YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME

CG

INDEX NO

PHYSICS

8867/02

Paper 2 Structured Questions

9 September 2024

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and class 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 any **one** question only.

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	
Paper 2	
Section A	
1	**/ 8**
2	**/ 10**
3	**/ 10**
4	**/5**
5	**/10**
6	**/17**
Section B	
7	**/20**
8	**/20**
Penalty	
Paper 2 Total	
	/80

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

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
elementary charge	e	=	1.60×10^{-19} C
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
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-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	=	$u^2 + 2as$
resistors in series	R	=	$R_1 + R_2 + \ldots\ldots\ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots$

BLANK PAGE

Section A

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

1 **(a)** Under certain conditions, the distance s moved in a straight line by an object in time t is given by

$$s = \frac{1}{2}at^2$$

where a is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 ……………………………………………………………………………………………………

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

(b) The variation with time t of the velocity v of a car that is moving in a straight line is shown in Fig. 1.1.

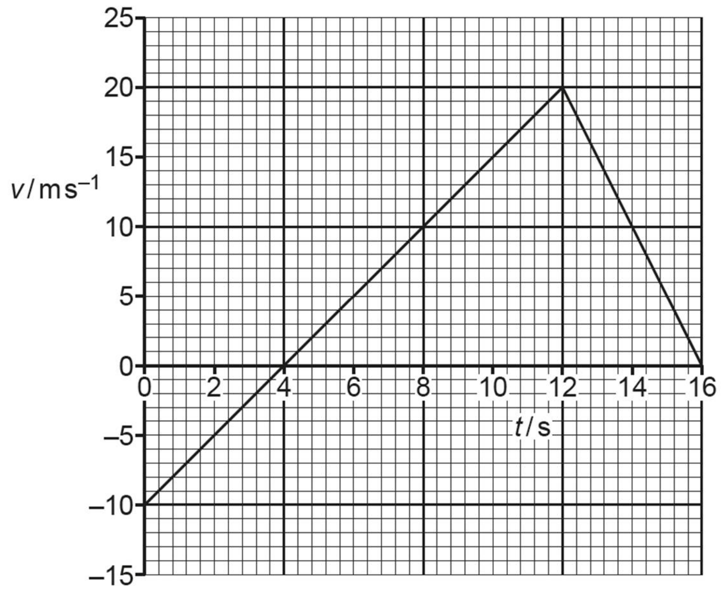

Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time t = 8.0 s and at time t = 14.0 s in terms of

magnitude, and

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

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

direction.

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

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

(ii) Determine the magnitude of the average acceleration of the car between time t = 0 to t =16.0 s.

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

(iii) The car is at point X at time t = 0 s.

Determine the magnitude of the displacement of the car from X at time t = 12.0 s.

displacement = ... m [2]

[Total: 8]

2 **(a)** State the *principle of conservation of momentum*.

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

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

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

(b) Two metal blocks A and B move along a horizontal frictionless surface to the right, as shown in Fig. 2.1.

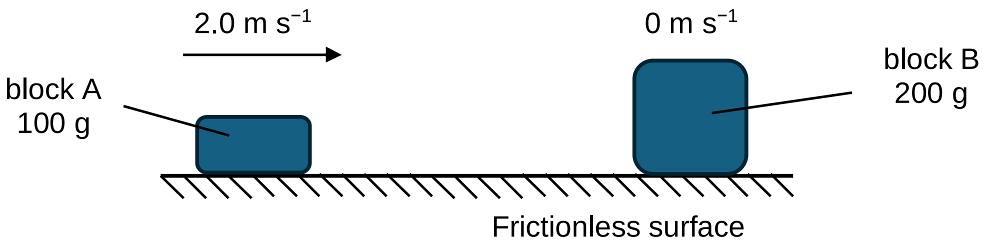

Fig. 2.1

Block A is 100 g and moves to the right with a velocity of 2.0 m s^{-1}. Block B is 200 g and initially at rest. After block A collides with the block B, block B moves off with a velocity of 1.3 m s^{-1} to the right.

(i) Determine the magnitude and direction of the velocity *v* of block A after the collision.

magnitude of *v* = ……………………… m s^{-1}

direction of *v* = ………………………… [3]

(ii) By showing appropriate calculations, explain whether the collision is elastic or inelastic.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(c) By using the relevant Newton's laws of motion, state and explain the relationship between the rate of change of momentum of one block and that of the other block.

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

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

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

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

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

[Total: 10]

3 A 60 cm wide wall mounted tabletop is attached to a wall at hinge A as shown in Fig. 3.1. The uniform tabletop weighs 130 N.

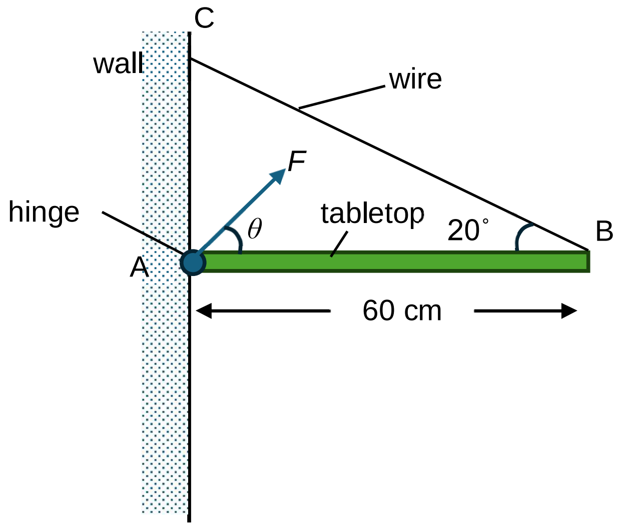

Fig. 3.1

It is supported by a light metal wire that is attached to the table at B. The hinge exerts a force F at an angle θ above the horizontal tabletop.

(a) **(i)** State the conditions necessary for the tabletop to be in equilibrium.

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

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

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

(ii) Hence, explain why the hinge at A cannot only exert a horizontal normal contact force.

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

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

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

(b) **(i)** Calculate the tension in the wire.

tension = …………………. N [2]

(ii) Hence, determine the magnitude of the force F and the angle θ.

F = ……………………… N

θ = …………………… ˚ [4]

[Total: 10]

4 Fig. 4.1 shows a light inextensible rope that passes over a light smooth pulley with a system of two blocks having the same dimension with masses 4.0 kg and 2.0 kg are attached to its two ends. The two blocks are initially at rest with the 4.0 kg block held 20.0 cm above the 2.0 kg block.

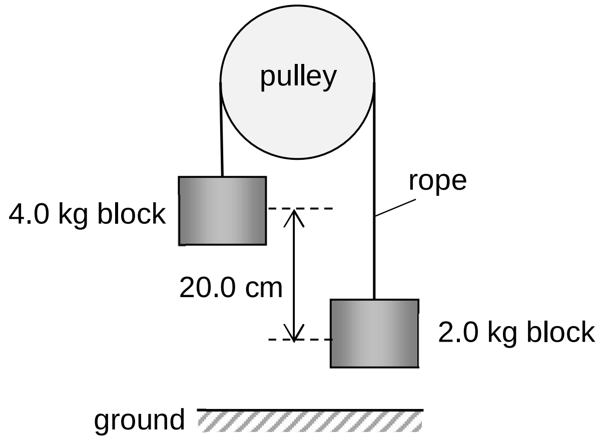

Fig. 4.1

(a) After the 4.0 kg block is released, the system of blocks begins to move.

Based on the principle of conservation of energy, describe the energy conversion happening for the system of blocks.

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

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

(b) The blocks are allowed to move until they are at the same height above the ground.

(i) State the distance travelled down by the 4.0 kg block.

distance = …………………………… m [1]

(ii) Hence, determine the speed of the blocks when they are at the same height above the ground.

speed of the blocks = ………………… m s^{-1} [3]

[Total: 5]

5 A wire of 1.63 mm in diameter and is made of copper. The maximum allowed current for this wire at normal operating temperature is 15.0 A.

Copper has a resistivity of $1.72 \times 10^{-8}\ \Omega$ m.

The 3.0 m length of this wire is used to connect an appliance from an ideal 12.0 V power supply.

(a) Determine,

(i) the number of electrons entering the wire every second at maximum allowed current,

number of electrons = ………………… s^{-1} [2]

(ii) the resistance of the wire,

resistance = …………………… Ω [2]

(iii) the maximum potential difference across the wire,

potential difference = ……………………… V [1]

(iv) the efficiency of power transfer from the power supply to the appliance.

efficiency = ……………………… % [2]

(b) In practice, the wire heats up when operating at maximum current for an extended period.

State and explain, at a microscopic level, how the resistivity of the wire will change when the wire heats up.

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

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

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

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

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

[Total: 10]

BLANK PAGE

6 A boat is powered by an outboard motor of variable power.

Fig. 6.1

(a) The drag force acting on the boat F when the boat is moving at speed v is given by

$$F = \frac{1}{2} c_D \rho A v^2$$

where c_D is the drag coefficient, ρ is the density of water and A is the frontal area of the boat.

Data for the moving boat moving at a certain constant speed is shown in the table.

F/kN	78 ± 1%
c_D	2.1 ± 0.1
ρ/kg m^{-3}	1030 ± 20
A/m^2	14.7± 0.3

Determine the speed v with its uncertainty at which the boat is moving.

v = …………………….. ± …………….. m s^{-1} [4]

(b) The variation of the power supplied by the outboard motor to maintain a speed v when the boat is carrying different total mass m is shown in Fig. 6.2

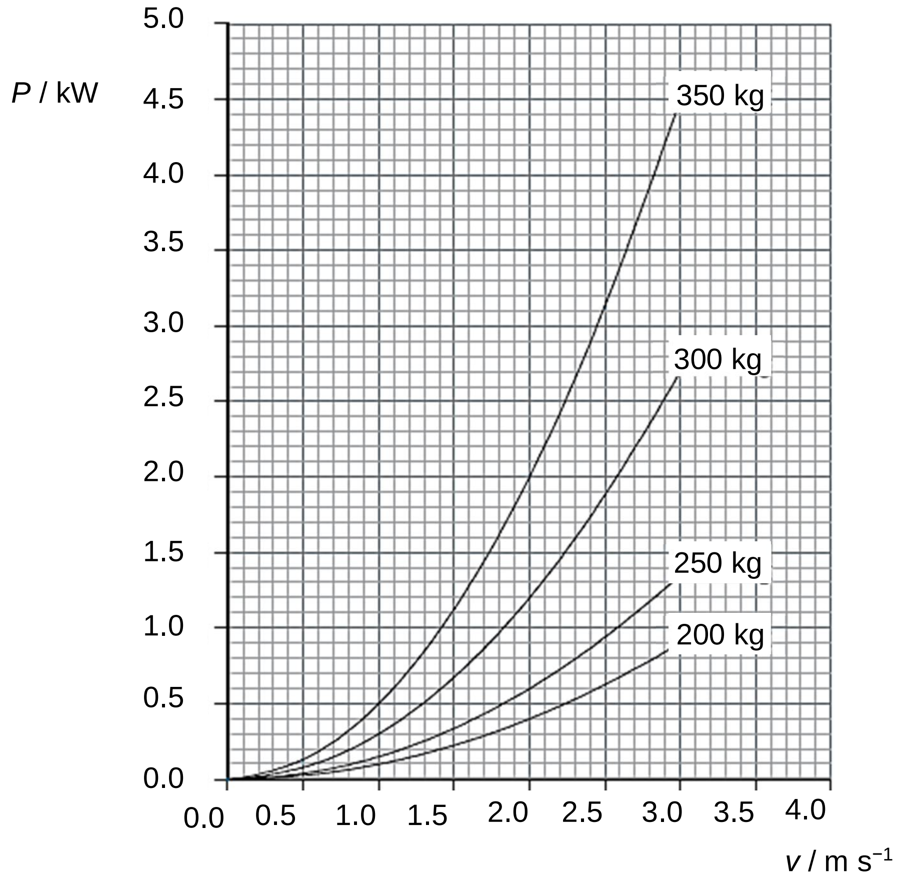

Fig. 6.2

(i) The boat is moving at a constant speed of v and its power output is P.

Explain how Newton's first law of motion applies to this boat.

....

....

.... [2]

(ii) A student thinks that the power P is proportional to the total mass m for a speed of 2.5 m s^{-1}.

Show, without drawing a graph, that this proposal is **not** correct.

[2]

(iii) Fig. 6.3 shows some of the data for v, ln (P / kW) and ln (v / m s^{-1}) for a boat of total mass 350 kg.

v / m s^{-1}	ln (P / kW)	ln (v / m s^{-1})
1.0	– 0.69	0.00
1.5	0.10	0.41
2.0	0.69	0.69
2.5	1.15	0.92
3.0	1.50	1.10

Fig. 6.3

Fig. 6.4 is a graph with the data in Fig. 6.3 partially plotted.

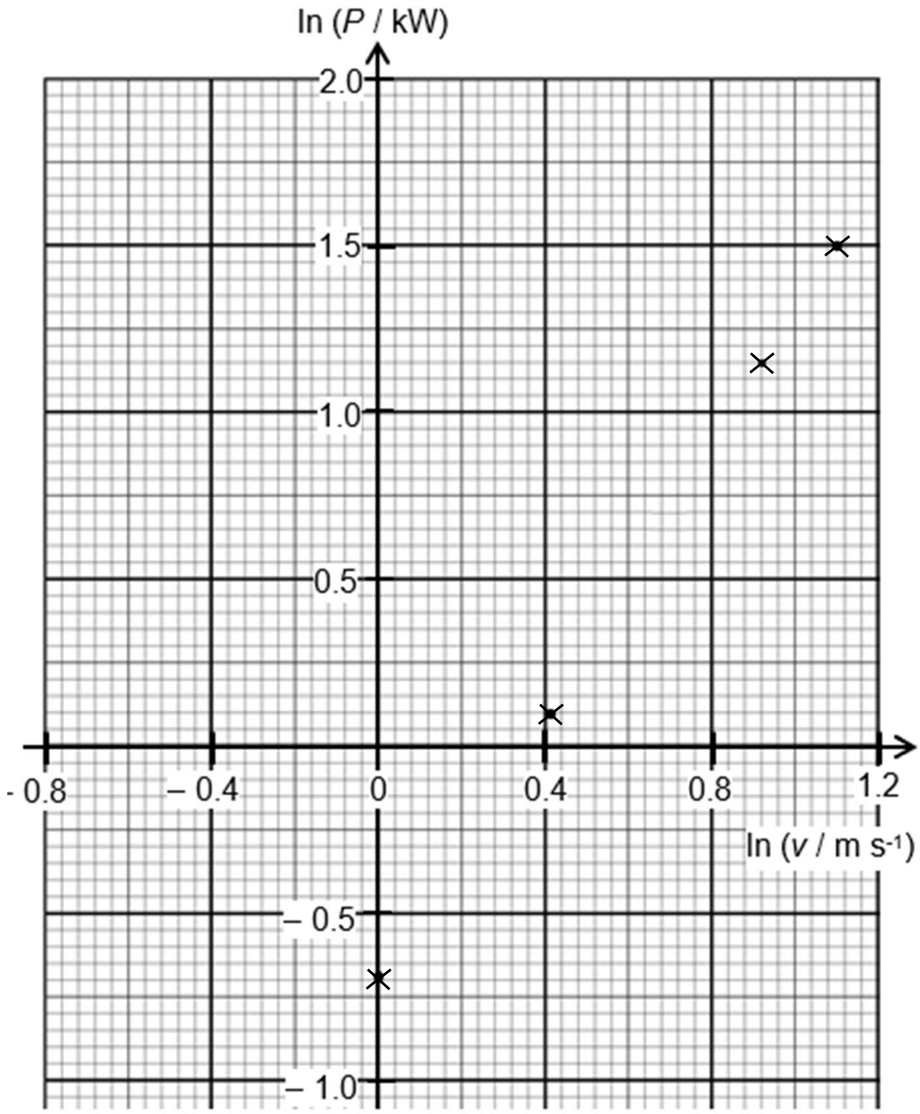

Fig. 6.4

1. Complete Fig. 6.4 using the data for the speed of 2.0 m s^{-1}.

[1]

2. It is proposed that the power P changes with speed v according to the expression

$$P = kv^n$$

where k is a constant and n is an integer.

Explain why the graph of Fig. 6.4 supports this proposal.

…………………………………………………………………………………………...

…………………………………………………………………………………………...

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

3. Use Fig. 6.4 to determine the value of n.

n = ………………………… [1]

(iv) Determine the drag force acting on the boat of total mass 300 kg and travelling at a steady speed of 2.5 m s^{-1}.

drag force = ………………………… N [2]

(c) At the steady speed of 2.5 m s^{-1} and with a total mass of 300 kg, the motor consumes diesel fuel at a rate of 1.1 litres per hour. The energy density for the diesel fuel used is 32 MJ per litre.

Calculate the efficiency of the outboard motor with the boat of total mass 300 kg travelling at the speed of 2.5 m s^{-1}.

efficiency = ………………………… [3]

[Total: 17]

Section B

Answer **one** question from this section.

7 **(a)** A Formula 1 racing car is travelling at a constant speed of 144 km h^{-1} around a horizontal corner of radius 80.0 m. The combined mass of the driver and the car is 800 kg. Fig. 7.1 shows the front view and Fig. 7.2 shows the top view.

Fig. 7.1

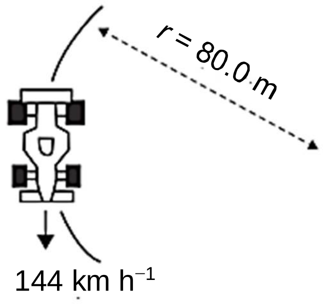

Fig. 7.2

(i) Calculate the magnitude of the net force acting on the racing car and driver as they go around the corner.

net force = ………………… N [2]

(ii) On Fig. 7.2, draw the direction of the net force acting on the racing car using an arrow. [1]

(iii) Explain why a net horizontal force is required for the car to travel around the corner.

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

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

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

(iv) State the origin of this horizontal force.

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

(b) Fig. 7.3 shows a geostationary satellite that orbits around the Earth in 24 hours. The satellite appears to remain stationary in relation to a fixed point X on the equator.

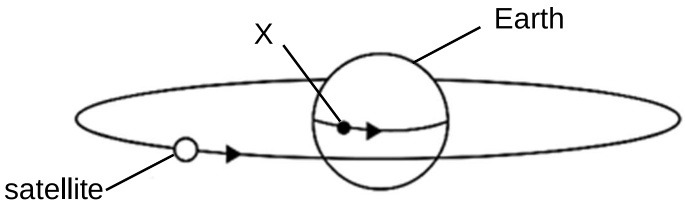

Fig. 7.3 (not to scale)

(i) Explain why geostationary satellites must be vertically above the equator to remain stationary relative to the Earth's surface.

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

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

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

(ii) The mass of Earth is 5.98×10^{24} kg and its radius is 6.37×10^{6} m.

Determine the altitude of a geostationary satellite.

altitude = ………………….… m [3]

(c) Fig. 7.4 shows the plan view of a schematic diagram of a mass spectrometer that is used to determine the relative abundance of carbon-12 and carbon-14 isotopes in a sample. Both ions of the carbon isotopes carry a charge of $+1.6 \times 10^{-19}$ C produced at the ion source. The isotopes are fed into three successive components of the mass spectrometer,

1. accelerator
2. velocity selector
3. deflector

A uniform magnetic flux density B of 0.500 T is applied in the velocity selector and deflector regions as shown in the Fig. 7.4. After deflection, the isotopes are collected at the respective detectors to determine their relative abundances.

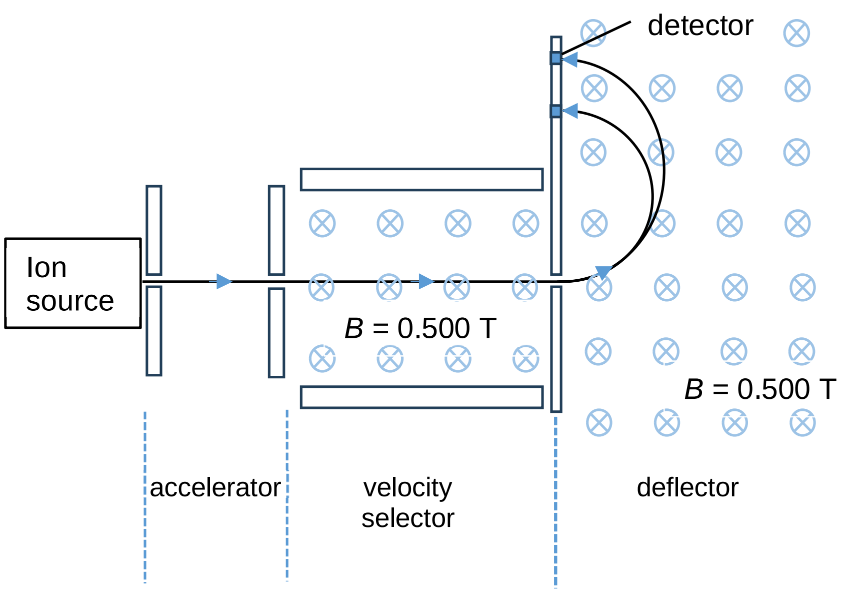

Fig. 7.4

(i) In the deflector region, an isotope of mass m and charge q is moving with speed v normal to a magnetic field of flux density B.

Show that the particle will move in a circular path of radius r given by the expression

$$r = \frac{mv}{Bq}$$

Explain your working.

[2]

(ii) The isotopes enter the deflector region with the same speed.

Determine the ratio of $\dfrac{\text{radius of circular path for carbon-14}}{\text{radius of circular path for carbon-12}}$.

[1]

(iii) A separation of 2.5 cm is required for the two collection points of the isotopes at the detector.

Determine the speed of the isotopes in the deflector region.

speed = ……….…………. m s^{-1} [4]

(iv) The isotopes that entered the deflector region were undeflected when they passed through the velocity selector.

Determine the electric field strength at the velocity selector.

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

(v) Draw on Fig. 7.4, the direction of the electric field in the velocity selector.

[1]

(vi) Determine the potential difference between the plates at the accelerator region in order to acquire the speed determined in **(c)(iii).**

potential difference = ………………… V [2]

[Total: 20]

8 **(a)** Nuclear power is generated through the fission of uranium-235. A common fission reaction produces 3 neutrons, a barium nucleus, and a krypton nucleus.

$$n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{X}_{Y}Kr + 3n$$

(i) Explain what is meant by the term *fission*.

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

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

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

(ii) State the values of X and Y.

X = ………………

Y = ……………… [2]

(iii) In a large nuclear plant that uses the above fission process produces energy at a rate of 6.4 GW.

The binding energy per nucleon of the nuclei are as follows:

nucleus	binding energy per nucleon / MeV
Ba	8.3
Kr	8.5
U	7.6

1. Define *binding energy per nucleon*.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………… [1]

2. Show that the amount of additional energy released in one fission reaction is 2.66×10^{-11} J,

additional energy released = ………………… J [3]

3. If all the energy is produced due to the fission of uranium-235, determine the number of fission reactions occurring per unit time.

number of reactions per unit time = …………………… s^{-1} [2]

4. Hence, determine the total mass of uranium-235 required to sustain the fission reaction for 1 hour.

mass = ………………………… kg [3]

(b) A negative-temperature-coefficient (NTC) thermistor can be used as a device to aid in the measurement of temperature in an oven. Fig. 8.1 shows a circuit to connect the NTC thermistor for use as a temperature sensor.

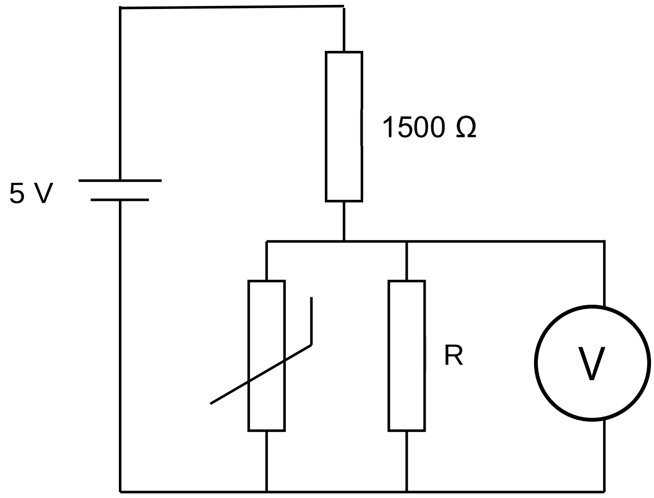

Fig. 8.1

The microchip in the oven detects the potential difference across the NTC thermistor to determine the temperature of the oven. The temperature-resistance graph for the NTC thermistor is shown in Fig. 8.2.

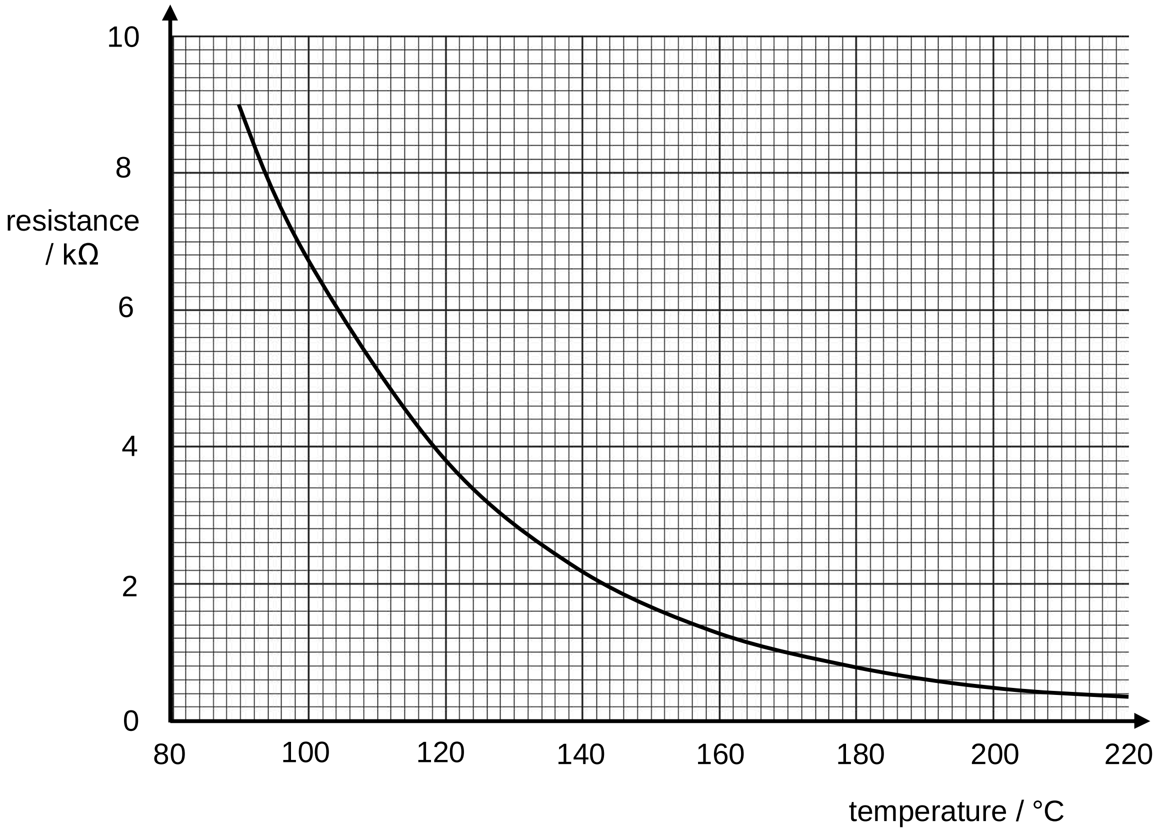

Fig. 8.2

(i) R is chosen to be 3000 Ω.

Determine the potential difference across the thermistor when the temperature is at 190 °C.

potential difference = …………………… V [4]

(ii) State and explain if the circuit provides a more precise reading of the potential difference across the thermistor when the temperature is high or low.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) Sketch the relationship between the temperature of the thermistor and the potential difference across it on Fig. 8.3. [2]

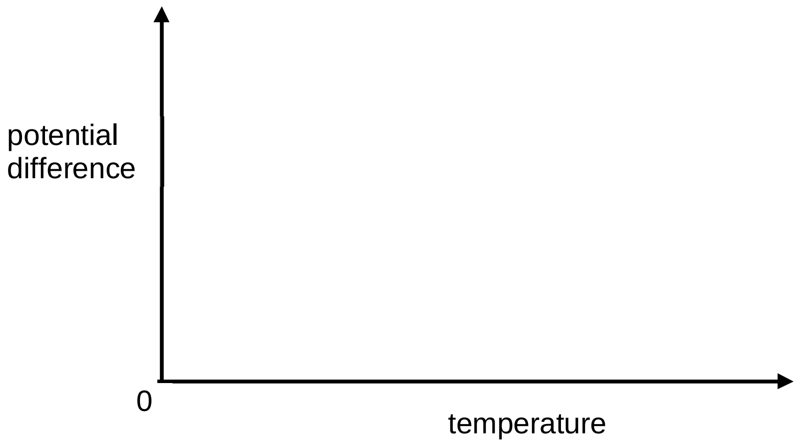

Fig. 8.3

[Total: 20]

Blank Page