OCR A-LEVEL PHYSICS A

PHYSICS



EXAM QUESTION PACK

UNIT G485 OLD SPECIFICATION PAPERS

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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

* G 4 8 5 0 1 *

* 6 8 0 8 5 5 4 4 7 4 *

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 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.

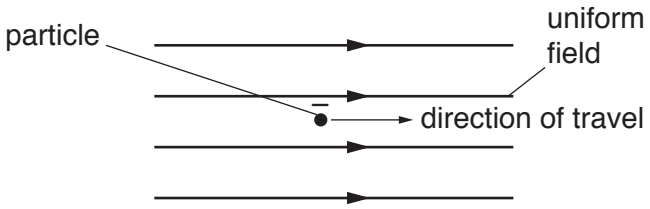


Fig. 1.1

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

(ii) an electric field

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

(iii) a magnetic field.

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

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

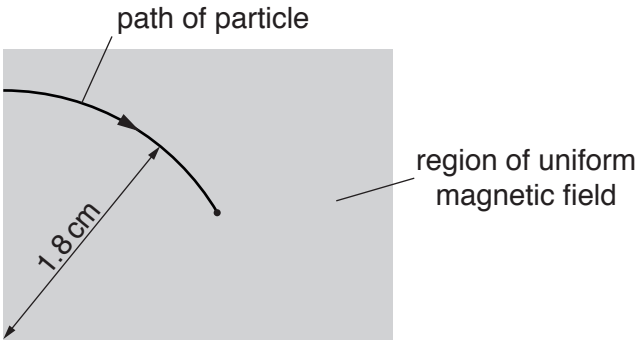


Fig. 1.2

The magnetic field has flux density 0.012 T.
The particle has mass 9.1×10^{-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.

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

(ii) Calculate the momentum p of the particle.

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

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(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]**

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

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

(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]**

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(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]**

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

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

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

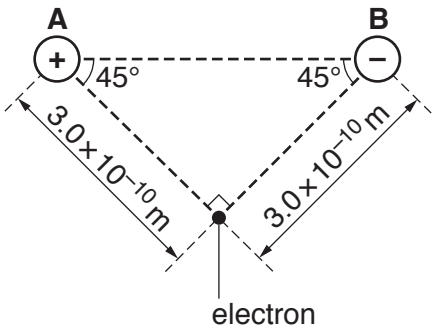


Fig. 3.1

The charge on the ion **A** is 1.6×10^{-19} C and the charge on the ion **B** is -1.6×10^{-19} C. The electron is at a distance of 3.0×10^{-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 2.6×10^{-9} N.

[2]

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(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]**

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

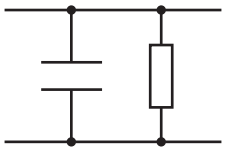


Fig. 4.1

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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..... **[4]**

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

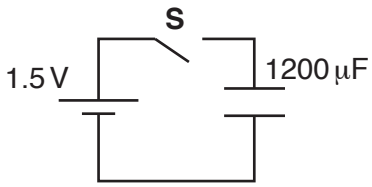


Fig. 4.2

The switch **S** is closed.

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

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

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(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.

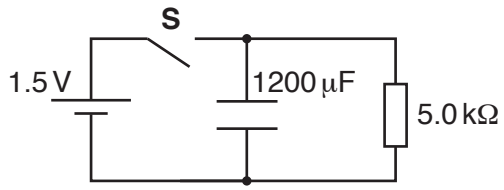


Fig. 4.3

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

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

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

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(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

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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 ν.

$^{0}_{1}e$: ..... ν : ..... **[1]**

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

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

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

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..... **[4]**

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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]**

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

(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 $2.0 \times 10^8\,W\,m^{-2}$ is used to destroy cancerous cells in a patient. The beam has a cross-sectional area of $6.0\,mm^2$. The cancerous cells are at a depth of 1.1 cm in muscle. The attenuation (absorption) coefficient of muscle is $5.0\,cm^{-1}$.
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]**

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7 **(a)** Describe the principles of magnetic resonance.

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..... **[4]**

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

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

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

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

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

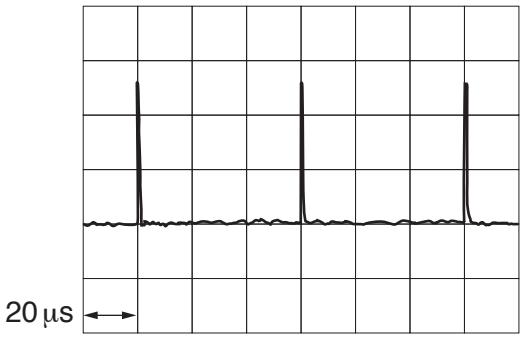


Fig. 7.1

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.

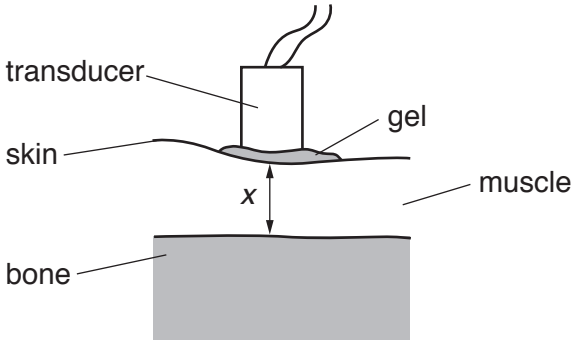


Fig. 7.2

Fig. 7.3 shows the new display.

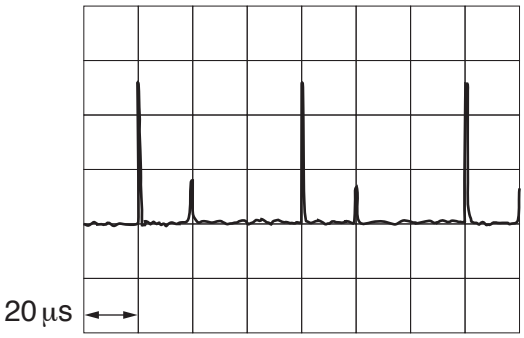


Fig. 7.3

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

.....

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

(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]**

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(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]**

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9 Beta Pictoris is a bright star in the night sky. Its distance from the Sun is 6.0×10^{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 3.3×10^{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]**

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(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 = 3.1×10^{16} m

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

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

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

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

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

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

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

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

(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

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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).

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GCE

Physics A

Unit **G485**: Fields, Particles and Frontiers of Physics

Advanced GCE

Mark Scheme for June 2017

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotation	Meaning
BOD	Benefit of doubt given
BP	Blank Page
CON	Contradiction
	Incorrect Response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct Response
AE	Arithmetic error
	Wrong physics or equation

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Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures and rounding errors:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper. Any exception to this rule will be mentioned in the Guidance.

Penalise a rounding error once only in the entire paper.

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Question			Answer	Marks	Guidance
1	a	i	Force is in the direction of the motion / field The particle accelerates (AW)	B1 B1	**Allow:** 'to the right'
		ii	Force is in the opposite direction to the motion / field The particle decelerates (AW)	B1 B1	**Allow:** 'to the left' **Allow:** 'slows down'
		ii	There is no force on the particle / its speed remains constant (AW)	B1	**Allow:** 'particle is unaffected by the field'
	b	i	Out of the plane of paper (AW)	B1	**Not** 'up'
		ii	$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.012 \times 1.6 \times 10^{-19} \times 0.018$ momentum = 3.5×10^{-23} (kg m s^{-1})	C1 C1 A1	**Allow** credit for alternative methods **Note** answer to 3 s.f. is 3.46×10^{-23} (kg m s^{-1}) **Allow** 2 marks for 3.5×10^{-21}; 1.8 used instead of 0.018 (m)
		iii	$E_k = \frac{p^2}{2m} = \frac{(3.46 \times 10^{-23})^2}{2 \times 9.1 \times 10^{-31}}$ kinetic energy = 6.56×10^{-16} (J) kinetic energy = 4100 (eV)	C1 A1	Possible ecf from **(ii)** **Note:** using $p = 3.5 \times 10^{-23}$ leads to E_k = 4200 (eV)
		iv	speed = $\frac{3.46 \times 10^{-23}}{9.1 \times 10^{-31}}$ or speed = 3.8×10^7 (m s^{-1}) time = $\frac{1}{6} \times \frac{2\pi \times 0.018}{3.8 \times 10^7}$ time = 5.0×10^{-10} (s)	C1 C1 A1	Possible ecf from **(ii)** **Allow** 1 mark for 3.0×10^{-9} (s); the time for one orbit **Allow** 1 sf answer
			Total	**14**	

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Question			Answer	Marks	Guidance
2	a		The atom has a (positive) nucleus which is surrounded by electrons The nucleus has protons and neutrons The nucleus is 10^4 / 10^5 times smaller than the atom (AW)	B1 B1 B1	
	b	i	$(^{222}_{86}\text{Rn} \rightarrow)$ $^{218}_{84}\text{Po}$ + $^{4}_{2}\text{He}$	B1 B1	**Allow** $^{4}_{2}\alpha$ for $^{4}_{2}\text{He}$
		ii	$\lambda = \frac{0.693}{3.8 \times 24 \times 3600}$ or $\lambda = 2.11 \times 10^{-6}$ (s^{-1}) $40 = 2.11 \times 10^{-6} \times N$ $N = 1.9 \times 10^{7}$	C1 C1 A1	Note N = 219 scores 2 out of 3 (3.8 used for T)
		iii	Number of air molecules / m³ = $40 \times 6.02 \times 10^{23} = (2.41 \times 10^{25})$ ratio = $\frac{1.9 \times 10^{7}}{2.41 \times 10^{25}}$ ratio = 7.9×10^{-19}	C1 A1	Possible ecf from **(ii)**
			Total	**10**	

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Question			Answer	Marks	Guidance
3	a		Force is proportional to product of charges and inversely proportional to separation^2. Mention of point charges / particles	M1 A1	**Allow** 'distance between' **Allow:** word equation or equation with symbols defined **Not** 'radius' or 'distance' in place of separation.
	b	i	$F = \frac{(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times(3.0\times10^{-10})^2}$ force = 2.56 $\times$ 10^{-9} (N)	C1 A1	**Allow** use of 9.0 $\times$ 10^9 in place of $\frac{1}{4\pi\times8.85\times10^{-12}}$ **Note** answer must be to more than 2 s.f. to score this mark
		ii	resultant force^2 = (2.56 $\times$ 10^{-9})^2 + (2.56 $\times$ 10^{-9})^2 resultant force = 3.6 $\times$ 10^{-9} (N)	C1 A1	Possible ecf from **(i)** **Note** using 2.6 $\times$ 10^{-9} gives an answer of 3.7 $\times$ 10^{-9} (N)
		iii	acceleration = $\frac{3.6\times10^{-9}}{9.1\times10^{-31}}$ acceleration = 4.0 $\times$ 10^{21} (m s^{-2})	B1	Possible ecf from **(ii)** **Allow** answer given to 1 s.f. **Note** using 3.7 $\times$ 10^{-9} gives an answer of 4.1 $\times$ 10^{21} (m s^{-2})
		iv	An arrow pointing to the left and parallel to the line **AB**	B1	
			Total	**8**	

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Question			Answer	Marks	Guidance
4	a		Capacitor is connected to a power supply / cell The power supply / cell is disconnected The p.d. across the capacitor is measured using a voltmeter and the time of discharge is measured using a stopwatch The time taken for the p.d. to decreases to 0.37 / $1/e$ of its initial p.d. is the time constant / CR of the circuit	B1 B1 B1 B1	 **Allow** 'discharge the capacitor (through resistor) **Allow** data-logger / computer This can be done using a *V*-*t* graph **Allow** plot a ln*V* – *t* graph and time constant = 1/gradient **Allow** substitute values into $V = V_o e^{-t/CR}$ to find CR
	b	i	energy = ½ × 1.5^2 × 1200 × 10^{-6} energy = 1.4 × 10^{-3} (J)	 B1	 **Note** answer to 3.s.f. is 1.35 × 10^{-3} (J)
		ii	charge = 1.5 × 1200 × 10^{-6} or charge = 1.8 × 10^{-3} (C) number of electrons = $\frac{1.8\times10^{-3}}{1.6\times10^{-19}}$ number of electrons = 1.1 × 10^{16}	C1 A1	
	c	i	power = $\frac{1.5^2}{5000}$ power = 4.5 × 10^{-4} (W)	 B1	
		ii	Time constant = CR = 5000 x 1200 x 10^{-6} (= 6.0) 1.0 = 1.5 $e^{-t/6.0}$ $\ln\left(\frac{1.0}{1.5}\right) = -\frac{t}{6.0}$ *t* = 2.4 (s)	C1 C1 A1	 **Note** answer to 3.s.f. is 2.43 (s)
			Total	**11**	

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Question			Answer	Marks	Guidance
5	a		positron and (electron) neutrino	B1	
	b		The total mass of the protons is <u>greater</u> than the total mass of the 'product' particles (ora) energy released = change in mass $\times$ c^2	B1 B1	
	c		High temperatures / quoted value of $T \sim 10^7$ K This allows the protons to come close together (to enable strong nuclear force to act) High pressure / density The ensures that there is a greater rate of fusion reactions (AW)	M1 A1 M1 A1	**Allow:** protons to overcome (electrostatic) repulsive force
	d		Gravitational collapse (of the dust cloud) increases the temperature of the cloud Fusion (of hydrogen) generates energy or A stable star is produced when gravitational pressure is balanced by pressure from gas / radiation When there is no more hydrogen, the outer layers of the star expand / (super) red giant formed Eventually the <u>core</u> collapses resulting in a supernova The remnant core is either a neutron star or a black hole The sequence of gravitational collapse, fusion / star formed, supernova and neutron star/black hole is correctly set out in the text.	B1 B1 B1 B1 B1 B1	
			Total	**13**	

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Question			Answer	Marks	Guidance
6	a		The X-ray photon disappears and creates an electron-positron pair	B1	
	b		$\frac{hc}{\lambda} = eV$	C1	
			potential difference = $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{18\times10^{-12}\times1.60\times10^{-19}}$	C1	
			potential difference = 6.9×10^4 (V)	A1	
	c		Use of $I = I_o e^{-\mu x}$ with $I_o = 2.0 \times 10^8$ $I = 2.0\times10^{8}\ e^{-1.1\times5.0}$	C1	**Allow** other correct methods
			intensity = $8.174... \times 10^5$ (W m^{-2})	C1	
			power = $8.174... \times 10^5 \times 6.0 \times 10^{-6}$ or power = 4.9 (W)	C1	**Allow FT** for their value of intensity
			energy = $4.9 \times 2.0 \times 60$ energy = 590 (J)	A1	
			Total	**8**	

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Question			Answer	Marks	Guidance
7	a		Any **four** from: Nuclei / proton behave like tiny magnets / have 'spin' (AW) The nuclei precess about the magnetic field (at the Larmor frequency) Radio waves of frequency equal to the Larmor frequency are used to excite / resonate the nuclei The nuclei absorb energy (from the radio waves) and flip into higher energy state and eventually flip back to the lower energy state by emitting radio wave (photons) The relaxation time depends on the (surrounding) tissues	B1×4	**Allow** answers in terms of 'alignment and anti-alignment of protons in the external magnetic field'
	b		MRI scanning is non-ionising (AW) Better 3D contrast of soft-tissues	B1 B1	
			Total	**6**	

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Question			Answer	Marks	Guidance
8	a		emf / voltage produced when a material is expanded / compressed / changes shape or When a p.d. is applied across the material it expands / contracts / changes shape	B1	**Allow** material oscillates / vibrates only if applied p.d. is alternating.
	b	i	Reflection of ultrasound from the bone (and muscle boundary)	B1	
		ii1	$x = ½ \times 20 \times 10^{-6} \times 1600$ $x = 1.6 \times 10^{-2}$ (m)	C1 A1	**Allow** 1 mark for 3.2×10^{-2} (m); twice the distance
		ii2	density = $\frac{1.7 \times 10^6}{1600}$ density = 1.1×10^3 (kg m^{-3})	C1 A1	Note answer to 3 sf is 1.06×10^3 (kg m^{-3})
	b	iii	$0.40 = \left(\frac{Z - 1.7 \times 10^6}{Z + 1.7 \times 10^6}\right)^2$ $0.6325 = \left(\frac{Z - 1.7 \times 10^6}{Z + 1.7 \times 10^6}\right)$ $Z = 7.6 \times 10^6$ (kg m^{-2} s^{-1})	C1 C1 A1	**Note** answer to 3.s.f. is 7.55×10^6 (kg m^{-2} s^{-1})
			Total	**8**	

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Question			Answer	Marks	Guidance
9	a		energy = $3.3 \times 10^{27} \times 1.0 \times 10^{6} \times 3.2 \times 10^{7}$ change in mass = $\frac{3.3\times10^{27}\times10^{6}\times3.2\times10^{7}}{(3.0\times10^{8})^{2}}$ change in mass = 1.2×10^{24} (kg)	C1 C1 A1	
	b		$g \propto M/r^2$; $g = 270 \times \frac{1.8}{1.8^2}$ gravitational field strength = 150 (N kg^{-1})	C1 A1	
	c		density $\propto M/r^3$; ratio = $\frac{1.8}{1.8^3}$ ratio = 0.31	C1 A1	
	d		distance = $\frac{6.0\times10^{17}}{3.1\times10^{16}}$ or distance = 19.35... (pc) parallax = $\frac{1}{19.35}$ parallax = 0.052 (arc second)	C1 A1	
			Total	**9**	

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Question			Answer	Marks	Guidance
10	a		Reference to $d\sin\theta = (n)\lambda$ Reference to the Doppler equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ Determination of wavelength of a spectral line from receding galaxy and of an identical line in the laboratory and correct description of how $\Delta\lambda$ is calculated	B1 B1 B1	
	b	i	Hubble constant = $\frac{740}{11}$ Hubble constant = 67 (km s^{-1} Mpc^{-1})	C1 A1	
		ii	Hubble constant = $\frac{67\times10^3}{10^6\times3.1\times10^{16}}$ or 2.16×10^{-18} (s^{-1}) age = $\frac{1}{2.161\times10^{-18}} = 4.63\times10^{17}$ (s) age = 1.446×10^{10} (y) uncertainty = $\left(\frac{2}{11}+\frac{20}{740}\right)\times1.446\times10^{10}$ age = $(1.4\pm0.3)\times10^{10}$ (y)	C1 C1 C1 A1	Possible ecf from **(i)**
		iii	Determine the gradient from the *v-d* graph which is (an average value for) Hubble constant. The age of the universe is the inverse of this gradient	B1 B1	
		iv	distance = $4.63\times10^{17}\times3.0\times10^8$ distance = 1.4×10^{26} (m)	C1 A1	Possible ecf from **(ii)**
			Total	**13**	

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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.

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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.

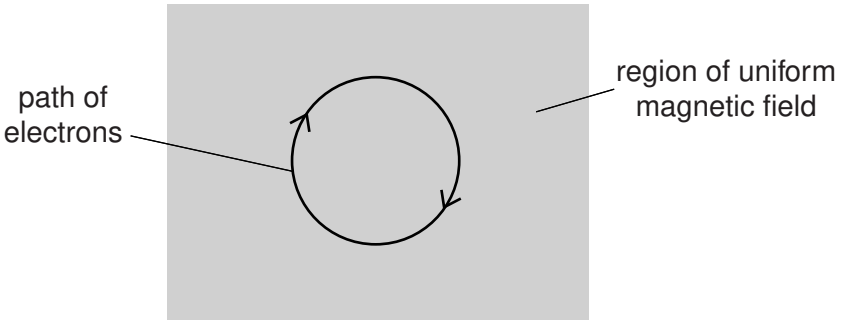


Fig. 1.1

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

(i) Calculate the magnetic flux density B.

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

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(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.

.....

.....

.....

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

Question 2 begins on page 4

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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.

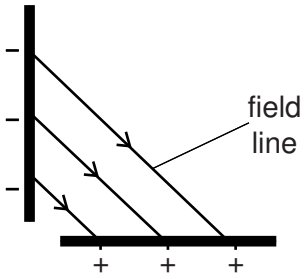


Fig. 2.1

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

.....

.....

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

(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 $\frac{1}{r^2}$.

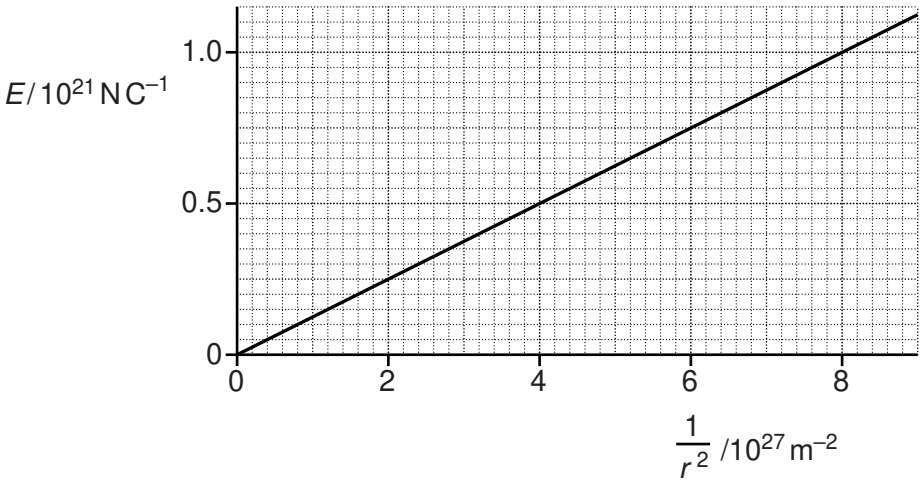


Fig. 2.2

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

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.

.....

.....

.....

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

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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.

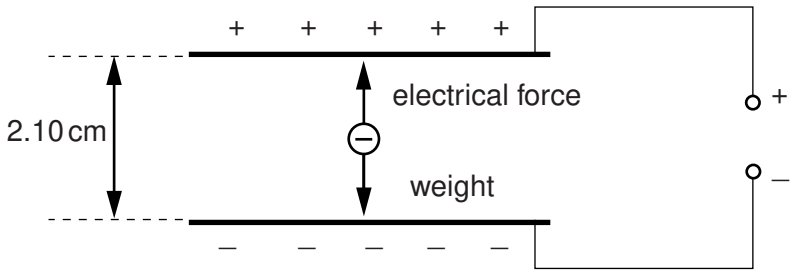


Fig. 2.3

The droplet is spherical and has a radius of 1.27×10^{-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 1.1×10^{-18} C.

[3]

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

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

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3 The question is about electromagnetic induction.

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

.....

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

(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*.

.....

.....

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

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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*.

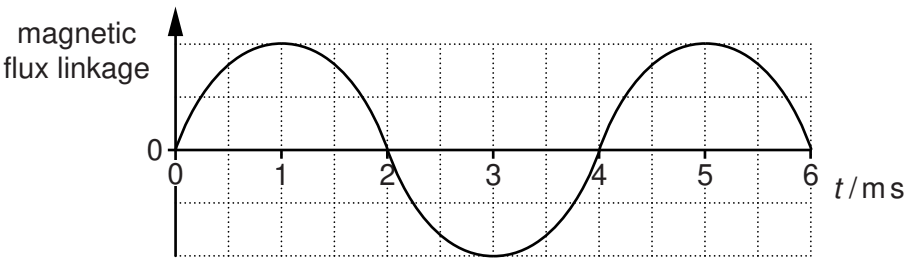


Fig. 3.1

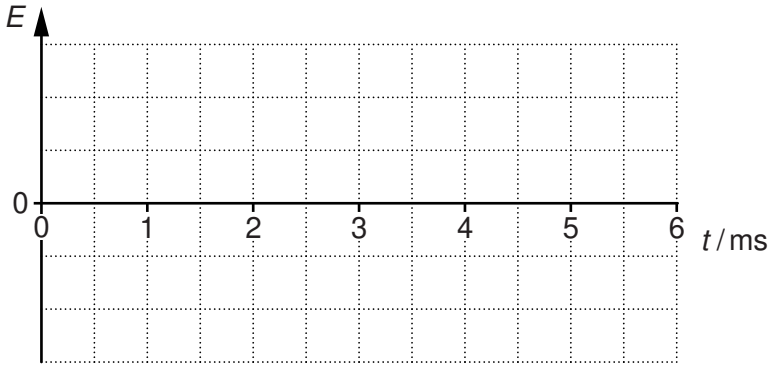


Fig. 3.2

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.

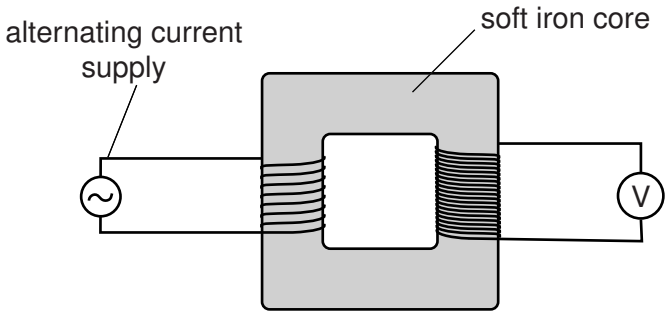


Fig. 3.3

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9

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

.....

.....

.....

.....

.....

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

Question 4 begins on page 10

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4 This question is about capacitors.

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

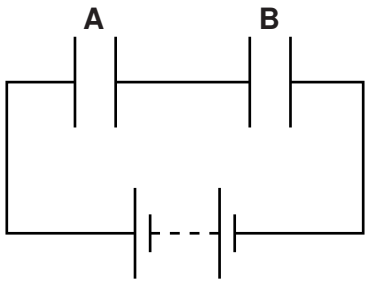


Fig. 4.1

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**.

.....

.....

.....

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

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

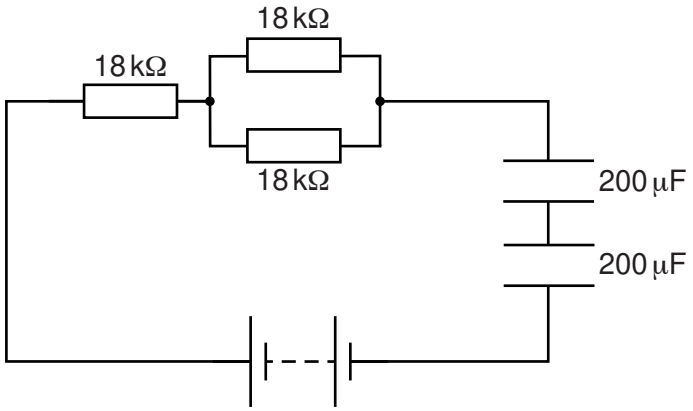


Fig. 4.2

Calculate the time constant of the circuit.

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

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(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.

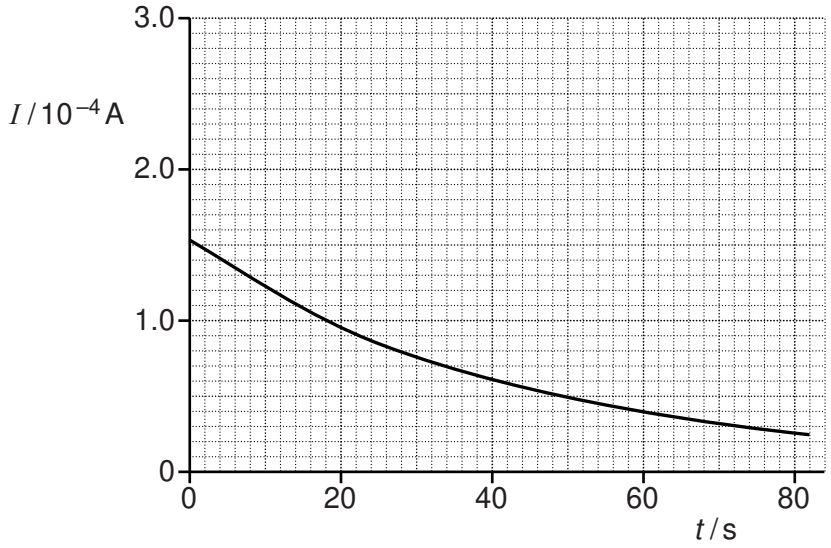


Fig. 4.3

(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]**

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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.

$$^{238}_{92}U + {}^{2}_{1}H \rightarrow {}^{238}_{93}Np + \text{.....} \quad \textbf{[1]}$$

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

$$^{238}_{93}Np \rightarrow {}^{238}_{94}Pu + \text{.....} + \text{.....} \quad \textbf{[2]}$$

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(b) Plutonium-238 is an alpha-emitter with a half-life of 88 years. The kinetic energy produced during each decay is $9.0 \cdot 10^{-13}$ 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]**

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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.

.....

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

(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.

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

(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 (π^-) is produced.

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

The π^- 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 π^- particle.

.....

.....

.....

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

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

.....

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

(ii) In the reaction

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

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

1 .....

.....

2 .....

.....
[2]

(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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.....

.....

..... **[4]**

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

.....

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

(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 = $1.7 \cdot 10^{-27}$ kg

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

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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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..... **[4]**

(b) A radiographer uses X-rays of wavelength $1.4 \cdot 10^{-11}$ 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.

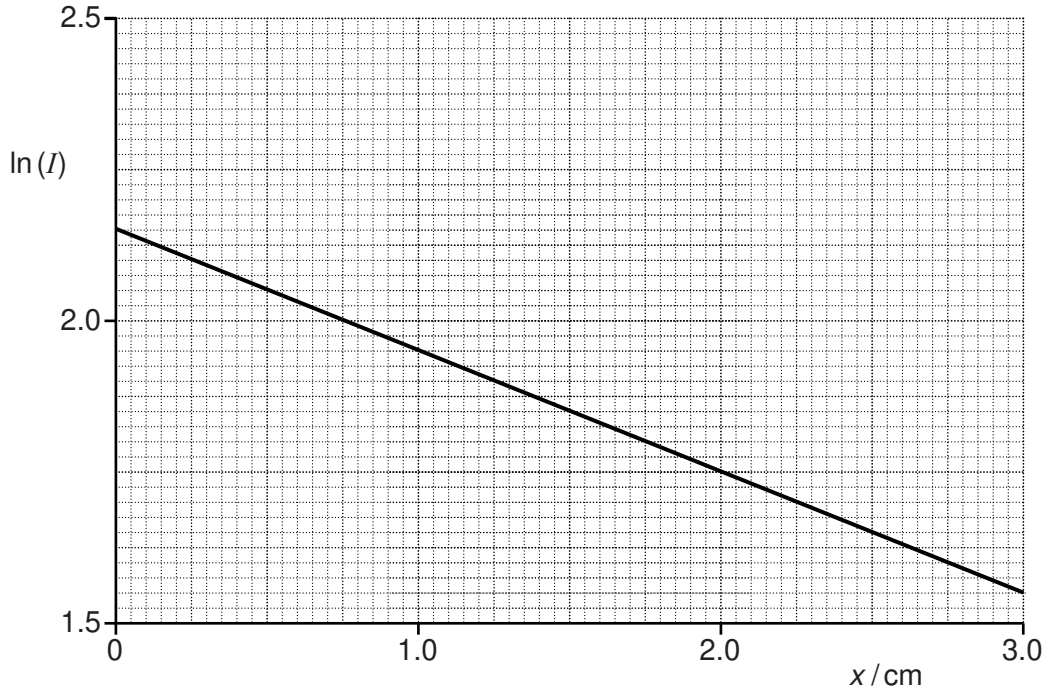


Fig. 8.1

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(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 μ of bone.

μ = ... cm^{-1} **[2]**

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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 $4.0 \cdot 10^8\,\text{rad}\,\text{s}^{-1}$.

(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.

.....

.....

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

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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*.

.....

.....

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

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

.....

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

(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.

.....

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

(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]**

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



Fig. 11.1

Andromeda is $2.4 \cdot 10^{22}$ m from the Earth. It has a diameter of $1.3 \cdot 10^{20}$ 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 $2.5 \cdot 10^{5}\,m\,s^{-1}$.
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]**

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(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 $2.0 \cdot 10^{30}$ 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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..... **[5]**

Question 12(b) begins on page 24

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(b) State *Hubble's law*.

.....

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

(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 = $3.2 \cdot 10^7$ s

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

END OF QUESTION PAPER

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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.

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OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **G485**: Fields, Particles and Frontiers of Physics

Advanced GCE

Mark Scheme for June 2016

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotation	Meaning
BOD	Benefit of doubt given
BP	Blank Page
CON	Contradiction
	Incorrect Response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct Response
AE	Arithmetic error
	Wrong physics or equation

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Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures and rounding errors:

If the data given in a question is to 2 sf, then allow to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Penalise a rounding error once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

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Question			Answers	Marks	Guidance
1	(a)		$(B = \frac{F}{IL})$ $F \rightarrow$ kg m s^{-2} / $I \rightarrow$ C s^{-1} and $L \rightarrow$ m T $\rightarrow$ kg C^{-1} s^{-1}	C1 A1	**Alternative:** $B = \frac{F}{Qv}$ $F \rightarrow$ kg m s^{-2} / $Q \rightarrow$ C and $v \rightarrow$ m s^{-1} C1 T $\rightarrow$ kg C^{-1} s^{-1} A1 **Allow** $\frac{\text{kg}}{\text{C s}}$, $\frac{\text{kg C}^{-1}}{\text{s}}$, etc.
	(b)	(i)	$F = \frac{9.11\times10^{-31}\times(7.0\times10^{6})^{2}}{2.5\times10^{-2}}$ / $F = 1.79 \times 10^{-15}$ (N) $(F = BQv)$ $1.79 \times 10^{-15} = B \times 1.6 \times 10^{-19} \times 7.0 \times 10^{6}$ (Any subject) $B = 1.6 \times 10^{-3}$ (T)	C1 C1 A1	**Alternative**: Allow *e* instead of *Q* $BQv = \frac{mv^2}{r}$ or $BQ = \frac{mv}{r}$ C1 $B = \frac{9.11\times10^{-31}\times7.0\times10^{6}}{1.6\times10^{-19}\times2.5\times10^{-2}}$ (Any subject) C1 $B = 1.6 \times 10^{-3}$ (T) A1 **Allow**: 2 marks for 7.97×10^{-4} (T); 5.0 cm used instead of 2.5 cm (Allow 8×10^{-4} T)
	(b)	(ii)	(period = $\frac{2\pi\times2.5\times10^{-2}}{7.0\times10^{6}}$) period = 2.2×10^{-8} (s)	B1	**Allow**: 1 mark for 4.5×10^{-8} (s) as ECF if 5.0 cm was used in **(i)**.
	(b)	(iii)	$BQ = mv/r$ (Allow any subject) or $\frac{v}{r} =$ constant T = distance/speed or $T = 2\pi r/v$ or $T \propto r/v$ (hence T is constant)	M1 A1	**Allow** other alternatives, e.g: $T = 2\pi m/QB$ M1 m, Q and B are constants (hence T is constant) A1 or The distance / circumference / r doubles M1 T = distance/speed or $T = 2\pi r/v$ or $T \propto r/v$ (hence T is constant) A1
			Total	**8**	

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Question			Answers	Marks	Guidance
2	(a)		Any **two** from: • Direction of the field (is incorrect) (AW) • The field lines should be curved / not straight (lines) • The field line(s) should be perpendicular at the plate(s) • The separation between the field lines cannot be the same / diagram shows a uniform field	B1×2	**Allow** answers on Fig. 2.1
	(b)	(i)	gradient = 1.25 ($\times 10^{-7}$) (Q = gradient $\times 4\pi \times 8.85 \times 10^{-12}$) charge = 1.4×10^{-17} (C)	C1 A1	**Ignore** POT **Allow** gradient in the range 1.20 to 1.30 ($\times 10^{-7}$) **Allow** full credit for substitution method ECF from incorrect value of calculated gradient
	(b)	(ii)	The gradient decreases Explanation: Q decreases / there are fewer protons	B1 B1	**Allow** E is smaller for the same r
	(c)	(i)	(E =) $\frac{1.5(\times 10^{3})}{2.10(\times 10^{-2})}$ or 7.14 ($\times 10^{4}$) (mass of droplet = $\frac{4}{3}\pi r^{3} \times \rho$ =) 8.15×10^{-15} (kg) (electrical force = weight / $EQ = mg$) $7.14 \times 10^{4} \times Q = 8.15 \times 10^{-15} \times 9.81$ (Any subject) and hence charge = 1.1(2) $\times 10^{-18}$ (C)	C1 C1 A1	**Allow** other correct methods **Ignore** POT **Note** there is no ECF for incorrect E or mass values **Allow** 1 mark for a bald 1.12 $\times 10^{-18}$ (C); answer to 3 SF or more but a bald 1.1 $\times 10^{-18}$ C scores zero
	(c)	(ii)	(number of electrons = $\frac{1.12 \times 10^{-18}}{1.6 \times 10^{-19}}$ =) 7 (An integer)	B1	**Note** there is no ECF from **(i)** since 1.1×10^{-18} C is given **Not** 6.88 or 6.9 when using 1.1×10^{-18} C, but allow either of the integers 7 or 6
			Total	**10**	

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Question			Answers	Marks	Guidance
3	(a)	(i)	(magnetic flux linkage = magnetic) flux × (number of) turns	B1	**Allow**: BAN, where *B* is (perpendicular magnetic) flux density / (perpendicular magnetic) field strength, *A* is (cross-sectional) area and *N* is (the number of) turns
	(a)	(ii)1	$N = \frac{L}{2\pi r}$ (Any subject)	B1	
	(a)	(ii)2	(magnetic flux linkage =) *BAN* (magnetic flux linkage =) $B \times \pi r^2 \times \frac{L}{2\pi r}$ (magnetic flux linkage =) $\frac{BrL}{2}$	C1 A0	No ECF from **(ii)1**
	(b)	(i)	e.m.f. (induced) ∝ rate of change of (magnetic) flux linkage	B1	**Allow** an 'equal sign' **Allow** $E = (-)\Delta N\phi/\Delta t$ where *E* is e.m.f. (induced), $N\phi$ is (magnetic) flux linkage and *t* is time **Not** voltage induced **Not** 'cutting *of* flux'
	(b)	(ii)	*E* is zero only at 1.0 ms, 3.0 ms and 5 ms Correct shape of graph	M1 A1	**Ignore** 'inversion' of the sinusoidal curve
	(c)		There is an alternating (magnetic) flux / flux density / field (in primary coil) Idea of flux / flux density / field within iron / core and The secondary coil is linked by an alternating (magnetic) flux (density / linkage)	M1 A1	**Allow** changing / varying for alternating throughout **Not** *alternating current in supply*
			Total	**8**	

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Question			Answers	Marks	Guidance
4	(a)		The charge / Q on each capacitor is the same $V \propto C^{-1}$	M1 A1	 **Allow** $Q = VC$ and some explanation
	(b)		(total resistance =) 27 (kΩ) or 27000 (Ω) (total capacitance =) 100 (μF) or 1.0×10^{-4} (F) (time constant =) $27 \times 10^3 \times 100 \times 10^{-6}$ time constant = 2.7 (s)	C1 C1 A1	 **Allow** 10^{-4} (F) **Note** 2.7×10^n with $n \neq 0$ scores 2 marks
	(c)	(i)	$(V =) 1.5 \times 10^{-4} \times 40 \times 10^3$ or 6 (V) $(Q =) 6.0 \times 1200 \times 10^{-6}$ charge = 7.2×10^{-3} (C)	C1 A1	**Allow** I in the range 1.50 to 1.55 **Allow** other correct methods Possible POT error **Not** C and R values from **(b)**
	(c)	(ii)	Current starts at 3.0 ($\times 10^{-4}$ A) Graph showing shorter time constant	B1 B1	**Allow** $\pm$ 0.05 $\times 10^{-4}$ (A)
			Total	**9**	

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Question			Answers	Marks	Guidance
5	(a)	(i)	$2\,{}^{1}_{0}\mathrm{n}$	B1	**Allow** answer in words, e.g. 'two neutrons' **Allow** $2 \times {}^{1}_{0}\mathrm{n}$
	(a)	(ii)	${}^{0}_{-1}\mathrm{e}$ / ${}^{0}_{-1}\beta^{(-)}$ ${}^{(o)}_{(0)}\bar{\nu}_{(e)}$	B1 B1	**Not** e / e^- / β / β^- **Allow** electron **Allow** (electron) anti-neutrino
	(b)	(i)	(activity =) $\frac{2000}{9.0\times10^{-13}}$ $(\lambda =)\ \frac{0.693}{88\times3.16\times10^{7}}$ ($A = \lambda N$) $2.22\times10^{15} = 2.49 \times 10^{-10} \times N$ (Any subject) (mass =) $\frac{8.91\times10^{24}}{6.02\times10^{23}}\times0.238$ mass = 3.5 (kg)	C1 C1 C1 A1	**Allow** other correct methods **Note** 2.22×10^{15} scores this C1 mark **Note** 2.49×10^{-10} (s^{-1}) scores this C1 mark **Note** $N = 8.91 \times 10^{24}$ scores all three C1 marks Possible ECF for incorrect value(s) of activity and or λ **Allow** 3 marks for 0.21 (kg) if 120 W is used
	(b)	(ii)	(energy =) 0.120 (kW) × 24 (h) energy = 2. 9 (kW h)	C1 A1	 **Allow** 1 mark for 48 (kW h); 2 kW used instead of 0.12 kW **Allow** 1 mark for 2900; 120 used instead of 0.12
			Total	**9**	

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Question			Answers	Marks	Guidance
6	(a)		Hadrons are made of quarks / they experience the strong (nuclear) force / interaction	B1	**Not** 'they are baryons' **Allow** 'held together by gluons' (AW) **Ignore** the number of quarks mentioned
	(b)		$\frac{2}{3}$ (e); $-\frac{1}{3}$ (e)	B1	**Allow** 0.67 (e) and – 0.33 (e)
	(c)		(proton =) u u d	B1	**Allow** up up down
	(d)		($p + n \rightarrow p + p + \pi^-$) u u d + u d d $\rightarrow$ u u d + u u d + π^- (left-hand side = d and right-hand side = u + π^-) π^- has one down quark or π^- has d and one anti-up quark or π^- has $\bar{u}$	C1 A1 A1	**Allow** other correct methods **Note:** This mark is for *substitution* **Note**: Any more than 2 quarks does not score the A1 marks **Allow** 3 marks for d $\bar{u}$
	(e)	(i)	$\Delta E = \Delta m\, c^2$ where ΔE is (change in) energy, Δm is (change in) mass and c is speed of light (in a vacuum)	B1	**Allow** energy = mass × speed of light^2 **Not** binding energy = mass defect × speed of light^2 **Not** energy = mass defect × speed of light^2
	(e)	(ii)	(KE =) $1.4 \times 10^8 \times 1.6 \times 10^{-19}$ or 2.24×10^{-11} (J) (mass of π^- =) $\frac{2.24 \times 10^{-11}}{(3.0 \times 10^8)^2}$ mass = 2.5×10^{-28} (kg)	C1 A1	
			Total	**9**	

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Question			Answers	Marks	Guidance
7	(a)		Any **two** from: • A nucleus is split / broken up in a fission reaction **OR** In a fusion reaction nuclei combine / fuse • High temperatures / pressures / (kinetic) energy required for fusion reaction • More energy per reaction produced in a fission reaction (ORA) • A neutron causes fission reaction • Chain reaction possible in fission • 'Larger' nuclei produced in fusion **OR** 'Smaller' nuclei produced in fission	B1×2	**Allow** alternative wording (AW) **Not** 'neutrons are produced in a fission reaction' because neutrons can also be produced in some fusion reactions
	(b)		There is repulsion (between nuclei) (At high temperatures nuclei) move fast / have more KE (At high temperature / pressure the nuclei) have greater chance of fusion / collision / interaction (AW) At high temperatures nuclei get close (enough) to experience the strong force **OR** At high pressures nuclei are close	B1 B1 B1 B1	**Allow** reference to 'particles' or protons instead of 'nuclei' **Not** 'enough / sufficient' KE …… **Allow** fuse / collide / interact more frequently **Allow** At high pressures … high density / greater number of nuclei per unit volume
	(c)	(i)	Mention of slow / thermal neutron(s) The nucleus splits up into two nuclei / smaller nuclei / daughter nuclei / smaller fragments (and neutrons)	B1 B1	 **Not** 'nucleus undergoes fission / decay / becomes unstable '
	(c)	(ii)	$\frac{3}{2}kT$ and $\frac{1}{2}mv^2$ $3\times1.38\times10^{-23}\times573=1.7\times10^{-27}\times v^2$ (Any subject) speed = 3.7×10^3 (m s^{-1})	C1 C1 A1	 **Allow** 1 mark for 2.7×10^3 (m s^{-1}); 300 used instead of 573 **Allow** 3 marks for 3.8×10^3 m s^{-1}; 1.675×10^{-27} kg or 1.673×10^{-27} kg (mass of proton) from Data Booklet used
			Total	**11**	

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Question			Answers	Marks	Guidance
8	(a)		Any **three** from: **Photoelectric effect:** Photon ejects / removes an electron (from the atom / metal) **Compton (scattering):** Photon emerges with less energy / longer wavelength / lower frequency <u>and</u> an electron escapes / ejected (from the atom) **Pair-production:** Photon produces an electron-positron (pair) **Scattering** : Photon is scattered by an electron ✎ **QWC:** (Intensity decreases in the original direction because) there are fewer <u>photons</u>	B1×3 B1	**Allow** consistent use of plurals throughout, e.g: Photons eject electrons
	(b)	(i)	($E = \frac{hc}{\lambda}$) (*E* =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.4\times10^{-11}}$ or (*f* =) 2.14 × 10^{19} (Hz) energy = 1.4 × 10^{-14} (J)	C1 A1	
	(b)	(ii)	gradient = (-) μ μ = 0.20 (cm^{-1})	C1 A1	**Allow** correct substitution into $\ln I = \ln I_0 - \mu x$; coordinates read to ± ½ small square **Allow** 1 SF answer of 0.2 (cm^{-1}) **Allow** answer in the range 0.19 to 0.21 (cm^{-1}) **Ignore** sign
			Total	**8**	

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Question			Answers	Marks	Guidance
9	(a)		$2\pi f = 4.0 \times 10^8$ / $f = 6.37 \times 10^7$ (Hz) $(\lambda = \frac{c}{f})$ $\lambda = \frac{3.0 \times 10^8}{6.37 \times 10^7}$ (Any subject) wavelength = 4.7 (m)	C1 C1 A1	**Allow** 1 mark for 0.75 (m); $f = 4.0 \times 10^8$ Hz used **Not** 1.5π **Allow** other correct methods, e.g: $\omega = 2\pi c/\lambda$ C1 $\lambda = 2\pi \times 3.0 \times 10^8/4.0 \times 10^8$ C1 wavelength = 4.7 (m) A1
	(b)		The (mean) time taken by the nuclei / protons to return to low / original / initial energy state. (AW)	B1	**Allow** 'the time taken for the number of excited nuclei / protons to decrease to 37% of the original value'
			Total	**4**	

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Question			Answers	Marks	Guidance
10	(a)		Applying a p.d across the material makes it expand / compress / deform / strain (ORA)	B1	**Allow**: Applying a varying p.d. produces vibrations / ultra-sound **Allow**: Ultrasound hitting the material produces a varying e.m.f. **Allow**: voltage or p.d. instead of e.m.f. **Not** current
	(b)	(i)	(acoustic impedance =) speed (of ultrasound in the material) × density (of material)	B1	**Not** $Z = \rho c$
	(b)	(ii)	Any **one** from: • Speed / wavelength is different • Travel slow(er) in air (ORA) • Ultrasound has short(er) wavelength in air (ORA) • Reflection(s) occur inside patient (ORA) • Greater attenuation (of ultrasound) inside patient (ORA)	B1	Penalise wrong physics, e.g 'travel faster in air' **Not** frequency **Not** acoustic impedance
	(c)		$(Z_{(m)} =) 1.38 \times 10^6$ / $(Z_{(f)} =) 1.69 \times 10^6$ $\frac{(1.38-1.69)^2}{(1.38+1.69)^2}$ or 0.01(02) intensity transmitted = 99 %	C1 C1 A1	 **Note**: 1.0(2)% scores 2 marks
			Total	**6**	

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Question			Answers	Marks	Guidance
11	(a)		angle = $\tan^{-1}(1.3\times10^{20}/2.4\times10^{22})$ angle = 0.31 (°)	B1	**Note**: Using $\sin^{-1}$ is correct; it gives the same answer of 0.31°
	(b)		$(\frac{\Delta\lambda}{\lambda}=\frac{v}{c})$ $\frac{\Delta\lambda}{656.3}=\frac{2.5\times10^{5}}{3.0\times10^{8}}$ (Any subject) $\Delta\lambda$ = 0.55 (nm)	C1 A1	**Note**: Answer to 3 sf is 0.547 (nm) **Note**: 5.5×10^{-10} on the answer line scores 1 mark
	(c)		$\frac{GMm}{r^2}=\frac{mv^2}{r}$ or $\frac{GM}{r}=v^2$ $\frac{GM}{0.65\times10^{20}}=(2.5\times10^{5})^2$ (Any subject) mass = 6.09×10^{40} (kg) (number of stars = $6.09\times10^{40}/2.0\times10^{30}$) number of stars = 3.0×10^{10}	C1 C1 C1 A1	**Allow** other correct methods. **Allow** the following for the first two C1 marks: $F=\frac{2.0\times10^{30}\times(2.5\times10^{5})^2}{0.65\times10^{20}}$ or 1.92×10^{21} (N) C1 $\frac{GM\times2.0\times10^{30}}{(0.65\times10^{20})^2}=1.92\times10^{21}$ (Any subject) C1 **Allow**: 2 out of 3 marks for use of 1.3×10^{20} (m); this gives an answer of 1.2×10^{41} (kg) Possible ECF from incorrect mass of galaxy **Allow** 1 SF answer for the estimation
			Total	**7**	

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Question			Answers	Marks	Guidance
12	(a)		Any **four** from: (The forces are separated) 1. Expansion / cooling 2. Creation of matter / pair production 3. More matter than antimatter 4. Quarks <u>and</u> leptons (soup) 5. Quarks combine to form hadrons / baryons / nucleons / protons / neutrons 6. Imbalance of neutrons and protons / (primordial) helium / lithium /beryllium (nuclei) produced 7. Hadrons / baryons / (neutrons and) protons / combine to form nuclei (Atoms formed) ✎ **QWC**: Correct sequencing of two steps from 4, 5 and 7	B1 × 4 B1	Annotation by the pencil icon
	(b)		(Recession) speed / velocity of <u>galaxy</u> is (directly) proportional to its distance (from us)	B1	
	(c)	(i)	(ρ =) $8 \times 1.673 \times 10^{-27}$ (kg m^{-3}) or 1.34×10^{-26} (kg m^{-3}) ($\rho = \frac{3H_0^2}{8\pi G}$) $H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 1.34 \times 10^{-26}}{3}}$ (Any subject) $H_0 = 2.7 \times 10^{-18}$ (s^{-1})	C1 C1 A1	**Allow** 1.7×10^{-27} kg or 1.675×10^{-27} kg (neutron) or 1.661×10^{-27} kg (u) **Note**: Answer is 2.8×10^{-18} (s^{-1}) when 1.7×10^{-27} kg is used
	(c)	(ii)	(age =) $\frac{1}{2.7 \times 10^{-18}}$ or 3.7×10^{17} (s) age = 1.2×10^{10} (y)	C1 A1	Possible ECF from **(c)(i)** **Allow** use of 1 y = 3.15×10^7 (s) or 3.16×10^7 (s) **Note**: Answer is 1.1×10^{10} (y) when 2.8×10^{-18} (s^{-1}) and 3.16×10^7 are used
			Total	**11**	

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Thursday 18 June 2015 – 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 page(s) 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.

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Answer **all** the questions.

1 **(a)** An electric field always exists around a charged particle.

Explain what is meant by an *electric field*.

.....

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

(b) State **one** difference and **one** similarity between the electric field of a point charge and the gravitational field of a point mass.

difference .....

.....

similarity .....

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

(c) Fig. 1.1 shows the uniform electric field between two vertical parallel plates **A** and **B**.

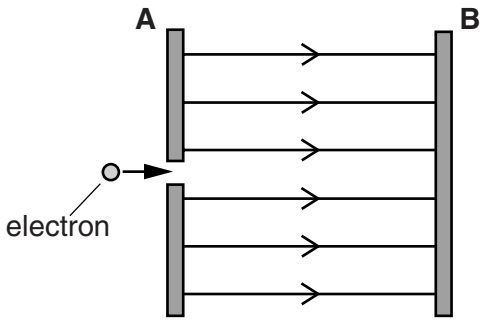


Fig. 1.1

The potential difference between the plates is 6 V. An electron of kinetic energy 4 eV is fired in a direction parallel to the electric field through a tiny hole in plate **A**.

Describe and explain the subsequent motion of the electron in the space between **A** and **B**. The weight of the electron has negligible effect on its motion between the plates.

.....

.....

.....

.....

.....

.....

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

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(d) Two different minerals acquire opposite charges when they are crushed into tiny particles. These oppositely charged mineral particles fall from a conveyor belt through the uniform electric field between two vertical parallel plates, as shown in Fig. 1.2.

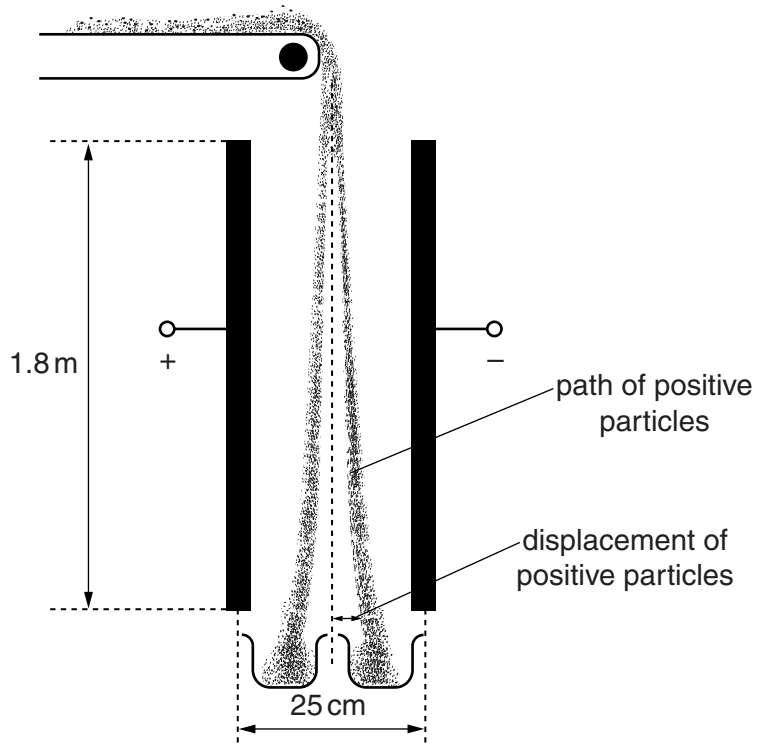


Fig. 1.2

The potential difference across the plates is 60 kV. The separation between the plates is 25 cm and each plate has length 1.8 m. The mineral particles fall through the air between the plates with a terminal velocity of $1.2\,m\,s^{-1}$. Each mineral particle has a charge of magnitude 1.5×10^{-13} C and a mass of 8.0×10^{-7} kg.

(i) Calculate the horizontal electric force experienced by a positively charged mineral particle as it falls between the plates.

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

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(ii) Calculate the horizontal displacement of a positively charged mineral particle after a 1.8 m fall through the electric field of the plates. Ignore any horizontal drag forces due to air.

displacement = ... m **[3]**

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2 **(a)** Fig. 2.1 shows a horizontal current-carrying wire placed in a uniform magnetic field.

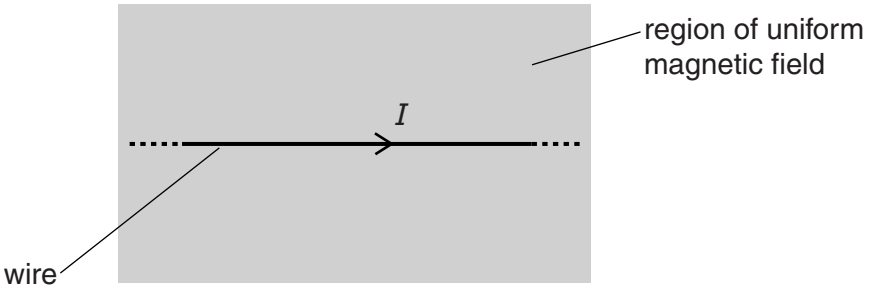


Fig. 2.1

The magnetic field of flux density 0.070 T is at right angles to the wire and into the plane of the paper. The weight of a 1.0 cm length of the wire is 6.8×10^{-5} N. The current I in the wire is such that the vertical upward force on the wire due to the magnetic field is equal to the weight of the wire.

(i) Calculate the current I in the wire.

I = ... A **[2]**

(ii) Suggest why it would be impossible for overhead cables carrying an alternating current to float in the Earth's magnetic field.

.....

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

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(b) A charged particle enters a region of uniform magnetic field. Fig. 2.2 shows the path of this particle.

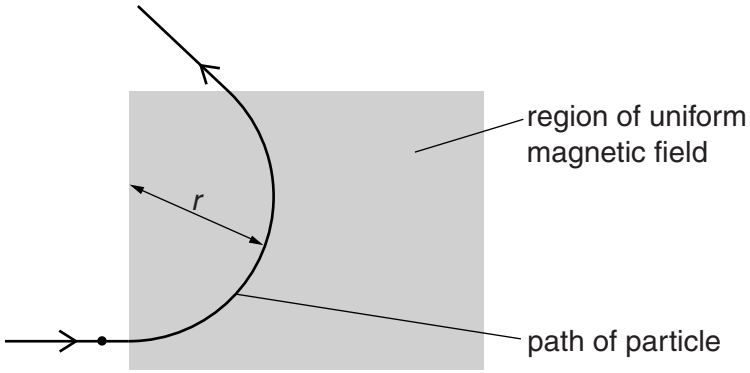


Fig. 2.2

The direction of the field is perpendicular to the plane of the paper. The magnetic field has flux density B. The particle has mass m, charge Q and speed v. The particle travels in a circular arc of radius r in the magnetic field.

(i) Derive an equation for the radius r in terms of B, m, Q and v.

[2]

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(ii) A thin aluminium plate is now placed in the magnetic field. Fig. 2.3 shows the path of an unknown charged particle.

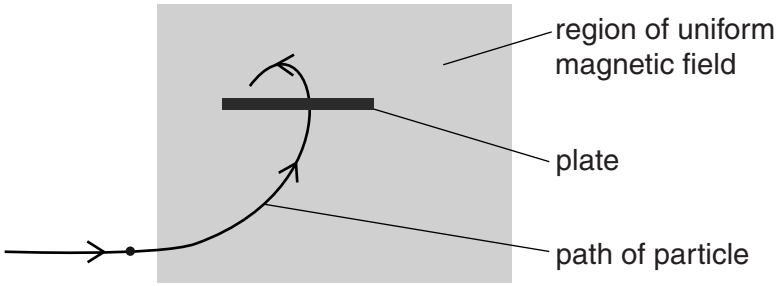


Fig. 2.3

The particle loses some of its kinetic energy as it travels through the plate. The initial radius of the path of the particle before it enters the plate is 4.8 cm. After leaving the plate the final radius of the path of the particle is 1.2 cm.

Calculate the ratio

$$\frac{\text{initial kinetic energy of particle}}{\text{final kinetic energy of particle}}.$$

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

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3 **(a)** State, with a reason, whether or not protons and neutrons are fundamental particles.

.....

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

(b) State **two** fundamental particles that can be classified as leptons.

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

(c) Some fruits, such as bananas, are naturally radioactive because they contain the unstable isotope of potassium-40 ($^{40}_{19}K$).

(i) The isotope of potassium-40 is a beta-minus emitter.

Complete the following decay equation for $^{40}_{19}K$.

$$^{40}_{19}K \rightarrow \text{.....}^{\text{.....}}_{\text{.....}}Ca + \text{.....} + \text{.....}$$ **[2]**

(ii) Explain why energy is released when a single nucleus of potassium-40 decays.

.....

.....

.....

.....

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

(iii) A banana contains 4.5×10^{-4} kg of potassium. About 0.012 % of the mass of potassium in the banana has the unstable isotope of potassium-40. This isotope of potassium-40 has a half-life of 4.2×10^{16} s. The molar mass of potassium-40 is 0.040 kg mol^{-1}.

Calculate the activity from this banana.

activity = ... Bq **[3]**

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4 **(a)** A charged capacitor is connected across the ends of a negative temperature coefficient (NTC) thermistor kept at a fixed temperature. The capacitor discharges through the thermistor. The potential difference V across the capacitor is maximum at time $t = 0$.

(i) On the axes of Fig. 4.1, carefully sketch a graph to show how the potential difference V across the capacitor varies with time t. Label this graph **L**.

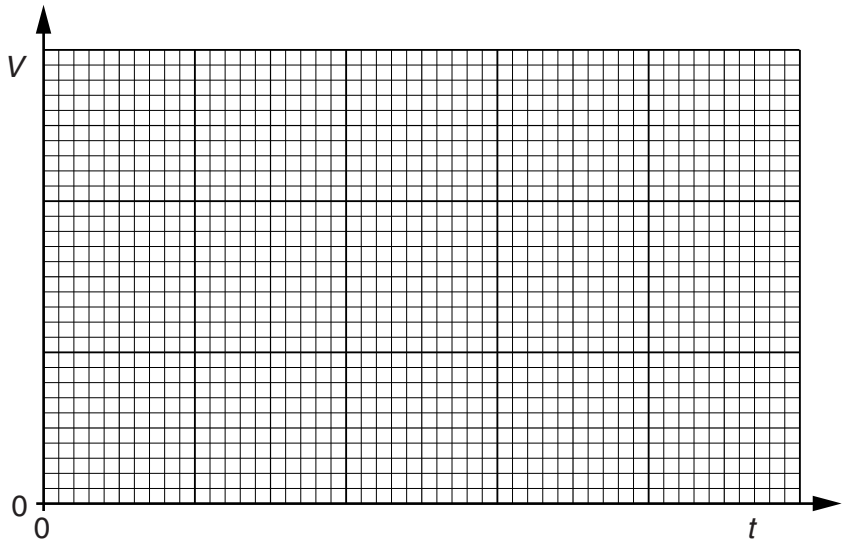


Fig. 4.1 **[1]**

(ii) The temperature of the thermistor is increased to a higher fixed value. On Fig. 4.1, sketch another graph to show the variation of V with t when the same charged capacitor is discharged across the ends of the hotter thermistor. Label this graph **H**. **[1]**

(iii) Explain how you can show that the graph sketched in **(i)** has a constant-ratio property (exponential decay).

.....

.....

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

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(b) Fig. 4.2 shows an electrical circuit.

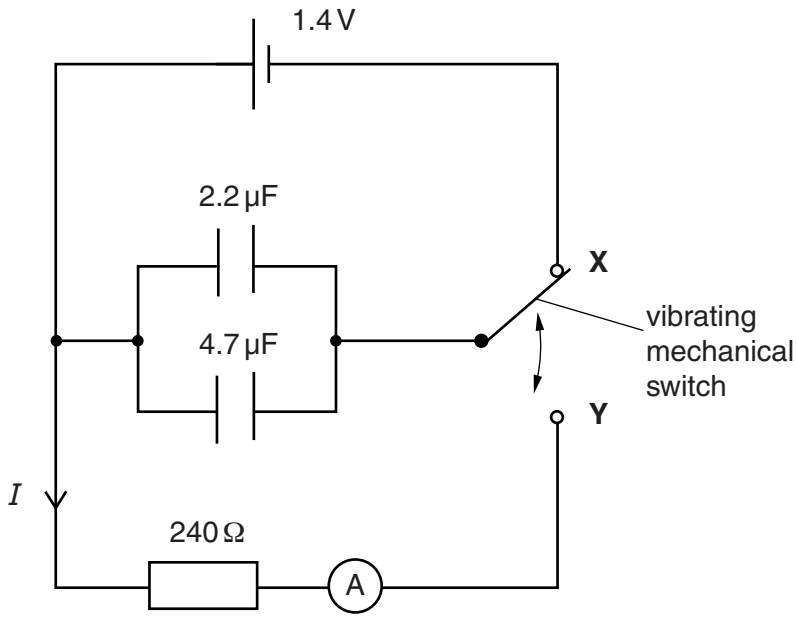


Fig. 4.2

The cell has e.m.f. 1.4 V and negligible internal resistance. The values of the capacitors and the resistor are shown in Fig. 4.2. A mechanical switch vibrates between contacts **X** and **Y** at a frequency of 120 Hz.

(i) Calculate the time constant of the circuit.

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

(ii) Calculate the value of the average current I in the resistor. Assume that the capacitors are fully discharged between each throw of the switch.

I = ... A **[3]**

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(iii) The frequency of vibration of the mechanical switch is doubled. Explain why the average current in the circuit is not doubled.

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

Question 5 starts on page 12

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5 **(a)** Explain how the experiments on the scattering of alpha-particles by a metal foil provided evidence for the nuclear model of the atom.

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

.....

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.....

.....

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

(b) Fig. 5.1 shows an alpha-particle ($^{4}_{2}$He) of kinetic energy 8.0 MeV moving directly towards a nucleus of aluminium-27 ($^{27}_{13}$Al), initially at rest.



Fig. 5.1

(i) The alpha-particle comes to rest instantaneously a short distance away from the aluminium nucleus. It then reverses its direction of travel. Describe and explain the motion of the aluminium nucleus at the instant the alpha-particle is at rest.

.....

.....

.....

.....

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

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(ii) Calculate the initial speed of the alpha-particle.

mass of alpha-particle = 6.6×10^{-27} kg

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

(iii) The electric force experienced by the alpha-particle when it is close to the aluminium nucleus is 270 N. Calculate the separation r between the alpha-particle and the aluminium nucleus when the alpha-particle experiences this force.

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

(iv) Consider the situation where the alpha-particle travels much closer to the aluminium nucleus than in **(b)(iii)**.

Discuss how the strong nuclear force may affect the resultant force on the alpha-particle.

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

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6 **(a)** Explain what is meant by the *binding energy* of a nucleus.

.....

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

(b) The fusion of protons occurs in a star when the temperature within the core is greater than about 10^7 K. It takes the fusion of 4 protons to form a helium-4 ($^4_2$He) nucleus. In this process, known as the proton–proton cycle, energy is released.

The net energy released in producing a single helium-4 nucleus is 4.53×10^{-12} J.
Calculate the binding energy per nucleon of the helium-4 nucleus.

binding energy per nucleon = ... J **[1]**

(c) The fusion of helium nuclei to make heavier elements occurs in red giants at temperatures above 10^8 K.

Explain why fusion of helium requires higher temperatures than the fusion of hydrogen (protons).

.....

.....

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

(d) Estimate the mean speed of helium nuclei at a temperature of 10^8 K.

mass of helium nucleus = 6.6×10^{-27} kg

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

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7 **(a)** A patient has an X-ray scan taken in hospital. The high-energy X-ray photons interact with the atoms inside the body of the patient.

Explain what is meant by a *photon* and state **one** of its main properties.

.....

.....

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

(b) An X-ray tube operates using a 150 kV supply. X-ray photons are produced inside the tube when a beam of high-speed electrons accelerated from the cathode collide with the metal anode. About 99% of the total kinetic energy of the electrons at the anode is converted into heat energy which heats the anode. The remaining energy is transformed into the energy of the X-ray photons.

The current in the electron beam between the cathode and the anode is 4.8 mA.

(i) Show that the number of electrons incident at the anode per second is $3.0 \times 10^{16}\,s^{-1}$.

[1]

(ii) The anode is made from metal of specific heat capacity $140\,J\,kg^{-1}\,K^{-1}$. It has a mass of 8.6 g. The X-ray tube is switched on. Calculate the initial rate of increase of temperature of the anode.

rate of temperature increase = ... °C s^{-1} **[3]**

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(iii) A single electron is responsible for producing an X-ray photon. Calculate the shortest wavelength of the X-rays produced from the X-ray tube.

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

(c) An X-ray scan of the heart and its blood vessels shows very poor contrast. Describe and explain a technique that can be used to reveal these blood vessels in an X-ray scan.

.....

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

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8 **(a)** Fig. 8.1 shows an image of a patient from a gamma camera scan.

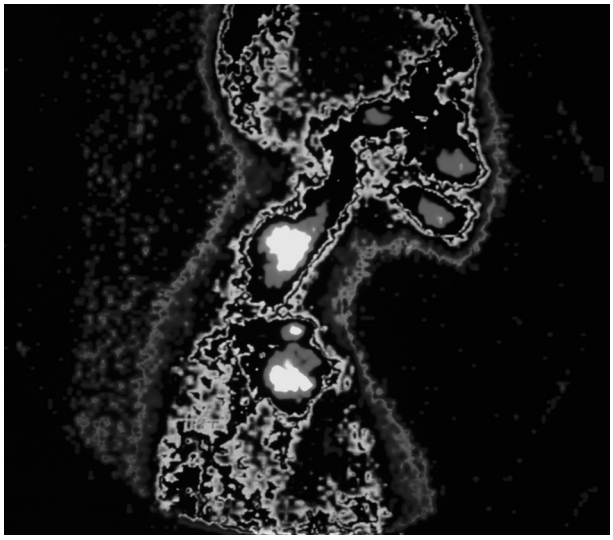


Fig. 8.1

The radioactive gamma-emitting tracer technetium-99m was injected into the patient before the scan. The image shows the distribution and intensity of gamma radiation emitted.

Discuss the advantages of using a gamma-emitting tracer in the patient rather than a beta-emitting tracer.

.....

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

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(b) Many hospitals are equipped with computerised axial tomography (CAT) scanners.

Describe how the components of a CAT scanner are used to produce a three-dimensional image of a patient.

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

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9 **(a)** Explain what is meant by *Doppler effect*.

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

(b) Describe how high-frequency ultrasound can be used to determine the speed of blood through the arteries of a patient.



In your answer you should make it clear how the speed is determined.

.....

.....

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

(c) A patient is scanned using ultrasound of frequency 2.4 MHz. The speed of ultrasound in the blood is 1.57 km s^{-1}. The acoustic impedance of blood is 1.66×10^6 kg m^{-2} s^{-1}.
Calculate

(i) the density of blood

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

(ii) the wavelength of ultrasound in the blood.

wavelength = ... m **[1]**

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(d) Fig. 9.1 shows a beam of ultrasound incident at right angles to the boundary between muscle and bone.

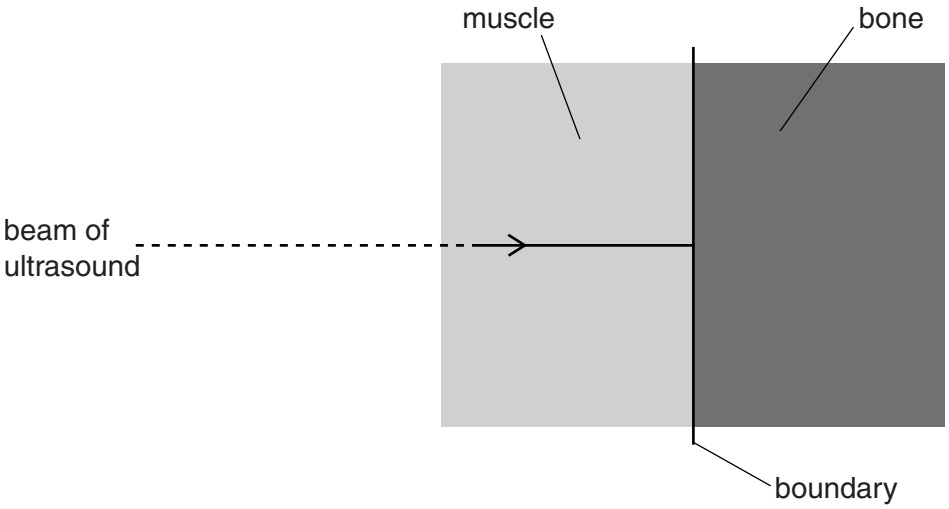


Fig. 9.1

The acoustic impedance of bone is 4 times that of muscle.

Calculate the percentage of ultrasound intensity transmitted into the bone.

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

(e) During an ultrasound scan it is important that most of the ultrasound from the transducer is transmitted into the patient. Describe and explain how this is achieved.

.....

.....

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

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Question 10 begins on page 22

PLEASE DO NOT WRITE ON THIS PAGE

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10 **(a)** Explain what is meant by a *white dwarf* when describing the evolution of a star.

.....

.....

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

(b) Antares is a red giant and one of the brightest stars in the night sky. The parallax angle for this star is 0.0059 arc seconds.

Calculate its distance in light years from us.
1 pc = 3.26 ly

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

(c) Sirius-B is a white dwarf. In comparison with Sirius-B, Antares has 12 times greater mass and has 1.1×10^5 times greater radius. The surface temperatures of Sirius-B and Antares are 25000 K and 4300 K respectively.

The intensity I of electromagnetic radiation emitted from the surface of a star is related to its temperature T in kelvin as follows:

$$I \propto T^4.$$

(i) Explain what is meant by *intensity*.

.....

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

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(ii) Calculate the ratio

1 $\dfrac{\text{mean density of Antares}}{\text{mean density of Sirius-B}}$

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

2 $\dfrac{\text{total power emitted from Antares}}{\text{total power emitted from Sirius-B}}$.

ratio = ... **[3]**

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11 **(a)** State Hubble's law.

.....

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

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity v. The fractional change z in the wavelength of a spectral line is given by the equation

$$z = \frac{v}{c}$$

where c is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is d.

Galaxy	$z / 10^{-3}$	$v / 10^{3}\,\mathrm{m\,s^{-1}}$	$d / 10^{23}\,\mathrm{m}$
A	1.12	336	1.50
B	1.61	483	2.14
C	1.85	555	2.46
D	2.26	678	3.00
Messier 109	3.38		

Fig. 11.1

(i) Complete the table by determining v and d for the galaxy Messier 109. **[2]**

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(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a v against d graph.

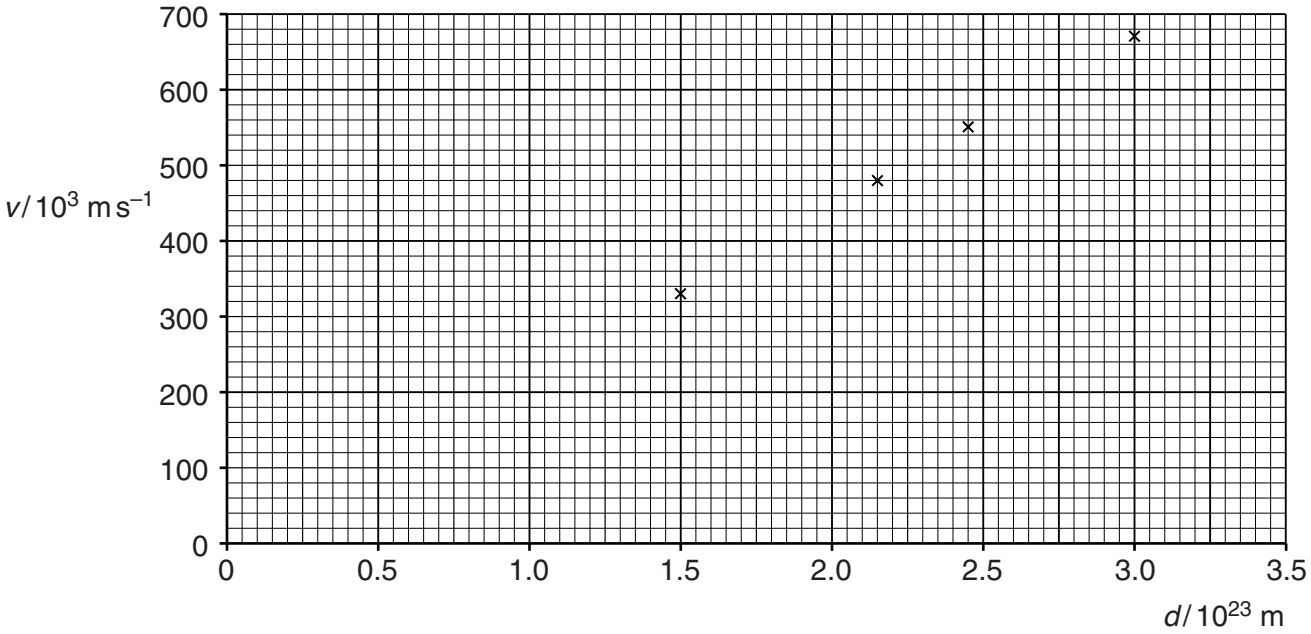


Fig. 11.2

Use Fig. 11.2 to determine the age of the Universe in years.
$1\,\text{y} = 3.16 \times 10^7\,\text{s}$

age = ... years **[3]**

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other.
Explain what is meant by the big bang and suggest **two** other observations that support the big bang model of the Universe.

.....

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.....

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

END OF QUESTION PAPER

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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.

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GCE

Physics A

Unit **G485**: Fields, Particles and Frontiers of Physics

Advanced GCE

Mark Scheme for June 2015

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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1. **Annotations**

Annotation	Meaning
BP	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error or reading/transcription error (*dual purpose*)
SF	Error in number of significant figures
	Correct response
AE	Arithmetic error
	Wrong physics or equation

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Abbreviations used in detailed mark scheme

Abbreviation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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12. CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures and rounding errors:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper. Any exception to this rule will be mentioned in the Guidance.

Penalise a rounding error once only in the entire paper.

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Question			Answer	Marks	Guidance
1	(a)		A region in which a charged particle experiences a force / acceleration	B1	**Allow**: Where a charge experiences a force **Allow**: Force per (unit positive) charge **Note**: Must have reference to charge and force/acceleration for the mark
	(b)		Difference: Any one from • gravitational field / force is attractive (AW) • electric field / force can be either attractive or repulsive (AW) Similarity: Any one from: • Force / field (strength) inversely proportional to distance squared • Radial fields	B1 B1	**Allow**: Gravitational force is in the direction of the field / towards the mass **Note**: For the second bullet point, must have reference to both attractive and repulsive or 'towards charge' and 'away from charge' **Allow**: (Both) obey the inverse-square law (with distance) or (Both) have $F \propto 1/r^2$ or $g \propto 1/r^2$ and $E \propto 1/r^2$ **Allow**: 'radius or separation' for 'distance'
	(c)		Any three from: • The electron is repelled by **B** / attracted by **A** / experience a force to the left • (Initially the) electron decelerates / slows down • It does not reach plate **B** / It reverses direction • When it returns to **A** it has 4 eV (of KE) • It stops 2/3 of the distance across the plates (AW)	B1 × 3	
	(d)	(i)	$E = 60 \times 10^3 \div 0.25$ / $E = 2.4 \times 10^5$ (V m^{-1}) $F = 2.4 \times 10^5 \times 1.5 \times 10^{-13}$ force = 3.6×10^{-8} (N)	C1 A1	**Allow**: $F = [1.5 \times 10^{-13} \times 60 \times 10^3]/0.25$ for the first C1 mark **Allow**: 1 mark for 7.2×10^{-8} (N); d = 12.5 cm used

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Question			Answer	Marks	Guidance
		(ii)	t = 1.8/1.2 (= 1.5 s) **or** $a = \frac{3.6\times10^{-8}}{8.0\times10^{-7}}$ (= 4.5 × 10^{-2} m s^{-2}) ($s = ut + \frac{1}{2}at^2$ and u = 0)	C1	Possible ecf from **(d)(i)**
			$s = \frac{1}{2}\times4.5\times10^{-2}\times1.5^2$	C1	**Note**: No ecf within calculation if $t \neq$ 1.8/1.2
			displacement = 5.1 × 10^{-2} (m)	A1	**Note**: Answer to 3 sf is 5.06 × 10^{-2} (m)
			Total	**11**	

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Question			Answer	Marks	Guidance
2	(a)	(i)	(weight = *BIL*) $6.8\times10^{-5} = 0.070\times I\times0.01$ (Any subject) I = 0.097 (A)	C1 A1	
		(ii)	The force on the cables will keep changing direction	B1	
	(b)	(i)	$BQv = mv^2 / r$ $r = \frac{mv}{BQ}$	M1 A1	**Allow** *e, q* instead of *Q* **Note**: *r* must be the subject of this equation
		(ii)	(*p* = *mv* = *BQr*; KE = ½ p^2/m) KE $\propto r^2$ ratio = $\frac{4.8^2}{1.2^2}$ ratio = 16	 C1 A1	 **Allow** full credit for correct alternative approaches **Allow** 16 : 1
			Total	**7**	

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Question			Answer	Marks	Guidance
3	(a)		They are not fundamental particles because they consist of quarks	B1	**Not**: They can be sub-divided
	(b)		Any two from: electron / positron / neutrino / antineutrino	B1	**Allow**: muon / tau
	(c)	(i)	$^{40}_{20}Ca$ $^{0}_{-1}e + \bar{\nu}_{(e)}$ or electron + (electron) antineutrino	B1 B1	**Allow**: $^{0}_{-1}\beta$ but not β^- or e^- for the electron
		(ii)	There is a decrease in mass Energy (released) given by $(\Delta)E = (\Delta)mc^2$ **or** Binding energy increases Energy (released) is the difference between the binding energies (of Ca and K nuclei)	M1 A1 M1 A1	**Ignore** Δm being referred to as the 'mass defect' **Allow**: binding energy per nucleon increases
		(iii)	$\lambda = \frac{0.693}{4.2\times10^{16}}$ / $N = \frac{0.012}{100}\times\frac{4.5\times10^{-4}}{0.040}\times6.02\times10^{23}$ $A = 1.65\times10^{-17}\times8.127\times10^{17}$ activity = 13 (Bq)	C1 C1 A1	**Allow**: 1 mark for either $\lambda = 1.65\times10^{-17}$ s^{-1} or $N = 8.127\times10^{17}$ **Note**: Answer to 3 sf is 13.4 (Bq) **Note**: 1.3×10^{3} (Bq) scores 2 marks; division by 100 omitted
			Total	**9**	

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Question			Answer	Marks	Guidance
4	(a)	(i)	Correct shape of (exponential) decay curve (labelled **L**)	B1	**Note**: The curve must show a gradient of decreasing magnitude as time increases and appear to have a finite value of V at $t = 0$ **Ignore** any levelling of the curve or $V = 0$ towards the end
		(ii)	Correct shape of curve (labelled **H**)	B1	**Note**: As **(i)** and this curve must show a smaller time constant than **(i)**; the initial V can be different **Note**: One of the curves must be labelled
		(iii)	Correct explanation in terms of constant-ratio for V values for fixed intervals of t	B1	**Allow** V is halved every half-life; V decreases to 0.37 (of its initial value) after every time constant **Note**: This can be scored on a suitably labelled sketch graph in either **(iii)** or Fig. 4.1
	(b)	(i)	(time constant = $6.9 \times 10^{-6} \times 240$) time constant = 1.7×10^{-3} (s)	B1	**Note**: Answer to 3 sf 1.66×10^{-3} (s)
		(ii)	charge = $6.9 \times 10^{-6} \times 1.4$ (= 9.66×10^{-6} C) (Δt = 1/120 = 0.0083 s) current = $\frac{6.9 \times 10^{-6} \times 1.4}{0.0083}$ current = 1.2×10^{-3} (A)	C1 C1 A1	Possible ecf from **(b)(i)** for value of total capacitance **Note**: Answer to 3 sf 1.16×10^{-3} (A) **Allow**: 2 marks for $9.66 \times 10^{-6} \times 60 = 5.8 \times 10^{-4}$ (A); Δt = 1/60 s used **Allow**: 2 marks for $9.66 \times 10^{-6} \times 240 = 2.3 \times 10^{-3}$ (A); Δt = 1/240 s used
		(iii)	The capacitors do not fully discharge (AW) Any one from: • Period (of switching) is (halved to) 4.2×10^{-3} (s) (and this time is comparable to the time constant) • The time constant (of the circuit) and period of mechanical switch are comparable / similar	B1 B1	
			Total	**9**	

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Question			Answer	Marks	Guidance
5	(a)		Observations: 1. Most of the alpha particles went straight / un-deflected through (the atom(s) / foil) (AW) 2. (Some of the) alpha particles were scattered / repelled / deflected through large angles (AW) Conclusions (QWC mark): • 1 showed that most of the atom is empty space **and** • 2 showed the existence of small / dense / positive nucleus	M1 M1 A1	**Not** 'reflected' **Allow**: The QWC mark even if 'alpha reflected at large angles' is mentioned in 2
	(b)	(i)	The aluminium nucleus has velocity / accelerates / moves to the right There is a repulsive force on the (aluminium) nucleus (to the right) / According to conservation of momentum the (aluminium) nucleus must move (to the right)	B1 B1	**Allow**: Moves away from the alpha particle
		(ii)	$8.0\times10^{6}\times1.6\times10^{-19}=\frac{1}{2}\times6.6\times10^{-27}\times v^{2}$ (Any subject) speed = 2.0×10^{7} (m s^{-1})	C1 A1	**Note**: Answer to 3 sf is 1.97×10^{7} (m s^{-1}) **Allow** 1 sf answer 2×10^{7} (m s^{-1})
		(iii)	Q = 13e or q = 2e or $F=\frac{Qq}{4\pi\varepsilon_0 r^2}$ $270=\frac{13\times1.6\times10^{-19}\times2\times1.6\times10^{-19}}{4\pi\times8.85\times10^{-12}\times r^{2}}$ (Any subject) distance = 4.7×10^{-15} (m)	C1 C1 A1	**Allow**: $F=k\frac{Qq}{r^2}$, where $k=9\times10^{9}$ **Note**: No credit for using Q and q as 13 and 2

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Question			Answer	Marks	Guidance
		(iv)	The strong force is attractive Correct explanation of size / direction of resultant force	M1 A1	**Allow**: The strong force is repulsive M1 Correct explanation of size / direction of resultant force A1
			Total	**12**	

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Question			Answer	Marks	Guidance
6	(a)		The (minimum) energy needed to separate / remove all the nucleons / protons and neutrons (to infinity)	B1	**Allow**: The energy released when (stationary) nucleons combine to form the nucleus **Allow**: The (minimum) energy required to break the nucleus into its (separate) nucleons **Allow**: binding energy = mass defect × speed of light^2 **Allow**: 'Work (done)' in place of 'energy'
	(b)		BE per nucleon = $4.53 \times 10^{-12}/4$ BE per nucleon = 1.13×10^{-12} (J)	 B1	 **Allow** 2 sf answer of 1.1×10^{-12} (J)
	(c)		The helium nucleus has greater charge / The helium nucleus experience greater repulsive force Helium nuclei need to get close together (for the strong force to initiate fusion)	B1 B1	
	(d)		$(\frac{1}{2} m v^2 = \frac{3}{2} kT)$ $\frac{1}{2} \times 6.6 \times 10^{-27} \times v^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times 10^8$ speed = 7.9×10^5 (m s^{-1})	C1 A1	 **Allow**: KE ≈ kT; this gives an answer of 6.47×10^5 (m s^{-1})
			Total	**6**	

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Question			Answer	Marks	Guidance
7	(a)		Quantum / packet of (electromagnetic) energy Any one from: Can travel in a vacuum / has speed of 3×10^8 m s^{-1} in a vacuum / has no charge / has no (rest) mass / causes ion-isation / has momentum	B1 B1	**Allow**: Particle of energy **Allow**: Travels at the speed of light / *c* in a vacuum
	(b)	(i)	number per second = $4.8 \times 10^{-3}/1.6 \times 10^{-19}$ number per second = 3.0×10^{16} s^{-1}	M1 A0	**Note**: This must be seen to gain a mark
		(ii)	(incident power =) $150 \times 10^3 \times 4.8 \times 10^{-3}$ or (incident power =) $3.0 \times 10^{16} \times 150 \times 10^3 \times 1.6 \times 10^{-19}$ ($P = mc[\Delta\theta/\Delta t]$) $0.99 \times 720 = 0.0086 \times 140 \times [\Delta\theta/\Delta t]$ rate of temperature increase = 590 (°C s^{-1})	C1 C1 A1	**Note** an incident power of 720 (W) scores this C1 mark **Note**: Answer to 3 sf is 592 (°C s^{-1}) **Allow**: 2 marks for 598 (°C s^{-1}) or 600 (°C s^{-1}); 99% omitted **Allow**: 2 marks for 1.97×10^{-14} (°C s^{-1}); 3.0×10^{16} omitted
		(iii)	(photon energy = maximum KE of electron) $E = 150 \times 10^3 \times 1.6 \times 10^{-19}$ or $E = 2.4 \times 10^{-14}$ (J) $2.4 \times 10^{-14} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$ (Allow any subject) wavelength = 8.3×10^{-12} (m)	C1 A1	**Allow**: $E = 720/3.0 \times 10^{16}$ **Allow**: 1 mark 8.3×10^{-10} (m); $E = 2.4 \times \underline{10^{-16}}$ (J) used
	(c)		Contrast material / iodine is injected (into the vessels) Any one from: The contrast material • large attenuation / absorption coefficient • has high *Z* (atoms) (and hence reveal the outline of the blood vessels)	B1 B1	**Not**: barium for this B1 mark **Not** 'large μ'
			Total	**10**	

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Question			Answer	Marks	Guidance
8	(a)		Gamma radiation will pass through the patient (and hence can be detected) / beta particles will be absorbed by the patient (and hence cannot be detected)	B1	
			Gamma radiation is not (very) ionising / gamma radiation does little damage to cells / beta particles are (very) ionising / beta particle damage cells	B1	**Allow**: 'Body' in place of 'cells'
	(b)		X-ray tube rotates around (the patient) / X-ray beam passes through the patient at different angles	B1	**Not**: Detector rotates around (the patient)
			A thin X-ray beam is used	B1	
			Image(s) of slice(s) / (cross) section(s) through the patient are taken	B1	
			X-ray tube moves / spirals along (the patient)	B1	**Allow**: Detectors moves / spirals along (the patient)
			The signals / information / pulses / data (from the detectors) are used by the computer (and its software) to produce a 3D image	B1	
			Total	**7**	

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Question			Answer	Marks	Guidance
9	(a)		Change in the frequency / wavelength because of source / 'observer' moving	B1	**Allow**: There is blue / red shift because of relative motion between source and observer
	(b)		Any <u>two</u> from: 1. Ultrasound transducer / device / probe emits and detects ultrasound 2. The transducer / device / probe is placed at an angle (to the artery) 3. Ultrasound is <u>reflected</u> by the blood / cells QWC mark - change in frequency / wavelength (of the reflected ultrasound) is related to speed of blood	B1 × 2 B1	 **Allow**: speed of blood ∝ change in frequency **Allow**: $\Delta f = 2vf\cos\theta/c$, where v is the speed of blood, c = speed of ultrasound; no need to define the other labels **Note**: Do not award this mark if $\Delta f = fv/c$ is used to determine the speed v of the blood
	(c)	(i)	$Z = \rho c$ density = $1.66 \times 10^6/1570$ density = 1060 (kg m^{-3})	 B1	 **Allow**: 1100 (kg m^{-3})
		(ii)	$\lambda = 1570/2.4 \times 10^6$ wavelength = 6.5×10^{-4} (m)	 B1	
	(d)		(fraction of intensity reflected =) $\frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ (fraction of intensity reflected =) $3^2/5^2$ (= 0.36) intensity = 64%	C1 C1 A1	 **Note**: 2 marks for 36% or 0.36
	(e)		Gel is used (between transducer and skin). The acoustic impedance / Z of gel is similar to that for skin hence less <u>reflection</u> (at the skin)	B1 B1	 **Allow**: There is acoustic / impedance matching so less <u>reflection</u> **Allow**: Without the gel, there is large difference between acoustic impedances of air and skin, hence large <u>reflection</u> **Note**: Must have reference to reflection
			Total	**11**	

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Question			Answer	Marks	Guidance
10	(a)		A core / 'star' left behind after a red giant (has shed its outer layers)	B1	**Allow**: It is the core of a red giant **Allow**: It is the remnant of a low-mass star **Allow**: A core / 'star' • supported by Fermi pressure / electron degeneracy (pressure) • with maximum mass of 1.4(4) solar masses / 1.4(4) M_o / Chandrasekhar limit **Not**: It is a collapsing red giant
	(b)		(parallax = 1/*d*) *d* = 0.0059^{-1} (pc = 169 .49 .... pc) distance = $0.0059^{-1} \times 3.26$ distance = 550 ly	 C1 A1	 **Allow** other correct methods
	(c)	(i)	power per (unit) area or power/area	B1	**Allow** 'energy per (unit) area per unit time' **Not**: power per m^2
		(ii)	**1** (density = mass/$\frac{4}{3}\pi r^3 \propto$ mass/r^3) ratio = $\frac{12}{(1.1\times10^5)^3}$ ratio = 9.0×10^{-15} **2** (power = intensity × surface area) power $\propto T^4r^2$ ratio = $\frac{4300^4 \times (1.1\times10^5)^2}{25000^4}$ ratio = 1.1×10^7	 C1 A1 C1 C1 A1	 **Allow**: 9.0×10^{-15} : 1 **Allow**: 1 sf answer of 9×10^{-15} **Note**: Answer to 3 sf is 1.06×10^7 **Allow**: 1.1×10^7 : 1
			Total	**9**	

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Question			Answer	Marks	Guidance
11	(a)		recessional speed / velocity of <u>galaxy</u> is proportional to its distance (from us)	B1	**Allow**: recessional speed of <u>galaxy</u> = Hubble constant × distance
	(b)	(i)	v = 1010 (10^3 m s^{-1}) d in the range 4.47 to 4.54 (10^{23} m)	B1 B1	**Note**: Answer to 4 sf is 1014 (10^3 m s^{-1})
		(ii)	(Straight line drawn through the points gradient = Hubble constant, H_0) gradient = 2.24×10^{-18} (s^{-1}) age = $(2.24 \times 10^{-18})^{-1}$ age = 4.46×10^{17} (s) age = 1.4×10^{10} (y)	 C1 C1 A1	 **Allow**: gradient in the range 2.21 to 2.27 × 10^{-18} **Allow** ecf from incorrect value of the gradient **Allow**: A maximum of 2 marks if values from the table are used instead of the gradient of the line drawn on Fig. 11.2 **Note**: No marks for a bald 14 billion years
	(c)		Big bang: Creation / birth / expansion / evolution of the universe or The universe was very hot / very dense / singularity (at the start) Evidence: Any <u>two</u> from: • Microwave / background radiation / 3 K (or 2.7 K) • Existence of (primordial) helium / lithium / lighter elements • Tiny variation (or ripples) in (background) temperature	B1 B1 × 2	 **Not**: More matter than antimatter / baryonic asymmetry
			Total	**9**	

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Thursday 19 June 2014 – 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 **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 **(a)** Fig. 1.1 shows a negatively charged metal sphere close to a positively charged metal plate.

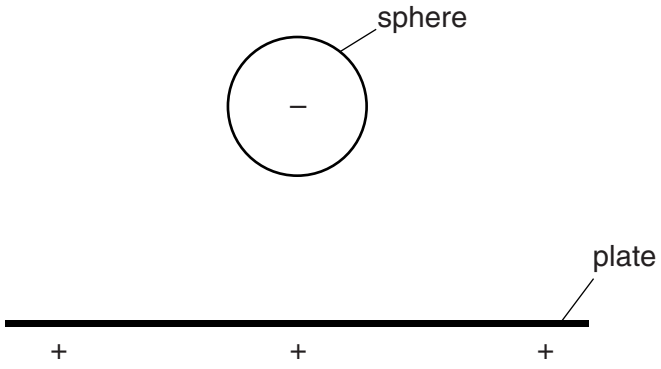


Fig. 1.1

On Fig. 1.1, draw a minimum of five field lines to show the electric field pattern between the plate and the sphere. **[2]**

(b) Fig. 1.2 shows two positively charged particles **A** and **B**.

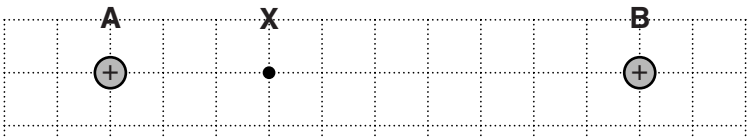


Fig. 1.2



Fig. 1.3

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At point **X**, the magnitude of the **resultant** electric field strength due to the particles **A** and **B** is zero.

(i) State, with a reason, which of the two particles has a charge of greater magnitude.

.....

.....

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

(ii) On Fig. 1.3 sketch the variation of the resultant electric field strength *E* with distance *d* from the particle **A**. **[3]**

(c) Fig. 1.4 shows a stationary positively charged particle.



Fig. 1.4

This particle creates both electric and gravitational fields in the space around it. Explain why the **ratio** of the electric field strength *E* to the gravitational field strength *g* at any point around this charge is independent of its distance from the particle.

.....

.....

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

[Total: 7]

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2 Fig. 2.1 shows the circular path described by a helium nucleus in a region of uniform magnetic field in a vacuum.

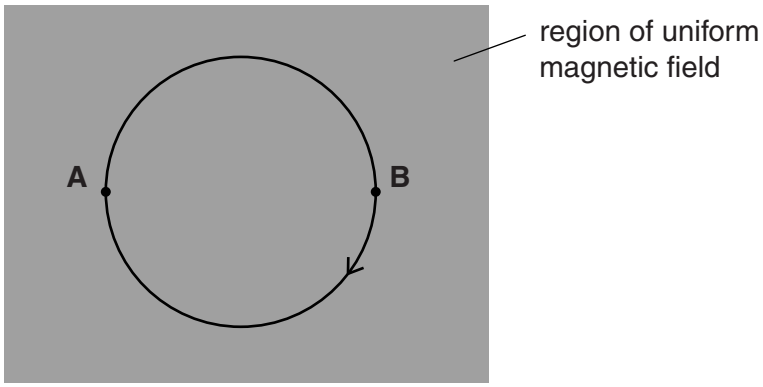


Fig. 2.1

The direction of the magnetic field is perpendicular to the plane of the paper. The magnetic flux density of the magnetic field is 0.20 mT. The radius of the circular path is 15 cm. The helium nucleus has charge + 3.2×10^{-19} C and mass 6.6×10^{-27} kg.

(a) Explain why the helium nucleus

(i) travels in a circular path

.....

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

(ii) has the same kinetic energy at **A** and **B**.

.....

.....

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

(b) Calculate the magnitude of the momentum of the helium nucleus.

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

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(c) Calculate the kinetic energy of the helium nucleus.

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

(d) A uniform electric field is now also applied in the region shaded in Fig. 2.1. The direction of this electric field is from **left** to **right**. Describe the path now followed by the helium nucleus in the electric and magnetic fields.

.....

.....

.....

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

[Total: 9]

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3 **(a)** Deuterium ($^{2}_{1}H$) and tritium ($^{3}_{1}H$) are isotopes of hydrogen.

(i) State **two** features common to all isotopes of hydrogen.

.....

.....

.....

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

(ii) Explain why the total mass of the individual nucleons of a deuterium nucleus is different from the mass of the deuterium nucleus.

.....

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

(b) A fusion reaction between two nuclei is shown below.

$$^{2}_{1}H \quad + \quad ^{3}_{1}H \quad \rightarrow \quad ^{4}_{2}He \quad + \quad ^{1}_{0}n$$

A neutron inside a nucleus is stable. However, a 'free' neutron, when outside the nucleus, undergoes beta decay with a half-life of about 11 minutes.

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

$$^{1}_{0}n \rightarrow \text{.....} + ^{0}_{-1}e + \text{.....}$$ **[2]**

(ii) Explain what is meant by the *half-life* of a free neutron.

.....

.....

.....

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

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(c) For the fusion reaction to occur the separation between the deuterium and tritium nuclei must be less than 10^{-14} m. This means that the average kinetic energy of these hydrogen nuclei needs to be about 70 keV. The energy released by the fusion reaction is 18 MeV.

(i) Calculate the repulsive electrical force between the deuterium and tritium nuclei at a separation of 10^{-14} m.

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

(ii) Assume that a mixture of these hydrogen nuclei behaves as an ideal gas.

Estimate the temperature of the mixture of nuclei required for this fusion reaction.

temperature = ... K **[3]**

(iii) In practice, fusion occurs at a much lower temperature. Suggest a reason why.

.....

.....

.....

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

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(iv) Calculate the change in mass in a single fusion reaction.

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

(v) Fig. 3.1 shows the variation of probability of fusion reaction with temperature T for deuterium and tritium and for deuterium and helium.

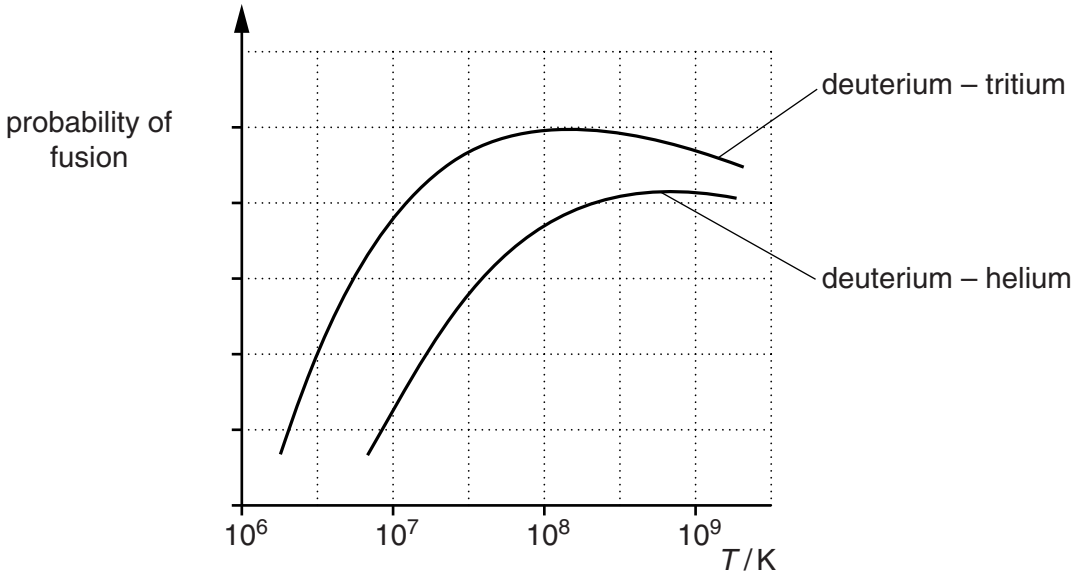


Fig. 3.1

Suggest why the probability of reaction at a given temperature is smaller for deuterium and helium.

.....

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

[Total: 17]

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Question 4 begins on page 10

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4 **(a)** Define the *time constant* of a capacitor-resistor discharge circuit.

.....

.....

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

(b) A student designs a circuit with a time constant of 5.0 s. State suitable values for resistance R and capacitance C for this circuit.

R = ... C = ... **[1]**

(c) Fig. 4.1 shows a circuit with a capacitor of capacitance 0.010 F.

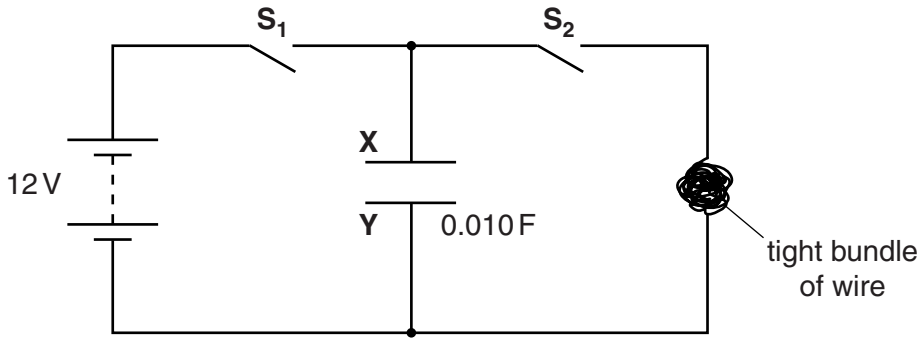


Fig. 4.1

A tight bundle of wire is made from 5.0 m of insulated wire of diameter 0.12 mm and resistivity $4.9 \times 10^{-7}\,\Omega\,m$. The material of the wire has density $8900\,kg\,m^{-3}$ and specific heat capacity $420\,J\,kg^{-1}\,K^{-1}$.

(i) Calculate the time constant of the circuit.

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

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(ii) Switch S_2 is open. Switch S_1 is closed. Explain in terms of the movement of electrons how **X** and **Y** acquire equal but opposite charge.

.....

.....

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.....

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.....

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

(iii) Switch S_1 is opened. The potential difference across the capacitor is 12V. Switch S_2 is now closed. Assume that all the energy stored by the capacitor is used to heat up the bundle of wire. Calculate the increase in the temperature of the bundle of wire.

increase in temperature = ... °C **[4]**

(iv) State and explain how your answer to **(iii)** would change when a 24V power supply is used to carry out the experiment.

.....

.....

.....

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

[Total: 14]

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5 **(a)** State Faraday's law of electromagnetic induction.

.....

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

(b) Fig. 5.1 shows a magnet being moved towards the centre of a flat coil.

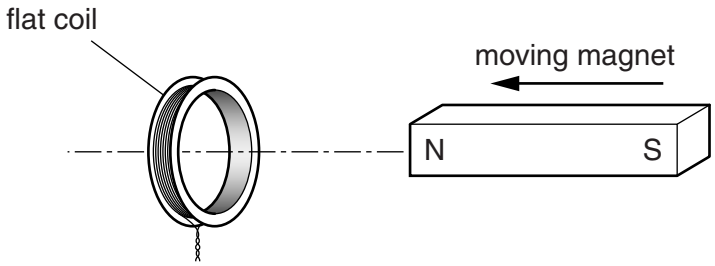


Fig. 5.1

A current is induced in the coil. Use ideas about energy conservation to state and explain the polarity of the face of the coil nearer the magnet.

.....

.....

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

(c) Fig. 5.2 shows the magnetic field from the north pole of a vertically held bar magnet.

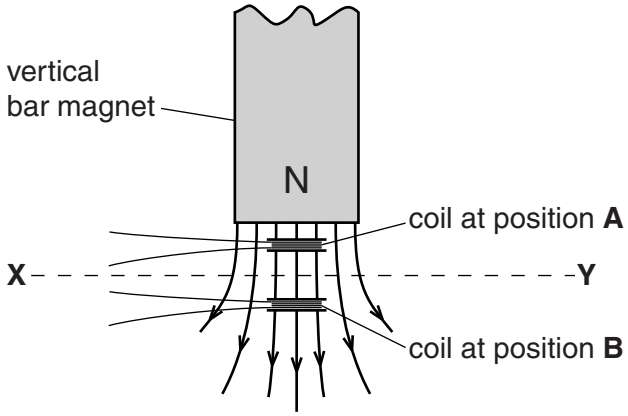


Fig. 5.2

(i) A small flat coil is placed at **A**. The coil is moved downwards from position **A** to position **B**. The plane of the coil remains horizontal between these two positions. Explain why there is no induced e.m.f. across the ends of the coil.

.....

.....

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

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(ii) Fig. 5.3 is a graph showing how the magnetic flux density *B* varies along the horizontal line **XY** in Fig. 5.2.

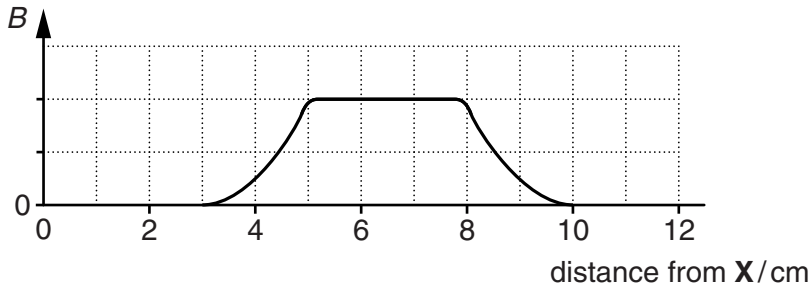


Fig. 5.3

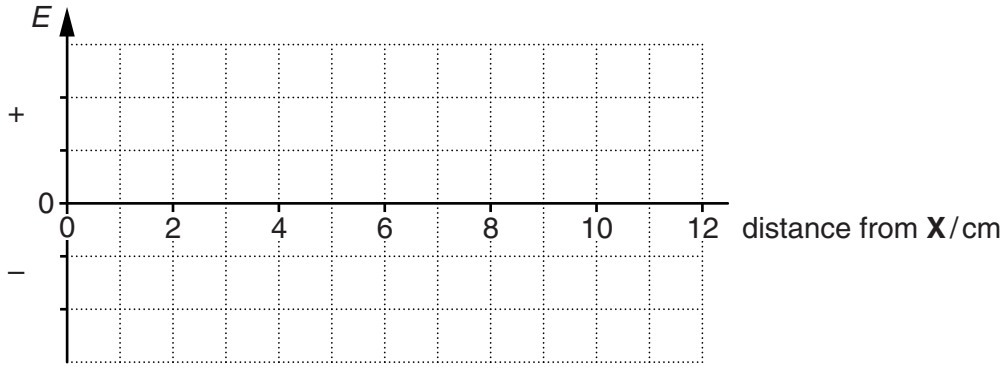


Fig. 5.4

The same small flat coil from **(i)** is moved at a constant speed from **X** to **Y**. The plane of the coil remains horizontal between **X** and **Y**.

On the axis provided in Fig. 5.4, sketch a graph to show the variation of the induced e.m.f. *E* across the ends of the coil with distance from **X**. **[3]**

[Total: 6]

Question 6 begins on page 14

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6 **(a)** Fig. 6.1 shows the quark composition of some particles.

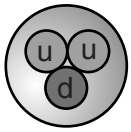
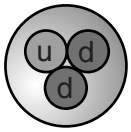
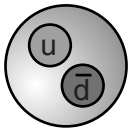
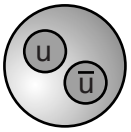
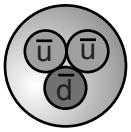
proton	neutron	**A**	**B**	**C**
				

Fig. 6.1

(i) Identify the anti-proton from the table of particles shown in Fig. 6.1.

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

(ii) State the value of the charge of particle **B**.

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

(b) The nuclei of carbon-14 are produced naturally in the upper atmosphere from the reactions of slow-moving neutrons with nitrogen nuclei.

(i) The reaction below shows a nuclear reaction between a neutron and a nitrogen nucleus.

$$^{1}_{0}\text{n} + {}^{14}_{7}\text{N} \rightarrow {}^{14}_{6}\text{C} + \mathbf{X}$$

Identify the particle **X**.

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

(ii) Carbon-14 has a half-life of 5700 years. The molar mass of carbon-14 is $0.014\,\text{kg}\,\text{mol}^{-1}$. The total activity from all the carbon-14 nuclei found on the Earth is estimated to be $1.1 \times 10^{19}\,\text{Bq}$. Estimate the total mass of carbon-14 on the Earth.

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

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(c) Energy in the core of a nuclear reactor is produced by induced nuclear fission of uranium-235 nuclei. Explain what is meant by *induced nuclear fission*.

.....

.....

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

(d) Many nuclear reactors use uranium-235 as fuel. Some of these reactors use water as both coolant and moderator. The control rods contain boron-10. Fig. 6.2 shows part of the inside of the core of a nuclear reactor.

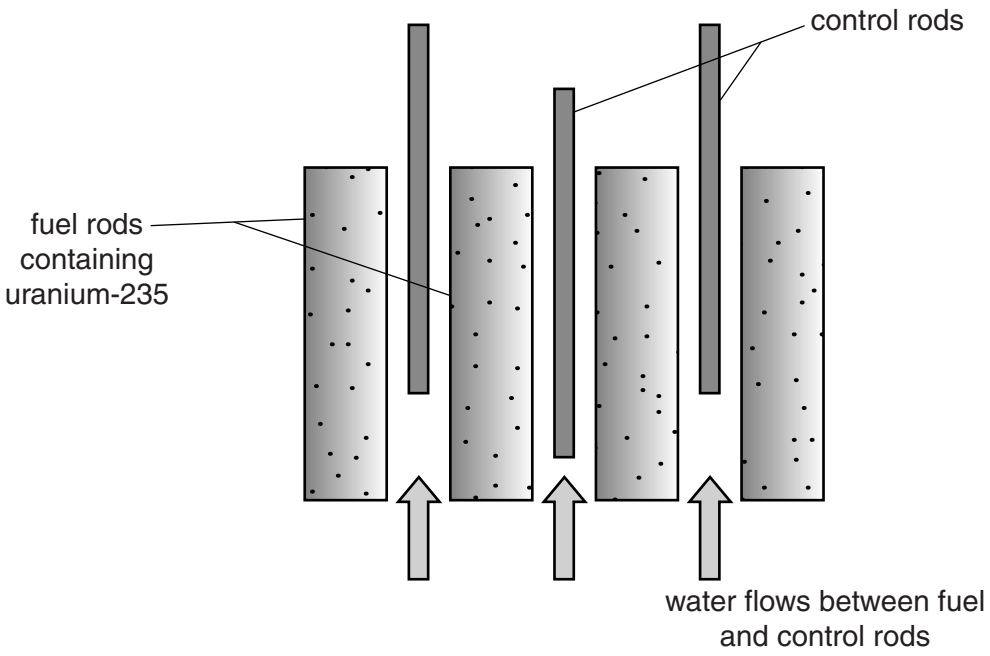


Fig. 6.2

Explain the purpose of using a moderator and control rods in the core of a nuclear reactor.

In your answer you should make clear how a moderator works at a microscopic level.

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.....

.....

..... **[4]**

[Total: 12]

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7 **(a)** X-rays are produced in an X-ray tube when fast moving electrons hit a metal target.

Fig. 7.1 shows a typical graph of intensity I against wavelength λ of X-rays emitted by an X-ray tube.

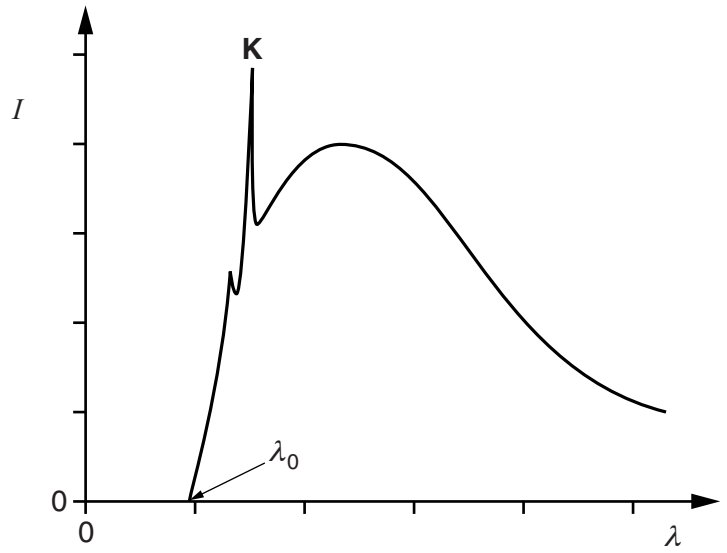


Fig. 7.1

High-speed electrons colliding with the atoms in the target metal can remove electrons from these atoms. The removal of such electrons creates 'gaps' in the lower energy levels of these atoms. These gaps are quickly filled by electrons in the higher energy levels making transitions to these lower energy levels. The electrons lose energy which is released as photons with particular wavelengths. These emission spectral lines are shown by the high intensity peaks such as **K** shown in Fig. 7.1.

Fig. 7.2 shows three of the energy levels, **A**, **B** and **C**, for the metal atoms of the target. The electron transition shown produces the peak **K**.

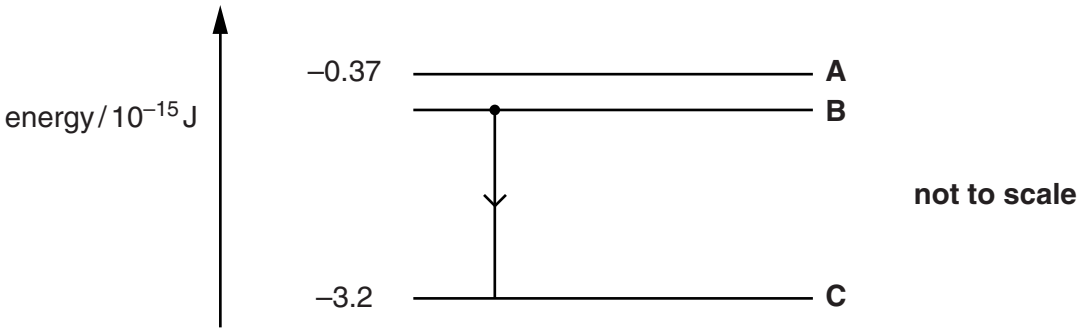


Fig. 7.2

(i) Explain what is meant by an *energy level* of an atom.

.....

.....

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

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(ii) The peak **K** occurs at a wavelength of 7.2×10^{-11} m. Calculate the value of the energy level **B**.

value of energy level = ... J **[3]**

(iii) In Fig. 7.1, the shortest wavelength λ_0 produced from an X-ray tube depends on the accelerating potential difference V. The maximum kinetic energy of a single accelerated electron is equal to the energy of a single X-ray photon of wavelength λ_0. Explain how λ_0 from the X-ray tube changes when the accelerating potential difference of the X-ray tube is **doubled**.

.....

.....

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

(b) X-rays are used to scan the human body. A parallel beam of X-rays is incident on a muscle. The attenuation (absorption) coefficient μ for X-rays in muscle is $0.96\,\text{cm}^{-1}$.

(i) Calculate the fraction of X-ray intensity **absorbed** by 2.3 cm of muscle.

fraction = ... **[3]**

(ii) The attenuation coefficients for X-rays in bone and fat are $2.8\,\text{cm}^{-1}$ and $0.90\,\text{cm}^{-1}$ respectively. Two X-ray images are taken, one with bone and muscle and another with muscle and fat. State and explain which image will give better contrast.

.....

.....

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

[Total: 10]

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8 **(a)** Fig. 8.1 shows a B-scan image of an ultrasound scan of a 12 week foetus.



Fig. 8.1

The outline of the head of the foetus can be seen in Fig. 8.1. Describe and explain the principles of a B-scan.

In your answer you should make clear how it is possible to distinguish the boundaries between different materials.

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

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(b) Fig. 8.2 shows an image of the brain using a positron emission tomography (PET) scanner.

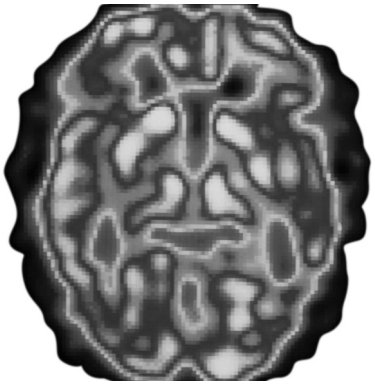


Fig. 8.2

The lighter regions in Fig. 8.2 show the active areas of the brain. Fluorine-18 is a common tracer injected into a patient before a PET scan.

Explain the basic principles of PET scanning, including how the image is formed.

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..... **[4]**

[Total: 7]

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9 Sirius A and B are binary stars in our galaxy at a distance of 8.6 ly from the Sun. Sirius B is a white dwarf of diameter 12 km and mass 2.0×10^{30} kg.

(a) Calculate the density of Sirius B.

density = ... unit ..... **[3]**

(b) The mass of the Sun is the same as Sirius B. The Sun has a diameter of 1.4×10^{9} m.

Calculate the ratio

$$\frac{\text{gravitational field strength on the surface of Sirius B}}{\text{gravitational field strength on the surface of the Sun}}.$$

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

(c) Calculate the parallax angle in arc seconds for Sirius B.

$1\,\text{pc} = 3.1 \times 10^{16}\,\text{m}$

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

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(d) Sirius A is moving towards the Earth at a relative velocity of $7600\,m\,s^{-1}$. Calculate the percentage change in the wavelength of a spectral line observed from this star compared with an identical spectral line observed in the laboratory.

percentage change = ... % **[2]**

(e) A student suggests that the distance of Sirius A can be calculated using Hubble's law and the speed given in **(d)**. Discuss whether this suggestion is correct or incorrect.

.....

.....

.....

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

[Total: 10]

Question 10 begins on page 22

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10 (a) State the *cosmological principle*.

.....

.....

.....

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

(b) State some of the properties of the microwave background radiation observed from the Earth. Discuss how the background microwave radiation is linked to the big bang model of the universe.

.....

.....

.....

.....

.....

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

(c) Calculate the age of our universe in years based on a critical density of the universe of $9.7 \times 10^{-27}\,\text{kg}\,\text{m}^{-3}$.

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

[Total: 8]

END OF QUESTION PAPER

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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.

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OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **G485**: Fields, Particles and Frontiers of Physics

Advanced GCE

Mark Scheme for June 2014

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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1. These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation	Meaning of annotation
BP	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
	correct response
	incorrect response
BOD	benefit of the doubt (where professional judgement has been used)
NBOD	benefit of the doubt **not** given
ECF	error carried forward
^	information omitted
CON	contradiction (in cases where candidates contradict themselves in the same response)
FT	follow through
SF	error in number of significant figures
POT	error in the power of 10 in calculation
AE	arithmetic or calculation error
NAQ	not answered question
?	wrong physics
RE	reading error

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Abbreviations, annotations and conventions used in the detailed Mark Scheme.

/	=	alternative and acceptable answers for the same marking point
(1)	=	separates marking points
allow	=	answers that can be accepted
not	=	answers which are not worthy of credit
reject	=	answers which are not worthy of credit
ignore	=	statements which are irrelevant
( )	=	words which are not essential to gain credit
__	=	underlined word (or the equivalent) must be present in answer to score a mark
ecf	=	error carried forward
AW	=	alternative wording
ora	=	or reverse argument

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Subject-specific Marking Instructions

CATEGORISATION OF MARKS
The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures*:

If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.

Any exception to this rule will be mentioned in the Guidance.
(***Note**: Significant figures are thoroughly assessed in G483 and G486 components of Physics A.)

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Question			Answers	Marks	Guidance
1	(a)		Correct direction of the electric field. A minimum of 5 field lines shown. Correct shape of field lines.	B1 B1	 Expect a minimum of 3 field lines to be normal (by eye) to the plate - ignore the angles made by the field lines at the sphere. Also there must not be any field lines within the sphere.
	(b)	(i)	($E \propto Q/r^2$ and the magnitude of E is the same due to each charge **A** and **B** at **X**. Therefore) **B** has a greater charge because **X** is further away from **B**.	B1	
		(ii)	Curve showing $E = 0$ at position of **X**. Curve showing E is positive between **A** and **X** and negative between **X** and **B** (or vice versa). The magnitude of E is small close to **A** and large close to **B**.	B1 M1 A1	**Allow** any graph, including a straight line. Tolerance for $E = 0$: $\pm$ ½ large square about **X.** **Note**: The curve must be continuous and pass through position of **X**. Ignore any curve to the right of **B** and to the left of **A**. **Note**: This mark can only be scored if the previous M1 has been awarded.
	(c)		Both E and g vary with 1/distance^2. (Hence the ratio is independent of the distance.)	B1	**Allow**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ and $g = \frac{GM}{r^2}$ **or** $E \propto \frac{1}{r^2}$ and $g \propto \frac{1}{r^2}$ **Allow** 'both are inverse square laws'.
			Total	**7**	

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Question			Answers	Marks	Guidance
2	(a)	(i)	A (constant) force acts at right angles to the velocity / motion (of the helium nucleus).	B1	**Note**: The answer must be in terms of force and not acceleration. **Allow** 'force is towards the centre of the circle'. **Not** 'there is a *centripetal* force' - unless explained. **Not** 'force is right angles to speed'.
	(a)	(ii)	No work done (by the force) / no acceleration in the direction of motion / no force in direction of motion	B1	**Allow** force / acceleration is at right angles to velocity / motion.
	(b)		$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.20 \times 10^{-3} \times 3.2 \times 10^{-19} \times 0.15$ momentum = 9.6×10^{-24} (kg m s^{-1})	C1 C1 A1	**Allow** $v = 1.45.. \times 10^3$ (m s^{-1}); $p = 1.45.. \times 10^3 \times 6.6 \times 10^{-27}$
	(c)		$v = 9.6 \times 10^{-24}/6.6 \times 10^{-27}$ or $v = 1.45... \times 10^3$ (m s^{-1}) KE = ½ $\times$ $6.6 \times 10^{-27} \times (1.45... \times 10^3)^2$ KE = 7.0×10^{-21} (J)	C1 A1	Possible ecf from **(b)** **Allow** 1 sf answer **Alternative**: ($E = p^2/2m$); KE = $\frac{(9.6\times10^{-24})^2}{2\times6.6\times10^{-27}}$ C1 KE = 7.0×10^{-21} (J) A1
	(d)		The helium nucleus moves to the right. The path is a clockwise curve / looped (in the plane of the paper).	B1 B1	**Not** if the path is shown as a straight line. **Allow** 2 marks for clockwise curve / loop to the right. **Allow** 1 mark for a sketch showing an 'upward curve to the right'
			Total	**9**	

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Question			Answers	Marks	Guidance
3	(a)	(i)	One proton / (same) charge / (same) element and (same) chemical property / one electron	B1	**Allow** (same) number of protons. **Allow** (same) number of electrons.
		(ii)	mass of nucleus < (total) mass of nucleons Energy must be supplied to the nucleus to free the nucleons / energy released when nucleons combine (to form the nucleus). $(\Delta)E = (\Delta)mc^2$ and $(\Delta)E$ is the (binding) energy and $(\Delta)m$ is the mass defect or the difference in mass.	B1 B1 B1	 **Allow** nucleus has binding energy.
	(b)	(i)	${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e} + \bar{\nu}_{(e)}$	B1,B1	**Allow** proton or ${}^{1}_{1}\text{H}$ or H^+ or p and (electron) antineutrino.
		(ii)	(Average) time taken for half of the neutrons (in a sample) to decay.	B1	**Note**: Must have reference to 'half' and 'neutrons' **Allow** 'the time taken for the activity of neutrons to halve'.
	(c)	(i)	$F = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(10^{-14})^2}$ force = 2.3 (N)	C1 A1	**Not** $Q = q = 1$
		(ii)	$E = 7.0\times10^4\times1.6\times10^{-19}$ (= 1.12 × 10^{-14} J) ($E = \frac{3}{2}kT$); $7.0\times10^4\times1.6\times10^{-19} = \frac{3}{2}\times1.38\times10^{-23}\times T$ temperature = 5.4 × 10^8 (K)	C1 C1 A1	 **Allow** any subject. Also, allow $E \approx kT$ since it is an estimate. **Allow** 1 sf answer.
		(iii)	Some nuclei will be travelling faster / have greater (kinetic) energy (to overcome electrostatic repulsion and hence cause fusion).	B1	**Allow** the pressures are high (enough to cause fusion). **Not** 'nuclei get close enough'.
		(iv)	($\Delta E = \Delta mc^2$); $18\times10^6\times1.6\times10^{-19} = \Delta m\times(3.0\times10^8)^2$ change in mass = 3.2 × 10^{-29} (kg)	C1 A1	**Allow** any subject **Allow** a maximum of 1 mark for 18MeV ± 70 keV.
		(v)	Helium (nucleus) has greater charge / more protons. The (electrostatic) repulsive force (between the deuterium and helium nuclei) is greater (hence smaller chance of fusion).	B1 B1	 Do **not** award this mark if 'helium nuclei are moving slower' is also given as the reason for smaller probability for fusion.
			Total	**17**	

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Question			Answers	Marks	Guidance
4	(a)		The time taken for the p.d / current / charge to decrease to 1/*e* of its (initial) value.	B1	**Allow** 37% instead of 1/*e*. **Not** time constant = *CR* on its own.
	(b)		Any suitable values with units, eg: 5 MΩ and 1 μF.	B1	
	(c)	(i)	$R = \frac{4.9\times10^{-7}\times5.0}{\pi\times(0.06\times10^{-3})^2}$ or R = 217 (Ω) time constant = 0.010 × 217 time constant = 2.2 (s)	C1 C1 A1	**Note**: An incorrect equation here for *A* prevents this and any subsequent marks. **Allow** 2 marks for 0.54 (s) – diameter of 0.12 mm used instead of radius 0.06 mm.
		(ii)	Electrons are removed from **X** or electrons are deposited on **Y**. **X** becomes positive or **Y** becomes negative (The size of charge is the same because) an equal number of electrons are removed and deposited (on the plates).	B1 B1 B1	**Allow** electrons move anticlockwise (in the circuit). There is no ecf from the previous B1 mark.
		(iii)	E = ½ × 0.010 × 12^2 or E = 0.72 (J) m = 8900 × [π × (0.06 × 10^{-3})^2 × 5.0] or 5.0(3) × 10^{-4} (kg) 5.03 × 10^{-4} × 420 × $\Delta\theta$ = 0.72 increase in temperature = 3.4 (°C)	C1 C1 C1 A1	**Note**: An incorrect equation here for *m* or *V* prevents this and any subsequent marks. Correct substitution into $mc\Delta\theta$ = 0.72; **allow** any subject. **Note**: Do not penalise using diameter here again if already penalised in **(c)(i)**.
		(iv)	Energy or V^2 increases by a factor of 4. The (change in temperature) increases by a factor of 4 (because $\Delta\theta \propto E$).	B1 B1	**Allow** the label *E* or *W* for energy. **Allow** $\Delta\theta$ = 13.6 (°C) for this B1 mark - possible ecf from **(iii)**.
			Total	**14**	

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Question			Answers	Marks	Guidance
5	(a)		The induced e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage.	B1	**Allow** $E = \frac{\Delta\Phi}{\Delta t}$ with all terms defined; E = induced e.m.f., Φ = (magnetic) flux linkage and t = time.
	(b)		North / N (pole). There is a repulsive force (between magnet and coil and the work done against this repulsive force is transferred to electrical energy in the coil).	B1	**Allow** - A south (pole) would cause attraction (between the coil and magnet) or there is gain in KE (of magnet which cannot happen hence it must be north pole).
	(c)	(i)	There is no change in (magnetic) flux (linkage) or there is no change in the (magnetic) flux density.	B1	**Allow** 'no change in (magnetic) field strength'.
		(ii)	E = 0 between 0 to 3 cm, 5 – 8 cm and 10 - 12 cm. Two 'pulses' where B is changing. The pulses have opposite signs.	B1 M1 A1	Tolerance: ± ¼ large square **Note**: The pulses must have E = 0 at 3 cm, 5 cm, 8 cm and 10 cm; tolerance ± ¼ large square.
			Total	**6**	

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Question			Answers	Marks	Guidance
6	(a)	(i)	**C**	B1	
		(ii)	Zero	B1	
	(b)	(i)	proton / ${}^{1}_{1}\mathrm{H}$ / ${}^{1}_{1}\mathrm{p}$ / p	B1	
		(ii)	$\lambda = \frac{0.693}{5700 \times 3.16 \times 10^{7}}$ or $\lambda = 3.847... \times 10^{-12}$ (s^{-1})	C1	
			$(A = \lambda N)$; $N = \frac{1.1 \times 10^{19}}{3.847... \times 10^{-12}}$ or $N = 2.859.. \times 10^{30}$	C1	**Allow** any subject **Allow** ecf within the calculation for an incorrect λ.
			mass = $\frac{2.859... \times 10^{30}}{6.02 \times 10^{23}} \times 0.014$		
			mass = $6.649... \times 10^{4}$ (kg) or 6.6×10^{4} (kg)	A1	**Allow** 6.7×10^{4} (kg)
	(c)		A (thermal / slow-moving) neutron splits the <u>nucleus</u> into two (smaller) nuclei	B1	**Allow** 'fast neutron'; **allow** 'decays' instead of 'splits'. **Not** 'splitting the atom'. **Not** 'particles' or 'fragments' in place of '(smaller) nuclei'.
			and (fast-moving) neutron(s).	B1	
	(d)		Any **three** from: 1. Fission reactions produce fast neutrons. 2. The moderator / water slows down (the fast-moving) neutrons. 3. Slow-moving neutrons have a greater chance of causing fission (of U-235). (ora) 4. The control rods absorb (some of the) neutrons. 5. (On average) one neutron survives between successive (fission) reactions.	B1×3	**Allow** boron / cadmium instead of control rods in 4. **Not** graphite for 4.
			QWC: The neutrons make collisions with the (moderator) nuclei <u>and</u> transfer (some of) their (kinetic) energy.	B1	**Allow** atoms / molecules instead of nuclei.
			Total	**12**	

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Question			Answers	Marks	Guidance
7	(a)	(i)	Discrete energy (of electrons in an atom) / quantised energy (of electrons in an atom) / permitted energy (states of electrons in an atom).	B1	
		(ii)	($E = \frac{hc}{\lambda}$) $E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{7.2\times10^{-11}}$ or $E = 2.763 \times 10^{-15}$ (J) value of energy level = - (3.2 - 2.763) $\times 10^{-15}$ (J) value of energy level = - 4.4 $\times 10^{-16}$ (J)	C1 C1 A1	**Note**: The answer must be negative to score the A1 mark **Note:** 4.4 $\times 10^{-16}$ (J) scores 2 marks
		(iii)	(λ_0 is) halved. Explanation: Reference to (photon / electron kinetic) energy doubled and E = hc/λ or $E \propto 1/\lambda$.	M1 A1	**Allow** explanation in terms of $eV = hc/\lambda$.
	(b)	(i)	($I = I_0 e^{-\mu x}$) fraction transmitted = $e^{-(0.96\times2.3)}$ fraction transmitted = 0.11 fraction absorbed or scattered = 1 – 0.11 fraction absorbed or scattered = 0.89	C1 C1 A1	**Allow** 3 marks for 89%. **Allow** 89/100
		(ii)	Bone and muscle have different (values for) μ hence better contrast. or Muscle and fat have similar (values for) μ hence poor contrast.	B1	
			Total	**10**	

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Question			Answers	Marks	Guidance
8	(a)		Ultrasound reflected at boundary (between materials). B-scan takes place in different directions. QWC: The intensity of the reflected ultrasound depends on the acoustic impedances of the materials (and this is greater when the difference between the acoustic impedances is greater).	B1 B1 B1	**Allow** B-scan is 'multiple A-scans'. **Allow** *Z* instead of acoustic impedance. **Not** attenuation coefficient for *Z*.
	(b)		Any **four** from: 1. The brain / body is surrounded by a ring of (gamma) detectors /gamma camera(s). 2. The positrons (from the F-18 nuclei) annihilate electrons. 3. The annihilation of a positron and an electron produces two (identical gamma) photons travelling in opposite directions. 4. The delay time between these two photons / gamma rays is used to determine the location of the annihilation / F-18 / tracer. 5. Computer connected to detectors / gamma camera and an image is formed by the computer (using the electrical signals from the detectors).	B1×4	**Not** positron**s** and electron**s** annihilate to produce photons travelling in opposite directions for 3. **Allow** an answer in terms of arrival times.
			Total	**7**	

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Question			Answers	Marks	Guidance
9	(a)		$V = \frac{4}{3}\pi \times (6\times10^3)^3$ or $V = 9.05 \times 10^{11}$ (m^3) density = $\frac{2.0\times10^{30}}{\frac{4}{3}\pi\times(6\times10^3)^3}$ density = 2.2×10^{18} kg m^{-3}	C1 C1 A1	**Note**: An incorrect equation here for *V* prevents this and any subsequent marks. The correct unit must also be included to score this A1 mark. **Allow** 2 marks for 2.76.... $\times 10^{17}$ kg m^{-3} – 12 km used instead of 6 km for the radius.
	(b)		$g \propto 1/r^2$ ratio = $\left(\frac{1.4\times10^9}{12\times10^3}\right)^2$ or ratio = $\left(\frac{0.7\times10^9}{6\times10^3}\right)^2$ ratio = 1.4×10^{10}	C1 A1	**Note**: The answer to 3 sf is 1.36×10^{10}. **Allow** 1 mark for 7.3×10^{-11} – inverse of the ratio.
	(c)		($p = 1/d$) $d = \frac{8.6\times9.5\times10^{15}}{3.1\times10^{16}}$ (pc) or $d = 2.64$ (pc) $p = 0.38$ (arc seconds)	C1 A1	**Allow** full credit for alternative methods.
	(d)		$(\frac{\Delta\lambda}{\lambda} = \frac{v}{c})$ fractional change = $\frac{7600}{3.0\times10^8}$ percentage change = 2.5×10^{-3} %	C1 A1	**Allow** 1 mark for 2.5×10^{-5} (factor of 100 missed out).
	(e)		The suggestion is incorrect because Hubble's law applies to (distant receding) galaxies. or The suggestion is incorrect because Hubble's law does not apply to stars in our own galaxy.	B1	Do **not** allow this mark if 'Sirius / star is moving towards us' is also included.
			Total	**10**	

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Question			Answers	Marks	Guidance
10	(a)		The universe is homogeneous. and isotropic (on a large scale).	B1 B1	
	(b)		The intensity of the microwaves is the same in all directions. These microwaves correspond to a temperature of 2.7 K or The temperature of the universe is 2.7 K. The expansion of the universe following the big bang led to cooling and hence we observe microwaves rather than short wavelength e.m. waves / gamma waves.	B1 B1 B1	**Allow** the microwave (background radiation) is isotropic. **Allow** 3 K **Allow** - The short e.m. / gamma waves during the early stages of the universe have been 'stretched out' / 'red-shifted' to microwaves by the expansion.
	(c)		$(\rho = \frac{3H_0^{\,2}}{8\pi G})$ $H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 9.7 \times 10^{-27}}{3}}$ $H_0 = 2.328 \times 10^{-18}$ (s^{-1}) (age = $1/H_0$) age = $\frac{1}{2.328 \times 10^{-18}}$ or age = 4.3×10^{17} (s) age = 1.4×10^{10} (y)	C1 C1 A1	**Allow** any subject Answer to 3 sf is 1.36×10^{10} (y)
			Total	**8**	

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RECOGNISING ACHIEVEMENT

Thursday 13 June 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

* G 4 8 5 0 1 *

* G 4 1 1 8 3 0 6 1 3 *

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 page(s) 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 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.
- You may use an electronic calculator.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 **(a)** Fig. 1.1 shows an arrangement of capacitors.

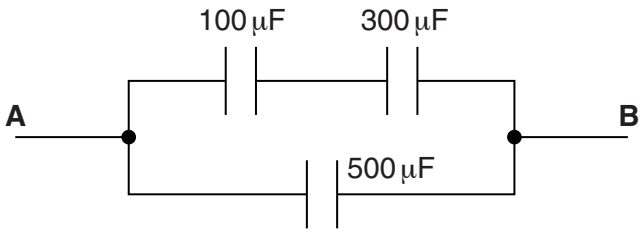


Fig. 1.1

Determine the total capacitance between **A** and **B**.

capacitance = ... μF **[2]**

(b) A capacitor of capacitance 500 μF is charged to 6.0 V. A student places her thumb and first finger across the terminals of the capacitor as shown in Fig. 1.2. This provides a high resistance path across the terminals of the capacitor causing it to discharge.

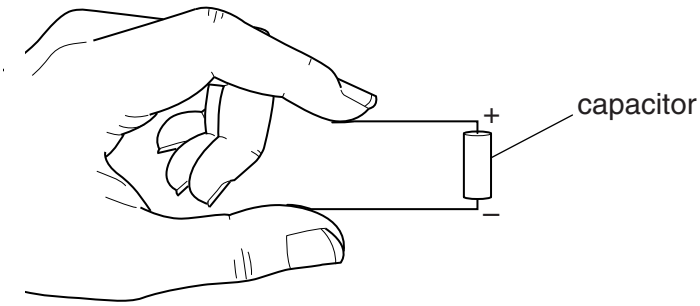


Fig. 1.2

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Fig. 1.3 shows the variation of potential difference V across the capacitor with time t.

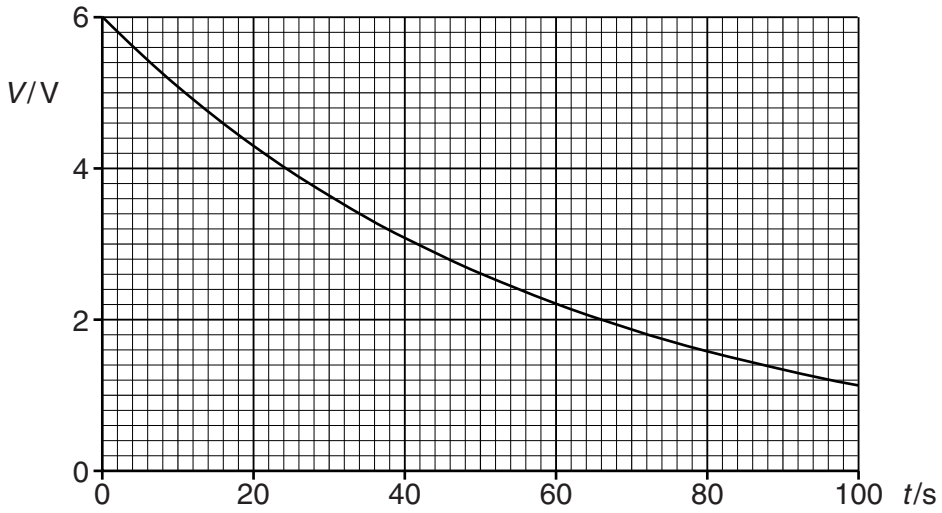


Fig. 1.3

(i) Use Fig. 1.3 to calculate the resistance across the terminals of the capacitor.

resistance = ... Ω **[3]**

(ii) Calculate the energy lost by the capacitor from time $t = 0$ to $t = 30$ s.

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

[Total: 8]

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2 Fig. 2.1 shows two identical negatively charged conducting spheres.

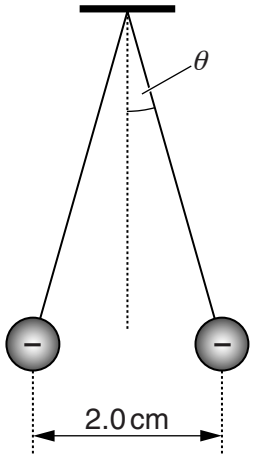


Fig. 2.1

The spheres are tiny and each is suspended from a nylon thread. Each sphere has mass 6.5×10^{-5} kg and charge -2.8×10^{-9} C. The separation between the centres of the spheres is 2.0 cm.

(a) Calculate the number of excess electrons on the surface of each sphere.

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

(b) Calculate the repulsive electrical force acting on each sphere.

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

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(c) (i) Each sphere is in equilibrium and experiences three forces. One of the forces acting on each sphere is the electrical force. State the other **two** forces acting on each sphere.

.....

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

(ii) Use your knowledge of vectors to determine the angle θ made by each thread with the vertical.

θ = ...° **[3]**

[Total: 7]

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3 Fig. 3.1 shows an arrangement used to accelerate electrons.

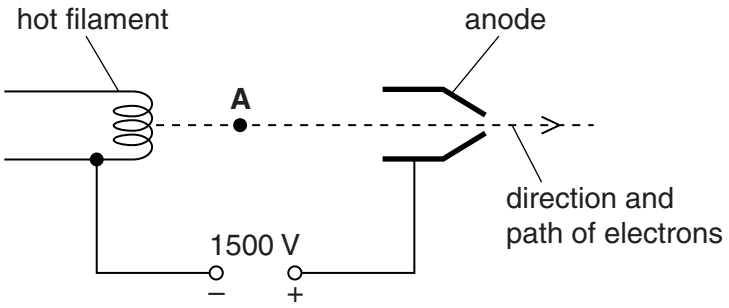


Fig. 3.1

(a) Draw an arrow on Fig. 3.1 to show the direction of the electric field at point **A**. **[1]**

(b) The potential difference between the filament and the anode is 1500V. The speed of an electron at the filament is negligible.

(i) Determine the kinetic energy in electronvolts (eV) of an electron at the anode.

kinetic energy = ...eV **[1]**

(ii) Calculate the speed v of an electron at the anode.

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

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(c) The electrons from the arrangement shown in Fig. 3.1 enter a region of space occupied by both uniform electric and magnetic fields, as shown in Fig. 3.2.

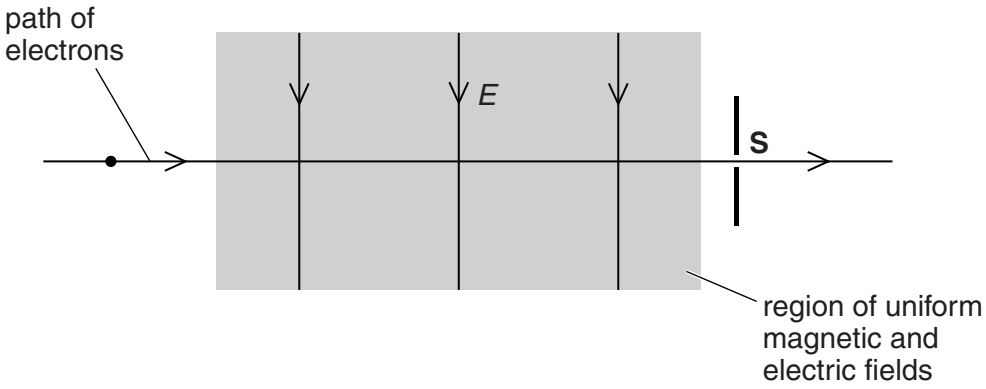


Fig. 3.2

The electric field strength of the electric field is E and its direction is shown in Fig. 3.2. The magnetic flux density of the magnetic field is B. The direction of the magnetic field is perpendicular to E and directed into the plane of the paper. B is increased until all the electrons pass through the slit **S** at a particular speed v. The path of the electrons is now horizontal as shown.

(i) Derive an expression for v in terms of E and B.

[2]

(ii) The magnetic flux density is increased further. The electric field strength is unchanged. Describe and explain what happens to the path of the electrons.

.....

.....

.....

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

[Total: 9]

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

.....

.....

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

(b) Fig. 4.1 shows a solenoid connected to a battery and the magnetic field through it when the switch **S** is closed.

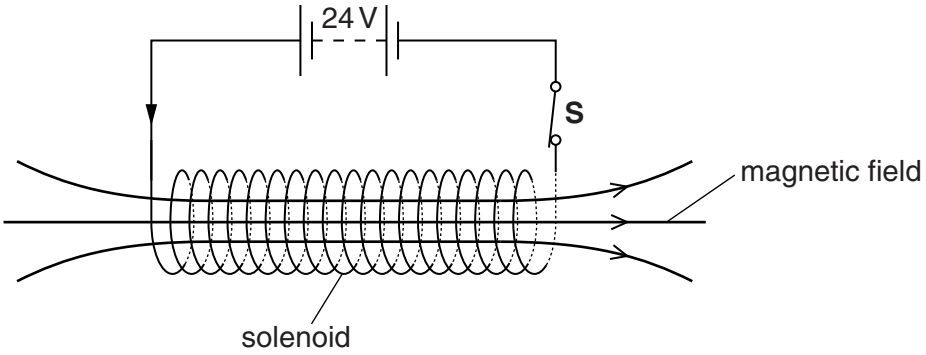


Fig. 4.1

(i) The battery has an e.m.f. of 24 V and negligible internal resistance. The solenoid is made from copper wire. The wire has radius 4.6×10^{-4} m and total length 130 m. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega$ m. Calculate the current in the solenoid.

current = ... A **[3]**

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(ii) A tiny electrical spark is created between the contacts of the switch **S** as it is opened. The spark is produced because an e.m.f. is induced across the ends of the solenoid by the collapse of the magnetic flux linked with the solenoid.

The initial magnetic flux density within the solenoid is 0.090T and may be assumed to be uniform. The solenoid has 1100 turns and cross-sectional area $1.3 \times 10^{-3}\,m^2$.

The average e.m.f. induced across the ends of the solenoid is 150V. Estimate the time taken for the magnetic flux to collapse to zero.

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

[Total: 7]

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5 **(a)** The diameter of a nucleus is about 10^{-14} m.

(i) Complete the sentence below.

The diameter of a nucleus is ..... times smaller than the diameter of an atom. **[1]**

(ii) Very high-energy electrons are diffracted by the nucleus when they have a wavelength similar to the nuclear diameter.

1 Estimate the momentum of an electron with a de Broglie wavelength equal to the diameter of a nucleus.

momentum = ... kg m s^{-1} **[2]**

2 Suggest why the speed of these electrons cannot be calculated by dividing the answer to **(ii)1** by the mass 9.11×10^{-31} kg.

.....

.....

.....

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

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(b) The table of Fig. 5.1 shows some of the isotopes of phosphorus and, where they are unstable, the type of decay.

Isotope	$^{29}_{15}P$	$^{30}_{15}P$	$^{31}_{15}P$	$^{32}_{15}P$	$^{33}_{15}P$
Type of decay	β^+	β^+	stable	β^-	β^-

Fig. 5.1

(i) State the difference between each of the isotopes shown in the table.

.....

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

(ii) Describe the structure of the proton in terms of up (u) and down (d) quarks.

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

(iii) Describe what happens in a beta-plus (β^+) decay using a quark model.

.....

.....

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

(iv) State **two** quantities conserved in a beta decay.

.....

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

(v) Examine the table of isotopes in Fig. 5.1 and suggest what determines whether an isotope emits β^+ or β^-.

.....

.....

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

[Total: 10]

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6 **(a)** Explain what is meant by the statement below.

Radioactivity is a random process.

.....

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

(b) Uranium-235 was present during the formation of the Solar System, including the Earth. The percentage of the original quantity of $^{235}_{92}U$ found in rocks today is 1.1%. The half-life of $^{235}_{92}U$ is 7.1×10^8 years. Calculate the age, in years, of the Earth.

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

(c) Fig. 6.1 shows the variation of binding energy per nucleon against nucleon number *A*.

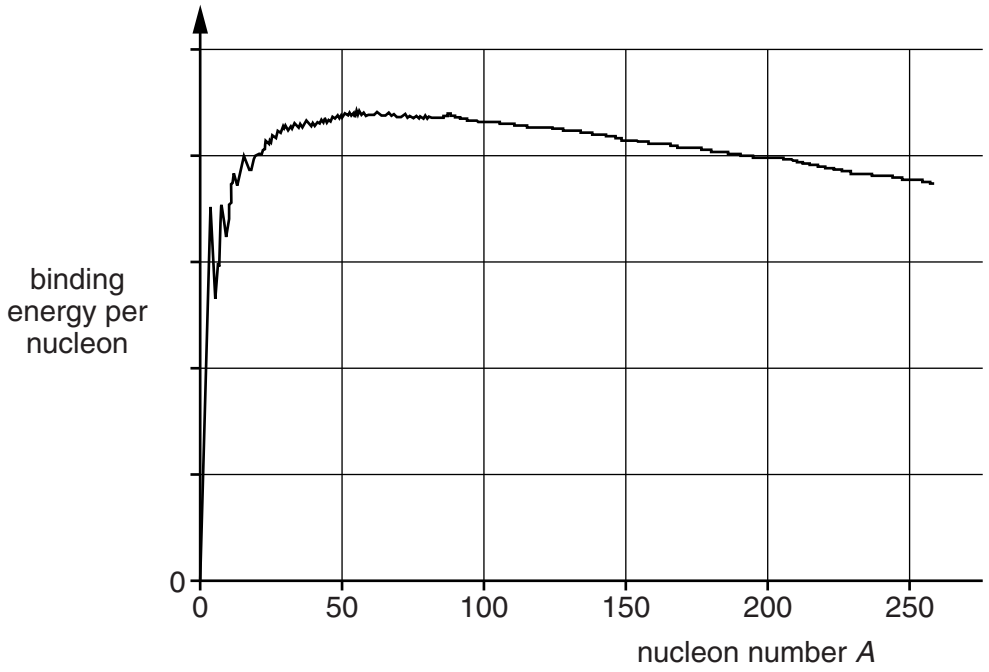


Fig. 6.1

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(i) Use Fig. 6.1 to estimate the value of the nucleon number of the most stable isotope.

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

(ii) Use Fig. 6.1 to explain why nuclei of $^{100}_{42}Mo$ cannot produce energy by **fusion**.

.....

.....

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

(iii) The mass of a $^{8}_{4}Be$ nucleus is 1.329×10^{-26} kg. Use data provided on the second page of the Data, Formulae and Relationships Booklet to determine the binding energy per nucleon for this nucleus.

binding energy per nucleon = ... J **[4]**

[Total: 10]

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7 **(a)** State **two** main properties of X-ray photons.

.....

.....

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

(b) Fig. 7.1 shows an X-ray photon interacting with an atom to produce an electron-positron pair in a process known as pair production.

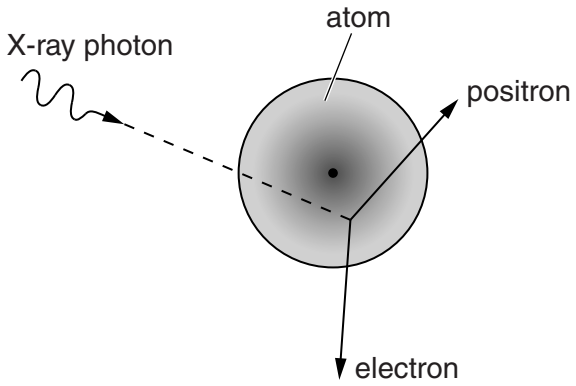


Fig. 7.1

Calculate the maximum wavelength of X-rays that can produce an electron-positron pair.

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

(c) Name an element used as a contrast material in X-ray imaging. Explain why contrast materials are used in the diagnosis of stomach problems.

.....

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.....

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

[Total: 8]

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8 Technetium-99m is a common medical tracer injected into patients before they have a scan with a gamma camera. Technetium-99m is a gamma emitter with a half-life of about 6 hours. Each gamma ray photon has energy 2.2×10^{-14} J.

A patient is given a dose with an initial activity of 500 MBq.

(a) Explain what is meant by *activity*.

.....

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

(b) Calculate the initial rate of energy emission from the dose of technetium-99m.

rate of energy emission = ... $J\,s^{-1}$ **[2]**

Question 8 continues on page 16

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(c) Name and describe the function of the main components of a gamma camera.



In your answer you should make clear how a good quality image can be achieved with these components.

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

[Total: 8]

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9 **(a)** State **two** main properties of ultrasound.

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.....

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

(b) Describe how the piezoelectric effect is used in an ultrasound transducer both to emit and receive ultrasound.

.....

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

(c) Explain why a gel is used between the ultrasound transducer and the patient's skin during a scan.

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

(d) Explain a method using ultrasound to determine the speed of blood in an artery in the arm.

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..... **[4]**

[Total: 10]

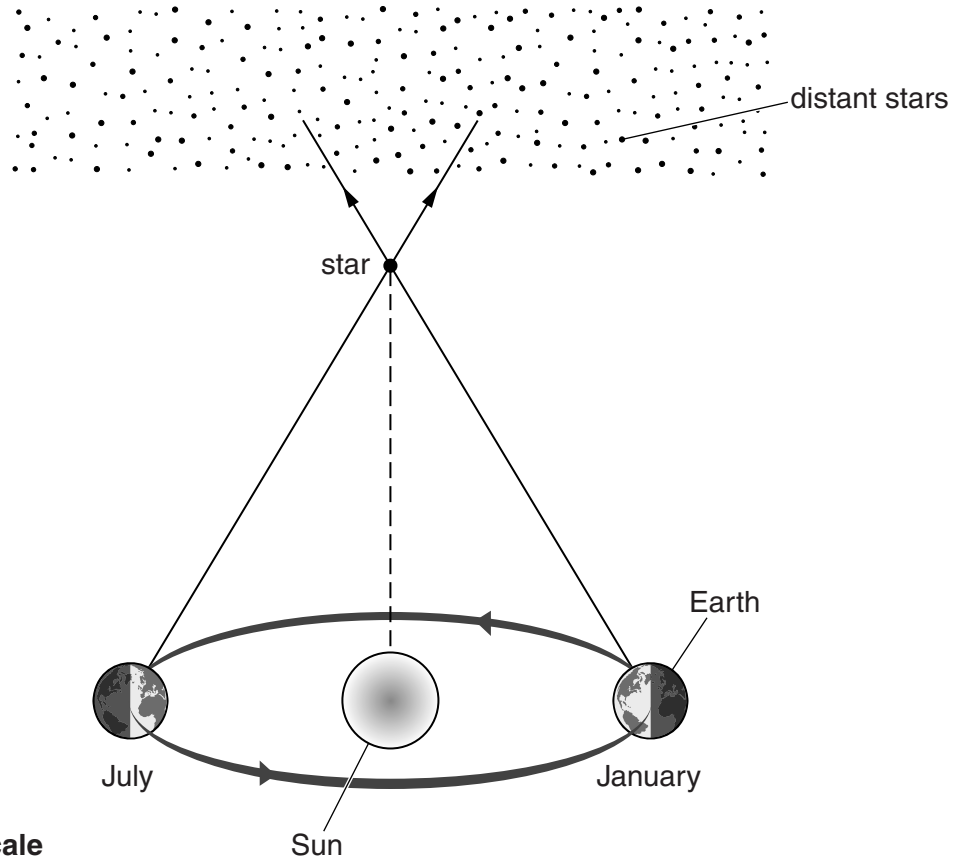
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10 **(a)** Calculate the distance of 1 light-year (ly) in metres.

distance = ... m **[1]**

(b) Fig. 10.1 shows an incomplete diagram drawn by a student to show what is meant by a distance of 1 parsec (pc).



not to scale

Fig. 10.1

Complete Fig. 10.1 by showing the distances of 1 pc and 1 AU, and the parallax angle of 1 second of arc (1″). **[1]**

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(c) A recent supernova, SN2011fe, in the Pinwheel galaxy, M101, released 10^{44} J of energy. The supernova is 2.1×10^{7} ly away.

(i) Calculate the distance of this supernova in pc.

1 pc = 3.1×10^{16} m

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

(ii) Our Sun radiates energy at a rate of 4×10^{26} W. Estimate the time in years that it would take the Sun to release the same energy as the supernova SN2011fe.

time = ... y **[2]**

(d) One of the possible remnants of a supernova event is a black hole. State **two** properties of a black hole.

.....

.....

.....

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

[Total: 8]

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11 **(a)** One estimate of the age of the universe is 13.7×10^9 years.

(i) Calculate the Hubble constant in $\text{km s}^{-1}\ \text{Mpc}^{-1}$ using this age.

$1\ \text{pc} = 3.09 \times 10^{16}\ \text{m}$

Hubble constant = ... $\text{km s}^{-1}\ \text{Mpc}^{-1}$ **[3]**

(ii) The wavelength of the hydrogen-alpha spectral line in the laboratory is 656 nm. Calculate the observed wavelength of this spectral line in the spectrum of the galaxy NGC 7469, which is 50.0 Mpc away from the Earth.

wavelength = ... nm **[4]**

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(b) State what is meant by the big bang. Describe how it explains the origin of the microwave background radiation.



In your answer, you should make clear how the microwave background radiation supports the Cosmological Principle.

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

Question 11 continues on page 22

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(c) Suggest how the microwave background radiation may evolve in the future.

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

(d) Recent observations of very distant supernovae have shown that the expansion of the universe may be accelerating. It is suggested that this is caused by *dark energy* which has the mysterious property of exerting a repulsive force on the universe. The universe may therefore be *open* rather than *flat* or *closed*.



Fig. 11.1

Complete Fig. 11.1 by sketching a suitable graph to illustrate an open universe. **[1]**

[Total: 15]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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Annotations

The following annotations are available on SCORIS.

Annotation	Meaning
✓	correct response
×	incorrect response
AE	arithmetic error
BOD	benefit of the doubt (where professional judgement has been used)
NBOD	benefit of the doubt **not** given
ECF	error carried forward
^	information omitted
CON	contradiction (in cases where candidates contradict themselves in the same response)
RE	rounding error
SF	error in the number of significant figures
POT	error in the power of 10 in a calculation
?	wrong physics or equation
NAQ	not answered question
FT	follow through

The following annotations are available on the marking scheme:

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	separates marking points
allow	answers that can be accepted
not	answers which are not worthy of credit
reject	answers which are not worthy of credit
ignore	statements which are irrelevant
( )	words which are not essential to gain credit
__	underlined words must be present in answer to score a mark
ecf	error carried forward
AW	alternative wording
ora	or reverse argument

Subject-specific Marking Instructions
One tick per mark. All questions must have appropriate annotation.

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures and rounding errors:
If the data given in a question is to 2 sf, then allow answers to 2 or more sf. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper. Any exception to this rule will be mentioned in the Guidance.
Penalise a rounding error once only in the entire paper.

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Question			Answer	Marks	Guidance
1	(a)		Series branch: Using $(100^{-1} + 300^{-1})^{-1}$ and C = 75 (μF) capacitance = 500 + 75 capacitance = 575 (μF)	C1 A1	 Possible ecf, if capacitance of series branch is incorrect
	(b)	(i)	**Time constant method:** 37% of 6.0 V is 2.2 V. The time taken to reach 2.2 V is equal to the time constant time constant = 60 (s) / CR = 60 (s) $500 \times 10^{-6} \times R = 60$ $R = \frac{60}{500 \times 10^{-6}}$ resistance = 1.2×10^5 (Ω) **Substitution method:** Correct values for p.ds and t substituted into $V = V_0 e^{-\frac{t}{CR}}$ Correct values substituted into $\ln(V / V_0) = -\frac{t}{CR}$ resistance = 1.2×10^5 (Ω)	 C1 A1 C1 C1 A1	**Note**: Allow full credit for other correct methods **Allow**: time constant in the range 58 s to 62 s Deduct 1 mark for misreading graph followed by ecf **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf **Eg**: $2.2 = 6.0e^{-\frac{60}{CR}}$ - values read to ± 1 small square **Eg:** $\ln(2.2/6.0) = -\frac{60}{500 \times 10^{-6} \times R}$ **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf. Using 575 (μF) gives 1.04×10^5 (Ω)
		(ii)	Correct p.ds from graph: 6 (V) and 3.6 (V) $\frac{1}{2} \times 500 \times 10^{-6} \times 6.0^2$ or $\frac{1}{2} \times 500 \times 10^{-6} \times 3.6^2$ energy is 9.00×10^{-3} (J) and 3.24×10^{-3} (J) energy lost = 5.76×10^{-3} (J) or 5.8×10^{-3} (J)	C1 C1 A1	**Allow** V value to be in the range 3.5 V to 3.7 at 30s **Note**: Do not penalise 10^n error from **(b)(ii)** again here **Allow** 1 mark for: $\frac{1}{2} \times 500 \times 10^{-6} \times (6.0 - 3.6)^2 = 1.44 \times 10^{-3}$ (J) **Note**: Do not penalise use of 575 μF again. This gives a value of 6.62×10^{-3} (J)
			Total	**8**	

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Question			Answer	Marks	Guidance
2	(a)		number = $\frac{2.8\times10^{-9}}{1.6\times10^{-19}}$ number = 1.75×10^{10} or 1.8×10^{10}	B1	Ignore a negative sign
	(b)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F = \frac{2.8\times10^{-9}\times2.8\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(2.0\times10^{-2})^2}$ force = 1.76×10^{-4} (N) or 1.8×10^{-4} (N)	C1 A1	**Note**: No credit for using charge equal to *e*
	(c)	(i)	Tension and weight	B1	**Allow**: force provided by the string / force in the string instead of tension **Not**: 'gravity' for weight **Allow**: force due to gravity **Allow**: gravitational (force)
		(ii)	(weight =) $6.5 \times 10^{-5} \times g$ $\tan\theta = 1.76 \times 10^{-4}/6.38 \times 10^{-4}$ $\theta = 15°$ Or Scale drawing of triangle of force θ in the range 13° to 18° θ in the range 14° to 16°	C1 C1 A1 C1 A1 A1	Deduct 1 mark for the use of 10 (m s^{-2}) followed by ecf **Note** that getting to this stage scores both C1 marks Possible ecf from **(b)** **Note**: No marks if mass is used instead of the weight
			Total	**7**	

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Question			Answer	Marks	Guidance
3	(a)		Arrow to the left	B1	
	(b)	(i)	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500 \times 1.6 \times 10^{-19}$ (= 2.4×10^{-16} J)	C1	Possible ecf from **(b)(i)**
			$2.4\times10^{-16} = \frac{1}{2}\times 9.11\times10^{-31}\times v^2$ (Allow any subject)	C1	
			$v = 2.3 \times 10^{7}$ (m s^{-1})	A1	**Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v = \sqrt{\frac{2\times1500}{9.11\times10^{-31}}} = 5.74\times10^{16}$ (m s^{-1}) does not score
	(c)	(i)	$F_{(E)} = Eq$ and $F_{(M)} = Bqv$		
			$Eq = Bqv$ (This mark is for equating the two equations)	M1	**Allow** an equivalent approach
			(Hence) $v = \frac{E}{B}$	A1	**Allow** any subject
		(ii)	Force due to magnetic field > force due to electric field	B1	**Allow**: magnetic force > electric force or $F_M > F_E$ or $Bqv > Eq$ or magnetic force is bigger and electric force is the same
			Electrons drift 'downwards'	B1	**Note**: This mark can be scored on Fig. 3.2
			Total	**9**	

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Question			Answer	Marks	Guidance
4	(a)		magnetic flux = magnetic flux density × area <u>normal</u> to the field	B1	**Allow**: $\phi = BA$, with terms defined; B = magnetic flux density or magnetic field strength and A = area <u>normal</u> to the field **Note**: If angle is used in the definition then it must be defined correctly
	(b)	(i)	$R = \frac{1.7\times10^{-8}\times130}{\pi\times(4.6\times10^{-4})^2}$ (Any subject) R = 3.3(2) (Ω) current = $\frac{24}{3.32}$ current = 7.2 (A)	C1 C1 A1	**Allow**: Possible ecf if value for R is incorrect after attempted use of the equation $R = \frac{\rho L}{\pi r^2}$.
		(ii)	e.m.f. = rate of change of magnetic flux linkage (initial ϕ =) $0.090 \times 1.3 \times 10^{-3}$ or 1.17×10^{-4} $150 = \frac{1100\times0.090\times1.3\times10^{-3}}{t}$ (Any subject) time = 8.6×10^{-4} (s)	 C1 C1 A1	**Allow**: (initial $N\phi$ =) $0.090 \times 1.3 \times 10^{-3} \times 1100$ or 0.129 **Allow**: 2 marks for 7.8×10^{-7} (s) if 1100 turns omitted
			Total	**7**	

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Question			Answer	Marks	Guidance
5	(a)	(i)	Any number in the range: 10^4 to 10^5	B1	
		(ii)1	$10^{-14} = \frac{h}{mv}$ momentum = $\frac{6.63 \times 10^{-34}}{10^{-14}}$ momentum = 6.6×10^{-20} (kg m s^{-1})	C1 A1	**Allow** 1 sf answer of 7×10^{-20} (kg m s^{-1})
		(ii)2	The mass of the electron is greater (than its rest mass / 9.11×10^{-31} kg)	B1	**Allow**: Dividing (momentum) by 9.11×10^{-31} (kg) would give a speed of 7.3×10^{10} (m s^{-1}) which is greater than the speed of light / *c* (this is not possible) (AW)
	(b)	(i)	Different number of <u>neutrons</u>	B1	**Not**: different number of nucleons / different mass number / different A
		(ii)	u u d	B1	
		(iii)	u $\rightarrow$ d + positron + neutrino	M1 A1	**Allow**: u u d $\rightarrow$ u d d **Allow**: symbols for positron (e^+ / β^+ / $^0_{+1}e$) and neutrino (υ) **Allow** full marks for an answer in words **Allow** 1 mark for p $\rightarrow$ n + e^+ + υ
		(iv)	Any <u>two</u> from: charge or proton number / momentum / mass-energy / nucleon number / lepton number / strangeness / baryon number / spin	B1	**Not**: <u>mass</u> on its own or <u>energy</u> on its own, but **allow** mass <u>and</u> energy
		(v)	β^+ when there are fewer neutrons / β^+ for lighter nuclei or β^- when there are more neutrons / β^- for heavier nuclei	B1	**Allow**: Alternative correct answers in terms of ratio of protons to neutrons
			Total	**10**	

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Question			Answer	Marks	Guidance
6	(a)		Impossible to predict when a nucleus will decay or impossible to predict which nucleus will decay	B1	
	(b)		$N = N_0 e^{-\lambda t}$ (λ =) 0.693/7.1 $\times 10^8$ $\lambda = 9.76 \times 10^{-10}$ y^{-1} $0.011 = e^{-(9.76\times10^{-10}\times t)}$ (age =) $\frac{\ln(0.011)}{-9.76\times10^{-10}}$ age = 4.6×10^9 (y)	C1 C1 A1	**Alternatives:** $N = N_0 e^{-\lambda t}$ (λ =) 0.693/[$7.1 \times 10^8 \times 3.16 \times 10^7$] C1 $\lambda = 3.089 \times 10^{-17}$ s^{-1} $0.011 = e^{-(3.089\times10^{-17}\times t)}$ C1 (age =) $\frac{\ln(0.011)}{-3.089\times10^{-17}}$ age = $1.46... \times 10^{17}$ (s) age = 4.6×10^9 (y) A1 Or $0.011 = \frac{1}{2^n}$ C1 $n = -\frac{\ln(0.011)}{\ln 2}$ or $n = 6.5$ C1 age = $6.5 \times 7.1 \times 10^8$ (y) age = 4.6×10^9 (y) A1
	(c)	(i)	number in the range 50 to 70	B1	
		(ii)	Correct reference to binding energy. Eg: The BE per nucleon will decrease for fusion (which is impossible unless external energy is supplied) (AW)	B1	

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Question			Answer	Marks	Guidance
		(iii)	(mass of nucleons =) $4 \times 1.673 \times 10^{-27} + 4 \times 1.675 \times 10^{-27}$	C1	**Allow**, due to misinterpretation of Data, Formulae and Relationship Booklet, the following (though incorrect):
			(Δm =) $[4 \times 1.673 \times 10^{-27} + 4 \times 1.675 \times 10^{-27}] - 1.329 \times 10^{-26}$	C1	(nucleon mass =) $8 \times 1.661 \times 10^{-27}$ (kg) C1 (Δm =) $[8 \times 1.661 \times 10^{-27}] - 1.329 \times 10^{-26}$ (kg) C1
			(mass defect =) 1.020×10^{-28} (kg)		(BE =) (-) $2.0 \times 10^{-30} \times (3.0 \times 10^{8})^2$ (= 1.8×10^{-13} J) C1 (BE per nucleon =) $1.8 \times 10^{-13}/8$
			BE = mass defect $\times c^2$		BE per nucleon = 2.25×10^{-14} (J) A1
			(BE =) $1.020 \times 10^{-28} \times (3.0 \times 10^{8})^2$ (= 9.180×10^{-12} J)	C1	
			(BE per nucleon) = $9.180 \times 10^{-12}/8$		
			BE per nucleon =1.148×10^{-12} (J)	A1	**Allow** 2 sf or 3 sf answer
			Total	**10**	

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Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: • Can travel in a vacuum • Travel at the speed of light / c / 3×10^8 <u>m s^{-1}</u> in <u>vacuum</u> • No charge / no (rest) mass • (Highly) ionising	B1 × 2	**Not**: EM radiation / wave because not *particulate* nature **Not**: Short wavelength or high frequency **Not**: High energy photons **Not**: reflect / refract / diffract
	(b)		$\frac{hc}{\lambda}$ <u>and</u> $E = mc^2$ $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda} = 2\times9.11\times10^{-31}\times(3.0\times10^{8})^{2}$ wavelength = 1.2×10^{-12} (m)	C1 C1 A1	**Allow**: $\frac{hc}{\lambda}$ and 1.02 <u>MeV</u> or 0.51 <u>MeV</u> for this first C1 mark **Allow**: Correct use of mass = 0.00055 u **Allow**: 2 marks for 2.4×10^{-12} (m) for omitting factor of 2 **Note**: Using the de Broglie equation with $v = c$, also gives an answer of 2.4×10^{-12} (m); this scores zero – see below: $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3.0\times10^{8}} = 2.4\times10^{-12}$ m scores zero
	(c)		Barium / iodine (Contrast medium absorbs X-rays because it) has large attenuation coefficient / has large absorption coefficient / has large Z values Ideal for imaging the <u>outline</u> (of soft tissues)	B1 B1 B1	 **Not**: X-rays are (easily) absorbed by the contrast material **Allow**: If there is a hole then the barium shows this up by flowing out / Barium is used to find blockage with explanation
			Total	**8**	

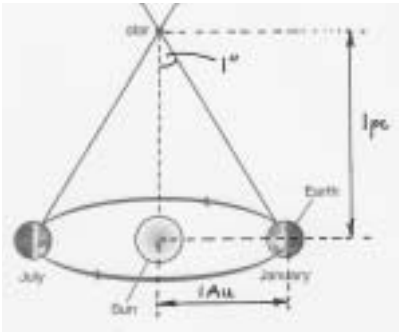
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Question			Answer	Marks	Guidance
8	(a)		Rate of decay / disintegration of <u>nuclei</u> or Number of γ (photons) emitted per unit time	B1	The question has 500 Bq. Hence a**llow** the following: Number of <u>nuclei</u> decaying per second / number of γ (photons) emitted per second **Not**: Rate of decay of atoms / molecules / particles
	(b)		(rate of energy =) $500 \times 10^{6} \times 2.2 \times 10^{-14}$ rate of energy emission = 1.1×10^{-5} (J s^{-1})	C1 A1	
	(c)		**Collimator / lead tubes** <u>and</u> ..... gamma (ray photons) travel along the axis of lead tubes (AW) **Scintillator / Sodium Iodide (crystal)** <u>and</u> ..... gamma ray / gamma photon produces (many) <u>photon**s**</u> of (visible) light **Photomultiplier (tubes) / photocathode and dynodes** <u>and</u> ..... (electrical) pulse / signal / electron<u>s</u> produced by photon(s) of visible light **Computer** <u>and</u> ..... signals / pulses /electrons (from photomultiplier tubes) are used to generate an image QWC: Quality of image improved by narrower / thinner / longer collimators OR longer scanning time	B1 B1 B1 B1 B1	**Not** 'it collimates' **Allow**: parallel rays / uni-directional rays travel along the lead tubes (AW) **Not** 'information / data' in place of signals
			Total	**8**	

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Question			Answer	Marks	Guidance
9	(a)		Longitudinal (wave) Frequency (sound) ≥ 20 kHz	B1 B1	**Allow**: high frequency (sound) that cannot be heard **Allow** any value of frequency ≥ 20 kHz **Not**: It is non-ionising
	(b)		Emission: (Piezoelectric film / crystal connected to an) alternating e.m.f / p.d / current making it vibrate / contract and expand / resonate (and hence emits ultrasound) (AW) Reception: (Ultrasound makes the piezoelectric film / crystal) vibrate / contract and expand / resonate and this produces (alternating) e.m.f. / p.d / current (AW)	B1 B1	**Note**: The alternating p.d. can be implied by the term *frequency* **Not** varying p.d.
	(c)		Without the gel, the ultrasound would be reflected (at the skin /air interface) or The gel allows (maximum) transmission of ultrasound (into the body) Gel and skin has similar acoustic impedance / *Z* (values) or There is a large difference between the *Z* (values) of air and skin	B1 B1	**Allow**: Gel is used for impedance matching
	(d)		Transducer placed at an angle to the artery / arm Ultrasound (pulses) are reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed Change in frequency is related to the speed (of blood) or change in wavelength is related to the speed	B1 B1 B1 B1	**Allow**: The wavelength / frequency is Doppler shifted (AW) **Allow**: $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$ where *c* is the speed of ultrasound and *v* is the speed of blood; no need to define the angle
			Total	**10**	

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Question			Answer	Marks	Guidance
10	(a)		(distance =) $3.0 \times 10^8 \times 3.16 \times 10^7$ distance = 9.48×10^{15} (m) ≈ 9.5×10^{15} (m)	B1	**Allow**: (distance =) $3.0 \times 10^8 \times 365(¼) \times 24 \times 3600$ **Allow** 1 mark for bald 9.48×10^{15} (m)
	(b)		Correct labelling of 1 pc, 1 AU and 1”  	B1	**Allow**: ‘hypotenuse’ labelled as 1 pc
	(c)	(i)	(distance =) $9.5 \times 10^{15} \times 2.1 \times 10^7$ (m) or 2.0×10^{23} (m) (distance in pc =) $2.0 \times 10^{23}/3.1 \times 10^{16}$ distance = 6.4×10^6 (pc)	C1 A1	Possible ecf from **(a)**
		(ii)	(time =) $10^{44}/4 \times 10^{26}$ (s) or 2.5×10^{17} (s) (time =) $2.5 \times 10^{17}/3.16 \times 10^7$ time = 7.9×10^9 years	C1 A1	**Allow**: 1 sf answer of 8×10^9 years
	(d)		Any <u>one</u> from: • Very dense / infinite density / very small / singularity Any <u>one</u> from: • (Very strong gravitational field therefore) light cannot escape from it / curves space / slows down time / emits Hawking radiation	B1 B1	
			Total	**8**	

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Question			Answer	Marks	Guidance
11	(a)	(i)	H_0 = 1/age H_0 = 1/(13.7 × 10^9 × 3.16 × 10^7) (H_0 =) 2.31 × 10^{-18} (s^{-1}) (H_0 =) $\frac{2.31\times10^{-18}\times3.09\times10^{16}\times10^{6}}{10^{3}}$ Hubble constant = 71.4 (km s^{-1} Mpc^{-1})	C1 C1 A1	 **Allow:** 2 sf answer **Special case**: Using H_0 = 1/13.7 × 10^9 = 7.30 × 10^{-11} (y^{-1}) gives an answer of 2.26 × 10^9 (km s^{-1} Mpc^{-1}) – allow 1 mark
		(ii)	$v = H_0$ d (v =) 71.4 × 50 or 3.57 × 10^3 (km s^{-1}) or 3.57 × 10^6 (m s^{-1}) $\frac{\Delta\lambda}{\lambda}=\frac{3.57\times10^{6}}{3.0\times10^{8}}(=1.19\times10^{-2})$ $\Delta\lambda$ = 656 × 1.19 × 10^{-2} or $\Delta\lambda$ = 7.80 (nm) wavelength = 656 + 7.80 wavelength = 664 (nm)	C1 C1 C1 A1	Possible ecf from **(a)** **Allow**: 2sf answer
	(b)		Big bang: Creation of the universe (from which space/time evolved) (AW) Any <u>three</u> from: 1. (At the start) the universe was hot / infinitely dense 2. Expansion of the universe led to cooling 3. The (current) temperature of universe is 2.7 K / 3 K 4. (The universe as a black body) is associated with microwaves at this temperature (AW) or The (wavelength of the) gamma radiation stretched to microwaves (by the expansion). QWC: (Cosmological principle is supported because) MBR is isotropic	B1 B1 × 3 B1	 **Not**: The universe now has microwaves. (The microwaves must be linked with current temperature) **Allow**: Microwaves have the same intensity in all directions

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Question			Answer	Marks	Guidance
	(c)		(For an open / flat universe) Further expansion will lead to cooling / temperature lower than 3K / temperature tend to absolute zero (AW) The wavelength (of the EM radiation) gets longer / frequency (of the EM radiation) gets smaller / energy of photons decreases / microwaves become radio waves	B1 B1	**Alternative**: Temperature (will eventually) increases if closed universe B1 The wavelength (of EM radiation) get smaller B1
	(d)		Graph starting from origin and having a shape consistent with either open or accelerated universe	B1	**Not** a straight line
			Total	**15**	

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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

G411600113

G 4 8 5 0 1

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.

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Answer **all** the questions.

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

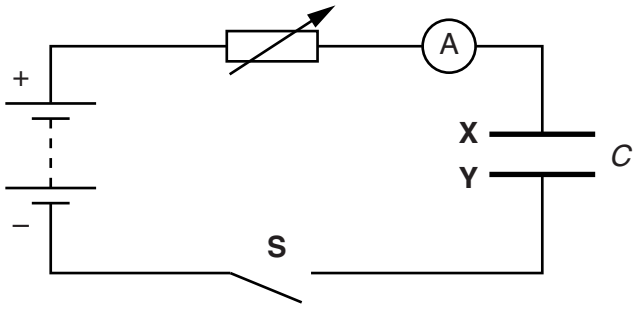


Fig. 1.1

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]**

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

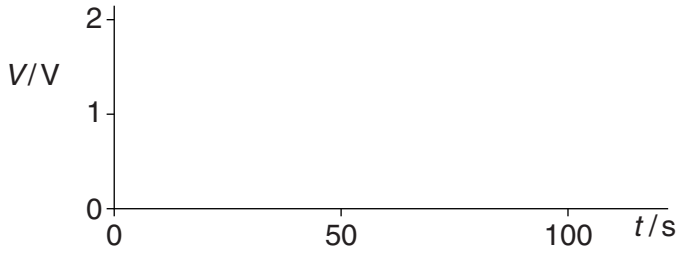


Fig. 1.2 **[2]**

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

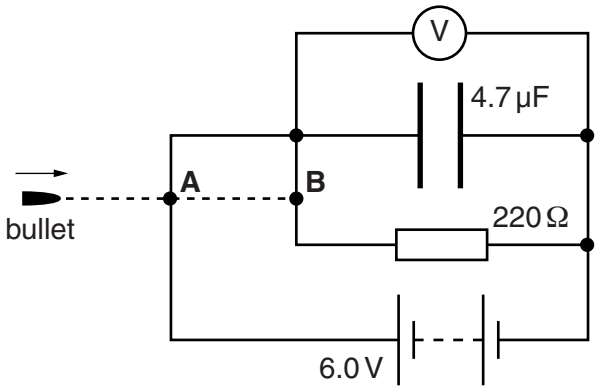


Fig. 1.3

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]

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

.....

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

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

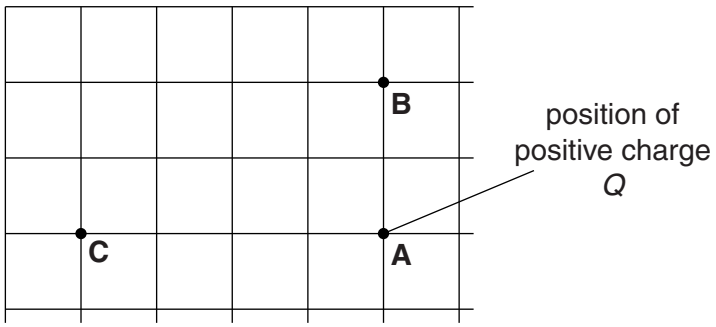


Fig. 2.1

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 $8.0 \times 10^5\,\text{N C}^{-1}$.

(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 = ... N C^{-1} **[2]**

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

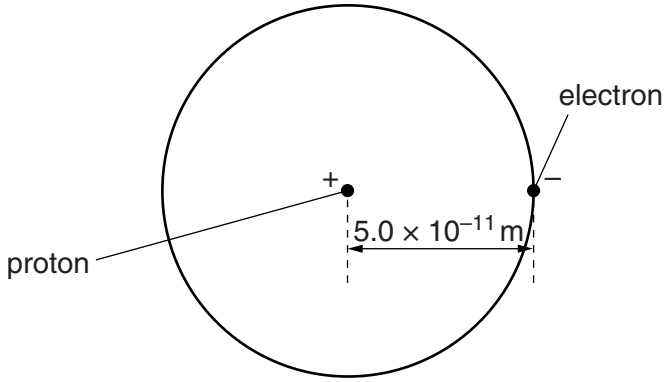


Fig. 2.2

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]**

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(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]

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Question 3 begins on page 8

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

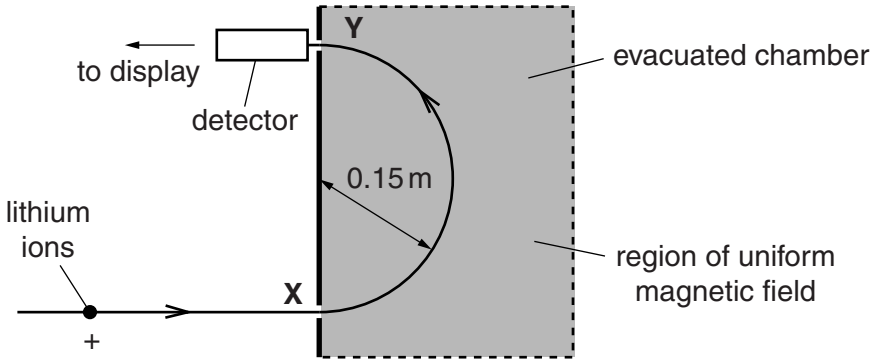


Fig. 3.1

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, $4.0 \times 10^{5}\,\text{m}\,\text{s}^{-1}$ and charge, $+1.6 \times 10^{-19}\,\text{C}$. 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 $1.2 \times 10^{-26}\,\text{kg}$.

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

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

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(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.

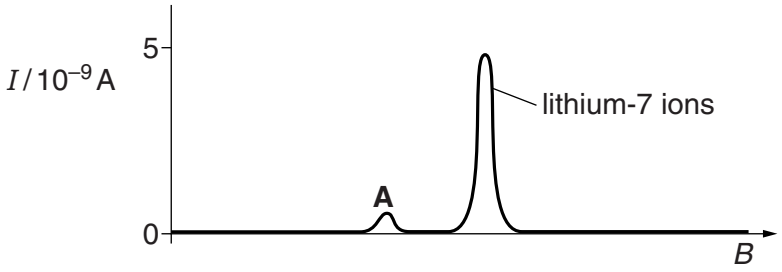


Fig. 3.2

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]

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

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

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

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

(ii) Fig. 4.1 illustrates this fission reaction.

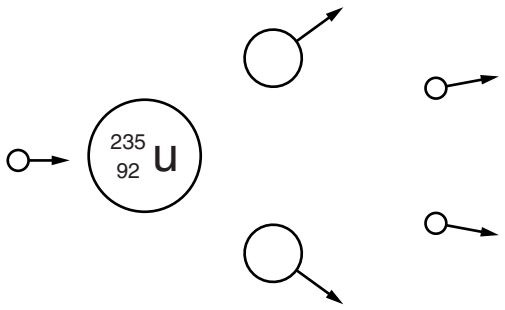


Fig. 4.1

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.

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

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

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(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]

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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]**

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(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]

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

.....

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

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

.....

.....

.....

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

(c) A beam of X-rays of intensity 3.0×10^9 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 cm^{-1}.

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

[2]

(ii) The cross-sectional area of the X-ray beam at the tumour is 5 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]**

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(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]

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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]

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(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]

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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.

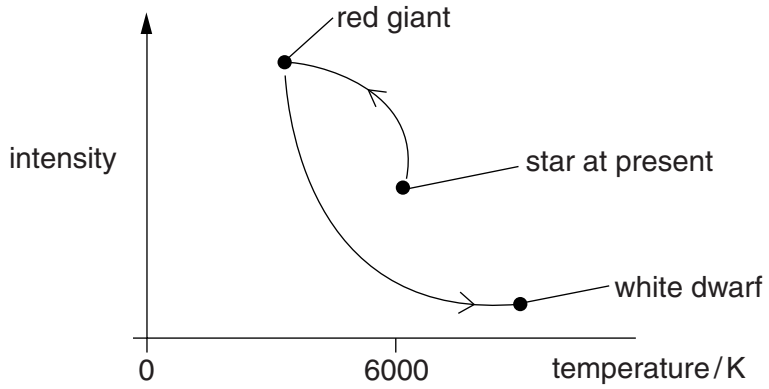


Fig. 8.1

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

.....

.....

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

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

.....

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

[Total: 8]

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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 $3.4 \times 10^{7}\,\text{m s}^{-1}$.

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

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

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(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

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ADDITIONAL ANSWER SPACE

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

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ADDITIONAL ANSWER SPACE

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for January 2013

Oxford Cambridge and RSA Examinations

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

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Annotations

The following annotations are available on the marking scheme:

/ = alternative and acceptable answers for the same marking point
(1) = separates marking points
allow = answers that can be accepted
not = answers which are not worthy of credit
reject = answers which are not worthy of credit
ignore = statements which are irrelevant
( ) = words which are not essential to gain credit
__ = underlined words must be present in answer to score a mark
ecf = error carried forward
AW = alternative wording
ora = or reverse argument

The following annotations are available in SCORIS.

Annotation	Meaning
	correct response
	incorrect response
	arithmetic error
	benefit of the doubt (where professional judgement has been used)
	benefit of the doubt **not** given
	error carried forward
	information omitted
	contradiction (in cases where candidates contradict themselves in the same response)

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Annotation	Meaning
	rounding error
	error in the number of significant figures
	error in the power of 10 in a calculation
	wrong physics or equation
	not answered question
	follow through

Highlighting is also available to highlight any particular points on the script.

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:
Q5(e), 6(d), 7(a), 8(a) and Q9(a)

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures and rounding errors:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf. If an answer is given to fewer than 2 sf, then penalise once only in the entire paper. Any exception to this rule will be mentioned in the Guidance.
Penalise a rounding error once only in the entire paper.

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Question			Answer	Marks	Guidance
1	(a)	(i)	Any <u>two</u> from: Correct direction of movement of electrons Electrons deposited on **Y** / removed from **X** An equal number of electrons removed and deposited on plates (AW)	B1 × 2	
		(ii)1	$Q = 40 \times 10^{-6} \times 100$ (= 4.0×10^{-3} C) $4.0 \times 10^{-3} = 1.6 \times C$ $C = 2.5 \times 10^{-3}$ (F)	C1 C1 A1	**Allow**: 2 marks for 2.5×10^{n} (F), where $n \neq -3$ (POT error)
		(ii)2	Graph starts at <u>origin</u> and has positive gradient A straight line graph that passes between 1-2 V at 100 s	M1 A1	
	(b)	(i)	$CR = 4.7 \times 10^{-6} \times 220$ (= 1.03×10^{-3} s) $4.00 = 6.00e^{-\frac{t}{1.03\times10^{-3}}}$ $t = -\ln(4.00/6.00) \times 1.03 \times 10^{-3}$ time = 4.2×10^{-4} (s)	C1 C1 A1	**Note**: Answer to 3 sf is 4.19×10^{-4} (s) **Allow**: 2 marks for $t = -lg(4.00/6.00) \times 1.03 \times 10^{-3} = 1.8 \times 10^{-4}$ s
		(ii)	speed = $\frac{0.100}{4.2\times10^{-4}}$ speed = 240 (m s^{-1})	B1	Possible ecf from **(b)(i)**
			Total	**11**	

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Question			Answer	Marks	Guidance
2	(a)		force per unit (positive) charge	B1	**Allow**: $E = \frac{F}{Q}$, where F = force on (a positive) charge Q
	(b)	(i)	The direction is different (AW)	B1	
		(ii)	$E \propto 1/r^2$ or distance is doubled ∴ E decreases by a factor of 4 electric field strength = 2.0×10^5 (N C^{-1})	C1 A1	**Not**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ on its own **Allow** 1 sf answer
	(c)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F_E = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$ F_E = 9.2×10^{-8} (N)	C1 C1 A1	 **Allow**: 1 mark if $Q = q = 1$ giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \frac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$ F_G = 4.06×10^{-47} (N) ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$ ratio = 2.3×10^{39}	C1 A1	 **Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m) $\lambda = h/mv$ $p = \frac{6.63\times10^{-34}}{2.0\times10^{-10}}$ p = 3.3×10^{-24} (kg m s^{-1})	C1 C1 A1	 Possible ecf for incorrect wavelength **Note**: Answer to 3 sf is 3.32×10^{-24} (kg m s^{-1}) **Allow**: 1 sf answer

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Question			Answer	Marks	Guidance
		(iii)2			Possible ecf from **(iii)1**
			$v = \frac{3.32\times10^{-24}}{9.11\times10^{-31}}$ (= 3.64×10^6 m s^{-1})	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times 9.11 \times 10^{-31} \times (3.64 \times 10^6)^2$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	**Note**: Answer to 3 sf is 6.05×10^{-18} (J) **Allow**: 1 sf answer
			or		
			$E_k = ½ p^2/m$	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times (3.32 \times 10^{-24})^2/9.11 \times 10^{-31}$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	
			Total	**15**	

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Question			Answer	Marks	Guidance
3	(a)		(Fleming's) left-hand rule	B1	
	(b)		The force is at right angles to the velocity (hence no work is done on the ions) / no (component of) force in the direction of motion / no (component of) acceleration in the direction of motion (AW)	B1	**Allow**: 'force is right angles to the motion'
	(c)	(i)	$F = \frac{mv^2}{r}$ force = $\frac{1.2\times10^{-26}\times(4.0\times10^{5})^{2}}{0.15}$ force = 1.3×10^{-14} (N)	C1 A1	**Note**: Answer to 3 sf is 1.28×10^{-14} (N)
		(ii)	$F = BQv$ $1.28 \times 10^{-14} = B \times 1.6 \times 10^{-19} \times 4.0 \times 10^{5}$ B = 0.20 (T)	C1 A1	Possible ecf from **(c)(i)** **Allow**: 1 sf answer of 0.2 (T)
		(iii)	number per second = $\frac{4.8\times10^{-9}}{1.6\times10^{-19}}$ number per second = 3.0×10^{10} (s^{-1})	C1 A1	**Allow**: 1 sf answer of 3×10^{10} (s^{-1})
	(d)		(height is smaller) hence less abundance (than lithium-7) position suggests that the ions are less massive / lighter fewer neutrons (than lithium-7)	B1 B1	**Allow**: fewer / less (than lithium-7)
			Total	**10**	

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Question			Answer	Marks	Guidance
4	(a)	(i)	momentum / mass-energy / charge / proton number / baryon number / nucleon number	B1	**Not**: 'energy' on its own
		(ii)	Some basic labelling of neutron(s), Xe and Sr Correct extension of diagram showing at least one of the neutrons interacting with U-235 nucleus and producing neutron(s) and 'fragments'	B1 B1	
	(b)	(i)	initial $m = 6.686 \times 10^{-27}$ (kg) or final $m = 6.681 \times 10^{-27}$ (kg) or $\Delta m = 0.005 \times 10^{-27}$ (kg) $\Delta E = 0.005 \times 10^{-27} \times (3.0 \times 10^{8})^{2}$ energy = 4.5×10^{-13} (J)	C1 C1 A1	
		(ii)	kinetic (energy)	B1	**Not**: heat / sound **Allow**: (gamma) photons / EM radiation
		(iii)	KE = $\frac{3}{2}kT$ KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 10^{9}$ KE = 2.1×10^{-14} (J)	C1 A1	**Allow**: 1 sf answer or 10^{-14} (J) because the temperature is given as 10^{9} K
		(iv)	Some nuclei will have KE greater than the mean KE (and hence cause fusion) (AW)	B1	
			Total	**10**	

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Question			Answer	Marks	Guidance
5	(a)		$\lambda = \frac{0.693}{6.6\times10^{3}}$ or $\lambda = \frac{\ln 2}{6.6\times10^{3}}$ decay constant = 1.1×10^{-4} (s^{-1})	C1 A1	**Note**: Answer to 3sf is 1.05×10^{-4} (s^{-1})
	(b)		$A = \lambda N$ $N = \frac{250\times10^{6}}{1.05\times10^{-4}}$ number = 2.38×10^{12} or 2.4×10^{12}	C1 A0	Possible ecf from **(a)** **Allow** full credit for bald 2.4×10^{12}
	(c)		mass of F-18 = $\frac{2.38\times10^{12}}{6.02\times10^{23}}\times0.018$ (= 7.116×10^{-14} kg) mass of FDG= $7.116\times10^{-14} / 0.099$ mass of FDG = 7.2×10^{-13} (kg)	C1 C1 A1	Possible ecf from **(b)** **Allow** full credit for using 2×10^{12}; answer is 6.04×10^{-13} (kg)
	(d)		$A = 250\times e^{-(1.05\times10^{-4}\times20\times60)}$ activity = 220 (MBq)	C1 A1	Possible ecf from **(a)** **Allow**: 1 mark for 249 (MBq); factor of 60 omitted
	(e)		(FDG/positron-emitting substance is injected into the patient) Any <u>three</u> from: 1. Annihilation of electron and positron 2. Positron-electron annihilation produces <u>two</u> gamma photons 3. The gamma photons travels in opposite directions 4. The patient is surrounded by (a ring of) gamma detectors 5. A 3-D image is created (using the detector-signals with the aid of computer software) **QWC**: The arrival times / delay times of the photons (at diametrically opposite detectors) are used to pinpoint areas of increased activity (AW)	B1 × 3 B1	**Allow**: rays / waves instead of photons in 2 and 3
			Total	**12**	

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Question			Answer	Marks	Guidance
6	(a)		(Fast-moving) electrons hit a metal / an anode The kinetic energy of the electrons is transferred into X-rays / photons / EM waves	B1 B1	**Allow**: (X-rays are produced by large) deceleration of electrons
	(b)		An X-ray photon interacts an electron (within the atom) The electron is ejected and the energy / frequency of the (scattered) photon is reduced	B1 B1	 **Allow**: The electron is ejected and the wavelength of the (scattered) photon is increased
	(c)	(i)	$I = I_0 e^{-\mu x}$ $I = 3.0 \times 10^9 \times e^{-(6.5 \times 1.7)}$ intensity = 4.8×10^4 (W m^{-2})	C1 C1 A0	
		(ii)	power of beam = $4.8 \times 10^4 \times 5.0 \times 10^{-6}$ (= 0.24 W) power absorbed by tumour = 0.24/10 = 0.024 (W) time = 200/0.024 time = 8.3×10^3 (s)	C1 C1 A1	Possible ecf from **(c)(i)** **Allow**: 2 marks for 8.3×10^2 (s) if 10% is omitted **Note**: Using 5×10^4 (W m^{-2}) gives an answer of 8000 (s)
	(d)		X-ray beam passes through the patient at different angles / X-ray tube rotates around the patient A thin fan-shaped beam is used (AW) Images of 'slices' through the patient (in one plane are produced with the help of computer software) X-ray tube / detectors are moved along (the patient for the next slice through the patient) Advantage: 3D image / better contrast between different (soft) tissues	B1 B1 B1 B1 B1	
			Total	**14**	

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Question			Answer	Marks	Guidance
7	(a)		Any <u>six</u> from: 1. Protons / nuclei have spin or they behave like (tiny) magnets 2. Protons precess around the magnetic field (provided by the strong electromagnet) 3. The frequency of precession is known as the *Larmor frequency* 4. (Transmitting) coils provide (pulses of) radio waves (of frequency equal to the Larmor frequency) 5. The protons absorb energy (from the radio waves) / resonate and enter into a high energy state (AW) 6. When protons return back to their low energy state and they emit (photons of) radio waves 7. The *relaxation time* is the (average) time taken for the protons to return back to their normal / low energy state 8. The relaxation time depends on the tissues (A computer processes all the signals from the receiving coils and with the help of computer software generates a 3D image)	B1 × 6	**Not**: Atoms / particles **Note**: Must have reference to radio (waves) in 4 and 6 **Allow** 'excited' for 'high-energy state' **Allow**: Relaxing protons emit radio waves
	(b)		Disadvantage: Patient with metallic objects cannot be scanned / patient has to remain still (for a long time) / confined space / difficult for patient suffering from claustrophobia / or another suitable suggestion Advantage: Non-ionising /non invasive / better contrast (between soft tissues) / or another suitable suggestion	B1 B1	 **Not** '3 D image' because it is given in **(a)**
			Total	**8**	

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Question			Answer	Marks	Guidance
8	(a)		Any <u>three</u> from: 1. (Interstellar dust and gas) cloud is drawn together by gravitational force / gravity 2. Loss in (gravitational) PE / KE increases / temperature increases 3. Fusion (of protons / hydrogen nuclei) takes place 4. Energy is released in fusion reactions 5. A stable star is formed when gravitational pressure is equal to internal / gas / radiation pressure QWC: The steps in the process are correctly sequenced	B1 × 3 B1	**Allow**: 'gravitational collapse'
	(b)	**(i)**	Any <u>two</u> from: • (extremely) dense / (very) hot / low luminosity • no fusion reactions occur • it is a remnant of a low-mass star • correct reference to Fermi pressure / electron degeneracy / Chandrasekhar's limit	B1 × 2	
		(ii)	Red giant identified (It is cooler but has) large <u>surface</u> area (and therefore radiates large amounts of energy)	B1 B1	
			Total	**8**	

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Question			Answer	Marks	Guidance
9	(a)		The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$' Any <u>two</u> assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)		(recessional) speed of <u>galaxy</u> $\propto$ its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	**Allow**: $v = H_0 x$, v = (recessional) speed of galaxy, x = distance and H_0 is Hubble constant / a constant
	(c)	(i)	$v = H_0 x$ $3.4 \times 10^7 = H_0 \times 1.4 \times 10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	 C1 A1 B1	**Note**: This is an independent mark **Note**: Allow full credit for an Hubble constant of 75 with unit km s^{-1} Mpc^{-1}
		(ii)1	age = $\frac{1}{2.4 \times 10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from **(i)**
		(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^8$ (= 1.25×10^{26} m) distance = $\frac{4.17 \times 10^{17} \times 3.0 \times 10^8}{3.1 \times 10^{16}}$ distance = 4.0×10^9 (pc)	C1 A1	Possible ecf from **(ii)1**
			Total	**12**	

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Monday 11 June 2012 – Afternoon

A2 GCE PHYSICS A

G485 Fields, Particles and Frontiers of Physics

Candidates answer on the Question Paper.

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

Other materials required:
- Electronic calculator

Duration: 2 hours

G 4 8 5

G411830612

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.
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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.

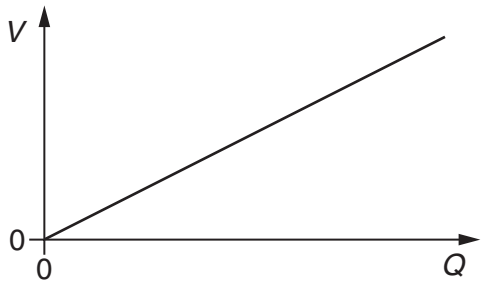


Fig. 1.1

State the quantity represented by the

(i) gradient of the graph

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

(ii) area under the graph.

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

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

capacitance = ... μF **[3]**

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

(i) charge stored by the capacitor

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

(ii) energy stored by the capacitor.

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

[Total: 10]

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

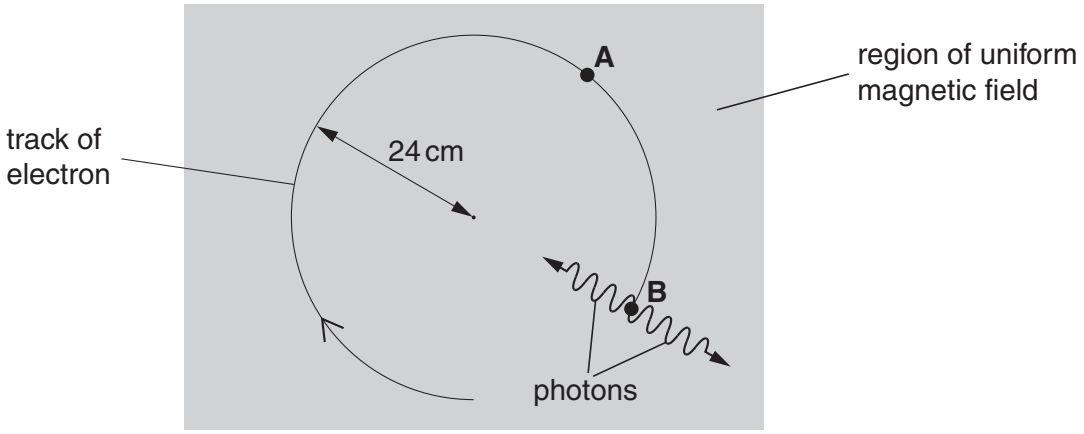


Fig. 2.1

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

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

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

.....

.....

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

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

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

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

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

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



In your answer, you should make your reasoning clear.

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

[Total: 9]

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

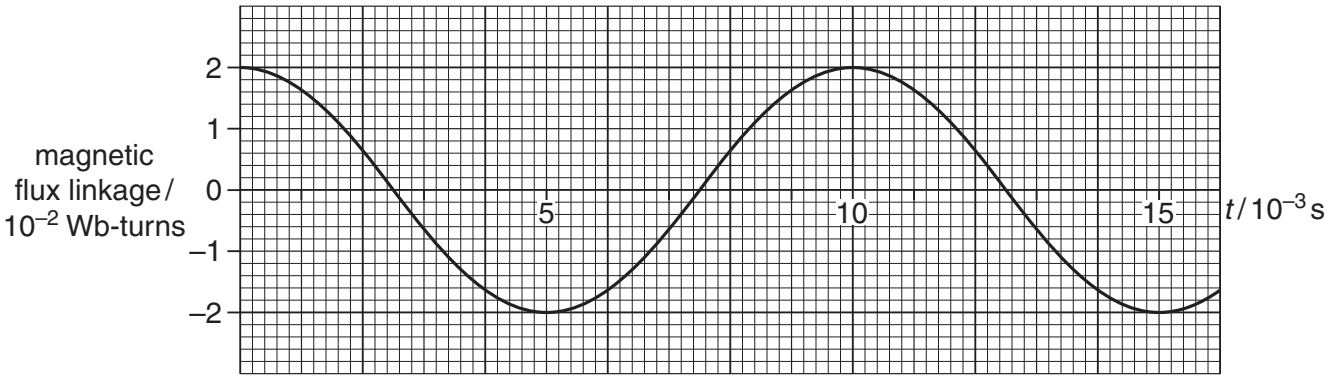


Fig. 3.1

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

(a) Use Fig. 3.1 to

(i) calculate the frequency of rotation of the coil

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

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

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

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

[3]

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

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

[Total: 9]

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

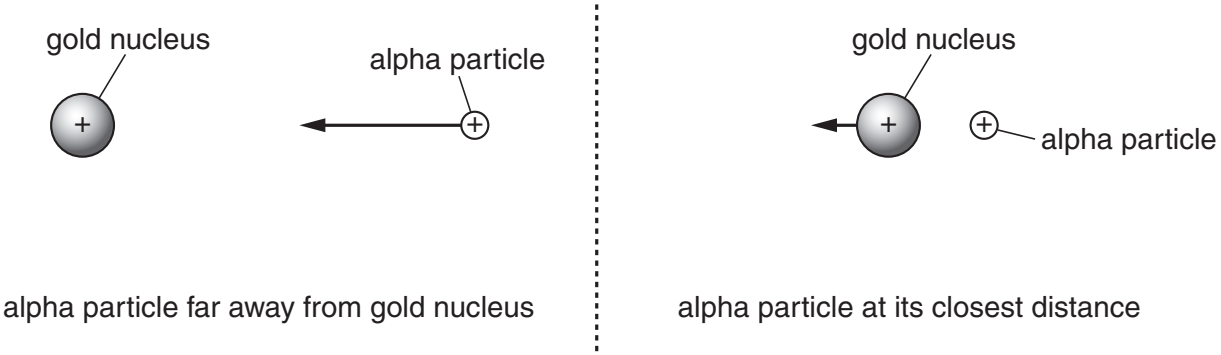


Fig. 4.1

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

.....

.....

.....

.....

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

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



[2]

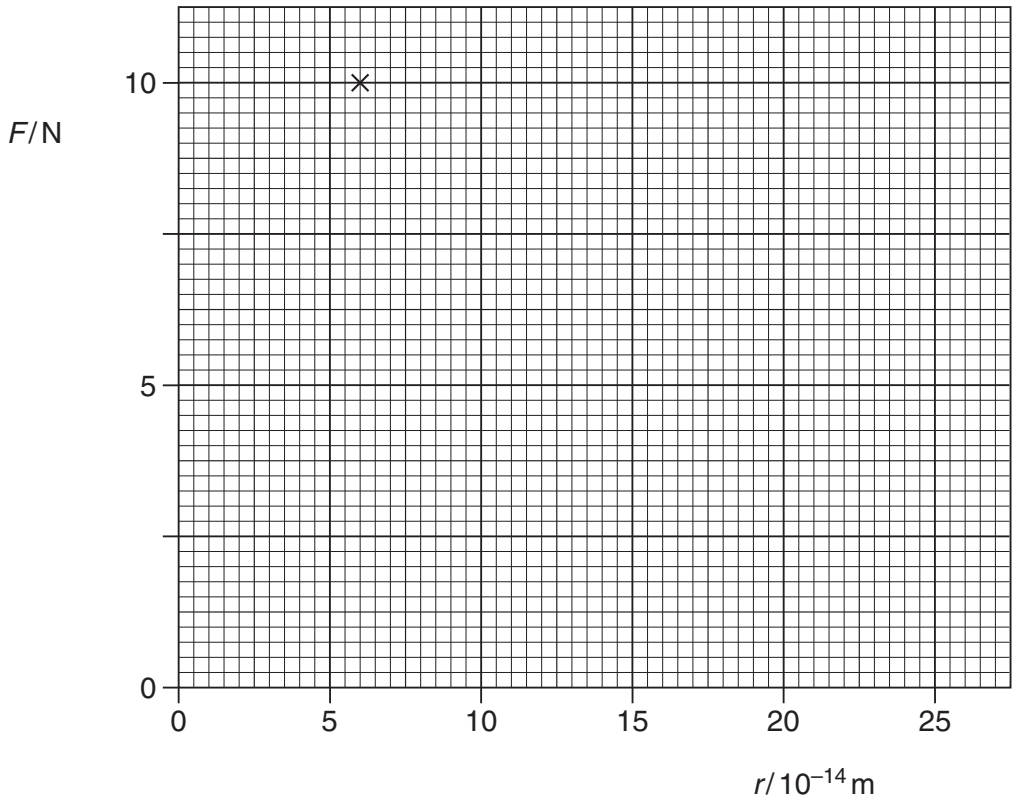
Fig. 4.2

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

[3]

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



[2]

Fig. 4.3

[Total: 9]

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

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

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

(b) The mass of an alpha particle is 6.65×10^{-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 62W for the onboard electronics.

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

[1]

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(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]

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6 The nuclear reaction represented by the equation

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

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

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

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.....

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

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



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

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

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

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

1. .....

.....

2. .....

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

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

.....

.....

.....

..... **[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 $3.3\,\text{cm}^{-1}$. Calculate the thickness in cm of bone that will reduce the X-ray intensity by half.

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

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

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

[Total: 10]

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



Fig. 8.1

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

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

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..... **[7]**

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

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

[Total: 9]

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

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..... **[4]**

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

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

[Total: 7]

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

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

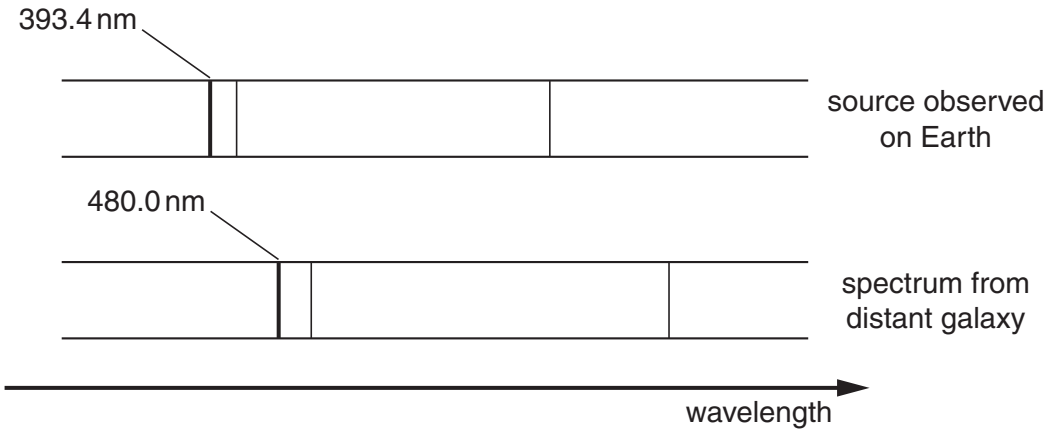


Fig. 10.1

(i) Describe an absorption spectrum.

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

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

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

[Total: 15]

END OF QUESTION PAPER

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ADDITIONAL PAGE

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

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for June 2012

Oxford Cambridge and RSA Examinations

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Annotations

Annotation Available in Scoris	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
	Omission mark
RE	Rounding error or ‘reading error’
SF	Error in number of significant figures
	Correct response
AE	Arithmetic error
	Wrong physics or equation

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Annotation Used in Mark Scheme	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

Q2(d), Q6(b), Q7(d), Q8(a)(b), Q9(a)(b), Q10(c).

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Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

Question			Answer	Marks	Guidance
1	(a)		(farad = 1) coulomb per (unit) volt	B1	**Allow**: C V^{-1}
	(b)	(i)	1/C	B1	**Allow**: 'inverse of *C*'
		(ii)	work (done) / energy	B1	
	(c)		**Diagram**: All 3 capacitors connected in **series** $\frac{1}{C}=\frac{1}{100}+\frac{1}{200}+\frac{1}{500}$ / $\frac{1}{C}=1.7\times10^{-2}$ capacitance = 59 (μF)	B1 C1 A1	**Note**: Correct symbol must be used for capacitor and at least one of the capacitance values (without the unit) must be shown **Allow**: Answer to 1 sf **Note**: Answer to 3sf is 58.8 (μF) **Allow**: 1.7 × 10^{-2} (μF) scores 1 mark from the C1A1
	(d)	(i)	Q = 0.040 × 60 charge = 2.4 (C)	C1 A1	**Allow**: 1 mark for 2.4 × 10^{n}, n ≠ 0 (POT error)
		(ii)	energy = $\frac{1}{2}\times\frac{2.4^2}{0.10}$ energy = 29 (J)	C1 A1	Possible ecf from **(d)(i)** **Note**: Answer to 3 sf is 28.8 (J) Allow full credit for correct use of ½ *VQ* or ½ V^2C; the final p.d is 24 (V)
			Total	**10**	

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Question			Answer	Marks	Guidance
2	(a)	(i)	Correct direction of force at **A** (and marked **F**)	B1	
		(ii)	The force is perpendicular to velocity / motion (hence no work done on the electron) or No (component of) acceleration / force in direction of velocity / motion (hence no work done on electron) or No distance moved in the direction of the force	B1	
	(b)		$F = \frac{mv^2}{r}$ force = $\frac{9.11\times10^{-31}\times(6.0\times10^{7})^2}{0.24}$ force = 1.4×10^{-14} (N)	C1 A1	**Note**: Answer to 3sf is 1.37×10^{-14} (N) **Allow**: 1 mark for 1.4×10^{n}; $n \neq -14$ (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^{7}$ B = 1.4×10^{-3} (T)	C1 A1	Possible ecf from **(b)** **Note**: Answer to 3 sf is 1.43×10^{-3} (T) for 1.37×10^{-14} (N) **Note**: Using 1.4×10^{-14} (N) gives 1.46×10^{-3} (T) **Note**: Using $B = mv/Qr$ gives 1.42×10^{-3} (T)
	(d)		Using $(E =) mc^2$ and $(E =) \frac{hc}{\lambda}$ **(QWC)** $2\times mc^2 = 2\times\frac{hc}{\lambda}$ or $mc^2 = \frac{hc}{\lambda}$ or $mc = \frac{h}{\lambda}$ Correct substitution (any subject) λ = 2.4×10^{-12} (m)	B1 C1 A1	Eg: $2\times9.11\times10^{-31}\times(3.0\times10^{8})^2 = 2\times\frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ Answer to 3 sf is 2.43×10^{-12} (m) **Allow**: 1 mark for 1.21×10^{-12} (m) or 4.86×10^{-12} (m) for the C1A1 marks
			Total	**9**	

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Question			Answer	Marks	Guidance
3	(a)	(i)	$f = \frac{1}{T} = \frac{1}{10\times10^{-3}}$ frequency = 100 (Hz)	B1	
		(ii)	$2.0\times10^{-2} = B\times1.6\times10^{-3}\times400$ $B = \frac{2.0\times10^{-2}}{1.6\times10^{-3}\times400}$ $B = 3.1\times10^{-2}$ (T)	C1 C1 A1	**Allow**: 2 mark for 3.1×10^{n}; $n \neq -2$ (POT error) Answer to 3 sf is 3.13×10^{-2} (T) **Special case**: 12.5 scores 1 mark; number of turns omitted
		(iii)	(e.m.f. = -) rate of change of flux <u>linkage</u> <u>Tangent</u> drawn on Fig. 3.1 at 2.5 (ms) or 7.5 (ms) or 12.5 (ms) Values substituted to determine the gradient. The gradient must be 12.5 ± 1.0 (V)	B1 B1 B1	**Allow**: $E = (-)\frac{\Delta(N\phi)}{\Delta t}$ or (e.m.f. =) gradient **Alternative**: maximum e.m.f. = $2\pi f \times$ maximum flux linkage C1 maximum e.m.f. = $2\pi \times 100 \times 2 \times 10^{-2}$ C1 maximum e.m.f. = 12.6 (V) or 4π (V) A1
	(b)		$P = \frac{V^2}{R}$ $P = \frac{12^2}{150}$ power = 0.96 (W)	C1 A1	Possible ecf from **(a)(iii)**
			Total	**9**	

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Question			Answer	Marks	Guidance
4	(a)		Any <u>two</u> from: 1. There is a repulsive (electrical) force (between the gold nucleus and the alpha particle) 2. Momentum is conserved (because there are no external forces) / initial momentum of alpha particle = final momentum of gold nucleus (because there are no external forces) 3. KE of alpha particle transformed into (electrical) PE	B1×2	**Allow**: (The gold nucleus and alpha particle experience) forces in opposite directions
	(b)		Correct directions of field shown on lines from **A** and **B** Correct curved field lines from **A** and **B**	B1 B1	
	(c)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ Q = 79e and q = 2e force = $\frac{79 \times 2 \times (1.60 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times (6.0 \times 10^{-14})^2}$ force = 10.1 (N)	C1 C1 C1 A0	**All** values must be substituted for this mark
	(d)		Correctly shaped curve with F decreasing as r increases Value of F is between 2 to 3 (N) at r = 12 × 10^{-14} m	M1 A1	**Note**: $F \propto 1/r^2$, hence F should be about 2.5 (N)
			Total	**9**	

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Question			Answer	Marks	Guidance
5	(a)		no: of neutrons = 142	B1	
	(b)	(i)	(5.6 MeV =) $5.6 \times \underline{10^6} \times \underline{1.6 \times 10^{-19}}$ energy = 8.96×10^{-13} (J)	M1 A0	**Allow**: $5.6 \times \underline{1.6 \times 10^{-13}}$
		(ii)	$\frac{1}{2} \times 6.65 \times 10^{-27} \times v^2 = 8.96 \times 10^{-13}$ $v = \sqrt{\frac{2 \times 8.96 \times 10^{-13}}{6.65 \times 10^{-27}}}$ speed = 1.6×10^7 (m s^{-1})	C1 A1	 Answer to 3 sf is 1.64×10^7 (m s^{-1}) **Note**: The answer is 1.65×10^7 (m s^{-1}) if 9×10^{-13} (J) is used
	(c)	(i)	activity = $\frac{62}{8.96 \times 10^{-13}}$ activity = 6.92×10^{13} (Bq)	C1 A0	**Allow**: activity = $\frac{62}{9 \times 10^{-13}}$ (= 6.89×10^{13} Bq) Possible ecf from **(b)(i)**
		(ii)	$\lambda = \frac{0.693}{T}$ $\lambda = \frac{0.693}{88 \times 3.16 \times 10^7}$ decay constant = 2.49×10^{-10} (s^{-1}) or 2.5×10^{-10} (s^{-1})	 C1 A1	 **Note**: ln2 = 0.693 **Allow**: 1 mark for using 88 years and getting an answer of 7.9×10^{-3}
		(iii)	**1** $A = \lambda N$ $N = \frac{6.92 \times 10^{13}}{2.49 \times 10^{-10}}$ number = 2.78×10^{23} or 2.8×10^{23} **2** mass = $\frac{2.78 \times 10^{23}}{6.02 \times 10^{23}} \times 0.24$ mass = 0.11 (kg)	 C1 A1 B1	 Possible ecf from **(c)(ii)** **Note**: '$7 \times 10^{13}/2.5 \times 10^{-10} = 2.8 \times 10^{23}$' Possible ecf for mass from incorrect value for number of nuclei
			Total	**10**	

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Question			Answer	Marks	Guidance
6	(a)		The neutrons interact with other uranium (nuclei) / the neutrons cause further (fission) reactions	B1	**Not**: neutrons interact with uranium <u>atoms</u> / <u>molecules</u> / <u>particles</u>
	(b)		**Fuel rod**: Contain the <u>uranium</u> (nuclei) / fissile material **Control rods**: Absorb (some of the) neutrons *Controlled chain reaction*: The control rods are inserted into the reactor so as to allow (on average) one neutron from previous reaction to cause subsequent fission (AW) **Moderator**: Slows down the (fast-moving) neutrons / lowers the KE of (fast moving) neutrons / makes the (fast moving) neutrons into thermal neutrons Slow moving neutrons have a greater chance of causing fission / of being absorbed (by U-235) / sustaining chain reaction	B1 B1 B1 B1 B1	**Show annotation on Scoris** **Not** 'contains fuel' **QWC mark** **Allow**: Fast moving neutrons are captured (easily) by uranium-238 (nuclei leaving insufficient number of nuclei for fission / chain reaction) for the last B1 mark
	(c)	(i)	power = $3.0 \times 10^9/0.22$ power = 1.36×10^{10} (W) or 1.4×10^{10} (W)	B1	
		(ii)	energy = $1.36 \times 10^{10} \times 8.64 \times 10^4$ energy = 1.18×10^{15} (J) or 1.2×10^{15} (J)	B1	Possible ecf from **(c)(i)**
		(iii)	(number of reactions per day) = $\frac{1.18\times10^{15}}{3.2\times10^{-11}}$ mass = $\frac{1.18\times10^{15}}{3.2\times10^{-11}}\times3.9\times10^{-25}$ mass = 14.4 (kg) or 14 (kg)	C1 A1	Possible ecf from **(c)(ii)** **Note**: Using 1.2×10^{15} (J) gives an answer of 14.6 (kg); allow 15 (kg)
	(d)		Nuclear waste is (radio)active for a long time (AW) Causes ionisation	B1 B1	**Allow**: '*Nuclear waste can have long* half *life'*
			Total	**12**	

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Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: (X-rays) are EM waves Travel at speed of light / 3×10^8 <u>m s^{-1}</u> (in a vacuum) Travel in a vacuum / empty space Transverse waves Can cause ionisation Have wavelength of about 10^{-10} <u>m</u> (X-rays are high energy) photons (AW)	B1×2	**Allow**: reference to diffraction / interference / refraction / reflection / polarisation for 1 mark
	(b)		(X-ray) <u>photon</u> interacts with an (orbital) <u>electron</u> The (scattered) photon has a longer wavelength / lower frequency / lower energy **AND** The electron is ejected (from the atom at high speed)	B1 B1	**Allow**: 'X-rays' instead of 'photons' for the second B1 mark
	(c)	(i)	Initial / original / incident <u>intensity</u>	B1	**Allow**: Initial / original / incident <u>power</u> <u>per</u> (unit) <u>area</u>
		(ii)	$0.5 = e^{-(3.3x)}$ $\ln(0.5) = -3.3x$ $x = \ln(0.5)/(-3.3)$ $x = 0.21$ (cm)	C1 C1 A1	**Allow**: $\ln(2) = 3.3x$ **Allow**: 2 marks for 2.1×10^n; $n \neq -1$ (POT error)
	(d)		A contrast material has large attenuation coefficient / large atomic number / large Z (and hence easily absorbs X-rays) Idea of revealing tissue	B1 B1	
			Total	**10**	

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Question			Answer	Marks	Guidance
8	(a)		Any <u>seven</u> from: 1. Protons / nuclei have spin / behave like (tiny) magnets 2. Protons / nuclei precess about the magnetic field (provided by the strong electromagnet) 3. Transmitting coils provide (pulses of) radio waves of frequency equal to the Larmor frequency 4. The protons / nuclei absorb energy / radio waves / resonate and flip into a higher energy state 5. When protons / nuclei flip back to a lower energy state they emit (photons of) radio waves 6. The relaxation time (of the protons/nuclei) depends on the (surrounding) tissues 7. The radio waves are picked up by the receiving coils 8. The gradient coils alter the magnetic flux density (through the body) 9. The Larmor frequency (of the protons / nuclei) varies through the body 10. The computer (processes all the signals from the receiving coils and) generates the image(s)	B1 × 7	**Show annotation on Scoris** **Not**: Atoms / particles for nuclei /protons. **Allow**: The protons / nuclei absorb energy / radio waves / resonate and get excited **Allow**: When protons / nuclei relax they emit (photons of) radio waves
	(b)		Ay <u>two</u> from: 1. PET scan: uses radioactive substance / uses positron-emitting substance / uses F(-18) / mention of gamma rays / mention of gamma photons 2. PET scan reveal the 'function' of the brain (AW) 3. MRI scan show variation in tissues (in the brain) (AW)	B1×2	**Allow**: MRI scan: no radioactive substance is required / mention of radio waves **Allow**: PET scans are used to diagnose dyslexia / Alzheimer (disease)
			Total	**9**	

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Question			Answer	Marks	Guidance
9	(a)		Any <u>four</u> from: 1. (Fusion is the) joining / fusing together of ('lighter') <u>nuclei</u> / <u>protons</u> (to make 'heavier' nuclei) 2. Mass decreases in the reaction and this is transformed into energy OR the products have greater binding energy 3. High temperatures / ~10^7 K needed for fusion 4. High pressure / density (required in the core) 5. The protons / nuclei repel (each other because of their positive charge) 6. The strong (nuclear) force comes into play when the protons / nuclei are close to each other	B1×4	**Not**: Atoms / particles for nuclei /protons.
	(b)		(When hydrogen / helium runs out) the outer layers of the star expands / a (super) red giant is formed The core (of the star) collapses (rapidly) / a <u>supernova</u> is formed (Depending on the initial mass of the star the remnant is either a) <u>neutron star</u> or a <u>black hole</u>	B1 B1 B1	
			Total	**7**	

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Question			Answer	Marks	Guidance
10	(a)		$F = \frac{GMm}{r^2}$ force = $\frac{6.67\times10^{-11}\times(10^{41})^2}{(4\times10^{22})^2}$ force = 4.2×10^{26} (N)	C1 C1 A1	**Allow**: 4×10^{26} (N) or 10^{26} since this is an estimation **Allow**: 2 marks for 4.2×10^{n}; $n \neq 26$ (POT error)
	(b)		Allow any <u>one</u> from: • The galaxies are receding / moving away from each other (because of the big bang) • Other galaxies may be pulling them in opposite direction • The acceleration is too small to collapse (other than over a very long period of time)	B1	
	(c)		Any <u>six</u> from: 1. (At the start it was) very hot / extremely dense / singularity 2. All forces were unified 3. Expansion led to cooling 4. Quarks / leptons (soup) 5. More matter than antimatter 6. Quarks combine to form hadrons / protons / neutrons 7. Imbalance of neutrons and protons / (primordial) helium produced 8. Atoms formed 9. Idea of gravitational force responsible for formation of stars / galaxies 10. Temperature becomes 2.7 K / 3 K or (the universe is saturated with cosmic) microwave background radiation	B1×6	**Show annotation on Scoris**
	(d)	(i)	Dark lines / bands against a background of <u>continuous</u> <u>spectrum</u>	M1 A1	

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Question			Answer	Marks	Guidance
		(ii)	$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ speed = $\frac{86.6}{393.4} \times 3.0 \times 10^8$ (Any subject) speed = 6.6×10^7 (m s^{-1}) or 66000 (km s^{-1}) $v = H_0 d$ $66000 = 50 \times d$ distance = 1300 (Mpc)	C1 C1 A1	**Allow**: 1 mark for $\frac{86.6}{480.0} \times 3.0 \times 10^8 = 5.41 \times 10^7$ (m s^{-1}) **Allow**: 2 marks for 1.3×10^n; $n \neq 3$ (POT error) **Note**: Answer is 1080 (Mpc) if 5.4×10^7 (m s^{-1}) is used; this value will score 2 marks
			Total	**15**	

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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

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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.

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Answer **all** the questions.

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

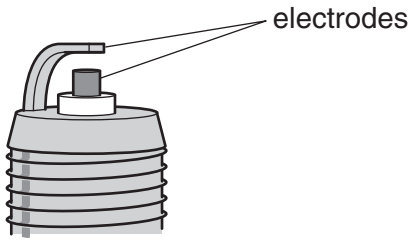


Fig. 1.1

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

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

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

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(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]

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

.....

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

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

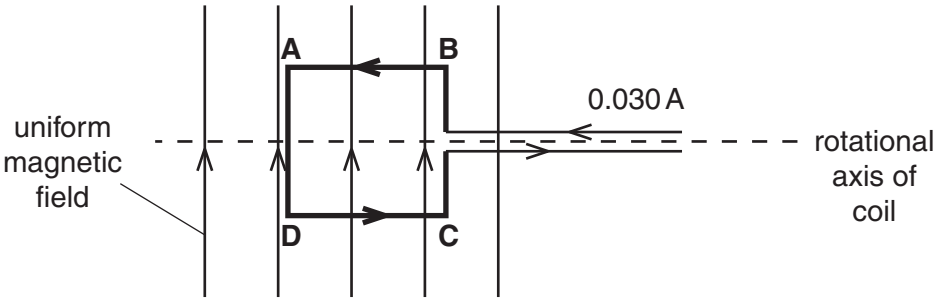


Fig. 2.1

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]**

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

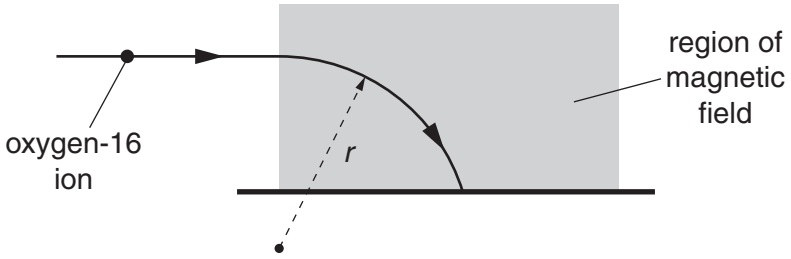


Fig. 2.2

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 4.5×10^6 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 2.0×10^{-13} N.

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

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

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

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

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

.....

.....

.....

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

[Total: 12]

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

.....

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

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

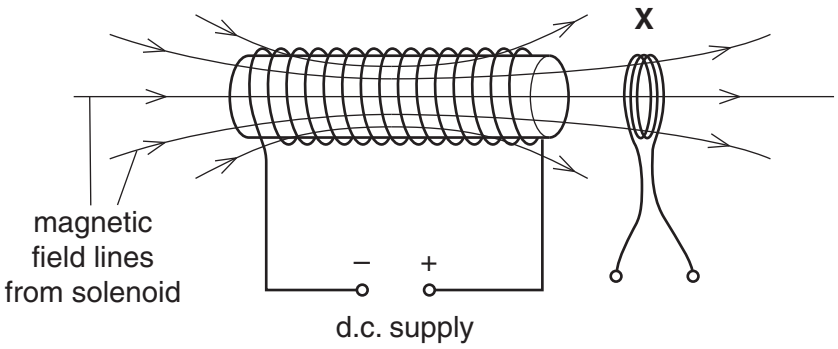


Fig. 3.1

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.

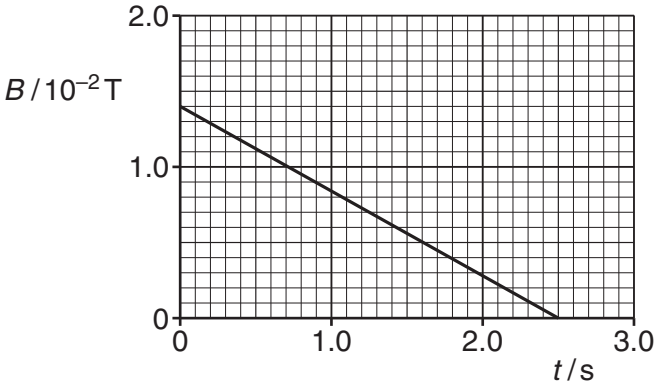


Fig. 3.2

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]**

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(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.

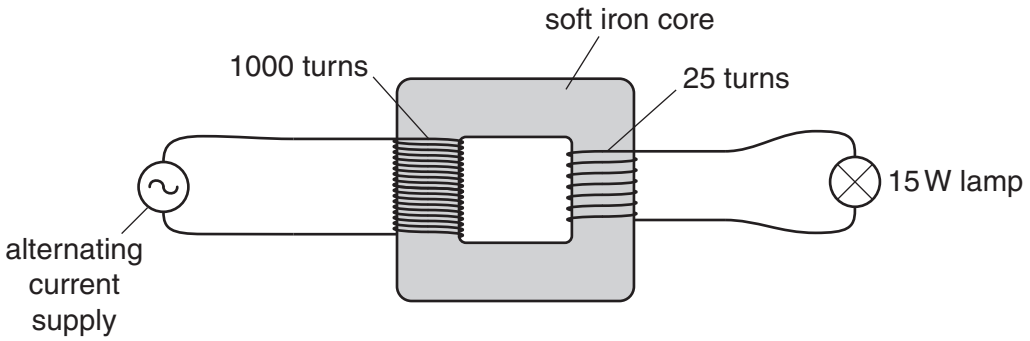


Fig. 3.3

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]

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

.....

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

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

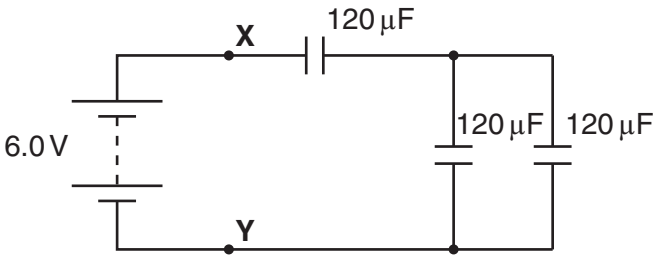


Fig. 4.1

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]**

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

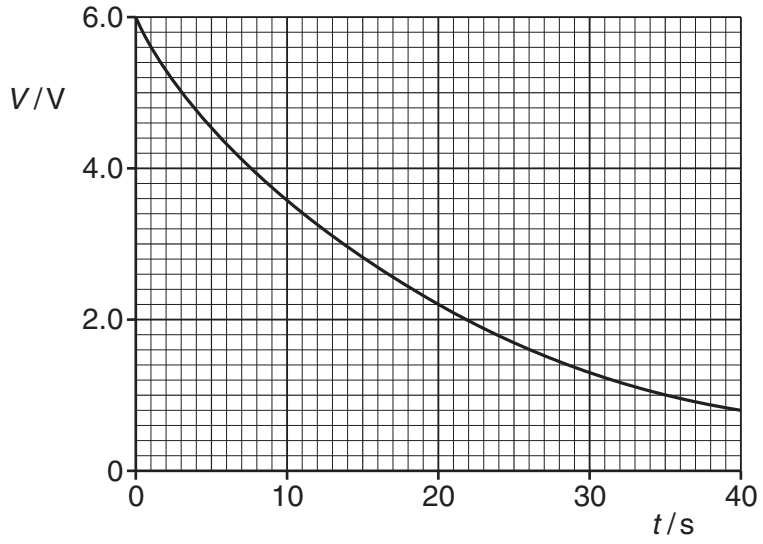


Fig. 4.2

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

[1]

2 Hence, calculate the resistance R of the resistor.

R = ... Ω **[2]**

[Total: 8]

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

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

Fig. 5.1

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

.....

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

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

1. .....

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

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

(i) Complete the nuclear reaction below.

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

[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]**

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(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]**

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

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..... **[4]**

[Total: 17]

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

.....

.....

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

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

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

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

[2]

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(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 $1.5 \times 10^{11}\,m$.

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

[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]

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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.

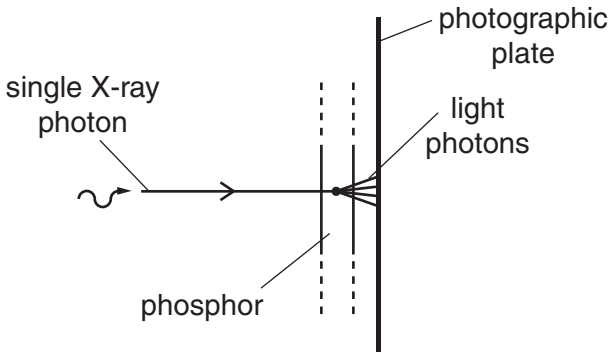


Fig. 7.1

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]**

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(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]

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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]**

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

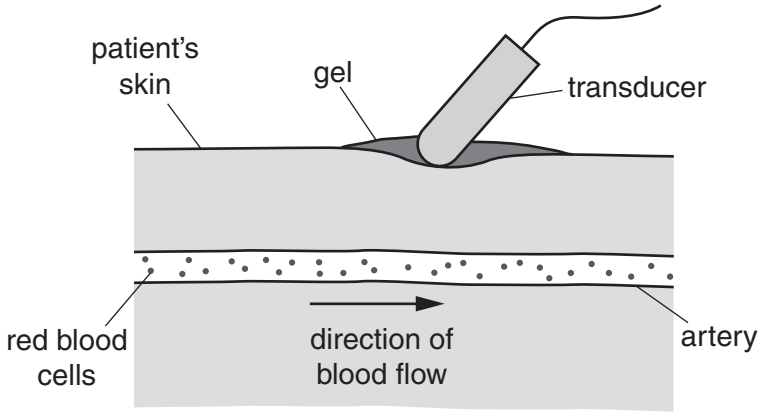


Fig. 8.1

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

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

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

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

[Total: 14]

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



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

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

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

State two properties of a white dwarf.

.....

.....

.....

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

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(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

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ADDITIONAL PAGE

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

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for January 2012

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Annotations available in Scoris

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

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Annotations in detailed mark scheme

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.

(Significant figures are rigorously assessed in the practical skills.)

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Question			Answers	Marks	Guidance
1	(a)		electric field strength = force per unit (positive) charge	B1	**Allow**: force/charge **Not**: *F*/*Q*
	(b)	(i)	$E = V / d$ $3.0\times10^{6} = V / 1.3\times10^{-3}$	C1	**Note**: This mark is for correct substitution
			V = 3900 (V)	A1	**Allow**: 1 mark if answer is 3.9×10^{n} (V), n ≠3 – POT error
		(ii)1	*Q* = *It* $Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$	C1	**Note**: This mark is for correct substitution
			charge = 1.1×10^{-10} (C) or 1.08×10^{-10} (C)	A1	
		(ii)2	number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$ number = 6.8×10^{8} or 6.75×10^{8}	B1	Possible ecf from **(b)(ii)1**
		(iii)	energy = *VQ* energy = $3900 \times 1.08 \times 10^{-10}$	C1	**Note**: No credit for using ½ *QV* Possible ecf from **(b)(ii)1**
			energy = 4.2×10^{-7} (J)	A1	
			Total	**8**	

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Question			Answers	Marks	Guidance
2	(a)		torque = one of the forces × <u>perpendicular</u> distance (between the forces)	B1	
	(b)	(i)	Into (plane of) paper	B1	**Not**: 'down'
		(ii)1	force = *BIL* = 0.060 × 0.03 × 0.015 force = 2.7×10^{-5} (N)	B1	
		(ii)2	torque = $2.7 \times 10^{-5} \times 0.015$ torque = 4.1×10^{-7} (N m) or 4.05×10^{-7} (N m)	C1 A1	Possible ecf from **(b)(ii)1** Do not allow 4.0×10^{-7} (N m) - rounding error
	(c)	(i)	$F = BQv$ $2.0 \times 10^{-13} = 0.14 \times Q \times 4.5 \times 10^{6}$ charge = 3.2×10^{-19} (C) or 3.17×10^{-19} (C)	C1 A1	**Allow**: Any subject
		(ii)	$F = mv^2 / r$ $2.0 \times 10^{-13} = \frac{2.7 \times 10^{-26} \times (4.5 \times 10^{6})^2}{r}$ radius = 2.7 (m) or 2.73 (m)	C1 C1 A1	**Allow**: Any subject
		(iii)	$BQv = mv^2/r$ Hence, radius ∝ mass	B1 B1	**Allow**: $r \propto m$
			Total	**12**	

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Question			Answers	Marks	Guidance
3	(a)		magnetic flux = (magnetic) flux density × (cross-sectional) area Idea of (magnetic) field normal to the plane of the area	M1 A1	Allow full credit for magnetic flux = *BA*, where *B* = magnetic flux density normal to area and *A* = (cross-sectional) area
	(b)	(i)	constant rate of change of (magnetic) flux / flux density	B1	**Not**: 'graph has constant gradient'
		(ii)	e.m.f. = rate of change of flux linkage e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$ e.m.f. = 3.2×10^{-3} (V) or 3.24×10^{-3} (V)	C1 C1 A1	**Allow**: $E=\frac{\Delta N\phi}{\Delta t}$ Deduct 1 mark if *B* is misread from the graph and then ecf **Allow**: 2 marks for an answer 3.24×10^{n} (if $n\neq-3$) **Allow**: 2 marks for 1.78×10^{-5} (when 180 has been missed out)
	(c)	(i)	$P = VI$ current in secondary = 15/6 or 2.5 (A) primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V) V_p = 240 (V) or I_s = 2.5 (A) primary current = 2.5/40 or 15/240 input current = 6.3×10^{-2} (A) or 6.25×10^{-2} (A)	 C1 A1	 The C1 mark is for either of these values
		(ii)	There is no change in flux density / (magnetic) flux / (magnetic) flux linkage	B1	**Not**: 'There is no change in the magnetic field'
			Total	**9**	

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Question			Answers	Marks	Guidance
4	(a)		capacitance = charge/p.d. or capacitance = charge per (unit) p.d.	B1	**Allow**: voltage instead of p.d. **Note**: Do not allow mixture of quantity and unit, e.g. 'charge per (unit) volt'
	(b)	(i)	$C_{parallel}$ = 240 (μF) C_T = (240 × 120)/(240 +120) or $C_T = (240^{-1} + 120^{-1})^{-1}$ total capacitance = 80 (μF)	C1 C1 A0	**Allow** :1 mark if C_T is not the subject, e.g: $\frac{1}{C_T} = \frac{1}{240} + \frac{1}{120}$
		(ii)	$E = \frac{1}{2}V^2C$ $E = \frac{1}{2} \times 6.0^2 \times 80 \times 10^{-6}$ energy = 1.4×10^{-3} (J) or 1.44×10^{-3} (J)	C1 A1	Possible ecf **Allow**: 1 mark for an answer 1.44×10^n ($n \neq -3$)
		(iii)1	6.0/*e* = 2.2 (V) (as on graph) Or 6.0 × 0.37 = 2.2 (V) (as on graph) Or At 20 (s), *V* = 2.2 (V), 2.2/6.0 = 0.37 (or e^{-1})	B1	**Allow**: Graph reading within ± 0.2 V
		(iii)2	*CR* = 20 $R = \frac{20}{80 \times 10^{-6}}$ $R = 2.5 \times 10^5$ (Ω)	C1 A1	**Allow**: Follow through with *CR* value from **(iii)1**
			Total	**8**	

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Question			Answers	Marks	Guidance
5	(a)		Same charge / number of protons	B1	**Not**: 'same chemical property'
	(b)		strong (nuclear force / interaction) gravitational (force)	B1 B1	**Allow**: 'gravity'
	(c)	(i)	$^{15}_{7}\text{N}$	B1	
		(ii)	(u d d) $\rightarrow$ (u u d)	B1	**Allow**: *One down quark becomes up quark* or d $\rightarrow$ u (+ electron + antineutrino)
	(d)	(i)	0.16 MeV = $0.16 \times 10^{6} \times 1.6 \times 10^{-19}$ $\frac{1}{2} \times 9.11 \times 10^{-31} \times v^{2} = 2.56 \times 10^{-14}$ speed = 2.4×10^{8} (m s^{-1}) or 2.37×10^{8} (m s^{-1})	C1 A1	**Allow**: 1 mark for using 9.8 MeV; answer is equal to 1.86×10^{9} (m s^{-1})
		(ii)	The mass of the electron increases / greater than 'rest mass'	B1	
	(e)	(i)	$\lambda = 0.693 / T$ $\lambda = 0.693/(5560 \times 3.16 \times 10^{7})$ $\lambda = 3.9 \times 10^{-12}$ (s^{-1}) or 3.94×10^{-12} (s^{-1})	C1 A1	**Allow**: 1 mark for 1.25×10^{-4} (if 5560 y used)
		(ii)	number = $\frac{1.0 \times 10^{-3}}{14} \times 6.02 \times 10^{23}$ number = 4.3×10^{19}	M1 A0	**Note**: This step must be seen to score 1 mark
		(iii)	activity = λN activity = $3.94 \times 10^{-12} \times 4.3 \times 10^{19}$ activity = 1.7×10^{8} (Bq) or 1.69×10^{8} (Bq)	C1 A1	Possible ecf from **(e)(i)** and **(e)(ii)**

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Question			Answers	Marks	Guidance
	(f)		Any **three** from: 1. Plants / living things take in carbon(-dioxide) or plants / living things stop taking in carbon after death 2. The ratio of carbon-14 to carbon-12 (nuclei) for the relic sample is determined 3. The current ratio of carbon-14 to carbon-12 nuclei is determined 4. The age of the relic is found using '$x = x_0 e^{-\lambda t}$' Limitation: The ratio of carbon-14 to carbon-12 is assumed to be constant / count(-rate) from relic may be comparable to background count(-rate)	B1×3 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: Any other valid comment for the limitation
			Total	**17**	

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Question			Answers	Marks	Guidance
6	(a)		(Minimum) energy to separate (all) nucleons / protons <u>and</u> neutrons (of a nucleus)	M1 A1	**Alternative**: B.E. = mass <u>defect</u> $\times c^2$ M1 mass defect = mass of nucleons – mass of nucleus A1
	(b)	(i)	BE of ^{2}H = $2 \times 1.8 \times 10^{-13}$ (J) or BE of ^{4}He = $4 \times 1.1 \times 10^{-12}$ (J) energy = $(4 \times 1.1 \times 10^{-12}) - 2 \times (2 \times 1.8 \times 10^{-13})$ energy = 3.68×10^{-12} (J) / 3.7×10^{-12} (J)	C1 C1 A0	**Note**: Ignore signs
		(ii)1	total surface area = $4\pi \times (1.5 \times 10^{11})^2$ power = $1400 \times (2.83 \times 10^{23})$ power = 3.96×10^{26} (W) / 4.0×10^{26} (W)	C1 C1 A0	
		(ii)2	number = $4.0 \times 10^{26} / 3.7 \times 10^{-12}$ number = 1.1×10^{38} (s^{-1}) or 1.08×10^{38} (s^{-1})	C1 A1	**Allow**: 10^{38} (s^{-1}) because the question is about an estimate
			Total	**8**	

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Question			Answers	Marks	Guidance
7	(a)		Any **two** from: 1. Electrons are accelerated through high voltage 2. (High speed) electron(s) hit metal 3. kinetic energy of electron(s) 'produces' X-ray (photons)	B1×2	**Allow**: X-rays are produced by (large) deceleration of electrons
	(b)	(i)	Packet /quantum of (electromagnetic) energy	B1	**Allow**: 'particle of (electromagnetic) energy'
		(ii)	$E = hc/\lambda$ and X-rays have shorter wavelength Or $E = hf$ and X-rays have higher frequency	B1	
	(c)		(KE of electron =) $1.6\times10^{-19}\times120\times10^{3}$ $eV = \frac{hc}{\lambda}$ $1.6\times10^{-19}\times120\times10^{3} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ wavelength = 1.0×10^{-11} (m) or 1.04×10^{-11} (m)	C1 C1 A1	**Allow**: 2 marks for $1.0(4)\times10^{-n}$ (m) ($n \neq 11$ - powers of ten error) **Allow**: 1×10^{-11} (m)
	(d)		Compton (scattering) Incoming photon collides with an electron, the electron is ejected and the photon is scattered / has lower energy Or Pair production Incoming photon (disappears and) produces electron-positron pair	M1 A1 --- M1 A1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: (Simple) scatter(ing) M1 The photon is absorbed and re-emitted without change in energy/wavelength/frequency A1
			Total	**9**	

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Question			Answers	Marks	Guidance
8	(a)		No entry into body / no cutting/incision of patient / no surgery Lower risk of infection / less trauma	B1 B1	
	(b)		Radioactive substance that is ingested / injected (into patient) Technetium(-99m) / Iodine(-131) / fluorine(-18)	B1 B1	 **Not**: barium
	(c)		**Collimator** – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator) Having thin / long / narrow (lead) tubes makes the image sharper / less blurred (**QWC mark**) **Scintillator** – gamma ray photon produces many/thousands of photons of (visible) light **Photomultiplier** - An electrical pulse is / electrons are produced from the light (photons) **Computer** – Signals (from photomultiplier tubes) are used to produce an image	B1 B1 B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(d)	(i)	$v = f\lambda$ $1500 = 2.0 \times 10^6 \times \lambda$ wavelength = 7.5×10^{-4} (m)	C1 A1	
		(ii)	Ultrasound is reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed (AW) The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / 'Δfrequency $\propto$ speed of blood'	B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded** **Not**: Doppler effect mentioned
			Total	**14**	

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Question			Answers	Marks	Guidance
9	(a)		Any four from: 1. (Sun / star formed from) dust cloud /nebula / (hydrogen) gas 2. Gravitational collapse (AW) 3. Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up 4. Fusion occurs (when temperature is about 10^7 K) 5. Protons / hydrogen nuclei combine to make helium (nuclei) 6. Stable size star is produced when thermal / radiation pressure is equal to gravitational pressure Steps sequenced correctly – **QWC mark**	B1× 4 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(b)		Any two from: 1. Very dense star 2. Hot star / high surface temperature / low luminosity 3. No fusion reactions take place / leaks away photons (from earlier fusion reactions) 4. Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses (AW)	B1×2	**Must use ticks on Scoris to show where the marks are awarded** **Not**: small in size, but allow 'smaller than main sequence star / Sun'
	(c)	(i)	Flat or universe will expand towards a (finite) limit or the rate of expansion will become/tend to zero	B1	
		(ii)	Hubble constant = 1/age $H_0 = 1/4.4\times10^{17}\ (=2.273\times10^{-18}\ s^{-1})$ density = $\frac{3H_0^{\ 2}}{8\pi G}$ density = $\frac{3H_0^{\ 2}}{8\pi G} = \frac{3\times(2.273\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ density = 9.2×10^{-27} (kg m^{-3}) or 9.24×10^{-27} (kg m^{-3}) density is about 10^{-26} (kg m^{-3})	C1 C1 A1 A0	**Allow**: 2 marks for a bald 9.24×10^{-27} (kg m^{-3}) answer **Note**: This mark can only be scored if working is shown

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Question			Answers	Marks	Guidance
		(iii)	number = $9.24 \times 10^{-27}/1.7 \times 10^{-27}$ number = 5.4 (Allow 5)	C1 A1	Possible ecf from **(c)(ii)** **Allow**: 2 marks for '$10^{-26}/1.7 \times 10^{-27}$ = 5.9 or 6'
	(d)		$\frac{1}{2}mv^2 = \frac{3}{2}kT$ / speed $\propto \sqrt{T}$ ratio = $\sqrt{\frac{10^8}{2.7}}$ ratio = 6.1×10^3 or 6.09×10^3	C1 A1	
			Total	**15**	

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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
- Ruler
- Protractor

Tuesday 21 June 2011
Morning

Duration: 1 hour 45 minutes

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G 4 8 5

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. 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. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).

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**.
-  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.
- You may use an electronic calculator.
- This document consists of **20** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 **(a)** Define *electromotive force*.

.....

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

(b) Define *magnetic flux*.

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.....

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

(c) Fig. 1.1 shows a simple transformer.

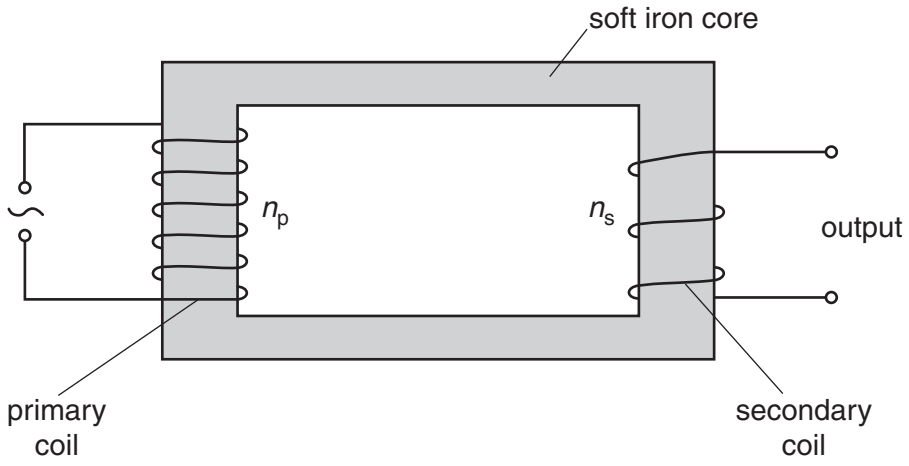


Fig. 1.1

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

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

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(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]

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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.

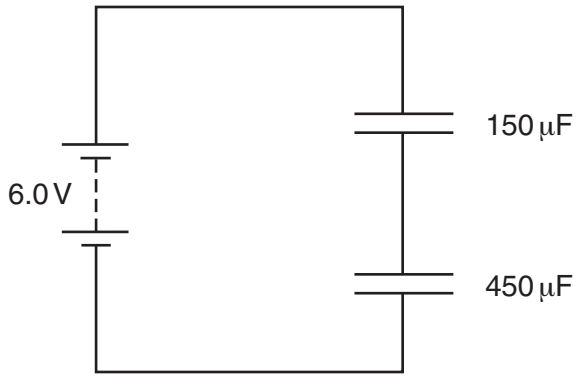


Fig. 2.1

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]**

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(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.

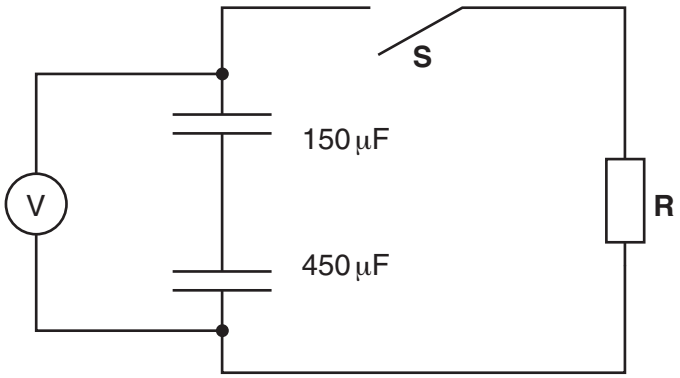


Fig. 2.2

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*.

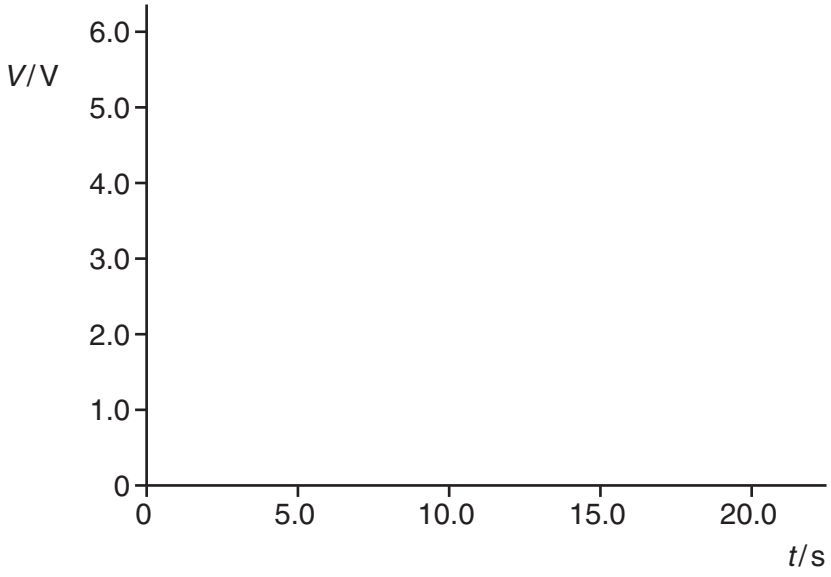


Fig. 2.3

[3]

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(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]

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

.....

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

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

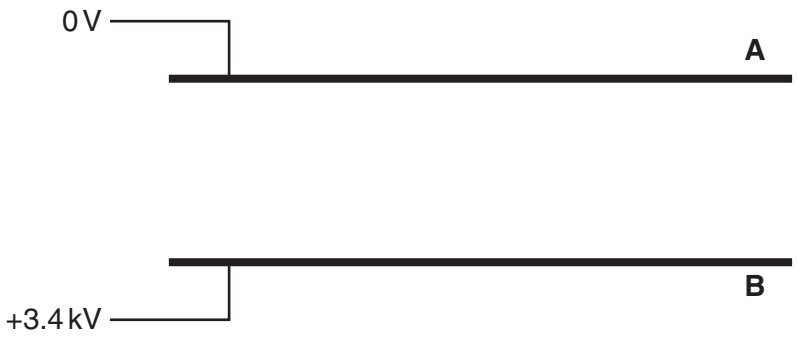


Fig. 3.1

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 $4.0 \times 10^7\,m\,s^{-1}$. 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.

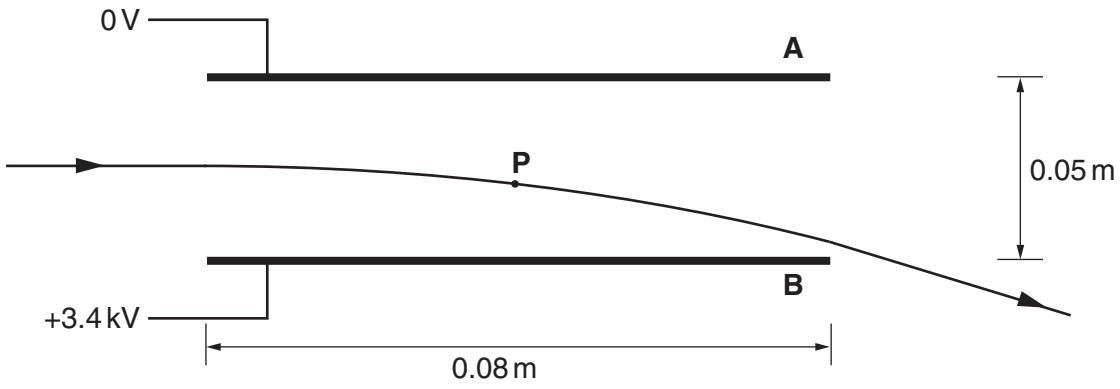


Fig. 3.2

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

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

[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 $1.2 \times 10^{7}\,m\,s^{-1}$.

[1]

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

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

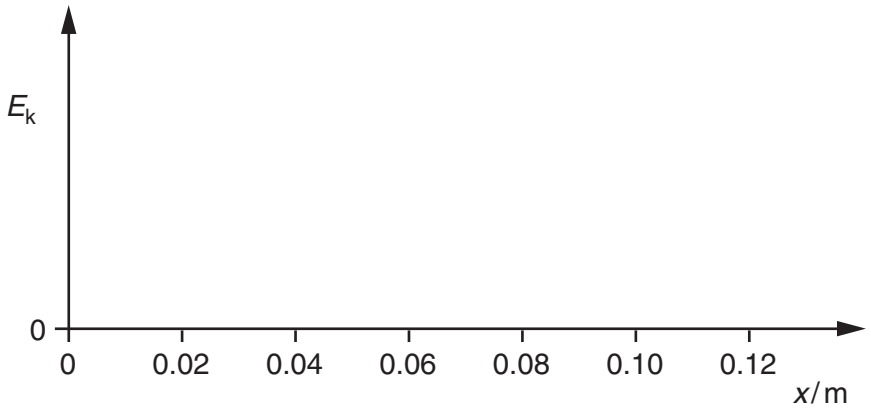


Fig. 3.3

[3]

[Total: 15]

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Turn over

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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.

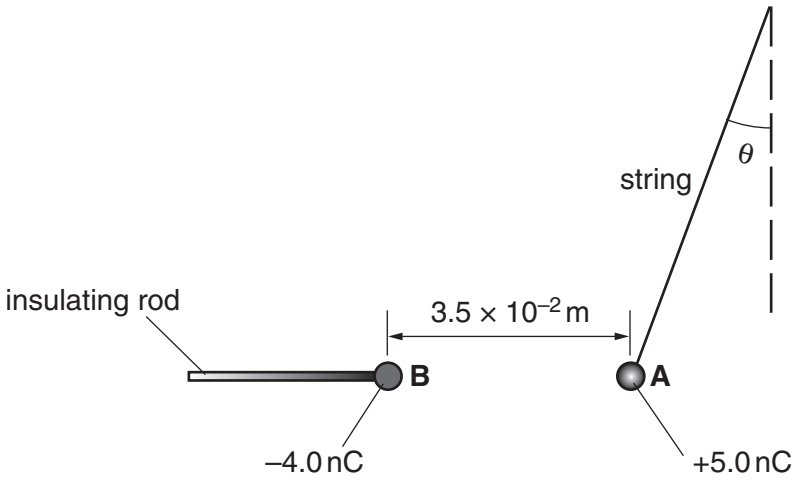


Fig. 4.1

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 = ... NC^{-1}

direction = ...

[4]

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

[2]

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(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.

$\theta =$ .....° **[3]**

[Total: 9]

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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.

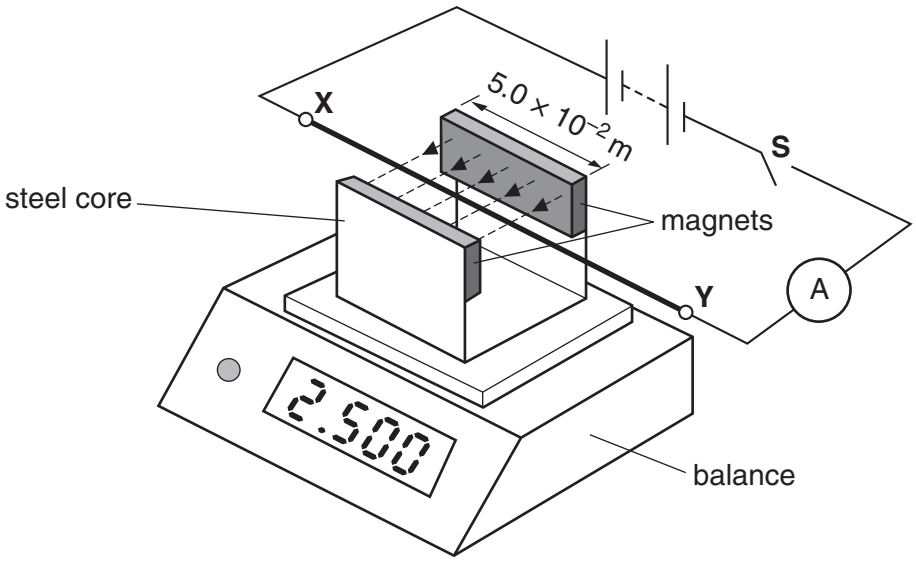


Fig. 5.1

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]**

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

reading on balance = ... N

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..... **[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]

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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.

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

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

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

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(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]

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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]**

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(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 .....

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closed .....

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flat .....

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

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

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

[Total: 8]

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

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..... **[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]

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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.

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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

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for June 2011

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The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:

Significant figures are rigorously assessed in the practical skills.
If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Additional Guidance.

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Question			Expected Answers	Marks	Additional guidance
1	(a)		Electromotive force is the energy transferred (from one form of energy) to <u>electrical</u> <u>per</u> unit charge	B1	**Allow:** 'electrical energy (gained) per unit charge' **Not:** electrical energy per coulomb
	(b)		Magnetic flux is the product of the (magnetic) flux density and the area (normal to the field)	B1	**Allow:** $\phi = BA$, where B = (magnetic) flux density and A = area. If $\phi = BA\cos\theta$ is used, then θ must be defined as the angle (between the normal to the plane of the area and the magnetic field) **Do not allow** 'field strength' for 'flux density'
	(c)	(i)	A changing (magnetic) flux is produced (in the primary coil / in the iron core) The iron core links this (magnetic) flux /(magnetic) flux density to the secondary coils The changing (magnetic) flux / (magnetic) flux density through secondary induces e.m.f. (in secondary coils)	B1 B1 B1	**Allow:** A changing (magnetic) flux density is produced (in the primary coil) but **not** '*changing (magnetic) field*' **Allow:** The rate of change of (magnetic) flux (linkage) induces an e.m.f. (in the secondary coil)
		(ii)	Any <u>one</u> from: More coils / turns on secondary Less coils / turns on primary Laminate the core	B1	**Not:** Increase frequency of alternating supply
	(d)	(i)	$\frac{n_s}{4200} = \frac{12}{230}$ (Any subject) number of turns = 219 or 220	C1 A1	 **Note:** A bald answer 219 or 220 scores 2 marks
		(ii)	current = $(12.0 - 11.8)/0.35$ current = 0.57 (A) --- $P = VI$ or $P = I^2R$ or $P = V^2/R$ $P = 0.2 \times 0.57$ or $P = 0.57^2 \times 0.35$ or $P = 0.2^2/0.35$ power = 0.114 (W) or 0.11 (W)	C1 A1 C1 A1	 Possible e.c.f. from **(ii)1**
			Total	**12**	

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Question			Expected Answers	Marks	Additional guidance
2	(a)		capacitance = charge / potential difference	B1	**Allow:** p.d. and voltage **Not:** charge per volt or coulombs per p.d
	(b)	(i)	$V = Q/C$ and Q = constant in series circuit $V = \frac{450}{450+150} \times 6.0$ potential difference = 4.5 (V)	C1 A1	**Allow:** 1 mark for an answer of 1.5 (V) **Note**: Using **(b)(ii)**, alternative marking scheme $V = 6.75 \times 10^{-4}/150 \times 10^{-6}$ C1 $V = 4.5$ V A1
		(ii)	charge = $150 \times 10^{-6} \times 4.5$ charge = 6.75×10^{-4} (C)	B1	Possible e.c.f. **Note**: Using **(b)(iii)** ... $Q = 6.0 \times 1.125 \times 10^{-4} = 6.75 \times 10^{-4}$ (C)
		(iii)	$\frac{1}{C} = \frac{1}{150} + \frac{1}{450}$ (working in μF) capacitance $C_T = 1.125 \times 10^{-4}$ (F) or 113 μ(F)	B1	**Possible alternative:** capacitance = $6.75 \times 10^{-4}/6.0$ capacitance = 1.125×10^{-4} (F) or 113 μ(F) Possible e.c.f. from **(ii)**
	(c)	(i)	time constant = CR time constant = $1.125 \times 10^{-4} \times 45 \times 10^{3}$ time constant = 5.06 (s)	M1 A0	**Note:** The mark is for multiplying correct C and R values Possible e.c.f. from**(b)(iii)**
		(ii)	Graph starting from 6.0 (V) Correct shaped curve Approximately correct value of V at CR	B1 B1 B1	**Note:** The (exponential decay) curve must not touch or cut the time axis **Note:** V is 2 to 2.5 (V) at $t \approx 5$ s

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Question			Expected Answers	Marks	Additional guidance
		(iii)	$\frac{1}{2}\times 4.5^2\times 150\times 10^{-6}$ and $\frac{1}{2}\times 1.5^2\times 450\times 10^{-6}$ ratio = $\frac{0.5\times 4.5^2\times 150\times 10^{-6}}{0.5\times 1.5^2\times 450\times 10^{-6}}$ ratio = 3 Or ½ Q^2/C_{150} and ½ Q^2/C_{450} ratio = C_{450} / C_{150} ratio = 3	C1 A1 C1 A1	**Allow:** with or without the 10^{-6} Possible e.c.f. from **(b)(i)** and **(b)(ii)** **Allow:** full credit for correct use of either ½QV or ½ Q^2/C
		(iv)	The ratio remains constant The charge / Q is the same for both capacitors	B1 B1	
			Total	**13**	

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Question			Expected Answers	Marks	Additional guidance
3	(a)		(Electric field strength is the) force <u>per</u> (unit positive) charge	B1	**Allow:** $E = F/Q$, *F* is the force on a (positive) charge *Q*
	(b)		Parallel and equally spaced lines at right angles to plates Correct <u>upward</u> direction of field shown on at least one field line	B1 B1	
	(c)	(i)	An arrow vertically downwards at **P**	B1	
		(ii)	$E = \frac{3400}{0.050}$ or $E = 6.8 \times 10^4$ (V m^{-1}) $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^{4}\times1.6\times10^{-19}}{9.11\times10^{-31}}$ or $a = \frac{1.09\times10^{-14}}{9.11\times10^{-31}}$ acceleration = 1.19×10^{16} (m s^{-2}) or 1.2×10^{16} (m s^{-2})	C1 C1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below $E = \frac{3400}{0.050\times10^{-2}}$ or $E = 6.8 \times 10^6$ (V m^{-1}) C1 $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^{6}\times1.6\times10^{-19}}{9.11\times10^{-31}}$ C1 acceleration = 1.19×10^{18} (m s^{-2}) A0
		(iii)	$t = \frac{0.04}{4.0\times10^{7}}$ time = 1.0×10^{-9} (s)	B1	**Allow:** 1×10^{-9} (s) or 10^{-9} (s)
		(iv)	initial vertical velocity = 0, final vertical velocity = *at* vertical velocity = $1.2 \times 10^{16} \times 1.0 \times 10^{-9}$ (**Allow:** $1 \times 10^{16} \times 1.0 \times 10^{-9}$) vertical velocity = 1.2×10^7 (m s^{-1})	 M1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below vertical velocity = $1.2 \times 10^{18} \times 1.0 \times 10^{-9}$ M1 vertical velocity = 1.2×10^9 (m s^{-1}) A0

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Question			Expected Answers	Marks	Additional guidance
		(v)	$v^2 = (4.0\times10^7)^2 + (1.2\times10^7)^2$ velocity = 4.2×10^7 (m s^{-1}) Or $v^2 = (4.0\times10^7)^2 + (1\times10^7)^2$ velocity = 4.1×10^7 (m s^{-1})	C1 A1 C1 A1	Possible ecf from **(iv)**
		(vi)	KE = ½ mv^2 KE = $0.5 \times 9.11 \times 10^{-31} \times (4.2 \times 10^7)^2$ kinetic energy = 8.04×10^{-16} (J) or 8.0×10^{-16} (J)	C1 A1	Possible ecf from **(v)** **Allow:** 1 sf answer if the answer comes out as 8.0×10^{-16} (J)
		(vii)	Graph starts at non-zero value for E_k Between 0 and 0.08 (m) the graph has increasing gradient Horizontal line after 0.080 (m)	B1 B1 B1	 **Note:** The E_k value for the horizontal line > E_k value at x = 0
			Total	**15**	

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Question			Expected Answers	Marks	Additional guidance
4	(a)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	C1	
			$\frac{(-)4.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ and $\frac{5.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$	C1	Ignore signs
			E_B = 1.17 × 10^5 (N C^{-1}) and E_A = 1.47 × 10^5 (N C^{-1})		
			field strength = (1.17 + 1.47) × 10^5 (N C^{-1})		
			field strength = 2.64 × 10^5 (N C^{-1}) or 2.6 × 10^5 (N C^{-1})	A1	**Allow:** 2 marks for 2.9(4) × 10^4 (N C^{-1}) when the fields are subtracted **Allow:** 2 marks for 6.6 × 10^4 (N C^{-1}) for using 3.5 × 10^{-2} m
			direction = to the left / towards B	B1	
	(b)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$	C1	
			force = $\frac{4.0\times10^{-9}\times5.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(3.5\times10^{-2})^2}$	C1	Ignore signs **Allow:** ε_0 in the equation
			force = 1.47 × 10^{-4} (N)	A0	
	(c)		(weight =) 4.5 × 10^{-5} × 9.81 or (weight =) 4.4(1) × 10^{-4} (N)	C1	**Allow:** weight = 4.5 ×10^{-5} × *g*
			$\tan\theta = \frac{1.5\times10^{-4}}{4.41\times10^{-4}}$	C1	
			angle = 18.8 (°) or 19 (°) (**Allow**: Full credit when angle is determined using a scale diagram)	A1	**Note:** Using force = 1.47 × 10^{-4} (N) gives an angle of 18.4°; hence allow 18° **Allow:** 2 marks for θ = 71°; this is the complementary angle **Allow:** 1 mark for '$\tan\theta = \frac{1.5\times10^{-4}}{4.5\times10^{-5}}, \theta = 73^0$' when mass is used instead of weight.
			Total	**9**	

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Question			Expected Answers	Marks	Additional guidance
5	(a)		Down(wards)	B1	**Note:** Can be on Fig. 5.1
	(b)		(Fleming's) left-hand rule	B1	**Allow:** Thumb in direction of force, first finger in direction of (magnetic) field and second finger in direction of (conventional) current
	(c)	(i)	force = $BIL = 0.080 \times 4.0 \times 5.0 \times 10^{-2}$ force = 0.016 (N)	B1	
		(ii)	reading = 2.500 – 0.016 reading = 2.484 (N) The force on core/magnets is up(wards) (According to Newton's third law) the forces (on the rod and steel core/magnets) are equal and opposite	B1 B1 B1	**Allow:** 'up and down' as equivalent to 'opposite'
	(d)		Resistance increases by a factor of 4 Current decreases by a factor of 4 The force decreases by a factor of 4 force = 0.004 (N)	C1 C1 A1	Possible e.c.f. from **(c)(i)** **Note:** force = **(c)(i)**/4 can score full marks **Special case:** Allow 1 mark for (resistance doubles, current is halved, hence) force = 0.008 (N)
			Total	**9**	

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Question			Expected Answers	Marks	Additional guidance
6	(a)		Any <u>four</u> from 1 to 5: 1. Most of the alpha particles went straight through (some deviated through small angles) 2. Hence most of the atom is empty space 3. Some / a very small number of alpha particles were scattered / repelled through large angles / angles more than 90° 4. This showed the existence of (a tiny) positive nucleus 5. The size of the nucleus is about 10^{-14} <u>m</u> ✍ QWC: Award a mark for one conclusion correctly linked to an observation	B1×4 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: 10^{-15} <u>m</u>
	(b)		Any <u>five</u> from: Gravitational (force) This force is attractive **AND** is long-ranged / obeys '$1/r^2$ relationship' <u>Strong</u> (nuclear force/interaction) This force is attractive (at larger distances) or repulsive at short distances **AND** is short-ranged / ~ 10^{-14} m Electrostatic / electrical (force) / coulomb (force) This force is repulsive between protons / zero between neutrons / zero between protons and neutrons **AND** is long-ranged / obeys '$1/r^2$ relationship'	M1 A1 M1 A1 M1 A1	**Allow:** gravity **Note**: Do not allow 'inverse square law'; allow 'inverse square law with distance' **Allow:** Electromagnetic (interaction/force)

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Question			Expected Answers	Marks	Additional guidance
	(c)	(i)	mass = $235 \times 1.7 \times 10^{-27}$ ($= 3.995 \times 10^{-25}$ kg)	C1	**Allow:** 1.66×10^{-27} kg for mass of nucleon
			volume = $\frac{4}{3}\pi \times (8.8 \times 10^{-15})^3$ ($= 2.855 \times 10^{-42}$ m^3)	C1	
			density = mass/volume		
			density = 1.4×10^{17} (kg m^{-3})	A1	**Allow:** 10^{17} (kg m^{-3}) for this estimation question **Note:** Omitting 235 gives 6.0×10^{14} (kg m^{-3}), allow 2 mark **Allow:** 1 mark if 92 or 143 is used to determine the mass of the nucleus; this gives a density value of 5.5×10^{16} (kg m^{-3}) and 8.5×10^{16} (kg m^{-3}) respectively
		(ii)	The nucleons / neutrons and protons are packed together with little or no empty space (AW)	B1	
			Total	14	

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Question			Expected Answers	Marks	Additional guidance
7	(a)		The critical density is the density for which the universe will expand towards a (finite) limit or rate of expansion **tends** to zero / which will result in a <u>flat</u> universe	B1	**Not:** critical density is given by $\frac{3H_0^2}{8\pi G}$
	(b)		Hubble constant = $\frac{65\times10^3}{10^6\times3.1\times10^{16}}$ Hubble constant = 2.1×10^{-18} s^{-1} critical density = $\frac{3H_0^2}{8\pi G}$ critical density = $\frac{3\times(2.1\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ critical density = 7.9×10^{-27} (kg m^{-3})	B1 C1 A1	Possible e.c.f. from value of Hubble constant within this calculation
	(c)	(i)	open: (density of universe < critical density hence) the universe will expand forever closed: (density of universe > critical density hence) the universe will (eventually stop expanding and then) contract / big crunch flat: (density of universe = critical density hence) the universe will expand towards a (finite) limit / rate of expansion **tends** to zero	B1 B1 B1	**Allow:** 'universe continues to expand' **Not:** 'The universe stops expanding' **Special case:** Award 1 mark for correct sketches if no explanation is given for open, closed and flat
		(ii)	Any <u>one</u> from: Existence of dark matter / black holes / neutrinos / dark energy / H_0 is not known accurately	B1	
			Total	**8**	

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Question			Expected Answers	Marks	Additional guidance
8	(a)		Less chance of infection	B1	
	(b)		Any <u>two</u> from: 1. Tracer is injected into the body / placed inside the body / circulates the body 2. Tracer is absorbed by organ / shows blockage 3. Beta detector / gamma camera (is used to detect radiation from the body)	B1×2	**Note:** No marks for ingesting substances (e.g barium)
	(c)		Any <u>five</u> from: 1. A positron / beta-plus emitting tracer / source is used 2. The positron annihilates with an electron (inside the patient) 3. This produces <u>two</u> gamma photons 4. The photons travels in opposite directions 5. The patient is surrounded by a ring of gamma detectors 6. The arrival times of the photons / delay time indicates location (of tumour inside the body) 7. A 3-D image is created (by the computer connected to the detectors)	B1×5	
			Total	**8**	

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Question			Expected Answers	Marks	Additional guidance
9	(a)		Any <u>three</u> from 1 to 4: 1. A (piezoelectric) crystal / transducer is used to send <u>pulse</u>(s) of ultrasound (into the patient) 2. Wave / ultrasound / pulse / signal is <u>reflected</u> (at the boundary of tissue) 3. The (intensity of the) <u>reflected</u> signal depends on the acoustic impedances (at the boundary) 4. The (time of) delay is used to determine the depth / thickness ✎ QWC: Award a mark for correct sequencing of the steps in the process	B1×3 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow:** $\frac{I_{(r)}}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ without symbols defined for the 3rd marking point **Note**: Do not allow marking points 2 or 3 for gel-skin interface
	(b)		A-scan is one directional / B-scan involves different directions or angles / B-scan consists of many A-scans / B-scan produces 2-D or 3-D image	B1	
			Total	**5**	

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Question			Expected Answers	Marks	Additional guidance
10	(a)		A neutron is absorbed by a (massive / uranium) nucleus The nucleus splits into two (smaller/daughter) nuclei and (one or more) neutrons	B1 B1	
	(b)		In a fission reaction there is a decreases in the mass (According to $\Delta E = \Delta mc^2$) mass is converted into energy Or The (total) binding energy of the products / smaller nuclei is greater than the binding energy of the original nucleus The difference in the binding energies is released as energy	M1 A1 M1 A1	**Allow:** The 'BE increases (in the reaction)'
	(c)		Moderator: water / graphite / carbon It slows down the (fast-moving) neutrons / reduces the (kinetic) energy of neutrons Slow-moving neutrons have greater chance of causing fission (than fast-moving neutrons)	B1 B1 B1	**Note**: If boron is mentioned, then do not award this B1 mark **Allow**: They become thermal neutrons
			Total	**7**	

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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

Wednesday 2 February 2011
Afternoon

Duration: 1 hour 45 minutes

G4835

OCE/17327

Candidate forename		Candidate surname	

Centre number						Candidate number				

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- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- 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.
- Answer **all** the questions.
- 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 **20** pages. Any blank pages are indicated.

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Answer **all** the questions.

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

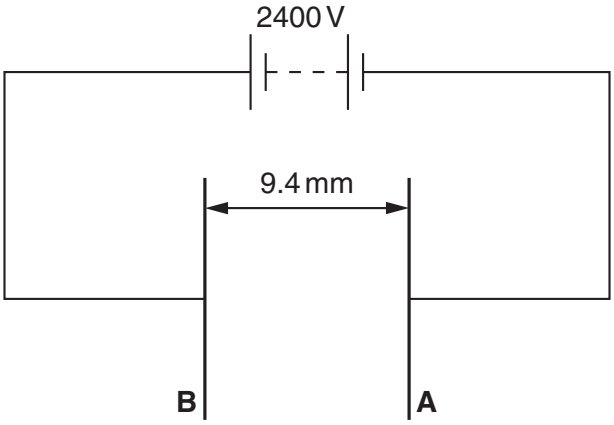


Fig. 1.1

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]**

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(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)**.

.....

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

[Total: 7]

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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 S_1 is closed and the capacitor is charged to a p.d. of 12 V.

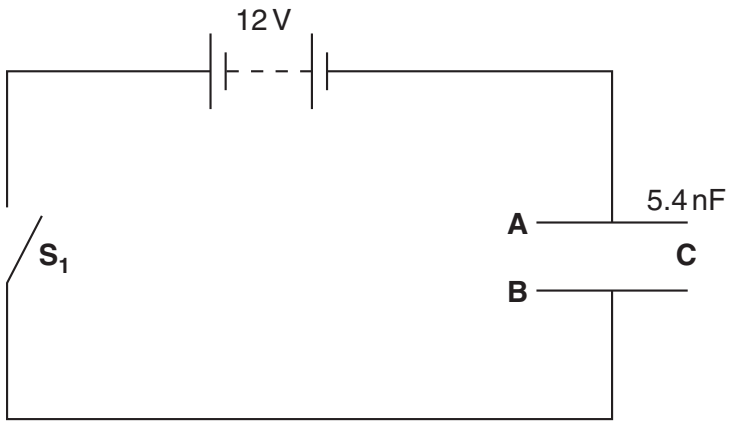


Fig. 2.1

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]**

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

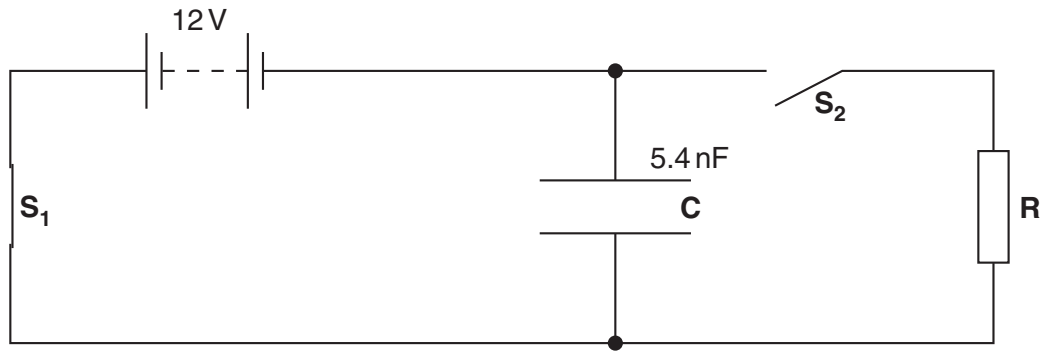


Fig. 2.2

The switch S_1 is now opened and switch 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]

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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.

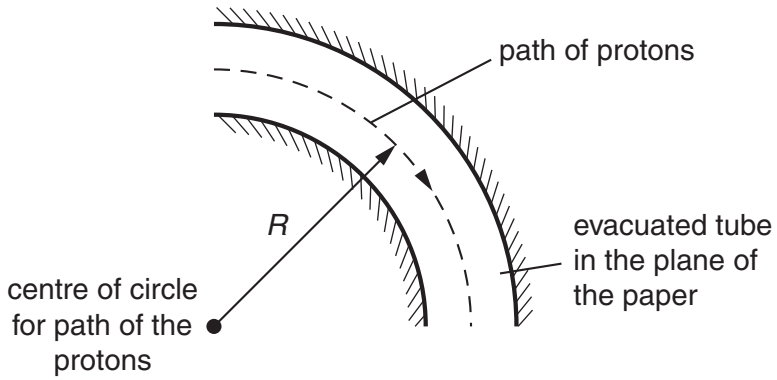


Fig. 3.1

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]**

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

.....

.....

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

[Total: 7]

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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 $km\,s^{-1}$ Mpc^{-1}. One parsec = 3.1×10^{16} m.

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

[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.

.....

.....

.....

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.....

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

[Total: 8]

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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]

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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.

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..... **[6]**

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

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

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

$1\ y = 3.2 \times 10^{7}\,s$

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

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

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

(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.

.....

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.....

..... **[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]

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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.

.....

.....

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.....

..... **[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]**

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(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]

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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.

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

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

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

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

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.....

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

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

.....

.....

.....

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

Total: [10]

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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]

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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]**

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(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

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ADDITIONAL PAGE

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

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ADDITIONAL PAGE

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GCE

Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

Mark Scheme for January 2011

Oxford Cambridge and RSA Examinations

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Question			Expected Answer	Mark	Additional Guidance
1	(a)	(i)	$E = \frac{V}{d} = \frac{2400}{9.4\times10^{-3}}$ $E = 2.55 \times 10^{5}$ (V m^{-1}) force = $E \times Q = 2.55 \times 10^{5} \times 1.60 \times 10^{-19}$ force = 4.09×10^{-14} (N)	C1 A1	**Allow** 1 mark for 4.1×10^{-n}, $n \neq 14$ **Allow** 2sf answer of 4.1×10^{-14} (N) Alternative: $F = \frac{Ve}{d} = \frac{2400\times1.60\times10^{-19}}{9.4\times10^{-3}}$ C1 force = $4.08(5) \times 10^{-14}$ (N) A1 [Allow: 4.08×10^{-14} (N)]
		(ii)	KE = $e \times V$ or KE = $F \times d$ KE = $1.6 \times 10^{-19} \times 2400$ or KE = $4.09 \times 10^{-14} \times 9.4 \times 10^{-3}$ KE = 3.84×10^{-16} (J)	C1 A1	**Allow** 2 sf answer Possible ecf if answer from **(a)(i)** is used
		(iii)	KE = $\frac{1}{2}mv^2$ $v = \sqrt{\frac{2\times3.84\times10^{-16}}{9.11\times10^{-31}}}$ speed = $2.9(0) \times 10^{7}$ (m s^{-1})	B1	Possible ecf if answer from **(a)(ii)** is used
	(b)		There is no change (to the gain in KE) work done or KE = Fd, F or E is halved and d is doubled or work done or KE = VQ and V is the same or work done or KE = VQ and this does not depend on distance	M1 A1	
			Total	7	

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Question			Expected Answer	Mark	Additional Guidance
2	(a)		coulomb <u>per</u> volt	B1	**Allow**: 1 F = 1 $\underline{CV^{-1}}$
	(b)	(i)	<u>Electrons</u> flow 'clockwise' / negative to positive These are deposited on (plate) **A** (and hence becomes negatively charged) or These are removed from (plate) **B** (and hence become positively charged)	B1 B1	**Not**: **A** becomes negative / **B** becomes positive
		(ii)1	$Q = C \times V = 5.4 \times 10^{-9} \times 12$ charge = 6.48×10^{-8} (C)	B1	
		(ii)2	energy = $\frac{1}{2}V^2C = \frac{1}{2} \times 12^2 \times 5.4 \times 10^{-9}$ energy = 3.89×10^{-7} (J)	B1	Possible ecf if Q used from **(ii)1**
	(c)	(i)	$R = \frac{12}{3.24 \times 10^{-6}}$ resistance = 3.7×10^6 (Ω)	M1 A0	**Allow**: 'R = 12/3.24μ' (= 3.7 MΩ)
		(ii)	time constant = CR = $5.4 \times 10^{-9} \times 3.7 \times 10^6$ or 0.02 (s) $I = I_0 e^{-t/CR} = 3.24 \times e^{-(0.080/0.020)}$ current = 0.059 (μA)	C1 A1	**Allow**: ecf for time constant **Allow**: 1 mark for 5.9×10^{-n}
	(d)		(Total) resistance of circuit <u>halved</u> / time constant is <u>halved</u> Rate of discharge is <u>doubled</u> / (initial) current is <u>doubled</u>	B1 B1	
			Total	10	

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Question			Expected Answer	Mark	Additional Guidance
3	(a)		Perpendicular out of plane of paper	B1	**Allow**: 'out of paper' **Not**: 'up the paper'
	(b)		$\frac{mv^2}{R} = BQv$ hence $v = \frac{BQR}{m}$	M1 A0	**Allow**: Use of *r* instead of *R* and *e* instead of *Q*
	(c)		speed = $\frac{2\pi \times 0.18}{2.0 \times 10^{-8}}$ or 5.66×10^7 (m s^{-1}) $5.66 \times 10^7 = \frac{B \times 1.60 \times 10^{-19} \times 0.18}{1.67 \times 10^{-27}}$ (Any subject) *B* = 3.28 (T)	C1 C1 A1	**Allow** : ecf for incorrect value for speed *v* Alternative : $t = (\frac{2\pi R}{v} =) \frac{2\pi m}{BQ}$ C1 $B = \frac{2\pi \times 1.67 \times 10^{-27}}{2.0 \times 10^{-8} \times 1.60 \times 10^{-19}}$ C1 *B* = 3.28 (T) A1
	(d)		The force / acceleration is perpendicular to the motion / velocity No work is done	B1 B1	**Allow**: 'speed' instead of 'velocity'
			Total	7	

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Question			Expected Answer	Mark	Additional Guidance
4	(a)		The speed of recession of a galaxy is proportional to its distance (from Earth / observer)	B1	
	(b)	(i)	$v = \frac{\Delta\lambda}{\lambda} \times c$ $v = 0.15 \times 3.0 \times 10^8$ speed = 4.5×10^7 (m s $^{-1}$)	M1 A0	**Allow**: '15% of $3.0 \times 10^8 = 4.5 \times 10^7$ (m s $^{-1}$)' **Not**: '0.15*c*'
		(ii)	distance = v / H_0 (Any subject) distance = $\frac{4.5 \times 10^7 \times 3.1 \times 10^{22}}{65 \times 10^3}$ distance = 2.15×10^{25} (m)	C1 A1	 Possible ecf from **(b)(i)** **Allow**: 1 mark for 2.15×10^n, $n \neq 25$
		(iii)	$H_0 = \frac{65 \times 10^3}{3.1 \times 10^{22}}$ (= 2.10×10^{-18} s^{-1}) age = $1/H_0$ = 4.77×10^{17} (s) age = 1.49×10^{10} (y)	C1 A1	 **Allow**: 1 mark for 1.49×10^n, $n \neq 10$
	(c)		Any two from: 1. Spectra from galaxies show shift to longer wavelengths (suggests galaxies are moving away from the Earth) 2. The more distant galaxies are moving faster (than the ones closer to our galaxy) 3. Existence of microwave background radiation (which is the same in all directions) / The temperature of universe is 3 K (after cooling due to expansion) / gamma (radiation) became microwaves (as the universe expanded) 4. Existence of primordial helium (produced in the early stages of the universe) 5. Temperature fluctuations (predicted and observed)	B1 × 2	**Not** 'red-shift' for 1. **Allow**: Reference to CMB (radiation) in 3. **Not** bald 'ripples' for 5.
			Total	8	

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Question			Expected Answer	Mark	Additional Guidance
5	(a)		Diagram showing (star,) 1 AU, 1 pc and angle of 1 arc second Distance from a base length of 1 AU that subtends an angle of 1 (arc) second or Parsec is a distance that gives a (stellar) parallax of 1 second (of arc) / 1/3600°	B1 B1	**Allow**: 1 pc is the distance calculated using: 1 AU/tan(1/3600°) **Not**: 1 pc = 3.26 ly **Not**: 1 pc = 3.1 $\times 10^{16}$ m
	(b)	(i)	distance (pc) = 1 / 0.275 distance = 3.64 (pc)	B1	
		(ii)	distance in m = 3.1 $\times$ 10^{16} $\times$ 3.64 = 1.127 $\times$ 10^{17} (m) distance in ly = 1.127 $\times$ 10^{17}/9.5 $\times$ 10^{15} distance in ly = 11.9	C1 A1	Possible ecf from **(b)(i)** **Alternative**: 1 pc = 3.26 ly C1 distance = 3.26 $\times$ 3.64 distance 11.9 (y) A1
			Total	5	

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Question			Expected Answer	Mark	Additional Guidance
6	(a)	(i)	Any <u>five</u> from: 1. Gas / dust (cloud) drawn together by gravitational forces 2. Loss in (gravitational) PE / KE increases / PE changes KE / temperature increase 3. Fusion of protons / hydrogen <u>nuclei</u> (produces helium nuclei and energy) 4. A stable star is formed when radiation pressure is equal to gravitational pressure 5. When hydrogen runs out the <u>outer layers</u> of the star expands / <u>core</u> shrinks 6. <u>Red giant</u> formed / eventually (the core becomes) a <u>white dwarf</u> QWC mark for '*correct sequencing of the processes from birth to death*'	B1 × 5 B1	**Allow**: 'Gravitational collapse of dust cloud'
		(ii)	Supernova followed by neutron star / black hole	B1 B1	
	(b)		$\Delta E = \Delta mc^2$ energy = $2.0\times10^{30}\times10^{-6}\times(3.0\times10^{8})^2$ or 1.8(0) × 10^{41} (J) time = 1.80 × 10^{41}/3.8 × 10^{26} (= 4.74 × 10^{14} s) time = 4.74 × 10^{14}/3.2 × 10^{7} time = 1.5 × 10^{7} (y)	 C1 C1 A1	**Alternative**: rate = 4.22 × 10^{9} (kg s^{-1}) C1 time = 2.0 × 10^{24}/4.22 × 10^{9} (= 4.74 × 10^{14} s) C1 time = 1.5 × 10^{7} (y) A1

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Question			Expected Answer	Mark	Additional Guidance
6	(c)	(i)	Any <u>four</u> from: 1. Protons / hydrogen <u>nuclei</u> to produce He <u>nuclei</u> (positrons and neutrinos) 2. There is electrostatic repulsion (between the protons) / The protons repel (each other because of their positive charge) 3. High temperatures / 10^7 K needed (for fusion) 4. (At high temperatures some of the fast moving) protons come close enough to each other for the strong (nuclear) force (to overcome the electrostatic repulsion) 5. High density / pressure (in the core of the Sun) 6. There is a decrease in mass, hence energy is released / products have greater binding energy	B1 × 4	**Not**: 'heat' in place of temperature in 3.
		(ii)	Kinetic (energy) Electromagnetic / photons	B1 B1	**Not**: heat / thermal (energy) **Not**: 'radiation' / 'wave energy'' **Allow**: Gamma
		(iii)	BE = 4 × 7.2 = 28.8 (MeV) BE = 28.8 × 1.6 × 10^{-13} BE = 4.6 × 10^{-12} (J)	C1 A1	 Possible ecf if BE value is incorrect
			Total	19	

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Question			Expected Answer	Mark	Additional Guidance
7	(a)		The application of a p.d. across a material / crystal causes an expansion / contraction / vibration (ora)	B1	**Allow**: reference to 'current' instead of p.d / e.m.f
	(b)		Any <u>two</u> from: • <u>Pulses</u> of ultrasound (sent into the body) • Wave / ultrasound / pulse / signal is <u>reflected</u> (at boundary of tissue) • Time of delay used to determine depth / thickness • The fraction of <u>reflected</u> signal is used to identify the tissue	B1 × 2	**Allow**: The <u>reflected</u> signal / ultrasound /amplitude / intensity is used to identify the tissue
			A-scan in one direction only / range or distance or depth finding	B1	
			B-scan uses a number of sensors or a sensor in different positions / angles (to build up a 2D/3D image)	B1	**Not**: 'B-scan is many A-scans'
	(c)	(i)	$Z = \rho c$; density → kg m^{-3} <u>and</u> speed →m s^{-1} (Hence Z → kg m^{-2} s^{-1})	M1 A0	
		(ii)	fraction = $\frac{(7.14-1.72)^2}{(7.14+1.72)^2}$ fraction = 0.37(4)	C1 A1	**Allow**: 37 %
		(iii)	(Acoustic) impedances of media are similar / identical No / reduced reflection (at boundary) Or The gel allows maximum transmission of ultrasound (into the body)	B1 B1	**Allow**: 'The Zs are the same'
		(iv)	$v = f\lambda$ wavelength = $\frac{1590}{1.2\times10^6}(=1.33\times10^{-3}$ m) (Any subject) wavelength = 1.33 (mm)	C1 A1	**Allow**: 1 mark for '4080/1.2 × 10^6 = 3.4 mm'
		(v)	Small wavelength means finer detail can be seen / greater resolution	B1	
			Total	13	

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Question			Expected Answer	Mark	Additional Guidance
8	(a)		Any <u>five</u> from: 1. Intensifier used as X-ray would pass through film 2. Intensifier converts X-ray <u>photon</u> to many visible (light) <u>photons</u> (which are absorbed by film) 3. *Lower exposure / fewer X-rays needed 4. Iodine / barium (used as contrast material) 5. *High Z number / large attenuation coefficient / large absorption coefficient (used to improve image contrast) 6. Contrast media are ingested / injected into the body 7. *Scan shows <u>outline</u> / <u>shape</u> of soft tissue QWC mark is acquired from clear expression of any of the marking points 3, 5 or 7	B1 × 5	
	(b)		X-rays produce visible light or In photoelectric effect electrons are emitted	B1	
	(c)	(i)	Any <u>two</u> from: • Simple X-ray is one directional / produces single image • CT image(s) taken at different angles / X-ray tube is rotated • Computer processes data / image constructed from many slices	B1 × 2	
		(ii)	Any <u>two</u> from: 1. X-ray image is 2D / CT scan produces 3D image 2. Greater detail / definition / contrast with CT scan / 'soft tissues can be seen' 3. Image can be rotated	B1 × 2	
			Total	10	

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Question			Expected Answer	Mark	Additional Guidance
9	(a)	(i)	composition for n and p: u d d & u u d charge for n and p: 0 & +1	B1 B1	**Allow**: charge 'e' instead of '+1' or '1'
		(ii)	up +2/3 (**+1/3**) 0 down -1/3 +1/3 (**0**)	B1 B1	**Allow**: charges in terms of 'e'
	(b)	(i)	${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + \bar{\nu}$	A2	**Allow**: '→ proton + electron + antineutrino' **Note**: -1 for any omission or error. Score = 0 if more than one error
		(ii)	weak (nuclear)	B1	
		(iii)	lepton(s) and hadron(s) / baryons(s)	B1	**Not**: Neutrons are mesons
			Total	8	

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Question			Expected Answer	Mark	Additional Guidance
10	(a)		**Spontaneous**: the decay cannot be induced / occurs without external influence **Random**: cannot predict when / which (nucleus) will decay next	B1 B1	
	(b)		The probability of decay of a <u>nucleus</u> <u>per</u> unit time	M1 A1	**Allow**: $\lambda = A / N$ (Any subject) C1 A = activity and N = number of <u>nuclei</u> A1
	(c)		Living plants / animals absorb carbon(-14) Once dead, the plant does not take in any more carbon(-14) The fraction of C-14 to C-12 (nuclei) or number of C-14 (nuclei) or activity of C-14 (nuclei) measured in dead <u>and</u> living (sample) $x = x_0 e^{-\lambda t}$ used with data above to estimate the age	B1 B1 M1 A1	
	(d)	(i)1	$\lambda = \ln 2 / T_{1/2}$ decay constant = 1.24×10^{-4} (y^{-1})	B1	
		(i)2	$A = A_0 e^{-\lambda t}$ $0.194 = 0.249 \times e^{-(1.24\times10^{-4}\times t)}$ $\ln(0.194/0.249) = -1.24\times10^{-4} t$ time = 2.0×10^3 (y)	C1 A1	
		(ii)	The activity is (very) small / decay is random	B1	
		(iii)	Activity so low that it cannot be differentiated from the background	B1	
			Total	13	

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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

OCE/23020

G 4 8 5

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.

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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.

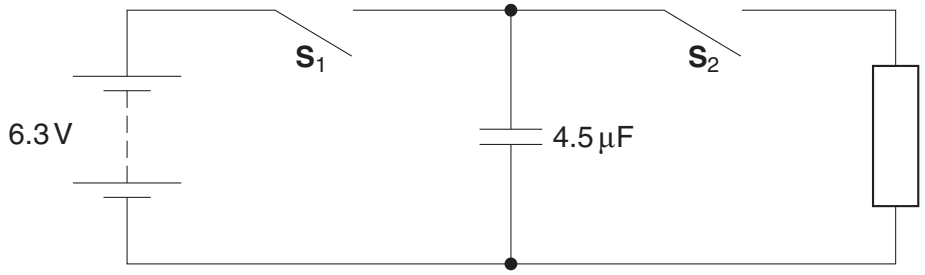


Fig. 1.1

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]**

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(c) Switch S_1 is opened and switch 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.

.....

..... **[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.

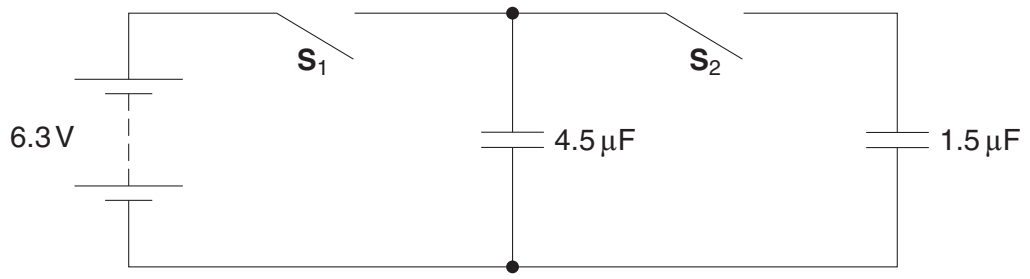


Fig. 1.2

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

(i) Calculate the total capacitance of the circuit when S_2 is closed.

capacitance = ... μF **[1]**

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

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

[Total: 11]

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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.

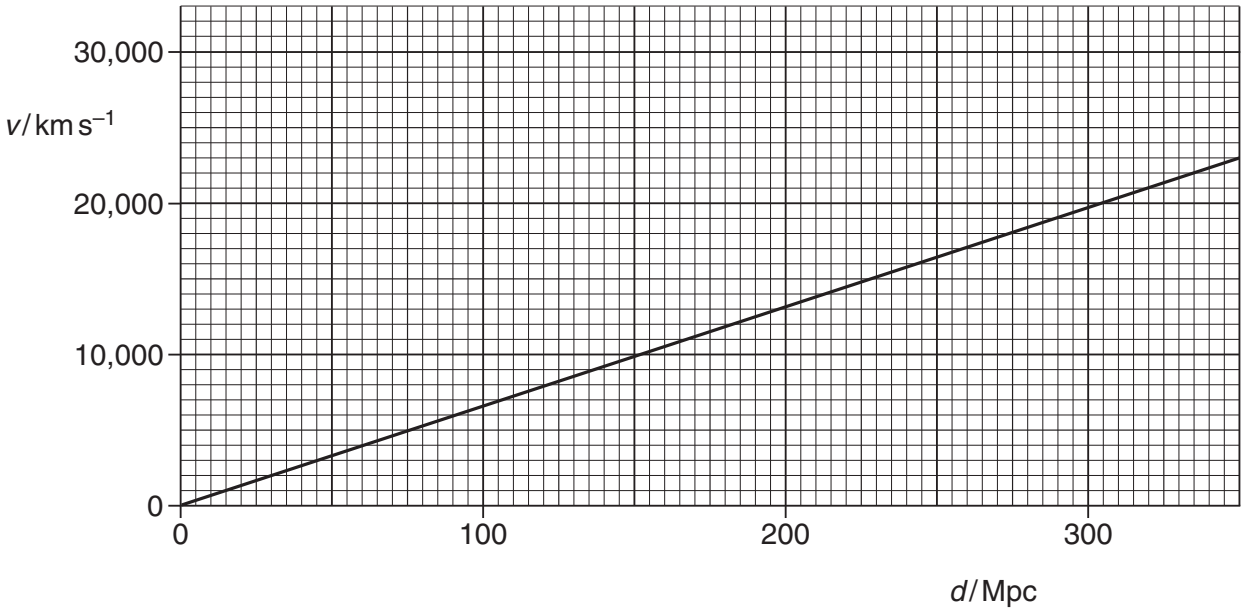


Fig. 2.1

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

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

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(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.

.....

.....

.....

.....

.....

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

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

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..... **[4]**

[Total: 16]

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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.

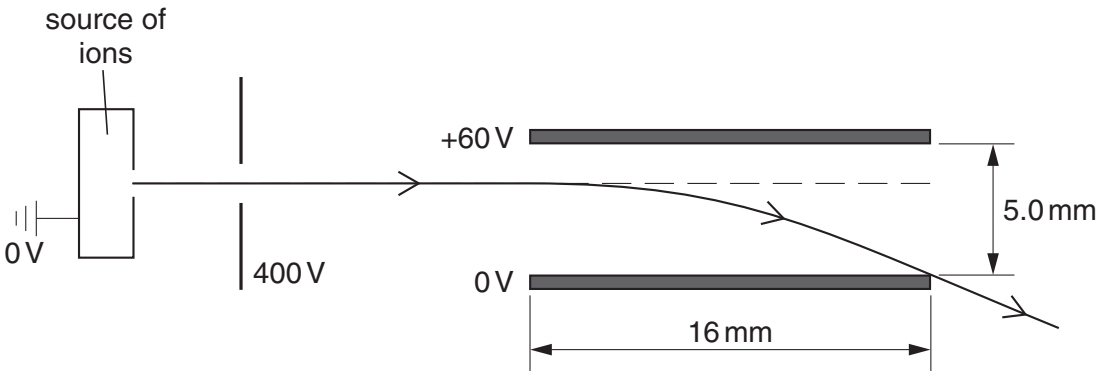


Fig. 3.2

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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 $2.0 \times 10^{5}\,m\,s^{-1}$.

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

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(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]

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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 0.035T. The plane of the coil is perpendicular to the magnetic field.

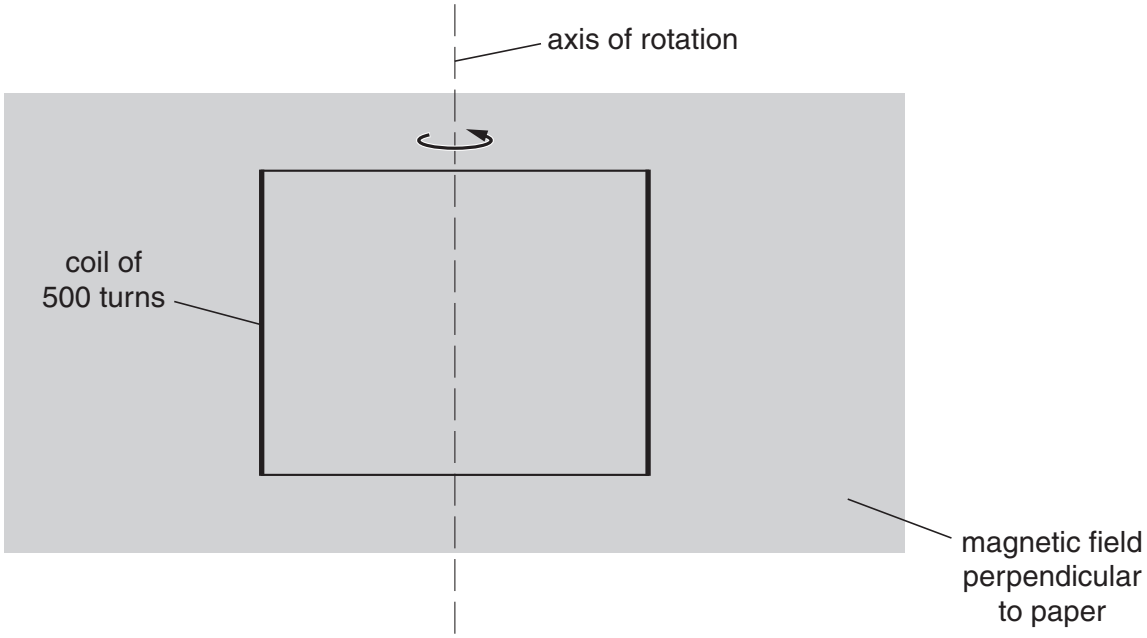


Fig. 4.1

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

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

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(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.

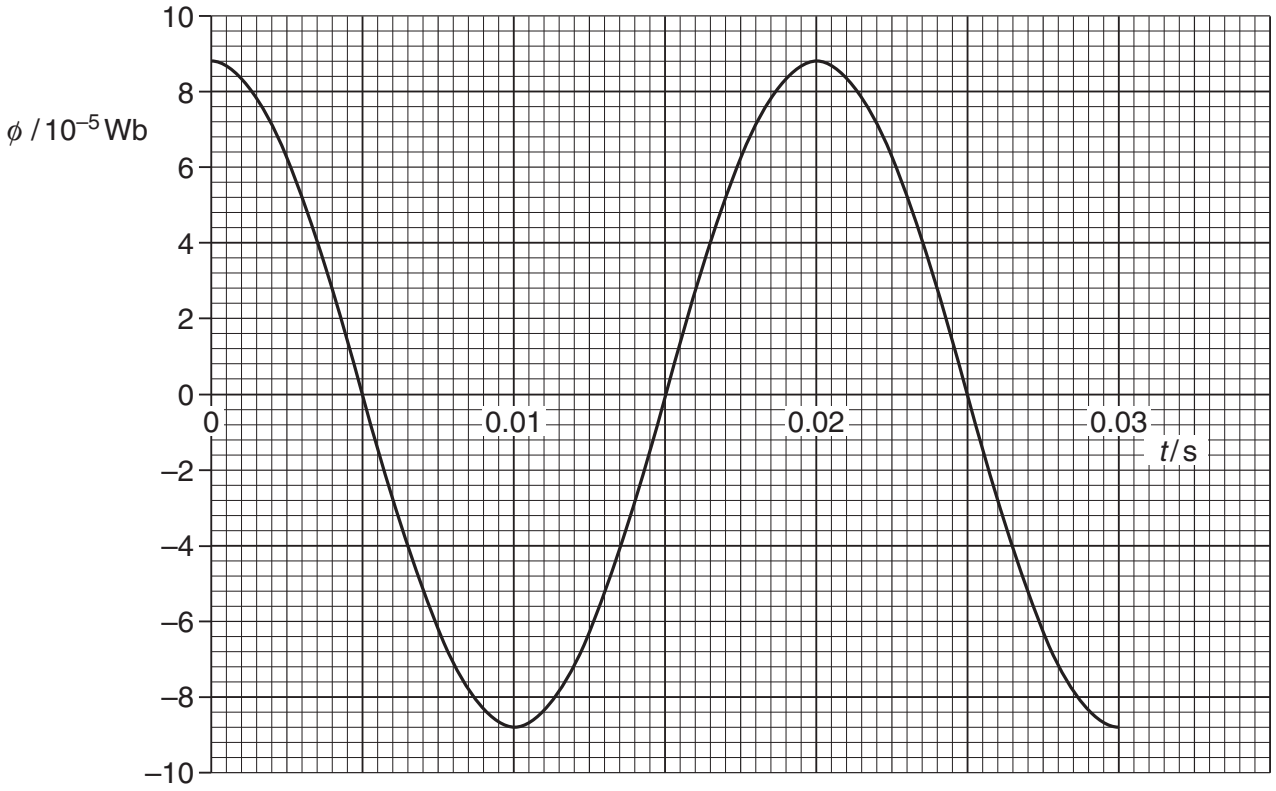


Fig. 4.2

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

.....

.....

.....

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

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(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]

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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]

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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]

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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]

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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]

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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]

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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.

.....

.....

.....

.....

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

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

.....

.....

.....

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

[Total: 10]

END OF QUESTION PAPER

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ADDITIONAL PAGE

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

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GCE

Physics A

Advanced GCE **G485**

Fields, Particles and Frontiers of Physics

Mark Scheme for June 2010

Oxford Cambridge and RSA Examinations

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Convention used when marking scripts

WRONG PHYSICS OR EQUATION – indicate by **?** on scoris
No credit is given for correct substitution, or subsequent arithmetic, in a physically incorrect equation.

ERROR CARRIED FORWARD – indicate by **ECF** on scoris
Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers.

ARITHMETIC ERROR – indicate by **AE** on scoris
Deduct 1 mark for the error and then follow through the working/calculation giving full credit for subsequent marks if there are no further errors. The ruling also includes power of ten (POT).

TRANSCRIPTION ERROR – indicate by **^** on scoris
This error is when there is incorrect transcription of data from the question, formulae booklet or previous answer. For example 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19}. Deduct the relevant mark and then follow through the working giving full credit for subsequent marks.

SIGNIFICANT FIGURES – indicate by **SF** on scoris
Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. An error in significant figures is penalised only once per paper.

BENEFIT OF DOUBT – indicate by **BOD** on scoris
This mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.

RUBRIC INFRINGEMENT
If the candidate crosses out an answer but does not make any other attempt, then the work that is crossed out should be marked and the marks awarded without penalty.

CONTRADICTION – indicate by **CON** on scoris No mark can be awarded if the candidate contradicts himself or herself in the same response. For example, '… t*he mass of the particle increases and decreases*.'

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Question			Expected Answers	Marks	Additional Guidance
1	a		Capacitance = charge per (unit) potential difference	B1	Allow: capacitance = charge / potential difference, charge/pd, charge/voltage but not charge / volt, coulomb /pd (no mixture of quantities and units. Allow 'over' instead of per
	b	(i)	Q = CV = 4.5 μ x 6.3 = 28.(35) (μC)	B1	Allow: 28 (≥ 2 sf)
		(ii)	$E = ½ CV^2 = 0.5 \times 4.5 \times \mu \times (6.3)^2$ $= 8.9(3) \times 10^{-5}$ (J) / 89.3 μ(J)	C1 A1	Allow use of E = ½ QV and the Q value from **(b)(i)** Q=28 E= 8.82 and Q=28.4 E=8.946 Allow ecf from **(b)(i)** penalise power of ten error (-1)
	c	(i)	Electrons / they move in an anticlockwise direction Charge on plates decreases / electrons neutralise positive charge p.d. decreases <u>exponentially</u>	B1 B1 B1	Alternatives for anticlockwise: from / lower plate around the circuit, from / lower plate through the resistor to top plate implied Capacitor discharges / loses charge
		(ii)	(dissipated as heat) in the resistor / wires	B1	
	d	(i)	Total capacitance = 1.5 + 4.5 = 6(.0) (μF)	A1	Allow one SF
		(ii)	Original charge on 4.5 μF capacitor is conserved (28.35 μC) V = (28.35 μ) / (1.5 + 4.5) μ = 4.7 (V)	C1 A1	ecf from **(b)(i) and (d)(i)**
			Total	**[11]**	

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Question			Expected Answers	Marks	Additional Guidance
2	a		static / homogeneous infinite / infinite number of stars	B1 B1	Uniform (density) Do not allow isotropic or fixed
	b	(i)	gradient of graph = H_0 value H_0 = 66 ± 4 (km s^{-1} Mpc^{-1})	C1 A1	
		(ii)	age = 1 / H_0 (H_0 = 2.1 x 10^{-18} s^{-1}) = (1 / 66 x 3.2 x 10^{-20} x 3.2 x 10^{7}) = 1.5 x 10^{10} (1.48 x 10^{10}) (year)	C1 C1 A1	ecf from H_0 value Or correct age in seconds (4.7 x 10^{17} s) Answer will depend on H_0 value in **(b)(i)** Minus one if Mega or kilo omitted
	c	(i)	ρ_c = $3H_0^2$ / $8\pi G$ = [3 x (2.1 x 10^{-18})^2] / (8 x π x 6.67 x 10^{-11}) = 7.9 x 10^{-27} (kg m^{-3})	C1 A1	If units of H_0 not converted or converted incorrectly then maximum one out of two ecf from H_0 value in **(b)(i)**
		(ii)	if average density of the Universe is less than critical then it will be too small to stop it expanding / it goes on forever if the average density of the Universe is greater than the critical value it will cause the contraction (and produce a big crunch) close to critical value and therefore a universe expands that will go towards a limit / expands at an ever decreasing rate asymptotic	B1 B1 B1	do not allow answers open, closed and flat

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2	d		galaxies are moving apart / universe is expanding if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point evidence in red shift either optical / microwave further away the galaxy the faster the speed of recession the existence of a (2.7 K) <u>microwave</u> background radiation there is more helium in the universe than expected **MAX 4**	**(B1)** **(B1)** **(B1)** **(B1)** **(B1)** **(B1)** **B4**	Allow stars for galaxies allow from a singularity allow statement that red shift is observed or that blue light becomes red or gamma from big bang has become microwave
			Total	**[16]**	

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Question			Expected Answers	Marks	Additional Guidance
3	a	(i)	uniformly spaced, vertical parallel lines must begin and end on the plates with a minimum of three lines arrow in the correct direction down	B1 B1	ignore any edge effects
		(ii)	E = V / d E = 60 / 5 x 10^{-3} = 12000 (V m^{-1})	A1	
	b	(i)	Use of energy qV and kinetic energy = ½ mv^2 v = $[(2qV)/m]^{1/2}$ v = $[(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ v = 1.97 x 10^5 (m s^{-1})	M1 M1 A0	
		(ii)	a = F / m a = Eq / m a = (12000 x 3.2 x 10^{-19}) / 6.6 x 10^{-27}) = 5.82 x 10^{11} (m s^{-2})	C1 A1	Both required for the mark
		(iii)	**1** t = $\underline{(16 \times 10^{-3}) / 2 \times 10^5}$ = 8 x 10^{-8} (s) **2** s = ½ a x t^2 = ½ [5.82 x 10^{11} x (8 x 10^{-8})^2] = 1.86 x 10^{-3} (m)	M1 A0 C1 A1	Answer will depend on number of sf used by candidate. Using u = 2 x 10^5 scores 0/2 Allow slight variation in answers that follow from the candidates working

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	c		Eq = Bqv B = E / v = 12000 / 2 x 10^5 = 0.060 (T)	**C1** **C1** **A1**	 Allow one sf unless answer is 0.061 when using v =1.97 x 10^5
	d		velocity (produced by p.d / 400 V) is less force due the magnetic field is reduced / Bqv is less / force due to the electric field is unchanged hence beam deflects down	**B1** **B1**	 Allow the resultant force is downward Allow towards the lower plate
			Total	**[15]**	

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Question			Expected Answers	Marks	Additional Guidance
4	a		magnetic flux = magnetic flux density x area (perpendicular to field direction)	B1	Allow equation with the symbols identified correctly Do not allow magnetic field or magnetic field strength
	b		Φ = NBA = 500 x 0.035 x 2.5 x 10^{-3} = 0.044 (0.04375) unit: Wb	C1 A1 B1	 [allow for one mark 8.75 x 10^{-5} (Wb) i.e. B x A] Allow: Wb turns and T m^2 and V s
	c	(i)	The component of B perpendicular to the area changes / the idea that the area changes relative to the field direction detail of how it varies / depends on cos θ / maximum when field is perpendicular to B / zero when area is parallel to B	B1 B1	Allow the idea that the direction of the field relative to the area of the coil varies with the orientation of the coil Do not allow reference to cutting of the flux by the coil
		(ii)	Induced / e.m.f is proportional / to <u>the rate</u> of change of (magnetic) flux	B1	Allow the emf produced is equal to the rate of change of flux or flux cutting
		(iii)	e.m.f. **max** when ϕ is **zero** or at 0.005 /0.015 /0.025 s e.m.f **zero** when ϕ is a **max** or at 0.0 / 0.01/ 0.02 s e.m.f. and ϕ have the same frequency allow e.m.f and ϕ out of phase by π/2/ emf follows a sin curve emf is the gradient of the graph **MAX 3**	(B1) (B1) (B1) (B1) (B1) B3	

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4		(iv)	ε = (change in flux linkage) / time = 0.04375 / 0.005 (8.8 x 10^{-5} x 500) / 0.005 = 8.75 (V)	 C1 A1	 [if N omitted then give one mark (ε = 0.0175)] [if 10^{-5} omitted then minus 1] [reading error from graph is penalised -1 (should be 8.8 and not 8.4)]
		(v)	Max e.m.f. is twice the original value as the rate of flux change is twice the original	B1 B1	Do not allow just larger Allow: the change in magnetic flux occurs in half the time Allow the max gradient will double
			Total	**[14]**	

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Question			Expected Answers	Marks	Additional Guidance
5	a		Magnetic resonance: **some <u>nuclei</u> behave as small magnets / certain <u>nuclei</u> possess a net spin / <u>nuclei</u>** line up in the magnetic field **Need for a strong magnetic field** the frequency of precession is known as Lamor frequency (1) **Application of RF pulses** produces resonance / flip energy states (1) **RF pulse turned off nuclei relax / flip back (and emit RF signal)** RF detected (by coil receiver) and processed (1) Use of non-uniform field / gradient field (1) To locate position of nuclei in body (1) **QWC mark: difference in the relaxation times for hydrogen in different tissues / materials** MAX (3) **MAX 8**	**B1** **B1** **B1** **B1** **B1** **MAX B8**	Allow protons instead of nuclei in the context of hydrogen nuclei or a single proton instead of nuclei There are 5 essential marks **(in bold)** and a maximum of THREE extra marks (1) Maximum of **8 marks** Do not allow 'atoms' for nuclei but penalise once only **Please annotate scripts as follows:** **Essential marks: ✓(ticks) on left hand side of candidate's work** **Extra marks: ✓(ticks) on right hand side of candidate's work**

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5	**b**		Advantage: not ionising radiation (as with X-rays) / better soft tissue contrast Disadvantage: heating effect of metal objects /effect on cardiac pacemakers / takes a long time to perform MRI scan	**B1** **B1**	Accept can view soft tissue in brain / skull Do not allow not harmful Do not allow no side effects
			Total	**[10]**	

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Question			Expected Answers	Marks	Additional Guidance
6	a	(i)	$A = \lambda N_0 = 4.5 \times 10^{23} \times 0.693 / (12 \times 3600)$ $= 7.22 \times 10^{18}$ (s^{-1})	C1 A1	allow one mark if the 12 hours is not converted into seconds. Answer is 2.6×10^{22} Allow one mark if the 12 hours is converted into minutes Answer 4.33×10^{20}
		(ii)	3 half lives $N = 5.6 \times 10^{22}$	A1	
		(iii)	$N = N_0 e^{-\lambda t}$ $= 4.5 \times 10^{23} \times e^{-(0.693 \times 50/12)}$ or use of 2^n $= 2.5 \times 10^{22}$	C1 A1	use of 2^n 50/12 half lives
	b		material with large λ / short half life have initial high activity hence precautions needed <u>for initial period</u> of disposal OR material with small λ / long half life activity will last for a long period hence need for long term disposal MAX 2	(B1) (B1) (B1) (B1) B2	
			Total	[7]	

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Question			Expected Answers	Marks	Additional Guidance
7	a	(i)	e: 0 and –1 N: 15 and 7 + (antineutrino)	B1	
		(ii)	e: 0 and +1 Si: 30 and 14 + (neutrino) correct 'neutrino' <u>in each case</u>	B1 B1	Allow 1 for +1 Correct symbols required for the neutrinos: ν and (Allow ν_e and ($_e$
	b	(i)	uud → udd	B1	Allow u → d
		(ii)	udd → uud	B1	Allow d → u
	c		weak(nuclear force)	B1	
			Total	[6]	

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Question			Expected Answers	Marks	Additional Guidance
8	a	(i)	mass of uranium is greater than (the sum of) the mass of the products $E = \Delta mc^2$ OR binding energy of the products is greater than that of uranium energy available is the difference between the binding energies of uranium and the sum of the products	M1 A1 M1 A1	
		(ii)	kinetic energy	B1	
	b	(i)	the neutron is a single nucleon / cannot be split further / no binding has occurred	B1	The neutron is not bound to anything
		(ii)	binding energy of uranium = 235 x 7.6 =1786 binding energy of products = 141 x 8.3 + 92 x 8.7 = 1170.3 + 800.4 energy available = 184.7 (MeV)	C1 A1	An answer of 9.4 (not using the number of nucleons) scores zero Allow ≥ 2 sf (180, 185, 184.7) Penalise 184 as an AE
			Total	[6]	

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Question			Expected Answers	Marks	Additional Guidance
9	a		$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ $= (1.6 \times 10^{-19} \times 1.6 \times 10^{-19}) / 4\pi\varepsilon_0 (2 \times 10^{-15})^2$ $= 57.5$ (N)	**C1** **A1**	Allow use of 9×10^9 instead of $1 / 4\pi\varepsilon_0$ (using this gives 57.6) Allow ≥ 2sf (58) If correct formula quoted and then AE (e.g. not squaring r or not squaring Q) then allow ecf in final answer for 2/3
	b		attractive strong (nuclear force)	**B1**	Do not it holds them together
	c		as the proton travels towards the stationary proton it experiences a repulsive force that slows it down. (It needs a high velocity) to get close enough (to the proton) / for the (attractive) short range force to have any effect	**B1** **B1**	
			Total	**[5]**	

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Question			Expected Answers	Marks	Additional Guidance
10	a		ANY ONE from X-rays interact with matter by: the photoelectric effect where an (orbital) electron is ejected from atom / atom is ionised Compton scattering where X-ray scattered by the interaction with (orbital) electron Pair production where X-ray photon interacts with the nucleus / atom and an electron and positron are produced [allow one mark for statement and one for explanation] **Max 2**	**(B2)** **(B2)** **(B2)** **B2**	Allow electrons ejected from metal surface if reference is made to <u>free</u> electrons Allow: X-ray diffraction **B1** X-ray passes through the 'slits' / atomic gap formed by the atoms **B1**

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	b		$I = I_0 e^{-\mu x}$ $0.1 = e^{-\mu 3}$ $0.5 = e^{-\mu x}$ $\ln 0.5 / \ln 0.1 = x/3$ $x = 0.903$ (mm)	**C1** **C1** **A1**	Calculation of $\mu = 0.768$ C1 Substitution into second equation C1 Allow 0.9 (1sf) If question misread and 0.9 used for change $\mu = 0.035$ and $x = 19.7$ (allow 20) give 2/3
10	**c**	**(i)**	Absorption of X-rays by (silver halide molecules) by a photographic film Uses of fluorescent / scintillator/ phosphor Photon releases electron (that is accelerated onto a fluorescent screen) number of electrons increased /multiplied **MAX B2** QWC: Phosphor / Intensifier/ it converts X-ray photon into increased number of 'visible' photons	**(B1)** **(B1)** **(B1)** **(B1)** **B2** **B1**	

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		(ii)	Different soft body tissue produce little difference in contrast/attenuation (Contrast media with) high atomic number / Z used / iodine or barium (used to give greater contrast) liquids injected or swallowed into soft tissue areas / or examples of such **MAX B2**	**(B1)** **(B1)** **(B1)** **B2**	This method produces good contrast for soft tissue /for similar Z values
			Total	**[10]**	

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