Oxford Cambridge and RSA

Wednesday 21 June 2017 – Morning

A2 GCE PHYSICS B (ADVANCING PHYSICS)

G495/01 Field and Particle Pictures

Candidates answer on the Question Paper.

OCR supplied materials:
- Data, Formulae and Relationships Booklet (sent with general stationery)
- Insert (inserted)

Other materials required:
- Electronic calculator
- Ruler (cm/mm)

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES
- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- 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. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

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.
- This document consists of **20** pages. Any blank pages are indicated.
- The questions in Section C are based on the material in the Insert.

Answer **all** the questions.

SECTION A

1 Here is a list of particles:

alpha **neutron** **neutrino** **proton**

(a) Which particle is a lepton? ....

(b) Which particle has the greatest charge? ....

(c) Which particle has the smallest mass? ....
[3]

2 Look at the graphs **A**, **B** and **C**.

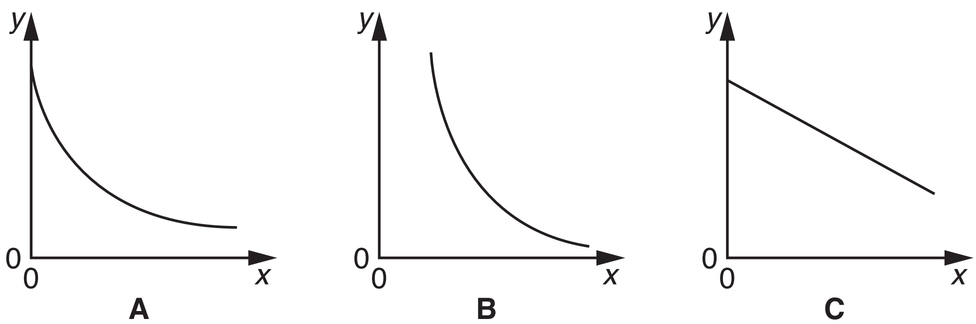


Fig. 2.1

Which graph, **A**, **B** or **C** in Fig. 2.1 is obtained when the *y* and *x* axes represent the two quantities given below?

(a) *y*-axis: the **electric field strength** around a positron
x-axis: **distance** from the centre of the positron

answer .... **[1]**

(b) *y*-axis: the **natural logarithm** of the **activity** of a radioisotope
x-axis: **time**

answer .... **[1]**

3 An ideal transformer has 800 turns of wire on its primary coil. It is used to step 240 V a.c. down to 12 V.

(a) Calculate the number of turns required for the secondary coil.

number of turns = ... **[2]**

(b) The current in the secondary coil is 4.8 A a.c.
Calculate the current in the primary coil.

current in primary coil = ... A **[2]**

4 A wire carrying a current $I = 480\,\text{mA}$ is at right angles to a magnetic field as represented in Fig. 4.1. The magnetic field density $B = 500\,\text{mT}$.

The length L of the wire is 11.0 cm.

(a) Calculate the force on the wire.

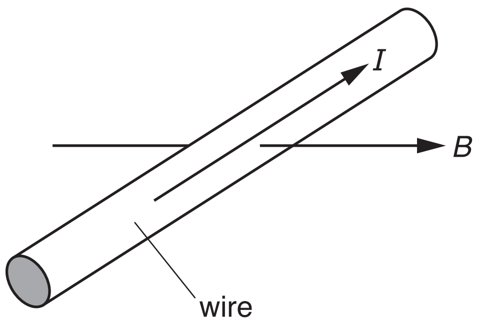


Fig. 4.1

force on wire = ... N **[2]**

(b) Show that the magnetic field density B can have the units $\text{kg}\,\text{C}^{-1}\,\text{s}^{-1}$

[2]

5 An electron is accelerated through a potential difference of 2000 V.

(a) Show that, if relativistic effects are ignored, the calculated velocity of the accelerated electron is more than $2.5 \times 10^7\,m\,s^{-1}$.

mass of electron = 9.1×10^{-31} kg

electronic charge = 1.6×10^{-19} C

[2]

(b) Calculate the relativistic factor of the accelerated electron and use your answer to explain if it is reasonable to ignore relativistic effects in the calculation in **(a)**.

rest energy of electron = 0.51 MeV

relativistic factor = ...

comment:

[2]

6 An electron in the lowest energy state in a hydrogen atom can be modelled as a standing wave of wavelength equal to four times the radius of the atom.

By considering how the potential energy and kinetic energy of the electron vary with its distance from the proton, explain why a hydrogen atom has a minimum diameter.

[3]

SECTION B

7 This question is about a simple generator as shown in Fig. 7.1.

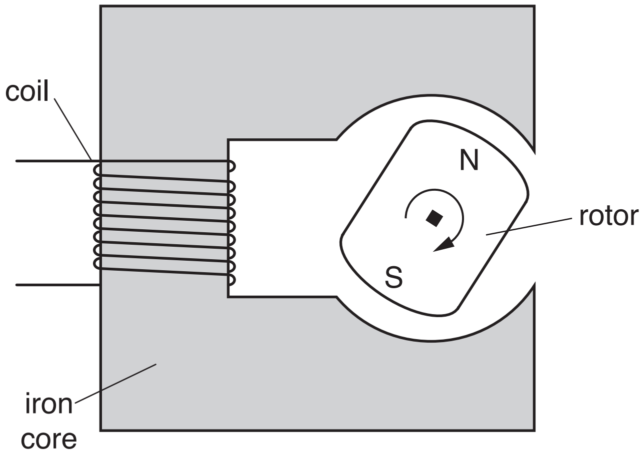


Fig. 7.1

(a) The rotor is a permanent magnet, with poles marked **N** and **S**.

On Fig. 7.1, sketch one complete flux loop which passes through the poles of the rotor. **[2]**

(b) The graph in Fig. 7.2 shows how the emf generated across the coil of the generator varies with time.

(i) On Fig. 7.2, sketch a graph to show how the flux linking the coil varies with time. **[2]**

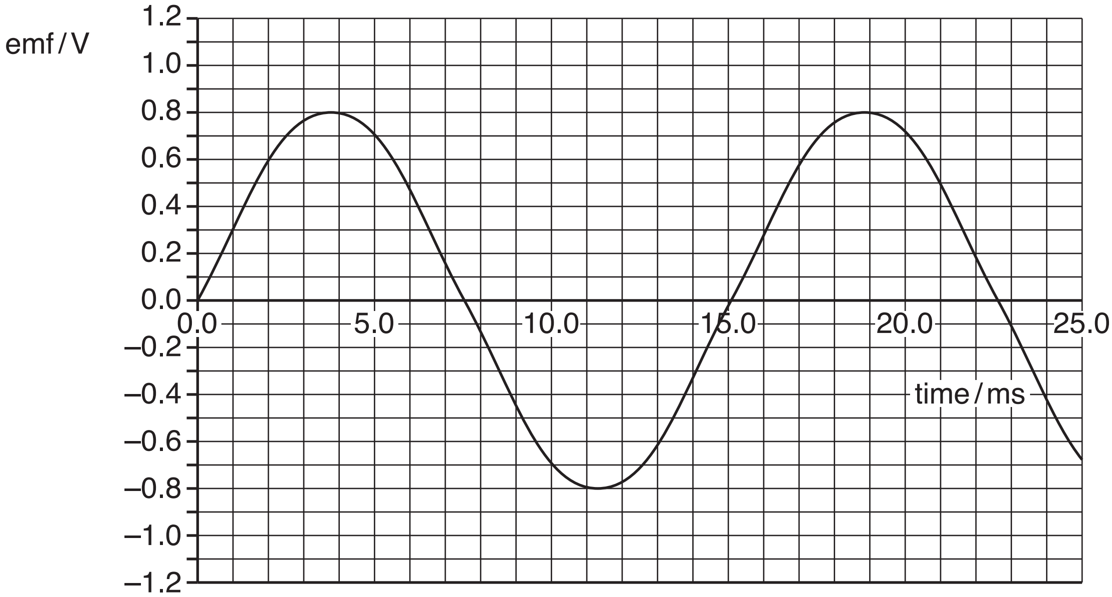


Fig. 7.2

(ii) Use data from the graph to calculate the number of rotations the rotor makes each second.

number of rotations per second = ...s^{-1} **[2]**

(iii) The coil has 320 turns. Use data from the graph to calculate the maximum rate of change of flux in the coil.

maximum rate of change of flux = ...$Wb\,s^{-1}$ **[2]**

(c) The core is made from solid iron. Explain why the emf across the coil increases when the solid iron core is replaced with one made from thin sheets of iron glued together.

[4]

8 This question is about the forces in electric fields.

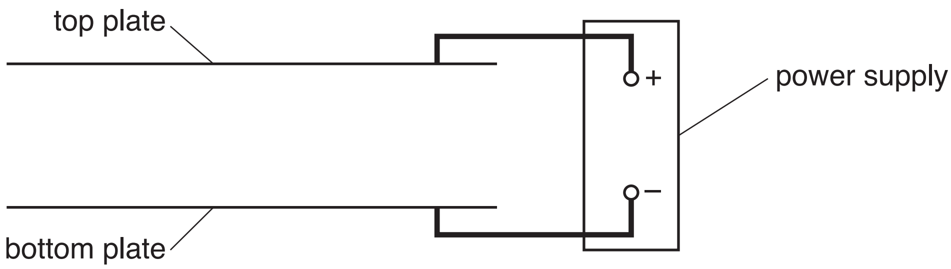


Fig. 8.1

(a) In Fig. 8.1 the plates are connected to a power supply. Draw five field lines in the gap between the plates. **[2]**

A small metal sphere is placed between the two horizontal plates as shown in Fig. 8.2.

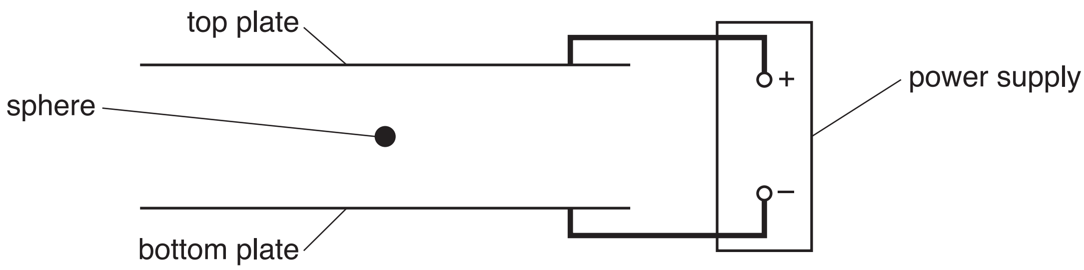


Fig. 8.2

(b) The sphere is given a charge of 4.6×10^{-14} C. It remains stationary between the plates when the electric field is present. Calculate the number of electrons needed to produce this charge and state whether electrons have been added to or removed from the sphere. Explain your reasoning.

number of electrons ....

reasoning:

[4]

(c) The sphere has mass = 7.2×10^{-9} kg. The separation between the plates is 10 mm. Calculate the potential difference between the plates required to hold the sphere stationary.

potential difference = ... V **[4]**

(d) The magnitude of the charge on the sphere can be changed by exposing the air between the plates to radiation from a beta source. Explain how this can alter the charge on the sphere and how the potential difference between the plates must be changed to keep the sphere stationary.

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

[4]

9 This question is about radon-222, a naturally-occurring, radioactive gas. It contributes almost half of the average absorbed dose for people in the UK.

(a) Radon-222 undergoes alpha decay. Complete the nuclear equation for the decay.

$$^{222}_{86}\text{Rn} \rightarrow \,^{......}_{......}\text{Po} + \,^{4}_{2}\text{He}.$$

[2]

(b) (i) The polonium (Po) is a short-lived radioisotope and produces a cascade of short-lived isotopes. Explain why the gamma photons released during the cascade can be neglected when estimating the risk of cancer from the decays.

[2]

(ii) The alpha particles emitted in the decay cascade from a single radon-222 nucleus have a combined energy of 6.3 MeV. This contributes about 47% of the annual background dose of 2.5 mSv per year. Show that about 130 nuclei of radon-222 must decay per second in a person of mass 70 kg to provide this dose.

quality factor of alpha particles = 20

1 year = 3.2×10^7 s

[4]

(c) The half-life of radon-222 is 3.8 days. Calculate the number of radon-222 nuclei required to produce an activity of 130 Bq.

number of nuclei = ... **[3]**

10 This question is about the scattering of protons from nuclei.

(a) When a beam of protons is fired at a very thin sheet of iron it is observed that most protons pass straight through the sheet whilst a few are reflected back.

In both cases, very little energy is transferred from the protons.

State and explain what these observations suggest about the structure of an iron atom.

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

[4]

(b) Fig. 10.1 shows the path of a proton deflected by the nucleus of an iron atom, $^{56}_{26}Fe$.

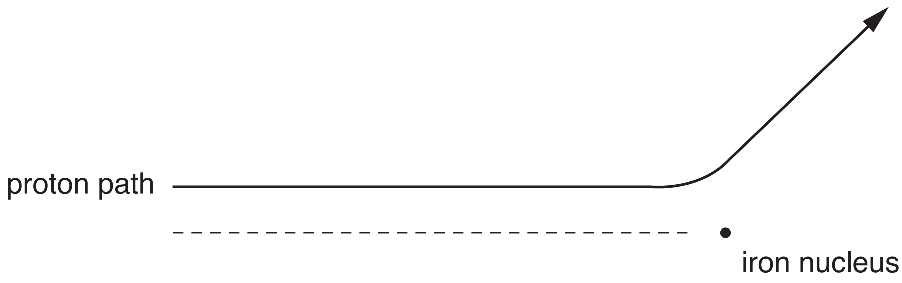


Fig. 10.1

The distance of closest approach of the proton to the nucleus is about 3.2×10^{-14} m.

Explain, using calculations, why the kinetic energy of the proton a long way from the nucleus must have been greater than 1.1 MeV.

[4]

SECTION C

These questions are based on the Advance Notice: *Heat, Light and Stars.*

11 Use the definition given in the article (line 7) to show that intensity can be measured in units of $\mathrm{W\,m^{-2}}$.

[2]

12 The energy required to ionise a hydrogen atom is 13.6 eV.

With reference to the Boltzmann Factor, show that at a temperature of 15 million K, it is likely that the hydrogen gas in the Sun's core will be ionised.

$e = 1.6 \times 10^{-19}\,\mathrm{C}$
Boltzmann constant, $k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$

[4]

13 In lines 18–19 it is stated that the total radiation emitted by a hot object increases with temperature. How is this evident from the Planck Curves (Fig. 1)?

[2]

14 In line 52, the temperature scale of Fig. 3 is described as logarithmic. With reference to the numbers along the *x*-axis of Fig. 3, explain what is meant by logarithmic in this case.

[2]

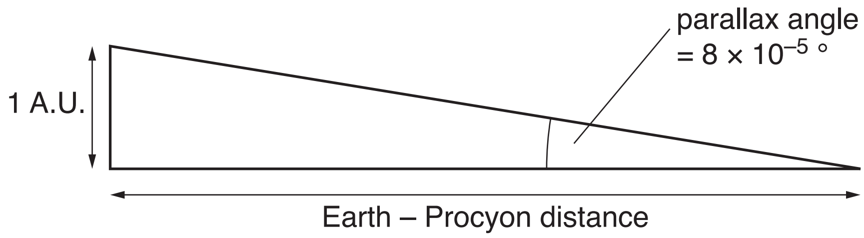
15 **(a)** Explain how Fig. 3 shows that stars which are of the same size as the Sun, but are more luminous, must be hotter than the Sun.

[2]

(b) Betelgeuse is positioned in the area labelled 'Red Giants' on the Hertzsprung-Russell diagram (Fig. 4). Other than the label, explain how the diagram suggests that Betelgeuse must be a giant star.

[2]

16 The star Procyon is closer to the Earth than most stars near it in the sky. Its apparent position in the sky changes by about 8×10^{-5} ° over six months. This is the 'parallax angle' as shown in Fig. 16.1.



Not to scale

Fig. 16.1

Calculate the Earth-Procyon distance in light years.

1 A.U. = 1.5×10^{11} m

speed of light = 3.0×10^{8} m s^{-1}

1 year = 3.2×10^{7} s

distance = ... light years **[4]**

17 The star Procyon is actually a double star system in which a large star (Procyon A) is orbited by a smaller companion (Procyon B).

Procyon B orbits the larger star at a distance of 2.25×10^{12} m. It takes 41 years to complete an orbit.

(a) Show that the centripetal acceleration of Procyon B is about $5 \times 10^{-5}\,\text{m}\,\text{s}^{-2}$.

[3]

(b) By equating the centripetal force to the gravitational force between the two stars, calculate the mass of Procyon A.

mass of Procyon A = ... kg **[2]**

18 Two red stars, Ran and Gienah, have a similar surface temperature (around 4800 K). Table 18.1 gives some other data about them:

Star name	Distance / m	Luminosity / W
Ran	9.5×10^{16}	1.3×10^{26}
Gienah	6.9×10^{17}	2.4×10^{28}

Table 18.1

Using this data, **calculate** the ratio:

$$\frac{\text{intensity of the radiation reaching Earth from Ran}}{\text{intensity of the radiation reaching Earth from Gienah}}$$

Show each stage in your working.

ratio = ... **[4]**

19 The core of the Sun is at a temperature of about 15 million K. This is hot enough for nuclear fusion to occur, with hydrogen being fused to produce helium.

(a) Explain why high temperatures are required for fusion to occur.

[4]

(b) Calculate the time taken for 15% of the Sun's present mass to be converted to energy at the current rate of fusion.

luminosity of the Sun = 3.9×10^{26} W
present mass of the Sun = 2.0×10^{30} kg
speed of light, $c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$
1 year = 3.2×10^{7} s

time = ...years **[4]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).