OCR
RECOGNISING ACHIEVEMENT

Friday 27 January 2012 – Afternoon

A2 GCE PHYSICS A

G485 Fields, Particles and Frontiers of Physics

Candidates answer on the Question Paper.

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

Other materials required:
- Electronic calculator

Duration: 2 hours

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- 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 pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

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.
- You are advised to show all the steps in any calculations.
- 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 meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **24** pages. Any blank pages are indicated.

DC (CW/SW) 56530/5 **R**

Answer **all** the questions.

1 Fig. 1.1 shows a close up of the two electrodes of a spark plug.

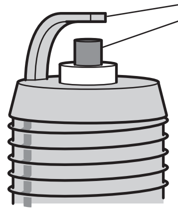

Fig. 1.1

The electrodes may be considered as two parallel plates. The electric field strength between the electrodes is almost uniform.

(a) Define *electric field strength*.

....

.... **[1]**

(b) The separation between the electrodes is 1.3 mm. An electric spark is produced when the electric field strength is $3.0 \times 10^6\,V\,m^{-1}$.

(i) Estimate the potential difference *V* between the electrodes when the spark is produced.

V = ... V **[2]**

(ii) The electric spark lasts for 4.0×10^{-2} s and produces an average current of 2.7×10^{-9} A.

1 Calculate the charge transferred between the electrodes.

charge = ... C **[2]**

2 Calculate the number of electrons transferred between the electrodes.

number = ... **[1]**

(iii) Estimate the total energy transferred by the electrons in **(ii)**.

energy = ... J **[2]**

[Total: 8]

2 **(a)** Define *torque of a couple*.

....

.... **[1]**

(b) Fig. 2.1 shows a current-carrying square coil placed in a uniform magnetic field.

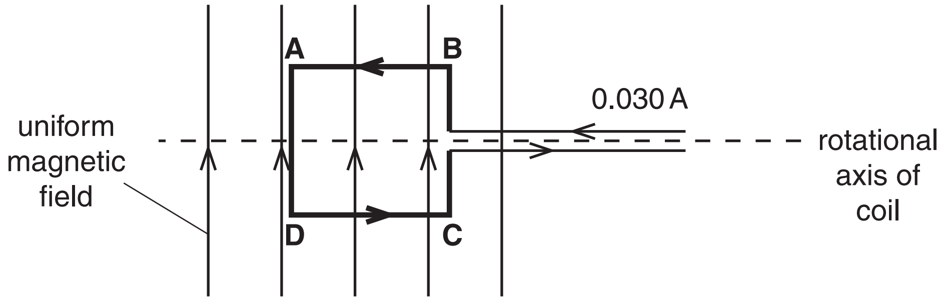

Fig. 2.1

The length of each side of the coil is 0.015 m. The plane of the coil is parallel to the magnetic field. The magnetic field is at right angles to the section **AB** of the coil and has magnetic flux density 0.060 T. The current in the coil is 0.030 A.

(i) Use Fleming's left-hand rule to determine the direction of the force on section **AB** of the coil.

.... **[1]**

(ii) The current-carrying coil will rotate because it experiences a torque. With the coil in the position shown in Fig. 2.1, calculate

1 the force experienced by the length **AB**

force = ... N **[1]**

2 the torque experienced by the coil.

torque = ... N m **[2]**

(c) Fig. 2.2 shows the path of a positive ion of oxygen-16 inside a mass spectrometer.

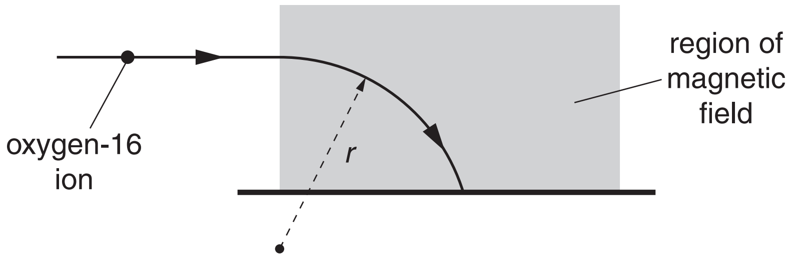

Fig. 2.2

The shaded area in Fig. 2.2 represents a region of uniform magnetic field of flux density 0.14 T. The direction of the magnetic field is out of the plane of the paper. The ion has a speed of $4.5 \times 10^6\,\text{m}\,\text{s}^{-1}$ and it enters the region at right angles to the magnetic field. While the ion is in the magnetic field, it describes a circular arc of radius r. The force experienced by the ion in the magnetic field is 2.0×10^{-13} N.

(i) Calculate the charge Q of the ion.

Q = ... C **[2]**

(ii) The mass of the ion is 2.7×10^{-26} kg. Calculate the radius r of the circular path.

r = ... m **[3]**

(iii) In Fig. 2.2, the oxygen-16 ion is replaced by an oxygen-18 ion. The oxygen-18 ion has the same speed and charge. Explain why this ion describes an arc of greater radius.

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.... **[2]**

[Total: 12]

3 **(a)** Define *magnetic flux*.

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.... **[2]**

(b) Fig. 3.1 shows an experiment to demonstrate electromagnetic induction.

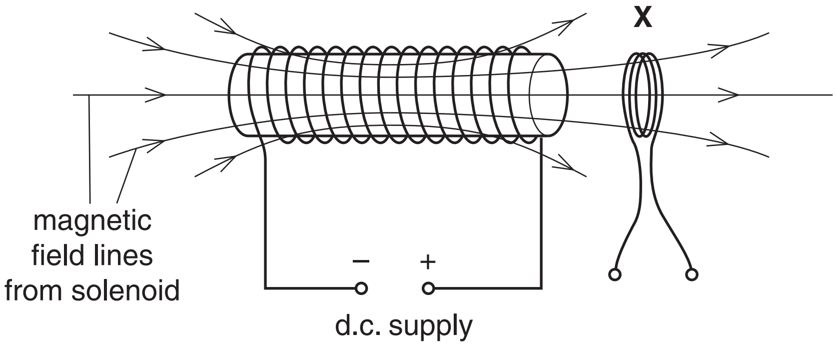

Fig. 3.1

The solenoid is connected to a variable voltage d.c. supply. A coil **X** is placed close to one end of the solenoid. The current in the solenoid is reduced. Fig. 3.2 shows the consequent variation of the magnetic flux density B at right angles to the plane of the coil **X** with time t.

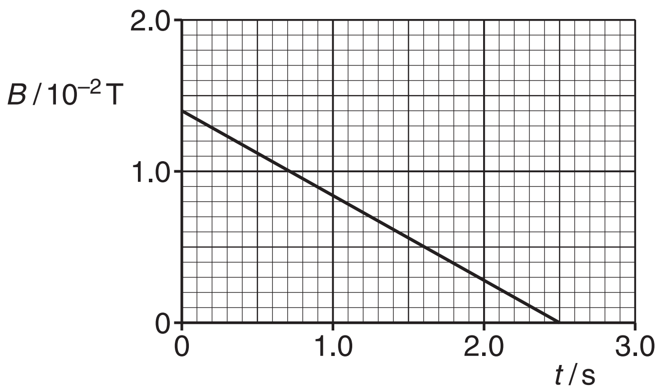

Fig. 3.2

The coil **X** has radius 3.2 cm and 180 turns.

(i) Explain why the induced e.m.f. across the ends of the coil has a constant value from $t = 0$ s to $t = 2.5$ s.

....

....

.... **[1]**

(ii) Calculate the magnitude of the induced e.m.f. across the ends of coil **X** from $t = 0\,\text{s}$ to $t = 2.5\,\text{s}$.

e.m.f. = ... V **[3]**

(c) Fig. 3.3 shows a transformer circuit.

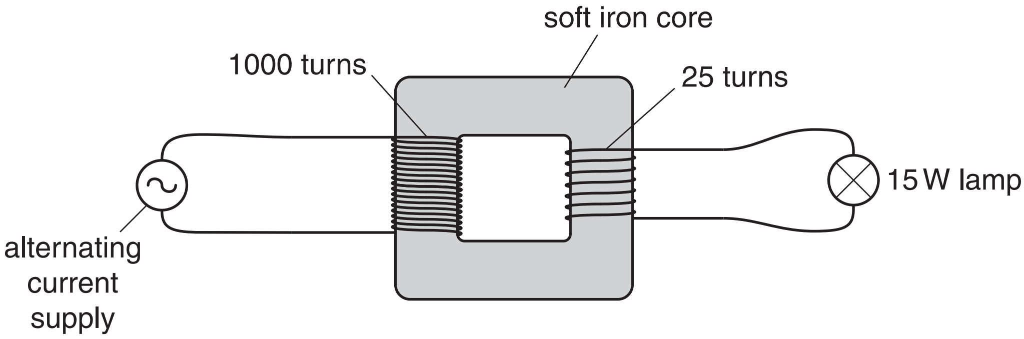

Fig. 3.3

The primary coil has 1000 turns and the secondary coil 25 turns. A lamp is connected to the output of the secondary coil. The potential difference across the lamp is 6.0 V and the lamp dissipates 15 W. The transformer has an efficiency of 100%.

(i) Calculate the current in the primary coil.

current = ... A **[2]**

(ii) The alternating voltage supply is replaced by a battery. Explain why the p.d. across the lamp is zero some time after the battery is connected.

....

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.... **[1]**

[Total: 9]

4 **(a)** Define *capacitance*.

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.... **[1]**

(b) Fig. 4.1 shows an arrangement of three identical capacitors connected to a 6.0 V battery.

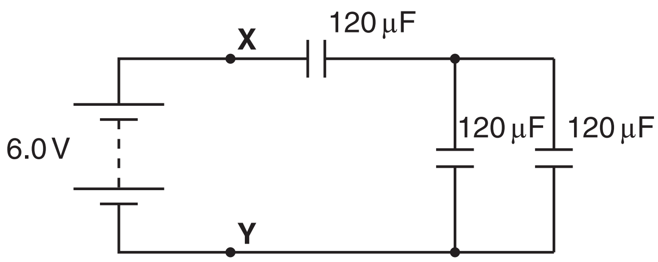

Fig. 4.1

Each capacitor has a capacitance of 120 μF.

(i) Show that the total capacitance of the circuit is 80 μF.

[2]

(ii) Calculate the total energy stored by the capacitors.

energy = ... J **[2]**

(iii) The battery is disconnected from the circuit shown in Fig. 4.1. The p.d. between points **X** and **Y** remains at 6.0 V. A fixed resistor of resistance R is now connected between **X** and **Y**. Fig. 4.2 shows the variation of the p.d. V across the resistor with time t.

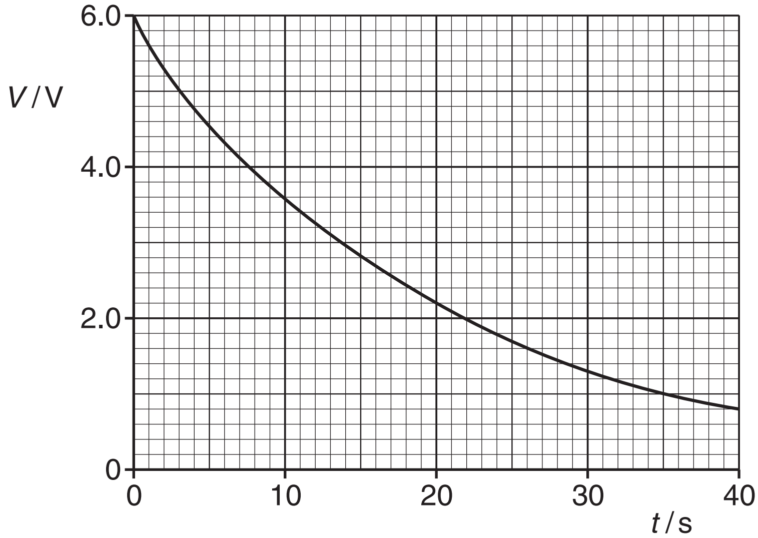

Fig. 4.2

1 Use Fig. 4.2 to show that the circuit has a time constant of 20 s.

[1]

2 Hence, calculate the resistance R of the resistor.

R = ... Ω **[2]**

[Total: 8]

5 The isotopes of carbon-14 ($^{14}_{6}C$) and carbon-15 ($^{15}_{6}C$) are beta-minus emitters. The table in Fig. 5.1 shows the maximum kinetic energy of each electron emitted and the half-life of the isotope.

isotope	maximum kinetic energy / MeV	half-life
$^{14}_{6}C$	0.16	5560 years
$^{15}_{6}C$	9.8	2.3 s

Fig. 5.1

(a) State one property common to all isotopes of an element.

....

.... **[1]**

(b) The neutrons and protons inside each isotope experience fundamental forces. Name the two fundamental forces experienced by both neutrons and protons.

1. ....

2. .... **[2]**

(c) An isotope of carbon-15 decays into an isotope of nitrogen (N).

(i) Complete the nuclear reaction below.

$$^{15}_{6}C \rightarrow {}^{......}_{......}N + {}^{0}_{-1}e + \overline{\nu}$$

[1]

(ii) Use the quark model to state the changes taking place within the nucleus of the carbon-15 atom.

....

.... **[1]**

(d) (i) Estimate the maximum speed of an electron from the nucleus of carbon-14.

speed = ... $m\,s^{-1}$ **[2]**

(ii) Suggest why the actual speed of the electron is much less than your answer in **(i)**.

....

.... **[1]**

(e) **(i)** Calculate the decay constant λ in s^{-1} of carbon-14.

λ = ... s^{-1} **[2]**

(ii) The molar mass of carbon-14 is $14\,g\,mol^{-1}$. Show that 1.0 mg of carbon-14 has 4.3×10^{19} nuclei.

[1]

(iii) Calculate the activity of the 1.0 mg mass of carbon-14.

activity = ...Bq **[2]**

(f) The isotope of carbon-14 is very useful in determining the age of a relic (e.g. ancient wooden axe) using a technique known as carbon-dating.
Describe carbon-dating and explain one of its major limitations.

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.... **[4]**

[Total: 17]

6 (a) Explain the term *binding energy* of a nucleus.

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.... **[2]**

(b) Nuclear fusion takes place in the core of the Sun. One of the simplest fusion reactions is shown below.

$$^{2}_{1}\text{H} + ^{2}_{1}\text{H} \rightarrow ^{4}_{2}\text{He}$$

(i) The binding energy per nucleon of $^{2}_{1}\text{H}$ is 1.8×10^{-13} J and the binding energy per nucleon of $^{4}_{2}\text{He}$ is 1.1×10^{-12} J. Show that the energy released in the reaction is 3.7×10^{-12} J.

[2]

(ii) The Sun radiates its energy uniformly through space. The mean intensity of the Sun's radiation reaching the Earth's atmosphere is about $1400\,W\,m^{-2}$. The mean radius of the Earth's orbit round the Sun is 1.5×10^{11} m.

1 Show that the mean power radiated from the surface of the Sun is 4.0×10^{26} W.

[2]

2 Assume all the radiated energy from the Sun comes from the fusion reaction shown in **(b)**. Estimate the number of helium-4 nuclei produced every second by the Sun.

number = ... s^{-1} **[2]**

[Total: 8]

7 **(a)** Describe in simple terms how X-ray photons are produced in a hospital X-ray machine.

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.... **[2]**

(b) Fig. 7.1 shows a simple X-ray intensifier screen.

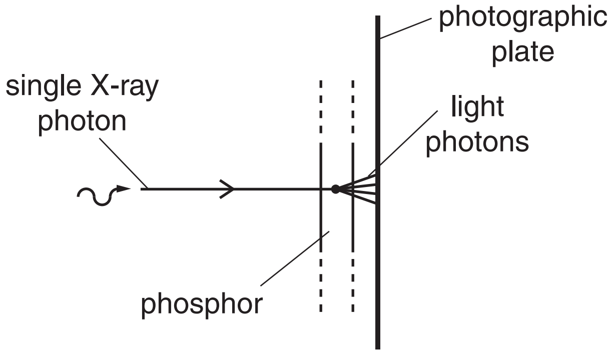

Fig. 7.1

A bright X-ray image can be produced using an image intensifier. A single X-ray photon incident on the phosphor produces about a thousand photons of visible light. The photons of visible light produce an image on a photographic plate.

(i) Explain what is meant by a *photon*.

....

.... **[1]**

(ii) Explain why an X-ray photon has greater energy than a photon of visible light.

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.... **[1]**

(c) In an X-ray machine, accelerated electrons hit a metal target. Most of the kinetic energy of the electrons is converted into heat, but a small amount is converted into X-ray photons.
Electrons having maximum kinetic energy create the shortest wavelength X-ray photons.
Calculate the shortest wavelength of X-ray photons emitted from an X-ray machine operating at 120 kV.

wavelength = ... m **[3]**

(d) X-ray photons interact with matter. One of the interaction mechanisms of the X-ray photons with atoms is known as the **photoelectric effect**. State another interaction mechanism.
Describe what happens to the X-ray photon interacting with a single atom using the mechanism you have stated.

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.... **[2]**

[Total: 9]

8 **(a)** In the treatment of patients, explain what is meant by a non-invasive technique. State one of its advantages.

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.... **[2]**

(b) Explain what is meant by a medical tracer. Name a medical tracer commonly used to diagnose the function of organs.

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.... **[2]**

(c) The main components of a gamma camera are the collimator, scintillator, photomultiplier tubes and the computer. Describe the function of each of these components.

In your answer, you must make clear how one of these components governs the sharpness of the image.

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(d) Fig. 8.1 shows an ultrasound transducer placed above an artery.

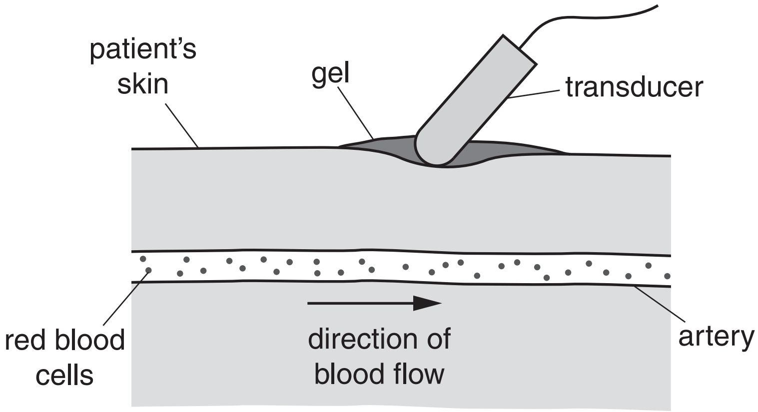

Fig. 8.1

(i) The speed of ultrasound in blood is 1500 $m\,s^{-1}$. Calculate the wavelength of the ultrasound of frequency 2.0×10^6 Hz.

wavelength = ... m **[2]**

(ii) Describe how the ultrasound is used to determine the speed of the blood in the artery.

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.... **[3]**

[Total: 14]

9 **(a)** Describe the formation of the Sun.

In your answer, you should make clear how the steps of the process are sequenced.

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.... **[5]**

(b) After the death of a low-mass star such as our Sun, the remnant core is a white dwarf.

State two properties of a white dwarf.

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.... **[2]**

(c) The ultimate fate of the universe depends on its density.

(i) State the fate of the universe if its density is equal to the critical density.

....

.... **[1]**

(ii) According to some cosmologists, the age of the universe is 4.4×10^{17} s (about 14 billion years). Show that according to this age, the critical density of the universe is about 10^{-26} kg m^{-3}.

[3]

(iii) Estimate the number of protons per cubic metre of space.

mass of proton = 1.7×10^{-27} kg

number = ... m^{-3} **[2]**

(d) The universe began from a big bang. At an early stage of the universe, the temperature was about 10^8 K. The expansion of the universe led to cooling. The present temperature of the universe is about 2.7 K. For a single **electron**, determine the ratio

$$\frac{\text{speed of electron at } 10^8\,\text{K}}{\text{speed of electron at } 2.7\,\text{K}}.$$

ratio = ... **[2]**

[Total: 15]

END OF QUESTION PAPER

ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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