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**OXFORD CAMBRIDGE AND RSA EXAMINATIONS
ADVANCED GCE**

G495

PHYSICS B (ADVANCING PHYSICS)

Field and Particle Pictures

WEDNESDAY 2 FEBRUARY 2011: Afternoon

DURATION: 2 hours

SUITABLE FOR VISUALLY IMPAIRED CANDIDATES

Candidates answer on the question paper.

OCR SUPPLIED MATERIALS:

**Data, Formulae and Relationships Booklet
Insert (inserted)**

OTHER MATERIALS REQUIRED:


Electronic calculator

READ INSTRUCTIONS OVERLEAF

INSTRUCTIONS TO CANDIDATES

- **Write your name, centre number and candidate number in the boxes on the first page. Please write clearly and in capital letters.**
- **Use black ink. Pencil may be used for graphs and diagrams only.**
- **Read each question carefully. Make sure you know what you have to do before starting your answer.**
- **Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).**
- **Answer ALL the questions.**

INFORMATION FOR CANDIDATES

- **The number of marks is given in brackets [] at the end of each question or part question.**
- **The total number of marks for this paper is 100.**
- **You may use an electronic calculator.**
-  **Where you see this icon you will be awarded marks for the quality of written communication in your answer.**

This means for example, you should

- **ensure that text is legible and that spelling, punctuation and grammar are accurate so that the meaning is clear;**
- **organise information clearly and coherently, using specialist vocabulary when appropriate.**
- **You are advised to show all the steps in any calculations.**
- **The questions in Section C are based on the material in the Insert.**

Answer ALL the questions.

SECTION A

- 1 A charging unit for a laptop computer uses a transformer to convert a 230V, 50 Hz mains supply to a 15V alternating supply.**

The primary coil has 3800 turns of wire. Assume the transformer is ideal.

- (a) Calculate the number of turns on the secondary coil.**

number of turns = _____ [2]

- (b) Put a ring around the ONE quantity which will NOT be the same for both coils of this transformer.**

magnetic flux

magnetic flux density

magnetic flux linkage [1]

- 2 Fig. 2.1 shows the electric field lines at the tip of a positively charged needle.

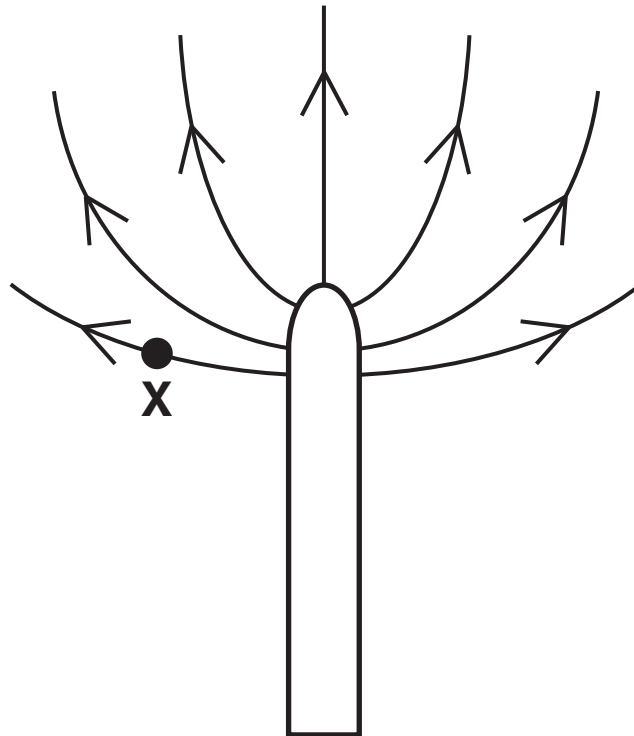


Fig. 2.1

- (a) Draw an equipotential line passing through X, in the field region shown. [1]
- (b) State the feature of the diagram that shows that the electrical field strength is NOT uniform near the tip of the needle.

[1]

3 Americium-241 emits alpha particles.



Here are the masses of the nuclei involved in the decay:

$${}_{95}^{241}\text{Am} = 4.0031 \times 10^{-25} \text{ kg}$$

$${}_{93}^{237}\text{Np} = 3.9365 \times 10^{-25} \text{ kg}$$

$${}_2^4\text{He} = 0.0665 \times 10^{-25} \text{ kg}$$

Calculate the energy released in the decay.

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

energy released = _____ J [2]

- 4 Fig. 4.1 shows how the electric field strength of a positive point charge varies with distance from the charge.

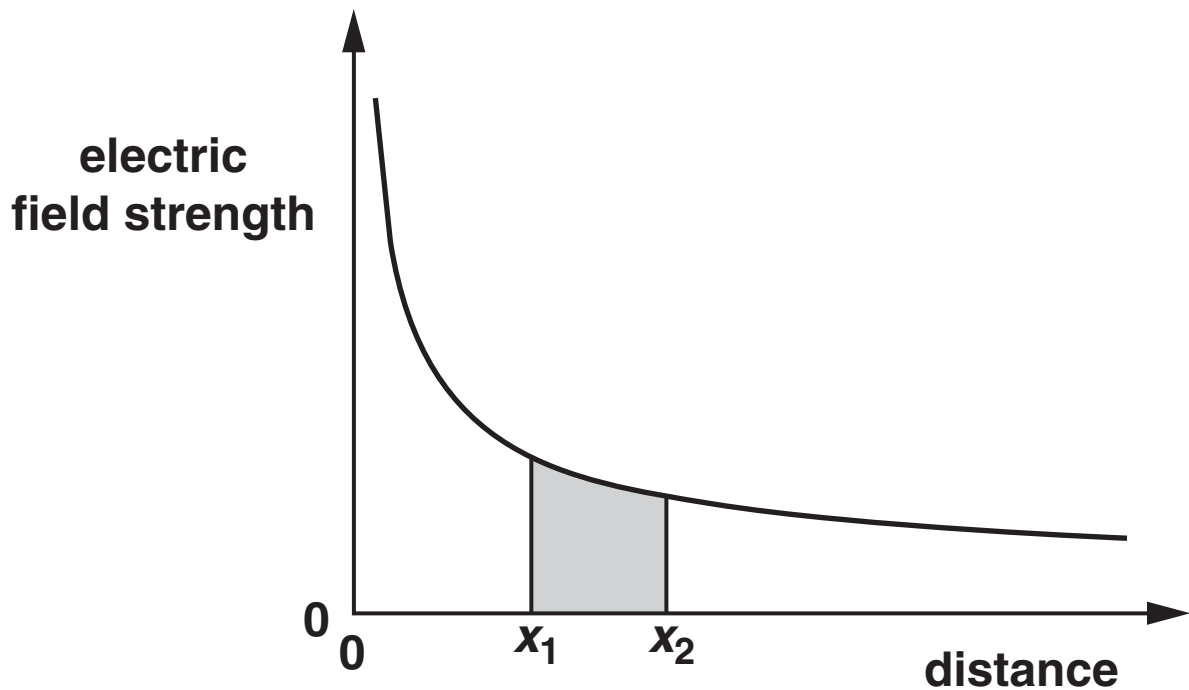


Fig. 4.1

State the quantity represented by the shaded area.

[2]

- 5 An electron in a hydrogen atom can be crudely modelled as a standing wave in a box of length about 1.5×10^{-10} m.

Fig. 5.1 shows the standing wave pattern for the lowest, $n = 1$, energy state.

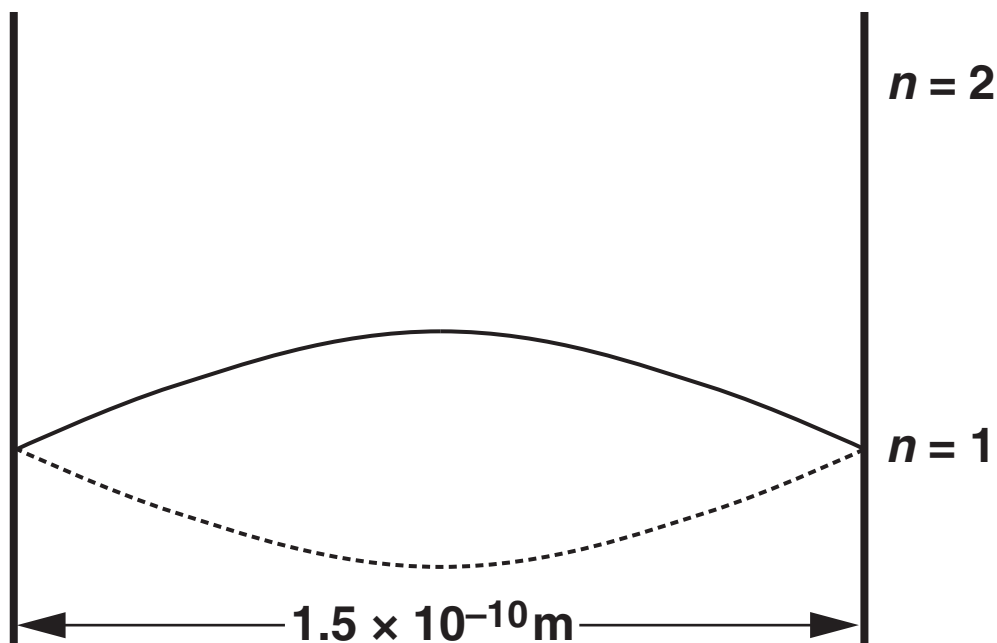


Fig. 5.1

- (a) State the wavelength of the standing wave.

wavelength = _____ m [1]

- (b) On Fig. 5.1 sketch the standing wave pattern for the $n = 2$ energy level. [1]

6 Here is a list of particles.

electron

neutron

photon

positron

(a) Which particle has zero rest energy?

(b) Which particle has positive charge?

(c) Which particle is a hadron ?

[3]

- 7 Fig. 7.1 represents the scattering of a high-energy electron by a quark within a particle. The electron loses energy in the scattering process.

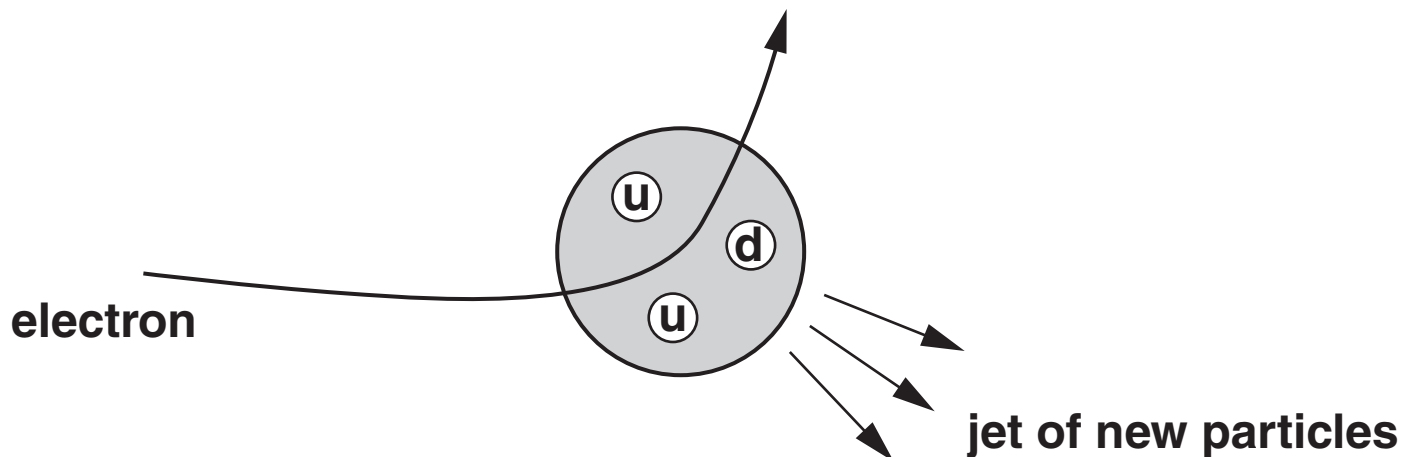


Fig. 7.1

charge on u quark = $+2/3 e$
charge on d quark = $-1/3 e$

- (a) State the name of the shaded particle containing three quarks.

particle name _____ [1]

- (b) Explain why the electron loses energy in the scattering process.

[2]

8 Fig. 8.1 shows a simple d.c. motor.

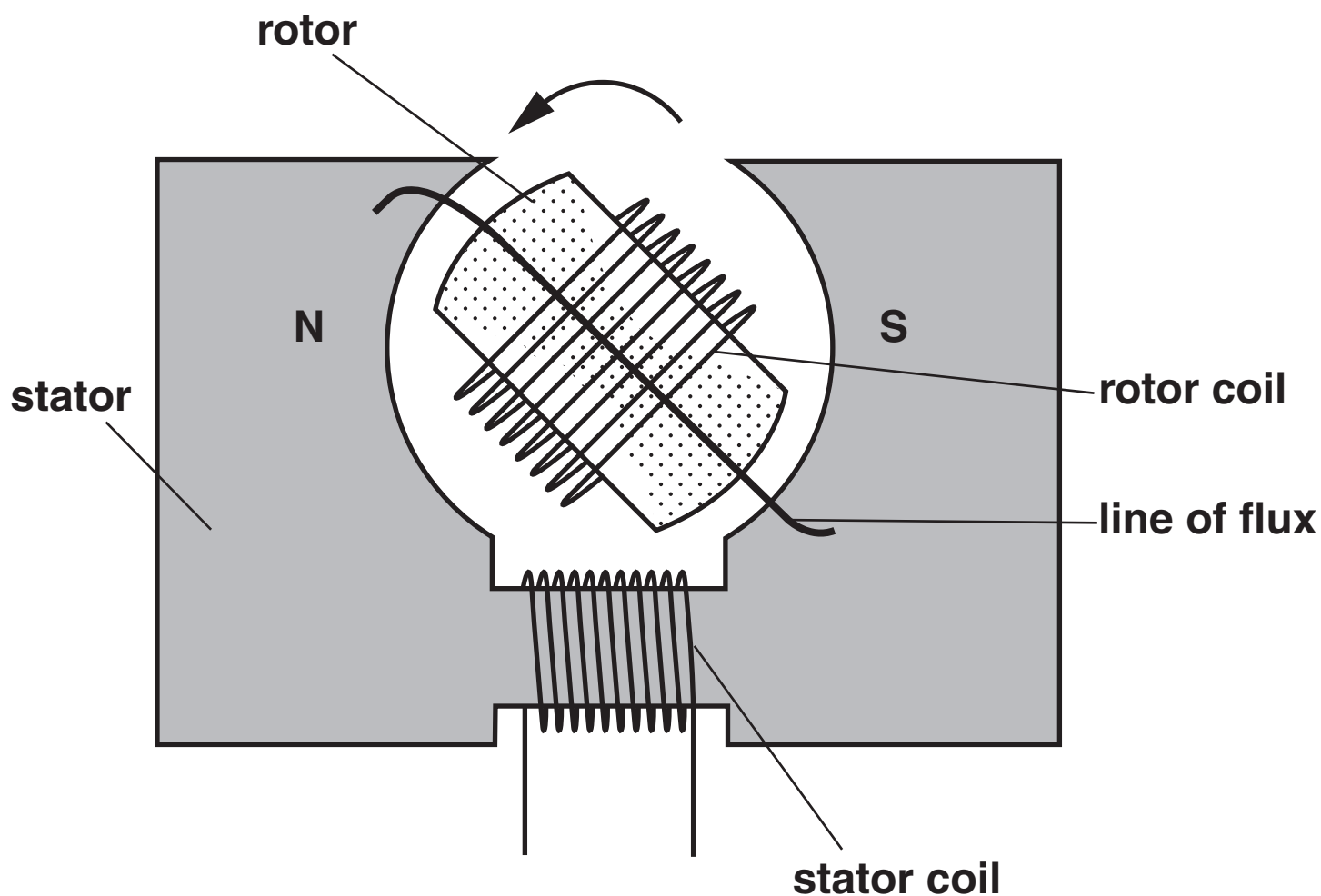
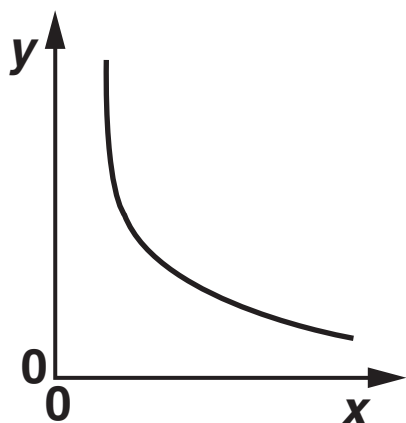


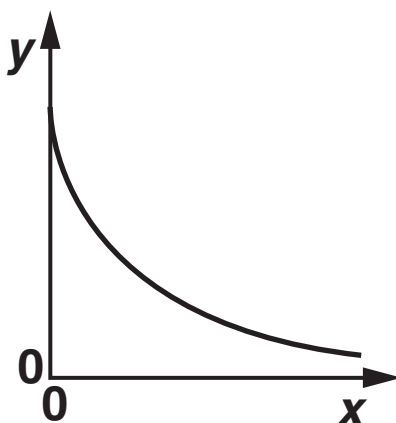
Fig. 8.1

- (a) There is a current in the stator coil and the rotor coils. Complete the line of flux drawn in the diagram. [1]
- (b) The rotor is turning anticlockwise. Mark the north and south poles of the rotor. [1]

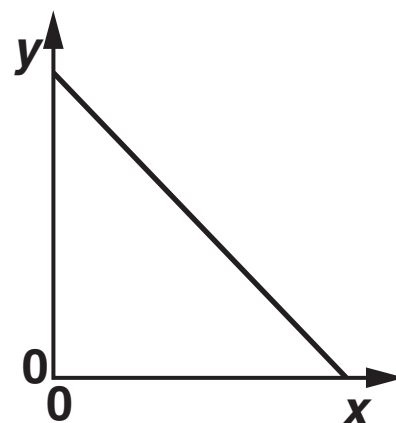
9 Here are three graphs:



A



B



C

Each row of the table shows possible pairs of x and y variables.

y variable	x variable	graph
activity of a sample of radioactive material	time	
natural log of activity of a sample of radioactive material	time	

Complete the third column with the most appropriate graph (A, B or C) for each row. [2]

[Section A Total: 21]

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SECTION B

10 This question is about the scattering of alpha particles by nuclei as shown in Fig. 10.1.

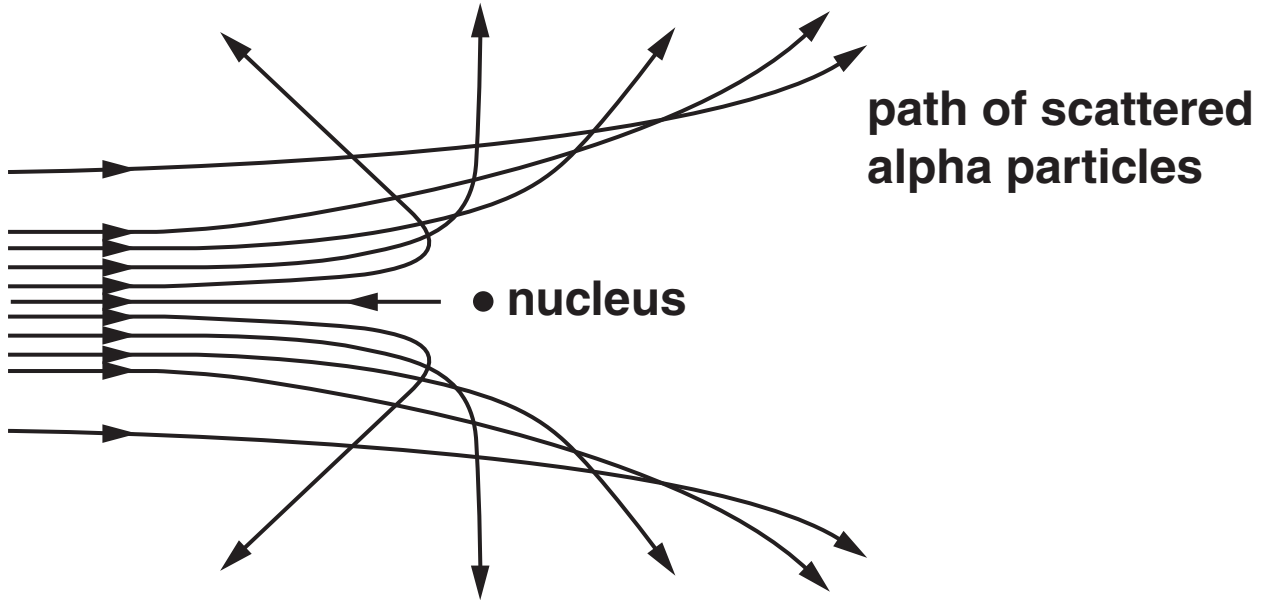


Fig. 10.1

Alpha particles of energy 5.0 MeV are fired at a thin gold foil. It is observed that 4 in every 100 000 alpha particles are scattered through large angles and 'bounce back' from the foil. It is assumed that these particles have made collisions with individual, stationary gold nuclei.

(a) State and explain any changes in the proportion of alpha particles which bounce back when the following changes are made to the experiment.

(i) A THICKER gold foil is irradiated with 5 MeV alpha particles.

[2]

(ii) The original gold foil is irradiated with alpha particles of HIGHER energy than 5 MeV.

[2]

(b) When a 5 MeV alpha particle makes a direct collision with a nucleus, the alpha particle is momentarily stationary.

(i) State the electrical potential energy of such an alpha particle when it is at its closest to the gold nucleus.

electrical potential energy = _____ MeV [1]

(ii) Convert the value in (i) into joules.

$$e = 1.6 \times 10^{-19} \text{ C}$$

electrical potential energy = _____ J [1]

(iii) Use the value in (ii) to calculate the distance of closest approach of the particle to the nucleus.

$$\begin{aligned} \text{charge on alpha particle} &= +2e \\ \text{charge on gold nucleus} &= +79e \end{aligned}$$

$$k = \frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9 \text{ N m}^{-2} \text{ C}^{-2}$$

distance = _____ m [2]

- (c) Assuming that the distance calculated in b(iii) equals the radius of the nucleus, the experiment suggests that the ratio $\frac{\text{nuclear radius}}{\text{atomic radius}}$ is about 6×10^{-5} .

Use the value of the ratio to estimate the density of a gold nucleus. State one other assumption that you make.

$$\text{density of gold} = 1.9 \times 10^4 \text{ kg m}^{-3}$$

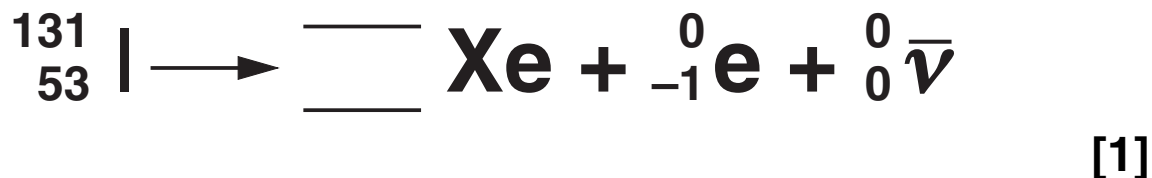
density = _____ kg m^{-3} [3]

[Total: 11]

11 This question is about an isotope used in medicine.

Iodine-131 undergoes beta decay.

(a) (i) Complete the decay equation below.



(ii) Here are four types of fundamental particle:

lepton

anti-lepton

quark

anti-quark

Circle the type of fundamental particle represented by ${}_0^0\bar{\nu}$ in the decay equation. [1]

(b) Iodine-131 has a half-life of 8 days. In a thyroid gland investigation, 4.0×10^{-11} gram of iodine is absorbed by the gland.

(i) Calculate the initial activity of the iodine-131 in the gland.

**decay constant, λ , of
iodine-131 = $1.00 \times 10^{-6} \text{ s}^{-1}$
molar mass of iodine-131 = 131 gram
 $N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$**

initial activity = _____ Bq [2]

(ii) Show that it will take about 50 days for the activity of the sample to fall to 1% of its original value.

[2]

- (iii) The mass of the thyroid gland is about 50 gram. Estimate the maximum dose in gray that the gland receives from 4.0×10^{-11} gram of iodine-131.

average energy of a β particle released in the decay of iodine-131 = 1×10^{-13} J

maximum dose = _____ Gy [2]

- (iv) Suggest TWO reasons why your estimate gives a maximum dose.

[2]

[Total: 10]

12 This question is about charges accelerated to high speeds. Fig. 12.1 shows a beam of electrons which are accelerated as they pass between two parallel charged electrodes.

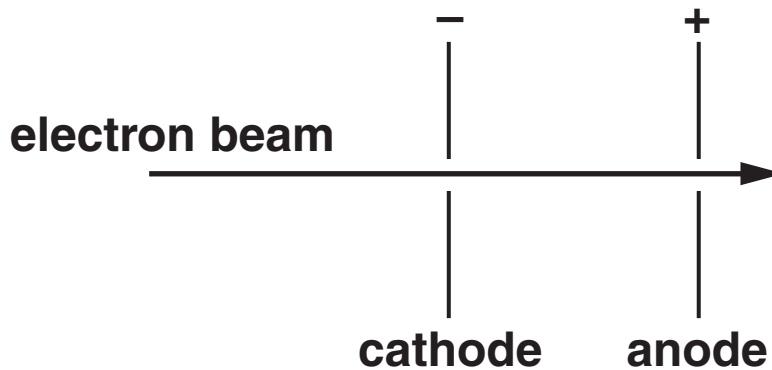


Fig. 12.1

(a) (i) Which of the graphs in Fig. 12.2 correctly shows the relationship between the acceleration of an electron (y -axis) and the distance from the cathode (x -axis) assuming that relativistic effects are not important?

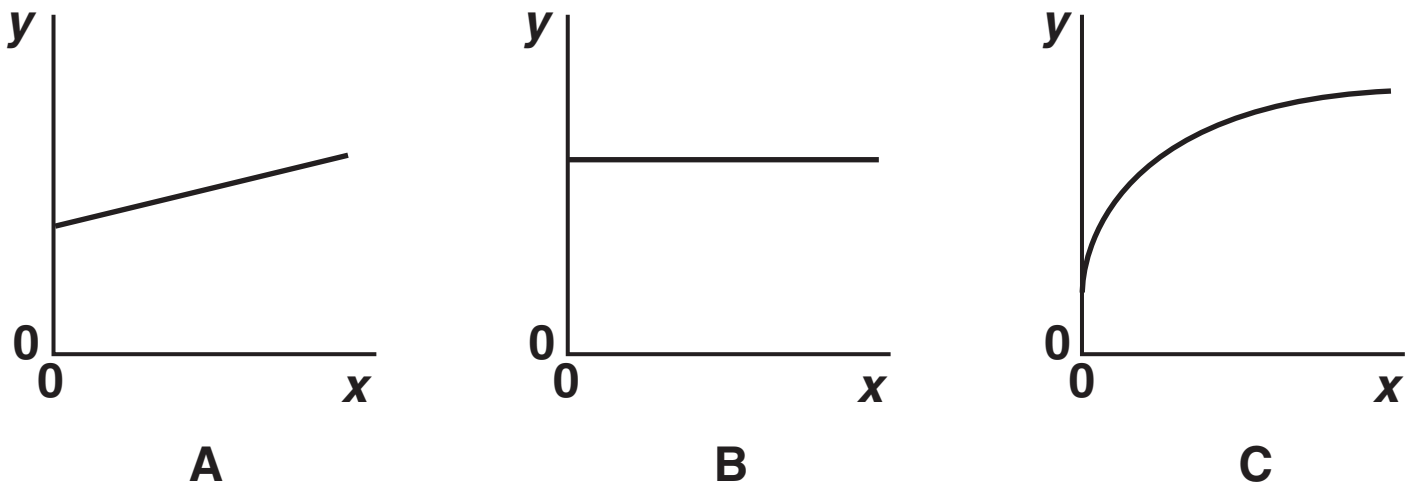


Fig. 12.2

The correct relationship is shown in graph _____ [1]

- (ii) The distance between the anode and cathode is 0.20 m. Calculate the strength of the uniform electric field between the anode and cathode when the p.d. is 70 kV.

field strength = _____ V m^{-1} [1]

- (b) The mass of an electron at rest is 9.1×10^{-31} kg. Show that the rest energy, E_{rest} , of the electron is about 8×10^{-14} J.

$$c = 3.0 \times 10^8 \text{ m s}^{-1}$$

[1]

- (c) The relativistic factor, γ , is given by

$$\gamma = \frac{E_{\text{total}}}{E_{\text{rest}}} = \frac{E_{\text{rest}} + E_{\text{kinetic}}}{E_{\text{rest}}}$$

- (i) When an electron is accelerated through a p.d. of 70 kV it gains a kinetic energy of 1.1×10^{-14} J. Calculate γ for the electron.

$\gamma =$ _____ [1]

(ii) The accelerating p.d. is doubled to 140 kV. Choose which of the statements below correctly describes how γ changes.

A γ increases by a factor of two when the p.d. doubles

B γ increases by a factor of less than two when the p.d. doubles

C γ increases by a factor of more than two when the p.d. doubles

the correct statement is _____ [1]

(d) According to classical physics the momentum of a particle of mass m and velocity v is given by

$$**$p = mv.$**$$

At very high speeds, relativistic physics shows that the momentum of the particle is given by

$$**$p = \gamma mv.$**$$

In an X-ray tube an electron is accelerated to a kinetic energy of 60 keV (about 1×10^{-14} J). Explain whether the classical equation will give an accurate value of the momentum of the particle or whether relativistic effects are important.

[3]

[Total: 8]

13 This question is about a simple a.c. generator as shown in Fig. 13.1.

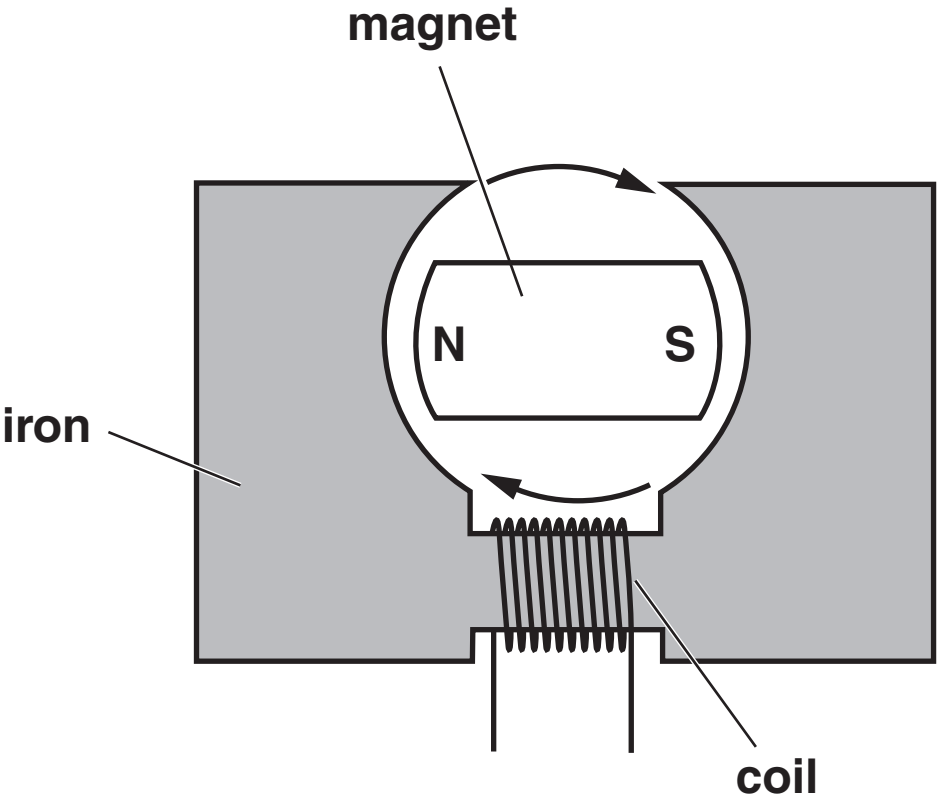


Fig. 13.1

Fig. 13.2 shows how the emf induced in the coil varies over time.

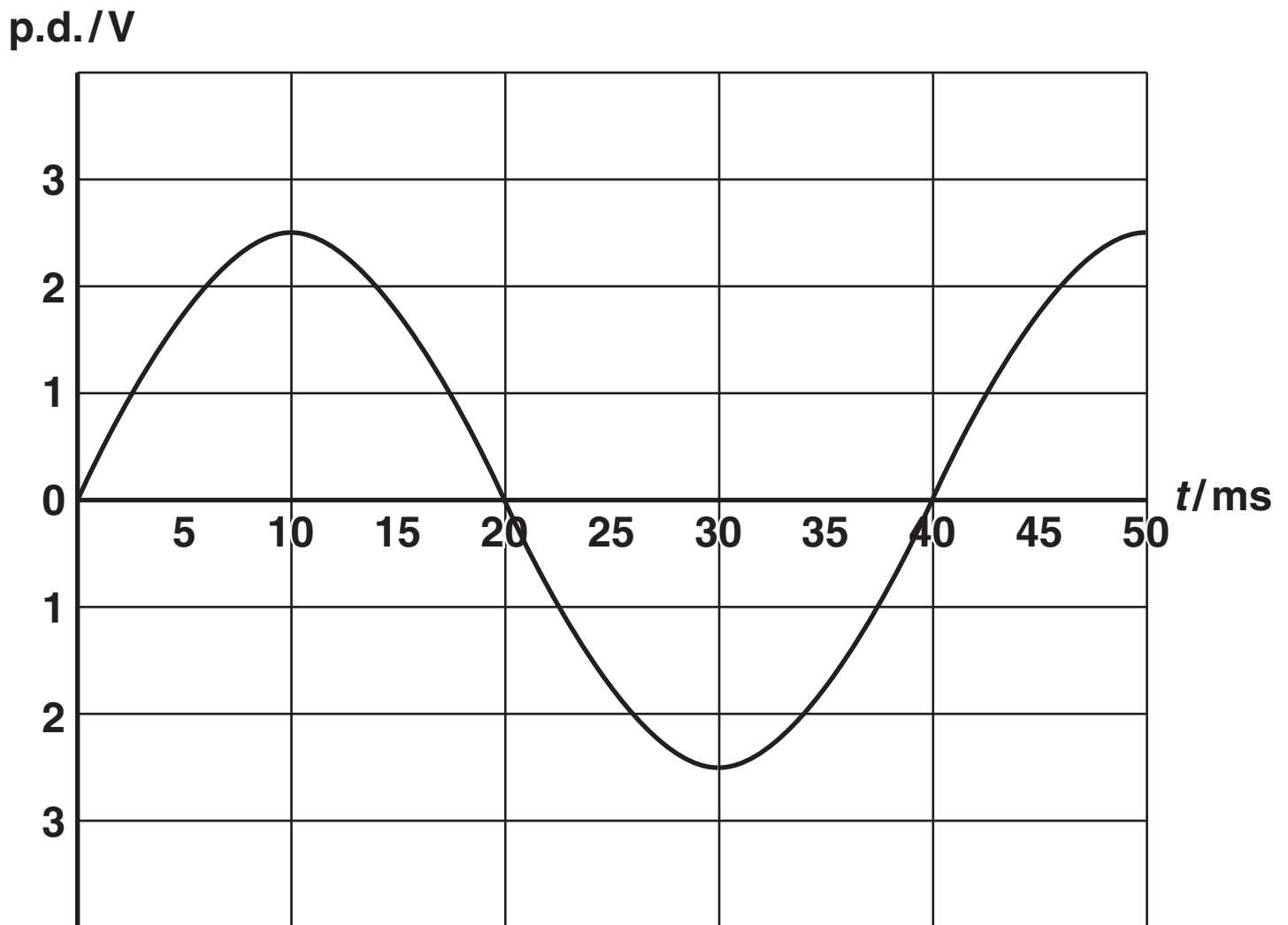


Fig. 13.2

(a) Use Fig. 13.2 to find the frequency f of the emf induced in the coil.

$f =$ _____ Hz [1]

- (b) The coil has 700 turns. Using data from the graph, explain by doing suitable calculations why the maximum rate of change of flux in the coil is 0.0036 Wb s^{-1} .

[3]

- (c) Assuming that the emf and flux are changing sinusoidally with frequency f , the rate of change of flux at time t is given by the equation

$$\text{rate of change of flux} = 2\pi f \times \text{maximum flux} \times \cos(2\pi ft).$$

The core has a cross section of $25 \text{ mm} \times 25 \text{ mm}$.

Calculate the MAXIMUM flux density in the core.

maximum flux density = _____ T [3]

(d) Suggest TWO modifications to the generator that would increase the emf induced without changing the speed of the rotor.

[2]

[Total: 9]

[Section B Total: 38]

SECTION C

THE QUESTIONS IN THIS SECTION ARE BASED ON THE
ADVANCE NOTICE.

- 14 Using Sir Fred Hoyle's comment (lines 1 to 3 in the article) calculate the distance from the surface of the Earth to space. Assume the car travels at 70 miles per hour

$$1 \text{ mile} = 1.6 \text{ km}$$

distance = _____ km [1]

[Total: 1]

15 This question is about temperature control in a space suit (lines 41 to 50 in the article).

A human, when working hard, can dissipate about 1 MJ of energy in an hour, warming the temperature of the body and its surroundings.

(a) Show that this rate of energy transfer is about 280 watts.

[1]

- (b) Explain how the rate of pumping of the water around the liquid cooling and ventilation garment (LCVG) would need to change in order to maintain the same temperature if the astronaut moved from a sunlit, warm area to an unlit, colder one.**



The steps of your explanation should be clear and in a logical order.

[3]

(c) One problem that would arise if the LCVG water pump failed would be that the gas inside the suit would heat up, resulting in an increase in the pressure.

(i) Show that the mass of gas in the space suit is about 80 gram. Assume that all the gas is oxygen.

volume of gas in the suit = 0.058 m^3

**density of oxygen gas in the
suit = 1.4 kg m^{-3}**

[1]

- (ii) Calculate the temperature reached by the oxygen in the space suit after five seconds. Assume that all the energy dissipated by the astronaut is transferred to the gas.

initial temperature of gas = 18°C

rate of energy transfer = 280W

specific thermal capacity of
oxygen = $900\text{J kg}^{-1}\text{ }^{\circ}\text{C}^{-1}$

temperature = _____ $^{\circ}\text{C}$ [3]

- (iii) As the temperature of the oxygen increases the pressure in the suit will rise. Calculate the factor that the pressure will rise by when the temperature rises to the value calculated in (ii).

Assume that the volume of the suit does not change.

factor = _____ [2]

[Total: 10]

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16 Fig. 16.1 shows how the Earth's atmospheric pressure varies with altitude.

(a) Explain what is meant by an *exponential relationship* and use data from Fig.16.1 (Fig. 3 in the article) to show that the relationship between pressure and altitude is exponential.



In your answer you should use appropriate technical terms spelled correctly.

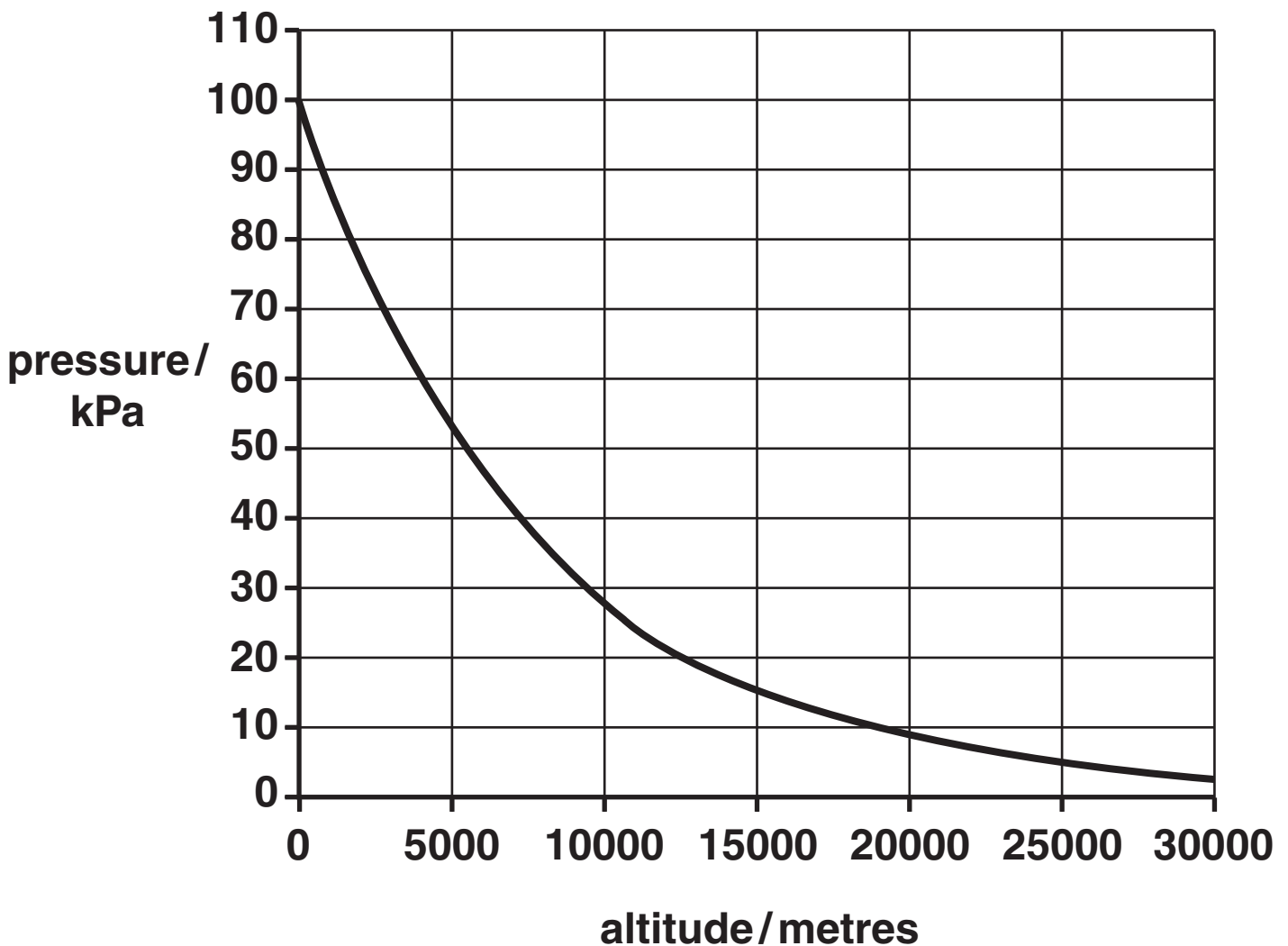


Fig. 16.1

[5]

(b) The gas pressure within the suit is much less than atmospheric pressure at sea level. Explain how the gas in the suit being almost 100% oxygen (lines 64–66 in the article) allows the astronaut to breathe at this reduced pressure.

[2]

[Total: 7]

17 This question is about the Thermal Micrometeoroid Garment (TMG) (lines 67 to 89 in the article). This comprises several layers, some of which are composite materials.

Explain what is meant by a *composite material* and explain a benefit of using a composite material in the TMG. Refer to one of the materials mentioned in the article in your answer.

[4]

[Total: 4]

18 Spacewalking astronauts are in constant danger of being struck by fast-moving tiny fragments of dust, called micrometeoroids (lines 95 to 103 in the article).

(a) Show that the kinetic energy of a typical micrometeoroid is about 1 kJ.

speed of micrometeoroid = 50 km s^{-1}

mass of micrometeoroid = $1.0 \times 10^{-6} \text{ kg}$

[2]

(b) Assume that 90% of this energy is used on impact to melt and then vaporise some of the aluminium in the outer layer of the helmet.

(i) By neglecting the energy used to melt the metal, calculate the mass of aluminium that can be vaporised by this amount of energy.

energy required to vaporise 1 kg of aluminium = 10.5 MJ

mass vaporised = _____ kg [2]

- (ii) Assuming the vaporised shape is a hemisphere, calculate the penetration depth, r (the radius of the hemisphere) of the micrometeoroid (Fig. 18.1).

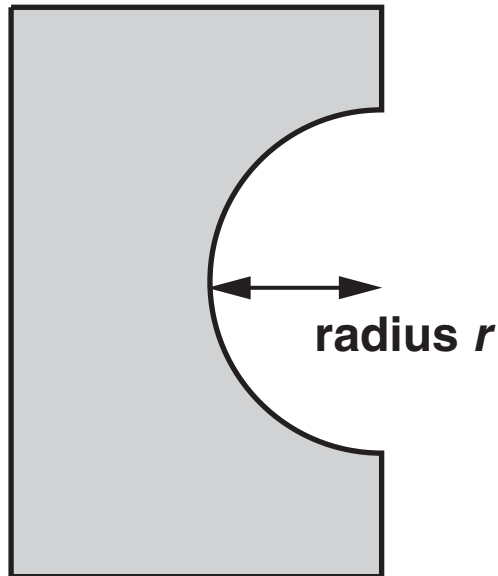


Fig. 18.1

density of aluminium = 2400 kg m^{-3}

volume of a sphere of radius $r = \frac{4}{3} \pi r^3$

penetration distance = _____ m [3]

[Total: 7]

19 Astronauts face the danger of the solar wind. This accounts for 10^6 tonnes (10^9 kg) of mass streaming from the Sun each second (lines 104 to 110 in the article).

- (a) (i) Show that the Sun emits about 6×10^{35} particles per second. Assume that each particle has mass equal to that of a proton.**

$$\text{mass of proton} = 1.7 \times 10^{-27} \text{ kg}$$

[2]

- (ii) The solar wind flux is the number of particles per m^2 per second.**

Use your answer to (i) to show that the solar wind flux at the Earth's distance from the Sun is about $2 \times 10^{12} \text{ m}^{-2} \text{ s}^{-1}$. Assume the solar wind is emitted evenly in all directions.

$$\text{mean Earth-Sun distance} = 1.5 \times 10^{11} \text{ m}$$

$$\text{surface area of a sphere} = 4\pi r^2$$

[2]

(b) The protons in the solar wind have energies of about 1 keV (1.6×10^{-16} J).

(i) Estimate the energy transferred to the suit and astronaut in one second assuming that the solar wind strikes an area of 1.5 m^2 .

energy = _____ J [1]

(ii) Discuss whether the solar wind protons are likely to be a significant health hazard for the astronaut.

The quality factor for protons is 20.

[3]

[Total: 8]

20 For space walks and other extra-vehicular activity, the astronauts wear a Mobile Manoeuvring Unit (MMU) which is fitted with a number of nitrogen gas thruster jets. The MMU itself has a mass of 100 kg.

(a) Show that the momentum of an astronaut wearing an MMU and moving forwards at 5 m s^{-1} is about $1 \times 10^3 \text{ kg m s}^{-1}$.

**total mass of astronaut, space suit and
MMU = 225 kg**

[1]

- (b) Using the information in (a), calculate the rate at which nitrogen gas would need to be expelled from the jet thrusters in order for the astronaut to increase his speed by 4 m s^{-1} in 20 seconds.

velocity of nitrogen gas expelled = 600 m s^{-1}

rate = _____ kg s^{-1} [3]

[Total: 4]

[Section C Total: 41]

END OF QUESTION PAPER

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