CANDIDATE NAME									
CIVICS GROUP	2	0	-			REGISTRATION NUMBER			

PHYSICS

8867/02

Paper 2 Longer Structured Questions

02 July 2021

2 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
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 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	
2	
3	
4	
5	
6	
Section B	
7	
8	
Total	

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

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	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$

Section A

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

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

………

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

(b) The displacement s moved by an object in time t may be given by the expression

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

where a is the acceleration of the object.

State one condition for this expression to apply to the motion of the object.

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

(c) A rock rolls down the slope of a cliff, inclined at 20°, and leaves the cliff at a speed of 50 m s^{-1} as shown in Fig 1.1. The rock lands onto another cliff that is at a horizontal distance of 25 m away from the first one.

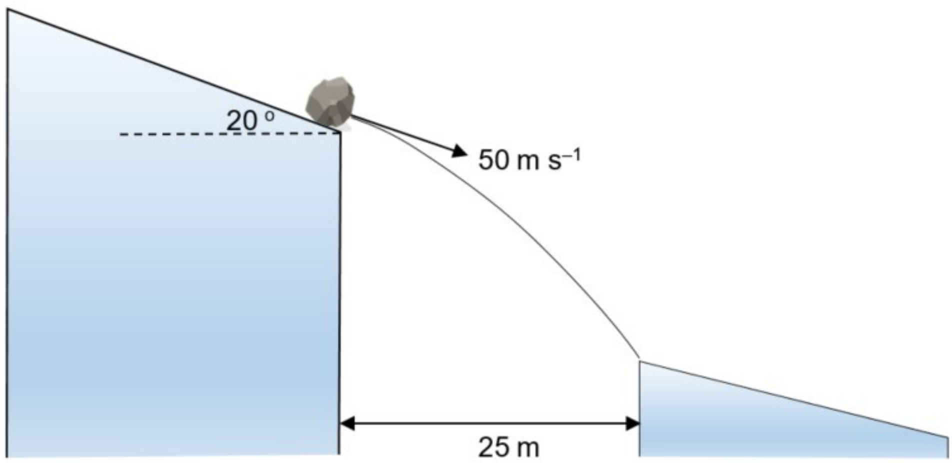


Fig. 1.1

(i) Calculate the duration of time that the rock experiences free fall.

time = ……………………… s [2]

(ii) Determine the angle, below the horizontal, of the direction of the rock's velocity upon landing.

angle = ……………………………….° [3]

(iii) A bridge connecting the edge of one cliff to the other is being proposed.

Calculate the minimum length of the bridge required.

length = ……………………… m [3]

(iv) On the axis of Fig. 1.2, sketch graphs to represent, during free fall, the variation with time of the rock's

1. vertical velocity and label this graph A [1]
2. horizontal velocity and label this graph B [1]

You are not required to state values on the axes.

Fig 1.2

[Total: 12]

2 **(a)** State the *Principle of Conservation of Momentum*.

………

………

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

(b) Two objects X and Y, with masses 2.0×10^3 kg and 3.0×10^3 kg respectively, traveling in the same direction collides head-on. Fig. 2.1 shows how the momentum of X varies with time.

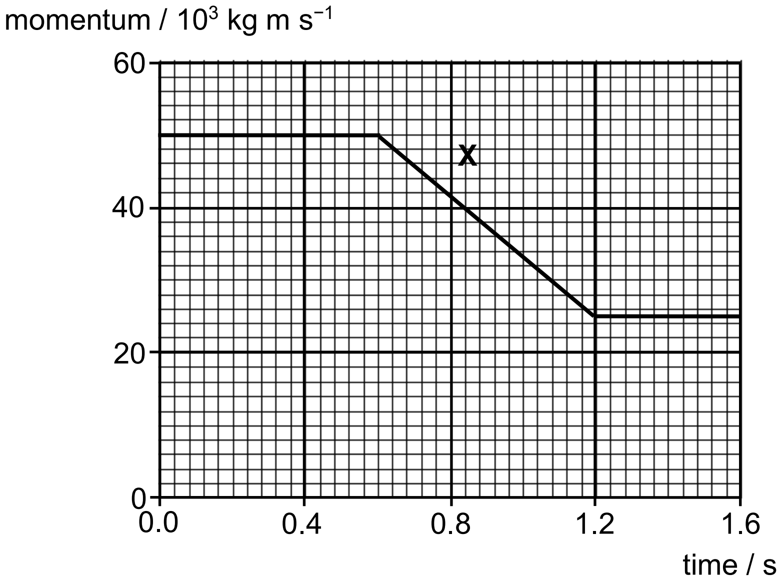


Fig 2.1

(i) Using information from Fig. 2.1, determine the change in momentum of X.

change in momentum of X = ……………………… kg m s^{-1} [1]

(ii) Object Y was traveling at a speed of 10 m s^{-1} before the collision. On Fig. 2.1, sketch the graph showing how the momentum of Y varies with time for the same time period. [2]

(iii) State and explain quantitatively whether the collision of the two objects is an example of an elastic collision.

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

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

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

(iv) Object Z has mass m and speed v as shown:

$m = (1240 \pm 20)$ kg
$v = (22.2 \pm 0.8)$ m s^{-1}

Calculate the kinetic energy of object Z together with its associated uncertainty in kJ.

kinetic energy of object Z = …………………….. ± ………………. kJ [3]

[Total: 9]

3 A lorry moves up a road that is inclined at 9.0° to the horizontal, as shown in Fig. 3.1.

The lorry has mass 2500 kg and the force due to air resistance is negligible.

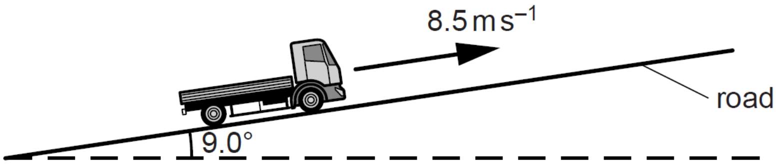


Fig 3.1

(a) At an instant in time, the lorry is travelling with an acceleration of 2.0 m s^{-2} at a speed of 8.5 m s^{-1}.

Calculate the instantaneous power from the engine to move the lorry up the road.

power = ………..………. W [3]

(b) The truck reaches a speed of 12 m s^{-1} when the driver jams on the brakes. The truck skidded with a kinetic friction of 500 N.

Calculate the distance travelled by the truck before it reaches a speed of 8.0 m s^{-1} where he regains control of the truck.

distance = ………………………. m [2]

[Total: 5]

4 **(a)** A satellite is in a circular orbit of radius *r* about the Earth of mass *M,* as illustrated in Fig. 4.1.

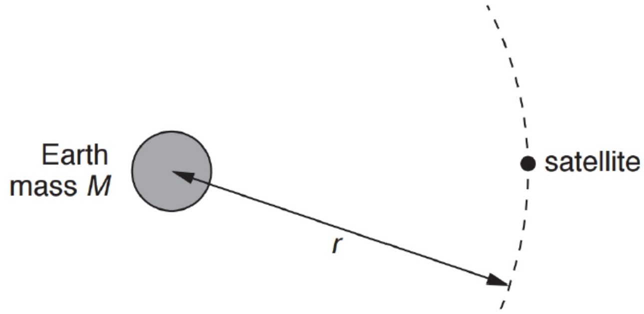


Fig. 4.1

The mass of the Earth may be assumed to be concentrated at its centre.

Show that the period *T* of the orbit of the satellite is given by the expression

$$T^2 = \frac{4\pi^2}{GM} r^3$$

where *G* is the gravitational constant. Explain your working. [2]

(b) State two features of a *geostationary* satellite.

1. ……………………………………………………………………………………..…………………

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

(c) The mass *M* of the Earth is 6.0×10^{24} kg. Calculate the speed of a geostationary satellite.

speed = ……………………… m s^{-1} [3]

(d) Explain why the geostationary satellite can be described as being weightless.

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

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

[Total: 9]

5 An electron travelling at a uniform speed of 1.5×10^7 m s^{-1} in vacuum enters the gap between two plane, parallel deflection plates along the line PQ, mid-way between the plates as shown in Fig. 5.1. The plates are 40 mm long and 20 mm apart, with the upper plate being at a positive potential V with respect to the lower one. The electron emerges from the plates at R with a velocity of 1.6×10^7 m s^{-1} at an angle of 20° to its original direction.

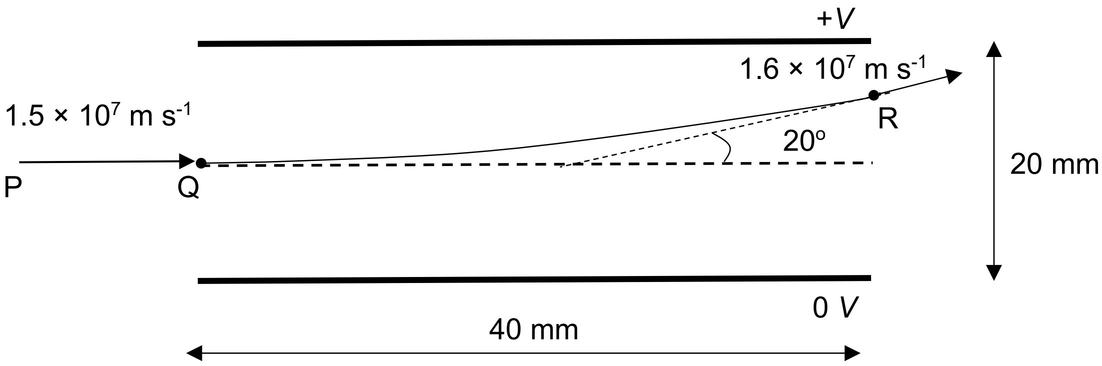


Fig. 5.1

(a) **(i)** Calculate the time taken by the electron to travel from Q to R.

time taken =…………..………. s [1]

(ii) **1.** Calculate the magnitude of the change in velocity Δv of the electron during its path between Q and R.

Δv = ……………………….. m s^{-1} [2]

2. Explain how you deduce the direction of the change in velocity of the electron using Newton's Second Law.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(iii) Using the values found in **(a)(i)** and **(ii)**, calculate the value of electric potential *V* at the top plate.

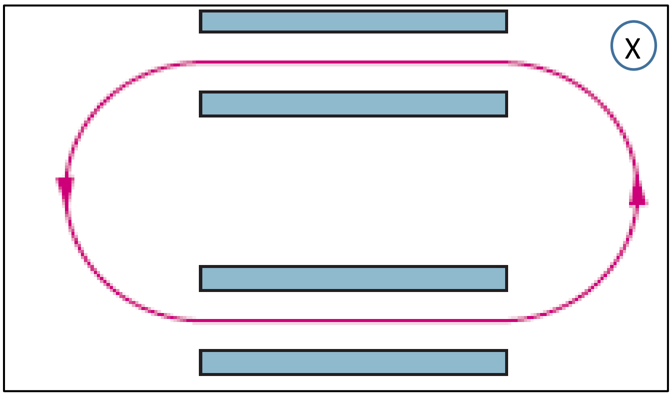
V = ………………………… V [2]

(iv) A magnetic field is applied to the region of uniform electric field such that the electron beam is undeflected.

Determine the magnitude of the magnetic flux density *B*.

B = ………………………… T [2]

(b) An additional pair of parallel plates with the same potential difference is added to the setup in **(a)(iv)**. The new configuration enables the electron to perform the motion as shown in Fig. 5.2.



The magnetic field is directed normally into the plane of the paper.

Fig. 5.2

Calculate the time taken for the electron to complete one cycle of the motion.

time taken = ……………………….. s [3]

[Total: 12]

6 Read the passage below and answer the questions that follow.

Racing competitions, such as Formula 1, have led to advances in technology that eventually make their way into road vehicles. Formula 1 teams compete to make the fastest possible within strict rules.

Formula 1 drivers experience large accelerations and decelerations. A Formula 1 car can stop in a straight-line distance of 80 m from a maximum speed of 185 km h^{-1}.

High accelerations and decelerations are limited by the friction *F* between the tyres and the road. This is related to the weight *W* of the car by the equation

$$F = \mu W$$

where μ is the coefficient of friction.

Before use in a race, tyres are kept warm in special tyre blankets. The coefficient of friction varies with the tyre surface temperature, as shown in Fig. 6.1.

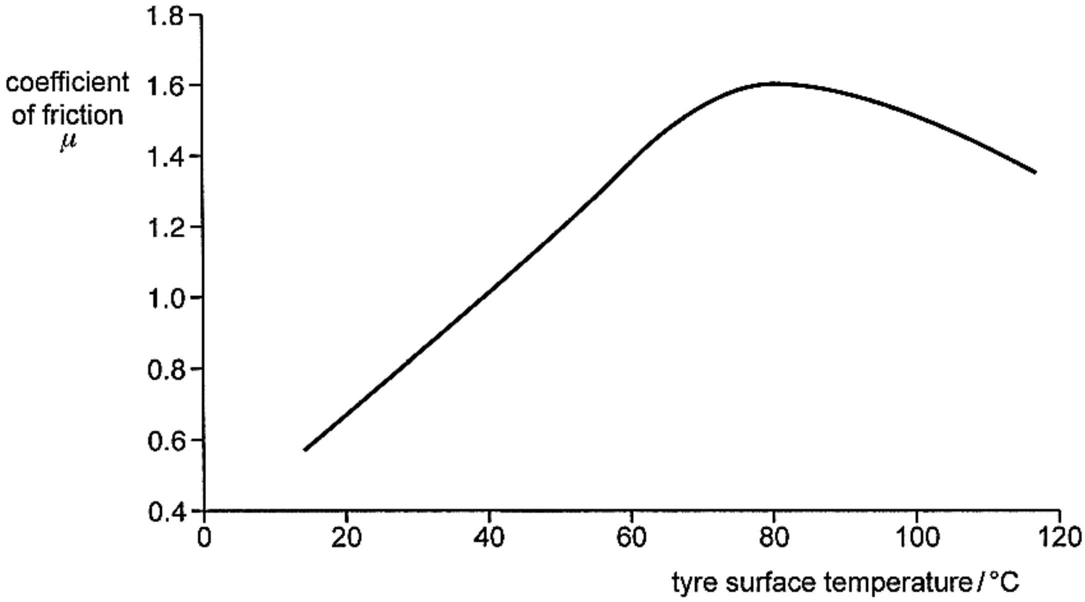


Fig. 6.1

A section through the road surface and a tyre at 20 °C in contact with the road is shown in Fig. 6.2.

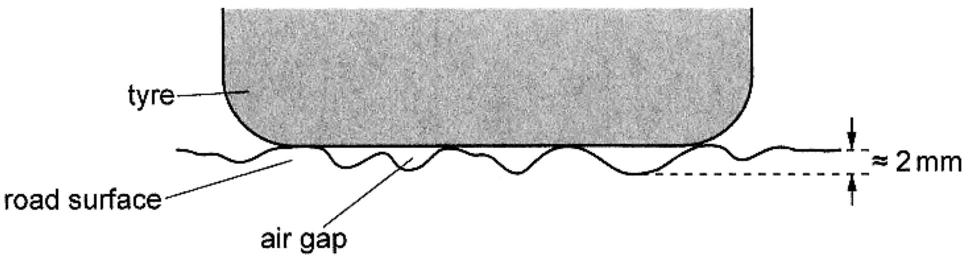


Fig. 6.2 (not to scale)

When the tyre is heated with the tyre blanket, the compound of the tyre becomes softer, increasing the contact area.

To make the tightest circular corner in the Singapore Street Circuit, drivers decelerate from 220 km h^{-1} to make it around the corner of radius 30 m. The tyres must withstand lateral (sideways) accelerations of up to 4*g* during cornering.

The mass of a typical Formula 1 car is about 750 kg. Greater accelerations and cornering speeds may be achieved with greater friction between tyres and the track. Features of the car, such as rear wings, appear to increase the weight of the car.

When a Formula 1 car accelerates, the weight distribution between the front and rear wheel changes. The cars are rear-wheel drive, which means the accelerating force is provided through the rear wheels. When accelerating, the contact force experienced by the rear wheels increases and this is called ‘weight transfer’.

The brakes used on Formula 1 cars consist of carbon fibre discs and pads. There is one set for each of the four wheels. Each set has a mass of 1.2 kg. There are at least 1000 small holes drilled into each disc. These brakes operate more effectively at high temperatures than materials used for brakes on road vehicles. It is predicted that brakes made from carbon fibre discs and pads will be the next big change to reach the everyday car market.

(a) Calculate the maximum deceleration a Formula 1 driver experience while braking to rest in a straight line.

deceleration = ………………………… m s^{-2} [2]

(b) **(i)** Determine the maximum speed a Formula 1 car can travel around the tightest circular corner at the Singapore Street Circuit.

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

(ii) By reference to Fig. 6.1 and Fig. 6.2, suggest and explain why the tyres are heated before use.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………[2]

(c) A cross-section of the rear wing on a Formula 1 car is shown in Fig. 6.3.

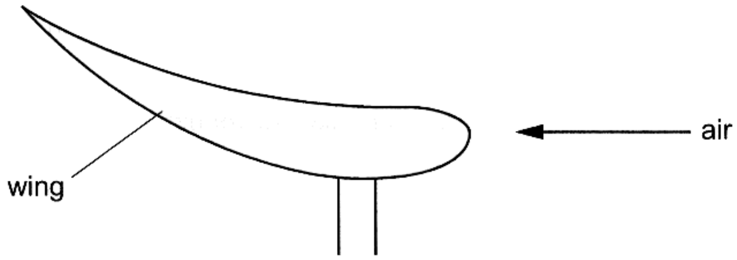


Fig. 6.3

The wing deflects air when the car is moving.

Explain, by reference to the change in momentum of the air, why this air flow appears to increase the weight of the car.

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

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

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

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

(d) Some of the forces acting on a Formula 1 car while accelerating from rest are shown in Fig. 6.4.

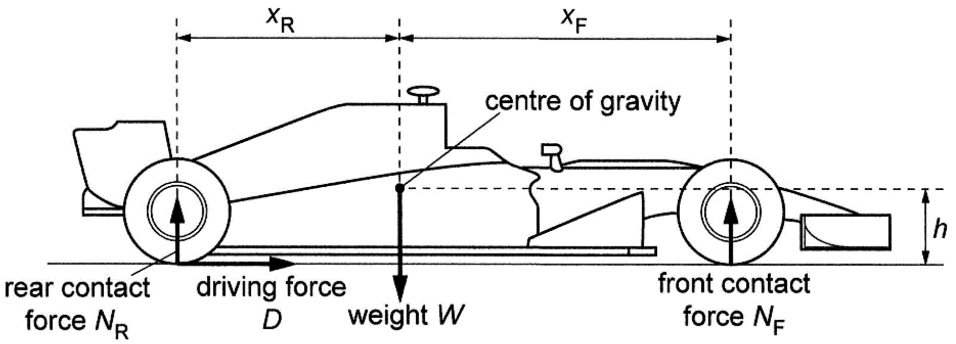


Fig. 6.4

N_R and N_F are the contact forces acting on the rear and front wheels, respectively. W is the weight of the car. D is the driving force acting on the rear wheels.

The centre of gravity is a vertical distance h above the ground. The centre of gravity is a horizontal distance x_R from the rear wheels and a horizontal distance x_F from the front wheels.

For the car accelerating from rest:

(i) take moments about the centre of gravity, to show that

$$N_R = \frac{Wx_F + Dh}{x_F + x_R}$$

[2]

(ii) determine a similar expression to that in **(d)(i)** for N_F.

[1]

(iii) Use your expressions in **(d)(i)** and **(d)(ii)** to show that there is a weight transfer between the front and rear wheels.

[2]

[Total: 13]

Section B

Answer any **one** question in this Section in the spaces provided.

7 **(a)** **(i)** Define *magnetic flux density*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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

(ii) State the *SI base unit* of magnetic flux density.

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

(iii) Explain, using a labelled diagram, how a current balance is used to measure the flux density of a magnetic field.

[5]

(b) A 12.0 V power supply has an internal resistance of 0.50 Ω. It is connected in a circuit with a resistor of resistance 4.0 Ω. There is also a resistor of resistance 3.0 Ω and an open switch.

The circuit is shown in Fig. 7.1.

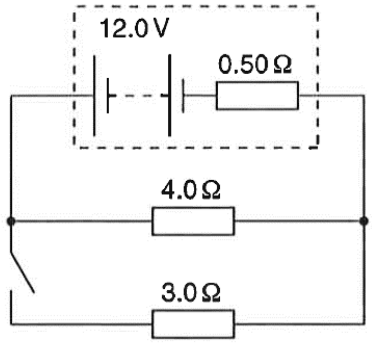


Fig. 7.1

The switch is now closed. Calculate the decrease in the power supplied to the 4.0 Ω resistor. Show all your working.

decrease in power = …………………. W [5]

(c) Bismuth-212 is an alpha emitter. The radioactive decay of bismuth-212 is a spontaneous and random process.

Explain what is meant by

(i) radioactive decay

....

....

....[2]

(ii) spontaneous process

....

....[1]

(iii) random process

....

....[1]

(d) An unstable nucleus of nucleon number (mass number) *A* undergoes α-decay, as shown in Fig. 7.1.

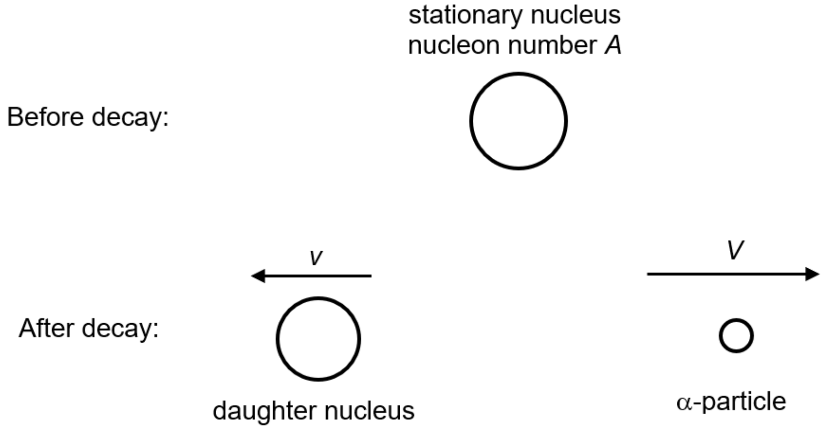


Fig. 7.1

The nucleus is stationary before the decay.

After the decay, the speed of the α-particle is V and that of the daughter nucleus is v.

(i) State an equation, in terms of A, V, and v, to represent conservation of linear momentum for this decay.

[1]

(ii) Show that the ratio

$$\frac{\text{kinetic energy of α-particle}}{\text{kinetic energy of daughter-particle}}$$

is equal to $(\frac{1}{4}A - 1)$.

[2]

[Total: 20]

8 **(a)** An engineer designs a resistor made from a thin layer of graphite mounted on an insulating base. Fig. 8.1 shows the arrangement.

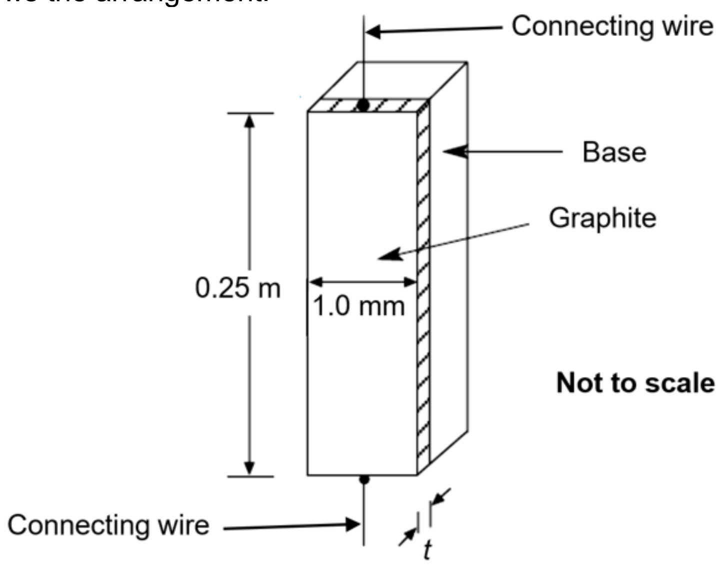


Fig. 8.1

(i) The graphite layer has a length of 0.25 m, a width of 1.0 mm, and a resistance of 1.2 kΩ. The resistivity of graphite is 15.0×10^{-5} Ω m.

Calculate the thickness *t* of the graphite layer.

thickness *t* = …………………. m [2]

(ii) The engineer has also some connecting wires and a cell. The cell has negligible internal resistance. He wants to connect a circuit to provide an output potential difference which is dependent on illumination. The output potential difference should increase with increasing brightness.

1. State another electrical component that he needs to complete the circuit.

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

2. With the electrical component in **(a)(ii)1.** and the newly designed graphite resistor, draw a circuit diagram to show how this circuit should be connected.

Your diagram should show the cell and the potential difference output clearly.

[2]

(iii) The circuit in Fig 8.2 was set up to vary the current in the graphite resistor with a cell of negligible resistance, a 500 Ω resistor and a rheostat.

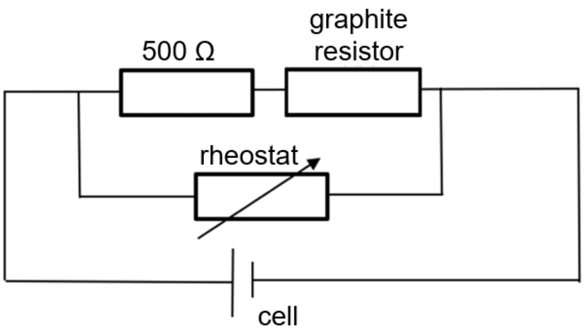


Fig. 8.2

1. Suggest a reason why this setup is inappropriate.

……………………………………………………………………………………………..

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

2. State the modification that can be made to Fig. 8.2 to vary the current in the graphite resistor using the existing components.

……………………………………………………………………………………………..

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

(b) The circuit shown in Fig. 8.3 consists of a battery of e.m.f 12 V and internal resistance 5.0 Ω, connected to a 20 Ω resistor in parallel with resistors of resistance 10 Ω and 50 Ω in series. A high resistance voltmeter is connected across the 50 Ω resistor.

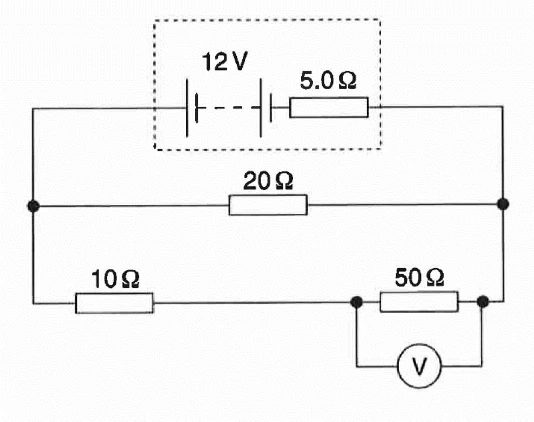


Fig. 8.3

Determine the value of the reading on the voltmeter. Show all your working clearly.

voltmeter reading = ………………….. V [4]

(c) Fig. 8.4 shows the variation with nucleon number of the binding energy per nucleon of a nucleus.

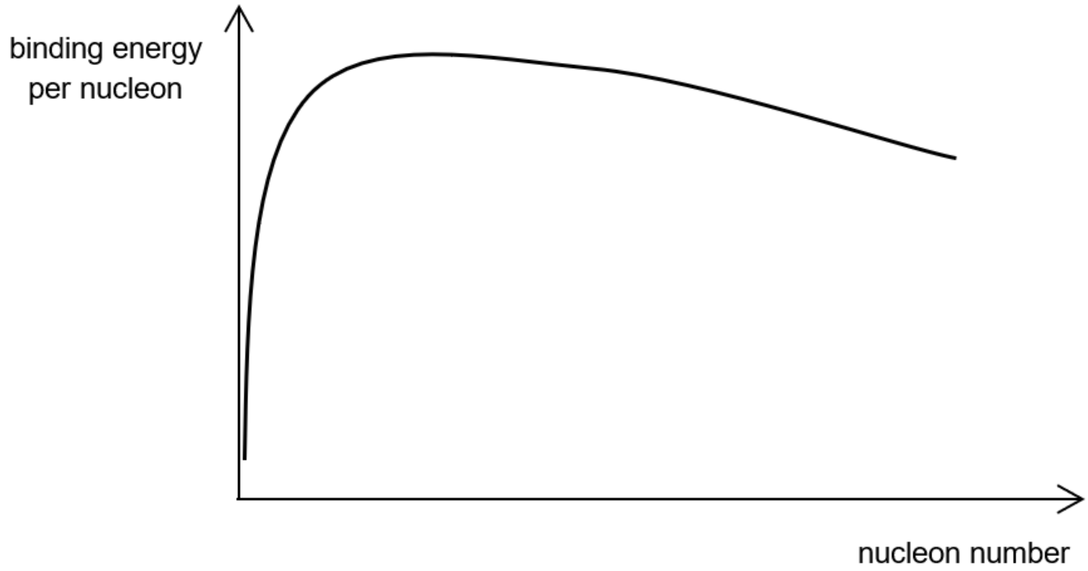


Fig. 8.4

One possible fission reaction is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2\,^{1}_{0}n$$

(i) On Fig. 8.4, mark possible positions for

1. the nucleus with the greatest stability (label this position S), [1]

2. the Uranium-235 $\left(^{235}_{92}U\right)$ nucleus (label this position U), [1]

3. the Krypton-90 $\left(^{90}_{36}Kr\right)$ nucleus (label this position Kr). [1]

(ii) Explain what is meant by *nuclear binding energy* of a nucleus.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(iii) Use Fig. 8.4 to explain why the nuclear fission of uranium-235 will release energy.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

[Total: 20]

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