Class	Index Number	Name
24S		

ST. ANDREW'S JUNIOR COLLEGE
JC 2 2025
Preliminary Examination

PHYSICS, Higher 2 **9749/03**

Paper 3 Longer Structured Questions **17th September 2025**
2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, index number and Civics Group on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 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.

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

At the end of the examination, fasten all your work securely together.

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

For Examiner's Use	
Section A	
1	**/ 10**
2	**/ 7**
3	**/ 15**
4	**/ 15**
5	**/ 13**
Section B	
6	**/ 20**
7	**/ 20**
Total	**/ 80**

This document consists of **24** printed pages including this page.

Data

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

Formulae

uniformly accelerated motion	$s = u t + \frac{1}{2} a t^2$
	$v^2 = u^2 + 2 a s$
work done on/by a gas	$W = p \Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	T / K = T / °C + 273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$v = \pm \omega \sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + ...$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_o \sin \omega t$
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	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{1/2}}$

Section A

Answer **all** questions in the spaces provided

1 **(a)** State what is meant by *parabolic motion*.

....

.... [2]

(b) A spring is used to launch a metal ball of mass 4.5×10^{-2} kg up a ramp. The spring is compressed by 8.0×10^{-2} m and held in equilibrium, as shown in Fig. 1.1.

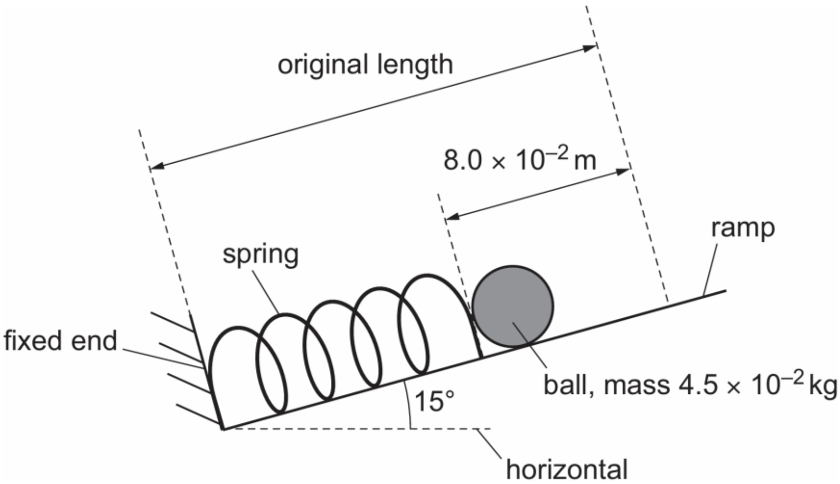

Fig. 1.1

The elastic potential energy stored in the spring at this compression is 0.24 J.
The ramp is at an angle of 15° to the horizontal.
The spring is released and expands quickly back to its original length.

(i) Calculate the average force the spring exerts on the ball during the expansion back to its original length.

average force = ... N [1]

(ii) The ball leaves the spring when the spring reaches its original length. Assume that all the elastic potential energy of the spring is transferred to the ball.

Calculate the speed of the ball as it leaves the spring.

speed = …………………… m s^{-1} [2]

(iii) The ball travels up the slope as shown in Fig.1.2.

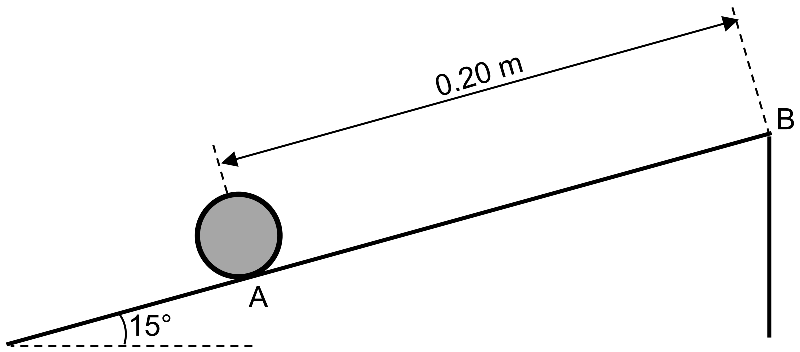

Fig. 1.2

At point A, the ball has a speed of 2.4 m s^{-1}. The ball will travel 0.20 m along the slope to reach point B, which is the end of the slope.

Show that the speed of the ball at point B is 2.2 m s^{-1}.

[1]

(c) The ball will leave the slope at point B. The height of the slope at B from the ground is 0.40 m, as shown in Fig. 1.3.

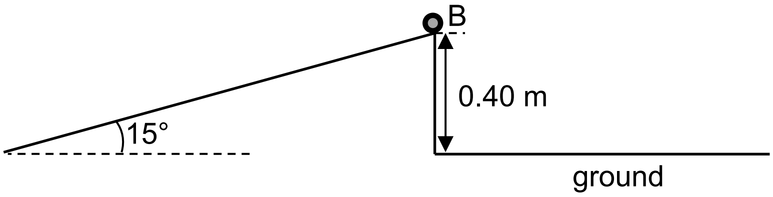

Fig. 1.3

(i) Determine the speed of the ball when it is at the maximum height.

speed = …………………… m s^{-1} [1]

(ii) Determine the time just before the ball hits the ground.

time = …………………… s [2]

(iii) Determine the horizontal displacement travelled by the ball from B to the point just before hitting the ground.

horizontal displacement = …………………… m [1]

2 A binary star system consists of two stars X and Y that orbit around their common centre of gravity C. The orbits are circular. Both stars can be considered as point masses.

The mass of star X is M and the mass of star Y is $2M$. The common centre of gravity is at a distance of D from star Y, and at a distance of $2D$ from star X, as shown in Fig. 2.1.

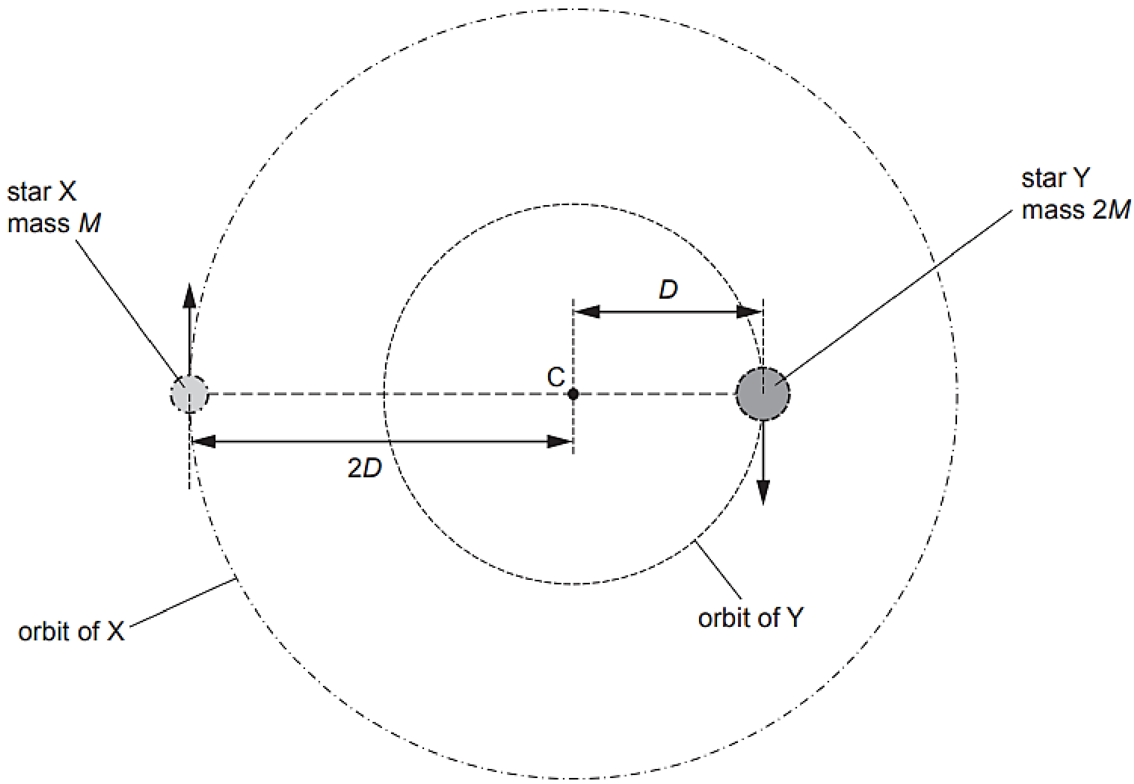

Fig. 2.1

(a) Star X orbits with angular velocity ω. Show that the angular velocity of the orbit of star Y is also ω.

[1]

(b) Deduce an expression, in terms of G, M and D, for the total energy E of the binary star system.

[4]

(c) The total energy E of the binary star system is negative.

Explain the physical significance of this negative value.

……

…… [1]

(d) Explain whether two identical electric charges could form a system in which the charges orbit around a common centre.

……

…… [1]

3 **(a)** Two coherent sources X and Y of microwaves of frequency 2.5×10^{10} Hz are of a distance of 0.18 m apart in a vacuum, as shown in Fig. 3.1.

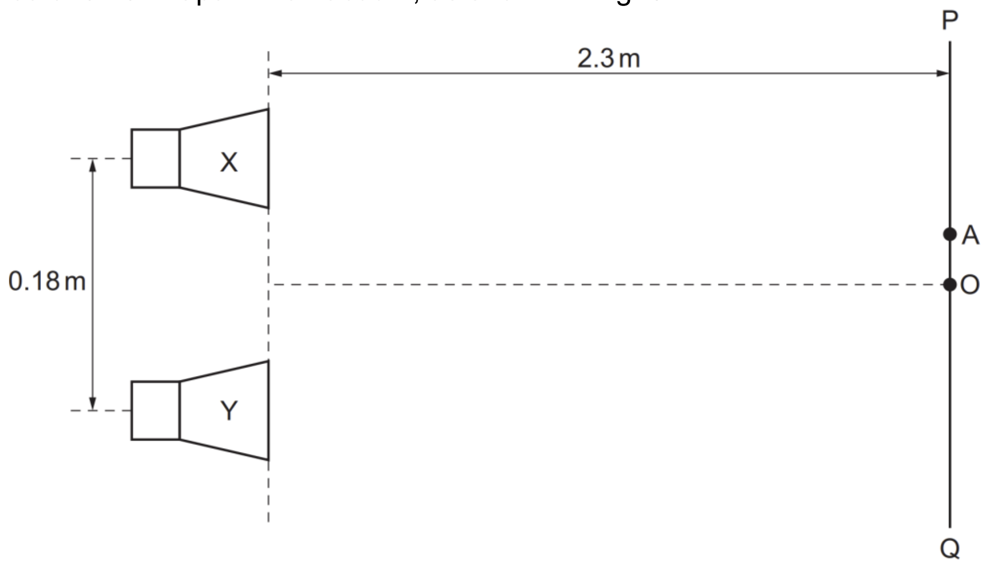

Fig. 3.1

There is a phase difference of **90°** between the waves emitted at the two sources.

A microwave detector moves along the line PQ, which is parallel to the line joining the two sources and 2.3 m away from it.

Point O is on the line PQ at a position that is equidistant from the two sources.
Point A is the position on the line PQ where the intensity of the microwaves is the greatest.

(i) Explain why the position of greatest intensity is **not** at point O.

....

....

....

.... [2]

(ii) On Fig. 3.1, draw a cross (X) to show the position of the point on line PQ where the intensity minimum that is closest to point O occurs. Label this point B. [1]

(iii) Use the formula for the double-slit interference of light to calculate the distance between adjacent intensity maxima on the line PQ.

distance = ... m [2]

(b) A pipe is open at one end and closed at the other end with a piston. The piston can slide freely and is at a distance of 45 cm from the open end of the pipe, as shown in Fig. 3.2.

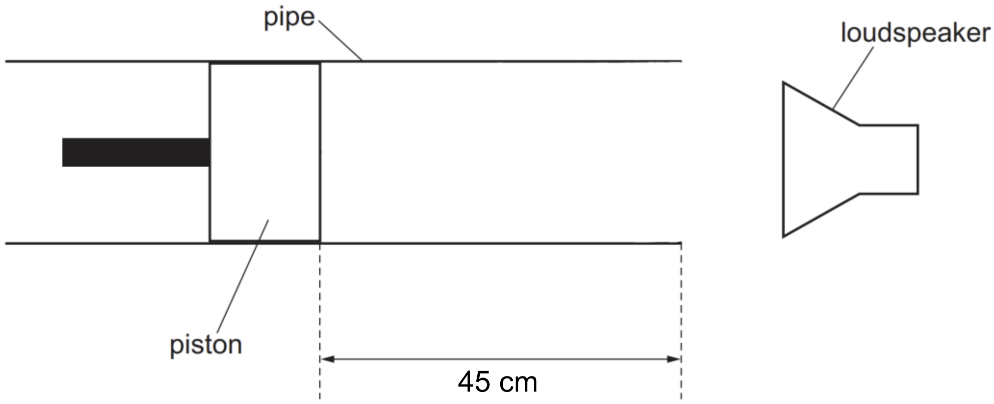

Fig. 3.2

A loudspeaker is positioned near the open end of the pipe. A loud sound is heard when the loudspeaker emits a sound wave of frequency 550 Hz. The speed of sound in the tube is measured to be 330 m s^{-1}.

(i) On Fig. 3.2, mark all the positions along the tube of

1. the displacement nodes (label these with the letter N),
2. the displacement antinodes (label these with the letter A). [2]

(ii) The frequency of the sound produced by the loudspeaker is gradually reduced.

Determine the lowest frequency at which a loud sound will be produced in the tube of length 45 cm.

frequency = …………………… Hz [2]

(iii) The piston is moved to the left. The frequency of the sound wave emitted by the loudspeaker is then changed so that a stationary wave is formed with the same number of antinodes as in **(b)(ii)**.

State and explain the change that is made to the frequency of the sound wave.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iv) An alternative, more reliable, method of measuring the speed of sound shows that 330 m s^{-1} is an underestimate. This underestimate cannot be attributed to the uncertainty in the measurement of either the frequency or the length of the pipe.

Suggest a reason that might have contributed to the underestimate.

.... [1]

(c) Two loudspeakers X and Y are connected to a signal generator and used to investigate interference. The loudspeakers emit sound waves of wavelength 0.16 m. The sound waves emitted from the two loudspeakers are in phase and have equal intensities.

The sound at point P is detected. Point P is 1.4 m from loudspeaker X and 1.8 m from loudspeaker Y, as shown in Fig. 3.3.

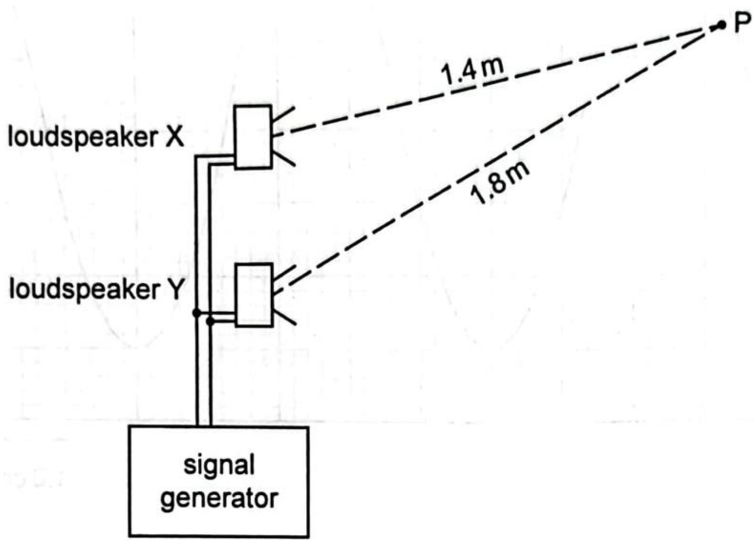

Fig. 3.3

The loudspeakers can be treated as point sources. The intensity at P of the sound from loudspeaker X is 4.5×10^{-6} W m^{-2}.

Show that the resultant intensity at point P is 2.2×10^{-7} W m^{-2}.

[3]

4 **(a)** Two charged spheres of unequal sizes, carrying charges of +*Q* and -*Q*, are positioned as shown in Fig. 4.1 below.

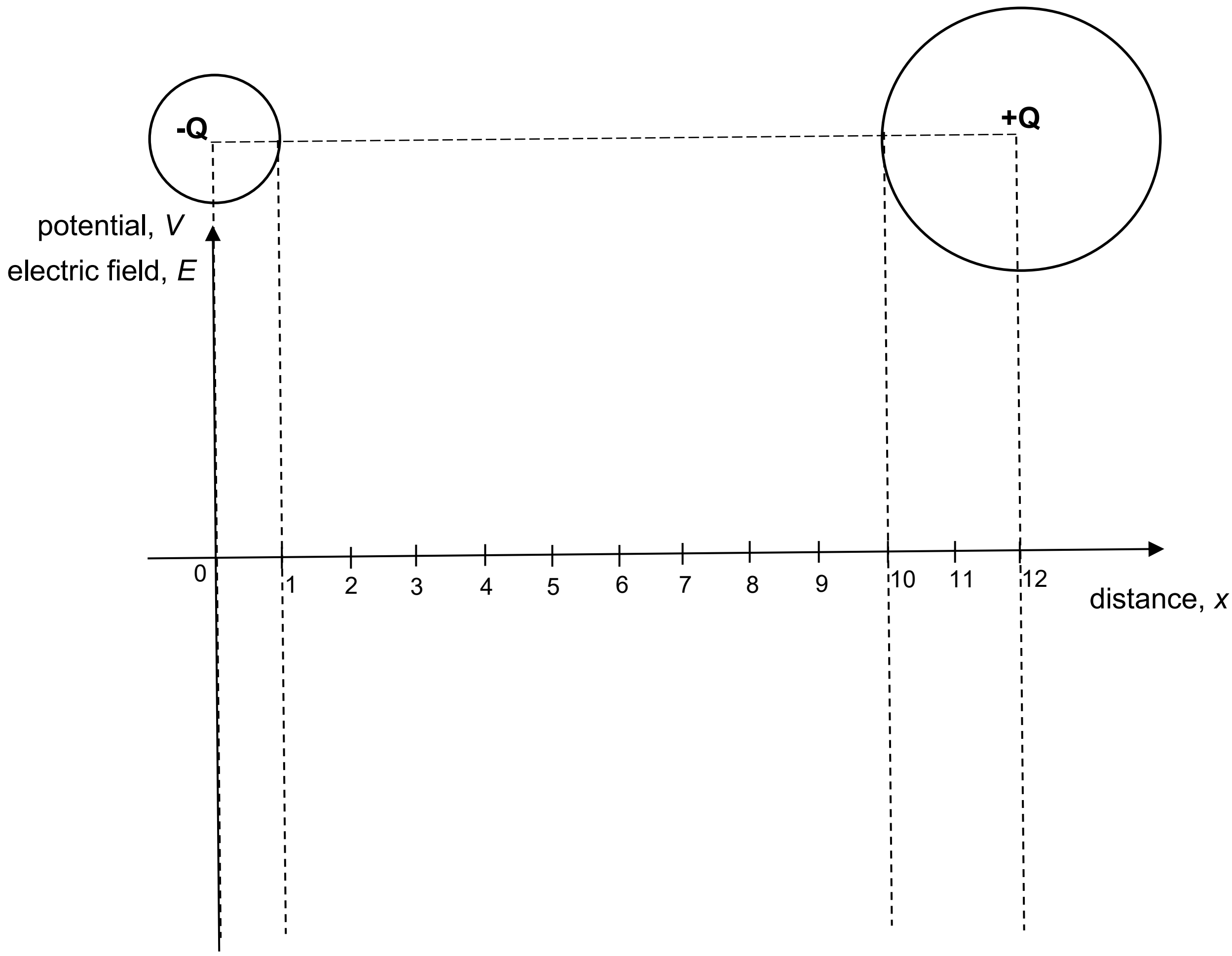

Fig. 4.1

(i) Draw the *V*-*x* graph of the two spheres on Fig. 4.1 that <u>spans from the centre of one sphere to the other</u>. Label the graph *V*. [3]

(ii) On the same figure, draw the *E*-*x* graph that spans the region <u>from 1 to 10 only</u>. Label the graph *E* and ensure that it is distinguishable from the graph in **(i)**.

Explain the position of either the turning point or the *x*-intercept of this graph.

……………………………………………………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………… [4]

(b) Two identical spherical drops of water, each carrying a charge of +2.0 × 10^{-10} C and with electric potential of 500 V on its surface, combine to form a single spherical drop.

Determine the approximate potential on the surface of the new drop formed.

potential = …………………………….. V [3]

(c) Fig. 4.2 below below shows a simple current balance set-up. The midpoints of the rectangular wire rest on two knife edges at **A** and **B**, where **AB** = **CD** = 0.15 m. There is a current of 6.0 A which enters the wire via the knife edge at **B** in the direction of **BC** and exits at the knife edge at **A**. A separate current is supplied to the solenoid to create a field which has a flux density of 35 mT.

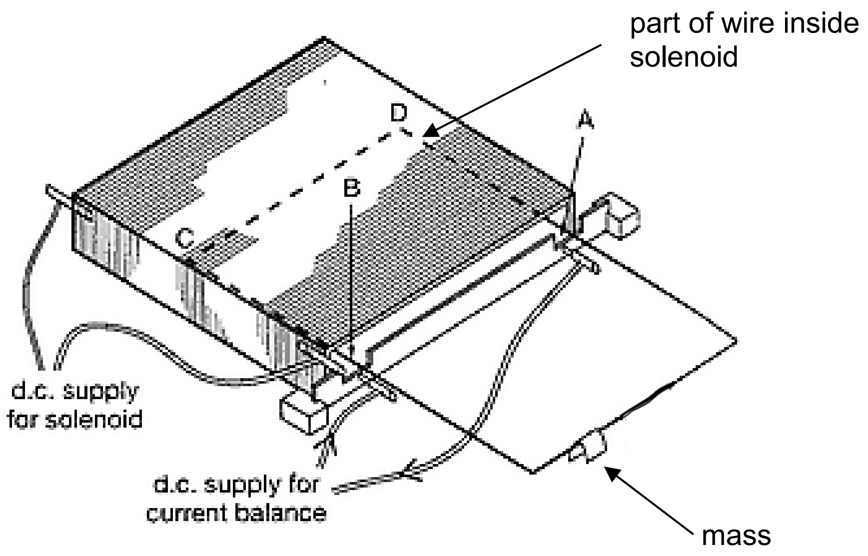

Fig. 4.2

(i) Indicate, with *an arrow*, the direction of the magnetic field on Fig. 4.2 above. [1]

(ii) Calculate the force acting on the wire at **CD**.

force = …………………………….. N [1]

(iii) Determine the mass needed to be placed on the wire at the other end for the wire to be horizontally balanced.

mass = …………………………….. kg [1]

(iv) The laboratory environment has a background magnetic field in the horizontal direction that may interfere with the set-up.

Suggest and explain how the effect due to the background magnetic field can be reduced without using any additional apparatus.

………………………………………………………………………………………...

………………………………………………………………………………………...

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

5 **(a)** Radioactive decay is both random and spontaneous.

(i) State what is meant by random.

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

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

(ii) State what is meant by spontaneous.

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

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

(iii) State **one** piece of evidence for the random nature of decay.

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

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

(b) **(i)** Describe the differences between nuclear fission and nuclear fusion.

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

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

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

(ii) Explain, with reference to the variation of binding energy per nucleon with nucleon number, why the processes of nuclear fission and nuclear fusion both result in a release of energy.

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

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

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

(c) Nuclei of an isotope of copper (Cu) each have 29 protons and 37 neutrons. This isotope is a β^- emitter.

(i) State the nuclide notation in the form ${}^{A}_{Z}X$ for this nucleus of copper.

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

(ii) The energy spectrum of the β^- radiation emitted by a sample of this isotope is shown in Fig. 5.1.

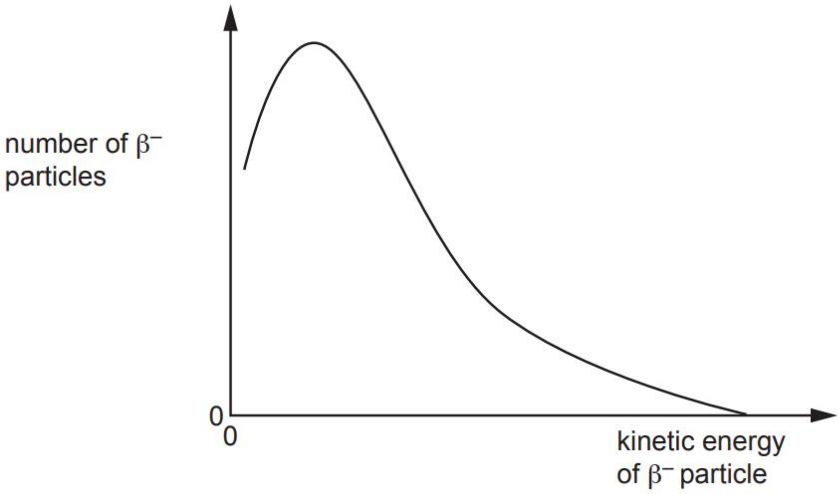

Fig. 5.1

Use Fig. 5.1 to explain why other particles apart from the β^- particles must be emitted during this decay.

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

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

(iii) In Fig. 5.1, sketch how the energy spectrum will look like if the beta decay were a two-body process. [1]

Section B

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

6 **(a)** **(i)** State the assumption of the kinetic theory of gases that explain why gas molecules could stay above ground.

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

(ii) The pressure P exerted by an ideal gas is given by the expression

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

where ρ is the density of the gas and $\langle c^2\rangle$ the mean square speed of the gas.

Starting with one gas molecule of mass, m, moving with speed c_x in the x-direction in a cubic container with length L, show how the above expression can be derived. Define any symbols used.

[5]

(b) **(i)** Explain what is meant by *specific latent heat of vaporisation.*

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

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

(ii) A sample of ethanol of mass 0.35 kg is vaporised at its boiling point of 78 °C, under an atmospheric pressure of 1.0×10^5 Pa.

Specific latent heat of vaporization = 0.95×10^6 J kg^{-1}
Density in liquid state = 790 kg m^{-3}
Density in gaseous state = 1.6 kg m^{-3}

1. Calculate the work done *by* the gas.

work done *by* gas = …………………………….. J [2]

2. Calculate the heat supplied into the system.

heat supplied into system = …………………………….. J [1]

3. Hence, calculate the increase in internal energy of the system.

increase in internal energy = …………………………….. J [2]

(c) A student determines the specific heat capacity of a liquid using the apparatus shown in Fig. 6.1 below.

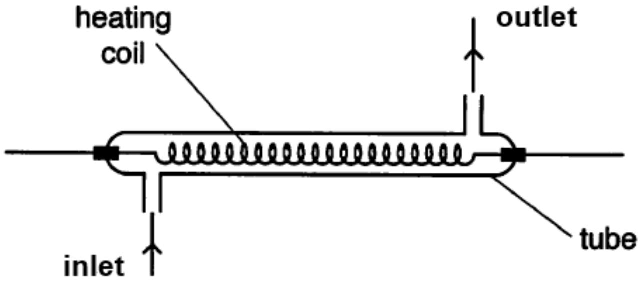

Fig. 6.1

The liquid flows through the tube at 0.15 kg min^{-1}, while the heater provides power at 25 W. The temperatures of the liquid at the inlet and outlet are 15 °C and 19 °C respectively. With the inlet and outlet temperatures unchanged, the flow rate increased to 0.23 kg min^{-1} and the power of the heater increased to 37 W.

(i) Determine the rate of heat loss of the liquid.

rate of heat loss = …………………………….. W [2]

(ii) Explain why it is necessary for the inlet and outlet temperatures to remain unchanged.

……………………………………………………………………………………………..

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

(d) The Otto Thermodynamic Cycle shows the pressure-volume (p-V) processes of internal combustion engines such as those used in airplane and car engines.

The cycle uses the following processes

A → B **Intake stroke**, gas is drawn into the cylinder at constant pressure.

B → C **Compression stroke**, *adiabatic* compression of air in the cylinder back to the original volume with no fuel added.

C → D **Rapid Combustion** at constant volume where pressure and temperature increase.

D → E **Expansion (Power) stroke**, *adiabatic* expansion as the pressure decreases.

E → B **Heat Rejection**, the ejection of spent, hot gases. The net volume change in this process is zero as the pressure adjusts back to the initial pressure.

B → A **Exhaust stroke**, as the piston moves back into the cylinder, the volume of gas decreases at constant pressure back to the initial stage.

(i) On the p-V axes below, complete the graph that represents the full Ideal Otto Cycle showing the processes **B → C → D → E → B** with the stages **C**, **D** and **E** clearly labelled. [3]

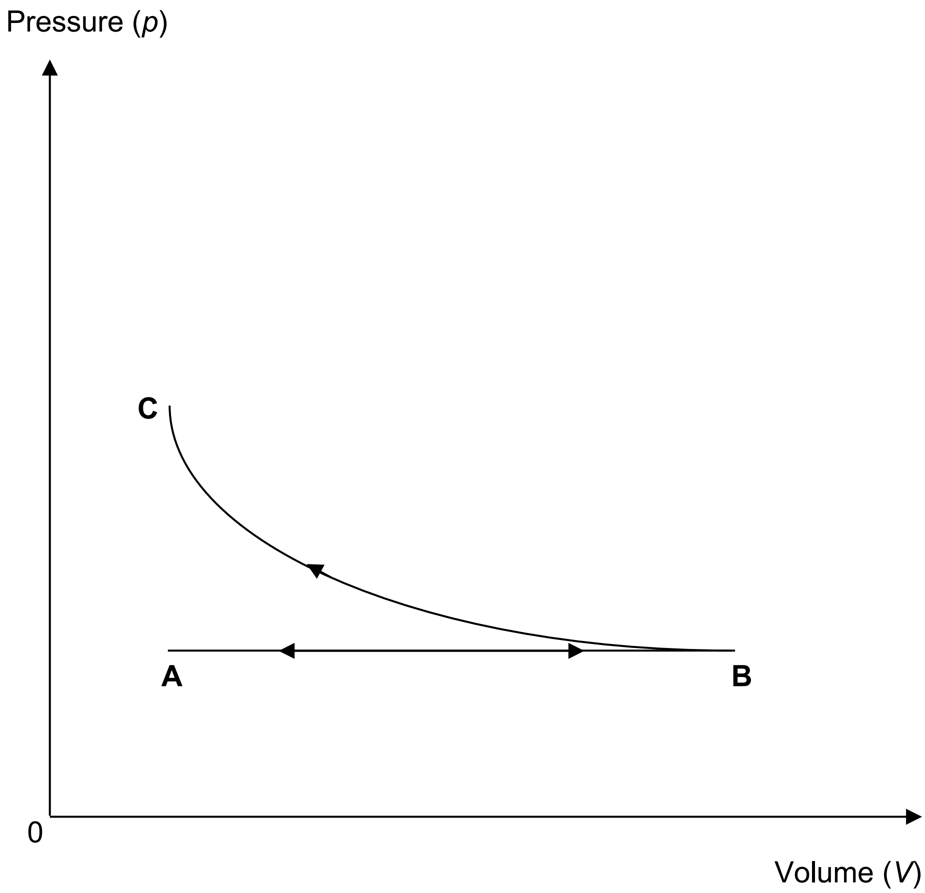

Fig. 6.2

(ii) Using a feature of the *p*-*V* diagram, describe how the power produced by the engine can be determined.

…………………………………………………………………………………………...

……………………………………………………………………………………… [1]

(iii) In reality, the *ideal* cycle does not occur due to energy losses within each process. Describe how the practical *p*-*V* diagram would differ from an ideal one.

…………………………………………………………………………………………...

……………………………………………………………………………………… [1]

7 **(a)** The EZ-Link card is a "contactless" smartcard used for payments in Singapore, especially for transportation.

Fig. 7.1 shows part of the internal circuitry and wiring of an EZ-link card. The circuitry consists of a transmitter which is connected to 3 wire loops around the edges of the card. The transmitter requires electrical energy to communicate with an external device such as a card reader. However, there is no internal power source in the card. The area of the EZ-Link card is 4.00×10^{-3} m^2.

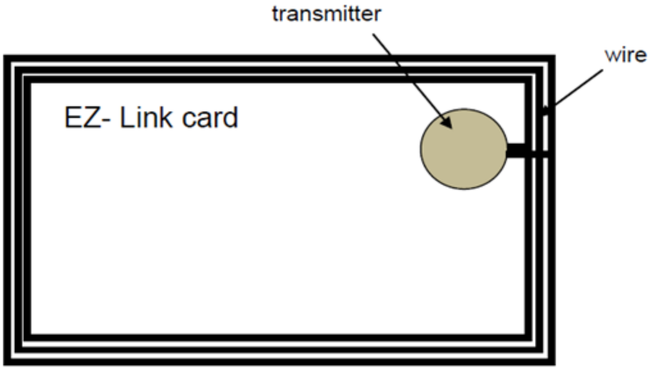

Fig. 7.1

Fig. 7.2 shows a card reader which produces a sinusoidal magnetic field of frequency 13.56×10^6 Hz.

Fig. 7.2

(i) State Faraday's Law and Lenz's Law.

Faraday's Law: ……………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Lenz's Law: ………………………………………………………………………………

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

(ii) Using Faraday's Law, explain how electrical energy is generated to power the transmitter of the EZ-link card when it is tapped onto the card reader.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) The card reader generates a magnetic field given by the equation $B = B_o \sin(2\pi ft)$.

1. Calculate the magnitude of the peak e.m.f. generated in the card in terms of B_o. Show your working clearly.

peak e.m.f. = …………………………….. B_o [3]

2. Calculate the peak magnetic flux density B_o if the card needs a r.m.s.voltage of 10.0 mV to operate.

peak magnetic flux density B_o = …………………………….. T [2]

(iv) The system is designed such that it can work if the card is tapped with either face. Explain briefly why this is possible.

………………………………………………………………………………………………

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

(b) Explain what is meant by the *root-mean-square* (r.m.s) value of an alternating current.

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

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

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

(c) A hair blower used in Singapore is rated at 240 V r.m.s., 1000 W. A student plans to bring the blower to the United States of America (USA), where the voltage is 120 V r.m.s..

(i) State one advantage of having alternating current from the mains rather than direct current.

………………………………………………………………………………………………

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

(ii) It was suggested that the student needs to bring a transformer along to USA to operate the blower.

Determine the transformer's turns ratio $\frac{N_s}{N_p}$.

$\frac{N_s}{N_p}$ = ………………………….. [1]

(iii) The primary coil of the transformer is connected to the 120 V r.m.s. supply of the USA outlet. The secondary coil is connected to the blower.

Determine the r.m.s. primary current when the blower is operating at 1000 W.

State also any assumption you have made in your working.

r.m.s. current = ………………………….. A [2]

(iv) The transformer is non-ideal and electrical energy is converted to thermal energy in the windings of the transformer at a rate of 600 W.

1. Determine the r.m.s. secondary current.

secondary current = …………………………….. A [3]

2. Calculate the efficiency of the transformer.

efficiency = …………………………….. % [1]

End of Paper

Solution for 2025 SAJC H2 Physics Prelim Paper 3

1 **(a)** constant velocity in one direction [1]
constant acceleration in the perpendicular direction to the velocity [1]

(b) **(i)** Work done by spring = Loss in elastic potential energy
$F_{ave} \times (8.0 \times 10^{-2}) = 0.24$
$F_{ave} = 3.0$ N [1]

(ii) Using Principle of conservation of energy,

Loss in Elastic PE = Gain in GPE + Gain in KE
$0.24 = mgh + ½ mv^2$ [1]
$0.24 = (4.5 \times 10^{-2})(9.81)(8.0 \times 10^{-2} \times \sin 15°) + ½(4.5 \times 10^{-2})v^2$
$v = 3.2$ m s^{-1} [1]

(iii) Using $v^2 = u^2 + 2as$,
$v^2 = 2.4^2 + 2(- 9.81 \sin 15°)(0.20)$ [1]
$v = 2.18 = 2.2$ m s^{-1}

(c) **(i)** Speed at maximum height = 2.18 cos 15° = 2.1 m s^{-1} [1]

(ii) Using $s_y = u_y t + ½ a_y t^2$, taking upward as positive,
$-0.40 = (2.18 \sin 15°)t + ½ (-9.81)t^2$ [1]
$t = 0.349 = 0.35$ s [1]

(iii) Horizontal displacement = (2.18 cos 15°)(0.349) = 0.735 m [1]

2 **(a)** $F = M_x D_x \omega_x^2 = M_y D_y \omega_y^2$
$(M)(2D)\,\omega_x^2 = (2M)(D)\,\omega_y^2$ [1]
$\omega_x = \omega_y$

(b) Gravitation force provides centripetal force
$GM(2M)/(3D)^2 = (2M)D\omega^2$
$\omega^2 = GM/(9D^3)$
$KE_x = ½\, M(2D\,\omega)^2 = 2GM^2/(9D)$ [1]
$KE_y = ½\,(2M)(D\,\omega)^2 = GM^2/(9D)$ [1]

$GPE = -\,GM(2M)/(3D)$ [1]
$E = 2GM^2/(9D) + GM^2/(9D) - GM(2M)/(3D)$
$E = -\,GM^2/(3D)$ [1]

(c) A negative total energy signifies that the system is gravitationally bound [1]

Or

The stars lack sufficient energy to overcome their mutual attraction and escape to an infinite separation.

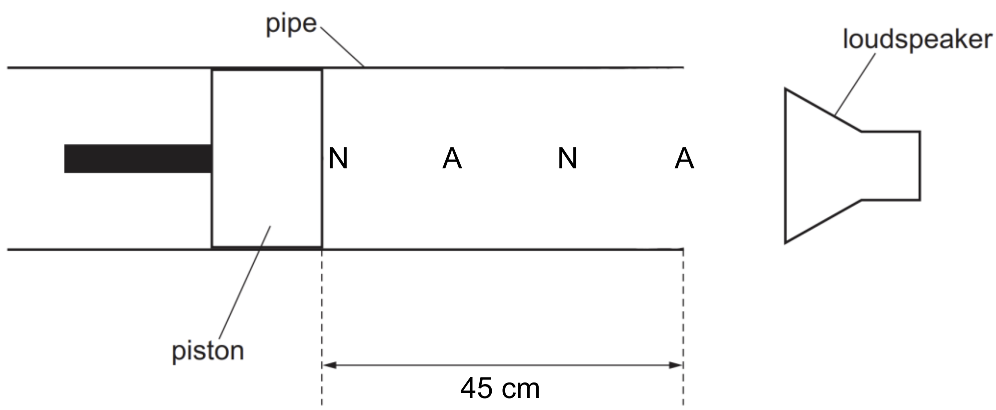
(d) Not possible since force between identical charges is repulsive and will not point towards the centre of motion. [1]

3 **(a)** **(i)** For maximum intensity, waves must be in phase at detection [1]
Phase difference at source means waves are not in phase / have 90° phase difference at O. [1]

(ii) Point B labelled on the line PQ below O and distance OB = distance OA [1]

(iii) $\lambda = (3.0 \times 10^8) / (2.5 \times 10^{10}) = 0.012$ m [1]
$x = \lambda D / a = (0.012)(2.3) / (0.18) = 0.153$ m [1]

(b) **(i)**



N at closed end and A at open end [1]
Correct number of N and A, and distance between N and A is constant [1]

(ii) Lowest frequency happens when $\frac{1}{4}\lambda = 0.45$
$\lambda = 1.8$ m [M1]
$f = 330 / 1.8 = 183$ Hz [A1]

(iii) the node-antinode distance is longer OR wavelength is longer [M1]
(speed of sound is constant so) the frequency is lower [A1]

(iv) End correction [1]

(c) Path difference = 0.4 m = 2.5 λ. Therefore, P is a minima [1]

Intensity α amplitude^2 and intensity α $(1/r)^2$, therefore amplitude α $1/r$

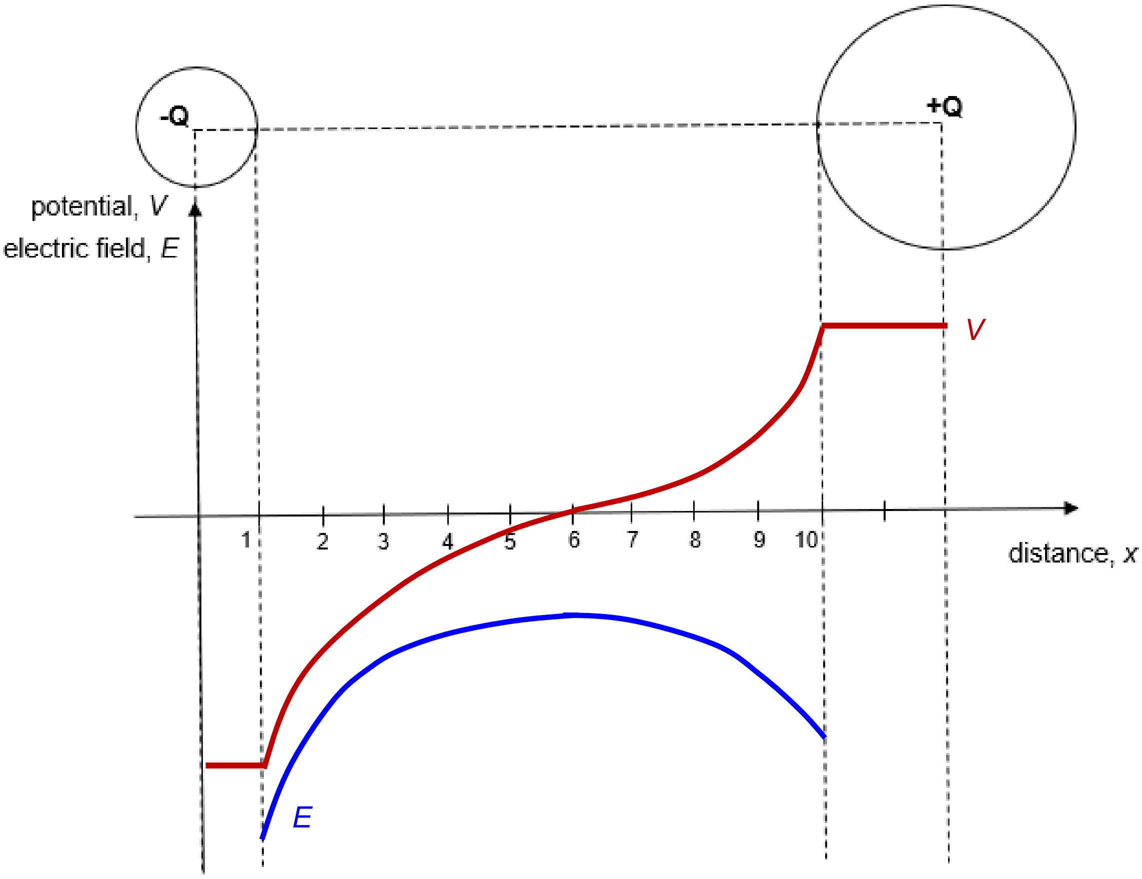
$$\frac{A_y}{A_x} = \frac{r_x}{r_y} = \frac{1.4}{1.8}$$ [1]

$$A_y = \frac{7}{9} A_x$$

$$\frac{I_{resultant}}{I_x} = \left(\frac{A_x - A_y}{A_x}\right)^2$$

$$\frac{I_{resultant}}{4.5 \times 10^{-6}} = \left(\frac{2}{9}\right)^2$$ [1]

Resultant $I = 2.22 \times 10^{-7}$ W m^{-2}



4 **(a)** **(i)** *V*-*x* graph:

Potential constant within both spheres [1]

Maximum potential for -*Q* (twice) higher than that of +*Q* [1]

Correct shape (hyperbola) and cut at 6 cm. [1]

(ii) E-x graph:

Graph is negative [1]

Magnitude of *E* at -*Q* is higher than that at +*Q*. [1]

Correct shape (hyperbola) [1]

As the spheres are taken to be point charges, the turning point of the graph is at x = 6 cm, which is in the middle of the centres of both spheres. [1]

(b) Volume, V, of each drop $\frac{4}{3}\pi r^3$, hence, $V \propto r^3$

After combining, the volume of new drop is 2V, hence,

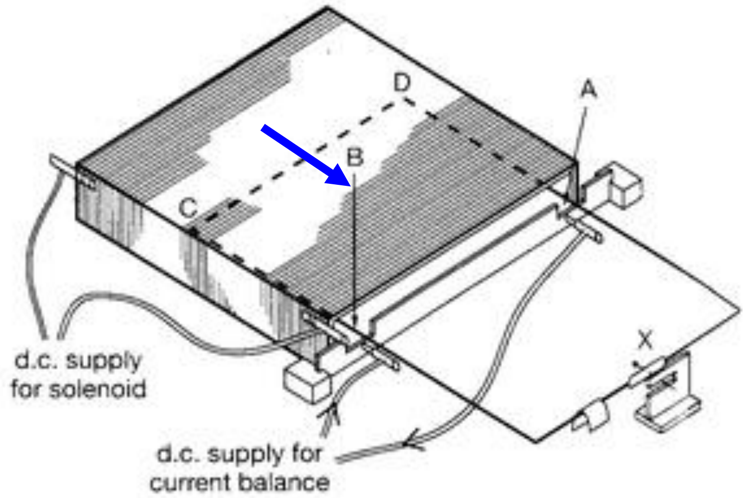
$V \propto r^3 \Rightarrow (\frac{r'}{r})^3 = \frac{2V}{V} \Rightarrow r' = (\sqrt[3]{2})r$ [1]

Potential, $V = \frac{Q}{4\pi\varepsilon_o r}$, hence,

$V \propto \frac{Q}{r} \Rightarrow \frac{V'}{V} = (\frac{Q'}{Q})(\frac{r}{r'}) = (\frac{2Q}{Q})(\frac{r}{(\sqrt[3]{2})r})$ [1]

$V' = \frac{2}{\sqrt[3]{2}}(500) = 793.7 \text{ V} = 790 \text{ (3 sf)}$ [1]

(c) **(i)**



(ii) F = BIL = (0.035)(6.0)(0.15) = 0.0315 N [1]

(iii) The perpendicular distance between the knife edge and each end is *d.*
Taking moments about **AB**,
Mg = 0.00315
M = 0.00321 kg [1]

(iv) Align the section **CD** so that it is parallel to the external magnetic field. [1]
There will be no moment caused by thus external magnetic field. [1]

5 **(a)** **(i)** cannot predict when a particular nucleus will decay [1]
or
cannot predict which nucleus will decay next

(ii) (decay is) not affected by external (environmental) factors [1]

(iii) fluctuations in (measured) count rate [1]

(b) **(i)** Any three points, 1 mark each: [3]
- large nuclei undergo fission whereas small nuclei undergo fusion
- fission involves one nucleus splitting into two (or more) (smaller) nuclei
- fusion involves two nuclei joining together to form one (larger) nucleus
- fission is (usually) initiated by neutron bombardment
- fusion is (usually) initiated by (very) high temperatures

(ii) binding energy per nucleon is greatest at nucleon numbers around 56 (may be shown on sketch graph with axes labelled 'binding energy per nucleon' and 'nucleon number') [1]

both fusion and fission involve an increase in binding energy (per nucleon) [1]

(c) **(i)** $^{66}_{29}\mathrm{Cu}$ [1]

(ii) the energy of the decay is fixed / constant [1]

the energies of the beta particles have a (continuous) range of values / varies / not constant [1]

another particle / an (anti)neutrino must possess the extra / remaining energy (difference between energy of the decay and the β kinetic energy) since total momentum has to be conserved [1]

(iii) Sharp peak at max KE, zero for all other energies (regardless of height) [1]

6 **(a)** **(i)** All collisions are perfectly elastic. [1]

(ii) Change in momentum of molecule after colliding with wall = $2mc_x$ [1]

Time between collision with the same wall = $\frac{2L}{c_x}$,

hence, by Newton's 2nd Law, force by wall on molecule = $\frac{2mc_x}{\frac{2L}{c_x}} = \frac{mc_x^2}{L}$ [1]

By Newton's 3rd Law, the molecule exerts this force on the wall and the pressure is $\frac{\text{Force on wall}}{\text{Area of wall}} = \frac{mc_x^2}{L^3}$ [1]

Extending to N molecules each with different speeds, total pressure

$$P = \frac{Nm\langle c_x^2\rangle}{L^3}$$ [1]

Since the molecules move randomly, $\langle c^2\rangle = \langle c_x^2\rangle + \langle c_y^2\rangle + \langle c_z^2\rangle = 3\langle c_x^2\rangle$,

$$P = \frac{Nm\langle c^2\rangle}{3L^3} = \frac{M\langle c^2_x\rangle}{3V}$$ where M = total mass, V = volume of cube. [1]

Hence, $P = \frac{1}{3}\rho\langle c^2\rangle$

(b) **(i)** It is the amount of heat required per unit mass to change a substance from the liquid phase to the gaseous phase without any change in temperature. [1]

(ii) **1.** Work done by the gas $= P\Delta V$

$= 1.0 \times 10^5 \left[\frac{0.35}{1.6} - \frac{0.35}{790}\right]$ [1]

$= +\,2.18 \times 10^4$ J (must be positive) [1]

2. $Q = ml_v$

$= (0.35)(0.95 \times 10^6)$

$= 3.33 \times 10^5$ J [1]

3. $\Delta U = Q + W$

$= 3.3325 \times 10^5 + (-\,2.18 \times 10^4)$ [1]

$= 3.11 \times 10^5$ J [1]

{For **3.**, suggest that if '-ve' not used for W, and the answer given is 3.54×10^5 J, one mark be awarded, ie. penalise only for wrong sign for W.}

(c) **(i)** $P = \frac{m}{t} c\Delta T + h$, where h is the rate of heat loss

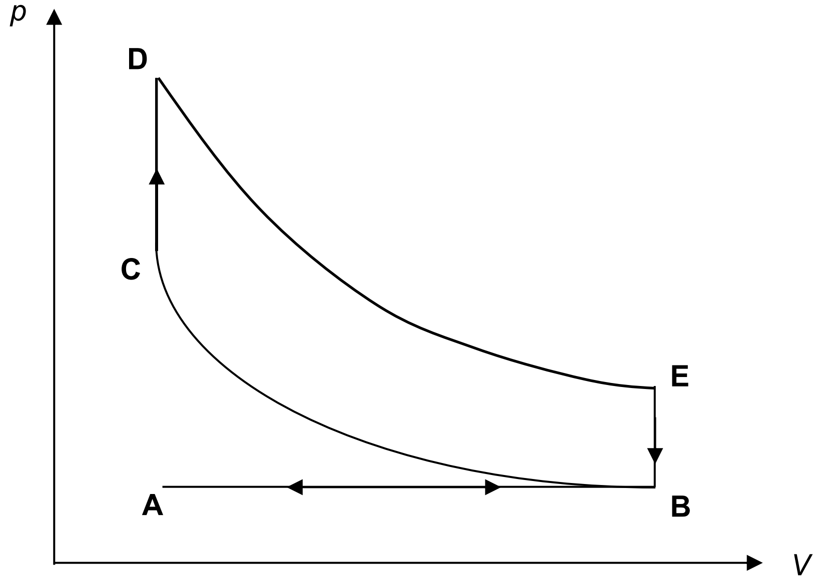
$25 = \frac{0.15}{60} c\,(19 - 15) + h$ ....(1)

$37 = \frac{0.23}{60} c\,(19 - 15) + h$ ....(2) [1]

$h = 2.50$ W [1]

(ii) The rate of heat lost would be different for each experiment causing error to the specific heat capacity calculated. [1]

(d) **(i)** **C** → **D** and **E** → **B:** Both vertical lines [1]
D → **E:** Downward curve [1]
such that **EB** is shorter than **CD** [1]



(ii) The area of the enclosed loop multiplied with the rate of the cycle (cycles per second). [1]

(iii) The area of the enclosed loop will be smaller (although the shape of the graph is unchanged). [1]

7 **(a)** **(i)** Faraday's law of electromagnetic induction states that the magnitude of the induced emf in a coil is directly proportional to the rate of change of magnetic flux linkage of the coil. [1]

Lenz's Law states that the direction of induced e.m.f. is such that its effects oppose the change which causes it. [1]

(ii) When the card is brought in range of a card reader, the varying (or sinusoidal) magnetic flux density / field generated by the card reader results in a changing magnetic flux linkage through the loops/coils of printed wire embedded in the card. [1]

By laws of electromagnetic induction, there is an emf induced in the coils (which is in the direction to oppose the varying magnetic field). [1]

The closed circuit allows the emf to induce a current (and thus supplies power to the internal transmitter, which can then send its data to the card reader). [1]

(iii) **1.** $\varepsilon = -\frac{d\emptyset}{dt} = -\frac{d(NBA\,sin2\pi ft)}{dt}$ = $- 2\pi f\ NBA\ cos\ 2\pi ft$ [1]

Peak e.m.f. $\varepsilon_o = 2\pi f\ NAB_o = 2\pi\ (13.56 \times 10^6)\ (3)\ (4.0 \times 10^{-3})B_o$ [1]

$= 1.02 \times 10^6\ B_o$ [1]

2. $V_{rms} = V_o / \sqrt{2}$ [1]

$10.0 \times 10^{-3} = 1.02 \times 10^6\ B_o / \sqrt{2}$

$B_o = 1.38 \times 10^{-8}$ T [1]

(iv) The alternating magnetic field from machine will still induce an emf with either face of the card placed on machine / Alternating current will flow regardless of which face is used to tap machine. [1]

(b) The root-mean-square value of an alternating current is the value / magnitude of a steady direct current that will dissipate energy at the same (average) rate as the alternating current in a given resistance. [1]

(c) **(i)** Alternating voltage can be stepped up or down easily. [1]

(ii) Step-up transformer with turns ratio $\frac{N_s}{N_p}$ = 240/120 = 2.0 [1]

(iii) Assuming no power losses in the transformer, [1]

P = IV

$1000 = 120\ I_p$

$I_p = 8.33$ A [1]

(iv) 1. By conservation of energy,

Power supplied to primary coil

= Power output from secondary coil + power loss in windings of transformer

= 1000 + 600 = 1600 W [1]

Output voltage of transformer V_s= 240 V

Secondary current = 1000 / 240 [1]

= 4.17 A [1]

2. efficiency = 1000/1600 x 100% = 62.5 % [1]