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Diagram 1: A circuit with a battery, two resistors R₁ and R₂, and a voltmeter V connected in series. A red 'X' is drawn over the voltmeter, and the text "voltmeter in series" is written below it.

Diagram 2: A circuit with a battery, two resistors R₁ and R₂, and a voltmeter V connected in parallel across R₂. A red 'X' is drawn over the voltmeter, and the text "ammeter in parallel" is written below it.

Diagram 3: A circuit with a battery, two resistors R₁ and R₂, and an ammeter A connected in parallel across R₁. A red 'X' is drawn over the ammeter, and the text "ammeter in parallel" is written below it.

Diagram 4: A circuit with a battery, two resistors R₁ and R₂, and an ammeter A connected in series with the battery. A red checkmark is drawn next to this diagram.

Question 3: Rank the equivalent resistance of the five circuits below from greatest to least. Show each calculation clearly.

- circuit 1**: Two resistors of 8Ω in series.
- circuit 2**: Two resistors of 8Ω in parallel.
- circuit 3**: One resistor of 4Ω.
- circuit 4**: Two resistors of 4Ω in parallel.

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Question 2: Resistors R₁ and R₂ have an equivalent resistance of 6 ohms when connected in the circuit shown below. The resistance of R₁ could be

- 1 Ω
- 5 Ω
- 8 Ω
- 4 Ω

Explain your answer choice.

$(6) = \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^{-1}$

$\frac{1}{6} = \frac{1}{R_1} + \frac{1}{R_2}$

$\frac{1}{6} - \frac{1}{8} > 0$

Diagram 5: A circuit with a battery, two resistors of 3Ω in series, and a third resistor of 3Ω in parallel across the middle section.

Diagram 6: A circuit with a battery, one resistor of 1Ω in series, and a second resistor of 3Ω in parallel across the middle section.

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3. Rank the equivalent resistance of the five circuits below from greatest to least. Show each calculation clearly.

i. circuit 1

(1)

ii. circuit 2

(2)

iii. circuit 3

(3)

iv. circuit 4

(4)

v. circuit 5

$R_T = 16\Omega$
 $= 8+8$

$R_T = 4\Omega$
 $R_p = \left(\frac{1}{8} + \frac{1}{8}\right)^{-1}$

1. In which circuit above are meters properly connected to measure current through R₁ and potential difference across R₂? Explain.

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1 2 3 4 5 6 7

1. In which circuit above are meters properly connected to measure current through R₁ and potential difference across R₂? Explain.

2. Resistors R₁ and R₂ have an equivalent resistance of 6 ohms when connected in the circuit shown below. The resistance of R₁ could be

(A) 1 Ω
(B) 5 Ω
(C) 8 Ω
(D) 4 Ω

Explain your answer choice.

iv. circuit 4

$\left(\frac{1}{4} + \frac{1}{2}\right)^{-1} = 6\Omega$

v. circuit 5

$\left(\frac{1}{3} + \frac{1}{3}\right)^{-1} = 1.7\Omega$

4Ω

3Ω

3Ω

3Ω

1Ω

3Ω

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4. Three identical resistors have an equivalent resistance of 12 ohms when connected in series. What is the equivalent resistance if they are connected in parallel?

$12\Omega = R_T = R_1 + R_2 + R_3 = 3R$

$R = 4\Omega$

$R_p = \left(\frac{1}{4} + \frac{1}{4} + \frac{1}{4} \right)^{-1}$

$= 1.3\Omega$

5. The diagram above shows a parallel circuit.

- What is the equivalent resistance?
- What is the current measured by the ammeter?
- What is the voltage drop across each resistor?
- What is the current through each resistor?

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5. The diagram above shows a parallel circuit.

- What is the equivalent resistance? ✓
- What is the current measured by the ammeter? ✓
- What is the voltage drop across each resistor? ✓
- What is the current through each resistor? ✓

(a) $R_T = \left(\frac{1}{20} + \frac{1}{30} + \frac{1}{60} \right)^{-1} = 10\Omega$

(b) $I_T = \frac{V_T}{R_T} = \frac{110V}{10\Omega} = 11A$

(c) B/c the 20Ω , 30Ω , and 60Ω resistor are in parallel they all have the same potential difference $\Rightarrow 110V$

(d) $I_{20\Omega} = \frac{110V}{20\Omega} = 5.5A$ $I_{30\Omega} = \frac{110V}{30\Omega} = 3.7A$

$I_{60\Omega} = \frac{110V}{60\Omega} = 1.8A$

6. Consider the series circuit shown above. A voltmeter and ammeter are connected as shown.

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Diagram: A series circuit diagram with a 15-volt source at the bottom. Above it is a parallel branch with a 5.0 Ω resistor and a 15.0 Ω resistor in series. To the right of the 15.0 Ω resistor is a resistor R. An ammeter shows 0.50 A. A voltmeter is connected across the 5.0 Ω resistor.

Handwritten Solutions:

- $V = IR = (0.50\text{A})(5.0\Omega) = 2.5\text{V}$
- $V_T = I_T R_T \quad R = R_T - 5 - 15 \Rightarrow$
 $15\text{V} = (0.50\text{A})R_T \Rightarrow R_T = 30\Omega \quad R = 10\Omega$

6. Consider the series circuit shown above. A voltmeter and ammeter are connected as shown.

- What reading would the voltmeter show? ✓
- What is the value of the resistor R? ✓

Diagram: A series circuit with a 12.0 V battery at the bottom. Three resistors are connected in series: 820 Ω, 680 Ω, and 470 Ω.

7. Determine (a) the equivalent resistance of the circuit shown above, (b) the voltage across each resistor.

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Diagram: A series circuit with a 12.0 V battery at the bottom. Three resistors are connected in series: 820 Ω, 680 Ω, and 470 Ω. Currents I_T, I₁, and I₂ are labeled flowing through the resistors.

Handwritten Solutions:

- $R_T = 470\Omega + \left(\frac{1}{680} + \frac{1}{820}\right)^{-1} = 841.7\Omega$
- $I_T = \frac{12.0\text{V}}{840\Omega} = 0.014\text{A}$
- $V_{470\Omega} = (0.014\text{A})(470\Omega) = 6.58 = 6.6\text{V}$

7. Determine (a) the equivalent resistance of the circuit shown above, (b) the voltage across each resistor, and (c) the current through each resistor.

(a) $I_T = I_{470\Omega} = 0.014\text{A}$
 $I_{680\Omega} = V_{680\Omega}/R = 5.4\text{V}/680\Omega = 0.0079\text{A}$
 $I_{820\Omega} = V_{820\Omega}/R = 5.4\text{V}/820\Omega = 0.0066\text{A}$

8. Calculate the terminal voltage for a battery with an internal resistance of 0.90Ω and an emf of 8.50V when the battery is connected in series with (a) an 81.0-Ω resistor, and (b) a 810.0-Ω resistor.

9. What is the internal resistance of a 12.0-V car battery whose terminal voltage drops to 8.4 V when the starter draws 75 A? What is the resistance of the starter?

8. Calculate the terminal voltage for a battery with an internal resistance of 0.90Ω and an emf of $8.50V$ when the battery is connected in series with (a) an $81.0-\Omega$ resistor, and (b) a $810.0-\Omega$ resistor.

(a) $V_T = E - Ir$ $E = I_T R_T \Rightarrow I_T = \frac{E}{R_T} = \frac{E}{R + r} = \frac{8.50V}{81.0 + 0.9\Omega} = 0.1038A$ ($V_T = 8.4V$) (a)

~~(b)~~ What is the internal resistance of a $12.0-V$ car battery whose terminal voltage drops to $8.4 V$ when the starter draws $75 A$? What is the resistance of the starter?

(b) $V_T = E - Ir$ $I_T = \frac{8.50}{810.0 + 0.9\Omega} = 0.01048A$
 $= 8.50 - (0.01048A)(0.9\Omega)$
 $= 8.49V \Rightarrow V_T = 8.5V$ (b)

10. A 5.0 -ohm resistor, a 20.0 -ohm resistor, and a 24 -volt source of potential difference are connected in parallel. A single ammeter is placed in the circuit to read the total current.

9. What is the internal resistance of a $12.0-V$ car battery whose terminal voltage drops to $8.4 V$ when the starter draws $75 A$? What is the resistance of the starter?

$$\begin{aligned} E &= 12.0V \\ \Delta V_T &= 8.4V \\ I &= 75A \end{aligned}$$

$$\begin{aligned} E &= I_T R_T \\ E &= I_T (R + r) \\ \therefore R &= \frac{E}{I_T} - r \\ &= \frac{12.0V}{75A} - 0.048\Omega = 0.112\Omega \end{aligned}$$

(i) $\therefore r = \frac{V - E}{-I} = \frac{(8.4V) - (12.0V)}{-75A} = 0.048\Omega$

(ii) $\therefore r = \frac{V - E}{-I} = \frac{(8.4V) - (12.0V)}{-75A} = 0.048\Omega$

10. A 5.0 -ohm resistor, a 20.0 -ohm resistor, and a 24 -volt source of potential difference are connected in parallel. A single ammeter is placed in the circuit to read the total current.

- On the diagram below, draw in wires connecting the components shown to make a complete circuit that will function as described above.

Diagram showing a 5.0Ω resistor symbol.

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10. A 5.0-ohm resistor, a 20.0-ohm resistor, and a 24-volt source of potential difference are connected in parallel. A single ammeter is placed in the circuit to read the total current.

- On the diagram below, draw in wires connecting the components shown to make a complete circuit that will function as described above.

(a) $R_T = \left(\frac{1}{5} + \frac{1}{20}\right)^{-1} = 4.0\Omega$

(b) $I_T = \frac{V_T}{R_T} = \frac{24V}{4.0\Omega} = 6.0A$

Determine the total resistance. (a)
Determine the total current measured by the ammeter. (b)

11. Three 240- Ω resistors can be connected together in four different ways, making combinations of series and/or parallel circuits. What are these four ways, and what is the net resistance in each case?

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8. Three 240- Ω resistors can be connected together in four different ways, making combinations of series and/or parallel circuits. What are these four ways, and what is the net resistance in each case?

(1) $R_T = 240 + 240 + 240 = 720\Omega$

(2) $R_T = \left(\frac{1}{240} + \frac{1}{240} + \frac{1}{240}\right)^{-1} = 80\Omega$

(3) $R_T = \left(\frac{1}{240} + \frac{1}{240}\right) + 240 = 360\Omega$

(4) $R_T = \left(\frac{1}{240} + \frac{1}{240+240}\right)^{-1} = 160\Omega$

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11. Three 240-Ω resistors can be connected together in four different ways, making combinations of series and/or parallel circuits. What are these four ways, and what is the net resistance in each case?

12. Complete a V-I-R chart for the circuit shown below.

$$R_T = \left(\frac{1}{10} + \frac{1}{2 + \left(\frac{1}{6} + \frac{1}{9} \right)^{-1}} \right)^{-1}$$

$$R_T = 3.6 \Omega$$

$$I_T = \frac{V_T}{R_T} = \frac{9V}{3.6\Omega} = 2.5A$$

$$V_T = V_{10\Omega} = 9V \Rightarrow I_{10\Omega} = \frac{V_T}{R} = \frac{9V}{10\Omega} = 0.9A$$

$$I_1 = I_T - I_2 = 2.5 - 0.9 = 1.6A$$

$$I_2 = \frac{V_T - 5.8V}{6\Omega} = 0.97A$$

$$I_4 = \frac{5.8V}{9.0\Omega} = 0.64A$$

$$V_{2\Omega} = I_1 R = (1.6A)(2\Omega) = 3.2V$$

$$r = 2.0 \Omega$$

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13. Three resistors are connected in parallel as shown above. What is the total power dissipated?

$$V_T = 110V$$

$$R_T = 10\Omega$$

$$P = \frac{V^2}{R} = \frac{(110V)^2}{(10\Omega)} = 1210W$$

14. Three resistors are connected in series as shown above. What is the total power dissipated?

$$V_T = 9.0V$$

$$R_T = 8.0\Omega + 2.0\Omega + 12.0\Omega = 22\Omega$$

$$P = \frac{V^2}{R} = \frac{(9.0V)^2}{22\Omega} = 3.7W$$

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