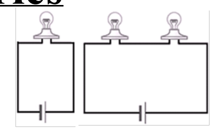
Combining Light Bulbs in Series

1. Build a circuit with one light bulb and observe its brightness. The brightness of a bulb is a measure of...



2. Then add a second bulb in series. Observe or infer what happens to the: *Increase, Decrease, or Remain the same*

Power of an individual bulb (= brightness)		↓
Total power of the circuit		↓
Resistance of an individual bulb		same
Total resistance of the circuit		↑
Total potential difference across the circuit		same
Potential difference across an individual bulb		↓
Total current in the circuit		↓
Current through an individual bulb		↓

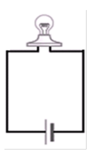
3. Unscrew one light bulb from its base (but leave the base in the circuit). What happens to the other light bulb? Why?

goes out - incomplete circuit

↑ ↓ same

Combining Light Bulbs in Series

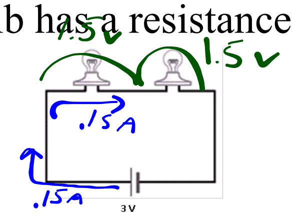
4. Assume each light bulb has a resistance of 10Ω. Analyze each circuit.



R	10Ω
V	3V
I	.3A
P	.9W

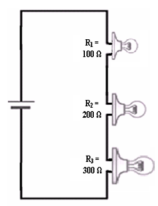
V = IR

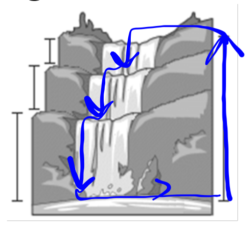
P = IV

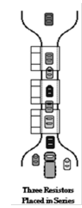


	Bulb #1	Bulb #2	Circuit Total
R	10Ω	10Ω	20Ω
V	1.5V	1.5V	3V
I	.15A	.15A	.15A
P	.225W	.225W	.45W

Analyzing Series Circuits







1. **Current:** Current is the same at all points in a series circuit. Current is the same through each resistor. $I_1 = I_2 = I_3 = I_T$

NOTE: conservation of electric charge

current for *all* would still change if circuit changed

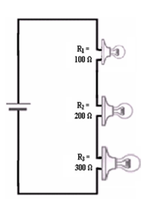
2. **Voltage:** The increase in potential provided by the battery is equal to the sum of the potential drops across each resistor.

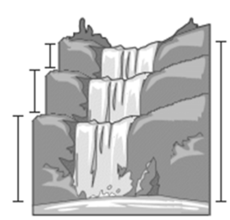
$$V_1 + V_2 + V_3 = V_T$$

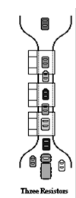
NOTE: conservation of energy

Kirchhoff's Second Law (Voltage law, Loop Rule)- Around any closed loop, the sum of the emf's (voltage rises) equals the sum of the potential differences (voltage drops).

Analyzing Series Circuits







3. **Resistance:** The total resistance of the circuit is the sum of the individual resistances.

$$R_{eq} = R_1 + R_2 + R_3$$

Equivalent resistance – the single resistance that could replace the several resistors in a circuit

NOTE: The total resistance is higher than any of the individual resistances.

4. **Power:** The total power used in the circuit is the sum of the power used by the individual resistors. $P_T = P_1 + P_2 + P_3$

NOTE: Conservation of energy principle

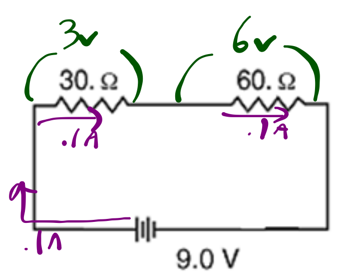
Analyzing Series Circuits

Series relationships

$$\frac{R_1}{R_2} = \frac{V_1}{V_2} = \frac{P_1}{P_2}$$

5. In a series circuit, which resistor, if any, will . . .
   a) have the greatest potential difference across it?
   Bigger
   b) have the most current running through it?
   same
   c) dissipate the most power?
   Bigger
   d) shine brightest (if it is a light bulb)?
   Bigger

6. Determine the current through each resistor, the potential drop across each resistor, and the power dissipated by each resistor in the circuit below.



$R_T = R_1 + R_2 = 30\Omega + 60\Omega = 90\Omega$

$I_T = \frac{V_T}{R_T} = \frac{9v}{90\Omega} = 0.1A = I_1 = I_2$

$V_1 = I_1 R_1 = .1A \times 30\Omega = 3v$

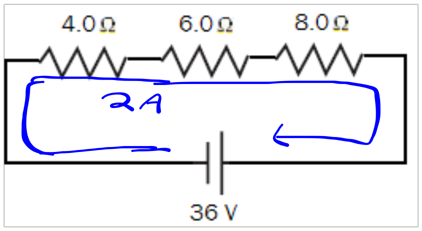
$V_2 = I_2 R_2 = .1A \times 60\Omega = 6v$

9v

$P_1 = I_1 V_1 = .1A \cdot 3v = .3$

$P_2 = I_2 V_2 = .1A \cdot 6v = .6w$

7. Find the potential difference across each resistor, the current through each resistor, and the power used by each resistor.



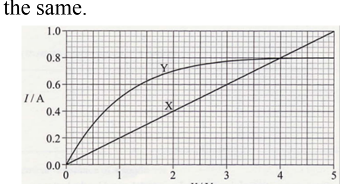
R_T

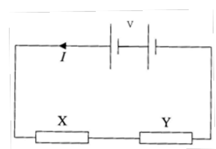
I_T

	I	V	P
R_4	2A	8v	16w
R_6	2A	12v	24w
R_8	2A	16v	32w

I-V Characteristics

1. The graph below shows the I-V characteristics of two conductors, conductors are connected in series to a battery whose voltage is such that the power dissipated in each of the two resistors is the same.





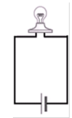
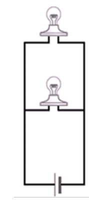
a) Determine the resistance of each resistor.

b) Determine the total voltage of the battery.

c) Determine the total power dissipated in the circuit.

d) The battery is replaced by another one such that the current through X is 0.2 amps. Determine the voltage of this battery.

Combining Light Bulbs in Parallel

1. Build a circuit with one light bulb and observe its brightness.
2. Add a second bulb in parallel. Observe or infer what happens to the:

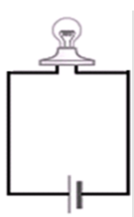
Power of an individual bulb (= brightness)		same
Total power of the circuit		↑
Resistance of an individual bulb		same
Total resistance of the circuit		↓
Total potential difference across the circuit		same
Potential difference across an individual bulb		same
Total current in the circuit		↑
Current through an individual bulb		same

3. Unscrew one light bulb from its base (but leave the base in the circuit). What happens to the other light bulb? Why? stays the same - still has same connection to battery

↑↓ same

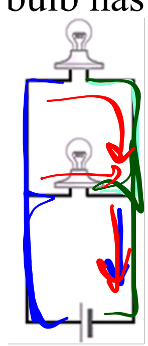
Combining Light Bulbs in Parallel

4. Assume each light bulb has a resistance of 10Ω. Analyze each circuit.



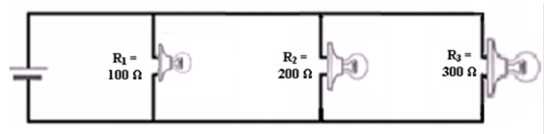
3 V

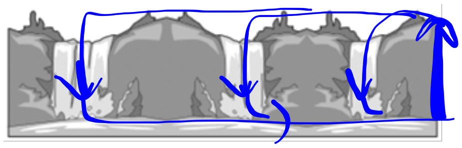
R	10Ω
V	3v
I	.3A
P	.9w

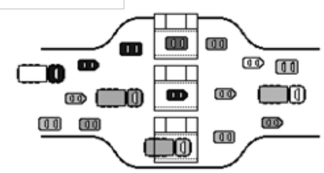


	Bulb #1	Bulb #2	Circuit Total
R	10Ω	10Ω	5Ω
V	3v	3v	3v
I	.3A	.3A	.6A
P	.9w	.9w	1.8w

Analyzing Parallel Circuits







Three Resistors Placed in Parallel

1. **Voltage:** The increase in potential provided by the battery is equal to the potential drop across each resistor.

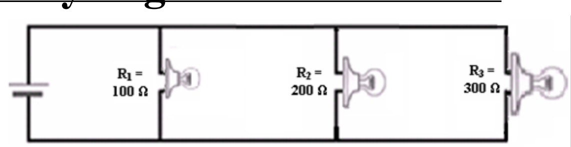
$$V_1 = V_2 = V_3 = V_T$$

2. **Current:** The total current coming out of (and going back into) the battery is equal to the sum of the individual currents going through each resistor.

$$I_1 + I_2 + I_3 = I_T$$

NOTE: conservation of electric charge

Analyzing Parallel Circuits



3. **Power:** The total power used in the circuit is the sum of the power used by the individual resistors.

$$P_1 + P_2 + P_3 = P_T$$

NOTE:

4. **Resistance:** The reciprocal of the total resistance is equal to the sum of the reciprocal of the individual resistances.

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

NOTE: total resistance is smaller than any individual resistor

Analyzing Parallel Circuits

5. A 3.0 Ω and a 6.0 Ω resistor are connected in parallel. What is their equivalent resistance?

Parallel relationships

$$\frac{R_1}{R_2} = \frac{I_2}{I_1} = \frac{P_2}{P_1}$$

6. In a parallel circuit, which resistor, if any, will . . .

a) have the greatest potential difference across it?

same

b) have the most current running through it?

smaller

c) dissipate the most power?

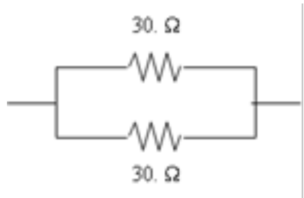
smaller

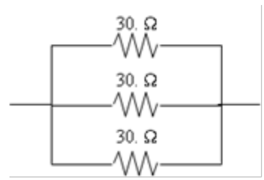
d) shine brightest (if it is a light bulb)?

smaller

Analyzing Parallel Circuits

7. Calculate the equivalent resistance of each resistor segment below.

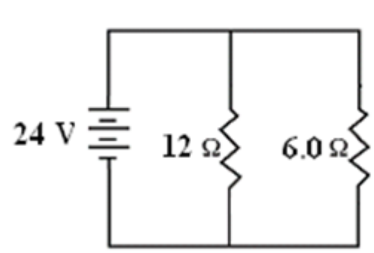




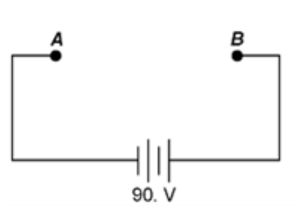
Shortcut for identical parallel resistors:

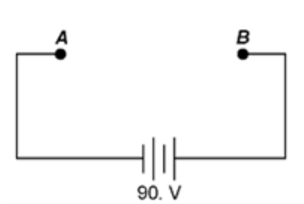
Analyzing Parallel Circuits

8. Calculate the voltage drop across each resistor and the current through each resistor. Calculate the total current in the circuit and the equivalent resistance of the circuit.



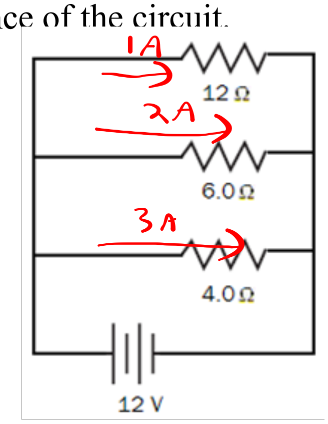
9. A 50. Ω, a 100. Ω and a 150. Ω resistor are to be connected in a circuit. What type of connection will give the highest resistance? The lowest resistance?
Complete each circuit and calculate each current.





Analyzing Parallel Circuits

10. *Calculate* the voltage drop across each resistor and the current through each resistor. Calculate the total current in the circuit and the equivalent resistance of the circuit.



$R_T = \left(\frac{1}{12\Omega} + \frac{1}{6\Omega} + \frac{1}{4\Omega}\right)^{-1} = 2\Omega$

$I_T = \frac{V_T}{R_T} = \frac{12v}{2\Omega} = 6A$

$V_T = V_4 = V_6 = V_{12} = 12v$

$I_4 = V/R_4 = \frac{12v}{4\Omega} = 3A$

$\frac{V_6}{R_6} = \frac{12v}{6\Omega} = 2A$

$\frac{V_{12}}{R_{12}} = \frac{12v}{12\Omega} = 1A$