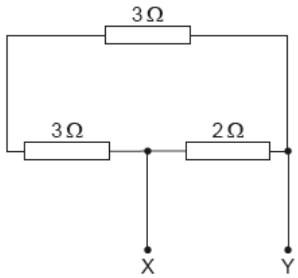
Electric fields and currents *[118 marks]*

1. Three resistors are connected as shown. What is the value of the total resistance between X and Y? *[1 mark]*



A. 1.5 Ω

B. 1.9 Ω

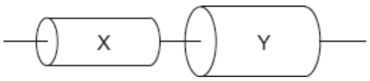
C. 6.0 Ω

D. 8.0 Ω

Markscheme

A

2. Two resistors X and Y are made of uniform cylinders of the same material. X and Y are connected in series. X and Y are of equal length and the diameter of Y is twice the diameter of X. *[1 mark]*



The resistance of Y is *R*.

What is the resistance of this series combination?

A. $\frac{5R}{4}$

B. $\frac{3R}{2}$

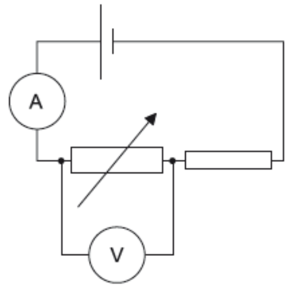
C. 3*R*

D. 5*R*

Markscheme

D

3. A cell with negligible internal resistance is connected as shown. The ammeter and the voltmeter are both ideal. *[1 mark]*



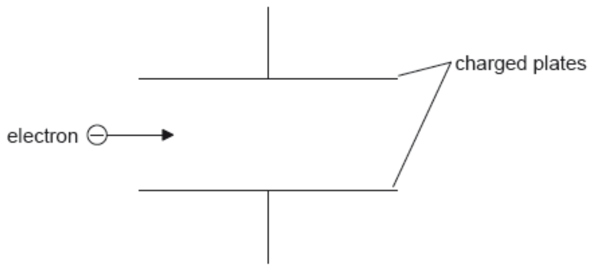
What changes occur in the ammeter reading and in the voltmeter reading when the resistance of the variable resistor is increased?

	Change in ammeter reading	Change in voltmeter reading
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

Markscheme

C

4. An electron enters the region between two charged parallel plates initially moving parallel to the plates. *[1 mark]*



The electromagnetic force acting on the electron

A. causes the electron to decrease its horizontal speed.

B. causes the electron to increase its horizontal speed.

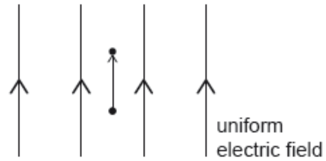
C. is parallel to the field lines and in the opposite direction to them.

D. is perpendicular to the field direction.

Markscheme

C

5. An ion of charge $+Q$ moves vertically upwards through a small distance s in a uniform vertical electric field. The electric field has a strength E and its direction is shown in the diagram. *[1 mark]*



What is the electric potential difference between the initial and final position of the ion?

A. $\frac{EQ}{s}$

B. EQs

C. Es

D. $\frac{E}{s}$

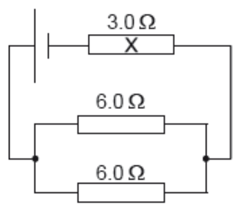
Markscheme

C

---

6. A cell of emf 6.0 V and negligible internal resistance is connected to three resistors as shown. *[1 mark]*

The resistors have resistance of 3.0 Ω and 6.0 Ω as shown.



What is the current in resistor X?

A. 0.40 A

B. 0.50 A

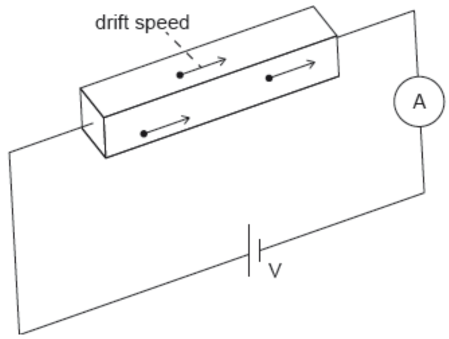
C. 1.0 A

D. 2.0 A

Markscheme

C

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 = 8.5×10^{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]*

Markscheme

$1.7 \times 10^{-8} \times \frac{0.10}{(0.02 \times 10^{-2})^2}$

0.043 «Ω»

[2 marks]

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

Markscheme

v «$= \frac{I}{neA}$» $= \frac{2}{8.5 \times 10^{22} \times 1.60 \times 10^{-19} \times 0.02^2}$

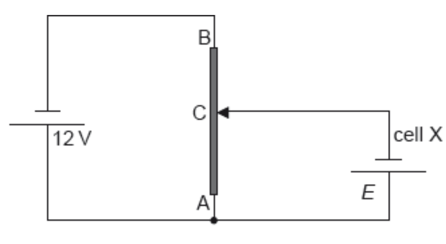
0.368 «cms^{-1}»

0.37 «cms^{-1}»

Award ***[2 max]*** *if answer is not expressed to 2 sf.*

[3 marks]

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



8a. State what is meant by the emf of a cell. *[2 marks]*

Markscheme

the work done per unit charge

in moving charge from one terminal of a cell to the other / all the way round the circuit

*Award **[1]** for "energy per unit charge provided by the cell"/"power per unit current"*

*Award **[1]** for "potential difference across the terminals of the cell when no current is flowing"*

Do not accept "potential difference across terminals of 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.

8b. Show that the resistance of the wire AC is 28 Ω. *[2 marks]*

Markscheme

the resistance is proportional to length / see 0.35 ***AND*** 1«.00»

so it equals 0.35 × 80

«= 28 Ω»

[2 marks]

8c. Determine *E*. *[2 marks]*

Markscheme

current leaving 12 V cell is $\frac{12}{80}$ = 0.15 «A»

OR

$E = \frac{12}{80} \times 28$

E = «0.15 × 28 =» 4.2 «V»

*Award **[2]** for a bald correct answer*

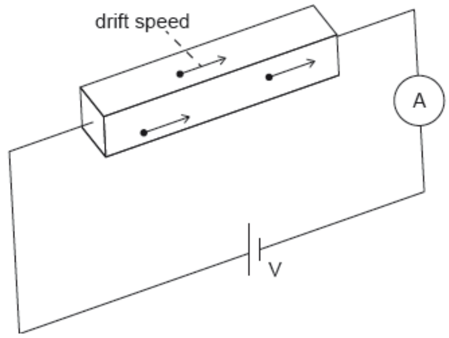
Allow a 1sf answer of 4 if it comes from a calculation.

Do not allow a bald answer of 4 «V»

Allow ECF from incorrect current

[2 marks]

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 = 8.5×10^{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.

9a. Calculate the drift speed *v* of the electrons in the conductor in cm s^{-1}. *[2 marks]*

Markscheme

v «$= \frac{I}{neA}$» $= \frac{2}{8.5 \times 10^{22} \times 1.60 \times 10^{-19} \times 0.02^2}$

0.37 «cms^{-1}»

[2 marks]

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

9b. Determine the electric field strength *E*. *[2 marks]*

Markscheme

V = *RI* = 0.086 «*V*»

« $\frac{V}{d} = \frac{0.086}{0.10} =$» 0.86 «V m^{-1}»

Allow ECF from 4(a).

Allow ECF from MP1.

[2 marks]

9c. Show that $\frac{v}{E} = \frac{1}{ne\rho}$. *[3 marks]*

Markscheme

ALTERNATIVE 1

clear use of Ohm's Law ($V = IR$)

clear use of $R = \frac{\rho L}{A}$

combining with $I = nAve$ and $V = EL$ to reach result.

ALTERNATIVE 2

attempts to substitute values into equation.

correctly calculates LHS as 4.3×10^9.

correctly calculates RHS as 4.3×10^9.

For ALTERNATIVE 1 look for:

$V = IR$

$R = \frac{\rho L}{A}$

$V = EL$

$I = nAve$

$V = I\frac{\rho L}{A}$

$EL = I\frac{\rho L}{A}$

$E = I\frac{\rho}{A}$

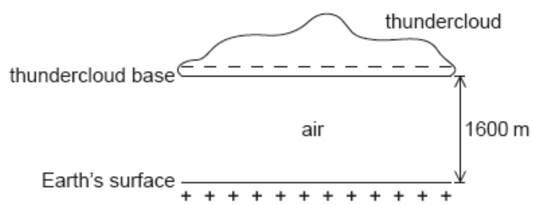
$E = nAve$

$\frac{\rho}{A} = nve\rho$

$\frac{v}{E} = \frac{1}{ne\rho}$

[3 marks]

A negatively charged thundercloud above the Earth's surface may be modelled by a parallel plate capacitor.



The lower plate of the capacitor is the Earth's surface and the upper plate is the base of the thundercloud.

The following data are available.

Area of thundercloud base	$= 1.2 \times 10^8 \text{ m}^2$
Charge on thundercloud base	$= -25 \text{ C}$
Distance of thundercloud base from Earth's surface	$= 1600 \text{ m}$
Permittivity of air	$= 8.8 \times 10^{-12} \text{ F m}^{-1}$

10a. Show that the capacitance of this arrangement is $C = 6.6 \times 10^{-7}$ F. *[1 mark]*

Markscheme

$C =$ «$\varepsilon \frac{A}{d} =$» $8.8 \times 10^{-12} \times \frac{1.2 \times 10^8}{1600}$

«$C = 6.60 \times 10^{-7}$ F»

[1 mark]

10b. Calculate in V, the potential difference between the thundercloud and the Earth's surface. *[2 marks]*

Markscheme

V = «

$\frac{Q}{C}$ =» $\frac{25}{6.6\times10^{-7}}$

V = 3.8 × 10^7 «V»

*Award **[2]** for a bald correct answer*

[2 marks]

10c. Calculate in J, the energy stored in the system. *[2 marks]*

Markscheme

ALTERNATIVE 1

E = «

$\frac{1}{2}QV$ =» $\frac{1}{2}$ × 25 × 3.8 × 10^7

E = 4.7 × 10^8 «J»

ALTERNATIVE 2

E = «

$\frac{1}{2}CV^2$ =» $\frac{1}{2}$ × 6.60 × 10^{-7} × (3.8 × $10^7)^2$

E = 4.7 × 10^8 «J» / 4.8 × 10^8 «J» if rounded value of V used

*Award **[2]** for a bald correct answer*

Allow ECF from (b)(i)

[2 marks]

Lightning takes place when the capacitor discharges through the air between the thundercloud and the Earth's surface. The time constant of the system is 32 ms. A lightning strike lasts for 18 ms.

10d. Show that about –11 C of charge is delivered to the Earth's surface. *[3 marks]*

Markscheme

Q = «$Q_0e^{-\frac{t}{\tau}}$ =» 25 × $e^{-\frac{18}{32}}$

Q = 14.2 «C»

charge delivered = *Q* = 25 – 14.2 = 10.8 «C»

«≈ –11 C»

Final answer must be given to at least 3 significant figures

[3 marks]

10e. Calculate, in A, the average current during the discharge. *[1 mark]*

Markscheme

I «= $\frac{\Delta Q}{\Delta t}=\frac{11}{18\times10^{-3}}$» ≈ 610 «A»

Accept an answer in the range 597 – 611 «A»

[1 mark]

10f. State **one** assumption that needs to be made so that the Earth-thundercloud system may be modelled by a parallel plate capacitor. *[1 mark]*

Markscheme

the base of the thundercloud must be parallel to the Earth surface

OR

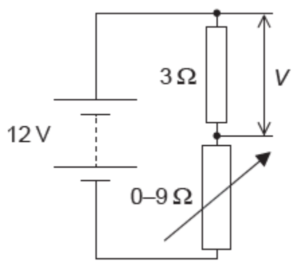
the base of the thundercloud must be flat

OR

the base of the cloud must be very long «compared with the distance from the surface»

[1 mark]

11. In the circuit shown, the fixed resistor has a value of 3 Ω and the variable resistor can be varied between 0 Ω and 9 Ω. *[1 mark]*



The power supply has an emf of 12 V and negligible internal resistance. What is the difference between the maximum and minimum values of voltage *V* across the 3 Ω resistor?

A. 3 V

B. 6 V

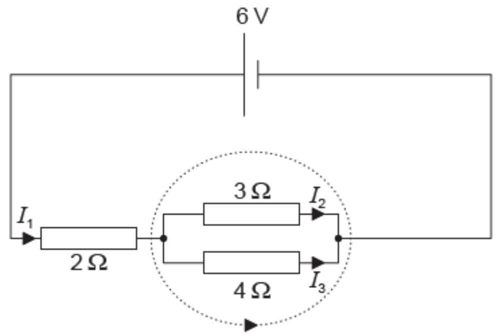
C. 9 V

D. 12 V

Markscheme

C

12. Kirchhoff's laws are applied to the circuit shown. *[1 mark]*



What is the equation for the dotted loop?

A. $0 = 3I_2 + 4I_3$

B. $0 = 4I_3 - 3I_2$

C. $6 = 2I_1 + 3I_2 + 4I_3$

D. $6 = 3I_2 + 4I_3$

Markscheme

B

13. Two wires, X and Y, are made from the same metal. The wires are connected in series. The radius of X is twice that of Y. The carrier drift speed in X is v_X and in Y it is v_Y. *[1 mark]*

What is the value of the ratio $\frac{v_X}{v_Y}$?

A. 0.25

B. 0.50

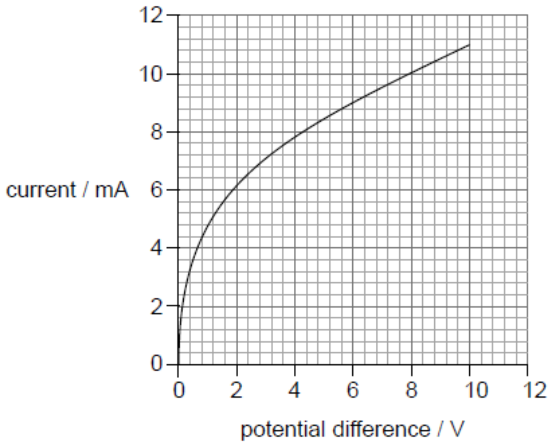
C. 2.00

D. 4.00

Markscheme

A

14. The graph shows the variation of current with potential difference for a filament lamp. *[1 mark]*



What is the resistance of the filament when the potential difference across it is 6.0 V?

A. 0.5 mΩ
B. 1.5 mΩ
C. 670 Ω
D. 2000 Ω

Markscheme

C

15. An electron is accelerated through a potential difference of 2.5 MV. What is the change in kinetic energy of the electron? *[1 mark]*

A. 0.4μJ

B. 0.4 nJ

C. 0.4 pJ

D. 0.4 fJ

Markscheme

C

16. A cell is connected in series with a resistor and supplies a current of 4.0 A for a time of 500 s. During this time, 1.5 kJ of energy is dissipated in the cell and 2.5 kJ of energy is dissipated in the resistor. *[1 mark]*

What is the emf of the cell?

A. 0.50 V

B. 0.75 V

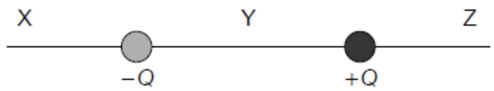
C. 1.5 V

D. 2.0 V

Markscheme

D

17. The diagram shows two equal and opposite charges that are fixed in place. *[1 mark]*



At which points is the net electric field directed to the right?

A. X and Y only

B. Z and Y only

C. X and Z only

D. X, Y and Z

Markscheme

C

18. A wire has variable cross-sectional area. The cross-sectional area at Y is double that at X. *[1 mark]*

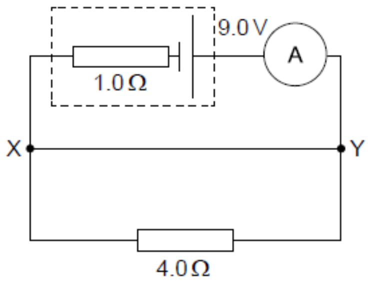
At X, the current in the wire is *I* and the electron drift speed is *v*. What is the current and the electron drift speed at Y?

	Current	Drift speed
A.	I	v
B.	I	$\frac{v}{2}$
C.	$2I$	v
D.	$2I$	$\frac{v}{2}$

Markscheme

B

19. A circuit contains a cell of electromotive force (emf) 9.0 V and internal resistance 1.0 Ω together with a resistor of resistance 4.0 Ω as shown. The ammeter is ideal. XY is a connecting wire. *[1 mark]*



What is the reading of the ammeter?

A. 0 A

B. 1.8 A

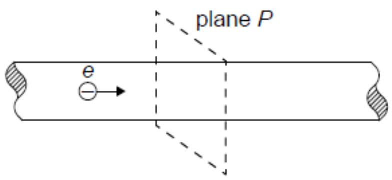
C. 9.0 A

D. 11 A

Markscheme

C

20. Electrons, each with a charge e, move with speed v along a metal wire. The electric current in the wire is I. *[1 mark]*



Plane P is perpendicular to the wire. How many electrons pass through plane P in each second?

A. $\frac{e}{I}$

B. $\frac{ve}{I}$

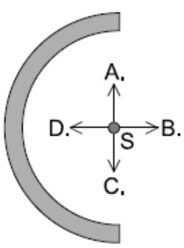
C. $\frac{I}{ve}$

D. $\frac{I}{e}$

Markscheme

D

21. Positive charge is uniformly distributed on a semi-circular plastic rod. What is the direction of the electric field strength at point S? *[1 mark]*



Markscheme

B

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 = 1.7×10^{-8} Ω m

22a. Calculate the current in the copper cable. *[1 mark]*

Markscheme

I «$= \frac{8.5 \times 10^3}{240}$» =35«A»

22b. Calculate the resistance of the cable. *[2 marks]*

Markscheme

$R = \frac{1.7 \times 10^{-8} \times 10}{6.0 \times 10^{-6}}$

= 0.028 «Ω»

Allow missed powers of 10 for MP1.

22c. Explain, in terms of electrons, what happens to the resistance of the cable as the temperature of the cable increases. *[3 marks]*

Markscheme

«as temperature increases» there is greater vibration of the metal atoms/lattice/lattice ions

OR

increased collisions of electrons

drift velocity decreases «so current decreases»

«as V constant so» *R* increases

*Award **[0]** for suggestions that the speed of electrons increases so resistance decreases.*

22d. 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.

Markscheme

recognition that power = flow rate × cΔT

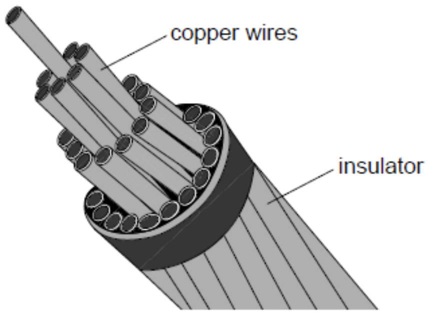
flow rate «$= \frac{\text{power}}{c\Delta T}$» $= \frac{8.5\times10^3}{4200\times35}$

= 0.058 «kg s^{-1}»

kg s^{-1} / g s^{-1} / l s^{-1} / ml s^{-1} / m^3 s^{-1}

Allow MP4 if a bald flow rate unit is stated. Do not allow imperial units.

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.



23a. 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]*

Markscheme

when an electric field is applied to any material «using a cell etc» it acts to accelerate any free electrons

electrons are the charge carriers «in copper»

Accept "free/valence/delocalised electrons".

metals/copper have many free electrons whereas insulators have few/no free electrons/charge carriers

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 x 10 $^{-8}$ Ω m.

23b. Calculate the radius of each **wire**. *[2 marks]*

Markscheme

area = $\frac{1.7\times10^{-3}\times35\times10^3}{64}$ «= 9.3 x 10^{-6} m^2»

23c. 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]*

Markscheme

«resistance of cable = 2Ω»

power dissipated in cable = 730^2 x 2 «= 1.07 MW»

power loss per meter $= \frac{1.07 \times 10^{-6}}{35 \times 10^{3}}$ ***or*** 30.6 «W m^{-1}»

*Allow **[2]** for a solution where the resistance per unit metre is calculated using resistivity and answer to (b)(i) (resistance per unit length of cable =5.7 x 10^{-5} m)*

23d. 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]*

Markscheme

30 = *m* x 390 x 3.5 x 10^{-2}

2.2 k«g»

Correct answer only.

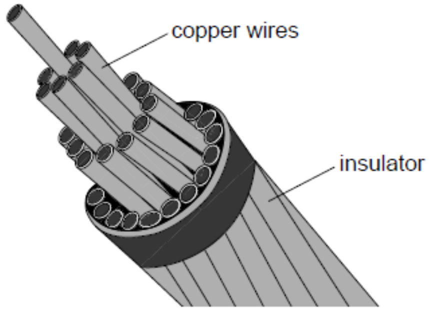
24. Calculate the power dissipated in the cable. *[2 marks]*

Markscheme

power = «35^2 × 0.028» = 34 «W»

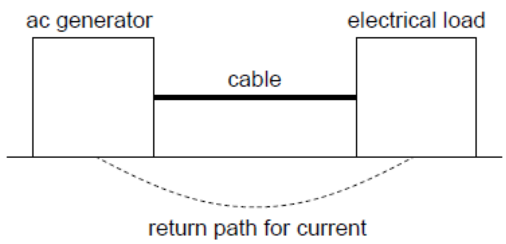
Allow 35 – 36 W if unrounded figures for R or I are used.
Allow ECF from (a)(i) and (a)(ii).

A cable consisting of many copper wires is used to transfer electrical energy from an alternating current (ac) generator to an electrical load. The copper wires are protected by an insulator.



The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 Ω. The cable is connected to the ac generator which has an output power of 110 MW when the peak potential difference is 150 kV. The resistivity of copper is 1.7 x 10^{-8} Ω m.

output power = 110 MW



25a. Calculate the radius of each **wire**. *[2 marks]*

Markscheme

area = $\frac{1.7\times10^{-3}\times35\times10^{3}}{64}$ «= 9.3 x 10^{-6} m^2»

radius = «$\sqrt{\frac{9.3\times10^{-6}}{\pi}}$ =» 0.00172 m

25b. Calculate the peak current in the **cable**. *[1 mark]*

Markscheme

I_{peak} «$= \frac{P_{peak}}{V_{peak}}$» = 730 « A »

25c. Determine the power dissipated in the cable per unit length. *[3 marks]*

Markscheme

resistance of cable identified as «$\frac{64}{32}$ =» 2 Ω

$\frac{\text{a power}}{35000}$ seen in solution

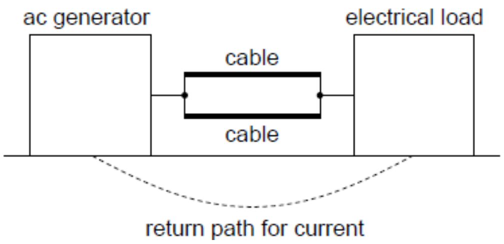
plausible answer calculated using $\frac{2I^2}{35000}$ «plausible if in range 10 W m^{-1} to 150 W m^{-1} when quoted answers in (b)(ii) used» 31 «W m^{-1}»

*Allow **[3]** for a solution where the resistance per unit metre is calculated using resistivity and answer to (a) (resistance per unit length of cable = 5.7 x 10^{-5} m)*

*Award **[2 max]** if 64 Ω used for resistance (answer x32).*

An approach from
*$\frac{V^2}{R}$ or VI using 150 kV is incorrect (award **[0]**), however allow this approach if the pd across the cable has been calculated (pd dropped across cable is 1.47 kV).*

To ensure that the power supply cannot be interrupted, two identical cables are connected in parallel.



25d. Calculate the root mean square (rms) current in each cable. *[1 mark]*

Markscheme

«$\frac{\text{response to (b)(ii)}}{2\sqrt{2}}$» = 260 «A»

25e. The two cables in part (c) are suspended a constant distance apart. Explain how the magnetic forces acting between the cables vary during the course of one cycle of the alternating current (ac). *[2 marks]*

Markscheme

wires/cable attract whenever current is in same direction

charge flow/current direction in both wires is always same «but reverses every half cycle»

force varies from 0 to maximum

force is a maximum twice in each cycle

*Award **[1 max]** if response suggests that there is repulsion between cables at any stage in cycle.*

The energy output of the ac generator is at a much lower voltage than the 150 kV used for transmission. A step-up transformer is used between the generator and the cables.

25f. Suggest the advantage of using a step-up transformer in this way. *[2 marks]*

Markscheme

higher voltage gives lower current

«energy losses depend on current» hence thermal/heating/power losses reduced

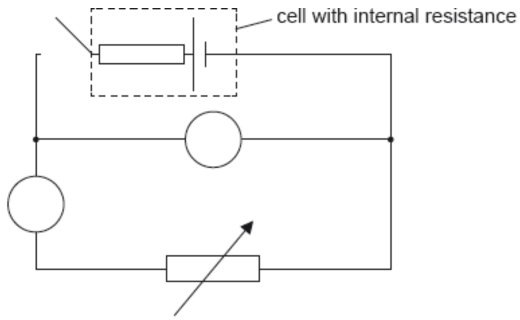
25g. The use of alternating current (ac) in a transformer gives rise to energy losses. State how eddy current loss is minimized in the transformer. *[1 mark]*

Markscheme

laminated core

Do not allow "wires are laminated".

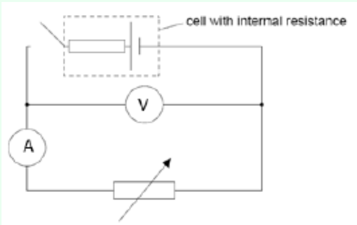
The circuit shown may be used to measure the internal resistance of a cell.



26a. 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]*

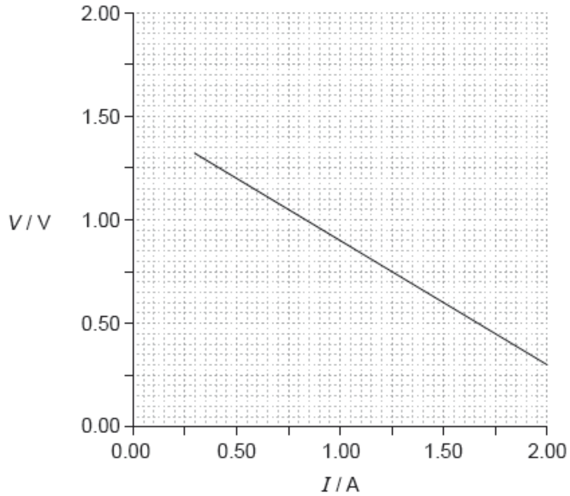
Markscheme

correct labelling of both instruments



[1 mark]

26b. 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.

Markscheme

V = E – Ir

large triangle to find gradient and correct read-offs from the line
OR
use of intercept E = 1.5 V and another correct data point

internal resistance = 0.60 Ω

For MP1 – do not award if only
$R = \frac{V}{I}$ *is used.*

For MP2 points at least 1A apart must be used.

For MP3 accept final answers in the range of 0.55 Ω to 0.65 Ω.

[3 marks]

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.

26c. State what is meant by a zero error. *[1 mark]*

Markscheme

a non-zero reading when a zero reading is expected/no current is flowing
OR
a calibration error

OWTTE
Do not accept just “systematic error”.

[1 mark]

26d. 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]*

Markscheme

the error causes «all» measurements to be high/different/incorrect

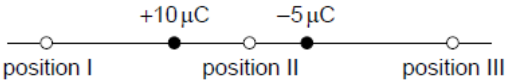
effect on calculations/gradient will cancel out
OR
effect is that value for *r* is unchanged

*Award **[1 max]** for statement of "no effect" without valid argument.*

OWTTE

[2 marks]

27. A –5µC charge and a +10µC charge are a fixed distance apart. *[1 mark]*



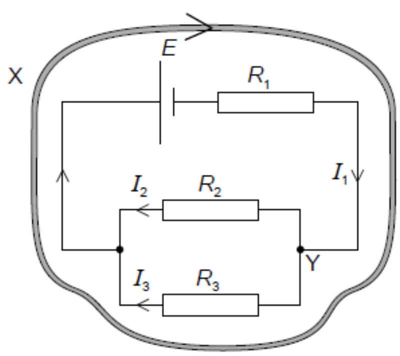
Where can the electric field be zero?

A. position I only
B. position II only
C. position III only
D. positions I, II and III

Markscheme

C

28. An electrical circuit is shown with loop X and junction Y. *[1 mark]*



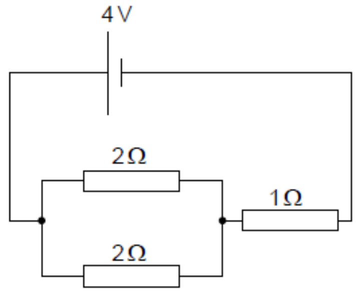
What is the correct expression of Kirchhoff's circuit laws for loop X and junction Y?

	Loop X	Junction Y
A.	$-E = I_1R_1 + I_3R_3$	$I_1 = I_2 + I_3$
B.	$-E = I_1R_1 + I_3R_3$	$I_1 + I_2 = I_3$
C.	$E = I_1R_1 - I_3R_3$	$I_1 = I_2 + I_3$
D.	$E = I_1R_1 - I_3R_3$	$I_1 + I_2 = I_3$

Markscheme

A

29. A cell of emf 4V and negligible internal resistance is connected to three resistors as shown. Two resistors of resistance 2Ω are connected in parallel and are in series with a resistor of resistance 1Ω. *[1 mark]*



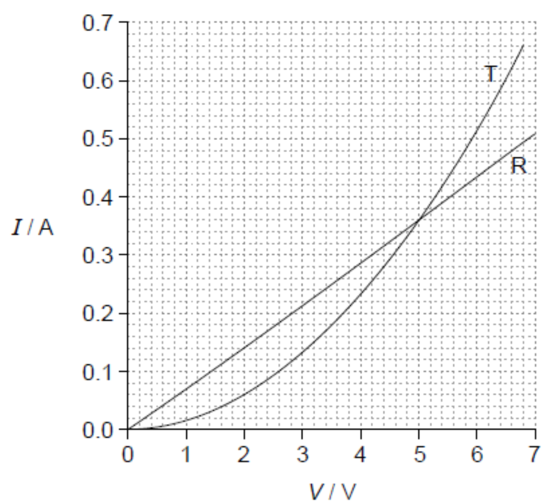
What power is dissipated in one of the 2Ω resistors and in the whole circuit?

	Power dissipated in 2Ω resistor / W	Power dissipated in whole circuit / W
A.	2	6
B.	1	6
C.	0.5	8
D.	2	8

Markscheme

D

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



30a. (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.

Markscheme

i

R_T decreases with increasing I

OR

R_T and I are negatively correlated

Must see reference to direction of change of current in first alternative.
Do not allow "inverse proportionality".
May be worth noting any marks on graph relating to 7bii

ii

at 0.4 A: $V_R > V_T$ ***or*** V_R= 5.6 V and V_T = 5.3 V

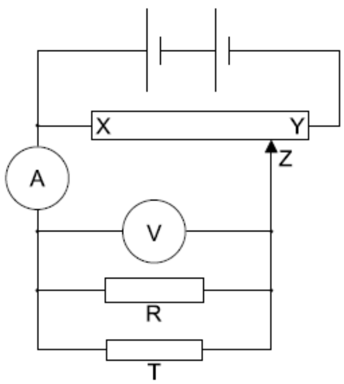
*Award **[0]** for a bald correct answer without deduction or with incorrect reasoning.*

Ignore any references to graph gradients.

so $R_R > R_T$ because $V = IR$ / $V \propto R$ «and I same for both»

Both elements must be present for MP2 to be awarded.

30b. 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.

Markscheme

i

decreases
OR
becomes zero at X

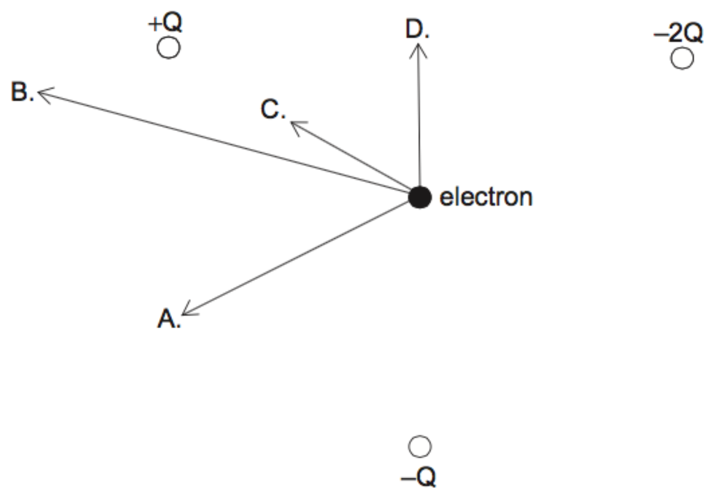
ii

realization that V is the same for R and T
OR
identifies that currents are 0.14 A and 0.06 A

*Award **[0]** if pds 2.8 V and 3.7 V or 1.4 V and 2.6V are used in any way. Otherwise award **[1 max]** for a bald correct answer. Explanation expected.*

2 V = 2 V OR 2.0 V

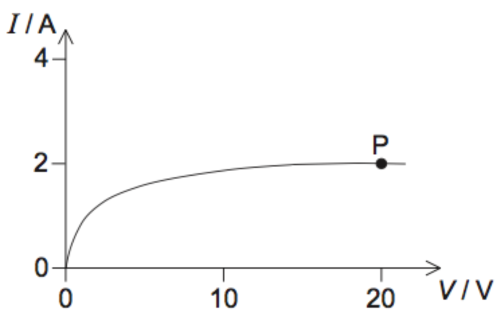
31. Three fixed charges, +Q, –Q and –2Q, are at the vertices of an equilateral triangle. What is the resultant force on an electron at the centre of the triangle? *[1 mark]*



Markscheme

B

32. The graph shows the variation of current *I* in a device with potential difference *V* across it. *[1 mark]*



What is the resistance of the device at P?

A. zero

B. 0.1Ω

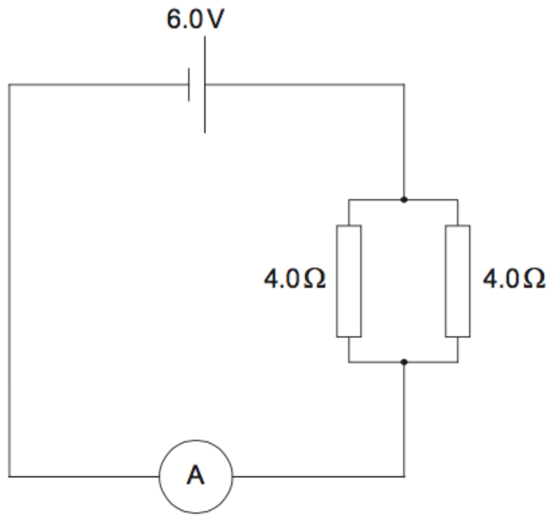
C. 10Ω

D. infinite

Markscheme

C

33. A circuit consists of a cell of electromotive force (emf) 6.0V and negligible internal resistance connected to two resistors of 4.0Ω. *[1 mark]*



The resistance of the ammeter is 1.0 Ω. What is the reading of the ammeter?

A. 2.0A

B. 3.0A

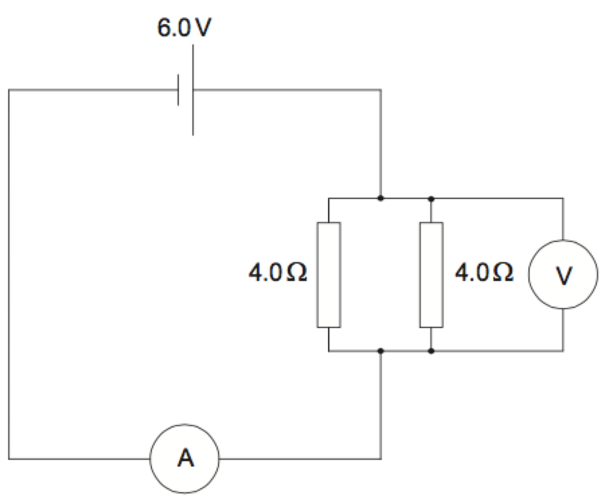
C. 4.5A

D. 6.0A

Markscheme

A

34. A circuit consists of a cell of electromotive force (emf) 6.0V and negligible internal resistance connected to two resistors of 4.0Ω. *[1 mark]*



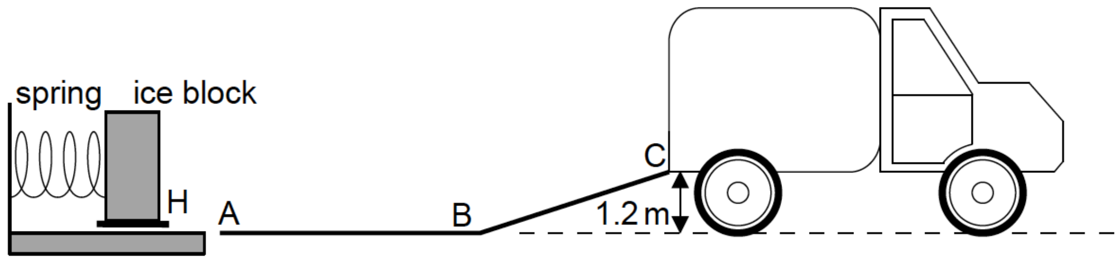
The ammeter has resistance equal to 1.0Ω and the voltmeter is ideal. What are the readings of the ammeter and the voltmeter?

	Ammeter	Voltmeter
A.	2.0A	3.0V
B.	3.0A	3.0V
C.	2.0A	4.0V
D.	3.0A	4.0V

Markscheme

C

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.

35a. (i) The block arrives at C with a speed of 0.90ms^{-1}. Show that the elastic energy stored in the spring is 670J. *[4 marks]*

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

Markscheme

(i)

$\ll E_{\text{el}} = \gg \frac{1}{2}mv^2 + mgh$

OR

«E_{el}=» E_P+E_K

$\ll E_{\text{el}} = \gg \frac{1}{2} \times 55 \times 0.90^2 + 55 \times 9.8 \times 1.2$

OR

669 J

«E_{el} = 669 ≈ 670J»

*Award **[1 max]** for use of g=10Nkg^{-1}, gives 682 J.*

(ii)

$\frac{1}{2} \times 55 \times v^2 = 670\text{J}$

$v = \ll \sqrt{\frac{2 \times 670}{55}} = \gg 4.9\text{ms}^{-1}$

If 682J used, answer is 5.0ms^{-1}.

35b. 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.

Markscheme

(i)

no force/friction on the block, hence constant motion/velocity/speed

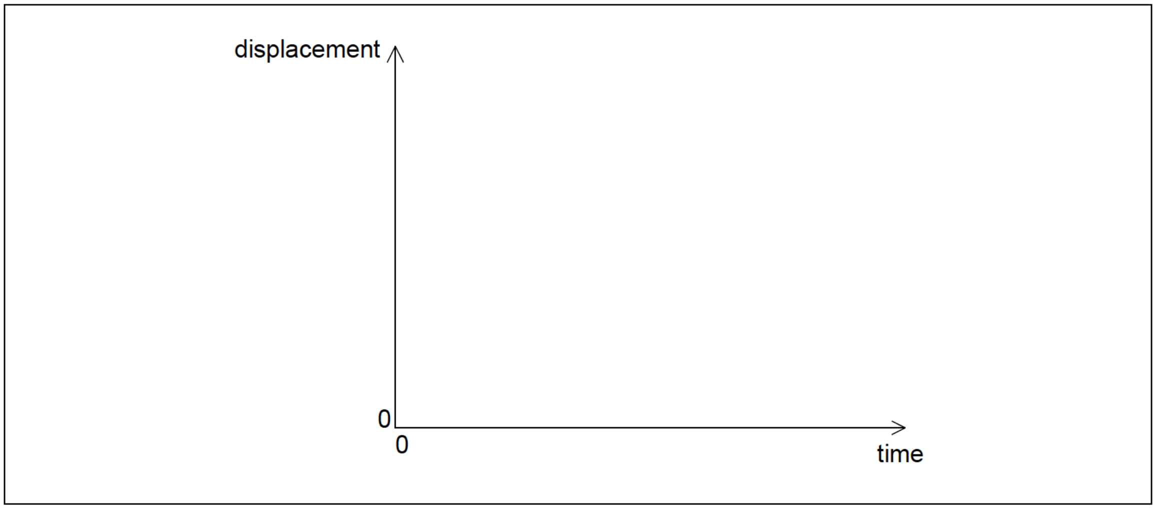
(ii)

force acts on block ***OR*** gravity/component of weight pulls down slope

velocity/speed decreases ***OR*** it is slowing down ***OR*** it decelerates

Do not allow a bald statement of “N2” or “F = ma” for MP1.
Treat references to energy as neutral.

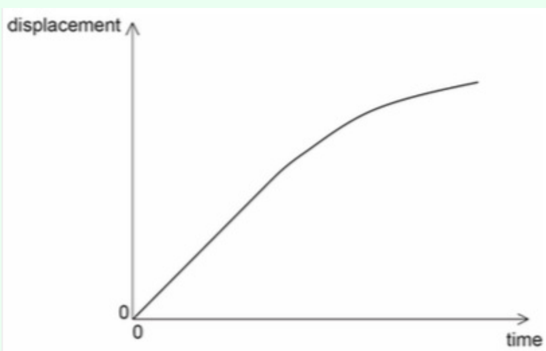
35c. On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) *[2 marks]*



Markscheme

straight line through origin for at least one-third of the total length of time axis **covered by candidate line**

followed by curve with decreasing positive gradient



Ignore any attempt to include motion before A.

Gradient of curve must always be less than that of straight line.

35d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. *[2 marks]*

Markscheme

$F \ll = \frac{\Delta p}{\Delta t} \gg = \frac{55 \times 4.9}{0.42}$

F=642≈640N

Allow ECF from (a)(ii).

35e. 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.

Markscheme

«energy supplied by motor =» 120 × 6.8 × 1.5 ***or*** 1224 J

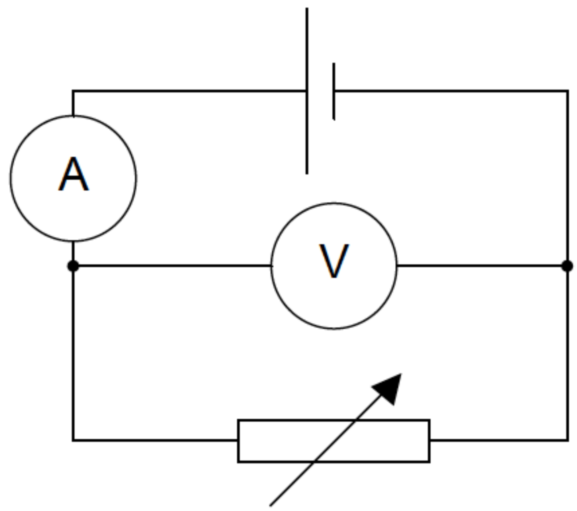
OR

«power supplied by motor =» 120 × 6.8 ***or*** 816 W

e = 0.55 ***or*** 0.547 or 55% ***or*** 54.7%

Allow ECF from earlier results.

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



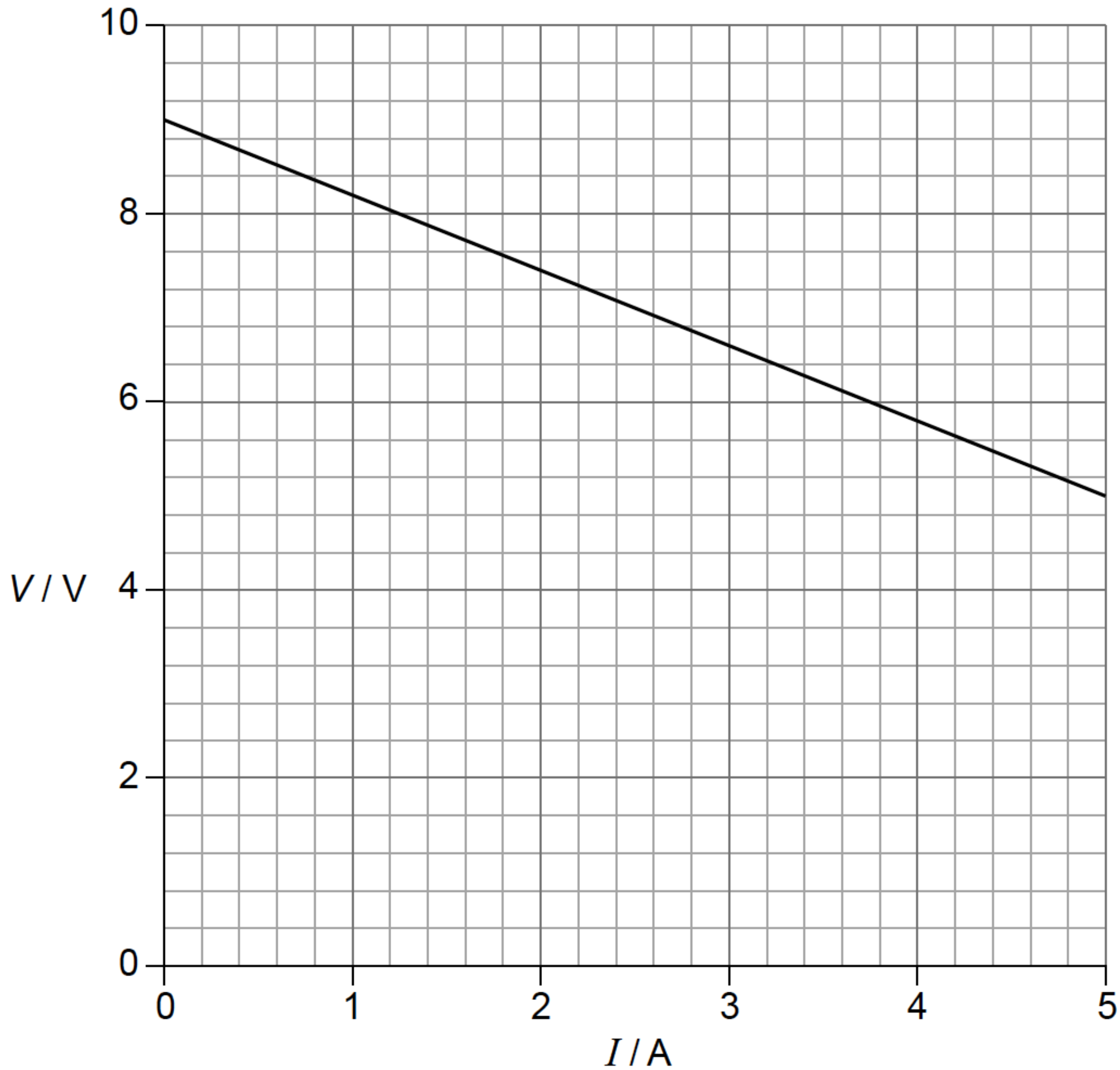
36a. State what is meant by an ideal voltmeter. *[1 mark]*

Markscheme

infinite resistance ***OR*** draws no current from circuit/component ***OR*** has no effect on the circuit

Do not allow "very high resistance".

36b. 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.

Markscheme

(i)
«vertical intercept = emf» = 8.8 – 9.2 V

(ii)
attempt to evaluate gradient of graph
=0.80Ω

Accept other methods leading to correct answer, eg using individual data points from graph.

Allow a range of 0.78 – 0.82 Ω.

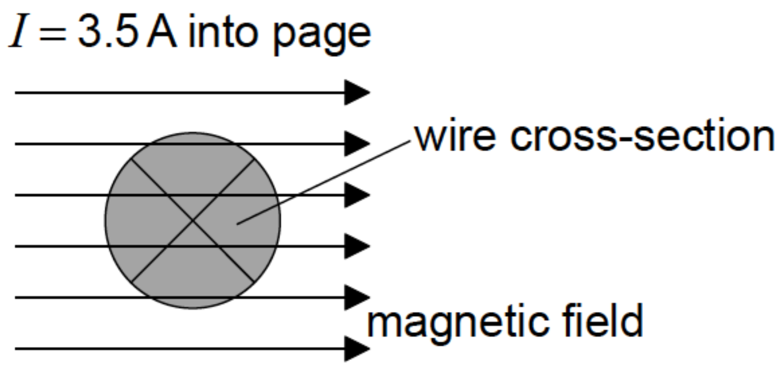
If $\varepsilon = I(R + r)$ is used then the origin of the value for R must be clear.

36c. 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]*

Markscheme

$3.5 = 2.4 \times 10^{28} \times \pi(1.2 \times 10^{-3})^2 \times 1.6 \times 10^{-19} \times v$ «$\Rightarrow v = 2.0 \times 10^{-4}\,ms^{-1}$»

36d. 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.

Markscheme

$F =$ «$qvB = 1.6 \times 10^{-19} \times 2.0 \times 10^{-4} \times 0.25 =$»$8.1 \times 10^{-24}$ N

directed down ***OR*** south