# Electricity-practice-1-ShortA

*[153 marks]*

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.

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.

1a. Show that the time taken for the battery to discharge is about $3 \times 10^3$ s. *[1 mark]*

1b. Deduce that the average power output of the battery is about 240 W. *[2 marks]*

1c. 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 marks]*

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.


1d. Calculate the component of weight for the bicycle and girl acting down the slope. *[1 mark]*

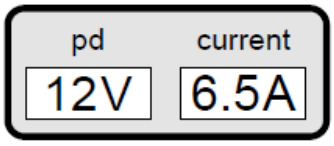
1e. The battery continues to give an output power of 240 W. Assume that the resistive forces are the same as in (a)(iii). *[2 marks]*

Calculate the maximum speed of the bicycle and the girl up the slope.

1f. On another journey up the slope, the girl carries an additional mass. *[2 marks]*

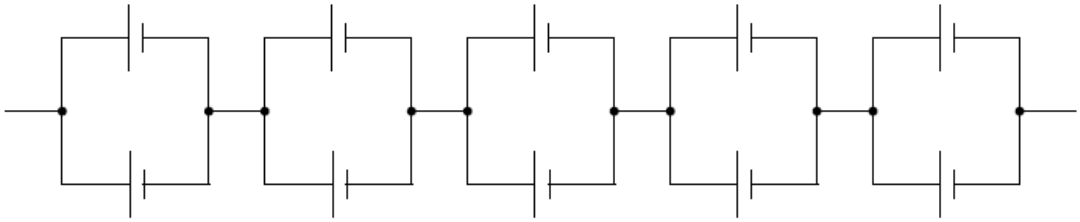
Explain whether carrying this mass will change the maximum distance that the bicycle can travel along the slope.

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.




1g. Determine the internal resistance of the battery. *[2 marks]*

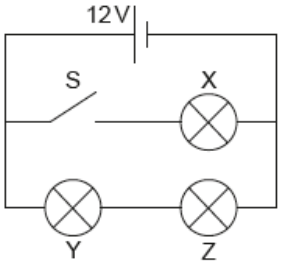
The battery is made from an arrangement of 10 identical cells as shown.



1h. Calculate the emf of **one** cell. *[1 mark]*

1i. Calculate the internal resistance of **one** cell. *[2 marks]*

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

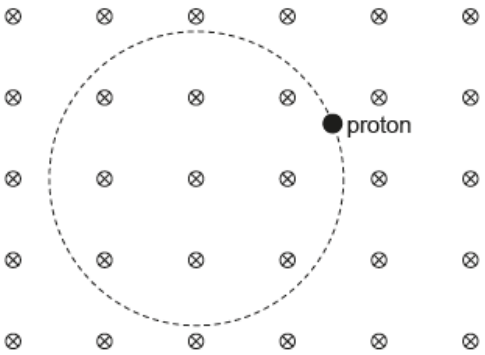



2a. The switch S is initially open. Calculate the total power dissipated in the circuit. *[2 marks]*

2b. The switch is now closed. State, without calculation, why the current in the cell will increase. *[1 mark]*

2c. The switch is now closed. Deduce the ratio $\frac{\text{power dissipated in Y with S open}}{\text{power dissipated in Y with S closed}}$. *[2 marks]*

A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.

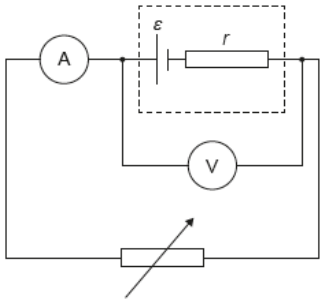



3a. Label with arrows on the diagram the magnetic force *F* on the proton. *[1 mark]*

3b. Label with arrows on the velocity vector *v* of the proton. *[1 mark]*

3c. The speed of the proton is $2.16 \times 10^6$ m $s^{-1}$ and the magnetic field strength is 0.042 T. For this proton, determine, in m, the radius of the circular path. Give your answer to an appropriate number of significant figures. *[3 marks]*

A student investigates the electromotive force (emf) $\varepsilon$ and internal resistance $r$ of a cell.



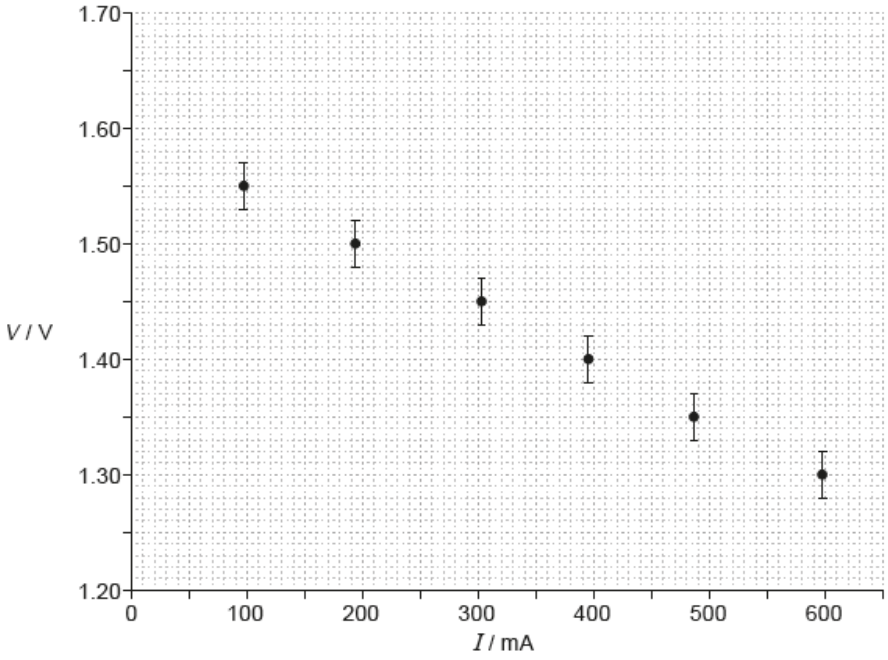

The current $I$ and the terminal potential difference $V$ are measured.

For this circuit $V = \varepsilon - Ir$.

The table shows the data collected by the student. The uncertainties for each measurement
are shown.

| $I$ / mA ± 1 mA | $V$ / V ± 0.02 V |
|---|---|
| 97 | 1.55 |
| 193 | 1.50 |
| 304 | 1.45 |
| 395 | 1.40 |
| 487 | 1.35 |
| 598 | 1.30 |

The graph shows the data plotted.

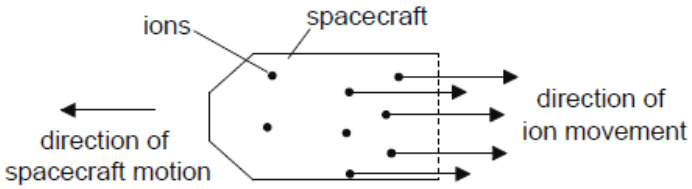



4a. The student has plotted error bars for the potential difference. Outline why no error bars are shown for the current. *[1 mark]*

4b. Determine, using the graph, the emf of the cell including the uncertainty for this value. Give your answer to the correct number of significant figures. *[3 marks]*

4c. Outline, **without** calculation, how the internal resistance can be determined from this graph. *[2 marks]*

Ion-thrust engines can power spacecraft. In this type of engine, ions are created in a chamber and expelled from the spacecraft. The spacecraft is in outer space when the propulsion system is turned on. The spacecraft starts from rest.




The mass of ions ejected each second is $6.6 \times 10^{-6}$ kg and the speed of each ion is $5.2 \times 10^{4}$ m s$^{-1}$. The initial total mass of the spacecraft and its fuel is 740 kg. Assume that the ions travel away from the spacecraft parallel to its direction of motion.

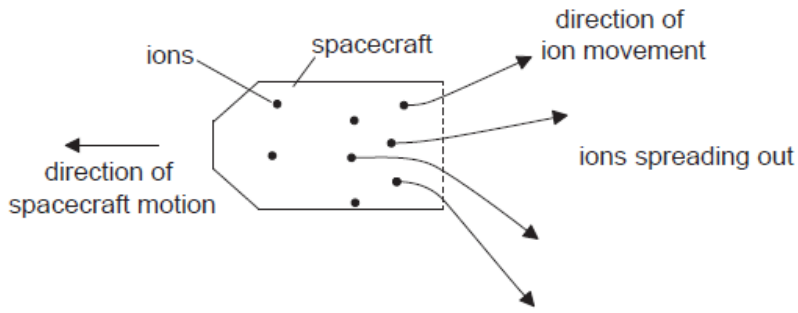
5a. Determine the initial acceleration of the spacecraft. *[2 marks]*

An initial mass of 60 kg of fuel is in the spacecraft for a journey to a planet. Half of the fuel will be required to slow down the spacecraft before arrival at the destination planet.

5b. Estimate the maximum speed of the spacecraft. *[2 marks]*

5c. Outline why scientists sometimes use estimates in making calculations. *[1 mark]*

In practice, the ions leave the spacecraft at a range of angles as shown.




5d. Outline why the ions are likely to spread out. *[2 marks]*

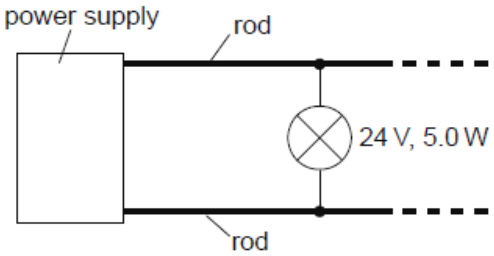
5e. Explain what effect, if any, this spreading of the ions has on the acceleration of the spacecraft. *[2 marks]*

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

5f. Outline what is meant by the gravitational field strength at a point. *[2 marks]*

5g. 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 mark]*

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

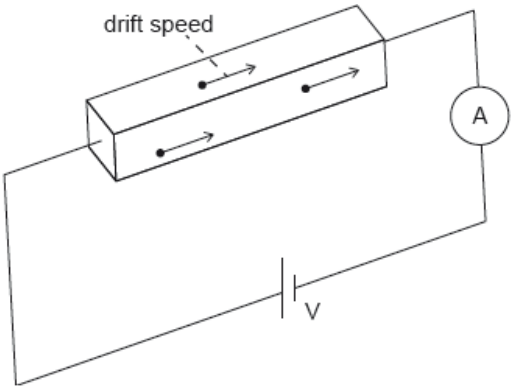
Resistivity of rod metal $7.2 \times 10^{-7}\ \Omega\,m$

6a. Each rod is to have a resistance no greater than 0.10 Ω. Calculate, in m, the minimum radius of each rod. Give your answer to an appropriate number of significant figures. *[3 marks]*

6b. Calculate the maximum number of lamps that can be connected between the rods. Neglect the resistance of the rods. *[2 marks]*

6c. 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 mark]*

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 = $8.5 \times 10^{22}$ $cm^{-3}$

resistivity $\rho = 1.7 \times 10^{-8}$ Ωm

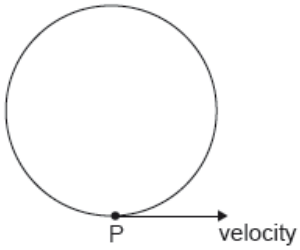
dimensions w × h × l = 0.020 cm × 0.020 cm × 10 cm.

The ammeter reading is 2.0 A.

7a. Calculate the resistance of the conductor. *[2 marks]*

7b. Calculate the drift speed *v* of the electrons in the conductor in cm $s^{-1}$. *[3 marks]*
State your answer to an appropriate number of significant figures.

An electron moves in circular motion in a uniform magnetic field.




The velocity of the electron at point P is $6.8 \times 10^5$ m $s^{-1}$ in the direction shown.

The magnitude of the magnetic field is 8.5 T.

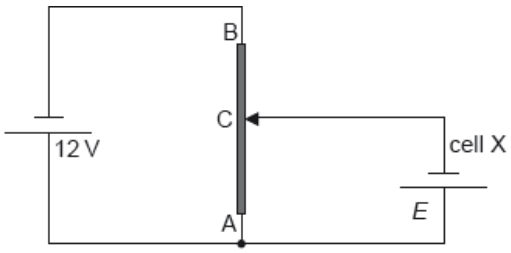
8a. State the direction of the magnetic field. *[1 mark]*

8b. Calculate, in N, the magnitude of the magnetic force acting on the electron. *[1 mark]*

8c. Explain why the electron moves at constant speed. *[1 mark]*

8d. Explain why the electron moves on a circular path. *[2 marks]*

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




9a. State what is meant by the emf of a cell. *[2 marks]*

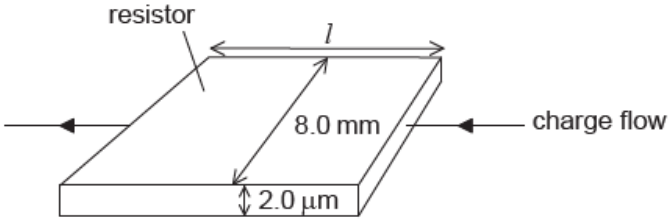
AB is a wire of uniform cross-section and length 1.0 m. The resistance of wire AB is 80 Ω. When the length of AC is 0.35 m the current in cell X is zero.

9b. Show that the resistance of the wire AC is 28 Ω. *[2 marks]*

9c. Determine *E*. *[2 marks]*

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

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.



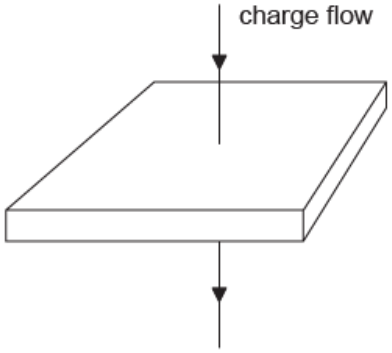

not to scale

10a. The resistance of the carbon film is 82 Ω. The resistivity of carbon is 4.1 x $10^{-5}$ Ω m. Calculate the length *l* of the film. *[1 mark]*

10b. 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 marks]*

10c. State why knowledge of quantities such as resistivity is useful to scientists. *[1 mark]*

10d. The current direction is now changed so that charge flows vertically through the film. *[2 marks]*

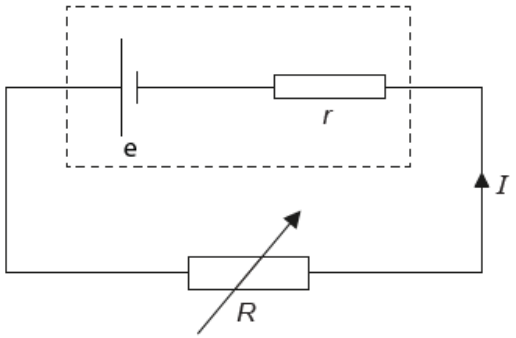



not to scale

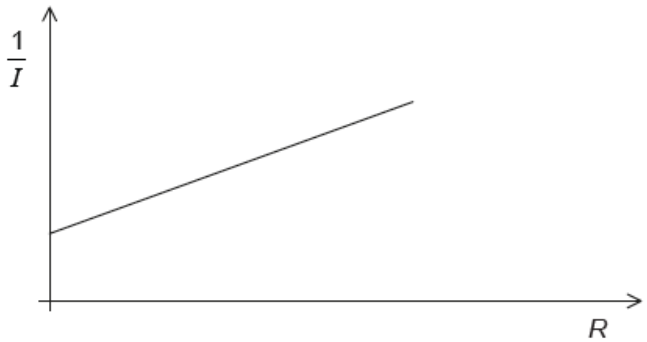
Deduce, without calculation, the change in the resistance.

10e. Draw a circuit diagram to show how you could measure the resistance of the carbon-film resistor using a potential divider arrangement to limit the potential difference across the resistor. *[2 marks]*

An electrical circuit is used during an experiment to measure the current *I* in a variable resistor of resistance *R*. The emf of the cell is e and the cell has an internal resistance *r*.




A graph shows the variation of $\frac{1}{I}$ with *R*.




11a. Show that the gradient of the graph is equal to $\frac{1}{e}$. *[2 marks]*

11b. State the value of the intercept on the $R$ axis. *[1 mark]*

A heater in an electric shower has a power of 8.5 kW when connected to a 240 V electrical supply. It is connected to the electrical supply by a copper cable.

The following data are available:

Length of cable = 10 m
Cross-sectional area of cable = 6.0 $mm^2$
Resistivity of copper = $1.7 \times 10^{-8}$ Ω m

12a. Calculate the current in the copper cable. *[1 mark]*

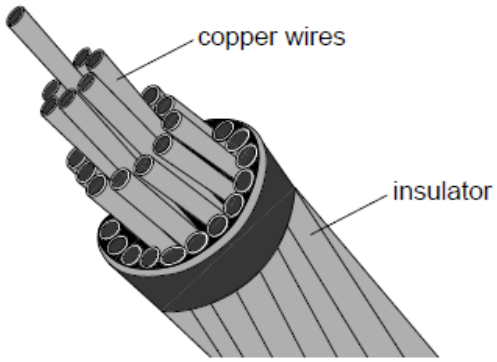
12b. Calculate the resistance of the cable. *[2 marks]*

12c. Explain, in terms of electrons, what happens to the resistance of the cable as the temperature of the cable increases. *[3 marks]*

12d. The heater changes the temperature of the water by 35 K. The specific heat capacity of water is 4200 J $kg^{-1}$ $K^{-1}$. *[4 marks]*

Determine the rate at which water flows through the shower. State an appropriate unit for your answer.

A cable consisting of many copper wires is used to transfer electrical energy from a generator to an electrical load. The copper wires are protected by an insulator.




13a. The copper wires and insulator are both exposed to an electric field. Discuss, with reference to charge carriers, why there is a significant electric current only in the copper wires. *[3 marks]*

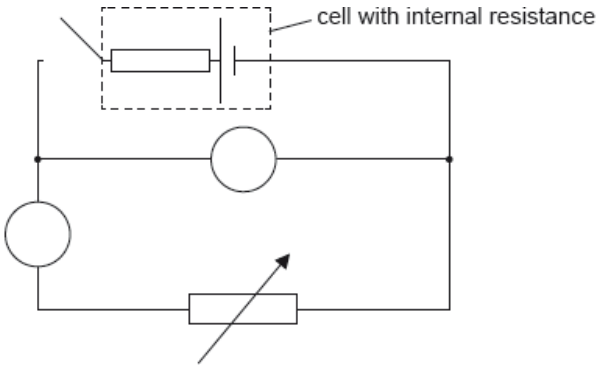
The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 Ω. The resistivity of copper is $1.7 \times 10^{-8}$ Ω m.

13b. Calculate the radius of each **wire**. *[2 marks]*

13c. There is a current of 730 A in the cable. Show that the power loss in 1 m of the cable is about 30 W. *[2 marks]*

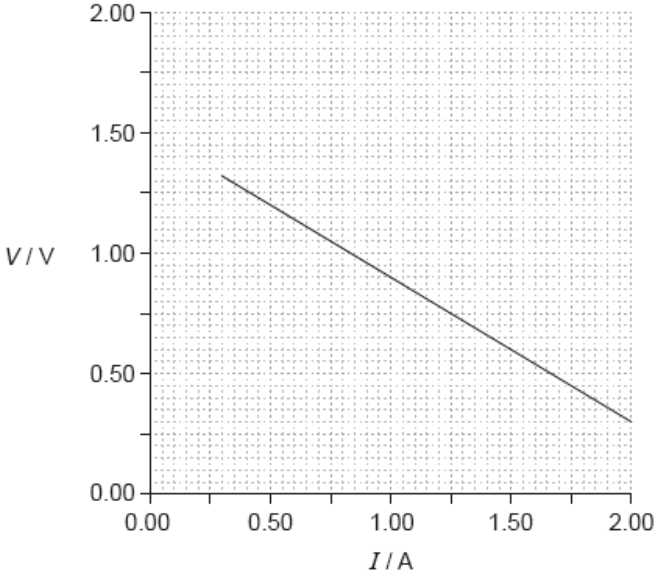
13d. When the current is switched on in the cable the initial rate of rise of temperature of the cable is 35 mK $s^{-1}$. The specific heat capacity of copper is 390 J $kg^{-1}$ $K^{-1}$. Determine the mass of a length of one metre of the cable. *[2 marks]*

The circuit shown may be used to measure the internal resistance of a cell.




14a. An ammeter and a voltmeter are connected in the circuit. Label the ammeter with the letter A and the voltmeter with the letter V. *[1 mark]*

14b. In one experiment a student obtains the following graph showing the variation with current *I* of the potential difference *V* across the cell. *[3 marks]*



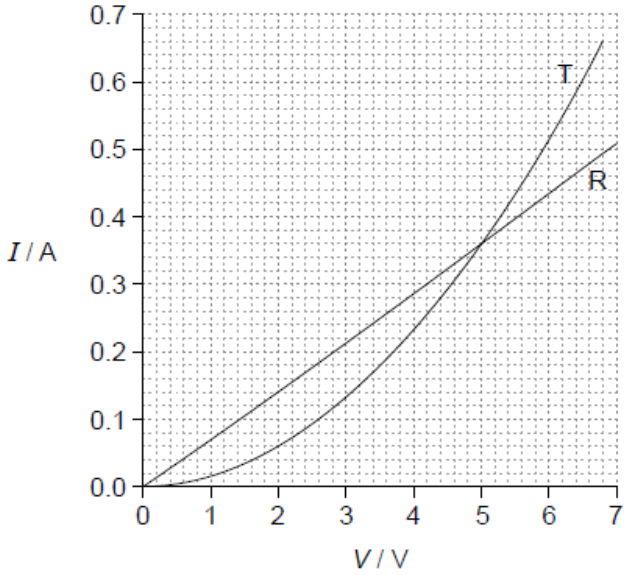

Using the graph, determine the best estimate of the internal resistance of the cell.

The ammeter used in the experiment in (b) is an analogue meter. The student takes measurements without checking for a “zero error” on the ammeter.

14c. State what is meant by a zero error. *[1 mark]*

14d. After taking measurements the student observes that the ammeter has a positive zero error. Explain what effect, if any, this zero error will have on the calculated value of the internal resistance in (b). *[2 marks]*

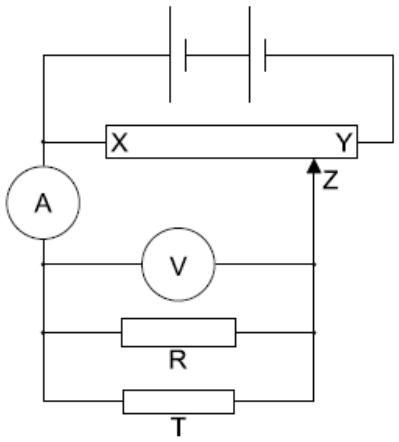
The graph shows how current *I* varies with potential difference *V* for a resistor R and a non-ohmic component T.




15a. (i) State how the resistance of T varies with the current going through T. *[3 marks]*

(ii) Deduce, without a numerical calculation, whether R **or** T has the greater resistance at $I$=0.40 A.

15b. Components R and T are placed in a circuit. Both meters are ideal. *[3 marks]*



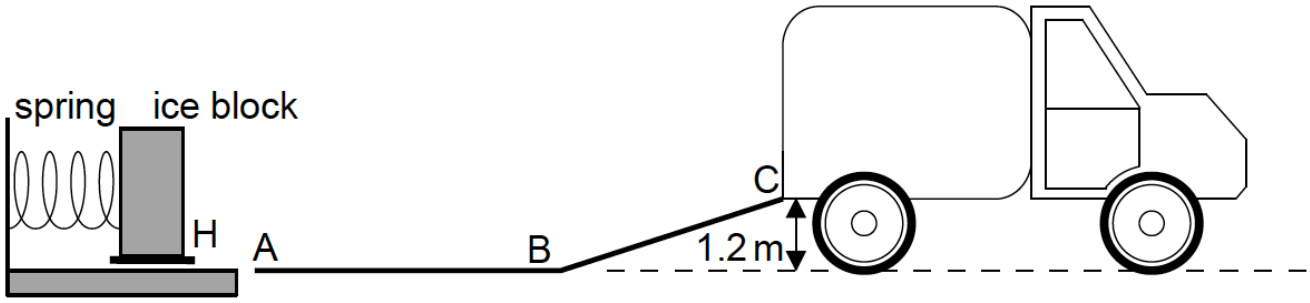

Slider Z of the potentiometer is moved from Y to X.

(i) State what happens to the magnitude of the current in the ammeter.

(ii) Estimate, with an explanation, the voltmeter reading when the ammeter reads 0.20 A.

---

A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a
ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.




Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

16a. (i) The block arrives at C with a speed of $0.90 ms^{-1}$. Show that the elastic energy stored in the spring is 670J. *[4 marks]*

(ii) Calculate the speed of the block at A.

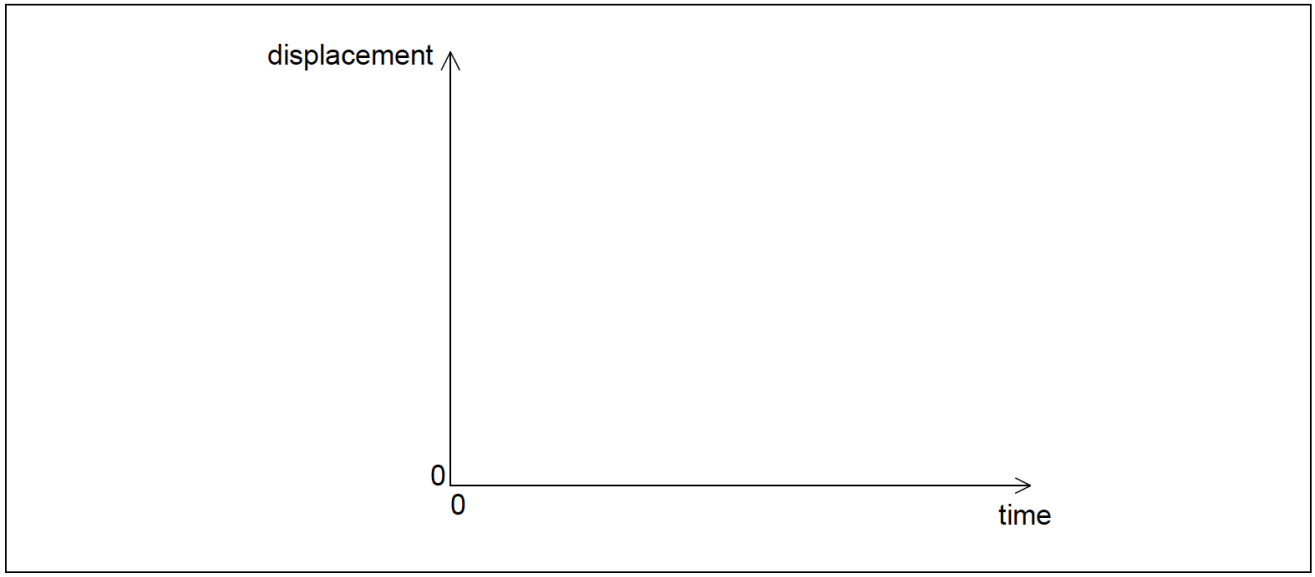
---

16b. Describe the motion of the block *[3 marks]*

(i) from A to B with reference to Newton's first law.

(ii) from B to C with reference to Newton's second law.

16c. On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) *[2 marks]*

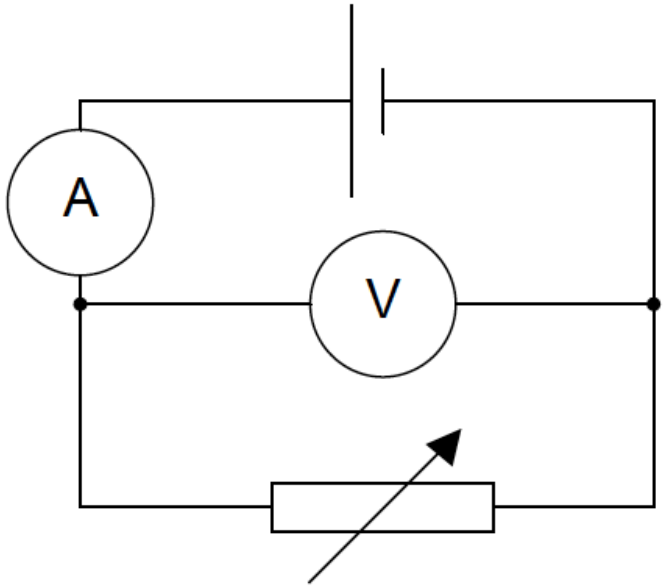



16d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. *[2 marks]*

16e. The electric motor is connected to a source of potential difference 120V and draws a current of 6.8A. The motor takes 1.5s to compress the spring. *[2 marks]*

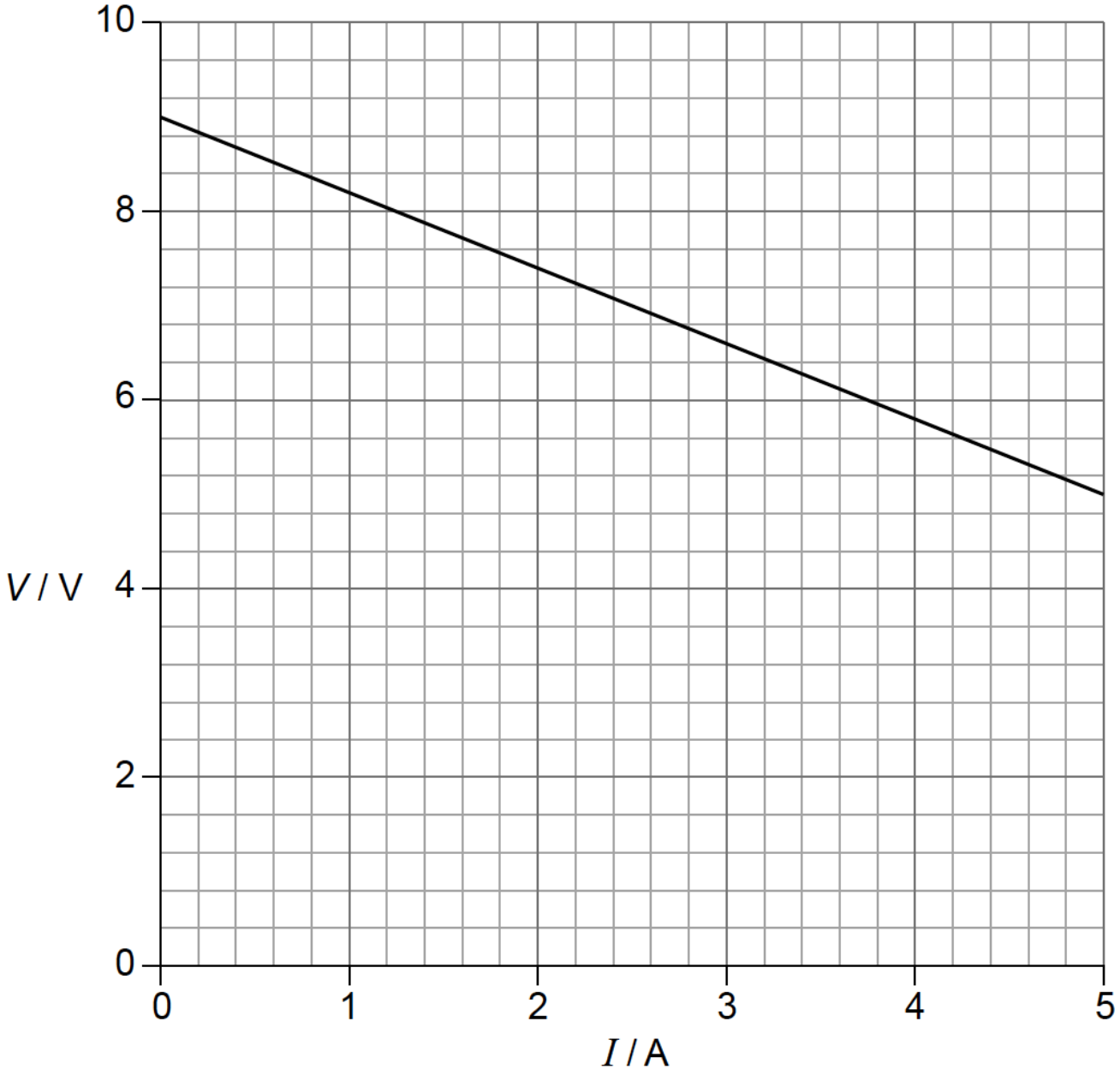
Estimate the efficiency of the motor.

In an experiment a student constructs the circuit shown in the diagram. The ammeter and the voltmeter are assumed to be ideal.




17a. State what is meant by an ideal voltmeter. *[1 mark]*

17b. The student adjusts the variable resistor and takes readings from the ammeter and voltmeter. The graph shows the variation of the voltmeter reading $V$ with the ammeter reading $I$. *[3 marks]*



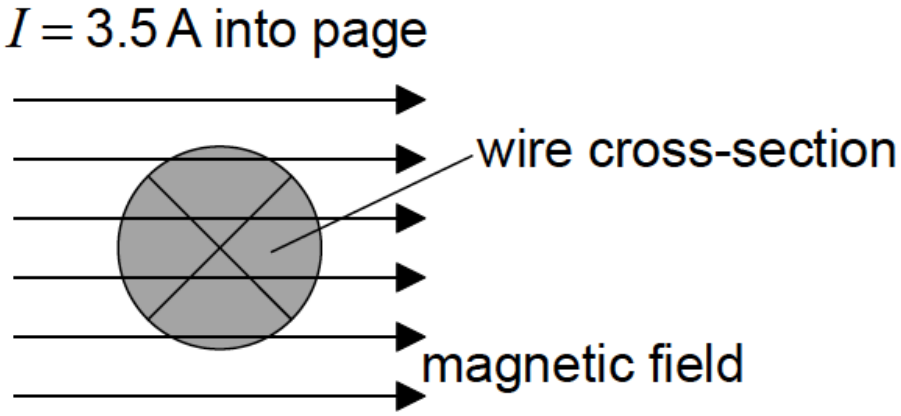

Use the graph to determine

(i) the electromotive force (emf) of the cell.

(ii) the internal resistance of the cell.

17c. A connecting wire in the circuit has a radius of 1.2mm and the current in it is 3.5A. The number of electrons per unit volume of the wire is $2.4\times10^{28}\text{m}^{-3}$. Show that the drift speed of the electrons in the wire is $2.0\times10^{-4}\text{ms}^{-1}$. *[1 mark]*

17d. The diagram shows a cross-sectional view of the connecting wire in (c). *[2 marks]*




The wire which carries a current of 3.5A into the page, is placed in a region of uniform magnetic field of flux density 0.25T. The field is directed at right angles to the wire.

Determine the magnitude **and** direction of the magnetic force on one of the charge carriers in the wire.

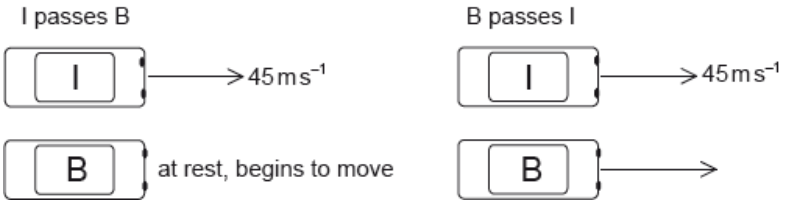
---

This question is in **two** parts. **Part 1** is about kinematics and Newton's laws of motion.

**Part 2** is about electrical circuits.

**Part 1** Kinematics and Newton's laws of motion

Cars I and B are on a straight race track. I is moving at a constant speed of $45\ \text{m}\,\text{s}^{-1}$ and B is initially at rest. As I passes B, B starts to move with an acceleration of $3.2\ \text{m}\,\text{s}^{-2}$.




At a later time B passes I. You may assume that both cars are point particles.

18a. Show that the time taken for B to pass I is approximately 28 s. *[4 marks]*

---

18b. Calculate the distance travelled by B in this time. *[2 marks]*

---

18c. B slows down while I remains at a constant speed. The driver in each car wears a seat belt. Using Newton's laws of motion, explain the difference in the tension in the seat belts of the two cars. *[3 marks]*

A third car O with mass 930 kg joins the race. O collides with I from behind, moving along the same straight line as I. Before the collision the speed of I is $45\ \mathrm{m\,s^{-1}}$ and its mass is 850 kg. After the collision, I and O stick together and move in a straight line with an initial combined speed of $52\ \mathrm{m\,s^{-1}}$.

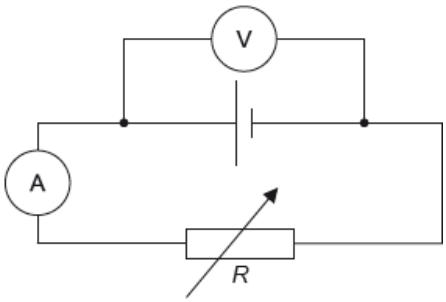
18d. Calculate the speed of O immediately before the collision. *[2 marks]*

18e. The duration of the collision is 0.45 s. Determine the average force acting on O. *[2 marks]*

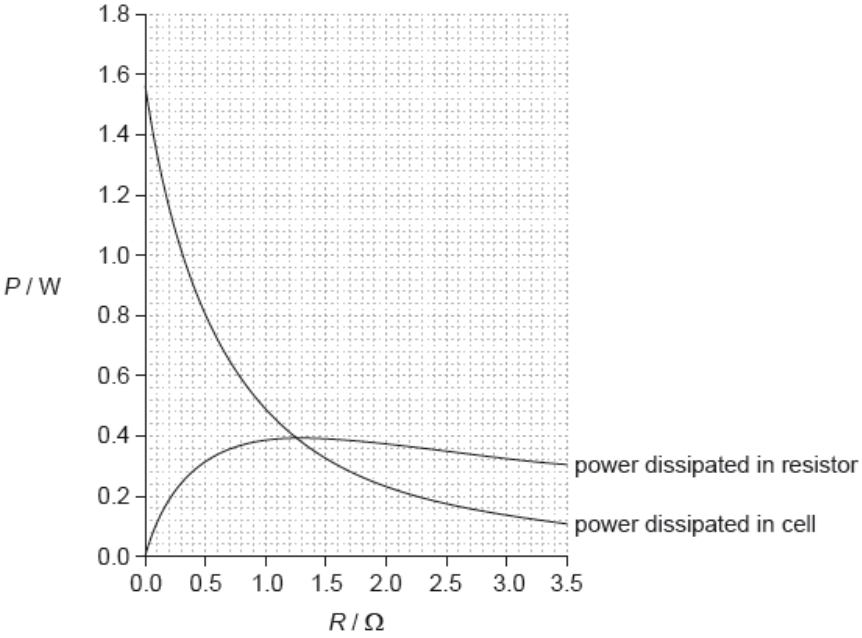
This question is in **two** parts. **Part 1** is about kinematics and Newton's laws of motion.

**Part 2** Electrical circuits

The circuit shown is used to investigate how the power developed by a cell varies when the load resistance $R$ changes.




The variable resistor is adjusted and a series of current and voltage readings are taken. The graph shows the variation with $R$ of the power dissipated in the cell and the power dissipated in the variable resistor.




18f. An ammeter and a voltmeter are used to investigate the characteristics of a variable resistor of resistance $R$. State how the resistance of the ammeter and of the voltmeter compare to $R$ so that the readings of the instruments are reliable. *[2 marks]*

18g. Show that the current in the circuit is approximately 0.70 A when $R = 0.80\ \Omega$. *[3 marks]*

The cell has an internal resistance.

18h. Outline what is meant by the internal resistance of a cell. *[2 marks]*

18i. Determine the internal resistance of the cell. *[3 marks]*

18j. Calculate the electromotive force (emf) of the cell. *[2 marks]*