Examiner only

5. *(a)* (i) Give a simple description of the structure of a capacitor. [2]

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(ii) Define the *capacitance* of a capacitor. [1]

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(b) An experimental torch has been made using a 5·0 F capacitor in place of a battery. Before the torch is needed the capacitor is charged to a potential difference of 4·0 V. When light is required a switch is pressed, connecting a light-emitting diode (LED) across the capacitor.

(i) The LED gives out a useful intensity of light until the potential difference has fallen to 3·2 V. Calculate the energy lost by the capacitor during this period. [3]

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(ii) The mean power input to the LED during this period is 40 mW. Calculate for how long the LED would give out light of a useful intensity. [2]

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(iii) If **two** 5·0 F capacitors were available for use in the torch, explain whether it would be better to connect them in series or parallel. [The same charging potential difference of 4·0 V is available.] [2]

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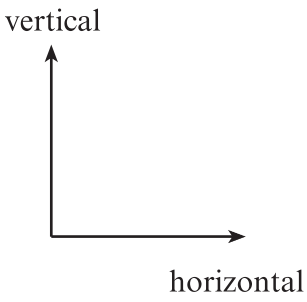
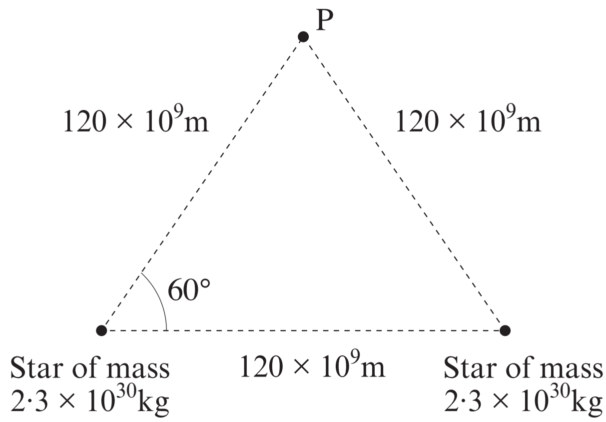
Examiner only

3. Two stars and point P form an equilateral triangle of side 120×10^9 m.





(a) Draw **two** arrows at P to represent the directions of the gravitational fields at **P** due to each of the two stars. [1]

(b) Explain why the horizontal component of the resultant gravitational field strength at **P** due to the two stars is zero. [2]

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(c) Calculate the resultant gravitational field at **P** due to the two stars. [3]

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(d) Mark with an X in the above diagram the point where the resultant gravitational field strength is zero. [1]

(e) Calculate the gravitational potential at **P**. [3]

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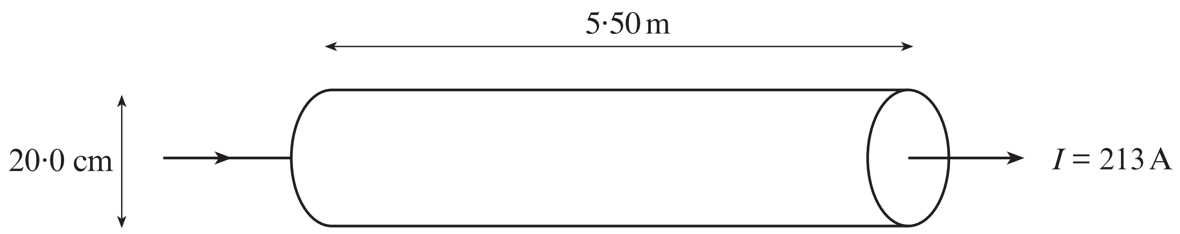
6. A large current of 213 A is passed through a thick copper rod of length 5·50 m and diameter 20·0 cm. The resistivity of copper is $1{\cdot}77 \times 10^{-8}\ \Omega$ m.



(a) Show that the resistance of the copper rod is 3·10 μΩ. [3]

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(b) Show that the power dissipated in the copper rod is around 0·14 W. [2]

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(c) The specific heat capacity of copper is $387\ \text{J K}^{-1}\ \text{kg}^{-1}$ and the mass of the rod is $1{\cdot}50 \times 10^{3}$ kg. Assuming that no heat is lost, show that the average rate at which the temperature of the copper rod rises is around $2{\cdot}4 \times 10^{-7}\ \text{K s}^{-1}$. [3]

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(d) Would it be safe to touch this copper rod? Explain your reasoning briefly. [2]

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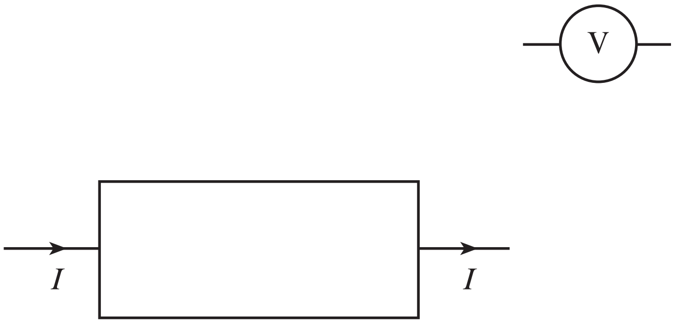
It would be inappropriate to measure this large current (213A) with an ammeter in series therefore a different method is employed. The magnetic field due to the current in the rod is found using a Hall probe. This value is then used to calculate the current in the rod.

(e) Explain briefly how the Hall voltage arises in a Hall probe. A diagram of a Hall probe and voltmeter is provided. You will need to connect the voltmeter to the Hall probe correctly. [5]

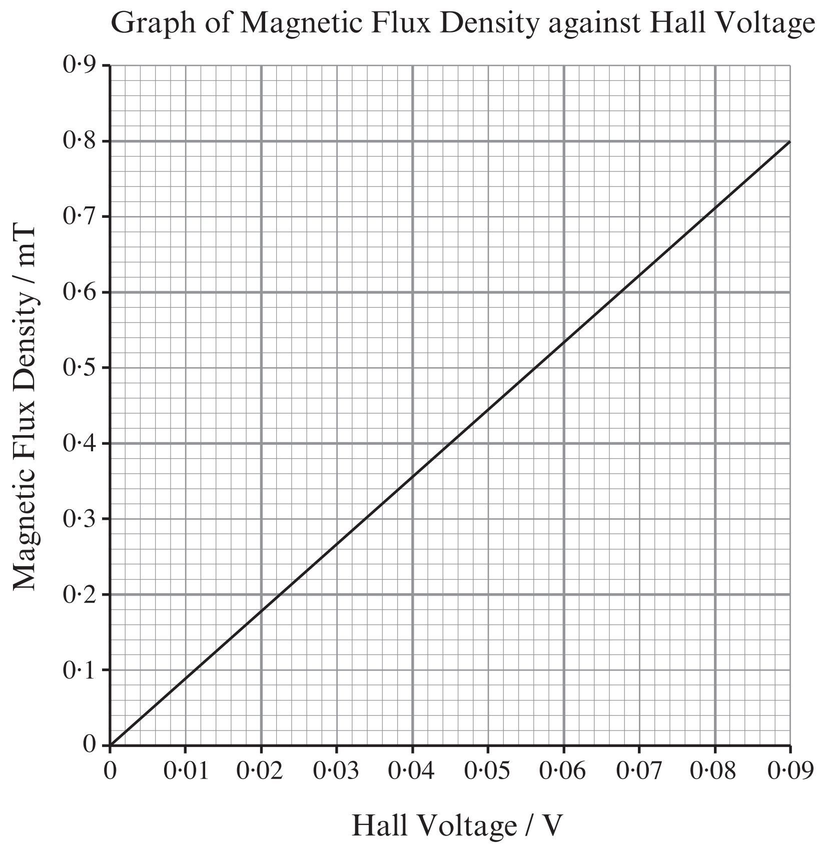


The magnetic flux density due to the current in the copper rod is given by $B = \dfrac{\mu_0 I}{2\pi a}$, where a is the distance from the centre of the rod.

(f) You are to measure the magnetic flux density due to the copper rod with a Hall probe. Where would you place the probe and how would it be orientated in order to obtain a maximum reading of the Hall voltage? [2]

Examiner only

(g) A calibration graph for the Hall probe used is shown below. The Hall voltage when the maximum reading [corresponding to part *(f)*] is obtained is 47 mV. Use this value to calculate the current in the copper rod.
[Hint: Assume that the size of the Hall probe is negligible] [3]



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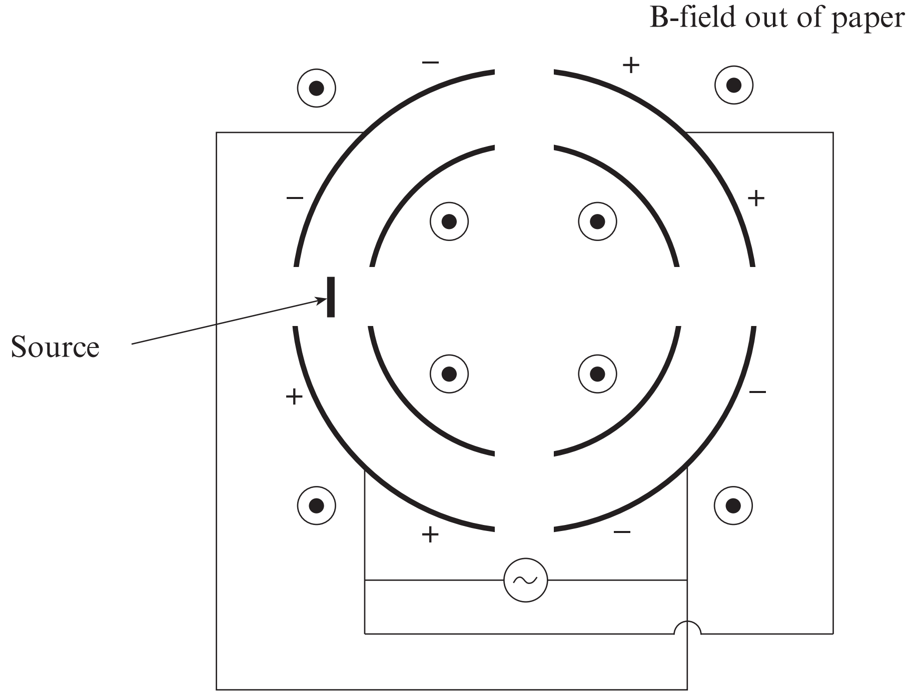
(c) Below is a simplified diagram of a proton synchroton.



(i) Sketch on the diagram the path of a proton including an arrow for direction. [2]

(ii) On the diagram, mark with a cross a point where the proton will be accelerated. [1]

(iii) How can the acceleration of the proton be increased? [1]

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(iv) As the proton's speed is increased its path remains constant. How is this achieved? [1]

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(d) (i) What is an electron's final speed after it is accelerated from rest through a potential difference of 300 kV? (Note that your answer should be greater than the speed of light). [3]

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(ii) The result obtained in *(d)*(i) is not valid because, as the electron approaches the speed of light, Einstein's theories must be applied leading to a lower final speed. Explain whether the same difficulty would be encountered when accelerating protons through the same potential difference? [3]

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MEDICAL PHYSICS

a) State the principles of magnetic resonance with reference to precession nuclei, resonance and relaxation time, and to apply the equation f = 42.6x10^6 B for the Lamor frequency [10]
b) State the advantages and disadvantages of ultrasound imaging, X-ray imaging and MRI in examining internal structures [10]