OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS B (ADVANCING PHYSICS)
Advances in Physics

2865/01

Candidates answer on the question paper

OCR Supplied Materials:
• Insert (Advance Notice article for this question paper) (inserted)
• Advancing Physics Data, Formulae and Relationships Booklet

Other Materials Required:
• Electronic calculator
• Ruler (cm/mm)

Tuesday 16 June 2009
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number					Candidate Number				

INSTRUCTIONS TO CANDIDATES

• Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
• Use black ink. Pencil may be used for graphs and diagrams only.
• Read each question carefully and make sure that 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, however additional paper may be used if necessary.
• Show clearly the working in all calculations, and round answers to only a justifiable number of significant figures.
• Section A (questions 1–6) is based on the Advance Notice article.

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 **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.
• There will be four marks for the quality of written communication assessed throughout the paper.
• This document consists of **24** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	Max.	Mark
1	8	
2	14	
3	10	
4	8	
5	9	
6	8	
7	13	
8	16	
QWC	4	
TOTAL	90	

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Turn over

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 Alexander Bell's metal detector (lines 3–19 in the article). Fig. 1.1 shows a simplified version of his apparatus.
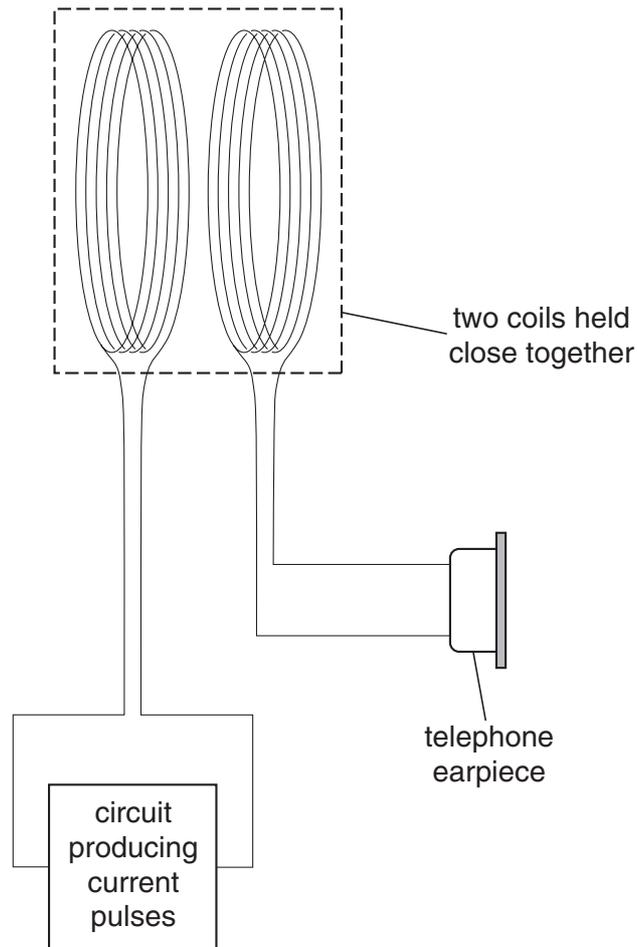

Fig. 1.1

(a) When there is a current in the left-hand coil, a magnetic field is produced.

Draw two flux loops on Fig. 1.1 to show the shape of the magnetic field linking the two coils.

[2]

 (b) In Bell's apparatus, the current was produced in pulses.

   The graph below shows one current pulse in the **left-hand** coil.

   Complete the other two graphs to show how

   (i) the flux linking the two coils changes with time

   (ii) the voltage induced in the **right-hand** coil changes with time.

current in
left-hand
coil
                                                                        time

 (i)

flux
linking
both
coils
                                                                        time

                                                                              [1]

 (ii)

voltage
induced in
right-hand
coil
                                                                        time
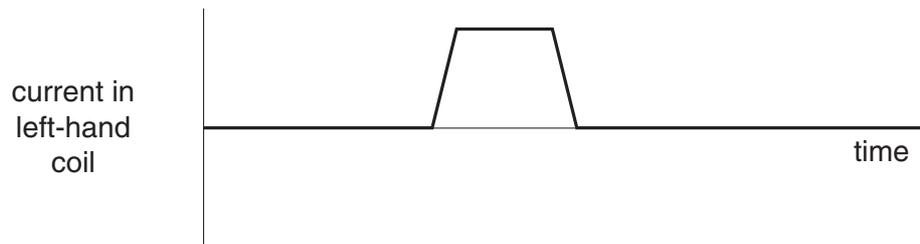
                                                                              [3]

 (c) In use, the pair of coils is placed very close to a piece of iron.

   (i) State what happens to the flux linking the coils.

   (ii) Explain what happens to the voltage induced in the right-hand coil.

                                                                              [2]

                                                                        [Total: 8]

2 This question is about the production of X-rays (lines 62–73 and Fig. 5 in the article).
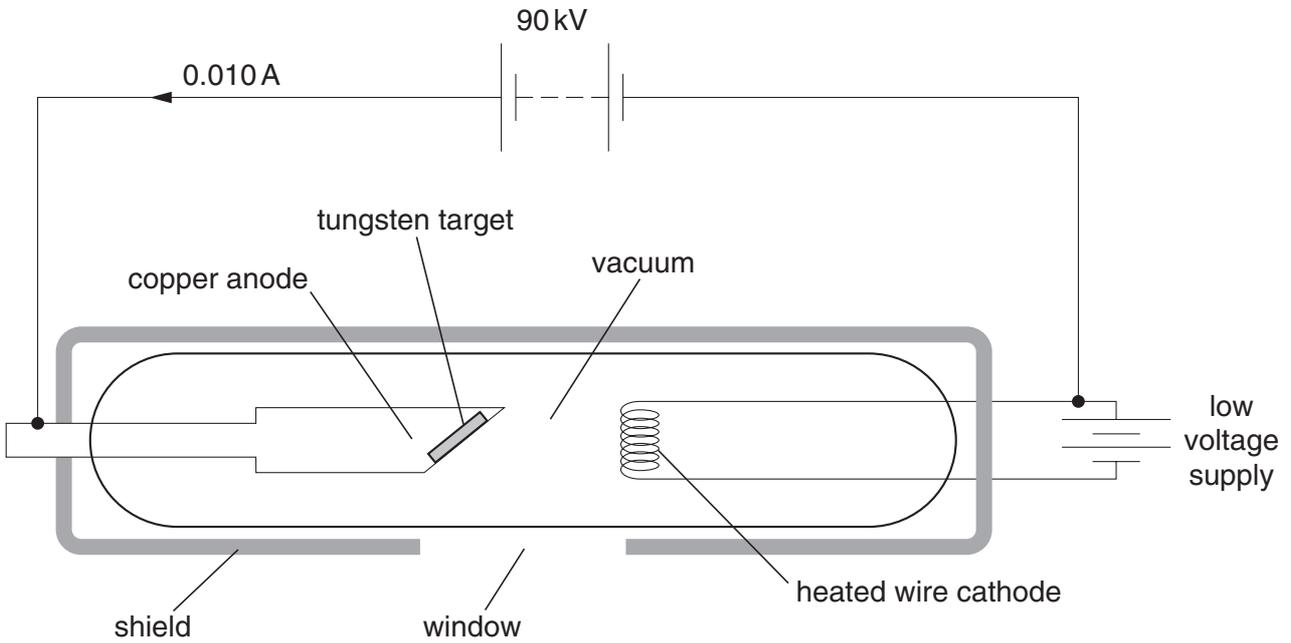
Fig. 2.1 shows a simple X-ray tube.

Fig. 2.1

(a) (i) The mean separation of the anode and cathode in the X-ray tube is 1.2 cm. Estimate a value for the electric field strength E in this region.

$E =$ .... $N C^{-1}$ **[1]**

(ii) Explain clearly why your answer to **(a)(i)** can only be an **estimate** of the field strength.

[1]

(iii) Draw **three** electric field lines in the region between the cathode and the anode in Fig. 2.1. **[2]**

(b) The low voltage supply shown on Fig. 2.1 is responsible for heating the wire cathode.

   (i) Explain why increasing the p.d. of the **low voltage** supply increases the temperature of the cathode.

[1]

   (ii) When any metal is heated, some free electrons in the metal are given enough energy to escape from the metal.

   Explain why increasing the temperature of the cathode increases the small fraction of electrons that escape.

[2]

   (iii) Suggest how the performance of the X-ray tube is changed by using a higher cathode temperature.

[1]

Turn over

(c) In use, there is a current of 0.010 A in the 90 kV circuit.

  (i) Show that the total power delivered to the X-ray tube is 900 W.

  [1]

  (ii) Only 1% of this power is radiated as X-rays. Calculate the power dissipated as heat in the anode.

  power .... W **[1]**

  (iii) Assume that the anode is entirely made of copper.

  Calculate the rate of rise of temperature of the anode.

  Justify the statement in the article that the anode 'has to be cooled to remove the heat produced' (lines 72–73 in the article).

  mass of anode = 0.80 kg
  specific thermal capacity of copper = 390 J kg^{-1} K^{-1}
  melting point of copper = 1100 °C

  rate of rise of temperature = ... °C s^{-1}

  [4]

  [Total: 14]

3 Fig. 3.1 shows the spectrum of X-rays produced by a tungsten X-ray tube (lines 62–73 in the article).
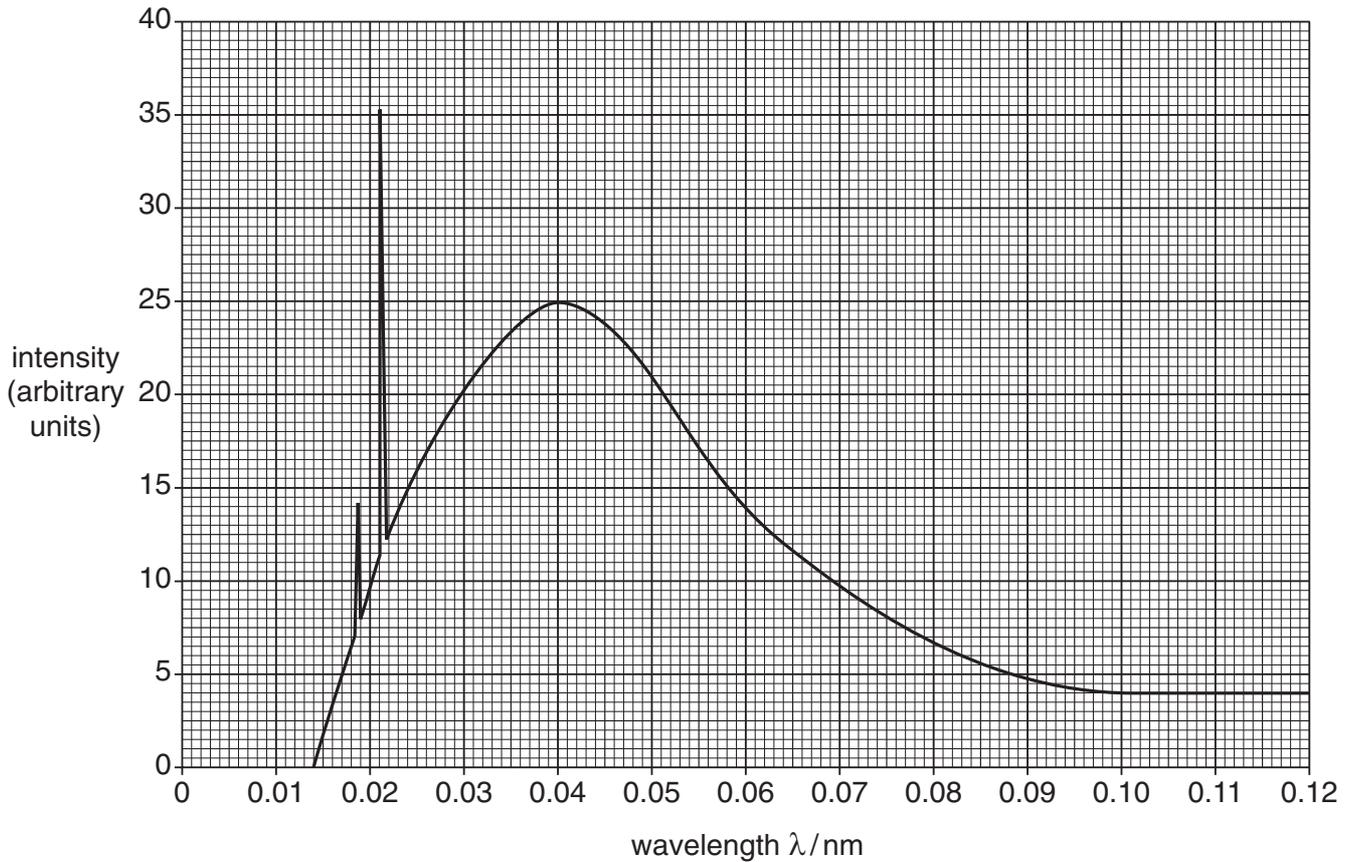
Fig. 3.1

(a) The article states that 'The decelerating electrons lose energy, which is emitted as X-rays of a range of wavelengths down to a minimum value, dependent on the electron energies used' (lines 64–65 in the article).

(i) Use the graph of Fig. 3.1 to show that the maximum energy of an emitted X-ray photon is about 1.0×10^{-14} J.

$c = 3.0 \times 10^8 \, \text{m s}^{-1}$
$h = 6.6 \times 10^{-34} \, \text{J s}$

[3]

(ii) Calculate the accelerating voltage V in the X-ray tube responsible for X-rays of this energy.

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

$V =$ .... V **[1]**

(b) The article states that 'when the electrons have enough energy to dislodge inner electrons in the atoms they hit, large intensities of certain well-defined wavelengths of X-rays are produced' (lines 66–67 in the article).

(i) Describe the feature of Fig. 3.1 which shows that this is taking place.

[1]

(ii) Tungsten X-ray tubes produce X-rays of two characteristic energies: 59 keV and 69 keV. Use Fig. 3.1 to explain which of these two energies is of greater intensity.

[2]

(iii) Fig. 3.2 is an energy level diagram for tungsten, where 0 represents the energy of a free electron.

Complete the diagram by adding two energy levels and arrows to show the transitions responsible for the two characteristic photons emitted by tungsten.

energy/keV

0

−10

−20

−30

−40

−50

−60

−70
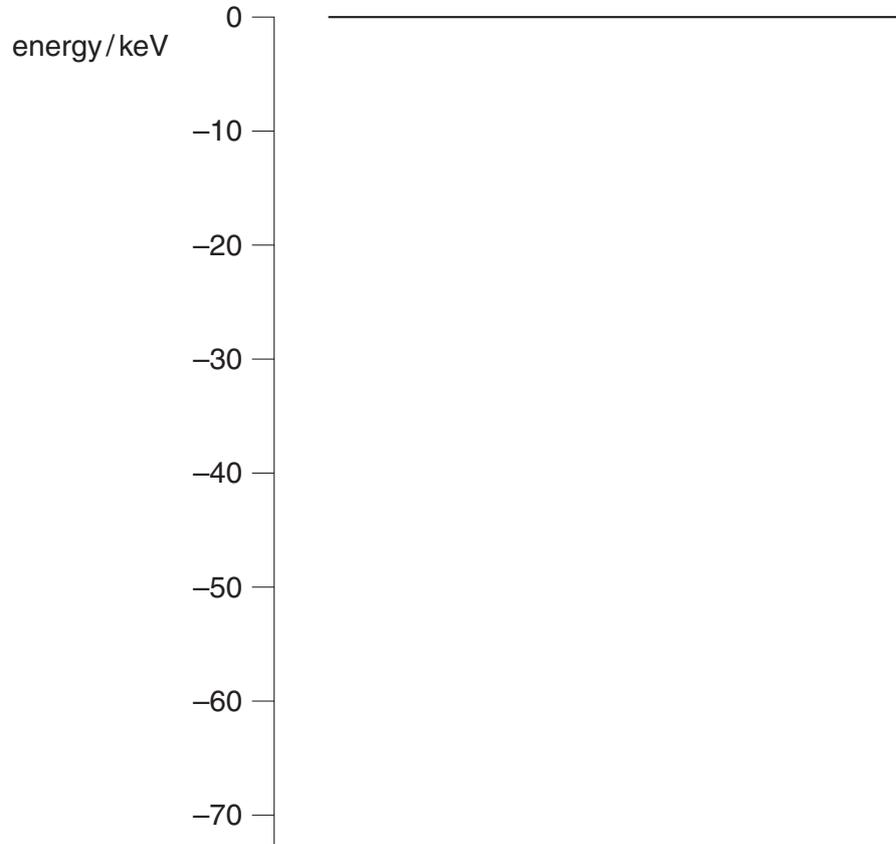
Fig. 3.2

[3]

[Total: 10]

4 This question is about the regular arrangement of atoms in a crystal lattice acting as a diffraction grating for X-rays (lines 46–61 and Figs. 3 & 4 in the article).

Fig. 4.1 shows a narrow beam of X-rays of wavelength 0.10 nm incident on an array of atoms with a lattice spacing of 0.28 nm.
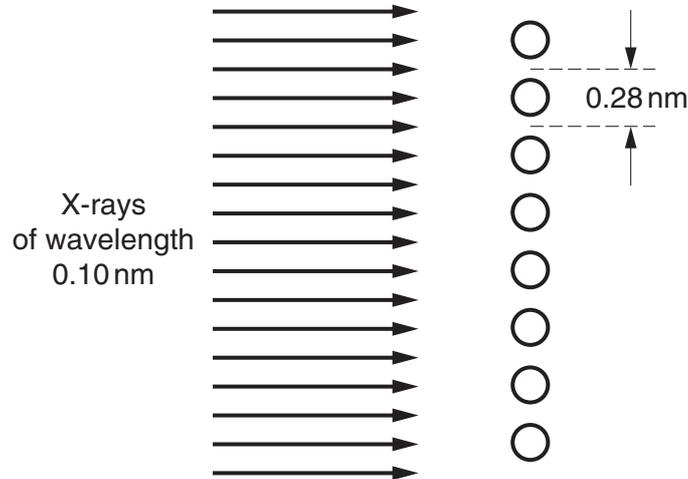
Fig. 4.1

(a) (i) Show that this array of atoms would produce a diffraction pattern with first-order maxima about 20° from the zero-order spot. Treat the rows of atoms as a diffraction grating with lines at the spacing given.

[2]

(ii) The X-rays used to form a diffraction pattern from a crystal lattice are produced by filtering. This reduces the range of wavelengths shown in **Fig. 3.1** on page 7 to one characteristic wavelength only.

Explain clearly what the consequences would be if the X-ray beam were not filtered in this way.

[2]

(b) When X-rays are directed head-on at a rectangular array of atoms, as shown in Fig. 4.2, a pattern of dots (diffraction maxima) is produced on photographic film.
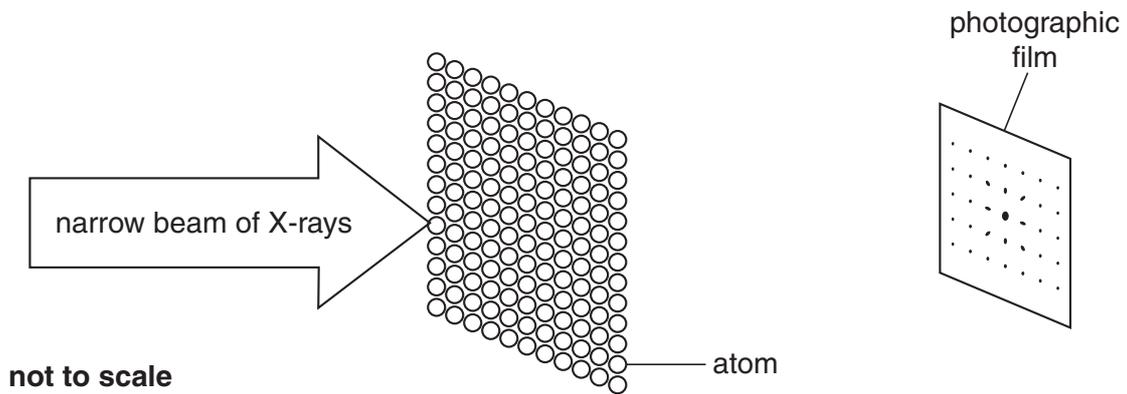
Fig. 4.2

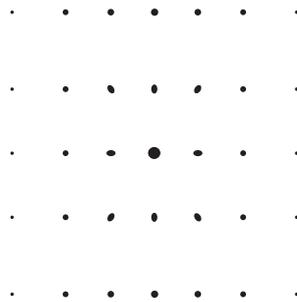Fig. 4.3 shows the patterns of dots on the film produced by X-rays diffracting from an array of atoms.

Fig. 4.3

(i) All of the atoms in the X-ray beam scatter X-rays in all directions.

Explain why no X-rays are detected on the photographic film except at those few places where dots appear.

[2]

(ii) In Fig. 4.3, the separation between dots in the vertical direction is about $\frac{3}{2}$ times greater than the separation between dots in the horizontal direction.

State and explain what this shows about the vertical and horizontal separations in the rows of atoms.

[2]

[Total: 8]

5 This question is about the risk associated with the dose received during an X-ray examination (lines 74–85 and Fig. 6 in the article).

(a) An X-ray tube emits X-ray photons of energy 2×10^{-15} J.

Calculate the number of photons emitted per second, given that the X-ray tube emits X-rays at a power of 2 W.

number = ... photons s^{-1} **[1]**

(b) A chest X-ray exposure lasts about 1 second. A mass of 25 kg of the body is exposed to the X-rays.

A student uses this to calculate the dose equivalent in sievert as follows:

Energy absorbed = power × time = 2 W × 1 s = 2 J

Absorbed dose = $\dfrac{\text{energy absorbed}}{\text{mass}} = \dfrac{2\,\text{J}}{25\,\text{kg}} = 0.08\,\text{Gy}$

Quality factor = 1 so dose equivalent = 0.08 Sv = 80 mSv

(i) Explain the meaning of the term 'quality factor'.

[2]

(ii) The student reads in her text-book that a typical dose equivalent for a chest X-ray is actually only 0.20 mSv.

Suggest why the calculation above gives a value that is much too high.

[1]

(iii) When the serious disease tuberculosis was common in Britain, adults would have two chest X-rays a year. Show that a typical risk of someone developing a cancer due to these chest X-rays over sixty years is less than 1 in 1000.

The risk of developing a cancer is about 3% per sievert.

[3]

(c) X-ray equipment in shoe-shops is no longer used (line 85 in the article), even though the risk involved is very small.

Suggest why this is so.

[2]

[Total: 9]

6 This question is about Magnetic Resonance Imaging (MRI) and Computerised Tomography (CT) scans (lines 101–130 and Figs. 7–9 in the article).

(a) In a CT scan (lines 101–114 in the article), the dose received by a patient is greater than the dose received during a normal flat X-ray photograph.

Explain why.

[1]

(b) In an MRI scan, 'a varying radio signal stimulates **resonant** signals from nuclei of odd nucleon number' (lines 116–117 in the article).

(i) The table below shows the commonest elements present in the human body:

element	commonest isotope	proportion of the human body by mass
oxygen	$^{16}_{8}O$	65%
carbon	$^{12}_{6}C$	18%
hydrogen	$^{1}_{1}H$	10%
nitrogen	$^{14}_{7}N$	3%
calcium	$^{40}_{20}Ca$	1.5%
phosphorus	$^{31}_{15}P$	1.0%

Explain why the article is justified in stating that the nuclei imaged in an MRI scan are 'effectively those of hydrogen' (lines 117–118 in the article).

[2]

Turn over

(ii) Describe one other example of **resonance**.

[1]

(c) Fig. 6.1 shows a CT scan and an MRI scan of a 'slice' through a human head (Fig. 8 and Fig. 9 in the article).
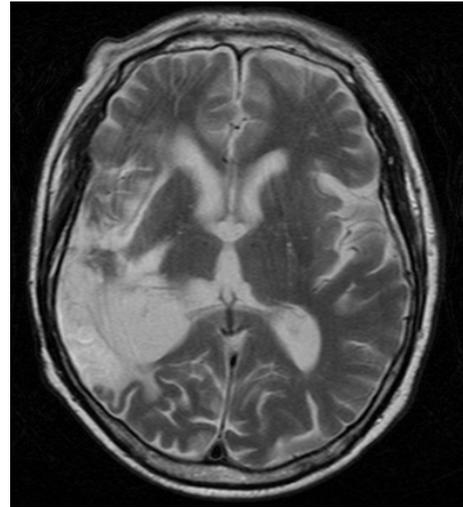
CT scan   MRI scan

Fig. 6.1

(i) Comparing the quality of the two images, state two ways in which the MRI scan shows more detail than the CT scan.

1.

2.

[2]

(ii) Both images have a lot of detail which is difficult to see clearly.

Choose one of the two images.

Suggest and explain one way in which this image might be enhanced digitally to make details clearer (lines 119–120 in the article).

[2]

[Total: 8]

Turn over

Section B

7 This question is about the domestic use of solar energy.
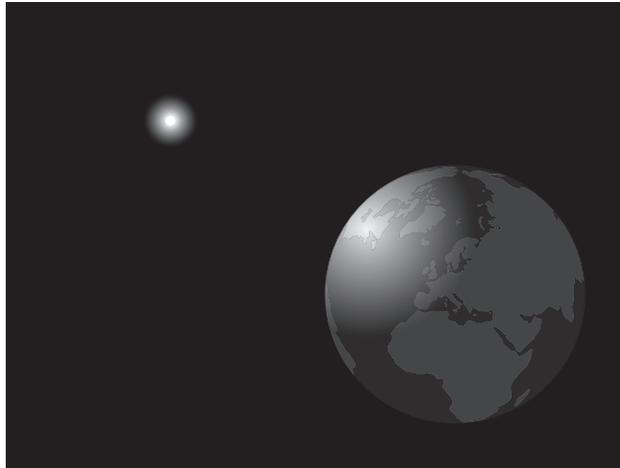
Fig. 7.1

The Sun's energy arrives at the upper atmosphere of the Earth with an intensity of $1.4\,kW\,m^{-2}$, which means that each m^2 of the upper atmosphere facing the Sun receives $1.4\,kJ$ each second.

(a) Explain, without calculation, how this figure allows scientists to calculate the power output of the Sun. You should state what other piece of information you need.

[2]

(b) Suggest two reasons why the average daytime solar power absorbed by a solar panel on a domestic roof top in Britain is less than $1.4\,kW\,m^{-2}$.

(i)

(ii)

[2]

(c) Solar panels, like those shown in Fig. 7.2, consist of large arrays of individual photovoltaic cells made from semiconductor materials. These convert the energy of the photons directly to electrical energy.
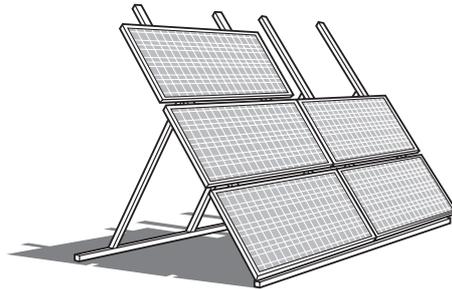
Fig. 7.2

(i) Photovoltaic cells have internal resistance.

Sketch on the axes below how you would expect the output voltage of a photovoltaic cell to vary as the current drawn from it increases from zero.
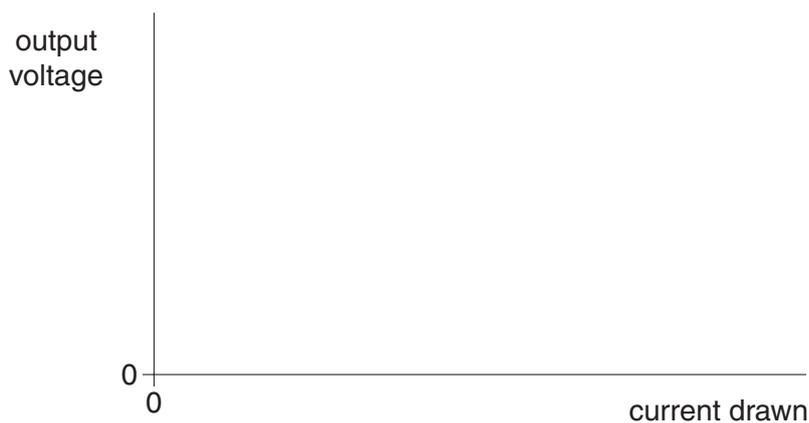
[2]

(ii) Explain why a useful electrical power source must have a low internal resistance.

[1]

(iii) Explain why the use of semiconductor materials makes a low internal resistance difficult to achieve in a single cell.

[1]

Turn over

(iv) Each individual cell in the photovoltaic array can be thought of as a cell with internal resistance in series, as shown in Fig. 7.3.
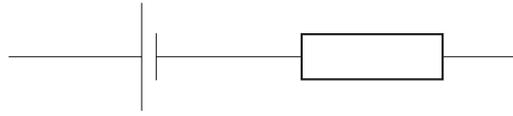
Fig. 7.3

An array of 100 photovoltaic cells could be connected all in parallel or all in series.

Describe and explain the differences in electrical behaviour between these two arrangements.

[2]

(d) A typical panel may have a maximum efficiency of conversion of input power to useful power delivered into an external load of about 12%. Assume that the **maximum** solar power reaching a rooftop location is about $1\,kW\,m^{-2}$.

Use this information above to estimate the **average** electrical output power from a $6\,m^2$ panel over a 24 hour period.

State clearly all the assumptions that you make.

[3]

[Total: 13]

8 This question is about a fairground ride like that shown in Fig. 8.1.
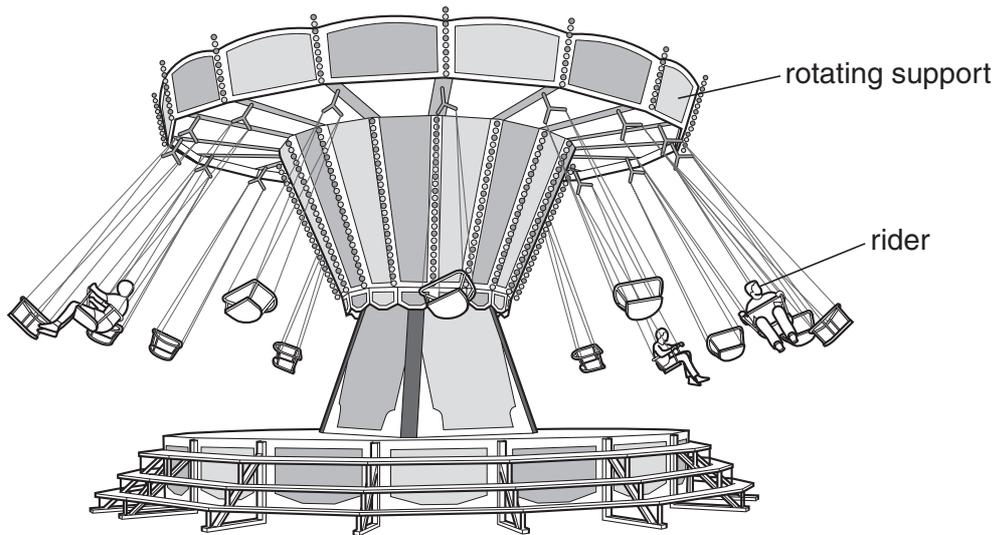
Fig. 8.1

(a) The rider labelled in Fig. 8.1 can be represented more simply as a mass on a single cable, as shown in Fig. 8.2.
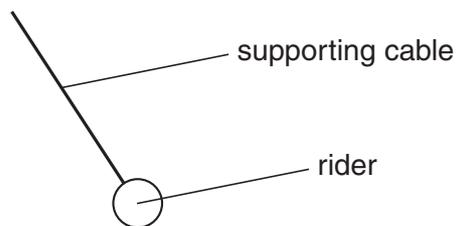

Fig. 8.2

(i) Draw a labelled vector diagram showing the two forces acting on this rider.

[2]

(ii) Add to your diagram a vector showing the **resultant force** on the rider.

Label this vector *F*. **[2]**

Turn over

(b) The angle that the cable makes with the vertical depends on the speed at which the ride rotates.

Fig. 8.3 shows a rider moving around in a circle of radius *r*.
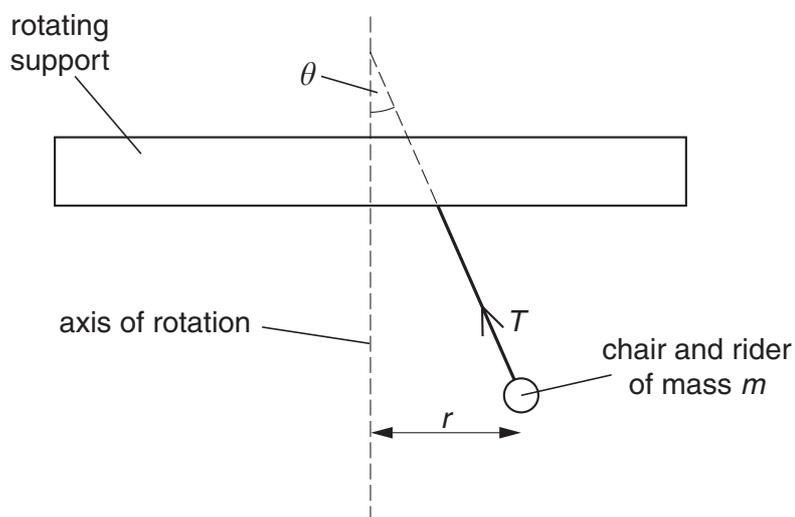
Fig. 8.3

At the instant shown in Fig. 8.3, the rider is moving at right angles to the plane of the diagram with speed *v*.

(i) Explain why the equation $T \cos \theta = mg$ gives one correct relationship between the variables.

[2]

(ii) Explain why the equation $T \sin \theta = \dfrac{mv^2}{r}$ gives another correct relationship between the variables.

[2]

(iii) Use the equations given in parts **(i)** and **(ii)** to show that the speed of the rider is given by

$$v = \sqrt{rg \tan \theta} \, .$$

[2]

(c) Two riders **A** and **B**, identical in weight, sit in different seats as shown in Fig. 8.4.

When the ride turns, the cable supporting rider **B**, who is further from the axis of rotation, makes a larger angle θ with the vertical than the cable supporting rider **A**. Both riders take the same time to go round in a circle once.
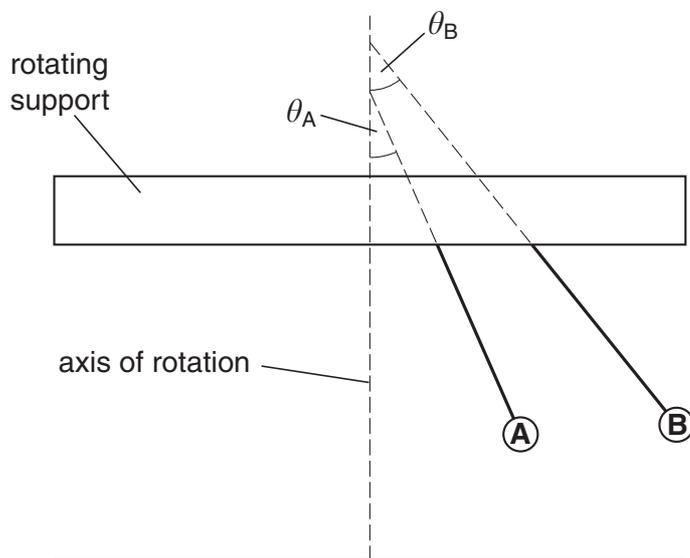

Fig. 8.4

Use this information with the results from part **(b)(i)** to explain why the cable supporting rider **B** is under greater tension than the cable supporting rider **A**.

[2]

QUESTION 8 CONTINUES ON THE NEXT PAGE

(d) In this particular ride, **four** steel cables each of cross-sectional area $1.3 \times 10^{-5}\,\text{m}^2$ and length 2.5 m support each chair.

  (i) Show that the force required to cause **one** of these cables to yield is about 4 kN.

       yield strength of steel = 310 MPa

                                                           [2]

  (ii) Give two reasons why cables are usually constructed from multiple strands of fine wire rather than one solid wire.

       1.

       2.

                                                           [2]

[Total: 16]

[Quality of Written Communication: 4]

END OF QUESTION PAPER