Surname	Centre Number	Candidate Number
Other Names		2

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5:
Electromagnetism, Nuclei & Options

A.M. THURSDAY, 20 June 2013

1¾ hours

1325
010001

ADDITIONAL MATERIALS

In addition to this paper, you will require a calculator, a **Case Study Booklet** and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use pencil or gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Write your answers in the spaces provided in this booklet. If you run out of space, use the continuation pages at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

This paper is in 3 sections, **A**, **B**, and **C**.

Section A: 60 marks. Answer **all** questions. You are advised to spend about 1 hour on this section.

Section B: 20 marks. The Case Study. Answer **all** questions. You are advised to spend about 20 minutes on this section.

Section C: Options; 20 marks. Answer **one option only.** You are advised to spend about 20 minutes on this section.

J U N 1 3 1 3 2 5 0 1 0 1

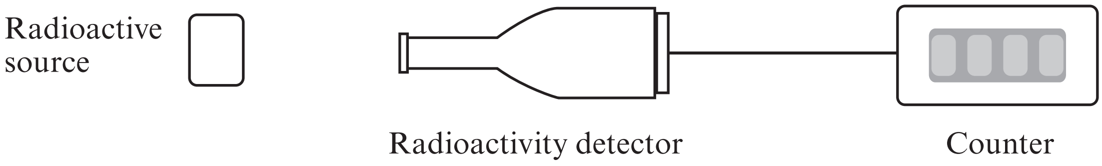
JD*(S13-1325-01)

Examiner only

SECTION A

1. A student is uncertain whether or not a radioactive source emits α, β or γ radiation or a combination of these radiations.

(a) Describe how the student would use a detector and counter along with suitable absorbers to find which radiation(s) are emitted by the radioactive source. [4]



....

....

....

....

....

....

....

....

(b) A radioactive isotope has a starting activity of 76.0×10^{15} Bq and a half life of 25.6 days.

(i) Calculate the activity after 51.2 days. .... [1]

(ii) Calculate the activity after 1 year. [4]

....

....

....

....

....

....

Examiner only

(iii) Calculate the number of radioactive nuclei present at the start. [2]

....

....

....

....

....

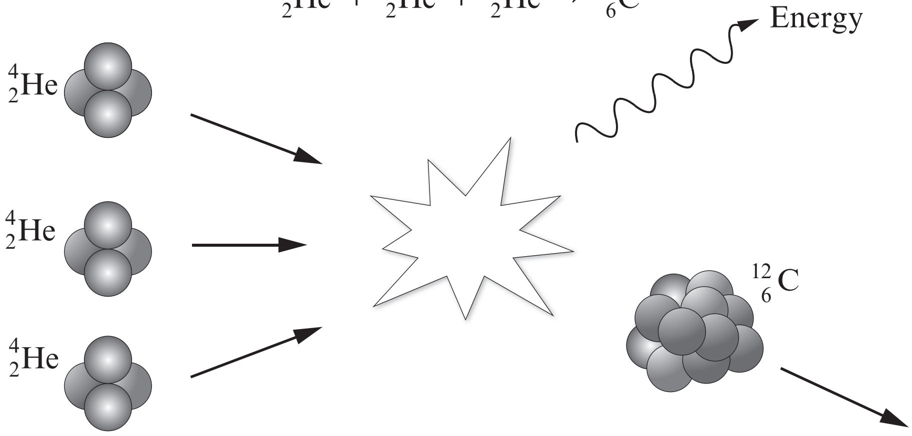
....

1325 010003

Examiner only

2. The following fusion reaction can occur inside stars with core temperatures of around 100 million kelvin.

$$^{4}_{2}He + ^{4}_{2}He + ^{4}_{2}He \rightarrow ^{12}_{6}C$$



(a) Calculate the energy released in the above reaction from the following data. [3]

Mass of $^{4}_{2}He$ = 4.0026 u Mass of $^{12}_{6}C$ = 12.0000 u 1 u = 931 MeV

....

....

....

....

....

....

Examiner only

(b) The isotope $^{62}_{28}Ni$ has a binding energy per nucleon of 8.795 MeV/nucleon and this is the highest known binding energy per nucleon.
Calculate the mass of a $^{62}_{28}Ni$ nucleus in unified atomic mass units (u) and give your answer to 5 significant figures. [5]

mass of proton = 1.00728 u, mass of neutron = 1.00866 u, 1u = 931 MeV

....

....

....

....

....

....

....

....

....

....

1325 010005

Examiner only

3. *(a)* A 131 nF capacitor is charged using a potential difference of 1.62 V. Calculate the charge stored by the capacitor. [2]

....

....

....

(b) This 131 nF capacitor is then disconnected from the power supply and a large resistor connected across its terminals. As the capacitor discharges, the pd across it decreases from 1.62 V to 0.47 V in 220 ms. Calculate the resistance of the resistor. [4]

....

....

....

....

....

....

....

....

Examiner only

(c) The plates of this 131 nF capacitor are square and are separated by 0.15 mm. Calculate the length of a side of the capacitor plate. [3]

....

....

....

....

....

....

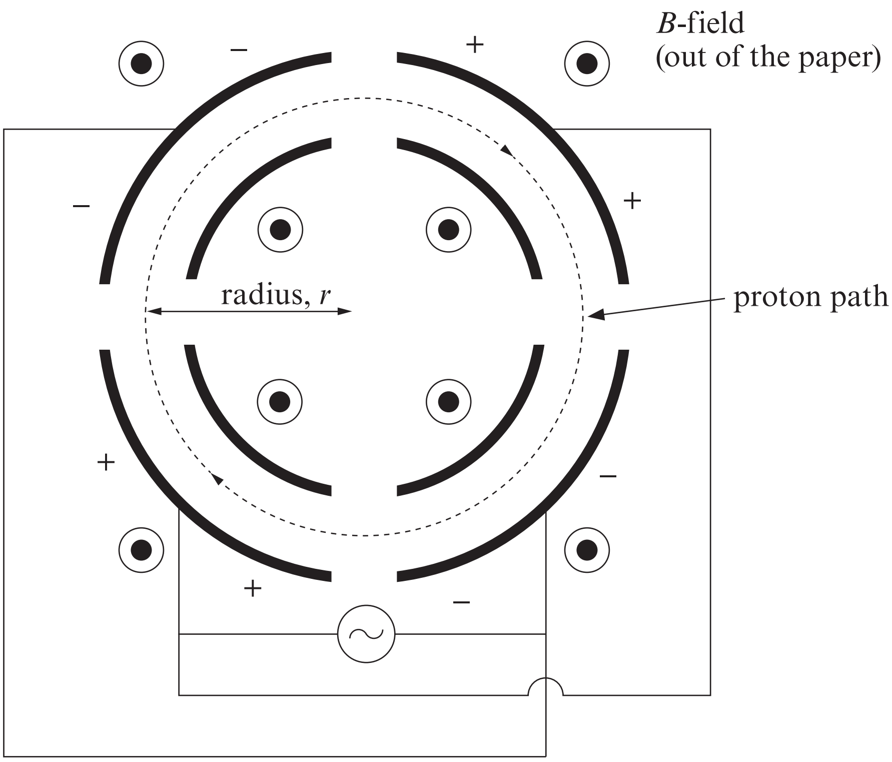
(d) In practice, how could the capacitance of this capacitor be increased by a factor of 100? [1]

....

1325 010007

Examiner only

4. The diagram below is an example of a particle accelerator called a synchrotron. In this synchrotron, protons are accelerated and their path is kept circular by a magnetic field which has to increase as the speed of the protons increases. The protons themselves are accelerated by the alternating potential difference applied to the quarter circle plates (see + and - in the diagram).



(a) Derive the equation $r = \frac{mv}{Be}$ for a particle of mass m and charge e moving with velocity v at right angles to a uniform magnetic field, B. [2]

....

....

....

....

....

....

Examiner only

(b) Use the equation $r = \frac{mv}{Be}$ to explain why the magnetic field must be increased as the speed of the protons increases. [2]

....

....

....

....

(c) Protons take 1.78 μs to complete a circuit of a synchrotron of radius 8.50 m. Calculate the strength of the magnetic field, *B*, required. [$m_{proton} = 1.67 \times 10^{-27}$ kg.] [4]

....

....

....

....

....

....

....

(d) (i) Modern synchrotrons use magnetic fields up to 10 T which cannot be produced using copper wires at room temperature. Explain why not, using $B = \mu_0 nI$. [2]

....

....

....

....

....

(ii) Hence, explain why superconducting magnets are used to produce large magnetic fields in synchrotrons. [1]

....

....

1325 010009

Turn over.

Examiner only

5. *(a)* State the **two** laws of electromagnetic induction (Faraday's law and Lenz's law). [3]

....

....

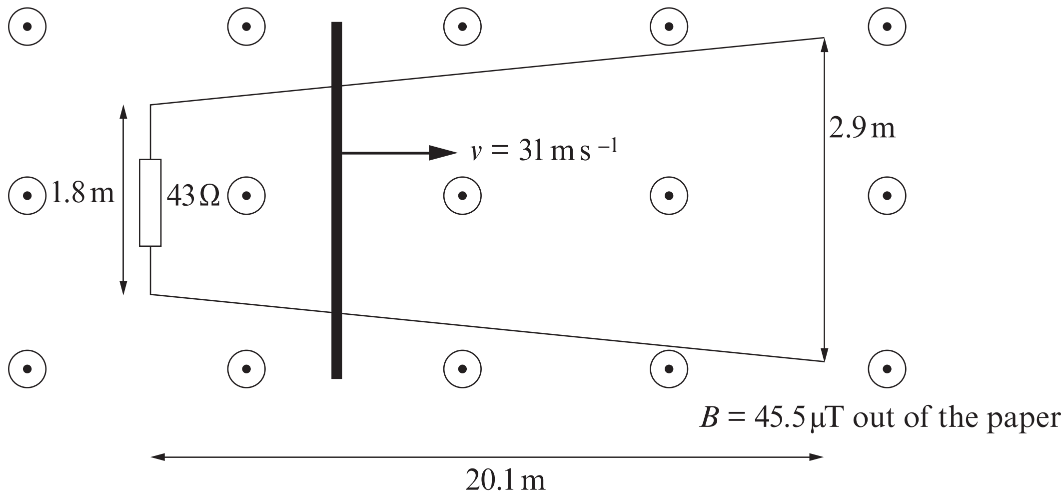
....

....

....

....

(b) A thick conducting bar is moved with constant speed over non-parallel conducting rails as shown below. The rails have negligible resistance and the *B*-field is uniform.



(i) Indicate the direction of the induced current on the diagram and explain how you arrived at your answer. [2]

....

....

....

....

Examiner only

(ii) The conductor moves at a constant speed of $31\,\text{m}\,\text{s}^{-1}$. Use Faraday's law to explain why the induced emf increases. [2]

....

....

....

....

(iii) The conductor starts moving from the end near the $43\,\Omega$ resistor. Calculate the mean current in the resistor when the conducting bar has travelled the full 20.1 m length of the track. [4]

....

....

....

....

....

....

....

....

....

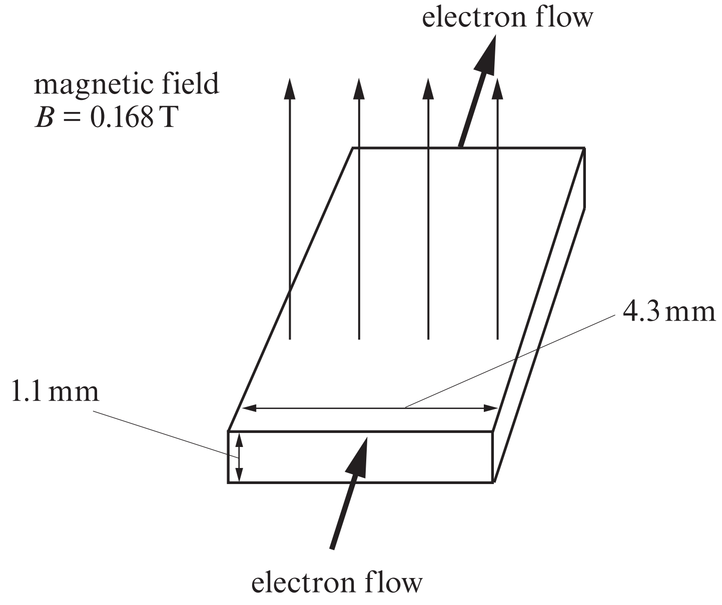
....

....

1325 010011

Examiner only

6. Electrons flow through a silicon wafer which is used as a Hall probe.



(a) Show on the above diagram:

(i) the face of the silicon wafer that becomes positively charged; [1]

(ii) how you would connect a voltmeter to measure the Hall voltage. [1]

(b) Calculate the drift velocity of the electrons given that the Hall voltage is 0.314 mV. [3]

....

....

....

....

(c) As electrons move through the wafer, explain why no work is done on them by the electric field, E_H. [1]

....

....

....

Examiner only

(d) The current flowing in the silicon wafer is 0.38 A. Calculate the number of free electrons per unit volume in the silicon wafer. [3]

....

....

....

....

....

....

....

....

....

1325 010013

Turn over.

Examiner only

SECTION B

The questions refer to the case study.
Direct quotes from the original passage will not be awarded marks.

7. *(a)* In your own words and referring to diagram 2 in the case study, explain lift in terms of Newton's laws. (See paragraph 3.) [2]

....

....

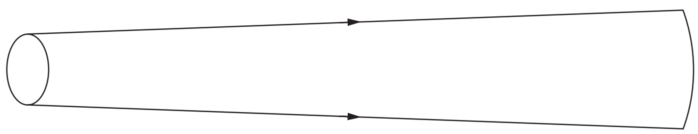
....

....

....

....

(b) The streamline diagram shows streamlines getting further apart. Explain why there must be a net force to the left acting on the air in the streamline.
(See paragraphs 6 & 7.) [2]



....

....

....

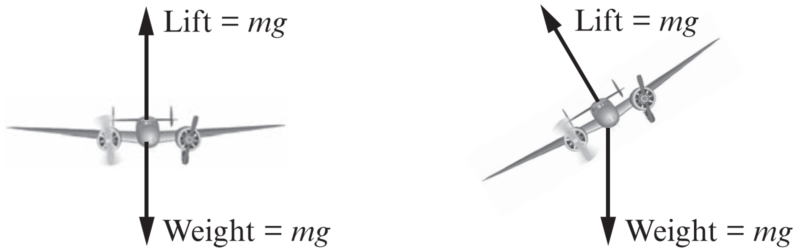
....

....

....

Examiner only

(c) An aeroplane is initially flying forward at a constant speed horizontally. It then tilts as shown. The magnitude of the lift force remains constant. Explain why the aeroplane must now accelerate downwards and to the left. [2]



....

....

....

....

....

....

(d) Houses can explode when tornados pass nearby. Explain this using Bernoulli's equation. (See paragraphs 7, 8 & 9.) [2]

....

....

....

....

....

....

(e) Check that the figure for lift (130 kN) for a super jumbo wing at 80 m s^{-1} is correct if you assume that the speed over the top of the wing is only 2% greater than 80 m s^{-1}. (See paragraph 13.) [3]

....

....

....

....

....

....

1325 010015

Examiner only

(f) Show that the lift coefficient has no units. (See paragraph 17.) [3]

(g) Calculate the lift coefficient for an Airbus super jumbo at take-off. (See paragraph 17.) [2]

(h) Draw a labelled diagram of the set up that might be employed using a hair dryer, stand, clamp, protractor, digital balance and metal plate to measure lift coefficient against angle of attack. (See paragraphs 18 and 19.) [4]

SECTION C: OPTIONAL TOPICS

Option A: **Further Electromagnetism and Alternating Currents** ☐

Option B: **Revolutions in Physics - The Newtonian Revolution** ☐

Option C: **Materials** ☐

Option D: **Biological Measurement and Medical Imaging** ☐

Option E: **Energy Matters** ☐

Answer the question on **one topic only.**

Place a tick (✓) in one of the boxes above, to show which topic you are answering.

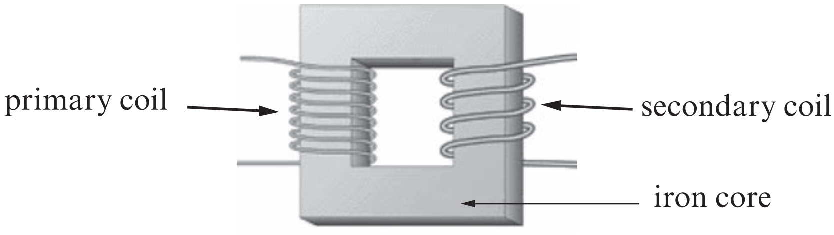
You are advised to spend about 20 minutes on this section.

1325 010017

Examiner only

Option A: Further Electromagnetism and Alternating Currents

8. *(a)* Explain how an alternating current in the primary coil leads to an alternating emf in the secondary coil. [3]



....

....

....

....

....

....

....

....

(b) State and explain briefly **three** ways in which the design of a transformer reduces energy losses. [3]

....

....

....

....

....

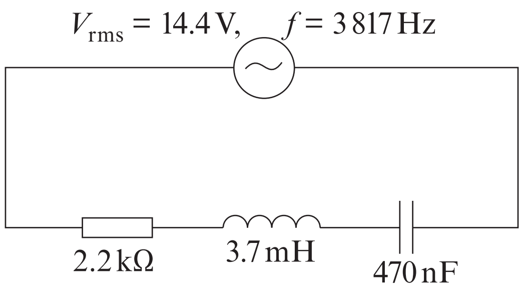
....

....

....

Examiner only

(c) (i) Calculate the reactances of the capacitor and inductor at the frequency shown. [3]



....

(ii) How can you tell that this is the resonance frequency of the circuit? [1]

....

(iii) Calculate the current at the resonance frequency of 3 817 Hz. [1]

....

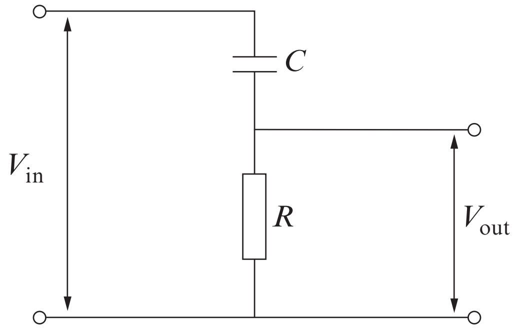
(iv) Calculate the current when the frequency is 38.17 kHz (the rms pd remains 14.4 V). [3]

....

1325
010019

Examiner only

(d) (i) Explain why the circuit shown is a high pass filter. [3]

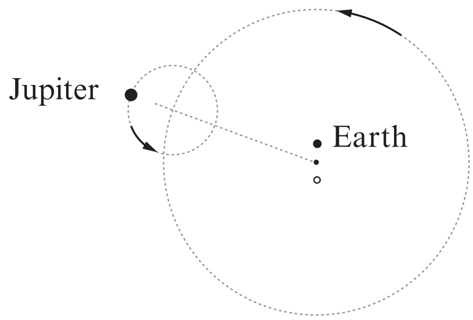


(ii) C = 470 nF and R = 2.2 kΩ. Using a phasor diagram or otherwise, calculate the frequency when $V_{out} = \frac{1}{\sqrt{2}} V_{in}$. [Hint: $\cos 45° = \frac{1}{\sqrt{2}}$.] [3]

Examiner only

Option B: Revolutions in Physics - The Newtonian Revolution

9. *(a)* (i) The diagram shows a simplified version of Ptolemy's scheme to account for the observed motion of Jupiter.



(I) **Label on the diagram** the following: *equant, deferent, epicycle.* [2]

(II) Explain whether Jupiter's observed motion is *prograde* or *retrograde* when it is in the position shown. [1]

....

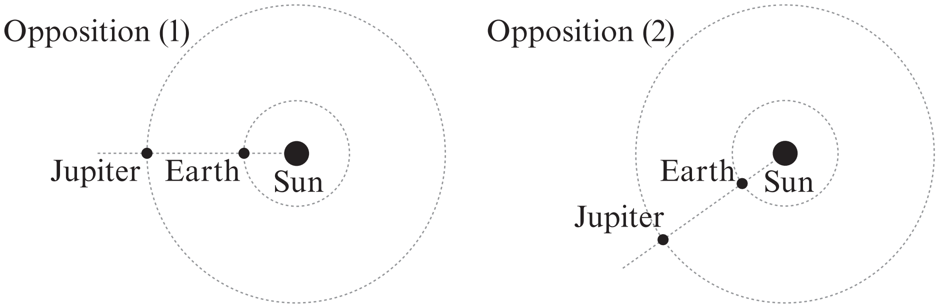
....

(III) Ptolemy's scheme predicts the motions of planets. What other changing feature of planets' appearances does the scheme predict? [1]

....

Examiner only

(ii) The diagrams show two successive *oppositions* of Jupiter and the Sun, as seen on a simplified Copernican scheme. Opposition (2) occurs time Δt after opposition (1).



It can be shown that $\frac{2\pi}{T_E}\Delta t - \frac{2\pi}{T_J}\Delta t = 2\pi$, or equivalently, $\frac{\Delta t}{T_E} - \frac{\Delta t}{T_J} = 1$, in which T_E and T_J are the periodic times of the Earth and Jupiter.

(I) Explain how the equation (either version) arises. [2]

....

....

....

....

....

(II) The time Δt, observed between successive oppositions is found to be 1.092 years. Calculate Jupiter's period of revolution in years. [2]

....

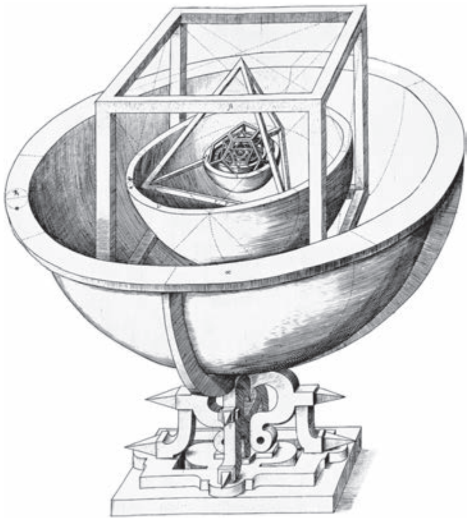
....

....

....

Examiner only

(b) The diagram shows a model illustrating an early idea of Kepler, involving the five regular solids.



(i) Explain Kepler's idea, and why, eventually, he rejected it. [2]

.....

.....

.....

.....

(ii) "By trying to make use of the regular solid, Kepler was following an ancient tradition." Discuss this statement briefly. [2]

.....

.....

.....

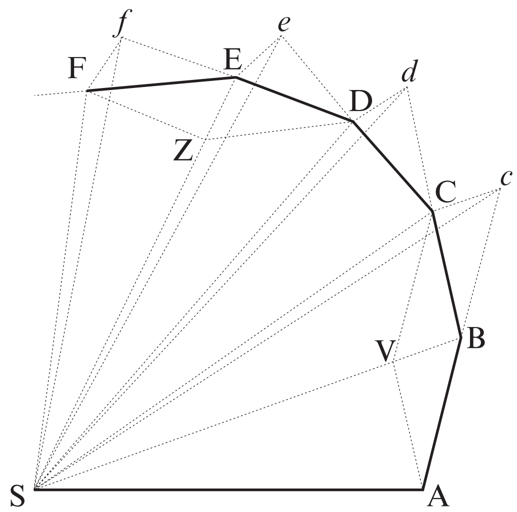
.....

.....

Turn over.

Examiner only

(c) The diagram is taken from Newton's *Principia* (Proposition I, Theorem I).



(i) Explain what the path ABCDEF represents, and why there are sharp changes of direction at **each** of the points A, B, C, D, E and F. [2]

....

....

....

....

(ii) What does Newton show, in Theorem I? [1]

....

....

....

Examiner only

(d) The Moon's mean orbital radius is 3.84×10^8 m, and its period of revolution is 27.3 days. The Earth's mean radius is 6.37×10^6 m.

(i) Calculate the ratio: $\dfrac{\text{orbital acceleration of the Moon}}{\text{acceleration due to gravity on Earth's surface}}$ [2]

....

....

....

....

....

(ii) Show clearly that this supports an inverse square law of gravitation. [2]

....

....

....

....

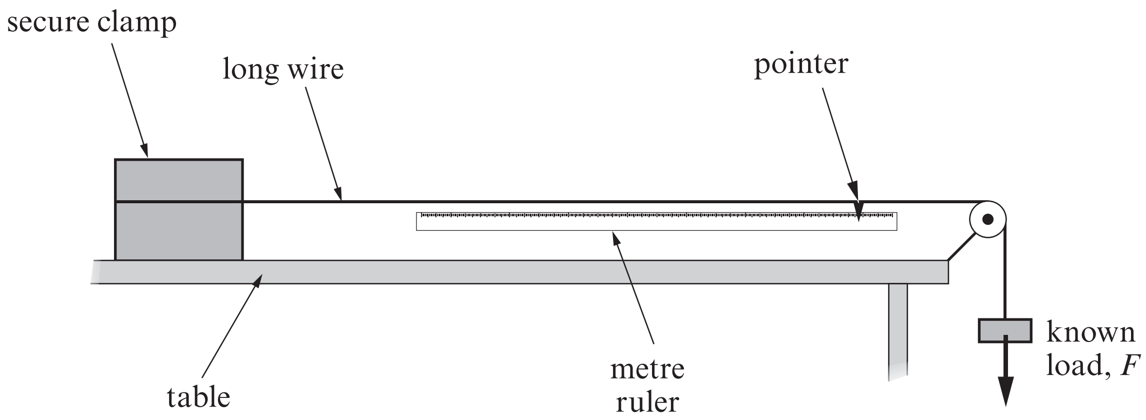
(iii) What assumption are you making about the Earth's mass distribution? [1]

....

Examiner only

Option C: Materials

10. *(a)* The diagram shows apparatus that may be used to obtain a value for the Young modulus of a metal in the form of a long wire. A known load, F, is applied to one end of the wire. The extension, Δx, of the wire is measured using the pointer and metre ruler.



(i) To obtain a value for the Young modulus, two other measurements must be made. State what these measurements are and what equipment you would use. [2]

....

....

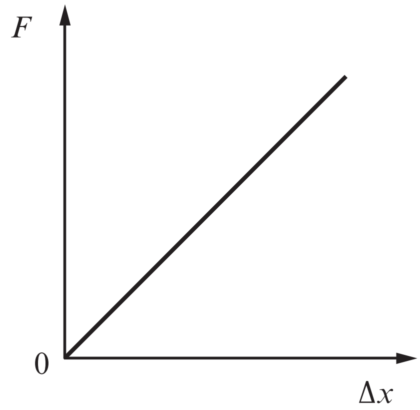
....

....

....

Examiner only

(ii) A graph of load, F, against extension, Δx, may be obtained from the experiment.



Explain how a value of the Young modulus may be obtained by using the measurements in part *(a)*(i) and information from the graph. [3]

....

....

....

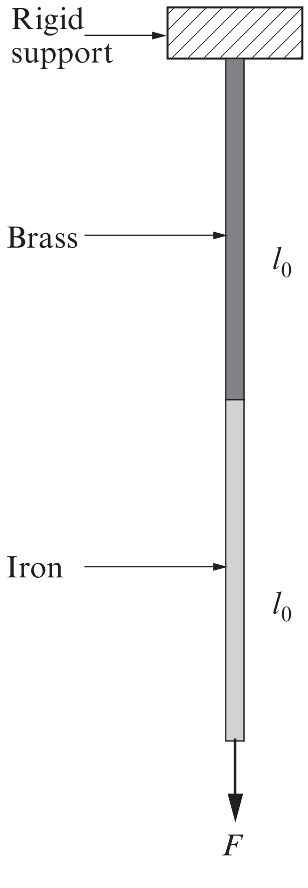
....

....

....

Examiner only

(b) Two wires, one of brass and one of iron, each of length l_0 and each with the same **diameter** are joined end to end and hung from a rigid support. A force, F, is applied as shown in the diagram.



(i) The extension in the brass wire, Δx_{brass} is given by: $\Delta x = \dfrac{Fl_0}{AE_{brass}}$

where A and E_{brass} represent the cross-sectional area of the wire and the Young modulus of brass respectively. Write down a similar expression for the extension of the iron wire. [1]

....

....

....

(ii) The strain energy, W, in the wire due to the stretching force F, is given by $\frac{1}{2}F\Delta x$, where Δx represents the total extension in the wire combination. Show that

$$W = \frac{F^2 l_0}{2A}\left(\frac{1}{E_{brass}} + \frac{1}{E_{iron}}\right)$$ [2]

....

....

....

....

....

....

(iii) Calculate W when $F = 47.0$ N. Assume the diameter of both wires is 1.0 mm and each has an unstretched length, l_0, of 2.0 m. [E_{brass} = 100 GPa; E_{iron} = 200 GPa.] [3]

....

....

....

....

....

....

Examiner only

(iv) Hence, or otherwise, determine the overall extension of the combination of wires when $F = 47.0$ N. [1]

....

....

....

(v) Explain, using the Young moduli given, which of the two wires has undergone the greater extension and hence determine the ratio $\frac{\Delta x_{brass}}{\Delta x_{iron}}$. [4]

....

....

....

....

....

....

....

(c) Use the information in the table below:

(i) to **complete** the table to determine whether the polymers given are examples of thermosetting or thermoplastic polymers; [2]

Name	Tensile strength / MPa	Maximum strain / %	Young modulus / GPa	Thermosetting or thermoplastic?
Melamine formaldehyde	65	0.6	12	
Low density polyethylene	17	500	0.3	

(ii) to explain which of the polymers given might be brittle and which of the two is the stiffer. [2]

....

....

....

....

Examiner only

Option D: Biological Measurement and Medical Imaging

11. *(a)* An X-ray machine emits X-rays of minimum wavelength 0.030 nm.

(i) Sketch a graph of intensity against wavelength for the resulting X-ray spectrum. **Label** the main features of the spectrum. [3]

(ii) Calculate the accelerating potential difference used to produce a spectrum with a minimum wavelength of 0.030 nm. [2]

....

....

....

....

(iii) When diagnosing and treating a child's broken arm, images of the arm are needed. What **two** properties of X-rays make them suitable for this imaging? [2]

....

....

....

....

Examiner only

(iv) X-ray imaging is not suitable for revealing brain tumours. Which imaging technique should be used? Give reasons for your choice. [3]

....

....

....

....

....

....

(b) The fraction, f, of ultrasound reflected back at a boundary between two materials of acoustic impedances Z_1 and Z_2 is given by the equation:

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

(i) Define acoustic impedance, Z. [1]

....

....

(ii) Using the information given in the table below determine the fraction of ultrasound reflected at an air / skin boundary. [2]

Medium	Density / $kg\,m^{-3}$	Velocity of ultrasound / $m\,s^{-1}$
Air	1.300	340
Skin	1 075	1 590

....

....

....

....

Examiner only

(iii) Explain the importance of your answer to *(b)*(ii) and state what ultrasound radiographers must do to obtain clear images of the body. [2]

....

....

....

....

....

(c) (i) Explain the difference between radiation exposure and absorbed dose. [2]

....

....

....

....

....

(ii) Explain why, for the same absorbed dose, the dose equivalent would be different for exposure to alpha particles than for gamma rays. [3]

....

....

....

....

....

....

....

Examiner only

Option E: Energy Matters

12. A new nuclear reactor has been proposed based on the reaction of lithium-7 and a proton to produce two α-particles.

$$^{1}_{1}\text{p} + {^{7}_{3}\text{Li}} \rightarrow {^{8}_{4}\text{Be}} \rightarrow {^{4}_{2}\text{He}} + {^{4}_{2}\text{He}} + 17.1\text{ MeV}$$

Although this is not a new nuclear reaction (it was the original splitting the atom experiment in 1932), there have been some theoretical developments that suggest this might be a useful reaction.

The above reaction is produced by ionising hydrogen and accelerating the resulting protons in a vacuum to an energy of around 300 keV. Unfortunately, in the past, only one in 30 million protons accelerated to the correct voltage have produced this nuclear reaction.

(a) (i) The above reaction is produced by accelerating ionised hydrogen with 300 kV. Explain **two** possible benefits of the system compared with fission reactors. [4]

....

....

....

....

....

....

....

(ii) Calculate the energy required to accelerate 30 million protons to an energy of 300 keV and explain why the above reaction does not seem profitable. [3]

....

....

....

....

....

Examiner only

(iii) There is around 10^{16} kg of ${}^{7}_{3}\text{Li}$ in the world's oceans and the mass of ${}^{7}_{3}\text{Li}$ can be taken as 7 u. Calculate the number of ${}^{7}_{3}\text{Li}$ atoms in the world's oceans. [2]

....

....

....

....

(iv) The total annual world energy consumption is around 5×10^{20} J. Assuming that each ${}^{7}_{3}\text{Li}$ atom can, ideally, provide an energy of 17.1 MeV, calculate the number of years ${}^{7}_{3}\text{Li}$ could supply the world's energy consumption. [3]

....

....

....

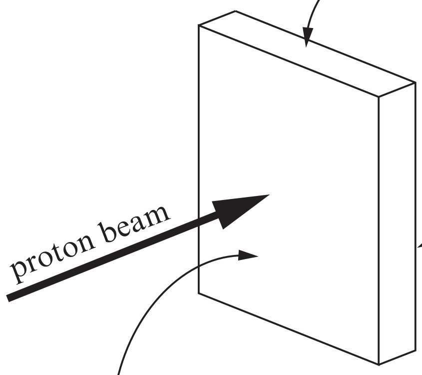
....

....

....

Examiner only

(b) (i) It has been suggested that lithium wafers of dimension 20 mm × 20 mm × 2.5 mm be used as a target for the proton bombardment, leading to the temperature difference shown. Calculate the heat transferred through the lithium wafer from the data shown. [3]



....

....

....

....

....

....

Examiner only

(ii) The heat transferred through the lithium wafer is used to raise the temperature of a flowing gas. By sending this gas quickly through a compressor, its temperature can be raised dramatically. Explain why the temperature of the gas increases using the first law of thermodynamics. [2]

....

....

....

....

....

(iii) Eventually, water will be boiled to produce superheated steam to drive turbines and generators. Explain why superheated steam at 500 °C leads to greater efficiencies than steam at 100 °C. [3]

....

....

....

....

....

....

....

....

END OF PAPER

Question number	Additional page, if required. Write the question numbers in the left-hand margin.

Examiner only

Question number	Additional page, if required. Write the question numbers in the left-hand margin.

Examiner only