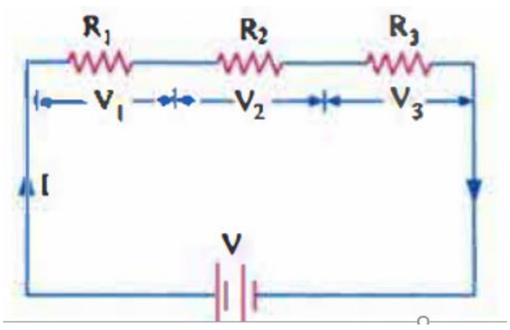
Resistive Circuits

The circuits in which the resistors are connected in series or parallel or parallel-series combinations.

1. Series Circuit

The circuit in which the resistors are connected end-to-end in series with the battery.in other words the same current passes through each component. Consider three resistors R_1, R_2 and R_3 are connected in series with the battery as shown in fig. As the result same current **I** flow through each resistor.



Then the voltage drop through each resistor are $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$. The sum of these voltage drops must be equal to the applied voltage.

$$\mathbf{V = V_1 + V_2 + V_3}$$

Total series resistance

When resistors are connected in series, the resistor values add because each resistor offers opposition to the current in direct proportion to its resistance. A greater number of resistors connected in series creates more opposition to current. More opposition to current implies a higher value of resistance. Thus, for every resistor that is added in series, the total resistance increases.

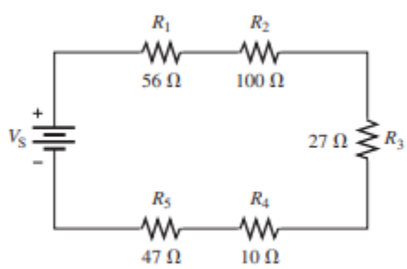
Series Resistance Formula

For any number of individual resistors connected in series, the total resistance is the sum of each of the individual values.

$$R_T = R_1 + R_2 + R_3 + \cdots + R_n$$

where R_T is the total resistance and R_n is the last resistor in the series string (n can be any positive integer equal to the number of resistors in series). For example, if there are four resistors in series ($n = 4$), the total resistance formula is

$$R_T = R_1 + R_2 + R_3 + R_4$$

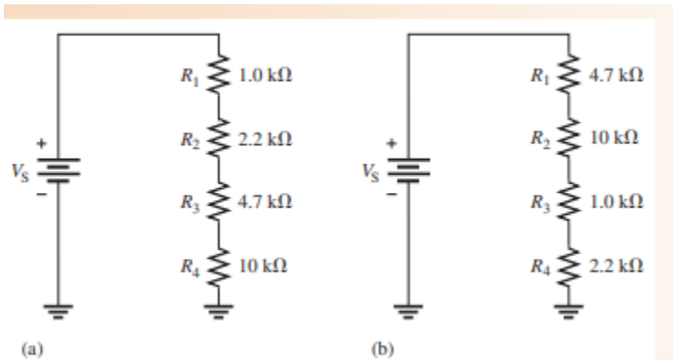


The total resistance of above circuit is

$$R_T = 56\,\Omega + 100\,\Omega + 27\,\Omega + 10\,\Omega + 47\,\Omega = 240\,\Omega$$

Example

Calculate the total resistance for each circuit



Equal value series resistor

If no of resistor of equal values are connected in series, then the total resistance is

$$\mathbf{R_T = nR}$$

Where n is the no of resistors.

Find the R_T of eight 22 Ω resistors in series.

Solution Find R_T by adding the values.

$$R_T = 22\,\Omega + 22\,\Omega + 22\,\Omega + 22\,\Omega + 22\,\Omega + 22\,\Omega + 22\,\Omega + 22\,\Omega = \mathbf{176\,\Omega}$$

However, it is much easier to multiply.

$$R_T = 8(22\,\Omega) = \mathbf{176\,\Omega}$$

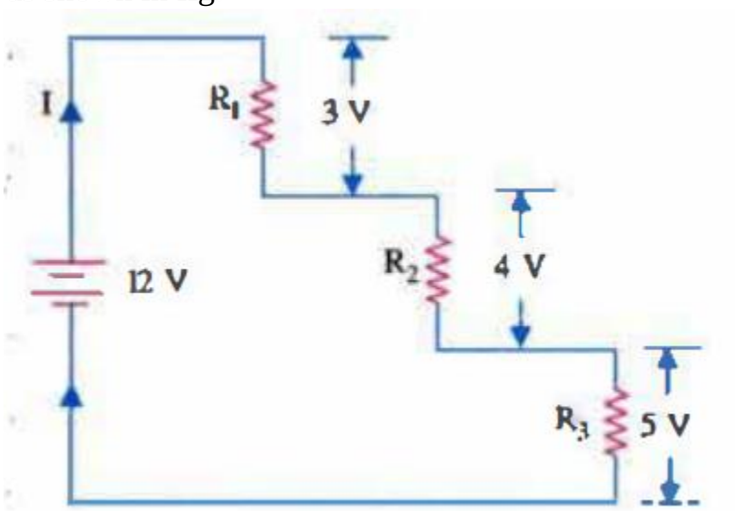
Characteristic of series circuit

1. Total resistance is equal to sum of all series resistances.
2. Current through all resistors is same.

The value of circuit current is given by

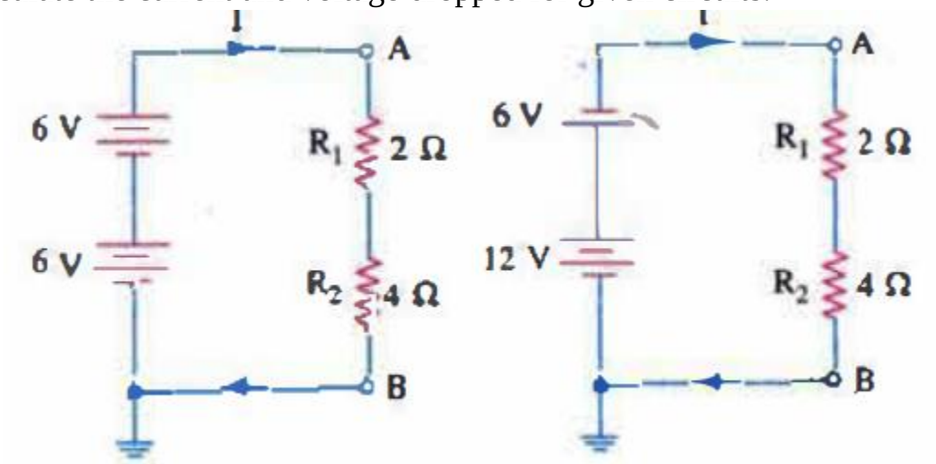
$$I = \frac{\text{applied voltage}}{\text{total resistance}} = \frac{V}{R}$$

3. The sum of individual **IR** dropped equal to applied voltage.
4. There is a stepped fall in the voltage as we go from one terminal of battery to the other as shown in fig.



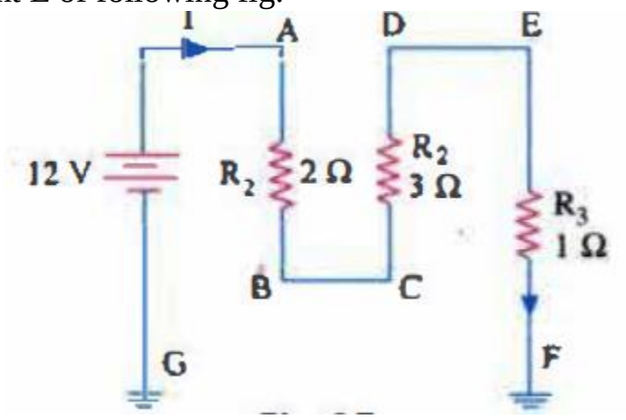
Problem

Calculate the current and voltage dropped for given circuits.



Problem

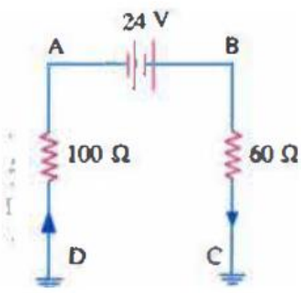
Compute i) total resistance ii) circuit current iii) p,d between A and E iv) potential at point E of following fig.



Problem

Calculate

1. *circuit current*
2. *potential of point C*
3. *potential of point B*
4. *point of lowest potential*
5. *value of lowest potential.*



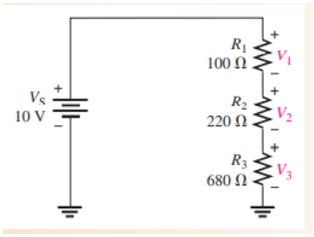
Voltage Divider Rule

The voltage divider rule is used to solve circuits to simplify the solution. Applying this rule can also solve simple circuits thoroughly. The main concept of this voltage divider rule is "The voltage is divided between two resistors which are connected in series in direct proportion to their resistance. The voltage divider rule is used to determine the voltage drop across the resistors when source current is unknown. The general formula used.

$$V_x = \left(\frac{R_x}{R_T}\right) V_S$$

Where V_S is the source voltage, R_T is the total resistance of the circuit and R_x is the resistance across the voltage is measured.

Example determine the voltage across each resistor.



$$V_1 = (\frac{R_1}{R_T})V_S$$

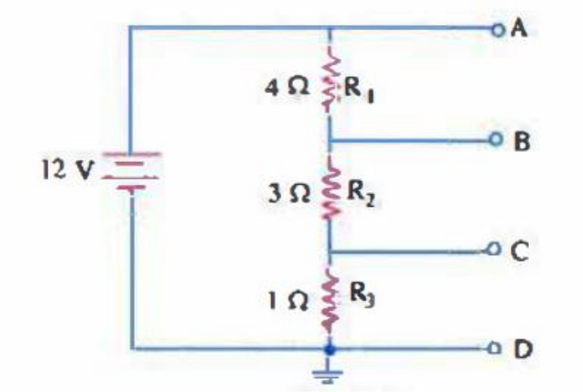
$R_T = 100 + 220 + 680 = 1000\Omega$

$$V_1 = (\frac{100}{1000})10\ V$$

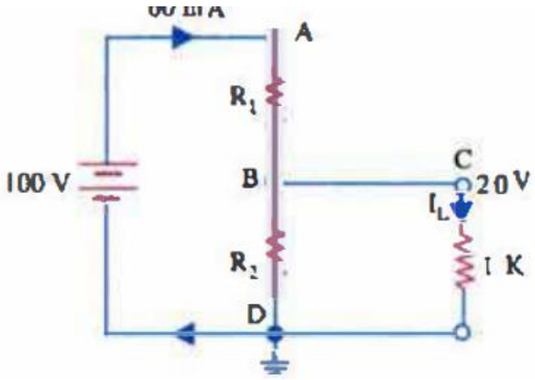
$$V_2 = (\frac{R_2}{R_T})V_S = (\frac{220}{1000})10, \qquad V_3 = (\frac{R_3}{R_T})V_S = (\frac{680}{1000})10$$

Problem

Determine the potential drop across A and B, B and C, C and D of following circuit

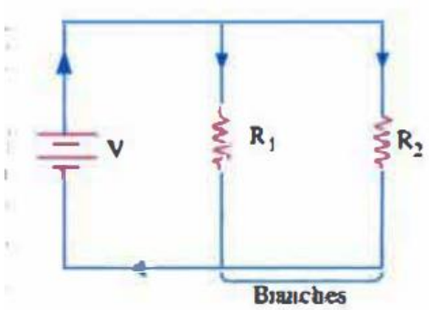


Example. For the following fig, *find values of R_1 and R_2 if the voltage applied across load resistor of 1 K is to be 20 V. The maximum current which the battery can supply is 60 mA*



Resistors in parallel

A parallel circuit is a branched arrangement in which two or more resistors are connected side by side across a single voltage source as shown in fig.

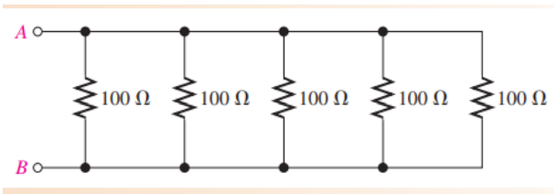


Features of parallel circuits

1. Voltage across each branch or resistor is same.
2. For the parallel resistor circuit, the reciprocal of the total resistance of the entire circuit is equal to the sum of reciprocal of individual resistor.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

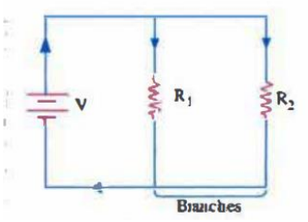
3. The current through each branch can be determined by $\frac{V}{R}$.
4. The sum of branch current is equal to the current supplied by battery.
5. If resistances of all the branches of the parallel circuit are equal, then the combined resistance equal the value of one branch resistance divided by the number of branches.



6. If the circuit contains two resistors as shown in fig. then the total resistance is determined as

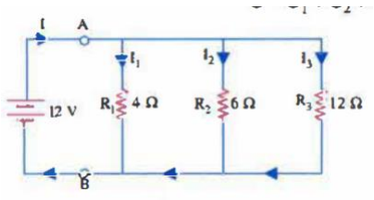
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2}$$

$$R = \frac{R_1 R_2}{R_1 + R_2}$$



Example

Determine i) total resistance of the circuit ii) current through each branch iii) current supplied by battery.

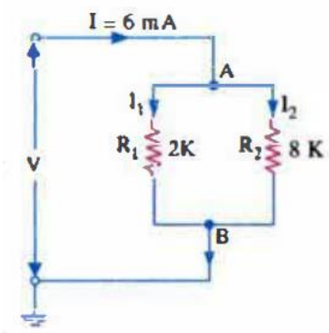


Current Divider Formula

Current divider formula is applied to determine current passing through a branch, is source voltage is not known. In the case of two branch circuit, the current can be determined as

$$I_1 = I \cdot \frac{R_2}{R_1 + R_2}$$

$$I_2 = I \cdot \frac{R_1}{R_1 + R_2}$$



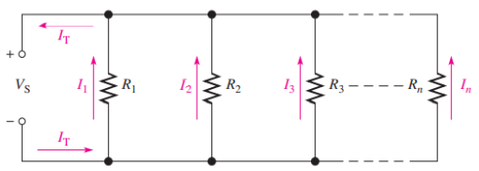
For the following circuit, the current through each branch is

$$I_1 = 6 \times \frac{8}{2+8} = 4.8 \text{ mA}; \qquad I_2 = 6 \times \frac{2}{2+8} = 1.2 \text{ mA}$$

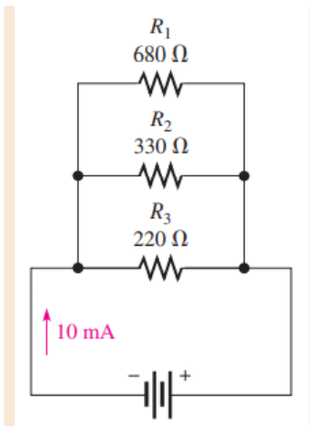
If the circuit contain more then two resistors, then the current through each branch or resistor can be determined by using

$$I_x = \left(\frac{R_T}{R_x}\right) I_T$$

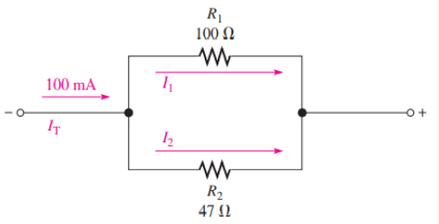
The current (I_x) through any branch equals the total parallel resistance (R_T) divided by the resistance (R_x) of that branch, and then multiplied by the total current (I_T) into the junction of parallel branches.



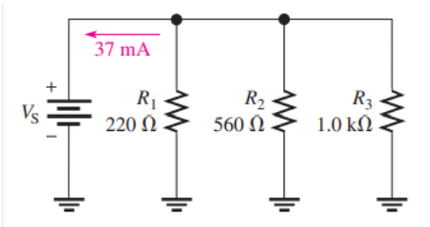
Problem. Determine the current through each resistors for following fig.



Problem. Determine the current $\mathbf{I_1}$ and $\mathbf{I_2}$



Problem Find the voltage across the parallel resistors.



Problem Determine the current through each resistor in parallel.