TEMASEK JUNIOR COLLEGE

2018 Preliminary Examination
Higher 2

PHYSICS

9749/01

Paper 1 Multiple Choice

14 September 2018
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Civics Group and Index Number on the Answer Sheet in the spaces 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 Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

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

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
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.	$v = v_o \cos\omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = Q/(4\pi\varepsilon_0 r)$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ the liquid. The speed is given by the equation

$$v = k\left(\frac{\Delta P}{\rho}\right)^n$$

where k is a constant that has no unit.

What is the value of n?

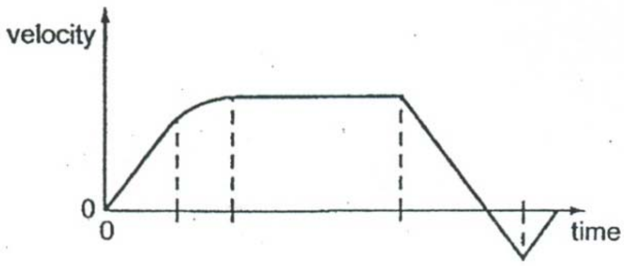
A 0.5 **B** 1 **C** 1.5 **D** 2

2 The diameter D of a sphere is measured to be 5.0 cm with a fractional uncertainty of 0.02.

What is the absolute uncertainty and fractional uncertainty of the radius R of the sphere?

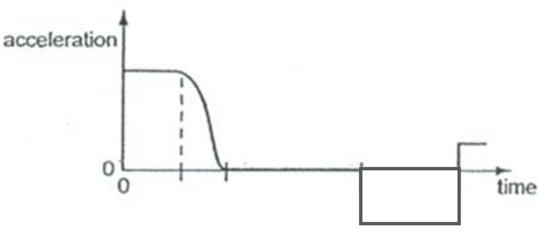
	absolute uncertainty of R	fractional uncertainty of R
A	0.05 cm	0.01
B	0.1 cm	0.01
C	0.05 cm	0.02
D	0.1 cm	0.02

3 A velocity-time graph of a journey is shown in the diagram.

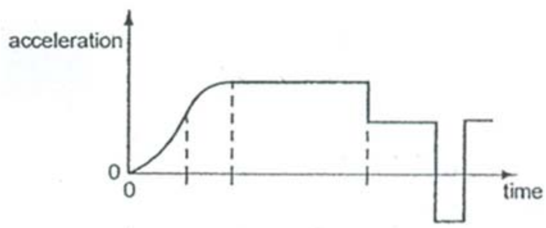


What is the shape of the acceleration-time graph for the same journey?

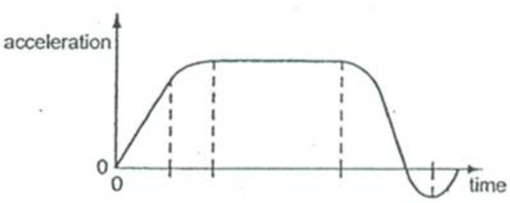
A



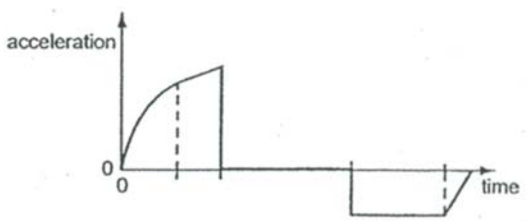
B



C



D

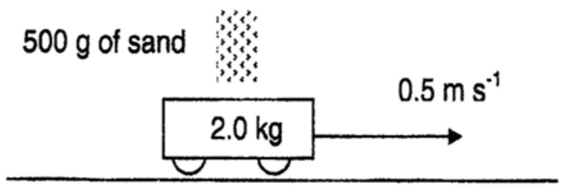


4 A hot-air balloon is moving vertically upwards with a constant speed of 3.00 m s^{-1}. A sandbag is dropped from the balloon. It takes 5.00 s for the sandbag to fall to the ground.

What was the height of the balloon when the sandbag was released?

A 29 m **B** 108 m **C** 123 m **D** 138 m

5 The diagram shows a 2.0 kg trolley moving on a frictionless horizontal table at a speed of 0.5 m s^{-1} and 500 g of sand is then released onto the trolley.

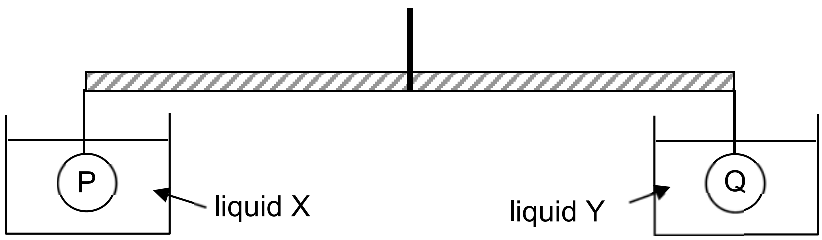


What is the change in the momentum of the trolley?

A zero **B** 0.15 N s

C 0.20 N s **D** 1.80 N s

6 Two objects P and Q having the same volume are hung at either ends of a light uniform rod and subsequently submerged in two different liquids X and Y respectively. The density of liquid X is less than that of liquid Y. The system is balanced when a string is hung right at the centre of the rod as shown in the figure below.



Which of the following statements is correct?

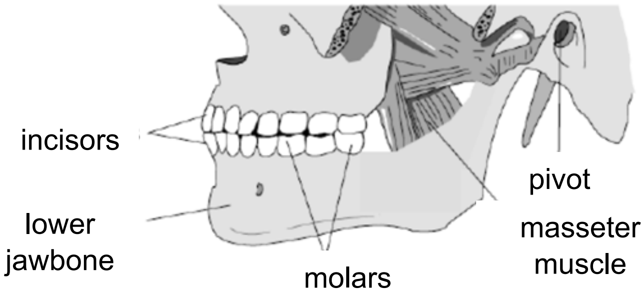
A Mass of P is larger than mass of Q.

B Mass of P is smaller than mass of Q.

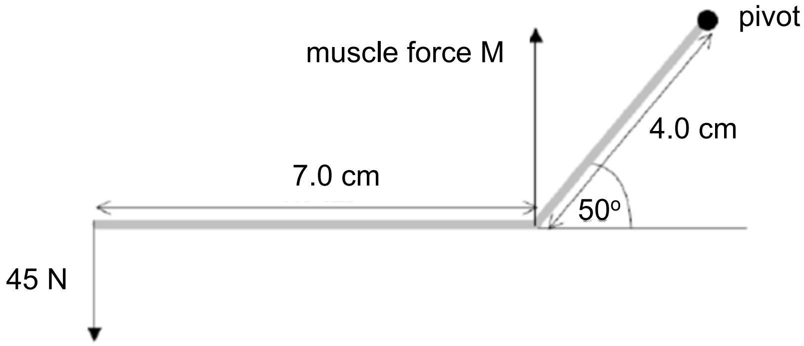
C P and Q experience the same magnitudes of upthrust.

D Upthrust acting on P is larger than the upthrust acting on Q.

7 The diagram below shows the position of a person's lower jawbone.



The lower jaw may be represented by the diagram below.

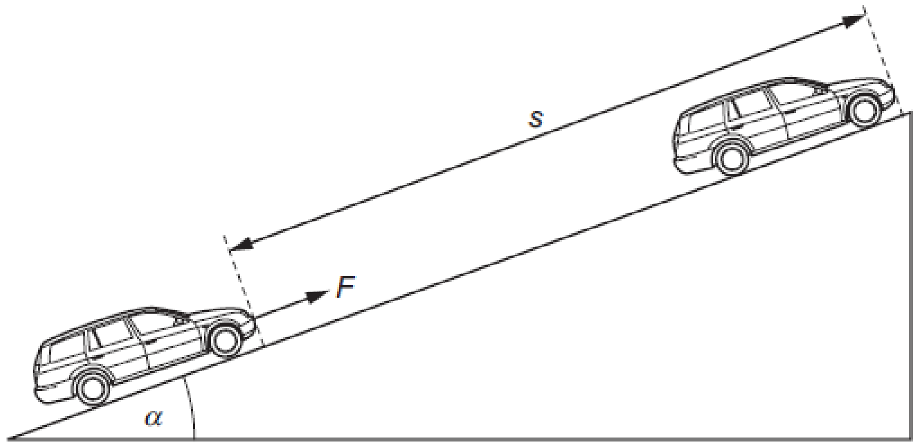


The jawbone has negligible mass. It consists of two straight parts of length 7.0 cm and 4.0 cm making an angle of 130° with each other. During one particular bite, a force of 45 N is applied by the teeth at the front of the jawbone.

What is the magnitude of muscle force M?

A 120 N **B** 140 N **C** 150 N **D** 170 N

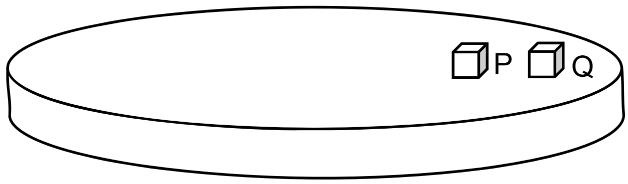
8 A constant force *F*, acting on a car of mass *m*, moves the car up a slope through a distance *s* at constant velocity *v*. The angle of the slope to the horizontal is α.



What is the ratio $\dfrac{\text{gravitational potential energy gained by car}}{\text{work done by force } F}$?

A $\dfrac{mgs\sin\alpha}{Fv}$ **B** $\dfrac{mv}{Fs}$ **C** $\dfrac{mv^2}{2Fs}$ **D** $\dfrac{mg\sin\alpha}{F}$

9 Two identical objects rest on a flat rough circular disc.



The disc starts from rest and starts spinning about its central axis with increasing rate. When the disc spins at a certain rate, one of the objects slides off the disc.

Which of the following statements is correct?

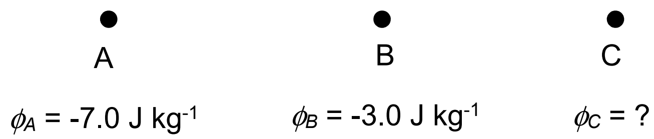
A The friction experienced by P and Q are always equal.

B P experiences larger friction than Q.

C Q will start to slide first due to larger angular velocity.

D Q will start to slide first due to larger radius.

10 Two points in space, A and B, have gravitational potentials of -7.0 J kg^{-1} and -3.0 J kg^{-1} respectively as shown below.

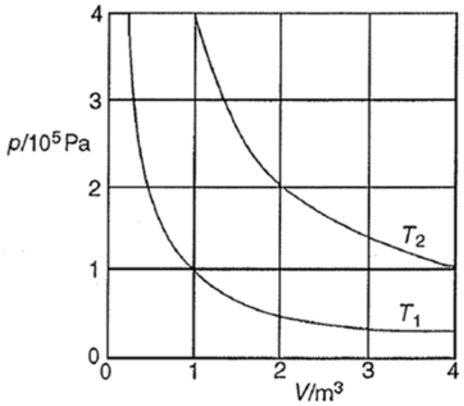


When a mass is moved from A to B, it gains gravitational potential energy of 20 J. When it is moved from B to C, it loses gravitational potential energy of 5.0 J.

What is the gravitational potential at C?

A - 8.0 J kg^{-1} **B** - 4.0 J kg^{-1} **C** - 2.0 J kg^{-1} **D** 2.0 J kg^{-1}

11 The two curves shown below are for a fixed mass of an ideal gas.



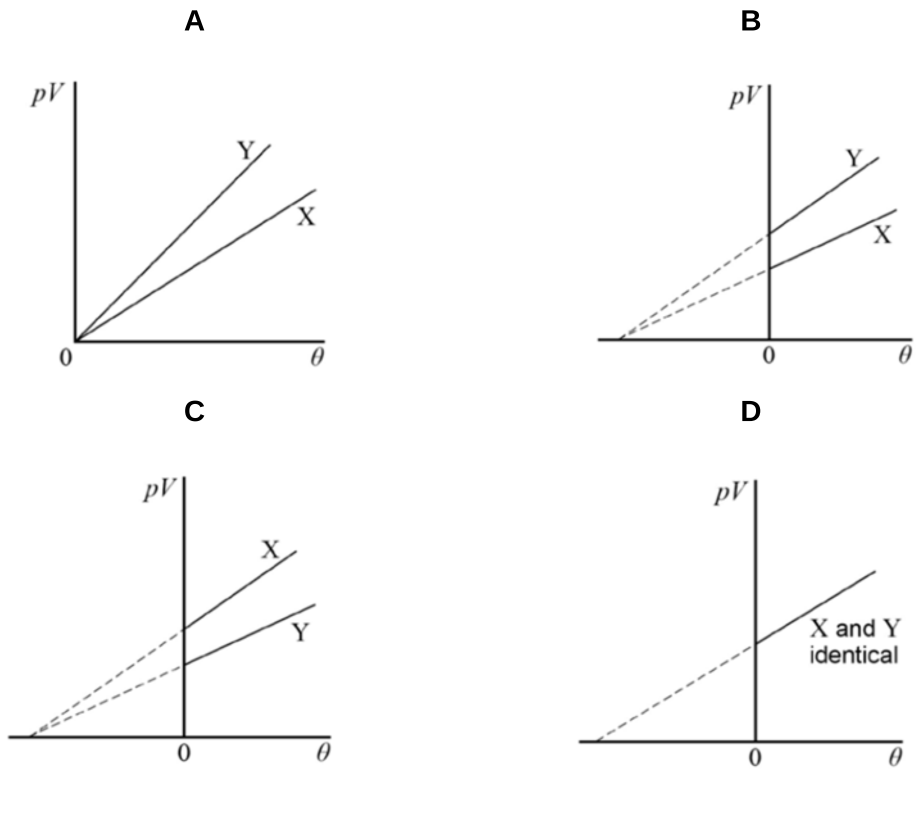
What is the ratio $\dfrac{\text{r.m.s. speed of the molecules at temperature } T_2}{\text{r.m.s. speed of the molecules at temperature } T_1}$?

A $\sqrt{2}$ **B** 2 **C** $2\sqrt{2}$ **D** 4

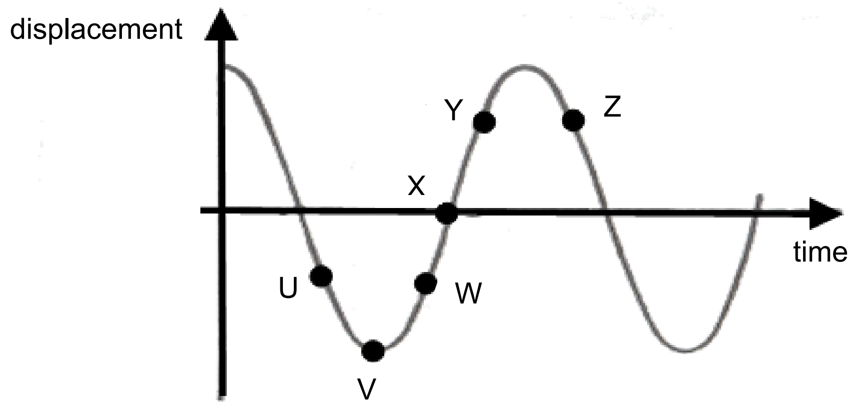
12 One mole of gas occupies a volume V at a pressure p and Celsius temperature θ. The graphs, **A** to **D**, show variation of pV with θ.

Line X is for one mole of nitrogen and line Y is for one mole of oxygen.
Relative molecular mass of nitrogen = 28
Relative molecular mass of oxygen = 32

Assuming both gases behave ideally, which of the following graphs is correct?



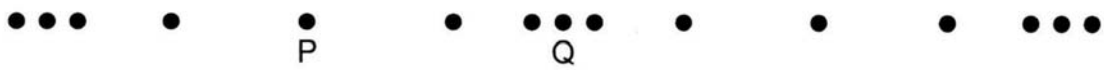
13 The diagram below shows a displacement-time graph of a body performing simple harmonic motion.



At which points, U, V, W, X, Y or Z, are the body travelling *and* accelerating in the opposite direction?

A U, Y **B** V, X **C** W, Z **D** X, Z

14 The diagram illustrates the displacement of particles in a longitudinal progressive waves of frequency *f* at an instant of time.



What is the time taken for a wavefront to travel the distance from P to Q?

A $\frac{1}{4f}$ **B** $\frac{1}{2f}$ **C** $\frac{1}{f}$ **D** $\frac{2}{f}$

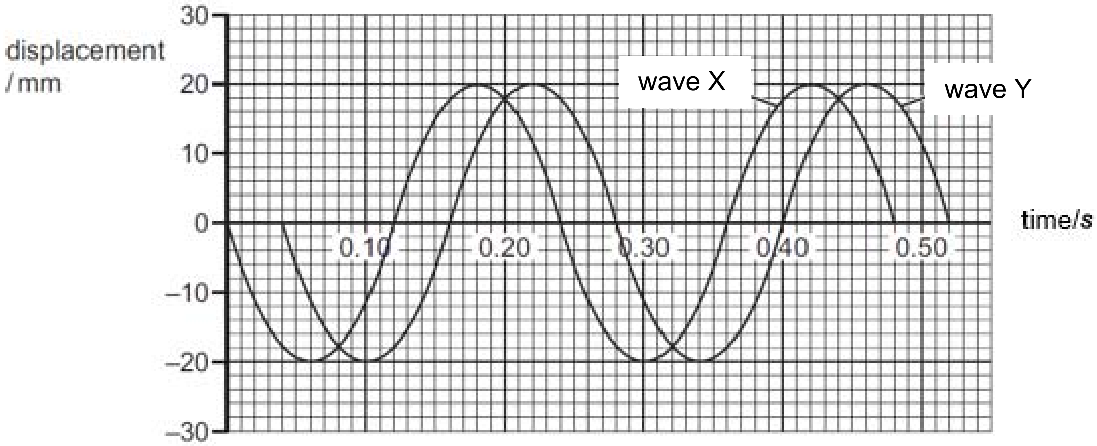
15 Plane polarised light of amplitude A is incident on a polarising filter aligned so that no light is transmitted.

The filter is now rotated through an angle of 30°.

What is the amplitude of the transmitted light?

A 0.25 A **B** 0.50 A **C** 0.75 A **D** 0.87 A

16 The diagram shows the variation with time of the displacement of two transverse progressive waves, X and Y.



Which of the following statements is correct?

A Wave X leads wave Y by $\pi/4$ rad.

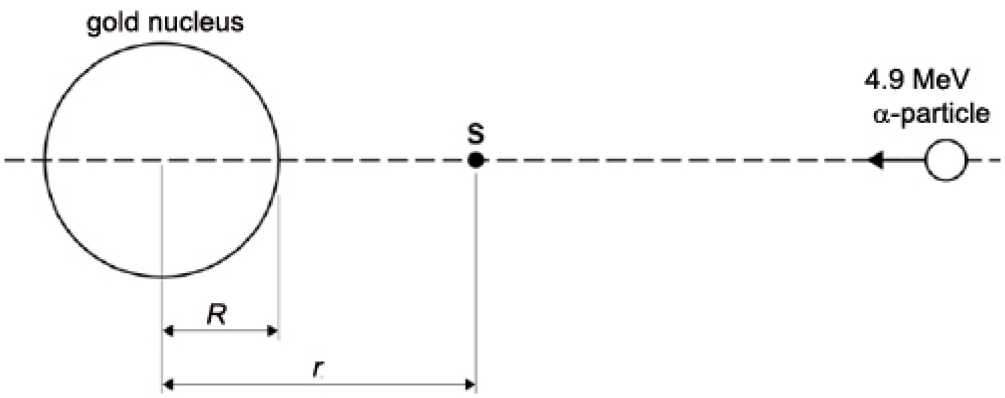
B Wave X lags wave Y by $\pi/4$ rad.

C Wave X leads wave Y by $\pi/3$ rad.

D Wave X lags wave Y by $\pi/3$ rad.

17 An α-particle with an initial kinetic energy of 4.9 MeV is directed towards the centre of a gold nucleus of radius *R* which contains 79 protons. The radius *R* of the gold nucleus is found to be 1.4×10^{-14} m.

The α-particle is brought to rest at point S, a distance *r* from the centre of the nucleus as shown in the figure.



What is the distance *r* of the α-particle to the nucleus?

A 1.4×10^{-14} m **B** 4.6×10^{-14} m **C** 2.2×10^{-7} m **D** 4.4×10^{-7}m

18 A wire of resistance *R* is melted and re-casted to half its original length.

What is the new resistance of the wire?

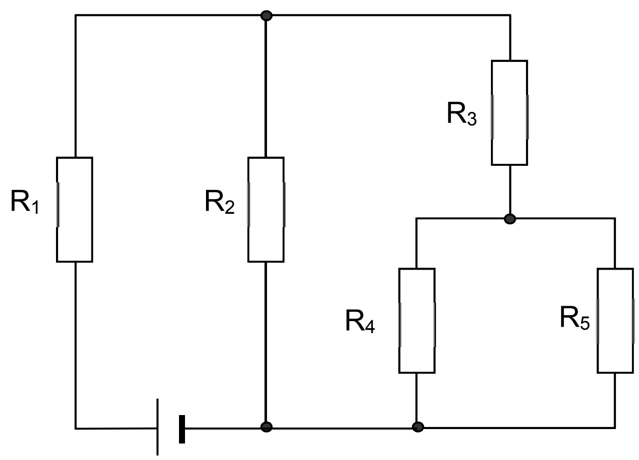
A *R*/4 **B** *R*/2 **C** *R* **D** 2*R*

19 The potential difference across a resistor is 12 V. The current in the resistor is 2.0 A. A charge of 4.0 C passes through the resistor.

What is the energy transferred in the resistor and the time taken for the charge to pass through the resistor?

	energy/J	time/s
A	3.0	2.0
B	3.0	8.0
C	48	2.0
D	48	8.0

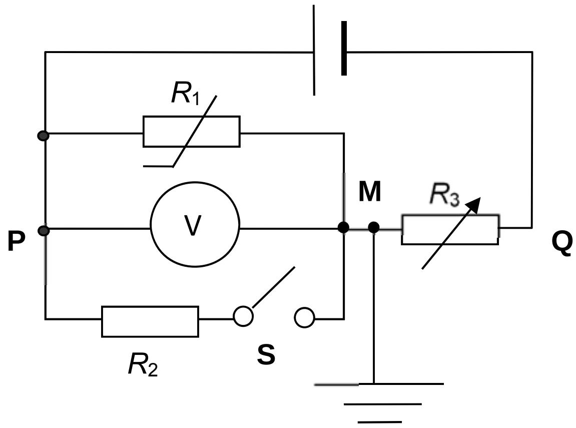
20 Each of the five resistors shown has the same resistance.



Which resistor will have the greatest potential difference across it?

A R_1 **B** R_2 **C** R_3 **D** R_4

21 A NTC thermistor R_1 is connected to an ideal battery of constant e.m.f. with two other resistors R_2 and R_3.



Assume that the voltmeter has infinite resistance.

Which of the following actions will cause an increase in the potential difference V measured by the voltmeter?

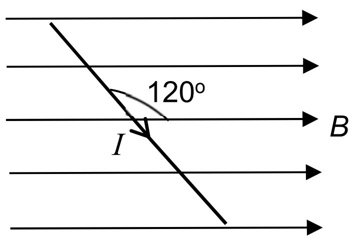
A Increase the temperature of the thermistor with S open

B Remove the earth connection at M with S open

C Close switch S

D Decrease resistance R_3 with S open

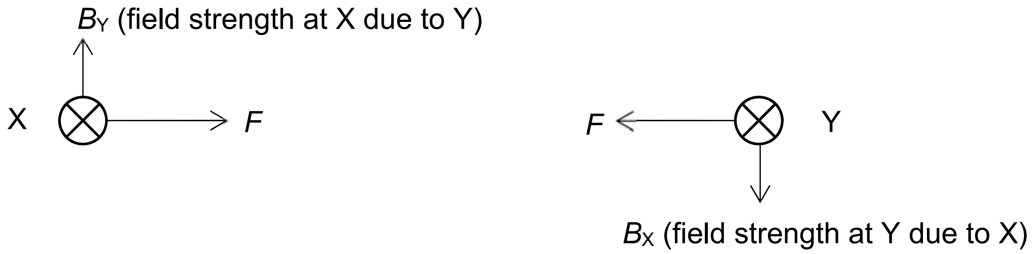
22 A wire 30 cm long with a mass of 4.0 g, is placed at an angle of 120° to a horizontal magnetic field of flux density 0.040 T. When a current I is passed through the wire, the wire accelerates uniformly upwards. The diagram below shows the top view of the set-up.



If the acceleration of the wire is 2.0 m s^{-2}, what is the current in the wire?

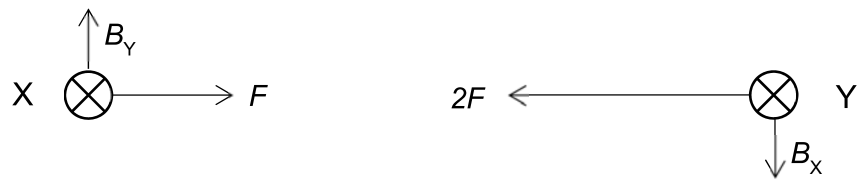
A 7.9 A **B** 4.5 A **C** 3.0 A **D** 0.77 A

23 Two long, parallel, straight wires X and Y carry equal currents into the plane of the page as shown. The diagram shows arrows representing the magnetic field strength *B* at the position of each wire and the magnetic force *F* on each wire.

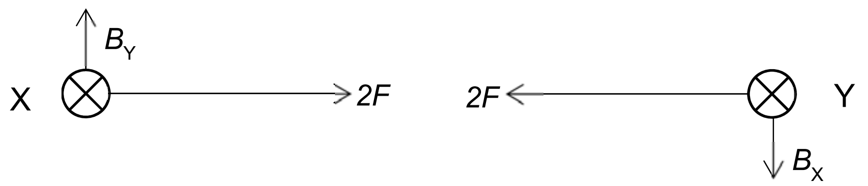


The current in wire Y is doubled. Which diagram best represents the magnetic field strengths and forces?

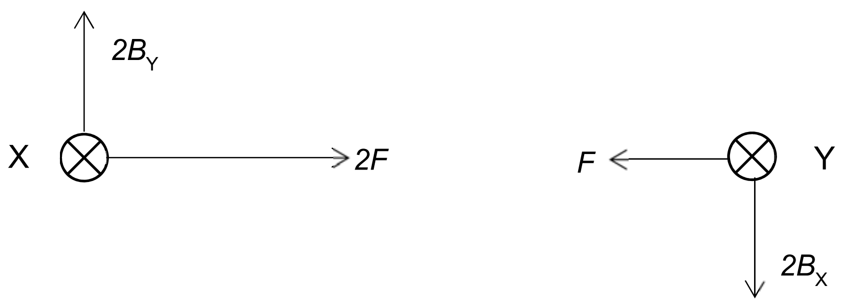
A



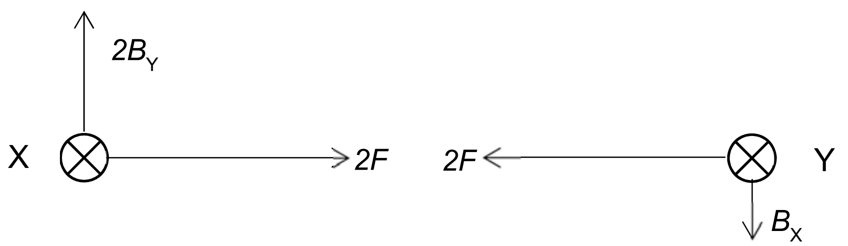
B



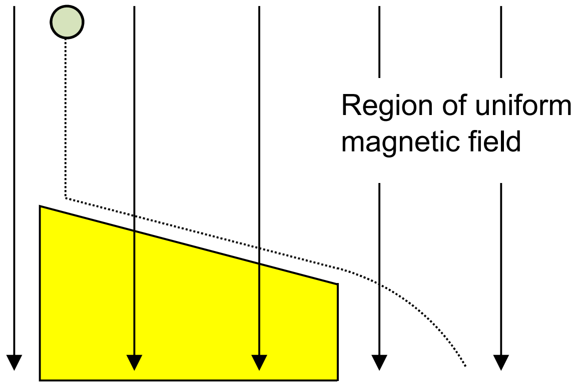
C



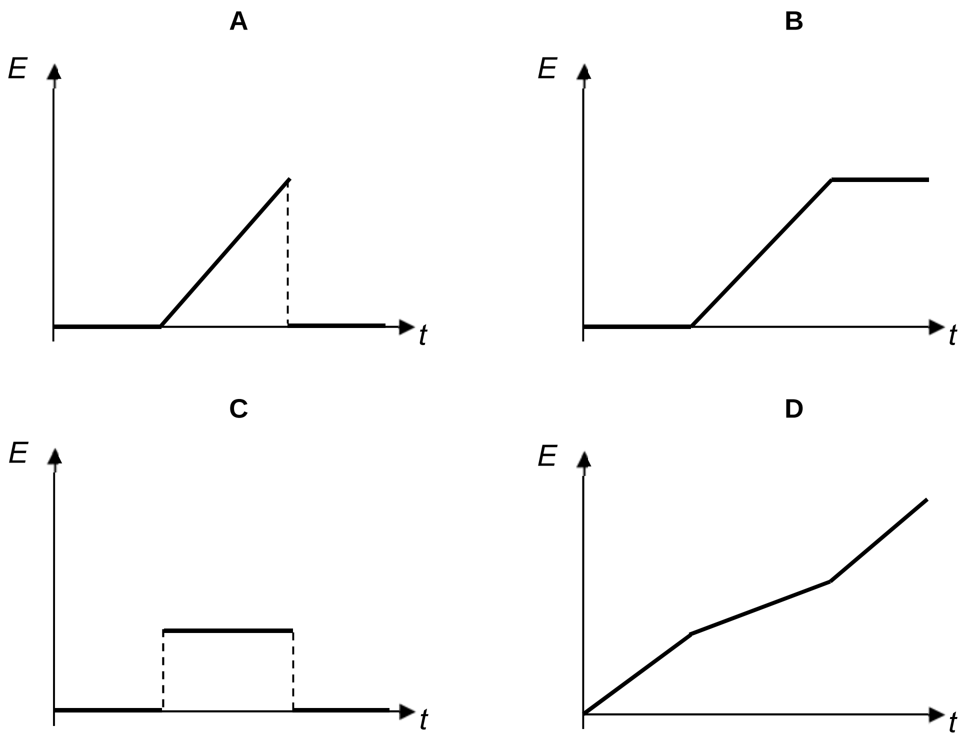
D



24 In a region of uniform magnetic field, a metal rod falls vertically from rest and lands on to a smooth slope. It continues to roll down the slope and launches off the slope as shown in the diagram.



Which graph best shows the variation with time *t* of the e.m.f *E* induced in the rod, from the time it is released?



25 A transformer with turns ratio of primary to secondary coil of 20:1 is 95% efficient due to joule heating effects.

A 240 V alternating voltage is connected to the primary coil and a 5.0 Ω resistor is connected to the secondary coil.

What is the current flowing in the primary coil?

A 48.0 A **B** 2.40 A **C** 0.126 A **D** 0.120 A

26 An alternating voltage V/V varies with time t/s according to the equation

$$V = 9\cos(100\pi t)$$

What is the mean power dissipated in a resistive load of 20 Ω?

A 2.0 W **B** 4.1 W **C** 6.4 W **D** 8.1 W

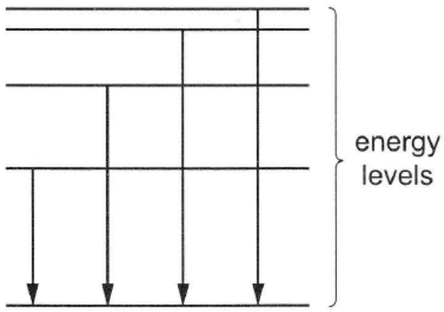
27 In 2010 the Japanese launched the world's first interplanetary solar sail spacecraft, called IKAROS. This works because photons reflected from the sail, of area A, undergo a change of momentum and, by Newton's third Law, exert a forward force on the sail.

A beam of light of intensity I is reflected at right angles to a solar sail.

If f is the frequency of the light, h is the Planck constant and c is the speed of light, what is the force exerted on the sail?

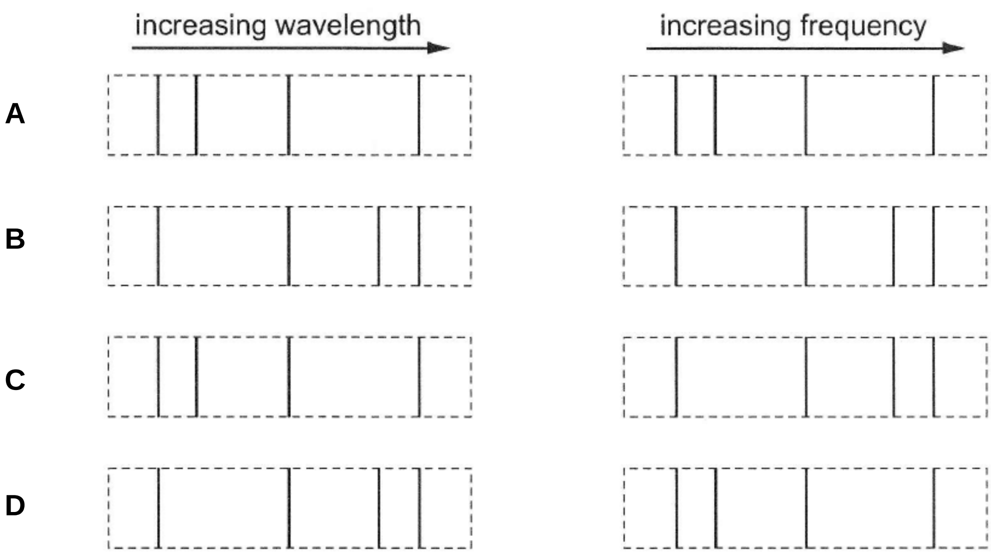
A $\dfrac{IA}{hf}$ **B** $\dfrac{2hf}{c}$ **C** $\dfrac{I}{c}$ **D** $\dfrac{2IA}{c}$

28 The diagram shows five electron energy levels in an atom and some transitions between them.



The line spectrum produced is in the visible spectrum and can be represented on a wavelength scale or a frequency scale.

Which diagram could represent the light emitted by the four transitions shown above?

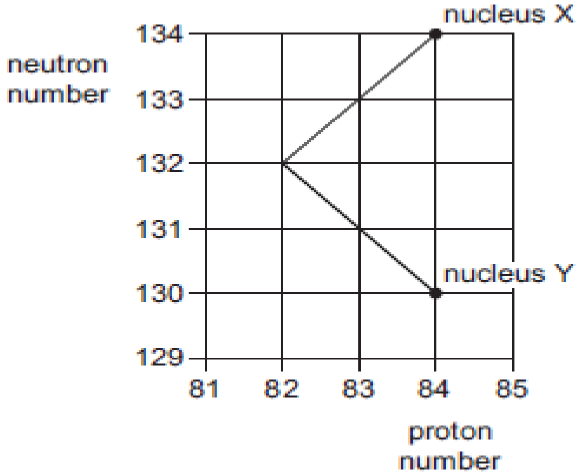


29 A detector is used for monitoring an α-source and a reading of 300 counts is observed. After a time equal to the half-life of the α-source, the reading has fallen to 155 counts.

If a 5 mm thick lead sheet is inserted between the α-source and the detector, what would the reading probably be?

A 0 counts **B** 5 counts **C** 10 counts **D** 20 counts

30 The graph of neutron number against proton number represents a sequence of radioactive decays.



Nucleus **X** is at the start of the sequence and, after the decays have occurred, nucleus **Y** is formed.

What is emitted during the sequence of decays?

A one α-particle followed by one β-particle
B one α-particle followed by two β-particles
C two α-particles followed by two β-particles
D two β-particles followed by one α-particle

2018 TJC H2 Physics Prelim Paper 1 Solutions

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	**C**	**A**	**B**	**C**	**B**	**D**	**D**	**D**	**B**	**B**	**D**	**A**	**B**	**B**
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C	**B**	**A**	**C**	**A**	**D**	**B**	**D**	**B**	**C**	**A**	**D**	**C**	**C**	**B**

1 **A** Units of $\Delta P = kgm^{-1}s^{-2}$, units of $\rho = kgm^{-3}$
Units of $\frac{\Delta P}{\rho} = m^2 s^{-2}$, hence n =0.5

2 **C** The absolute uncertainty of the diameter is 0.02 x 5.0 = 0.1 cm.
The absolute uncertainty of the radius will be 0.1 cm / 2 = 0.05 cm
The fractional uncertainty of the radius will be 0.05 cm / 2.5 cm = 0.02.

3 **A** a-t graph obtained from gradient of v-t graph

4 **B** Taking downwards as positive,
$S = ut + ½ at^2$
$= -3.00 \times 5.00 + ½\, 9.81(5.00)^2 = 108$ m

5 **C** By conservation of momentum:
$(2.0)(0.5) = (2.0 + 0.500)v_f \rightarrow v_f = 0.4$ m s^{-1}.
change in momentum = $p_f - p_i$ = 2.0 (0.4 – 0.5) = - 0.2 Ns

6 **B** By AP, upthrust = weight of fluid displaced. Liquid X has smaller density and hence exerts a smaller upthrust.

Balanced rod implies object P must have a smaller weight and hence smaller mass.

7 **D** Take moments about pivot,

M(4.0 cos 50°) = 45 (7.0 + 4.0 cos 50°) => M = 170 N

8 **D** GPE gained = mgh = mg sin α .s
Work done by force = F s
Divide the 2 eqns give answer D.

9 **D** Frictional force on the object provides the centripetal force $mr\omega^2$. Both objects have the same angular velocity and same mass, but the centripetal force required for Q is larger due to larger radius. When the centripetal force required exceeds the frictional force available, Q starts to slide.

10 **B** $\Delta U = m\Delta\phi \propto \Delta\phi$

$$\frac{\Delta U_{BC}}{\Delta U_{AB}} = \frac{\Delta\phi_{BC}}{\Delta\phi_{AB}} \Rightarrow \frac{-5.0}{+20} = \frac{\phi_C + 3.0}{-3.0 + 7.0}$$

$\Rightarrow \phi_C = -4.0$ J kg^{-1}

11 **B**

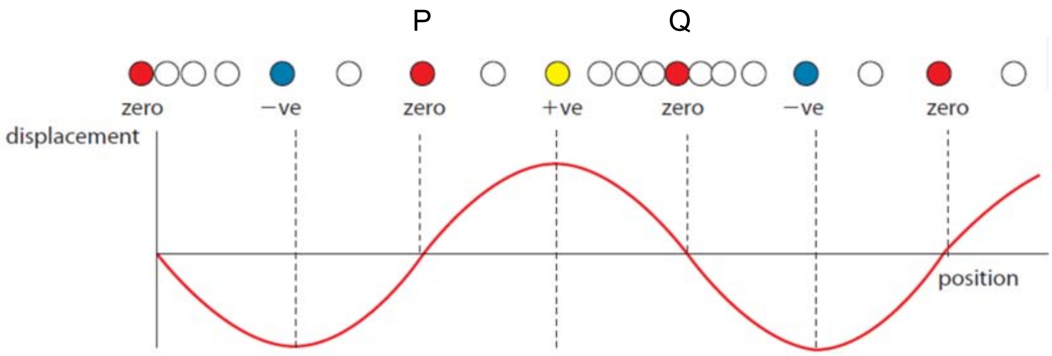
$$C_{rms} = \sqrt{\frac{3RT}{M}} \propto \sqrt{T} \propto \sqrt{PV} \text{ since } PV = nRT$$

$$\frac{C_{rms2}}{C_{rms1}} = \sqrt{\frac{P_1V_1}{P_2V_2}} = \sqrt{\frac{2(2)}{1(1)}} = 2$$

12 D If the gases are ideal $PV = nRT = nR(\theta + 273)$
So the graph of PV vs θ has a positive gradient (nR where n =1) , a y-intercept ($273nR$) and cuts the x scale at -273 (set $PV = 0$).

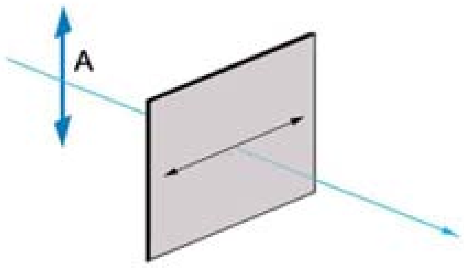
13 A At U, velocity is down (away from equilibrium point), acceleration is up (towards equilibrium point)
At Y, velocity is up, acceleration is down.

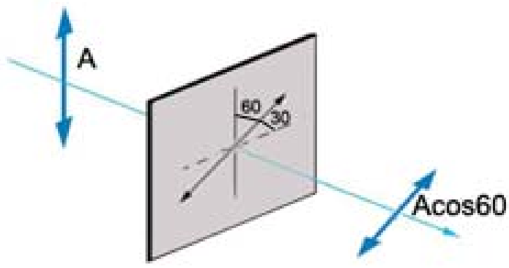
14 B



Distance between P and Q is ½ λ.
So time taken should be ½ T = 1/2f

15 B





Initially axis of polarization is 90^{o} to polarized light, so zero light transmitted

When polaroid is rotated 30^{o}, the two axes are now 60^{o} to each other.

Resolve A with respect to new polarization axis. It is A cos 60^{o} = 0.50 A

16 C Phase difference $\phi = \dfrac{t}{T} \text{x} 2\pi = \dfrac{4}{24} \text{x} 2\pi = \pi/3$
For time-axis, whichever (crest) is behind is leading.

17 B As α particle moves near nucleus, it experiences an electric force of repulsion that causes it to slow down to zero velocity. The distance r is known as the distance of closest approach.

loss in ke = gain in pe
$= Qq / 4\pi\varepsilon_o r$
$4.9 \times 10^{6} \times 1.60 \times 10^{-19} \times 10^{6} = (2 \times 1.6 \times 10^{-19})(79 \times 1.6 \times 10^{-19})/4\pi \times 8.85 \times 10^{-12} r$
$r = 4.64 \times 10^{-14}$ m

18 A $R = \frac{\rho l}{A}, \quad V = Al$

When re-cast, length = $l/2$, cross-sectional area = $2A$ since V is conserved.

Thus new resistance, $R' = \frac{\rho l/2}{2A} = \frac{1}{4}\frac{\rho l}{A} = \frac{1}{4}R$

19 C Energy = power x time = VIt = VQ = 12x4.0 = 48 J
Current I = Q/t so time t =Q/I = 4.0/2.0 = 2.0 s

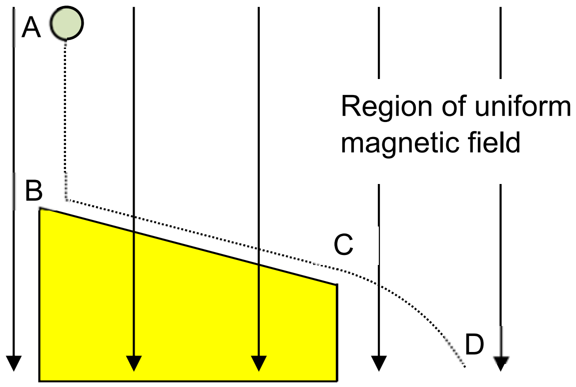
20 A Combined resistance of R_4 and R_5 = R/2
Combined resistance of R_3, R_4 and R_5 = 3R/2
Combined resistance of R_2, R_3, R_4 and R_5 = 3R/5
By potential divider principle, potential difference across R_1 is greater than potential difference across combined resistance of R_2, R_3, R_4 and R_5
Hence, R_1 has the greatest potential difference.

21 D By potential divider principle, voltmeter reading increases when effective resistance across thermistor is increased or resistance R_3 is reduced.

22 B $F_B - mg = ma$
$BIL\sin\theta - mg = ma$
$0.040 \times I \times 0.30 \times \sin 60^\circ - (0.0040 \times 9.81) = 0.0040 \times 2.0$
$I = 4.5$ A

23 D Current in Y is doubled ⇒ B_Y is doubled. The force F is doubled for both wires too, as it is an equal action and reaction force.

24 B



$E = Blv$, where v is the horizontal component of the rod's velocity. From point A to B, the rod is moving vertically along the magnetic field, hence E is zero. From B to C, as the rod rolls down the slope, the component of its weight parallel to the slope caused its velocity to increase. Hence, the horizontal velocity component increases at a constant rate and E increases linearly too. From C to D, the rod is moving in projectile motion. Its horizontal velocity component is constant and E remains constant.

25 C The output voltage is 240/20 = 12 V, and output current is 12/5 A.
Output power = V x I = 12 x12/5 = 28.8, which is 0.95 of the input power.

$0.95 \times 240\ I = 28.8$

$I = 0.126$ A

26 **A** $\langle P \rangle = V_{rms}^2/R$

$= (9/\sqrt{2})/\ 20 = 2.0$ W

27 **D** Total force exerted due to reflection of photons $F = \dfrac{N(2mc)}{t}$

But intensity of light $I = \dfrac{Nhf}{tA}$, $\quad so \dfrac{N}{t} = \dfrac{IA}{hf}$

Also $E = mc^2 = hf$

Total force $F = \dfrac{IA}{hf}(2mc) = \dfrac{IA}{mc^2}(2mc) = \dfrac{2IA}{c}$

28 **C** Since $\Delta E = hf$, from energy level diagram, the energy difference is lesser towards bigger f (emission from higher levels).

Wavelength is inversely proportional to frequency, hence the spectrum is in opposite order.

29 **C** Let C be original number of counts due to the α-source.
Let B be the background count.
C + B = 300 ------ (1)
0.5C + B = 155 ------ (2)
Solving, C = 290
Lead would block all the counts due to the α-source.
Hence, only background count of 10 is detected.

30 **B**

TEMASEK JUNIOR COLLEGE

2018 Preliminary Examination
Higher 2

CANDIDATE NAME	

CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/02

Paper 2 Structured Questions

24 August 2018

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name 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 an 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 brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total	

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
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.	$x = x_o \sin\omega t$
velocity of particle in s.h.m.	$v = v_o \cos\omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = Q/(4\pi\varepsilon_0 r)$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 A skateboarder starts from rest at point A as shown in Fig. 1.1.

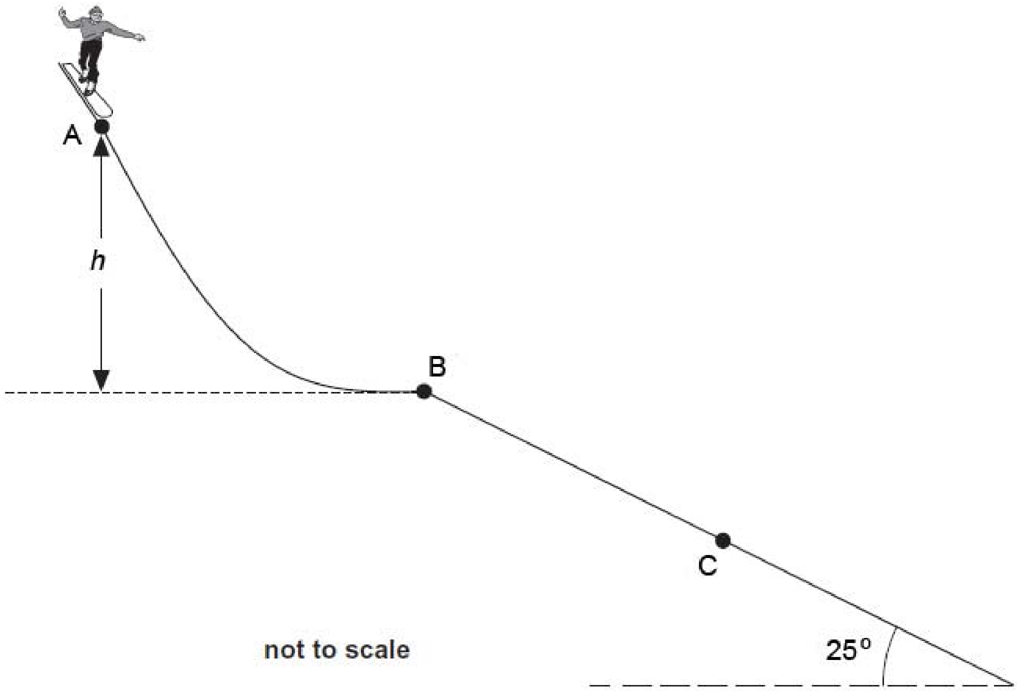


Fig. 1.1

The skateboarder reaches a speed of 17 m s^{-1} at point B.

Consider the skateboarder to be a point mass of 65 kg and ignore the effects of friction and air resistance.

(a) Calculate the height difference, h, between point A and point B.

h = ... m [2]

(b) The skateboarder takes off at point B, travelling horizontally with a velocity of 17 m s^{-1}. He lands at point C after being in the air for 1.6 s.

(i) Calculate v_v, the vertical component of his velocity, just before landing at point C.

v_v = ... m s^{-1} [2]

(ii) On Fig. 1.2**,** sketch the variation with time of the vertical component of the velocity v_v of the skateboarder from point B to point C.

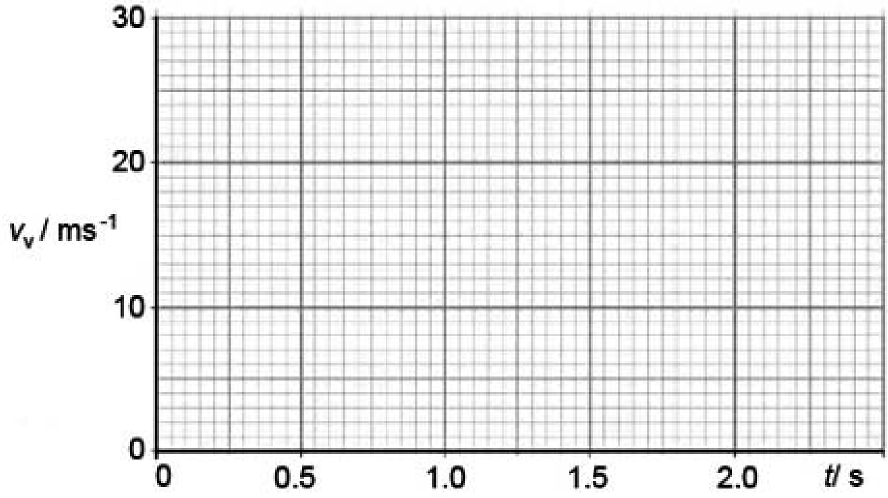


Fig. 1.2 [2]

(iii) Show that the magnitude of the resultant velocity just before landing at point C is 23 m s^{-1}.

[1]

(c) Explain why it is safer for the skateboarder to land on a downward slope than on a horizontal surface.

....

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....

....

.... [2]

2 A rod PQ is attached at P to a vertical wall, as shown in Fig. 2.1.

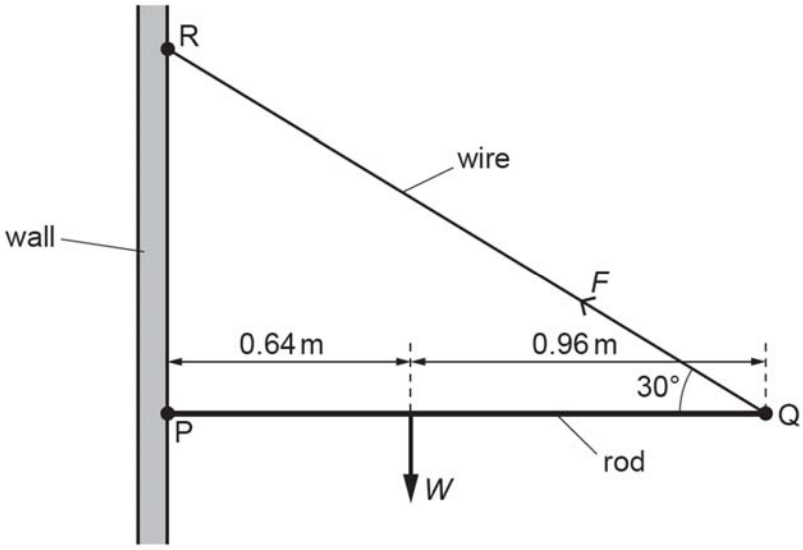

Fig. 2.1

The length of the rod is 1.60 m. The weight *W* of the rod acts at 0.64 m from P. The rod is kept horizontal and in equilibrium by a light wire attached to Q and to the wall at R. The wire provides a force *F* of 44 N on the rod at 30° to the horizontal.

(a) Determine

(i) the vertical component of *F*,

vertical component = ... N [1]

(ii) the horizontal component of *F*.

horizontal component = ... N [1]

(b) Determine the weight *W* of the rod.

W = ... N [2]

(c) Explain why the wall must exert a force on the rod at P to keep the rod in equilibrium.

....

....

....

.... [2]

(d) On Fig. 2.1, draw an arrow to represent the force acting on the rod at P. Label your arrow with the letter S. Explain how you arrive at the answer.

....

....

.... [2]

(e) Fig. 2.2 and Fig. 2.3 show two set-ups where the wire is attached to a different point on the rod.

Draw an arrow on each figure to represent the force acting on the rod at P. Label your arrows with the letter S_1 and S_2 respectively.

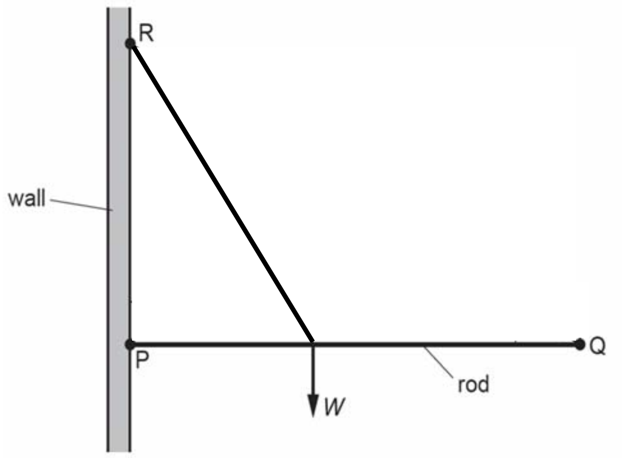

Fig. 2.2

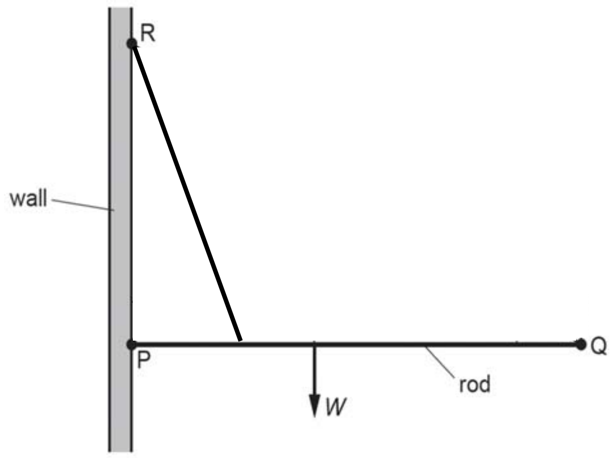

Fig. 2.3

[2]

3 **(a)** **(i)** State one difference between a stationary wave and a progressive wave.

....

....

....

.... [1]

(ii) State why electromagnetic waves can be polarised but sound waves cannot be polarised.

....

.... [1]

(b) In Fig. 3.1, T_1 and T_2 are two adjacent transmitters 1.0 m apart with a receiver aerial R at mid-point between them. The transmitters are set up to emit polarised coherent microwaves of wavelength 3.0 cm.

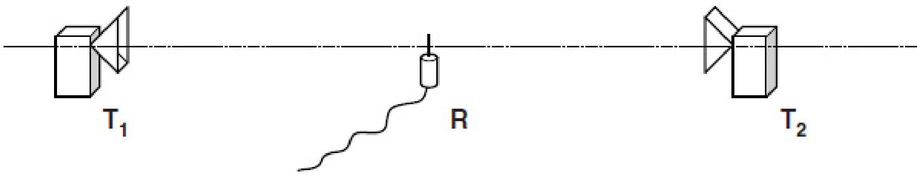

Fig. 3.1

(i) A student observes that the signal at the receiver R falls from maximum to zero when receiver R moved 0.75 cm towards a transmitter.

Explain these observations.

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....

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....

.... [4]

(ii) With R at the mid-point between T_1 and T_2, the student rotates T_2 through 90^o about an axis through T_1 and T_2 as shown in Fig. 3.2.

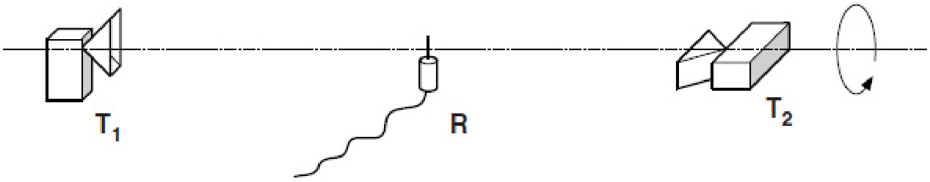

Fig. 3.2

The student observes that the intensity of the signal at R is halved.

The detected signal remains the same when R is moved 0.75 cm towards a transmitter.

Explain these observations.

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....

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.... [3]

4 A d.c. power supply of e.m.f. 8.7 V and negligible internal resistance is connected by two identical connecting wires to three identical filament lamps, as shown in Fig. 4.1.

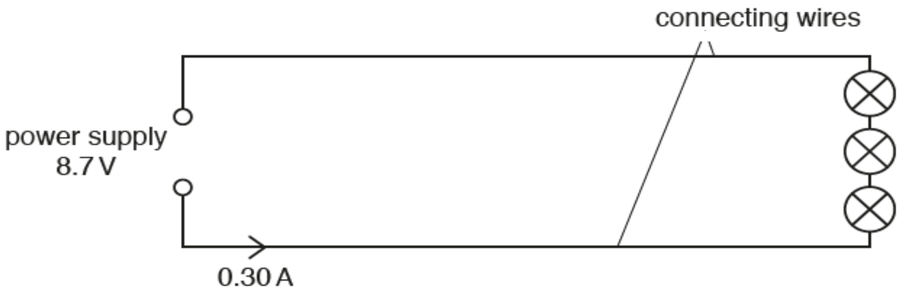

Fig. 4.1

The power supply provides a current of 0.30 A to the circuit.

The *I* –*V* characteristic for one of the lamps is shown in Fig. 4.2.

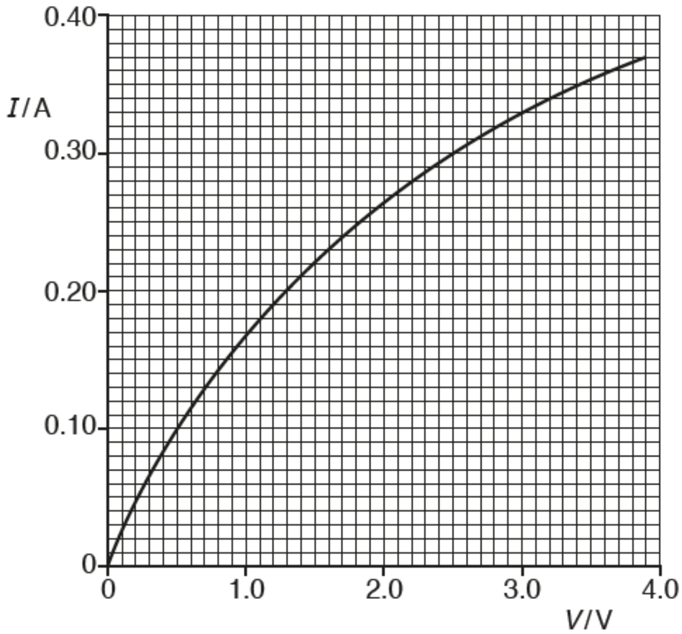

Fig. 4.2

(a) Show that the resistance of each connecting wire in Fig. 4.1 is 2.0 Ω.

[3]

(b) The resistance of the connecting wires does not vary with temperature.
On Fig. 4.2, sketch the *I*–*V* characteristic for **one** of the connecting wires. [2]

(c) Calculate the power loss in one of the connecting wires.

power loss = ... W [1]

(d) Some data for the connecting wires are given below.

cross-sectional area = 0.40 mm^2
resistivity = 1.7×10^{-8} Ω m
number density of free electrons = 8.5×10^{28} m^{-3}

Calculate

(i) the length of one of the connecting wires,

length = ... m [2]

(ii) the drift speed of a free electron in the connecting wires.

drift speed = ... m s^{-1} [2]

5 **(a)** A particle has mass *m*, charge +*q* and speed *v*.

State the magnitude and direction of the force, if any, on the particle when the particle is travelling along the direction of

(i) a uniform gravitational field of field strength *g*,

....

.... [2]

(ii) a uniform magnetic field of flux density *B*.

....

.... [1]

(b) Two charged horizontal metal plates, situated in a vacuum, produce a uniform electric field of field strength *E* between the plates. The field strength outside the region between the plates is zero.

The particle in **(a)** enters the region of the electric field at right-angles to the direction of the field, as illustrated in Fig. 5.1.

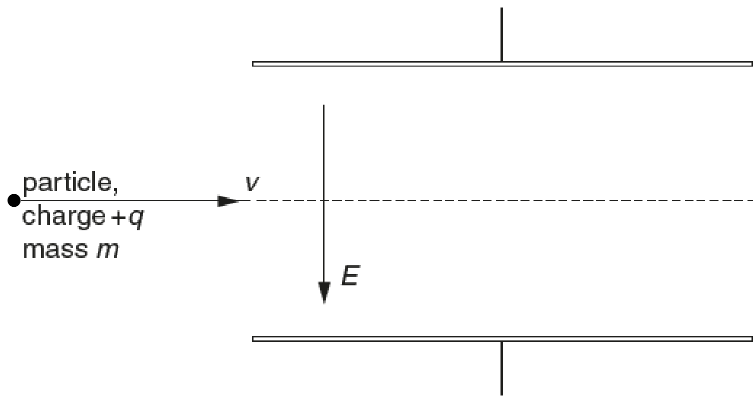

Fig. 5.1

A uniform magnetic field is applied in the same region as the electric field so that the particle passes undeviated through the region between the plates.

(i) State the direction of the magnetic field.

....

.... [1]

(ii) Derive, with clear explanations, an expression for the speed v in terms of the magnitudes of the electric field strength E and the magnetic flux density B.

[2]

(c) The same particle in (a) now enters a non-uniform magnetic field B at an angle θ with the horizontal as shown in Fig. 5.2.

By considering the components of the velocity parallel to and at right angles to the magnetic field, explain the subsequent path of the charged particle in the field.
Draw a sketch to illustrate the path in Fig. 5.2.

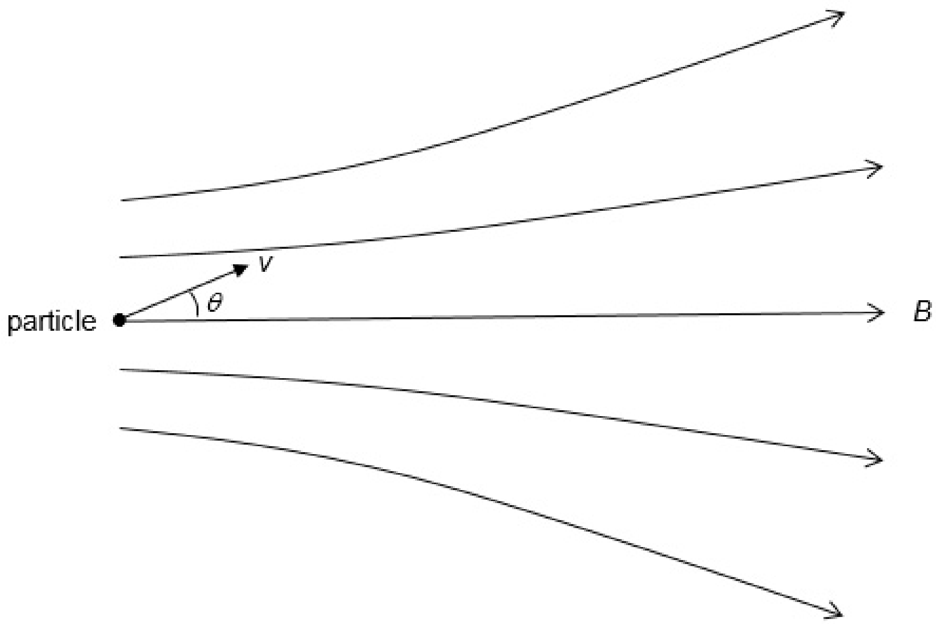

Fig. 5.2

....

....

....

.... [4]

6 **(a)** Explain what is meant by *binding energy* of a nucleus.

....

....

.... [1]

(b) **(i)** Give a sketch on Fig. 6.1 to show the variation of the binding energy per nucleon with nucleon number.

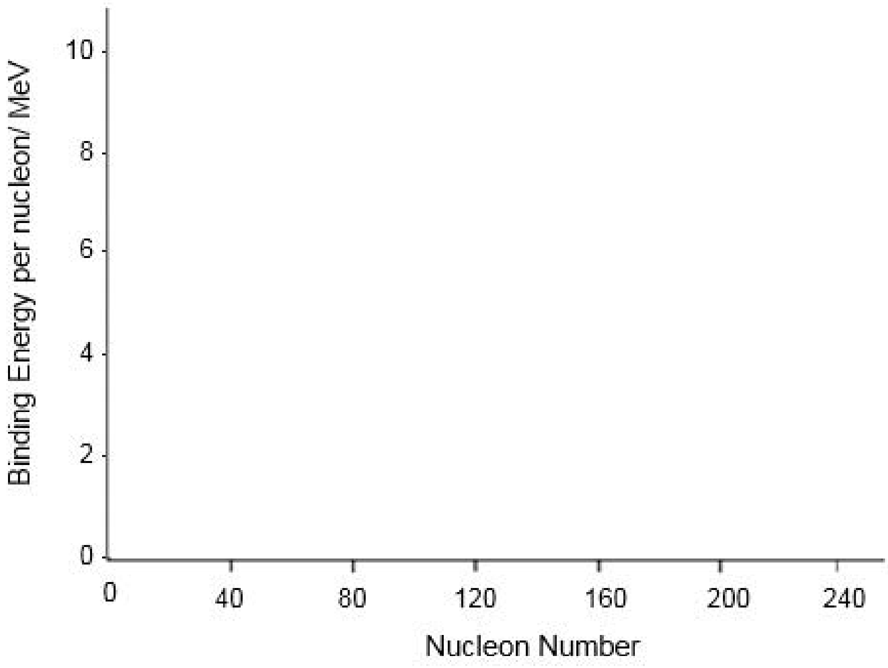

Fig. 6.1 [2]

(ii) With reference to your sketch in Fig. 6.1, explain how fission can be a potential source of energy.

....

....

.... [1]

(c) When a Uranium-235 nucleus undergoes fission, two nuclides are produced with the release of energy as shown in the equation below.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{139}_{54}Xe + ^{95}_{38}Sr + 2\,^{1}_{0}n$$

The masses of the nuclides are as follows:

nuclide	mass
$^{235}_{92}U$	235.043929 u
$^{139}_{54}Xe$	138.918793 u
$^{95}_{38}Sr$	94.919359 u
$^{1}_{0}n$	1.008665 u

(i) Explain how a chain reaction is able to occur for this nuclear fission.

....

.... [1]

(ii) Calculate the energy released in one reaction.

energy released = ... J [3]

(iii) Singapore's energy consumption in 2017 was approximately 50 TWh. Assuming an efficiency of 8.0 %, determine how long (in months) that the energy released from the fission of 2.0 kg of Uranium can be used to power Singapore.

time = ... months [4]

7 The decay of radioactive materials is a *random* process. On average, nuclides which decay quickly exist only for a short period of time, while nuclides which decay slowly last longer. One difficulty that arises with these calculations is when the radioactive material is a mixture of two or more nuclides. This question considers the case when a mixture of two radioactive nuclides is present. In decommissioning a nuclear power station, this difficulty is compounded by the presence of about a hundred different radioactive nuclides in significant quantities.

(a) Explain what it means to say that radioactive decay is a *random* process.

....

....

....

.... [2]

(b) State two physical quantities which do not cause a change in the rate of decay of a radioactive material.

1. ....

2. .... [2]

(c) Fig. 7.1 gives the variation with time of the total activity A_{mix} of a mixture of cobalt and nickel together with the separate activities A_c and A_N due to cobalt and nickel.

time/year	A_c / Bq	A_N / Bq	A_{mix} / Bq	ln (A_{mix} / Bq)
0	6900	250	7150	8.87
5	3540	241	3781	8.24
10	1820	232	2052	7.63
20	479	215	694	6.54
30	126	199	325	5.78
40	33.3	185	218	5.39
50	8.79	172	181	5.20
60	2.32	159	161	5.08
70	0.611	147	148	4.99
80	0.161	137	137	4.92
90	0.425	127	127	4.85
100	0.0112	118	118	4.77

Fig. 7.1

Fig. 7.2 shows the variation of ln A_{mix} with respect to time.

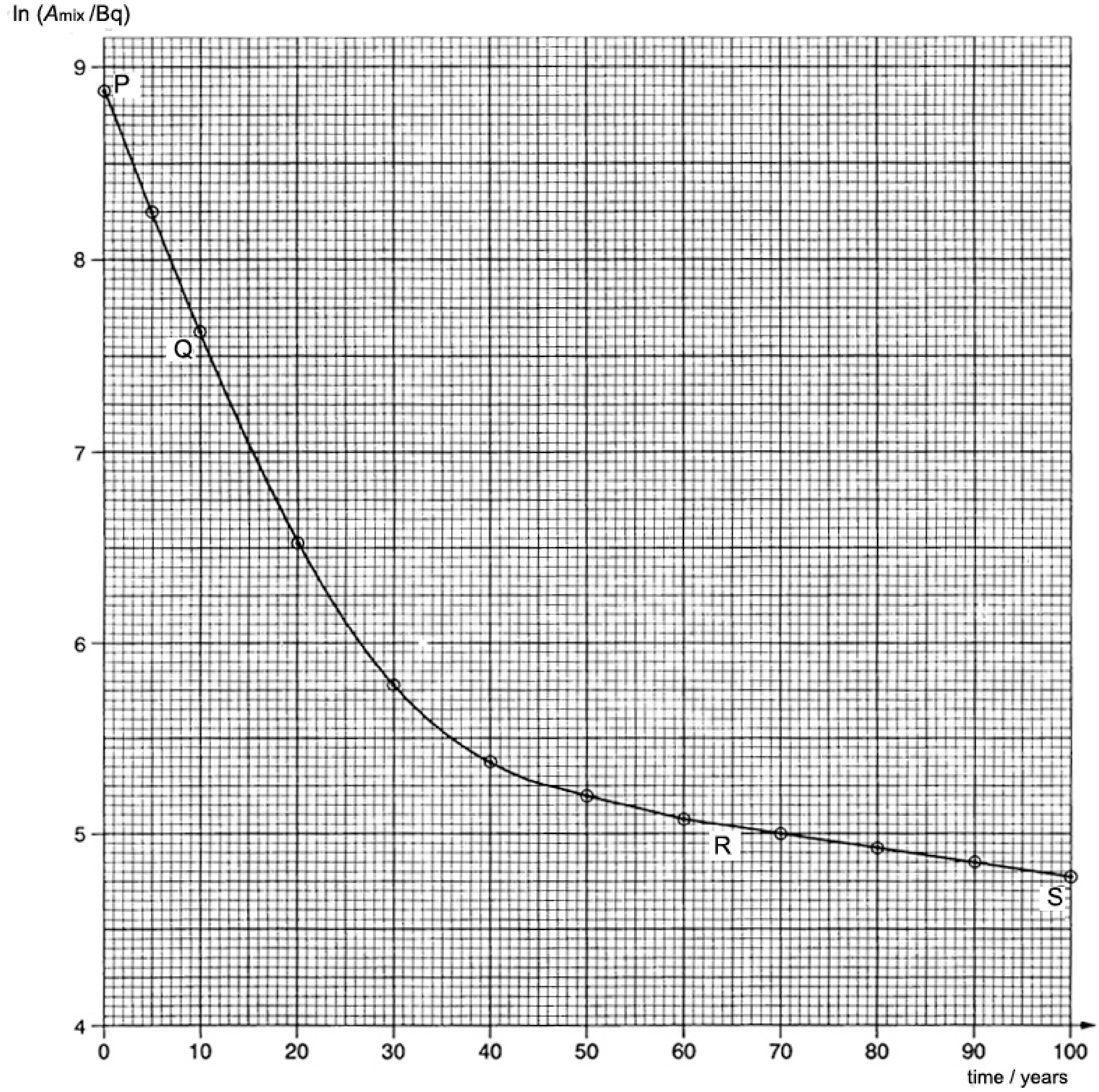

Fig. 7.2

(i) Explain the following:

1. PQ on the graph corresponds mainly to the decay of cobalt.

....

....

.... [2]

2. RS on the graph corresponds mainly to the decay of nickel.

....

....

.... [1]

3. The shape of QR is a curve.

....

....

....

.... [2]

(ii) Determine the gradients of

1. PQ,

2. RS.

gradient of PQ = ... $year^{-1}$

gradient of RS = ... $year^{-1}$ [4]

(iii) Given that the general decay law is of the form $x = x_o\ exp\ (-\lambda t)$, use the gradients found in **(ii)** to estimate values of the decay constants for the cobalt and the nickel nuclides.

decay constant of cobalt = ... $year^{-1}$

decay constant of nickel = ... $year^{-1}$ [1]

(iv) Use your answer to **(iii)** to calculate the half-lives of the cobalt and nickel.

half-life of cobalt = ... years

half-life of nickel = ... years [3]

(d) In an actual reactor, activities of radioactive materials can often be 10^{12} times larger than those given in Fig. 7.1. Explain when and why each of these two nuclides would pose the greater hazard.

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.... [3]

Solutions to 2018H2P2

1	**(a)**		Use of *mgh = ½ m v^2* ***and*** *makes h subject*	C1
			h = 14.7 or 15 (m)	A1
	(b)	**(i)**	Calculate the final vertical velocity at C (using v = 0 + at=9.81x1.6)	C1
			v = 15.7 or 16 (m s^{-1})	A1
		(ii)	Straight line of positive gradient) □ Starting at 0 ms^{-1} and ends at 16 ms^{-1} at 1.6 s.	A1 A1
	(b)	**(iii)**	Use of pythagoras' theorem: resultant $v^2 = 15.7^2 + 17^2$ v = 23 or 23.1 m s^{-1}	M1
	(c)		slope: smaller change in vertical component of velocity/ smaller change in vertical component of momentum by Newton's second law, the force experienced = rate of change of momentum is less, so less risk of injury Bonus mark: if she bends her knees during landing, she increases time for (same) change of momentum, so force exerted on her is even lesser.	B1 B1

2	**(a)**	**(i)**	(vertical component = 44 sin 30° =) 22 N	A1
		(ii)	(horizontal component = 44 cos 30° =) 38(.1) N	A1
	(b)		W × 0.64 = 22 × 1.60 C1 (W =) 55 N	C1 A1
	(c)		For a system in equilibrium, net force = 0	B1
			F has a horizontal component (not balanced by W) or F has 38 N acting horizontally or 38 N acts on wall or vertical component of F does not balance W or F and W do not make a closed triangle of forces	B1
	(d)		line from P towards point on wire vertically above W and direction up three non-parallel coplanar forces must act through the same line	B1 B1
	(e)		line from P towards right line from P towards point on wire vertically below W and direction down	B1 B1

3 **(a)** **(i)** Any difference about Amplitude/Phase difference/Energy B1

Comparison between a stationary wave and a progressive wave

	Stationary	Progressive
Energy	No net transfer of energy from one point to another. Energy is confined within the wave and there is interchange of K.E. and P.E.	Energy is transferred in the direction of travel of the wave.
Phase	All particles between two adjacent nodes are *in phase*. Particles on opposite sides of a node will be in *anti-phase*.	All points within one wavelength vibrate with different phase.
Amplitude	Varies from zero at nodes to maximum at antinode.	Same for all particles in the wave.
Wavelength	2 x distance between adjacent nodes or antinodes	Distance between adjacent particles which are in phase.
Frequency	All particles vibrate in SHM with same frequency except at nodes	All points vibrate in SHM with same frequency.
Waveform	Does not advance	Advances in the direction of velocity of the wave

(ii) only transverse waves can be polarised B1

(b) **(i)** the waves of equal f and amplitude in opposite direction
interfere/superpose producing a stationary wave B1
stationary wave has nodes and antinodes B1
the resultant signal is zero at a node distance from max (antinode) B1
to zero (node) is $\lambda/4$ = 0.75 cm B1

(ii) emitted waves are polarised (in vertical plane) B1
when T_2 is rotated by 90°, the two waves at right angles superposed to B1
produce a resultant constant amplitude (of $A\sqrt{2}$)

Since intensity is proportional to square of amplitude , signal intensity is halved) B1

Note:no stationary wave is produced since waves are at right angles to each other)

4 **(a)** p.d. across one lamp = 2.5 V C2
resistance = [(8.7 – 7.5) / 0.3] / 2
= 2.0 Ω A1

(b) straight line through the origin M1
with gradient of 0.5. A1

(c) $P = I^2 R$
$= 0.30^2 \times 2.0$
= 0.18 W A1

Alternative method:
use $P = V I$ or $P = V^2 / R$

(d) **(i)** $R = \rho l / A$ C1
$l = (2.0 \times 0.40 \times 10^{-6}) / 1.7 \times 10^{-8}$
= 47 m A1

(ii) $I = A n v q$
$v = 0.30 / (0.40 \times 10^{-6} \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19})$ C1
$= 5.5 \times 10^{-5}$ m s^{-1} A1

5	**(a)**	**(i)**	force = mg in the direction of the field	M1 A1
		(ii)	no force	B1
	(b)	**(i)**	force due to E-field downwards so force due to B-field upwards into the plane of the paper	M1 A1
		(ii)	force due to magnetic field = Bqv force due to electric field = Eq	B1
			forces are equal (and opposite) so Bv = E or Eq = Bqv so E = Bv	B1
	(c)		Component of velocity at right angle to the field results in a magnetic force at right angle to both this velocity and the field	B1
			radius r =mv/Bq, as B decreases, radius r increases The particle describes a helical path with increasing radius and increasing pitch.	B1

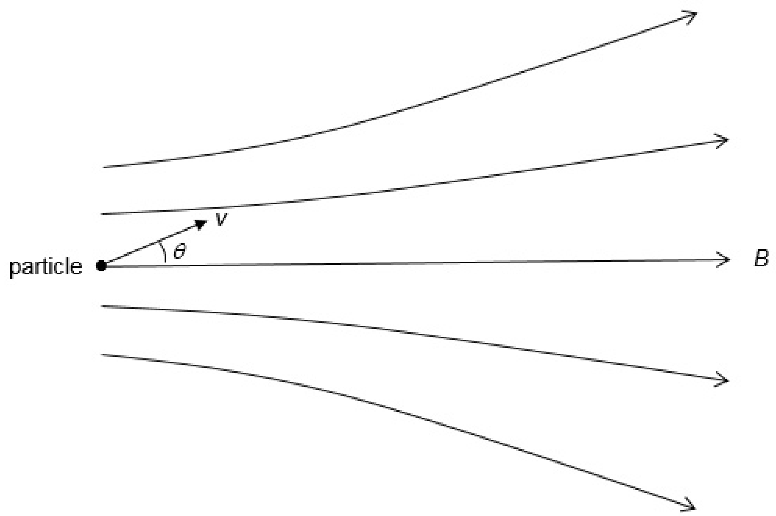
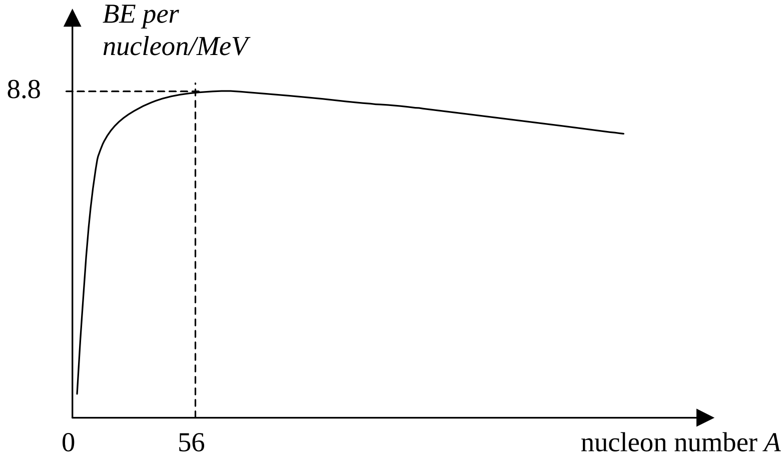


Diagram helical path with increasing radius B1
Correct Direction of path B1

6 **(a)** The binding energy of a nucleus is the energy released when a nucleus is formed from its constituent protons and neutrons. B1

(b)(i)



Correct Shape B1

Correct labelling for max BE B1

(b)(ii) In nuclear fission, a heavy nucleus splits to give two daughter nuclei of greater binding energy per nucleon. Hence, there is an overall energy release during the process. B1

(c)(i) A **chain reaction** is able to occur as the neutrons released in the fission produce an additional fission in at least one further nucleus. B1

(c)(ii) Energy released in one reaction = $(m_u + m_n - (m_{xe} + m_{sr} + 2m_n))\ uc^2$ M2

= (235.043929 + 1.008665 – (138.918793 + 94.919359 + 2(1.008665)) x x $[3 \times 10^8]^2$

= 2.94×10^{-11} J A1

(c)(iii) No of reactions that will take place in 2 kg Uranium M1

= $(2000/235) \times 6.02 \times 10^{23}$

= 5.12×10^{24}

Energy from 2 kg of Uranium = $2.94 \times 10^{-11} \times 5.12 \times 10^{24}$ M1

Useful Energy from 2 kg of Uranium = $0.080 \times 2.94 \times 10^{-11} \times 5.12 \times 10^{24}$ M1

= 1.21×10^{13} J

Amount of time t = $(1.21 \times 10^{13}/(50 \times 10^{12})) \times 12$ = 2.9 months A1

7	**(a)**	Random – it cannot predict which and when a nucleus will decay.	B1
		Nucleus has a constant probability of decay per unit time.	B1
	(b)	it is not affected by any external factors such as 1. temperature, 2. pressure	B2
	(c)(i)	**1** (from Fig 7.1, it can be deduced $T_{1/2}$ for Co is around 5 years	B1
		and for Ni is around 90 years.)	
		So activity of Co should be higher at the start. Region P is dominantly due to activity of Co.	A1
		Hence ln A_{mix} against t graph should give a straight line PQ	
		2 In region RS, most of Co has decayed, so activity is mainly due to Ni	B1
		3 In region QR, both Co and Ni contribute to the activity	B1
		Activity A_{mix} is sum of A_C and A_N	A1
		Hence ln A_{mix} against t graph gives a curve.	
	(ii)	**1** grad of PQ = (7.63 – 8.87) / 10	B1
		= - 0.124 yr^{-1}	A1
		2 grad of RS = (4.77 – 5.08) / 40	B1
		= - 0.00775 yr^{-1}	A1
	(iii)	$\ln A = \ln A_o - \lambda t$ Hence decay constant λ= magnitude of gradient = same as above decay constant of cobalt = 0.124 yr^{-1} decay constant of nickel = 0.00775 yr^{-1}	A1
	(iv)	$T_{1/2} = \ln 2 / \lambda$	M1
		Cobalt: $T_{1/2}$ = ln 2 / 0.124 = 5.59 yr	A1
		Nickel: $T_{1/2}$ = ln 2 / 0.00775 = 89.4 yr	A1
	(d)	Co has very high initial activity (because of large decay constant at the start) – hence more hazardous) award 1 mk if student mentioned both will be hazardous initially as they are in large dosage	B1
		As half life of Co is short (5.59 years) – activity will be small after that number of years, hence less hazardous.	B1
		However Ni has a long half-life (about 90 years), it remains hazardous for a long time.	B1

TEMASEK JUNIOR COLLEGE

2018 Preliminary Examination
Higher 2

CANDIDATE NAME	

CIVICS GROUP		INDEX NUMBER	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

13 September 2018

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your Civics group, index number and name 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 a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

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.

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

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total	

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/{}^\circ\text{C} + 273.15$
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	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = Q/(4\pi\varepsilon_0 r)$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 A solar propulsion engine uses solar power to ionize and accelerate atoms of xenon. The speed of the ejected xenon ions relative to the spaceship is 3.0×10^4 m s^{-1} as shown in Fig. 1.1.

Fig. 1.1

Fig. 1.2 shows the variation with time t of the acceleration a of the spaceship as a result of the ejection of xenon ions.

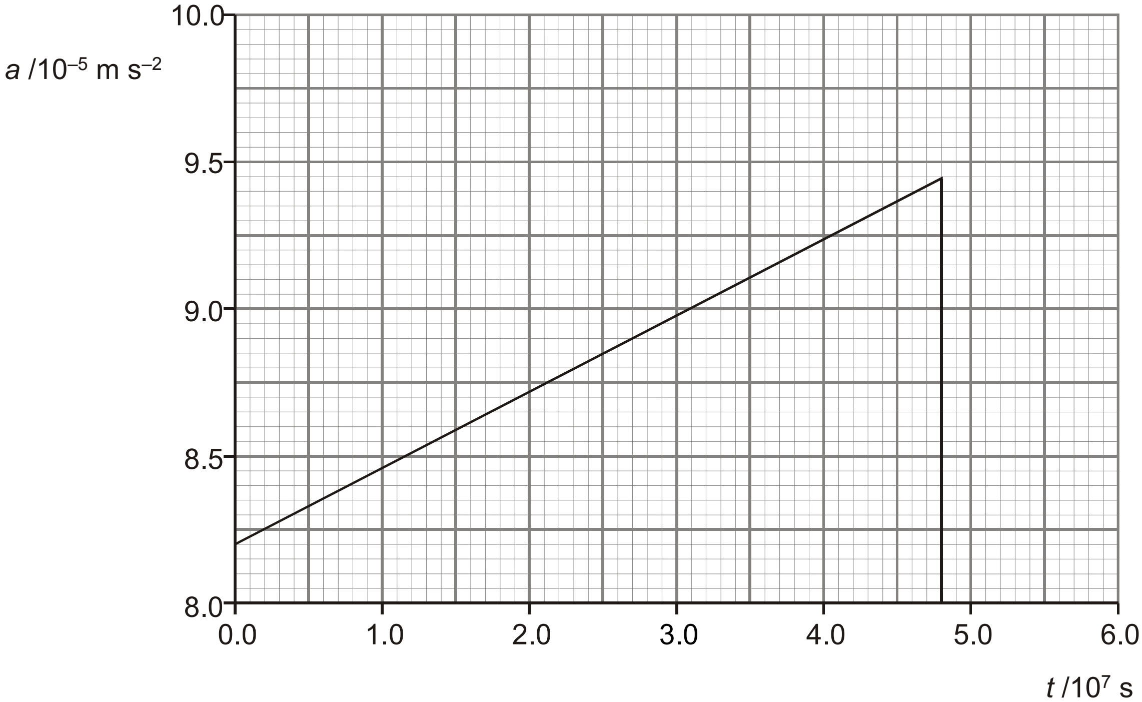


Fig. 1.2

(a) The xenon ions are ejected at a constant rate of 1.7×10^{-6} kg s^{-1}. Calculate the force exerted on the spaceship by the xenon ions.

force = ... N [2]

(b) Explain why the acceleration of the spaceship is increasing with time.

....

....

.... [1]

(c) The solar propulsion engine is switched on at time $t = 0$ when the initial velocity of the spaceship is zero.

Use Fig. 1.2 to determine the final velocity of the spaceship when the fuel runs out.

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

(d) Sketch on Fig. 1.3 the corresponding variation with time t of the velocity v of the spaceship from $t = 0$ to $t = 6.0 \times 10^7$ s.

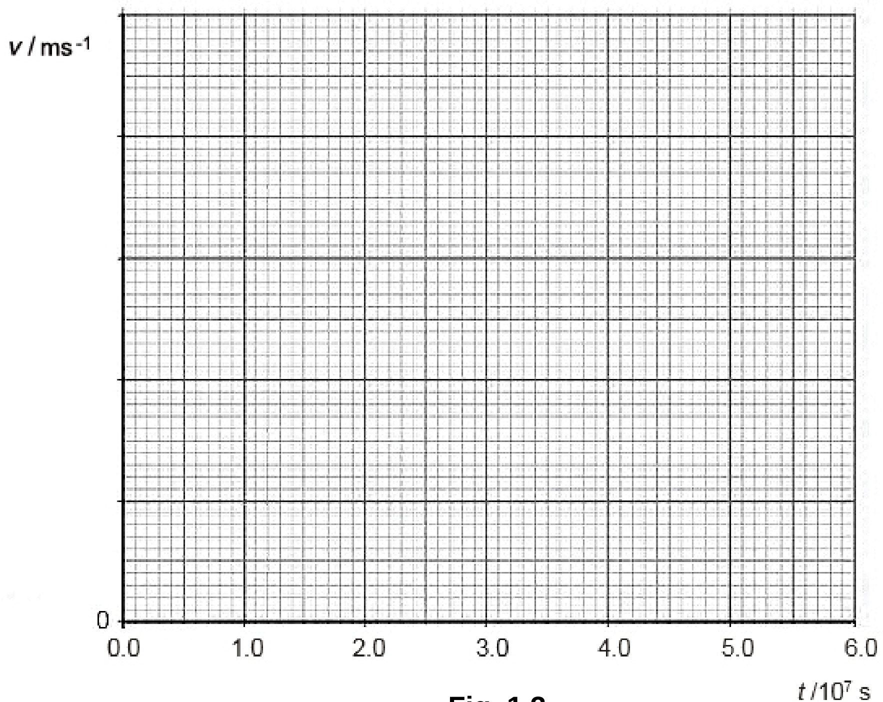


Fig. 1.3

[2]

2 **(a)** Explain what is meant by *escape speed*.

....

.... [1]

(b) A planet has radius R and the acceleration of free fall at its surface is g. The planet may be considered to be a sphere with its mass concentrated at its centre.

Deduce that the escape speed v_{es} is given by the expression

$$v_{es} = \sqrt{2gR}$$

Explain your working and state **one** assumption that is made in the derivation.

Assumption: ....

.... [3]

(c) Calculate the escape speed for a spherical planet of radius 1.7×10^3 km having an acceleration of free fall of 1.6 m s^{-2} at its surface.

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

(d) The mean translational kinetic energy E_K of a helium-4 atom at thermodynamic temperature T is given by the expression

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

where k is Boltzmann's constant.

Determine the surface temperature of the planet such that helium-4 atoms on the surface of the planet are able to reach the escape speed calculated in **(c)**.

temperature = ... K [2]

(e) Suggest **one** reason why, at temperatures below that calculated in **(d)**, helium atoms can still escape from the planet.

....

....

.... [1]

3 **(a)** A block of mass 0.40 kg slides in a straight line with a constant speed of 0.30 m s^{-1} along a smooth horizontal surface, as shown in Fig. 3.1.

Fig. 3.1

The block hits a spring and decelerates. The speed of the block becomes zero when the spring is compressed by 8.0 cm.

(i) Calculate the initial kinetic energy of the block.

kinetic energy = ... J [1]

(ii) The variation of the compression *x* of the spring with the force *F* applied to the spring is shown in Fig. 3.2.

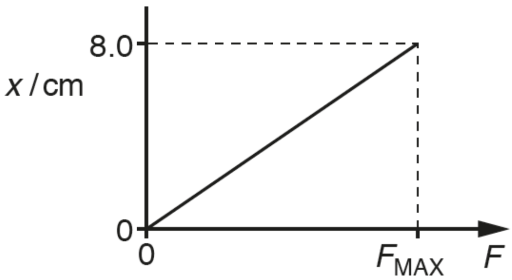


Fig. 3.2

Use your answer in **(a)(i)** to determine the maximum force F_{MAX} exerted on the spring by the block. Explain your working.

F_{MAX} = ... N [2]

(iii) Calculate the maximum deceleration of the block.

deceleration = ... m s^{-2} [1]

(iv) State and explain whether the block is in equilibrium

1. before it hits the spring,

....

....

2. when its speed becomes zero.

....

.... [2]

(b) The energy E stored in a spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.

The mass m of the block in **(a)** is now varied. The initial speed of the block remains constant and the spring continues to obey Hooke's law.

On Fig. 3.3, sketch the variation with mass m of the maximum compression x_0 of the spring.

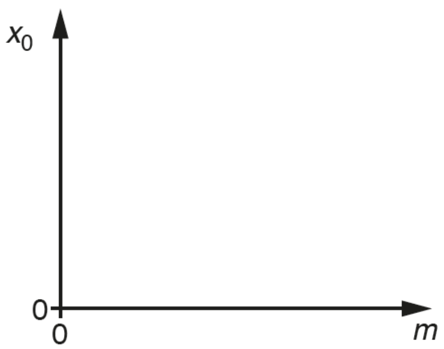


Fig. 3.3

[2]

4 A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in Fig. 4.1.

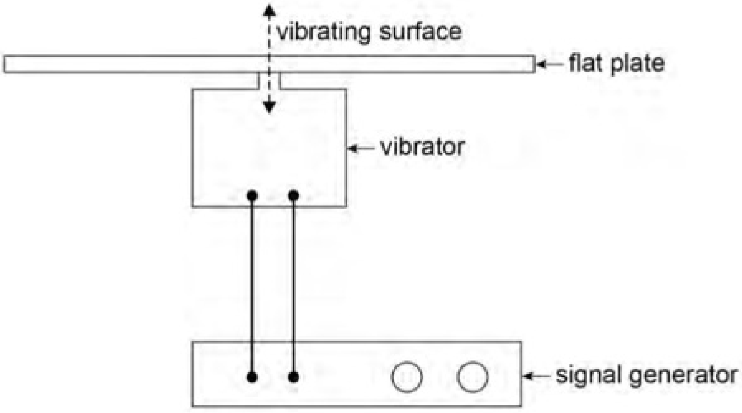


Fig. 4.1

Taking upward direction as positive, the variation with time *t* of the velocity *v* for the vibrating plate at one frequency is shown in Fig. 4.2.

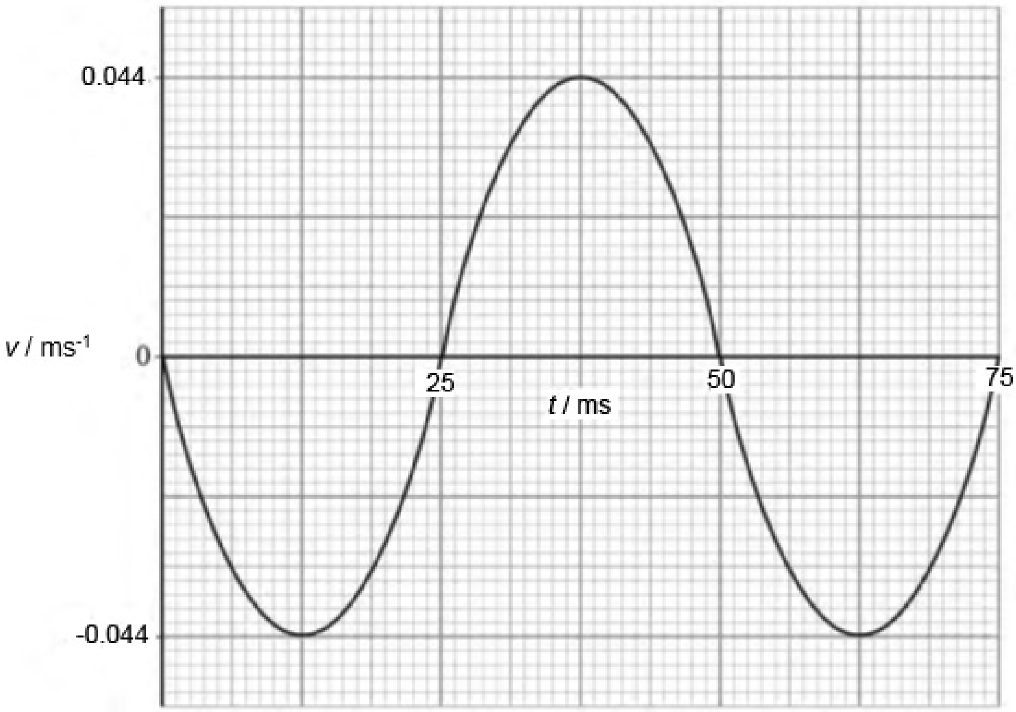


Fig. 4.2

(a) Show that the maximum displacement of the plate is 3.5×10^{-4} m.

[1]

(b) Draw on Fig. 4.3 the variation with time t of the displacement s of the plate between 0 and 75 ms.

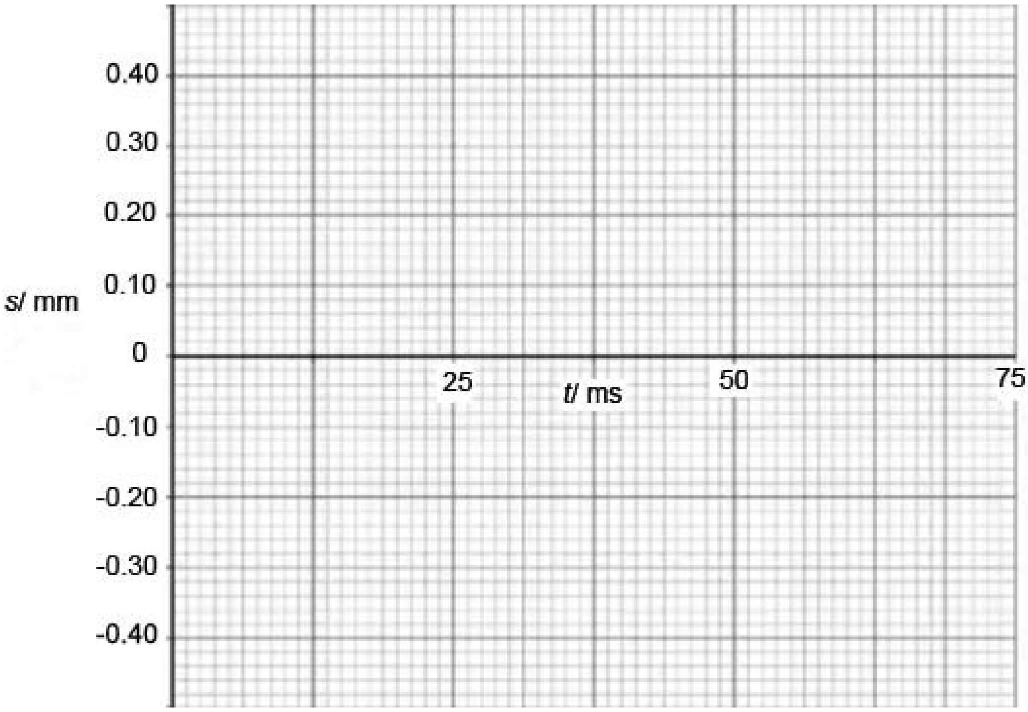


Fig. 4.3 [2]

(c) State **one** time at which the plate has maximum potential energy.

time = ... s [1]

(d) A small quantity of fine sand is placed onto the surface of the plate. Initially the sand grains stay in contact with the plate as it vibrates. The frequency of the vibrator is then gradually increased. Above a particular frequency the sand grains lose contact with the surface.

Explain how and why this happens.

....

....

....

....

....

....

.... [3]

5 Fig. 5.1 shows some equipotential lines around an electricity transmission cable at +200 kV.

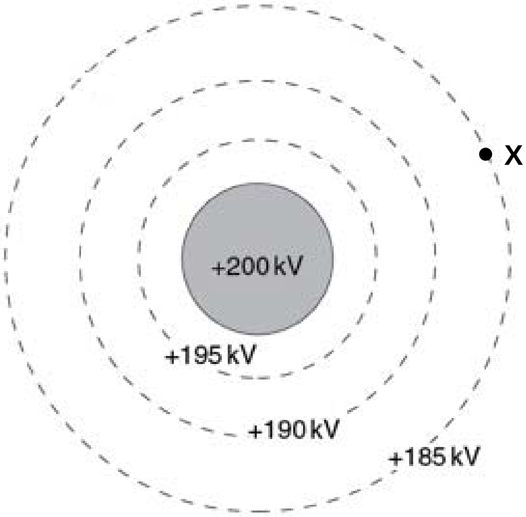


Fig. 5.1

(a) State the feature of the diagram which shows that the electric field strength decreases with distance from the transmission cable.

....

....

....

.... [2]

(b) The 195 kV equipotential line is 5.0 mm from the surface of the 200 kV transmission cable. Use this information to estimate the electric field strength at the surface of the cable.

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

(c) An electron is released from rest at point X. Determine the speed of the electron when it reaches the surface of the transmission cable.

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

(d) Fig. 5.2 shows the transmission cable surrounded on three sides by an earthed metal shield at zero potential.

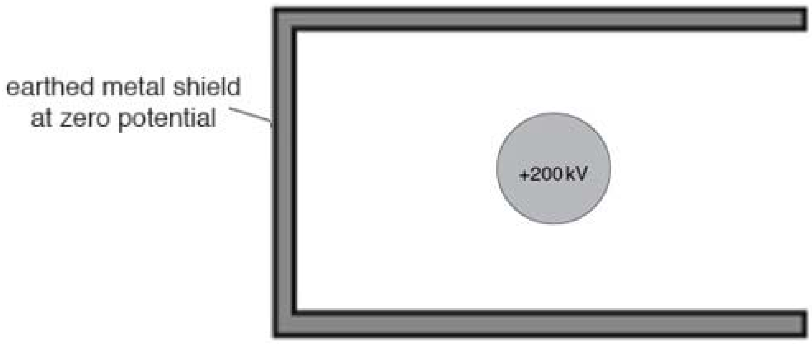


Fig. 5.2

On Fig. 5.2, sketch the shape of the electric field within and beyond the shield by drawing field lines from the cable to the shield and in the space beyond the open end.

[3]

6 Two coils P and Q are placed close to one another, as shown in Fig. 6.1.

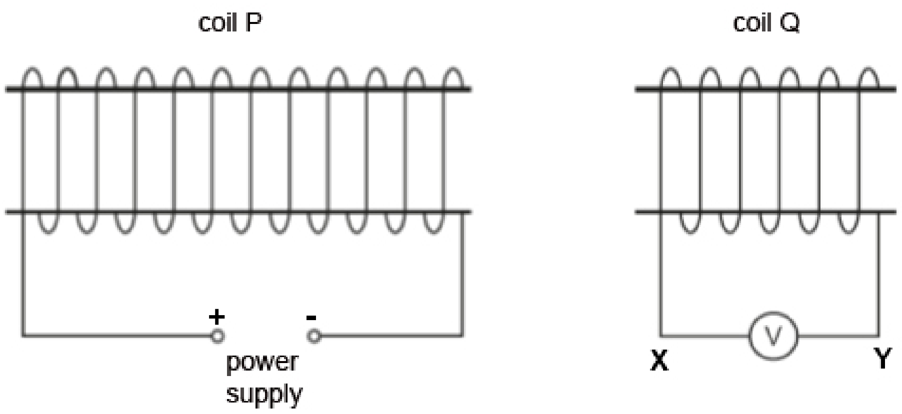


Fig. 6.1

(a) The current in coil P is constant. An iron rod is inserted into coil P.

During the time that the rod is moving,

(i) explain why, there is a reading on the voltmeter connected to coil Q.

....

....

....

....

....

.... [2]

(ii) state and explain whether point X or point Y on coil Q is at a higher potential.

....

....

....

....

....

....

....

.... [3]

(b) The current in coil P is now varied as shown in Fig. 6.2.

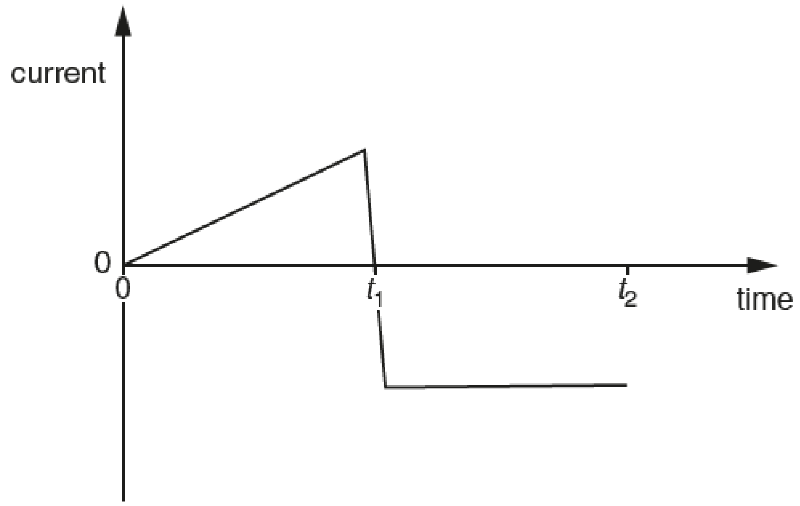


Fig. 6.2

On Fig. 6.3, show the variation with time of the reading of the voltmeter connected to coil Q for time $t = 0$ to time $t = t_2$.

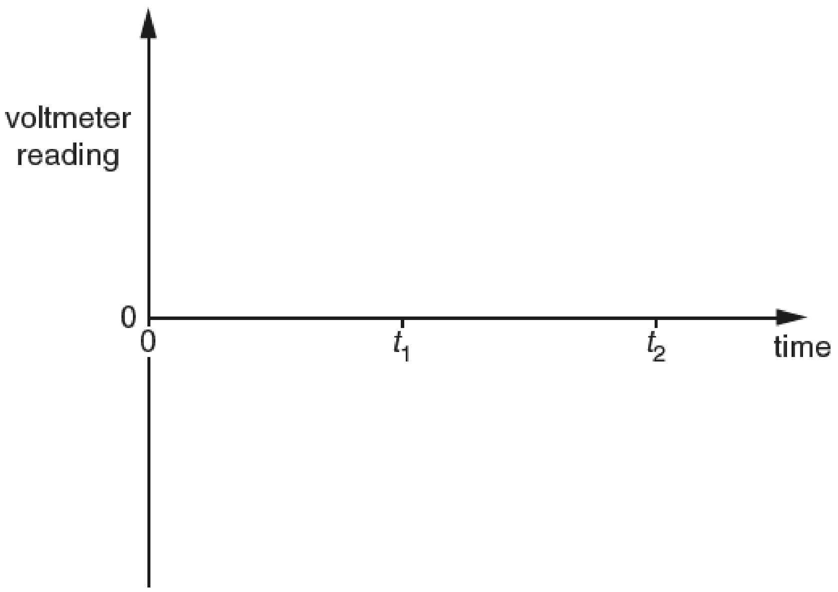


Fig. 6.3

[3]

7 **(a)** By reference to the photoelectric effect, state what is meant by the *threshold frequency*.

....

.... [1]

(b) Electrons are emitted from a metal surface when light of a particular wavelength is incident on the surface. Explain why the emitted electrons have a range of values of kinetic energy below a maximum value.

....

....

....

.... [2]

(c) The wavelength of the incident radiation is λ. The variation with 1/λ of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is shown in Fig. 7.1.

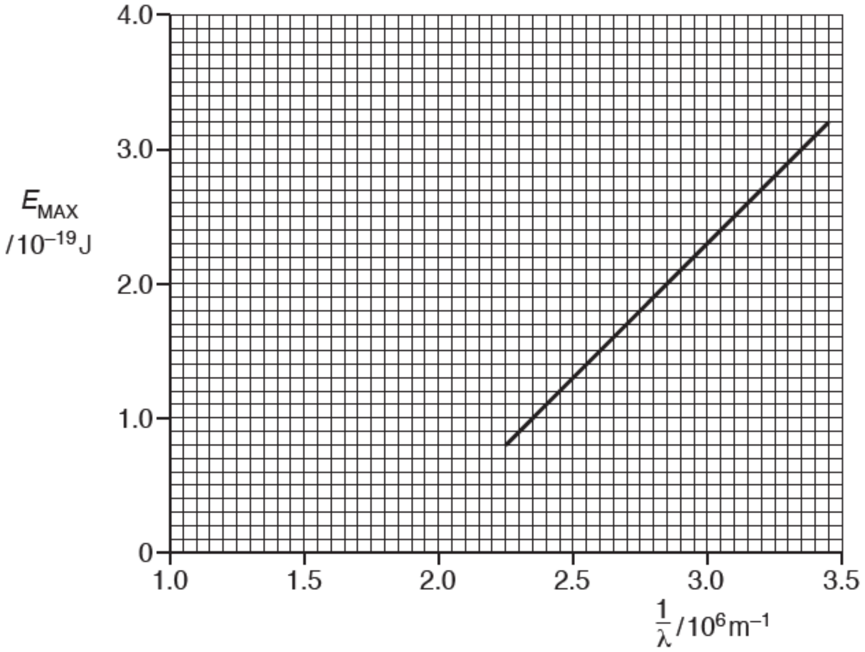


Fig. 7.1

(i) Use Fig. 7.1 to determine the threshold frequency f_0.

f_0 = ... Hz [2]

(ii) Use your answer in **(i)** to calculate the work function energy Φ.

Φ = ... J [2]

(iii) State an evidence from Fig. 7.1 that the classical wave theory cannot explain.

....

....

.... [1]

(iv) If the intensity of the radiation is doubled, state the changes in the graph, if any.

....

....

.... [1]

(v) Caesium metal has a lower work function energy than the metal in **(c)**.

On the axes of Fig. 7.1, sketch a line to show the variation with $1/\lambda$ of E_{MAX} for caesium metal. Label this line **C**.

[2]

Section B

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

8 **(a)** The internal energy of an ideal gas is dependent on its state, and is given by the sum of the *random* kinetic energies of all its molecules.

(i) The state of an ideal gas depends on pressure, volume and two other quantities. Write down these two other quantities.

....

.... [2]

(ii) Explain why it is important to include the word *random* in this definition.

....

.... [1]

(iii) Explain why the potential energy of the molecules is not included in this definition.

....

.... [1]

(iv) State two physical conditions under which a real gas will behave approximately as an ideal gas.

....

.... [2]

(b) The pressure p exerted by an ideal gas is given by the equation

$$p = \frac{1}{3}\rho < c^2 >$$

(i) What do the symbols ρ and $<c^2>$ represent?

....

.... [2]

(ii) Use this equation to derive an expression for the total internal energy of n moles of an ideal gas at temperature T.

[2]

(iii) Air contains oxygen and nitrogen molecules. Assuming air is an ideal gas, state and explain whether each of the following quantities is the same for oxygen and nitrogen molecules in air at a given temperature.

1. mean translational kinetic energy per molecule

....

.... [1]

2. root mean square speed

....

.... [1]

(c) A heat engine uses 10 moles of an ideal gas as a working substance. Fig. 8.1 shows the changes in pressure and volume of the gas during one cycle ABCA of operation of the engine.

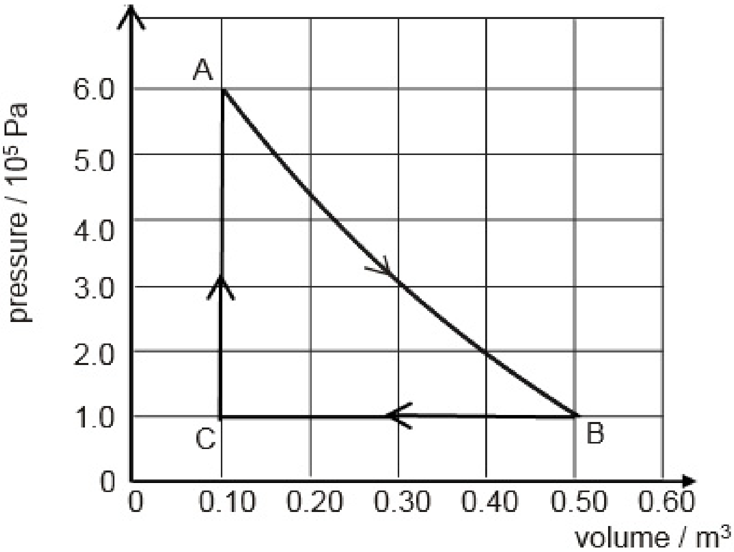


Fig. 8.1

(i) Using values from Fig. 8.1, calculate the temperature of the gas at point A.

temperature = ... K [2]

(ii) Show that the process A $\rightarrow$ B does not take place at a constant temperature.

....

.... [1]

(iii) Use Fig. 8.1 to estimate the net work done by the gas during one cycle.

work done = ... J [2]

(iv) Hence, or otherwise, state the amount of heat absorbed by the gas during one cycle.

heat absorbed = ... J [1]

(v) If the temperature at A is maintained throughout the process A $\rightarrow$ B, state and explain how your answer in **(c)(iv)** may change.

....

....

....

....

.... [2]

9 **(a)** State the *Principle of Superposition*.

....

....

....

.... [2]

(b) Laser beam of red light of wavelength 644 nm is incident normally on a diffraction grating having 550 lines per millimetre, as illustrated in Fig. 9.1.

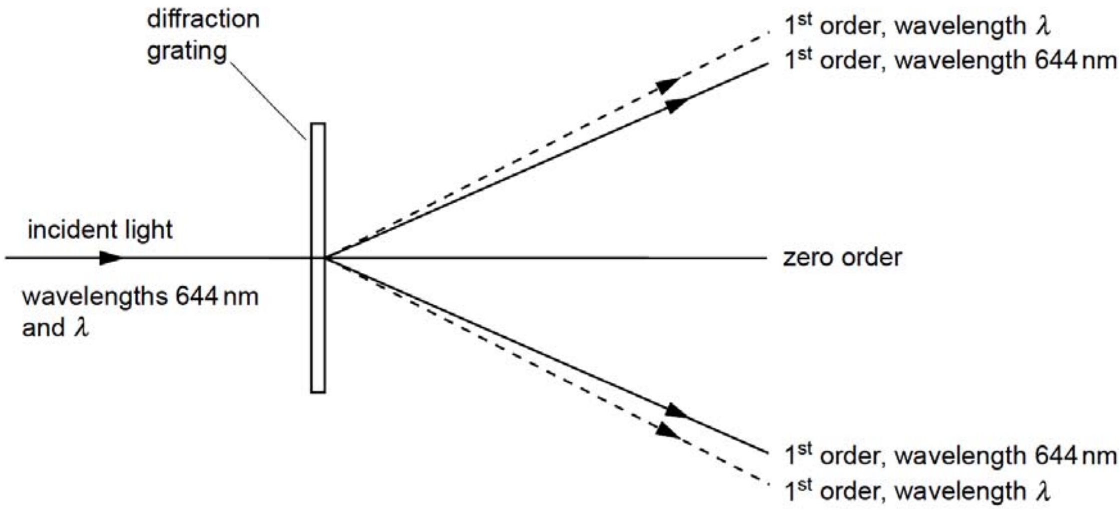


Fig. 9.1

Another laser beam of red light of wavelength λ is also incident normally on the grating. The first order diffracted light of both wavelengths is illustrated in Fig. 9.1.

(i) Determine the total number of bright spots of wavelength 644 nm that are visible.

total number of bright spots = ... [3]

(ii) State and explain

1. whether λ is greater or smaller than 644 nm,

....

....

.... [1]

2. in which order of diffracted light there is the greatest separation of the two wavelengths.

....

....

.... [1]

(c) The laser beam of red light of wavelength 644 nm is now placed in front of two slits as shown in Fig. 9.2.

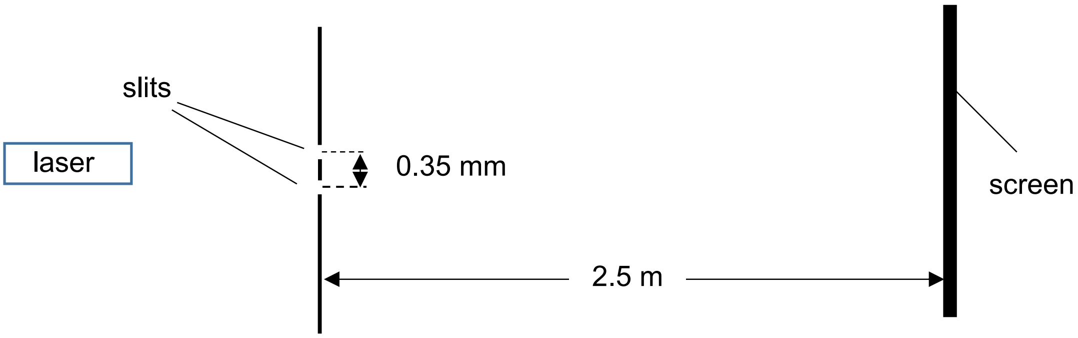


Fig. 9.2 (not to scale)

The distance from the slits to the screen is 2.5 m. The separation of the slits is 0.35 mm. The width of each slit is 2.4×10^{-5} m. The maximum intensity of the interference pattern formed on the screen is I.

(i) Explain how the interference pattern is formed on the screen.

....

....

....

....

....

.... [3]

(ii) One of the slits is now covered with an opaque object.

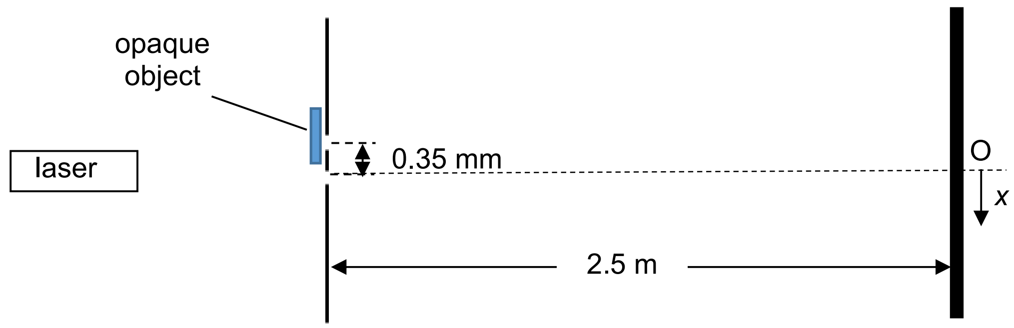


Fig. 9.3

An interference pattern is observed on the screen centred at O.

1. Calculate the width of the central fringe observed on the screen.

width = ... m [3]

2. On Fig. 9.4, sketch a graph to show the variation with distance *x* from point O of the intensity of the light observed on the screen. Draw at least 3 maxima.

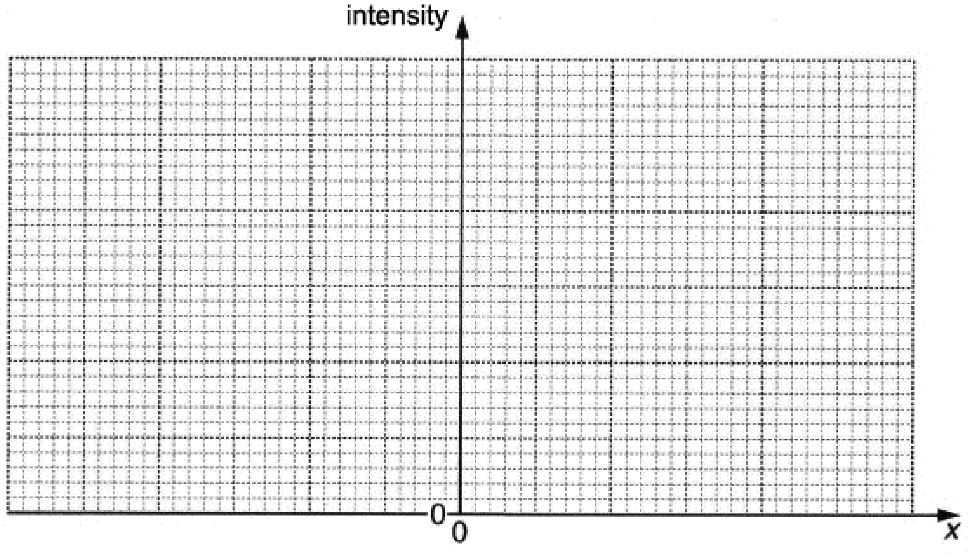


Fig. 9.4

[3]

3. Deduce, in terms of I, the maximum intensity of the interference pattern produced.

intensity = ... [2]

(iii) The laser together with another identical laser are positioned as seen in Fig. 9.5 such that the light from both sources pass through the uncovered slit at an angle of θ to each other.

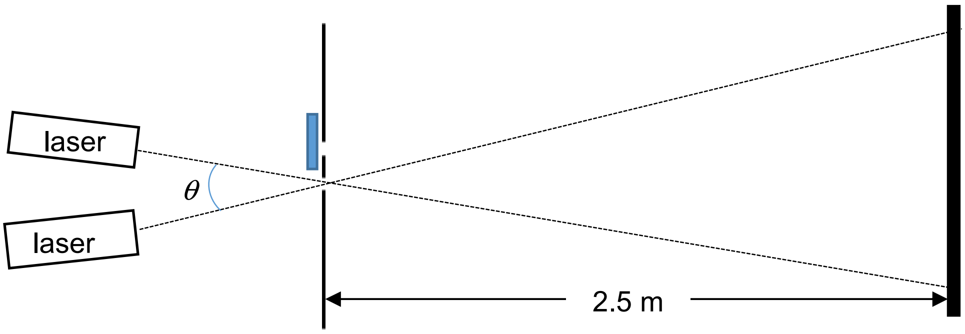


Fig. 9.5

State and explain whether the interference patterns formed by the two sources are resolved if θ is equal to 2.0°.

....

....

....

....

.... [2]

2018H2P3Solutions

1 **(a)** $F_{\text{on fuel}} = v\dfrac{dm}{dt}$ C1

$= 3.0\times10^{4}\times1.7\times10^{-6} = 0.051\,\text{N} = F_{\text{on rocket}}$ A1

(b) Since F is constant and a = F/m, with *m* <u>decreases</u> with time, *a* <u>increases</u> with time. B1

(c)

change in velocity = area under graph

= ½(9.45 + 8.20) × 10^{-5} × 4.80 × 10^{7} = 4240 m s^{-1} M2

final v = 4240 - 0 = 4240 m s^{-1} A1

(d) Shape is parabolic from t = 0 to t = 4.8 x 10^{7} s, starting from v = 0 to final v at 4240 m s^{-1} B1

Between t = 4.8 x 10^{7} to t = 6.0 x 10^{7} s, no more force so constant v at 4240 m s^{-1} B1

2 **(a)** speed (of object) at surface (of planet) / specified starting point so that object may move to infinity / escape gravitational field of planet B1

(b) loss in kinetic energy = gain in (gravitational) potential energy

$\frac{1}{2}mv^{2} = \frac{GMm}{R}$ C1

But $g = \frac{GM}{R^{2}}$ C1

Hence $v = \sqrt{2gR}$ *(no mark for answer)*

assumption: *e.g.* planet is isolated / no friction / no atmosphere *etc.* A1

(c) $v = \sqrt{2(1.6)1.7\times10^{6}}$ C1

$= 2.3\times10^{3}$ m s^{-1} A1

(d) $\frac{1}{2}\left(4\times1.66\times10^{-27}\right)\left(2.3\times10^{3}\right)^{2} = \frac{3}{2}\left(1.38\times10^{-23}\right)T$ C1

T = 850 K A1

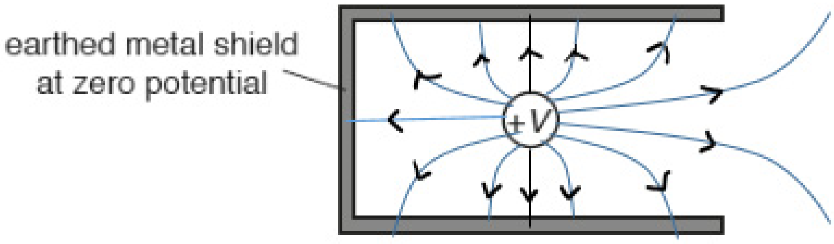
(e) atoms have a distribution of speeds / atoms may collide in upper atmosphere and gain speed B1

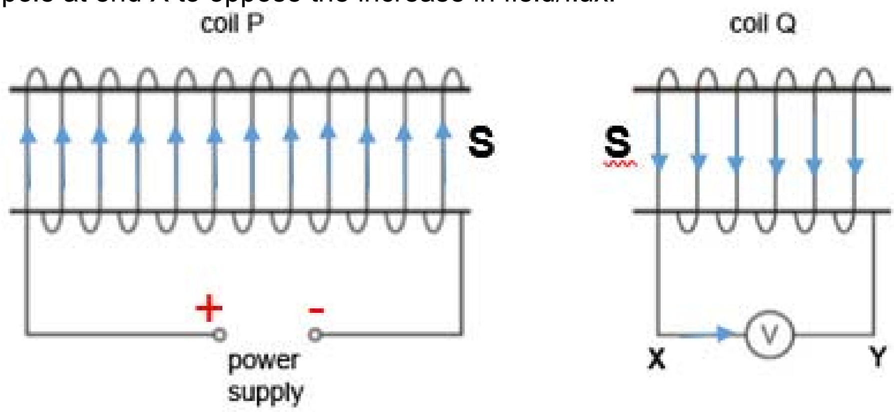
3	**(a)**	**(i)**	Initial kinetic energy of block = $\frac{1}{2}mv^2 = \frac{1}{2}(0.40)(0.30)^2 = 1.8\times10^{-2}$ J	B1
		(ii)	(change in) kinetic energy = work done on spring / (change in) elastic potential energy	C1
			$1.8\times10^{-2} = \frac{1}{2}F_{MAX}(0.080)$	
			$F_{MAX} = 0.45(\text{N})$	A1
		(iii)	$a = F_{MAX} / m$ = 0.45 / 0.40 = 1.1 (m s^{-2})	A1
		(iv)	1. constant velocity / resultant force is zero, so in equilibrium	B1
			2. decelerating / resultant force is not zero, so not in equilibrium	B1
	(b)		curved line from the origin ($x_o^2 \propto m$ or $x_o \propto \sqrt{m}$)	M1
			with decreasing gradient	A1

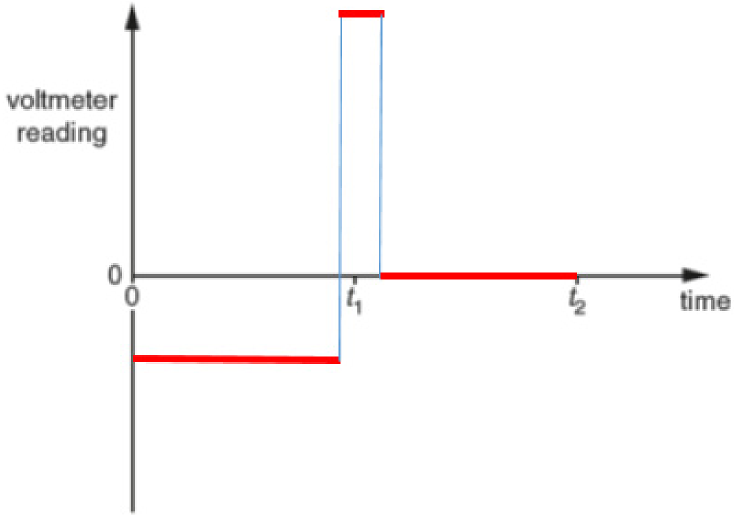
4	**(a)**	$f = 1/T$ =1/0.05=20 Hz $v_o = \varpi x_o = (2\pi f) x_o$ $x_o = 0.044/2\pi(20) = 3.5 \times 10^{-4}$ m	M1
	(b)	Cosine shape drawn,	A1
		maximum at t = 0, amplitude 3.5×10^{-4} m	A1
	(c)	(any of the following when the velocity is zero) 0.00s, 0.025s,0.050s or 0.075s □	A1
	(d)	Acceleration of plate (in shm) is proportional to $(\text{frequency})^2$ or $a = \omega^2 x = (2\pi f)^2 x$.	B1
		As frequency increases, acceleration increases until it is equal to g, the acceleration due to gravity.	M1
		When the sand and plate are both free falling at g, the acceleration due to gravity, there is zero contact force between sand and plate when the vibrating surface.	A1

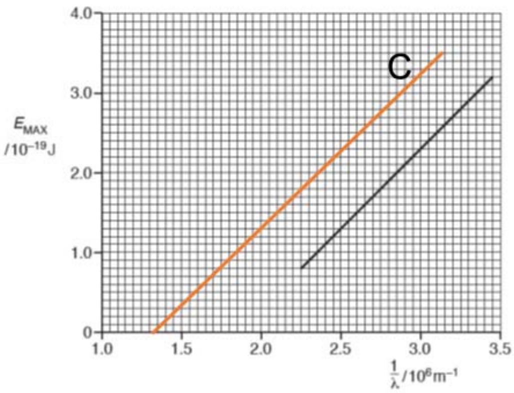
5	(a)	Equipotential lines are closer together near the cable but further apart away from cable.	B1
		Since electric field strength = potential gradient(E = dV/dx), so E decreases with distance	B1
	(b)	E = dV/dx = (200-195) x 10^3/0.0050	M1
		= 1.0 x 10^6 Vm^{-1}	A1
	(c)	Gain in ke = loss in pe	M1
		$\frac{1}{2} mv^2 = eV$ $v = \sqrt{2eV/m} = \sqrt{2 \times 1.6\times10^{-19} \times 1500/9.11\times10^{-31}}$	
		= 2.30 x 10^7 ms^{-1}	A1

(d) Correct pattern/shape/arrow direction B1
Lines fall perpendicularly to surface of shield B1
Some lines drawn diverging outside open end of shield B1



6	(a)	(i)	iron rod concentrates/improves flux density / flux/B-field in coil P by Faraday's law, change of flux in coil Q produces induced e.m.f.	B1 B1
		(ii)	By Lenz's law, an induced emf is produced in coil Q to oppose increase in flux by RHGR induced current should externally from X to Y to set up a field/S-pole at end X to oppose the increase in field/flux.  X has higher potential.	M1 M1 A1
	(b)		constant reading (either polarity) from time zero to near t_1 spike in one direction near t_1 clearly showing a larger voltage of opposite polarity zero reading from near t_1 to t_2	B1 B1 B1

7	**(a)**	minimum frequency of e.m. radiation/a photon (not "light") for emission of electrons from a metal surface	B1
	(b)	E_{MAX} corresponds to electron emitted from surface electron (below surface) requires energy to bring it to surface,so less than E_{MAX}	B1 B1
	(c)(i)	$1/\lambda_0 = 1.85 \times 10^6$ (allow 1.82 to 1.88) $f_0 = c / \lambda_0 = 3.00 \times 10^8 \times 1.85 \times 10^6$ $= 5.55 \times 10^{14}$ Hz	C1 A1
	(c)(ii)	$\Phi = hf_0$ $= 6.63 \times 10^{-34} \times 5.55 \times 10^{14}$ (allow ECF from (c)(i)) $= 3.68 \times 10^{-19}$ J	 C1 A1
	(c)(iii)	The classical wave theory cannot explain the existence of the threshold frequency [since it predicts that if sufficiently intense light is used, the electrons would absorb enough energy to escape.]	B1
	(c)(iv)	No change in the graph [Max kinetic energy is independent of the intensity of light]	B1
	(c)(v)	sketch: straight line with same gradient x- intercept is less since threshold frequency is less 	M1 A1

Section B

8 **(a)** **(i)** Amount of substance — B1
Thermodynamic temperature. — B1

(award 1 mark for "no of moles and temperature".)

(ii) Molecules collide with one another in a haphazard manner hence they possess different kinetic energies at any time. — B1

(iii) No intermolecular forces in ideal gas, hence no potential energy — B1

(iv) Low pressure — B2
High temperature

(b) **(i)** ρ = density of gas — B1
$\langle c^2 \rangle$ = mean square speed — B1

(ii) $p = 1/3 \ \rho \langle c^2 \rangle$ — M1
=> $pV = 1/3 \ M \langle c^2 \rangle$ since $\rho = M/V$
For ideal gas, $pV = n RT$
Hence, $1/3 \ M \langle c^2 \rangle = n RT$ — B1

Total KE = $½ M \langle c^2 \rangle = 3/2 \ n RT$

(iii) 1. Same because average K.E. is proportional to temperature — B2
2. Different because the masses of the gases are different.

(c) **(i)** pV = nRT — M1
$(6.0 \times 10^5)(0.10) = (10)(8.31)$ T — A1

T = 722 K

(ii) The products of p and V are not constant. For example, the product of p and V is 5.0×10^4 J at B, but 6.0×10^4 J at A. — B1
(Accept calculation of temperature at B = 600 K)

(iii) Work done in one cycle estimated from the area enclosed — M1
= 8.8×10^4 J — A1
(Note the positive sign as net work is done by the gas)

(iv) In one cycle $\Delta U = q + W = 0$ => $q = 8.8 \times 10^4$ J — A1

(v) Curve for process A $\rightarrow$ B gentler/enclosed area larger — B1
Hence *W* larger implies, *q is* larger. — B1

9 **(a)** The Principle of Superposition states that <u>when two or more waves of the same kind overlap</u>, the <u>resultant displacement at any point at any instant</u> — B1 B1 is the vector sum of the displacements that the individual waves would have separately produced at that point and at that instant.

(b) $d \sin \theta = n\lambda$ M1

(i) $\left(\frac{10^{-3}}{550}\right) \sin 90 = n(644 \times 10^{-9})$

$n = 2.8$ A1

Highest order that can be seen is the 2nd order.

Hence total number of bright lines observed is 5. A1

(ii)
1. Since θ is greater, λ is also greater. B1
2. When n is larger, Δθ is larger, thus the greatest separation occurs in the second order. B1

(c) **(i)** The coherent waves from the laser meet at a point on the screen with a constant phase/path difference. B1

When waves meet in phase with phase difference of n(2π rad) or path difference of nλ where n is an integer, constructive interference occurs. B1

When the waves meet exactly out of phase (any equivalent explanation of minima e.g. (n+½)λ or (n+½)×2 π rad, destructive interference occurs. B1

(ii) 1.

$\sin \theta = \frac{\lambda}{b}$ M1

$\sin \theta = (6.44 \times 10^{-7})/(2.4 \times 10^{-5})$

$\theta = 1.54°$ A1

tan 1.54° = $O'Y$ /2.5

$O'Y$ = 0.067 m

Width = 0.067 x 2 = 0.134 m A1

2.

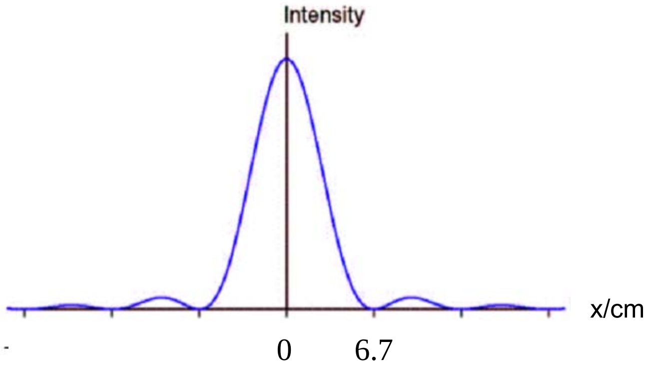


Diagram should show 3 maximas, symmetrical about O B1
Correct shape, with decreasing intensity B1
Correct spacing labelled B1
Any missing- minus 1 mark

(ii) 3.
$I \propto A^2$
With 2 slits,
When Intensity = I, amplitude of maxima = A + A
With 1 slit, C1
Amplitude of maxima = A
$I' = (A/2A)^2 \times I = \frac{1}{4} I$ A1

(iii) Rayleigh criterion stated. B1

Yes as the interference patterns formed by the two sources are resolved when θ is equal or greater than 1.54°. B1