OCR Physics Unit 5

Past Paper Pack

2010-2013

THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE

PHYSICS A

Fields, Particles and Frontiers of Physics

G485

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Friday 18 June 2010
Morning

Duration: 1 hour 45 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. 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.

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 **20** pages. Any blank pages are indicated.

Answer **all** the questions.

1 **(a)** Define *capacitance*.

....

.... **[1]**

(b) Fig. 1.1 shows a circuit consisting of a resistor and a capacitor of capacitance 4.5 μF.

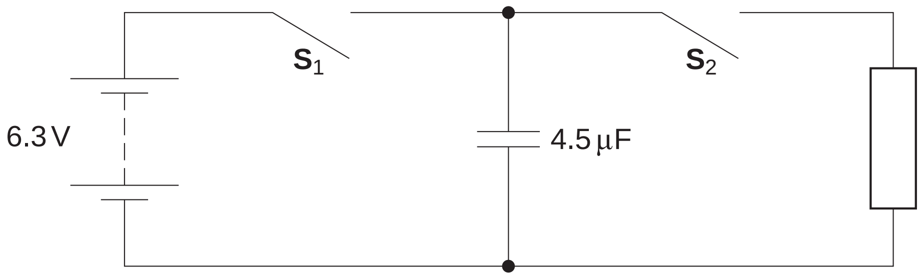

Fig. 1.1

Switch **S_1** is closed and switch **S_2** is left open. The potential difference across the capacitor is 6.3 V.

Calculate

(i) the charge stored by the capacitor

charge = ... μC **[1]**

(ii) the energy stored by the capacitor.

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

(c) Switch $\mathbf{S_1}$ is opened and switch $\mathbf{S_2}$ is closed.

(i) Describe and explain in terms of the movement of electrons how the potential difference across the capacitor changes.

....

....

....

.... **[3]**

(ii) The energy stored in the capacitor decreases to zero. State where the initial energy stored in the capacitor is dissipated.

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.... **[1]**

(d) Fig.1.2 shows the 4.5 μF capacitor now connected in parallel with a capacitor of capacitance 1.5 μF. Both switches are open and both capacitors are uncharged.

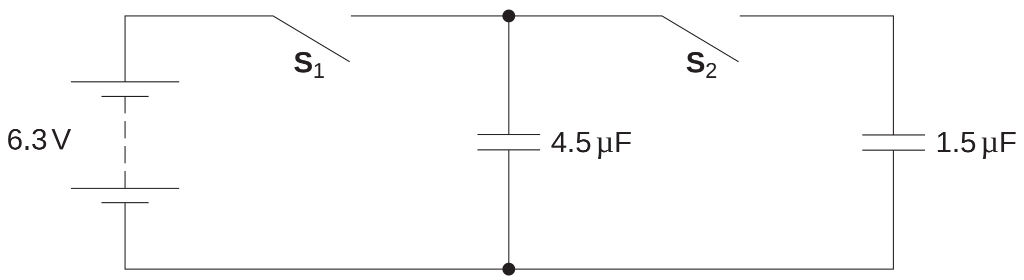

Fig. 1.2

Switch $\mathbf{S_1}$ is closed. The potential difference across the 4.5 μF capacitor is now 6.3 V. Switch $\mathbf{S_1}$ is opened and then switch $\mathbf{S_2}$ is closed.

(i) Calculate the total capacitance of the circuit when $\mathbf{S_2}$ is closed.

capacitance = ... μF **[1]**

(ii) Calculate the final potential difference across the capacitors.

potential difference = ... V **[2]**

[Total: 11]

2 **(a)** Olbers' paradox is based on two assumptions about the nature of our Universe. State these two assumptions.

....

....

.... **[2]**

(b) Fig. 2.1 shows how the recessional speed *v* of galaxies varies with their distance *d* from the Earth.

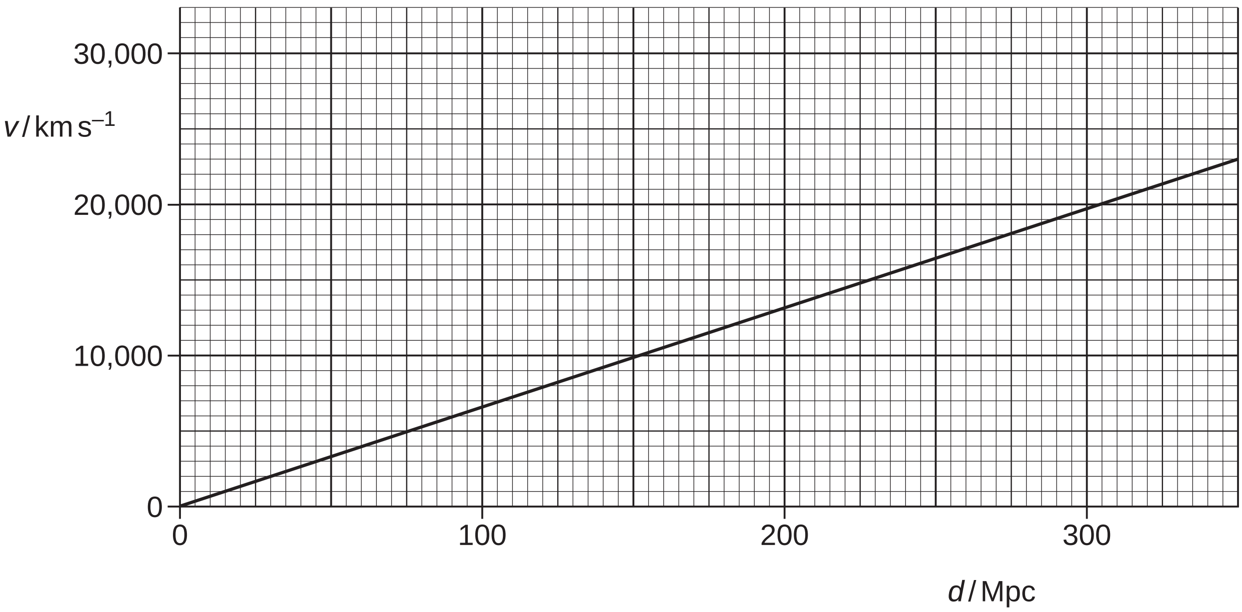

Fig. 2.1

(i) Use Fig. 2.1 to determine the Hubble constant.

Hubble constant = ... km s^{-1} Mpc^{-1} **[2]**

(ii) Hence estimate the age of the Universe in years.

1 year = 3.2×10^7 s and 1 pc = 3.1×10^{16} m

age = ... y **[3]**

(c) **(i)** Calculate the critical density of the Universe using the Hubble constant determined in **(b)(i)**.

critical density = ... kg m^{-3} **[2]**

(ii) Describe how the fate of the Universe depends on its average density.

....

....

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.... **[3]**

(d) Describe the evidence for the hot big bang model of the Universe.

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.... **[4]**

[Total: 16]

3 **(a)** Fig. 3.1 shows two charged horizontal plates.

Fig. 3.1

The potential difference across the plates is 60 V. The separation of the plates is 5.0 mm.

(i) On Fig. 3.1 draw the electric field pattern between the plates. **[2]**

(ii) Calculate the electric field strength between the plates.

electric field strength = ... $V\,m^{-1}$ **[1]**

(b) Positive ions are accelerated from rest in the horizontal direction through a potential difference of 400 V. The charged plates in **(a)** are then used to deflect the ions in the vertical direction. Fig. 3.2 shows the path of these ions.

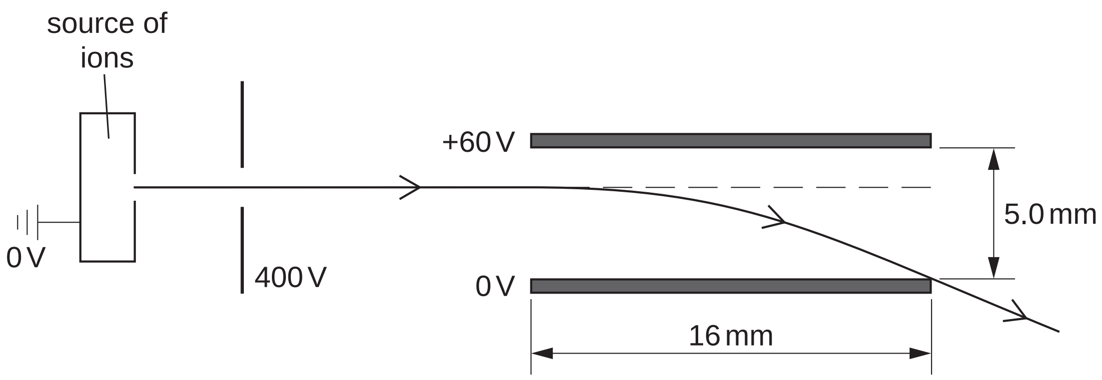

Fig. 3.2

Each ion has a mass of 6.6×10^{-27} kg and a charge of 3.2×10^{-19} C.

(i) Show that the horizontal velocity of an ion after the acceleration by the 400 V potential difference is $2.0 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

[2]

(ii) The ions enter at right angles to the uniform electric field between the plates. Calculate the vertical acceleration of an ion due to this electric field.

acceleration = ... $\mathrm{m\,s^{-2}}$ **[2]**

(iii) The length of each of the charged plates is 16 mm.

1 Show that an ion takes about 8.0×10^{-8} s to travel through the plates.

[1]

2 Calculate the vertical deflection of an ion as it travels through the plates.

deflection = ... m **[2]**

(c) A uniform magnetic field is applied in the region between the plates in Fig. 3.2. The magnetic field is perpendicular to both the path of the ions and the electric field between the plates.

Calculate the magnitude of the magnetic flux density of field needed to make the ions travel horizontally through the plates.

magnetic flux density = ... T **[3]**

(d) Ions of the same charge but greater mass are accelerated by the potential difference of 400 V described in **(b)**. Describe and explain the effect on the deflection of the ions after they have travelled between the plates using the same electric and magnetic fields of **(c)**.

....

....

....

.... **[2]**

[Total: 15]

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

....

.... **[1]**

(b) Fig. 4.1 shows a generator coil of 500 turns and cross-sectional area $2.5 \times 10^{-3}\,m^2$ placed in a magnetic field of magnetic flux density 0.035 T. The plane of the coil is perpendicular to the magnetic field.

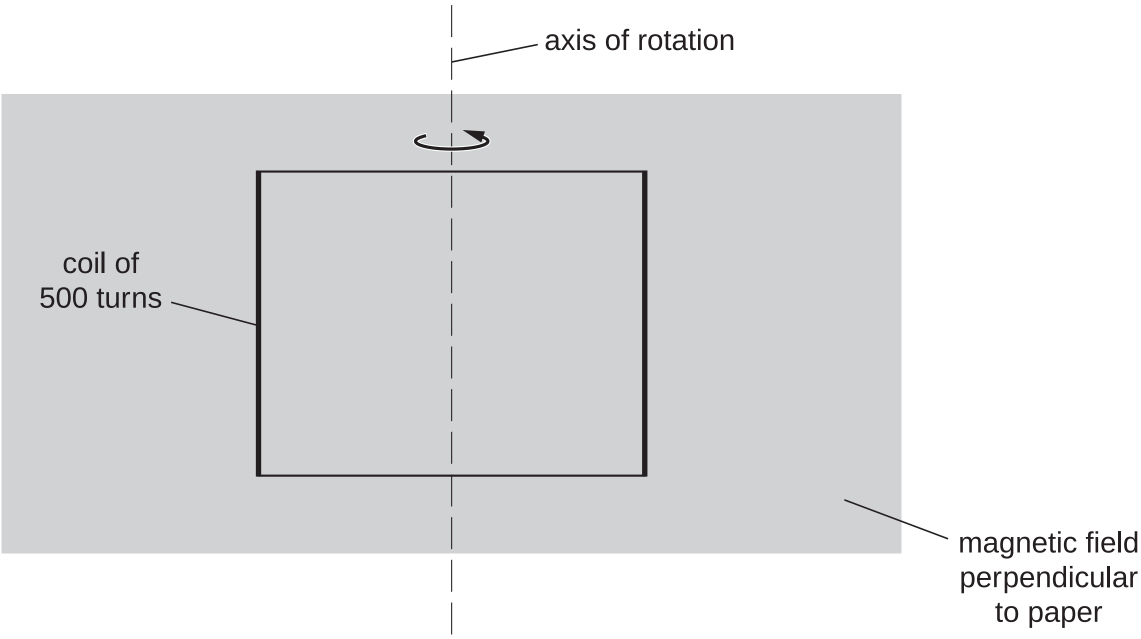

Fig. 4.1

Calculate the magnetic flux linkage for the coil in this position. Give a unit for your answer.

magnetic flux linkage = ... unit .... **[3]**

(c) The coil is rotated about the axis in the direction shown in Fig. 4.1.

Fig. 4.2 shows the variation of the magnetic flux ϕ against time t as the coil is rotated.

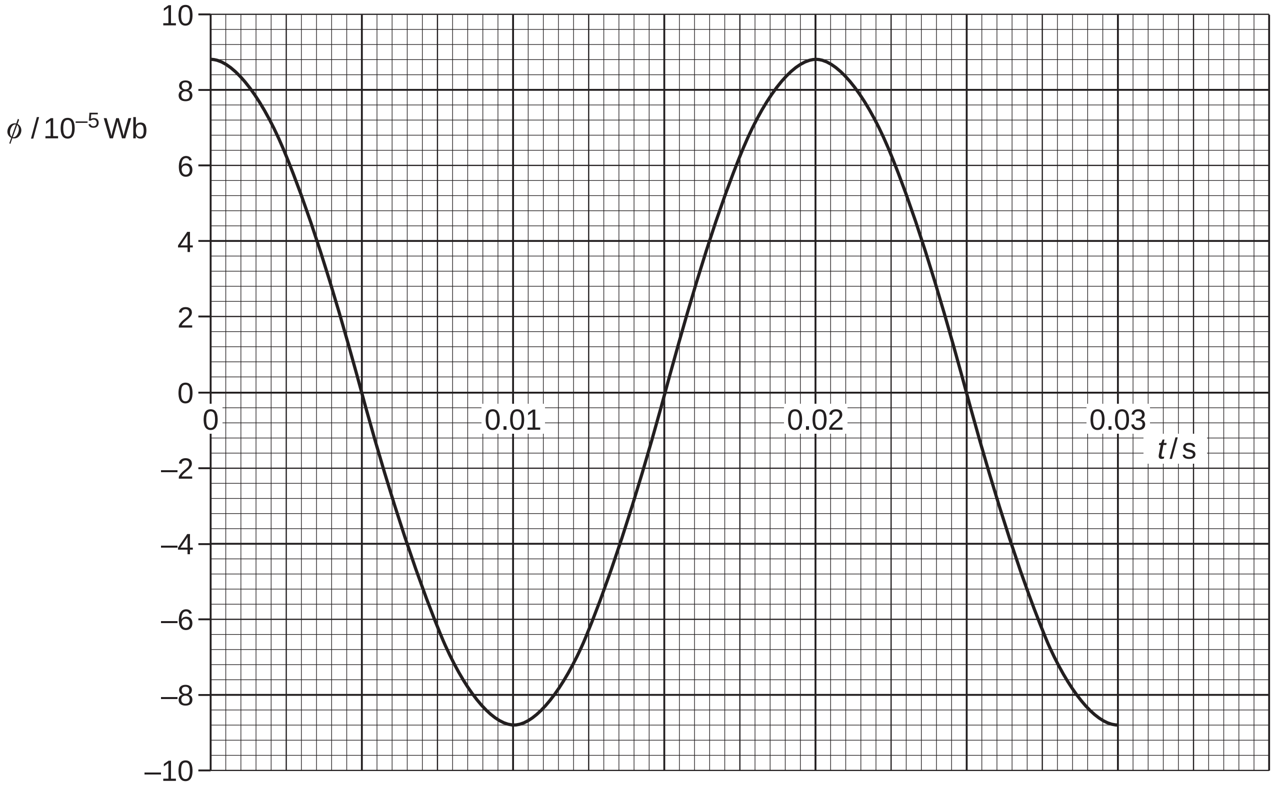

Fig. 4.2

(i) Explain why the magnitude of the magnetic flux through the coil varies as the coil rotates.

....

....

....

.... **[2]**

(ii) State Faraday's law of electromagnetic induction.

....

.... **[1]**

(iii) Use Fig. 4.2 to describe and explain the variation with time of the induced e.m.f. across the ends of the coil.

....

....

....

....

.... **[3]**

(iv) Use Fig. 4.2 to determine the magnitude of the average induced e.m.f. for the coil between the times 0 s and 0.005 s.

average e.m.f. = ... V **[2]**

(v) State and explain the effect on the magnitude of the maximum induced e.m.f. across the ends of the coil when the coil is rotated at twice the frequency.

....

....

.... **[2]**

[Total: 14]

5 **(a)** Outline the main principles of the use of magnetic resonance to obtain diagnostic information about internal organs.

In your answer, you should make clear how the principles you describe allow body structures to be distinguished.

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.... **[8]**

(b) Describe one advantage and one disadvantage of MRI.

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....

.... **[2]**

[Total: 10]

6 **(a)** A sample of a radioactive isotope contains 4.5×10^{23} active undecayed nuclei. The half-life of the isotope is 12 hours. Calculate

(i) the initial activity of the sample

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

(ii) the number of active nuclei of the isotope remaining after 36 hours

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

(iii) the number of active nuclei of the isotope remaining after 50 hours.

number = ... **[2]**

(b) Explain why the activity of a radioactive material is a major factor when considering the safety precautions in the disposal of nuclear waste.

....

....

....

.... **[2]**

[Total: 7]

7 There are two types of beta decay, beta-plus and beta-minus. An isotope of carbon ${}^{15}_{6}C$ decays by beta emission into an isotope of nitrogen ${}^{15}_{7}N$. An isotope of phosphorus ${}^{30}_{15}P$ decays by beta emission into an isotope of silicon ${}^{30}_{14}Si$.

(a) Complete the following decay equations for the carbon and phosphorus isotopes.

(i) carbon decay

$$ {}^{15}_{6}C \rightarrow {}^{\cdots}_{\cdots}e + {}^{\cdots}_{\cdots}N + \ldots\ldots $$

(ii) phosphorus decay

$$ {}^{30}_{15}P \rightarrow {}^{\cdots}_{\cdots}e + {}^{\cdots}_{\cdots}Si + \ldots\ldots $$

[3]

(b) State the two beta decays in terms of a quark model of the nucleons.

(i) beta-plus decay

(ii) beta-minus decay

[2]

(c) Name the force responsible for beta decay.

.... **[1]**

[Total: 6]

8 **(a)** The following nuclear reaction occurs when a slow-moving neutron is absorbed by an isotope of uranium-235.

$$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

(i) Explain how this reaction is able to produce energy.

....

....

.... **[2]**

(ii) State in what form the energy is released in such a reaction.

.... **[1]**

(b) The binding energy per nucleon of each isotope in **(a)** is given in Fig. 8.1.

isotope	binding energy per nucleon / MeV
$^{235}_{92}U$	7.6
$^{141}_{56}Ba$	8.3
$^{92}_{36}Kr$	8.7

Fig. 8.1

(i) Explain why the neutron $^{1}_{0}n$ does not appear in the table above.

....

.... **[1]**

(ii) Calculate the energy released in the reaction shown in **(a)**.

energy = ... MeV **[2]**

[Total: 6]

9 A proton travelling at a high velocity is fired at a stationary proton. It stops momentarily at a distance of 2.0×10^{-15} m from the stationary proton.

(a) Calculate the electrostatic force acting on each proton when separated by 2.0×10^{-15} m.

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

(b) The two protons fuse together. Explain how the protons are able to remain together.

....

.... **[1]**

(c) Explain why the proton must have a very large velocity for the fusion to occur and the protons to remain together.

....

....

....

.... **[2]**

[Total: 5]

10 **(a)** State and describe **one** way in which X-ray photons interact with matter.

....

....

....

.... **[2]**

(b) The intensity of a collimated beam of X-rays is reduced to 10% of its initial value after passing through 3.0 mm of soft tissue. Calculate the thickness of soft tissue that reduces the intensity to 50% of its initial value.

thickness = ... mm **[3]**

(c) X-rays are used to image internal body structures.

(i) Explain how image intensifiers are used to improve the quality of the X-ray image.

In your answer, you should explain clearly the process involved which makes the image brighter.

....

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....

.... **[3]**

(ii) Explain how contrast media are used to improve the quality of the X-ray image.

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....

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.... **[2]**

[Total: 10]

END OF QUESTION PAPER

ADVANCED GCE

PHYSICS A **G485**

Fields, Particles and Frontiers of Physics

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Wednesday 2 February 2011
Afternoon

Duration: 1 hour 45 minutes

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Centre number						Candidate number				

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1 **(a)** Fig. 1.1 shows a circuit consisting of two parallel plates **A** and **B** connected to a high voltage power supply.

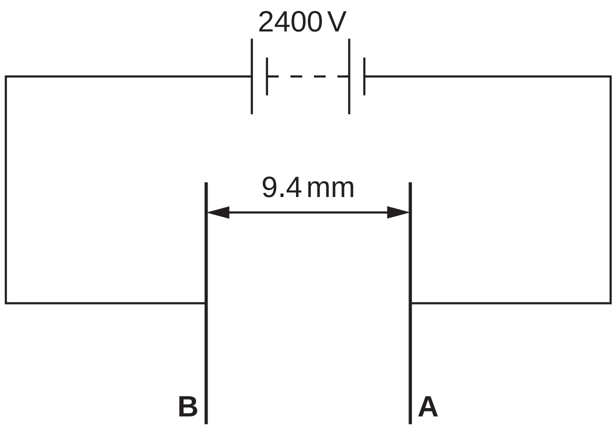

Fig. 1.1

The separation of the plates is 9.4 mm and the p.d. across the plates is 2400 V. There is a vacuum between the plates. Electrons are accelerated from plate **A** to plate **B**.

Calculate

(i) the force acting on an electron when it is between the plates

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

(ii) the gain in kinetic energy of an electron when it travels from **A** to **B**

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

(iii) the speed of the electron when it reaches plate **B**. Assume that the speed of the electron is initially zero at plate **A**.

speed = ... m s^{-1} **[1]**

(b) The separation between the plates is doubled but the p.d. across the plates is kept the same. Explain how this would affect the answer to **(a)(ii)**.

....

....

....

.... **[2]**

[Total: 7]

2 **(a)** Define the *farad*.

.... **[1]**

(b) Fig. 2.1 shows a capacitor **C** of capacitance 5.4 nF connected to a battery. The switch $\mathbf{S_1}$ is closed and the capacitor is charged to a p.d. of 12 V.

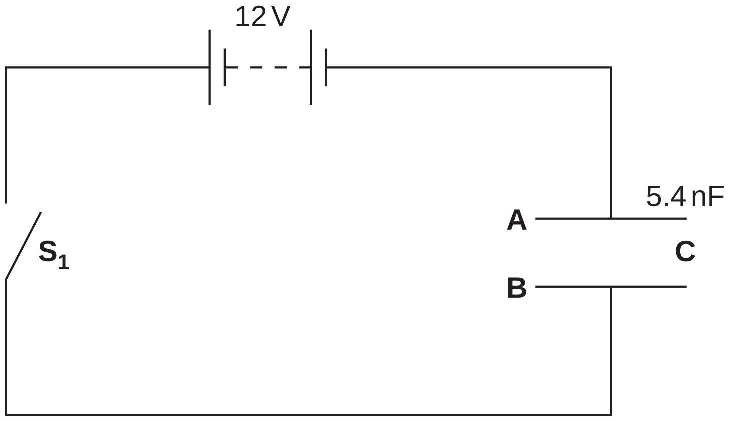

Fig. 2.1

The plates of the capacitor are labelled **A** and **B**.

(i) Explain how the plates of the capacitor become charged in terms of the movement of charged particles in the circuit.

....

....

....

.... **[2]**

(ii) Calculate

1 the charge stored by the capacitor

charge = ... C **[1]**

2 the energy transferred to the capacitor.

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

(c) Fig. 2.2 shows the capacitor **C** connected to a resistor **R**.

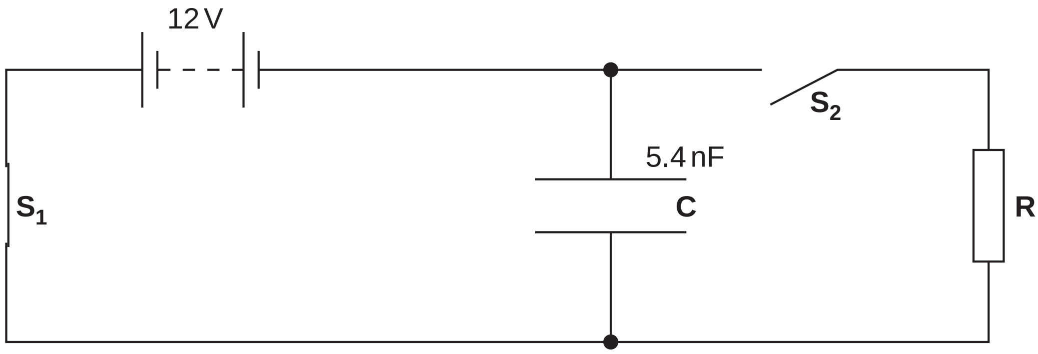

Fig. 2.2

The switch $\mathbf{S_1}$ is now opened and switch $\mathbf{S_2}$ is closed. The current in the resistor **R** is monitored. The initial current through **R** is 3.24 μA.

(i) Show that the resistance of the resistor **R** is 3.7 MΩ.

[1]

(ii) Calculate the current through **R** after a time t = 0.080 s.

current = ... μA **[2]**

(d) Explain the effect on the initial rate of discharge of the capacitor when a second resistor of resistance 3.7 MΩ is connected in parallel with the resistor **R**.

....

....

....

.... **[2]**

Total: [10]

3 Fig. 3.1 shows part of an accelerator used to produce high-speed protons. The protons pass through an evacuated tube that is shown in the plane of the paper.

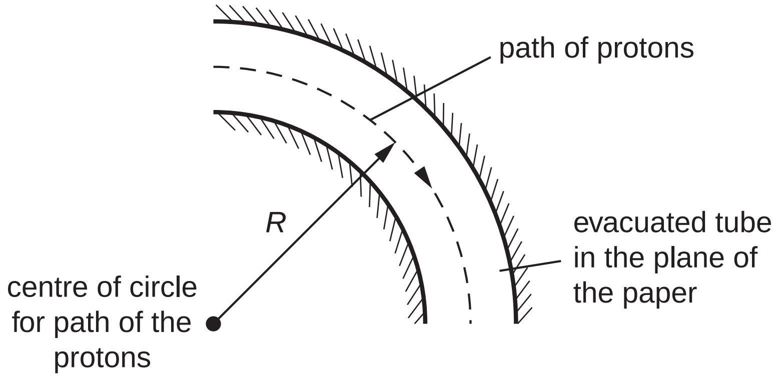

Fig. 3.1

The protons are made to travel in a circle of radius *R* by a magnetic field of flux density *B*.

(a) State clearly the direction of the magnetic flux density *B* that produces the circular motion of the protons.

.... **[1]**

(b) Show that the relationship between the velocity *v* of the protons and the radius *R* is given by $v = \frac{BQR}{m}$ where *Q* and *m* are the charge and mass of a proton respectively.

[1]

(c) Calculate the magnetic flux density *B* of the magnetic field needed to keep protons in a circular orbit of radius 0.18 m. The time for one complete orbit is 2.0×10^{-8} s.

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

(d) Explain why the magnetic field does not change the speed of the protons.

....

....

....

.... **[2]**

[Total: 7]

4 **(a)** State Hubble's Law.

....

.... **[1]**

(b) The dark lines of the spectrum observed from a distant galaxy are red-shifted by 15% of their normal wavelengths.

The Hubble constant is estimated to be 65 $\text{km s}^{-1}\ \text{Mpc}^{-1}$. One parsec = 3.1×10^{16} m.

(i) Show that the speed of the galaxy is $4.5 \times 10^{7}\ \text{m s}^{-1}$.

[1]

(ii) Estimate the distance of the galaxy from the Earth.

distance = ... m **[2]**

(iii) Estimate the age of the universe in years.

1 year = 3.2×10^{7} s

age = ... y **[2]**

(c) The age of the universe is calculated from the time of the big bang. Describe **two** observations that directly support the idea of the big bang.

....

....

....

....

....

.... **[2]**

[Total: 8]

5 **(a)** Define the *parsec*. Draw a diagram to illustrate your answer.

....

.... **[2]**

(b) The star Tau Ceti has a parallax of 0.275 seconds of arc.

Calculate the distance of Tau Ceti from Earth

(i) in parsec (pc)

distance = ... pc **[1]**

(ii) in light year (ly).

1 pc = 3.1×10^{16} m

distance = ... ly **[2]**

[Total: 5]

6 **(a)** **(i)** Describe the formation of a star such as our Sun and its most probable evolution.

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

.... **[6]**

(ii) Describe the probable evolution of a star that is much more massive than our Sun.

.... **[2]**

(b) The present mass of the Sun is 2.0×10^{30} kg. The Sun emits radiation at an average rate of 3.8×10^{26} J s^{-1}. Calculate the time in years for the mass of the Sun to decrease by one millionth of its present mass.

1 y = 3.2×10^{7} s

time = ... y **[3]**

(c) The following nuclear equation summarises a typical fusion reaction cycle that occurs in the Sun.

$$4\,{}^{1}_{1}\text{H} \longrightarrow {}^{4}_{2}\text{He} + 2\,{}^{0}_{1}\text{e} + 2\nu$$

(i) Explain the process of nuclear fusion in the core of the Sun. In your explanation refer to the conditions necessary for fusion to occur.

....

....

....

....

....

.... **[4]**

(ii) Name two forms of energy produced in thermonuclear reactions.

1. ....

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

(iii) The binding energy per nucleon of ${}^{1}_{1}$H and ${}^{4}_{2}$He are 0 and 7.2 MeV respectively. Calculate the energy produced in joules for the fusion reaction above.

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

[Total: 19]

7 **(a)** Describe the *piezoelectric effect*.

....

.... **[1]**

(b) Describe how ultrasound scanning is used to obtain diagnostic information about internal structures of a body. In your description include the differences between an A-scan and a B-scan.

....

....

....

....

....

.... **[4]**

(c) Fig. 7.1 shows the speed of ultrasound, density and acoustic impedance for muscle and bone.

material	speed of ultrasound / $m\,s^{-1}$	density / $kg\,m^{-3}$	acoustic impedance / $10^6\,kg\,m^{-2}\,s^{-1}$
muscle	1590	1080	1.72
bone	4080	1750	7.14

Fig. 7.1

(i) Show that the unit for acoustic impedance is $kg\,m^{-2}\,s^{-1}$.

[1]

(ii) An ultrasound pulse is incident at right angles to the boundary between bone and muscle. Calculate the fraction of reflected intensity of the ultrasound.

fraction of reflected intensity = ... **[2]**

(iii) What is meant by *acoustic impedance matching*? Explain why a gel is used to produce an effective ultrasound image.

....

....

....

.... **[2]**

(iv) The frequency of the ultrasound in the muscle is 1.2 MHz. Calculate the wavelength of the ultrasound in millimetres (mm).

wavelength = ... mm **[2]**

(v) Suggest why it is desirable to have ultrasound of short wavelength for a scan.

....

....

.... **[1]**

[Total: 13]

8 **(a)** Describe the use of image intensifiers and contrast media when X-rays are used to produce images of internal body structures.

In your answer, you should make clear how the appearance of the image is linked to the techniques used.

.... **[5]**

(b) A student suggests an image intensifier uses the photoelectric effect. Explain why this suggestion is **incorrect**.

.... **[1]**

(c) **(i)** Explain how the production of a CAT scan image differs from that of a simple X-ray image.

.... **[2]**

(ii) Describe the advantages of a CAT scan compared to an X-ray image.

.... **[2]**

Total: [10]

9 **(a)** **(i)** Complete Fig. 9.1 to show the quark composition and charge for neutrons and protons.

	quark composition	charge
neutron		
proton		

Fig. 9.1

[2]

(ii) Complete Fig. 9.2 to show the composition of quarks.

quark	charge	baryon number	strangeness
up		+ 1/3	
down			0

Fig. 9.2

[2]

(b) When a neutron decays it can produce particles that include an electron.

(i) Complete the decay equation below for a neutron.

$^{1}_{0}n \rightarrow$

[2]

(ii) Name the interaction responsible for the decay of the neutron.

.... **[1]**

(iii) Electrons and neutrons belong to different groups of particles. Name the group of particles to which each belongs.

electrons ....

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

[Total: 8]

10 **(a)** Describe what is meant by the **spontaneous** and **random** nature of radioactive decay of unstable nuclei.

....

....

....

.... **[2]**

(b) Define the *decay constant*.

....

.... **[2]**

(c) Explain the technique of radioactive carbon-dating.

....

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.... **[4]**

(d) The activity of a sample of living wood was measured over a period of time and averaged to give 0.249 Bq. The same mass of a sample of dead wood was measured in the same way and the activity was 0.194 Bq. The half-life of carbon-14 is 5570 years.

(i) Calculate

1 the decay constant in y^{-1} for the carbon-14 isotope

decay constant = ... y^{-1} **[1]**

2 the age of the sample of dead wood in years.

age = ... y **[2]**

(ii) Suggest why the activity was measured over a long time period and then averaged.

....

.... **[1]**

(iii) Explain why the method of carbon-dating is not appropriate for samples that are greater than 10^5 years old.

....

.... **[1]**

[Total: 13]

END OF QUESTION PAPER

OCR
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PHYSICS A

G485

Fields, Particles and Frontiers of Physics

Candidates answer on the question paper.

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- Ruler
- Protractor

Tuesday 21 June 2011
Morning

Duration: 1 hour 45 minutes

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Centre number						Candidate number				

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1 (a) Define *electromotive force*.

....

.... **[1]**

(b) Define *magnetic flux*.

....

....

.... **[1]**

(c) Fig. 1.1 shows a simple transformer.

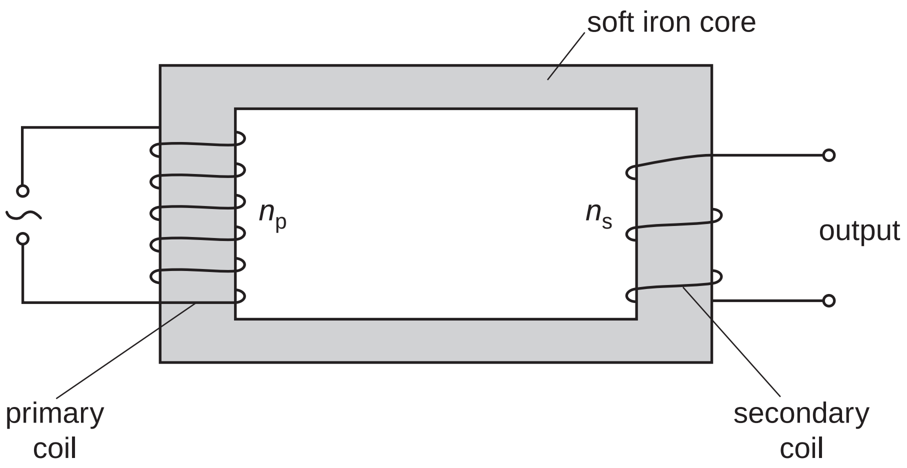

Fig. 1.1

(i) The primary coil is connected to an alternating voltage supply. Explain how an e.m.f. is induced in the secondary coil.

....

....

....

....

....

....

.... **[3]**

(ii) State how you could change the transformer to increase the maximum e.m.f. induced in the secondary coil.

....

....

.... **[1]**

(d) A transformer with 4200 turns in the primary coil is connected to a 230 V mains supply. The e.m.f. across the output is 12 V. Assume the transformer is 100% efficient.

(i) Calculate the number of turns in the secondary coil.

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

(ii) The transformer output terminals are connected to a lamp using leads that have a total resistance of 0.35 Ω. The p.d. across the lamp is 11.8 V. Calculate

1 the current in the leads connected to the lamp

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

2 the power dissipated in the leads.

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

[Total: 12]

2 **(a)** Define *capacitance*.

....

.... **[1]**

(b) Fig. 2.1 shows two capacitors of capacitance 150 μF and 450 μF connected in series with a battery of e.m.f. 6.0 V. The battery has negligible internal resistance.

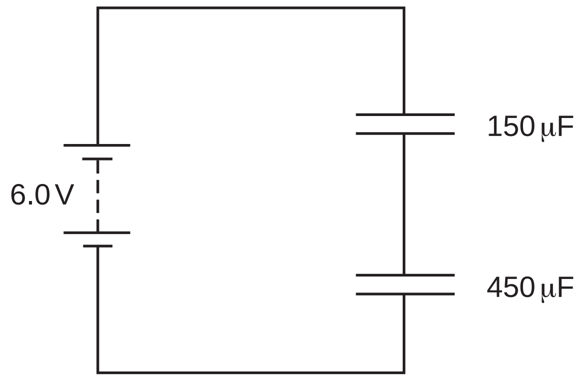

Fig. 2.1

For the circuit shown in Fig. 2.1, calculate

(i) the potential difference across the 150 μF capacitor

potential difference = ... V **[2]**

(ii) the charge stored by the 150 μF capacitor

charge = ... C **[1]**

(iii) the total capacitance of the circuit.

capacitance = ... F **[1]**

(c) The fully charged capacitors shown in **(b)** are disconnected from the battery. The capacitors are then connected in series with a resistor **R** of resistance 45 kΩ and an open switch **S** as shown in Fig. 2.2.

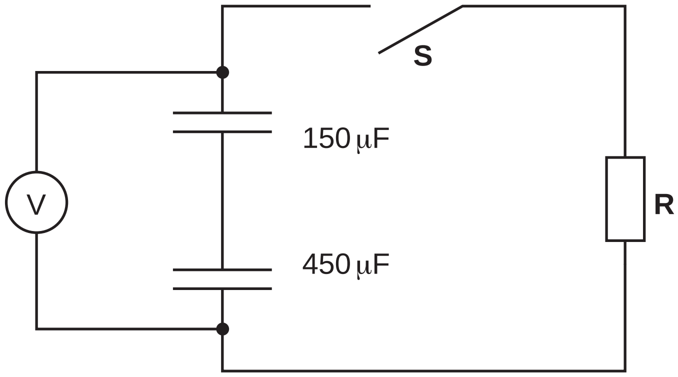

Fig. 2.2

The p.d. *V* across the capacitors is measured with a voltmeter of infinite resistance.
The switch **S** is closed at time *t* = 0 and measurements of *V* are made at regular time intervals.

(i) Show that the time constant for the circuit is about 5 s.

[1]

(ii) On Fig. 2.3 sketch the variation of p.d. *V* with time *t*.

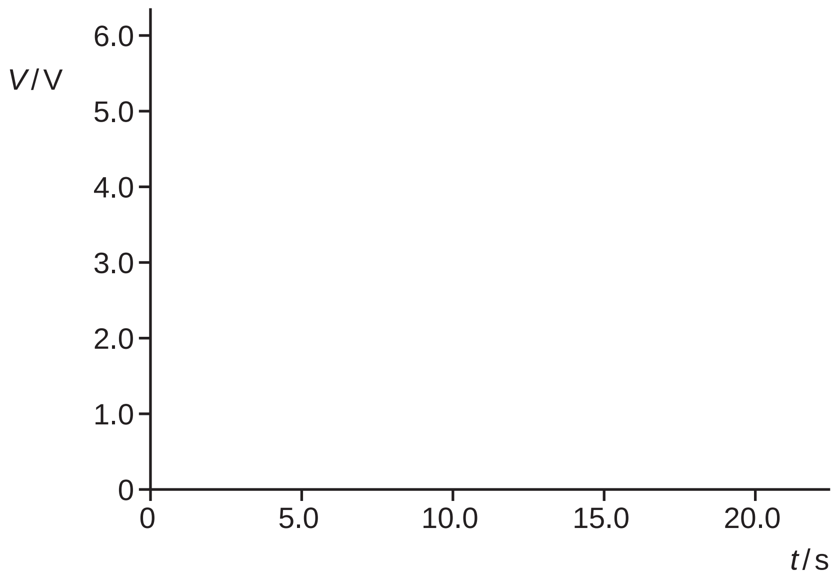

Fig. 2.3

[3]

(iii) At time t = 0 calculate the ratio

$$\frac{\text{energy stored by the 150}\,\mu\text{F capacitor}}{\text{energy stored by the 450}\,\mu\text{F capacitor}}.$$

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

(iv) State and explain how the ratio varies with time.

....

....

.... **[2]**

[Total: 13]

3 **(a)** Define *electric field strength*.

....

.... **[1]**

(b) Fig. 3.1 shows two horizontal, parallel metal plates **A** and **B**.

Fig. 3.1

The potential difference across the plates is 3.4 kV and the arrangement provides a uniform electric field between the plates.

On Fig. 3.1 draw at least six lines to represent the electric field between the plates. **[2]**

(c) A beam of electrons enters between the plates at right angles to the electric field. The horizontal velocity of the electrons is $4.0 \times 10^7\,\mathrm{m\,s^{-1}}$. The path of the electrons is shown on Fig. 3.2. The horizontal length of each plate is 0.080 m and the separation of the plates is 0.050 cm. **P** is a point 0.040 m from where the beam enters the plates.

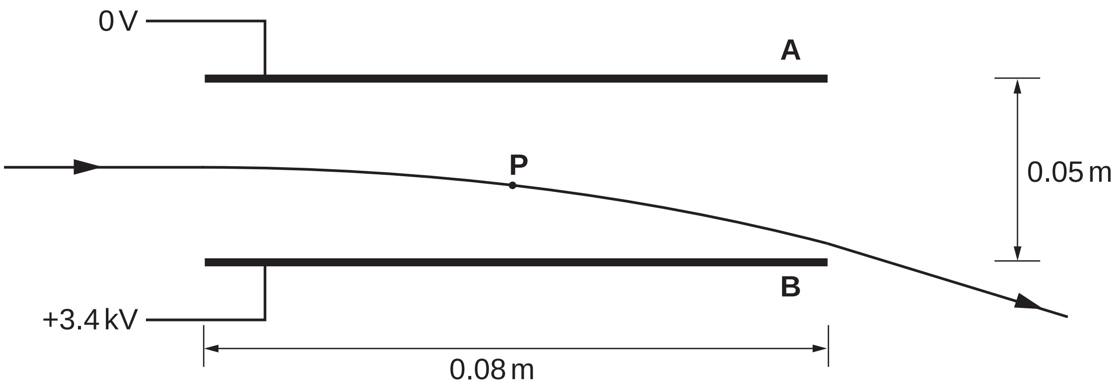

Fig. 3.2

(i) Draw an arrow on Fig. 3.2 to show the direction of the acceleration of an electron at **P**. **[1]**

(ii) Show that the acceleration of an electron between the plates is about $1 \times 10^{16}\,\mathrm{m\,s^{-2}}$.

[2]

(iii) Calculate the time taken for an electron on entering the plates to reach **P**.

time = ... s **[1]**

(iv) Show that the vertical velocity of the electron at **P** is $1.2 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

[1]

(v) Calculate the magnitude of the resultant velocity of the electron at **P**.

magnitude of the velocity = ... $\mathrm{m\,s^{-1}}$ **[2]**

(vi) Calculate the kinetic energy of the electron at **P**.

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

(vii) On Fig. 3.3 sketch the variation of kinetic energy E_k of the electron with the horizontal distance x it travels through the electric field and beyond. No calculations are required.

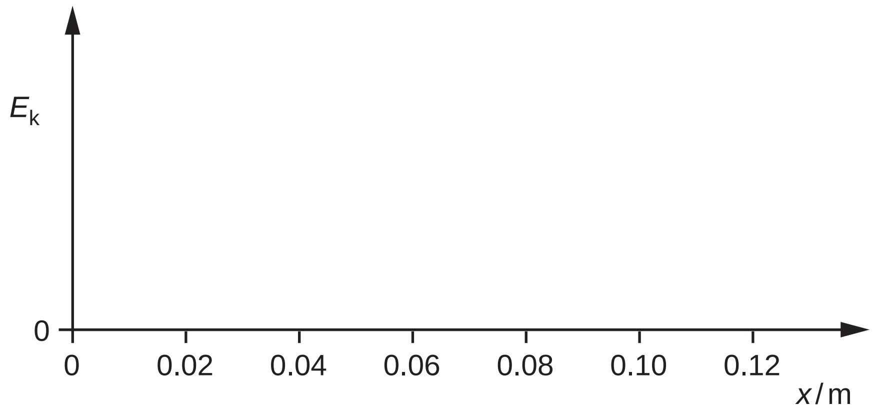

Fig. 3.3

[3]

[Total: 15]

4 A small, charged metal sphere **A** is hung from an insulating string. The charge on **A** is +5.0 nC. Fig. 4.1 shows the effect on **A** when a charged sphere **B** on an insulated rod is positioned close to it. The string makes an angle θ with the vertical.

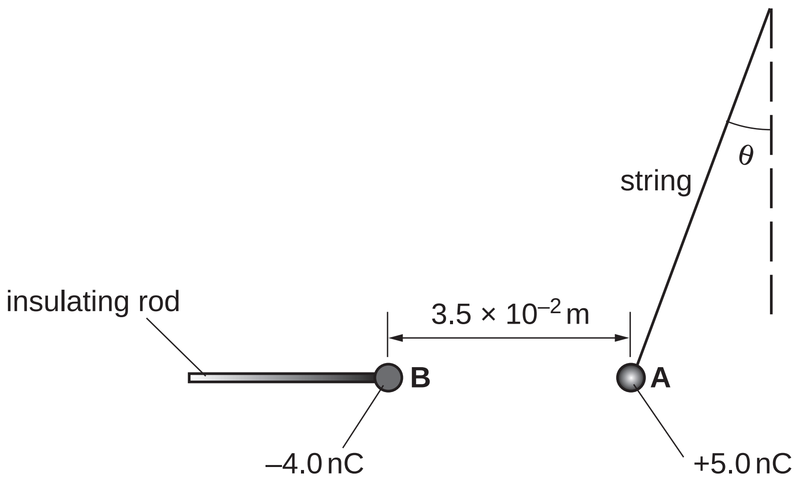

Fig. 4.1

The charge on **B** is −4.0 nC. The separation between the centres of the two spheres is 3.5×10^{-2} m.

(a) Determine the magnitude and direction of the electric field strength at the **midpoint** between the two charged spheres.

electric field strength = ... $N\,C^{-1}$

direction = ...

[4]

(b) Show that the electric force on **A** is 1.5×10^{-4} N.

[2]

(c) The mass of sphere **A** is 4.5×10^{-5} kg. Use the method of resolving vectors or a vector triangle to determine the angle θ made by the string with the vertical.

θ = ...° **[3]**

[Total: 9]

5 Fig. 5.1 shows a rigid, straight metal rod **XY** placed perpendicular to a magnetic field. The magnetic field is produced by two magnets that are placed on a U-shaped steel core. The steel core sits on a digital balance.

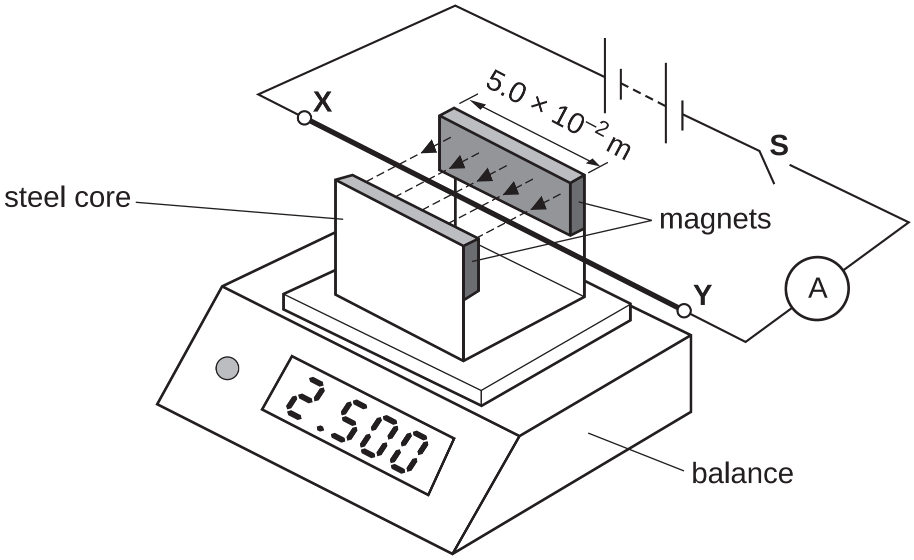

Fig. 5.1

The weight of the steel core and the magnets is 2.500 N. The rod is clamped at points **X** and **Y**. The rod is connected to a battery, switch and ammeter as shown in Fig. 5.1. The direction of the magnetic field is perpendicular to the rod.

Switch **S** is closed.

(a) State the direction of the force that now acts on the rod due to the magnetic field.

.... **[1]**

(b) State how you determined the direction of the force.

....

....

.... **[1]**

(c) The length of the rod in the magnetic field is 5.0×10^{-2} m and the current in the rod is 4.0 A. Assume that the magnets provide a uniform magnetic field of magnetic flux density 0.080 T.

(i) Calculate the force acting on the rod due to the magnetic field.

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

(ii) State and explain the new reading on the balance.

reading on balance = ... N

....

....

....

....

.... **[3]**

(d) The rod is replaced by another rod of the same material having half the diameter of the first wire and the same length. The potential difference across this rod is the same. Calculate the force on this rod due to the magnetic field.

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

[Total: 9]

6 **(a)** In experiments carried out to determine the nature of atoms, alpha particles were fired at thin metal foils. Describe how the alpha-particle scattering experiments provide evidence for the existence, charge and size of the nucleus.

In your answer, you should make clear how your conclusions link with your observations.

.... **[5]**

(b) Describe the nature and range of the **three** forces acting on the protons and neutrons in the nucleus.

.... **[5]**

(c) The radius of a $^{235}_{92}U$ nucleus is 8.8×10^{-15} m. The average mass of a nucleon is 1.7×10^{-27} kg.

(i) Estimate the average density of this nucleus.

density = ... $kg\,m^{-3}$ **[3]**

(ii) State one assumption made in your calculation.

....

.... **[1]**

[Total: 14]

7 (a) Explain what is meant by the *critical density* of the universe.

....

.... **[1]**

(b) Cosmologists have determined the Hubble constant to be 65 km s^{-1} Mpc^{-1}. Calculate the Hubble constant in s^{-1} and hence determine the critical density of the universe.

1 pc = 3.1×10^{16} m

Hubble constant = ... s^{-1}

critical density = ... kg m^{-3} **[3]**

(c) **(i)** Explain the terms *open*, *closed* and *flat* when describing the possible evolution of the universe. On Fig. 7.1 sketch and label graphs to illustrate your answer.

Fig. 7.1

open ....

....

....

closed ....

....

....

flat ....

....

.... **[3]**

(ii) Suggest a reason why it is difficult to predict the future of the universe.

....

....

.... **[1]**

[Total: 8]

8 **(a)** State one reason for using non-invasive techniques in medical diagnosis.

....

.... **[1]**

(b) Describe the use of medical tracers to diagnose the condition of organs.

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.... **[2]**

(c) Describe the principles of positron emission tomography (PET).

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.... **[5]**

[Total: 8]

9 **(a)** Describe the principles of ultrasound scanning.

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

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.... **[4]**

(b) Explain the difference between an ultrasound A-scan and B-scan.

....

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.... **[1]**

[Total: 5]

TURN OVER PAGE FOR QUESTION 10.

10 **(a)** Describe the process of induced nuclear fission.

....

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....

.... **[2]**

(b) Explain how nuclear fission can provide energy.

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.... **[2]**

(c) Suggest a suitable material which can be used as a moderator in a fission reactor and explain its role.

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.... **[3]**

[Total: 7]

END OF QUESTION PAPER

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.

Answer **all** the questions.

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

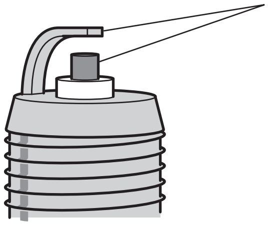

Fig. 1.1

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 $3.0 \times 10^6\,\mathrm{V\,m^{-1}}$.

(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.

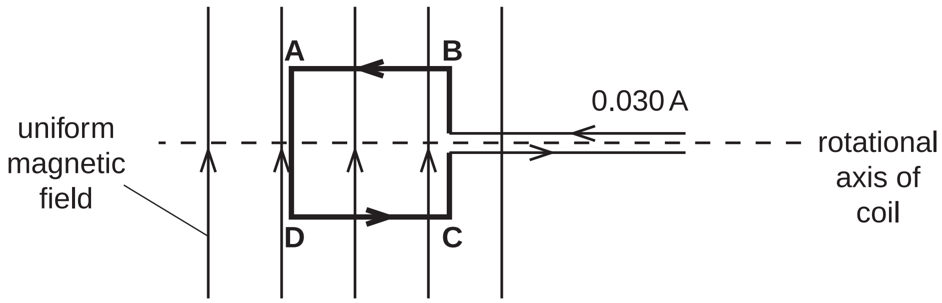

Fig. 2.1

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.

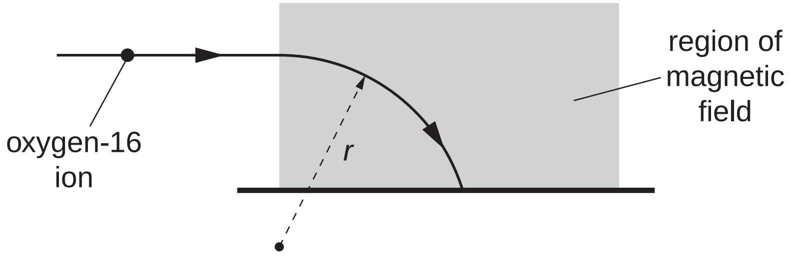

Fig. 2.2

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 $4.5 \times 10^6\,\text{m s}^{-1}$ 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 $2.0 \times 10^{-13}\,\text{N}$.

(i) Calculate the charge *Q* of the ion.

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

(ii) The mass of the ion is $2.7 \times 10^{-26}\,\text{kg}$. 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.

....

....

....

.... **[2]**

[Total: 12]

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

....

.... **[2]**

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

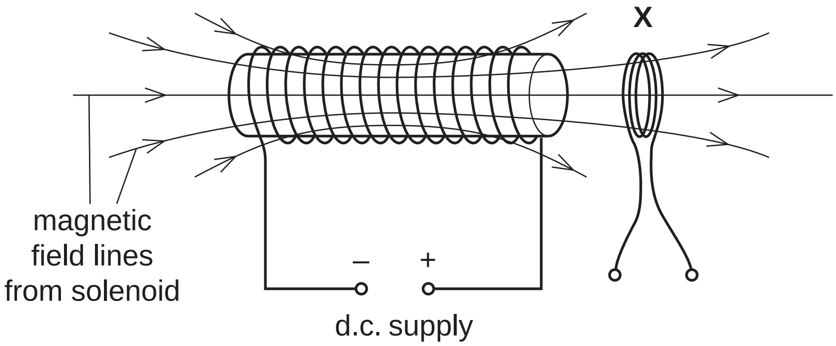

Fig. 3.1

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*.

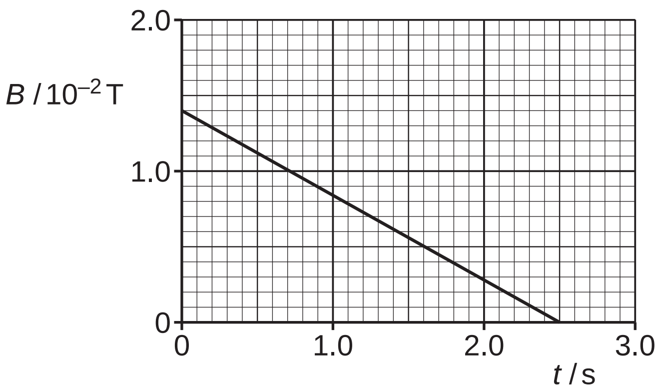

Fig. 3.2

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 s to t = 2.5 s.

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

(c) Fig. 3.3 shows a transformer circuit.

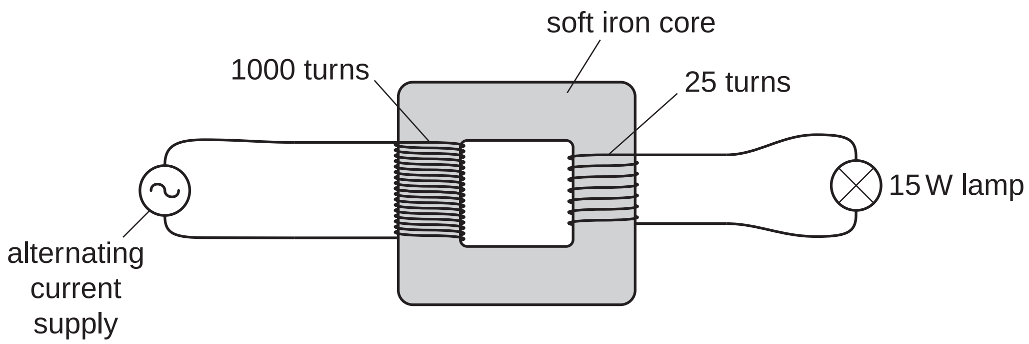

Fig. 3.3

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.

....

....

....

....

.... **[1]**

[Total: 9]

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

....

.... **[1]**

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

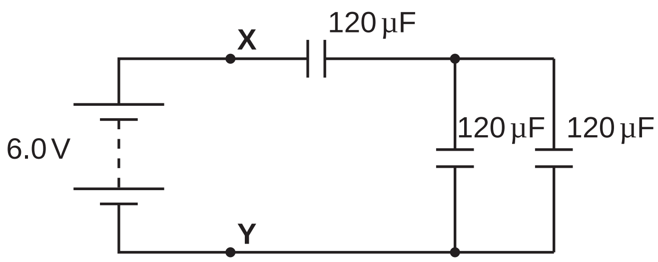

Fig. 4.1

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 6.0V. 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*.

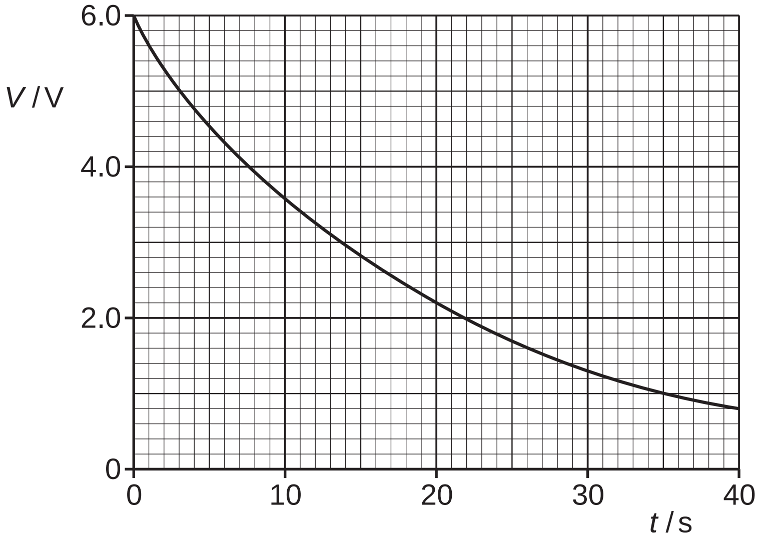

Fig. 4.2

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.

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

[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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....

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....

....

.... **[4]**

[Total: 17]

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

....

....

.... **[2]**

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

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

(i) The binding energy per nucleon of $^{2}_{1}H$ is 1.8×10^{-13} J and the binding energy per nucleon of $^{4}_{2}He$ 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.

....

....

.... **[2]**

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

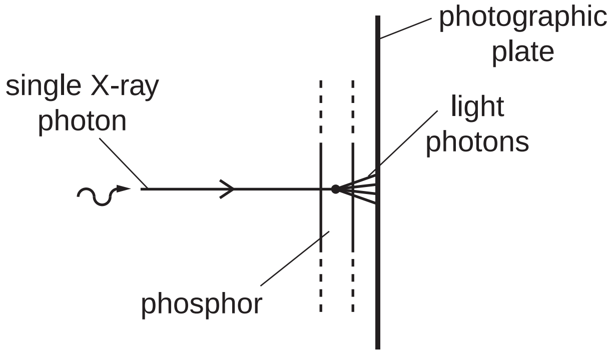

Fig. 7.1

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.

....

.... **[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.

....

....

.... **[2]**

[Total: 9]

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

....

....

.... **[2]**

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

....

....

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

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

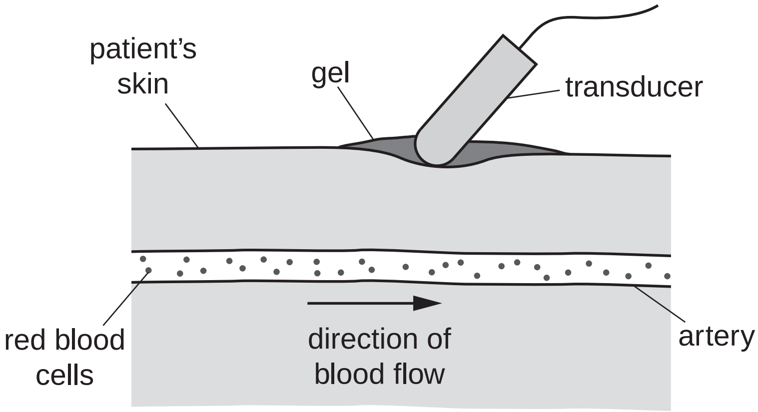

Fig. 8.1

(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.

.... **[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.

.... **[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 $10^{-26}\,\text{kg}\,\text{m}^{-3}$.

[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

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

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 (DTC 00682 6/11) 52029/5

Answer **all** the questions.

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

....

.... **[1]**

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

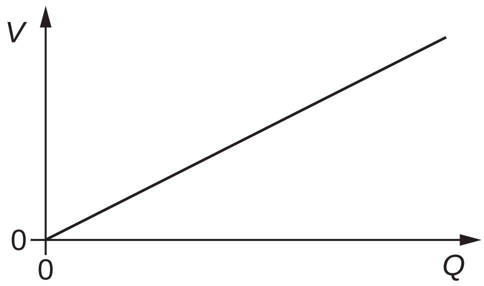

Fig. 1.1

State the quantity represented by the

(i) gradient of the graph

.... **[1]**

(ii) area under the graph.

.... **[1]**

(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]

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

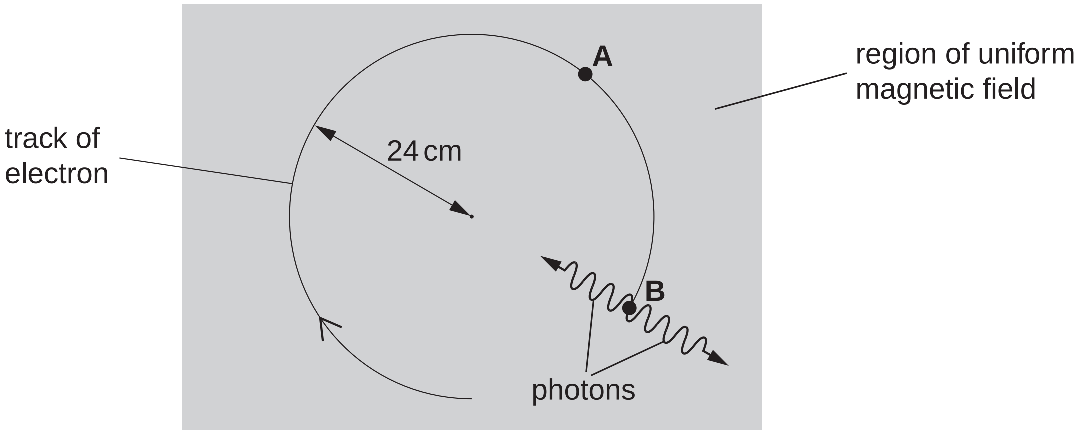

Fig. 2.1

The magnetic field is perpendicular to the plane of Fig. 2.1. The speed of the electron is $6.0 \times 10^7\,\text{m}\,\text{s}^{-1}$ 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]**

(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]

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

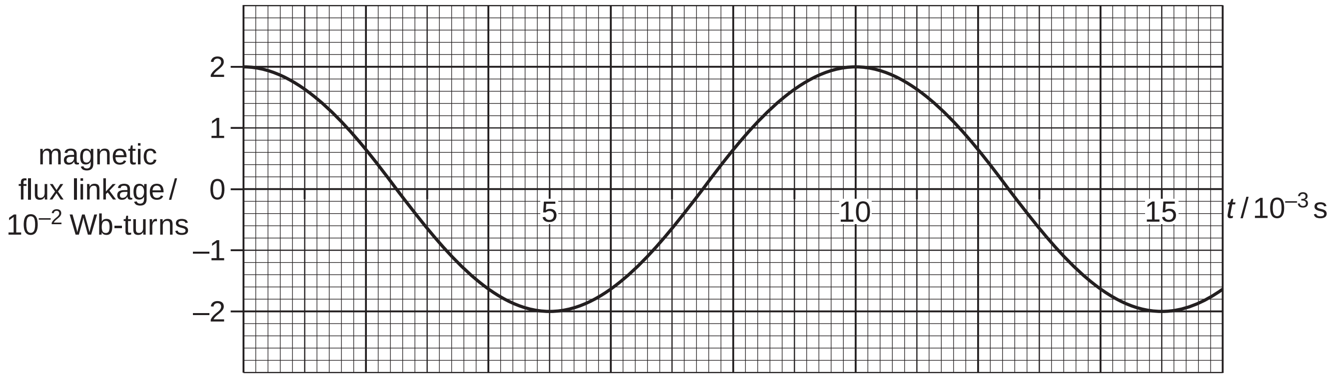

Fig. 3.1

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]**

(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]

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.

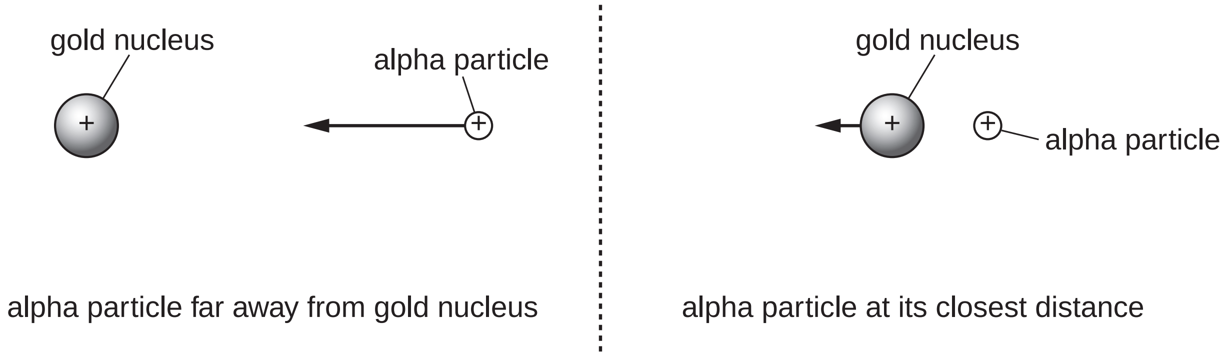

Fig. 4.1

(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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....

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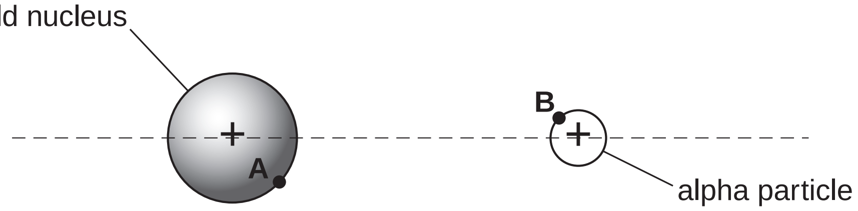
....

.... **[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.



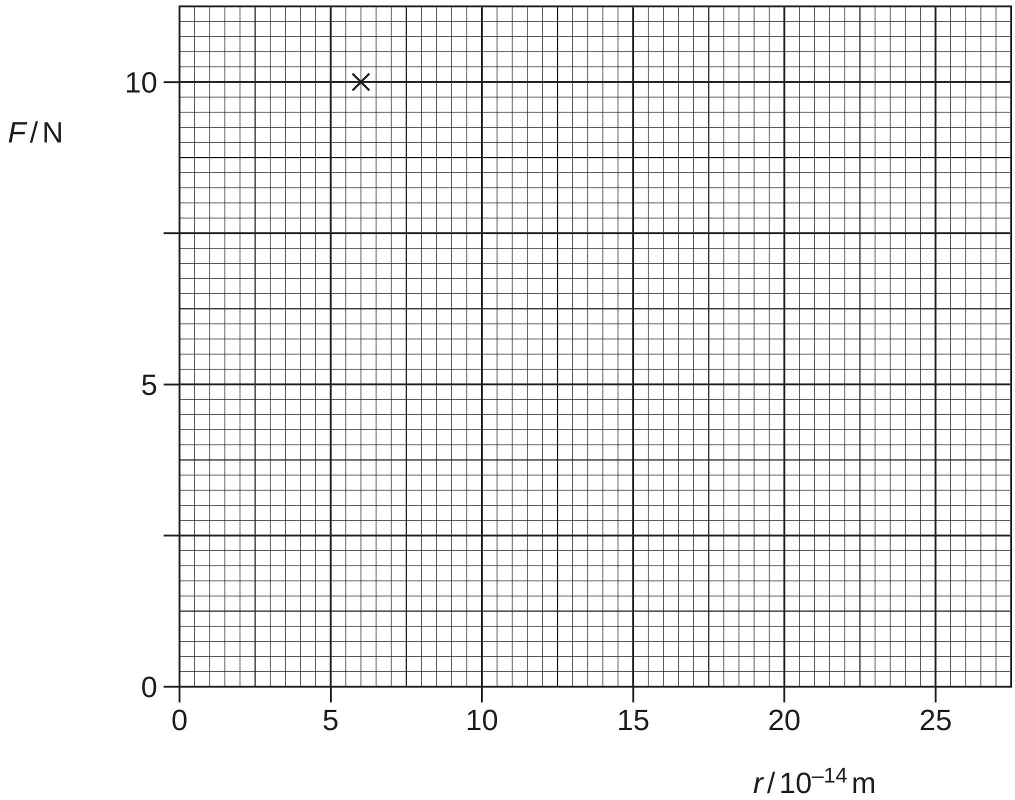
[2]

Fig. 4.2

(c) Show that the electrical force experienced by the alpha particle at its closest distance of 6.0×10^{-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]

5 The radioactive nucleus of plutonium ($^{238}_{94}Pu$) decays by emitting an alpha particle ($^{4}_{2}He$) of kinetic energy 5.6 MeV 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 6.65×10^{-27} kg.

(i) Show that the kinetic energy of the alpha particle is about 9×10^{-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 62 W 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 7×10^{13} Bq.

[1]

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

1 year = 3.16×10^{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]

6 The nuclear reaction represented by the equation

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

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]**

(c) In the nuclear reactor of a power station, each fission reaction of uranium produces 3.2×10^{-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 = 8.64×10^4 s

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

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

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

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

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....

.... **[2]**

[Total: 12]

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

1. ....

....

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 μ depends on the material.

(i) State what I_0 represents in this equation.

.... **[1]**

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

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

(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]

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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.... **[7]**

(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]

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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.... **[4]**

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

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.... **[3]**

[Total: 7]

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 4×10^{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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.... **[6]**

(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.

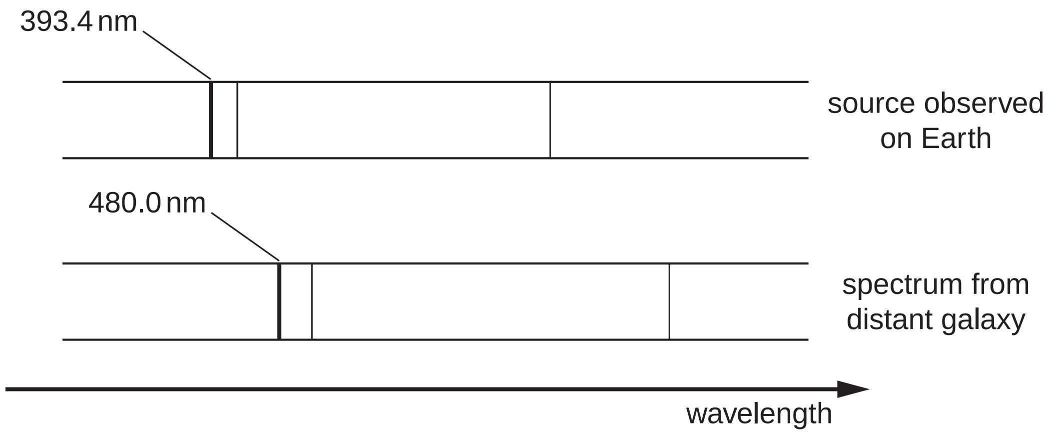

Fig. 10.1

(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

OCR
RECOGNISING ACHIEVEMENT

Wednesday 23 January 2013 – Afternoon

A2 GCE PHYSICS A

G485/01 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				

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  - 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 (KN/SW) 56626/5

Turn over

Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a circuit with a capacitor of capacitance *C*.

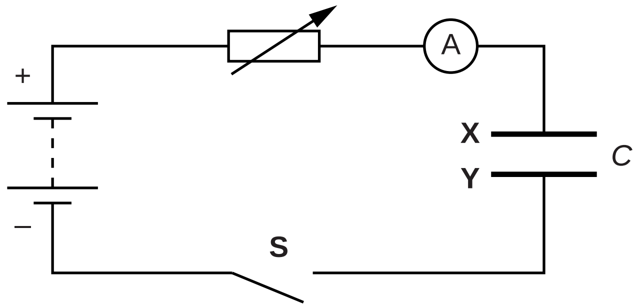

Fig. 1.1

The switch **S** is closed. The resistance of the variable resistor is manually adjusted so that the current in the circuit is kept **constant**.

(i) Explain in terms of movement of electrons how the capacitor plates **X** and **Y** acquire an equal but opposite charge.

....

....

....

....

.... **[2]**

(ii) The initial charge on the capacitor is zero. After 100 s, the potential difference across the capacitor is 1.6 V. The constant current in the circuit is 40 μA.

1 Calculate the capacitance *C* of the capacitor.

C = ... F **[3]**

2 On Fig. 1.2, sketch a graph to show the variation of potential difference *V* across the capacitor with time *t*.

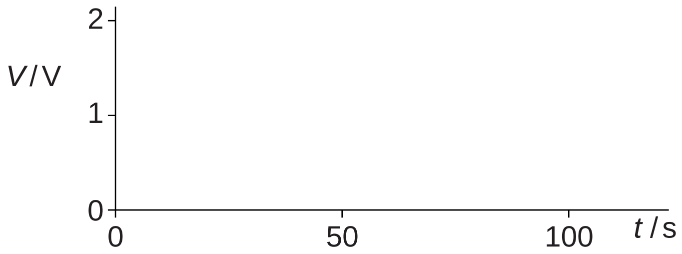

Fig. 1.2

[2]

(b) Fig. 1.3 shows an arrangement used to determine the speed of a bullet.

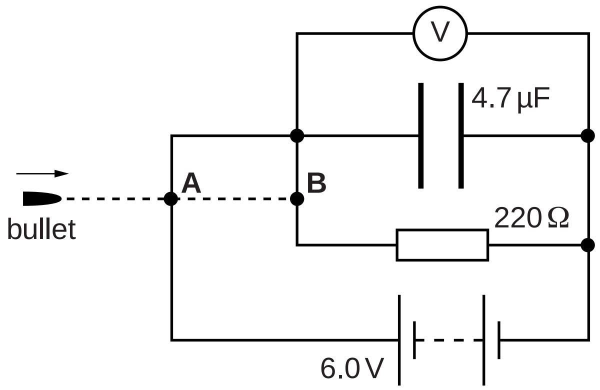

Fig. 1.3

The value of the resistance of the resistor and the value of the capacitance of the capacitor are shown in Fig. 1.3. The voltmeter reading is initially 6.0 V. The bullet first breaks the circuit at **A**. The capacitor starts to discharge **exponentially** through the resistor. The capacitor stops discharging when the bullet breaks the circuit at **B**. The final voltmeter reading is 4.0 V.

(i) Calculate the time taken for the bullet to travel from **A** to **B**.

time = ... s **[3]**

(ii) The separation between **A** and **B** is 0.10 m. Calculate the speed of the bullet.

speed = ... m s^{-1} **[1]**

[Total: 11]

Turn over

2 (a) Define *electric field strength* at a point in space.

....

.... **[1]**

(b) Fig. 2.1 shows an evenly spaced grid.

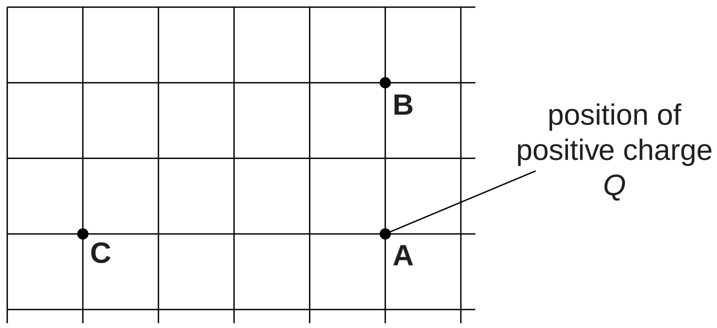

Fig. 2.1

A, **B** and **C** are points on the grid. A positive charge Q is placed on the grid at point **A**. The magnitude of the electric field strength at point **B** due to the charge Q is $8.0 \times 10^5\,\mathrm{N\,C^{-1}}$.

(i) Apart from the magnitudes of the electric field strength, state another difference between the electric field at points **B** and **C**.

....

.... **[1]**

(ii) Determine the magnitude of the electric field strength at point **C**.

electric field strength = ... $\mathrm{N\,C^{-1}}$ **[2]**

(c) The simplest atom is that of hydrogen with one proton and one electron, see Fig. 2.2.

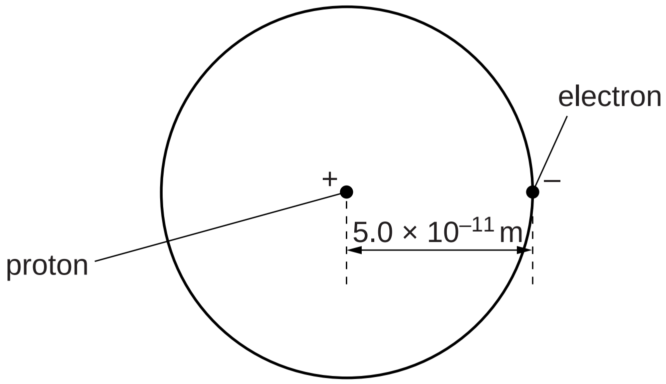

Fig. 2.2

The mean separation between the proton and the electron is shown in Fig. 2.2.

(i) Calculate the magnitude of the electrical force F_E acting on the electron.

F_E = ...N **[3]**

(ii) The gravitational force F_G acting on the electron due to the proton is very small compared with the electrical force F_E it experiences.

Calculate the ratio $\frac{F_E}{F_G}$.

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

(iii) A simplified model of the hydrogen atom suggests that the de Broglie wavelength of the electron is four times the mean separation between the proton and the electron shown in Fig. 2.2.

Estimate

1 the momentum p of the electron

p = ... kg m s^{-1} **[3]**

2 the kinetic energy E_k of the electron.

E_k = ... J **[3]**

[Total: 15]

3 Fig. 3.1 shows a section through a mass spectrometer.

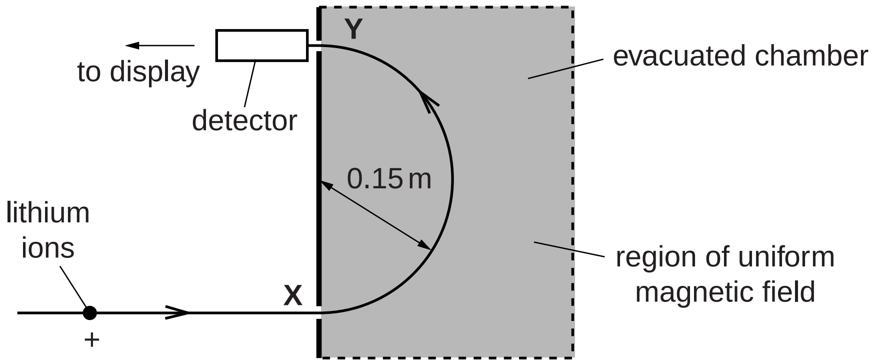

Fig. 3.1

A beam of positive lithium ions enter the evacuated chamber through the hole at **X**. The ions travel through a region of uniform magnetic field. The magnetic field is directed vertically into the plane of the diagram. The ions exit and are detected at **Y**.

(a) Name the rule that may be used to determine the direction of the force acting on the ions.

.... **[1]**

(b) Explain why the speed of the ions travelling from **X** to **Y** in the magnetic field does not change despite the force acting on the ions.

....

....

.... **[1]**

(c) The lithium-7 ions are detected at **Y**. All the ions have the same speed, $4.0 \times 10^{5}\,\mathrm{m\,s^{-1}}$ and charge, $+1.6 \times 10^{-19}\,\mathrm{C}$. The radius of the semi-circular path of the ions in the magnetic field is 0.15 m. The mass of a lithium-7 ion is $1.2 \times 10^{-26}\,\mathrm{kg}$.

(i) Calculate the force acting on a lithium ion as it moves in the semi-circle.

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

(ii) Calculate the magnitude of the magnetic flux density B.

B = ... T **[2]**

(iii) The current recorded by the detector at **Y** is 4.8×10^{-9} A. Calculate the number of lithium-7 ions reaching the detector per second.

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

(d) Fig. 3.2 shows the variation of current I in the detector with magnetic flux density B.

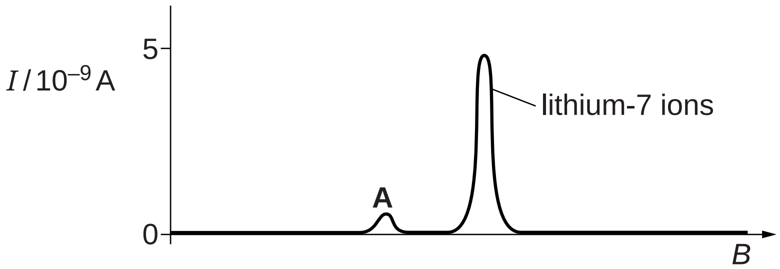

Fig. 3.2

The peak **A** is due to ions of another isotope of lithium. These ions have the same speed and charge as the lithium-7 ions. Explain the significance of the 'height' and position of peak **A**.

....

....

....

....

.... **[2]**

[Total: 10]

4 **(a)** In the core of a nuclear reactor, one of the many fission reactions of the uranium-235 nucleus is shown below.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n$$

(i) State **one** quantity that is conserved in this fission reaction.

.... **[1]**

(ii) Fig. 4.1 illustrates this fission reaction.

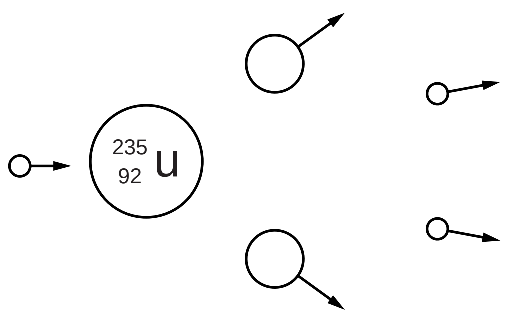

Fig. 4.1

Label all the particles in Fig. 4.1 and extend the diagram to show how a chain reaction might develop. **[2]**

(b) Fusion of hydrogen nuclei is the source of energy in most stars. A typical reaction is shown below.

$$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$$

The $^{2}_{1}H$ nuclei repel each other. Fusion requires the $^{2}_{1}H$ nuclei to get very close and this usually occurs at very high temperatures, typically 10^9 K.

(i) Use the data below to calculate the energy released in the fusion reaction above.

mass of ${}^{2}_{1}H$ nucleus = 3.343×10^{-27} kg

mass of ${}^{3}_{2}He$ nucleus = 5.006×10^{-27} kg

mass of ${}^{1}_{0}n$ = 1.675×10^{-27} kg

energy = ... J **[3]**

(ii) State in what form the energy in **(b)(i)** is released.

.... **[1]**

(iii) The ${}^{2}_{1}H$ nuclei in stars can be modelled as an ideal gas. Calculate the mean kinetic energy of the ${}^{2}_{1}H$ nuclei at 10^{9} K.

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

(iv) Suggest why some fusion can occur at a temperature as low as 10^{7} K.

....

....

.... **[1]**

[Total: 10]

5 Fluorodeoxyglucose (FDG) is a radiopharmaceutical used for PET scans. It contains radioactive fluorine-18, which is a positron-emitter with a half-life of 6.6×10^3 s.
A patient is injected with FDG which has an initial activity of 250 MBq.

(a) Calculate the decay constant of fluorine-18.

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

(b) Show that the initial number of fluorine-18 nuclei in the FDG is about 2×10^{12}.

[1]

(c) About 9.9% of the mass of FDG is fluorine-18. Use your answer in **(b)** to determine the initial mass of FDG given to the patient. The molar mass of fluorine-18 is 0.018 kg mol^{-1}.

mass = ... kg **[3]**

(d) A typical PET scan takes 20 minutes. Determine the activity of FDG in the patient after this time.

activity = ... MBq **[2]**

(e) Positron emission tomography (PET) can be used to locate an area of increased activity within the brain. Describe the principles of PET.

In your answer you should make clear how the position of increased activity is located.

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.... **[4]**

[Total: 12]

6 **(a)** Describe briefly how X-rays are produced in an X-ray tube.

....

....

.... **[2]**

(b) Describe the Compton Effect in terms of an X-ray photon.

....

....

....

.... **[2]**

(c) A beam of X-rays of intensity $3.0 \times 10^9\ \text{W m}^{-2}$ is used to target a tumour in a patient. The tumour is situated at a depth of 1.7 cm in soft tissue. The attenuation (absorption) coefficient μ of soft-tissues is $6.5\ \text{cm}^{-1}$.

(i) Show that the intensity of the X-rays at the tumour is about $5 \times 10^4\ \text{W m}^{-2}$.

[2]

(ii) The cross-sectional area of the X-ray beam at the tumour is $5\ \text{mm}^2$. The energy required to destroy the malignant cells of the tumour is 200 J. The tumour absorbs 10% of the energy from the X-rays. Calculate the total exposure time required to destroy the tumour.

time = ... s **[3]**

(d) Describe the operation of a computerised axial tomography (CAT) scanner. State **one** of the advantages of a CAT scan image over a conventional X-ray image.

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.... **[5]**

[Total: 14]

7 (a) A magnetic resonance imaging (MRI) scanner is a valuable item of diagnostic equipment found in most hospitals. It is capable of generating a three-dimensional image of the patient. The following terms are used in the description of MRI scanners.

- Larmor frequency of the protons
- resonance of the protons
- relaxation times of the protons

Describe the operation of the MRI scanner with particular reference to these terms.

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.... **[6]**

(b) An MRI scan can take a long time and it does produce an unpleasant loud noise. State one other disadvantage and one advantage of an MRI scan.

disadvantage ....

....

advantage ....

.... **[2]**

[Total: 8]

8 (a) Describe briefly the sequence of events which occur in the formation of a star, such as our Sun, from interstellar dust and gas clouds.

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

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.... **[4]**

(b) Fig. 8.1 shows the evolution of a star similar to our Sun on a graph of intensity of emitted radiation against temperature.

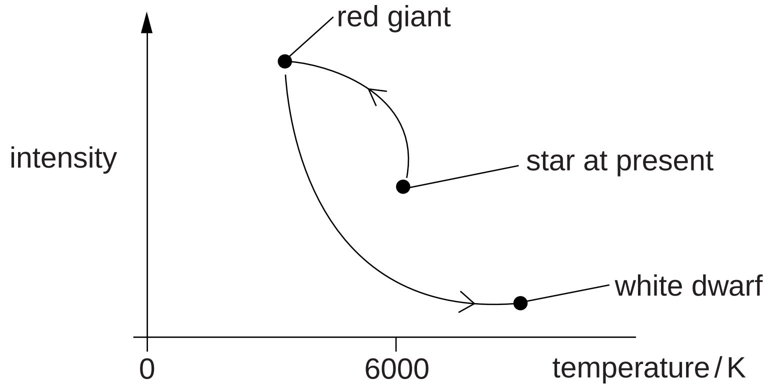

Fig. 8.1

(i) The final evolutionary stage of the star is a white dwarf. Describe some of the characteristics of a white dwarf.

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.... **[2]**

(ii) Explain why, in its evolution, the star is brightest when at its coolest.

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.... **[2]**

[Total: 8]

9 **(a)** State Olbers' paradox and the two assumptions made about the Universe.

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.... **[3]**

(b) State Hubble's law and explain how it resolves Olbers' paradox.

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.... **[2]**

(c) A galaxy at a distance of 1.4×10^{25} m is observed to be receding from the Earth at a velocity of $3.4 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

(i) Calculate the Hubble constant H_0 based on this data.

H_0 = ... unit .... **[3]**

(ii) Estimate

1 the age in years of the Universe

1 year = 3.2×10^7 s

age = ...years **[2]**

2 the maximum distance in parsec (pc) we can observe from the Earth.

1 pc = 3.1×10^{16} m

distance = ... pc **[2]**

[Total: 12]

END OF QUESTION PAPER

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^{2} N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^{2} kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}$ kg
electron-volt	$1\ \text{eV} = 1.60 \times 10^{-19}$ J
	$1\ \text{day} = 8.64 \times 10^{4}$ s
	$1\ \text{year} \approx 3.16 \times 10^{7}$ s
	$1\ \text{light year} \approx 9.5 \times 10^{15}$ m

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n \ln(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Unit 1 – Mechanics

$F_x = F\cos\theta$
$F_y = F\sin\theta$

$a = \frac{\Delta v}{\Delta t}$

$v = u + at$

$s = \frac{1}{2}(u + v)t$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$F = ma$

$W = mg$

moment = Fx

torque = Fd

$\rho = \frac{m}{V}$

$p = \frac{F}{A}$

$W = Fx\cos\theta$

$E_k = \frac{1}{2}mv^2$

$E_p = mgh$

efficiency = $\frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \frac{1}{2}Fx \quad E = \frac{1}{2}kx^2$

stress = $\frac{F}{A}$

strain = $\frac{x}{L}$

Young modulus = $\frac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \frac{\rho L}{A}$

$P = VI \quad P = I^2R \quad P = \frac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_{\text{out}} = \frac{R_2}{R_1 + R_2} \times V_{\text{in}}$

$v = f\lambda$

$\lambda = \frac{ax}{D}$

$d\sin\theta = n\lambda$

$E = hf \quad E = \frac{hc}{\lambda}$

$hf = \phi + \text{KE}_{\text{max}}$

$\lambda = \frac{h}{mv}$

$R = R_1 + R_2 + \ldots$

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$

Unit 4 – Newtonian World

$F = \frac{\Delta p}{\Delta t}$

$v = \frac{2\pi r}{T}$

$a = \frac{v^2}{r}$

$F = \frac{mv^2}{r}$

$F = -\frac{GMm}{r^2}$

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

$f = \frac{1}{T}$

$\omega = \frac{2\pi}{T} = 2\pi f$

$a = -(2\pi f)^2 x$

$x = A\cos(2\pi ft)$

$v_{max} = (2\pi f)A$

$E = mc\Delta\theta$

$pV = NkT$

$pV = nRT$

$E = \frac{3}{2}kT$

Unit 5 – Fields, Particles and Frontiers of Physics

$E = \frac{F}{Q}$

$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$

$E = \frac{V}{d}$

$F = BIL\sin\theta$

$F = BQv$

$\phi = BA\cos\theta$

induced e.m.f. = – rate of change of magnetic flux linkage

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$

$Q = VC$

$W = \frac{1}{2}QV \qquad W = \frac{1}{2}CV^2$

time constant = CR

$x = x_0 e^{-\frac{t}{CR}}$

$C = C_1 + C_2 + \ldots$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

$A = \lambda N$

$A = A_0 e^{-\lambda t}$

$N = N_0 e^{-\lambda t}$

$\lambda t_{1/2} = 0.693$

$\Delta E = \Delta mc^2$

$I = I_0 e^{-\mu x}$

$$Z = \rho c$$

$$\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$$\text{age of Universe} = \frac{1}{H_0}$$

$$\rho_0 = \frac{3H_0^{\,2}}{8\pi G}$$