OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE **2865/01**

PHYSICS B (ADVANCING PHYSICS)

Advances in Physics

TUESDAY 17 JUNE 2008 Afternoon

Time: 1 hour 30 minutes

Candidates answer on the question paper

Additional materials (enclosed): Insert (Advance Notice article for this question paper)

Additional materials (required):
Advancing Physics Data, Formulae and Relationships Booklet
Electronic calculator

CUP/T44680

Candidate Forename		Candidate Surname	
Centre Number		Candidate Number	

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre number and Candidate number in the boxes above.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you understand you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided.
- Show clearly the working in all calculations, and round answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- The number of marks for each question is given in brackets [ ] at the end of each question or part question.
- The total number of marks for this paper is **90**.
- The values of standard physical constants are given in the Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.
- You will be awarded four marks for the quality of written communication throughout the paper.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**9**	
2	**7**	
3	**8**	
4	**12**	
5	**11**	
6	**9**	
7	**13**	
8	**17**	
QWC	**4**	
TOTAL	**90**	

This document consists of **25** printed pages, **3** blank pages and an insert.

Answer **all** the questions.

Section A

The questions in this section are based on the Advance Notice article.
You are advised not to spend more than 60 minutes on this section.

1 This question is about Viking navigation (lines 3–16 in the article).

(a) Electromagnetic waves, such as light, can be partially polarised.

(i) State what this tells you about the nature of electromagnetic waves.

[1]

(ii) The blue wavelengths of light in the sky are partially polarised, and this is particularly noticeable at sunset.

When the sky is viewed through a polarizing filter held at the correct angle, a dark band can be seen overhead.

This allows the navigator to work out where the Sun must be (Fig. 1.1).

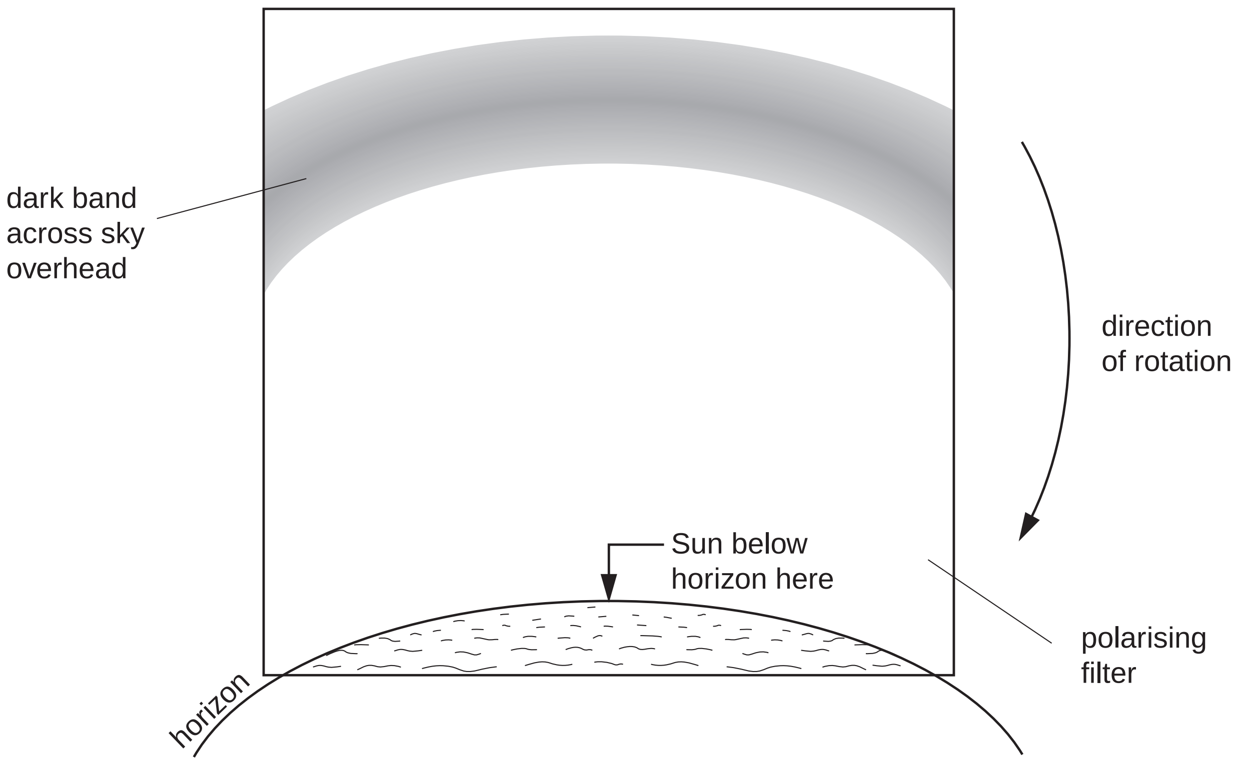

Fig. 1.1

Describe what would be seen as the polarising filter is rotated through 360° (1 rotation) in the direction shown in Fig. 1.1.

[2]

(b) Fig. 1.2 shows one Viking voyage from Greenland to North America. The North Magnetic pole of the Earth is marked and the direction of geographic North is shown by the meridian lines.

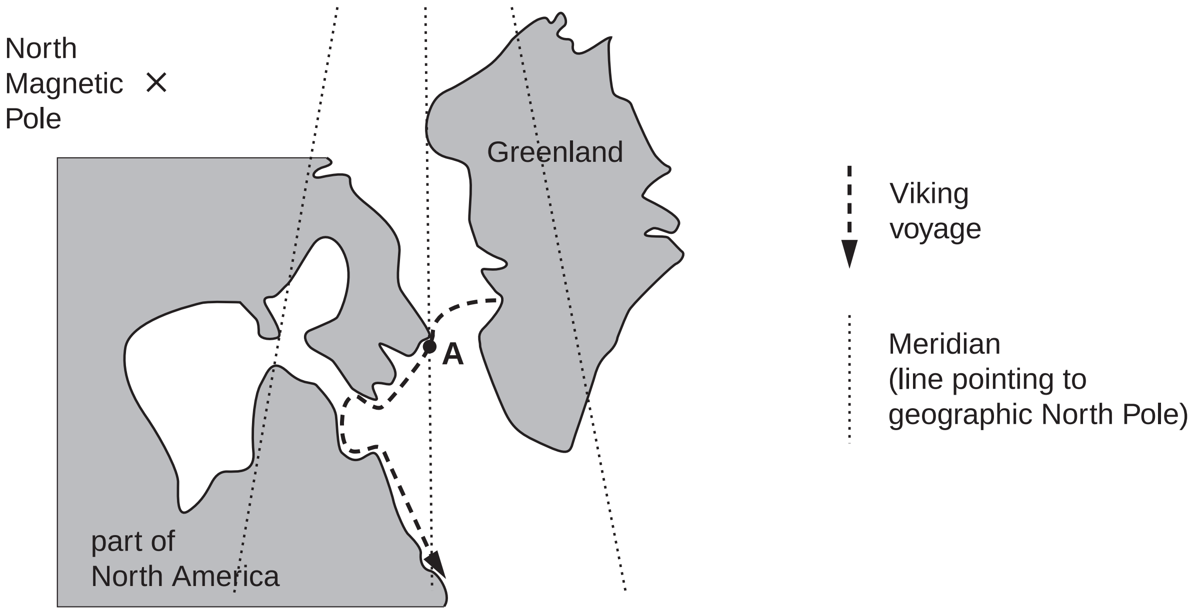

Fig. 1.2

(i) Explain why magnetic compasses could mislead Viking navigators at the point marked **A**.

[2]

(ii) The article states '… for most Europeans the magnetic compass became an essential aid to navigation.' (lines 21–22 in the article)

Explain why the compass errors found near Greenland would not be significant much further south and east, in Europe.

[2]

(iii) Compasses do not point only in a horizontal direction. They also point downwards, because the Earth's magnetic field is not perfectly horizontal at most points on Earth.

Use the ideas of horizontal and vertical vector components to suggest why a simple compass using a pivoted magnetic needle (Fig. 1.3), is more difficult to use for direction finding near the Earth's North Magnetic Pole.

Fig. 1.3

[2]

[Total: 9]

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2 This question is about William Gilbert's model of the Earth (lines 24–42 and Figs. 1 and 2 in the article).

(a) Gilbert was struck with the similarity between static electricity and magnetism (lines 26–28 in the article).

Describe one similarity and one difference between electric and magnetic fields.

similarity:

difference:

[2]

(b) One of Gilbert's own drawings showed the directions in which compasses pointed when placed near his magnetic model of the Earth. (Fig. 2.1)

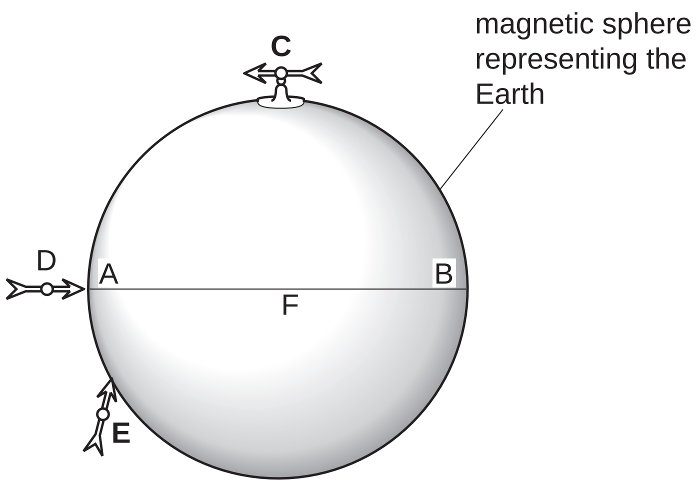

Fig. 2.1

Draw flux loops on Fig. 2.1 passing through the small compasses **C** and **E** shown, and mark the positions of the North and South magnetic poles. [3]

(c) Gilbert had a theory that the continents attracted compasses. He modelled the Earth as a solid spherical magnet with a hole representing the Atlantic Ocean (lines 33–42 in the article).

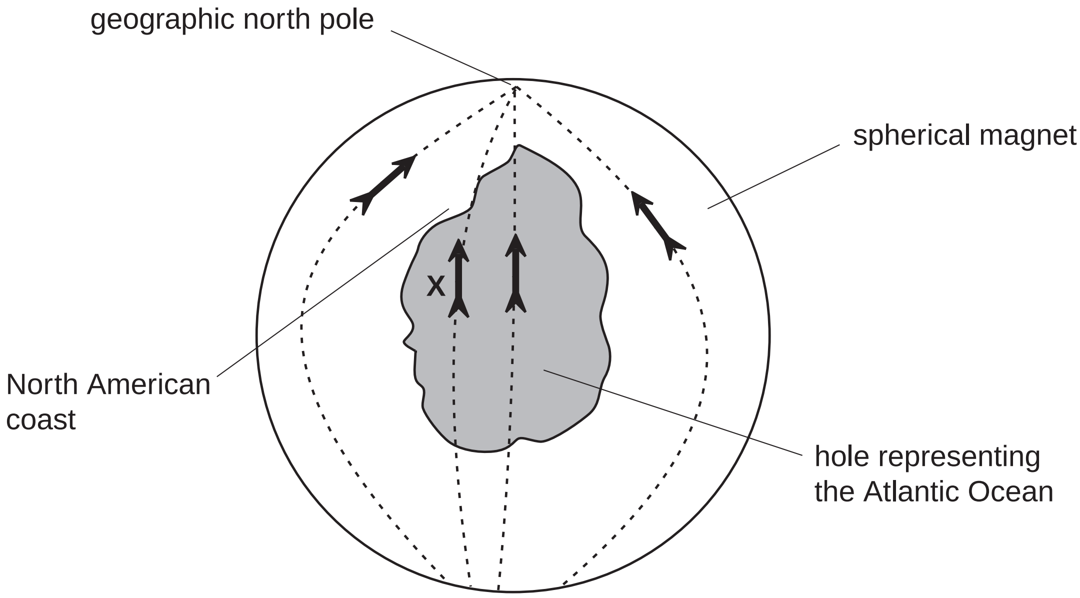

Fig. 2.2

Use magnetic circuit ideas to explain why the one arrow marked **X** does not point along the dotted line, while the other three do. You may draw flux lines on Fig. 2.2 to help you.

[2]

[Total: 7]

3 This question is about the internal structure of the Earth (lines 51–56 and Fig. 3A in the article).

(a) By applying Newton's gravitational law to a mass of 1 kg near the Earth's surface, show that the mass of the Earth is about 6×10^{24} kg.

$g = 9.8\ \text{N kg}^{-1}$
$G = 6.7 \times 10^{-11}\ \text{N m}^2\,\text{kg}^{-2}$
mean radius of Earth, $R = 6.4 \times 10^6$ m

[3]

(b) Data from seismometers show that the radius of the Earth's core is 3.5×10^6 m.

(i) Show that the volume of the Earth's core is about $2 \times 10^{20}\ \text{m}^3$.

[1]

(ii) The density of the Earth's core is $11\,000\ \text{kg m}^{-3}$. Calculate its mass.

mass of core = ……………………….. kg [1]

(c) The mean density of rocks in the Earth's crust is about 3000 kg m^{-3}.

Calculate the mean density of the mantle and crust to justify the statement that 'The increase in pressure in the interior of the Earth does lead to an increase in density but this is not nearly enough to account for the density doubling …' (lines 54–55 in the article).

volume of Earth = 1.0×10^{21} m^{3}

mean density of mantle and crust = ……………………….. kg m^{-3} [3]

[Total: 8]

4 This question is about the velocities of S waves and P waves inside the Earth (lines 61–70 and Fig. 3 in the article).

(a) P and S waves start off from the same point in the crust. Two paths through the mantle of the Earth, both starting in the same direction, are shown in Fig. 4.1.

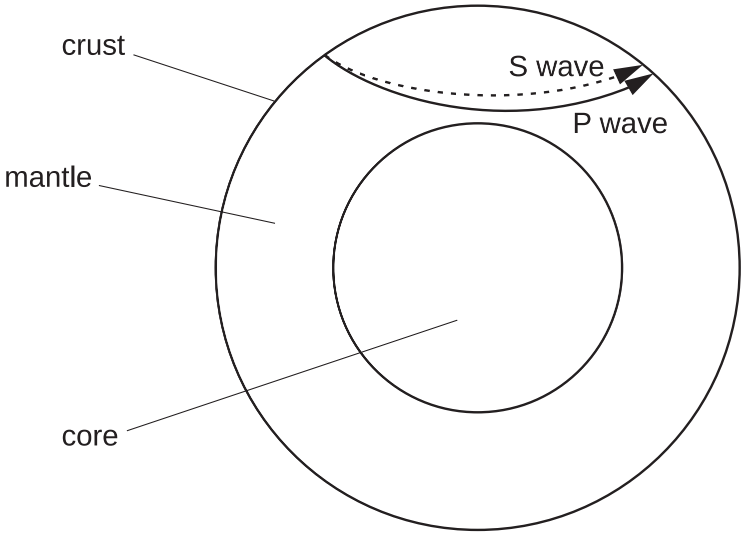

Fig. 4.1

(i) Explain why the paths of the waves are curved.

[1]

(ii) Suggest why the paths of the two waves curve differently.

[2]

(b) These velocities depend on the density and an elastic modulus of the materials of the Earth.

The velocity v_S of the S waves within the Earth is given by the equation

$$v_S = \sqrt{\frac{E}{\rho}}$$

where E is the elastic modulus and ρ the density of the material.

(i) Show that S waves travel at about 4000 m s^{-1} at a point in the mantle where $E = 5.0 \times 10^{10}$ Pa and $\rho = 3200$ kg m^{-3}.

[1]

(ii) Both E **and** ρ increase with depth in the mantle.

Given that the wave velocities **increase** with increase of depth, state and explain whether E or ρ has the greater percentage increase for a given increase in depth.

[2]

(c) The velocity of P waves within the Earth is given by the equation

$$v_P = \sqrt{\frac{7E}{3\rho}}.$$

Use this equation to predict the velocity of P waves at a depth where S waves travel at 4000 m s^{-1}.

velocity = ……………………….. m s^{-1} [2]

(d) When P waves pass into the core, they are refracted as shown in Fig. 4.2

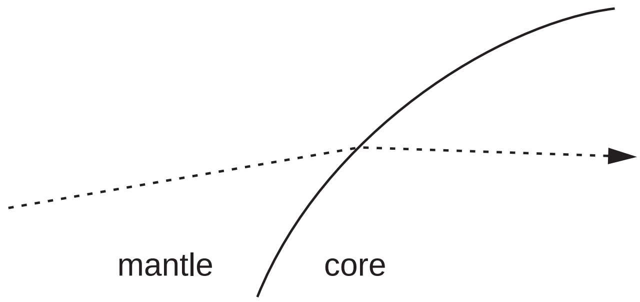

Fig. 4.2

(i) Label on Fig. 4.2 the angles that you would need to find to confirm that the P waves travel 1.7 times faster in the mantle than they do in the core (lines 72–74 in the article). [2]

(ii) State and explain how Fig. 4.2 shows that the mantle and core are made of very different materials.

[2]

[Total: 12]

5 **(a)** One theory of the source of the energy in the core is that liquid iron is crystallising into solid iron (lines 99–101 in the article).

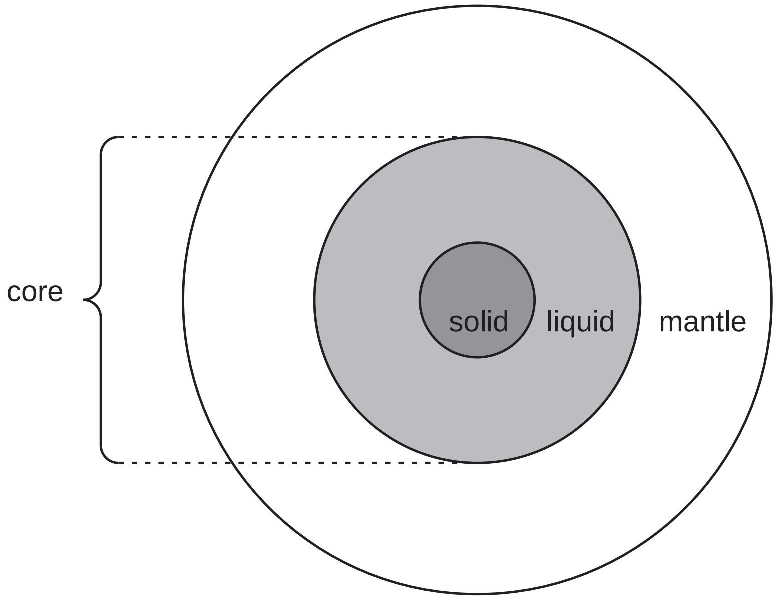

Fig. 5.1

The mass of the solid inner iron core of the Earth is 1.0×10^{23} kg.

(i) Show that this contains about 2×10^{24} mol of iron.
molar mass of iron = 56 g

[2]

(ii) When one mole of iron solidifies, it releases 1.5×10^{4} J of energy.

Calculate the time, in years, it must have taken for the inner core to solidify from a liquid state, assuming that it is losing energy at a rate 9×10^{12} W.
1 year = 3.2×10^{7} s

time = ……………………… years [3]

(iii) Justify the statement in the article, 'However, the energy produced by this method over the known age of the Earth, when compared with the measured rate at which energy is emitted by the cooling Earth, is too small' (lines 101–103 in the article).

[1]

(b) Another theory is that the Earth's core is heated by radioactive decay (lines 105–107 in the article).

The core contains considerable quantities of radioactive isotopes of uranium, thorium and potassium. The table shows the half-lives of two of these isotopes.

isotope	half life / 10^9 years
potassium-40	1.3
uranium-238	4.5

(i) The Earth was formed 4.6×10^9 years ago.

Put a tick by the **one** correct row in the table below showing the amounts of these isotopes remaining in the core now as a percentage of the original amount present.

potassium-40	**uranium-238**	
about $\frac{1}{10}$	slightly less than $\frac{1}{2}$	
about $\frac{1}{10}$	slightly more than $\frac{1}{2}$	
about $\frac{1}{4}$	slightly less than $\frac{1}{2}$	
about $\frac{1}{4}$	slightly more than $\frac{1}{2}$	

[1]

(ii) It is now thought that the Earth's core contains about 8×10^{41} atoms of potassium-40 dissolved in the iron.

Calculate the energy emitted per second by the decay of potassium-40 and compare this with the 9×10^{12} W emitted from the core.

energy released in one decay of potassium-40 = 7.7×10^{-14} J
1 year = 3.2×10^{7} s

[4]

[Total: 11]

6 This question is about the geodynamo (lines 86–98 in the article).

(a) A simple model of a self-exciting dynamo has a conductor of length L moving at a speed v perpendicular to a magnetic field of flux density B. It moves a distance x in a time dt.

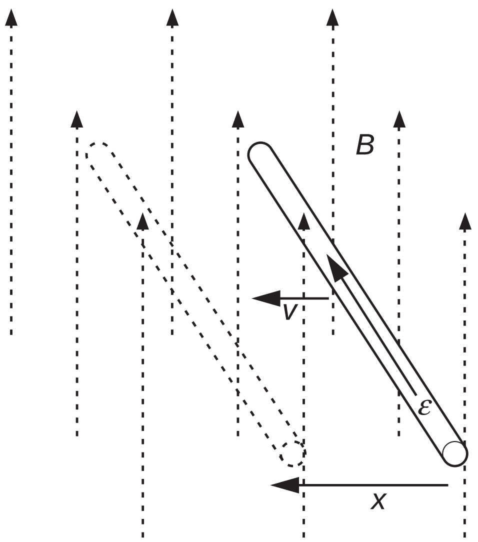

Fig. 6.1

The following mathematical argument derives an equation for the induced emf ε.

....

$$\varepsilon = -\frac{d(N\Phi)}{dt}$$

....

$$\varepsilon = -\frac{d(BA)}{dt}$$

....

$$\varepsilon = -\frac{dA}{dt}B$$

....

$$\varepsilon = -\frac{d(xL)}{dt}B = -\frac{dx}{dt}LB$$

....

$$\varepsilon = -vLB$$

Write the following comments on the dotted lines above so that each justifies the equation that follows.

$A = xL$
$N = 1$ and $\Phi = BA$
using Faraday's law of electromagnetic induction
the flux density is constant
velocity is rate of change of displacement

[3]

(b) In the self-exciting dynamo, the emf ε produces a current I.

This current loop generates the magnetic field B that we observe.

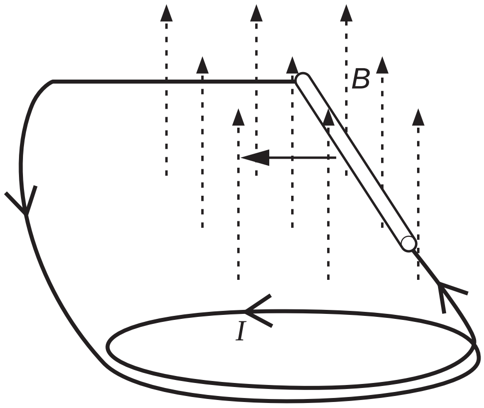

Fig. 6.2

The rotation of the Earth produces a swirling motion in the liquid core. This moving liquid is the 'conducting rod' that generates the emf which produces the current.

The following table contains data on three planets of the Solar System.

planet	core nature	period of rotation / Earth days
Earth	Liquid outer core of radius 3500 km	1
Jupiter	Unknown: possibly a rocky core of radius 9600 km surrounded by a liquid metallic mantle	0.4
Venus	Core of radius 3000 km; not known if outer core is liquid or if whole core is solid	243

(i) Using data from the table above, suggest reasons why Venus has almost no magnetic field.

[2]

(ii) Using data from the table above, suggest reasons why Jupiter has an extremely large magnetic field compared with that of the Earth.

[2]

(c) Computer models (lines 111–114 in the article) have been used to predict the behaviour of the geodynamo. Explain clearly why computer models have been necessary.

[2]

[Total: 9]

Section B

7 This question is about radioactive tracers and medical imaging.

Technetium-99m, ${}^{99m}_{43}\text{Tc}$, is a commonly used radioactive isotope, which when injected into the bloodstream can be used to provide information about the function of various organs.

The 'm' indicates that it is metastable. This means that the nucleus is at a higher energy level than that of a normal technetium ${}^{99}_{43}\text{Tc}$ nucleus.

(a) The equation, Fig. 7.1, shows how ${}^{99m}_{43}\text{Tc}$ can be produced from the decay of a radioactive isotope of molybdenum.

$$ {}^{\cdots\cdots\cdots}_{\cdots\cdots\cdots}\text{Mo} \longrightarrow {}^{99m}_{43}\text{Tc} + {}^{0}_{-1}\text{e} + \bar{\nu} $$

Fig. 7.1

(i) Complete the equation by adding the nucleon (mass) number and proton number of the molybdenum (Mo) isotope in the spaces on Fig. 7.1. [1]

(ii) Write down the name of the particle represented by the symbol $\bar{\nu}$ in the equation, Fig. 7.1.

particle: …………………………….[1]

(b) The ${}^{99m}_{43}\text{Tc}$ decays to ${}^{99}_{43}\text{Tc}$ by emitting a gamma photon with an energy of 140 keV.

(i) Show that 140 keV is about 2.2×10^{-14} J.

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

[2]

(ii) Calculate the reduction in mass of the ${}^{99m}_{43}\text{Tc}$ nucleus when it changes.

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

mass reduction = ……………….. kg [2]

(iii) Suggest why gamma radiation is the most appropriate radiation for a radioactive tracer used in medicine in this way.

[1]

(c) A typical sample of technetium-99m injected into an adult patient has an average activity of 400 MBq for the six hours it remains in the body.

Show that the total dose equivalent received by a patient of mass 65 kg in this procedure will be less than the recommended maximum of 20 mSv.

State any assumptions and estimates that you make.

quality factor for gamma radiation = 1

[4]

(d) A syringe shield, shown in Fig. 7.2, constructed out of tungsten and lead glass, is placed around the syringe used to inject the radioisotope into the patient

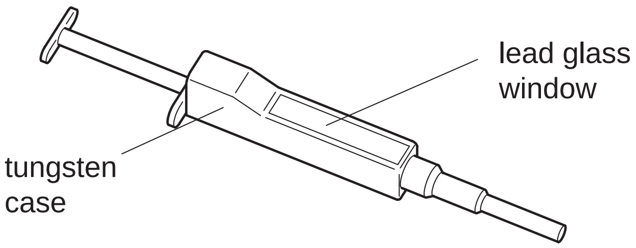

Fig. 7.2

(i) Although the activity of the sample is low enough to inject into a patient, the syringe needs to be shielded. Explain why.

[1]

(ii) State one important **physical property** that the materials used for the shielding must have. Explain your reasoning.

[1]

[Total: 13]

8 This question is about oscillations.

(a) A student suspends a 0.8 kg mass from the end of a spring, which extends by a distance of 20 cm.

(i) Show that the spring constant of the spring is about 40 N m^{-1}.

g = 9.8 m s^{-2}

[2]

(ii) The student allows the mass to oscillate vertically on the spring.

Show that the period of oscillation is about 0.9 s.

[2]

(b) The student then considers deflecting the electron beam in an oscilloscope to match the oscillating motion of the mass on the spring.

The electron gun in the oscilloscope accelerates electrons through a potential difference of 3000 V.

(i) Show that the electrons leave the electron gun at a velocity of about 3 x 10^7 m s^{-1}.

e = 1.6 x 10^{-19} C

mass of electron, m_e = 9.1 x 10^{-31} kg

[2]

The high speed electrons pass between two parallel plates in the oscilloscope and are initially deflected by a **constant** potential difference applied between points **A** and **B** as shown in Fig. 8.1.

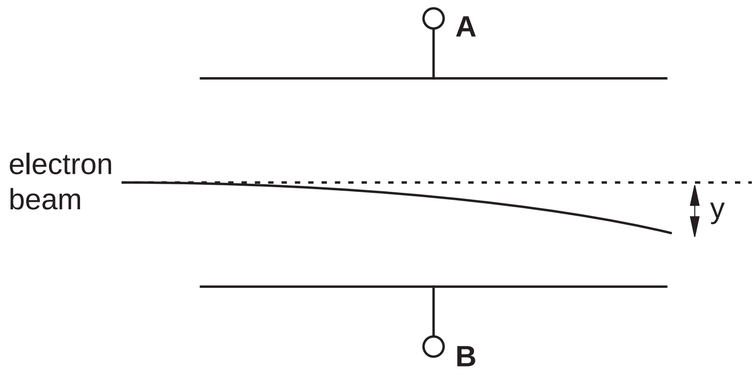

Fig. 8.1

(ii) Draw on Fig. 8.1 **five** field lines showing the uniform electric field between the plates. [2]

(iii) The path taken by the electrons has exactly the same shape as a projectile thrown horizontally near the Earth's surface.
Explain why the two paths have the same shape.

[2]

(iv) The constant potential difference between the plates **A** and **B** is replaced by a sinusoidal alternating voltage.

Calculate the frequency of the voltage required for the oscillation of the oscilloscope trace to match that of the mass on the spring in **(a)**.

frequency = ………………. Hz [1]

(c) Another oscillating system is a vessel containing gas.

Pistons connected to vessels containing gas are often used to replace conventional springs in vehicle suspension systems.

These systems allow the bodywork of a vehicle to move vertically relative to the wheels (Fig. 8.2).

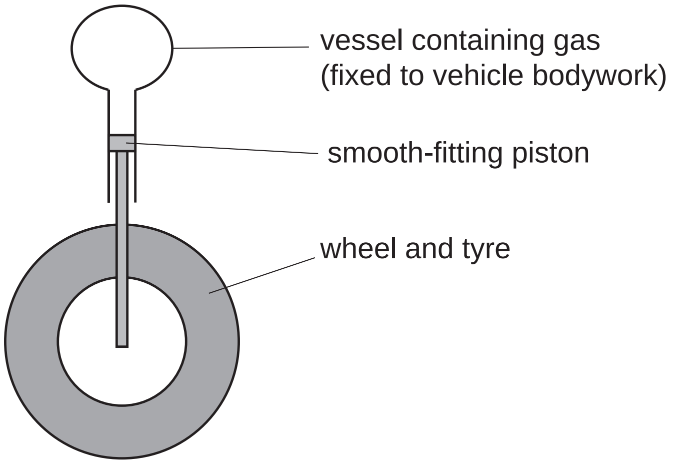

Fig. 8.2

(i) Write down **two** factors which determine the equilibrium position of the piston.

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

(ii) Suggest and explain one change that could be made to this system to increase its 'spring constant'.

[2]

(iii) In one vertical movement of the piston, the gas pressure increased from 2.0×10^5 Pa to 3.0×10^5 Pa while the volume dropped from 1.0×10^{-3} m^3 to 0.75×10^{-3} m^3.

Explain clearly how this information shows that the temperature of the gas in the cylinder has not remained constant but has increased.

[2]

[Total: 17]

Quality of Written Communication [4]

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