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# Monday 11 June 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

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*G411830612*

| Candidate forename | | Candidate surname | |
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| Centre number | | | | | | Candidate number | | | | |
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**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.

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Answer **all** the questions.

**1** **(a)** Capacitance is measured in farads. Define the *farad*.

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

**(b)** Fig. 1.1 shows the graph of potential difference $V$ against charge $Q$ stored for a capacitor of capacitance $C$.

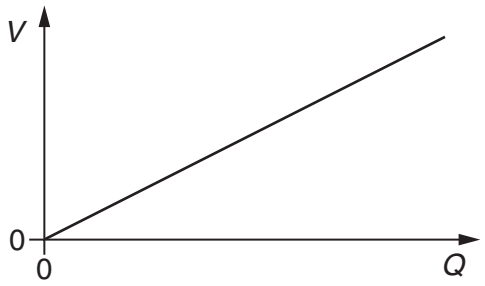



**Fig. 1.1**

State the quantity represented by the

**(i)** gradient of the graph

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

**(ii)** area under the graph.

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

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**(c)** You are given three capacitors of capacitances 100 μF, 200 μF and 500 μF. Calculate the **minimum** total capacitance of these three capacitors in a combination. Show how the capacitors are connected.

capacitance = ..... μF **[3]**

**(d)** A 0.10 F capacitor is charged at a constant rate with a **steady current** of 40 mA for a time of 60 s. Calculate the final

**(i)** charge stored by the capacitor

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

**(ii)** energy stored by the capacitor.

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

**[Total: 10]**

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**2** Fig. 2.1 shows the circular track of an electron moving in a uniform magnetic field.

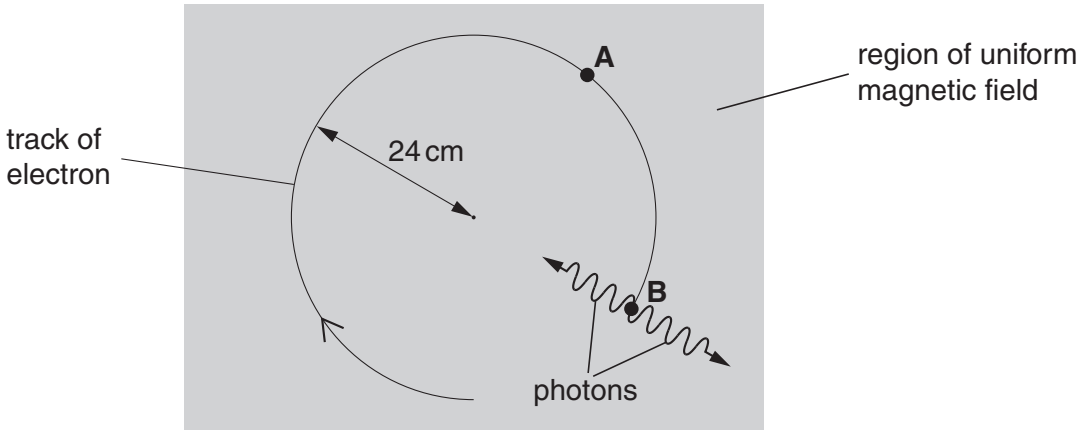



**Fig. 2.1**

The magnetic field is perpendicular to the plane of Fig. 2.1. The speed of the electron is $6.0 \times 10^7\,m\,s^{-1}$ and the radius of the track is 24 cm. At point **B** the electron interacts with a stationary positron.

**(a) (i)** On Fig. 2.1, draw an arrow to show the force acting on the electron when at point **A**. Label this arrow **F**. **[1]**

**(ii)** Explain why this force does not change the speed of the electron.

.....

.....

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

**(b)** Calculate the magnitude of the force *F* acting on the electron due to the magnetic field when it is at **A**.

*F* = ..... N **[2]**

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**(c)** Calculate the magnetic flux density of the magnetic field.

magnetic flux density = ..... T **[2]**

**(d)** At point **B**, the electron and the positron annihilate each other. A positron has a positive charge and the same mass as the electron. The particles create two gamma ray photons. Calculate the wavelength of the gamma rays assuming the kinetic energy of the electron is negligible.



*In your answer, you should make your reasoning clear.*

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

**[Total: 9]**

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**3** Fig. 3.1 shows the variation of the magnetic flux **linkage** with time *t* for a small generator.

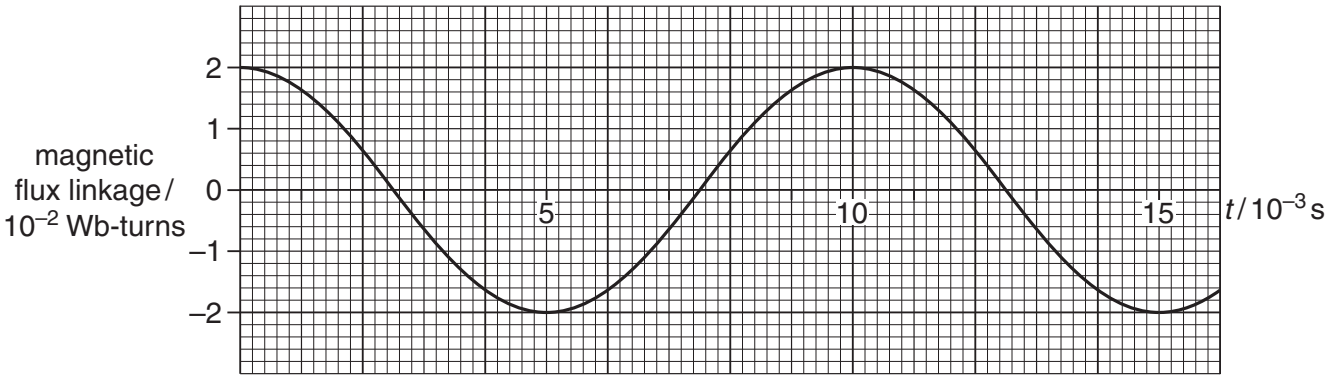



**Fig. 3.1**

The generator has a flat coil of negligible resistance that is rotated at a steady frequency in a uniform magnetic field. The coil has 400 turns and cross-sectional area $1.6 \times 10^{-3}\,m^2$. The output from the generator is connected to a resistor of resistance $150\,\Omega$.

**(a)** Use Fig. 3.1 to

**(i)** calculate the frequency of rotation of the coil

frequency = ..... Hz **[1]**

**(ii)** calculate the magnetic flux density *B* of the magnetic field

*B* = ..... T **[3]**

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**(iii)** show that the **maximum** electromotive force (e.m.f.) induced in the coil is about 12 V.

**[3]**

**(b)** Hence calculate the **maximum** power dissipated in the resistor.

power = ..... W **[2]**

**[Total: 9]**

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**4** An alpha particle is fired at high speed directly towards a stationary nucleus of a gold atom. At its distance of closest approach to the gold nucleus, the alpha particle stops and the gold nucleus has a small velocity, see Fig. 4.1. The alpha particle and the gold nucleus both have positive charges.

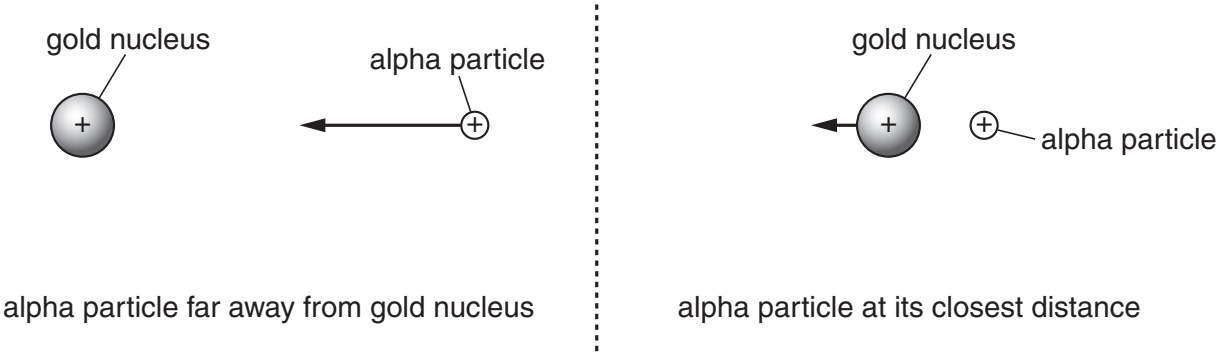



**Fig. 4.1**

**(a)** Explain why, at this distance of closest approach, the gold nucleus has a velocity and the alpha particle does not.

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

**(b)** Fig. 4.2, shows the alpha particle at its closest distance to the gold nucleus. Draw one electric field line from point **A** and one from point **B**. For each field line, show the direction of the field.




**[2]**

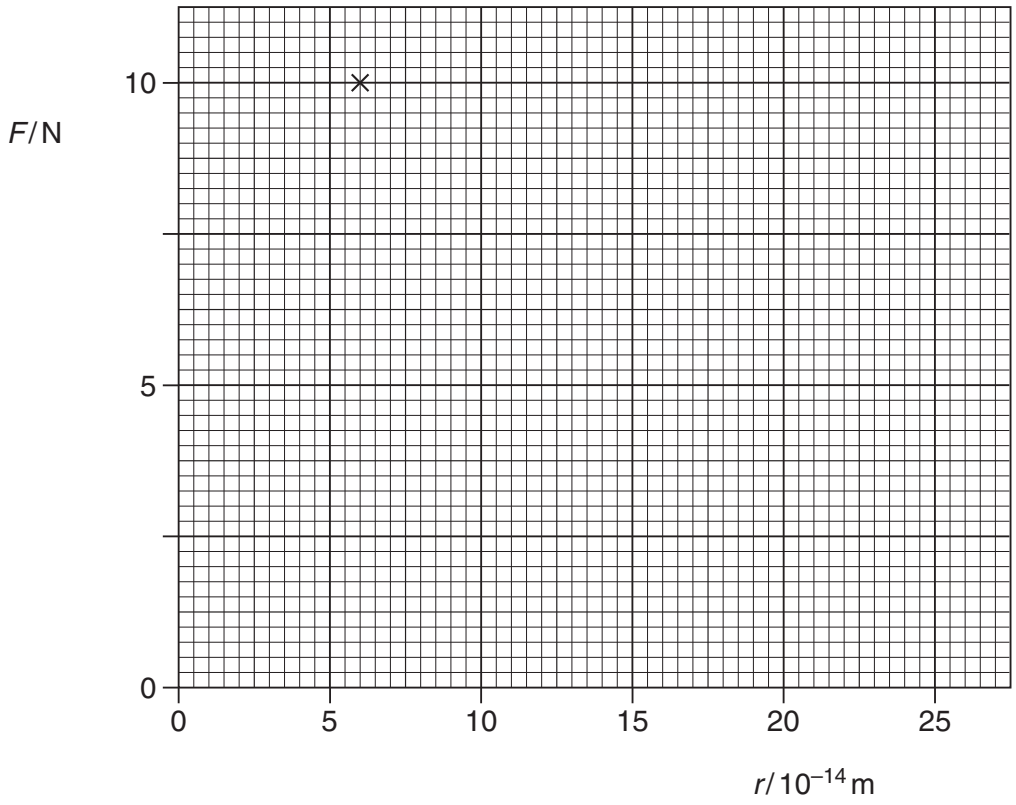
**Fig. 4.2**

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**(c)** Show that the electrical force experienced by the alpha particle at its closest distance of $6.0 \times 10^{-14}$ m to the gold nucleus is about 10 N. The gold nucleus has 79 protons and the alpha particle has 2 protons.

**[3]**

**(d)** On Fig. 4.3, sketch a graph to show the variation of the electrical force $F$ on the alpha particle with distance $r$ from the centre of the gold nucleus. The value of $F$ at the distance of closest approach has been marked on the graph.




**[2]**

**Fig. 4.3**

**[Total: 9]**

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**5** The radioactive nucleus of plutonium ($^{238}_{94}$Pu) decays by emitting an alpha particle ($^{4}_{2}$He) of kinetic energy 5.6MeV with a half-life of 88 years. The plutonium nucleus decays into an isotope of uranium.

**(a)** State the number of neutrons in the **uranium** isotope.

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

**(b)** The mass of an alpha particle is $6.65 \times 10^{-27}$ kg.

**(i)** Show that the kinetic energy of the alpha particle is about $9 \times 10^{-13}$ J.

**[1]**

**(ii)** Calculate the speed of the alpha particle.

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

**(c)** In a space probe, a source containing plutonium-238 nuclei is used to generate 62W for the onboard electronics.

**(i)** Use your answer to **(b)(i)** to show that the initial activity of the sample of plutonium-238 is about $7 \times 10^{13}$ Bq.

**[1]**

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**(ii)** Calculate the decay constant of the plutonium-238 nucleus.

1 year = $3.16 \times 10^7$ s

decay constant = ..... $s^{-1}$ **[2]**

**(iii)** The molar mass of plutonium-238 is 0.24 kg. Calculate

**1** the number of plutonium-238 nuclei in the source

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

**2** the mass of plutonium in the source.

mass = ..... kg **[1]**

**[Total: 10]**

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**6** The nuclear reaction represented by the equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{94}_{39}\mathrm{Y} + {}^{139}_{53}\mathrm{I} + 3\,{}^{1}_{0}\mathrm{n}$$

takes place in the core of a nuclear reactor at a power station.

**(a)** Describe how this reaction can lead to a chain reaction.

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

**(b)** Explain the role of fuel rods, control rods and a moderator in a nuclear reactor.



*In your answer you should make clear how chain reactions are controlled in the reactor.*

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..... **[5]**

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**(c)** In the nuclear reactor of a power station, each fission reaction of uranium produces $3.2 \times 10^{-11}$ J of energy. The electrical power output of the power station is 3.0 GW. The efficiency of the system that transforms nuclear energy into electrical energy is 22%. Calculate

**(i)** the total power output of the reactor core

power output = ..... W **[1]**

**(ii)** the total energy output of the reactor core in one day

1 day = $8.64 \times 10^4$ s

energy output = ..... J **[1]**

**(iii)** the mass of uranium-235 converted in one day. The mass of a uranium-235 nucleus is $3.9 \times 10^{-25}$ kg.

mass = ..... kg **[2]**

**(d)** Discuss the physical properties of nuclear waste that makes it dangerous.

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

**[Total: 12]**

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**7** **(a)** State two properties of X-rays.

1. .....

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2. .....

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

**(b)** Explain what is meant by the *Compton effect*.

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

**(c)** The intensity $I$ of a collimated beam of X-rays decreases exponentially with thickness $x$ of the material through which the beam passes according to the equation $I = I_0 e^{-\mu x}$. The attenuation (absorption) coefficient $\mu$ depends on the material.

**(i)** State what $I_0$ represents in this equation.

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

**(ii)** Bone has an attenuation coefficient of $3.3\,\text{cm}^{-1}$. Calculate the thickness in cm of bone that will reduce the X-ray intensity by half.

thickness = ..... cm **[3]**

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**(d)** Explain the purpose of using a contrast medium such as barium when taking X-ray images of the body.

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

**[Total: 10]**

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**8** **(a)** Fig. 8.1 shows an MRI scanner.



**Fig. 8.1**

The main components of an MRI scanner are a strong electromagnet, radio frequency transmitting coils, radio frequency receiving coils, gradient coils and a computer.

- Outline the principles of magnetic resonance.
- Describe how these components are used to obtain diagnostic information about the internal organs.

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**(b)** Discuss the major differences between an MRI scan and a positron emission tomography (PET) scan of the brain.

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

**[Total: 9]**

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**9** **(a)** A star radiates energy produced from fusion reactions within its core. Explain what is meant by *fusion* and explain the conditions necessary for fusion to occur in the core of a star.

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**(b)** Describe and explain the evolution of a star much more massive than our Sun.

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..... **[3]**

**[Total: 7]**

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**10 (a)** In the universe there are about $10^{11}$ galaxies, each with about $10^{11}$ stars with each star having a mass of about $10^{30}$kg. Estimate the attractive gravitational force between two galaxies separated by a distance of $4 \times 10^{22}$m.

force = ..... N **[3]**

**(b)** Explain why the galaxies do not collapse on each other.

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

**(c)** Describe qualitatively the evolution of the universe immediately after the big bang to the present day. You are not expected to state the times for the various stages of the evolution.

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**(d)** Fig. 10.1 shows some absorption spectral lines of the spectrum of calcium as observed from a source on the Earth and from a distant galaxy.

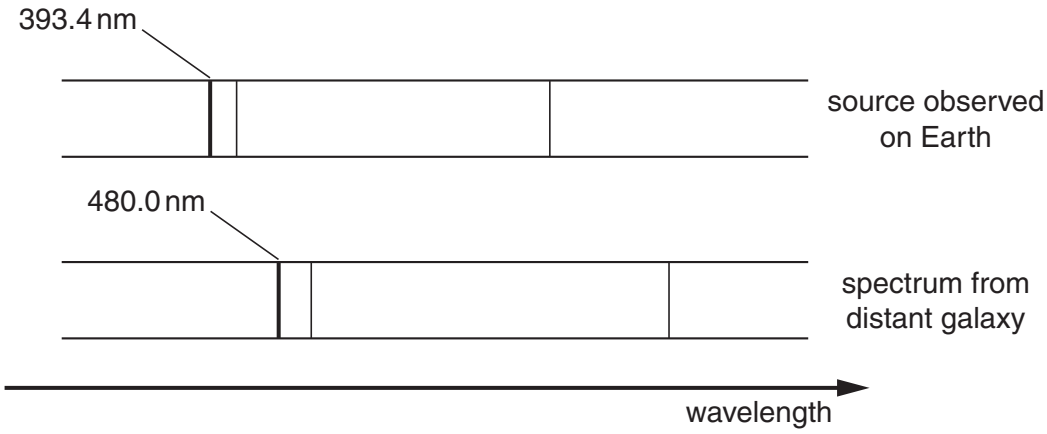



**Fig. 10.1**

**(i)** Describe an absorption spectrum.

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

**(ii)** Use Fig. 10.1 to calculate the distance of the galaxy in Mpc. The Hubble constant has a value of 50 km $s^{-1}$ $Mpc^{-1}$.

distance = ..... Mpc **[3]**

**[Total: 15]**

**END OF QUESTION PAPER**

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## 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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