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EG160: Experiment 2

Ohm's Law

Objective :- To understand Ohm's law, to verify Ohm's law for a simple circuit. To understand and verify Ohm's law for series and parallel combination of resistances.

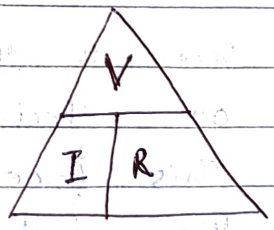
- To understand Non-Ohmic devices.

Theory :- The Ohm's law states that the current through a conductor is directly proportional to the voltage across its terminals.

$$\therefore V \propto I$$

$$V = IR$$

where, R is the proportionality constant known as resistance of the conductor.



In the given figure, the horizontal line represents fraction and vertical line represents multiplication. To find Ohm's law equation in different form, it is convenient to use this figure known as Ohm's Law Triangle.

To find V, put V on left hand side of equal to and use other two with the sign between them (represented by line)

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this gives, $V = IR$.

Repeat same to find I and R in terms of other two factors corresponding to them.

Mathematical Proof of Ohm's Law :-

To proof ohm's law mathematically, we have to proof that $\frac{V}{i}$ = constant.

Consider a cylindrical conductor of length l and cross-sectional area A having n number of electrons per unit volume. Let a potential difference of V be applied at its end. Assuming the potential drop throughout the conductor is uniform, therefore, electric field E built inside the conductor is

$$E = \frac{V}{l} \quad \text{--- (I)}$$

Due to this electric field a force eE acts on electron in opposite direction to the field. This force produces an acceleration of $\frac{eE}{m}$ and the electron slowly reaches a velocity (V_d) which is almost constant (due to collisions with other electrons and positive ions). Let us assume the average distance and time between two collisions be d and τ.

$$\therefore d = \frac{1}{2}\left(\frac{eE}{m}\right)\tau^2 \quad \text{--- (II)}$$

and, $V_d = \frac{d}{\tau}$

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$$\therefore \quad v_d = \frac{eE\tau}{2m} \quad \text{— (III)}$$

$$v_d = \frac{e\tau V}{2ml} \quad \text{— (IV)} \quad \left(\text{from (I)} \; E = \frac{V}{l}\right)$$

Now, consider a length $v_d \Delta t$ of the conductor. The volume of this portion is $A v_d \Delta t$. Since free electron density is n, therefore number of free electrons in this region is $n A v_d \Delta t$. Thus, the charge ΔQ in this area is,

$$\Delta Q = en A v_d \Delta t$$

Since this charge crosses area A in time Δt, the current is given by,

$$i = \frac{\Delta Q}{\Delta t} = neAv_d$$

$$i = \frac{neAe\tau V}{2ml} \quad \left(\text{from (IV)}\right)$$

$$V = \left(\frac{2ml}{ne^2\tau A}\right) i$$

Since, n and τ remains constant at a particular temperature, the quantity $\frac{2ml}{ne^2\tau A}$ is constant.

Hence, $\frac{V}{i}$ is constant and ohm's law is proved.

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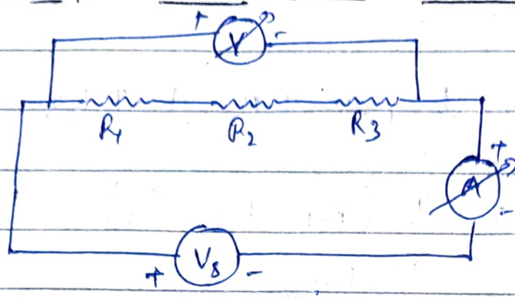
Ohm's law for resistances in series



Three resistors are connected in series to a source voltage V_s. Since current in each resistor in a series circuit is same, let this current be I,

The equivalent resistance of the circuit is,

$$R_{eq} = R_1 + R_2 + R_3 \quad \text{--- (I)}$$

$$\therefore \text{ current } \quad I = \frac{V_s}{R_{eq}} \Rightarrow V_s = I R_{eq} \quad \text{--- (II)}$$

The source voltage should be equal to the sum of voltage drops across each resistor.

From Ohm's Law,

$$V_1 = I R_1$$
$$V_2 = I R_2$$
$$V_3 = I R_3$$

$$\therefore V_1 + V_2 + V_3 = I(R_1 + R_2 + R_3)$$

$$V_1 + V_2 + V_3 = I R_{eq} \quad \text{(from (I))}$$

$$V_1 + V_2 + V_3 = V_s \quad \text{(from (II))}$$

Hence, Ohm's law is verified for series combination

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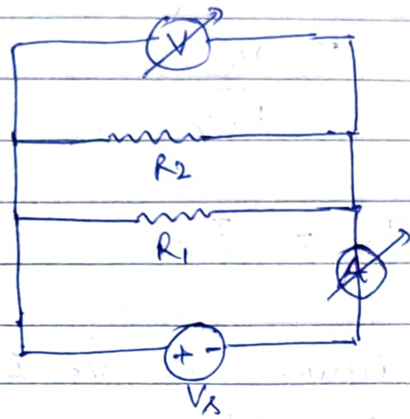
of resistors.

Ohm's Law for resistances in parallel



Two resistors are connected in parallel to a source voltage V_s. Since voltage across each resistor in parallel circuit is same, voltage across R_1 and R_2 is V_s.

The equivalent resistance of the circuit is

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \quad \text{--- (1)}$$

∴ total current supplied by source V_s is $(I_T) = \frac{V_s}{R_{eq}}$ — (11)

Let the current through R_1 and R_2 be I_1 and I_2 respectively,

From Ohm's Law,

$$I_1 = \frac{V_s}{R_1}$$

$$I_2 = \frac{V_s}{R_2}$$

The total current I_T should be equal to current sum through each resistor,

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$$\therefore \quad I_1 + I_2 = \frac{V_s}{R_1} + \frac{V_s}{R_2}$$

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

$$= \frac{V_s}{R_{eq}} \quad \text{(from (1))}$$

$$\therefore \quad I_1 + I_2 = I_T \quad \{\text{from (11)}\}$$

Hence, Ohm's law is verified for parallel combination of resistors.

Note-: The devices which do not obey Ohm's law are known as Non-ohmic devices. In the case of Non-ohmic devices, the V versus I graph is not linear. Examples of such devices are diodes, thermistors etc.

Procedure to perform the experiment -:

Step-1: Set the value of resistance. Keep it constant throughout the experiment.

Step-2: The voltmeter must be connected in parallel to resistor and ammeter must be connected in series with the resistor.

Step-3: Vary the source voltage and note the readings of voltage and current using voltmeter and ammeter.

Step-4: Plot the V-I graph for observed readings.

Step-5: V-I graph will come out to be a straight line, which verifies the Ohm's law.

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For series combination, voltmeter will be placed parallel to the combination of resistors and ammeter will be in series with resistors. We have to keep the resistances values fixed and note down the readings to plot the graph.

For parallel combination, ammeter will be placed in series with the combination of resistors and voltmeter will be placed parallel to resistors. We have to keep the resistances values fixed and note down the readings to plot the graph.

Simulation Results

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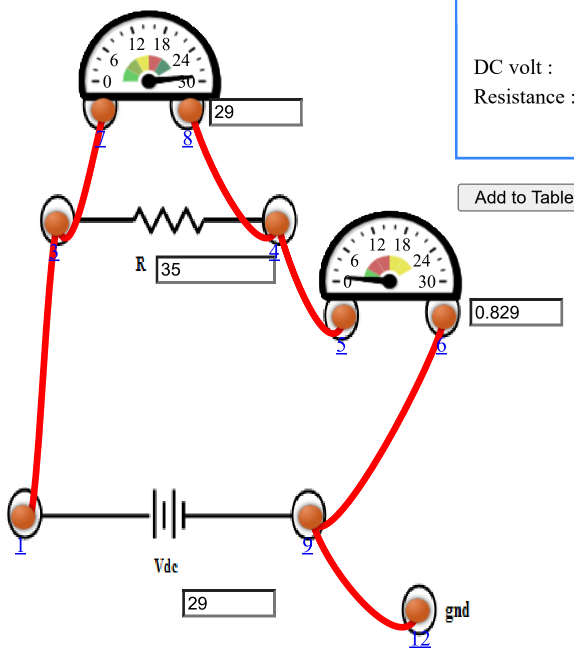
Ohm's Law

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 35 KΩ

4	8	0.229
5	10	0.286
6	13	0.371
7	16	0.457
8	19	0.543
9	22	0.629
10	24	0.686
11	29	0.829



CONTROLS

DC volt : Volt

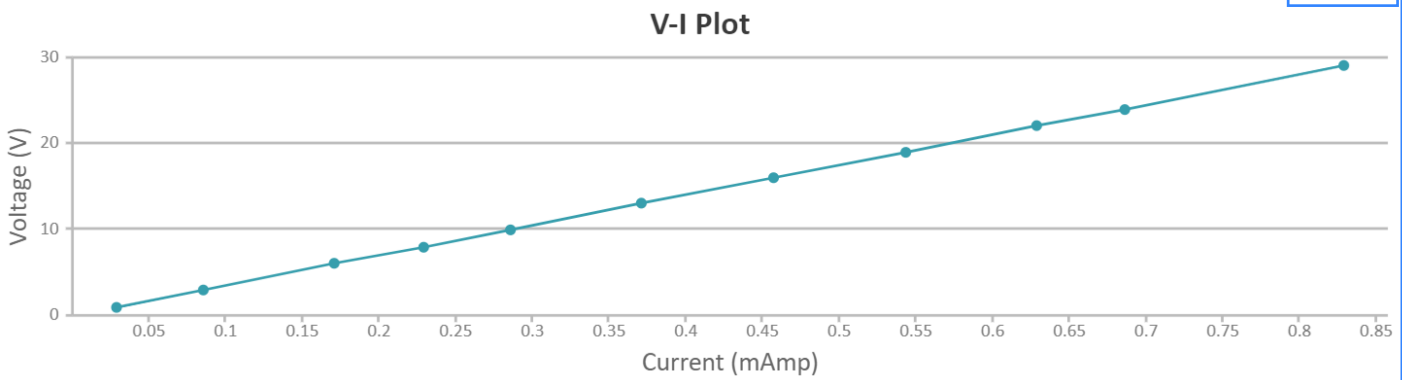
Resistance : Kohms

Add to Table | Plot | Clear

Check connection | Delete all connection

GRAPH PLOT

Print



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Ohm's Law Series

INSTRUCTION

CONTROLS

DC volt : Volt
Resistance1 : Kohr
Resistance2 : Kohr

Add to Table | Plot | Clea
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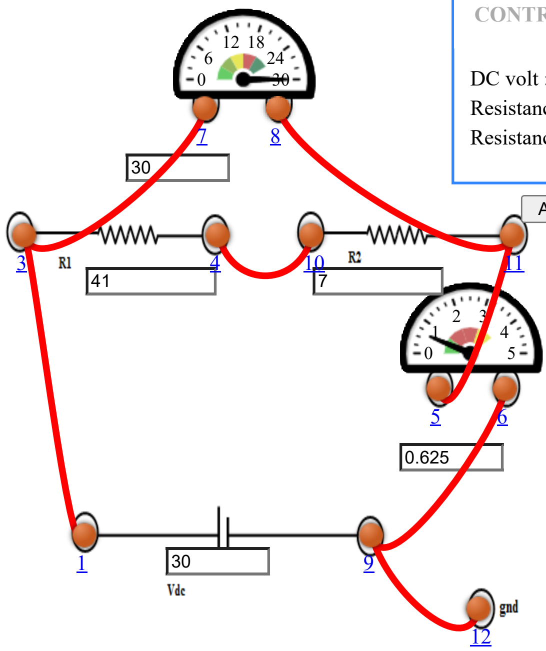


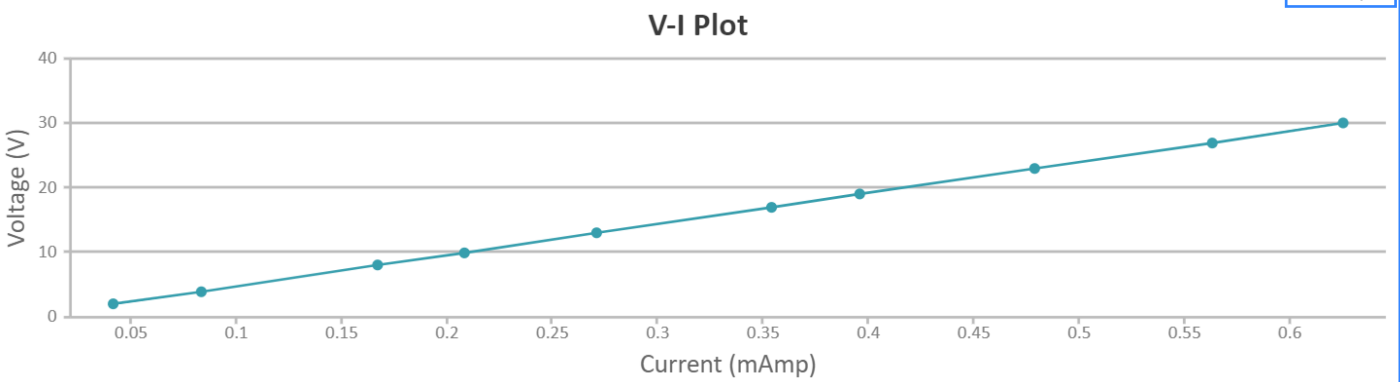
EXPERIMENTAL TABLE

Resistance(R_1): 41 KΩ
Resistance(R_2): 7 KΩ
Resistance(R_{eq}): 48 KΩ

3	8	0.167
4	10	0.208
5	13	0.271
6	17	0.354
7	19	0.396
8	23	0.479
9	27	0.563
10	30	0.625

GRAPH PLOT

Print



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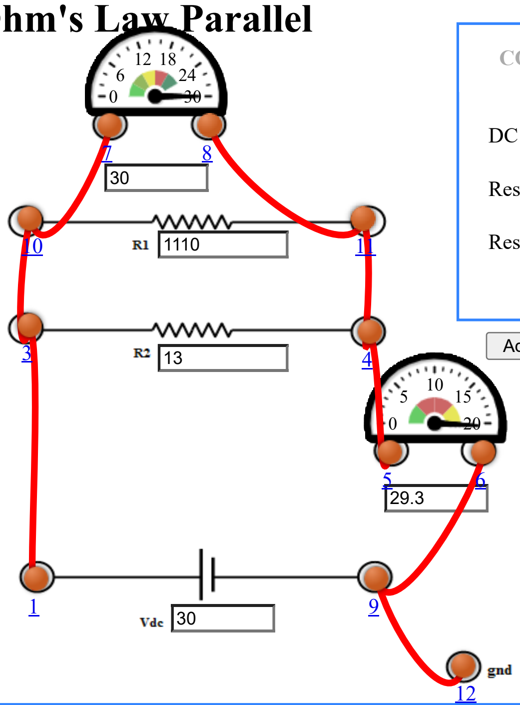
Ohm's Law Parallel

INSTRUCTION



CONTROLS

DC volt : V

Resistance1 :

Resistance2 :

Add to Table | Plot | Cl

Check connection | Delete connec

EXPERIMENTAL TABLE

Resistance(R_1): 1110 Ω

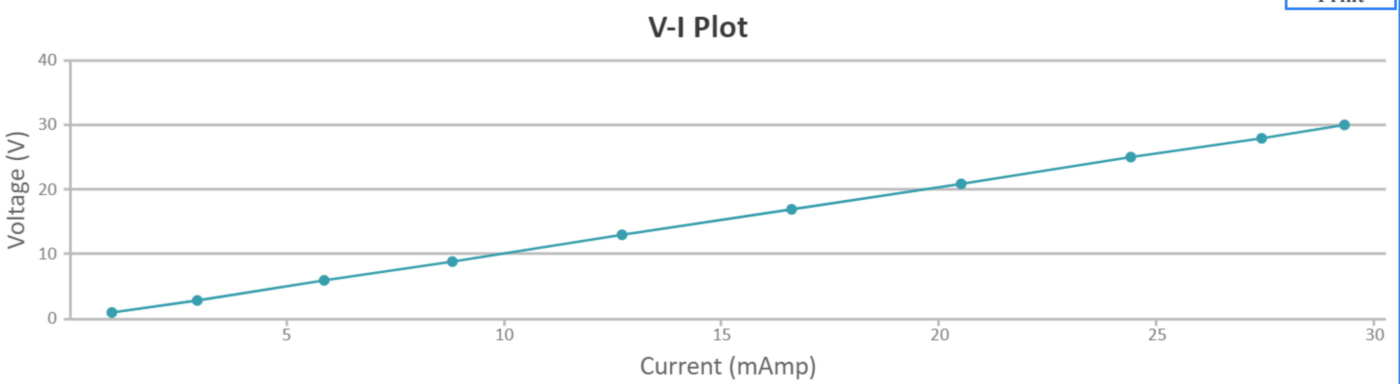
Resistance(R_2): 13 KΩ

Resistance(R_{eq}): 0.129984 Ω

3	6	5.87
4	9	8.80
5	13	12.7
6	17	16.6
7	21	20.5
8	25	24.4
9	28	27.4
10	30	29.3

GRAPH PLOT

Print

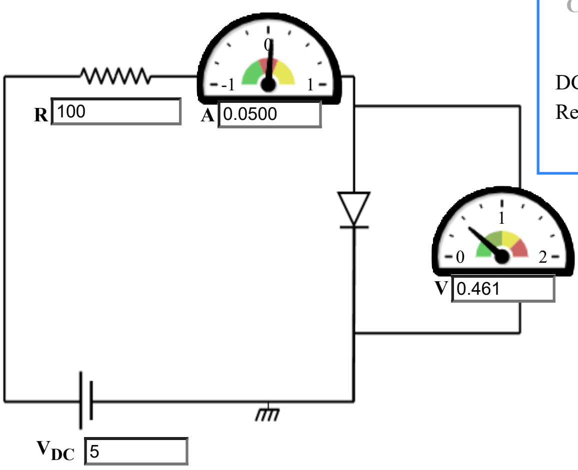


Non Ohmic Device

INSTRUCTION

EXPERIMENTAL TABLE

5	0.487	0.135	37
6	0.483	0.119	42
7	0.479	0.102	49
8	0.477	0.0926	54
9	0.474	0.0820	61
10	0.471	0.0735	68
11	0.469	0.0685	73



CONTROLS

DC volt : Vol

Resistance : Ko

Add to Table | Plot | C

GRAPH PLOT

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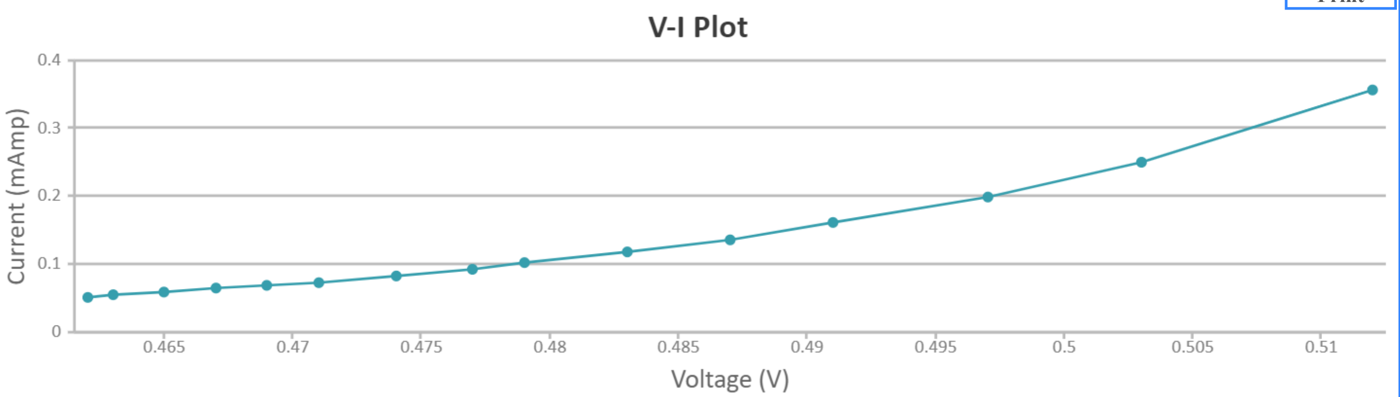

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Conclusion-: Performing the experiment in the simulator, following conclusions can be drawn,

- The V-I graph is observed to be linear for resistor, which verifies that the current through a resistor is directly proportional to the voltage difference across its terminals. Hence, resistor is an Ohmic device.

- The V-I graph is observed to be a curve for a diode. Hence, current through a diode is not directly proportional to the voltage across its terminals. Hence, diode is a Non-ohmic device.

Quiz Performance

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BASIC ELECTRONICS VIRTUAL LABORATORY (../INDEX.HTML)

Home (../../index.html) () > Basic Electronics Lab (../index.html) > Ohms Law (index.html)

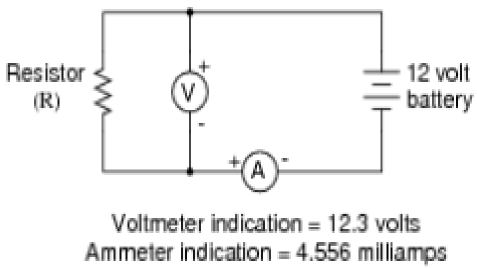
Ohms Law

THEORY (#) PROCEDURE (#) SIMULATION (#) QUIZ (#) ASSIGNMENT (#) REFERENCES (#)

Quiz

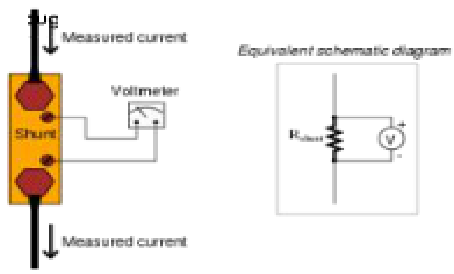
Test Your Knowledge!!

✓ 1. What is the value of this resistor, in ohms



- 270 Ω
- 27 kΩ
- 2700 kΩ
- 2.7 kΩ

✓ 2. Shunt resistance is labeled with the following rating: 150 A , 50 mV. What is the resistance of this shunt, in ohms?



Shunt resistors are often used as current-measuring devices, in that they are designed to drop very precise amounts of voltage as large electric currents pass through them. By measuring the amount of voltage dropped by a shunt resistor, you will be able to determine the amount of current going through it:

- 333.3 μΩ
- 33.33 mΩ
- 3.333 Ω

3.333 mΩ

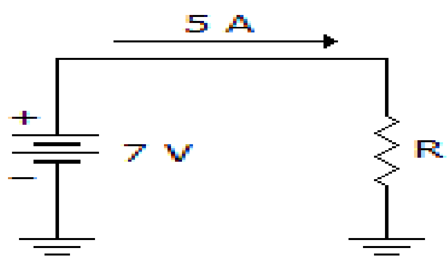
✓ 3. If doubling the voltage across a resistor doubles the current through the resistor then

- the resistor value decreased
- the resistor value did not change
- the resistor value increased
- it is impossible to determine the change in the resistor value

✓ 4. If the voltage across a fixed value of resistance is increased five times, what does the current do?

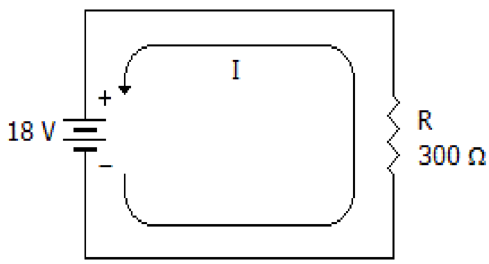
- Not enough information
- It decreases by a factor of five.
- It stays the same.
- It increases by a factor of five

✓ 5. What is the power in the given circuit?



- 3.6 W
- 245 W
- 175 W
- 35 W

✗ 6. If the voltage in the given circuit was cut in half, what would the current equal?



- 30 mA
- 60 mA
- 10 mA
- 90 mA

✓ 7. Resistance and current are _________.

- inversely proportional

directly proportional

not related

similar to voltage

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