OCR
Oxford Cambridge and RSA

# Tuesday 28 June 2016 – Morning

## 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 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

**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 **28** pages. Any blank pages are indicated.

Answer **all** the questions.

**1** **(a)** The unit of magnetic flux density is the tesla, T.
Express this unit in terms of kg, C and s.

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

**(b)** Fig. 1.1 shows the circular path travelled by electrons in a region of uniform magnetic field in a vacuum.

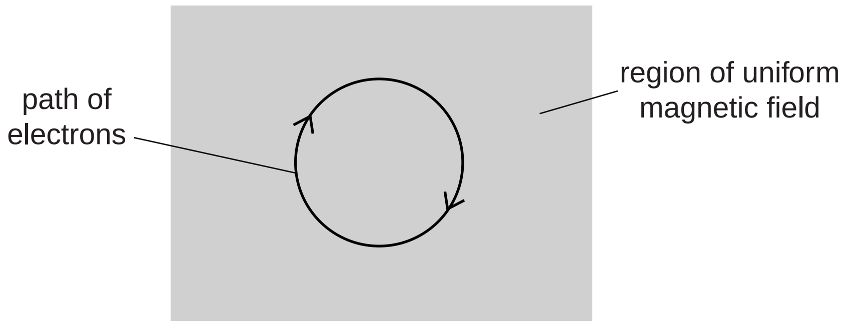


**Fig. 1.1**

The direction of the magnetic field is perpendicular to the plane of the paper. The electrons have a speed of $7.0 \times 10^{6}\,\text{m}\,\text{s}^{-1}$ and travel in a circular path of diameter 5.0 cm.

**(i)** Calculate the magnetic flux density *B*.

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

**(ii)** Calculate the period *T* of the electrons in their circular orbit.

*T* = ...................................................... s **[1]**

**(iii)** The speed of the electrons is doubled. The period stays the same. Explain why.

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**Question 2 begins on page 4**

**2** This question is about electric fields.

**(a)** Fig. 2.1 shows the electric field pattern drawn by a student for two oppositely charged plates.

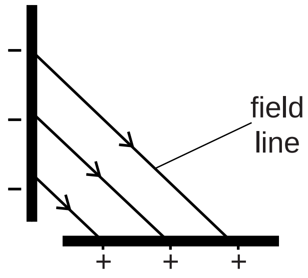


**Fig. 2.1**

State **two** errors made by the student in this drawing of the field pattern.

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**(b)** At a distance $r$ from the centre of a radioactive nucleus the electric field strength is $E$.

Fig. 2.2 shows the graph of the electric field strength $E$ against $\frac{1}{r^2}$.

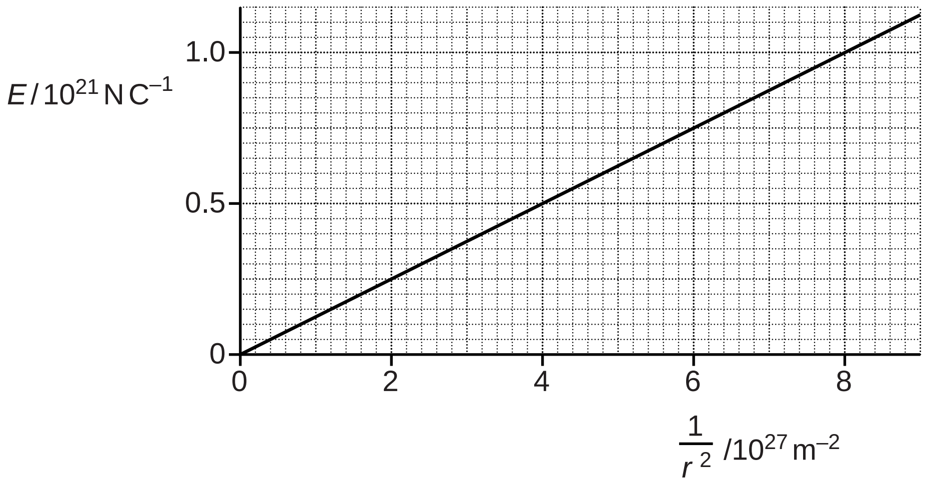


**Fig. 2.2**

**(i)** The electric field strength is given by the equation $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$.

Determine the gradient of the line and hence calculate the charge on the nucleus.

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

**(ii)** The radioactive nucleus emits an alpha particle.
State the change, if any, to the graph shown in Fig. 2.2 for the resultant (daughter) nucleus. Explain your answer.

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**(c)** A negatively charged droplet of oil is held **stationary** between two horizontal plates. The potential difference between the plates is 1.50 kV. Fig. 2.3 shows the two forces acting on this charged droplet.

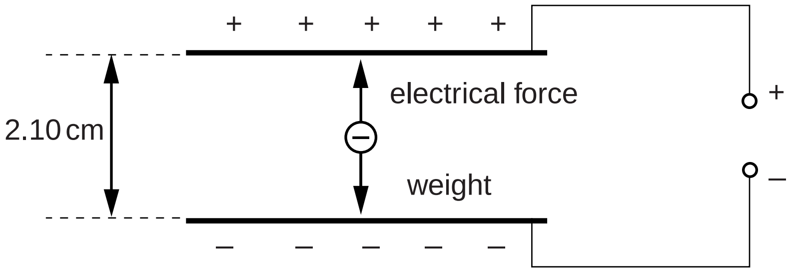


**Fig. 2.3**

The droplet is spherical and has a radius of $1.27 \times 10^{-6}$ m. The density of oil is 950 kg m$^{-3}$. The separation between the plates is 2.10 cm.

**(i)** Show that the magnitude of the charge on the droplet is about $1.1 \times 10^{-18}$ C.

**[3]**

**(ii)** Calculate the number of electrons causing the charge on the droplet.

number of electrons = .......................................................... **[1]**

3 The question is about electromagnetic induction.

(a) (i) Define *magnetic flux linkage*.

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(ii) A thin insulated wire has length $L$. The wire is used to make a flat coil of mean radius $r$. A uniform magnetic field of flux density $B$ is applied normal to the plane of the coil.

1 The number of turns $N$ of the coil can be determined using $L$ and the circumference of the coil.
Write an equation for $N$ in terms of $L$ and $r$.

[1]

2 Hence show that the magnetic flux linkage for this coil is given by the equation $\frac{BrL}{2}$.

[1]

(b) (i) State *Faraday's law of electromagnetic induction*.

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**(ii)** A coil rotates in a uniform magnetic field. Fig. 3.1 shows the variation of magnetic flux linkage with time $t$.

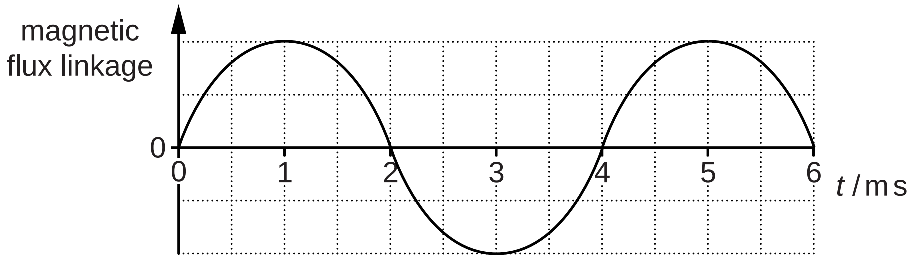


**Fig. 3.1**

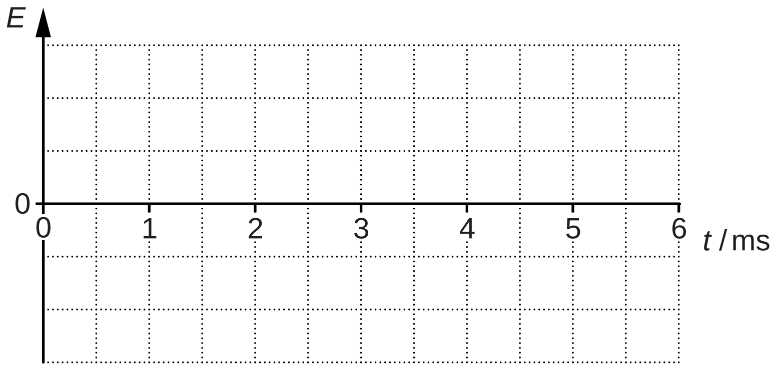


**Fig. 3.2**

On Fig. 3.2 sketch a graph to show the variation of the induced e.m.f. $E$ across the ends of the coil with time $t$. **[2]**

**(c)** Fig. 3.3 shows a diagram of a simple transformer.

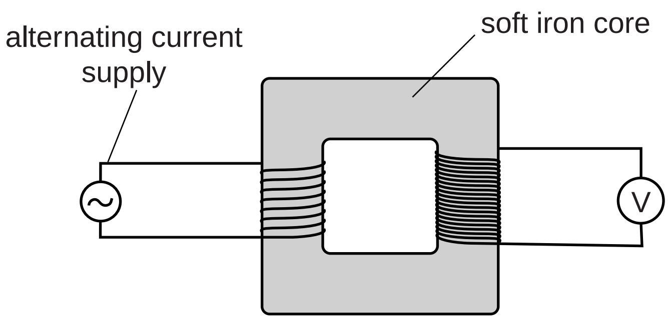


**Fig. 3.3**

Explain how an electromotive force (e.m.f.) is induced across the ends of the secondary coil.

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**Question 4 begins on page 10**

**4** This question is about capacitors.

**(a)** Fig. 4.1 shows two capacitors **A** and **B** connected in series to a battery.

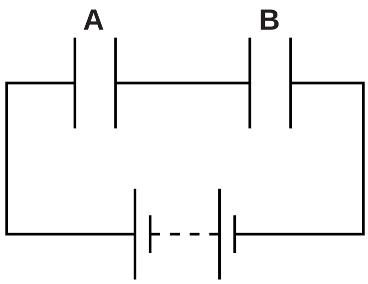


**Fig. 4.1**

The capacitance of **B** is twice the capacitance of **A**.
Explain why the potential difference across capacitor **A** is twice the potential difference across capacitor **B**.

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**(b)** Fig. 4.2 shows a circuit with an arrangement of capacitors and resistors.

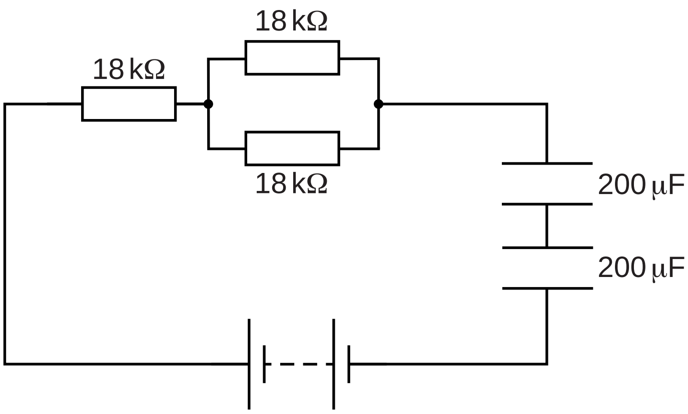


**Fig. 4.2**

Calculate the time constant of the circuit.

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

**(c)** A charged capacitor of capacitance 1200 μF is connected across the terminals of a resistor of resistance 40 kΩ.
Fig. 4.3 shows the variation of the current $I$ in the resistor against time $t$.

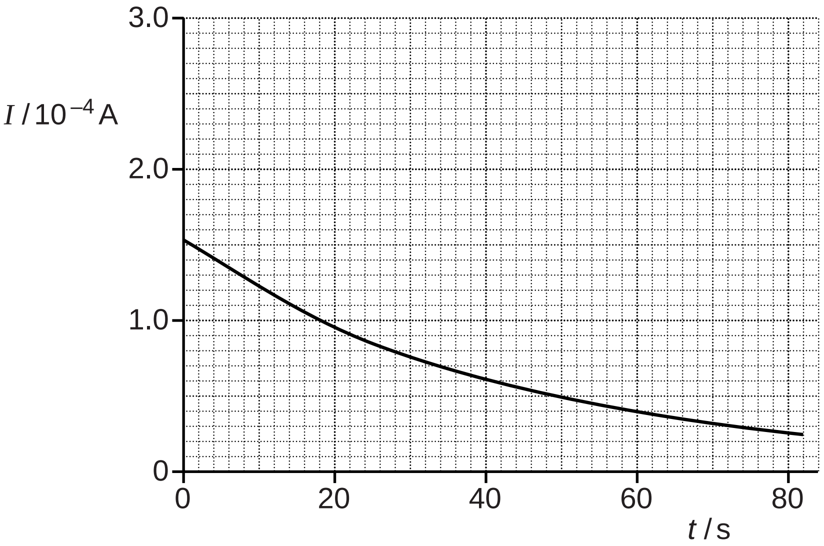


**Fig. 4.3**

**(i)** Use Fig. 4.3 to calculate the initial charge stored by the capacitor.

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

**(ii)** The capacitor is charged again to the same initial potential difference. It is now discharged across two 40 kΩ resistors connected in **parallel**.
On Fig. 4.3 draw carefully a graph to show the variation of the current $I$ in the combination of resistors with time $t$. **[2]**

5 The space probe, Curiosity, roaming on the surface of Mars, is powered by a radioisotope thermoelectric generator (RTG). The generator transforms thermal energy into electrical energy. The thermal energy comes from the radioactive decay of plutonium-238.
Fig. 5.1 shows an image of Curiosity.

**Fig. 5.1**

**(a)** The plutonium-238 ($^{238}_{94}Pu$) isotope can be artificially produced by bombarding uranium-238 ($^{238}_{92}U$) with deuterium ($^{2}_{1}H$). This produces an intermediate isotope of neptunium-238 ($^{238}_{93}Np$) and neutrons. The isotope of $^{238}_{93}Np$ then decays by beta-minus emission to form plutonium-238.

**(i)** Complete the following reaction.

$$^{238}_{92}U \quad + \quad ^{2}_{1}H \quad \longrightarrow \quad ^{238}_{93}Np \quad + \quad \ldots\ldots\ldots\ldots$$ **[1]**

**(ii)** Complete the following decay equation for $^{238}_{93}Np$.

$$^{238}_{93}Np \quad \longrightarrow \quad ^{238}_{94}Pu \quad + \quad \ldots\ldots\ldots\ldots \quad + \quad \ldots\ldots\ldots\ldots$$ **[2]**

**(b)** Plutonium-238 is an alpha-emitter with a half-life of 88 years. The kinetic energy produced during each decay is $9.0 \times 10^{-13}$ J. The RTG on Curiosity produces 120 W of electrical power from 2000 W of thermal power.

**(i)** Calculate the mass of plutonium-238 on board Curiosity.

molar mass of plutonium-238 = 0.238 kg mol$^{-1}$

mass = ...................................................... kg **[4]**

**(ii)** Calculate the output electrical energy in kW h from the RTG in a day.

energy = ................................................. kW h **[2]**

**6 (a)** An electron is an example of a *lepton* and a proton is an example of a *hadron*.
State a property of a hadron.

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**(b)** State the charge, in terms of the elementary charge *e*, on an up quark and a down quark.

charge on up quark = ............... *e* charge on down quark = ............... *e* **[1]**

**(c)** The quark composition of a neutron is u d d.
State the quark composition of a proton.

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**(d)** In large particle accelerators, short-lived particles called pions are created by colliding high-speed protons (p) with stationary neutrons (n). The equation below shows a reaction in which a negative pion ($\pi^-$) is produced.

$$p + n \rightarrow p + p + \pi^-$$

The $\pi^-$ particle consists of a quark and an anti-quark.
Use the information provided about the neutron and your answer to **(c)** to write an equation for the reaction in terms of up (u) and down (d) quarks. Hence determine the quark composition of the $\pi^-$ particle.

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**(e)** **(i)** State Einstein's mass-energy equation and define all the terms.

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**(ii)** In the reaction

$$p + n \longrightarrow p + p + \pi^-$$

the $\pi^-$ particle is produced when the proton colliding with a stationary neutron has a minimum kinetic energy of $1.4 \times 10^8$ eV. The mass of a proton and a neutron may be assumed to be the same.
Calculate the mass of the $\pi^-$ particle.

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

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**7** **(a)** Energy is released in both fission and fusion reactions.
Describe **two** differences between fission and fusion reactions.

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2 ..........................................................................................................................................

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**(b)** Fusion reactions between hydrogen nuclei occur inside stars. Explain why very high temperatures and high pressures within stellar cores are necessary for fusion.

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**(c)** **(i)** Describe what is meant by an induced fission reaction of a uranium-235 nucleus.

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**(ii)** Neutrons moving inside a fission reactor can be modelled as the particles of an ideal gas at a temperature of about 300 °C.
Estimate the mean speed of the neutron.

mass of neutron = $1.7 \times 10^{-27}$ kg

speed = ................................................ $\mathrm{m\,s^{-1}}$ **[3]**

**8** **(a)** A patient is having an X-ray scan. The X-rays interact with the atoms in the patient. Name and describe the **three** methods by which X-rays interact with matter.

*In your answer, you should make clear why the transmitted intensity of the X-rays decreases.*

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**(b)** A radiographer uses X-rays of wavelength $1.4 \times 10^{-11}$ m to investigate how the intensity $I$ of X-rays transmitted through bone varies with its thickness $x$.
Fig. 8.1 shows a graph of ln ($I$) against $x$.

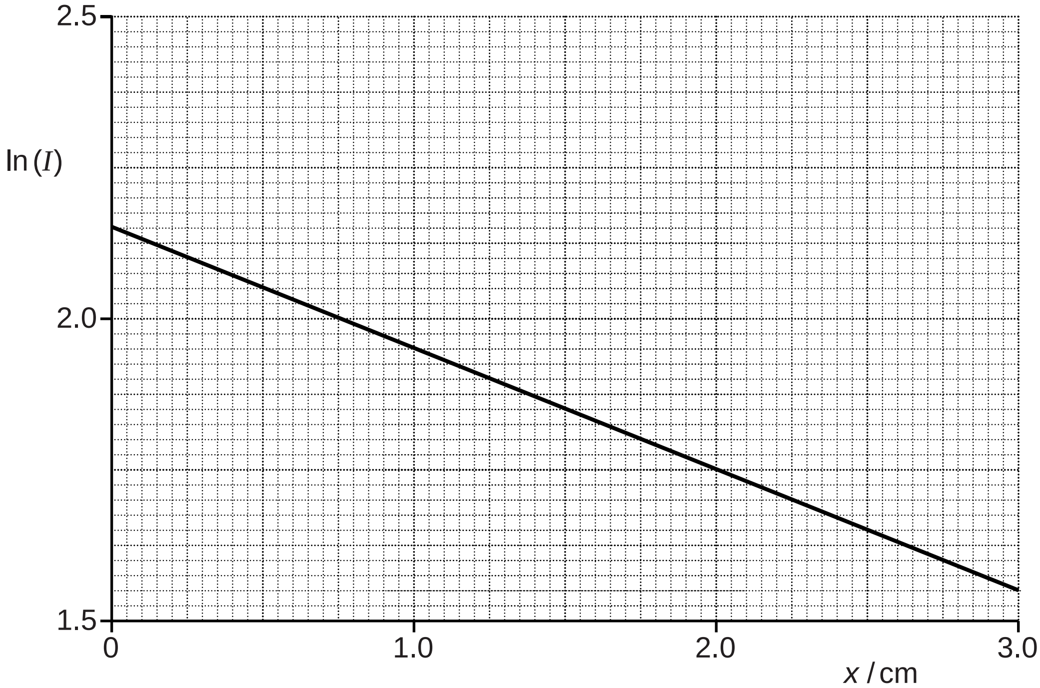


**Fig. 8.1**

**(i)** Calculate the energy of a single X-ray photon of this wavelength.

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

**(ii)** Use Fig. 8.1 to determine the absorption (attenuation) coefficient $\mu$ of bone.

$\mu$ = ................................................. $cm^{-1}$ **[2]**

**9** A patient is placed in an MRI scanner. The protons inside the patient precess in the strong magnetic field of the scanner with an angular frequency of $4.0 \times 10^8\,\text{rad}\,\text{s}^{-1}$.

**(a)** Calculate the wavelength of the radio waves absorbed by the resonating protons within the patient.

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

**(b)** Explain what is meant by the *relaxation time* of protons.

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**10** **(a)** An ultrasound transducer has a material inside that uses the piezoelectric effect to both emit and receive ultrasound.
Explain what is meant by the *piezoelectric effect*.

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**(b)** **(i)** Define the *acoustic impedance* of a material.

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**(ii)** Suggest **one** main difference between a pulse of ultrasound of frequency 1 MHz in air and the same ultrasound pulse passing through a patient.

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**(c)** A parallel beam of ultrasound is incident at right angles to a boundary between muscle and fat. The table of Fig. 10.1 gives some information about these two materials.

| Material | Density / $kg\,m^{-3}$ | Speed of ultrasound / $m\,s^{-1}$ |
|---|---|---|
| muscle | 952 | 1450 |
| fat | 1070 | 1580 |

**Fig. 10.1**

Determine the percentage of ultrasound intensity **transmitted** at the boundary between muscle and fat.

intensity transmitted = ...................................................... % **[3]**

**11** Fig. 11.1 shows a diagram of Andromeda, our nearest galaxy.

**Fig. 11.1**

Andromeda is $2.4 \times 10^{22}$ m from the Earth. It has a diameter of $1.3 \times 10^{20}$ m.

**(a)** Calculate the maximum angle in degrees subtended by Andromeda at the Earth.

angle = ...................................................... ° **[1]**

**(b)** All the stars in Andromeda rotate about its centre. Some stars in Andromeda are moving towards us and some are moving away from us. The outermost stars in Andromeda have a rotational speed of $2.5 \times 10^5$ m s$^{-1}$.
The wavelength of the hydrogen-alpha spectral line in the laboratory is 656.3 nm. The wavelength of this spectral line from the outermost stars is Doppler shifted when observed from the Earth.
Calculate the change in wavelength of this spectral line due to this rotation.

change in wavelength = .................................................. nm **[2]**

**(c)** The circular motion of the outermost stars is due to the gravitational attraction of all the stars in Andromeda. Assume that the mass of Andromeda providing the gravitational force on these outermost stars is all at the centre of this galaxy.
The average mass of a star is $2.0 \times 10^{30}$ kg.
Estimate the total number of stars in Andromeda.

number of stars = ........................................................ **[4]**

**12 (a)** Describe the evolution of the Universe from the separation of the four fundamental forces to the formation of atoms.

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

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**Question 12(b) begins on page 24**

**(b)** State *Hubble's law*.

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**(c)** Some cosmologists have estimated the critical density of the Universe to be equivalent to about 8 protons per cubic metre.

**(i)** Calculate the Hubble constant $H_0$ in $s^{-1}$.

$H_0$ = .................................................... $s^{-1}$ **[3]**

**(ii)** Estimate the age of the Universe in years.

1 y = $3.2 \times 10^7$ s

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

**END OF QUESTION PAPER**

## ADDITIONAL ANSWER SPACE

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