Past-paper walk-through

Kirchhoff's laws ▪ 10.2

eXercise

Questions in this set

- 9702/11 N25 Q34 ▪ 1 mark
- 9702/11 N25 Q37 ▪ 1 mark
- 9702/12 N25 Q37 ▪ 1 mark
- 9702/14 N25 Q36 ▪ 1 mark
- 9702/21 N25 Q5 ▪ 10 marks
- 9702/11 J25 Q36 ▪ 1 mark
- 9702/12 J25 Q37 ▪ 1 mark
- 9702/13 J25 Q35 ▪ 1 mark
- 9702/14 J25 Q34 ▪ 1 mark
- 9702/14 J25 Q35 ▪ 1 mark

Questions in this set

- 9702/24 J25 Q6 ▪ 8 marks
- 9702/12 M25 Q35 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 34

9702/11 N25 ▪ Q34 ▪ 1 mark

The diagram shows a circuit containing a battery and cells with negligible internal resistance.

Some values of current, electromotive force (e.m.f.) and resistance are shown.

One resistor is labelled P.

What is the resistance of resistor P? **[1]**

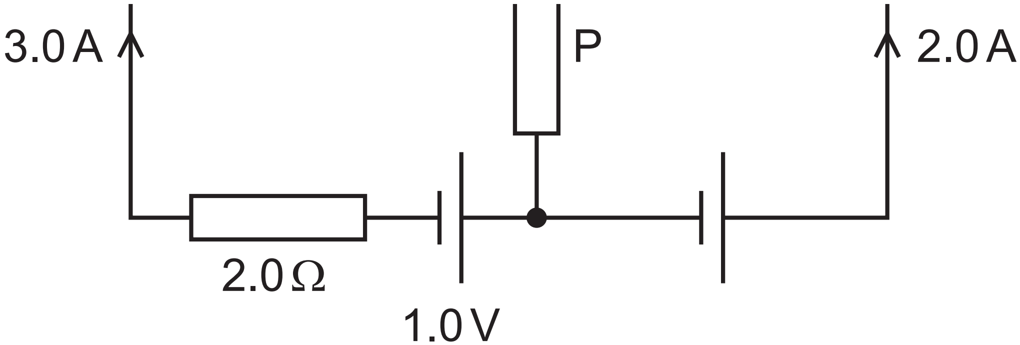
A $0.40\,\Omega$

B $0.80\,\Omega$

C $2.0\,\Omega$

D $2.8\,\Omega$

Question 34



Solution 34

- **A** $0.40\,\Omega$ ✓
- **B** $0.80\,\Omega$
- **C** $2.0\,\Omega$
- **D** $2.8\,\Omega$

Why

- Both outer currents flow up towards the top node, so P carries their sum: $3.0 + 2.0 = 5.0$ A.
- Round the left loop the 1.0 V cell opposes the 9.0 V battery, so the driving e.m.f. is $9.0 - 1.0 = 8.0$ V.
- $8.0 = (3.0)(2.0) + 5.0R_P$, giving $R_P = 2.0/5.0 = 0.40\ \Omega$.

Question 37

9702/11 N25 ▪ Q37 ▪ 1 mark

The diagram shows the currents in part of an electric circuit.

The resistors are identical.

Which equation is **not** correct? **[1]**

A $I_1 = I_2 + I_4 + I_5$

B $I_2 = I_1 - I_3$

C $I_2 = I_3 + I_4 + I_5$

D $I_4 = I_3 - I_5$

Solution 37

- **A** $I_1 = I_2 + I_4 + I_5$
- **B** $I_2 = I_1 - I_3$
- **C** $I_2 = I_3 + I_4 + I_5$ ✓
- **D** $I_4 = I_3 - I_5$

Why

- Two junctions are shown: the first gives $I_1 = I_2 + I_3$ and the second gives $I_3 = I_4 + I_5$.
- A, B and D are just those two relations rearranged.
- C adds I_3 to $I_4 + I_5$, but those already *are* I_3 – it counts the lower branch twice.

Question 37

9702/12 N25 ▪ Q37 ▪ 1 mark

The principles of conservation of which two quantities are associated with Kirchhoff's first and second laws? **[1]**

A \begin{tabular}{ll} first law: charge & second law: energy \end{tabular}

B \begin{tabular}{ll} first law: charge & second law: voltage \end{tabular}

C \begin{tabular}{ll} first law: energy & second law: charge \end{tabular}

D \begin{tabular}{ll} first law: voltage & second law: charge \end{tabular}

Question 37

	first law	second law
A	charge	energy
B	charge	voltage
C	energy	charge
D	voltage	charge

Solution 37

- **A** \begin{tabular}{ll} first law: charge & second law: energy \end{tabular} ✓
- **B** \begin{tabular}{ll} first law: charge & second law: voltage \end{tabular}
- **C** \begin{tabular}{ll} first law: energy & second law: charge \end{tabular}
- **D** \begin{tabular}{ll} first law: voltage & second law: charge \end{tabular}

Why

- The first law concerns currents at a junction and follows from conservation of charge.
- The second law concerns e.m.f.s and p.d.s round a loop and follows from conservation of energy.
- Voltage is not itself a conserved quantity, which rules out B and D.

Question 36

9702/14 N25 ▪ Q36 ▪ 1 mark

Four resistors of resistance R, $2R$, $3R$ and $4R$ are connected to form a network.

A battery of negligible internal resistance and a voltmeter are connected to the resistor network as shown.

The voltmeter reading is 2 V.

What is the electromotive force (e.m.f.) of the battery? **[1]**

A 2 V

B 4 V

C 6 V

D 10 V

Solution 36

A 2 V

B 4 V

C 6 V ✓

D 10 V

Why

- The battery sits directly across the $4R$, so the same e.m.f. appears across the chain beside it.
- That chain is $3R + 2R + R = 6R$ in series, carrying a current $E/6R$.
- The voltmeter reads across the $2R$: $V = (E/6R)(2R) = E/3$, so $E = 3 \times 2 = 6$ V.

Question 5

9702/21 N25 ▪ Q5 ▪ 10 marks

(a) State Kirchhoff's first law. **[1]**

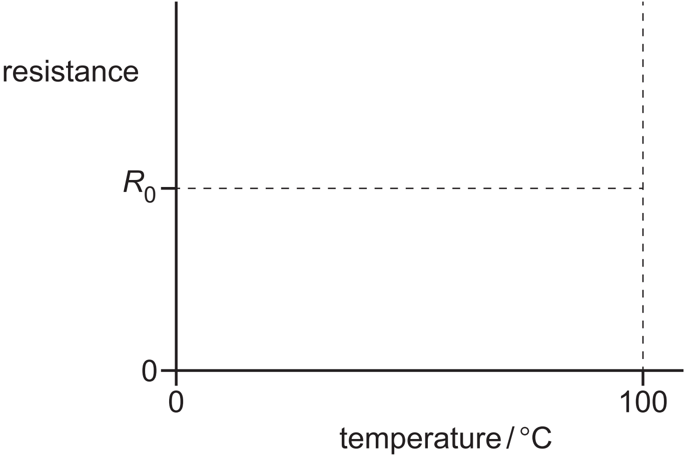
(b)(i) The thermistor has resistance R_0 at a temperature of $0°$C.
On Fig. 5.2, sketch a possible variation of the resistance of the thermistor with temperature between $0°$C and $100°$C. **[2]**

(b)(ii) With reference to the current in the cell, explain why the current in resistor R decreases with increasing temperature of the thermistor. **[3]**

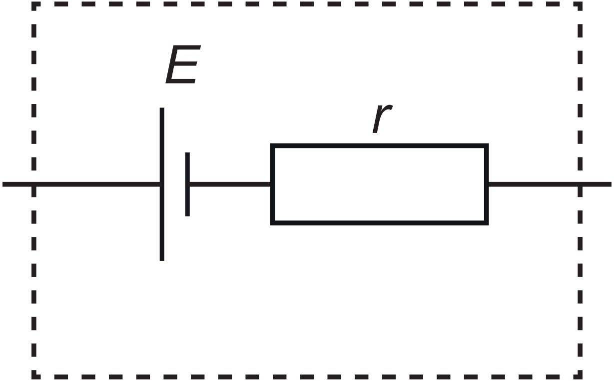
(c)(i) the current in the cell **[2]**

(c)(ii) the resistance of the thermistor. **[2]**

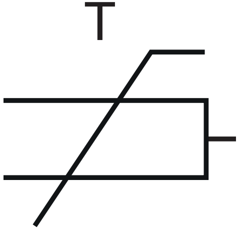
Question 5



Question 5



Question 5



Solution 5

(a)

Mark scheme

- sum of current(s) into junction = sum of current(s) out junction or
- (algebraic) sum of current(s) at a junction is zero **B1**

Solution 5

(b)(i)

Worked steps

A thermistor's resistance **falls** as it gets hotter, and it never reaches zero.

- Start the line at $(0°\text{C}, R_0)$.
- Draw it falling all the way to $100°\text{C}$, curving so it gets less steep.
- Keep it above the axis throughout — a line that touches $R = 0$ loses the mark.

Mark scheme

- line with negative gradient **C1**
- line from 0 °C to 100 °C, starting at (0, R0) with negative gradient throughout and never reaching R = 0 **A1**

Solution 5

(b)(ii)

Mark scheme

- (resistance of T decreases so) total resistance (of circuit) decreases **B1**
- current in cell increases (so p.d. across internal resistance increases) **B1**
- terminal p.d. decreases (and resistance of R is constant) so current in R decreases **B1**

Solution 5

(c)(i) Worked steps

Work out the lost volts first, then use them with the internal resistance.

- P.d. across R (and so across the parallel combination) $= 6.00 \times 0.200 = 1.20$ V.
- Lost volts inside the cell $= E - V = 1.50 - 1.20 = 0.30$ V.
- $I = \dfrac{0.30}{0.12}$
- $I = 2.5$ A

Solution 5

Mark scheme

- p.d. across r
- $= 1.50 - (6.00 \times 0.200)$
- $(= 0.30 \text{ V})$ **C1**
- current in cell $= 0.30 \ / \ 0.12$
- $= 2.5 \text{ A}$ **A1**

Solution 5

(c)(ii) Worked steps

Kirchhoff's first law at the junction: what leaves the cell splits between the two branches.

- Current in the thermistor $= 2.5 - 0.200 = 2.3$ A.
- Both branches share the same p.d., 1.20 V.
- $R_{\mathsf{T}} = \dfrac{1.20}{2.3}$
- $R_{\mathsf{T}} = 0.52\ \Omega$

Solution 5

Mark scheme

- current in thermistor $= 2.5 - 0.200$
- $(= 2.3\text{ A})$ **C1**
- resistance of T $= (6.00 \times 0.200) / 2.3$
- $= 0.52\ \Omega$ **A1**

Question 36

9702/11 J25 ▪ Q36 ▪ 1 mark

Two resistors of resistances R_1 and R_2 are connected in parallel.

What is the combined resistance between X and Y? **[1]**

A $R_1 + R_2$

B $\frac{R_1 R_2}{R_1 + R_2}$

C $\frac{R_1 + R_2}{R_1 R_2}$

D $\frac{R_1}{R_2}$

Solution 36

A $R_1 + R_2$

B $\frac{R_1 R_2}{R_1 + R_2}$ ✓

C $\frac{R_1 + R_2}{R_1 R_2}$

D $\frac{R_1}{R_2}$

Why

- For two resistors in parallel, $1/R = 1/R_1 + 1/R_2$.
- Putting that over a common denominator gives $R = R_1 R_2/(R_1 + R_2)$.
- A is the series formula; a parallel combination is always smaller than either resistor.

Question 37

9702/12 J25 ▪ Q37 ▪ 1 mark

Each of Kirchhoff's two laws presumes that some quantity is conserved.

Which row states Kirchhoff's **first** law and names the quantity that is conserved? **[1]**

A statement: The algebraic sum of currents at a junction is zero. quantity: charge

B statement: The algebraic sum of currents at a junction is zero. quantity: energy

C statement: The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop. quantity: charge

D statement: The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop. quantity: energy

Question 37

	statement	quantity
A	The algebraic sum of currents at a junction is zero.	charge
B	The algebraic sum of currents at a junction is zero.	energy
C	The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop.	charge
D	The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop.	energy

Solution 37

A statement: The algebraic sum of currents at a junction is zero. quantity: charge ✓

B statement: The algebraic sum of currents at a junction is zero. quantity: energy

C statement: The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop. quantity: charge

D statement: The e.m.f. in a loop is equal to the algebraic sum of the product of current and resistance round the loop. quantity: energy

Why

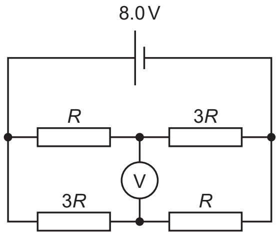
- The first law says the algebraic sum of the currents at a junction is zero.
- Charge cannot pile up at a point, so what flows in must flow out – conservation of charge.
- Energy conservation is the *second* law, about e.m.f.s and p.d.s round a loop.

Question 35

9702/13 J25 ▪ Q35 ▪ 1 mark

35 Two resistors of resistance R and two resistors of resistance $3R$ are connected to a cell of e.m.f. 8.0 V as shown.

The cell has negligible internal resistance.



What is the reading on the voltmeter?

Question 35

What is the reading on the voltmeter?

A 0.0 V **B** 2.0 V **C** 4.0 V **D** 6.0 V

Solution 35

Answer: **C**

Why

- Each branch is a potential divider across the same 8.0 V.
- One midpoint sits at $8.0 \times 3R/4R = 6.0$ V and the other at $8.0 \times R/4R = 2.0$ V.
- The voltmeter reads the difference: $6.0 - 2.0 = 4.0$ V.

Question 34

9702/14 J25 ▪ Q34 ▪ 1 mark

34 The sum of the electrical currents into a point in a circuit is equal to the sum of the currents out of the point.

Which statement is correct?

A This is Kirchhoff's first law, which results from the conservation of charge.

B This is Kirchhoff's first law, which results from the conservation of energy.

C This is Kirchhoff's second law, which results from the conservation of charge.

D This is Kirchhoff's second law, which results from the conservation of energy.

Solution 34

Answer: **A**

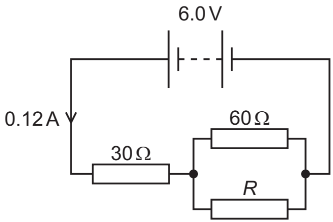
Why

- Currents in equalling currents out is Kirchhoff's first law.
- It follows from conservation of charge – charge cannot accumulate at a point.
- The loop rule is the second law, and that one follows from conservation of energy.

Question 35

9702/14 J25 ▪ Q35 ▪ 1 mark

35 A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected to three resistors, as shown.



The current in the battery is 0.12 A.

What is resistance *R*?

Question 35

A $12\,\Omega$ **B** $30\,\Omega$ **C** $50\,\Omega$ **D** $60\,\Omega$

Solution 35

Answer: **B**

Why

- Total resistance is $V/I = 6.0/0.12 = 50\ \Omega$.
- The $30\ \Omega$ and $60\ \Omega$ in parallel give $30 \times 60/90 = 20\ \Omega$.
- So $R = 50 - 20 = 30\ \Omega$.

Question 6

9702/24 J25 ▪ Q6 ▪ 8 marks

A battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance is connected in series with a variable resistor and a uniform resistance wire XY, as shown in Fig. 6.1.

Wire XY has length 2.00 m and resistance $8.0\ \Omega$. The resistance *R* of the variable resistor is adjusted so that the potential difference across wire XY is 2.4 V.

(a) Determine *R*. **[2]**

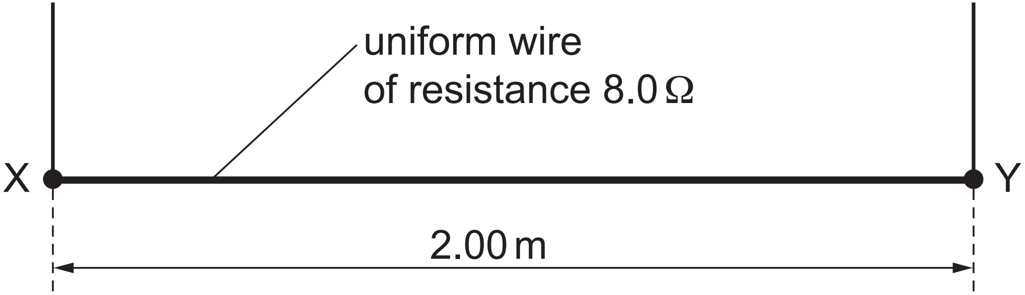
(b) Explain why the potential difference *V* between any two points on wire XY is proportional to the distance *L* between those points. **[2]**

(c)(i) Calculate *E*. **[2]**

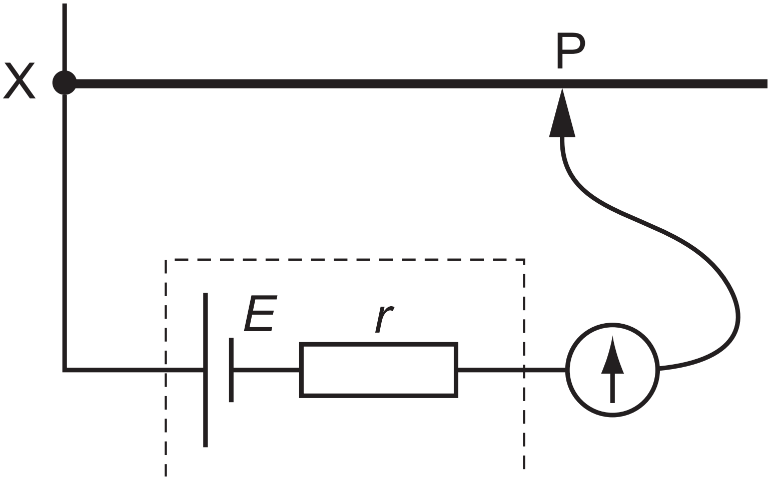
(c)(ii) The value of *R* is now decreased.

State and explain the change that must be made to the position of P on wire XY so that the galvanometer reads zero again. **[2]**

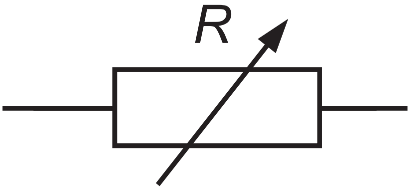
Question 6



Question 6



Question 6



Solution 6

(a) Worked steps

R and the wire are in series, so they share the 6.0 V in proportion to their resistances.

- Current is the same in both: $I = \dfrac{V_{\mathrm{XY}}}{R_{\mathrm{XY}}} = \dfrac{2.4}{8.0} = 0.30$ A.
- The variable resistor takes the rest of the e.m.f.: $6.0 - 2.4 = 3.6$ V.
- $R = \dfrac{3.6}{0.30}$
- $R = 12\ \Omega$

Mark scheme

- $2.4/6.0 = 8/(R + 8)$

Solution 6

- $R = 12\Omega$
- **or**
- $I = 2.4/8$
- $= 0.30$
- $R = (6 - 2.4)/0.3$ or $R = (6/0.3) - 8$
- $R = 12\Omega$

Solution 6

(b)

Mark scheme

- $V = I(\rho L/A)$ or $V = IR$ and $R = (\rho L/A)$
- I, ρ, A are constant (so $V \propto L$)

Solution 6

(c)(i) Worked steps

The wire is uniform, so p.d. along it is proportional to length — that is the whole point of a potentiometer.

- $\dfrac{E}{V_{\mathrm{XY}}} = \dfrac{L_{\mathrm{XP}}}{L_{\mathrm{XY}}}$
- $E = 2.4 \times \dfrac{1.24}{2.00}$
- $E = 1.5\ \mathrm{V}$

Solution 6

Mark scheme

- $V_{XP}/V_{XY} = L_{XP}/L_{XY}$
- $E/2.4 = 1.24/2.00$
- $E = 1.5V$

Solution 6

(c)(ii)

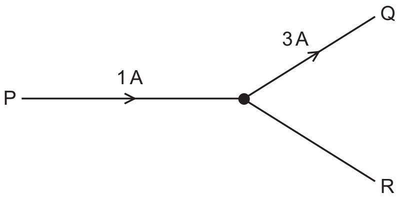
Mark scheme

- p.d. across XY / wire increases / p.d. across XP increases
- so P moved towards X / away from Y / to the left

Question 35

9702/12 M25 ▪ Q35 ▪ 1 mark

35 The diagram shows a junction in a circuit where three wires, P, Q and R, meet. The currents in P and Q are 1 A and 3 A respectively, in the directions shown.



How much charge passes a given point in wire R in a time of 5 s?

A 0.4 C **B** 2 C **C** 10 C **D** 20 C

Solution 35

Answer: **C**

Why

- Kirchhoff's first law: the current into a junction equals the current out.
- With 3 A in and 1 A out, wire R must carry $3 - 1 = 2$ A.
- $Q = It = 2 \times 5 = 10$ C; D assumes R carries the sum instead of the difference.