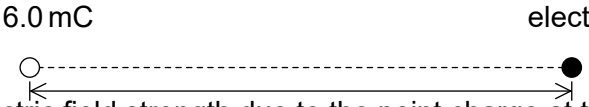
5. An electron is placed at a distance of 0.40 m from a fixed point charge of –6.0 mC.



(a) Show that the electric field strength due to the point charge at the position of the electron is $3.4 \times 10^{8}\,\text{N C}^{-1}$.

[2]

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(b) (i) Calculate the magnitude of the initial acceleration of the electron. [2]

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(This question continues on the following page)

(Question 5 continued)

(ii) Describe the subsequent motion of the electron. [3]

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Answer **all** questions. Answers must be written within the answer boxes provided.

1. A girl rides a bicycle that is powered by an electric motor. A battery transfers energy to the electric motor. The emf of the battery is 16 V and it can deliver a charge of 43 kC when discharging completely from a full charge.

(a) The maximum speed of the girl on a horizontal road is 7.0 m s^{-1} with energy from the battery alone. The maximum distance that the girl can travel under these conditions is 20 km.

(i) Show that the time taken for the battery to discharge is about 3×10^3 s. [1]

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(ii) Deduce that the average power output of the battery is about 240 W. [2]

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(iii) Friction and air resistance act on the bicycle and the girl when they move. Assume that all the energy is transferred from the battery to the electric motor. Determine the total average resistive force that acts on the bicycle and the girl. [2]

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(This question continues on the following page)

(Question 1 continued)

(b) The bicycle and the girl have a total mass of 66 kg. The girl rides up a slope that is at an angle of 3.0° to the horizontal.

(i) Calculate the component of weight for the bicycle and girl acting down the slope. [1]

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(ii) The battery continues to give an output power of 240 W. Assume that the resistive forces are the same as in (a)(iii).

Calculate the maximum speed of the bicycle and the girl up the slope. [2]

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(c) On another journey up the slope, the girl carries an additional mass. Explain whether carrying this mass will change the maximum distance that the bicycle can travel along the slope. [2]

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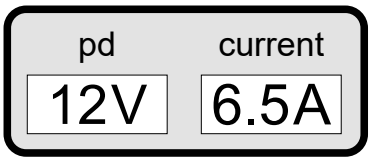
(This question continues on the following page)

(Question 1 continued)

(d) The bicycle has a meter that displays the current and the terminal potential difference (pd) for the battery when the motor is running. The diagram shows the meter readings at one instant. The emf of the cell is 16 V.



Determine the internal resistance of the battery. [2]

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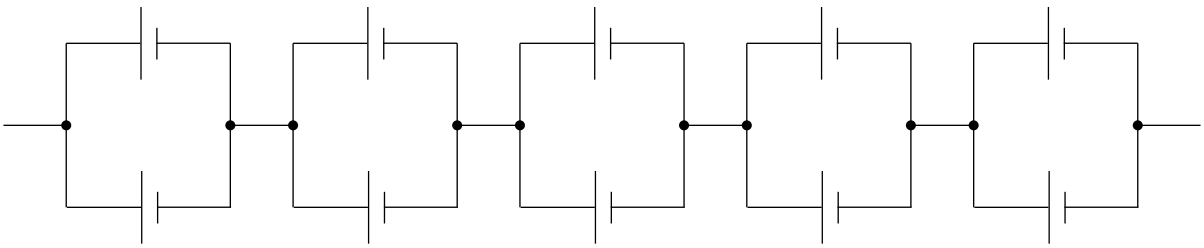
(e) The battery is made from an arrangement of 10 identical cells as shown.



Calculate

(i) the emf of **one** cell. [1]

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(ii) the internal resistance of **one** cell. [2]

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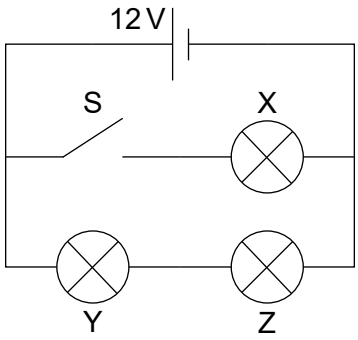
4. Three identical light bulbs, X, Y and Z, each of resistance $4.0\,\Omega$ are connected to a cell of emf 12 V. The cell has negligible internal resistance.



(a) The switch S is initially open. Calculate the total power dissipated in the circuit. [2]

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(b) The switch is now closed.

(i) State, without calculation, why the current in the cell will increase. [1]

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(ii) Deduce the ratio $\frac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$. [2]

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(This question continues on the following page)

(Question 1 continued)

(d) On arrival at the planet, the spacecraft goes into orbit as it comes into the gravitational field of the planet.

(i) Outline what is meant by the gravitational field strength at a point. [2]

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(ii) Newton's law of gravitation applies to point masses. Suggest why the law can be applied to a satellite orbiting a spherical planet of uniform density. [1]

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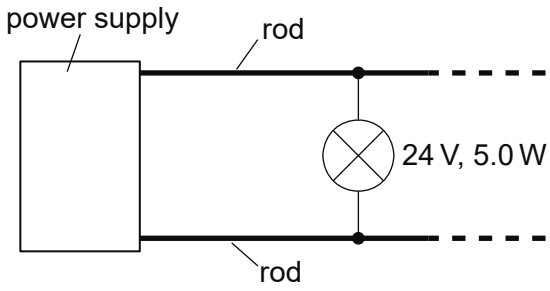
2. A lighting system consists of two long metal rods with a potential difference maintained between them. Identical lamps can be connected between the rods as required.



The following data are available for the lamps when at their working temperature.

Lamp specifications	24 V, 5.0 W
Power supply emf	24 V
Power supply maximum current	8.0 A
Length of each rod	12.5 m
Resistivity of rod metal	$7.2 \times 10^{-7}\ \Omega\,\text{m}$

(a) Each rod is to have a resistance no greater than $0.10\ \Omega$. Calculate, in m, the minimum radius of each rod. Give your answer to an appropriate number of significant figures. [3]

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(b) Calculate the maximum number of lamps that can be connected between the rods. Neglect the resistance of the rods. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) One advantage of this system is that if one lamp fails then the other lamps in the circuit remain lit. Outline **one** other electrical advantage of this system compared to one in which the lamps are connected in series. [1]

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3. A chicken's egg of mass 58 g is dropped onto grass from a height of 1.1 m. The egg comes to rest in a time of 55 ms. Assume that air resistance is negligible and that the egg does not bounce or break.

(a) Determine the magnitude of the average decelerating force that the ground exerts on the egg. [4]

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(b) Explain why the egg is likely to break when dropped onto concrete from the same height. [2]

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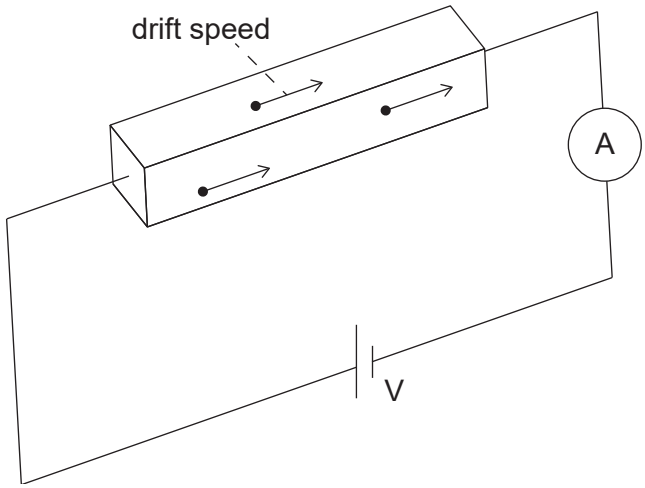
4. An ohmic conductor is connected to an ideal ammeter and to a power supply of output voltage V.



The following data are available for the conductor:

density of free electrons $= 8.5 \times 10^{22}\,\text{cm}^{-3}$
resistivity $\rho = 1.7 \times 10^{-8}\,\Omega\text{m}$
dimensions $w \times h \times l = 0.020\,\text{cm} \times 0.020\,\text{cm} \times 10\,\text{cm}$.

The ammeter reading is 2.0 A.

(a) Calculate the resistance of the conductor. [2]

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(b) Calculate the drift speed v of the electrons in the conductor in $\text{cm}\,\text{s}^{-1}$. [2]

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(This question continues on the following page)

(Question 4 continued)

(c) The electric field E inside the sample can be approximated as the uniform electric field between two parallel plates.

(i) Determine the electric field strength E. [2]

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(ii) Show that $\frac{v}{E} = \frac{1}{ne\rho}$. [3]

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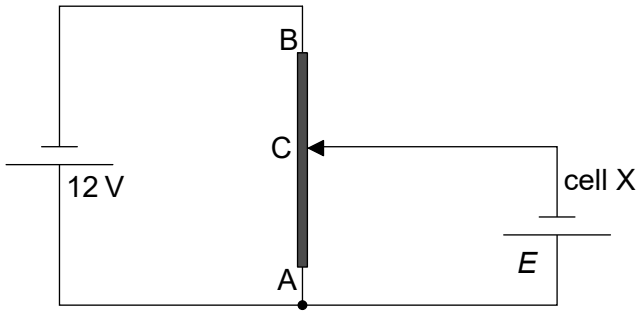
4. The diagram shows a potential divider circuit used to measure the emf *E* of a cell X. Both cells have negligible internal resistance.



(a) State what is meant by the emf of a cell. [2]

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(b) AB is a wire of uniform cross-section and length 1.0 m. The resistance of wire AB is 80 Ω. When the length of AC is 0.35 m the current in cell X is zero.

(i) Show that the resistance of the wire AC is 28 Ω. [2]

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(ii) Determine *E*. [2]

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(This question continues on the following page)

(Question 4 continued)

(c) Cell X is replaced by a second cell of identical emf E but with internal resistance 2.0 Ω. Comment on the length of AC for which the current in the second cell is zero. [2]

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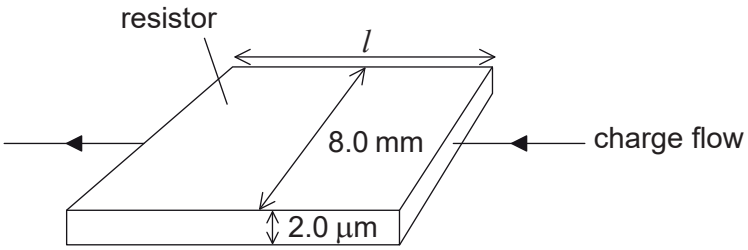
4. Electrical resistors can be made by forming a thin film of carbon on a layer of an insulating material.

(a) A carbon film resistor is made from a film of width 8.0 mm and of thickness 2.0 μm. The diagram shows the direction of charge flow through the resistor.



not to scale

(i) The resistance of the carbon film is $82\,\Omega$. The resistivity of carbon is $4.1\times10^{-5}\,\Omega\,\text{m}$. Calculate the length l of the film. [1]

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(ii) The film must dissipate a power less than 1500 W from each square metre of its surface to avoid damage. Calculate the maximum allowable current for the resistor. [2]

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(iii) State why knowledge of quantities such as resistivity is useful to scientists. [1]

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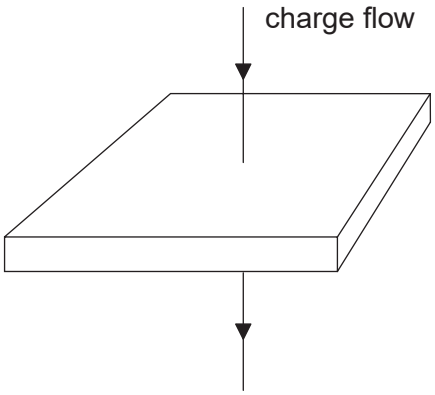
(This question continues on the following page)

(Question 4 continued)

(b) The current direction is now changed so that charge flows vertically through the film.



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Deduce, without calculation, the change in the resistance. [2]

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