WJEC CBAC

GCE A level

1325/01

PHYSICS

ASSESSMENT UNIT PH5:

ELECTROMAGNETISM, NUCLEI & OPTIONS

A.M. MONDAY, 18 June 2012

1¾ hours plus your additional time allowance

Surname ______________________________

Other Names ______________________________

Centre Number ______________________________

Candidate Number 2 ______________________________

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 or your usual method.

Write your name, centre number and candidate number in the spaces provided on the front cover.

Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

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

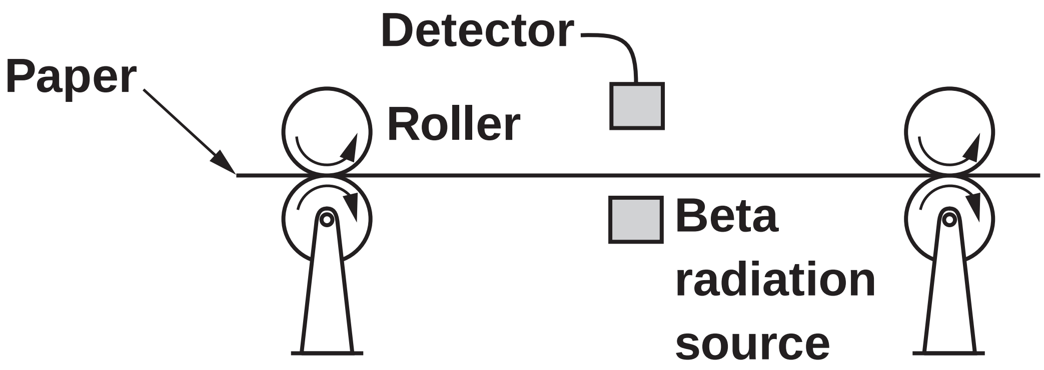
Section A: 60 marks. Answer ALL questions. You are advised to spend about 1 hour on this section.

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.

SECTION A

1. **The thickness of paper is measured using a beta radiation source and detector (see below).**



(a) **Explain why it would be inappropriate to use either alpha radiation or gamma radiation for this task. [2]**

1(b) The beta radiation source most commonly used is strontium-90 which decays as shown. Place the correct numbers on the lines. [2]

$$^{90}_{38}\mathrm{Sr} \longrightarrow {}^{\_\_\_\_}_{\_\_\_\_}\mathrm{Y} + {}^{\_\_\_\_}_{\_\_\_\_}\beta$$

(c) The half life of strontium-90 is 28.8 years. Show that its decay constant is $7.6 \times 10^{-10}\ \mathrm{s}^{-1}$. [2]

1(d) If the initial activity of the strontium-90 source is 140 GBq, calculate its activity after 10 years. [2]

1(e) Calculate the mass of strontium-90 required to produce an activity of 140 GBq. [3]

2. One of the nuclear reactions that occurs inside a nuclear power station is:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + 3\,^{1}_{0}\text{n}$$

The masses of the relevant nuclei are as follows:

Mass of $^{235}_{92}\text{U}$ = 234.9933 u

Mass of $^{92}_{36}\text{Kr}$ = 91.9064 u

Mass of $^{141}_{56}\text{Ba}$ = 140.8836 u

Mass of $^{1}_{0}\text{n}$ = 1.0087 u

(a) Calculate the energy released in this nuclear reaction (1 u = 931 MeV). [3]

2(b) Explain briefly how this reaction can lead to a chain reaction. [2]

2(c) Explain briefly the different purposes of the moderator and control rods in a nuclear reactor.

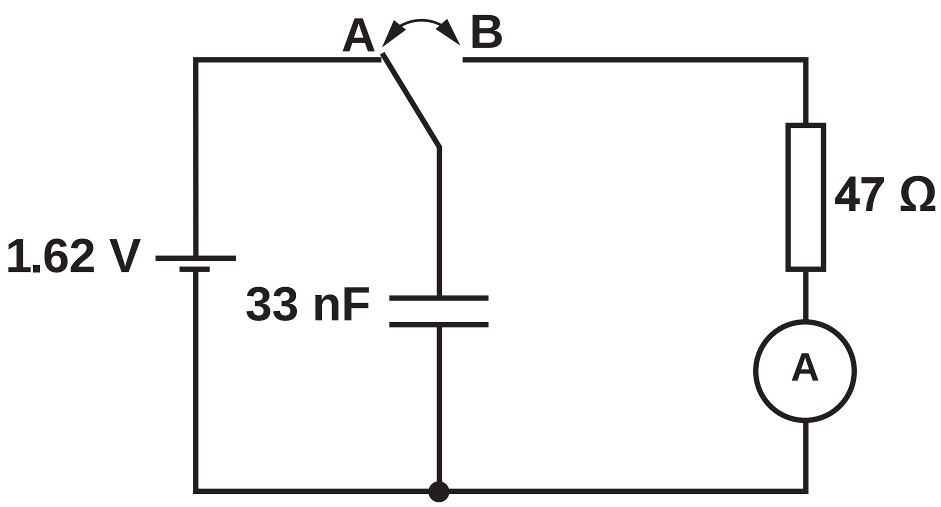
[3]

2(d) Discuss briefly the problems associated with disposing of waste products from a nuclear power station. [2]

3(a) (i) A capacitor has plates of area 8.2×10^{-4} m^2 and a separation of 0.77 mm. Calculate the capacitance of the capacitor assuming that there is air (or a vacuum) between the plates. [2]

(ii) Keeping the dimensions of the capacitor the same, how could you increase its capacitance? [1]

3(b) Another capacitor is charged and discharged using the following circuit.

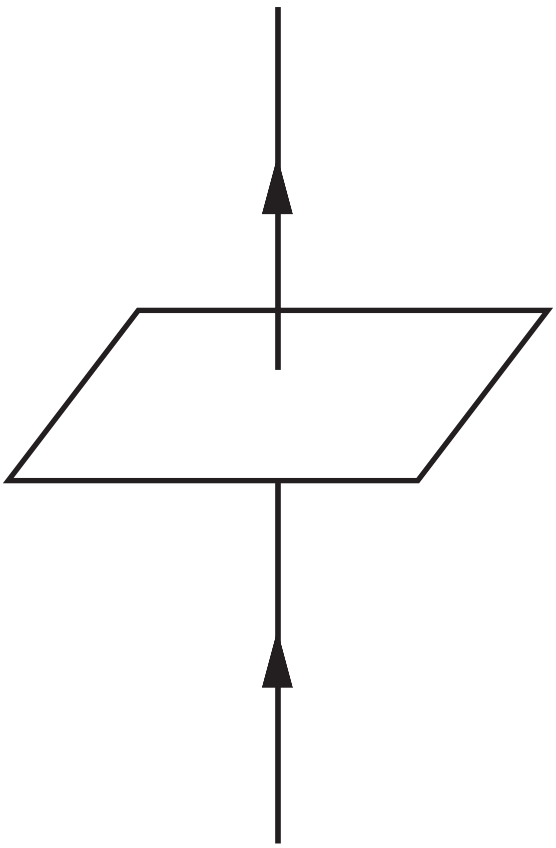


(i) Calculate the charge stored by the capacitor when fully charged. [2]

3(b) (ii) **The fully charged capacitor is now discharged through the 47 Ω resistor by moving the switch to B. Calculate the charge still remaining on the capacitor after it has been discharging for 50.0 μs and comment on the magnitude of your answer.** **[3]**

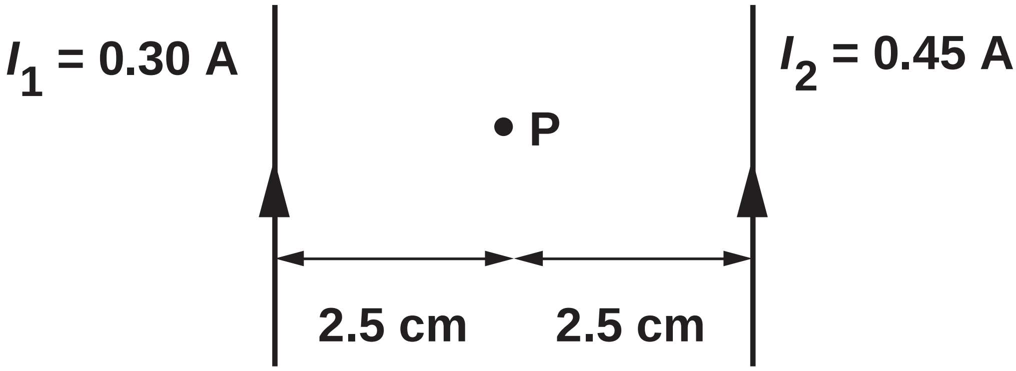
3(b) (iii) **The capacitor is charged and discharged a total of 20 000 times per second. Calculate the average current through the ammeter.**

[2]



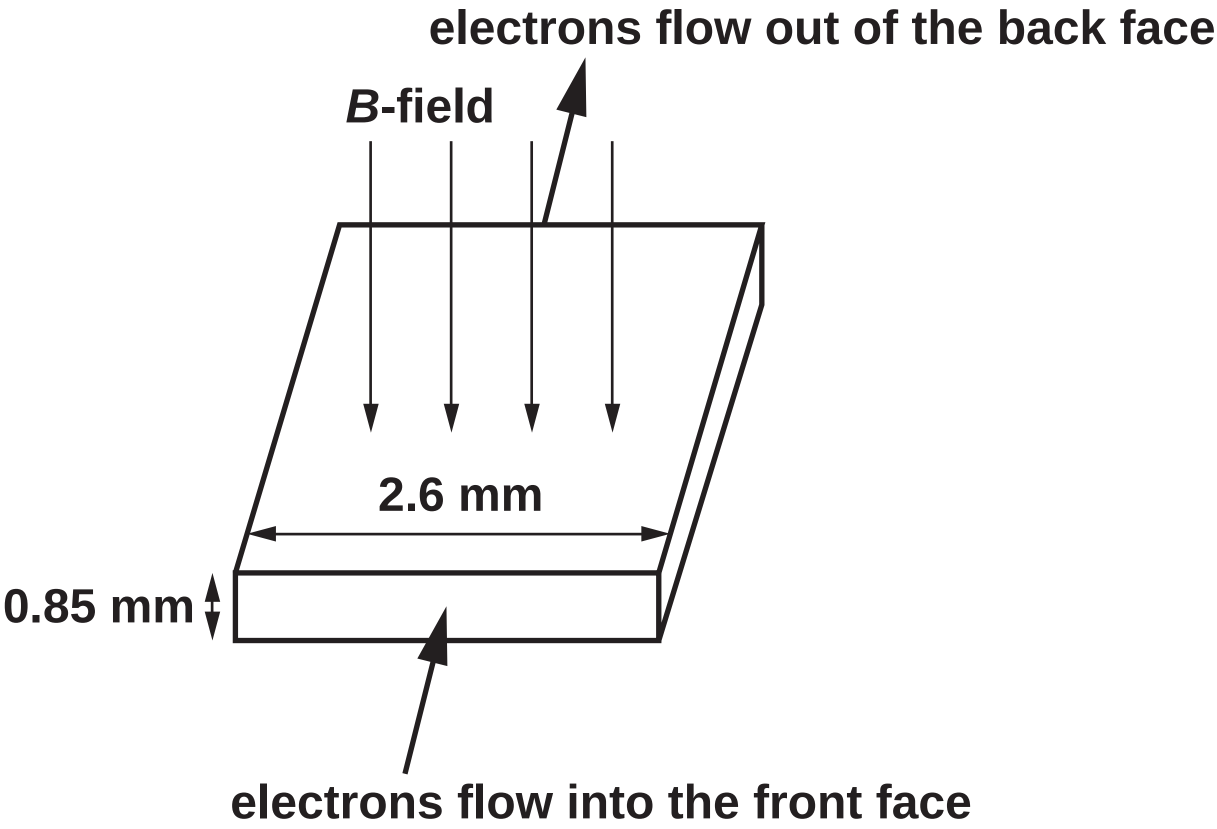
4(a) Sketch opposite the magnetic field due to the current-carrying wire shown. [2]

(b) Two long, straight wires carry currents as shown.



(i) Calculate the resultant magnetic field strength at point P in the above diagram and STATE ITS DIRECTION. [4]

4(b) (ii) Explain why there is an attractive force between the two long wires in the diagram on page 17. [3]


electrons flow out of the back face
B-field
2.6 mm
0.85 mm
electrons flow into the front face

5. Electrons flow through a gold wafer which is used as a Hall probe (see diagram opposite).

(a) Explain which face of the wafer becomes negatively charged due to the Hall effect. [3]

5(b) The electric field due to the Hall voltage is 3.2×10^{-6} V m^{-1}. Calculate the Hall voltage. [2]

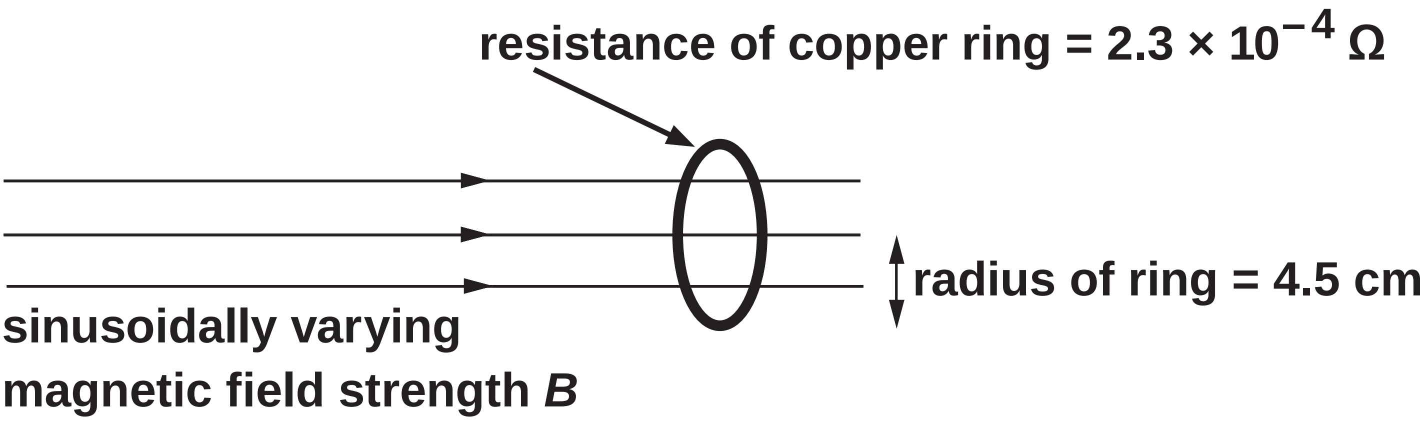
5(c) **The following equation is used in conjunction with the Hall effect: $eE = Bev$.**
State what the forces eE and Bev are and explain why they are equal. [2]

5(d) **The current flowing in the wafer is 0.82 A and the concentration of free electrons in gold is 5.9×10^{28} m^{-3}. Calculate the magnetic field strength, B. [Hint: Use $I = nAve$] [3]**

6(a) State Faraday’s law of electromagnetic induction.

[2]

6(b) A circular copper heating ring works by being placed in a sinusoidally varying magnetic field. A large sinusoidal current is then induced in the ring and the ring becomes hot (see below).

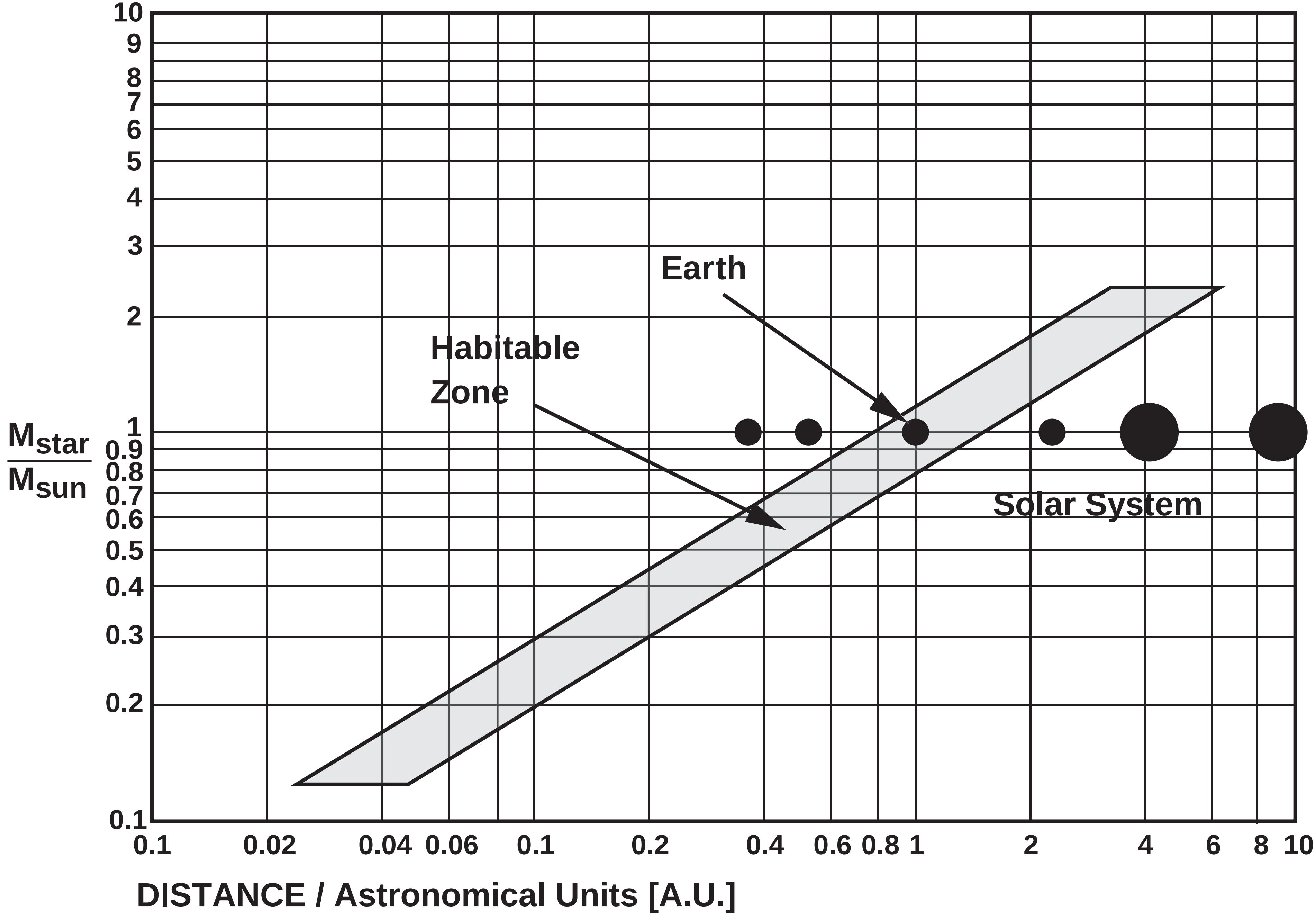


(i) The maximum rate at which the magnetic field strength changes is 72 T s^{-1}. Show that the maximum current flowing in the ring is approximately 2000 A. [4]

6(b) (ii) Calculate the rms value of the induced current. [2]

6(b) (iii) **Calculate the mean power dissipated in the heating ring. [2]**

Graph of Star Mass (relative to our Sun) v Planet Distance from the Star



SECTION B

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

7(a) Explain briefly why all the Solar System planets appear on the same horizontal line on the graph opposite. [1]

7(b) **Place crosses on the graph opposite page 29 to represent:**

(i) **an exoplanet orbiting a star twice the mass of the Sun and at a distance four times the Sun-Earth separation; [1]**

(ii) **an exoplanet orbiting a star 0.25 times the mass of the Sun and at a distance of 0.04 times the Sun-Earth separation. [1]**

7(c) Explain whether or not abundant liquid water could be found on EACH of the planets in part (b). [See also Paragraph 2.] [2]

7(d) **Derive the equation** $v_s = M_p \sqrt{\frac{G}{M_s d}}$

from the equations in the box in Paragraph 8. [2]

7(e) **Explain how the equation** $v_s = M_p \sqrt{\frac{G}{M_s d}}$

agrees with the statement "the Doppler method is most sensitive to large planets which are close to small stars". [Paragraph 8.] [4]

7(f) **Explain whether or not the orbital parameters scatter plot (opposite) confirms the statement “the Doppler method is most sensitive to large planets which are close to small stars.” [2]**

7(g) PLACE A CROSS to show the position of the planet Earth on the orbital parameters scatter plot (opposite page 34). [2]

(h) Jupiter's radius is $^1/_{20}$ that of the Sun. Calculate the fractional (or percentage) change in the Sun's apparent intensity as Jupiter transits in front of the Sun (as measured by a very distant observer). [Paragraph 9.] [2]

7(i) **Explain briefly how radial velocity measurements combined with transit measurements lead to the mean density of an exoplanet. [Paragraph 21.] [3]**

Source

**Scattergraph – http://en.wikipedia.org/wiki/
File:Exoplanet_Period–Mass_Scatter.png**

SECTION C: OPTIONAL TOPICS

Option A: FURTHER ELECTROMAGNETISM AND ALTERNATING CURRENTS ☐

Option B: REVOLUTIONS IN PHYSICS - ELECTROMAGNETISM AND SPACE-TIME ☐

Option C: MATERIALS ☐

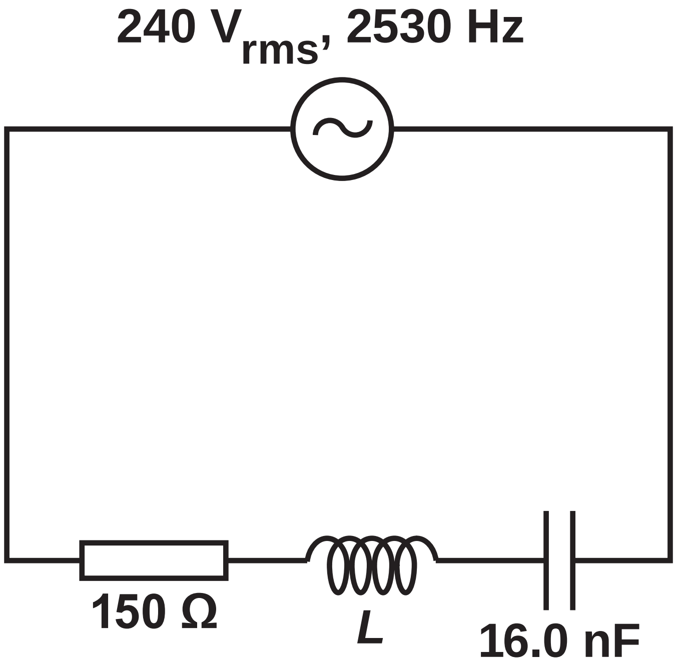
Option D: BIOLOGICAL MEASUREMENT AND MEDICAL IMAGING ☐

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.


240 V_rms, 2530 Hz
150 Ω
L
16.0 nF

OPTION A: FURTHER ELECTROMAGNETISM AND ALTERNATING CURRENTS

C8(a) A long solenoid is used in a LCR circuit (see diagram opposite).

(i) If the resonance frequency of the circuit is 2530 Hz, calculate L, the inductance of the solenoid. [3]

8(a) (ii) **Explain why the rms current at resonance is 1.6 A. [2]**

8(a) (iii) **Calculate the rms pd across the capacitor at resonance. [3]**

8(a) (iv) **Write down the following values at resonance: [4]**

the rms pd across the inductor;

____

the mean power dissipation in the inductor;

____

the mean power dissipation in the capacitor;

____

the phase angle between the applied voltage and the current.

____

8(b) The self-inductance of a coil is defined by the equation $E = -L\,\dfrac{\Delta I}{\Delta t}$

Give the meanings of: [2]

E ______________________________

L ______________________________

$\dfrac{\Delta I}{\Delta t}$ ______________________________

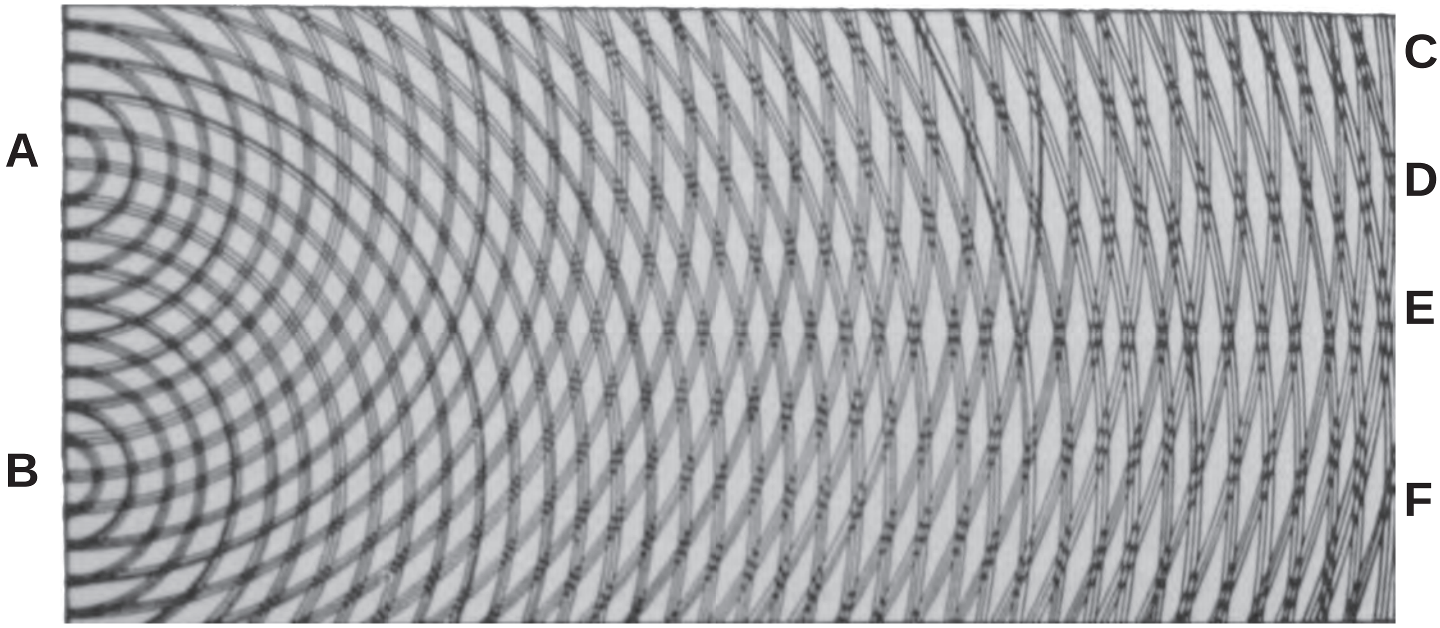
8(c) **The magnetic field strength, B, at the centre of a long solenoid is given by the equation $B = \mu_0 nI$.**

Use Faraday's law to show that the self inductance of a long solenoid is given by

$$L = \mu_0 n^2 lA$$

where l is the length of the solenoid and A is its cross-sectional area. [4]

8(d) A long solenoid is of length 2.70 m, has 3400 turns per unit length and its turns have a radius of 4.50 cm. Calculate its self-inductance. [2]


A
B
C
D
E
F

OPTION B: REVOLUTIONS IN PHYSICS

C9(a) The diagram opposite was used by Thomas Young in connection with the behaviour of waves.

(i) What does the diagram show?
As part of your answer, you should label significant features. [2]

9(a) (ii) Young's experiments, and his interpretation of them, are now seen as the rebirth of the wave theory of light. How did the theories proposed earlier by Newton and by Huygens differ (if at all) from Young's theory? [3]

9(b) (i) Describe the experiment in which Faraday discovered ELECTROMAGNETIC INDUCTION. Include a sketched labelled diagram. [4]

9(b) (ii) What did Faraday mean by MAGNETIC LINES OF FORCE, and what use did he make of them in describing and/or explaining electromagnetic phenomena? [2]

9(b) (iii) How did Maxwell represent lines of force in his vortex ether? [2]

9(c) (i) State the two postulates on which Einstein's SPECIAL THEORY OF RELATIVITY is based. [2]

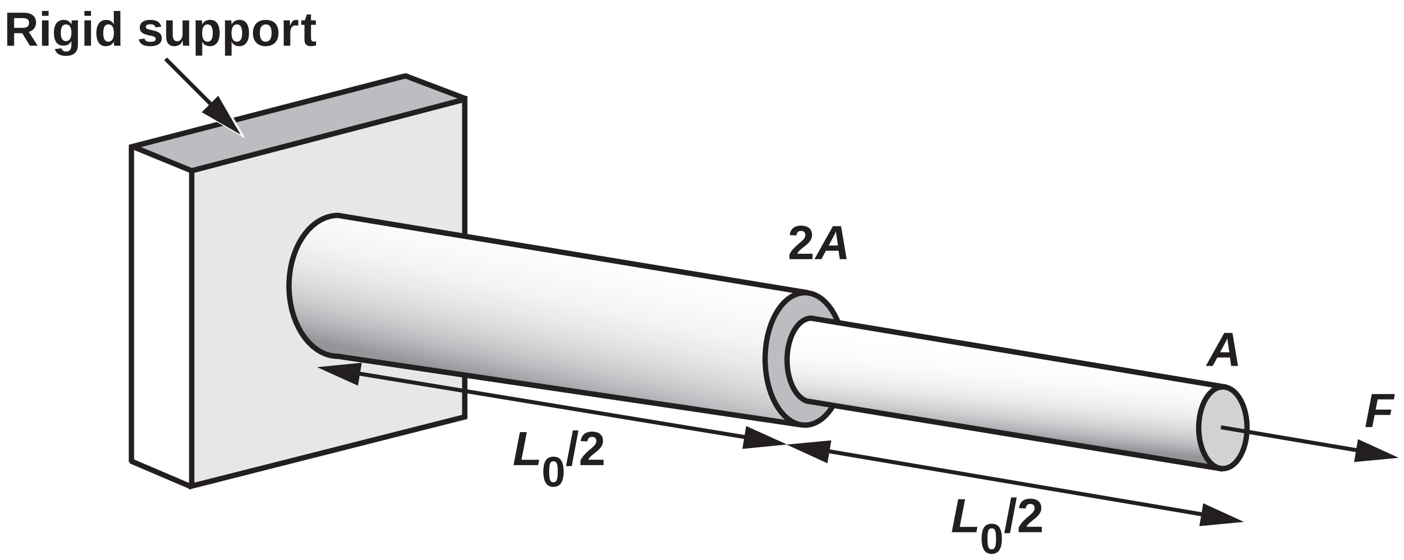
9(c) (ii) A charged pion moving in the *x*-direction at a speed of 0.60 c activates a detector placed at *x* = 0, and decays at *x* = 0.36 m.

(I) Calculate the PROPER TIME between the events of the pion being detected and the pion decaying. [4]

9(c) (ii) (II) What does this PROPER TIME tell us? [1]

OPTION C: MATERIALS

C10(a) Materials can be classified as being CRYSTALLINE, AMORPHOUS or POLYMERIC. Choose two of the terms in italics and explain their meaning in terms of their microscopic structure and give one example of each of your chosen materials. [3]


Rigid support
2A
A
F
$L_0/2$
$L_0/2$

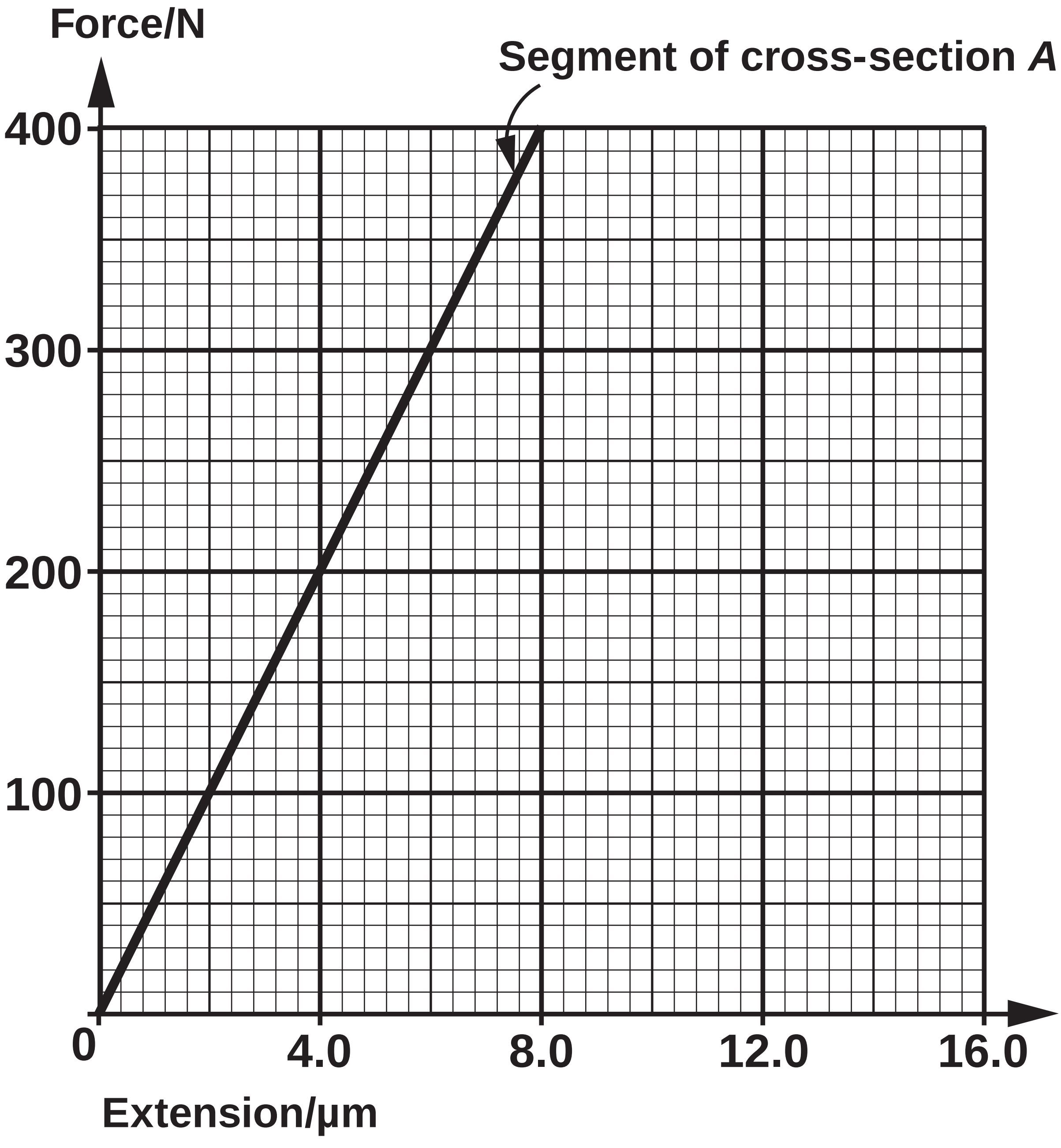
10(b) The bar in the figure opposite is made from a single piece of material. It consists of two segments of equal length $L_0/2$ and cross-sectional area A and $2A$.

THE DIAGRAM IS NOT DRAWN TO SCALE

(i) Show that the TOTAL extension Δx of the bar under the action of an applied force F, as shown in the diagram, can be given by

$$\Delta x = \frac{3FL_0}{4AY}$$

where Y represents the Young Modulus of the material in the bar. [3]



Force/N
Segment of cross-section *A*
400
300
200
100
0
4.0
8.0
12.0
16.0
Extension/μm

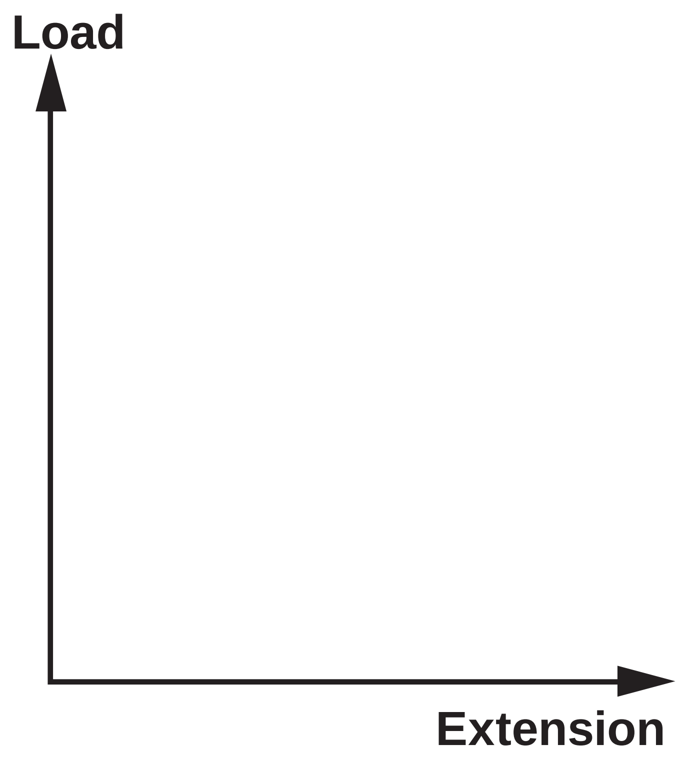
10(b) (ii) **The graph opposite shows the variation of extension with applied force for the segment of cross-section *A*.**

(I) **Draw (on the same grid) the expected force-extension graph for the segment of cross-section 2*A*. [1]**

(II) **Determine the Young modulus of the metal in the bar given that L_0 = 4.0 m and *A* = 5 × 10^{-4} m^2. [3]**

10(b) (ii) (III) **Calculate the elastic potential energy stored in the bar when *F* = 200 N. [3]**

10(c) (i) **When a specimen of rubber is gradually loaded and then unloaded it may show ELASTIC HYSTERESIS and PERMANENT SET. Explain the meaning of the terms in italics. Illustrate your answer with a sketch of the load-extension graph which would be obtained. [3]**



10(c) (ii) By REFERRING TO THE MOLECULAR STRUCTURE of rubber explain why

(I) rubber has a low value of the Young modulus compared with metals. [2]

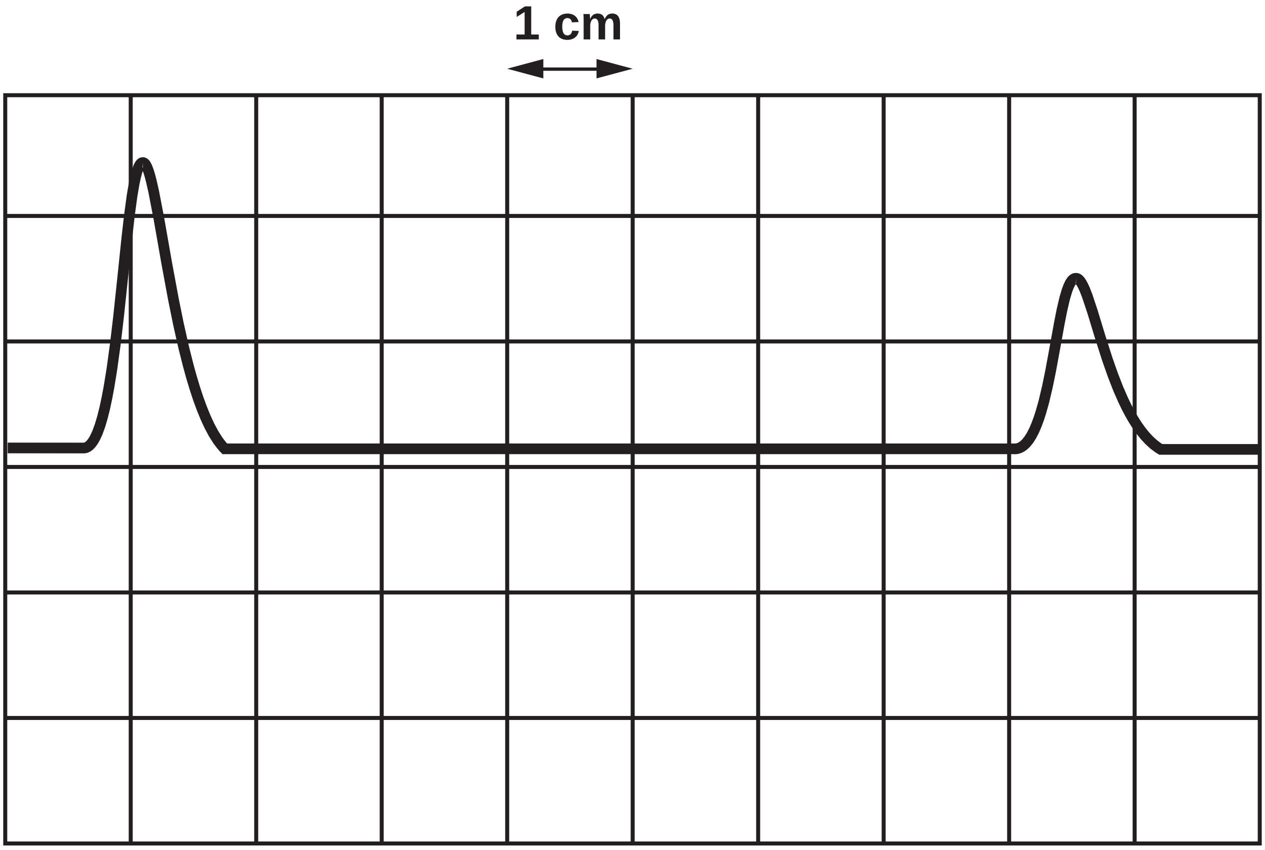
10(c) (ii) (II) the value of the Young modulus increases with a rise in temperature.

[2]

OPTION D: BIOLOGICAL MEASUREMENT AND MEDICAL IMAGING

C11(a) (i) **Ultrasound can be used to carry out two different types of test, an amplitude scan (A-scan) and a brightness scan (B-scan). State the differences in the type of information obtained from an A-scan and a B-scan. [2]**

(ii) **Give an example of when a B-scan would be used in medicine. [1]**


1 cm

11(a) (iii) **An A-scan is used to determine the thickness of a layer of skin and fat in a patient's body. The grid opposite shows the interval between the initial pulse and the reflected pulse on a cathode ray oscilloscope (CRO). The time base is set so that 1 cm represents 2 μs.**

(I) **If the speed of ultrasound in skin and fat is 1.45×10^3 m s^{-1}, calculate the thickness of the layer of skin and fat. [3]**

11(a) (iii) (II) How would the trace opposite page 66 change if no gel was placed between the ultrasonic probe and the patient's skin? [1]

____

____

____

____

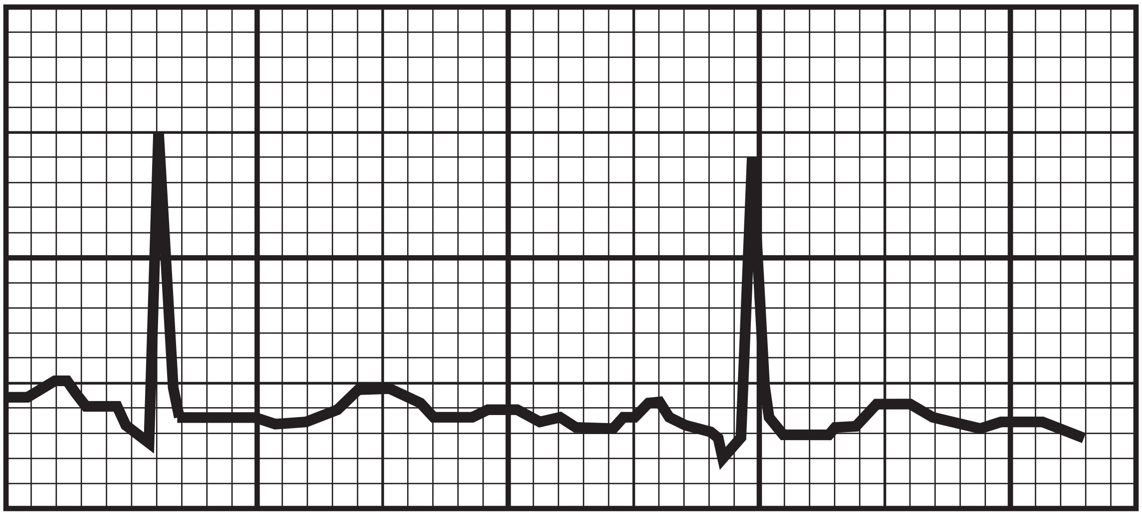
11(b) (i) X-ray tubes use a hot wire to produce electrons. What happens to the X-ray output if the current to the hot wire increases? Explain your answer. [2]

11(b) (ii) An X-ray tube accelerates electrons through a potential difference of 80 kV, giving a BEAM current of 0.45 A. Calculate:

(I) the number of electrons reaching the target every second; [1]

(II) the maximum photon energy of the X-rays produced. [1]

11(b) (iii) **Computerised axial tomography (CT scans) use a rotating X-ray tube to build up high contrast images of slices through the body. Explain why CT scans are NOT offered for regular checking of healthy patients. [1]**



11(c) **Electrodes are placed on a healthy patient in order to record the electrical behaviour of the heart. One trace obtained is shown opposite.**

COMPLETE THE GRAPH opposite by adding suitable axes, scales and units. [3]

(d) **Explain, briefly, how Magnetic Resonance Imaging (MRI) can produce detailed images of slices through the body. [3]**

11(e) When using ionising radiation in medicine the different types of radiation are given a Quality, or Q factor. Do beta particles have a higher, lower or the same Q factor as alpha particles? Explain your answer. [2]

OPTION E: ENERGY MATTERS

C12. **Suppose that a new power station is required to meet the increased electricity demand in London. It is proposed that the site of the derelict Battersea power station in central London be used. There are two options for the new power station - a coal powered station or a nuclear powered station.**

(a) **Write down some suitable points for and against both coal and nuclear power and discuss whether or not central London is a suitable location for such power stations. [5]**

12(b) Show that the efficiency $\frac{Q_1 - Q_2}{Q_1}$ can be written as $1 - \frac{T_2}{T_1}$ for a Carnot cycle. [2]

12(c) Calculate the maximum efficiency of a heat engine operating between 50 °C and 500 °C. [1]

12(d) Coal produces 25 GJ of thermal energy per tonne (1000 kg) and a 35% efficient coal power station produces 3.6 GW of electrical power.

(i) Calculate the mass of coal burned per second by the power station. [3]

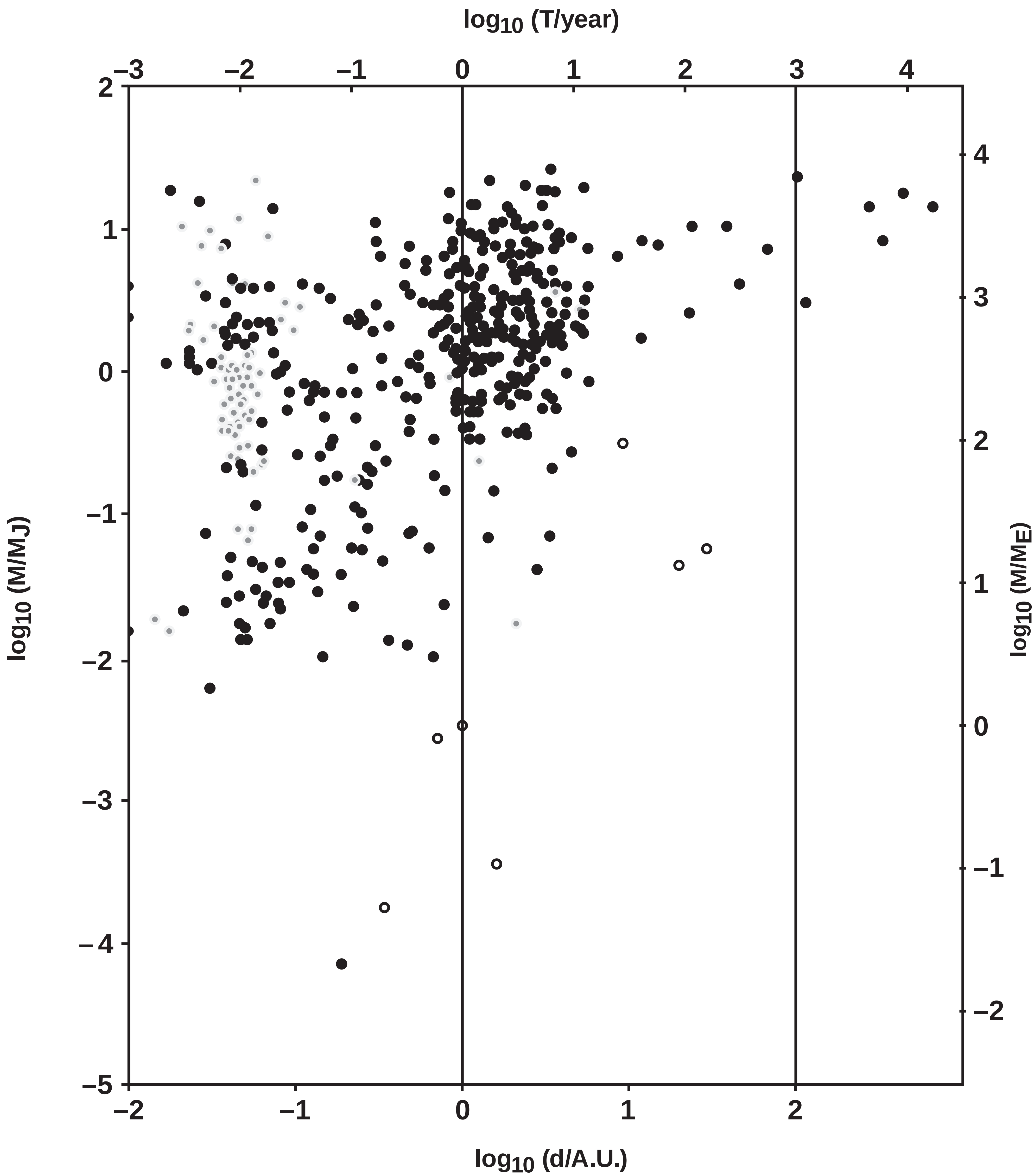
12(d) (ii) Each GJ of energy produced by the power station releases 2.1 kg of pollutants (other than CO_2) into the atmosphere. Calculate the mass of these other pollutants produced by the power station every day. [2]

12(e) **In Combined Heat and Power (CHP) stations the waste heat is transferred to hot water pipes for heating nearby houses. The hot water is at a temperature of 80 °C and is transferred in iron pipes of DIAMETER 32.0 cm.**

(i) **Calculate the total surface area of 90 m of pipes of diameter 32.0 cm. [2]**

12(e) (ii) **The thermal conductivity of iron is 77 W m^{-1} K^{-1}, the iron is of thickness 2.54 cm and the temperature of the outside of the iron is 35 °C. Use the thermal conductivity equation to estimate the heat lost per second through the iron pipes. [3]**

12(e) (iii) **Explain briefly the most appropriate way of reducing the heat losses from the hot iron pipes. [2]**


log10 (T/year)
–3
–2
–1
0
1
2
3
4
2
1
0
–1
–2
–3
–4
–5
log10 (M/MJ)
4
3
2
1
0
–1
–2
log10 (M/ME)
–2
–1
0
1
2
log10 (d/A.U.)