OCR RECOGNISING ACHIEVEMENT

# SPECIMEN

**Advanced GCE**

**G485 QP**

**PHYSICS A**

Unit G485: Fields, Particles and Frontiers of Physics

**Specimen Paper**

Candidates answer on the question paper.

Additional Materials:
Data and Formulae sheet
Electronic calculator

Time: 2 hours

Candidate Name

Centre Number

Candidate Number

**INSTRUCTIONS TO CANDIDATES**

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED.

**INFORMATION FOR CANDIDATES**

- The number of marks is given in brackets [ ] at the end of each question or part question.
- ✎ Where you see this icon you will be awarded marks for the quality of written communication in your answer.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

| FOR EXAMINER'S USE | | |
|---|---|---|
| **Qu.** | **Max.** | **Mark** |
| **1** | **8** | |
| **2** | **12** | |
| **3** | **14** | |
| **4** | **10** | |
| **5** | **9** | |
| **6** | **6** | |
| **7** | **10** | |
| **8** | **13** | |
| **9** | **6** | |
| **10** | **12** | |
| **TOTAL** | **100** | |

This document consists of **18** printed pages and **2** blank pages.

Answer **all** the questions.

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

..................................................................................................................................

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

**(b)** Ionic solids consist of a regular arrangement of positive and negative ions. Fig. 1.1 shows two neighbouring ions in a particular ionic solid. The ions **A** and **B** may be considered as two point charges of equal magnitude, $1.6 \times 10^{-19}$ C, and opposite sign, with a separation of $2.0 \times 10^{-10}$ m. The ion **A** is positive.

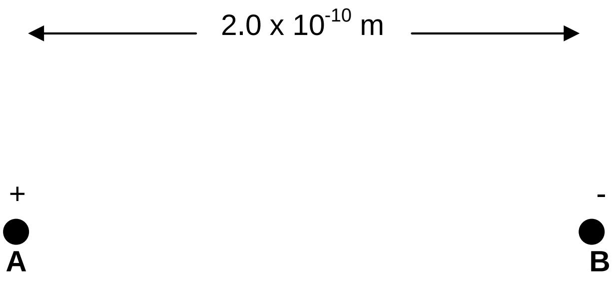


**Fig. 1.1**

**(i)** On Fig. 1.1, draw electric field lines to represent the field in the region around the two charges. **[3]**

**(ii)** Calculate the magnitude of the electric field strength at the mid point between the charges.

electric field strength =............................$NC^{-1}$ **[3]**

**(iii)** State and explain a factor that might affect the tensile strength of an ionic material.....

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

**[Total: 8]**

**2** Fig.2.1 shows two capacitors, **A** of capacitance 2μF, and **B** of capacitance 4μF, connected in parallel. Fig. 2.2 shows them connected in series. A two-way switch **S** can connect the capacitors either to a d.c. supply, of e.m.f. 6 V, or to a voltmeter.

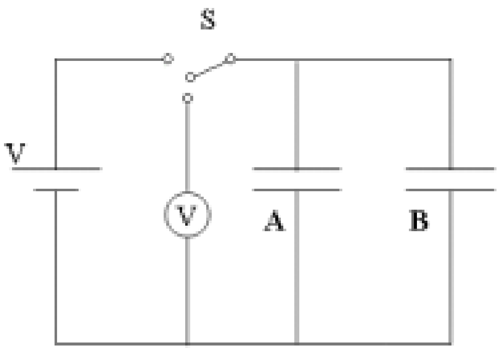


**Fig. 2.1**

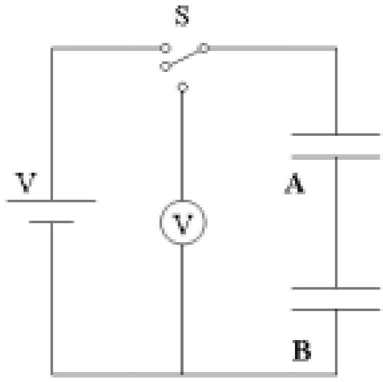


**Fig. 2.2**

**(a)** Calculate the total capacitance of the capacitors

**(i)** when connected as in Fig. 2.1

capacitance = ........................................ μF **[1]**

**(ii)** when connected as in Fig. 2.2

capacitance = ........................................ μF **[2]**

**(b)** The switch in the circuit shown in Fig. 2.1 is then connected to the battery. Calculate

**(i)** the potential difference across capacitor **A**

potential difference = ................................ V **[1]**

**(ii)** the total charge stored on the capacitors.

charge = ............................................... .μC **[2]**

**[Turn over**

**(c)** The switch in the circuit shown in Fig.2.2 is then connected to the battery. Calculate the total energy stored in the two capacitors.

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

**(d)** The switch S in the circuit of Fig. 2.1 is moved to connect the charged capacitors to the voltmeter. The voltmeter has an internal resistance of 12 MΩ.

**(i)** Explain why the capacitors will discharge, although very slowly.

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**(ii)** Calculate the time *t* taken for the voltmeter reading to fall to a quarter of its initial reading.

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

**[Total: 12]**

**3** **(a)** Describe briefly one scattering experiment to investigate the size of the nucleus of the atom. Include a description of the properties of the incident radiation which makes it suitable for this experiment.

✎ In your answer, you should make clear how evidence for the size of the nucleus follows from your description.

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**(b)** Complete the table below for the **three** types of ionising radiation.

| radiation | nature | range in air | penetration ability |
|---|---|---|---|
| $\alpha$ | | | 0.2 mm of paper |
| $\beta$ | electron | | |
| $\gamma$ | | several km | |

**[3]**

**(c)** Describe briefly, with the aid of a sketch, an absorption experiment to distinguish between the three radiations listed above.

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**[Total: 14]**

**4** Fig. 4.1 shows a square flat coil of insulated wire placed in a region of a uniform magnetic field of flux density *B*. The direction of the field is vertically out of the paper. The coil of side x has N turns.

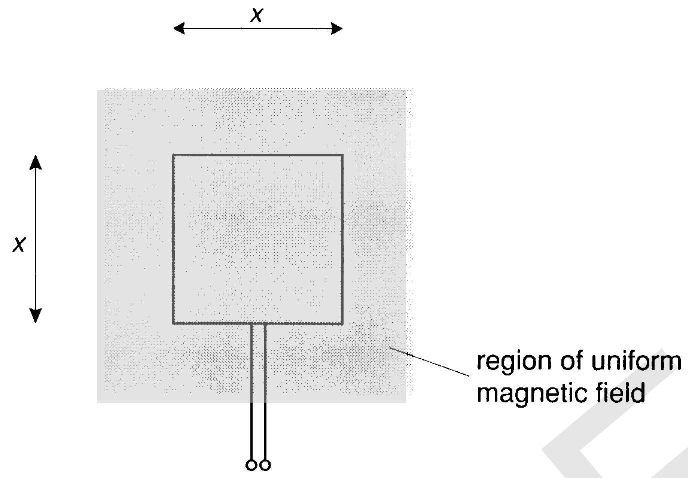


**Fig. 4.1**

**(a)** **(i)** Define the term *magnetic flux*.

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**(ii)** Show that the magnetic flux linkage of the coil in Fig. 4.1 is $NBx^2$.

**[2]**

**(b)** The coil of side x = 0.020 m is placed at position **Y** in Fig. 4.2 The ends of the 1250 turn coil are connected to a voltmeter. The coil moves sideways steadily through the region of magnetic field of flux density 0.032 T at a speed of 0.10 m $s^{-1}$ until it reaches position **Z**. The motion takes 1.0 s.

**[Turn over**

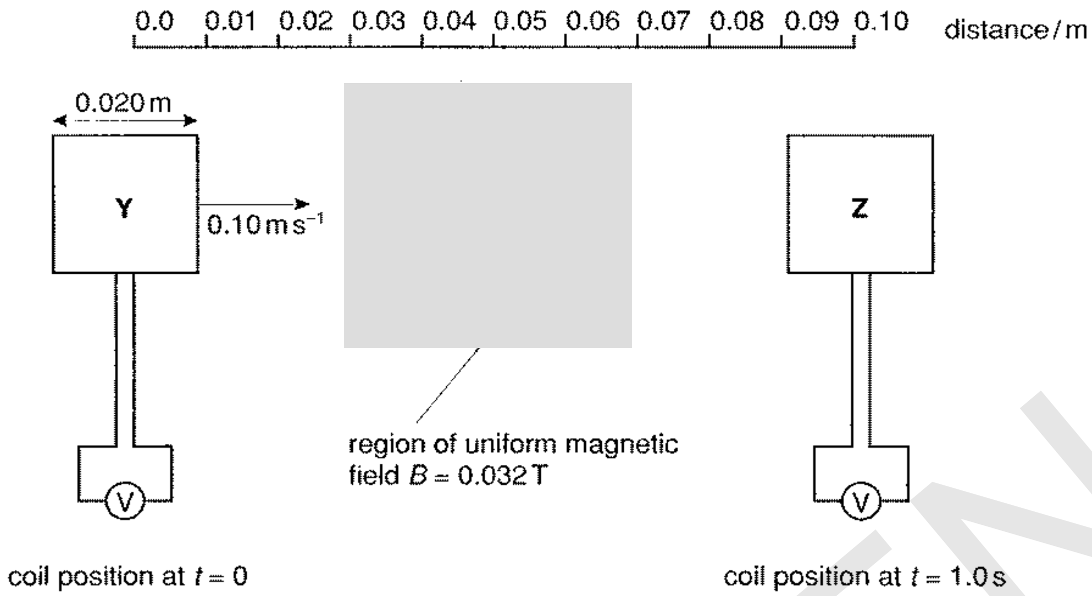


**Fig. 4.2**

**(i)** Show that the voltmeter reading as the coil enters the field region, after t = 0.20s, is 80 mV. Explain your reasoning fully.

**[3]**

**(ii)** On Fig. 4.3, draw a graph of the voltmeter reading against time for the motion of the coil from **Y** to **Z**. Label the y- axis with a suitable scale. **[4]**

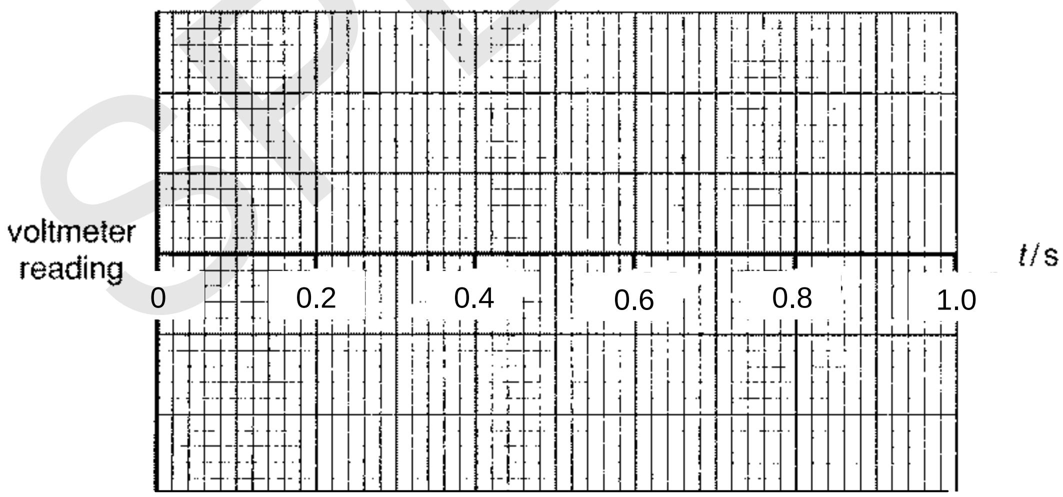


**Fig. 4.3**

**[Total: 10]**

**5 (a)** State the Cosmological Principle.

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**(b)** Describe the important properties of the cosmic microwave background radiation and how the standard model of the Universe explains these properties. Explain their significance as evidence for the past evolution of the Universe.

✎ *In your answer, you should make clear how your explanation links with the evidence.*

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**(c)** Explain why our understanding of the very earliest moments of the Universe is unreliable.

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**[Total: 9]**

**6 (a)** The future of the Universe may be *open*, *closed* or *flat*. Explain the meaning of the terms in italics, using a graph to illustrate your answer.


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**(b)** The mean density of the Universe, $\rho_0$, is thought to be approximately $1 \times 10^{-26}$ kg m$^{-3}$. Calculate a value for the Hubble constant $H_0$.

$H_0$ = ...................................................... s$^{-1}$ **[2]**

**[Total: 6]**

**7** The quality of ultrasound images in increasing at a phenomenal pace, thanks to advances in computerised imaging techniques. The computer technology is sophisticated enough to monitor and display tiny ultrasound signals from a patient.

The ratio of reflected intensity to incident intensity for ultrasound reflected at a boundary is related to the acoustic impedance $Z_1$ of the medium on one side of the boundary and the acoustic impedance $Z_2$ of the medium on the other side of the boundary by the following equation.

$$\frac{\text{reflected intensity}}{\text{incident intensity}} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

**(a)** State **two** factors that determine the value of the acoustic impedance.

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**(b)** An ultrasound investigation was used to identify a small volume of substance in a patient. It is suspected that this substance is either blood or muscle.

During the ultrasound investigation, an ultrasound pulse of frequency of $3.5 \times 10^6$ Hz passed through soft tissue and then into the small volume of unidentified substance. A pulse of ultrasound reflected from the front surface of the volume was detected 26.5 μs later. The ratio of the reflected intensity to the incident intensity, for the ultrasound pulse reflected at this boundary was found to be $4.42 \times 10^{-4}$. Fig. 7.1 shows data for the acoustic impedances of various materials found in a human body.

| **medium** | **acoustic impedance $Z$ / kg m$^{-2}$ s$^{-1}$** |
|---|---|
| air | $4.29 \times 10^2$ |
| blood | $1.59 \times 10^6$ |
| water | $1.50 \times 10^6$ |
| brain tissue | $1.58 \times 10^6$ |
| soft tissue | $1.63 \times 10^6$ |
| bone | $7.78 \times 10^6$ |
| muscle | $1.70 \times 10^6$ |

**Fig. 7.1**

**(i)** Use appropriate data from Fig. 7.1 to identify the unknown medium. You must show your reasoning.

medium = .................................................... **[4]**

**[Turn over**

**(ii)** Calculate the depth at which the ultrasound pulse was reflected if the speed of ultrasound in soft tissue is 1.54 km $s^{-1}$.

depth = .................................................. cm **[2]**

**(iii)** Calculate the wavelength of the ultrasound in the soft tissue.

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

**[Total: 10]**

**8** An average person in the UK will have at least 30 X-ray photographs taken in their lifetime.

In order to take an X-ray photograph, the X-ray beam is passed through an aluminium filter to safely remove low energy X-ray photons before reaching the patient.

**(a)** Suggest why it is necessary to remove these low energy X-rays.

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**(b)** The average linear attenuation coefficient for X-rays that penetrate the aluminium is 250 $m^{-1}$. The intensity of an X-ray beam after travelling through 2.5 cm of aluminium is 347 W $m^{-2}$.

Show that the intensity incident on the aluminium is about $2 \times 10^5$ W $m^{-2}$.

**[3]**

**(c)** The X-ray beam at the filter has a circular cross-section of diameter 0.20 cm. Calculate the power of the X-ray beam from the aluminium filter. Assume that the beam penetrates the aluminium filter as a parallel beam.

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

**[Turn over**

**(d)** In an X-ray tube, the efficiency of conversion of the kinetic energy of the electrons into X-rays is 0.15%.

**(i)** Calculate the power required in the electron beam in order to produce X-rays of power 18 W.

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

**(ii)** Calculate the velocity of the electrons if the rate of arrival of electrons is $7.5 \times 10^{17}$ $s^{-1}$. Relativistic effects may be ignored.

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

**(iii)** Calculate the p.d. across the X-ray tube required to give the electrons the velocity calculated in **(ii)**.

p.d. = ....................................................... V **[3]**

**[Total: 13]**

**9** Discuss briefly the advantages and disadvantages of scanning using MRI techniques.

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**[Total: 6]**



**[Turn over**

**10** Fig. 10.1 shows the variation with nucleon number (mass number) of the binding energy per nucleon for various nuclides.

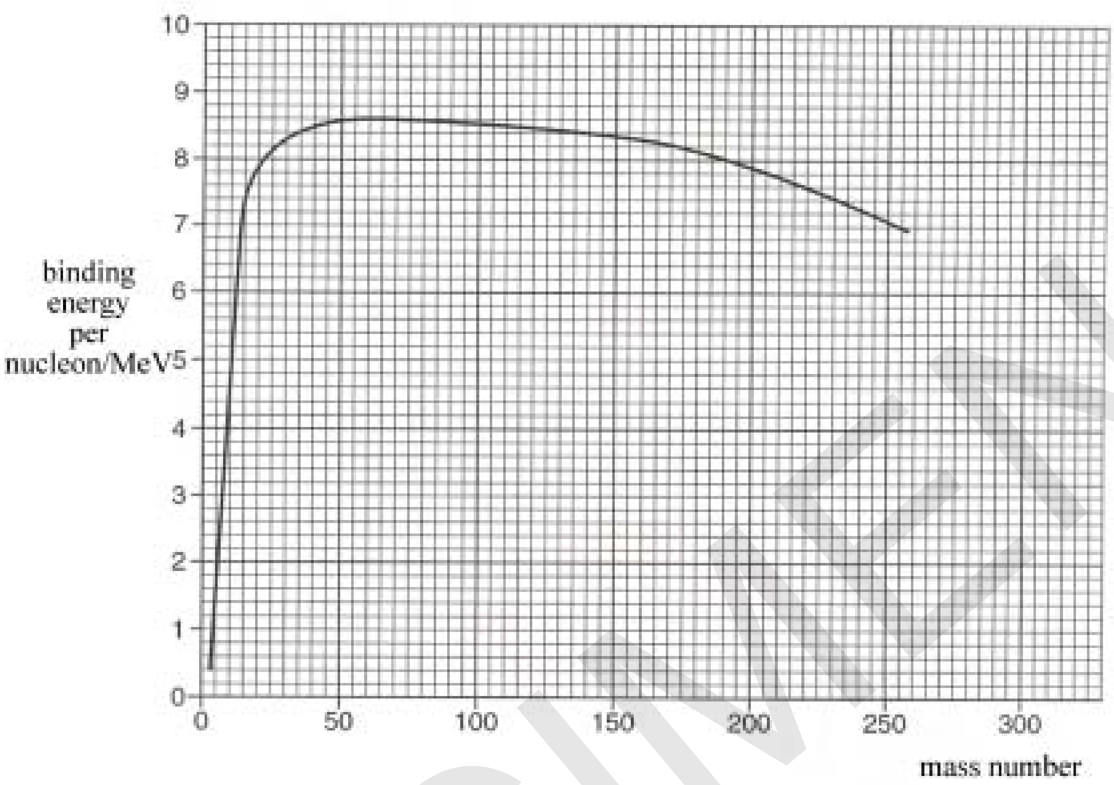


**Fig. 10.1**

**(a)** **(i)** State the number of nucleons in the nucleus of $^{94}_{37}$Rb. ....................................................

**(ii)** State the number of protons in the nucleus of $^{142}_{55}$Cs. ....................................................

**(iii)** State the number of neutrons in the nucleus of $^{235}_{92}$U. ....................................................

**[2]**

**(b)** Use Fig. 10.1 to calculate the energy released when a $^{235}_{92}$U nucleus undergoes fission, producing nuclei of $^{94}_{37}$Rb and $^{142}_{55}$Cs.

energy = ............................................. MeV **[4]**

**(c)** Discuss **two** advantages and **two** disadvantages of producing electrical power by nuclear fission.

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**[Total: 12]**

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**OXFORD CAMBRIDGE AND RSA EXAMINATIONS**

**Advanced GCE**

# PHYSICS A G485 MS

Unit G485: Fields, Particles and Frontiers of Physics

**Specimen Mark Scheme**

The maximum mark for this paper is **100**.



  [Turn Over

| Question Number | Answer | Max Mark |
|---|---|---|
| **1(a)** | Force per unit positive charge | **[B1]** |
| **(b)(i)** | Suitable recognisable pattern around (not just between) the charges<br>Quality mark: symmetry, spacing, lines joined to charges<br>Consistent arrows toward B on some lines | **[B1]**<br>**[B1]**<br>**[B1]** |
| **(ii)** | Use of $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$<br>The electric field strength $E$ at the midpoint is given by<br>$E = \dfrac{1.6\times10^{-19}}{4\pi\varepsilon_0(1.0\times10^{10})^2} = 1.44\times10^{11}$ ($NC^{-1}$).<br>The electric field strength from each charge at the midpoint is to the 'right'.<br>Therefore, resultant electric field strength $E_T$ is twice the value above.<br>$E_T = 2 \times 1.44 \times 10^{11} = 2.88 \times 10^{11}$ ($NC^{-1}$) | **[C1]**<br>**[C1]**<br>**[A1]** |
| **(iii)** | The separation between the ions because this has an effect on the breaking force. (Allow the size of ionic 'charges') | **[B1]** |
| **2(a)(i)** | $C_p = 2 + 4 = 6$ μF | **[A1]** |
| **(ii)** | 1/C = 1/2 + 1/4<br>$C_s$ = 4/3 =1.33 μF | **[C1]**<br>**[A1]** |
| **(b)(i)** | 6.0 V | **[A1]** |
| **(ii)** | $Q = C_pV$<br>= 6 x 6 = 36 μC | **[C1]**<br>**[A1]** |
| **(c)** | $E = ½ C_sV^2$<br>$= 24 \times 10^{-6}$ | **[C1]**<br>**[A1]** |
| **(d)(i)** | The capacitors discharge <u>through</u> the voltmeter. | **[B1]** |
| **(ii)** | $V = V_0 e^{-t/CR}$<br>$1/4 = e^{-t/(6\times12)}$<br>$\ln 4 = t/72$<br>$t = 72\ln 4 \approx 100$ s | **[C1]**<br>**[C1]**<br>**[A1]** |

| Question Number | Answer | Max Mark |
|---|---|---|
| **3(a)** | Any **seven** from:<br>$\alpha$ - particle scattering<br>suitable diagram with source, foil, moveable detector<br>2 or more trajectories shown<br>vacuum<br>most particles have little if any deflection<br>large deflection of very few<br>reference to Coulomb's law /elastic scattering<br>alphas repelled by nucleus (positive charges)<br>monoenergetic<br>OR electron scattering<br>High energy diagram with source sample, moveable detector / film<br>Vacuum<br>Electron accelerator or other detail<br>Most have zero deflection<br>Characteristic angular distribution with minimum<br>Minimum not zero<br>De Broglie wavelength<br>Wavelength comparable to nuclear size hence high energy | **[B1 x 7]** |
| | ✐ Clearly shows how evidence for the size of the nucleus follows from what is described. | **[1]** |
| **(b)** | He nucleus, a few cm / 3 to 10 cm<br>About 1 m / 0.3 to 2 m / several m, 1 to 10 mm Al / 1 mm Pb<br>(high energy) e-m radiation, 1 to 10 cm of Pb / several m of concrete<br>only 2 correct 1 mark, only 4 correct 2 marks | **[B3]** |
| **(c)** | Source, absorbers placed in front of detector on diagram | **[B1]** |
| | Explanation of how results identify the source<br>(2 marks possible)<br>Allowance for background (max 2)<br>(allow for distance expt to a max 2) | **[B2]** |

| Question Number | Answer | Max Mark |
|---|---|---|
| 4(a)(i) | flux = B x A (normal to B) with symbols explained | [B1] |
| (ii) | linkage = N x flux<br>A = $x^2$ so linkage = $NBx^2$ | [B1]<br>[B1] |
| (b)(i) | Statement of Faraday's law or indication<br>e.g. V = d(NBx2) / dt from (a)(ii)<br>V = NBx2dx/dt or V = NBxv / argue area swept out per second as xv<br>V = 1250 x 0.032 x 0.02 x 0.1<br>= 0.08 or 80 mV | <br><br>[B1]<br>[B1]<br>[B1]<br>[A0] |
| (ii) | equal positive and negative regions<br>equal positive and negative values of 'maxima' labelled on y-axis<br>value changes within correct time zones, t= 0.2 to 0.4, 0.6 to 0.8 s<br>'square pulse' shape<br>*sinusoidal graphs score zero marks* | [B1]<br>[B1]<br>[B1]<br>[B1] |
| 5(a) | Universe is isotropic /same in all directions<br>Homogeneous / evenly distributed | [B1]<br>[B1] |
| (b) | Any four from:<br>Uniform intensity in all directions / everywhere<br>Structure in background intensity / ripples<br>Produced when matter and radiation decoupled<br>Originally gamma radiation<br>(gamma) red-shifted to microwave / originally higher energy<br>Evidence that universe began with big bang<br>Temperature corresponds to 2.7 K / 3K / that predicted by big bang model<br>Link between evidence and explanation. | [B1 x 4]<br><br>[1] |
| (c) | Any two from:<br>No experimental evidence / no physical evidence<br>State of matter unknown / laws of physics unknown<br>Energies unreproducible / ref. to very high temperature | [B1 x 2] |

| Question Number | Answer | Max Mark |
|---|---|---|
| 6(a) | Open: Universe expands for all time<br>Flat: expands to a limit (but never reaches it)<br>Closed: Universe contracts / collapses back<br>Reference to role of gravity / critical density<br>Marks for (a) can be gained on a labelled diagram | <br>[B1]<br>[B1]<br>[B1]<br>[B1] |
| (b) | $H_o^2 = (1 \times 10^{-26} \times 8 \times \pi \times 6.67 \times 10^{-11}) / 3$<br>$H_o = 2.36 \times 10^{-18}\ s^{-1}$ | [C1]<br>[A1] |
| 7(a) | Density (of medium)<br>Speed of ultrasound (in medium) or any factors that affect the speed of ultrasound in the medium e.g. Young modulus | [B1]<br><br>[B1] |
| (b)(i) | blood:<br>$f = (1.59 \times 10^{-6} – 1.63 \times 10^{-6})^2 / (1.59 \times 10^{-6} + 1.63 \times 10^{-6})^2$<br>$f = 1.54 \times 10^{-4}$<br>muscle:<br>$f = 1.70 \times 10^{-6} - 1.63 \times 10^{-6})^2 / ( 1.70 \times 10^{-6} + 1.63 \times 10^{-6})^2$<br>$f = 4.4 \times 10^{-4}$<br>so the medium is muscle<br>*(bald muscle scores zero)* | <br><br><br>[B1]<br><br>[B1]<br>[B1]<br>[A1] |
| (ii) | (s = u x t)<br>$s = 1.54 \times 10^3 \times 26.5 \times 10^{-6} = 0.0408$ m<br>depth = 0.0408 / 2 = 0.020 m | <br>[C1]<br>[A1] |
| (iii) | $\lambda = 1.54 \times 10^3 / 3.5 \times 10^6$<br>$= 4.4 \times 10^{-4}$ m<br>(do not penalise the same power of ten error in (iii) as in (ii) | <br>[C1]<br>[A1] |

| Question Number | Answer | Max Mark |
|---|---|---|
| 8(a) | Low energy X-rays are absorbed by the skin / undesirable as can cause damage /greater ionising | [B1] |
| (b) | $I = I_0\ e^{-\mu x}$     $\ln I = \ln I_0 - \mu x$<br>$I_0 = 347 / e^{-250 \times 0.025}$     $\ln I_0 = \ln 347 + 250 \times 0.025$<br>$I_0 = 1.79 \times 10^5\ Wm^{-2}$ | [C1]<br>[C1]<br>[A1] |
| (c) | P = I x A<br>$P = 347 \times \pi \times (0.010 \times 10^{-2})^2$<br>$P = 1.09 \times 10^{-3}$ W | <br>[C1]<br>[A1] |
| (d)(i) | P = 18 x 100 / 0.15<br>P= 12000 W | [C1]<br>[A1] |
| (ii) | Energy of one electron = $12000 / 7.5 \times 10^{17} (1.6 \times 10^{-14})$<br>$½\ m v^2 = 1.6 \times 10^{-14}$<br>$v = 1.9 \times 10^8\ m\ s^{-1}$ | [C1]<br><br>[A1] |
| (iii) | tube current = $7.5 \times 10^{17} \times 1.6 \times 10^{-19} = 0.12$ A<br>P = V x I = 12000<br>V = 12000 / 0.12 = 100000 V or 100 kV<br>Or: $V = W/Q = 1.6 \times 10^{-14} / 1.6 \times 10^{-19} = 1.0 \times 10^5$ (V) | <br>[C1]<br>[C1]<br>[A1] |
| 9 | Any **six** from:<br>method does not use ionising radiation<br>hence no radiation hazard to patient or staff<br>gives better soft tissue contrast than CT scans<br>generates data from a 3D volume simultaneously<br>information can be displayed on a screen as a section in any direction<br>there are no moving mechanisms involved in MRI<br>There is no sensation, after effects at the field strengths used for routine diagnosis<br>Strong magnetic field could draw steel objects into the magnet<br>Metallic objects may become heated<br>Cardiac pacemakers may be affected by the magnetic fields<br>CT scanners better for viewing bony structures | [B1 x 6] |

| Question Number | Answer | Max Mark |
|---|---|---|
| 10(a)(i)(ii)(iii) | Rb 94<br>Cs 55<br>U143<br>-1 for each error | [B2] |
| (b) | Values from graph: U 7.4 MeV allow 7.3 to 7.4<br>Rb 8.6 MeV allow 8.5 to 8.6<br>Cs 8.4 MeV | [C1] |
| | Total binding energies: U 235 x 7.4 (1739<br>Rb 94 x 8.6 (808)<br>Cs 142 x 8.4 (1193) | [B2] |
| | Total energy released = 808 + 1193 – 1739<br>= 262 MeV<br>(Range of allowed answers to be discussed at Standardisation meeting)<br>allow 8.6 + 8.4 – 7.4 = 9.4 MeV for 1 mark only | [A1] |
| (c) | Any six from: (two advantages and two disadvantages needed)<br>problems with the reaction getting out of control<br>maintaining the reaction so that it proceeds continuously<br>does not produce acid rain or waste gases that could cause pollution<br>risks from radiation: emissions due to an accident(1); emissions<br>from radioactive wastes(1) long half life of some of the waste products(1)<br>other examples are likely to be added but should be related to Scientific reasons rather than political. | [B1 x 6] |
| | **Paper Total** | **[100]** |

**Assessment Objectives Grid (includes QWC)**

| Question | AO1 | AO2 | AO3 | Total |
|---|---|---|---|---|
| **1(a)** | 1 | | | **1** |
| **1(b)(i)** | 1 | 2 | | **3** |
| **1(b)(ii)** | | 3 | | **3** |
| **1(b)(iii)** | 1 | | | **1** |
| **2(a)(i)** | | 1 | | **3** |
| **2(a)(ii)** | | 2 | | **2** |
| **2(b)(i)** | | 1 | | **1** |
| **2(b)(ii)** | | 2 | | **2** |
| **2(c)** | | 2 | | **2** |
| **2(d)** | 1 | 3 | | **4** |
| **3(a)** | 6 | | 2 | **8** |
| **3(b)** | 3 | | | **3** |
| **3(c)** | 1 | 2 | | **3** |
| **4(a)(i)** | 1 | | | **1** |
| **4(a)(ii)** | 2 | | | **2** |
| **4(b)(i)** | | 3 | | **3** |
| **4(b)(ii)** | | 4 | | **4** |
| **5(a)** | 2 | | | **2** |
| **5(b)** | | 3 | 2 | **5** |
| **5(c)** | | | 2 | **2** |
| **6(a)** | 2 | 2 | | **4** |
| **6(b)** | | 2 | | **2** |
| **7(a)** | 2 | | | **2** |
| **7(b)(i)** | | | 4 | **4** |
| **7(b)(ii)** | | 2 | | **2** |
| **7(b)(iii)** | | 2 | | **2** |
| **8(a)** | 1 | | | **1** |
| **8(b)** | | 3 | | **3** |
| **8(c)** | | 2 | | **2** |
| **8(d)(i)** | | 2 | | **2** |
| **8(d)(ii)** | | 2 | | **2** |
| **8(d)(iii)** | | 3 | | **3** |
| **9** | 6 | | | **6** |
| **10(a)** | 2 | | | **2** |
| **10(b)** | | 4 | | **4** |
| **10(c)** | 2 | 4 | | **6** |
| **Totals** | **32** | **54** | **14** | **100** |