  $M_2$  and at a distance of  $r$  from  $M_1$ . [2]

Since  $g = F/M_1$   
 and  $F = GM_1M_2/r^2$  [Both equations to get 1]  
  
 Therefore,  $g = GM_1M_2/r^2 / M_1$   
 $= GM_2/r^2$  [1]

**(b)** Information related to the Earth and the Moon is given below:

$$\frac{\text{Radius of Earth}}{\text{Radius of Moon}} = 3.7$$

$$\frac{\text{Mass of Earth}}{\text{Mass of Moon}} = 81$$

The center-to-center distance of the Moon from the Earth is  $3.84 \times 10^8$  m and the gravitational field strength due to the Earth at its surface is  $9.8 \text{ N kg}^{-1}$ .

**(i)** Using these data, calculate the gravitational field strength due to the Moon at its surface.

Since  $g \propto M/r$ ,  
 $\frac{g_M}{g_E} = \left(\frac{M_M}{M_E}\right) \left(\frac{r_E}{r_M}\right)^2$  [M1]  
 $= (1/81)(3.7)^2$   
 $= 0.169$   
  
 Therefore,  $g$  due to Moon =  $0.169 \times 9.81$   
 $= 1.66 \text{ N kg}^{-1}$  [A1]

gravitational field strength = .....  $\text{N kg}^{-1}$  [3]

- (ii) There is a point on the line between the Earth and the Moon at which their combined gravitational field strength is zero.

Calculate the distance between this point and the centre of the Earth.

$$\frac{GM_E}{r^2} = \frac{GM_M}{(3.84 \times 10^8 - r)^2}$$

$$81 = \frac{r^2}{(3.84 \times 10^8 - r)^2} \quad [1]$$

$$r = 3.46 \times 10^8 \text{ m} \quad [1]$$

distance = ..... m [2]

- (iii) The Moon orbits around the Earth with a period of 27.3 days.

1. Calculate the angular speed of the Moon.

$$\omega = 2\pi/T$$

$$= 2\pi/(27.3 \times 24 \times 60 \times 60)$$

$$= 2.66 \times 10^{-6} \text{ rad s}^{-1} \quad [1]$$

angular speed = ..... rad s<sup>-1</sup> [1]

2. Calculate the mass of the Earth.

Gravitational acceleration provides centripetal acceleration.

$$GM/r^2 = r\omega^2$$

$$M = r^3\omega^2/G \quad [M1]$$

$$= (3.84 \times 10^8)^3 \times (2.66 \times 10^{-6})^2 / 6.67 \times 10^{-11}$$

$$= 6.0 \times 10^{24} \quad [A1]$$

..... kg [2]

3. Determine the gravitational force between the Earth and the Moon.

Mass of Moon = 1/81 Mass of Earth

$$F = GM_E M_M / r^2$$

$$= [6.67 \times 10^{-11} (6.0 \times 10^{24})^2 / 81] / (3.84 \times 10^8)^2 \quad [1]$$

$$= 2.01 \times 10^{20} \quad [1]$$

gravitational force = ..... N [2]

4. Tidal action on the Earth's surface causes the radius of the orbit of the Moon to increase by 4.0 cm each year. Using your answer in **(b)(iii)(3)**, determine the change, in one year, of the gravitational potential energy of the Moon.

$$\begin{aligned} &\text{Change in potential energy} \\ &= \text{Work done by external force} \\ &= 2.01 \times 10^{20} \times 0.04 \text{ [1]} \\ &= 8.04 \times 10^{18} \text{ J [1]} \end{aligned}$$

change in potential energy = ..... J [2]

- (c) (i) Explain, by considering the respective field force, why gravitational potential energy is negative whereas electric potential energy can be positive or negative.

Gravitational forces are **always attractive**, whereas electric forces **can be attractive or repulsive**. [1]

.....[1]

- (ii) The Earth may be assumed to be an isolated sphere of radius  $6.4 \times 10^3$  km with its mass of  $6.0 \times 10^{24}$  kg concentrated at its centre. A 2.0 kg mass is projected vertically from the surface of the Earth so that it reaches a maximum altitude of  $1.3 \times 10^4$  km.

Calculate, for this mass,

1. the change in gravitational potential energy

$$\begin{aligned} &\text{Change in GPE} \\ &= -GMm/r_2 - (-GMm/r_1) \\ &= GMm (1/r_1 - 1/r_2) \\ &= 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 2.0 (1/6.4 \times 10^6 - 1/(6.4 \times 10^6 + 1.3 \times 10^7)) \text{ [M1]} \\ &= 8.38 \times 10^7 \text{ J [A1]} \end{aligned}$$

change in gravitational potential energy = ..... J [2]

2. the speed of projection from the Earth's surface, assuming air resistance is negligible.

$$\begin{aligned} &\text{By COE, Loss in KE} = \text{Gain in GPE} \\ &\frac{1}{2} m v^2 = 8.38 \times 10^7 \\ &\frac{1}{2} (2) v^2 = 8.38 \times 10^7 \text{ [M1]} \\ &v = 9150 \text{ m s}^{-1} \text{ [A1]} \end{aligned}$$

speed = ..... m s<sup>-1</sup> [2]

- 9 (a) By reference to energy transfers, distinguish between electromotive force (e.m.f.) and potential difference (p.d.).

e.m.f. ....	Emf: electrical energy converted from other forms of energy per unit charge delivered round a complete circuit.	.....
.....		.....
p.d. ....	Pd: The potential difference between two points in a circuit is the amount of energy converted from electrical to other forms of energy per unit charge passing from one point to the other	.....
.....		..... [2]

- (b) A circuit is set up as shown in Fig. 9.1.

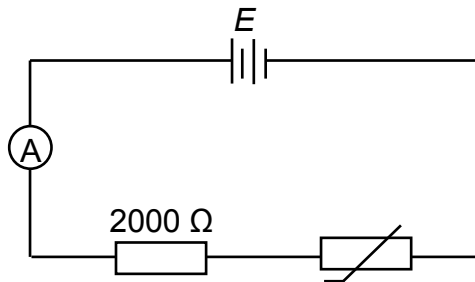


Fig. 9.1

The source of e.m.f.  $E$  is found to provide  $2.4 \times 10^5$  J of electrical energy to the  $2000 \Omega$  resistor and thermistor when a charge of  $2.2 \times 10^4$  C passes through the ammeter. At room temperature, the thermistor has a resistance of  $1800 \Omega$ .

- (i) Sketch on Fig. 9.2 the variation with temperature  $\theta$  of resistance  $R$  in a thermistor. [1]

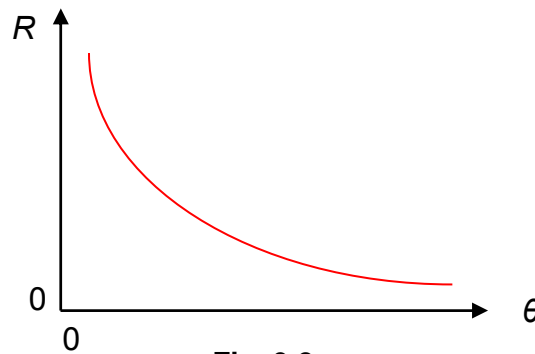


Fig. 9.2

- (ii) For the thermistor at room temperature,

1. show that  $E$  is 11 V. [1]

$E = \frac{W}{Q} = \frac{2.4 \times 10^5}{2.2 \times 10^4} = 11\text{V} \quad \text{[M1]}$
--

2. determine the time taken for a charge of  $2.2 \times 10^4$  C to pass through the ammeter.

$$Q = It = \frac{E}{R}t$$

$$\Rightarrow t = \frac{QR}{E} = \frac{2.2 \times 10^4 \times 3800}{11} \quad [\text{M1}]$$

$$= 7.6 \times 10^6 \text{ s} \quad [\text{A1}]$$

time = ..... s [2]

3. show that the fraction of power dissipated in the thermistor is 0.47. [1]

$$\text{fraction} = \frac{I^2 R_T}{I^2 R_T + I^2 R} = \frac{R_T}{R_T + R} = \frac{1800}{1800 + 2000} \quad [\text{M1}]$$

$$= 0.474$$

- (c) A uniform resistance wire PQ of length 1.2 m is subsequently connected across the resistor and thermistor, as shown in Fig. 9.3. A sensitive voltmeter is connected between point Y and a moveable contact M on the wire.

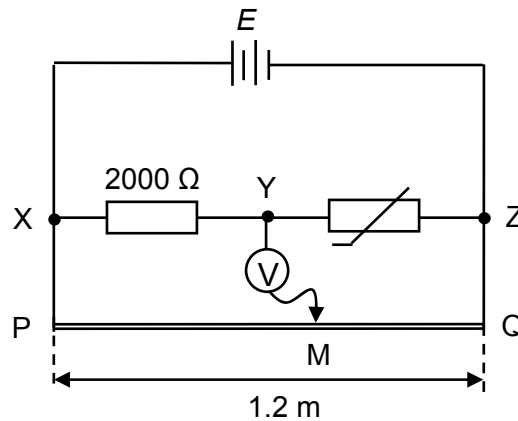


Fig. 9.3

- (i) At room temperature, the contact M is moved along PQ until the voltmeter shows zero reading.

Calculate the length of wire between M and Q.

Potential difference between MQ and YZ has to be the same for voltmeter to register zero reading.

$$\frac{L}{1.2} = \frac{1800}{3800} \quad [\text{M1}]$$

$$L = 0.568 \text{ m} \quad [\text{A1}]$$

length of wire = ..... m [2]

(ii) State and explain the effect, if any, on the length of the wire between M and Q for the voltmeter to remain at zero deflection if each of the following changes takes place independently.

1. The thermistor is warmed slightly.

(As temperature rises), resistance of thermistor decreases and by Potential Divider Principle, the potential difference across the thermistor drops. ....

For zero deflection, the potential difference across the thermistor and across MQ have to be the same. Since the pd across MQ is proportional to its length, MQ is shorter. ....

.. [2]

2. A uniform wire with a bigger cross sectional area is used to replace PQ.

While the bigger cross-sectional area will result in a lower resistance in the wire PQ, as the potential difference across PQ did not change, the potential difference per unit length remains the same. ....

Since potential difference across thermistor (and resistor) did not change, the length of wire will not need to change. ....

.. [2]



- (d) The circuit shown in Fig. 9.4 is used to compare potential differences.

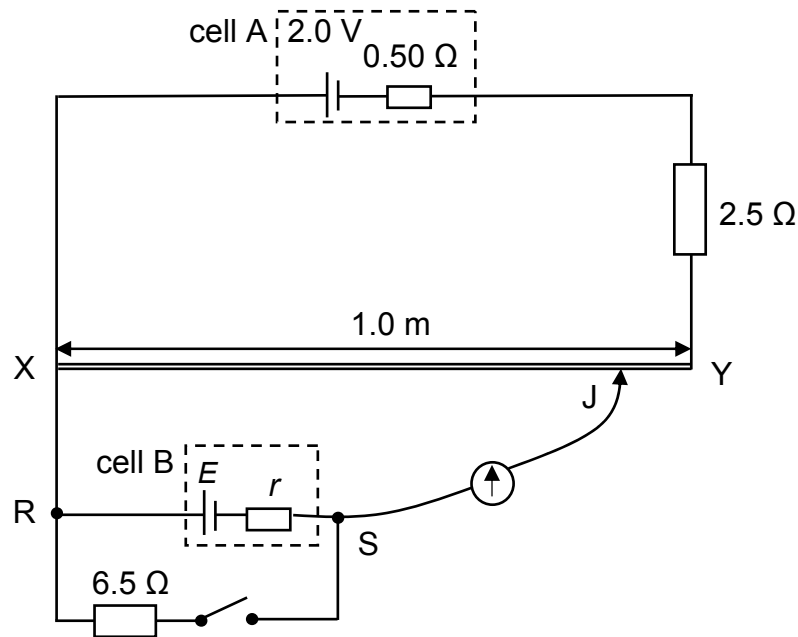


Fig. 9.4

The uniform resistance wire XY has length 1.0 m and resistance 8.0 Ω. Cell A has e.m.f. 2.0 V and internal resistance 0.50 Ω. Cell B has e.m.f.  $E$  and internal resistance  $r$ .

- (i) The switch is opened. The galvanometer shows no deflection when the moveable contact J is adjusted so that the length XJ is 0.90 m.

Show that the e.m.f.  $E$  of cell B is 1.3 V.

[2]

$$V_{XY} = \frac{8.0}{8.0 + 0.50 + 2.5} \times 2.0 = 1.455 \text{ V} \quad [\text{M1}]$$

At null deflection,  $V_{XJ} = \text{e.m.f. of cell B.}$

$$E = \frac{0.90}{1.0} \times 1.455 = 1.31 \text{ V} \quad [\text{M1}]$$

(ii) The switch is now closed.

1. For the galvanometer to show no deflection, contact J has to be adjusted so that length XJ is 0.75 m.

Determine the internal resistance  $r$  of cell B.

At null deflection,  $V_{XJ} = V_{RS}$

$$V_{XJ} = \frac{0.75}{1.0} \times 1.455 = 1.091 \text{ V} \quad [\text{M1}]$$

$$I = \frac{V}{R} = \frac{1.091}{6.5} = 0.1679 \text{ A} \quad [\text{M1}]$$

$$E = V + Ir \Rightarrow r = \frac{E - V}{I} = \frac{1.3 - 1.091}{0.1679} = 1.25 \text{ } \Omega \quad [\text{A1}]$$

$r = \dots\dots\dots \Omega$  [3]

2. A resistor is connected in parallel with the  $6.5 \text{ } \Omega$  resistor.

Deduce how the balanced length XJ would be affected.

With resistor connected in parallel, load resistance of cell B would decrease.  
 This would cause terminal p.d. of cell B to decrease. [1]  
 Since no change in potential difference per unit length along wire XY,  
 Balance length XJ would decrease. [A1]

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

**END OF PAPER**



