Pages 264–269 Exam practice questions

1 Answer A

2 Answer A

3 Answer C

4 Answer B

5 Answer C

6 Answer B

7 Answer A

8 Answer C

9 Answer A

10 Answer C

11 a) Electromotive force (e.m.f.) is defined as the electrical work done per unit (coulomb) of charge as it flows through a source of electrical energy such as a cell, generator or power supply unit (p.s.u.). [1]

Internal resistance is the resistance inside a source of e.m.f. which leads to electrical energy being transferred to heat inside the source of e.m.f. [1]

b) $V = \mathcal{E} - Ir\ [1] = 12\ \mathrm{V} - (500\ A\ \times 5.0 \times 10^{-3}\ \Omega) = 9.5\ \mathrm{V}[1]$

12 a) As the two resistors in parallel have the same resistance,

$$R_{\mathrm{T}} = 50\ \Omega + \frac{800\ \Omega}{2}[1] = 450\ \Omega\ [1]\ (\text{or } 500\ \Omega \text{ to } 1\ \text{s.f.})$$

b) $P = \frac{V^2}{R} \Longrightarrow V = \sqrt{PR}\ [1] = \sqrt{(2.0\ \mathrm{W} \times 800\ \Omega)} = 40\ \mathrm{V}\ [1]$

c) Current through $50\ \Omega$ resistor $= 2 \times$ current through $800\ \Omega$ resistor.

Current through 800 Ω resistor = $\sqrt{\frac{P}{R}} = \sqrt{\frac{2.0\ W}{800\ \Omega}} = 0.050\ \mathrm{A}\ [1]$

Current through 50 Ω resistor = 0.10 A [1]

d) p.d. across 50 Ω resistor = *IR* = 0.10 × 50 = 5 V

$\Rightarrow$ e.m.f. = 40 V + 5 V = 45 V [1]

13 a) As the two resistors in parallel have the same resistance,

$$R_T = 5\ \Omega + \frac{5\ \Omega}{2}[1] = 7.5\ \Omega\ [1]\ (\text{or } 8\ \Omega \text{ to } 1\ \text{s.f.})$$

b) e.m.f. of P and Q in parallel = 1.2 V $\Rightarrow$ total e.m.f. = 3 × 1.2 V = 3.6 V [1]

c) Total current, $I_{\mathrm{T}} = \frac{\mathcal{E}}{R_{\mathrm{T}}}[1] = \frac{3.6\ \mathrm{V}}{7.5\ \Omega} = 0.48\ \mathrm{A} \Longrightarrow$ current through Q $= 0.24\ \mathrm{A}\ [1]$

d) Total charge (per second) through Q = current through Q [1] = 0.24 C [1]

e) P and Q will supply electrical energy for the longest period of time. This is because the charge flowing through P and Q (per second) is half the charge per second through R and S [1]. As e.m.f. is energy per charge, P and Q only need to supply half the energy each of R or S and so will supply energy for longer. [1]

14 a) p.d. across 330 Ω resistor = IR = 14.0 × 10^{-3} A × 330 Ω [1] = 4.62 V [1] = 4.6 V (2 s.f.)

b) $V_{1\,k} = \mathcal{E} - V_{330}$ [1] = 12 V − 4.62 V = 7.38 V[1] = 7.4 V (2 s. f.)

c) Total resistance, $R_{\mathrm{T}} = \frac{V}{I_T}$ [1] $= \frac{7.4\ \mathrm{V}}{14.0 \times 10^{-3}\ \mathrm{A}} = 530\ \Omega$ [2]

d) $\frac{1}{R} = \frac{1}{R1} + \frac{1}{R2}$; $\frac{1}{530} - \frac{1}{1000} = \frac{1}{R_{\mathrm{T}}}$; R_{T} = 1120 Ω [3]

e) As T increases, the resistance of the n.t.c. thermistor drops. The total resistance of the circuit also drops [1] so the current, measured by the ammeter increases, as $I \propto \frac{1}{R}$. [1]

15 a) $R_{A-E} = 10\ \mathrm{k\Omega} + 10\ \mathrm{k\Omega} = 20\ \mathrm{k\Omega}$ [1]; $R_{B-F} = 5\ \mathrm{k\Omega} + 2.5\ \mathrm{k\Omega} = 7.5\ \mathrm{k\Omega}$ [1];

$$\frac{1}{R_T} = \frac{1}{20 \times 10^3} + \frac{1}{7.5 \times 10^3} \Rightarrow R_T = 5454\ \Omega\ [1] = 5500\ \Omega\ (2\ \mathrm{s.f.})$$

b) Total current, $I_{\mathrm{T}} = \frac{\mathcal{E}}{R_{\mathrm{T}}} = \frac{6\ V}{5454\ \Omega} = 1.1 \times 10^{-3}$ A [1]

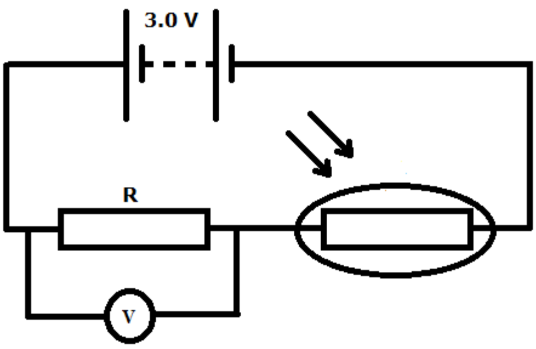
c)

Position of the voltmeter	p.d., V /V
C–E	3
D–F	2
C–D	1

d) i) p.d. across A–E remains constant as the connections are directly across the battery [1], this means the p.d. across C–E remains constant as well. [1]

ii) As the resistance across the thermistor decreases, the p.d. across D–F decreases [1] as $V \propto R$. [1]

16 a)



Correct symbols [1]
Correct connection [1]

b) $V_{\mathrm{thermistor}} = \mathcal{E} - V_{\mathrm{resistor}}$ [1] = 3.0 V − 0.80 V = 2.2 V[1]

c) $I_{\mathrm{T}} = \frac{V}{R_{\mathrm{T}}}$ [1] $= \frac{2.2\ \mathrm{V}}{1500\ \Omega} = 1.46 \times 10^{-3}\ \mathrm{A} = 1.5 \times 10^{-3}\ \mathrm{A}$ (2 s. f.)

d) $R_{\mathrm{resistor}} = \frac{V}{I_T}$ [1] $= \frac{0.80\ \mathrm{V}}{1.46 \times 10^{-3}\ \mathrm{A}} = 547.9\ \Omega$ [1] = 550 Ω (2 s. f.)

e) As the resistance falls so the total current increases. [1] This causes the p.d. across the fixed resistor to increase as $V \propto I$. [1]

f) If the resistance of the voltmeter is the same as the fixed resistor, their combined resistance is half the resistance of the fixed resistor. [1] This means the total resistance of the circuit drops and the total current will increase. [1]

17 a) $R_{\mathrm{T}} = \frac{\mathcal{E}}{I_{\mathrm{T}}}[1] = \frac{12\ \mathrm{V}}{2.2\ \mathrm{A}} = 5.45\ \Omega\ [1] = \ 5.5\ \Omega\ (2\ \mathrm{s.f.})$

b) $R_{\mathrm{T}} = R + \left(\frac{1}{\frac{1}{R}+\frac{1}{2R}}\right)[1] = \frac{5R}{3} = 5.45\ \Omega\ [1] \Longrightarrow R = 3.27\ \Omega\ [1]\ = 3.3\ \Omega\ (2\ \mathrm{s.f.})$

c) The p.d. across QR, $V = IR_{\mathrm{parallel}} = 2.2\ \mathrm{A}\ \times (5.45\ \Omega - 3.27\ \Omega\ )[1] = 4.796$ $\mathrm{V} = 4.8\ \mathrm{V}\ (2\ \mathrm{s.f.})$. The current through Q and R, $I = \frac{V}{R}\ [1] = \frac{4.796\ \mathrm{V}}{(2 \times 3.27\ \Omega\ )} = 0.73\ \mathrm{A}\ [1]$

d) $P=I^2R = (2.2\ \mathrm{V})^2 \times 3.27\ \Omega = 15.83\ \mathrm{W}$ [1] = 16 W (2 s.f.)

18 a) p.d. across R_2 is 12 V – 7.5 V = 4.5 V. $I = \frac{V}{R_2} = \frac{4.5\ V}{150\ \Omega} = 0.030\ \mathrm{A}\ [1]$

b) $P = I^2R$ [1] = $(0.030)^2 \times 150\ \Omega$ = 0.135 W [1] = 0.14 W (2 s.f.)

c) $R_1 = \frac{V}{I}[1] = \frac{7.5\ \mathrm{V}}{0.030\ \mathrm{A}} = 250\ \Omega\ [1]$

d) Initially the thermistor must have the same resistance as R_2 at the temperature of the rest of the circuit. [1] If the voltmeter reading changes, the temperature of the thermistor must have changed. If the voltmeter reading goes up, then the thermistor must be hotter, and if it goes down, it must be colder. [1]

19 a) Total resistance = sum of all resistors, $R_T = 120\ \mathrm{k\Omega} + 8.0\ \mathrm{k\Omega} + 42\ \mathrm{k\Omega} = 170\ \mathrm{k\Omega}\ [1]$

Total current, $I_T = \frac{\mathcal{E}}{R_T} = \frac{9.0\ \mathrm{V}}{170 \times 10^3\ \Omega} = 5.29 \times 10^{-5}\ \mathrm{A}\ [1] = 5.3 \times 10^{-5}\ A\ (2\ \mathrm{s.f.})$

b) $V = IR = 5.29 \times 10^{-5}\ \mathrm{A} \times 8.0 \times 10^3\ \Omega = 0.4232\ \mathrm{V}\ [1] = 0.42\ \mathrm{V}\ (2\ \mathrm{s.f.})$

c) As the resistance of the LDR drops, so the total current increases. [1] This causes the p.d. across R to increase as $V \propto I$. [1]

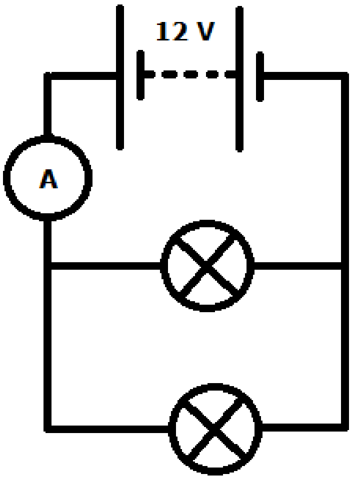
d) If p.d. across R is 0.90 V, then the current through R must be

$I = \frac{V}{R} = \frac{0.90\ \mathrm{V}}{8.0 \times 10^3\ \Omega} = 1.125 \times 10^{-4}\ \mathrm{A}.$

Total resistance must therefore be $R_{\mathrm{T}} = \frac{\mathcal{E}}{I} = \frac{9.0\ \mathrm{V}}{1.125 \times 10^{-4}\ \mathrm{A}} = 80\ 000\ \Omega\ [1]$

$\Longrightarrow R_{\mathrm{variable}} = 80000\ \Omega - 12000\ \Omega - 8000\ \Omega = 60\ 000\ \Omega\ [1]$

20 a)



Correct symbols [1]
Correct connection [1]

b) Current flowing through each bulb, $I = \frac{P}{V} = \frac{32}{12} = 2.6\ \text{A}\ [1] \Longrightarrow I_T = 2 \times 2.6\ \text{A} = 5.2\ \text{A}\ [1]$

c) $P = \frac{V^2}{R} \Longrightarrow R = \frac{V^2}{P}[1] = \frac{(12\ \text{V})^2}{32\ \text{W}} = 4.5\ \Omega[1]$

d) If ammeter has a higher resistance, the total resistance of the circuit will increase, causing the total current drawn from the battery to decrease. [1] This reduces the current flowing through each bulb, reducing their power and their brightness. [1]

e) p.d. across each bulb in series $= \frac{12\ \text{V}}{2} = 6.0\ \text{V} \Longrightarrow P = \frac{V^2}{R} = \frac{(6.0\ \text{V})^2}{4.5\ \Omega} = 8.0\ \text{W}$. [1] Power is therefore ¼ of power in parallel – the bulbs will be substantially dimmer. [1]

f) If one bulb malfunctions, the other will still work, increasing safety. [1]

21 a) Current flowing through X, $I_X = \frac{P_X}{V_X}\ [1] = \frac{36\ \text{W}}{12\ \text{V}} = 3.0\ \text{A}[1]$

Current flowing through Y, $I_Y = \frac{P_Y}{V_Y} = \frac{2.0\ \text{W}}{4.5\ \text{V}} = 0.4\ \text{A}\ [1].$

b) As p.d. across X = 12 V [1], then p.d. across R_1 = 24 V – 12 V = 12 V [1]

c) Current through R_1 = 3.0 A + 0.4 A = 3.4 A [1]

d) $R_{R_1} = \frac{V_{R_1}}{I_{R_1}} = \frac{12\ \text{V}}{3.4\ \text{A}} = 3.53\ \Omega\ [1] = 3.5\ \Omega\ (2\ \text{s.f.})$

e) $V_{R_2} = 12\ \text{V} - 4.5\ \text{V} = 7.5\ \text{V}\ [1]$

f) $R_2 = \frac{V_{R_2}}{I_{R_2}}[1] = \frac{7.5\ \text{V}}{0.40\ \text{A}} = 18.75\ \Omega[1] = 19\ \Omega\ (2\ \text{s.f.})$

g) Total resistance of circuit increases. Total current drawn decreases. [1] PD across R_1 decreases. [1]

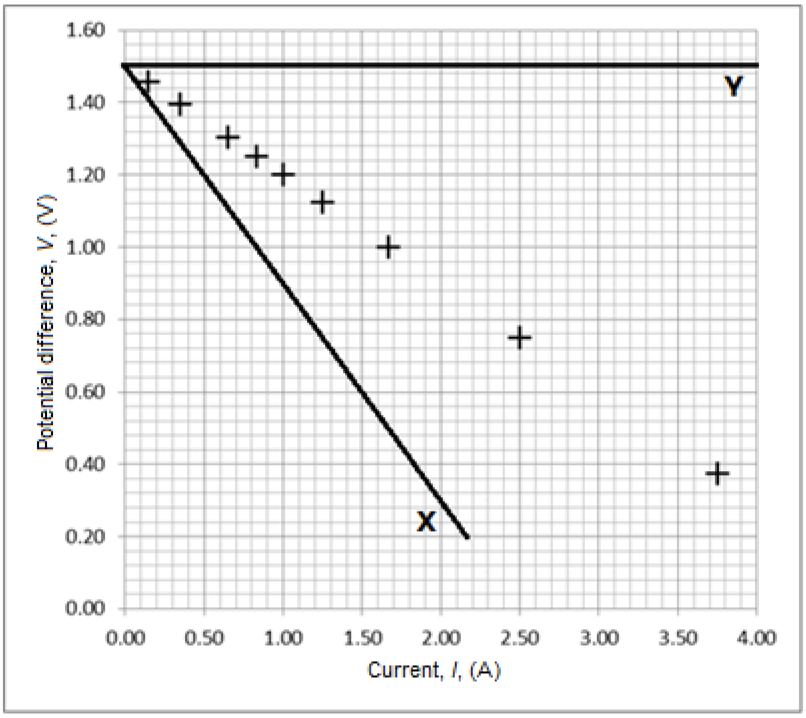
h) The PD across R_1 decreases, so the PD across X increases, so it gets brighter.

22 a) $V = \mathcal{E} - Ir$, so as *I* increases *Ir* increases [1] and $\mathcal{E} - Ir$ decreases [1].

b) $\mathcal{E}$ = *y*-intercept of *V*–*I* graph =1.50 V [1]

r is the gradient of *V*–*I* graph = $\frac{(1.46 - 0.38)}{(3.75 - 0.15)}[1] = 0.30\ \Omega\ [1]$

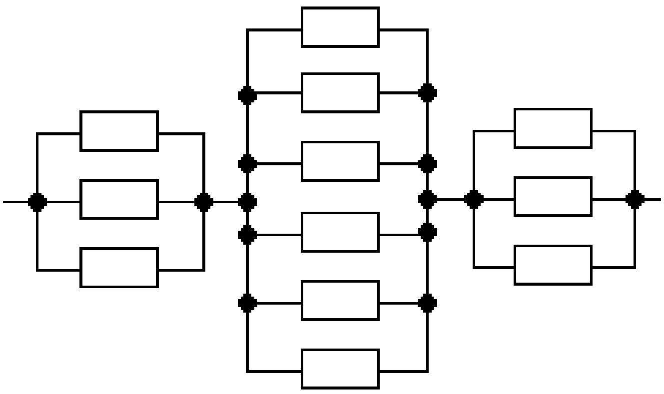
c)



d) As above.

Pages 269–273 Stretch and challenge questions

23 a) The circuit is equivalent the one shown below:



b) Resistance of three 1 Ω resistors in parallel = $\frac{1}{3}$ Ω.

Resistance of six 1 Ω resistors in parallel = $\frac{1}{6}$ Ω.

Total resistance = $\frac{1}{3} + \frac{1}{6} + \frac{1}{3}$ Ω = 0.83 Ω.

24 C

25 B

26 A

27 D

28 A

29 **a)** AC – $R_1 + R_2$ = 1.5 V / 37.5 mA

$R_1 + R_2 = 40\ \Omega$

BD – $R_3 + R_4$ = 1.5 V / 25 mA

$R_3 + R_4 = 60\ \Omega$

AB – $R_1 + R_5 + R_3$ = 1.5 V / 30 mA

$R_1 + R_5 + R_3 = 50\ \Omega$

CD – $R_2 + R_5 + R_4$ = 1.5 V / 15 mA

$R_2 + R_5 + R_4 = 100\ \Omega$

b) For R_5 add: AB + CD gives $R_1 + R_5 + R_3 + R_2 + R_5 + R_4 = 50 + 100\ \Omega$.

And using AC and BD we obtain 40 Ω + 60 Ω + 2 R_5 = 150 Ω. So that $R_5 = 25\ \Omega$.

c) For CD connected together, we have $R_2 + R_4$ in parallel with 25 Ω.

Using CD, ($R_2 + R_5 + R_4 = 100\ \Omega$) we find $R_2 + R_4$ is 75 Ω

75 Ω in parallel with 25 Ω is 18.75 Ω

And this is in series with $R_1 + R_3$ which from AB is 25 Ω

Resulting in 25 Ω +18.75 Ω which is 44 Ω.

d) An intuitive guess that the fault is ¼ of the distance from A or C (15 metres). Some justification gains the second mark $R_1 + R_3 = 25\ \Omega$; $R_2 + R_4 = 75\ \Omega$, or even further with:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$So\ R_1 + \frac{R_1 R_4}{R_2} = 25$$

$$R_1\left(1 + \frac{R_4}{R_2}\right) = 25$$

Similarly

$$R_2\left(1 + \frac{R_4}{R_2}\right) = 75$$

$$\frac{R_1}{R_2} = \frac{1}{3} = \frac{15\text{ metres}}{45\text{ metres}}$$

OR

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$So\ R_3 + \frac{R_2 R_3}{R_4} = 25$$

$$R_3\left(1 + \frac{R_2}{R_4}\right) = 25$$

Similarly

$$R_2\left(1 + \frac{R_2}{R_4}\right) = 75$$

$$\frac{R_3}{R_4} = \frac{1}{3} = \frac{15\ \text{metres}}{45\ \text{metres}}$$

30 a) Max. 4

Current flows and power is converted/heat energy produced (in the thermistor).

Calculation $P = V^2/R = 25/120 = 0.2$ W

This causes the temperature of the thermistor to rise and its resistance to fall.

Increased current flows so more heat energy is produced.

Cycle continues until thermistor overheats/is destroyed.

b) 50 Ω as the variation of R_{th} would be relative to (50 + 120) Ω, the (change in potential is the change in R_{th} relative to) smallest total resistance.

c) 50 Ω is the smallest resistance and might be too little to prevent the 'thermal runaway' described in part (a)

31 a) 40 V. B is at the same potential as X because no current flows along BX.

b) i) 200 – 40 = 160 V

ii) $\frac{(200\ \text{m} - 40\ \text{m})}{d} = \frac{160\ \text{m}}{d}$ or reciprocal

c) 40 V

d) So that X is at the same potential and then the same current flows into the ground through R.

e) $\frac{(300\ \text{m} - 40\ \text{m})}{(50\ \text{m} - d)} = \frac{260\ \text{m}}{(50\ \text{m} - d)}$

f) i) Because the same currents flowed along AX and BX, so

$I = \frac{V_{\text{AX}}}{R_{\text{AX}}} = \frac{V_{\text{BX}}}{R_{\text{BX}}}$ and R is proportional to length.

ii) $\frac{160\ \text{m}}{d} = \frac{260\ \text{m}}{(50\ \text{m} - d)}$; $260d = 50 \times 160 - 160d$; hence d = 19 km

32 a) $R = \frac{V}{I} \Longrightarrow P = (I \times R) \times I = I^2R \Longrightarrow P = V \times \left(\frac{V}{R}\right) = \frac{V^2}{R}$

b) Fixed V applied to the heater, so $P = \frac{V^2}{R}$ and hence low R needed.

c) Case 1: same p.d .across each wire, so $\frac{V^2}{R}$ implies smaller R for larger power, so copper glows first (because R is lower).

OR

Case 2: same current through each wire, so I^2R implies larger R for a larger power, so iron glows first (larger R).

d) Expression $I = kV^4$ needed. As $P = VI$ so $P = kV^5$, so 6 W $= k \times (230\ \text{V})^5 \Longrightarrow$

$k = 9.3 \times 10^{-12}\ \text{W V}^{-5}$ or $P_{1200} = 6 \times \left(\frac{1200}{230}\right)^5 \Longrightarrow P_{1200} = 23\ \text{kW}$