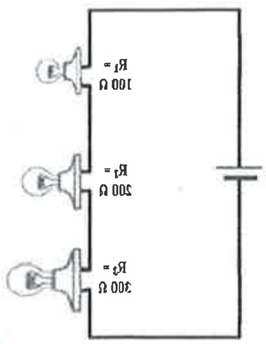
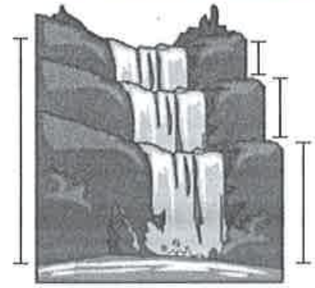
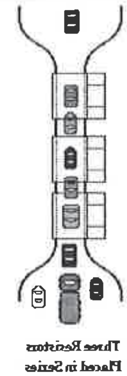
Analyzing Series Circuits







SAME

1. **Current:** Current is the same at all points in a series circuit. Current is the same through each resistor.

$$I_T = I_1 = I_2 = I_3$$

NOTE: Current is the same if the circuit is the same

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

SUM

$$V_T = V_1 + V_2 + V_3$$

NOTE: conservation of energy

Gustav Robert Kirchhoff (1824-1887)

Kirchhoff's Second Law (Voltage Law, Loop Rule):
Around any closed loop, the voltage rise is equal to the voltage drop.

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

SUM

$$R_T = R_1 + R_2 + R_3 \qquad R_T = R_{eq}$$

Equivalent resistance – Single resistance that could replace all resistance in a circuit.

NOTE: R_T is always greater than any individual resistance.

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

SUM

$$P_T = P_1 + P_2 + P_3$$

NOTE: conservation of energy

Series relationships

$V = IR \qquad P = IV$

$$\frac{V_1}{V_2} = \frac{I_1 R_1}{I_2 R_2} = \frac{P_1}{P_2} = \frac{I_1 V_1}{I_2 V_2}$$

5. In a series circuit, which resistor, if any, will . . .

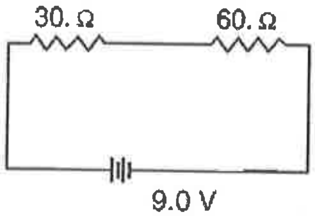
a) have the greatest potential difference across it?
largest resistance

b) have the most current running through it?
none (same current)

c) dissipate the most power?
largest resistor

d) shine brightest (if it is a light bulb)?
largest resistance is the one that draws the most power

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



P	I	V	R
0.3W	0.1A	3V	30.Ω
0.6W	0.1A	6V	60.Ω

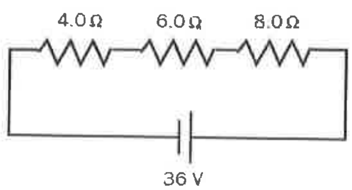
$V=IR$

$P=IV$

$I_T = \frac{V_T}{R_T} = \frac{9.0V}{90\Omega}$

$I_T = 0.1A$

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



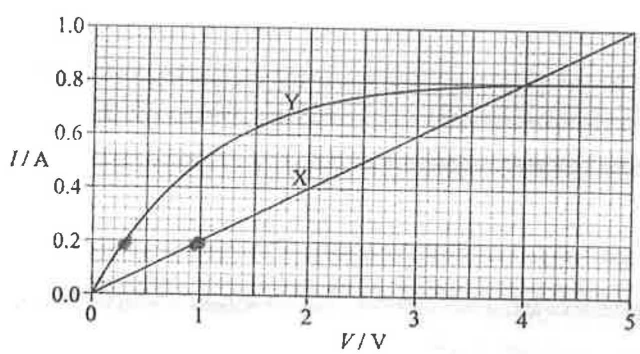
R	I	V	P
4.0Ω	2A	8V	16W
6.0Ω	2A	12V	24W
8.0Ω	2A	16V	32W

$R_T = 18\Omega$

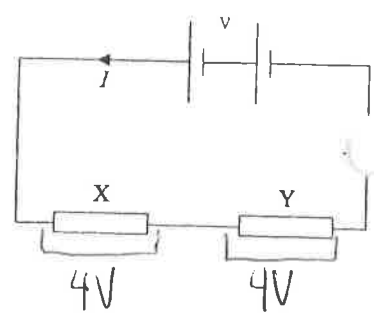
$I_T = \frac{36V}{18\Omega} = 2A$

I-V Characteristics

1. The graph below shows the I-V characteristics of two conductors, X and Y. The 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.



$V=IR$



a) Determine the resistance of each resistor.

$R = \frac{V}{I} = \frac{4V}{0.8A} = 5\Omega$

b) Determine the total voltage of the battery.

$4V + 4V = 8V$

c) Determine the total power dissipated in the circuit.

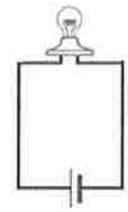
$P_T = I_T V_T = (0.8A)(8V) = 6.4W$

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

"X" + "Y"

$1.0V + 0.3V = 1.3V$

Combining Light Bulbs in Parallel



1. Build a circuit with one light bulb and observe its brightness

same ↑ ↓

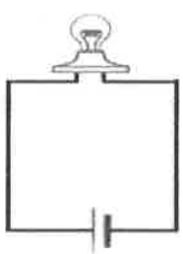
2. Add a second bulb in parallel. Observe or infer what happens to the:

	PREDICTION	RESULT
Power of an individual bulb		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?

The other light bulb stays on because the circuit is still intact.

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



3 V

R	10Ω
V	3V
I	0.3A
P	0.9W

$V = IR$

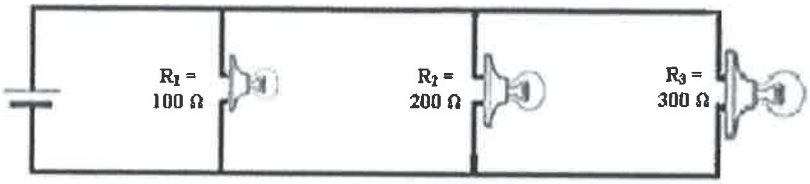
$P = IV$

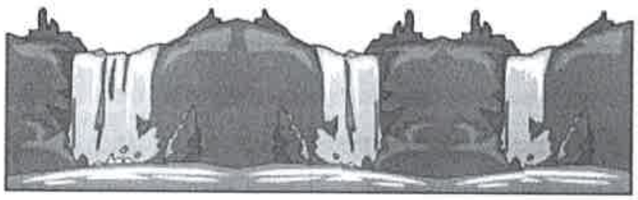
$R_{eq} = \left(\frac{1}{R_T}\right)^{-1}$ $R_{eq} = \left(\frac{1}{10\Omega} + \frac{1}{10\Omega}\right)^{-1}$

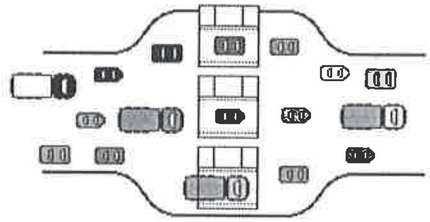
$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$

	Bulb #1	Bulb #2	Circuit Total
R	10Ω	10Ω	5Ω
V	3V	3V	3V
I	0.3A	0.3A	0.6A
P	0.9W	0.9W	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.

SAME $V_T = V_1 = V_2 = V_3$

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.

SUM $I_T = I_1 + I_2 + I_3$

NOTE: conservation of electric charge

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

SUM $P_T = P_1 + P_2 + P_3$

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

SUM OF R^{-1} $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ $R_T = R_{eq}$

$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)^{-1}$

NOTE: Total resistance of the system is less than any individual resistance.

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

$R_{eq} = \left(\frac{1}{3.0\Omega} + \frac{1}{6.0\Omega}\right)^{-1} = 2.0\Omega = R_T$

Parallel relationships

$V = IR \quad P = IV$

$\frac{V_1}{V_2} = \frac{I_1 R_1}{I_2 R_2} \quad I_2 R_2 = I_1 R_1$

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

$\frac{P_1}{P_2} = \frac{I_1 V_1}{I_2 V_2}$

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

a) have the greatest potential difference across it?
none - same voltage

b) have the most current running through it?
smallest resistor

c) dissipate the most power?
smallest resistor

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