Candidate's Name ………………………………………….……… CTG ……….……

YISHUN JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATIONS 2018

PHYSICS **9749/1**

HIGHER 2 **14th September 2018**

1 hour

Paper 1 Multiple Choice

Additional Material:
Optical Mark Sheet

READ THESE INSTRUCTIONS FIRST

Do not open this booklet until you are told to do so.

Write your name and CTG on the Optical Mark Sheet in the spaces provided.
Shade your NRIC in the space provided.

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

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

Read the instructions on the Optical Mark Sheet carefully.

INFORMATION FOR CANDIDATES

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.

Data

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

Formulae

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

1 A student counts the oscillations of a simple pendulum but mistakenly starts by counting "1" instead of "0" when the bob is released. He finishes at a count of "10".

What is the percentage error in the student's calculation of the period, due to this mistake?

A 10% low **B** 10% high **C** 11% low **D** 11% high

2 A ball is thrown horizontally from the top of a tower and fall towards the ground below. The initial velocity of the stone is v.

Assuming that air resistance is negligible, what is the vertical velocity and horizontal displacement of the ball t seconds after leaving the tower?

	Vertical velocity	Horizontal displacement
A	gt	$\frac{1}{2} gt^2$
B	$v + gt$	$vt + \frac{1}{2} gt^2$
C	gt	$vt + \frac{1}{2} gt^2$
D	gt	vt

3 A ball of mass 0.050 kg, initially moving at 0.40 m s^{-1}, is struck by a racket exerting an average force of 250 N in the opposite direction for 1.2 ms. What is the final speed of the ball?

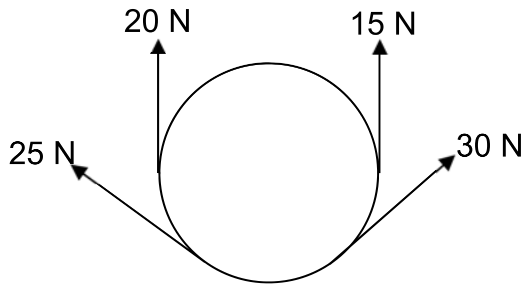
A 5.6 m s^{-1} **B** 6.0 m s^{-1} **C** 6.4 m s^{-1} **D** 12.2 m s^{-1}

4 A sub-atomic particle of mass 0.113 u collides head-on elastically with a stationary neutron. If the neutron moves off with a speed of 3.8×10^6 m s^{-1}, what is the initial speed of the sub-atomic particle?

A 1.49×10^7 m s^{-1} **B** 1.87×10^7 m s^{-1}

C 3.74×10^7 m s^{-1} **D** 4.85×10^7 m s^{-1}

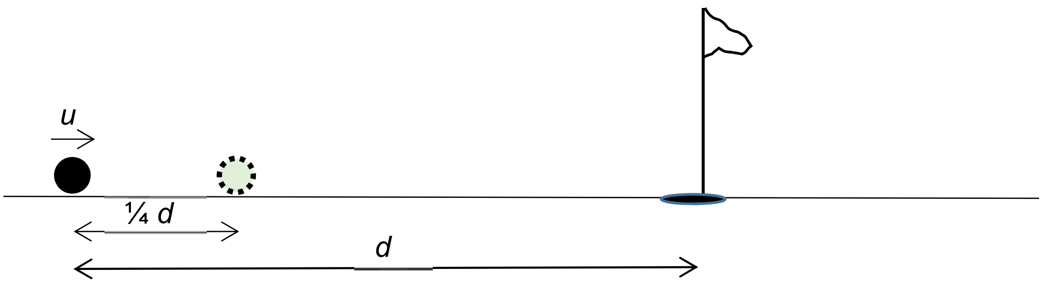
5 Four coplanar forces act on a circular disc as shown.



What is the net force and net torque on the disc?

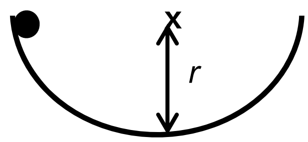
	Net force	Net torque
A	Zero	Non-zero
B	Zero	Zero
C	Non-zero	Non-zero
D	Non-zero	Zero

6 A golfer badly misjudges a hit, sending the ball only one-quarter of the distance to the hole. The hit gave the ball an initial speed of u, along a straight line on the grass. If the force of resistance due to the grass is constant, what should be the minimum initial speed needed to get the ball to the hole from its original position?



A $2u$ **B** $3u$ **C** $4u$ **D** $8u$

7 A small object of weight *mg* is released from rest at the rim of a smooth semi-spherical bowl of radius *r*. What is the magnitude of the normal force (in terms of *mg*) acting on the object when it passes the bottom of the bowl?



A *mg* **B** 2.0 *mg* **C** 2.5 *mg* **D** 3.0 *mg*

8 A car travels over a hump of radius *r*. When it is at the highest point of the hump, the driver whose safety belt is not secured, becomes weightless for an instant. What is the speed of the car, in terms of *r* and *g*, at this particular instant?

A $\sqrt{\frac{rg}{2}}$ **B** $\frac{\sqrt{rg}}{2}$

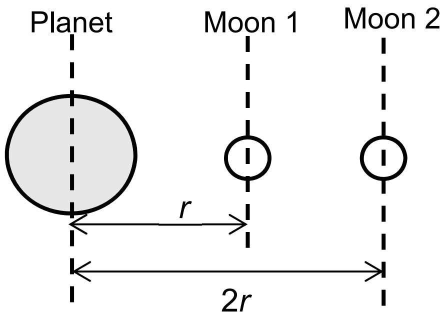
C $\sqrt{rg}$ **D** rg

9 A satellite is at a height *h* above the surface of the Earth. If the radius of the Earth is *r*, and the acceleration due to gravity at the Earth's surface is *g*, the period of orbit of the satellite will be

A $2\pi\sqrt{\frac{r+h}{g}}$ **B** $2\pi\sqrt{\frac{(r+h)^2}{gr}}$

C $2\pi\sqrt{\frac{r^2}{g(r+h)}}$ **D** $2\pi\sqrt{\frac{(r+h)^3}{gr^2}}$

10 A planet has two moons with identical mass. Moon 1 is in circular orbit of radius r. Moon 2 is in a circular orbit of radius $2r$.



What is the ratio of $\dfrac{\text{Force exerted by planet on Moon 2}}{\text{Force exerted by planet on Moon 1}}$?

A 4 **B** 2 **C** 0.5 **D** 0.25

11 A flask of volume 3.0×10^{-4} m^3 contains nitrogen gas at a pressure of 2.5×10^5 Pa and temperature of 27 ^{O}C.

What is the number of nitrogen molecules in the flask?

A 0.030 **B** 0.25 **C** 1.8×10^{22} **D** 2.0×10^{23}

12 Which of the following statements is not a valid assumption of kinetic theory of gases?

A Intermolecular forces between molecules are negligible.

B The molecules experience negligible change in momentum on collision with the walls of the container.

C The molecules experience negligible change in average kinetic energy on collision with the walls of the container.

D The duration of a collision is negligible compared with time between collisions.

13 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is the same direction as the acceleration.

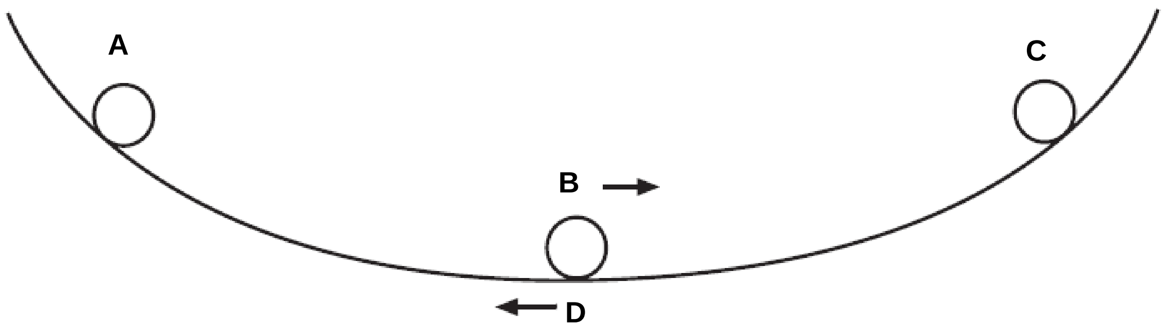
B It is the opposite direction to the velocity.

C It is the same direction as the displacement.

D It is proportional to the displacement.

14 A ball bearing rolls on a concave surface, as shown in the diagram, in approximate simple harmonic motion. It is released from **A** and passes through the lowest point **B** before reaching **C**. It then returns through the lowest point **D**.

At which stage, **A**, **B**, **C** or **D**, does the ball bearing experience maximum acceleration to the left?



15 Consider a sound source of power, P, emitting energy uniformly in all directions. A sensitive microphone at a distance 5.0 m from the sound source detects the intensity of the sound as 3.0×10^{-4} W m^{-2}. The microphone is then moved to 10.0 m from the sound source. In order to detect sound of intensity that is doubled at this new location, that is, 6.0×10^{-4} W m^{-2}, the power of the source must be increased to

A 2P

B 4P

C 8P

D 16P

16 A car passes you on the highway and you notice the tail lights of the car are 1.26 m apart. The car is 14.4 km away when the tail lights appear to merge into a single spot of light.

What is the angular resolution as the lights just appear to merge into a single spot of light?

A 4.73×10^{-3} radians **B** 8.75×10^{-3} radians

C 4.73×10^{-5} radians **D** 8.75×10^{-5} radians

17 In a Young's double-slit experiment, a coherent monochromatic light illuminates the two slits, producing an interference pattern on a screen some distance away.

Which modification increases the separation between the dark fringes on the screen?

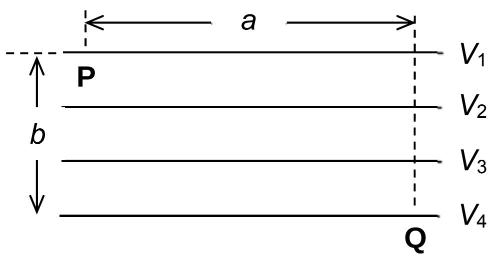
A Increasing the slit separation

B Decreasing distance between the screen and the slits

C Using monochromatic light of higher intensity

D Using monochromatic light of lower frequency

18 An electron, placed at a point **P** inside a uniform electric field, experiences a force of magnitude F. The horizontal lines below are equipotential lines and $V_4 > V_1$.

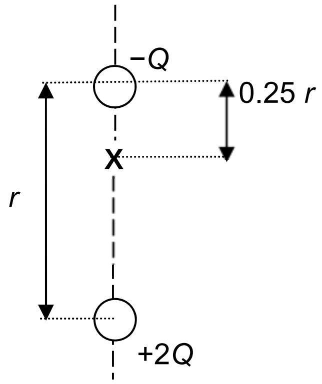


The electron is moved from **P** to **Q**. What is the work done on the electron?

A $-Fb$ **B** $-Fa$

C Fb **D** Fa

19 Two point charges of −Q and +2Q are lined up in a vertical straight line as shown below. The distance between them is r.



What is the electric potential energy of a point charge +3Q when it is placed at position X, a distance 0.25 r from –Q?

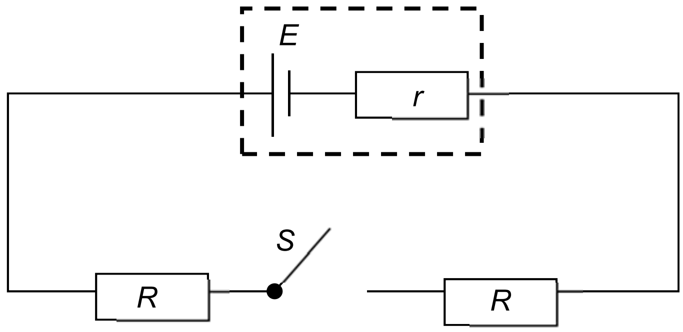
A $\dfrac{5Q^2}{\pi\varepsilon_0 r}$

B $\dfrac{Q^2}{\pi\varepsilon_0 r}$

C $-\dfrac{5Q^2}{\pi\varepsilon_0 r}$

D $-\dfrac{Q^2}{\pi\varepsilon_0 r}$

20 A battery, with an e.m.f E and internal resistance r, is connected to a switch S and two identical resistors in series. Each resistor has resistance R.



Which of the following statements is correct when the switch S is closed?

A The rate at which energy is dissipated across R is $\dfrac{E^2}{4R}$.

B The rate at which energy is dissipated across R is $\dfrac{E^2 r}{2R+r}$.

C The rate at which energy is dissipated across r is $\dfrac{E^2 r}{(2R+r)^2}$.

D It is impossible to determine the rate at which energy is dissipated across R.

21 Wire X has resistivity ρ. Another wire Y, of the same resistance as X, has triple the length and double the diameter of wire X.

The resistivity of wire Y is

A $\dfrac{4\rho}{3}$

B $\dfrac{3\rho}{4}$

C $\dfrac{3\rho}{2}$

D $\dfrac{2\rho}{3}$

22 With 4 resistors, each having a resistance of 12 Ω, it is **impossible** to arrange all 4 resistors to have an effective resistance of

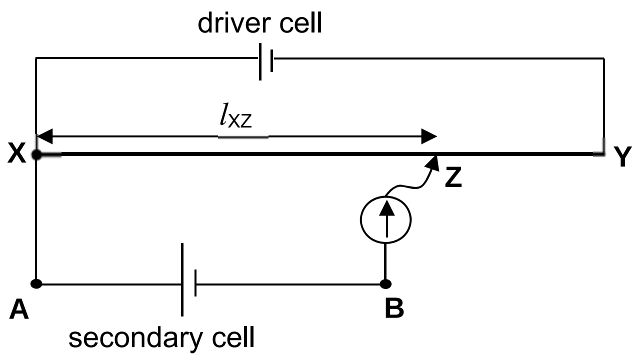
A 9.0 Ω

B 12 Ω

C 20 Ω

D 24 Ω

23 In a typical potentiometer circuit as shown below, the balance length l_{XZ} is **NOT** increased by



A decreasing the e.m.f. of the driver cell.

B increasing the e.m.f. of the secondary cell.

C adding a fixed resistor in series with the driver cell.

D adding a fixed resistor in series with the secondary cell.

24 A wire has diameter 0.35 mm and the number density of charge carriers is 7.8×10^{28} m^{-3}. The current in the wire is 0.15 A.

What is the drift velocity of the charge carriers?

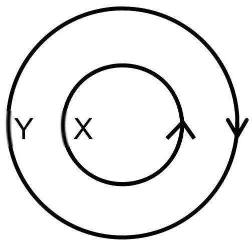
A 1.2×10^{-18} m s^{-1}

B 3.1×10^{-11} m s^{-1}

C 3.1×10^{-5} m s^{-1}

D 1.2×10^{-4} m s^{-1}

25 Two flat circular coils, X and Y, each with 100 turns, are arranged as shown in the diagram. X has radius 0.120 m and carries a current of 1.5 A in the anti-clockwise direction, Y has radius 0.180 m and carries a current of 1.0 A in the clockwise direction. Both coils are arranged such that their centres coincide.



What is the magnitude and direction of the total magnetic flux density at the centre of the coils?

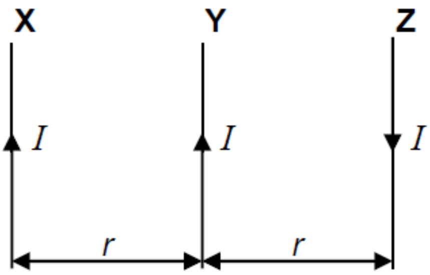
A $347\mu_o$ into the page

B $347\mu_o$ out of the page

C $905\mu_o$ into the page

D $905\mu_o$ out of the page

26 The figure below shows three parallel wires **X**, **Y** and **Z** which carry currents I of equal magnitude in the directions shown.



The resultant force experienced by **X** due to the currents in **Y** and **Z** is

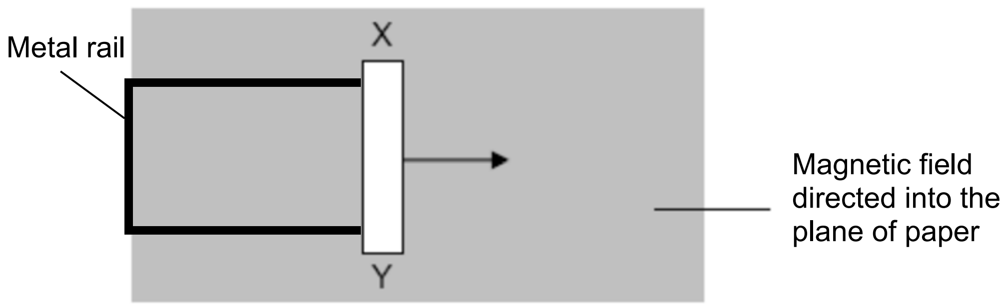
A zero.

B away from Y

C towards Y.

D along Y.

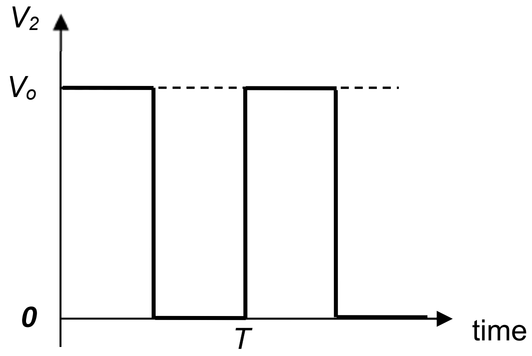
27 A metal rod XY is moving to the right on a metal rail, perpendicular to a magnetic field as shown below.



Which of the following correctly describes the magnetic force acting on the rod and the potential of the rod?

	Magnetic force on rod	Potential of rod
A	directed to the left	X is higher than Y
B	directed to the right	X is higher than Y
C	directed to the left	Y is higher than X
D	directed to the right	Y is higher than X

28 A sinusoidal potential difference with peak voltage V_o is applied across a resistor R and produces heat at a mean rate W. What is the mean rate of heat produced when another potential difference with the same peak voltage, as shown below, is applied across the same resistor?



A W

B $\sqrt{2}\,W$

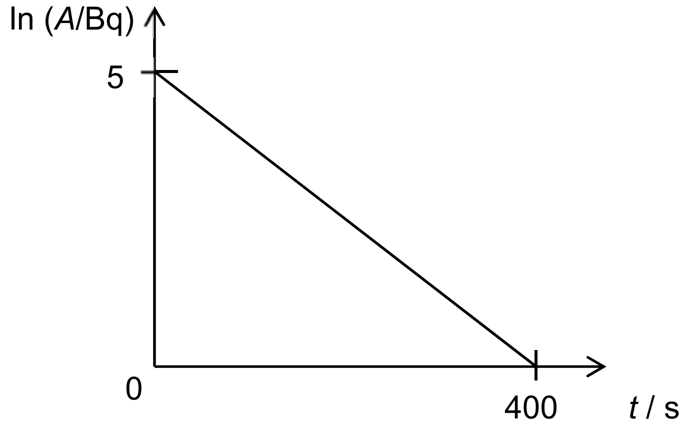
C $2W$

D $4W$

29 The transition of electrons between three consecutive energy levels in a particular atom gives rise to three spectral lines. The shortest and longest wavelengths of those spectral lines are λ_1 and λ_2 respectively. The wavelength of the other spectral line is

A $\frac{\lambda_1+\lambda_2}{2}$ **B** $\lambda_1 - \lambda_2$ **C** $\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$ **D** $(\frac{1}{\lambda_1} - \frac{1}{\lambda_2})^{-1}$

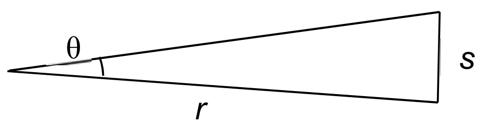
30 The graph below shows how the natural logarithm of the activity A of a radioactive isotope varies with time t. What is the half-life of the isotope?

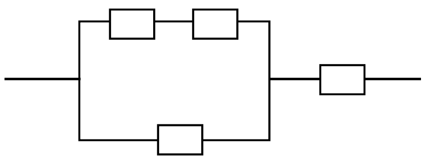
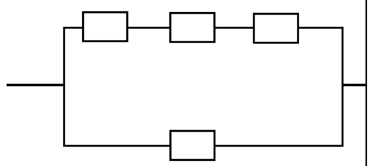
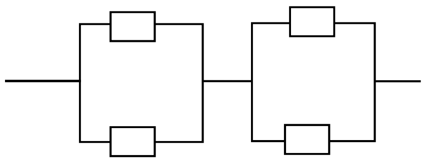


A 200 s **B** 55 s **C** 24 s **D** 0.42 s

--- End of paper ---

S/N	Answer	Explanation
1	A	Let t be the timing displayed on the students' stopwatch. True period = $t \div 9$ Mistaken period = $t \div 10$ Absolute error = $(t \div 9) - (t \div 10) = t / 90$ Percentage error = (Absolute error ÷ True period) × 100% = $[(t / 90) \div (t \div 9)] \times 100\%$ = 10 % The mistaken period is smaller than the true period. Thus the error is "low".
2	D	$v_y = 0$, $a_x = 0$, $a_y = g$
3	A	From N2L, $\langle F \rangle = \Delta mv \div \Delta t$ $\Rightarrow 250 = 0.050v - [-0.050(0.40)] \div (1.2 \times 10^{-3})$ $\Rightarrow v = 5.6$ m s^{-1}
4	B	Conservation of Linear Momentum: $0.113u_1 + 0 = 0.113v_1 + 1(3.8 \times 10^6)$ Elastic: $u_1 - 0 = 3.8 \times 10^6 - v_1$ Thus, $u_1 = 1.87 \times 10^7$ m s^{-1}
5	D	From the diagram, it is obvious that the net force is not zero (all forces are pointing upwards or have a vertical component pointing upwards) Taking the centre of the disc as a pivot, the sum of anti-clockwise moments = $(15 + 30)r$, where r is the radius of the disc. This expression is equal to the sum of clockwise moments = $(20 + 25)r$.
6	A	Net work done = change in KE First hit: $- F_f (1/4\ d) = 0 - ½\ m\ u^2$ --- (1) Second hit: $- F_f (d) = 0 - ½\ m\ u_1^{\ 2}$ --- (2) Thus, (2) / (1) $\Rightarrow 4 = u_1^{\ 2} / u^2$ $\Rightarrow u_1 = 2\ u$
7	D	By C.O.M.E., Gain in KE = Loss in GPE Thus, $½\ m\ v^2 = mgr$

		$mv^2/\mathrm{r} = 2.0\ mg$ --- (1) For circular motion, $\Sigma F = mv^2/r$ *Thus,* $N - mg = 2.0\ mg$ $N = 3.0\ mg$
8	**C**	For circular motion, $\Sigma F = mv^2/r$ $mg - N = mv^2/r$ $mg = mv^2/r$ [weightless $\Rightarrow N = 0$] $v = \sqrt{(rg)}$
9	**D**	Kepler's Third Law: General expression is $T^2 = (4\pi^2 / GM)\ r^3$ Using symbols in this question, we have $T^2 = (4\pi^2 / GM)\ (r + h)^3$ But, $g = GM / r^2$ Thus, $T^2 = (4\pi^2 / g\ r^2)\ (r + h)^3$
10	**D**	When separation r is doubled, force F decreases by 4 times.
11	**C**	$pV = NkT$ $N = pV / kT = (2.5 \times 10^5)\ (3.0 \times 10^{-4}) / [1.38 \times 10^{-23} \times (273.15 + 27)] =$ 1.8×10^{22}
12	**B**	
13	**B**	Damping force opposes motion
14	**C**	Maximum displacement and always directed towards the centre.
15	**C**	I = P/ A so with twice the I and twice the r(which makes 4 times of A), P has to increase 8 folds.
16	**D**	 $s \approx r\theta$ $1.26 \approx 14.4 \times 10^3\ \theta$ $\theta \approx 8.75 \times 10^{-5}$ radians
17	**D**	$x = \lambda D / a$ - lower f, longer λ
18	**C**	Imagine there are parallel plates, bottom plate will be higher potential, thus the force on the electron is directed vertically downwards.

19	**D**	Total Electric potential energy = $\frac{3Q(2Q)}{4\pi\varepsilon_0\left(\frac{3r}{4}\right)}+\frac{3Q(-Q)}{4\pi\varepsilon_0\left(\frac{r}{4}\right)}$ $= -\frac{Q^2}{\pi\varepsilon_0 r}$
20	**C**	current across r is $\left(\frac{E}{2R+r}\right)$. Hence P = $\left(\frac{E}{2R+r}\right)^2 r$
21	**A**	$\frac{\rho_x l_x}{A_x}=\frac{\rho_y(3l_x)}{4A_X}$ $\rho_y=\frac{4}{3}\rho_x$
22	**D**	 20 Ω  9 Ω  12 Ω
23	**D**	At null deflection, no current flows through secondary cell, hence no effect if you placed resistor in series with it.
24	**D**	Using I = nAvq V = 0.15 / [$7.8 \times 10^{28} \times (0.35 \times 10^{-3} / 2)^2\ \pi \times 1.6 \times 10^{-19}$] = 1.2×10^{-4} m s^{-1}
25	**B**	For X, B = (100)(1.5)μ_o / (2)(0.120) = 625 μ_o out of the plane. For Y, B = (100)(1.0)μ_o / (2)(0.180) ≈ 278 μ_o into the plane. Therefore, resultant B = 625 μ_o – 278 μ_o = 347 μ_o out of the plane.
26	**C**	Attraction towards Y and Z.
27	**A**	By Fleming's RHR, induced current flow from Y to X in the rod, hence X is of higher potential.

		Induced current will cause an opposing effect to the change and thus the magnetic force will be directed to the left.
28	**A**	For sinusoidal input, Mean Power, W = $\frac{V_{rms}{}^2}{R} = \frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R} = \frac{V_0{}^2}{2R}$ Mean power for square wave, P_B = $\frac{V_{rms}{}^2}{R} = \frac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{R} = \frac{V_0{}^2}{2R}$ = W
29	**D**	For the spectral line with <u>shortest</u> wavelength, the energy difference between the involved levels = $\frac{hc}{\lambda_1}$, which is the <u>largest</u> For the spectral line with <u>longest</u> wavelength, the energy difference between the involved levels = $\frac{hc}{\lambda_2}$, which is the <u>smallest</u> Thus, the energy difference between levels for the third spectral line = $\frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$ Let the wavelength of this third spectral line be λ_3. Thus, the energy difference can also be expressed as $\frac{hc}{\lambda_3}$. We then have $\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} - \frac{hc}{\lambda_2}$
30	**B**	Given $A = A_o \exp(-\lambda t)$, then, $\ln A = \ln A_o - \lambda t$ Thus, the gradient = $-\lambda$ $\Rightarrow 5/400 = -\lambda = \ln 2 / t_{1/2}$ $\Rightarrow t_{1/2} = 55$ s

Candidate's Name ………………………………………….………… CTG ……………

YISHUN JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2018

PHYSICS **9749/2**
HIGHER 2 **28th August 2018**
2 hours

Paper 2 Structured Questions

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

READ THESE INSTRUCTIONS FIRST

Write your name and CTG in the spaces provided on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided on the question paper.
For numerical answers, **all** working should be shown clearly.

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

For Examiner's Use	
Paper 2 (30.0%)	
1	/3
2	/7
3	/10
4	/15
5	/10
6	/15
7	/20
Penalty	
Total	
	/ 80

Data

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

Formulae

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

[Turn over

1 Archimedes' number, Ar, is dimensionless (unitless) and is used in the study of objects in fluids. The number is given by the following expression

$$\mathrm{Ar} = \frac{gL^3\rho_\ell(\rho - \rho_\ell)}{\mu^2}$$

whereby g is the acceleration due to gravity, L is the characteristic length of the object, ρ_l is the density of the fluid, ρ is the density of the object and μ is the dynamic viscosity of the fluid.

Determine the units of μ..

units of μ.= …………………….... [3]

2 **(a)** Explain what is meant by the following terms when used in the context of forces.

(i) Centre of gravity

....

....

.... [1]

(ii) Friction

....

....

.... [1]

(b) Fig. 2.1 shows a man performing a bungee jump.

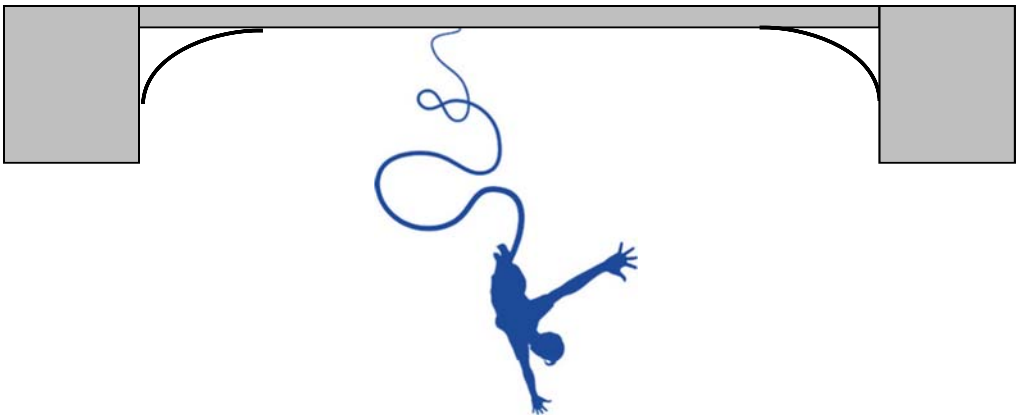


Fig. 2.1

He falls 42 m before the elastic rope secured to him starts to exert some force on him. The force-extension graph for this rope is shown in Fig. 2.2.

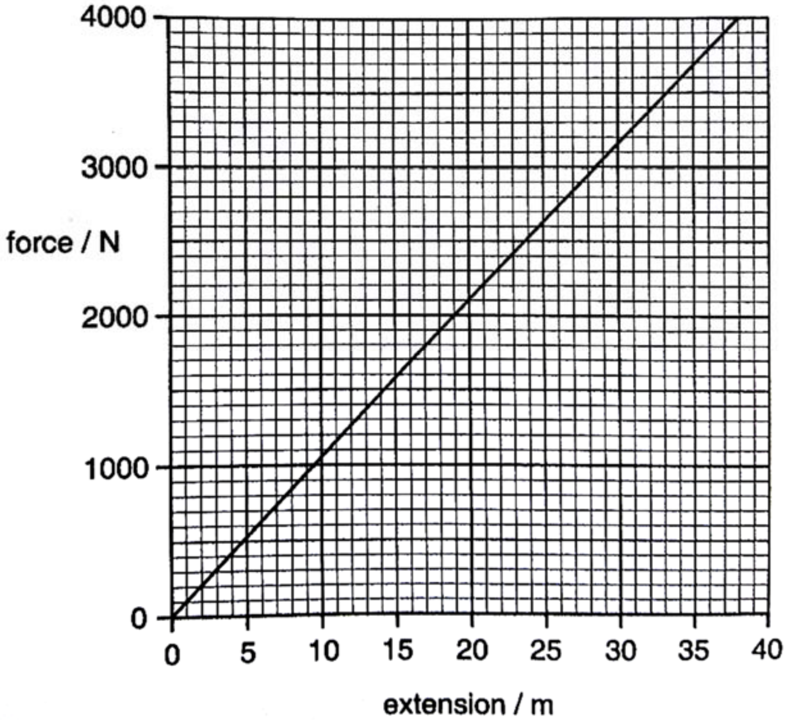


Fig. 2.2

The total distance the man falls before he stops for the first time is 78 m.

(i) Deduce

1. the extension of the rope when the man stops for the first time, and

extension = ……………………. m [1]

2. the elastic potential energy stored in the rope at this time.

elastic potential energy = ……………………. J [2]

(ii) Show that the man has a mass of approximately 90 kg.

[2]

3 **(a)** A cylinder of fixed volume contains some nitrogen gas at a pressure of 2.1×10^5 Pa. The gas has a density 1.5 kg m^{-3} and the molar mass of nitrogen is 14 g, calculate

(i) the root-mean-square speed of the nitrogen molecules,

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

(ii) the temperature of the nitrogen gas in the cylinder.

temperature = …………………….K [2]

(iii) Using kinetic theory of gases, state and explain what will happen to the pressure of the nitrogen gas when the temperature of the gas is increased.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [3]

(b) A refrigerator door is opened and room temperature air (25 ^{o}C) filled the 1.5 m^3 compartment of the refrigerator. A 2.0 kg chicken, also at room temperature, is placed in the refrigerator and the door is closed.

If the power rating of the refrigerator is 200 W, with an efficiency of 0.80, calculate the time required to cool the chicken and air in the refrigerator to thermal equilibrium at a temperature of 4.0^{o}C.

(Density of air = 1.25 kg m^{-3}, specific heat capacity of air = 1.02×10^3 J kg^{-1} K^{-1}, specific heat capacity of chicken = 3.48×10^3 J kg^{-1} K^{-1})

time required = …………………….s [3]

4 A rod is attached vertically to a horizontal turntable at point **P**, 0.080 m from the centre **Q**, as shown in Fig. 4.1.

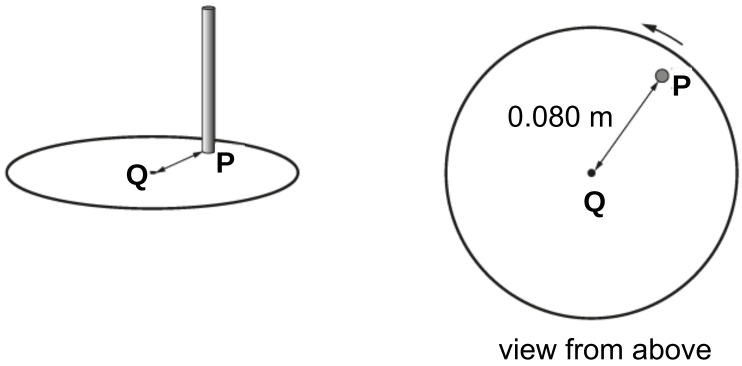


Fig. 4.1

(a) The turntable rotates around **Q** at 45 rotations per minute. Calculate

(i) the angular velocity of the rod,

angular velocity of rod = ...rad s^{-1} [2]

(ii) the acceleration of the rod and state its direction.

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

direction of acceleration= .... [1]

(b) When the rod is illuminated from the side, its shadow on a screen oscillates.

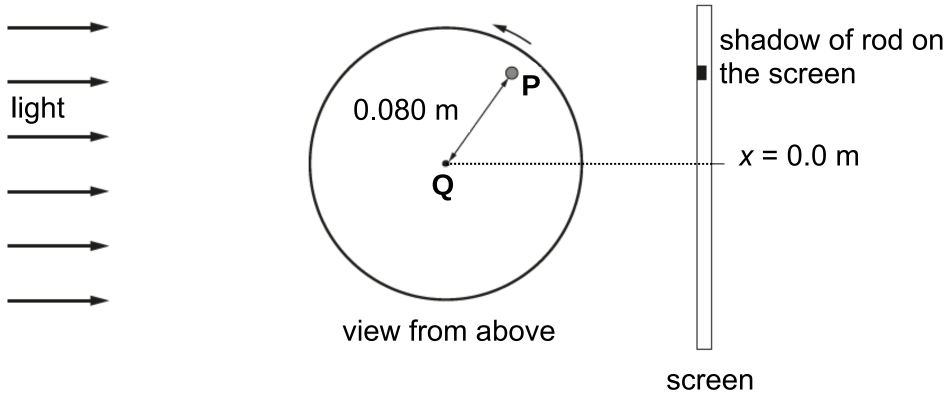


Fig. 4.2

[Turn over

The displacement x in metres of the centre of the shadow from the centre of oscillation and the acceleration a of the shadow may be written

$$x = A\sin(\omega t)$$

where t is time in seconds, A is the amplitude of oscillation and ω is the angular velocity of the rod.

(i) Using the values given in **(a)**,

1. calculate the period of oscillation of the shadow, and

period of oscillation = ... s [1]

2. derive an expression for the acceleration of the shadow in terms of t.

expression for acceleration = ... [2]

(ii) Determine the acceleration of the shadow at t = 0.20 s.

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

(iii) In Fig. 4.3, sketch the variation of acceleration of the oscillation with time for at least two cycles. Label the necessary values.

[3]

Fig. 4.3

(iv) Fig. 4.4 shows a second rod, which is now attached vertically to the turntable at point **R**, 0.060 m from centre **Q**, such that angle **PQR** is a right angle.

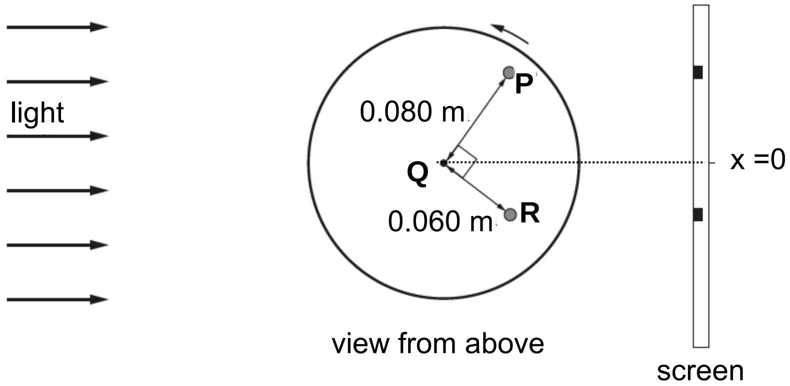


Fig. 4.4

If the expression for displacement of the shadow of the first rod at **P** in **(b)** is A sin(ωt), derive an expression for displacement of the shadow of the second rod at **R** with the necessary values of its amplitude and ω.

expression for displacement = ... [2]

5 **(a)** The graph Fig. 5.1 shows how the resistance, R_R, of a metal resistor and the resistance, R_{Th}, of a thermistor change with temperature.

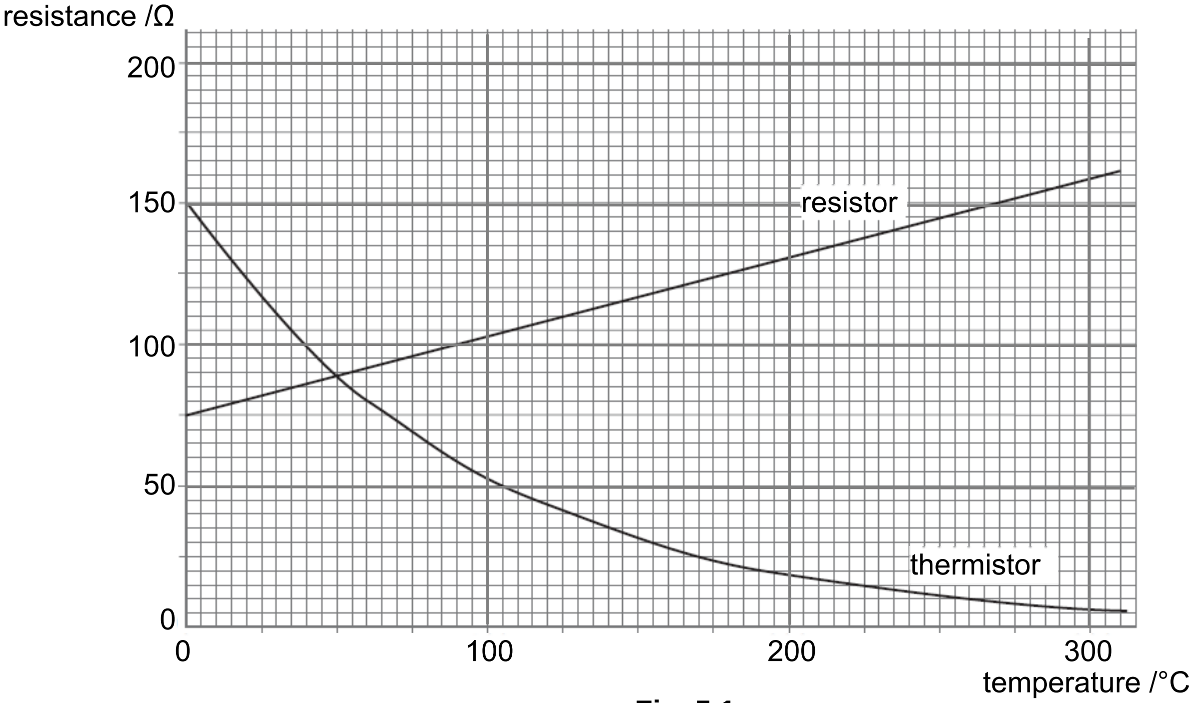


Fig. 5.1

(i) State the values of the resistance R_R and R_{Th} at a temperature of 105 °C.

R_R = ... Ω [1]

R_{Th}= .... Ω [1]

(ii) The resistor and thermistor are connected in series to a 12 V battery of negligible internal resistance, as shown in Fig. 5.2.

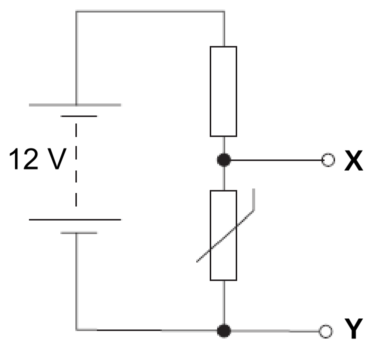


Fig. 5.2

Calculate the potential difference across **XY** at 105 °C.

potential difference across **XY** = ... V [2]

(iii) Assuming that the temperature of the resistor always equals the temperature of the thermistor, deduce the temperature, without any further calculations when the potential difference across the resistor is 6.0 V. Explain your answer.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) Fig. 5.3 shows a potentiometer, made from uniform resistance wire AB of length *l* and resistance *R,* connected in series with an e.m.f. source *E*.

It is used to change the potential difference across an appliance of resistance *S*.

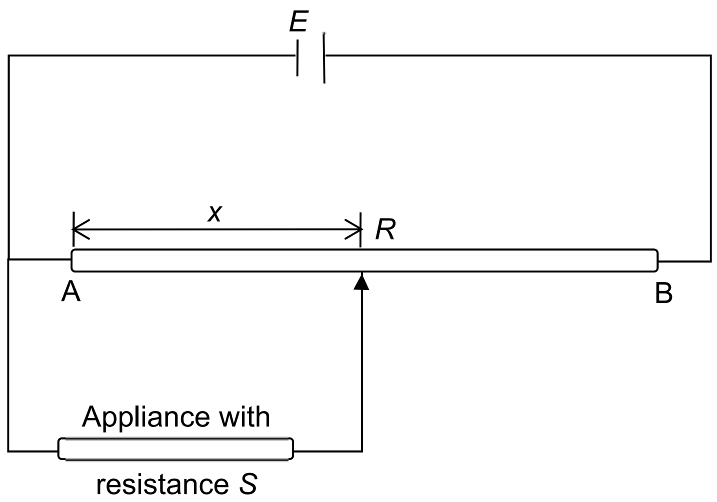


Fig. 5.3

(i) Derive an expression of the potential difference across the appliance as a function of the distance *x* of the sliding contact from the end A of the resistance wire in terms of *E*, *x* and *l* . Explain your working clearly.

expression of potential difference = ... [2]

(ii) Hence or otherwise, calculate the current through the appliance when

E = 5.0 V, x = 20.0 cm, l = 1.00 m and S = 10.0 Ω.

current through appliance = ... A [1]

(iii) The appliance is removed and replaced with a cell of unknown e.m.f. ε and a galvanometer is connected in series with the cell, as shown in Fig. 5.4.

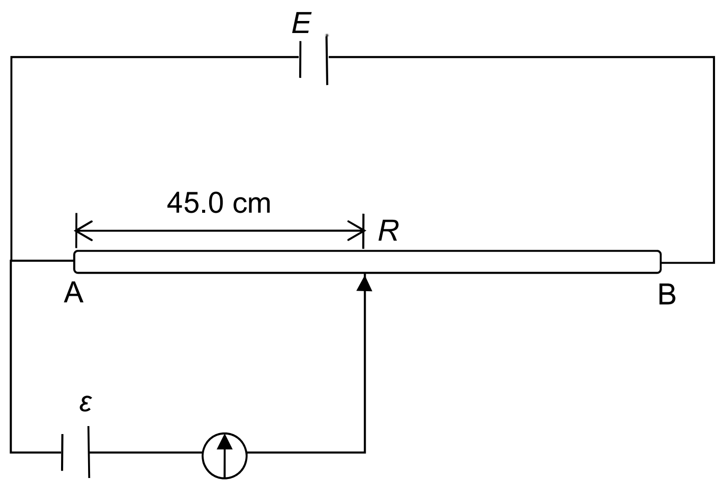


Fig. 5.4

The galvanometer shows null deflection when the sliding contact is at the 45.0 cm mark. Calculate ε, using the values of E and l given in **(b)(ii)**.

ε = ... V [1]

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

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

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

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

(b) Light shines on a metal surface which is part of the circuit shown in Fig. 6.1 below. The wavelength of the light is shorter than the threshold wavelength, λ_m of the metal.

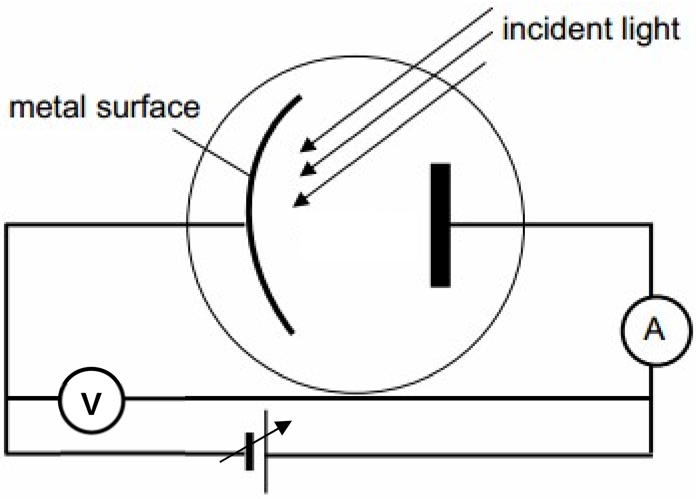


Fig. 6.1

Fig. 6.2 below shows the variation of ammeter reading with voltmeter reading.

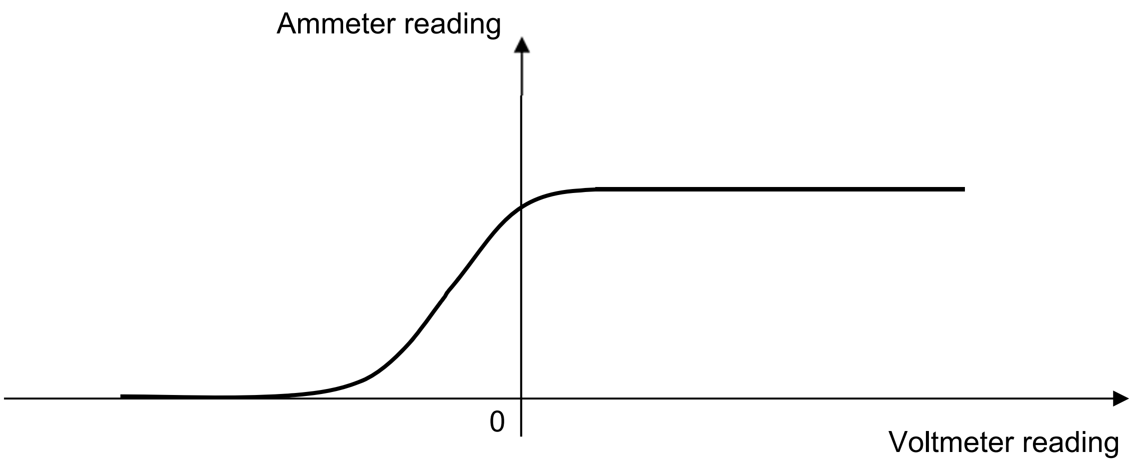


Fig. 6.2

(i) The incident light has now a longer wavelength but the same intensity as the earlier light. This new wavelength is also shorter than λ_m. Sketch, on Fig. 6.2, the new graph.

[2]

(ii) At constant frequency of incident light, use quantum theory to explain why

1. photocurrent is proportional to intensity of the light, and

....

....

....

....

.... [2]

2. there is hardly any delay in time between irradiation of the metal surface and emission of electrons from the metal surface.

....

....

.... [1]

(c) Fig. 6.3 shows the experimental set-up for an electron diffraction experiment.

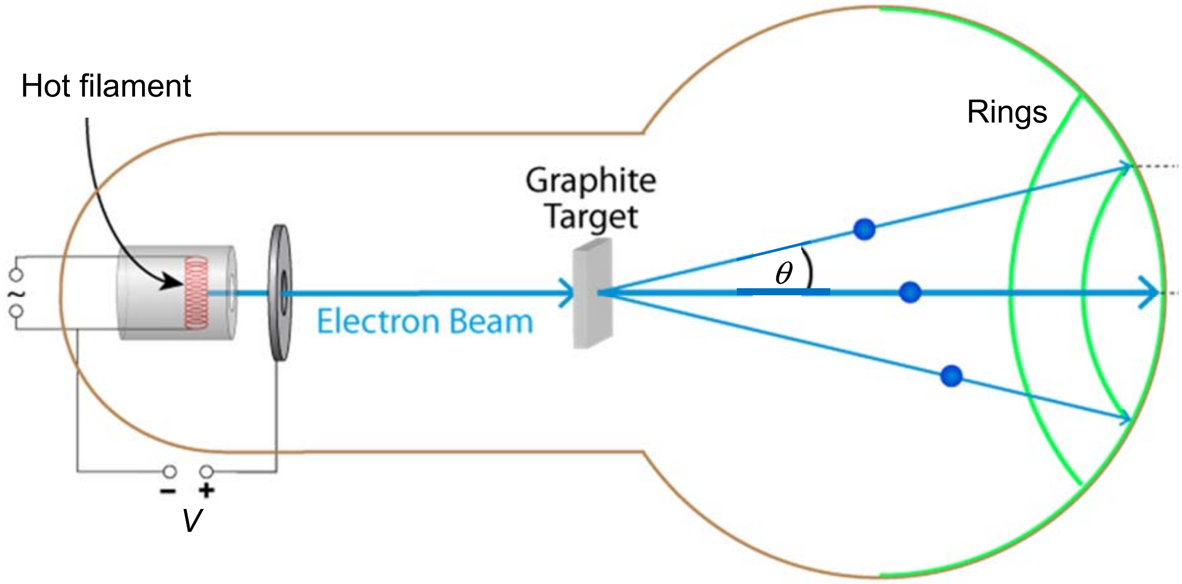


Fig. 6.3

Bright rings appear on the curved screen.

When V was 625 V, it was found that first off-centre maxima (ring) occurred at $\theta = 9.96°$.

The diffraction of the electron beam is in accordance to the following expression

$$2d \sin \theta = n\, \lambda_{dB}$$

whereby d is the inter-atomic distance in the target, n the order number and λ_{dB} the de Broglie wavelength of an electron in the beam.

(i) Determine the values of

1. λ_{dB} , and

λ_{dB} = ………………………… m [2]

2. *d*.

d = ………………………… m [2]

(ii) State and explain what happens to the rings when the value of *V* is decreased.

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

………………………………………………………………………………….. [4]

7 Bridges, a type of structure commonly found in daily life, are often built to span over physical obstacles such as a body of water or a valley, for the purpose of providing passage over the obstacles.

Designs of bridges depend mainly on the function of the bridge, the nature of the terrain where the bridge is constructed and anchored, the material used to make it, and the funds available to build it. Common types of bridges are beam, truss, cantilever and suspension bridges. A beam bridge, support by pillars at its both ends, span across a stream, is illustrated in Fig. 7.1.

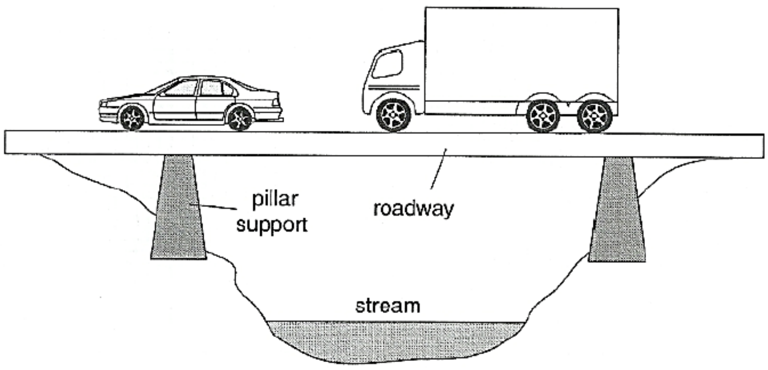


Fig. 7.1

The traditional building materials for bridges are stones, wood and steel, and more recently reinforced and pre-stressed concrete. These materials have different qualities of strength, workability, durability and resistance against corrosion. They differ also in their structure, texture and colour. For bridges, one should use a material which results in the best bridge in terms of shape, technical quality, functionality, economics and compatibility with the environment.

(a) Bridges bend when vehicles or pedestrians cross them. Hence, it is important to ensure that bridges do not bend too much when they are loaded.

Fig. 7.2 shows a simple model of a beam bridge built to investigate how the deflection of a wooden beam varies with the amount of load applied to the beam. The beam of length L, is supported on its two ends. A load of weight W is hung from the center of the beam. The deflection d is measured for the different loads and length of beams. A series of graphs are plotted as shown in Fig. 7.3.

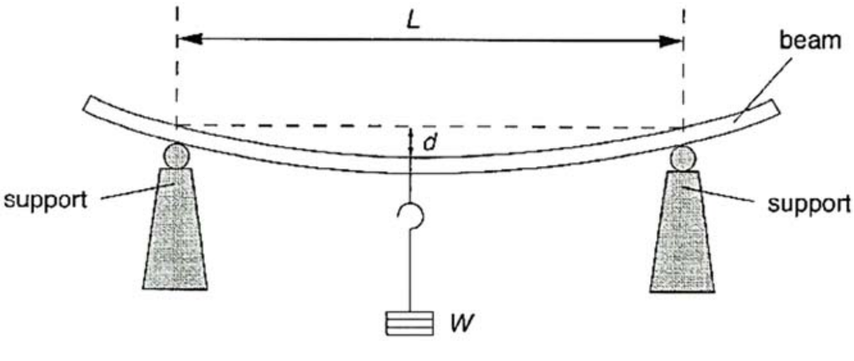


Fig. 7.2

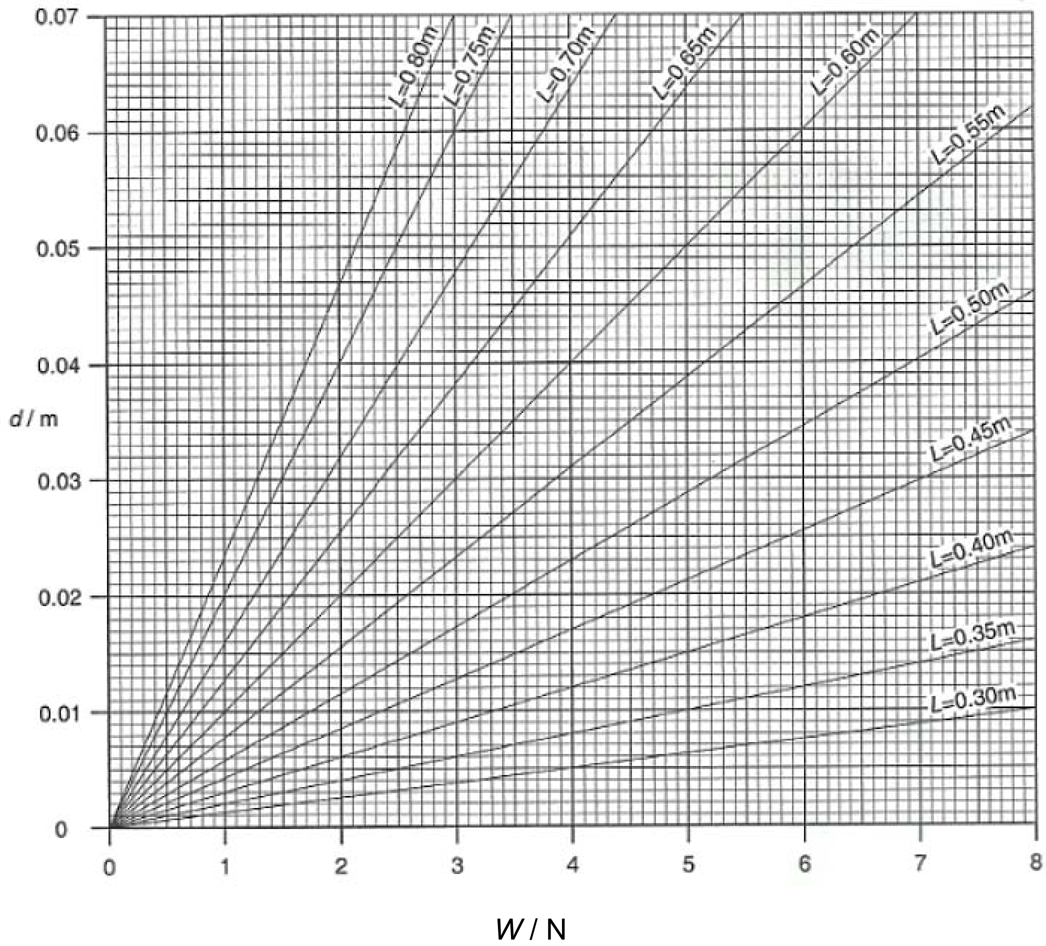


Fig. 7.3

The relation between d and L is thought to follow the expression

$$d = k\,L^n$$

where k and n are constant.

(i) A load of 3 N is applied to the different length of beams. [3]

Complete Fig. 7.4.

L / cm	d / cm	log (L /cm)	log (d /cm)
30	0.40	1.48	-0.40
35			
40	0.90	1.60	-0.046
45			
50	1.70	1.70	0.230
55	2.30	1.74	0.362
60	3.00	1.78	0.477
65			
70	4.80	1.85	0.681
75	6.00	1.88	0.778

Fig. 7.4

(ii) Plot a graph of log (d / cm) against log (L / cm) in Fig. 7.5. [3]

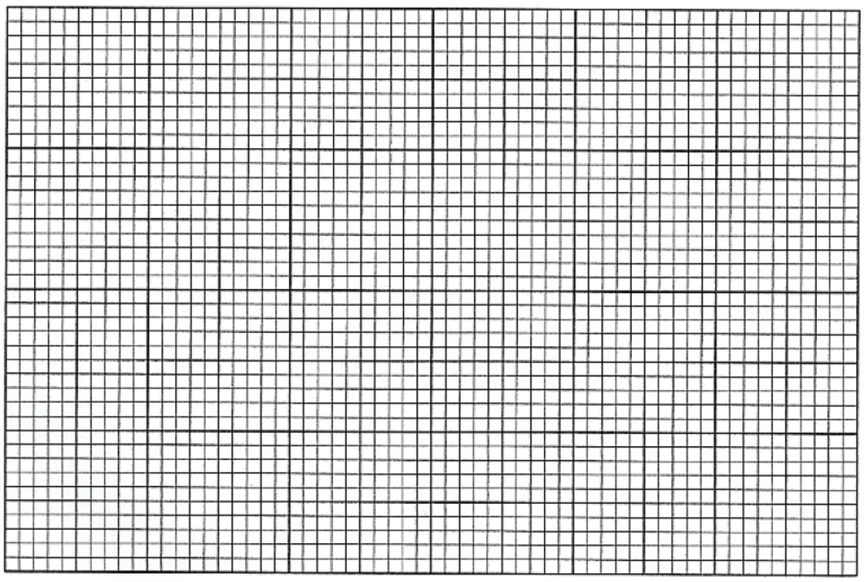


Fig. 7.5

(iii) Using Fig. 7.5, determine the value of k. The unit of k is not required.

k = ……………………….. [2]

(b) A beam bridge supported at both of its ends might also sag under its own weight. Hence the stiffness of the materials used to build the bridges is important. A physical quantity, Young's modulus, *Y*, also known as elastic modulus, is a measure of stiffness of material. It is the ratio of tensile stress to tensile strain exerted on the material, i.e.

$$Y = \text{Tensile stress} / \text{Tensile strain}$$

To measure the Young's modulus of the wooden beam in Fig. 7.2, forces *F* of same magnitude but opposite direction is applied on both ends of a wooden beam of length Lo = 1.000 m and cross-sectional area *A* of 5.0×10^{-5} m^2 as shown in Fig. 7.6. Under tension forces, the beam will elongate. Its extension in length is denoted as ΔL.

The tensile stress of the wooden beam is the ratio of the force *F* to the cross-sectional area *A*. While the tensile strain of the wooden beam is the ratio of the extension of length ΔL to the original length *L*.

$$\text{Tensile stress} = F / A$$

$$\text{Tensile strain} = \Delta L / L$$

Fig. 7.6

Fig. 7.7 shows the forces applied to the beam and the respective extension of the beam.

F / N	ΔL / mm
1.0	0.018
2.0	0.032
3.0	0.060
4.0	0.072
5.0	0.092
6.0	0.112

Fig. 7.7

(i) Plot a graph of force F against extension ΔL in Fig. 7.8. [3]

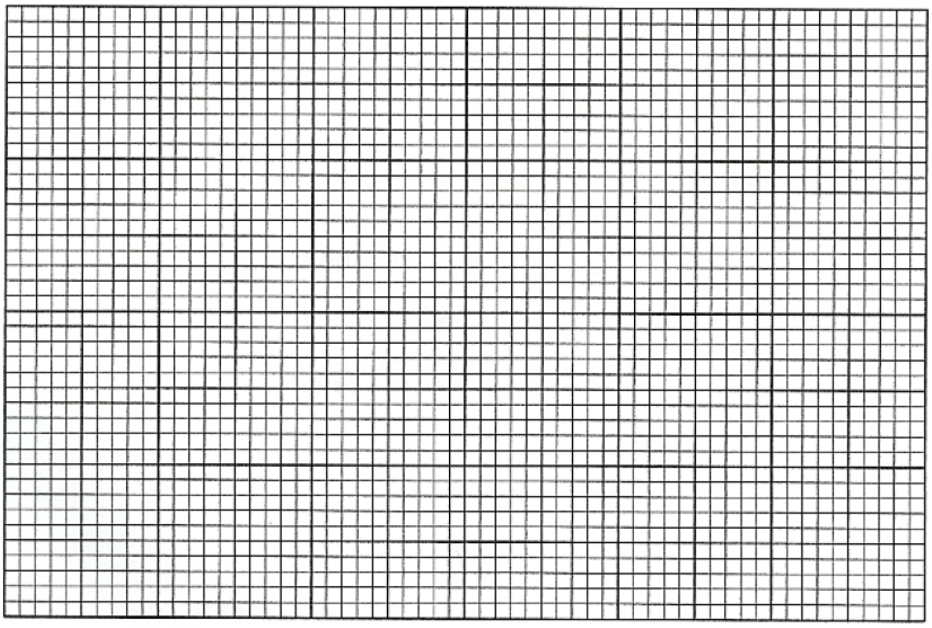


Fig. 7.8

(ii) From Fig. 7.8, determine the gradient of the graph.

gradient = ……………………….. [2]

(iii) Hence or otherwise, determine the Young's Modulus, Y, of the wooden beam.

Y = ……………………….N mm^{-2} [2]

(iv) A structural engineer wants to use a stiffer material instead of wood to construct a beam bridge.

1. Suggest a material which is stiffer than wood and can be used to construct a beam bridge.

………………………………………………………………………………... [1]

2. In Fig. 7.8, sketch the force against extension graph of a beam made of a stiffer material than wood. Label the graph S. Explain your answer.

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………… [2]

(c) The loading of the beam is often non-uniform along its length, as shown in Fig. 7.9. This means that the moments of forces have to be considered.

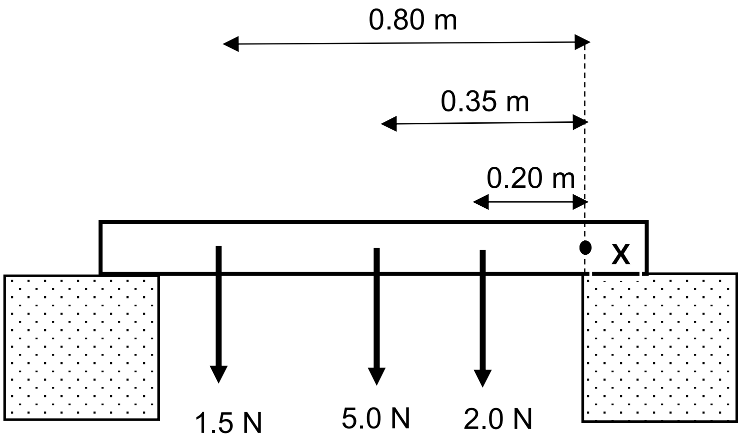


Fig. 7.9

Calculate the total moment of the forces acting on the beam about point X in Fig. 7.9. You may assume that the weight of the beam is negligible.

moment = ………………………..N m [2]

--- End of paper ---

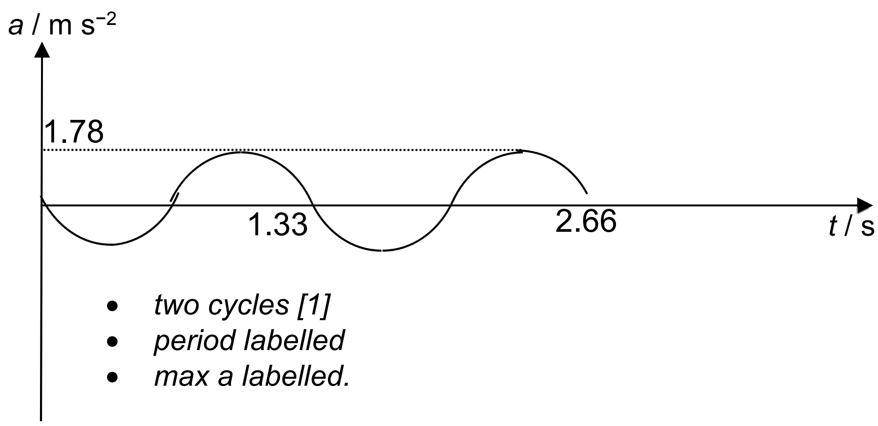
Suggested Solutions

1	From the given equation, $\mu^2 = gL^3 \rho_l (\rho - \rho_l) / Ar$ $[\mu^2] = (\text{m s}^{-2})\ (\text{m})^3\ (\text{kg m}^{-3})\ (\text{kg m}^{-3})$ Thus $[\mu] = \text{kg m}^{-1}\ \text{s}^{-1}$	**1** **1** **1**

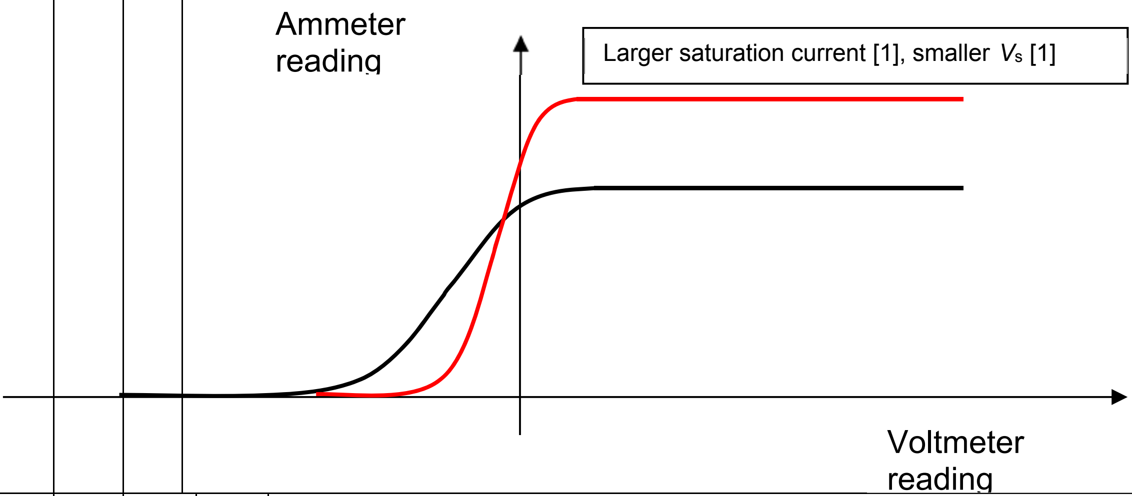
2	**(a) (i)**	The point of a body through which the entire weight of the body appears to act.	**1**
	(ii)	The force between two surfaces that opposes relative motion between them.	**1**

2	**(b)**	**(i)**	**1.** $x = 78 - 42 = 36$ m **2.** EPE = ½ Fx = ½ (3800)(36) = 68400 J	**1** **1** **1**
	(b)	**(ii)**	GPE lost = EPE gained or a statement to the same effect $Mgh = 68400$ $M = 68400 / (9.81 \times 78) = 89.4$ kg ≈ 90 kg	**1** **1**

3	**(a)**	**(i)**	$pV = (1/3)\, N\, m\langle c^2\rangle$ where $\rho = Nm/v$ $p = 1/3\, \rho \langle c^2\rangle$ $(\langle c^2\rangle)^{0.5} = [(3 \times 2.1 \times 10^5) / 1.5]^{0.5}$ $= 648\ (650)\ \text{m s}^{-1}$	 **1** **1**
		(ii)	$\frac{1}{2} m \langle c^2\rangle = 3/2\, kT$, $m = Mr / N_A$ $T = (m \langle c^2\rangle) / 3k$ $= [(14 \times 10^{-3}) / (6.02 \times 10^{23})] * (648^2) / (3 \times 1.38 \times 10^{-23})$ $= 236\ (240)$ K	 **1** **1**
		(iii)	When the temperature of the gas is increased, the <u>frequency of collisions on the wall</u> will increase and the <u>root-mean-square speed of the molecules will increase.</u> The gas molecules exert <u>a greater force on the walls</u> of the container due to greater change in momentum. Hence <u>pressure will increase</u>.	**1** **1** **1**
	(b)	Energy to be removed by refrigerator = energy loss by chicken + air $Q = 2.0 \times 3.48 \times 10^3\ (25 - 4.0) + 1.25 \times 1.50 \times (1.02 \times 10^3) \times (25 - 4.0)$ $= 1.86 \times 10^5$ J $Qsup = (1.86 \times 10^5) / 0.80$ $t = Qsup / P = 1160\ (1200)$ s		 **1** **1** **1**

4	**(a)**	**(i)**	$\omega = \frac{45(2\pi)}{60}$ $= 4.71 rad\ s^{-1}$	**1** **1**
		(ii)	a = rω^2 = (0.08)(4.712389)^2 = 1.78 m s^{-2} towards the centre	**1** **1** **1**
	(b)	**(i)**	**1.** Period = 2π/T = 1.33 s	**1**
			2. Differentiation twice from x = A sin (ωt) OR a = - ω^2 x = - ω^2 A sin (ωt) input values :a =- 0.080 x22.2 sin (4.71*t*) = -1.7765 sin (4.71*t)* = -1.78 sin (4.71*t)*	**1** **1**
		(ii)	a = -1.78 sin (4.71x 0.20) = 1.44 m s^{-2}	**1** **1**
		(iii)	 • *two cycles [1]* • *period labelled* • *max a labelled.*	**1** **1** **1**
		(iv)	0.060 cos 4.71t Cosine expression [1] allow sin (4.71 t - π/2) Correct values [1]	**1** **1**

5	**(a)**	**(i)**	R_R = 105 Ω R_{Th} = 50 Ω	**1** **1**
		(ii)	$V = \frac{50}{105+50} \times 12$ = 3.87 V	**1** **1**
		(iii)	The p.d across resistor and thermistor is equal so this implies that the resistance across each component is equal. Hence the temperature is 50 °C	**1** **1**
	(b)	**(i)**	p.d across length x = $\frac{x}{l}E$ Since the appliance is parallel to length of x, p.d is the same. Thus p.d across the appliance is x = $\frac{x}{l}E$	**1** **1**
		(Ii)	p.d across appliance = 20 / 100 x 5.0 = 1.0 V current = 1/10.0 = 0.10 A	**1**
		(iii)	ε = 45.0 / 100 x 5.0 = 2.25 V	**1**

6	(a)	The emission of electrons from the surface of a metal when EM radiation [1] of high enough frequency [1] is incident on the surface.			
	(b)	(i)			
	(b)	(ii)	1.	Increasing the intensity while keeping frequency constant increases the number of photons arriving per unit time. [1] Thus, the number of electrons emitted per unit time increases. Hence current increases proportionately. [1]	
	(b)	(ii)	2.	Photons travel at the speed of light. As soon as a photon collides with an electron, its energy is **immediately (and fully) imparted** to it. [1]	
	(c)	(i)	1.	Using gain in KE = loss in EPE, we have $\frac{1}{2} m v^2 = e V$ $\Rightarrow v = \sqrt{(2eV / m)}$ $= \sqrt{(2e \times 625 / 9.11\times10^{-31})}$ $= 1.4817 \times 10^7$ [1] Since $\lambda_{dB} = h / (mv)$ we have $\lambda_{dB} = 6.63 \times 10^{-34} / (9.11\times10^{-31} \times 1.4817 \times 10^7) = 4.9117 \times 10^{-11}$ m [1]	
	(c)	(i)	2.	From the given formula, $d = 1 \times 4.9117\times10^{-11} \div (2 \times \sin 9.96°)$ [1] $= 1.42 \times 10^{-10}$ m [1]	
	(c)	(ii)	Rings become larger. [1] P.d. decreases $\rightarrow$ KE / speed of incident electrons on film decreases [1]		

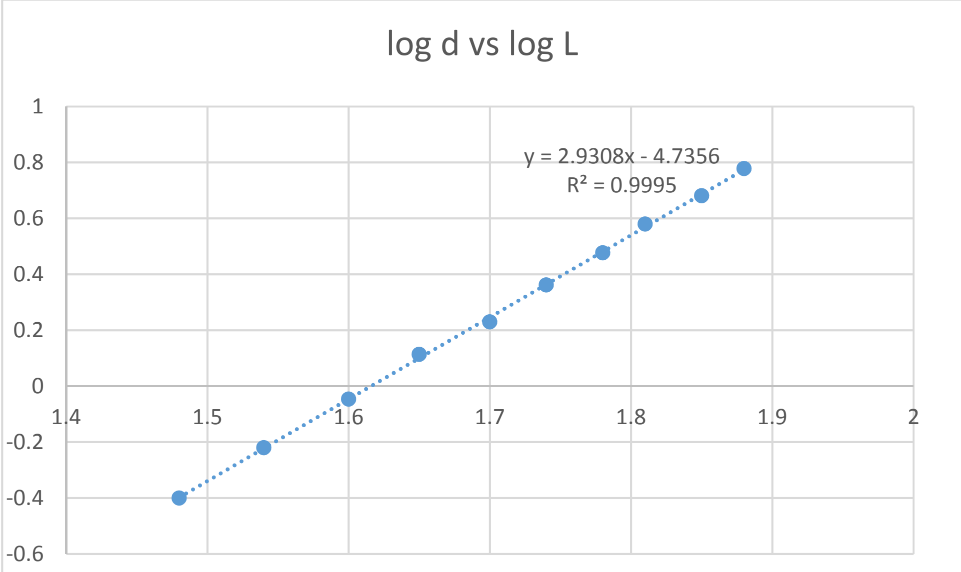
			→ de Broglie wavelength increases [1] → diffraction angle, θ increases [1]	

7	(a)	(i)	(see table below)	3
		(ii)	(see graph below)	3
		(iii)	Need to calculate gradient first and use substitution method to find y-intercept. Values of gradient in the range of 3.0 log k is the y-intercept which is -4.74. k = 1.8 x 10^{-5}	1 1

(i)

L / cm	d / cm	log (L /cm)	log (d /cm)
30	0.40	1.48	-0.40
35	0.60	1.54	-0.22
40	0.90	1.60	-0.046
45	1.30	1.65	0.114
50	1.70	1.70	0.230
55	2.30	1.74	0.362
60	3.00	1.78	0.477
65	3.80	1.81	0.580
70	4.80	1.85	0.681
75	6.00	1.88	0.778

(ii)

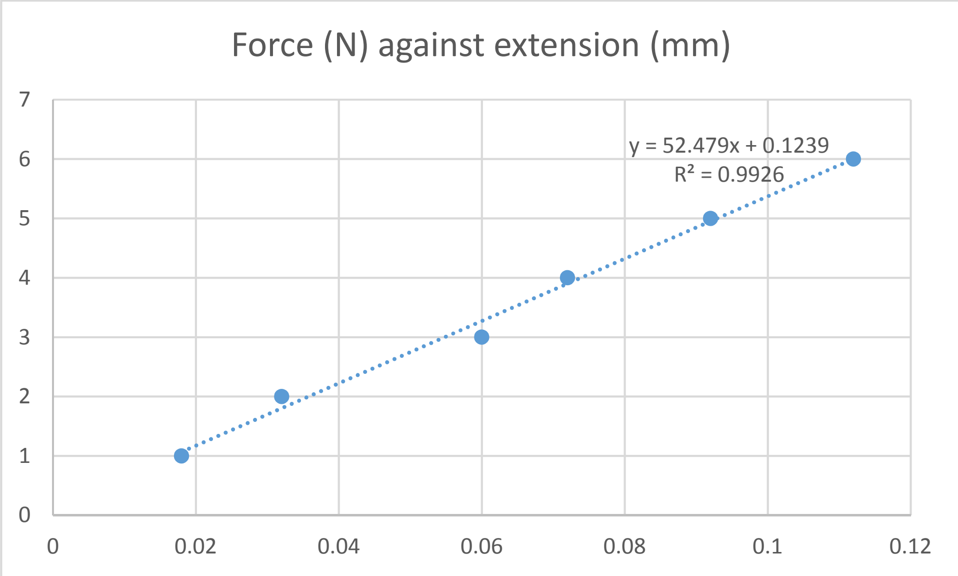


1 mark for correct labelling of axis with units

1 mark for plotting of all points

1 mark for best fit line

[Turn over

<table>
<tr><td></td><td>(b)</td><td>(i)</td><td>

1 mark for correct labelling of axis with units
1 mark for plotting of all points
1 mark for best fit line</td><td>3</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Gradient = $\Delta y / \Delta x$
= 52.5 (within 10% tolerance)</td><td>1
1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>Y = $(F/ \Delta L)\ (L / A)$
$= 52.5\ [1\times10^3 / (5.0 \times 10^{-5})\times10^6]$
$= 1.05\ (1.1) \times 10^3$ N mm^{-2}</td><td>
1
1</td></tr>
<tr><td></td><td></td><td>(iv)</td><td>1. Steel / concrete/ stone/brick (reject glass, iron –rust, aluminum, plastic, metal-state the type?)
2. Since material is stiffer than wood, its Y should be greater than that of wood. The graph should have a gradient steeper than that of the wood.
Correct graph of steeper gradient (take note of y-intercept of graph, should approach origin)</td><td>1
1
1</td></tr>
<tr><td></td><td>(c)</td><td colspan="2">Moment about X = 0.20 (2.0) + 0.35 (5.0) + 0.80(1.5)
= 3.35 (3.4) N m</td><td>1
1</td></tr>
</table>

Candidate's Name ……………………………………….(   ) CTG ……….

YISHUN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATIONS 2018

PHYSICS **9749/3**

HIGHER 2 12th September 2018

2 hours

Paper 3 Longer Structured Questions

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

READ THESE INSTRUCTION FIRST

Write your name and CTG in the spaces provided on this cover page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

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

Write your answers in the spaces provided on the question paper.
For numerical answers, **all** working should be shown clearly.

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

For Examiner's Use	
Paper 3 (35.0 %)	
Section A	
1	**/8**
2	**/7**
3	**/10**
4	**/10**
5	**/5**
6	**/15**
7	**/5**
Section B	
8	**/20**
9	**/20**
Penalty	
Total	**/80**

This question paper consists of 24 printed pages.

Data

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

Formulae

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

Section A

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

1 A vehicle travels from one traffic junction to another. Its acceleration-time (a-t) graph is shown in Fig. 1.1.

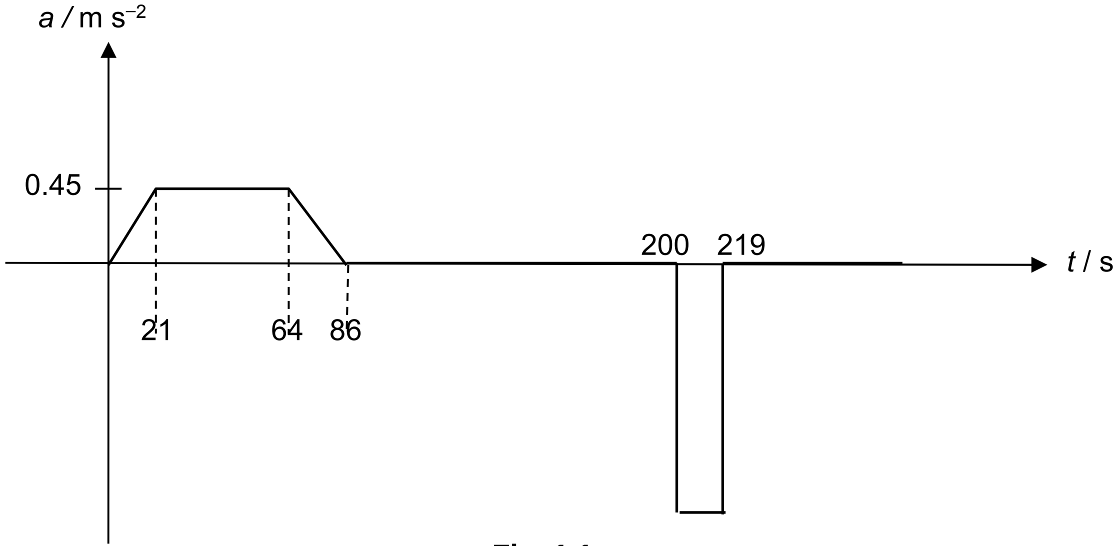


Fig. 1.1

(a) Use Fig. 1.1 to determine the average acceleration of the vehicle over the first 200 s.

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

(b) Given that the velocity of the vehicle is 0 m s^{-1} at t = 0 s and t = 219 s, determine

(i) the magnitude of its maximum velocity, and

magnitude of maximum velocity = …………………… m s^{-1} [2]

(ii) sketch its corresponding velocity-time (v-t) graph from t = 0 s to t = 219 s in Fig 1.2.

[4]

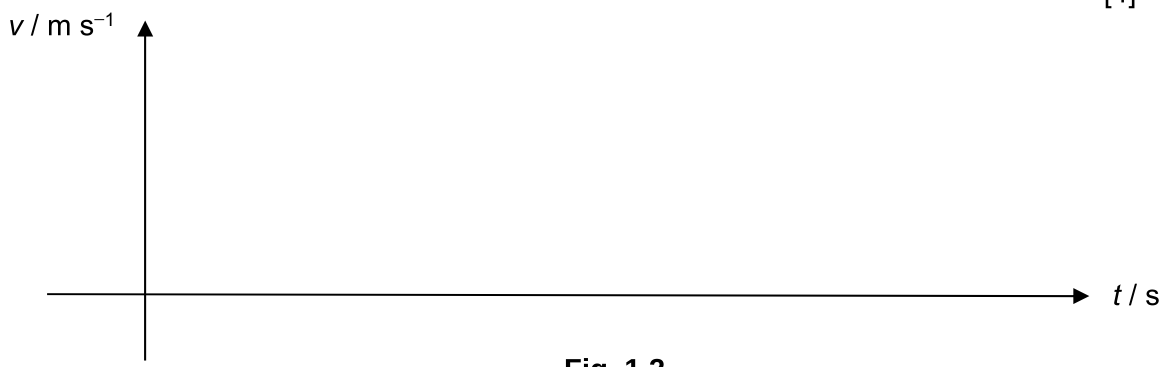


Fig. 1.2

2 Fig. 2.1 shows two men, both with the same mass *m*, weighing themselves using identical weighing scales, at two different locations on the surface of the Earth. Both scales are in good working condition. Man **P** weighs himself at the North pole and has a reading of 589.2 N whereas man **E** weighs himself at the equator and has a reading of 587.4 N. The rotational acceleration of the Earth about an axis through its poles is given as a_c.

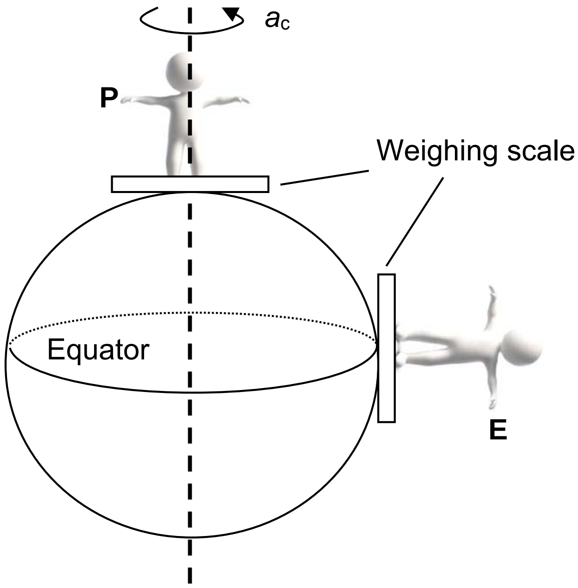


Fig. 2.1

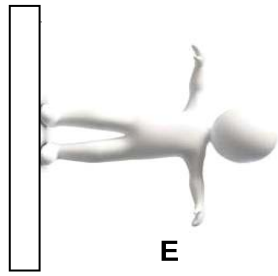


Fig. 2.2

(a) Fig. 2.2 shows an enlarged diagram of man **E** and his weighing scale. On Fig. 2.2, sketch and label all the forces acting on man **E**.

[2]

(b) Hence, or otherwise, explain why the scale readings at **P** and **E** are not the same.

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

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

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

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

(c) Given that m = 60 kg, deduce a_c.

a_c= …………………… m s^{-2} [2]

3 **(a)** Define *gravitational potential* at a point.

....

.... [1]

(b) Fig. 3.1 shows three equipotential surface centred about the Earth, each with its value indicated.

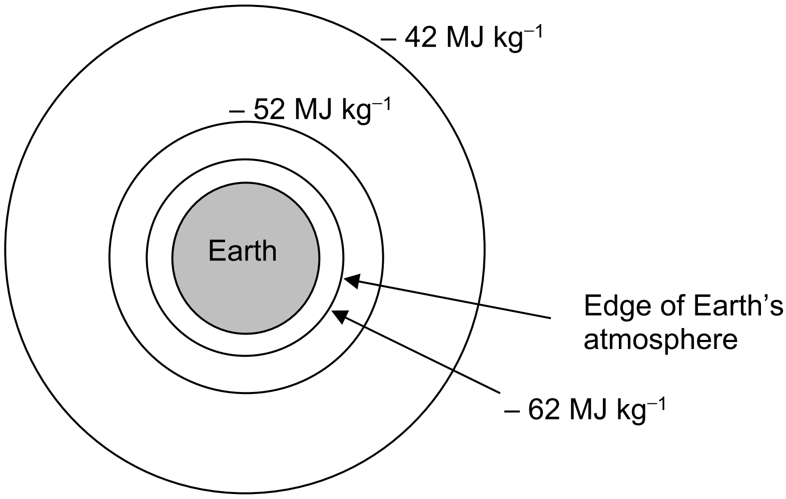


Fig. 3.1

(i) Explain why

1. the spacing between equipotential surfaces are not the same,

....

.... [1]

2. the values of equipotential is negative.

....

....

....

.... [2]

(ii) The potential at the Moon's orbit around the Earth is -1.0 MJ kg^{-1}.
If a spacecraft uses only the gravitational attraction of the Earth to travel from the Moon to the top of the Earth's atmosphere, determine its arrival speed.

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

(iii) The gravitational potential at the edge of the Earth's atmosphere is $-$ 61.6 MJ kg^{-1}.
If the radius of the Earth is 6371 km and its mass is 5.97×10^{24} kg , determine the height of this edge of the atmosphere from the Earth's surface.

height = …………………. m [3]

4 **(a)** State the *first law of thermodynamics*.

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

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

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

(b) A diesel engine containing an ideal gas at a pressure of 1.0×10^5 Pa, temperature of 300 K and volume of 10×10^{-4} m^3 undergoes a cyclic process in the sequence as follows:

A the gas is compressed adiabatically (i.e. no net heat transfer) to a pressure of

16×10^5 Pa, temperature of 660 K and volume of 1.4×10^{-4} m^3

B the gas is expanded at constant pressure to a volume of 6.0×10^{-4} m^3

C the gas continued to expand adiabatically to a pressure of 7.8×10^5 Pa to its original volume

D the gas is cooled at constant volume to its original temperature and pressure

(i) Illustrate these changes on the *p*-*V* diagram in Fig. 4.1.

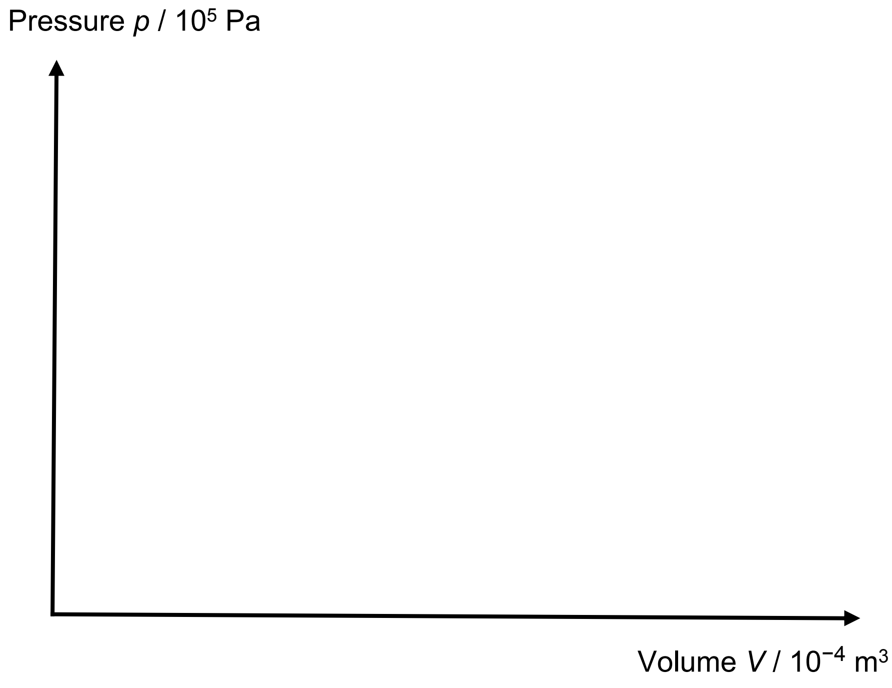


Fig. 4.1 [4]

(ii) Fig. 4.2 shows the changes in internal energy, heat supplied and work done on gas during the cyclic process. Complete Fig. 4.2.

	Heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A	0	300	300
B	2580		
C	0	−440	−440
D	−1700		

[3]

Fig 4.2

(iii) Assuming that the efficiency of the diesel engine is defined as ratio of net work done by the gas in the whole cycle to heat supplied to gas during process **B**, calculate the efficiency of this engine.

efficiency of engine = ……………………. [2]

5 **(a)** Two point charges of −6.0 μC and +6.0 μC are arranged at points **A** and **B** respectively as shown in Fig. 5.1.

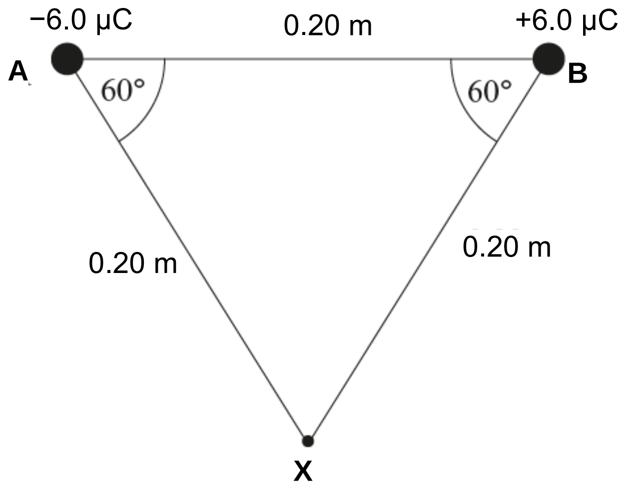


Fig. 5.1

Indicate clearly on Fig. 5.1 the directions of

(i) the electric field at **X** due to charge at **A** (label it E_A), [1]

(ii) the electric field at **X** due to charge at **B** (label it E_B), and [1]

(iii) the resultant (net) electric field at **X** due to both charges (label it E_R). [1]

(b) Determine the magnitude of the resultant electric field at **X**.

electric field strength = ... N C^{-1} [2]

6 Fig. 6.1 shows the main components of a mass spectrometer which are an ion chamber and a velocity selector. The positive ions emerging from the ion chamber, pass through the velocity selector consisting of regions **R** and **S**. A uniform electric field and a uniform magnetic field (indicated by the shaded area) are applied in region **R**. While only a uniform magnetic field (indicated by the shaded area) is applied in region **S**.

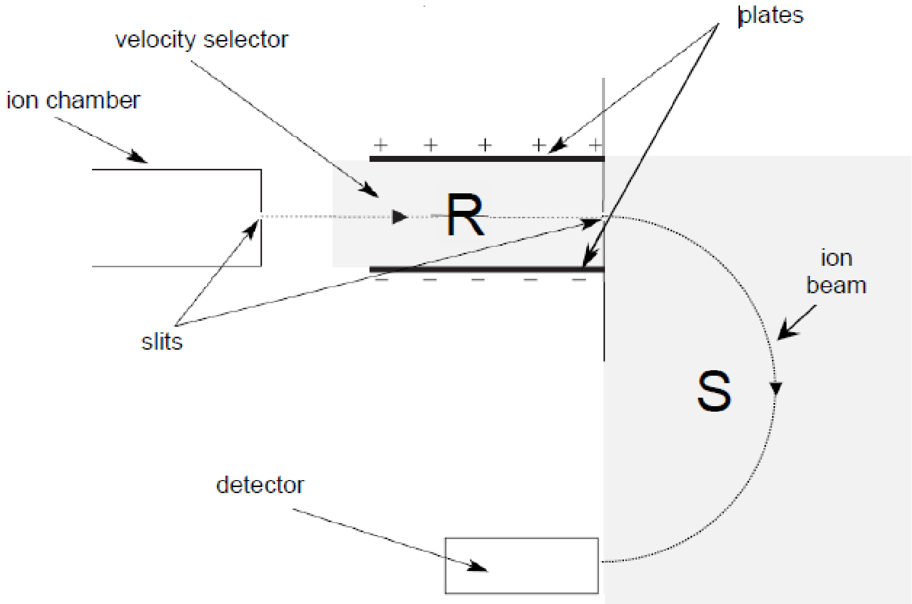


Fig. 6.1

(a) Draw the electric field lines between the plates in the region **R** of the velocity selector in Fig.6.1. [2]

(b) Suggest the purpose of the two slits.

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

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

(c) In the regions **R** and **S**, uniform magnetic fields are applied so that the beam of positive ions is undeflected in **R** and deflected into a circular path in **S**.

(i) State the direction of the magnetic fields in regions **R** and **S**.

region **R** = ... [1]

region **S** = ... [1]

(ii) Explain why positive ions passing through the second slit have the same velocity regardless of their mass.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

(iii) State and explain what happens to the ions that move slower than the ones that pass through the second slit.

…………………………………………………………………………………………..

…………………………………………………………………………………………..

…………………………………………………………………………………………..

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

(d) A student sets up the apparatus shown in Fig. 6.2(a) and (b) to determine the acceleration of a cart down a ramp. Fig. 6.2(a) shows the set−up from the front view and Fig. 6.2(b) shows the side view of the set−up.

As the cart passes the coils which are suspended, an e.m.f. is induced in each coil. The outputs of the coils are monitored using the voltage sensors connected to a datalogger and computer. The voltage sensors, datalogger and computer are not drawn Fig. 6.2(a) and Fig. 6.2(b). Fig. 6.3 shows the computer printouts after one test.

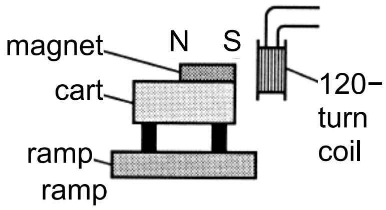


Fig. 6.2(a)

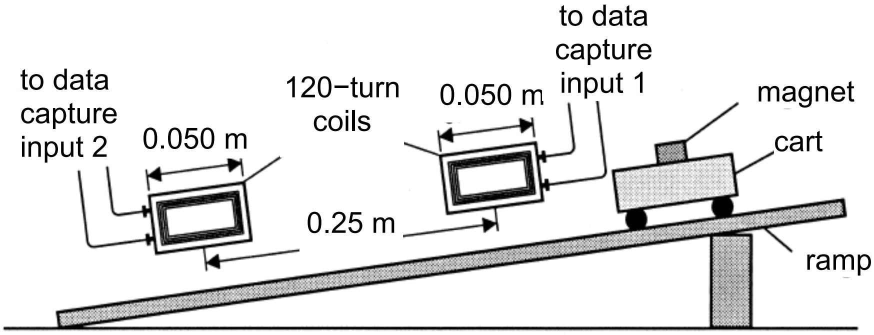


Fig. 6.2(b)

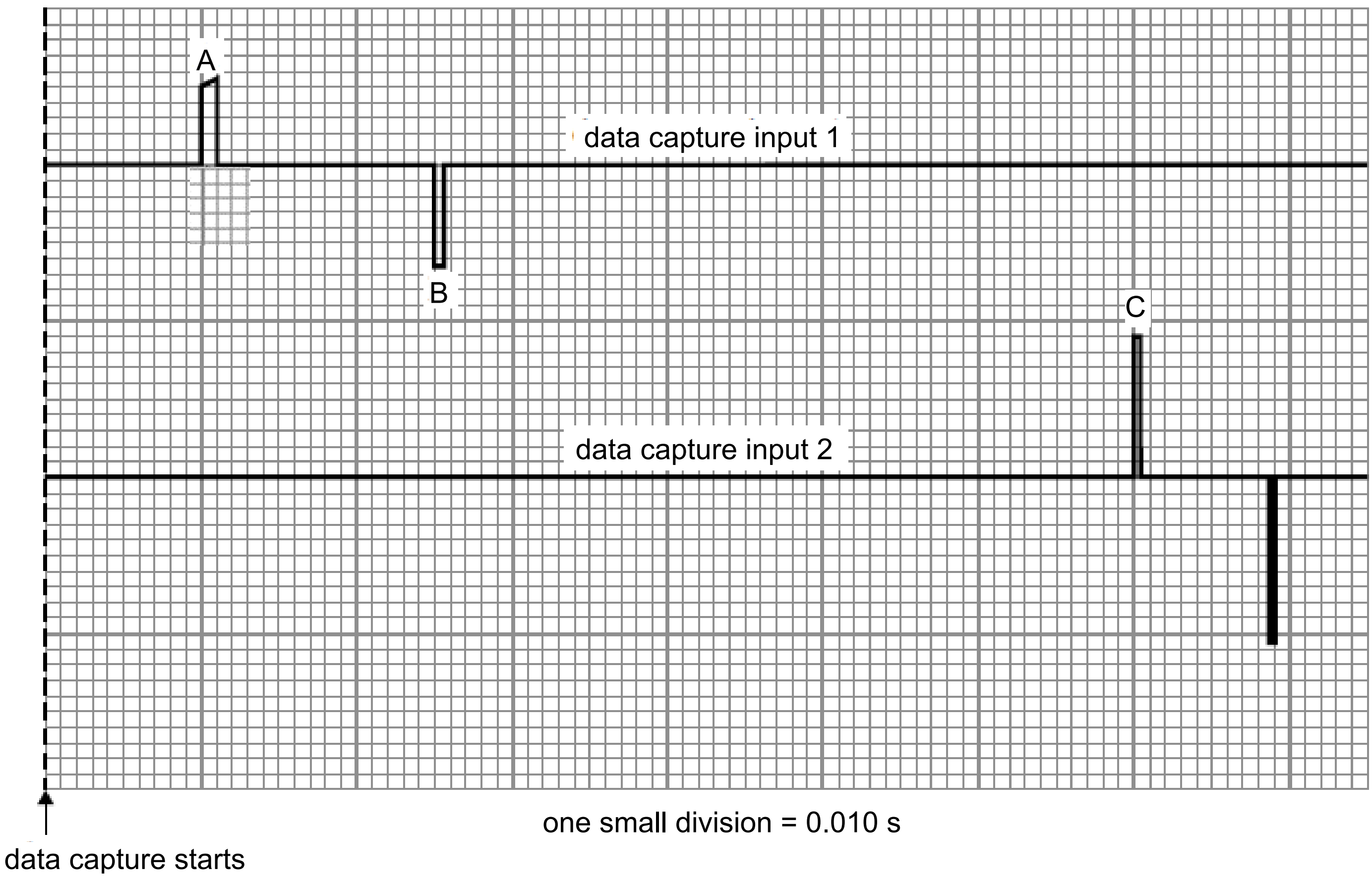


Fig. 6.3

Explain why

(i) e.m.f. is induced in both coils.

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

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

(ii) pulse **B** is in the opposite direction to pulse **A**,

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

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

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

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

(iii) the amplitude of pulse **C** is larger than pulse **A**.

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

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

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

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

7 **(a)** Domestic users in the United Kingdom are supplied with mains electricity at a root-mean-square voltage (r.m.s.) of 230V.

(i) State what is meant by *root-mean-square voltage*.

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

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

(ii) Calculate the peak power dissipated in a lamp connected to the mains supply when the r.m.s. current is 0.26 A.

peak power =.................................... W [2]

(b) Another alternating voltage is shown in Fig. 7.1.

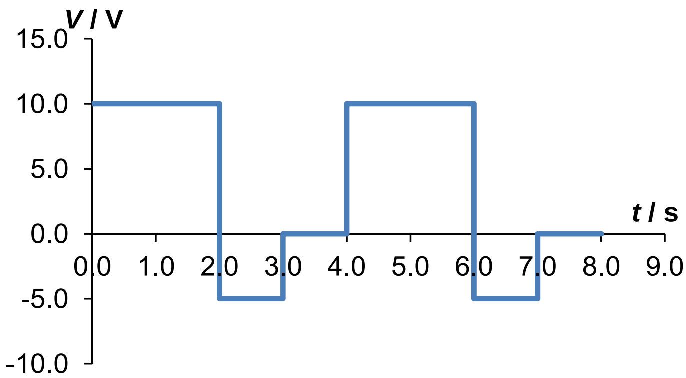


Fig. 7.1

Determine the root-mean-square voltage.

root-mean-square voltage = ...V [2]

Section B

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

8 **(a)** To determine the speed of sound, a student facing a brick wall claps her hands at point **P**, which is a measured distance, d, from the brick wall, as shown in Fig. 8.1(a). A microphone at **P** is connected to a timing device, arranged so as to record the time, t, between the original clap and its echo. The experiment is carried out for three distances d, and the results are plotted as shown in Fig.8.1(b).

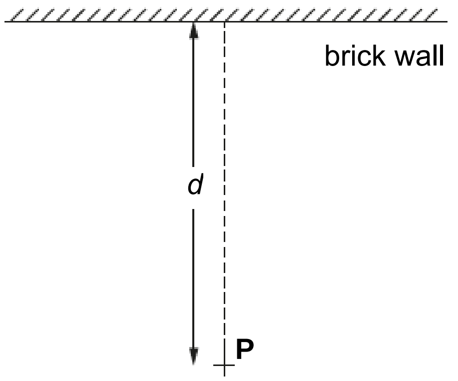


Fig. 8.1(a)

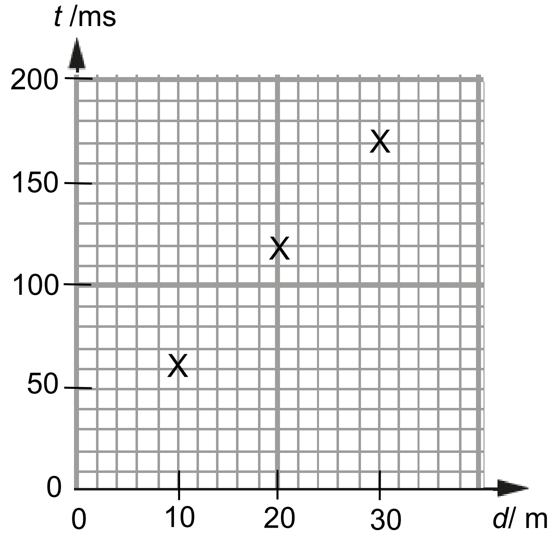


Fig. 8.1(b)

Determine a value for the speed of sound. Explain your working.

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

(b) In another experiment, as shown in Fig. 8.2, the student sets up two small loudspeakers, S_1 and S_2, connected to the same signal generator, set to 8 300 Hz.

She moves a microphone along the line AB, and finds maxima of sound at the positions shown by dots along AB, with minima in between.

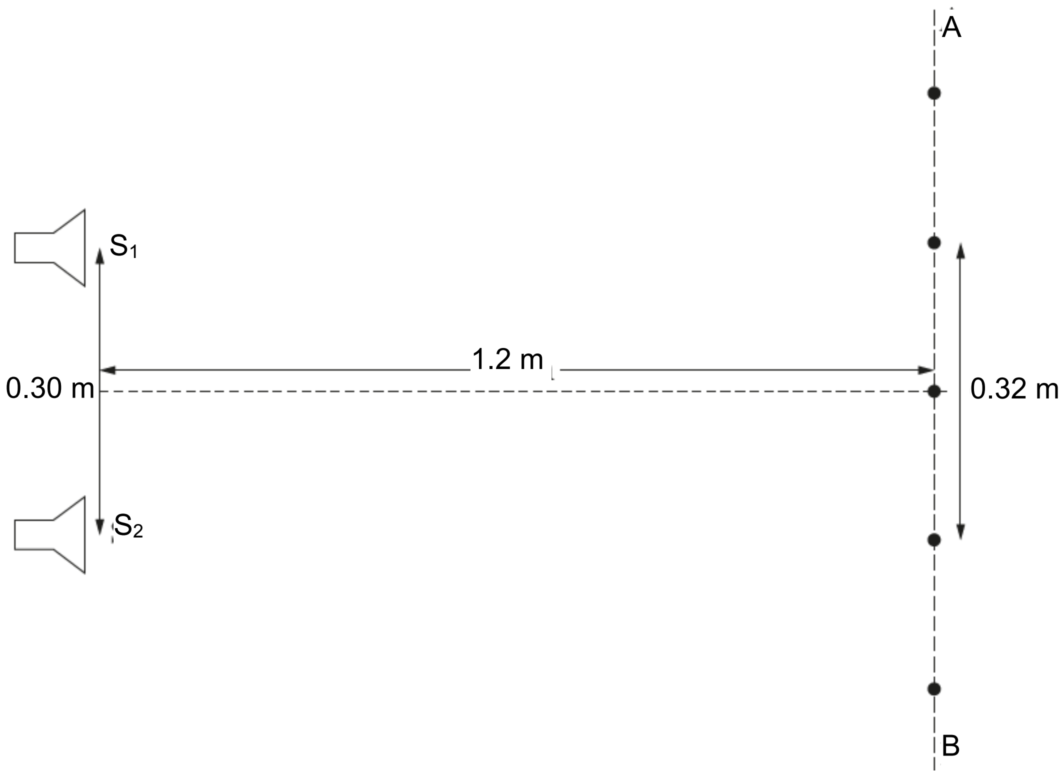


Fig. 8.2

(i) Determine the wavelength of the sound produced from S_1 and S_2.

wavelength = ... m [2]

(ii) Hence, calculate the speed of sound from this experiment.

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

(iii) **1.** Label with a letter 'M' on one of the dots along the line AB for which the path difference is $S_2M - S_1M = 2\lambda$. [1]

2. Explain why 'M' is a maxima.

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(iv) When the signal generator is set to 300 Hz, the student does not find a succession of maxima and minima as the microphone is moved along the line AB. Explain why this happens.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

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

(c) Fig. 8.3 shows an arrangement used to analyse the light emitted by a source. The light source emits a range of wavelengths from 500 nm to 700 nm. The light is incident on a diffraction grating that has 10000 lines per metre. The diffracted pattern is formed on the screen placed at a distance away from the grating. OX is the line that indicates the direction of the undiffracted light.

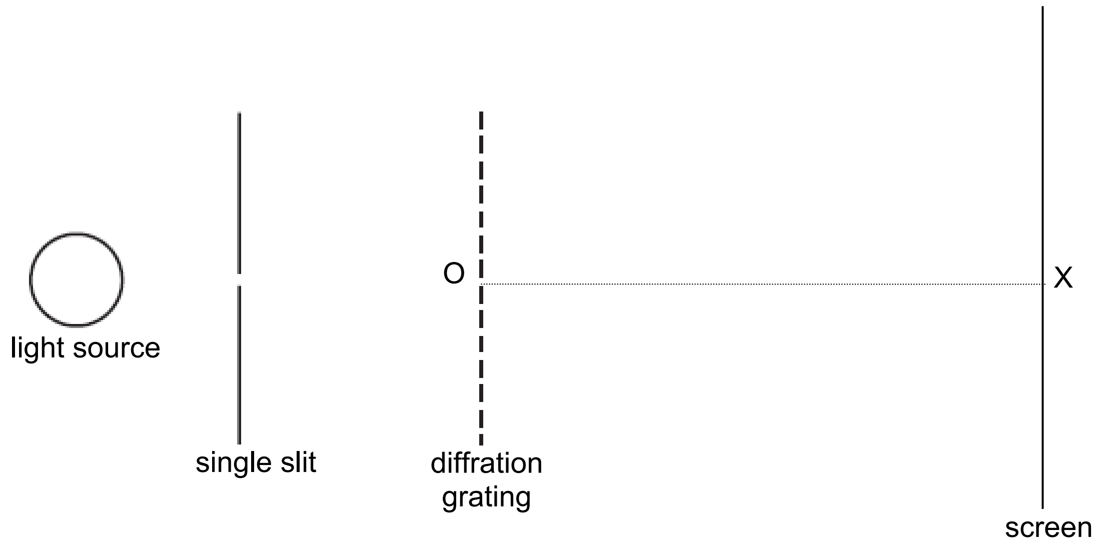


Fig. 8.3

(i) Calculate the angle from OX at which the first order maximum for the light of wavelengh of 500 nm is formed.

angle from OX = ... ° [2]

(ii) Calculate the maximum angular separation of the first order spectrum on the same side of OX.

maximum angular separation = ... ° [2]

(iii) Calculate the maximum linear separation of the first order spectrum if the screen is placed at 2.0 m from the diffraction grating.

maximum linear separation = ... m [2]

(iv) The single slit is initially illuminated by light from a point source that is 0.020 m from the slit.

State and explain how the intensity of light incident on the single slit changes when the light source is moved to a position 0.050 m from the slit.

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

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

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

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

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

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

9 **(a)** Fig. 9.1 shows the first three energy levels of copper.

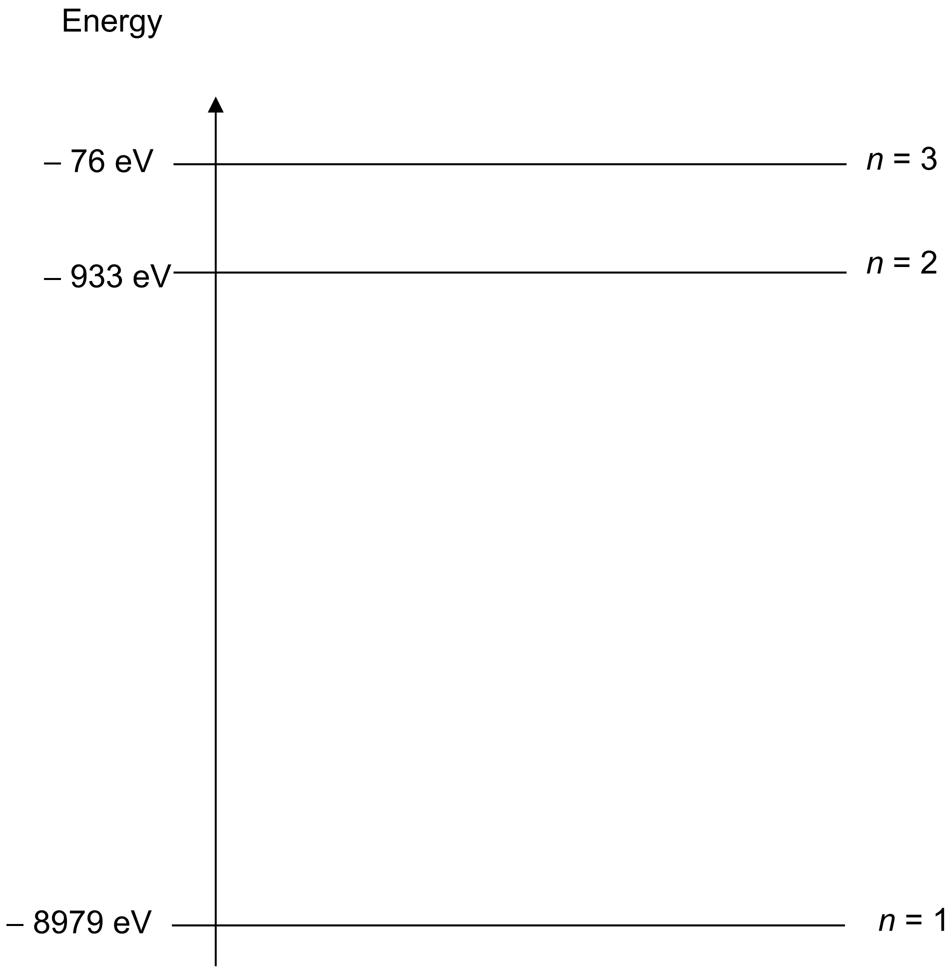


Fig. 9.1

In a particular experimental X-ray tube, a copper target is used. Electrons in the tube are accelerated by a potential difference of 10 kV before entering the target. X-rays then emerge from the target.

(i) Determine

1. the minimum wavelength of the X-ray photons.

minimum wavelength = ………………….. m [3]

2. the wavelength corresponding to the K-alpha characteristic line.

wavelength = ……………… m [2]

(ii) Sketch the X-ray spectrum of copper on Fig. 9.2 below. Use the answers in **(a)(i)** to label two important values of wavelength on your spectrum.

Fig. 9.2

[3]

(b) The diameter of a nucleus is of the order of magnitude of 10^{-15} m. Show, using the uncertainty principle, that an electron does not exist inside the nucleus.

[3]

(c) The decay of a calcium-45 nucleus (chemical symbol: Ca; Z = 20) releases a scandium-45 (chemical symbol: Sc; Z = 21) nucleus. Write a nuclear equation to deduce the type of decay that takes place.

type of decay = …………………………….. [2]

(d) Radon-219 is a naturally radioactive element, a member of the noble gas family found in soil. Data for the α-decay of Radon-219 to form Polonium-215 are given in Fig. 9.3 below.

Nucleus	*Mass of nucleus / u*
Radon-219	219.009523
Polonium-215	214.999469
Helium-4	4.002603

Fig. 9.3

Determine the energy released during the decay.

energy released = …………………….. MeV [3]

(e) Bismuth-210 undergoes β-decay. The emitted β-particles have a range of energies up to a maximum of 1.17 MeV.

Using conservation laws, explain why this range of energies leads to the suggestion that, apart from the β-particle, another particle must be emitted by the Bismuth-210 nucleus.

……

……

……

……

……

……

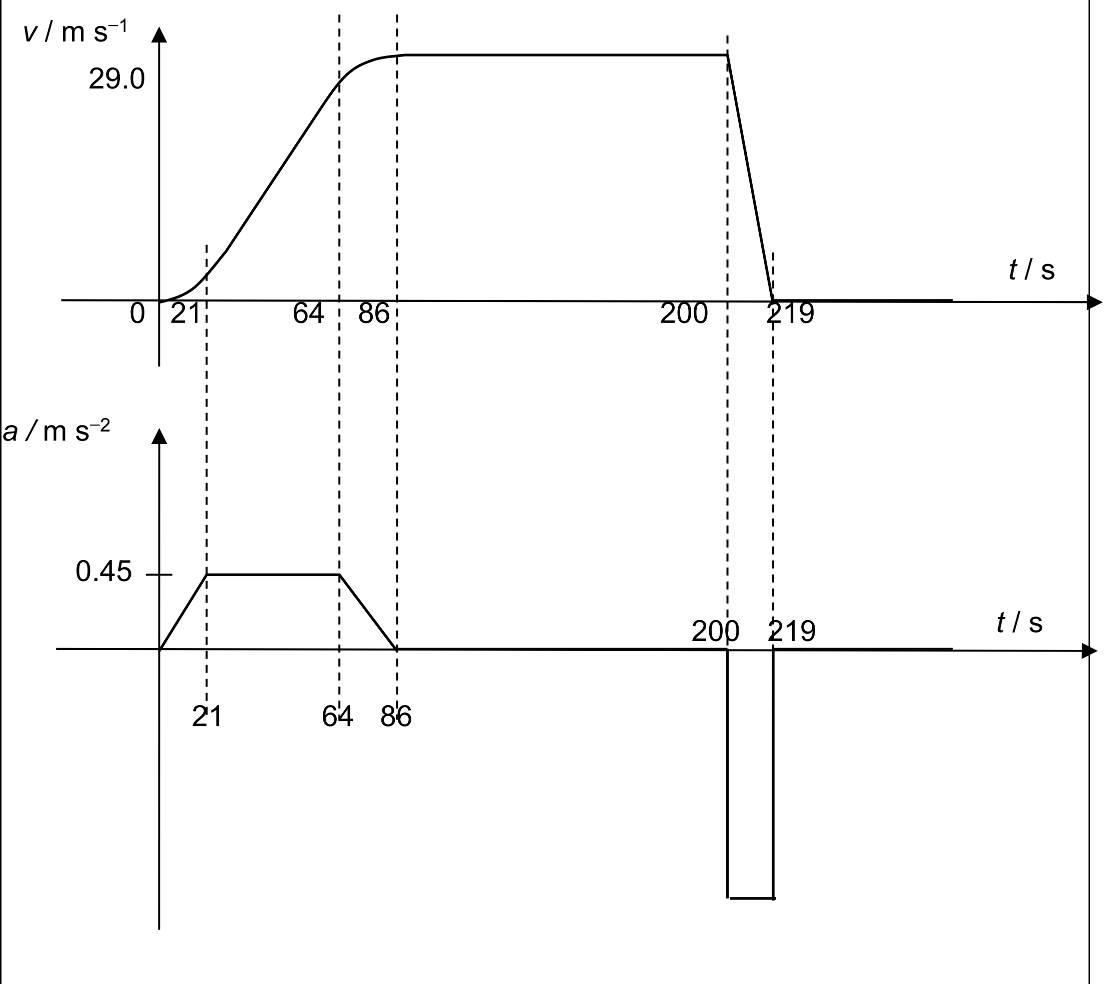
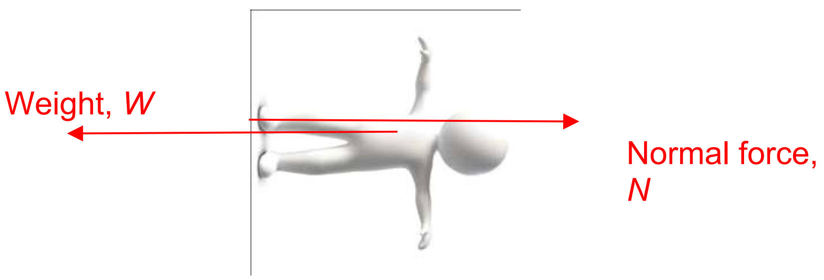
……

……

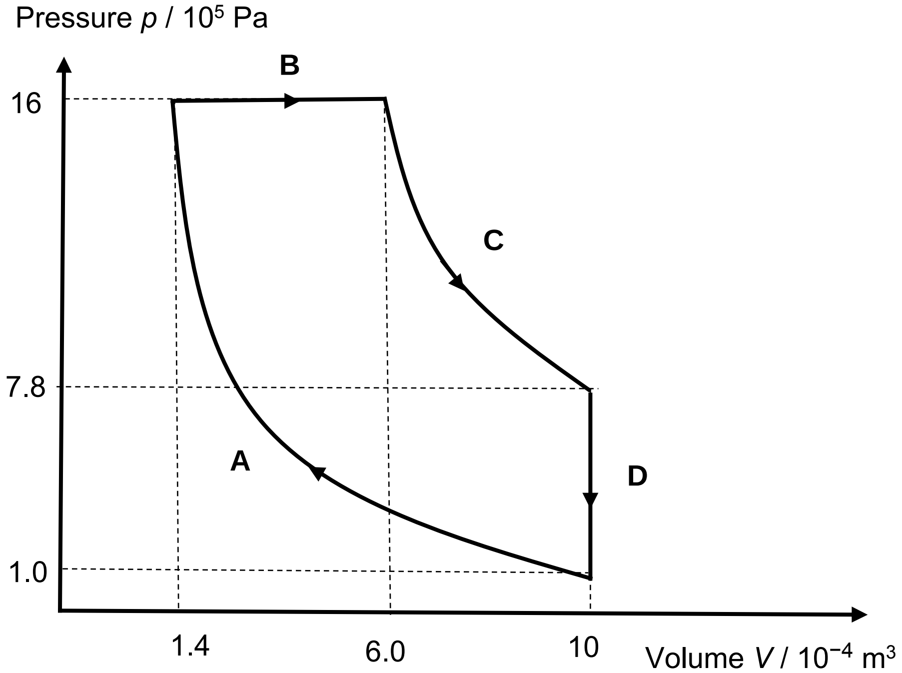
…… [4]

- End of Paper -

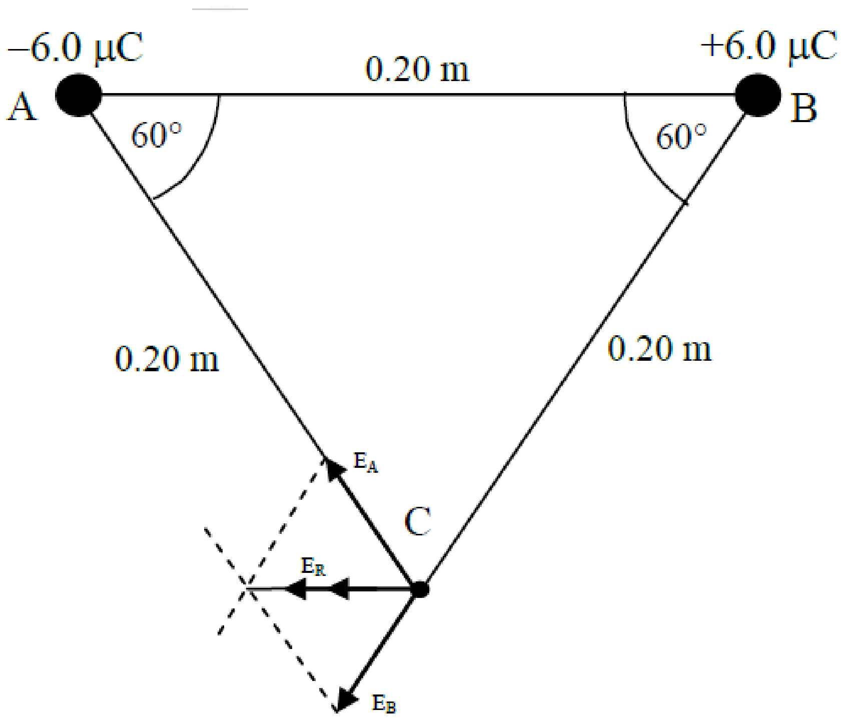
Suggested Solution
Section A

1	**(a)**		Δv = area under *a*-*t* graph = ½ (21)(0.45) + (43)(0.45) + ½ (22)(0.45) = 29 $< a > = \Delta v / \Delta t$ = 29 / 200 = 0.15 (0.145) m s^{-2}	**1** **1**
	(b)	**(i)**	v_{max} = area under *a*-*t* graph (from t = 0 to t = 86 s) = ½ (86 + 43) (0.45) = 29.0 m s^{-1}	**1** **1**
		(ii)		
2	**(a)**		[1] for the correct pair of forces [1] for length of W > N 	

	(b)		The scale reads the normal force. The normal force of man **P** is equal to his weight, whereas the normal force of man **E** is the difference between his weight and the centripetal force as man **E** is undergoing circular motion.	1 1 1
	(c)		$589.2 - 587.4 = 60\ a_c$ $a_c = 0.030\ \text{m s}^{-2}$	1 1
3	(a)		Gravitational potential at a point is the work done <u>per unit mass</u> in bringing a <u>small test mass</u> from <u>infinity to that point</u>.	1
	(b)	(i)	**1.** The gravitational field is non uniform. Accept: Gravitational potential varies inversely proportional to the distance from the centre of Earth to a point.	1
	(b)	(i)	**2.** Gravitional potential is taken to be zero at infinitiy. The gravitational forces are attractive and thus negative work has to be done by an external force to bring the mass from infinity to that point at constant speed.	1 1
	(b)	(ii)	By Priniciple of Conservation of Mechanical Energy, $GPE_i + KE_i = GPE_f + KE_f$ $m\Phi_m + 0 = m\Phi_E + \frac{1}{2} mv^2$ [1] $v^2 = 2(\Phi_m - \Phi_E)$ $v = \{2[-1.0 - (-62.0)]\}^{0.5}$ [1] $= 1.1 \times 10^4\ \text{m s}^{-1}$ [1]	
	(b)	(iii)	Since gravitational potential, $\phi = -GM/r$, $-61.6 \times 10^6 = -(6.67 \times 10^{-11})(5.97 \times 10^{24}) / (6371 \times 10^3 + h)$ where h is the height of the upper edge of the atmosphere correct substitution of ϕ, G, M [1] $r = r_E + h$ [1] Thus, $h = 9.3 \times 10^4$ m (93.3 km) [1]	

4	(a)	The <u>INCREASE</u> in the internal energy of a system is equal to the sum of heat supplied <u>TO</u> the system and the work done <u>ON</u> the system.	1
	(b) (i)		4
	(ii)	see table below	3
	(iii)	Net work done on gas = 300 + (-740) + (-440) + 0 = - 880 J Heat supplied to gas during B = 2580 J Ratio = 880 / 2580 = 0.34	1 1

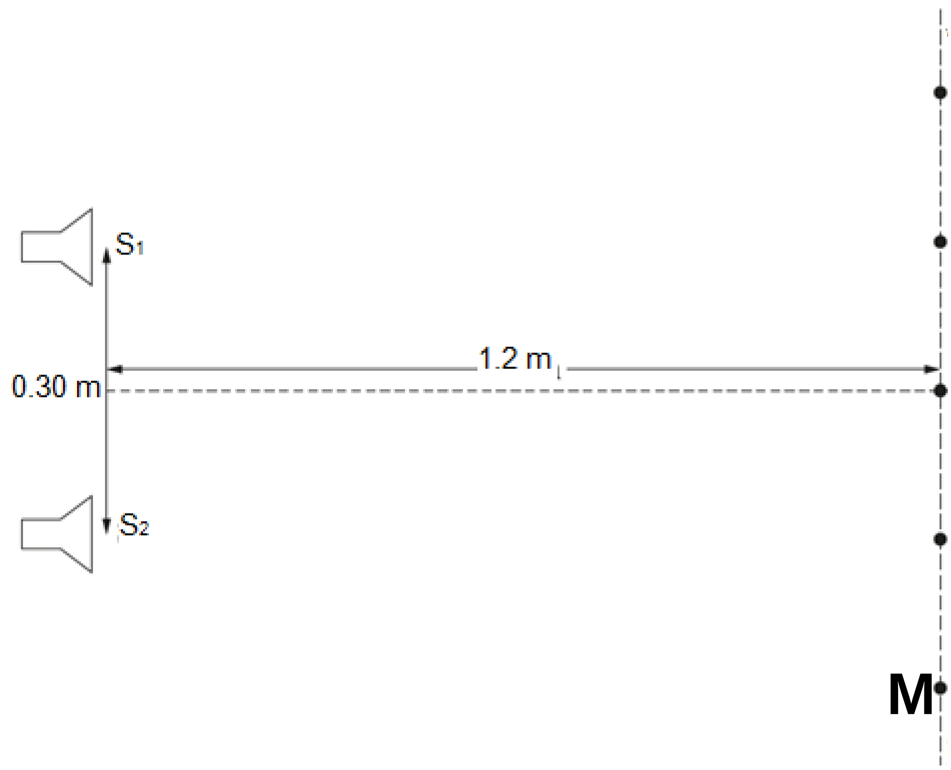
	Heat supplied to gas / J	Work done on gas / J	Increase in internal energy of gas / J
A	0	300	300
B	2580	-740	1840
C	0	-440	-440
D	-1700	0	-1700

5	(a)		1 1 1
	(b)	$E_R = \frac{1}{4\pi\varepsilon_o}\frac{6\times10^{-6}}{0.2^2}\cos 60^\circ \times 2$ $= 1.35\times10^6\ NC^{-1}$ Right substitution.	1 1

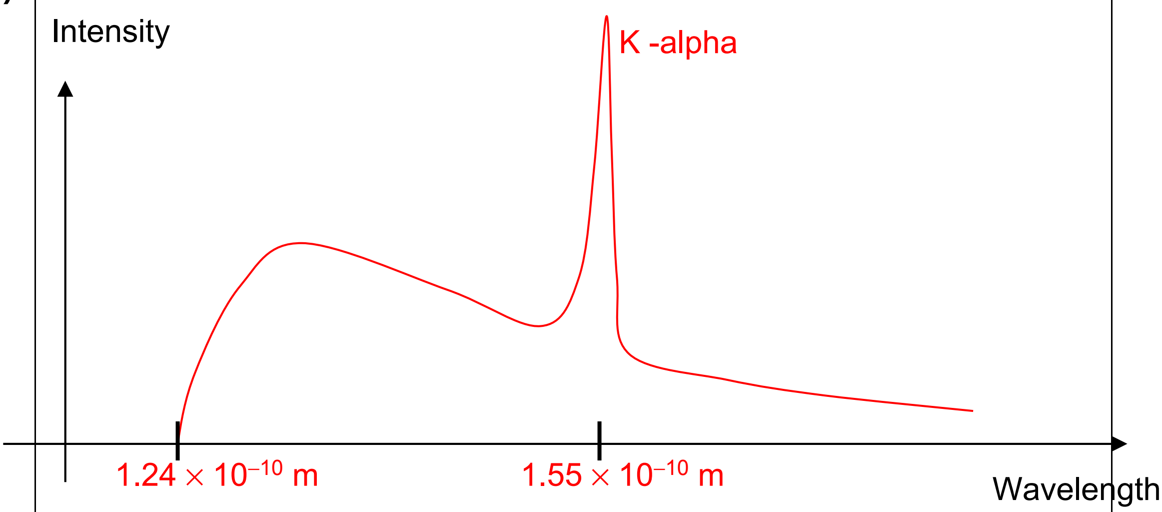
6	(a)	good attempt at evenly spaced parallel lines, and downward arrow.		1 1
	(b)	To produce a fine/ narrow beam /ions parallel to each other		1
	(c)	(i)	*(region R) into page* *(region S) out of page*	1 1
		(ii)	Electric force is downward with the magnetic force is directed upward. Electric force is equal to *qE* while magnetic force is equal to *Bqv*. They are equal to each other which gives v = E/B and mass is not included in the relation.	1 1 1
		(iii)	It will hit below the slit nearer to the bottom plate. Since electric force is greater than the magnetic force.	1 1
	(d)	(i)	There is a change in magnetic flux linkage though the coil as the cart approaches and leaves the coil.	1

	(d)	**(ii)**	The direction of the induced e.m.f. is such that the current would flow to oppose the change producing it. As the cart passes A, the flux linkage is increasing and as the cart passes B, magnetic flux linkage is decreasing so e.m.f. induced is in opposite direction.	**1** **1**
	(d)	**(iii)**	The cart has accelerated between A and C/ moves faster/ more KE at C. The change of magnetic flux linkage takes place within a shorter time frame, hence rate of change of magnetic flux is greater. This induced e.m.f. is greater.	**1** **1**
7	**(a)**	**(I)**	effective direct voltage that produces the same heating effect as the alternating voltage.	**1**
		(ii)	Vo = 325.269 V Peak P = 325.269 x 0.26 $\sqrt{2}$ =120 W	**1** **1**
	(b)	$\langle V^2 \rangle = \frac{(10)^2(2.0)+(5^2)(1.0)}{4.0}$ = 56.25 V V_{rms} = 7.5 V		**1** **1**

Section B

8	**(a)**	Calculate speed for d = 10, 20, 30 m: Velocity v_1 = 10 x **2** / 60 x 10^{-3} = 333.33333 m s^{-1} v_2 = 20 x **2** / 120 x 10^{-3} = 333.33333 m s^{-1} v_3 = 30 x **2** / 170x 10^{-3} = 352.94 m s^{-1} Explanation: The value of d is multiplied by 2 (or half the t) because the sound travels from the source to wall and back again to source. Find the average. : v_{ave} = 339.87 = 340 m s^{-1} [Alternatively, students can solve via drawing a BFL, determining its gradient, equating the gradient value to 2/v and then find v. Drawing a BFL is akin to taking average.]			 1 1 1
	(b)	**(i)**	Use $\lambda = ax/D$ With x = 0.16 m, …. λ = 0.040 m		 1 1
	(b)	**(ii)**	$v = f\lambda$ = 8300 x 0.040 = 332 m s^{-1}		 1
		(iii)	**1.**		1

			2.	The path difference is equal to an <u>integer</u> number of wavelengths (and sources are in phase) OR Waves from S_1 and S_2 <u>arrive in phase at **M**</u> ["Constructive interefence" as the sole answer will not gain any credit. This is just paraphrasing the question]	**1**
		(iv)	Calculate that λ = 1.1 m Use $\lambda = ax/D$ to calculate x = 4.4 m The first order maximum is found at 4.4 m which is too far away from the central fringe. (The length of the screen AB appears to be slightly greater than 0.64 m only. So there is a central maxima, but the next maxima is 4.4 m away, and the first minima is 2.2 m away, so no succession of maxima and minima).		**1** **1** **1**
	(c)	**(i)**	$d = 1.0 \times 10^{-4}$ m $n\lambda = d \sin\theta$ With n = 1, θ = 0.286°		**1** **1**
		(ii)	For λ = 700 nm, n = 1, we have θ_{700} = 0.4011° Thus $\Delta\theta = \theta_{700} - \theta_{500}$ = 0.4011 – 0.2865 = 0.115°		**1** **1**
		(iii)	Let y be the distance of the maxima from **X**, as measured along the screen. Then y_{700} = 2.0 tan 0.4011° and y_{500} = 2.0 tan 0.2865°. Thus, linear separation = $y_{700} - y_{500}$ = 0.00400 m		 **1** **1**
		(iv)	lower intensity (because energy spreads) use or statement of inverse square law ($I \propto 1/r^2$) ratio of the initial intensity to the final intensity = $(0.02/0.05)^2$ = 0.16 or intensity falls by factor of 6.25		**1** **1** **1**

9	**(a)**	**(i)**	1. Using $e\,V_{acc} = h\,c\,/\,\lambda_{min}$, [1] we have $\lambda_{min} = (6.63 \times 10^{-34})\,(3.0 \times 10^{8})\,/\,(1.60 \times 10^{-19} \times 10 \times 10^{3})$ [1] $= 1.24 \times 10^{-10}$ m [1]	
		(i)	2. Using $\Delta E_{(2\rightarrow1)} = h\,c\,/\,\lambda$, we have $\lambda = (6.63 \times 10^{-34})\,(3.0 \times 10^{8})\,/\,[\,(-933) - (-8979)\,] \times 1.60 \times 10^{-19}$ [1] $= 1.55 \times 10^{-10}$ m [1]	
	(a)	**(ii)**	 Shape [1] Minimum wavelength labelled [1] K-alpha wavelength labelled [1]	
	(b)		Using formula $\Delta p_x\,\Delta x \geq h$, $\Delta p_x \geq 6.63 \times 10^{-34}\,/\,(1 \times 10^{-15}) = 6.63 \times 10^{-19}$ [1] $\Delta v \geq 6.63 \times 10^{-19}\,/\,(9.11 \times 10^{-31}) = 7.3 \times 10^{11}$ m s^{-1} [1] Thus, Δv > c, which is impossible [1]	
	(c)		$^{45}_{20}Ca \rightarrow ^{45}_{21}Sc + ^{0}_{-1}e$ [1] (Negative) beta decay [1]	

	(d)	Mass difference = 219.009523 – (214.999469 + 4.002603) [1] = 0.007451 u Energy released = $(0.007451 \times 1.66 \times 10^{-27})(3 \times 10^{8})^2$ [1] $= 1.1132 \times 10^{-12}$ J = 6.96 MeV [1]	
	(e)	Without a second emitted particle, all β-particles would have the same energy [1] Range of β-particle energy values means range of momenta (speeds) [1] For COM and COE [1], there must be another particle to share the momentum and energy [1]	