This part of the experiment is prepared with Online LaTeX Editor Overleaf and the circuits are drawn in LTspice. Visit the website for the code here:

https://www.overleaf.com/read/xqffqxgzqdrq#0f7ad1

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3. PRELIMINARY WORK

The units of the resistance values are not given in figures. In the answer sections, the resistance values are assumed to have ohm units.

3.1 Calculate the values of the currents I, I_1, I_2, I_3 and I_4 and the voltages V_1, V_2, V_3, V_4 and V_5 in *Figure 6*. Show the meter connections for these measurements.

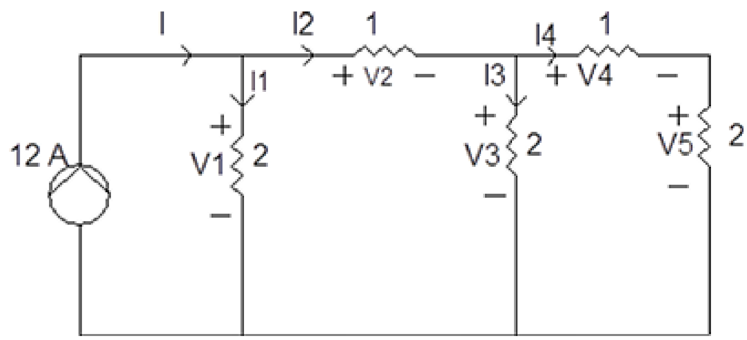
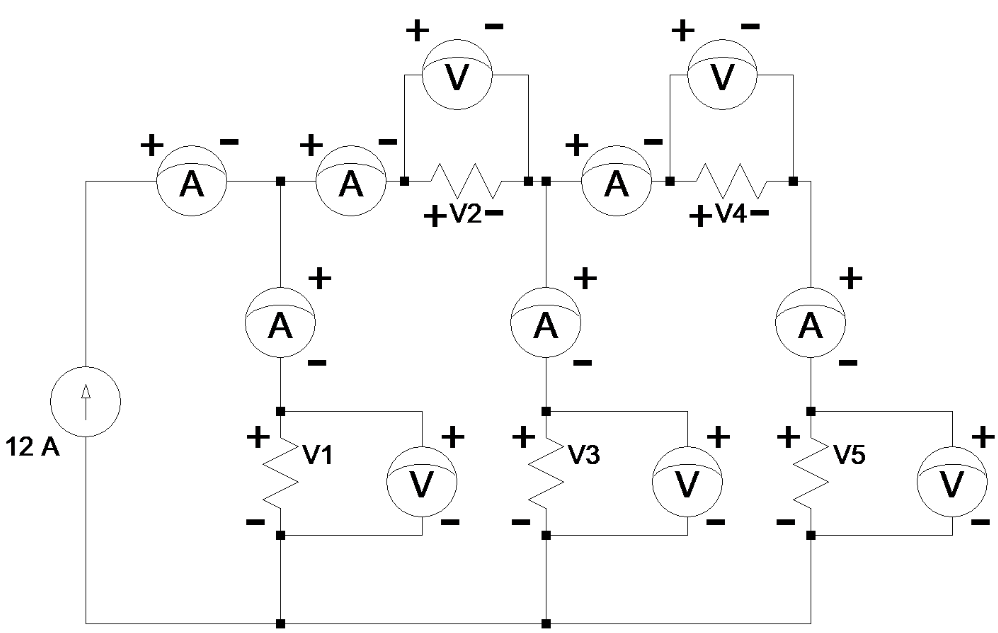


Figure 6.

Answer: The connections of meters should be as follows.



The ammeters are connected properly so the current enters from the positive side. As for the type of connection, the ammeters are connected in series. Meanwhile, the voltmeters are connected in parallel to the resistors. This will help us accurately measure the desired values.

Let's calculate I. Since the main current has not yet been distributed, I is equal to the current provided by the source.

$\boxed{I = 12\text{A}}$

From Kirchhoff's Current Law, one may obtain these equations:

$$-I + I_1 + I_2 = 0 \;\rightarrow\; I = I_1 + I_2$$
$$-I_2 + I_3 + I_4 = 0 \;\rightarrow\; I_2 = I_3 + I_4$$
$$I - I_1 - I_3 - I_4 = 0 \;\rightarrow\; I = I_1 + I_3 + I_4$$

We may benefit from Kirchhoff's Voltage Law but first, name several points for ease.

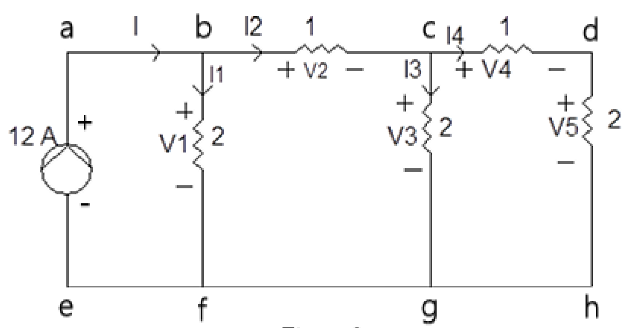


Figure 6.

b-c-g-f-b $\rightarrow\; V_2 + V_3 - V_1 = 0 \;\rightarrow\; V_1 = V_2 + V_3$

c-d-h-g-c $\rightarrow\; V_4 + V_5 - V_3 = 0 \;\rightarrow\; V_3 = V_4 + V_5$

b-c-d-h-g-f-b $\rightarrow\; V_2 + V_4 + V_5 - V_1 = 0 \;\rightarrow\; V_1 = V_2 + V_4 + V_5$

Eventually, we may use Ohm's Law. Note that V_4 and V_5 have the same current, which is I_4. Let R_1, R_2, R_3, R_4, R_5 be the corresponding resistance of V_1, V_2, V_3, V_4, V_5, respectively.

$$V_1 = I_2 \cdot R_2 + I_3 \cdot R_3 = I_2 + 2I_3$$

$$V_1 = I_2 \cdot R_2 + I_4 \cdot R_4 + I_4 \cdot R_5 = I_2 + 3I_4$$

From these two equations, we get:

$$I_2 + 2I_3 = I_2 + 3I_4 \;\rightarrow\; I_3 = \frac{3}{2}I_4 \text{ (1)}$$

We need to find another equation to solve the problem.

$$V_3 = I_4 \cdot R_4 + I_4 \cdot R_5 = 3I_4$$

$$V_3 = I_1 \cdot R_1 - I_2 \cdot R_2 = 2I_1 - I_2$$

From these two equations, we get:

$$2I_1 - I_2 = 3I_4$$

$$2I_1 - I_3 - I_4 = 3I_4 \; [I_2 = I_3 + I_4]$$

$$2I_1 - I_3 = 4I_4 \;\; [Substitute \text{ (1)}]$$

$$I_1 = \frac{11}{4}I_4 \text{ (2)}$$

As earlier, we found the equations $I = I_1 + I_3 + I_4$ and $I_2 = I_3 + I_4$. We now have the relation between all variables. Using (1) and (2),

$$I = \frac{21}{11}I_1 = \frac{21}{10}I_2 = \frac{21}{6}I_3 = \frac{21}{4}I_4$$

$$\boxed{I_1 = \frac{11}{21}I = \frac{11 \cdot 12}{21} = \frac{44}{7} \approx 6.29\text{A}} \quad \boxed{I_2 = \frac{10}{21}I = \frac{10 \cdot 12}{21} = \frac{40}{7} \approx 5.71\text{A}}$$

$$\boxed{I_3 = \frac{6}{21}I = \frac{6 \cdot 12}{21} = \frac{24}{7} \approx 3.43\text{A}} \quad \boxed{I_4 = \frac{4}{21}I = \frac{4 \cdot 12}{21} = \frac{16}{7} \approx 2.29\text{A}}$$

Apply Ohm's Law again with numerical values.

$$\boxed{V_1 = I_1 \cdot R_1 = \frac{44}{7} \cdot 2 = \frac{88}{7} \approx 12.57\text{V}} \quad \boxed{V_2 = I_2 \cdot R_2 = \frac{40}{7} \cdot 1 = \frac{40}{7} \approx 5.71\text{V}}$$

$$\boxed{V_3 = I_3 \cdot R_3 = \frac{24}{7} \cdot 2 = \frac{48}{7} \approx 6.86\text{V}} \quad \boxed{V_4 = I_4 \cdot R_4 = \frac{16}{7} \cdot 1 = \frac{16}{7} \approx 2.29\text{V}}$$

$$\boxed{V_5 = I_4 \cdot R_5 = \frac{16}{7} \cdot 2 = \frac{32}{7} \approx 4.58\text{V}}$$

3.2 For the circuit given in *Figure 7*, the values of R_1 and V_1 are given. Find out the values of R_2 and I.

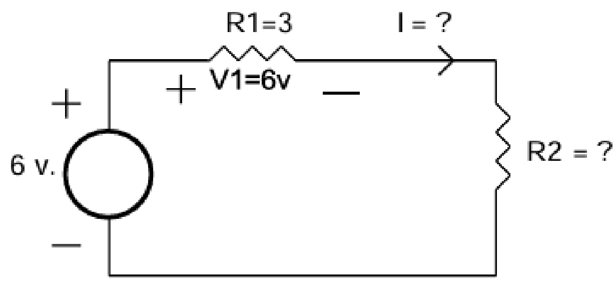


Figure 7.

Answer: First off, we can determine the sign of each terminal of R_2. Let it be plus (+) sign upper side and minus (-) sign on the other side of the resistor.

The Ohm's Law states that the resistance can be found if the voltage across and the current through the circuit element are known.

$$I = \frac{V_1}{R_1} = \frac{6V}{3\Omega} = 2A \ \rightarrow \ \boxed{I = 2\text{A}}$$

We use Kirchhoff's Voltage Law in order to find the voltage across R_2. Let us choose the node at the top left corner and traverse the circuit in the clockwise direction. We get such an equation:

$$V_1 + I \cdot R_2 - 6V = 0 \ \rightarrow \ 6V + I \cdot R_2 - 6V = 0 \ \rightarrow \ I \cdot R_2 = 0$$

Since we know the value of the current, which is different from zero, the resistance R_2 equals zero.

$$\boxed{R_2 = 0}$$

3.3 Find the equivalent resistance R_{ab} between points a and b for the circuit in *Figure 8.*

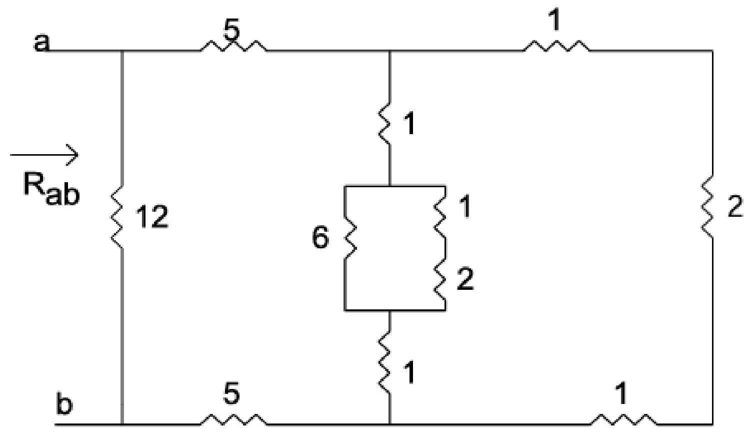


Figure 8.

Answer: Recall that R_{eq} is equal to the sum of the resistance of the resistors connected in series. R_{eq} is equal to the reciprocal of the sum of the reciprocal of each resistance of the resistors connected in parallel. In mathematical notation:

$$R_{eq,s} = \sum_{i=1}^{n} R_i = R_1 + R_2 + ... + R_n \qquad \frac{1}{R_{eq,p}} = \sum_{i=1}^{n} \frac{1}{R_i} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}$$

We approach this question by resolving the resistors in their simplest connectedness.

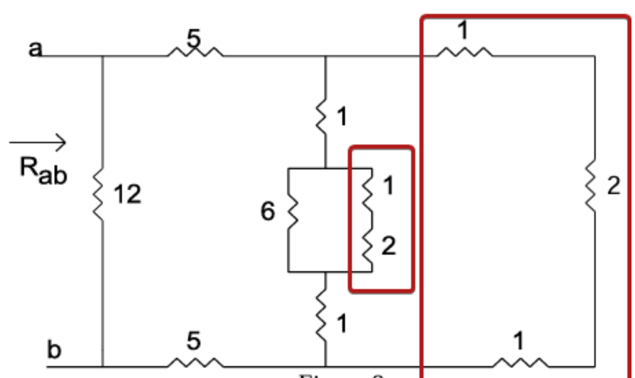
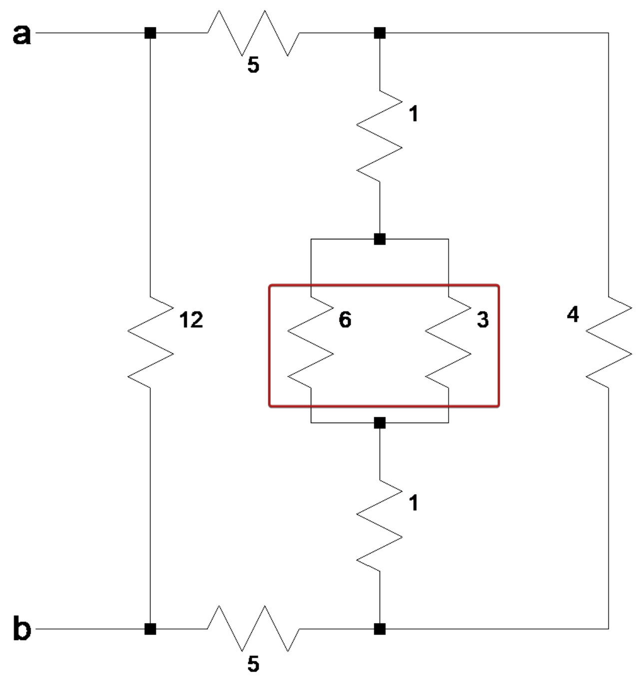
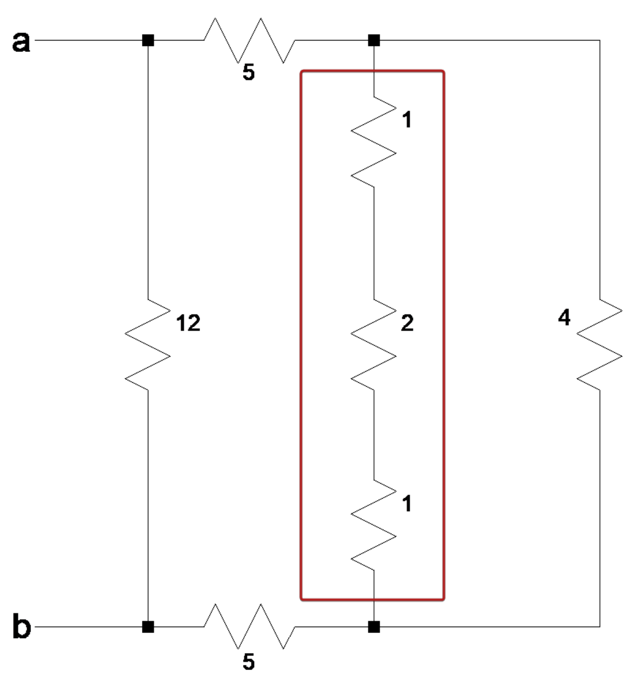


Figure 8.

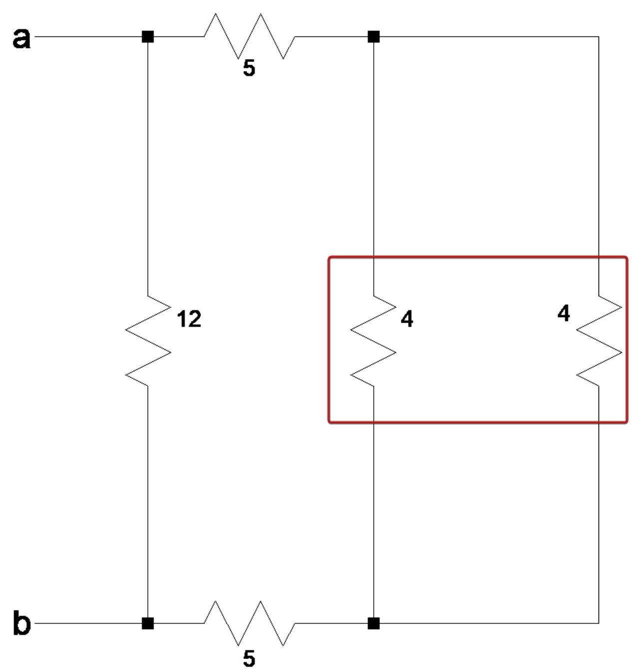
$$R_{eq,left} = 1 + 2 = 3\Omega \quad R_{eq,right} = 1 + 2 + 1 = 4\Omega$$



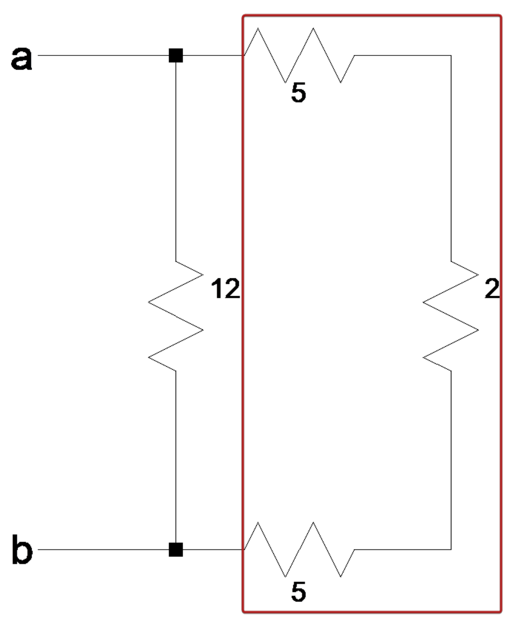
$$\frac{1}{R_{eq}} = \frac{1}{6} + \frac{1}{3} \;\rightarrow\; R_{eq} = 2\Omega$$



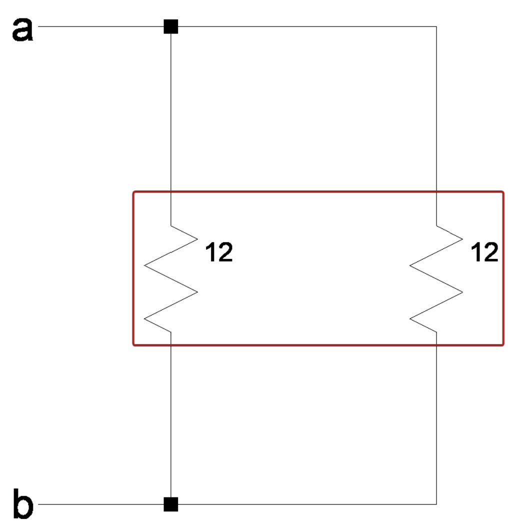
$$R_{eq} = 1 + 2 + 1 = 4\Omega$$



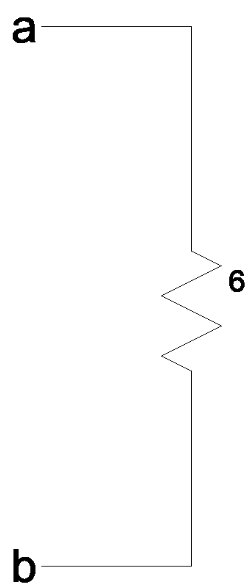
$$\frac{1}{R_{eq}} = \frac{1}{4} + \frac{1}{4} \;\rightarrow\; R_{eq} = 2\Omega$$



$$R_{eq} = 5 + 2 + 5 = 12\Omega$$



$$\frac{1}{R_{eq}} = \frac{1}{12} + \frac{1}{12} \quad \rightarrow \quad R_{eq} = 6\Omega$$



Therefore, we conclude that $\boxed{R_{ab} = 6\Omega}$.

3.4 For the circuit shown in *Figure 9*, the value of R_2 is to be measured using the ohmmeter. However, the connection in *Figure 9* does not give the correct value of the resistor. Why? Redraw the circuit showing the true connections.

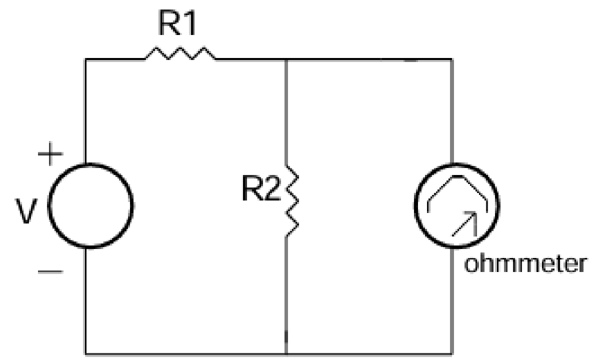
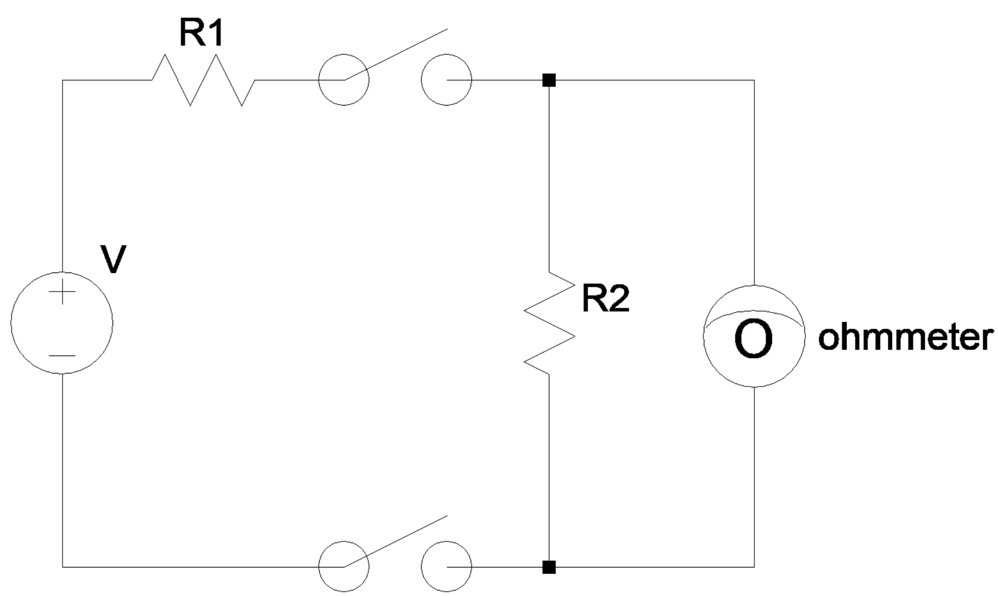


Figure 9.

Answer: When using an ohmmeter, one must check whether the circuit is live. If so, the measurement of the ohmmeter would deflect because there would be another power source in conjunction with the ohmmeter's. To handle this, we may add switches to the circuit so R_1 and V get disconnected from the other components.



The ohmmeter is now connected to the terminals of R_2, and we expect it measures the resistance correctly.

3.5 *Figure 10* shows a carbon resistor. For each of the resistance values given, write down the correct color bands.

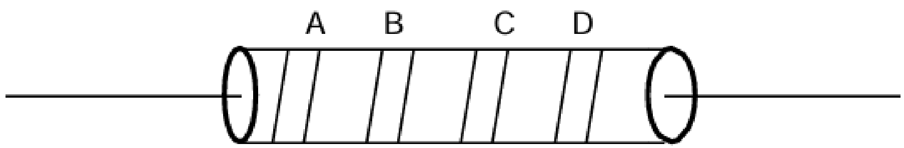


Figure 10.

a) 100 ± 10%   b) 120 ± 5%   c) 220 ± 20%   d) 330 ± 10%

Answer: Use the formula $R = AB \times 10^C \pm D\%\ \Omega$.

a) $D\% = 10\% \ \rightarrow \boxed{\text{D} = 10}$

$AB \times 10^C = 100$

$\boxed{A = 1, B = 0, C = 1} \ \rightarrow \ 10 \times 10^1 = 100$

b) $D\% = 5\% \ \rightarrow \boxed{\text{D} = 5}$

$AB \times 10^C = 120$

$\boxed{A = 1, B = 2, C = 1} \ \rightarrow \ 12 \times 10^1 = 120$

c) $D\% = 20\% \ \rightarrow \boxed{\text{D} = 20}$

$AB \times 10^C = 220$

$\boxed{A = 2, B = 2, C = 1} \ \rightarrow \ 22 \times 10^1 = 220$

d) $D\% = 10\% \ \rightarrow \boxed{\text{D} = 10}$

$AB \times 10^C = 330$

$\boxed{A = 3, B = 3, C = 1} \ \rightarrow \ 33 \times 10^1 = 330$

Looking up the color chart, the color bands are given below.

Option\Band	A	B	C	D
a)	Brown	Black	Brown	Silver
b)	Brown	Red	Brown	Gold
c)	Red	Red	Brown	None
d)	Orange	Orange	Brown	Silver

3.6 For the resistor shown in *Figure 10*, the color bands of A, B, C and D are given below. Write down the values of the resistors and their tolerances.

	A	B	C	D
a)	Red	Black	Red	Silver
b)	Red	Red	Brown	Gold
c)	Green	Blue	Gold	Gold
d)	Violet	Gray	Orange	Silver
e)	Red	White	Orange	Gold

Answer: We use the formula $R = AB \times 10^C \pm D\%\ \Omega$

a) $R = 20 \times 10^2 \pm 10\% \ \rightarrow \ \boxed{R = 2.0 \times 10^3 \pm 10\%\ \Omega}$

b) $R = 22 \times 10^1 \pm 5\% \ \rightarrow \ \boxed{R = 2.2 \times 10^2 \pm 5\%\ \Omega}$

c) $R = 56 \times 10^{-1} \pm 5\% \ \rightarrow \ \boxed{R = 5.6 \pm 5\%\ \Omega}$

d) $R = 78 \times 10^3 \pm 10\% \ \rightarrow \ \boxed{R = 7.8 \times 10^4 \pm 10\%\ \Omega}$

e) $R = 29 \times 10^3 \pm 5\% \ \rightarrow \ \boxed{R = 2.9 \times 10^4 \pm 5\%\ \Omega}$