**RAFFLES INSTITUTION**
**2017 Preliminary Examination**

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**PHYSICS** **9749/01**
**Higher 2**

**26 September 2017**
Paper 1 Multiple Choice Questions **1 hour**

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Additional Materials: OMR Form

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**READ THESE INSTRUCTIONS FIRST**

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your index number, name and class on the OMR Form in the spaces provided. Shade the appropriate boxes.

There are **thirty** questions on 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 OMR Form.

**Read the instructions on the OMR Form 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 appropriate scientific calculator is expected, where necessary.

This document consists of **13** printed pages and **1** bank page.

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

**1** Which of the following contains only SI base units?

**A** kilogram, metre, mole, ampere

**B** metre, mole, ampere, mass

**C** kelvin, kilogram, coulomb, second

**D** ampere, kelvin, gram, mole

**2** Which of the following estimates is **not** reasonable?

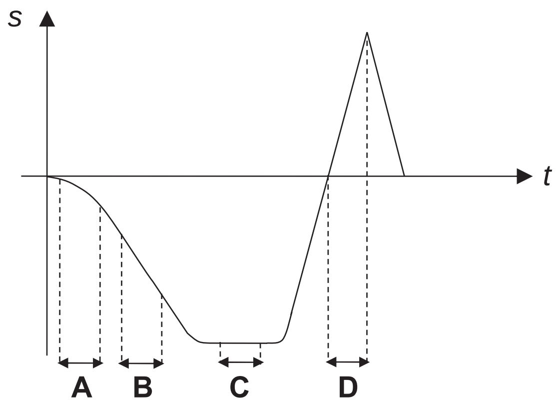
**A** The average density of a car is about 300 kg $m^{-3}$.

**B** The mass of one sheet of paper in this booklet is about 5 g.

**C** The useful power delivered by a crane in lifting a 1000 kg concrete block is about $10^4$ W.

**D** A typical classroom in RI contains about 3000 moles of air molecules at room temperature.

**3** The graph shows the variation with time *t* of the displacement *s* of a vehicle moving along a straight road.



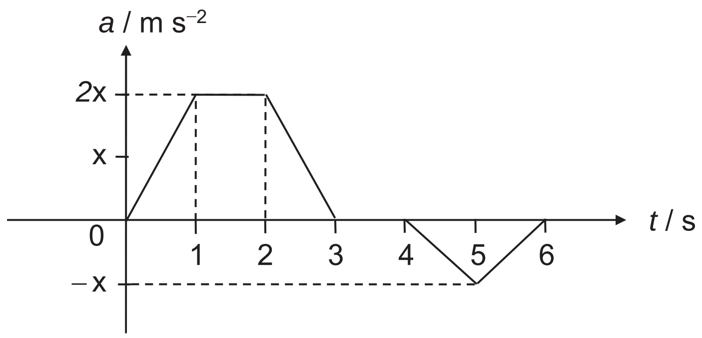

During which time interval is the acceleration of the vehicle the greatest?

**4** A hot air balloon is rising at an angle of 20.0° above the horizontal with a speed of 3.50 m $s^{-1}$. When it is 300 m above the ground, a ball is projected at an angle of 5.00° above the horizontal with a speed of 10.0 m $s^{-1}$ relative to the balloon. Air resistance is negligible.

What is the time taken for the ball to hit the ground?

**A** 7.61 s **B** 7.91 s **C** 7.94 s **D** 8.03 s

5 The variation with time $t$ of acceleration $a$ for a 2.0 kg mass moving along a straight line is shown. The change in momentum of the mass in 6.0 s is 30 kg m $s^{-1}$.




What is the value of $x$?

**A** 3.0 **B** 5.0 **C** 6.0 **D** 10

6 In a perfectly elastic collision between two particles, it is always true that

**A** the initial speed of one particle is equal to the final speed of the other particle.

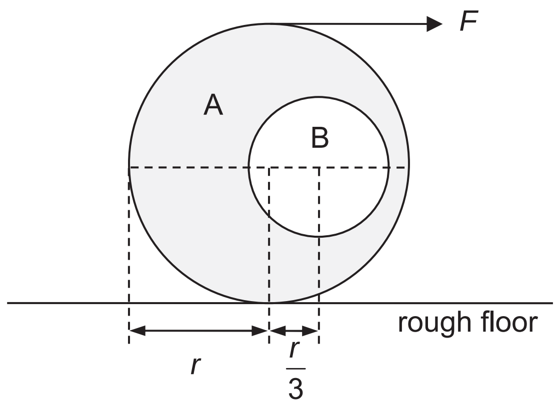
**B** whatever their initial states of motion, neither particle can be stationary after the collision.

**C** their total momentum is conserved, but some kinetic energy may be lost after the collision.

**D** their relative speed of approach is equal to their relative speed of separation.

7 A uniform cylinder A of radius $r$ and weight 48 N is placed on a rough floor. When a cylindrical hole B is drilled through cylinder A, the weight of the remaining portion is 36 N. The centre of B is at a distance of $\frac{r}{3}$ from the centre of A as shown.

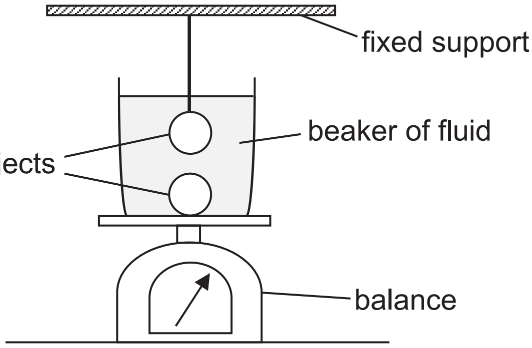
A force $F$ is applied horizontally to the top of the cylinder so that the centres of A and B are at the same height from the floor as shown.




What is the force $F$ required to keep the cylinder in this equilibrium position?

**A** 2.0 N **B** 4.0 N **C** 6.0 N **D** 12 N

**8** A beaker of fluid has weight $Z$. A solid object of weight $X$ in air displaces weight $Y$ of the fluid when it is fully immersed in the fluid. An identical solid object is placed at the bottom of the beaker as shown.




What is the balance reading?

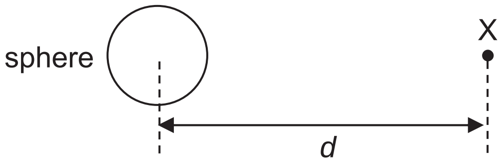
**A** $X + Z$ **B** $2Y + Z$ **C** $X + Y + Z$ **D** $2X - 2Y + Z$

**9** Two objects have masses $m_1$ and $m_2$, and kinetic energies $K_1$ and $K_2$, respectively.

If the momentum of mass $m_2$ is two times that of mass $m_1$, the ratio $\frac{K_1}{K_2}$ is equal to

**A** $\frac{m_2}{4m_1}$ **B** $\frac{m_2}{2m_1}$ **C** $\frac{4m_2}{m_1}$ **D** $\frac{4m_1}{m_2}$

**10** A positive point charge X is released from rest a distance $d$ from the centre of a positively charged sphere as shown.




Which of the following statements best describes the work done in moving point charge X in time $t$, if X is a positron and if X is a proton?

**A** The work done on the positron is the same as that on the proton because the same force acts on them.

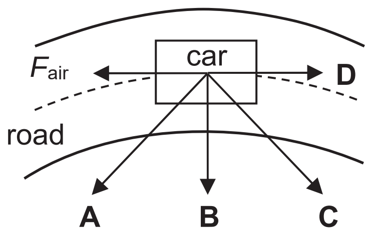
**B** The work done on the positron is the same as that on the proton because of the principle of conservation of energy.

**C** The work done on the positron is more than that on the proton because the positron moves a larger distance than the proton.

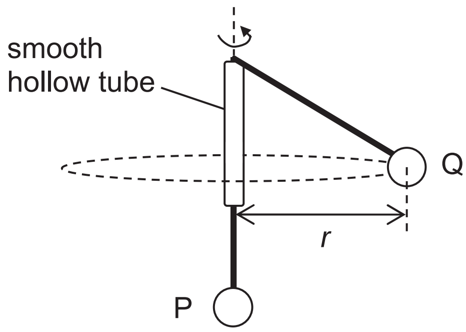
**D** The work done on the positron is less than that on the proton because the force acting on the positron weakens more rapidly than that on the proton.

**11** A car is travelling at a constant speed on a horizontal circular road as shown. $F_{air}$ is the air resistance on the car.

Which of the arrows best represents the horizontal force of the road on the car?



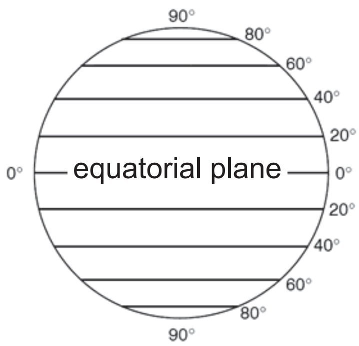

**12** Two masses P and Q are connected by a light inextensible string through a smooth hollow tube as shown. When mass Q is swung in a horizontal circle at a constant speed of 2.3 m s$^{-1}$, mass P remains stationary.




If the mass of P is twice the mass of Q, what is radius *r* of the horizontal circle?

**A** 0.14 m **B** 0.31 m **C** 0.93 m **D** 3.21 m

**13** All geostationary satellites lie on the equatorial plane of 0° latitude.




There is no geostationary satellite at the other latitudes shown because such a satellite would

**A** require a continuous input of energy to maintain its orbit.

**B** not have a period of 24 hours.

**C** orbit from east to west.

**D** be too heavy.

**14** A gas cylinder is fixed with a safety valve which releases a gas when the pressure inside the cylinder reaches $1.5 \times 10^6$ Pa. The mass of the gas that the cylinder can hold at 20 °C is 20 kg.

What is the maximum temperature of the gas if the cylinder were to hold a mass of 15 kg?

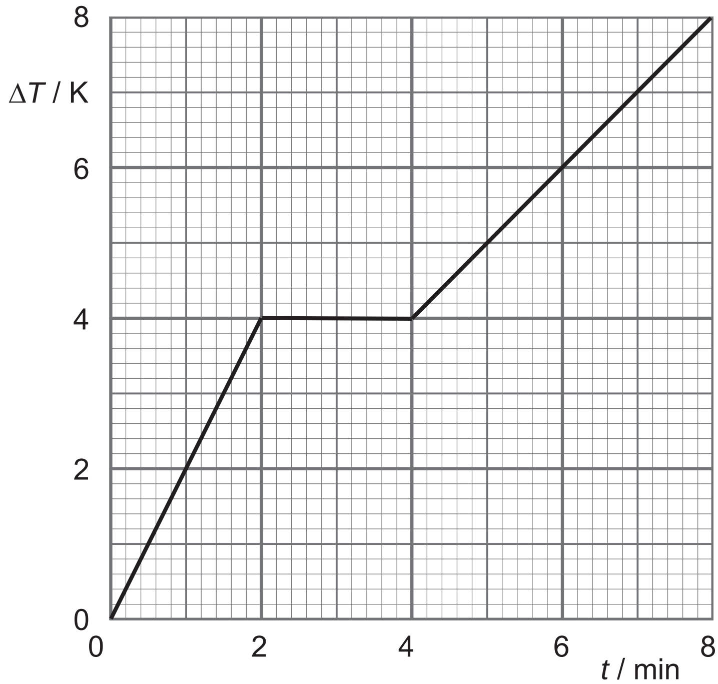
**A** 15 °C  **B** 27 °C  **C** 120 °C  **D** 390 °C

**15** A molecule of gas A has half the mass of a molecule of gas B. The molecules of gas A have a root-mean-square speed of *c* at a temperature of 30.0 °C. Assume that both gases are ideal.

What is the root-mean-square speed of the molecules of gas B at 300 °C

**A** 0.945 *c*  **B** 0.972 *c*  **C** 1.94 *c*  **D** 2.24 *c*

**16** The graph shows the variation of temperature change $\Delta T$ with time *t* for 1 kg of a substance, initially solid at room temperature. The substance is heated at a uniform rate of 1000 J $min^{-1}$.




What can be deduced from this graph?

**A** After 2 min of heating, the substance is all liquid.

**B** After 8 min of heating, the substance is all gaseous.

**C** The specific heat capacity of the substance is smaller when liquid than when solid.

**D** The specific latent heat of fusion of the substance is 2000 J $kg^{-1}$.

**17** To determine the specific latent heat of vaporisation of water, a student uses a heater to boil water. When the water is boiling, the mass of water vapour produced per minute is measured at two different powers of the heater.

The student repeats the experiment using a different power of the heater to

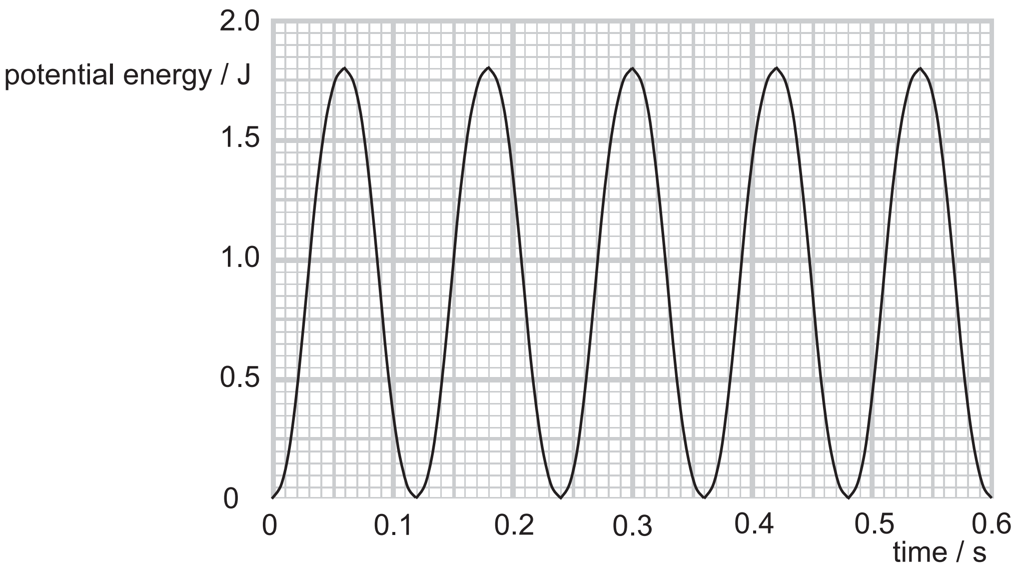
**A** reduce random errors in the measurements of the mass of water vapour produced per minute.

**B** allow the rate of heat loss from the apparatus to be eliminated from the calculations.

**C** determine an average value of the specific latent heat of vaporisation.

**D** check for reproducibility of the measurements.

**18** A particle performs simple harmonic motion of amplitude 0.050 m. The graph shows the variation of the potential energy of the particle with time.




What is the mass of the particle?

**A** 0.53 kg **B** 1.8 kg **C** 2.1 kg **D** 2.8 kg

**19** An oscillator vibrates vertically in a ripple tank and moves to the right with speed $v$, as shown in Fig. 19(a).

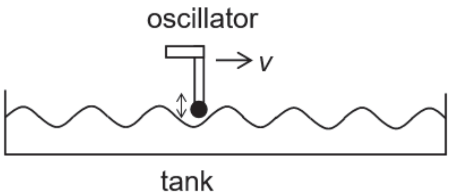



**Fig. 19(a)**

Fig. 19(b) represents the water waves as seen from the top of the ripple tank. The speed of the water waves is 20 cm s$^{-1}$.

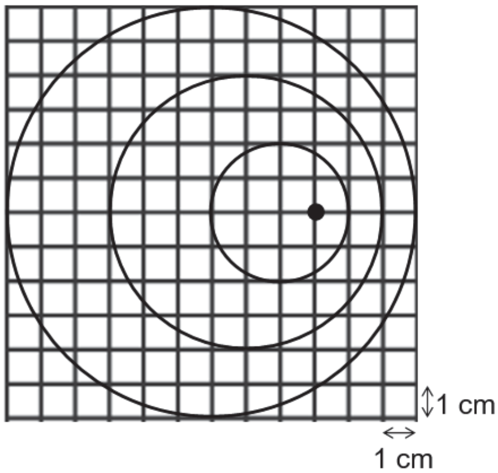
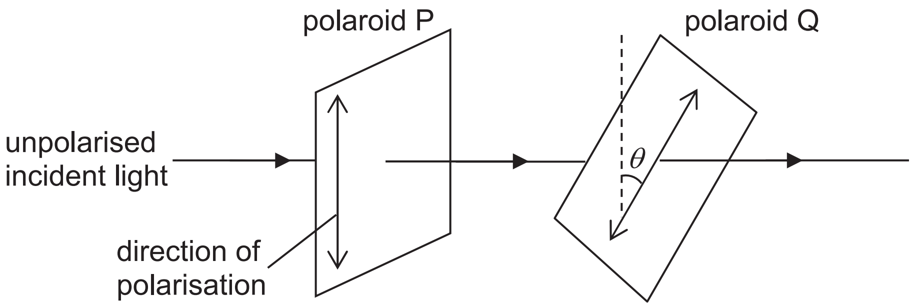



**Fig. 19(b)**

What is the speed $v$ and frequency $f$ of the oscillator?

| | $v$ / cm s$^{-1}$ | $f$ / Hz |
|---|---|---|
| **A** | 10 | 5.0 |
| **B** | 10 | 10 |
| **C** | 20 | 5.0 |
| **D** | 20 | 10 |

**20** Two sheets of polaroids P and Q are placed such that their directions of polarisation are at an angle $\theta$ to each other as shown.




A beam of light passes through both polaroids. After passing through polaroid Q, the transmitted beam has intensity $I$ when $\theta$ is 30°.

When $\theta$ is 120°, what is the intensity of the transmitted beam?

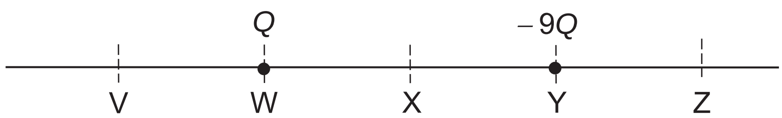
**A** $0.19\,I$ **B** $0.25\,I$ **C** $0.33\,I$ **D** $0.58\,I$

**21** The lowest resonant frequency emitted by a cylindrical pipe that is open at both ends is *f*.

What is the lowest resonant frequency emitted by a pipe of the same length that is closed at one end?

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

**22** Points V, W, X, Y and Z are evenly spaced along a straight line. A positive charge of magnitude *Q* is placed at point W. A negative charge of magnitude 9*Q* is placed at point Y.




Which of the following gives the directions of the electric fields at points *V*, *X* and *Z*?

| | at point V | at point X | at point Z |
|---|---|---|---|
| **A** | to the left | to the right | to the left |
| **B** | to the left | no net electric field | to the left |
| **C** | no net electric field | to the left | to the right |
| **D** | no net electric field | to the right | to the left |

**23** Which of the following statements regarding the filament of a light bulb is true?

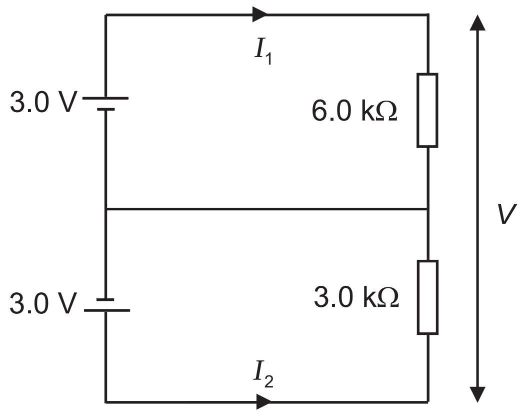
**A** The filament is ohmic if its resistance is always equal to the ratio of the potential difference across it to the current through it.

**B** The filament is ohmic if its resistivity does not depend on its physical dimensions.

**C** The filament is ohmic if its resistance is constant at a fixed temperature.

**D** The filament is ohmic regardless of the potential difference applied across it.

**24** Two 3.0 V cells are connected to resistors of resistance 3.0 kΩ and 6.0 kΩ as shown.

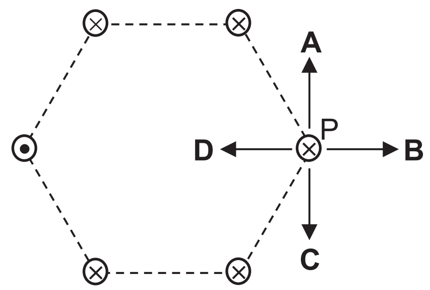



What are the currents $I_1$ and $I_2$, and the potential difference $V$?

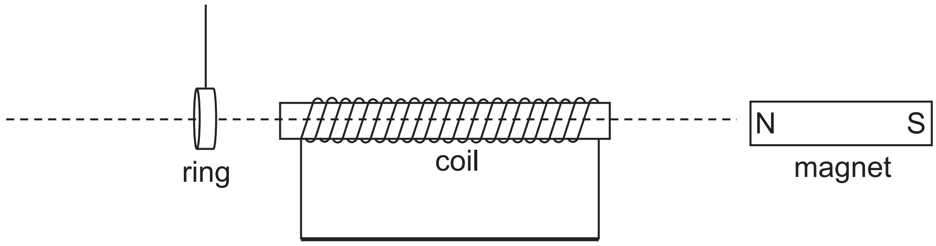
| | $I_1$ / mA | $I_2$ / mA | $V$ / V |
|---|---|---|---|
| **A** | 0 | 0 | 0 |
| **B** | 0.50 | 1.0 | 0 |
| **C** | 0.50 | 1.0 | 6.0 |
| **D** | 0.67 | 0.67 | 6.0 |

**25** Six vertical wires are placed at the corners of a regular hexagon. The wires carry equal currents in the directions shown.

What is the direction of the force acting on wire P?



**26** An aluminium ring is suspended near one end of a long coil of wire and a magnet is placed near the other end with its north pole facing the coil as shown. Assume that the magnetic field from the magnet does not reach the ring.




Which of the following describes the motion of the ring when the magnet is first pushed towards the coil, and then pulled away?

| | magnet pushed towards coil | magnet pulled away from coil |
|---|---|---|
| **A** | ring swings left | ring swings left |
| **B** | ring swings right | ring swings left |
| **C** | ring swings left | ring swings right |
| **D** | ring swings right | ring swings right |

**27** The magnetic flux linking a conducting loop changes sinusoidally with time.

Which of the following describes the phase difference between the magnetic flux linkage and the e.m.f. induced?

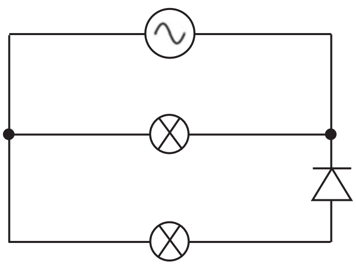
**A** They are in phase with each other.

**B** They are out of phase by $\pi/4$ rad.

**C** They are out of phase by $\pi/2$ rad.

**D** They are out of phase by $\pi$ rad.

**28** An alternating current supply of negligible internal resistance is connected to two identical bulbs and an ideal diode as shown. The resistance of each bulb is $R$ and the peak voltage of the a.c. supply is $V_0$.



Which of the following is the average power dissipated in the circuit?

**A** $\dfrac{3V_0^2}{4R}$ **B** $\dfrac{3V_0^2}{2R}$ **C** $\dfrac{3V_0^2}{\sqrt{2}R}$ **D** $\dfrac{3V_0^2}{R}$

**29** Photoelectrons are emitted when an electromagnetic radiation is incident on a metal surface.

When the intensity and wavelength of the radiation are reduced,

**A** the maximum kinetic energy of the photoelectrons is reduced, but their rate of emission is increased.

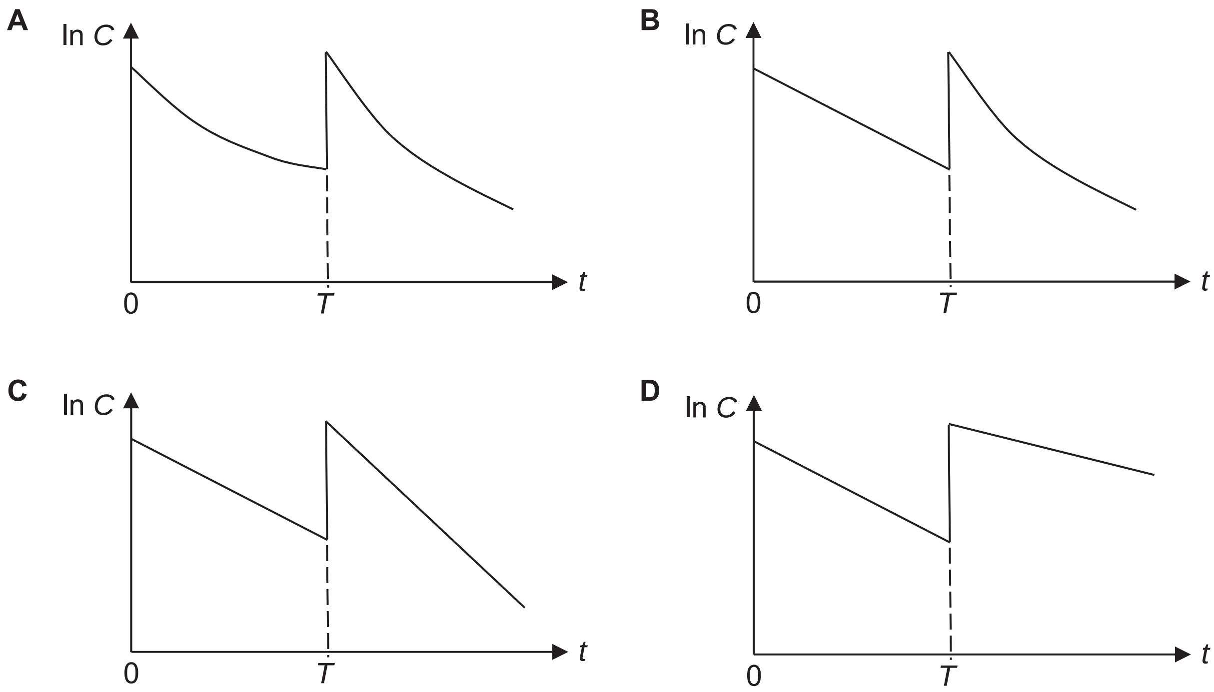
**B** both the maximum kinetic energy of the photoelectrons and their rate of emission are reduced.

**C** both the maximum kinetic energy of the photoelectrons and their rate of emission are increased.

**D** the maximum kinetic energy of the photoelectrons is increased, but their rate of emission is reduced.

**30** At time $t$ = 0, a radioactive gas is injected into a sealed vessel. At time $t$ = $T$, a different radioactive gas of a shorter half-life than the first gas is injected into the same vessel.

Which of the following graphs best represents the variation of the logarithm of the count-rate $C$ of the gases with time $t$?




**End of Paper 1**

| Centre Number | Index Number | Name | Class |
|---|---|---|---|
| 3016 | | | |

**RAFFLES INSTITUTION**
**2017 Preliminary Examination**

**PHYSICS** **9749/02**
**Higher 2**

**14 September 2017**
Paper 2 Structured Questions **2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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. The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| **1** | / 10 |
| **2** | / 10 |
| **3** | / 10 |
| **4** | / 10 |
| **5** | / 10 |
| **6** | / 10 |
| **7** | / 20 |
| **Deduction** | |
| **Total** | / 80 |

This document consists of **20** printed pages.

**Data**

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| permittivity of free space | $\varepsilon_0 = 8.85 \times 10^{-12}$ F m$^{-1}$ |
| | $= (1/(36\pi)) \times 10^{-9}$ F m$^{-1}$ |
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| 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**

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| 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. | $x = x_0 \sin \omega t$ |
| 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 | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

**1** A sphere is projected with velocity $u$ from the bottom of a ramp which is inclined at an angle $\theta$ to the horizontal as shown in Fig. 1.1.

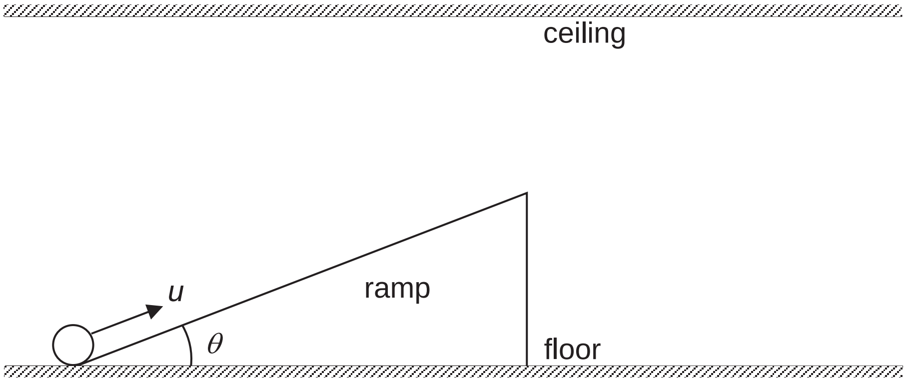



**Fig. 1.1 (not to scale)**

**(a)** Define *acceleration*.

..........................................................................................................................................

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

**(b)** **(i)** When $u = 9.0\ \text{m s}^{-1}$ and $\theta = 26°$, the sphere leaves the ramp after 0.70 s.

Show that the sphere leaves the ramp at a speed of $6.0\ \text{m s}^{-1}$.

[1]

**(ii)** Determine the height of the ramp.

height = ................................ m [2]

**(c)** After the sphere leaves the ramp, it continues to travel upwards until it hits the ceiling at an angle of 5.0° to the horizontal as shown in Fig. 1.2.

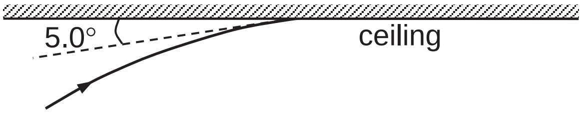



**Fig. 1.2 (not to scale)**

**(i)** Show that the vertical component of velocity of the sphere just before hitting the ceiling is 0.47 m $s^{-1}$.

[1]

**(ii)** Calculate the vertical displacement of the sphere from the instant it leaves the ramp to the instant it hits the ceiling.

vertical displacement = .................................. m [2]

**(iii)** State and explain whether the momentum of the sphere is conserved in the collision with the ceiling.

..........................................................................................................................................

..........................................................................................................................................

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

**(c)** Using answers in **(b)(ii)** and **(c)(ii)**, sketch on Fig. 1.3 the variation with the horizontal displacement $x$ of the vertical displacement $y$ of the sphere from the instant it is projected up the ramp to the instant it hits the floor.


**Fig. 1.3**

[2]

**2** A car travels at 50.0 km $h^{-1}$ due north for 25.0 minutes, after which it travels at 65.0 km $h^{-1}$ in the north-east direction for another 30.0 minutes.

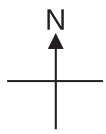
**(a)** Distinguish between *vector* and *scalar* quantities.

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** **(i)** Using a scale of 1.0 cm to represent a speed of 10 km $h^{-1}$, draw a vector diagram to show the change in velocity $\Delta v$ of the car. The direction of north is indicated.




[2]

**(ii)** Hence, or otherwise, determine the magnitude of the average acceleration of the car if it takes 30.0 seconds to change its velocity.

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

**(c)** **(i)** Calculate the total distance travelled by the car.

total distance = .................................. km [1]

**(ii)** The uncertainty of each velocity measurement is 0.5 km $h^{-1}$, and that of each time measurement is 0.5 minute.

Determine the actual uncertainty in the total distance travelled.

actual uncertainty = .................................. km [3]

**(iii)** Hence, express the total distance travelled with its associated uncertainty.

total distance = .............................. ± .................................. km [1]

**3** **(a)** State *the principle of conservation of linear momentum*.

..........................................................................................................................................

.........................................................................................................................................,

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

**(b)** A block X of mass 2.2 kg travelling at a speed of 6.0 m $s^{-1}$ on a smooth floor collides head-on and sticks together with a block Y of mass 1.0 kg which is travelling at a speed of 2.0 m $s^{-1}$ in the opposite direction, as shown in Fig. 3.1. The collision lasts for 0.35 s.

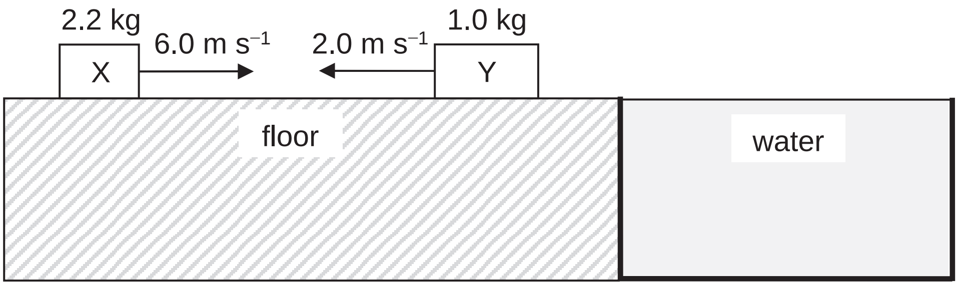



**Fig. 3.1**

**(i)** Show that the blocks move with a speed of 3.5 m $s^{-1}$ to the right after the collision.

[2]

**(ii)** Determine the magnitude of the average force acting on either block during the collision.

average force = ................................ N [2]

**(iii)** The blocks then slide off the edge of the floor and into a tank of water as shown in Fig 3.1. The density of water is 1000 kg $m^{-3}$.

The blocks have uniform densities and their dimensions are shown in Fig. 3.2.

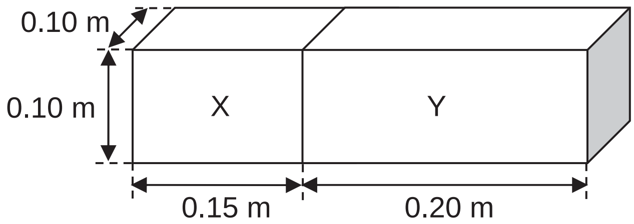



**Fig. 3.2**

**1.** The blocks eventually achieved equilibrium when they are submerged at depth *h* as shown in Fig. 3.3.

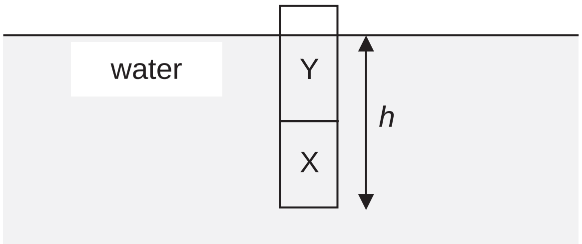



**Fig. 3.3**

Explain how the blocks achieved this final position. You may draw a diagram if you wish.

..........................................................................................................

..........................................................................................................

..........................................................................................................

..........................................................................................................

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

**2.** Calculate *h*.

*h* = .................................. m [2]

**4 (a)** Define *work*.

................................................................................................................................................

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

**(b)** Using your definition in **(a)**, derive an expression for the increase in gravitational potential energy $\Delta E_p$ when an object of mass $m$ is raised vertically through a distance $\Delta h$ near the Earth's surface. The acceleration of free fall near the Earth's surface is $g$.

[2]

**(c)** Fig. 4.1 shows a block P of mass 1.0 kg and a block Q of mass 3.0 kg connected by a light inextensible cord passing over a frictionless pulley. Block P starts from rest and moves up a rough slope inclined at an angle of 30° to the horizontal, while block Q falls from a height of 0.45 m above a spring. The frictional force between block P and the slope is 6.3 N.

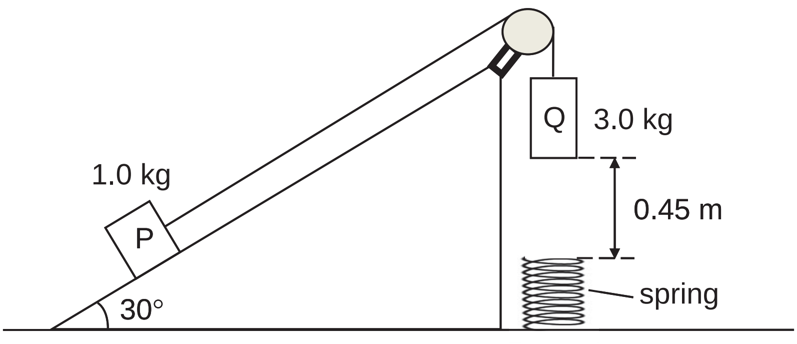



**Fig. 4.1**

**(i)** State the energy changes that take place from the time the blocks are released to the instant just before block Q makes contact with the spring.

................................................................................................................................................

................................................................................................................................................

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

**(ii)** Show that the loss in gravitational potential energy of the blocks just before block Q makes contact with the spring is 11 J.

[1]

**(iii)** Determine the total kinetic energy of the blocks just before block Q makes contact with the spring.

total kinetic energy = .................................. J [2]

**(iv)** Show that the maximum compression of the spring when the blocks first come to rest is 0.168 m. The spring has a force constant of 800 N $m^{-1}$ and the string remains taut at all times.

[2]

**(v)** Use your answers in **(ii)** and **(iii)** to explain why the maximum compression in **(iv)** decreases when the angle of the slope is larger.

..................................................................................................................................

..................................................................................................................................

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

**5** An ideal gas A is contained in an insulated cylinder to prevent the loss of heat, while an ideal gas B is contained in a cylinder without any insulation, as shown in Fig. 5.1.

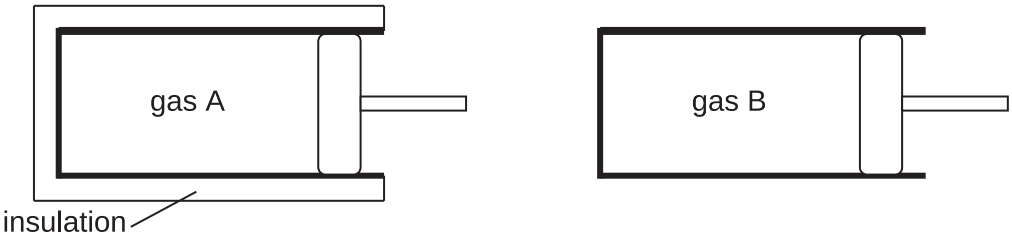



**Fig. 5.1**

Initially, the two gases have the same volume of $2.90 \times 10^{-4}$ m$^3$, the same pressure of $1.05 \times 10^5$ Pa and the same temperature of 303 K.

**(a)** Explain what is meant by the *internal energy* of an ideal gas.

.......................................................................................................................................

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

**(b)** Determine the number of molecules in gas A.

number of molecules = ............................... [2]

**(c)** Determine the mean translational kinetic energy of a molecule of gas A.

mean translational kinetic energy = ............................... J [1]

**(d)** When gas A is compressed to a volume of $2.10 \times 10^{-4}$ m$^3$, its temperature rises to 357 K. Gas B is compressed very slowly to the same volume of $2.10 \times 10^{-4}$ m$^3$.

**(i)** Determine the change in internal energy of gas A during the compression.

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

**(ii)** Determine the work done on gas A during the compression.

work done on the gas = .................................... J [1]

**(iii)** On Fig. 5.2, sketch the variation with volume of the pressure of gas A and gas B. Include appropriate labels, and values of pressure and volume.


**Fig. 5.2**

[3]

**6** A variable resistor R is connected between the terminals of a battery of e.m.f. *E* and internal resistance *r*, as shown in Fig. 6.1.

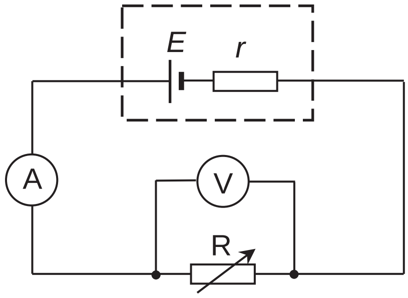



**Fig. 6.1**

As the resistance of R is varied from its maximum to minimum value, the variation of the potential difference *V* across R with the current *I* through R is shown in Fig. 6.2.

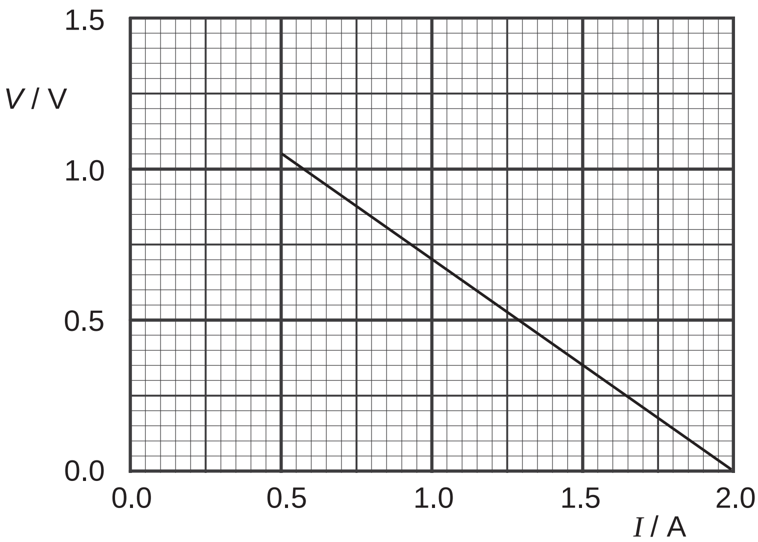



**Fig. 6.2**

**(a)** **(i)** Use Fig. 6.2 to determine the values of *E* and *r*.

*E* = .............................. V

*r* = .............................. Ω [3]

**(ii)** Explain why, in the circuit of Fig. 6.1, the current $I$ through R cannot be varied from 0 to 0.5 A.

............................................................................................................................................

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

**(b)** When the power dissipated in R is the maximum,

**(i)** state the value of the resistance of R in terms of $r$,

resistance = .................................. [1]

**(ii)** calculate the value of the current $I$ through R,

$I$ = .................................. A [2]

**(iii)** calculate the efficiency of transfer of power from the supply to R.

efficiency = .................................. % [1]

**(c)** Determine the maximum efficiency of transfer of power to R of the circuit in Fig. 6.1.

maximum efficiency = .................................. % [2]

**7** A bubble chamber is a vessel filled with a superheated liquid (usually hydrogen) used for detecting charged particles moving through it. It was invented in 1952 by Donald A. Glaser, for which he was awarded the 1960 Nobel Prize in Physics.

Typically, the charged particles possess very high energies and move at speeds close to that of light. They create ionization tracks (ionization causes the particle to lose energy), around which the liquid vaporizes to form microscopic bubbles. As the bubbles grow in size, they become large enough to be seen or photographed.

The entire bubble chamber is subjected to a constant magnetic field that causes charged particles to travel in circular paths. The radius of the path is dependent on the charge and momentum of the particle.

By analyzing one such track, a substantial amount of information can be obtained about the charged particle, such as its momentum, energy, charge, mass and identity. The energies of the charged particles are usually expressed in MeV and their momentum in MeV $c^{-1}$, where $c$ is the speed of light in vacuum.

Fig 7.1 shows a life-size photograph of a track of a charged particle moving in the plane of the paper in a particular bubble chamber where a uniform magnetic field is acting perpendicularly into the paper.

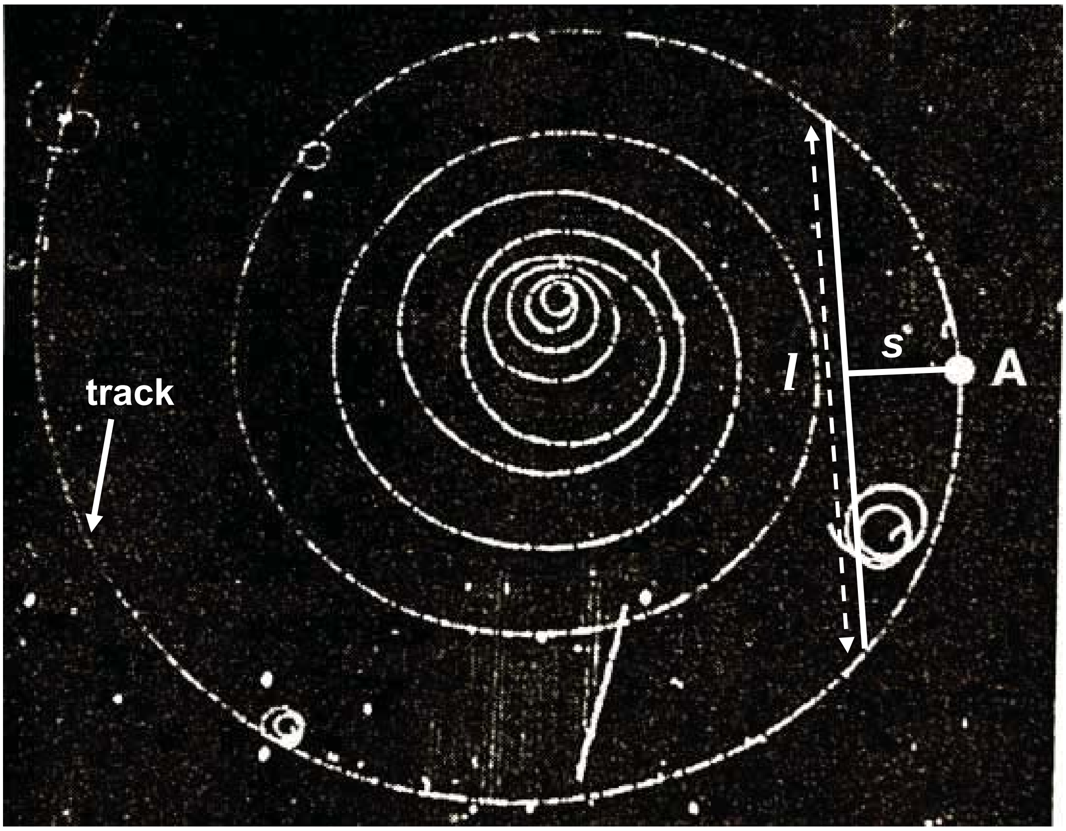



**Fig 7.1 (to scale)**

**(a)** **(i)** Show that the momentum $p$ of the charged particle in Fig. 7.1 is related to its charge $q$, the radius $r$ of the track and the magnetic flux density $B$ of the magnetic field by

$$p = Bqr\ .$$

[2]

**(ii)** For the track indicated in Fig 7.1, state and explain whether the charged particle is moving in a clockwise or anti-clockwise direction.

..........................................................................................................................................

..........................................................................................................................................

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

**(iii)** State whether the particle is positively or negatively charged.

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

**(b)** **(i)** By measuring the lengths $l$ and $s$ in Fig 7.1, the radius $r$ of the path at point A can be determined from

$$r = \frac{l^2}{8s} + \frac{s}{2}\ .$$

**1.** Using a ruler, measure and record the lengths $l$ and $s$.

$l$ = .................................. cm

$s$ = .................................. cm [2]

**2.** Calculate the value of $r$.

$r$ = .................................. cm [1]

**(ii)** **1.** Show that a momentum of 1.0 MeV $c^{-1}$ is equal to $5.3 \times 10^{-22}$ kg m $s^{-1}$

[1]

**2.** The magnetic field in the bubble chamber has a magnetic flux density of 0.50 T. The magnitude of the charge of the charged particle is $1.6 \times 10^{-19}$ C.

Use the expression in **(a)(i)** and your answer in **(b)(i)(2)** to determine the momentum of the particle in MeV $c^{-1}$.

$p$ = .......................... MeV $c^{-1}$ [2]

**(iii)** At a momentum of 1.0 MeV $c^{-1}$, the speed $v$ of the charged particle is 0.89 $c$. It is known that at such a high speed, the momentum $p$ of the charged particle is related to its velocity $v$ and rest mass $m_0$ by

$$p = \frac{m_0 v}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

where all quantities are in SI units.

Determine the rest mass $m_0$ of the charged particle, and hence identify it.

$m_0$ = .............................. kg

identity : .............................. [2]

**(c)** In instances when it is not possible to determine the momentum of a charged particle from the radius of its track, it can be found from its range. The range *d* is the total distance travelled by the charged particle before it comes to rest.

Theory suggests that the range *d* of a charged particle is related to its initial momentum *p* by the equation

$$\lg d = n \lg p + \lg k$$

where *n* and *k* are constants.

Some of the values of lg (*d* / cm) and lg (*p* / MeV $c^{-1}$) are plotted in Fig. 7.2 for a charged particle.

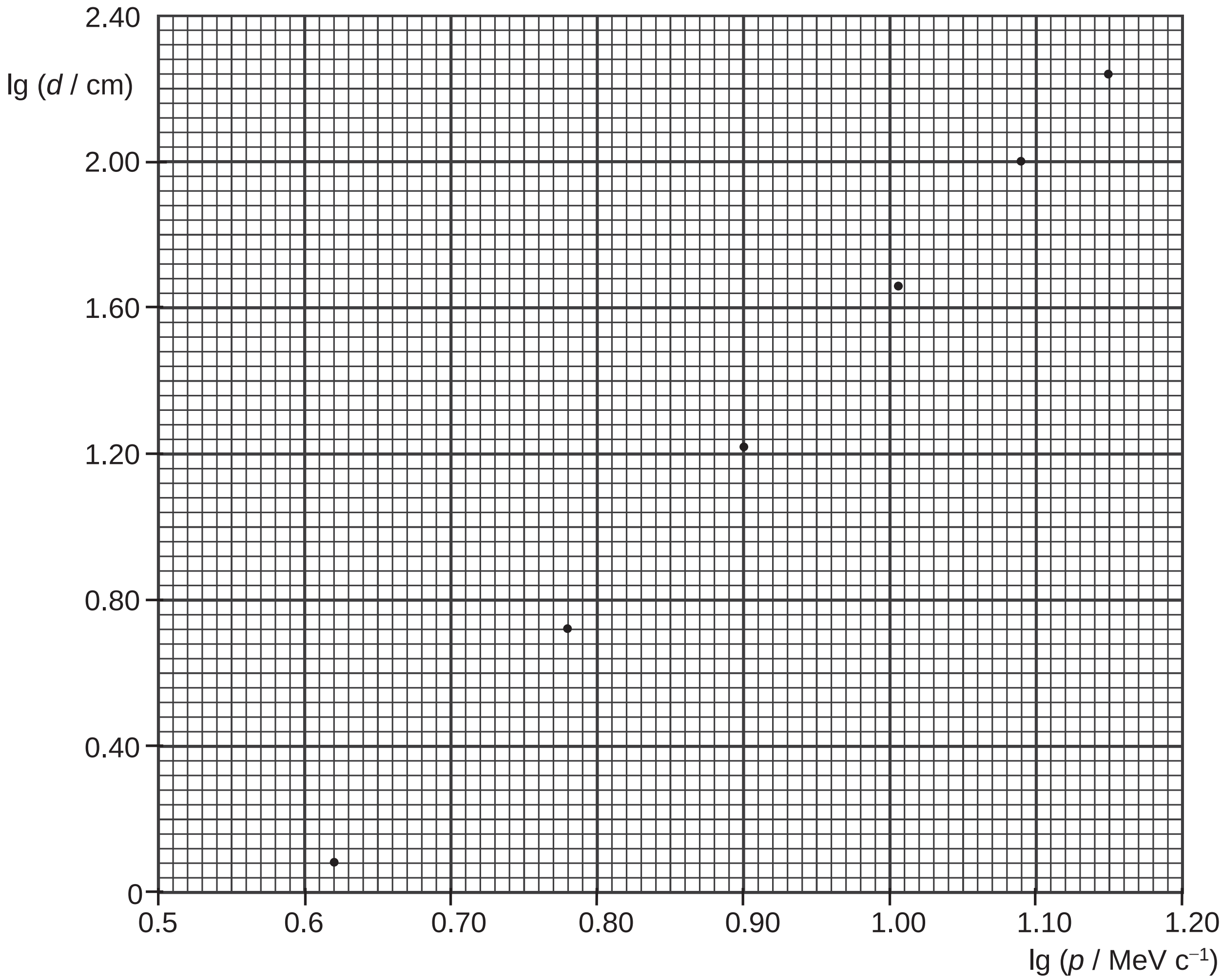



**Fig. 7.2**

**(i)** Draw the line of best-fit for all the points. [1]

**(ii)** Use Fig. 7.2 to determine the values of $n$ and $k$. Express $n$ to the nearest integer.

$n$ = ..................................................

$k$ = .................................................. [4]

**(iii)** Express $p$ in terms of $d$.

[1]

**(iv)** Suggest an example of when it is not possible to determine the radius directly from the track of a particle in a photograph.

..........................................................................................................................................

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

**End of Paper 2**

| Centre Number | Index Number | Name | Class |
|---|---|---|---|
| 3016 | | | |

**RAFFLES INSTITUTION**
**2017 Preliminary Examination**

**PHYSICS** **9749/03**
**Higher 2**

**19 September 2017**
Paper 3 Longer Structured Questions **2 hours**

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

**READ THESE INSTRUCTIONS FIRST**

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use 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.

**Section A**
Answer **all** questions.

**Section B**
Answer **one** question only and **circle the question number** on the cover page.

You are advised to spend one and half hours on Section A and half an hour on Section B.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | | |
|---|---|---|
| Section A | 1 | / 10 |
| | 2 | / 10 |
| | 3 | / 11 |
| | 4 | / 10 |
| | 5 | / 9 |
| | 6 | / 10 |
| Section B (circle 1 question) | 7 | / 20 |
| | 8 | / 20 |
| Deduction | | |
| Total | | / 80 |

This document consists of **23** printed pages and **1** blank page.

## DATA AND FORMULAE

### 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 | $B = \frac{\mu_0 N I}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 n I$ |
| radioactive decay | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

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## Section A

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

**1** A buoy floats in the sea next to a seawall. A lamp at the top of the buoy oscillates through a vertical distance of 0.22 m, as shown in Fig. 1.1. The oscillations are simple harmonic with a frequency of 0.40 Hz.

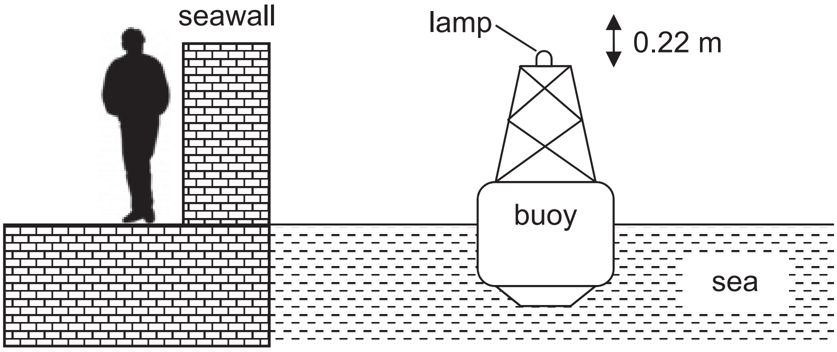


**Fig. 1.1**

**(a)** Define *simple harmonic motion*.

..............................................................................................................................................

..............................................................................................................................................

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

**(b)** State the amplitude of the oscillation.

amplitude = .............................. m [1]

**(c)** Calculate the angular frequency of the oscillation.

angular frequency = .............................. rad $s^{-1}$ [2]

**(d)** On Fig. 1.2, sketch the variation of the velocity of the lamp with its displacement from the equilibrium position as it moves downwards from its equilibrium position to its lowest position. Label the axes with appropriate values. Take upward displacement to be positive.

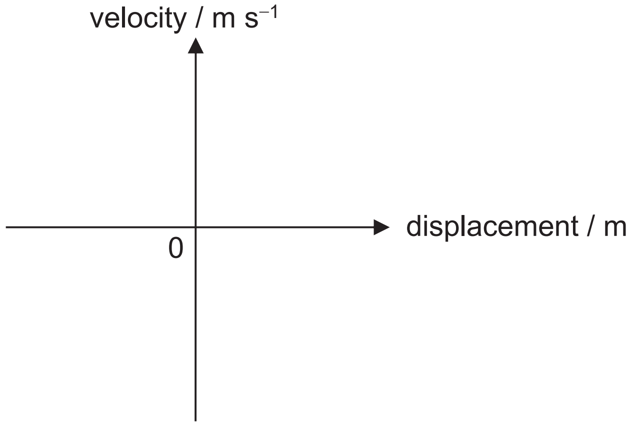


**Fig. 1.2**

[2]

**(e)** The lamp is above the top of the seawall for 1.8 s for each cycle of oscillation.

Determine the distance of the equilibrium position of the lamp from the top of the seawall.

distance = .................................... m [3]

**2** Fig. 2.1 shows a dipper vibrating at a constant frequency on the surface of a pond. Ripples spread out as progressive transverse waves with circular wavefronts. Assume that the energy of the wave is spread over the entire circumference of the ripple and that no energy is lost in the propagation of the ripple.

Two identical plastic balls placed on the water surface at points P and Q are observed to move up and down. The distance between points P and Q is shorter than one wavelength.

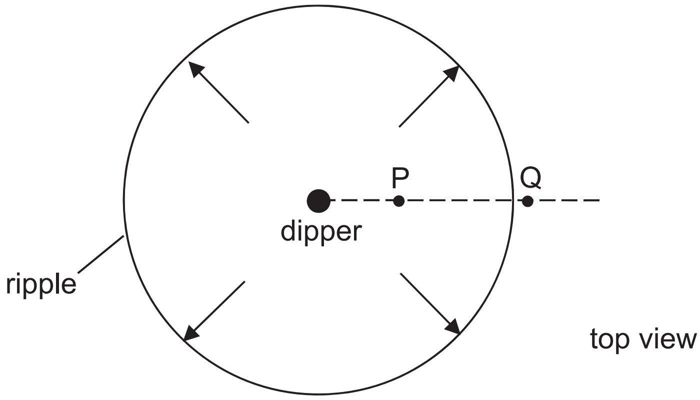


**Fig. 2.1**

The variation of the displacements of points P and Q with time is shown in Fig. 2.2. The solid line represents point P and the dotted line point Q.

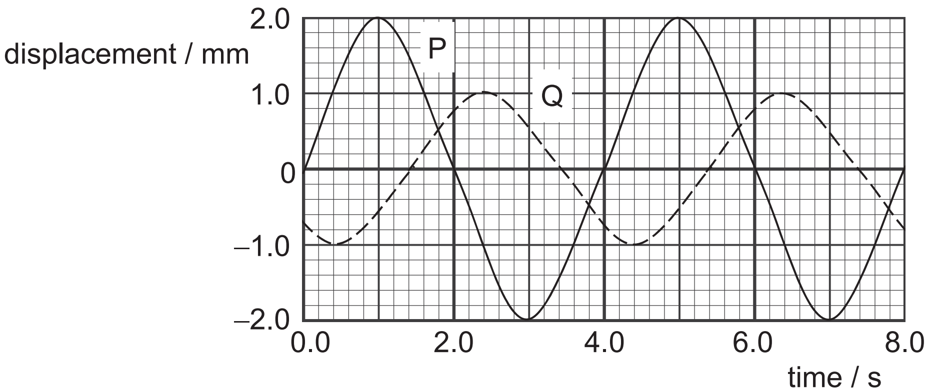


**Fig. 2.2**

**(a)** Explain what is meant by a *progressive transverse* wave.

progressive : ..................................................................................................

..................................................................................................

transverse: ..................................................................................................

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

**(b)** State the period of the wave.

period = .............................. s [1]

**(c)** Determine the phase difference between the waves reaching points P and Q.

phase difference = ............................ rad [2]

**(d)** The distance of point P from the dipper is 150 mm. Use Fig. 2.2 to show that the distance of point Q from the dipper is 600 mm.

[2]

**(e)** Using answers in **(c)** and **(d)**, determine the wavelength of the ripples.

wavelength = ............................ mm [2]

**(f)** On Fig. 2.3, sketch a possible variation of the displacement of a wave with distance from the dipper for two wavelengths. Numerical values are not expected.


**Fig. 2.3**

[1]

**3** **(a)** A satellite orbits the Earth at a constant speed and height. Two radio waves transmitters on the surface of the Earth emit coherent waves of equal amplitudes, as shown in Fig. 3.1.

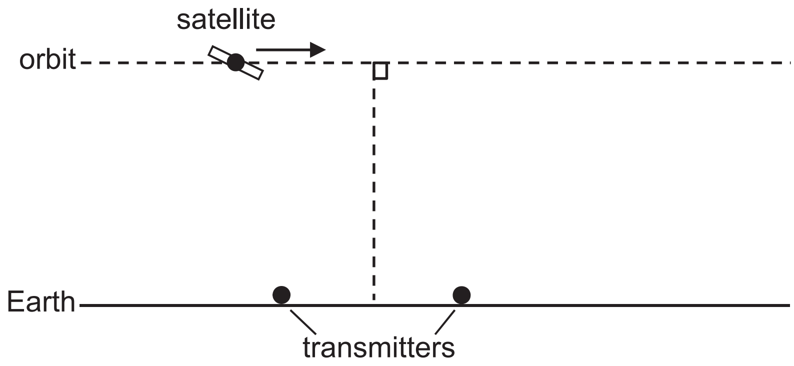


**Fig. 3.1**

The intensity of the signal that the satellite receives varies periodically.

**(i)** State what is meant by *coherent* waves.

..................................................................................................................................

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

**(ii)** Explain why the intensity of the signal varies periodically.

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

..................................................................................................................................

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

**(iii)** The transmitters are 150 m apart and the radio waves emitted have a wavelength of 1.2 m. The speed of the satellite is $8.0 \times 10^3$ m s$^{-1}$ and the signal it receives varies in intensity with a frequency of 4.0 Hz.

Calculate the height of the satellite above the surface of the Earth.

height = .............................. m [3]

**(b)** The Arecibo telescope is one of the largest telescopes on Earth which scans the sky for sources that emit electromagnetic waves. The dish of the telescope has a diameter of 300 m.

Two distant sources are emitting radio waves of wavelength 1.2 m. They are separated by a distance of $2.0 \times 10^{12}$ m from each other and $3.0 \times 10^{16}$ m from the telescope.

**(i)** Determine whether the telescope can resolve these two sources.

[3]

**(ii)** Fig. 3.2 shows the intensity distribution of the diffraction pattern formed by one of the sources.

Sketch the intensity distribution of the other source if the diffraction patterns formed by the two sources are just resolved according to the Rayleigh criterion.

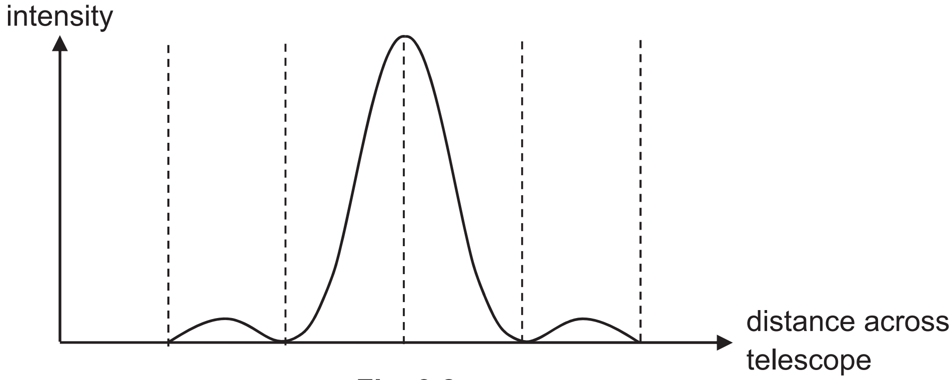


**Fig. 3.2**

[1]

**4** A metal sphere of radius 20 mm and charge –12 nC is placed in a vacuum.

**(a)** **(i)** Define *electric field strength* at a point.

..................................................................................................................................................

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

**(ii)** Calculate the magnitude of the electric field strength at the surface of the sphere.

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

**(iii)** On Fig 4.1, sketch the variation of the electric field strength $E$ with distance $d$ from the centre of the sphere. Numerical values are not expected.

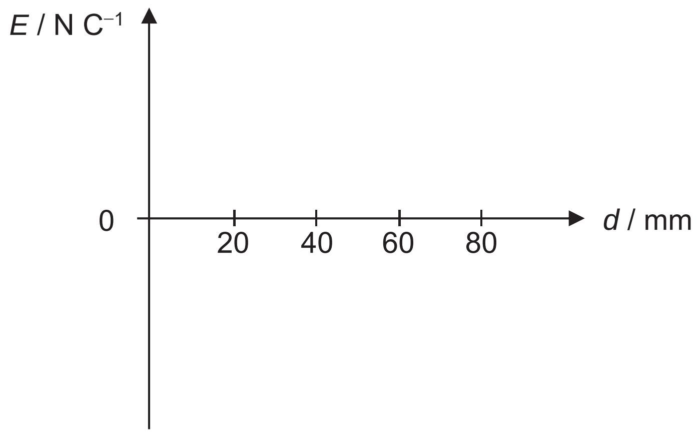


**Fig. 4.1**

[2]

**(iv)** A positive point charge of mass 0.030 g and charge 6.0 nC is released from rest at a distance of 60 mm from the centre of the sphere.

Determine the kinetic energy of the point charge when it reaches a distance of 40 mm from the centre of the sphere.

kinetic energy = .................................. J [2]

**(v)** With reference to Fig. 4.1, suggest how the change in potential between $d$ = 40 mm and $d$ = 60 mm can be obtained.

..................................................................................................................................

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

**(b)** The negatively charged sphere is now brought close to an earthed metal plate.

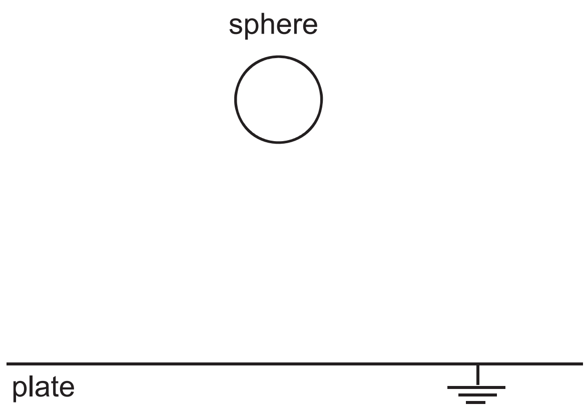


**Fig. 4.2**

Draw electric field lines to represent the electric field in the region between the sphere and the plate. [2]

**5** A long straight wire carrying a current of 2.0 A is placed on the same plane as a square coil of wire of 50 turns. The coil is moved perpendicularly away from the straight wire at a constant speed, as shown in Fig. 5.1. The length of each side of the coil is 1.0 cm.

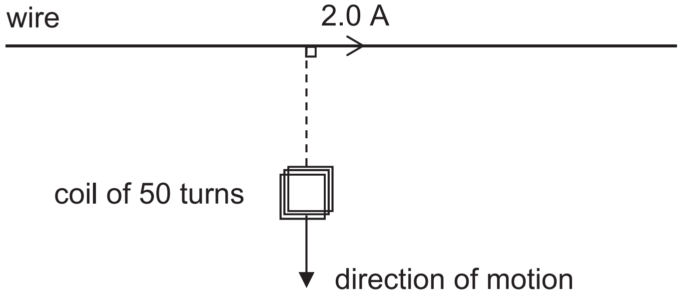


**Fig. 5.1**

**(a)** Show that the magnetic flux density at a distance of 10 cm from the wire is $4.0 \times 10^{-6}$ T.

[1]

**(b)** The coil is moved such that the distance between the wire and the centre of the coil changes from 10.0 cm to 20.0 cm in a duration of 0.40 s.

**(i)** State Faraday's law of electromagnetic induction.

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** Calculate the average e.m.f. induced in the coil.

Assume that the magnetic flux density through the coil is the same as the value at the centre of the coil.

average e.m.f. = .............................. V [3]

**(c)** **(i)** With reference to Lenz's law, state and explain the direction of the induced current in the coil.

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

**(ii)** Hence, explain why work has to be done to move the coil away from the straight wire at a constant velocity.

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..........................................................................................................................................

..........................................................................................................................................

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

**6 (a)** A beam of white light, consisting of wavelengths between 400 nm and 700 nm, is incident on a cool sodium gas at low pressure. Fig. 6.1 shows the four lowest energy levels of the sodium atom.

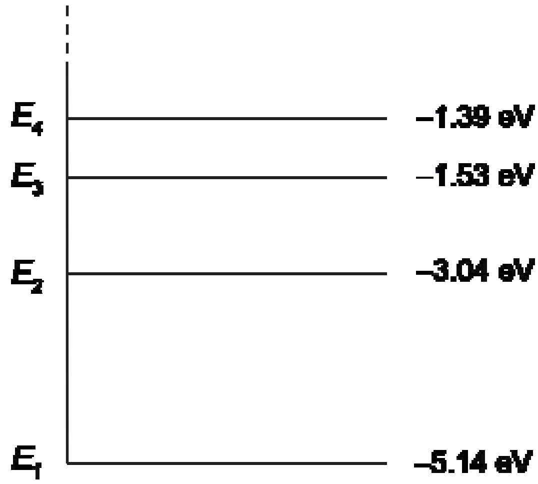


**Fig. 6.1**

**(i)** Explain the formation of an absorption line spectrum.

[3]

**(ii)** Show that the wavelength of the photon that causes the transition from $E_1$ to $E_2$ is 592 nm.

[1]

**(iii)** Determine the number of absorption spectral lines that are observed. Show your working.

number of observable lines = .............................. [2]

**(b)** An electron microscope uses an array of electromagnetic lenses to accelerate and focus a beam of electrons to create an enlarged image of a specimen.

**(i)** Determine the kinetic energy, in eV, of an electron which has a de Broglie wavelength that is the same as the wavelength of the photon in **(a)(ii)**.

kinetic energy = .............................. eV [2]

**(ii)** Suggest one advantage and one disadvantage of an electron microscope over an optical microscope.

Advantage: ..............................................................................................................

..............................................................................................................................

Disadvantage: ..........................................................................................................

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

## Section B

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

**7** A binary star system consists of two stars of masses $5.00 \times 10^{31}$ kg and $3.00 \times 10^{31}$ kg, as shown in Fig. 7.1. The line XY passes perpendicularly to the line AB, joining the centres of the two stars, at point D. A point C on the line XY is $1.86 \times 10^{12}$ m from point A and $1.31 \times 10^{12}$ m from point B.

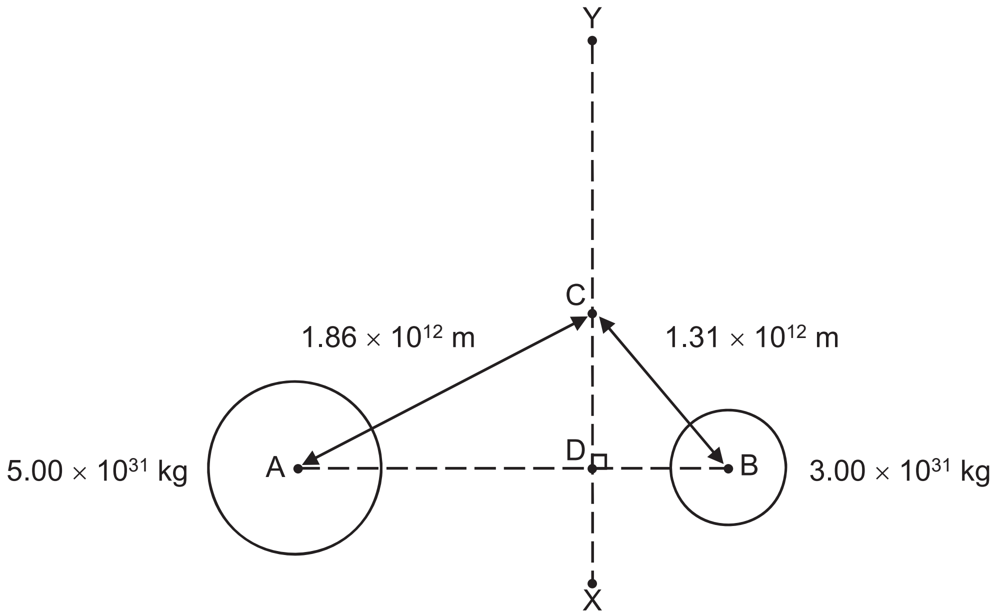


**Fig. 7.1**

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

..................................................................................................................................

..................................................................................................................................

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

**(ii)** Explain why gravitational potential is negative.

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

**(iii)** Show that the gravitational potential at point C is $-3.32 \times 10^{9}$ J kg$^{-1}$.

[1]

**(b)** An asteroid passes through point C with speed *u*.

Determine the minimum value of *u* such that the asteroid is just able to escape from the gravitational attraction of the binary star system.

minimum value of *u* = .............................. m s$^{-1}$ [2]

**(c)** Fig. 7.2 shows the variation of gravitational potential $\phi$ with distance from point X to point Y.

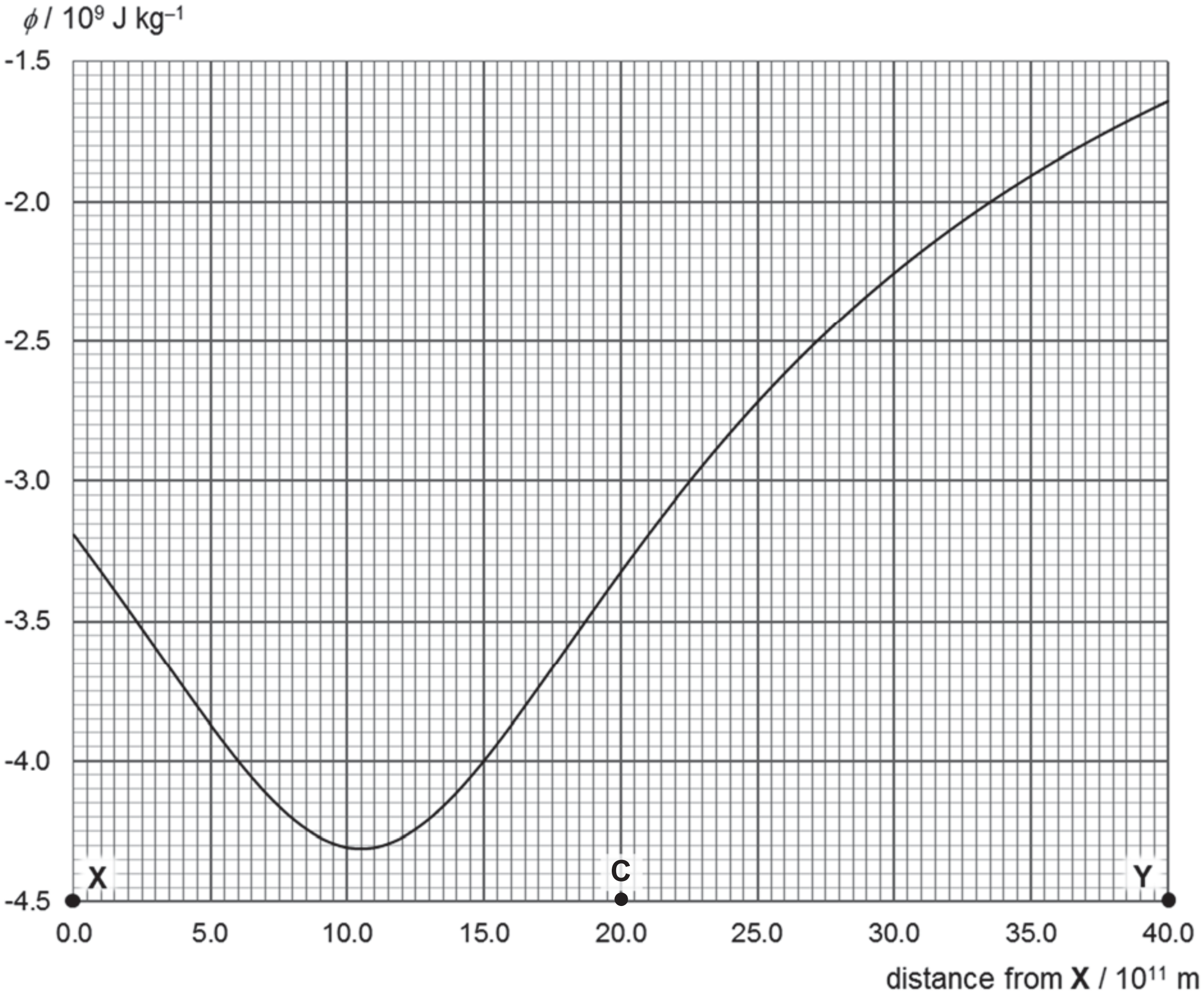


**Fig. 7.2**

Using Fig. 7.2,

**(i)** determine the magnitude of the component of gravitational field strength along the line XY at point C. Show your working.

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

**(ii)** label the position of point D on the curve. Explain how it is determined.

..........................................................................................................................................

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

**(iii)** show that the separation between the centres A and B of the two stars is $2.50 \times 10^{12}$ m.

[2]

**(d)** The separation of the centres of the two stars remains constant at $2.50 \times 10^{12}$ m as they rotate about a common centre.

Determine the distance of the centre of rotation of the binary star system from point A. Explain your working.

distance = ................................ m [3]

**(e)** The star of mass $5.00 \times 10^{31}$ kg has a radius of $1.00 \times 10^{9}$ m.

**(i)** Calculate the mean density of this star.

mean density = .............................. kg $m^{-3}$ [1]

**(ii)** Suggest, with a reason, whether the density is likely to vary with distance from the centre of the star.

..............................................................................................................................

..............................................................................................................................

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

**8** Uranium-235 is an isotope of uranium and makes up about 0.70% of natural uranium. It is a common isotope used in nuclear power plant. The half-life of uranium-235 is $7.0 \times 10^8$ years.

**(a)** Explain what is meant by

**(i)** *isotopes*,

..........................................................................................................................................

..........................................................................................................................................

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

**(ii)** *fission*,

..........................................................................................................................................

..........................................................................................................................................

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

**(iii)** *half-life*.

..........................................................................................................................................

..........................................................................................................................................

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

**(b)** In a particular nuclear fission of uranium-235 (U), caesium-137 (Cs) and rubidium-95 (Rb) isotopes are produced, as represented by the following equation:

$$^{235}_{92}\text{U} + ^{p}_{q}\text{n} \rightarrow ^{137}_{55}\text{Cs} + ^{95}_{r}\text{Rb} + x\,^{p}_{q}\text{n}$$

**(i)** Determine the values of $p$, $q$, $r$ and $x$.

$p$ = ..............................

$q$ = ..............................

$r$ = ..............................

$x$ = .............................. [2]

**(ii)** Fig. 8.1 shows the variation of binding energy per nucleon with nucleon number.

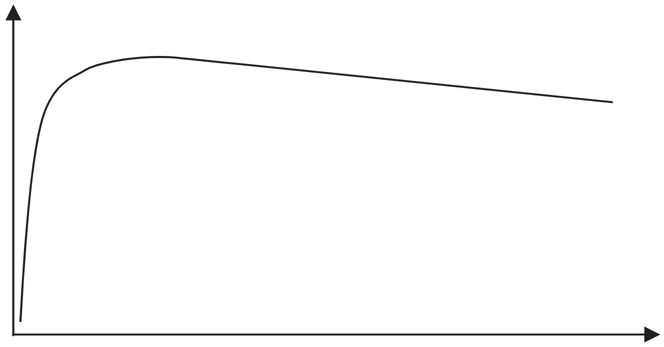


**Fig. 8.1**

Using Fig. 8.1,

**1.** mark the approximate positions of U, Cs and Rb on the curve, [1]

**2.** explain why the fission of uranium-235 releases energy.

.................................................................................................................................

.................................................................................................................................

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

**(iii)** The energy released in this nuclear fission is 289 MeV. The rest masses of the nuclei are

| | |
|---|---|
| caesium-137, | *m* |
| uranium-235, | 235.1727 u |
| rubidium-95, | 94.92964 u |
| neutron, | 1.008665 u |

Determine the value of *m*.

*m* = .............................. kg [3]

**(c)** Caesium-137 is a radioactive isotope that has a half-life of 30.2 years and it is highly soluble in water.

During the Fukushima nuclear accident in Japan in 2011, 27.0 kg of caesium-137 was released into the environment.

**(i)** Suggest one method of removing caesium-137 from contaminated water.

........................................................................................................................................

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

**(ii)** Calculate the decay constant of caesium-137. Include the unit in your answer.

decay constant = ........................................ [3]

**(iii)** Determine the activity of caesium-137 when it was released during the accident.

activity = .................................... Bq [2]

**(iv)** Caesium-137 decays by beta emission to form barium-137.

Explain why the kinetic energy of the beta particle is lower than the total energy released in the beta decay.

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........................................................................................................................................

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

**End of Paper 3**

| Centre Number | Class Index Number | Name | Class |
|---|---|---|---|
| 3016 | | | |

**RAFFLES INSTITUTION**
**2017 Preliminary Examination**

**PHYSICS** **9749/04**
**Higher 2** **23 August 2017**

Paper 4 Practical Test **2 hour 30 minutes**

Candidates answer on the Question Paper.
No additional materials are required.

**READ THESE INSTRUCTIONS FIRST**

Write your index number, name and class in the spaces provided at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided in this booklet.
The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

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.

| | |
|---|---|
| **Shift** | |
| **Laboratory** | |

| **For Examiner's Use** | |
|---|---|
| **1** | / 11 |
| **2** | / 12 |
| **3** | / 20 |
| **4** | / 12 |
| **Total** | / 55 |

1 This investigation considers the determination of the resistivity of a nichrome wire.

**(a)** **(i)** Use the apparatus provided to determine the resistance per unit length $\frac{R}{L}$ of the nichrome wire.

Draw a diagram of the circuit used.

[1]

Present your measurements and calculations clearly.

$\frac{R}{L}$ = .................................... [2]

**(ii)** Determine the percentage uncertainty in your value of $\frac{R}{L}$.

percentage uncertainty = .................................... [1]

**(b)** **(i)** Use the wooden rod provided to determine, as accurately as you can, the diameter *d* of the nichrome wire.

Explain the method used and write down the diameter *d* of the nichrome wire.

..........................................................................................................................................

..........................................................................................................................................

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..........................................................................................................................................

$d$ = .................................... [2]

**(ii)** The resistance per unit length $\frac{R}{L}$, resistivity $\rho$ and cross-sectional area $A$ of a wire are related by the equation $\frac{R}{L} = \frac{\rho}{A}$.

Determine the resistivity $\rho$ of the nichrome wire. Show your working clearly.

$\rho$ = .................................... [2]

**(c)** State a significant source of error in this experiment.

..........................................................................................................................................

..........................................................................................................................................

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

**(d)** Nichrome has a high melting point and can withstand heating without breaking. It is the most popular material used to make heating elements.

Suggest another two possible reasons why nichrome is an ideal choice for making heating elements.

..........................................................................................................................................

..........................................................................................................................................

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

**[Total: 11 marks]**

**2** This investigation considers the variation of the period of oscillation of an equilateral triangular wire framework with the size of the framework.

**(a)** Measure and record the length *L* of the thinner 75 cm wire.

*L* = ..................................... [1]

**(b)** **(i)** Carefully bend this wire into an equilateral triangle. (An equilateral triangle has three sides of equal length.) Use a small piece of Blu-tack to join the open ends of the wire together.

**(ii)** Suspend the triangle from a pin as shown in Fig. 2.1.

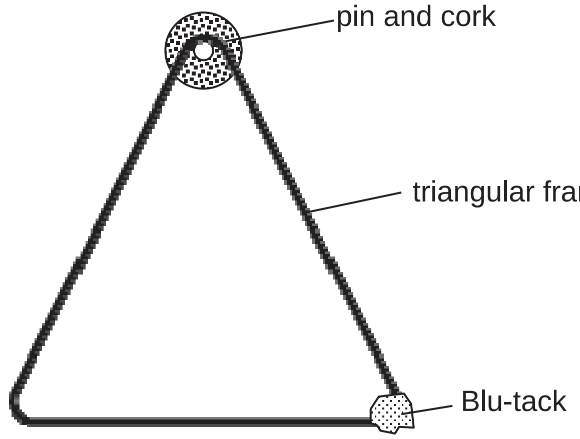


**Fig. 2.1**

**(iii)** Gently displace the framework through a small angle and release it so that it performs small oscillations in the vertical plane of the triangle as shown in Fig. 2.2.

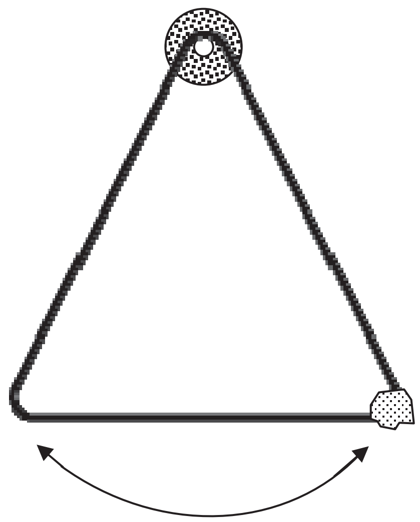

**Fig. 2.2**

**(iv)** Make and record measurements to determine the period *T* of these oscillations.

*T* = ......................................

**(c)** Remove the wire from the pin. Straighten the wire and use the wire cutter to reduce its length by about 10 cm.

***Safety: Put on the safety goggle. Hold on to the 10 cm section of the wire to be removed when cutting the wire to prevent it from flying off.**

**(d)** Repeat steps **(a)**, **(b)** and **(c)** to obtain further sets of readings for *L* and *T*, where $L \geq 25$ cm.

[7]

**(e)** Theory suggests that $T^2$ is proportional to *L*.

Plot a graph of $T^2$ against *L* on Fig. 2.3.

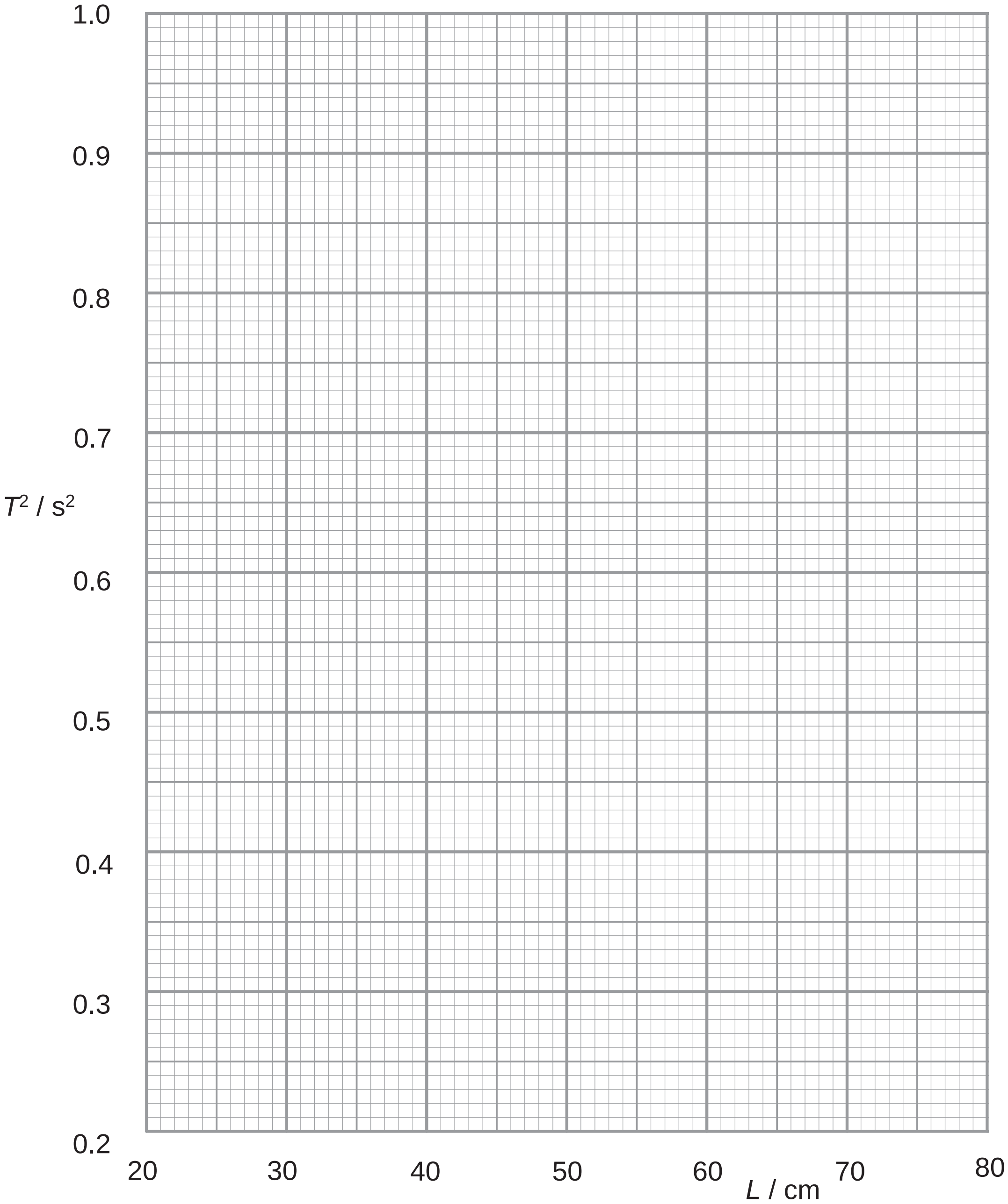


**Fig. 2.3**

[2]

**(f)** By using the thicker 50 cm wire that is bent into an equilateral triangle, and by making one further measurement, explain whether the theory in **(e)** will be successful in predicting the period of other equilateral triangular wire frameworks made of different materials.

..................................................................................................................................................

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

**[Total: 12 marks]**

**3** This investigation considers the equilibrium of two connected masses.

**(a)** Set up the apparatus as shown in Fig 3.1.

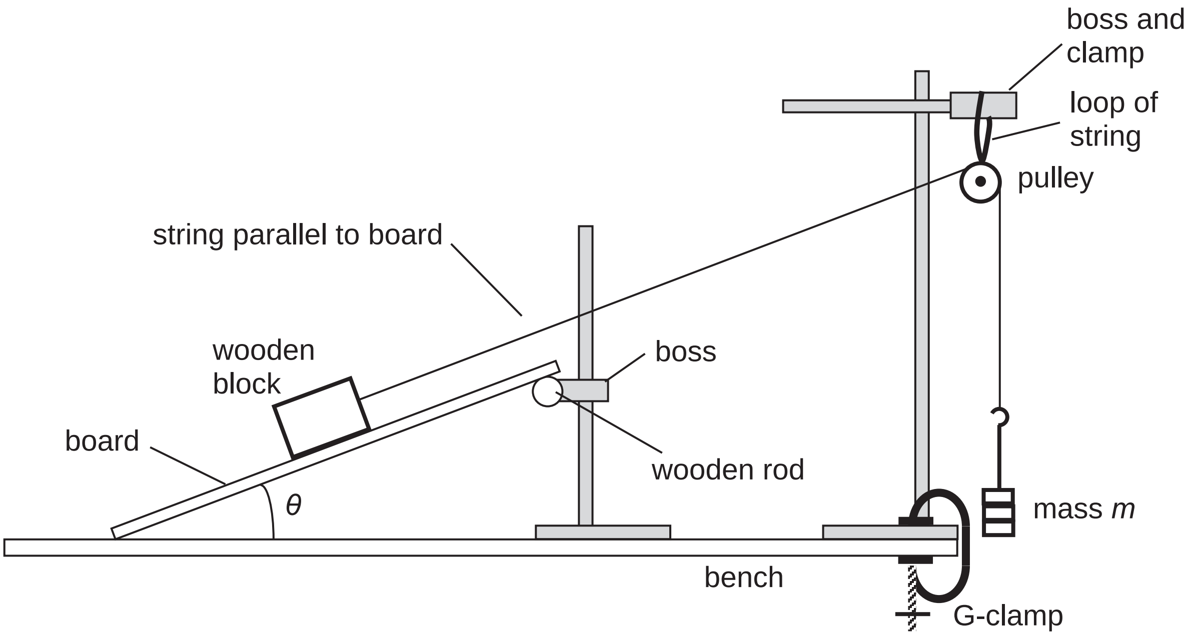


**Fig. 3.1**

**(b)** **(i)** Hang a mass $m$ of 110 g from the pulley.

Tilt the board and adjust the height of the pulley such that the wooden block is just about to slide up the board and the string to the left of the pulley is parallel to the board.

Measure and record $\theta$.

$\theta$ = ......................................

**(ii)** Estimate the percentage uncertainty in the value of $\theta$ in **(i)**.

percentage uncertainty = ...................................... [1]

**(c)** Decrease the value of $m$ and repeat step **(b)(i)** to obtain further sets of readings for $m$ and $\theta$, where 60 g ≤ $m$ ≤ 110 g.

[7]

**(d)** Theory suggests that sin $\theta$ and $m$ are related by the equation

$$\sin\theta = Am + B$$

where $A$ and $B$ are constants.

Plot a suitable graph to determine $A$ and $B$.

$A$ = ....................................

$B$ = .................................... [4]

[3]

**(e)** Comment on any anomalous data or results that you may have obtained. Explain your answer.

..........................................................................................................................................

..........................................................................................................................................

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

**(f)** $A$ and $M$ are related by the equation

$$A = \frac{1}{M}$$

where $M$ is the mass of the wooden block.

**(i)** Use your answer in **(d)** to determine the experimental value of the mass $M_{experiment}$ of wooden block.

$M_{experiment}$ = .................................... [1]

**(ii)** Measure and record the actual mass $M_{actual}$ of the wooden block using the electronic balance. Hence, determine the percentage error of $M$.

$M_{actual}$ = ....................................

percentage error of $M$ = .................................... [1]

**(g)** **(i)** State one significant source of error in this experiment.

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..........................................................................................................................................

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

**(ii)** Suggest an improvement that could be made to the experiment to address the source of error identified in **(g)(i).** You may suggest the use of other apparatus or a different procedure.

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..........................................................................................................................................

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

**[Total: 20 marks]**

**Please turn over for Question 4.**

**4** Photographic films are coated with a layer of silver compounds which is sensitive to light. When a film is exposed to light, the silver compounds undergo a chemical reaction. By developing the exposed film using solvents, the opacity of the film changes as silver gets deposited on the film. Opacity is the degree of impenetrability to visible light.

Design an experiment to determine how the opacity of a developed film depends on the energy per unit area of light incident on the film.

You are provided with sheets of unexposed photographic film, developing solvents, a light intensity meter, a lamp and other equipment usually found in a physics lab.

You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

**(a)** the identification and control of variables,

**(b)** the equipment you would use,

**(c)** the procedure to be followed,

**(d)** how the opacity of a processed film would be determined,

**(e)** any precautions that would be taken to improve the accuracy and safety of the experiment.

**Diagram**

[12]

**End of Paper 4**