Unit 14 · Electrical Circuits

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

She used the formula for X in the **left** gap. Here the known 20 Ω faces the 36 cm part of the wire and X faces the 64 cm part, so $\frac{20}{X} = \frac{36}{64}$ and $X = \frac{64}{36} \times 20 = \mathbf{35.6}$ Ω. A check: the balance point is nearer the left end, so the left resistance is the smaller one, and X must be more than 20 Ω, not less.

MARKING SCHEME

- ✓ The error: X is in the right gap, so it faces 100 − l, not l.
- ✓ 20/X = 36/64.
- ✓ X = 35.6 Ω (larger than 20 Ω, as the balance point near the left end shows).

2 Design it

ANSWER A · 4

i. The current must be I = 0.010 V ÷ 5.0 Ω = 2.0 mA. The total resistance is 2.0 V ÷ 0.0020 A = 1000 Ω, so the series resistance is 1000 − 5.0 = **995** Ω.

ii. k = 10 mV ÷ 10 m = **1.0 mV/m**.

iii. l = E/k = 6.3 ÷ 1.0 = **6.3 m** from the end A.

iv. Straight across the wire, the whole 2.0 V would be across 10 m (0.2 V/m) and 6.3 mV would balance only 3 cm from A: the reading could not be made accurately. A small gradient spreads the small e.m.f. over a long length, so the potentiometer is far more sensitive.

MARKING SCHEME

- ✓ I = 2.0 mA and the series resistance 995 Ω.
- ✓ k = 1.0 mV/m.
- ✓ Balance length 6.3 m.
- ✓ A small gradient makes the balance length long (more sensitive); with the cell alone it would be only about 3 cm.

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ No change with a cell of twice the e.m.f. (the condition has no e.m.f. in it).
- ✓ No change when the cell and galvanometer are interchanged.
- ✓ Interchanging the gap resistances moves it to 100 − l.

4 Show that

MARKING SCHEME A · 3

- ✓ The shunt's current $(n - 1)I_g$ and the equal p.d.s.
- ✓ S = G/(n − 1).
- ✓ GS/(G + S) simplified to G/n.

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5 Check the readings

ANSWER HA · 4

(The readings are made up, for a cell of internal resistance 1.0 Ω.)

i. $r = (l_1/l_2 - 1)R$: 1.00, 1.00, 1.27, 1.00, 1.00 Ω.

ii. Four readings agree: **$r = 1.0$ Ω**.

iii. The reading for R = 6 Ω (it gives 1.27 Ω). With r = 1.0 Ω, $l_2 = l_1R/(R + r) = 80.0 \times 6 \div 7 =$ **68.6 cm**.

MARKING SCHEME

- ✓ The row 1.00, 1.00, 1.27, 1.00, 1.00 Ω.
- ✓ r = 1.0 Ω from the four that agree.
- ✓ The odd reading is at R = 6 Ω.
- ✓ l_2 should have been 68.6 cm.

6 Work backwards

ANSWER A · 4

i. No current flows in the cell's branch, so 6.0 ÷ 30 = 0.20 A flows through both resistors, and the p.d. across the 20 Ω resistor is 0.20 × 20 = 4.0 V. The cell balances it: **E = 4.0 V**.

ii. Let V be the p.d. across the 20 Ω resistor. The currents into its top junction add to zero: (6.0 − V)/10 + (3.0 − V)/1.0 = V/20, so 0.6 + 3.0 = V(0.1 + 1 + 0.05), and V = 3.13 V. The cell's current is (3.0 − 3.13)/1.0 = −0.13 A: **0.13 A flows into its + terminal**, so the 3.0 V cell is being charged.

MARKING SCHEME

- ✓ 0.20 A through the resistors and 4.0 V across the 20 Ω resistor.
- ✓ E = 4.0 V.
- ✓ A correct junction (or loop) equation, giving 3.13 V across the 20 Ω resistor.
- ✓ 0.13 A into the + terminal of the 3.0 V cell (it is charged).

7 What if?

MARKING SCHEME A · 3

- ✓ The resistance becomes ¾ of what it was.
- ✓ $P = V^2/R$, so the power becomes 4/3 (33% more).
- ✓ More current and heat than the coil was made for: not safe.

8 Correct the misconceptions

ANSWER U · 3

1. At the balance point a potentiometer takes **no** current from the cell, so it measures the e.m.f. itself.
2. The high resistance is joined **in series** with the galvanometer (a low resistance in parallel makes an ammeter).
3. A superconductor **expels** the magnetic field from its interior when it is cooled below its critical temperature (the Meissner effect); keeping the field is what a perfect conductor would do.

MARKING SCHEME

- ✓ No current is drawn at balance.
- ✓ The high resistance goes in series.
- ✓ A superconductor expels the field (the Meissner effect).

9 Which explanation fits?

MARKING SCHEME U · 2

- ✓ Anjali: the current through the internal resistance lowers the terminal p.d.
- ✓ Reading 1.44 V.

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10 Think

ANSWER HA · 2

Either the test cell's + terminal is joined to the wrong end of the wire (not the end where the driver cell's + terminal is), or the p.d. across the whole wire is less than the test cell's e.m.f. (a weak driver cell, or too much resistance in the rheostat). Check the connections first; if the + terminals are right, reduce the rheostat's resistance (or use a stronger driver cell): if a balance point appears, the p.d. across the wire was too small.

MARKING SCHEME

- ✓ The two faults: + terminals not at the same end, or the p.d. across the wire less than the e.m.f.
- ✓ A sensible test that tells them apart (check the terminals, then raise the current in the wire).

11 Make your own

ANSWER HA · 2

For example: "A 10 Ω resistance is in the right gap of a meter bridge and an unknown resistance in the left gap. The balance point is 71.4 cm from the left end. Find the unknown resistance." $X = 71.4 \div 28.6 \times 10 = 25.0\ \Omega$. Any problem whose numbers give 25 Ω with the balance point away from 50 cm is right.

MARKING SCHEME

- ✓ A sensible meter bridge problem with the balance point away from the middle.
- ✓ Solved correctly to 25 Ω.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	11	14	8	**33**

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