Preliminary Examination
Year 6
Higher 2

CANDIDATE NAME				
CLASS	6	C		

INDEX NUMBER | | |

PHYSICS

9646/01

Paper 1 Multiple Choice

September 2016

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and index number on the Answer Sheet.

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

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	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_0	=	8.85×10^{-12} F m^{-1}
			$(1/(36\pi)) \times 10^{-9}$ 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,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos\omega t$
	$= \pm\omega\sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

1 In thermal physics, the rate of flow of thermal energy, $\frac{d\theta}{dt}$ can be found using the equation $\frac{d\theta}{dt} = kA\frac{(T_2 - T_1)}{L}$. k is defined as the thermal conductivity of material, A is the total cross sectional area of conducting surface of material and T_2 and T_1 are the temperatures across the conducting surface of thickness L.

Deduce the SI base unit for thermal conductivity.

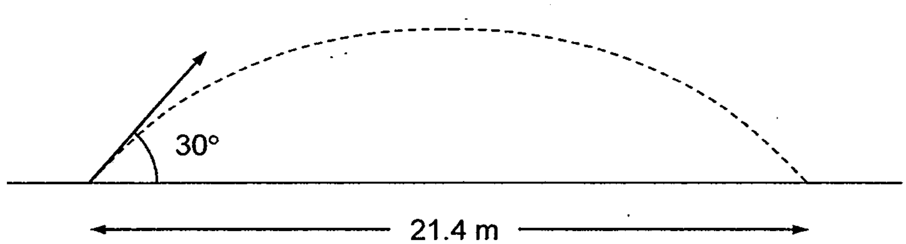
A $\text{kg m s}^{-3}\text{ K}^{-1}$ **B** $\text{kg m}^{-2}\text{ K}^{-1}$ **C** $\text{W m}^{-1}\text{ K}^{-1}$ **D** $\text{J m}^{-2}\text{ K}^{-1}$

2 The period of oscillation of a simple pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$. Given that the length of the pendulum, l is (20.0 ± 0.1) cm, Jiang Xiao measured the period, T to be (0.89 ± 0.02) s.

What is the best way Jiang Xiao should express the calculated value of acceleration due to gravity, g in m s^{-2}?

A 9.97 ± 0.50 **B** 9.9 ± 0.5 **C** 10.0 ± 0.5 **D** 10 ± 1

3 A ball is projected at an angle of 30° above the horizontal and travels a horizontal distance of 21.4 m.



Determine the new horizontal distance travelled by the ball if it is now projected at the same initial speed but at an angle of 45° above the horizontal. Assume that air resistance is negligible.

A 24.7 m **B** 26.2 m **C** 30.3 m **D** 37.1 m

4 An object is projected vertically upwards in an evacuated column. It takes time t to reach the highest point of its motion, and it takes a further time t to fall back to its initial position.

The column is then filled with a dense gas so that air resistance acting on the object cannot be ignored. The object is again projected vertically upwards with the same initial speed. It now takes time t_1 to reach the highest point of its motion, and a further time t_2 to fall back to its initial position.

Which of the following options is correct?

A $t_1 = t_2$ and $t_1 < t$
B $t_1 < t_2$ and $t_1 = t$
C $t_1 < t_2$ and $t_1 < t$
D $t_1 = t_2$ and $t_1 = t$

5 A lift is moving upwards and slowing down. A man of weight W is in the lift and he experiences a normal force N from the lift.

Which of the following relationships is correct?

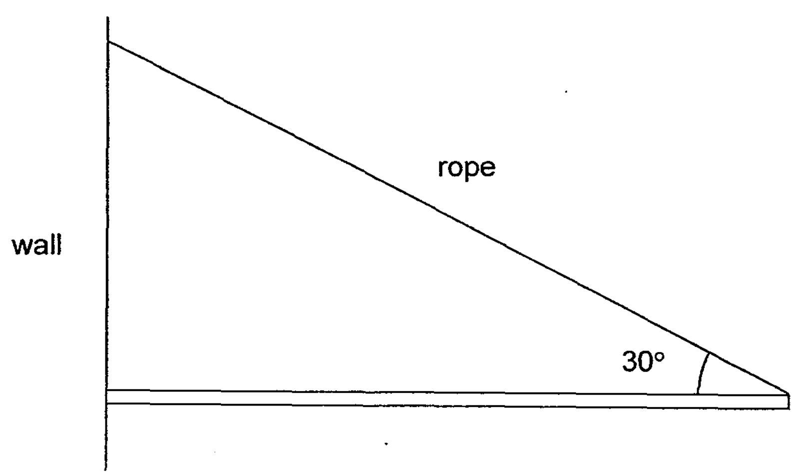
A $N = 2W$ **B** $2W > N > W$ **C** $N = W$ **D** $N < W$

6 A ball A of mass M is moving towards the right with speed $\frac{1}{2}V$. A ball B of mass $2M$ is moving towards the left with speed $\frac{1}{3}V$. Both balls are involved in a head-on elastic collision.

Calculate the final velocities of the two balls.

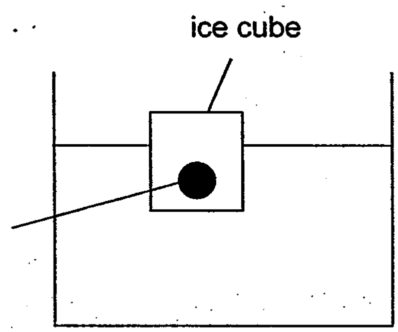
	Velocity of ball A	Velocity of ball B
A	$\frac{5}{6}V$ towards the left	$\frac{1}{3}V$ towards the right
B	$\frac{5}{18}V$ towards the right	$\frac{4}{9}V$ towards the left
C	$\frac{5}{18}V$ towards the left	$\frac{1}{9}V$ towards the right
D	$\frac{11}{18}V$ towards the left	$\frac{2}{9}V$ towards the right

7 One end of a uniform pole is attached to a hinge on a wall. The other end of the pole is attached to a rope. Given that the pole has a mass of 12.5 kg, determine the magnitude of the force that the hinge exerts on the pole.



A 70.8 N **B** 123 N **C** 142 N **D** 173 N

8 An ice cube containing a metal sphere is placed in a cylinder of water.



Which one of the following statements correctly describes the change in water level within the cylinder after the ice melts?

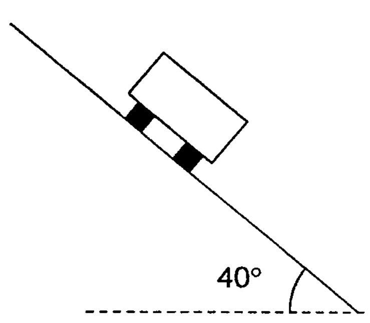
- **A** The water level remains at the same height
- **B** The water level rises
- **C** The water level drops
- **D** Not enough information is given to determine the change in water level

9 The engine of a boat supplies a constant power of 110 kW to propel the boat forward. The boat attains a maximum speed of 21.0 m s^{-1}. Given that the magnitude of the resistive force acting on the boat is proportional to the square of the boat's speed, calculate the resultant force acting on the boat when it is moving with a speed of 15.0 m s^{-1}.

A 2.67 kN **B** 3.59 kN **C** 4.66 kN **D** 7.33 kN

10 A car of mass 825 kg is going through horizontal circular motion on a race-track at a constant speed of 33.0 m s^{-1}. A frictional force of constant magnitude of 1.37 kN is acting in the downslope direction as the car is moving.

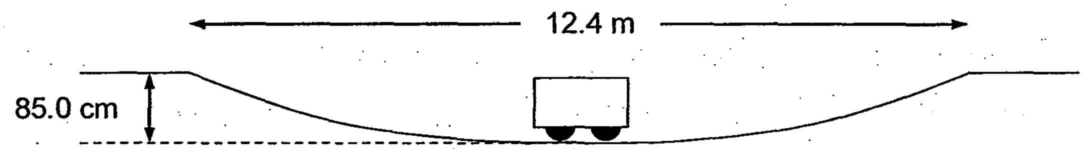
Determine the radius of the circle that the car is moving in.



A 76.3 m **B** 105 m **C** 120 m **D** 180 m

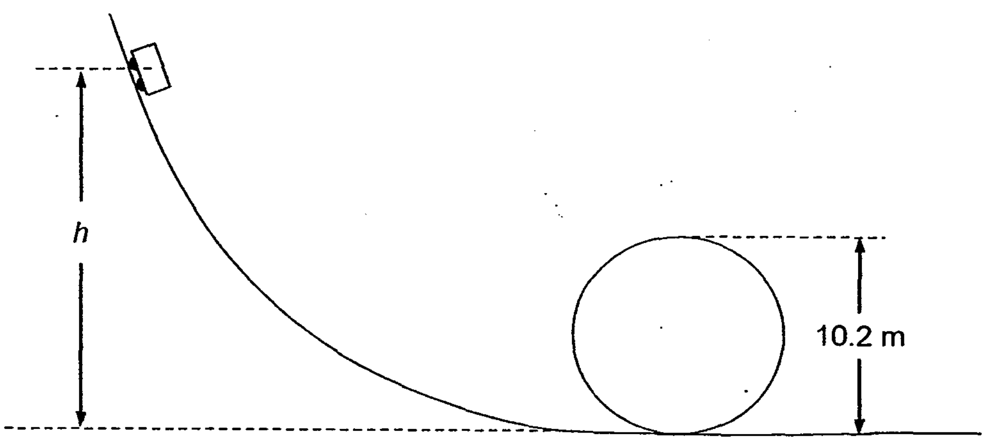
11 A car of mass 930 kg goes across a large circular pothole in the ground. The pothole has a width of 12.4 m and a depth of 85.0 cm. The car has a speed of 11.9 m s^{-1} when it is at the lowest point of the pothole.

Calculate the magnitude of the normal force acting on the car when it is at the lowest point of the pothole.



A 12.1 kN **B** 14.8 kN **C** 19.7 kN **D** 30.4 kN

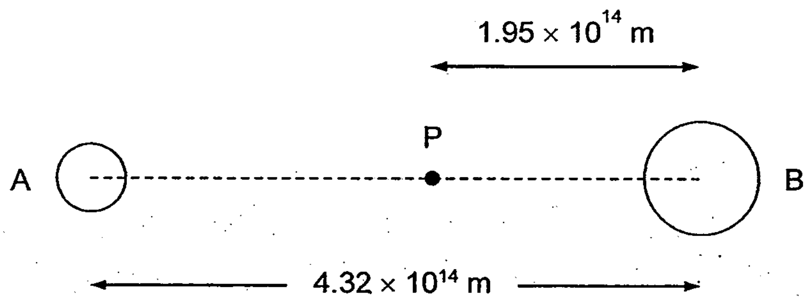
12 A cart slides down a frictionless track as shown in the figure below. At a height *h* above the ground, the cart is moving with a speed of 4.10 m s^{-1}. The cart just manages to remain in contact with the track at the highest point of the track 10.2 m above the ground.



Determine the height *h*.

A 11.9 m **B** 14.4 m **C** 16.2 m **D** 24.6 m

13 Star A of mass 7.22×10^{32} kg is at a distance of 4.32×10^{14} m away from star B of mass 1.57×10^{33} kg.



Calculate the resultant gravitational field strength at point P.

A 5.98×10^{-7} N kg^{-1} towards the left
B 1.90×10^{-6} N kg^{-1} towards the right
C 3.13×10^{-6} N kg^{-1} towards the left
D 3.61×10^{-6} N kg^{-1} towards the right

14 Given that the mass of the Earth is 5.98×10^{24} kg, calculate the linear speed of a geostationary satellite orbiting around the Earth.

A 3.07×10^{3} m s^{-1} **B** 8.86×10^{3} m s^{-1}
C 1.20×10^{4} m s^{-1} **D** 4.71×10^{4} m s^{-1}

15 A body oscillates with simple harmonic motion freely in a horizontal straight line. The total mechanical energy of the body is E.

Determine the total mechanical energy of the body if it now performs simple harmonic motion in a horizontal straight line with both its amplitude and period of oscillation doubled.

A $0.5E$ **B** E **C** $2E$ **D** $4E$

16 Which one of the following is not true for a forced oscillation?

A The amplitude of the system undergoing forced oscillation is always constant, even when the frequency of the external oscillatory force changes.
B When the frequency of the external oscillatory force is equal to the natural frequency of the system, there is maximum energy transfer.
C The frequency of the system undergoing forced oscillation is the same as the frequency of the external oscillatory force.
D The maximum amplitude of the system undergoing forced oscillation depends on the degree of damping.

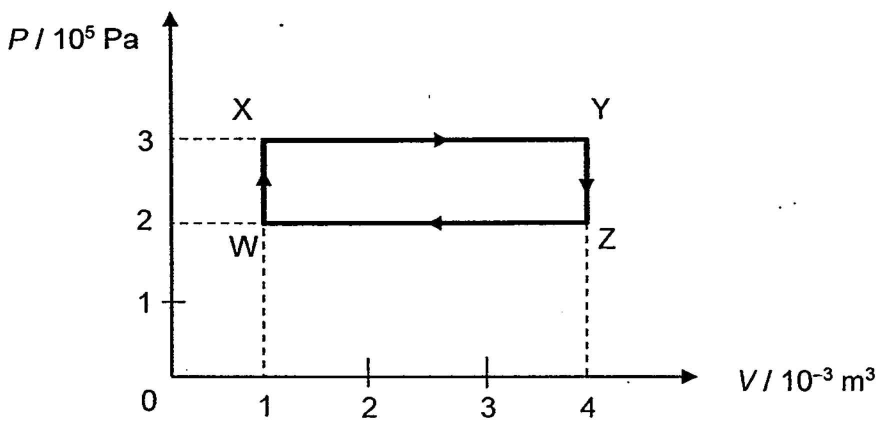
17 Equal masses of four different liquids (A, B, C and D) at 20°C are separately heated at the same rate. Their boiling points and specific heat capacities are shown in the table below.

Liquid	Boiling Point / °C	Specific Heat Capacity / J kg^{-1} K^{-1}
A	50	1000
B	60	530
C	80	850
D	360	140

Which liquid will be the last to boil?

A Liquid A **B** Liquid B **C** Liquid C **D** Liquid D

18 A mass of an ideal gas of volume V and pressure P undergoes the cycle of changes as shown.



At which points is the temperature of the gas lowest and highest?

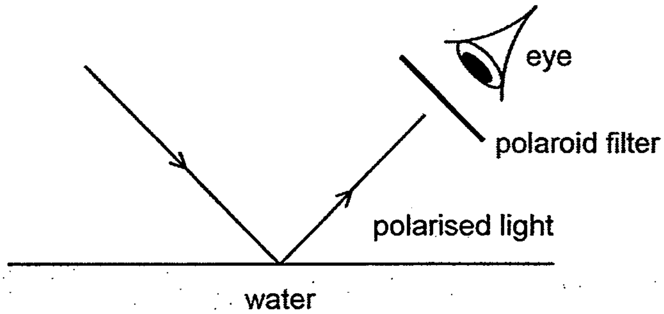
	Lowest Temperature	Highest Temperature
A	W	X
B	W	Y
C	Y	X
D	Z	Y

19 A wave has frequency of 5.0 Hz. It travels through a medium at a speed of 8.0 km s^{-1}.

What is the phase difference, in radians, between two points 2.0 km apart?

A 0 **B** $\pi/4$ **C** $\pi/2$ **D** π

20 Light reflected from the surface of water is polarised. A polaroid filter is used to view a water surface.

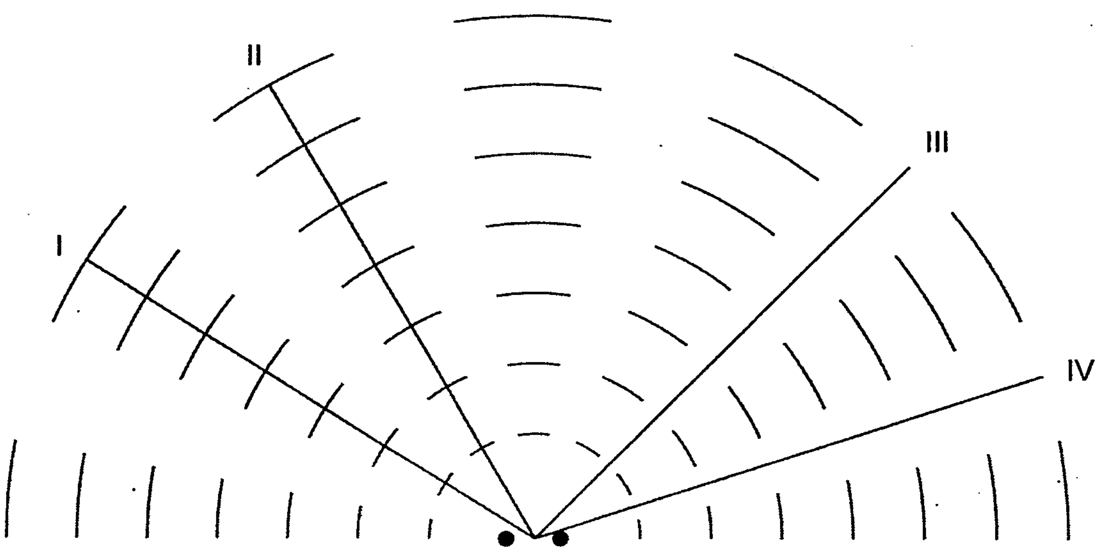


The polaroid filter is rotated through 180° in the plane perpendicular to the reflected light.

Which statement could describe the observations?

A The brightness changes from a maximum to a minimum.
B The brightness changes from a minimum to a maximum.
C The brightness changes from a maximum to a minimum to a maximum.
D The brightness changes from a minimum to a maximum to a minimum to a maximum.

21 Two identical sources in a ripple tank generate waves of wavelength λ. The interfering waves produce the wave pattern shown below.

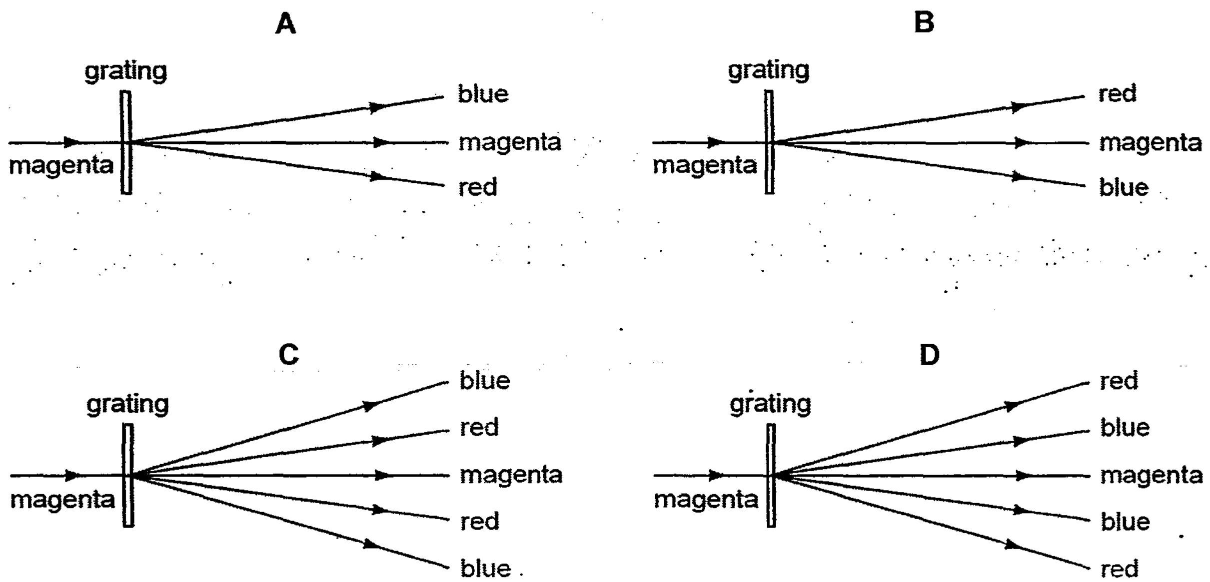


Along which of the labelled lines is the path difference between the waves from the sources equal to 1.5λ?

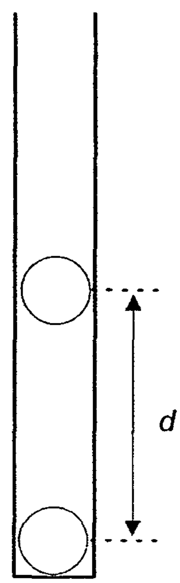
A I **B** II **C** III **D** IV

22 Magenta light consisting of a mixture of blue and red light is incident on a diffraction grating.

What is the expected arrangement of first order fringes about the central zero order?



23 Two charged plastic balls in a vertical test tube are in equilibrium a distance *d* apart as shown.



If the charge on each ball was to be doubled, the distance between the balls in the test tube would become

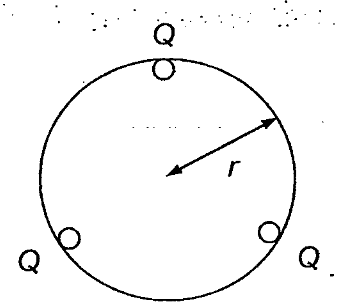
A 1.4*d* **B** 2*d* **C** 4*d* **D** 8*d*

24 X and Y are two points in an electric field. The potentials at X and Y are V_X and V_Y respectively where $V_X > V_Y$. A small positive test charge $+q$ is placed at X.

Which of the following is the work done per unit charge by the electric field on the charge as the charge moves from point X to point Y?

A $-(V_X - V_Y)$ **B** $+(V_X - V_Y)$
C $-(V_X - V_Y)/q$ **D** $+(V_X - V_Y)/q$

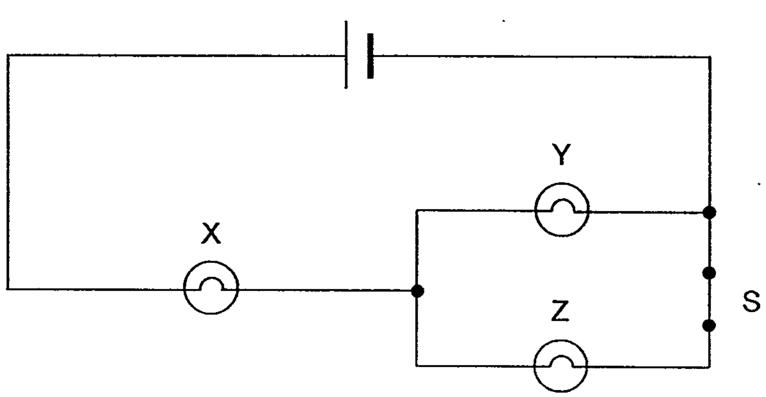
25 Three small conductors, on the edge of an insulating disc of radius r, are each given a charge Q as shown. The frequency of rotation of the disk is f.



What is the equivalent electric current at the edge of the disc?

A $3Qf$ **B** $\frac{3Q}{f}$ **C** $6\pi Qf$ **D** $\frac{2Qf}{\pi r}$

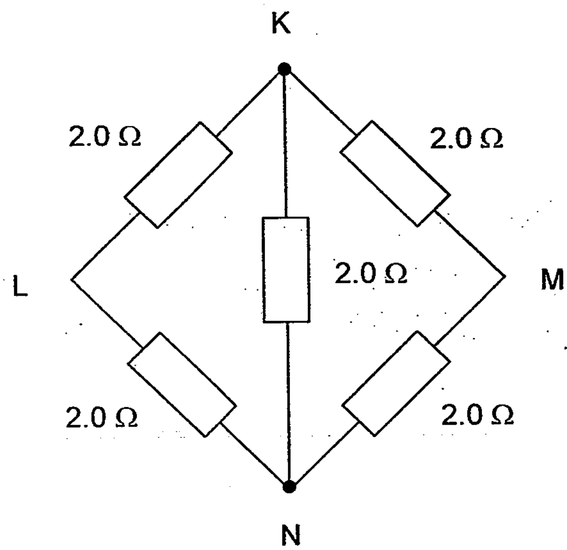
26 In the circuit, X, Y and Z are three identical bulbs. Initially, switch S is closed.



When switch S is open, what will happen to the brightness of bulb X and Y?

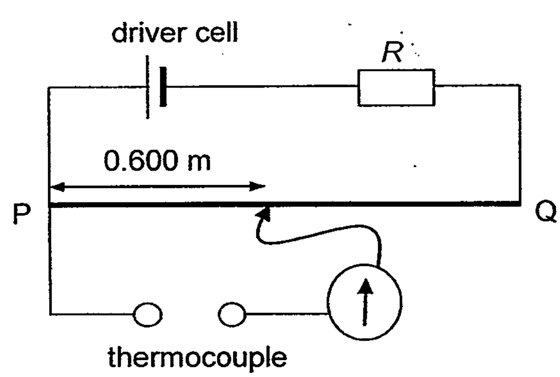
	Bulb X	Bulb Y
A	Decreases	Increases
B	Increases	Decreases
C	Decreases	Decreases
D	Increases	Increases

27 In the circuit shown, determine the equivalent resistance between L and M.



A 1.0 Ω B 2.0 Ω C 3.0 Ω D 4.0 Ω

28 The diagram shows a simple potentiometer circuit for measuring a small e.m.f. produced by a thermocouple.

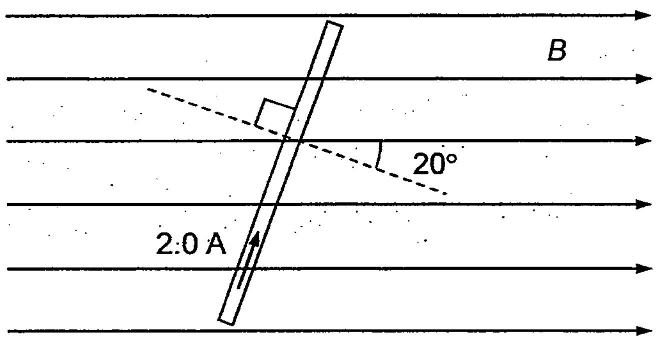


The meter wire PQ has a resistance of 5.0 Ω and the driver cell has an e.m.f. of 4.0 V. If the balance point is obtained 0.600 m from P when measuring the thermocouple e.m.f. of 6.00 mV, what is the resistance of the resistor *R*?

A 95 Ω B 495 Ω C 995 Ω D 1995 Ω

29 A straight conductor is in the plane of a uniform magnetic field as shown. The current in the conductor is 2.0 A and the normal of the conductor is at an angle 20° to the magnetic field of flux density of B. The force per unit length on the conductor due to the current in the magnetic field is 5.5 N m^{-1}.

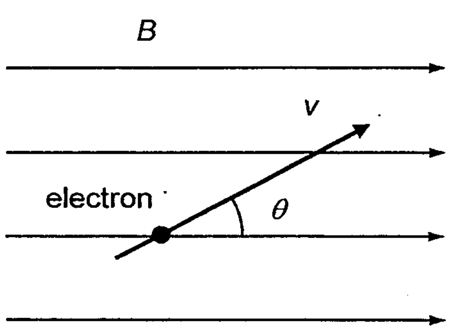
Top view



Calculate the value of B.

A 0.9 T **B** 1.8 T **C** 2.9 T **D** 8.0 T

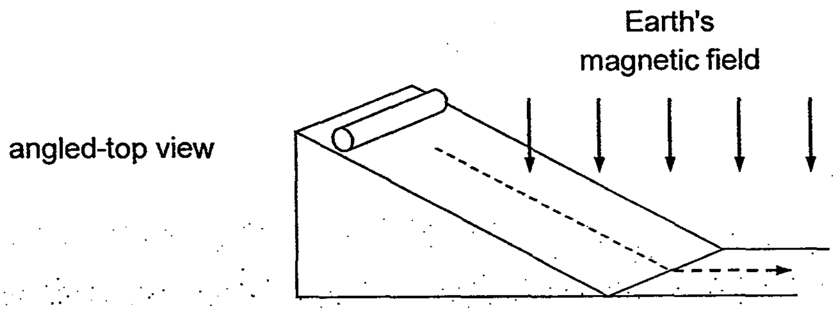
30 An electron of elementary charge e, is moved with a constant velocity v at an angle of θ to a magnetic flux density B. Hongting is unsure of the nature of the subsequent path of the electron.



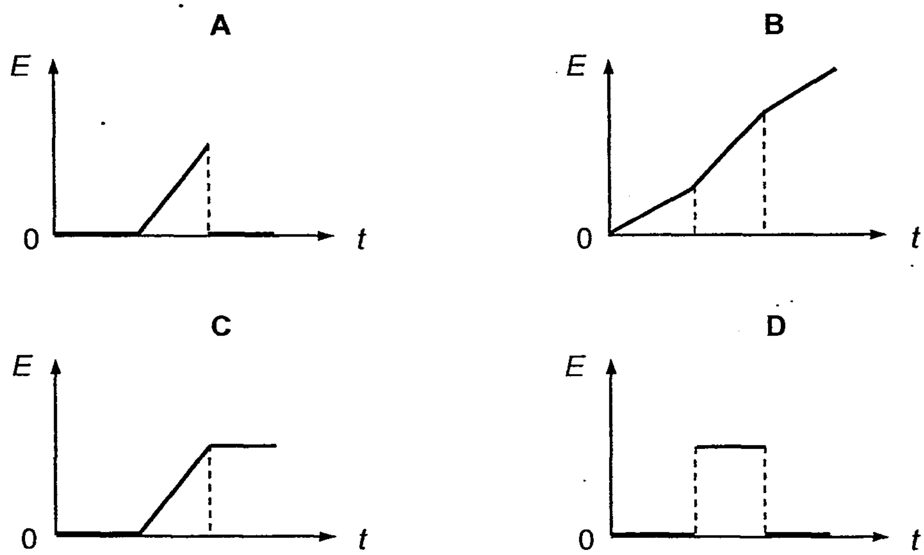
Which of the following statement describes the centripetal force acting on the electron and its subsequent path?

	Centripetal force on the electron	Path of the electron
A	$Bev \cos \theta$	circular
B	$Bev \sin \theta$	circular
C	$Bev \cos \theta$	helical
D	$Bev \sin \theta$	helical

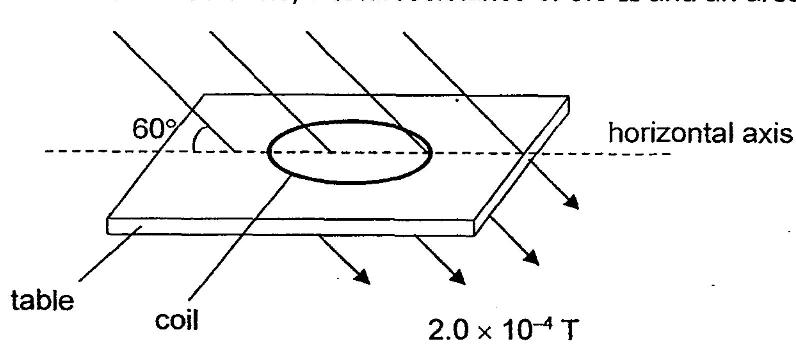
31 In a region of uniform magnetic field directed vertically downwards, a metal rod falls vertically from rest and lands on to a slope. It continues to roll down the slope and launches off the slope as shown.



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?



32 A magnetic field of flux density 2.0×10^{-4} T passes through a coil of wire as shown below. The field makes an angle of 60° with the plane of the horizontal non-magnetic table on which the coil rests. The coil has 500 turns, a total resistance of 5.0 Ω and an area of 25 cm^2.



Calculate the amount of charge that flows if the coil is turned through 180° about the horizontal axis.

A 4.3×10^{-5} C **B** 8.7×10^{-5} C **C** 3.6×10^{-4} C **D** 2.1×10^{-2} C

33 An ammeter uses the heating effect of a current to produce the deflection of the pointer. The reading which is proportional to the heating, is X when a direct current I flows through the meter.

When inserted in a circuit in which an alternating current of r.m.s. value I flows, the reading is

A $\frac{X}{2}$, because the constantly changing current produces a constantly changing heating effect which averages to one half that of the direct current.

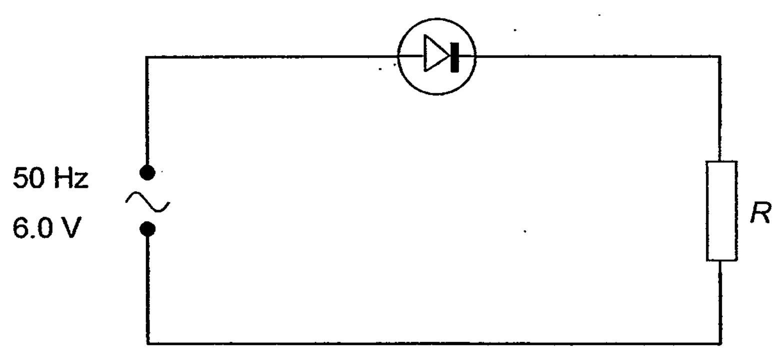
B $\frac{X}{\sqrt{2}}$, because it measures r.m.s. current which is obtained by recalibrating the scale for a.c. use by dividing all scale readings by $\sqrt{2}$.

C X, because it measures the r.m.s. current which gives the same deflection on the scale as the direct current.

D $\sqrt{2}X$, because it measures the peak current which is $\sqrt{2}$ times the direct current.

34 The figure below shows the circuit diagram for a half-wave rectifier. The supply to the rectifier is rated as 50 Hz , 6.0 V.

Calculate the average power dissipated in the load resistor of R = 2.0 Ω.



A 9.0 W

B 18 W

C 25 W

D 36 W

35 When X-rays are produced in an X-ray tube, the metal anode is either cooled or is made to spin rapidly.

Which of the following is the correct reason for this procedure?

A It reduces the intensity of the line spectrum of the metal target.
B More of the energy of the bombarding electrons is transferred to X-ray photon energy.
C Most of the energy of the bombarding electrons is transferred to thermal energy.
D It gives rise to a continuous distribution of X-ray wavelengths.

36 The intensity of a beam of monochromatic light is doubled.

Which one of the following represents the corresponding change, if any, in the momentum of each photon of the radiation?

A increased fourfold
B doubled
C halved
D the same

37 One of the characteristic of laser light is that it has to be monochromatic.

Which of the following statement explains this characteristic?

A The excited electrons are in a metastable state.
B The system is in a state of population inversion.
C Stimulated emission causes the emitted photon and the incident photon to be of the same phase.
D Photons of the same energy as that of the incident photons are emitted when the electrons transit down from a higher energy level.

38 A p-n junction is formed when a p-type semiconductor is in contact with an n-type semiconductor. The most important property of a p-n junction is that it rectifies an alternating current.

Which of the following statements is false?

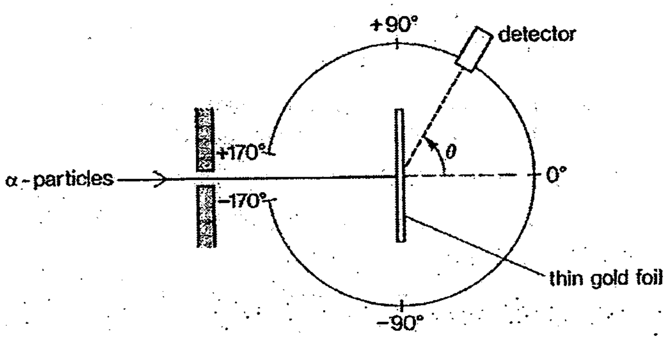
A During reverse bias condition of a p-n junction, the p-type semi-conductor becomes less negative.

B During reverse bias condition of a p-n junction, the width of the depletion region becomes larger as the externally applied p.d. adds to the junction potential.

C During forward bias condition of a p-n junction, if the applied p.d. overcomes the junction potential, electrons will cross steadily from the n-type side to the p-type side while the holes will cross steadily in the opposite direction.

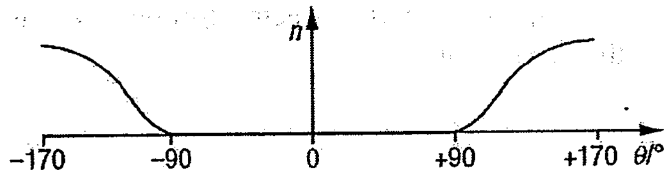
D Under increasingly high reverse biased p.d., current can increase sharply through the p-n junction.

39 In repeating Rutherford's α-particle scattering experiment, Jin Yang used the apparatus shown, in a vacuum, to determine n, the number of α-particles incident per unit time on a detector held at various angular positions θ.

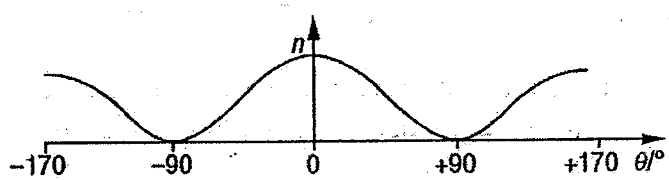


Which graph best represents the variation with θ of n?

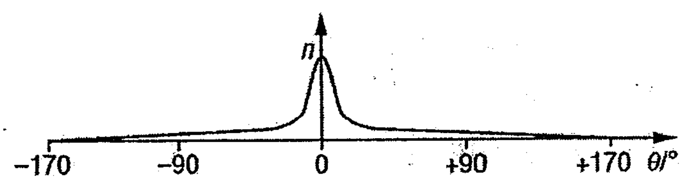
A



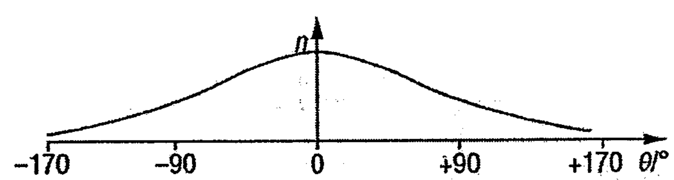
B



C



D



40 A radioactive nucleus emits a beta-particle. The daughter nucleus formed then decays, emitting an alpha-particle. The daughter nucleus of this decay then emits a beta-particle and gamma radiation.

How does the final nucleus compare with the original nucleus?

A It is a nucleus of a different element of higher proton number.
B It is a nucleus of a different element of lower proton number.
C It is a nucleus of an isotope of the original element.
D It is a nucleus identical to the original nucleus.

Answers

1	2	3	4	5	6	7	8	9	10
A	C	A	C	D	D	B	C	C	B

11	12	13	14	15	16	17	18	19	20
B	A	B	A	B	A	C	B	C	C

21	22	23	24	25	26	27	28	29	30
C	D	B	B	A	A	B	D	C	D

31	32	33	34	35	36	37	38	39	40
C	B	C	A	C	D	D	A	C	C

Preliminary Examinations
Year 6
Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

PHYSICS

9646/02

Paper 2 Structured Questions

September 2016

1 hour 45 minutes

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

READ THESE INSTRUCTIONS FIRST

Write your class, index number and name on all the work you hand in.
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.
DO **NOT** WRITE IN ANY BARCODES.

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	11
2	4
3	9
4	8
5	7
6	6
7	15
8	12
Total	72

Data

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

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,	$\phi = -\frac{GM}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm \omega\sqrt{x_0^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas,	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T \propto \exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

For Examiner's Use

1 An elastic rope is attached to a man on one end and to a bridge on the other end. The man has a mass of 80.0 kg while the rope has a natural length of 25.0 m and an elastic constant of 120 N m^{-1}. The man steps off the bridge and falls vertically downwards from rest. Assume that air resistance acting on the man is negligible.

(a) Determine the maximum speed of the man after he steps off the bridge.

maximum speed = ... m s^{-1} [4]

(b) Calculate the extension of the elastic rope when the man is at the lowest point of his motion.

extension = ... m [2]

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(c) Sketch on Fig. 1.1 three well-labelled graphs for the variation with downward displacement *s* of

(i) the gravitational potential energy of the man, (Label as **G**)
(ii) the elastic potential energy stored in the rope and (Label as **E**)
(iii) the kinetic energy of the man. (Label as **K**)

Assume that gravitational potential energy of the man is zero at the lowest point of the man's motion. Take $s = 0$ m as the start point of motion. [5]

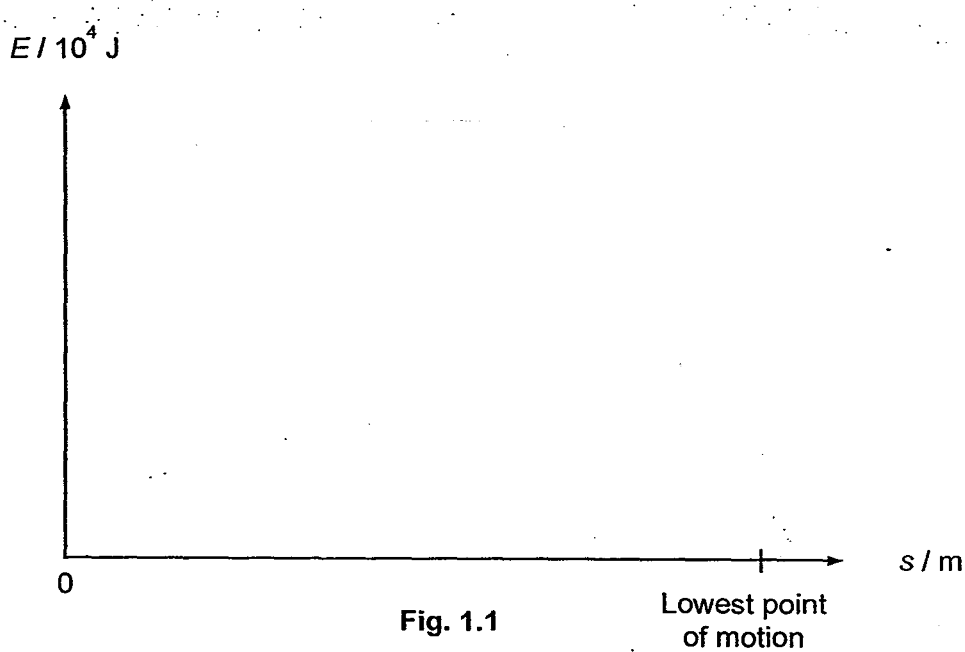

Fig. 1.1

2 An aluminium ball of density 2.70×10^3 kg m^{-3} falls through a column of unknown fluid with acceleration a. A tin ball of density 7.28×10^3 kg m^{-3} falls through the same fluid with acceleration $2a$.

Determine the density of the fluid, assuming that drag force due to the fluid is negligible.

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

3 (a) A cube of volume V contains N molecules of an ideal gas. Each molecule has a component c_x of velocity normal to one side S of the cube, as shown in Fig. 3.1.

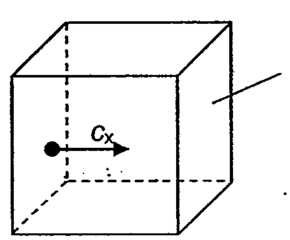

Fig. 3.1

Using the kinetic theory of gases with some simplifying assumptions, it can be shown that the pressure p of the gas due to the component c_x of velocity is given by the expression

$$pV = Nmc_x^2$$

where m is the mass of one molecule.

Show how the earlier expression leads to the following relation

$$pV = \frac{1}{3}Nm<c^2>$$

where $<c^2>$ is the mean square speed of the molecules. [3]

(b) Show that the mean kinetic energy of a molecule of the gas E is related to the thermodynamic temperature T of the gas by the expression [2]

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

(c) The density of neon gas at a temperature of 273 K and a pressure of 1.02×10^5 Pa is 0.900 kg m^{-3}. Neon may be assumed to be an ideal gas.

(i) Calculate the root-mean-square speed of the neon atoms at 273 K.

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

(ii) Determine the fractional change in root-mean-square speed of neon atoms when the temperature increases from 273 K to 546 K.

fractional change = ... [2]

4 (a) The electric field around a small conducting sphere is illustrated by the solid lines in Fig. 4.1. The equipotential lines are represented by the dotted lines.

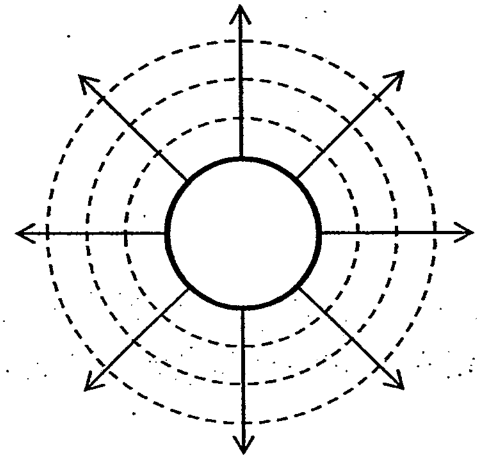

Fig. 4.1

(i) State and explain, using Fig. 4.1,

1. whether the sphere is positively or negatively charged, and

....

....[1]

2. why it appears as if the charge is concentrated at the centre of the sphere.

....

....[1]

(ii) Explain why the electric field lines cannot cross each other.

....

....[1]

(iii) Explain why the equipotential lines are always perpendicular to the electric field lines.

....

....

....[2]

(b) The electric field around some conducting charged spheres is shown in Fig. 4.2. Points A, B and C are all located at $y = 0.06$ m.

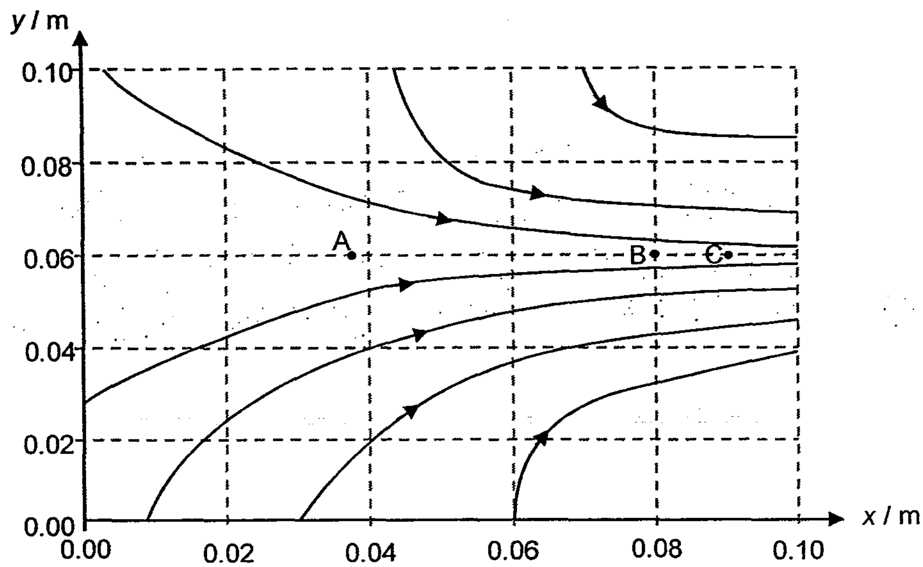

Fig. 4.2

(i) An electron is released from rest at point B.
Describe the subsequent motion of the electron.

....

....

....

....[2]

(ii) Points B and C are separated by a potential difference of 20 V.
Estimate the electric field strength midway between them.

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

5 **(a)** By reference to 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) An evacuated tube contains two parallel metal electrodes, one of which is an emitter of electrons and the other a collector. When the emitter is illuminated with electromagnetic radiation of frequency *f*, photoelectrons are emitted. The potential difference *V* between the collector and the emitter is adjusted, and the photocurrent *I* is measured. Fig. 5.1 shows the variation with *V* of *I*.

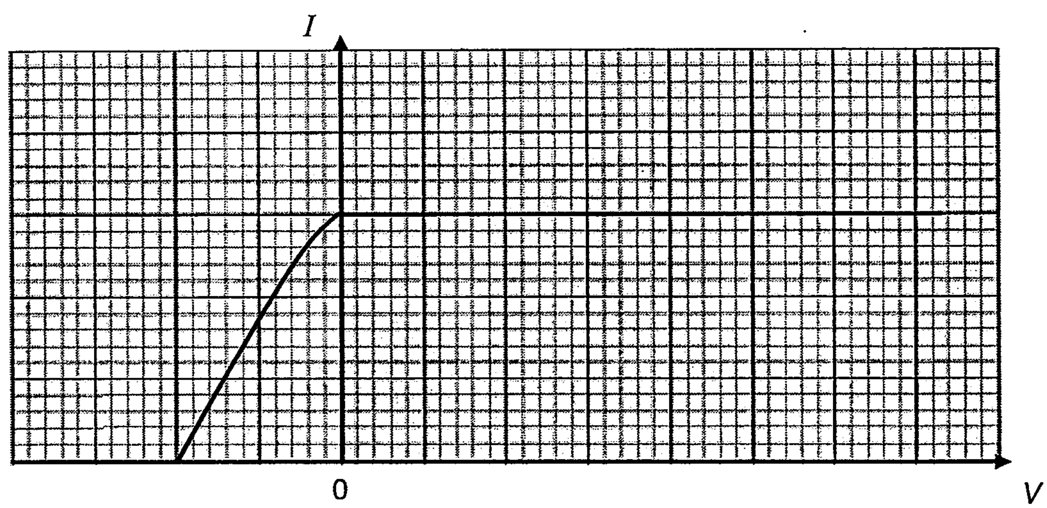

Fig. 5.1

The following changes are made separately to the experimental parameters.

(i) The frequency of the electromagnetic radiation is kept constant but its intensity is reduced by half. On Fig. 5.1, sketch a graph to show the variation with *V* of *I* for this reduced intensity. Label the graph **(i)**. [2]

(ii) The frequency of the electromagnetic radiation is increased but its intensity is kept constant. On Fig. 5.1, sketch a graph to show the variation with *V* of *I* for this increased frequency. Label the graph **(ii)**. [2]

For Examiner's Use

6 The fusion of deuterium nuclei can be represented by the equation

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He$$

You may use the following data:

nuclide	mass / u
$^{2}_{1}H$	2.01419
$^{4}_{2}He$	4.00277

(a) Calculate the minimum energy released in this reaction.

energy = ... J [3]

(b) In a fusion reactor, the energy released in the above reaction is used to generate electricity. This process is 52% efficient. If the average output of the power station is 5.00 MW, how long will 2.00 kg of deuterium fuel last?

time = ... s [3]

7 When the structure of the Earth near the surface is surveyed in prospecting for oil or minerals, one frequently used method is that of seismic reflection surveying. The process can be very complex because the strata in the Earth's crust are by no means regular, and also the quantity of data that is usually received is very large. Some of the principles behind the practice of seismic reflection surveying are explained and used in this question. The data have, however been simplified.

In a place where there is horizontal change in rock type at a certain depth, an explosion is set off. Fig. 7.1 shows an arrangement of eight detectors ($D_1 - D_8$) to detect vibrations from the explosion at source S, a short time after the explosion.

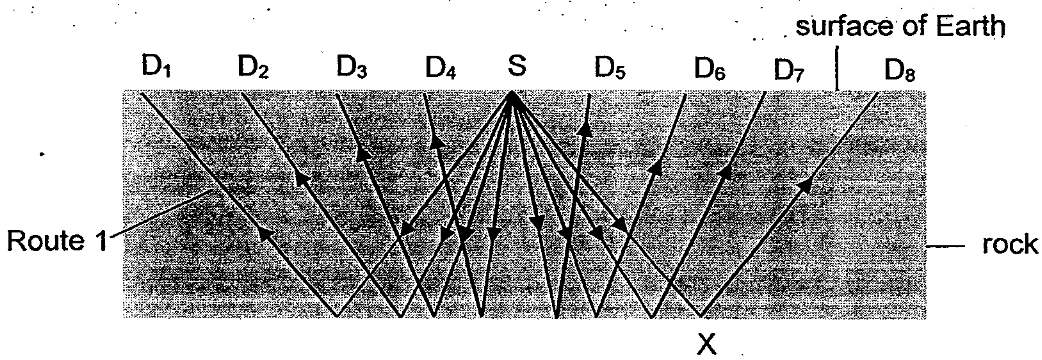

Fig. 7.1

Fig. 7.2 shows the traces received from the eight detectors printed alongside one another. Time $t = 0$ is the time the explosion commences.

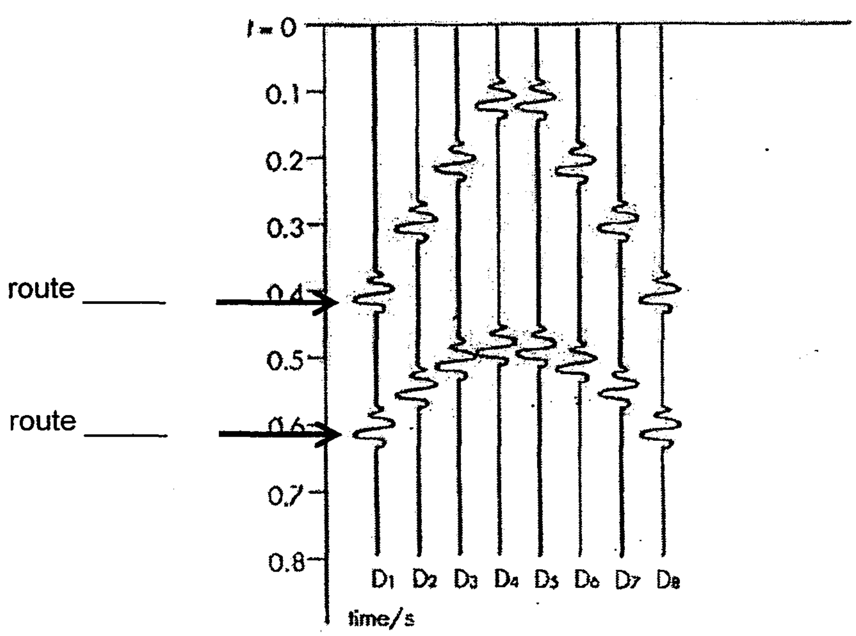

Fig. 7.2

The rock through which the waves are travelling is known to have a density of 2700 kg m^{-3} and in rock of this density, the speed of P-waves is 3.1 km s^{-1}. P-waves are longitudinal waves and are responsible for the pulses shown in Fig. 7.2. S-waves are transverse waves and always arrive after the P-waves.

Answer the following questions, taking data from the diagrams where necessary.

(a) What is meant by a *longitudinal wave*?

....

....[1]

(b) The speed v of a P-wave is given by

$$v = \sqrt{\frac{A}{\rho}}$$

where A is a constant and ρ is the density of the rock.

Determine the value and unit of A.

value = ... [1]

unit of A = ... [1]

(c) Apart from Route 1 shown in Fig. 7.1, draw, *on the same figure*, another shorter route P-waves can take to get from S to detector D_1. Label it Route 2. [1]

(d) For the detector D_1 shown in Fig. 7.2, indicate the route number corresponding to the two routes in which the P-waves arrive at the detector in **(c)**. [1]

(e) The amplitude for each pulse of the same detector in Fig. 7.2 should *NOT* be the same. Suggest why this is so.

....

....

....[2]

(f) Determine

1. the distance SD_8, and

distance = ... km [1]

2. the distance SXD_8.

distance = ... km [1]

(g) Use your answer in **(f)** to determine the depth of the rock in Fig. 7.1.

depth = ... km [2]

(h) In Fig. 7.2, an arrow shape develops when only eight detectors are used.

1. Sketch, on Fig. 7.3, the arrow pattern obtained when S-waves, travelling at 2.4 km s^{-1} are added. [2]

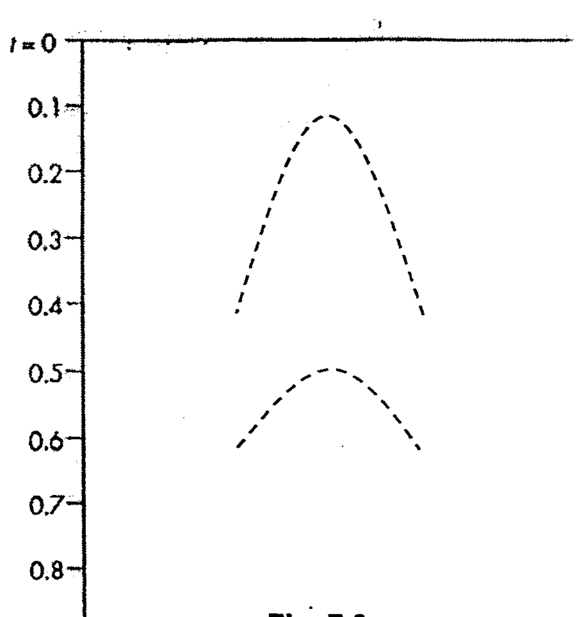

Fig. 7.3

2. Sketch, on Fig. 7.5, the arrow pattern obtained when P-waves travelled through a rock of uneven depth as shown in Fig. 7.4. **[1]**

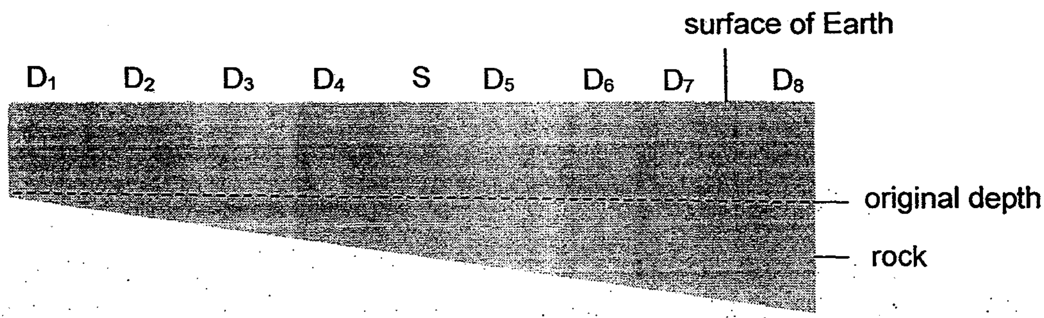

Fig. 7.4

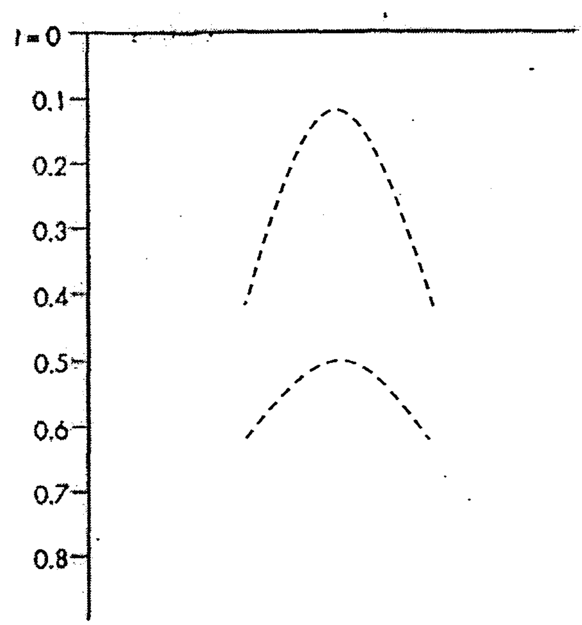

Fig. 7.5

3. Name one other factor, besides those listed in **(h) 1.** and **(h) 2.** which may affect the traces shown in Fig. 7.2.

....

....[1]

8 A student is investigating the angle at which a glass cylinder containing oil topples, as shown in Fig. 8.1. A cylinder containing a mass m of oil can be tilted through a maximum angle $\emptyset$ from the vertical before it topples.

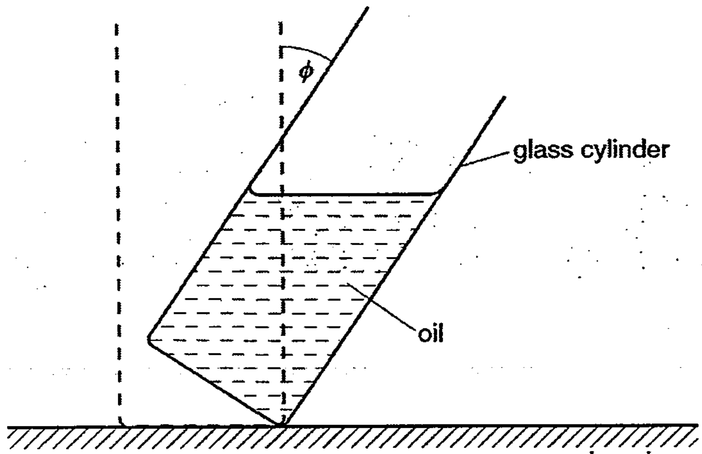

Fig. 8.1

It is suggested that the relationship between m and $\emptyset$ is

$$\frac{1}{tan\emptyset} = \frac{am}{\rho d^3} + b$$

where d is the diameter of the cylinder, ρ is the density of the oil and a and b are constants.

Design a laboratory experiment to test the relationship between $\emptyset$ and m. Explain how your results could be used to determine values for a and b. You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

(a) the procedure to be followed,

(b) the measurements to be taken,

(c) the control of variables,

(d) the analysis of data,

(e) the safety precautions to be taken.

For Examiner's Use

Diagram

For Examiner's Use

For Examiner's Use

[12]

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DHS	Mark Scheme	Syllabus
	Year 6 Preliminary Examinations H2 Physics 2016	9646

Paper 1

Question Number	*Key*	*Question Number*	*Key*
1	**A**	21	**C**
2	**C**	22	**D**
3	**A**	23	**B**
4	**C**	24	**B**
5	**D**	25	**A**
6	**D**	26	**A**
7	**B**	27	**B**
8	**C**	28	**D**
9	**C**	29	**C**
10	**B**	30	**D**
11	**B**	31	**C**
12	**A**	32	**B**
13	**B**	33	**C**
14	**A**	34	**A**
15	**B**	35	**C**
16	**A**	36	**D**
17	**C**	37	**D**
18	**B**	38	**A**
19	**C**	39	**C**
20	**C**	40	**C**

Paper 2

1 **(a)** Man is moving at maximum speed when resultant force acting on him is zero.

$mg = ke$ [C1]

$e = \frac{mg}{k} = \frac{80.0 \times 9.81}{120} = 6.54$ m [M1]

Applying Principle of Conservation of Energy,
Total energy before stepping off = Total energy at maximum speed

$0 + 0 + 0 = \frac{1}{2}mv^2 + \frac{1}{2}ke^2 - mg(l + e)$ [M1]

$v = \sqrt{\frac{2mg(l+e) - ke^2}{m}} = \sqrt{\frac{2 \times 80.0 \times 9.81 \times (25.0 + 6.54) - 120 \times 6.54^2}{80.0}}$

$= 23.6$ m s^{-1} [A1] [4]

(b) Applying Principle of Conservation of Energy,
GPE at highest point = EPE at lowest point

$mg(l + e) = \frac{1}{2}ke^2$ [M1]

$e = 25.8$ m [A1] [2]

(c)(i) At highest point,

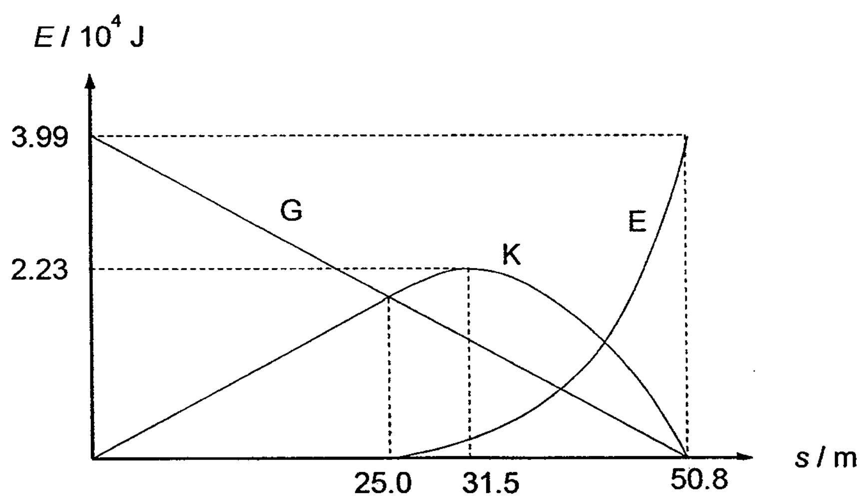
$GPE = mg(l + e) = 80.0 \times 9.81 \times (25.0 + 25.8)$
$= 3.99 \times 10^4$ J [C0]

Straight line with correct labels on y-axis and x-axis [B1]

(ii) Exponential curve with correct start and end points [B1]

(iii) $E_{k0} = \frac{1}{2}mv_0^2 = \frac{1}{2} \times 80.0 \times 23.6^2 = 2.23 \times 10^4$ J [C1]

Straight line from $s = 0$ m to $s = 25.0$ m [B1]
Curve from $s = 25.0$ m to $s = 50.8$ m, with correct label on y-axis [B1] [5]



2 Resultant force acting on aluminium ball:

$F_a = W_a - U_a = \rho_a V_a g - \rho_f V_a g = (\rho_a - \rho_f)V_a g$ [M1]

$a = \frac{F_a}{m_a} = \frac{(\rho_a - \rho_f)V_a g}{\rho_a V_a} = \left(\frac{\rho_a - \rho_f}{\rho_a}\right) g$ Eqn 1 [M1]

Resultant force acting on tin ball:

$F_t = (\rho_t - \rho_f)V_t g$

$a_t = 2a = \frac{F_t}{m_t} = \left(\frac{\rho_t - \rho_f}{\rho_t}\right) g$ Eqn 2

Dividing Eqn 1 by Eqn 2:

$\frac{1}{2} = \left(\frac{\rho_a - \rho_f}{\rho_a}\right)\left(\frac{\rho_t}{\rho_t - \rho_f}\right)$ [M1]

$\rho_f = \frac{\rho_t \rho_a}{2\rho_t - \rho_a} = \frac{7.28\times10^3 \times 2.70\times10^3}{2\times7.28\times10^3 - 2.70\times10^3} = 1.66\times10^3$ kg m^{-3} (citric acid) [A1] [4]

3 **(a)** Molecule has component of velocity in 3 directions
(or $\langle c^2 \rangle = \langle c_x^2 \rangle + \langle c_y^2 \rangle + \langle c_z^2 \rangle$) [B1]

Random motion of molecules, so averaging gives $\langle c_x^2 \rangle = \langle c_y^2 \rangle = \langle c_z^2 \rangle$ or [B1]

so $\langle c_x^2 \rangle = \frac{1}{3}\langle c^2 \rangle$ [B1]

Hence $pV = Nmc_x^2 = \frac{1}{3}Nm\langle c^2 \rangle$ [A0] [3]

(b) Mean kinetic energy of a molecule $= \frac{1}{2}m\langle c^2 \rangle$ [M1]

Ideal gas equation $pV = NkT$ [M1]

so $pV = \frac{1}{3}Nm\langle c^2 \rangle = NkT$

then $E = \frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}\frac{1}{3}m\langle c^2 \rangle = \frac{3}{2}kT$ [A0] [2]

(c)(i) From $pV = \frac{1}{3}Nm\langle c^2 \rangle$:

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

$1.02 \times 10^5 = \frac{1}{3}(0.900)\langle c^2 \rangle$ [M1]

or $\sqrt{\langle c^2 \rangle} = 583$ m s^{-1} [A1] [2]

(ii) From **(b)**, since $<c^2> \alpha\ T$

$$\frac{c_{546}}{c_{273}} = \sqrt{\frac{546}{273}}$$

Root-mean-square speed at 546K = 824 m s^{-1} [M1]

Fractional change = $\frac{824-583}{583} = 0.41$ [A1] [2]

4 (a)(i)

1. Positively charged, field lines directed outwards [B1] [1]

2. Field lines meet at centre of sphere when extrapolated backwards or field lines appear to radiate from centre as if charge is concentrated at the centre [B1] [1]

(ii) Direction of field line at a point indicates the direction of the resultant force experienced by a positive charged placed at that point

At any point, there can only be one resultant force acting in one direction, so field lines cannot cross [B1] [1]

(iii) Electric field is the negative potential gradient [B1]

Tangent to equipotential lines, potential gradient and hence component of field is zero [B1]

So field must be perpendicular to equipotential lines

Or

Movement along equipotential line requires no work [B1]

hence such movement is always perpendicular to the field/force [B1]

Or

Electric field is the negative potential gradient [B1]

Gradient points in the direction of greatest change of potential [B1]

Gradient (field) is perpendicular to equipotential line (for greatest change) [2]

(b)(i) Electron move to left (against direction of field lines) [B1]

as field strength weakens, acceleration to the left decreases all while gaining speed to the left [B1] [2]

(ii) Assuming uniform field between B and C, $E = \frac{\Delta V}{d}$

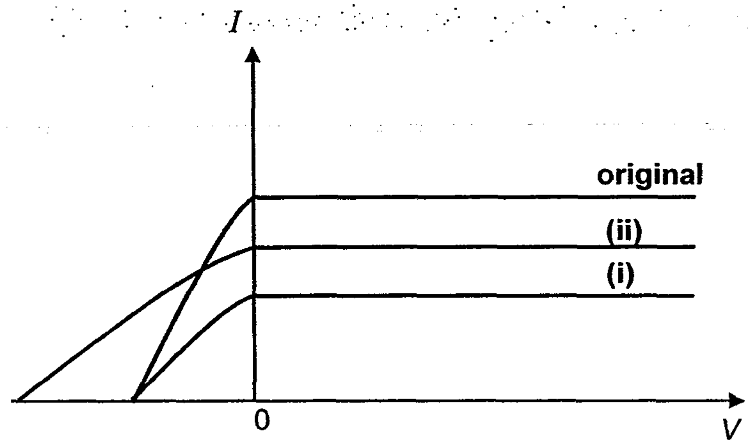
E = 2000 V m^{-1} [A1] [1]

5 **(a)** Minimum frequency of <u>e.m. radiation / a photon (not light)</u> for emission of electron from surface [B1] [1]

(b) Max KE corresponds to electron emitted from surface [B1]
Electron (below surface) requires energy to bring it to surface, so less KE_{max} [B1] [2]

(c)(i) ½ intensity ➔ current is reduced by half [B1]
same V_s [B1] [2]

(ii) Frequency is increased but intensity is constant ➔ no of photons is reduced so current decreases [B1]
but higher V_s [B1] [2]



6 **(a)** Applying conservation of mass-energy
$2\, m_H c^2 = m_{He} c^2 + \text{energy}$ [C1]
so energy = $(2 \times 2.01419 - 4.00277)(1.66 \times 10^{-27})(3.00 \times 10^{8})^2$ [M1]
$= 3.83 \times 10^{-12}$ J [A1] [3]

(b) Number of nuclei in 2.00 kg of deuterium

$$= \frac{2.00}{2.01419 \times 1.66 \times 10^{-27}} = 5.98 \times 10^{26}$$ [M1]

$$\text{Efficiency} = \frac{\text{Output energy}}{\text{Input energy}}$$

$$0.52 = \frac{(5.00 \times 10^{6})t}{(0.5)(5.98 \times 10^{26})(3.83 \times 10^{-12})}$$ [M1]

$t = 1.2 \times 10^{8}$ s [A1] [3]

7 **(a)** A longitudinal wave is one in which the <u>oscillation of the molecules</u> of the wave is <u>along the direction of transfer of energy</u> of the wave. [B1] [1]

(b) $A = \rho v^2 = (2700)(3100)^2 = 2.59 \times 10^{10}$ [A1]
Units of $A = (\text{kg m}^{-3})(\text{m s}^{-1})^2 = \text{kg m}^{-1}\text{ s}^{-2} = \text{Pa}$ [A1] [2]

(c) **(d)** [2]

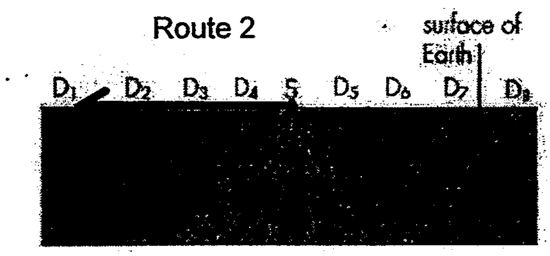


Fig. 7.1

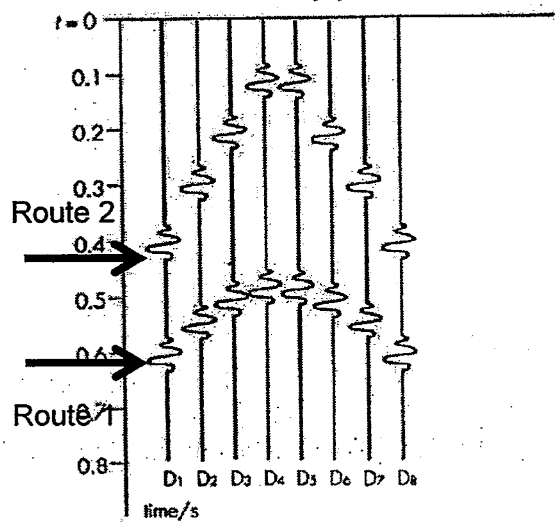


Fig. 7.2

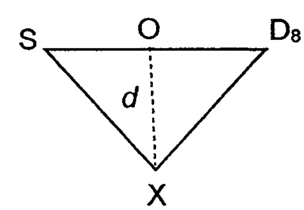
(e) The waves should be weaker after traveling longer distances, [B1]
hence direct waves should show larger amplitude than reflected waves. [B1] [2]

(f) **1.** SD_8, $t = 0.41$ s
$SD_8 = (3.1)(0.41) = 1.27$ km [A1] [1]

2. SXD_8, $t = 0.61$ s
$SXD_8 = (3.1)(0.61) = 1.89$ km [A1] [1]

(g) Assume $SX = XD_8$

Using Pythagoras Theorem,



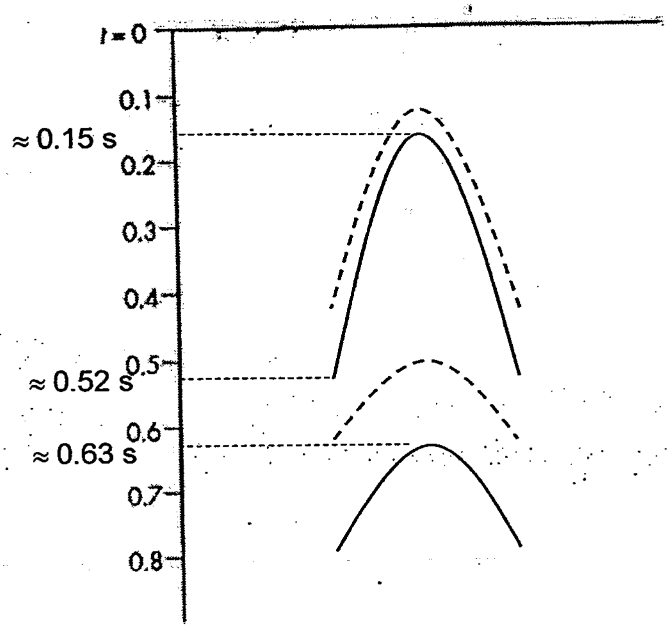
$$\text{depth } d = \sqrt{(XD_8)^2 - (OD_8)^2}$$

$$= \sqrt{\left(\frac{SXD_8}{2}\right)^2 - \left(\frac{SD_8}{2}\right)^2}$$ [M1]

$$= \sqrt{\left(\frac{1.89}{2}\right)^2 - \left(\frac{1.27}{2}\right)^2}$$

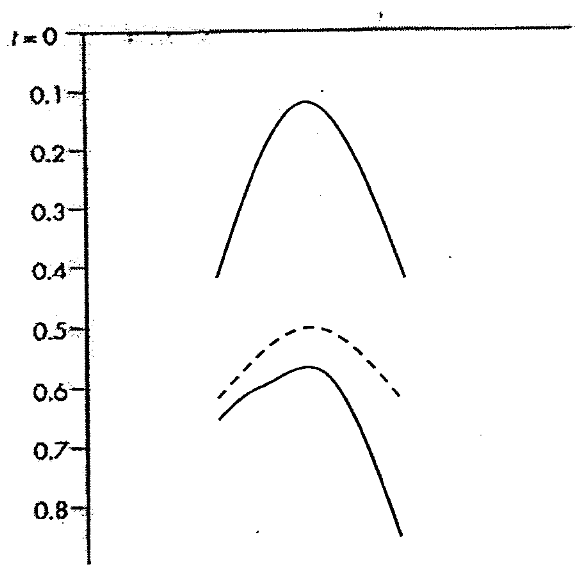
$= 0.70$ km [A1] [2]

(h)1.



Graph is lower, [A1]
at a time factor about (3.1/2.4) = 1.3 times later [A1] [2]

2. [A1] [1]



3. Any one of the following:

- An extra layer of rock halfway down that can cause partial reflection
- Double reflection before reaching detector
- Some refraction takes place at intermediate level (as a result of density changes)

[B1] [1]

8 Defining problem

{ m independent / vary m ; (tan)Ø dependent / measure tan(Ø) } [P1]

Keep temperature of the oil constant or
Use same (diameter) cylinder (not "same size") [P2]

Measurement

Labelled diagram showing labelled, supported, protractor positioned to determine Ø for tilted cylinder or allow distances marked to determine Ø and use of a rule [M1]
Use of balance/scales to measure the mass of the oil/cylinder and
Mass of oil = mass (oil + cylinder) – mass of cylinder [M2]
Use of vernier caliper / micrometer/ rule to measure d [M3]
Repeat each experiment for same value of m and average Ø [M4]

Data Analysis

Plot a graph of $\dfrac{1}{\tan\varnothing}$ against m

a = gradient $\times pd^3$ and b = y-intercept;

Relationship valid if **straight line** obtained that does NOT pass through the origin/ has an intercept.
a and b needed to be the subject of the formula for this mark to be scored [A1]

Safety

Precaution linked to preventing spilling oil
e.g. use a tray/lid/cloth to absorb oil (do not allow just wiping or mopping)
Or precaution linked to preventing glass cylinder breaking e.g. padding/cushion
Or use of gloves to prevent skin irritation (do not allow "because oil is slippery") [S1]

Additional detail

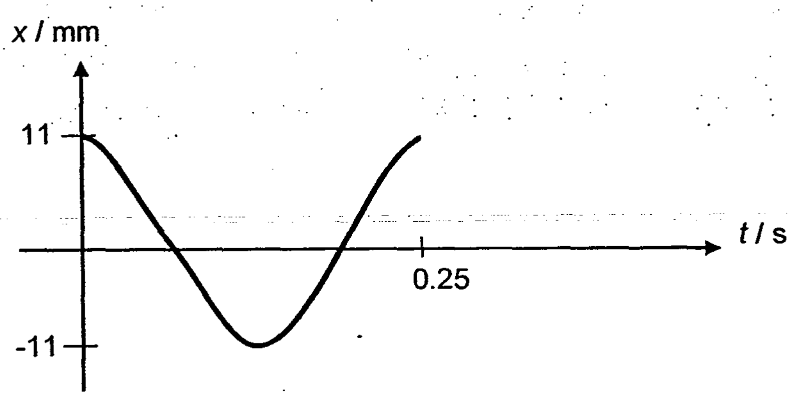
Repeat measurements of d in different directions and average [D1]
Use of video with slow motion/frame by frame playback to determine Ø [D2]
Use of large protractor to reduce percentage uncertainty or trigonometry relationship related to measurements to be taken. [D3]
Slowly/gently/gradually tilt cylinder of oil/ use of rough surface [D4]
Experimental method to determine density of oil and $\rho = m/V$ i.e. need to mention how the volume of oil could be measured and then an appropriate equation to find density.[D5]
(Do not allow vague computer methods) max 4 [12]

Paper 3

1 **(a)** Simple harmonic motion is defined as the oscillatory motion of a body whose acceleration is directly proportional to the displacement from a fixed point (the equilibrium position) and this acceleration is always in opposite direction to its displacement from that fixed point. [B2]

(b) **(i)** π radians/180^0 [A1]

(ii)



Correct shape [B1]
Correct labelling of values [B1]

(iii) $v = \pm\omega\sqrt{x_o^{\,2} - x^2}$

$= \pm(8\pi)\sqrt{(11\times10^{-3})^2 - (3\times10^{-3})^2}$ [M1]

$= 0.27$ m s^{-1} [A1]

(iv) For the needle to be in contact with the cloth, *x* must be 3 mm.
Let the times at which this occurs in one cycle be t_1 and t_2.
Therefore,

$3 = 11\cos(8\pi t)$ [M1]

$t_1 = 0.0515$ s and $t_2 = 0.1985$ s [C1]

Hence duration of time = 0.1985 s – 0.0515 s = 0.15 s
Or 0.25 – (2 x 0.0515) = 0.15 s [A1]

2 **(a)** charges in metal do not move (in electrostatic equilibrium) [M1]
No (resultant) force on the charges so no electric field. [A1]

(b) ΔV is area under the graph
ΔV = 3.9×10^3 V (allow 4.2 to 3.6) [C1]
Gain in KE = Loss in PE

$\frac{1}{2} mv^2 = 1.6 \times 10^{-19} \times 3.9 \times 10^3$

$\frac{1}{2} (9.11 \times 10^{-31})v^2 = 6.24 \times 10^{-16}$ J [C1]

$v = 3.7 \times 10^7$ m s^{-1} [A1]

Or $E_{ave} = (25 + 60) \times 10^4 = 42.5 \times 10^4$

$F_{ave} = q E_{ave} = (1.6 \times 10^{-19})(42.5 \times 10^4)$ [C1]

Gain in KE = work done = F_{ave} x displacement

$\frac{1}{2} mv^2 = (1.6 \times 10^{-19})(42.5 \times 10^4) \times 0.01$ [C1]

$v = 3.86 \times 10^7$ m s^{-1} [A1]

3 (a) Electromotive force of a source is the work done per unit charge when non-electrical energy is transferred into electrical energy when the charge is moved round a complete circuit.

Potential difference between two points in a circuit is the work done per unit charge when electrical energy is transferred into non-electrical energy when the charge passes from one point to the other.

work done per unit charge for both [B1]

distinguish between two points in circuit and source [B1]

distinguish conversion of different energy forms [B1]

(b) (i) internal resistance of the cell or the resistance of the ammeter is not zero or the resistance of the voltmeter is not infinite [B1]

(ii) resistance = $\frac{9.98}{4.00 \times 10^{-3}} = 2495\ \Omega$ [A1]

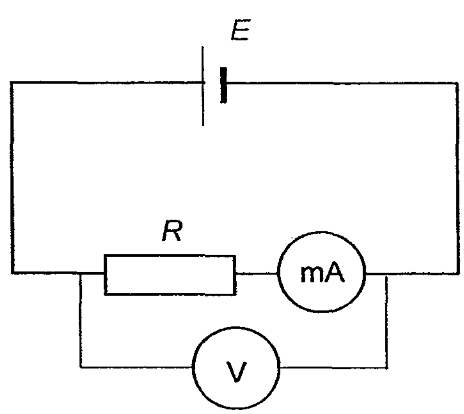
(iii) The current used in **(ii)** is not the current through the component and it includes the current through the voltmeter. [B1]

(iv) From **(ii)**, the voltmeter and the component are in parallel [B1] with an effective resistance about 2.5 kΩ. Using the formula for resistors in parallel,

$$\frac{1}{R_{effective}} = \frac{1}{R_{wire}} + \frac{1}{R_{voltmeter}}$$ [M1]

since the resistance of the component is about 5.0 kΩ, the resistance of the voltmeter is about 5.0 kΩ [A1]

(v) 1.



2. Ammeter connected in series with R to measure current in R only [B1]. The voltmeter measures the p.d. across R and ammeter. However, the p.d. across the ammeter is negligible as the resistance of the ammeter is much lower than R. [B1].

4 **(a)** $E_\beta = \frac{hc}{\lambda_\beta} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{19.0\times10^{-12}} = 1.0468\times10^{-14}$ J

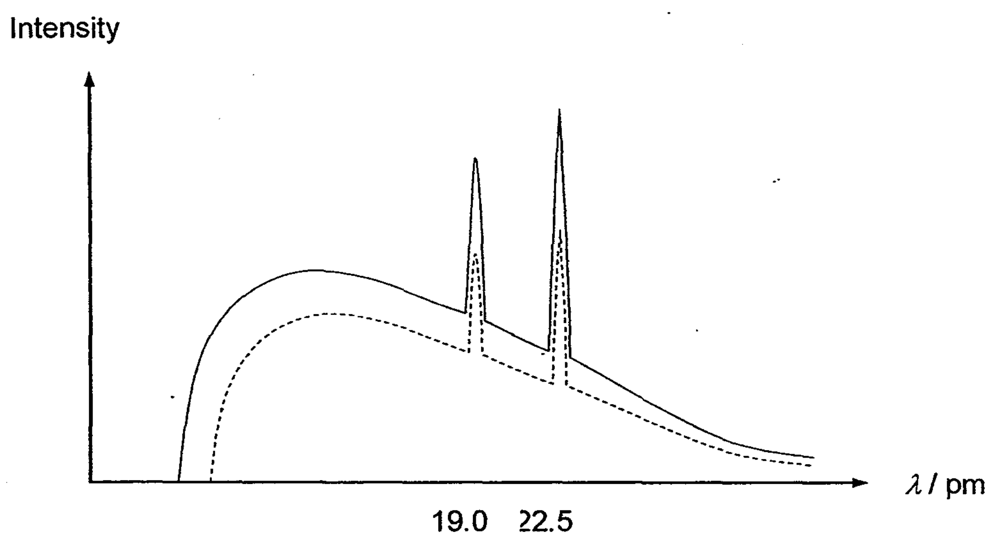
$= 65.428$ keV

$E_\alpha = 55.250$ keV [C1]

$E_1 = -8.20 - 65.428 = -73.63$ keV [A1]

$E_2 = -73.6 + 55.250 = -18.38$ keV [A1]

(b)



Higher cut-off wavelength and intensity lower than the original [B1]

Same wavelengths for characteristic peaks. [B1]

5 **(a)** The count rate will be a fraction of the activity. [B1]
The activity is equal to the total number of disintegrations in the source per unit time, whereas the count rate (as recorded by a GM tube and a rate meter) is a fraction of the activity of the source and denotes the number of particles detected per unit time. [B1]

(b) **(i)** Decay constant is the probability of decay of a nucleus per unit time. [B1]

(ii) **1.** $T = \frac{\ln 2}{\lambda} = 151$ s [A1]

2. $C = C_0 e^{-\lambda t}$

$(8.3\times10^3 - 2.0\times10^2) = (7.6\times10^8 - 2.0\times10^2)e^{-4.6\times10^{-3}t}$ [M1]

$t = 2489$ s = 41.5 minutes [A1]

(iii) Factoring in background count:
Count rate = 1000 – 200 = 800 per second

Application of inverse square law: $\frac{800}{3^2} = 88.9$ counts per second [M1]

Factoring in background count: Count rate = 200 + 88.9 = 289 s^{-1} [A1]

6 (a) (i) $\phi = -\frac{GM}{R} = -5.37\times10^{10}$

$m\phi + \frac{1}{2}mv^2 = 0$ [M1]

$v = \sqrt{-2\phi} = \sqrt{2\times5.37\times10^{10}}$

$= 3.28\times10^5$ [A1]

(ii) An atmosphere can be found around the planet, so energy is lost when the satellite does work against resistive forces. [B1] This means that the satellite must have greater kinetic energy at launch or

There are other planets or stars near the planet. [B1]

(iii) $m\phi + \frac{1}{2}mv^2 = -\frac{GMm}{r} + \frac{GMm}{2r}$

$\phi + \frac{1}{2}v^2 = -\frac{GM}{2r}$ [M1]

$r = -\frac{GM}{2\phi + v^2}$

$= -\frac{6.67\times10^{-11}\times4.13\times10^{27}}{2\times-5.37\times10^{10} + (2.78\times10^5)^2}$

$= 9.15\times10^6$ m [A1]

(b) (i) $E_{tP} = U_P + E_{kP} = m\phi_P + \frac{1}{2}mv_P{}^2$

$= (-10.26\times10^{10})m + \frac{1}{2}m(4.02\times10^5)^2$

$= (-2.18\times10^{10})m$ [M1]

$E_{tP} < U_Q$ [M1]

Object will land on planet A. [A1]

(ii) Applying Principle of Conservation of Energy,

$E_{kP} + U_P = E_{kA} + U_A$

$E_{kA} = (8.08\times10^{10})m + m(-10.26\times10^{10}) - m(-19.15\times10^{10})$ [M1]

$= (1.70\times10^{11})m$

$v_A = \sqrt{2\times1.70\times10^{11}} = 5.83\times10^5$ [A1]

(iii) g = gradient of graph = 0 m s^{-2}

$F = mg = 0$ N

(iv) The negative gradient of a point on the graph gives the resultant gravitational field strength at the point. [C0]

For resultant gravitational field strength to be zero at point Q, the gravitational field strength of planet A at Q must have the same magnitude as the gravitational field strength of planet B at Q. [B1]

Because planet A is more massive, point Q has to be further from planet A for its field strength to have the same magnitude as that from planet B. [B1]

(c) (i) Gravitational force acting on either star must point towards the centre of mass at all times to provide the required centripetal force. [B1] This means that both stars must be on opposite sides of the centre of mass at all times. [B1] Hence both stars must travel through the same angular displacement per unit time.

(ii) $F_C = F_D$

$m_C r_C \omega^2 = m_D r_D \omega^2$

$\frac{r_C}{r_D} = \frac{m_D}{m_C} = \frac{7.11\times10^{30}}{2.64\times10^{31}} = \frac{7.11}{26.4}$

$r_C + r_D = d = 1.50 \times 10^{12}$

$r_D = 1.18 \times 10^{12}$ m [M1]

$\frac{G m_D m_C}{d^2} = m_D r_D \omega^2$

$\omega = \sqrt{\frac{G m_C}{r_D d^2}} = \sqrt{\frac{6.67\times10^{-11}\times2.64\times10^{31}}{1.18\times10^{12}\times(1.50\times10^{12})^2}}$ [M1]

$= 2.57 \times 10^{-8}$ rad s^{-1} [A1]

(iii) When the planet and star C are on opposite sides of star D, resultant force acting on the planet is large. [B1] When the planet and star C are on the same side of star D, resultant force acting on the planet is lower in magnitude. [B1] Hence, the orbit of the planet will not be a perfect circle.

7 **(a)** progressive: all particles have same amplitude.
stationary: maximum (antinode) to minimum/zero amplitude (node) [B1]
progressive: adjacent particles are not in phase
stationary: wave particles are in phase (between adjacent nodes) [B1]

(b) **(i)** correctly identified particle (labelled O)
any point on the wave with positive displacement. [B1]
(ii) arrow drawn at X pointing vertically upwards [B1]
(iii) distance = 2 × 0.06 cm = 0.0012 m [A1]

(c) **(i)** Sound wave travels down the tube and is reflected in opposite direction from the water surface [B1]
Incident and reflected waves of the same frequency/wavelength/period **and** speed superpose/ meet/ ovelap to give standing wave [B1]

(ii) $\frac{1}{2}\lambda = 65.0$ cm [C1]
Speed = $0.650 \times 2 \times 256 = 330$ m s^{-1} [A1]

(d) **(i)** 1 path difference = $5.2 \times 10^{-6} \times \sin 10° = 9.03 \times 10^{-7}$ m [A1]
2 $d\sin\theta = \lambda$
$\sin\theta = (5.9 \times 10^{-7}) / (5.2 \times 10^{-6})$ [C1]
$\theta = 6.51°$ [A1]
3 $d\sin\theta = n\lambda$
$n = (5.2 \times 10^{-6}) / (5.9 \times 10^{-7}) = 8.8$ [C1]
Number = 8 + 8 + 1 = 17 [A1]

(e) **(i)** progressive: energy is transferred/ propagated through the water/ wave profile/wavefronts move [B1]

(ii) to produce coherent waves/ waves with constant (zero) phase difference [B1]

(iii) minimum distance is λ, 20 mm [A1]

(iv) 1. path difference is λ [B1] , so water vibrates with amplitude about 2 x 3.2 mm [B1]
2. path difference is ½ λ, so little/ no motion/ displacement/ amplitude [B1]

8 (a) (i) The magnetic flux density of a magnetic field is defined as the force per unit length per unit current acting on a straight conductor placed normal to field. [B2]

(ii) Magnetic force provides the centripetal force.

$$Bev = m_e r\omega^2$$

$$Ber\omega = m_e r\omega^2$$

$$Be = \frac{2\pi m_e}{T}$$

$$T = \frac{2\pi m_e}{Be}$$

$$t = \frac{T}{2} = \frac{\pi m_e}{Be}$$ [M1]

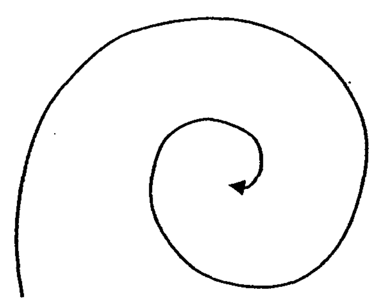
Time taken:

$$t = \frac{\pi m_e}{Be} = \frac{\pi(9.11\times10^{-31})}{0.050(1.6\times10^{-19})}$$ [C1]

$= 3.6 \times 10^{-10}$ s [A1]

(iii) The electron collides with the air particles in the medium. It thus loses kinetic energy and its velocity decreases. [B1]

From the equation, $r = \frac{mv}{Bq}$ as v decrease, r decrease. Hence r decreases continuously and a spiral path would be formed. [A1]



Accept path that shows a decrease in radius. [A1]

(b) (i) As the disc rotates, it continuously cuts the magnetic field lines. [B1]
According to Faraday's law of electromagnetic induction, since there is a rate of change of magnetic flux, there will be an induced e.m.f. generated between the axle and the rim of the disc. [B1]

(ii) Consider a point at the rim, as the disc rotates, applying Fleming's left hand rule, these electrons move out of paper, giving rise to conventional current into paper. The direction of the induced current is from the rim to the axle. [M1]
Hence, the axle will be at a higher potential than the rim. [A1]

(iii) $E = -\dfrac{d\phi}{dt}$

Magnitude of e.m.f. induced = BAf

$$0.025 = 0.50 \times \pi(0.09)^2 \times f$$ [M1]

f = 1.96 Hz [A1]

(iv) The e.m.f. induced in the disc is opposite in polarity compared to that of the cell, where the former drives current through the resistor from the right to left, while the latter drives current through the resistor from left to right. [B1]
When the speed of rotation is small, the induced e.m.f. is small and so current flows in the direction dictated by the cell. [B1]
However, as the speed of rotation increases, the rate of cutting of fluxes increases, and so the induced e.m.f. across the rim and axle increases. If it is large enough, then the current will flow in the opposite direction, due to the stronger induced e.m.f. compared to that of the cell. [B1]

(c) **(i)** $\dfrac{N_P}{N_S} = \dfrac{V_P}{V_S} = \dfrac{8}{3}$

Therefore, $V_P = V_S\left(\dfrac{8}{3}\right)^n$ [M1]

$$230000 = 240\left(\frac{8}{3}\right)^n$$

$n = 6.999$

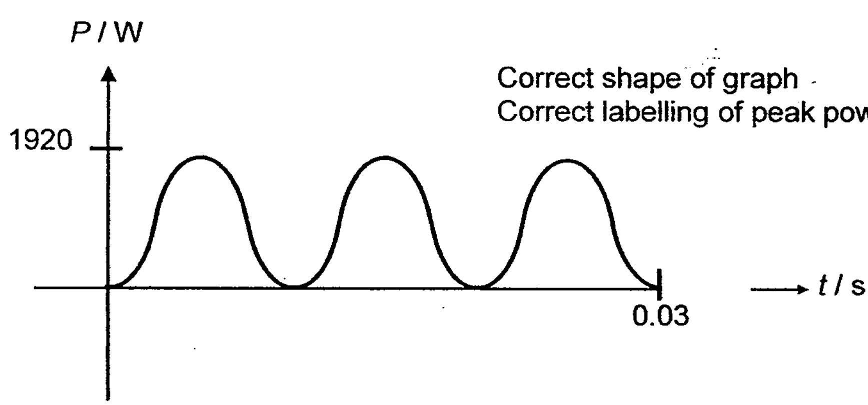
Number of transformers required = 7 [A1]

(ii) Peak power = average power x 2

$$= \left(\frac{240^2}{60}\right) \times 2$$

= 1920 W

Period = 0.02 s



Correct shape of graph [B1]
Correct labelling of peak power [B1]