OCR
Oxford Cambridge and RSA

# Wednesday 21 June 2017 – 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 | |
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| Centre number | | | | | | Candidate number | | | | |
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### INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

### INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 **(a)** A negatively charged particle is travelling in a **uniform** field.
Fig. 1.1 shows the particle travelling along the direction of the field.

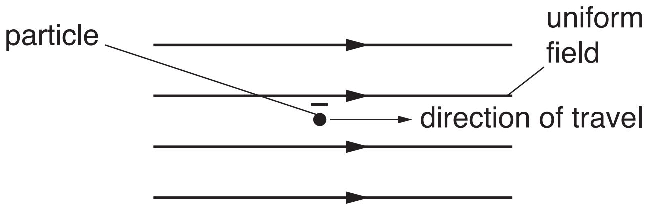


**Fig. 1.1**

Describe and explain the motion of the particle in terms of the force it experiences when the particle is in just

**(i)** a gravitational field

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**(ii)** an electric field

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**(iii)** a magnetic field.

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**(b)** Fig. 1.2 shows a particle travelling in a circular path in a uniform magnetic field.

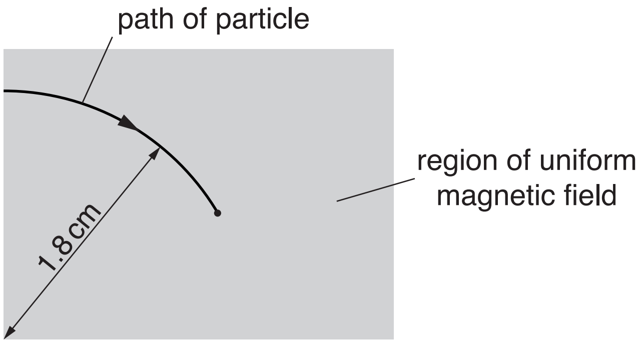


**Fig. 1.2**

The magnetic field has flux density 0.012 T.
The particle has mass $9.1 \times 10^{-31}$ kg and a charge of $+1.6 \times 10^{-19}$ C. The radius of the circular path is 1.8 cm.

**(i)** State the direction of the magnetic field.

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**(ii)** Calculate the momentum $p$ of the particle.

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

**(iii)** Calculate the kinetic energy of the particle in eV.

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

**(iv)** Calculate the time it takes for the particle to travel through an angle of 60°.

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

**2** **(a)** Describe the basic structure of the atom and the relative diameters of the atom and the nucleus.

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**(b)** Radon is a naturally occurring radioactive gas that comes from the ground and collects in houses with poor ventilation.

The activity in the basement of a house from radon-222 is 40 Bq per $m^3$ of air.

The isotope of radon $^{222}_{86}Rn$ is an alpha-emitter and it decays into polonium (Po). The half-life of the radon isotope is 3.8 days.

**(i)** Write the decay equation for a nucleus of $^{222}_{86}Rn$.

$^{222}_{86}Rn \rightarrow$ **[2]**

**(ii)** Calculate the number of radon-222 nuclei responsible for an activity of 40 Bq.

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

**(iii)** There are 40 moles of air molecules per m$^3$.
Calculate the following ratio for the air in the basement

$$\frac{\text{number of radon-222 nuclei per m}^3}{\text{number of air molecules per m}^3}.$$

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

**3** **(a)** State *Coulomb's law*.

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**(b)** Fig. 3.1 shows two oppositely charged ions **A** and **B** and an electron.

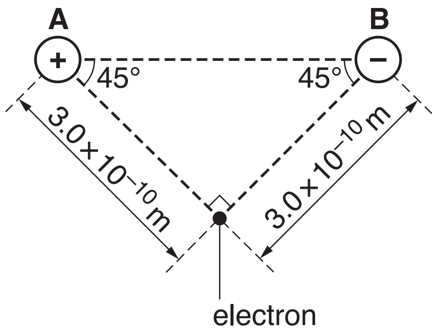


**Fig. 3.1**

The charge on the ion **A** is $1.6 \times 10^{-19}$ C and the charge on the ion **B** is $-1.6 \times 10^{-19}$ C. The electron is at a distance of $3.0 \times 10^{-10}$ m from each ion and at an angle of 45° to the line joining the centres of **A** and **B**.

**(i)** Show that the attractive force $F$ experienced by the electron due to the ion **A** alone is $2.6 \times 10^{-9}$ N.

**[2]**

**(ii)** Calculate the magnitude of the resultant force experienced by the electron.

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

**(iii)** Calculate the magnitude of the acceleration of the electron.

acceleration = ................................................. m s$^{-2}$ **[1]**

**(iv)** Draw an arrow on Fig. 3.1 to show the direction of the acceleration of the electron. **[1]**

**4** **(a)** Fig. 4.1 shows a capacitor connected to a resistor.

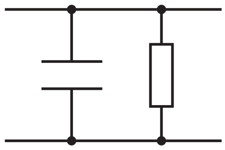

**Fig. 4.1**

The capacitance and resistance values of the components are not known.
The time constant of the circuit shown in Fig. 4.1 is estimated to be about one minute.
Describe how you can carry out an experiment in the laboratory to determine the time constant of the circuit.

*In your answer you should make clear how you make the measurements to determine the time constant.*

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**(b)** Fig. 4.2 shows a capacitor of capacitance 1200 μF connected to cell of e.m.f 1.5 V.

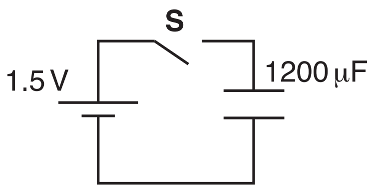


**Fig. 4.2**

The switch **S** is closed.

**(i)** Calculate the final energy stored by the capacitor.

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

**(ii)** Calculate the number of electrons transferred to the negatively charged plate of the capacitor.

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

**(c)** Fig. 4.3 shows the capacitor from **(b)** now connected across a resistor of resistance 5.0 kΩ.

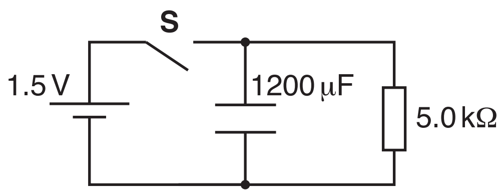


**Fig. 4.3**

The switch **S** is closed and then opened at time $t = 0$.

**(i)** Calculate the maximum power dissipated in the resistor.

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

**(ii)** Calculate the time *t* when the potential difference across the capacitor is 1.0 V.

*t* = .................................... s **[3]**

**Question 5 begins on page 12**

**5** Fusion reactions produce energy in the core of stars. The fusion of protons ($^{1}_{1}H$) in stars like our Sun can be summarised by the following nuclear reaction.

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

**(a)** Name the particles $^{0}_{1}e$ and $\nu$.

$^{0}_{1}e$ : ................................. $\nu$ : ................................. **[1]**

**(b)** Explain in terms of the masses of the particles why energy is released in the reaction shown above.

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**(c)** State and explain the conditions in the core of stars that make fusion possible.

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**(d)** Describe the formation of a star much more massive than our Sun from a large dust and gas cloud and its most probable evolution to death.

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

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6 **(a)** Briefly describe the process of *pair-production* in terms of an X-ray photon interacting with an atom.

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**(b)** High-speed electrons hitting a metal target in an X-ray tube produce X-ray photons. Calculate the accelerating potential difference required for the electrons to produce X-ray photons of **maximum** wavelength 18 pm.

potential difference = ........................................................ V **[3]**

**(c)** A uniform beam of X-rays of intensity $2.0 \times 10^{8}\,\mathrm{W\,m^{-2}}$ is used to destroy cancerous cells in a patient. The beam has a cross-sectional area of $6.0\,\mathrm{mm^{2}}$. The cancerous cells are at a depth of 1.1 cm in muscle. The attenuation (absorption) coefficient of muscle is $5.0\,\mathrm{cm^{-1}}$.
The radiographer estimates a total exposure time of 2.0 minutes to destroy the cancerous cells.
Calculate the total incident energy on the cancerous cells.

energy = ........................................................ J **[4]**

7 (a) Describe the principles of magnetic resonance.

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(b) State **two** advantages of MRI scanning compared with CAT scanning.

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

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**(b)** An ultrasound transducer produces pulses of ultrasound. Fig. 7.1 shows the display of an oscilloscope connected to the transducer.

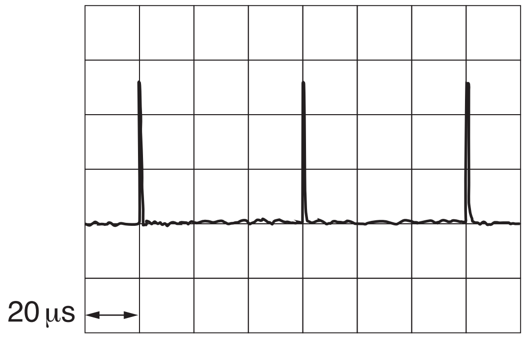


**Fig. 7.1**

The transducer is now placed on the skin of the patient's arm to determine the thickness *x* of the muscle as shown in Fig. 7.2.

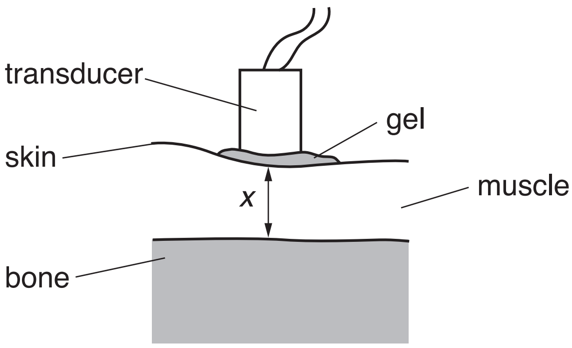


**Fig. 7.2**

Fig. 7.3 shows the new display.

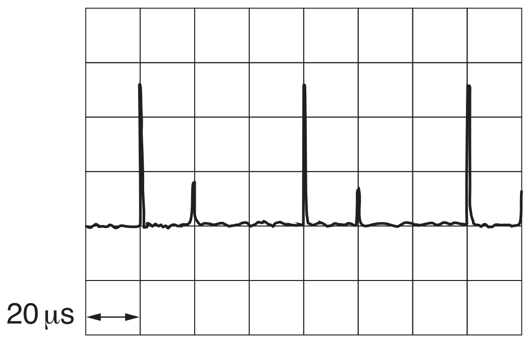


**Fig. 7.3**

**(i)** Explain why Fig. 7.3 is different from Fig. 7.1.

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**(ii)** The speed of the ultrasound in muscle is 1600 $m\,s^{-1}$.

**1** Use Fig. 7.3 to determine the thickness $x$ of the muscle.

$x$ = ...................................................... m **[2]**

**2** The acoustic impedance of the muscle is $1.7 \times 10^6\,kg\,m^{-2}\,s^{-1}$.
Calculate the density of the muscle.

density = ................................................ $kg\,m^{-3}$ **[1]**

**(iii)** The fraction of the intensity of the ultrasound reflected at the bone-muscle boundary is 40%. The acoustic impedance *Z* of bone is greater than the acoustic impedance of muscle.
Calculate the acoustic impedance of bone.

acoustic impedance = ........................................ $kg\,m^{-2}\,s^{-1}$ **[3]**

**9** Beta Pictoris is a bright star in the night sky. Its distance from the Sun is $6.0 \times 10^{17}$ m. In comparison with the Sun, Beta Pictoris has 1.8 times greater mass and also has 1.8 times greater diameter.

**(a)** Beta Pictoris emits electromagnetic radiation at a rate of $3.3 \times 10^{27}$ W.
Estimate the decrease in the mass of Beta Pictoris in a time of 1.0 million years.
$1\,y = 3.2 \times 10^{7}\,s$

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

**(b)** The gravitational field strength at the surface of the Sun is $270\,N\,kg^{-1}$.
Calculate the gravitational field strength at the surface of Beta Pictoris.

gravitational field strength = ............................................. $N\,kg^{-1}$ **[2]**

**(c)** Calculate the ratio

$$\frac{\text{mean density of Beta Pictoris}}{\text{mean density of Sun}}.$$

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

**(d)** Calculate the parallax angle for this star in arc seconds.
1 pc = $3.1 \times 10^{16}$ m

parallax angle = ...................................... arc seconds **[2]**

**10** **(a)** Describe how the recession speed $v$ of a distant galaxy can be determined using a diffraction grating to analyse the light from the galaxy.

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**(b)** A group of astronomers determined the distance $d$ of a galaxy and its recession speed $v$. Their results are shown below.

$d = 11 \pm 2\,\text{Mpc}$ $\quad\quad$ $v = 740 \pm 20\,\text{km}\,\text{s}^{-1}$

**(i)** Calculate a value for the Hubble constant in $\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$.

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

**(ii)** Determine the age of the universe in years. Include an absolute uncertainty in your value.
$1\,pc = 3.1 \times 10^{16}\,m$
$1\,y = 3.2 \times 10^{7}\,s$

age = ........................ ± ........................ y **[4]**

**(iii)** The answer in **(ii)** is from the observation on one galaxy alone.
Describe how the astronomers can obtain a much more reliable value for the age of the universe from a graph of *v* against *d* for many galaxies.

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**(iv)** Use your answer to **(ii)** to estimate the farthest distance *D* that astronomers can observe from the Earth.

*D* = ...................................................... m **[2]**

**END OF QUESTION PAPER**

## ADDITIONAL ANSWER SPACE

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