EUNOIA JUNIOR COLLEGE
JC2 PRELIMINARY EXAMINATIONS 2025
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME

| CIVICS GROUP | 2 | 4 | - | | |
|---|---|---|---|---|---|

REGISTRATION NUMBER

**PHYSICS**
Longer Structured Questions

**9749/03**

**September 2025**

**2 hours**

**READ THESE INSTRUCTIONS FIRST**

Write your name, civics group and registration number on all the work you hand in.
The use of an approved scientific calculator is expected where appropriate.

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

**Section B**
Answer **one** question only.

Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.
The number of marks is given in brackets [ ] at the end of each question or part question.

| For Examiner's Use | |
|---|---|
| Section A | |
| Q1 | 13 |
| Q2 | 12 |
| Q3 | 9 |
| Q4 | 15 |
| Q5 | 11 |
| Section B | |
| Q6 | 20 |
| Q7 | 20 |
| s.f. | |
| P3 Total | 80 |

This document consists of **25** printed pages and **3** blank pages.

**Data**

| | |
|---|---|
| speed of light in free space, | $c = 3.00 \times 10^{8}\ \text{m s}^{-1}$ |
| permeability of free space, | $\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$ |
| permittivity of free space, | $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ |
| | $(1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$ |
| elementary charge, | $e = 1.60 \times 10^{-19}\ \text{C}$ |
| the Planck constant, | $h = 6.63 \times 10^{-34}\ \text{J s}$ |
| unified atomic mass constant, | $u = 1.66 \times 10^{-27}\ \text{kg}$ |
| rest mass of electron, | $m_e = 9.11 \times 10^{-31}\ \text{kg}$ |
| rest mass of proton, | $m_p = 1.67 \times 10^{-27}\ \text{kg}$ |
| molar gas constant, | $R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$ |
| the Avogadro constant, | $N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$ |
| the Boltzmann constant, | $k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$ |
| gravitational constant, | $G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$ |
| acceleration of free fall, | $g = 9.81\ \text{m s}^{-2}$ |

**Formulae**

| | |
|---|---|
| uniformly accelerated motion, | $s = ut + \frac{1}{2}at^2$ <br> $v^2 = u^2 + 2as$ |
| work done on/by a gas, | $W = p\Delta V$ |
| hydrostatic pressure, | $p = \rho gh$ |
| gravitational potential, | $\phi = -\frac{Gm}{r}$ |
| 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. | $v = v_0 \cos \omega t$ <br> $= \pm \omega \sqrt{\left(x_0^2 - x^2\right)}$ |
| 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, | $V = \frac{Q}{4\pi\varepsilon_0 r}$ |
| alternating current/voltage, | $x = x_0 \sin \omega t$ |
| magnetic flux density due to a long straight wire | $B = \frac{\mu_0 I}{2\pi d}$ |
| magnetic flux density due to a flat circular coil | $B = \frac{\mu_0 NI}{2r}$ |
| magnetic flux density due to a long solenoid | $B = \mu_0 nI$ |
| radioactive decay, | $x = x_0 \exp(-\lambda t)$ |
| decay constant | $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$ |

## Section A

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

**1** A vertical tube of length 0.60 m is open at both ends, as shown in Fig. 1.1.

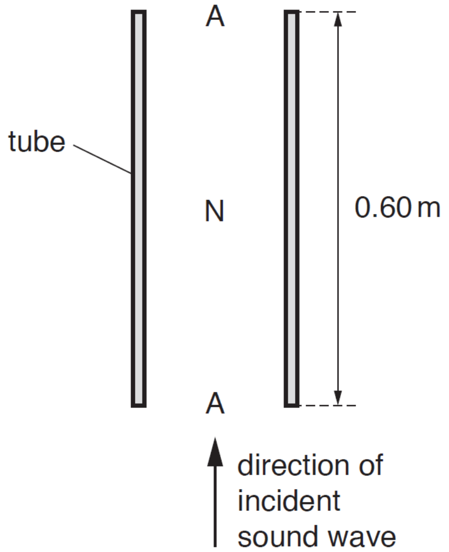


**Fig. 1.1**

An incident sinusoidal sound wave of a single frequency travels up the tube. A stationary wave is then formed in the air column in the tube with antinodes A at both ends and a node N at the midpoint.

**(a)** Explain how the stationary wave is formed from the incident sound wave.

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**(b)** **(i)** On Fig. 1.2, sketch a graph to show the variation of the amplitude of the stationary wave with height *h* above the bottom of the tube.

[2]

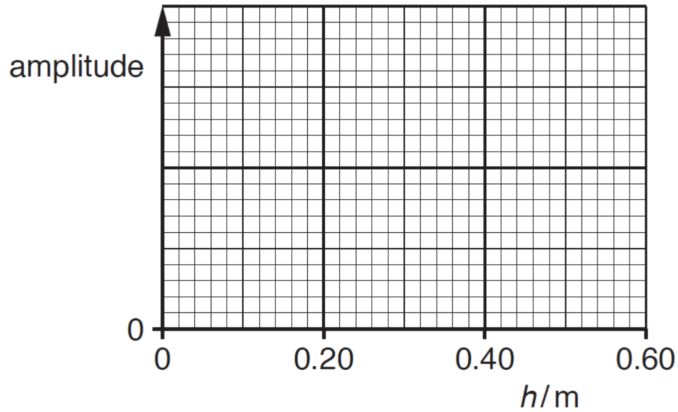


**Fig. 1.2**

**(ii)** On Fig. 1.3, sketch a graph to show the variation of the intensity of the stationary wave with height *h* above the bottom of the tube.

[1]

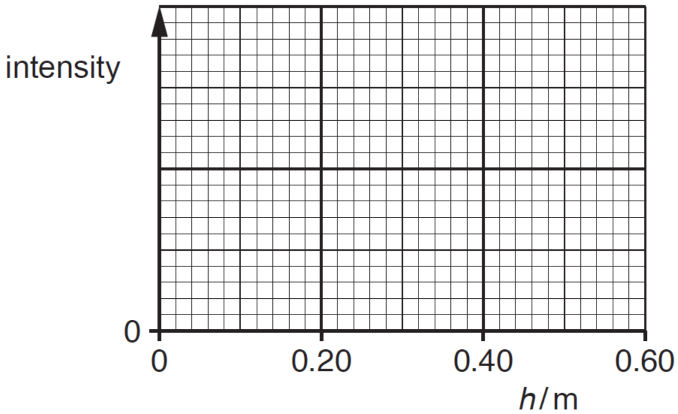


**Fig. 1.3**

**(c)** For the stationary wave, state:

**(i)** the direction of the oscillations of an air particle at a height of 0.15 m above the bottom of the tube.

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

**(ii)** the phase difference between the oscillations of a particle at a height of 0.10 m and a particle at a height of 0.20 m above the bottom of the tube.

phase difference = ........................................................ ° [1]

**(iii)** the phase difference between the oscillations of a particle at the top of the tube and a particle at the bottom of the tube.

phase difference = ........................................................ ° [1]

**(d)** The speed of the sound wave is 340 m $s^{-1}$.

Calculate the frequency of the sound wave.

frequency = .................................................... Hz [2]

**(e)** The frequency of the sound wave is gradually increased until a stationary wave is next formed.

**(i)** Determine the frequency of this stationary wave.

frequency = .................................................... Hz [1]

**(ii)** The microphone is initially placed at the bottom of the tube and moved upwards.

Determine the shortest distance from bottom of the tube when the microphone detects a displacement node.

distance = .......................................................... m [1]

[Total: 13]

**2** **(a)** A piece of resistance wire PQ of length 120 cm and diameter 1.1 mm has resistivity $1.1 \times 10^{-6}\ \Omega$ m.

**(i)** Show that the resistance of the wire PQ is 1.4 Ω. [1]

**(ii)** Wire PQ is now connected to a circuit as shown in Fig. 2.1 below. A voltmeter is connected to point X and Y, where X is the mid-point between PQ.

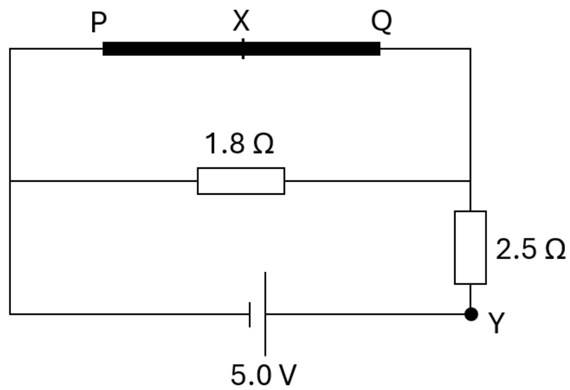


**Fig. 2.1**

Determine the reading on the voltmeter.

voltmeter reading = ……………………… V [3]

**(b)** Two long straight parallel wires A and B carrying currents $I_A$ and $I_B$ respectively are positioned 5.0 cm apart as shown in Fig. 2.2. Currents $I_A$ and $I_B$ are directed along the same direction.

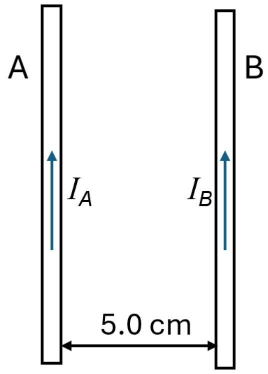


**Fig. 2.2**

**(i)** Explain why the two wires are attracted to one another.

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**(ii)** The currents are now replaced with alternating currents.

$I_A$ is represented by the equation:

$$I_A = -3.0 \cos(200\pi t)$$

$I_B$ is represented by the graph shown in Fig. 2.3.

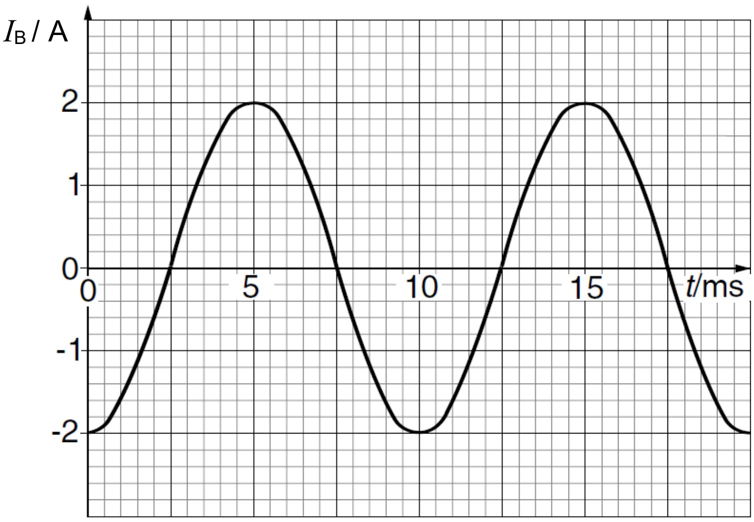


**Fig. 2.3**

**1.** Determine the instantaneous force per unit length acting on wire A when $t$ = 6.5 ms.

force per unit length = ……………………….. N $m^{-1}$ [3]

**2.** A diode is connected in series to wire A such it is reversed biased.

Sketch in in Fig. 3.2 the graph of the attractive force per unit length acting on wire A against time $t$ from $t$ = 0 ms to $t$ = 15 ms. Numerical value of the force per unit length is not required.

[2]

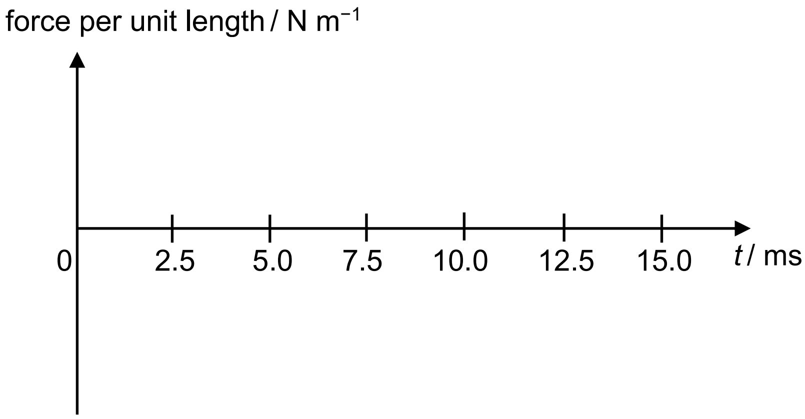


**Fig. 3.2**

**3.** The diode in **(b)(ii)2.** remains connected.

Determine the mean power dissipated across wire A given that the resistance of wire A is 15 Ω.

mean power = …………………….. W [1]

[Total: 12]

**3** **(a)** The variation with pressure $p$ of the volume $V$ of a fixed mass of an ideal gas is shown in Fig. 3.1.

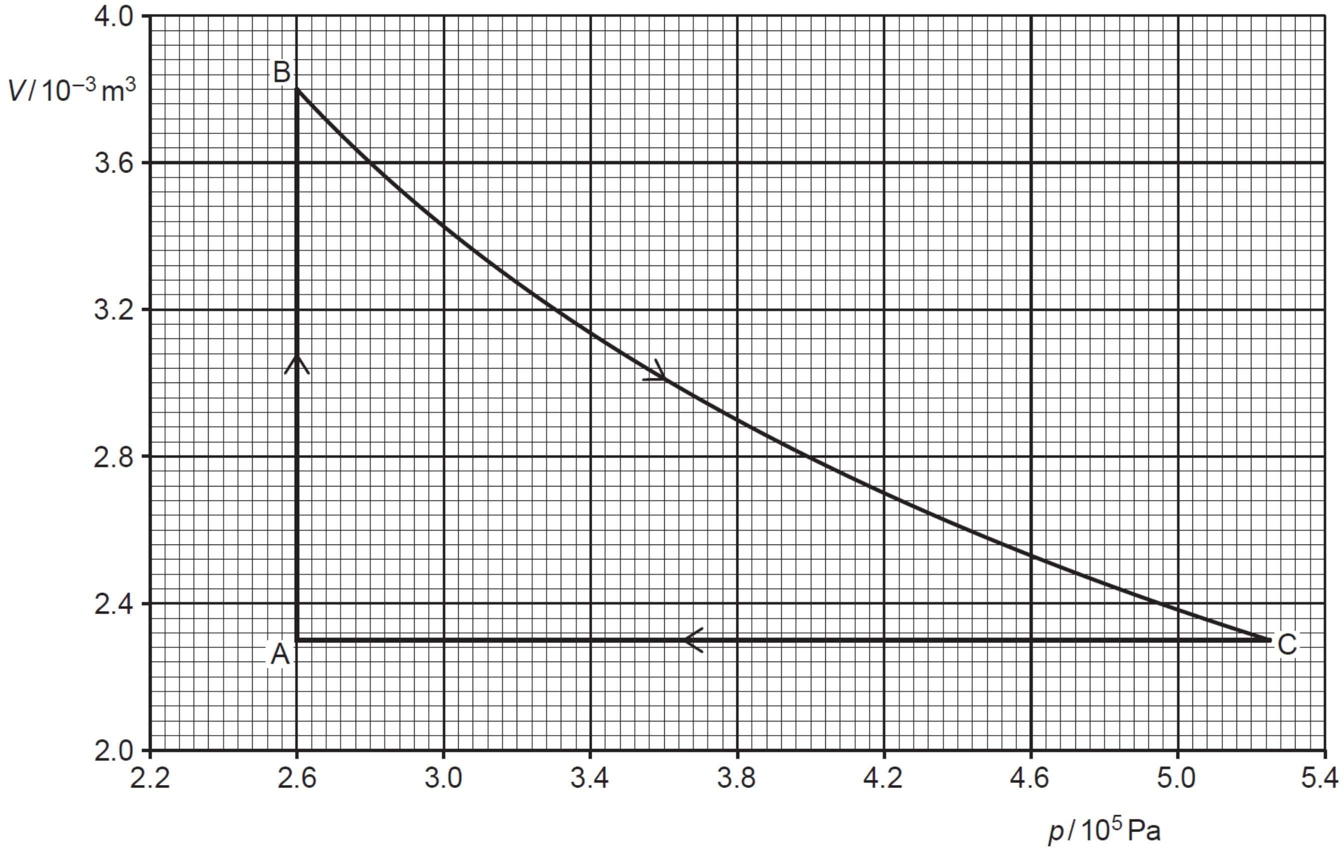


**Fig. 3.1**

The gas undergoes a cycle of changes A to B to C to A.

During the change A to B, the volume of the gas increases from $2.30 \times 10^{-3}$ m$^3$ to $3.80 \times 10^{-3}$ m$^3$.

**(i)** Show that the magnitude of the work done during the change A to B is 390 J.

[1]

**(ii)** State and explain the total change, if any, in the internal energy of the gas during one complete cycle.

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

**(b)** During the change A to B, 1370 J of thermal energy is transferred to the gas.

During the change B to C, no thermal energy enters or leaves the gas. The work done on the gas during this change is 550 J.

Use these data and the information in **(a)** to complete Table 3.1.

**Table 3.1**

| change | thermal energy supplied to gas / J | work done on gas / J | increase in internal energy of gas / J |
|---|---|---|---|
| A to B | | | |
| B to C | | | |
| C to A | | | |

[4]

**(c)** Use the first law of thermodynamics to explain why the specific latent heat of vaporisation is greater than the specific latent heat of fusion for a particular substance.

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[Total: 9]

**4** **(a)** A heavy aluminium disc has a radius of 0.36 m. The disc rotates with the wheels of a vehicle and forms part of an electromagnetic braking system on the vehicle.

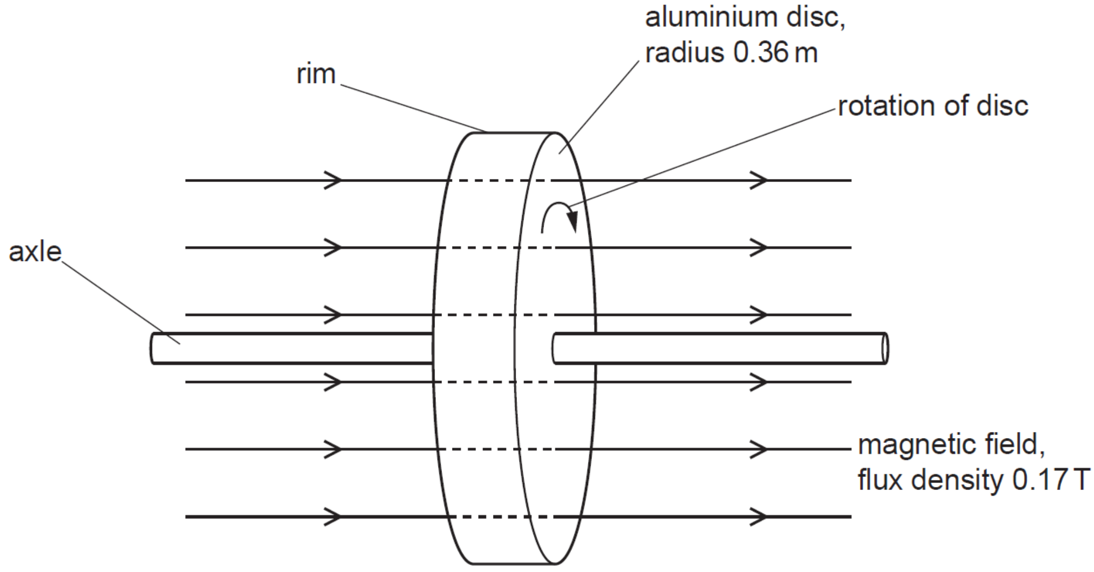


**Fig. 4.1**

In order to activate the braking system, a uniform magnetic field of flux density 0.17 T is switched on. This magnetic field is perpendicular to the plane of rotation of the disc, as shown in Fig. 4.1.

**(i)** Define magnetic flux linkage.

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**(ii)** The disc is rotating at a rate of 25 revolutions per second.

Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

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

**(iii)** The axle and the rim are connected to an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 4.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

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**(b)** A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 4.2.

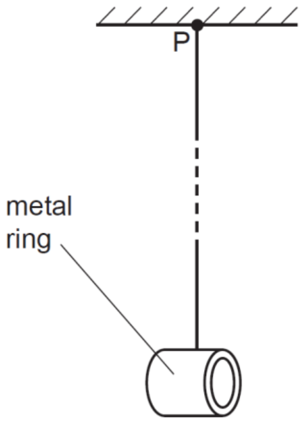


**Fig. 4.2**

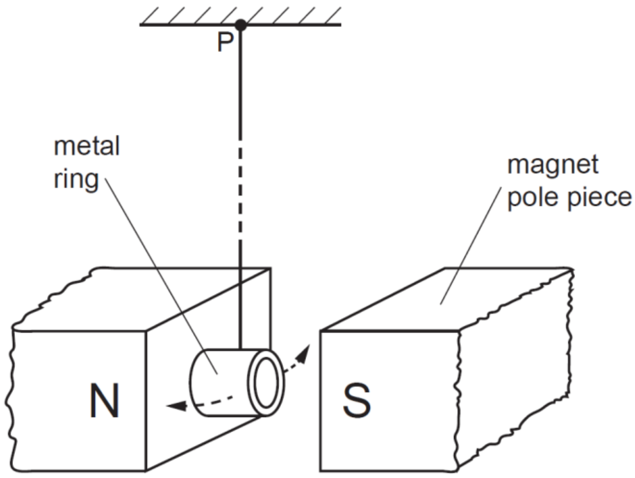


**Fig. 4.3**

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 4.3.

**(i)** The ring is again displaced a distance *d* and then released.

Explain why the ring completes fewer oscillations before coming to rest.

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.................................................................................................................... [4]

**(ii)** The ring in **(b)** is now cut so that it has the shape shown in Fig. 4.4.

**Fig. 4.4**

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

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[Total: 15]

**5** **(a)** **(i)** State what is meant by nuclear binding energy.

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**(ii)** On Fig. 5.1, sketch a line to show the variation with nucleon number *A* of the binding energy per nucleon *E* of a nucleus.

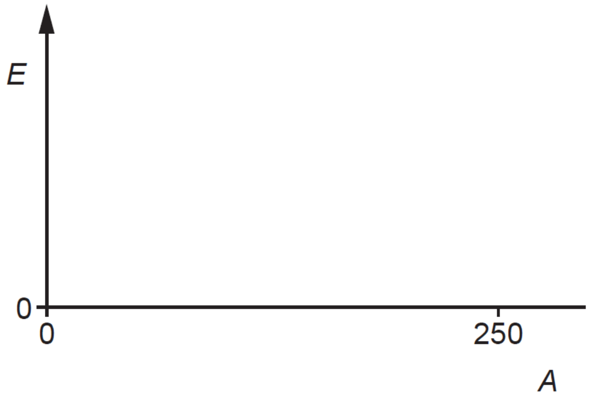


**Fig. 5.1**

[1]

**(b)** In one type of nuclear process, deuterium ($^{2}_{1}H$) undergoes the reaction

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n \ .$$

**(i)** State the name of this type of nuclear process.

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

**(ii)** Explain, with reference to your line in **(a)(ii)**, why this reaction results in the release of energy.

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

**(c)** Table 5.1 shows the masses of the particles involved in the reaction in **(b)**.

**Table 5.1**

| particle | mass / u |
|---|---|
| ${}^{1}_{0}n$ | 1.008 665 |
| ${}^{2}_{1}H$ | 2.014 102 |
| ${}^{3}_{2}He$ | 3.016 029 |

Calculate the energy released when 1.00 mol of deuterium undergoes the reaction.

energy = ...................................................... J [5]

[Total: 11]

## SECTION B

Answer any ONE of the two questions.

**6** A cylindrical tube, sealed at one end, has cross-sectional area $A$ and contains some sand. The total mass of the tube and the sand is $M$.

The tube floats upright in a liquid of density $\rho$, as illustrated in Fig. 6.1.

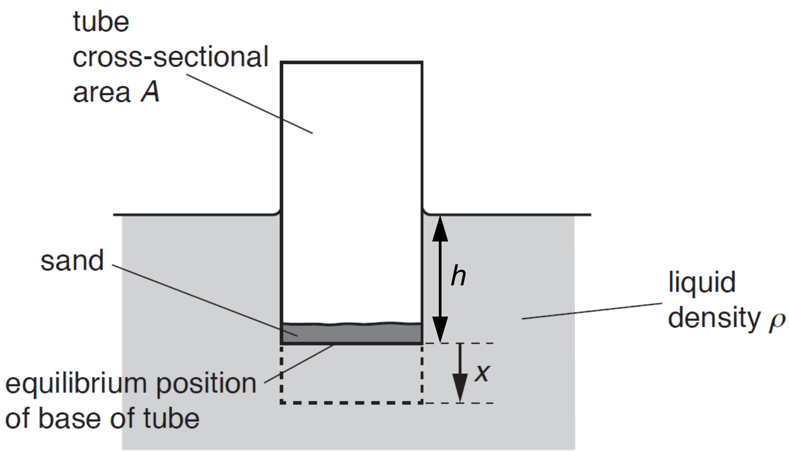


**Fig. 6.1**

At equilibrium, the tube has a depth $h$ submerged under water. The tube is pushed a short distance downwards into the liquid and then released.

**(a)** State and explain, by considering the forces acting on the tube, the direction of the resultant force acting on the tube immediately after its release.

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

**(b)** Show that the acceleration a of the tube is given by the expression

$$a = -\left(\frac{A\rho g}{M}\right)x$$

where $x$ is the vertical displacement of the tube from its equilibrium position.

[3]

**(c)** Use the expression in **(b)** to explain why the tube undergoes simple harmonic oscillations in the liquid.

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

**(d)** A student conducted an experiment and obtained the following measurements:

$M$ = 0.17 kg
$A = 4.5 \times 10^{-4}$ m$^2$
period of oscillation = 1.3 s

**(i)** Determine the angular frequency $\omega$ of the oscillations.

$\omega$ = ................................................ rad s$^{-1}$ [2]

**(ii)** Determine the density $\rho$ of the liquid in which the tube is floating.

$\rho$ = ................................ kg m$^{-3}$ [3]

**(iii)** **1.** Show that total energy of the oscillation is given by

$$\frac{1}{2}M\omega^2 {x_o}^2$$

where $x_o$ represents the amplitude of the oscillation.

[3]

**2.** Hence determine the total energy of the oscillation when the amplitude of the oscillation is 0.20 m.

total energy = ………………………………….. J [1]

**(iv)** During each complete oscillation the total energy of the system decreases by 8.0% of the total energy at the start of that oscillation.

Determine the decrease in total energy, in mJ, of the system by the end of the first 6 complete oscillations.

energy lost = .................................................. mJ [2]

**(v)** The variation with time of the depth *h* for undamped oscillation is shown in Fig. 6.2.

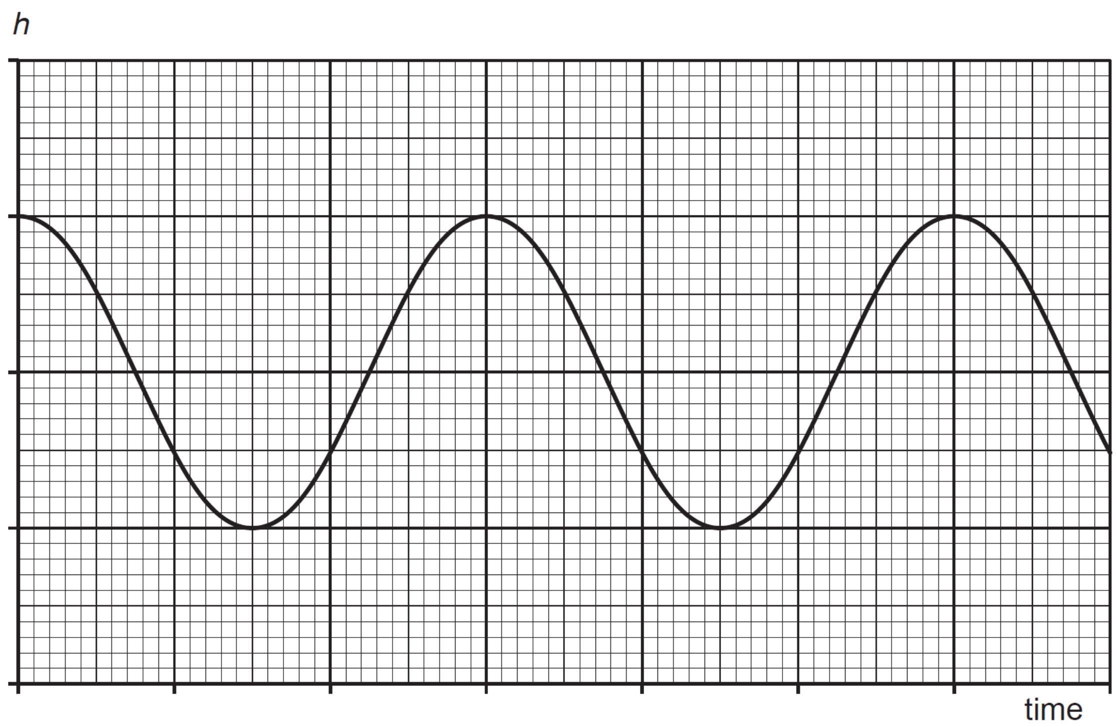


**Fig. 6.2**

On Fig. 6.2, draw a line to show light damping of the oscillations. Numerical values are not required

[2]

[Total: 20]

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

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

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**(b)** An isolated uniform spherical planet has gravitational potential $\phi$ at its surface.

A particle of mass *m* is projected vertically upwards from the surface. The particle is given just enough kinetic energy to travel to an infinite distance away from the planet, escaping from the gravitational pull of the planet, without any additional work being done on it.

Show that the speed *v* at which the particle is projected upwards from the surface of the planet is given by

$$v = \sqrt{-2\phi}\ .$$

[3]

**(c)** The Moon may be considered to be an isolated uniform sphere of mass $7.3 \times 10^{22}$ kg and radius $1.7 \times 10^{6}$ m.

Calculate the gravitational potential at the surface of the Moon.

gravitational potential = ................................ J kg$^{-1}$ [2]

**(d)** A particle is moving upwards at the surface of the Moon.

Use the expression in **(b)** and your answer in **(c)** and to determine the minimum speed of this particle that will result in it escaping from the gravitational pull of the Moon.

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

**(e)** Hydrogen may be assumed to be an ideal gas.

The mass of a hydrogen molecule is $3.34 \times 10^{-27}$ kg.

Calculate the root-mean-square (r.m.s.) speed of a hydrogen molecule in hydrogen gas that is at a temperature of 400 K.

r.m.s. speed = ............................................... m s$^{-1}$ [3]

**(f)** The surface of the Moon reaches temperatures of approximately 400 K when in direct sunlight.

With reference to your answer to **(d)** and **(e),** suggest why it is still possible for the Moon to not have an atmosphere consisting of hydrogen.

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

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

**(g)** Fig. 7.1 shows the path of a comet of mass $2.20 \times 10^{14}$ kg as it passes around a star of mass $1.99 \times 10^{30}$ kg.

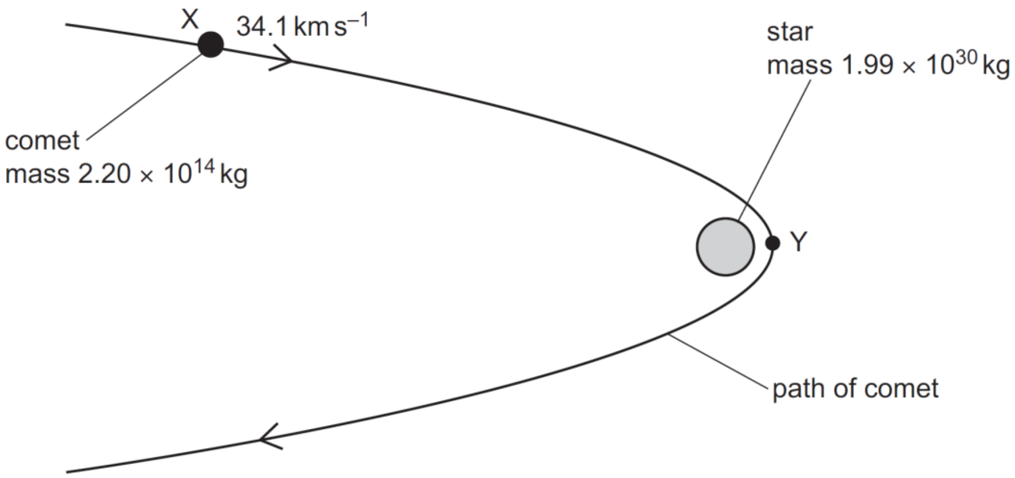


**Fig. 7.1**

At point X, the comet is $8.44 \times 10^{11}$ m from the centre of the star and is moving at a speed of 34.1 km $s^{-1}$.

At point Y, the comet passes its point of closest approach to the star. At this point, the comet is a distance of $6.38 \times 10^{10}$ m from the centre of the star.

Both the comet and the star can be considered as point masses at their centres.

**(i)** Determine the speed, in km $s^{-1}$, of the comet at point Y.

speed = .............................................. km $s^{-1}$ [4]

**(ii)** A second comet passes point X with the same speed as the original comet and travelling in the same direction. This comet is gradually losing mass. The mass of this comet when it passes point X is the same as the mass of the original comet.

Suggest, with a reason, how the path of the second comet compares with the path shown in Fig. 7.1.

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

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

**(iii)** A third comet passes point X in the same direction as the original comet but with a greater speed. Sketch a possible path for this comet starting at X in Fig. 7.1 and label this path P.

[1]

[Total: 20]

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