YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE NAME			
CG		INDEX NO	

PHYSICS

9749/03

Paper 3 Longer Structured Questions

11 September 2024

2 hours

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

READ THESE INSTRUCTIONS FIRST

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

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

Section A
Answer **all** questions.
Section B
Answer **one** question only.

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

For Examiner's Use	
Paper 3	
Section A	
1	**/12**
2	**/11**
3	**/7**
4	**/12**
5	**/9**
6	**/9**
Section B	
7	**/20**
8	**/20**
Penalty	
Paper 3 Total	
	/80

This document consists of **28** printed pages and **4** blank pages.

[Turn over

Data

speed of light in free space, c = 3.00×10^{8} m s^{-1}

permeability of free space, μ_0 = $4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space, ε_0 = 8.85×10^{-12} F m^{-1}

$(1/(36\pi)) \times 10^{-9}$ F m^{-1}

elementary charge, e = 1.60×10^{-19} C

the Planck constant, h = 6.63×10^{-34} J s

unified atomic mass constant, u = 1.66×10^{-27} kg

rest mass of electron, m_e = 9.11×10^{-31} kg

rest mass of proton, m_p = 1.67×10^{-27} kg

molar gas constant, R = 8.31 J K^{-1} mol^{-1}

the Avogadro constant, N_A = 6.02×10^{23} mol^{-1}

the Boltzmann constant, k = 1.38×10^{-23} J K^{-1}

gravitational constant, G = 6.67×10^{-11} N m^{2} kg^{-2}

acceleration of free fall, g = 9.81 m s^{-2}

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

hydrostatic pressure, $p = \rho g h$

gravitational potential, $\phi = -\frac{Gm}{r}$

temperature, $T/K = T/^{\circ}C + 273.15$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle C^2 \rangle$

mean translational kinetic energy of an ideal gas molecule, $E = \frac{3}{2}kT$

displacement of particle in s.h.m. $x = x_o \sin \omega t$

velocity of particle in s.h.m., $v = v_o \cos \omega t$

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

electric current, $I = Anvq$

resistors in series, $R = R_1 + R_2 + \ldots\ldots\ldots$

resistors in parallel, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$

electric potential, $V = \frac{Q}{4\pi\varepsilon_o r}$

alternating current/voltage, $x = x_o \sin \omega t$

magnetic flux density due to a long straight wire, $B = \frac{\mu_o I}{2\pi d}$

magnetic flux density due to a flat circular coil, $B = \frac{\mu_o N I}{2r}$

magnetic flux density due to a long solenoid, $B = \mu_o n I$

radioactive decay, $x = x_o \exp(-\lambda t)$

decay constant, $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** A particular type of slide for children in a theme park is called a 'drop slide'. This is a slide in which the first part of the fall is vertical. Fig.1.1 shows a child of mass 52 kg on a drop slide.

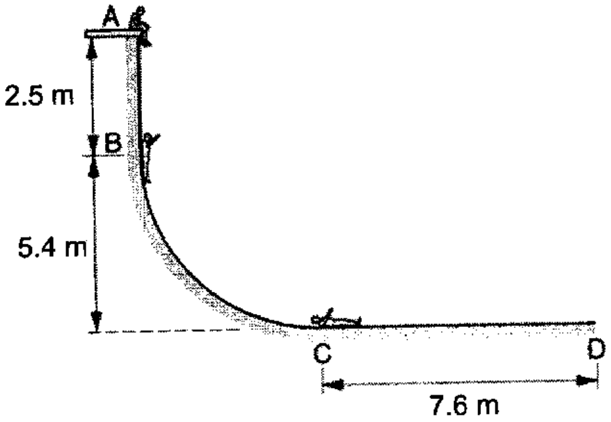

Fig.1.1 (not to scale)

The child drops from A, a distance of 2.5 m, before reaching the surface of the slide at B. There is no resistive force from A to B.

He then travels down a bend from B to C, while falling a further vertical distance of 5.4 m. At C, the child's speed is the same as it was at B.

After this, the child travels 7.6 m horizontally before stopping at D.

(i) Determine the speed of the child at C.

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

(ii) The speed is the same at B and C.

Describe the energy changes from A to B to C.

....

....

.... [2]

(iii) Calculate the average frictional force slowing the man between C and D.

force = ... N [2]

(b) Fig.1.2 shows a 'swing ride' in a carousel, where a man sitting on the rotating swing tilts away from the axis of rotation.

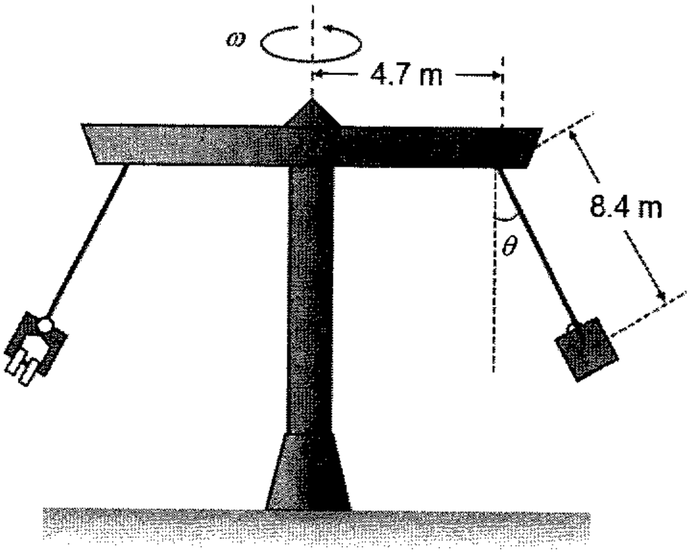

Fig. 1.2 (not to scale)

(i) Explain why the supporting cable holding the chair tilts as the carousel rotates.

....

....

....

.... [2]

(ii) Treat the man and his seat as one entity. Draw and label all the forces acting on it in Fig. 1.3 as the carousel rotates with a constant angular speed.

Fig. 1.3

[1]

(iii) Calculate the necessary angular speed ω for the swings to assume an angle $\theta = 35^\circ$ with the vertical.

angular speed = ... rad s^{-1} [3]

[Total: 12]

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2 **(a)** State the *first law of thermodynamics*.

....

....

.... [1]

(b) An ideal gas undergoes a cycle of changes as shown in Fig. 2.1.

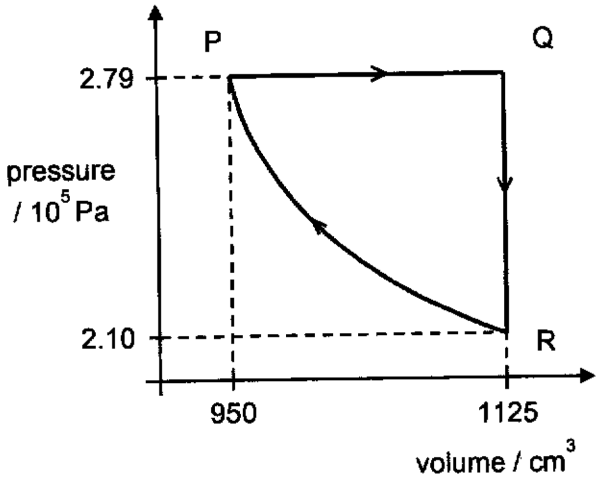

Fig. 2.1

The gas is initially at point P. It is heated, and its volume increases at constant pressure to point Q. The gas is allowed to cool at constant volume to R. It then undergoes a compression back to P.

(i) For the gas shown in Fig. 2.1, determine

1. the work done **on** the gas from P to Q.

work done = ... J [2]

2. the heat loss to the surrounding from Q to R.

heat loss = ... J [3]

(ii) There is no heat exchange between the gas and the surrounding when the gas changes from point R to P.

Using the first law of thermodynamics, state and explain if the temperature increases, decreases or stays the same during the change from point R to P.

....

....

....

.... [2]

(iii) The molar heat capacity of the gas is the amount of heat supplied to 1 mol of gas to raise its temperature by 1 K.

For the transition from P to Q, the molar heat capacity of the gas is 20.8 J mol^{-1} K^{-1} and its temperature at P and Q are 350 K and 414 K respectively.

Determine the heat supplied to the gas in this transition.

heat supplied = ... J [3]

[Total: 11]

3 A pendulum consists of a bob (small metal sphere) attached to the end of a piece of string. The other end of the string is attached to a fixed point. The bob oscillates with small oscillations about its equilibrium position, as shown in Fig. 3.1.

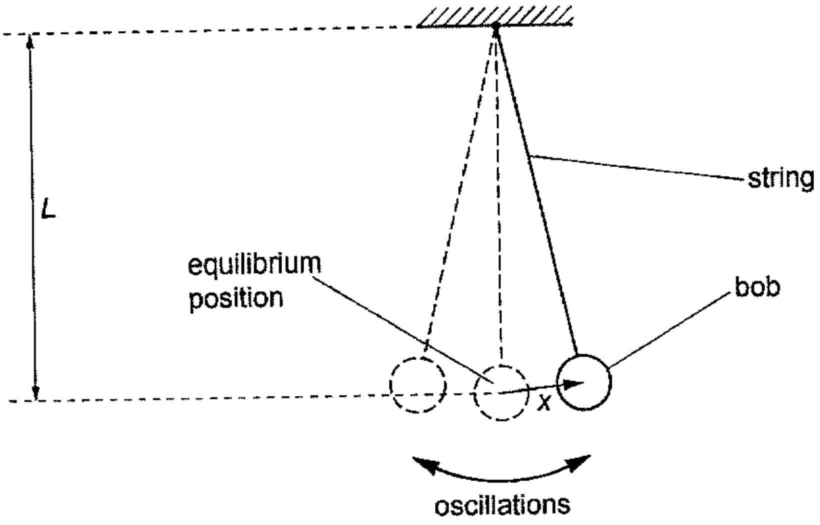

Fig. 3.1

The length L of the pendulum, measured from the fixed point to the centre of the bob, is 1.24 m. The acceleration a of the bob varies with its displacement x from the equilibrium position as shown in Fig. 3.2.

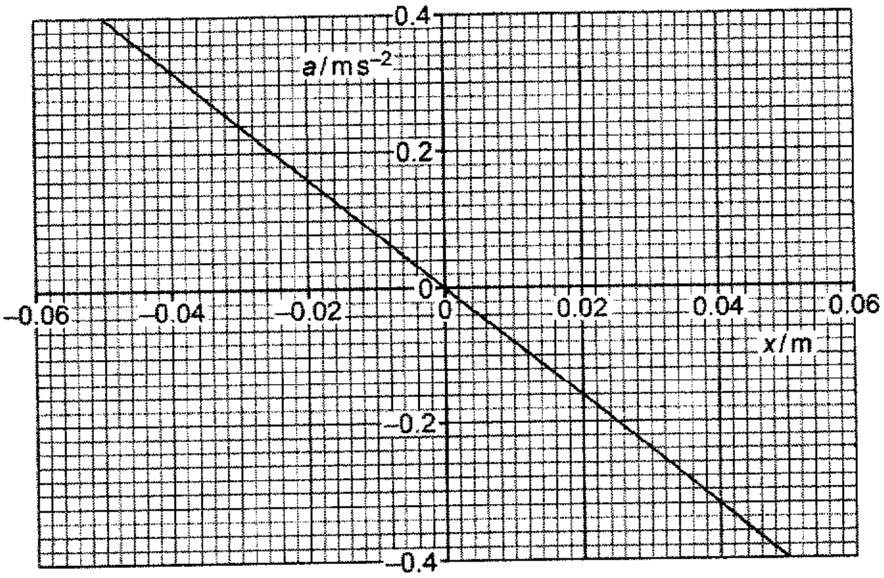

Fig. 3.2

(a) State how Fig. 3.2 shows that the motion of the pendulum is simple harmonic.

....

....

.... [2]

(b) The angular frequency ω is related to the length L of the pendulum by

$$\omega = \sqrt{\frac{k}{L}}$$

where k is a constant.

Use Fig. 3.2 to determine k.

k = ... m s^{-2} [3]

(c) While the pendulum is oscillating, the length of the string is increased in such a way that the total energy of the oscillations remains constant.

Suggest and explain qualitatively the effect of this change on the amplitude of the oscillations.

....

....

.... [2]

[Total: 7]

4 **(a)** State Coulomb's law.

....

....

.... [1]

(b) A charged sphere X is supported on an insulating stand. A second charged sphere Y is suspended by an insulating thread so that sphere Y is in equilibrium at the position shown in Fig. 4.1.

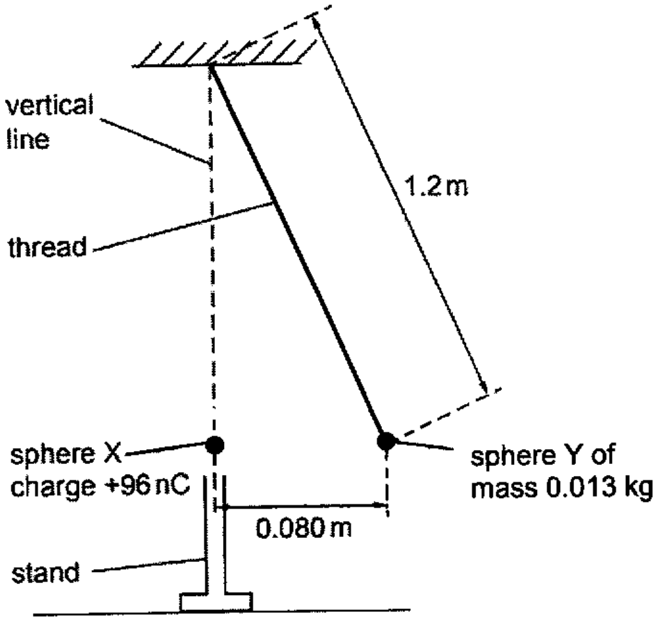

Fig. 4.1

The charge on sphere X is +96 nC and the mass of sphere Y is 0.013 kg.
Assume that the spheres behave as point charges.

The length of the thread is 1.2 m and the centres of sphere X and sphere Y are separated horizontally by a distance of 0.080 m.

(i) Show that the charge on sphere Y is +63 nC.

[2]

(ii) Hence, determine the net potential at the mid-point between sphere X and sphere Y.

potential = ... V [2]

(c) An electron, with a speed of 2.0×10^7 m s^{-1}, enters the region between two parallel plates P and Q, that are separated by a distance of 18 mm, as shown in Fig. 4.2. The length of the parallel plate is 20 cm.

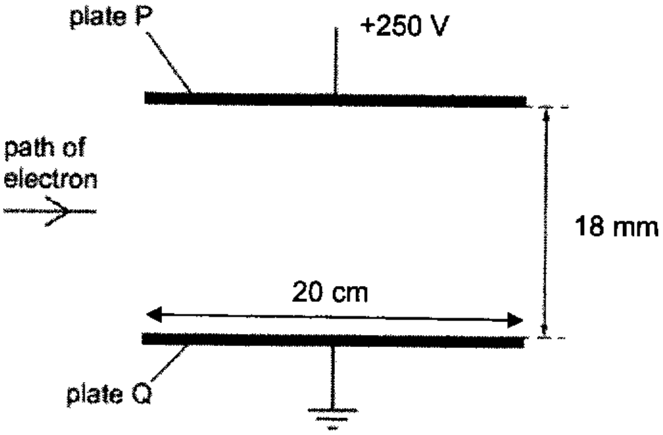

Fig. 4.2 (not to scale)

The space between the plates is a vacuum.

The potential difference between the plates is 250 V. The electric field may be assumed to be uniform in the region between the plates and zero outside this region.

(i) Show that the acceleration of the electron within the parallel plate is 2.4×10^{15} m s^{-2}.

[2]

(ii) Determine the speed with which the electron leaves the parallel plates.

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

(iii) State and explain the difference in the path if a proton enters the parallel plates with the same initial velocity instead of the electron.

....

....

.... [2]

[Total: 12]

5 **(a)** The variation with potential difference V of the current I in a semiconductor diode is shown in Fig. 5.1.

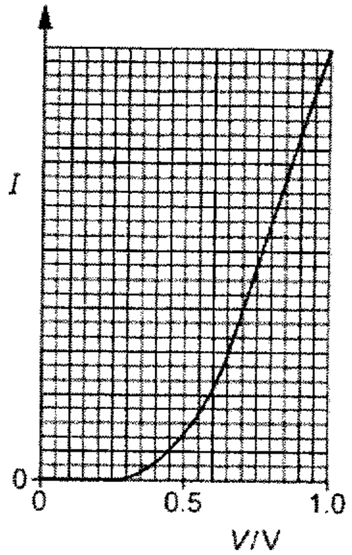

Fig. 5.1

Use Fig. 5.1 to describe qualitatively,

(i) the resistance of the diode in the range $V = 0$ to $V = 0.25$ V, and

....

.... [1]

(ii) the variation, if any, in the resistance of the diode as V changes from $V = 0.75$ V to 1.0 V.

....

.... [1]

(b) A battery of electromotive force (e.m.f.) 6.2 V and internal resistance 2.0 Ω is connected in a circuit to a uniform resistance wire, a voltmeter, a fixed resistor and a switch, as shown in Fig. 5.2.

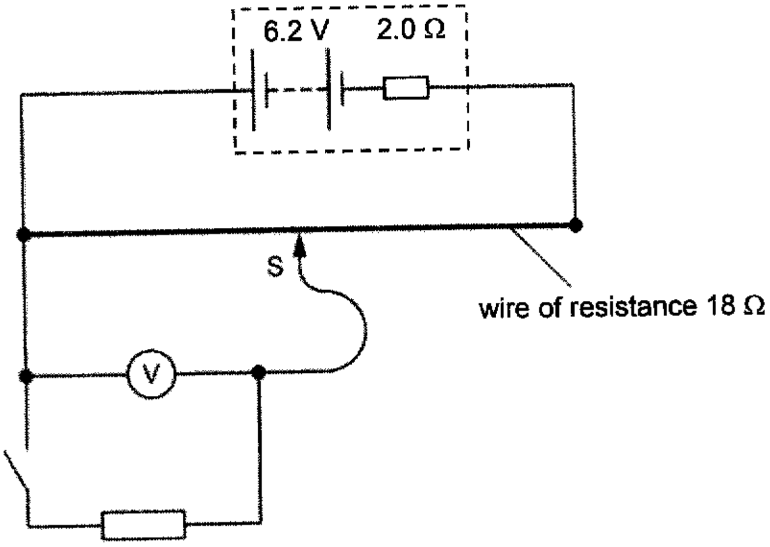

Fig. 5.2

The resistance wire has resistance 18 Ω, length 0.94 m and diameter 0.30 mm.

(i) Calculate the resistivity ρ of the material of the resistance wire.

ρ = ... Ω m [1]

(ii) The slider S is positioned half-way along the length of the wire. The switch is open.

Determine the reading on the voltmeter.

voltmeter reading = ... V [2]

(iii) The switch is now closed.

State whether there is an increase, decrease or no change to

1. the current in the battery, and

....

2. the voltmeter reading.

....

[2]

(c) The circuit in **(b)** is altered by changing the battery for one of a different e.m.f.

The switch is open.

A student records the following data for the resistance wire:

current in the wire	0.93 A
mean drift speed of charge carriers	1.3×10^{-3} m s^{-1}
number density of charger carriers	9.0×10^{28} m^{-3}

(i) Determine the charge q of a charge carrier in the wire suggested by this data.

q = ... C [1]

(ii) With reference to the value of q, explain why the data by the student cannot be correct.

....

.... [1]

[Total: 9]

6 **(a)** Negative ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field and are deflected in a semi-circular arc, as shown in Fig. 6.1.

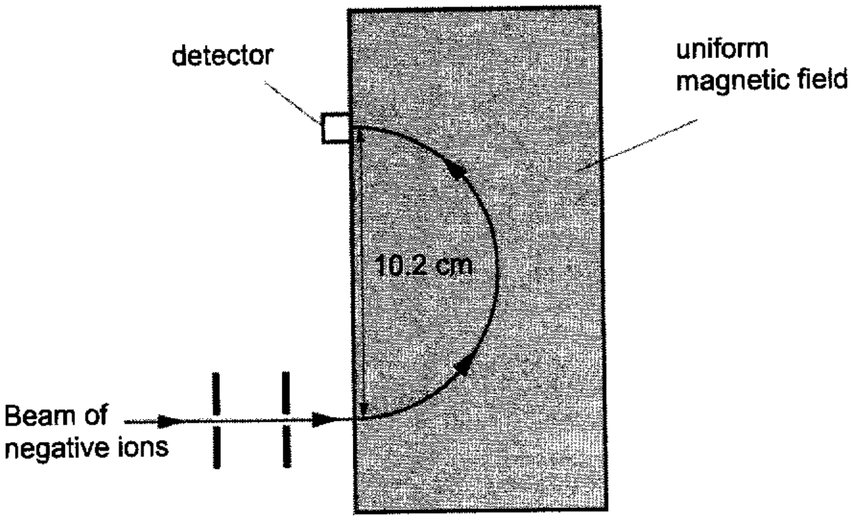

Fig. 6.1

The ions, travelling at a constant speed 5.6×10^5 m s^{-1}, are detected at a detector when the diameter of the arc in the magnetic field is 10.2 cm.

(i) Explain why the path of the particle in the magnetic field is the arc of a circle.

....

....

....

.... [2]

(ii) With reference to Fig. 6.1, state the direction of the magnetic field.

.... [1]

(iii) The ions have mass 20u and charge of magnitude 1.60×10^{-19} C (where u is the unified atomic mass unit).

Determine the value of magnetic flux density. Explain your working.

magnetic flux density = ... T [3]

(b) A uniform electric field is now switched on in the same region as the magnetic field in **(a)**. The magnitude of the electric field is adjusted so that the ion moves undeviated through the two fields.

(i) On Fig 6.1, draw an arrow to show the direction of the electric field. [1]

(ii) Determine the magnitude of the electric field strength.

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

[Total: 9]

Section B

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

7 **(a)** Two balls X and Y are supported by long strings, as shown in Fig. 7.1

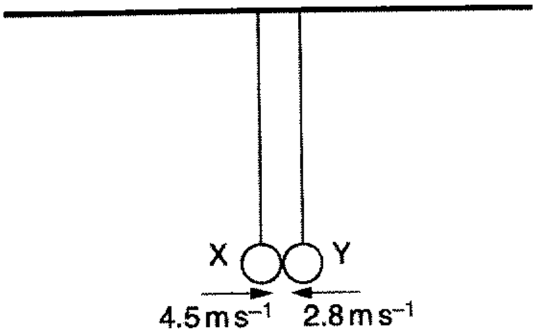

Fig. 7.1

The balls are each pulled back and released towards each other. When the balls collide at the position shown in Fig. 7.1, the strings are vertical, and the ball rebound in opposite directions.

Table 7.1 shows the mass and velocity data for X and Y before and after this collision.

Table 7.1

ball	mass / g	velocity just before collision / m s^{-1}	velocity just after collision / m s^{-1}
X	50	+4.5	–1.8
Y	*M*	–2.8	+1.4

(i) Determine the mass *M* of Y.

mass = ... g [2]

(ii) State what is meant by an elastic collision.

....

.... [1]

(iii) Hence, or otherwise, by showing relevant calculations, determine if the collision in Fig. 7.1 is elastic or inelastic.

....

.... [2]

(iv) A student said that it is possible for both balls to be concurrently stationary at some point in the collision.

State and explain if this is possible.

....

....

.... [2]

(b) A block of mass 0.50 kg slides in a straight line with a constant speed of 0.25 m s^{-1} along a horizontal surface, as shown in Fig. 7.2.

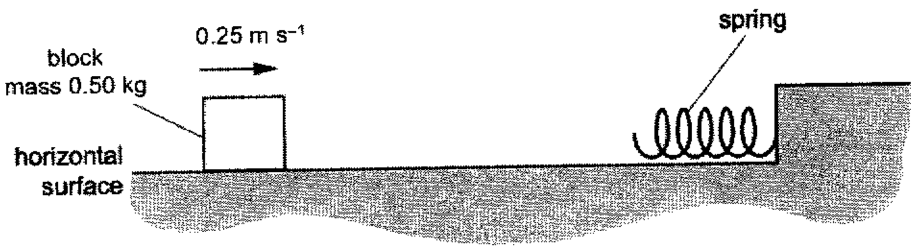

Fig. 7.2

Assume that there are no resistive forces opposing the motion of the block.

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

The variation of the compression *x* of the spring with the force *F* applied to the spring is shown in Fig. 7.3.

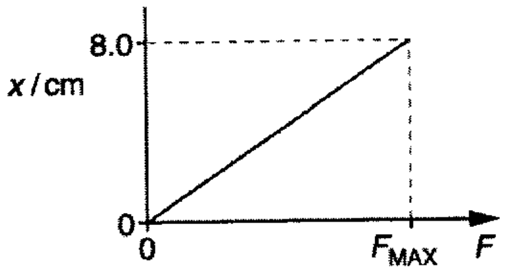

Fig. 7.3

(i) On Fig. 7.3, shade the area on the graph that represents the maximum elastic potential energy stored in the spring.

[1]

(ii) Hence, calculate the maximum force F_{MAX} applied on the spring.

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

(iii) The spring is replaced with another spring that is stiffer.

On Fig. 7.3, sketch the compression-force curve of the new spring.

[2]

(c) The Republic of Singapore Navy operates 4 Invincible class submarines, as seen in Fig. 7.4. The submarine displaces 2.2×10^6 kg of sea water when it is completely submerged. At neutral buoyancy, the weight of the submarine is equal to its upthrust. The submarine has 2 ballast tanks located at the front and back of the submarine respectively. Each ballast tank has a volume of 50 m^3, which can be partially or completely filled with sea water or air.

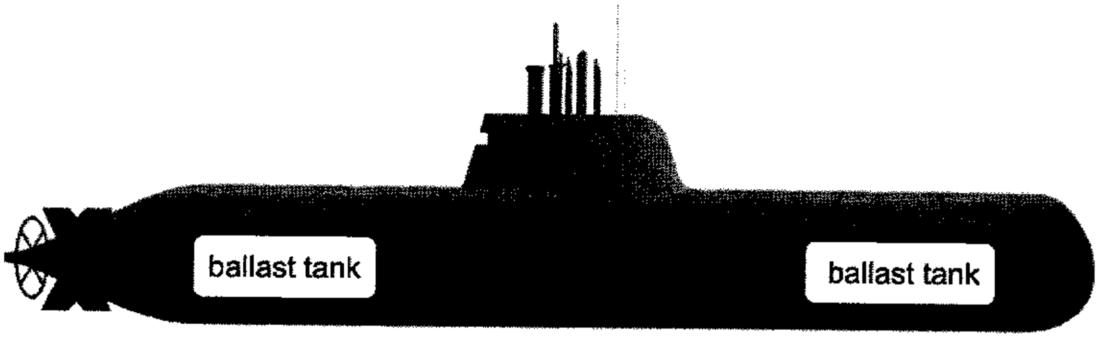

Fig 7.4

At neutral buoyancy, both ballast tanks are 25% filled with sea water. To descend, the submarine pumps air out of the 2 ballast tanks and fills them completely with sea water.

(i) Given that the density of sea water is 1030 kg m^{-3}, show that the increase in weight of the submarine when the ballast tanks are filled from 25% to 100% with sea water is 7.6×10^5 N.

[1]

(ii) Hence, calculate the maximum acceleration of the submarine.

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

(iii)

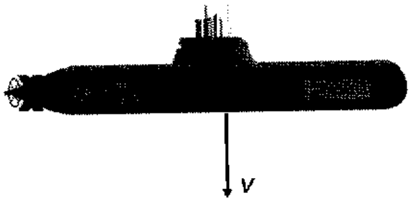

Fig. 7.5

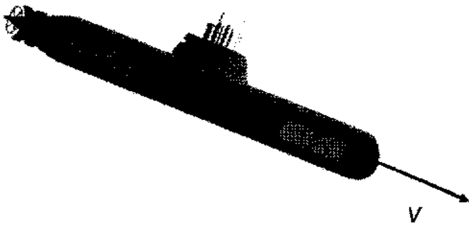

Fig. 7.6

In practice, the submarine does not descend vertically downwards (Fig. 7.5) but descends by moving forward at a downward angle (Fig 7.6).

Explain why this method allows the submarine to descend at a faster rate.

....

....

.... [2]

(iv) Dive planes are installed on both side of the submarine. Each dive plane can be rotated about an axis such that its front edge points upwards or downwards. In Fig. 7.7, the submarine is travelling rightwards, and the dive plane is angled downwards. As a result, the water flowing past the dive plane is deflected upwards, and the submarine can assume the dive angle seen in Fig. 7.6.

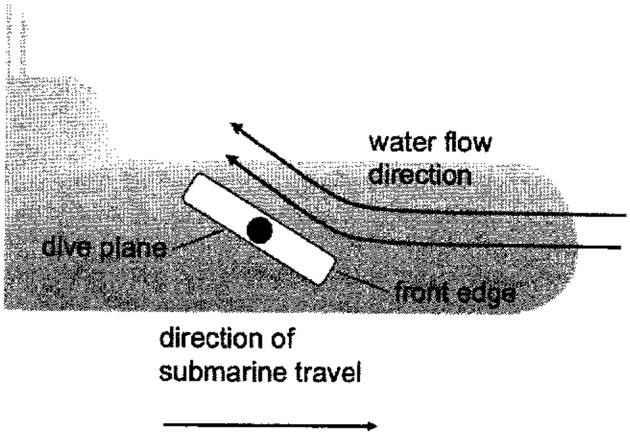

Fig. 7.7

By considering Newton's laws of motion, explain how the angled dive plane helps the submarine achieve the dive angle seen in Fig. 7.6.

....

....

....

.... [3]

[Total: 20]

8 **(a)** The data for iron-56 ($^{56}_{26}Fe$) nucleus is given below.

Mass of proton = 1.00728 u

Mass of neutron = 1.00866 u

Mass of iron-56 nucleus = 55.92132 u

Show that the binding energy per nucleon of iron-56 nucleus is 8.8 MeV. Explain your answer clearly.

[3]

(b) Fig. 8.1 shows the variation with nucleon number (mass number) *A* of the binding energy per nucleon E_B of nuclei.

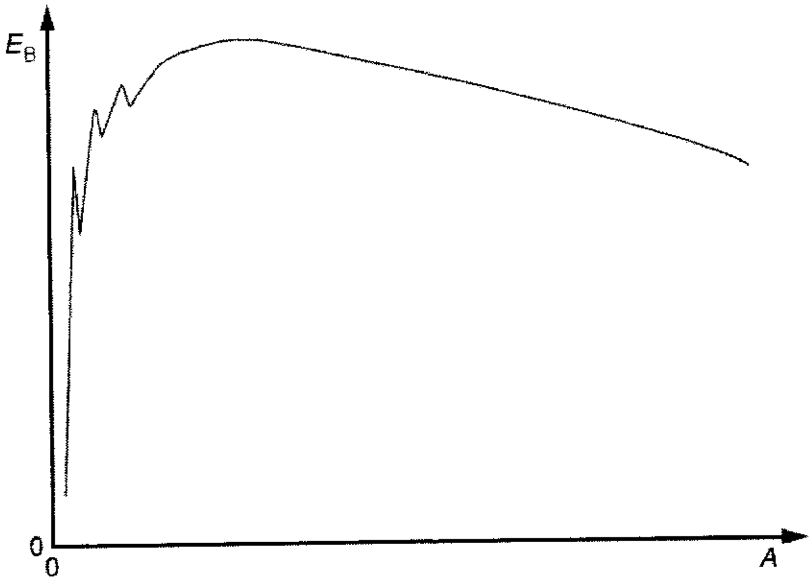

Fig 8.1

(i) On Fig 8.1, label the approximate position of iron-56 with the symbol Fe.

[1]

(ii) The nuclear fusion process in a particular star is described by

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + X.$$

1. State the particle X.

.... [1]

2. Using Fig. 8.1, explain why the mentioned nuclear fusion process will result in a release of energy.

....

....

....

.... [2]

(iii) Table 8.1 shows the mass defects of three nuclei.

Table 8.1

nucleus	mass defect / u
$^{2}_{1}H$	0.002388
$^{3}_{1}H$	0.009105
$^{4}_{2}He$	0.030377

Determine the energy released when one nucleus of $^{4}_{2}He$ is formed in this fusion reaction.

energy released = ... J [2]

(c) Thorium-234 ($^{234}_{90}\text{Th}$) undergoes β-decay to form an isotope of protactinium-234 (Pa).

The emitted β-particles have a range of energies up to a maximum value.

Use conservation laws to explain why this range of energies leads to the suggestion that another particle is emitted by the decaying thorium-234 nucleus together with the β-particle.

....

....

....

....

....

.... [3]

(d) The variation with time *t* of the number of unstable nuclei *N* in a sample of Thorium is shown in Fig. 8.2.

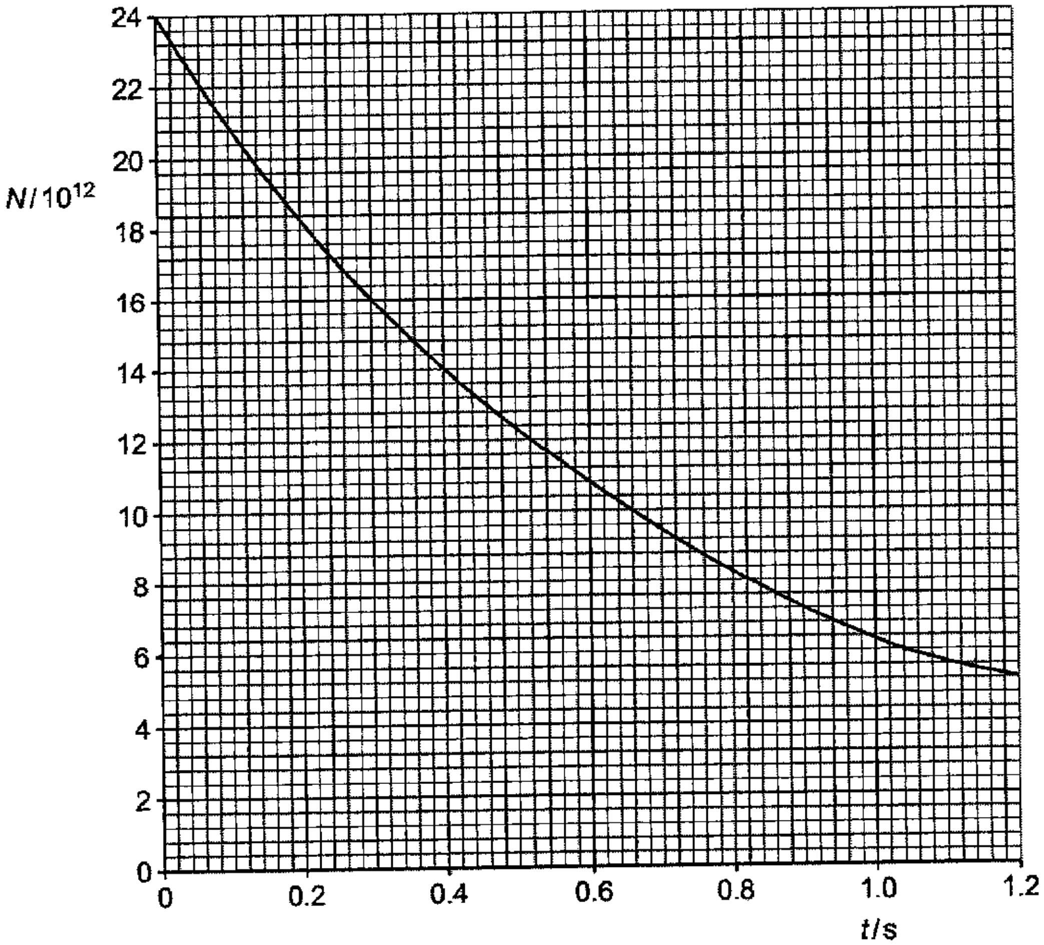

Fig. 8.2

At time t = 0 s, the sample contains only Thorium-234.

(i) Use Fig. 8.2 to determine the decay constant λ of Thorium-234.

λ = ... s^{-1} [2]

(ii) Assuming that protactinium-234 is stable, on Fig. 8.2, sketch a line to show the variation with time t of the number of protactinium nuclei in the sample. Label this line P.

[2]

(iii) Determine the activity at time t = 1.5 s of the sample of Thorium-234.

activity = ... Bq [3]

(iv) A Geiger counter is used to measure the count rate at t = 1.5 s, explain why the value recorded is lower than the answer found in **(d)(iii)**.

....

.... [1]

[Total: 20]

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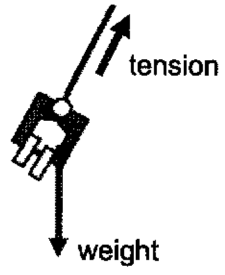
2024 JC2 Prelim Exam H2 Physics Paper 3 Solution

1	(a)	(i)	Because the speed at B is the same at C, the gain in KE is due to the loss of GPE from A to B only. Gain in KE in the end = Loss in GPE from A to B $\frac{1}{2}mv^2 = mgh$ $v = \sqrt{2gh} = \sqrt{2(9.81)(2.5)}$ $= 7.0 \text{ m s}^{-1}$	C1 A1
		(ii)	From A to B, the gravitational potential energy drop is converted to kinetic energy of the child. From B to C, the further loss in gravitational potential energy is not converted into kinetic energy but dissipated as work done against contact friction (or thermal energy and sound). Thus, the child's speed is unchanged.	B1 B1
		(iii)	Work done against friction $= Fs$ $Fs = \text{loss of KE from C to D}$ $= KE_C - KE_D$ $F(7.6) = \frac{1}{2}(54)(7.0)^2 - 0$ $F = 168 \text{ N (3sf)}$ **OR** $v^2 = u^2 + 2a_{ave}s$ $0 = 7.0^2 + 2a_{ave}(7.6)$ average accel., $a_{ave} = -3.22 \text{ m s}^{-2}$ Average frictional force $= ma_{ave} = (52)(3.22)$ $= 168 \text{ N}$	M1 A1 (M1) (A1)
	(b)	(i)	When the carousel rotates, the chair and its occupant will travel in a straight-line if not for the cable attached to it. A horizontal (centripetal) force is required in order to pull the man towards the centre. This is provided by the horizontal components of the tension on the cable holding the chair. Thus, the cable has to tilt to provide for the needed centripetal force.	M1 A1
		(ii)	 All forces must be indicated and labelled in words (not in letters or symbols). Tension on cable and gravitational force (or weight) on person and seat. Deduct mark if FBD includes *centripetal* or *centrifugal* force, *normal* force or any irrelevant forces.	B1

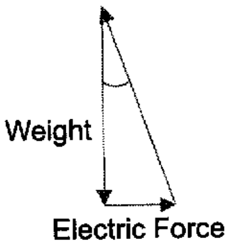
		(iii)	Along the y-direction: $T\cos\theta = mg$ (balanced) Along the x-direction: $T\sin\theta = mr\omega^2$ (unbalanced due to centripetal rotation) $r = 4.7 + 8.4\sin 35° = 9.518$ m $\tan\theta = \frac{mr\omega^2}{mg} = \frac{r\omega^2}{g}$ $\tan 35° = \frac{(9.518)\omega^2}{9.81}$ $\omega = 0.85$ rad s^{-1}	**C1** **C1** **A1**

2	**(a)**			The first law of thermodynamics states that the increase in internal energy of a system is the sum of the heat (thermal energy) supplied to the system and the work done on the system.	**B1**
	(b)	**(i)**	**1.**	$W_{on} = -P\Delta V$ $= -(2.79\times10^5)[(1125-950)\times10^{-6}]$ $= -48.825 = -48.8$ J (3sf) Max 1m for positive answers.	**C1** **A1**
			2.	$\Delta U = Q_{in} + W_{on}$ $W_{on} = 0$, since no volume change for Q → R $Q_{in} = \Delta U = \Delta\left(\frac{3}{2}pV\right)$ $= \frac{3}{2}\left[(2.10\times10^5)(1125\times10^{-6}) - (2.79\times10^5)(1125\times10^{-6})\right]$ $= -116.44$ $Q_{loss} = -Q_{in} = 116$ J (3sf) Max 2m for negative answers, but do not penalize if same type of mistake in **1.**	**C1** **C1** **A1**
		(ii)		Since there is no heat loss/gained, and there is (positive) work done on the gas through the compression (decrease in volume), the internal energy will increase. Hence, the temperature will increase.	**M1** **A1**

		(iii)	At point P: $pV = nRT$ $(2.79\times10^{5})(950\times10^{-6}) = n(8.31)(350)$ $n = 0.09113 = 0.091$ mol (2sf)	**B1**
			OR At point Q: $pV = nRT$ $(2.79\times10^{5})(1125\times10^{-6}) = n(8.31)(414)$ $n = 0.09124 = 0.091$ mol (2sf)	**(B1)**
			$Q = nC(\Delta T)$ $= 0.091(20.8)(414-350)$	**C1**
			$= 121$ J (3sf)	**A1**
			OR $\Delta U = \frac{3}{2}nR\Delta T = W_{on} + Q_{in}$ $\frac{3}{2}(0.091)(8.31)(414-350) = -48.8 + Q_{in}$	**(C1)**
			$Q_{in} = 121$ J (3sf)	**(A1)**

3	**(a)**		The graph shows a linear line passing through the origin. This shows that acceleration is proportional to displacement.	**B1**
			The graph shows a negative gradient. This means that acceleration and displacement is always in opposite direction.	**B1**
	(b)		$a = -\omega^2 x$ Hence, using one of the data point (−0.04,0.32), $0.32 = -\omega^2(-0.04)$	**C1**
			$\omega^2 = 8.0$ $\omega = \sqrt{\frac{k}{L}} \Rightarrow k = \omega^2 L$ $k = (8.0)(1.24)$	**C1**
			$= 9.92$ m s^{-2}	**A1**
	(c)		Increasing the length decreases the angular frequency.	**M1**
			Since total energy of oscillation = $\frac{1}{2}m\omega^2 x_0^{\ 2}$, and total energy does not change, the amplitude is inversely proportional to angular frequency^2. increasing the length will increase the amplitude of oscillation.	**A1**

4	**(a)**		Coulomb's law states that the magnitude of the electric force between two point charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of their separation.	**B1**

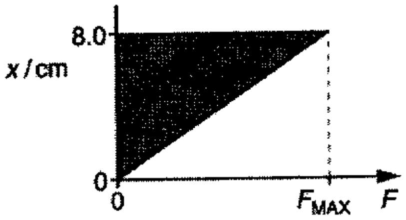
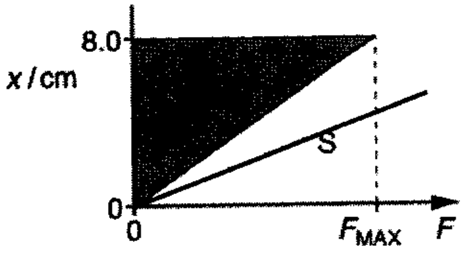
	(b)	(i)	Electric force, $F_E = \frac{96\times10^{-9}\times Q_Y}{4\times\pi\times8.85\times10^{-12}\times0.080^2}$ angle to the vertical, $\theta=\sin^{-1}\left(\frac{0.080}{1.2}\right)(=3.823^\circ)$ $F_E = mg\tan\theta$ $=(0.013)(9.81)\tan(3.823^\circ)$ OR $=(0.013)(9.81)\left[\frac{0.080}{\sqrt{1.2^2-0.080^2}}\right]$  $\frac{96\times10^{-9}\times Q_Y}{4\times\pi\times8.85\times10^{-12}\times0.080^2}=(0.013)(9.81)\tan(3.823^\circ)$ $Q_Y = 63$ nC (shown)	M1 M1 A0
		(ii)	$\phi_{net}=\frac{96\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.040}+\frac{63\times10^{-9}}{4\times\pi\times8.85\times10^{-12}\times0.040}$ $=21580+14162$ $=3.57\times10^4$ V	C1 A1
	(c)	(i)	$E=\frac{V}{d}=\frac{250}{0.018}\left(=1.389\times10^4\text{ V m}^{-1}\right)$ $a=\frac{F}{m}=\frac{qE}{m}=\frac{\left(1.6\times10^{-19}\right)\left(1.389\times10^4\right)}{\left(9.11\times10^{-31}\right)}$ $=2.4\times10^{15}\text{ m s}^{-2}\ (2\text{sf})$	M1 M1 A0
		(ii)	time taken to travel through the parallel plates = length/ speed $=\frac{20\text{ cm}}{2.0\times10^7}\left(=1.0\times10^{-8}\text{ s}\right)$ final vertical speed $=u_y+a_yt=0+\frac{F}{m}t$ $=\left(2.4\times10^{15}\right)\left(1.0\times10^{-8}\right)$ $\left(=2.4\times10^7\text{ m s}^{-1}\right)$ speed $=\sqrt{\left(2.0\times10^7\right)^2+\left(2.4\times10^7\right)^2}$ $=3.1\times10^7\text{ m s}^{-1}$	C1 C1 A1
		(iii)	The polarity of the charge is different, so the force will be in the opposite direction to that of the electron. Hence, the proton will be deflected down instead of up. The mass of the proton is heavier than that of the electron, so the acceleration is lower. Hence, the deflection will be less than that of the electron.	B1 B1

5	(a)	(i)	Resistance is infinite / very high	B1
		(ii)	Resistance decreases as V increases (Ratio of V/I increases)	B1
	(b)	(i)	$R = \rho L/A$ $\rho = (18\times\pi(0.15\times10^{-3})^2/0.94$ $= 1.4\times10^{-6}\ \Omega$ m	B1

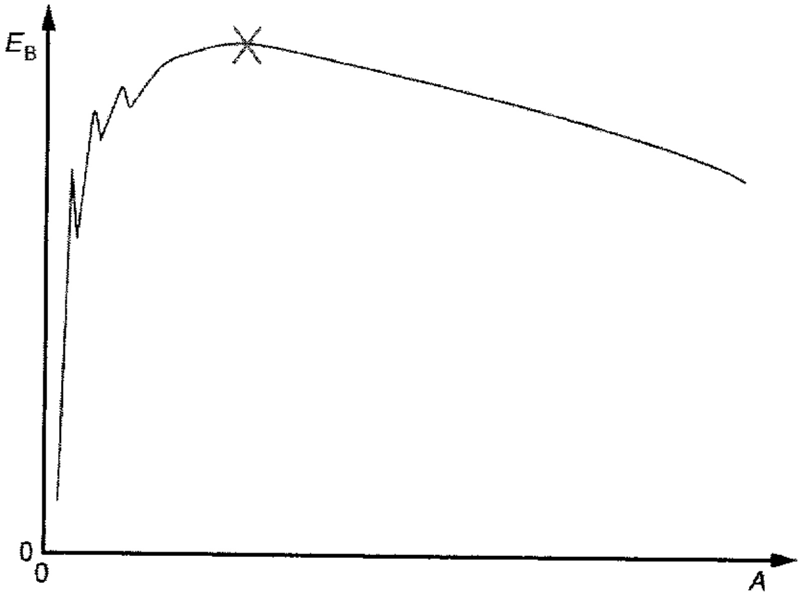
		(ii)	p.d. across wire = $\frac{18}{18+2.0}(6.2) = 5.58$ V Since S is at the mid-point, pd across half the length of the wire = ½ (5.58) Voltmeter reading = 2.8 V	**C1** **A1**
		(iii)	Current in the battery: increase Voltmeter reading: decrease	**B1** **B1**
	(c)	**(i)**	$I = Anvq$ $q = 0.93/[(\pi(0.15 \times 10^{-3})^2) \times (9.0 \times 10^{28}) \times (1.3 \times 10^{-3})]$ $= 1.1 \times 10^{-19}$ C	**A1**
		(ii)	The charge carriers in a metal wire are the electrons which has a charge of 1.6 × 10^{-19} C. Charge q is less than 1.6 × 10^{-19} C the elementary charge. So the value must be wrong	**B1**

6	**(a)**	**(i)**	Since the velocity is always right angle to the magnetic field, by Fleming's left hand rule, the magnetic force always be right angle to its velocity. The force only changes the direction of the motion and not its speed. This results in circular motion.	**B1** **B1**
		(ii)	Out of page	**B1**
		(iii)	The magnetic force provides the centripetal force $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr} = \frac{(20 \times 1.66 \times 10^{-27})(5.6 \times 10^5)}{(1.6 \times 10^{-19})(0.051)}$ $B = 2.3$ T	**B1** **C1** **A1**
	(b)	**(i)**	Upwards	**B1**
		(ii)	$qE = Bqv$ $E = Bv = (2.3)(5.6 \times 10^5)$ $= 1.3 \times 10^6$ V m^{-1}	**C1** **A1**

7	**(a)**	**(i)**	$m_x u_x + m_Y u_Y = m_x v_x + m_Y v_Y$ $50(4.5) + M(-2.8) = 50(-1.8) + M(1.4)$ $M = 75$ g	**M1** **A1**
		(ii)	Total kinetic energy of the system before and after collision is the same.	**B1**

		(iii)	Using KE: $\frac{1}{2}m_x u_x^2 + \frac{1}{2}m_x u_x^2 = \frac{1}{2}\left[0.050(4.5)^2 + 0.075(-2.8)^2\right] = 0.80 \text{ J}$ $\frac{1}{2}m_x v_x^2 + \frac{1}{2}m_x v_x^2 = \frac{1}{2}\left[0.050(-1.8)^2 + 0.075(1.4)^2\right] = 0.15 \text{ J}$ Since final KE < initial KE, inelastic collision **OR** Using relative speed $u_X - u_Y = 4.5 - (-2.8) = 7.3 \text{ m s}^{-1}$ $v_Y - v_X = 1.4 - (-1.8) = 3.2 \text{ m s}^{-1}$ Since relative speeds are not the same, inelastic collision	**M0** **M1** **A1** **(M0)** **(M1)** **(A1)**
		(iv)	Since total initial momentum is not zero, having both objects concurrently at rest means that instantaneous total momentum is zero. Hence, not possible due to conservation of linear momentum	**B1** **B1**
	(b)	(i)		**B1**
		(ii)	$\Delta KE = \Delta EPE$ $\frac{1}{2}mv^2 = \frac{1}{2}F_{MAX}x$ $\frac{1}{2}(0.50)(0.25)^2 = \frac{1}{2}F_{MAX}(0.080)$ $F_{MAX} = 0.39 \text{ N}$	**M1** **A1**
		(iii)	 B1: Line should be less steep B1: Line should extend further rightward than original	**B1** **B1**
	(c)	(i)	Net increase in weight when ballasts are completely filled with sea water from 25% full: $\Delta W = 0.75(2 \times 50)(1030)(9.81)$ $\Delta W = 757822.5 = 7.6 \times 10^5 \text{ N}$	**M1** **A0**

		(ii)	New mass of submarine $m = 2.2\times10^6 + \frac{757822.5}{9.81} = 2277250$ kg $a = \frac{\Delta W}{m} = \frac{757822.5}{2277250}$ $a = 0.33$ m s^{-2}	**M1** **A1**
		(iii)	When the submarine descends at an angle, the surface area that is considered for drag is smaller. Hence the downward component of velocity of the submarine is higher when it is descending at an angle.	**M1** **A1**
		(iv)	The water molecules gain an upward momentum after impact with the angled dive plane. Hence by N2L, an upward force is exerted on the water molecules due to the dive plane. By N3L, a downward force is exerted on the dive plane by the water molecules, resulting in the submarine being pushed downwards	**M1** **A1** **B1**

8	**(a)**		Binding energy = [Total mass of the unbounded nucleons - mass of iron nucleus]c^2 $\text{BE} = \left[(26\times1.00728 + 30\times1.00866) - 55.92132\right]uc^2$ $= (0.52776)(1.66\times10^{-27})(3\times10^8)^2$ $= 7.88\times10^{-11}$ J BE per nucleon $= \frac{7.88\times10^{-11}}{56} = 1.4\times10^{-12}\text{J} = \frac{1.4\times10^{-12}}{1.6\times10^{-19}}$ eV $= 8.8$ MeV	**B1** **M1** **M1** **A0**
	(b)	**(i)**	Near to the highest point on the graph 	**B1**
		(ii)1.	Neutron	**B1**
		(ii)2.	Since the nucleus are of nucleon numbers less that Fe-56, base on the graph, the binding energy per nucleon increases with higher nucleon number. The energy used to break the hydrogen isotopes are thus less than the energy released use to form helium nucleus	**B1** **B1**

		(iii)	Energy released = BE of products – BE of reactants = (mass defect of products - mass defect of reactants)c^2 = $(0.030377 - 0.002388 - 0.009105)uc^2$ = 2.8×10^{-12} J	 C1 A1
	(c)		If there is no other particle, beta particle would always have the same energy. By conservation of energy and momentum, there must be another particle to share energy/momentum	B1 M1 A1
	(d)	(i)	Comparing the interval between N = 12 x 10^{12} and N = 12 x 10^{12}, $\Delta t = 0.52$ s Therefore, half-life = 0.52 s $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{0.52}$ $= 1.3\ \text{s}^{-1}$	 M1 A1
		(ii)	Check that number of thorium + protactium is always N (marker to check they intersect at 12, and two more values to add to 24 x 10^{12}) Increasing graph with decreasing gradient	B1 B1
		(iii)	initial activity $= (\lambda)$(initial number of nucleons) $= (1.3)(24 \times 10^{12})(= 3.1 \times 10^{13})$ Activity at 1.5 s $= 3.1 \times 10^{13} e^{-(1.3)(1.5)}$ $= 4.4 \times 10^{12}$ Bq	C1 C1 A1
		(iv)	The Geiger counter was only used to count the radioactive particle that enters the GM tube. Since the radioactive particle are released in random direction, not all the radioactive particle us captured by the counter.	B1