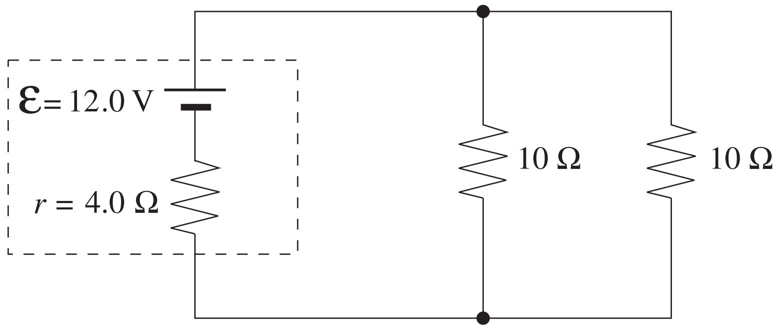
CIRCUITRY
PROVINCIAL EXAMINATION ASSIGNMENT
ANSWER KEY / SCORING GUIDE

PART A: Multiple Choice (each question worth ONE mark) not edited

Q	K	Q	K
1.	B	20.	A
2.	C	21.	A
3.	A	22.	C
4.	C	23.	B
5.	A	24.	C
6.	C	25.	C
7.	A	26.	A
8.	C	27.	C
9.	D	28.	C
10.	A	29.	B
11.	A	30.	D
12.	A	31.	B
13.	D	32.	B
14.	B	33.	C
15.	B	34.	D
16.	A	35.	D
17.	D	36.	C
18.	B	37.	C
19.	A		

1. a) For the circuit below, what is the terminal voltage of the battery? **(4 marks)**



$$R_{parallel} = 5.0\ \Omega$$

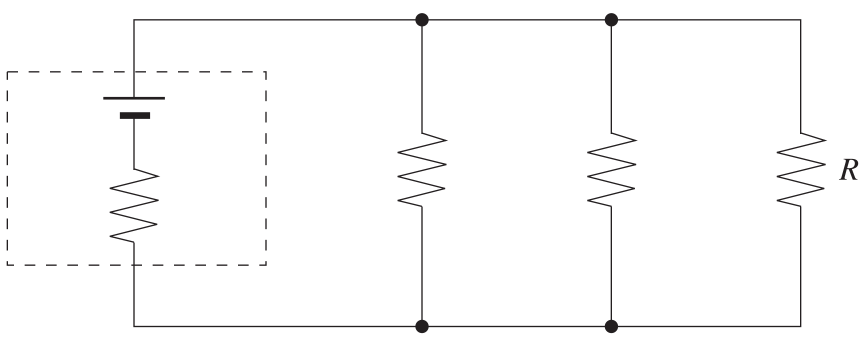
$$R_{total} = 9.0\ \Omega$$

$$I_{total} = \frac{V}{R} = \frac{12.0}{9.0} = 1.33\ \text{A}$$

$$Ir \text{ drop} = 1.33(4.0) = 5.3\ \text{V}$$

$$V_{terminal} = 12.0 - 5.3 = 6.7\ \text{V}$$ ← **4 marks**

b) If resistor *R* is added in parallel to the circuit as shown, what is the effect on the terminal voltage? **(1 mark)**

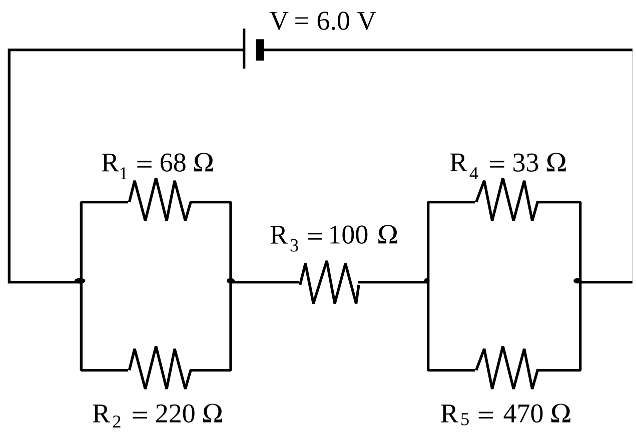


- ☐ increase
- ☐ no change
- ☑ decrease

c) Using principles of physics, explain your choice for b). **(4 marks)**

Additional *R* in parallel results in an overall lower *R*, thus an increase in current. (2 marks) As a consequence, a greater voltage drop *Ir* occurs across the internal resistance resulting in a smaller terminal voltage. (2 marks)

2. Consider the circuit shown in the diagram below.



a) What is the total resistance of the circuit? **(3 marks)**

$$\frac{1}{R_1^{||}} = \frac{1}{68\ \Omega} + \frac{1}{220\ \Omega}$$

$$R_1^{||} = 51.9\ \Omega$$

$$\frac{1}{R_2^{||}} = \frac{1}{33\ \Omega} + \frac{1}{470\ \Omega}$$

$$R_2^{||} = 30.8\ \Omega$$

$$\therefore R_T = R_1^{||} + 100\ \Omega + R_2^{||}$$

$$= 51.9\ \Omega + 100\ \Omega + 30.8\ \Omega$$

$$= 182.7\ \Omega \rightarrow 1.8 \times 10^2\ \Omega$$

← **3 marks**

b) What is the current through the 100 Ω resistor? **(2 marks)**

$$I_{circuit} = I_{100} = \frac{V}{R_T}$$

$$= \frac{6.0\ V}{182.7\ \Omega}$$

$$= 3.3 \times 10^{-2}\ \text{A}$$

← **2 marks**

c) What is the power dissipated in the 100 Ω resistor? **(2 marks)**

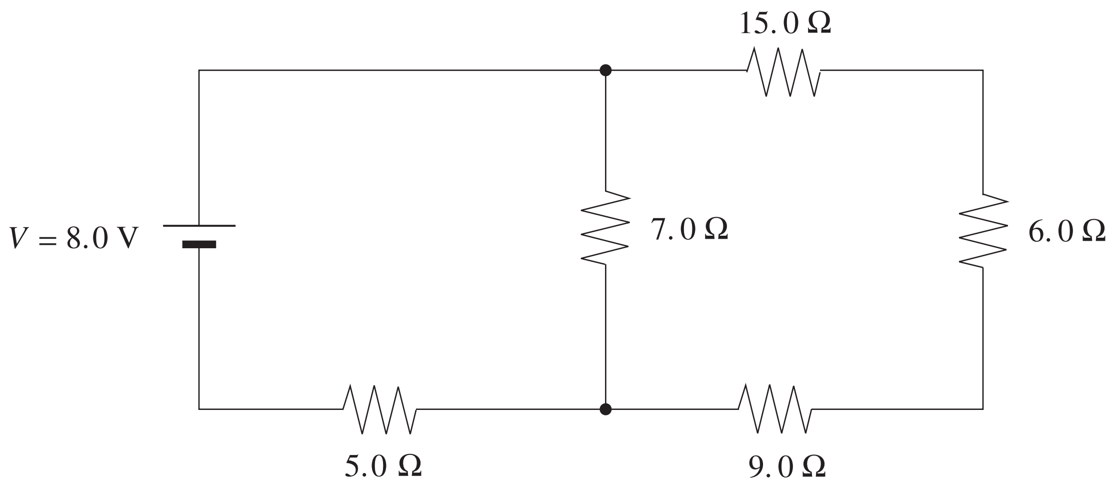
$$P_{100} = I^2 R$$

$$= (0.0328\ A)^2 \cdot 100\ \Omega$$

$$= 0.11\ \text{W}$$

← **2 marks**

3. What is the potential difference across the $6.0\ \Omega$ resistor in the circuit shown? **(7 marks)**



$$R_{p_1} = 15.0\ \Omega + 6.0\ \Omega + 9.0\ \Omega$$

$$= 30.0\ \Omega$$ ← **1 mark**

$$\frac{1}{R_p} = \frac{1}{7.0} + \frac{1}{30.0}$$

$$R_p = 5.68$$ ← **1 mark**

$$R_T = 5.0 + 5.68$$

$$= 10.68$$ ← **1 mark**

$$I_T = \frac{V_T}{R_T} = \frac{8.0}{10.68} = 0.75$$ ← **1 mark**

$$V_p = V_T - V_5$$

$$= 8.0\ \text{V} - 0.75 \times 5.0$$

$$= 4.25$$ ← **1 mark**

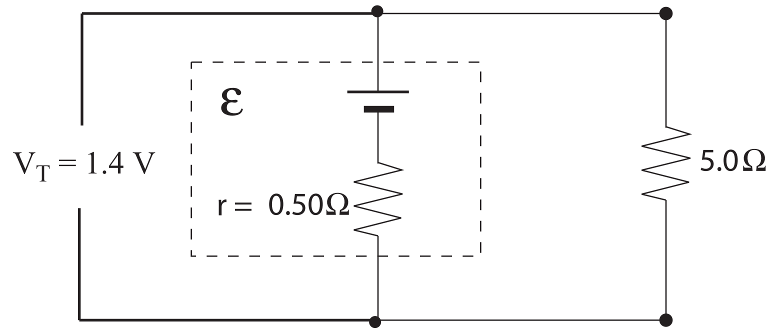
$$I_p = \frac{V_p}{R_p} = \frac{4.25}{30.0} = 0.142$$ ← **1 mark**

$$\text{V}_6 = I_p R$$

$$= 0.142 \times 6.0$$

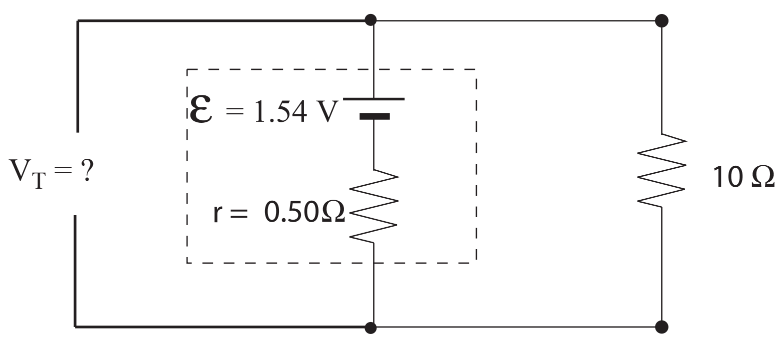
$$= 0.85\ \text{V}$$ ← **1 mark**

4. A cell has an internal resistance of $0.50\ \Omega$. It has a terminal voltage of 1.4 V when connected to a $5.0\ \Omega$ external resistance. What will its terminal voltage be if the $5.0\ \Omega$ resistor is replaced by a $10.0\ \Omega$ resistor? **(7 marks)**



$I = \frac{1.4\ \text{V}}{5.0\ \Omega} = 0.28$ A ← **1 mark**

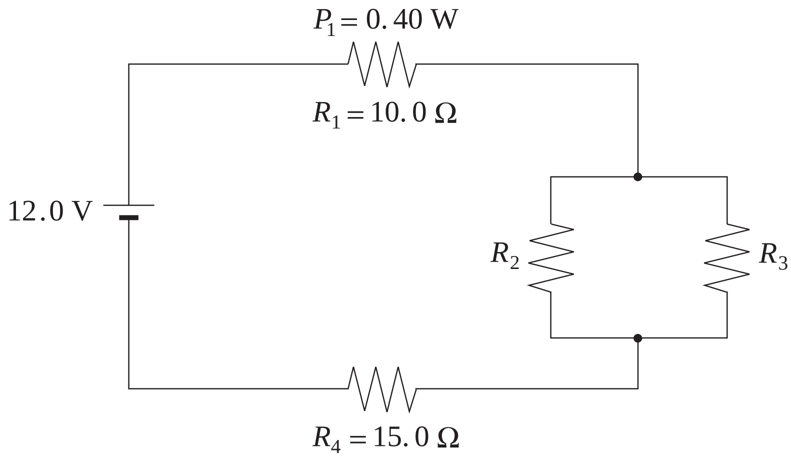
$\varepsilon = V_T + Ir = 1.4\ \text{V} + (0.28\ \text{A})(0.50\ \Omega) = 1.54$ V ← **3 marks**



$I = \frac{1.54\ \text{V}}{10.5\ \Omega} = 0.147$ A ← **1 mark**

$V_T = \varepsilon - Ir = 1.54\ \text{V} - (0.147\ \text{A})(0.50\ \Omega) = 1.47$ V ← **2 marks**

5. In the circuit below, resistor R_1 dissipates $0.40\ \text{W}$. Resistors R_2 and R_3 are identical.



What is the resistance of R_2? **(7 marks)**

Key:

$$P = I^2R$$
$$P_1 = I^2R_1$$
$$I = \left(\frac{P_1}{R_1}\right)^{\frac{1}{2}} = \left(\frac{0.40}{10}\right)^{\frac{1}{2}} = 0.20\ \text{A}$$
$\leftarrow$ **2 marks**

$$V_1 = IR = 0.2(10) = 2\ \text{V}$$
$\leftarrow$ **1 mark**

$$V_4 = IR = 0.2(15) = 3\ \text{V}$$
$\leftarrow$ **1 mark**

$$V_3 = V_4 = 12 - V_1 - V_4 = 7\ \text{V}$$
$\leftarrow$ **1 mark**

$$I_2 = I_3$$
$\leftarrow$ **1 mark**

$$V_3 = I_3R_3$$
$$7 = 0.1\ R_2$$
$$R_2 = 70\ \Omega$$
$\leftarrow$ **1 mark**

Alternate Key:

$$P = I^2 \cdot R$$

$$P_1 = I^2 \cdot R_1$$

$$\therefore I = \left(\frac{P_1}{R_1}\right)^{\frac{1}{2}}$$

$$= \left(\frac{0.40}{10.0}\right)^{\frac{1}{2}}$$

$$= 0.20 \text{ A}$$ ← **2 marks**

$$\therefore R_{circuit} = \frac{V}{I}$$

$$= \frac{12.0}{0.20}$$

$$= 60.0\ \Omega$$ ← **2 marks**

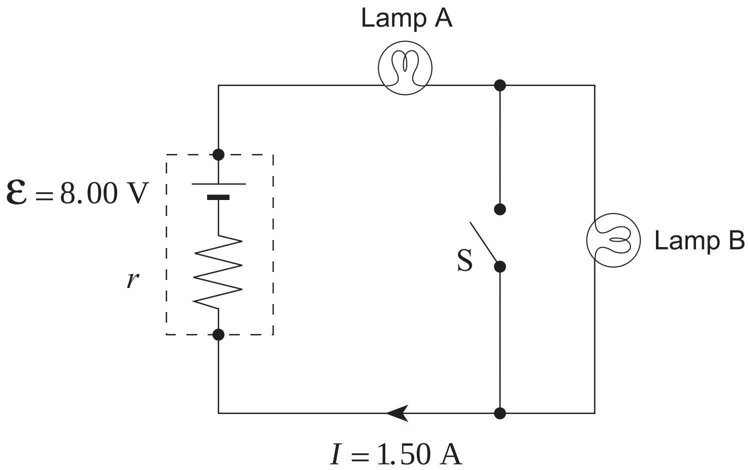
$$\therefore R_{||} = 60.0\ \Omega - (10.0\ \Omega + 15.0\ \Omega)$$

$$= 35.0\ \Omega$$ ← **2 marks**

$$\therefore R_2 = R_3 = 2 \cdot 35.0\ \Omega$$

$$= 70.0\ \Omega$$ ← **1 mark**

6. The circuit shown consists of an 8.00 V battery and two light bulbs. Each light bulb dissipates 5.0 W. Assume that the light bulbs have a constant resistance. Switch S is open.



a) If a current of 1.50 A flows in the circuit, what is the internal resistance r of the battery?

(4 marks)

Resistance Solution:

$$P = I^2 R$$

$$\therefore R_{bulb} = \frac{P}{I^2}$$

$$= \frac{5.0}{(1.50)^2}$$

$$= 2.22\ \Omega \quad \leftarrow \textbf{1 mark}$$

$$R_T = \frac{\mathcal{E}}{I}$$

$$= \frac{8.00}{1.50}$$

$$= 5.33\ \Omega \quad \leftarrow \textbf{1 mark}$$

$$\therefore r = R_T - 2\cdot\left(R_{bulb}\right)$$

$$= 5.33 - 2(2.22) \quad \leftarrow \textbf{1 mark}$$

$$= 0.89\ \Omega \quad \leftarrow \textbf{1 mark}$$

Voltage Solution:

$$\left.\begin{aligned} P &= IV \\ 5 &= 1.5\ V \\ V_{bulb} &= 3.3\ \text{V} \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} V_{terminal} &= 3.3 \times 2 \\ V_{terminal} &= 6.7 \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} V_{terminal} &= \mathcal{E} - Ir \\ 6.7 &= 8 - 1.5r \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$r = 0.89\ \Omega \leftarrow \textbf{1 mark}$$

Power Solution:

$$P_T = IV$$

$$= 1.5(8)$$

$$= 12\ \text{W} \quad \leftarrow \textbf{1 mark}$$

$$P_{bulbs} = 2(5) = 10 \quad \leftarrow \textbf{1 mark}$$

$$P_r = 12 - 10 \quad \leftarrow \textbf{1 mark}$$

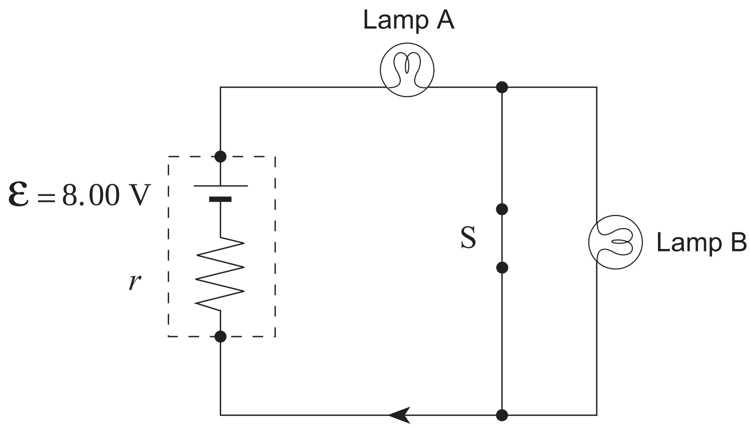
$$P_r = 2\ \text{W}$$

$$P = I^2 R$$

$$r = \frac{2}{1.5^2}$$

$$= 0.89\ \Omega \quad \leftarrow \textbf{1 mark}$$

b) The switch S is now closed



Lamp A will now be **(1 mark)**

i) ☑ brighter.

☐ the same brightness as before.

☐ dimmer.

(Check one response.)

The battery's terminal voltage will now be **(1 mark)**

ii) ☐ greater than before.

☐ the same as before.

☑ less than before.

(Check one response.)

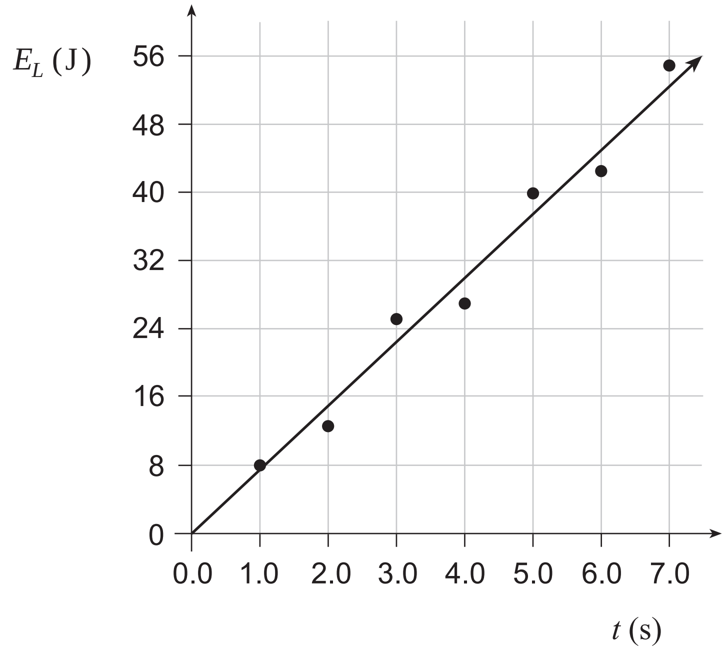
c) Using principles of physics, explain your answers to b). **(3 marks)**

Total circuit resistance decreases when the switch is closed. Therefore, the circuit current increases. ← 1 mark

Since $P = I^2R$, the power dissipated by Lamp A increases and it will therefore be brighter. ← 1 mark

Since the circuit current has increased, the voltage drop across the internal resistance increases and the terminal voltage drops. ← 1 mark

7. The graph shows the light energy E_L emitted by a bulb versus time t.



a) Find the power output of the bulb. **(2 marks)**

$$P = \frac{\Delta E}{\Delta t} \qquad \leftarrow \textbf{1 mark}$$

$$\cong 7.6 \text{ W} \qquad \leftarrow \textbf{1 mark}$$

b) If this bulb is 20% efficient, find the power delivered to the bulb. **(3 marks)**

$$\frac{P_{out}}{P_{in}} = 0.20$$

$$\frac{7.6}{P_{in}} = 0.20$$

$$P_{in} \cong 38 \text{ W} \qquad \leftarrow \textbf{3 marks}$$

8. A 12 V battery from a car is used to operate a 65 W headlight.

a) How much energy does the headlight use in 1.5 hours? **(2 marks)**

$$E = P \times t \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

$$= 65 \times 1.5 \times 3\,600 \quad \leftarrow 1 \text{ mark}$$

$$= 3.5 \times 10^{5} \text{ J} \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

b) What total charge passes through the headlight during this time? **(3 marks)**

$$Q = \frac{\Delta E}{V} \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

$$= \frac{3.5 \times 10^{5} \text{ J}}{12 \text{ V}} \quad \leftarrow 2 \text{ marks}$$

$$= 29\,000 \text{ C} \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

OR

$$Q = It \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

$$= (5.42 \text{ A})(5\,400 \text{ s}) \quad \leftarrow 2 \text{ marks}$$

$$= 29\,000 \text{ C} \quad \leftarrow \tfrac{1}{2} \text{ mark}$$

c) What is the total number of electrons that pass through the headlight during this time period? **(2 marks)**

$$N = \frac{Q}{e} \quad \leftarrow 1 \text{ mark}$$

$$= \frac{29\,000}{1.6 \times 10^{-19} \text{ C}} \quad \leftarrow 1 \text{ mark}$$

$$= 1.8 \times 10^{23} \text{ electrons}$$

9. Two identical light bulbs, wired in parallel to a battery, are equally bright. When one of the bulbs burns out, however, the other bulb is observed to glow brighter. Using principles of physics, explain why the battery causes the remaining bulb to glow more brightly. **(4 marks)**

When one of two bulbs, wired in parallel to a battery, burns out, the resistance of the circuit increases. ← 1 mark

This results in a smaller current being delivered by the battery. ← 1 mark

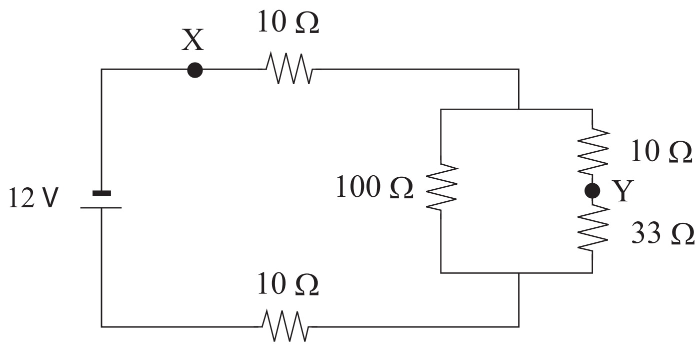
The internal resistance of the battery causes the terminal voltage to increase, because $V_T = \mathcal{E} - Ir$. ← 1 mark

The bulb will now dissipate more power, because $P = \frac{V^2}{R}$. ← 1 mark (not in isolation)

If the number of paths for current is reduced to one, the current increases in the remaining path. ← 1 mark

← Any 4 for 4 marks

10. What is the potential difference between points X and Y? **(7 marks)**



$$\left.\begin{aligned} R_T &= 10\Omega + 10\Omega + \left(\frac{1}{100\Omega} + \frac{1}{(10\Omega + 33\Omega)}\right)^{-1} \\ &= 10\Omega + 10\Omega + 30\Omega \\ &= 50\Omega \end{aligned}\right\} \text{2 marks}$$

$$I_T = \frac{V_T}{R_T} = \frac{12V}{50\Omega} = 0.24A \Big\} \text{ 1 mark}$$

$$V_X = 10\Omega \times 0.24A = 2.4V \} \text{0.5 mark}$$

$$I = \frac{7.2V}{43\Omega} = 0.167A \Big\} \text{ 2 marks}$$

$$V_Y = 10\Omega \times 0.167A = 1.67V \} \text{0.5 mark}$$

$$\therefore V_{XY} = 2.4V + 1.67V = 4.07V \} \text{1 mark}$$