Ch 27-Current & Resistance

Electric Current

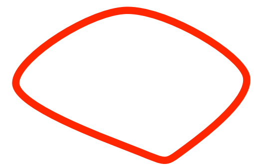
Current = the time-rate at which charge flows

$$I_{avg} = \frac{\Delta Q}{\Delta t} \qquad [\text{Amperes}] = \frac{[\text{Coulombs}]}{[\text{second}]}$$

$$I_{inst} = \frac{dQ}{dt}$$

Why would charges move?

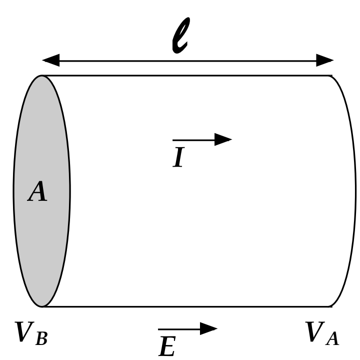
In loop of wire, V is constant, so E=-dV/dr = 0.



A battery producing a potential V, however, creates an electric field in the wire, causing charges to feel a force.

Resistivity

As the electric field pushes through the wire, there is a resistance R to the flow of charge based on the length of the wire, the cross-sectional area, and the material's *resistivity* ρ to the current flow:



$$R = \rho \frac{L}{A}$$

$$\rho_{copper} = 1.7 \times 10^{-8} \ \ \Omega \bullet m \ \ (20°C)$$

$$\rho_{carbon} = 3.5 \times 10^{-5} \ \ \Omega \bullet m \ \ (20°C)$$

Temperature & Resistivity

Resistivity ρ, and therefore, resistance *R*, vary somewhat with temperature. α represents a *temperature coefficient of resistivity*.

$$R = \rho \frac{L}{A}$$

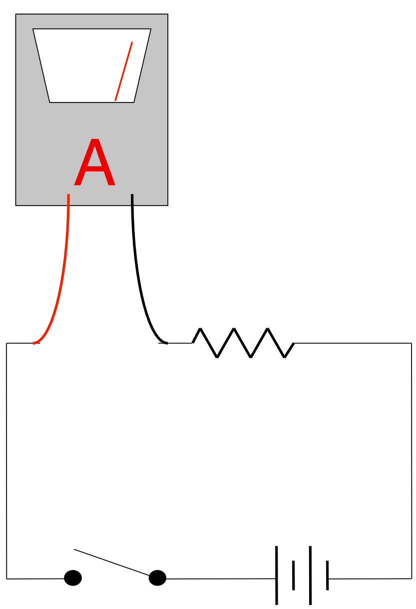
$$\rho = \rho_0[1 + \alpha(T - T_0)]$$

$$\alpha_{copper} = 3.9 \times 10^{-3} \quad {}^{\circ}C^{-1}$$

$$\alpha_{carbon} = -0.5 \times 10^{-3} \quad {}^{\circ}C^{-1}$$

(Note that although all of this is true, and although the general expression $R = \rho \frac{L}{A}$ does occasionally show up on AP tests, the temperature dependence part generally does not.)

Ohm's Studies

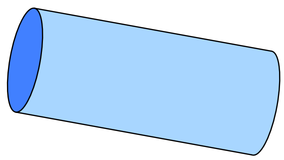


(Ammeters measure charge flow--current--and must be placed directly into the circuit (in that way they can measure how much charge *passes through* them. Ammeters have *very low* resistance to charge flow associated with them, which means it is important NOT to inadvertently hook them up *across* an element (i.e., in the way one hooks up a voltmeter).

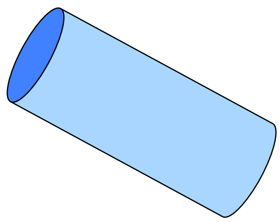
Classic Analogy

Think of current and potential as water flowing through a pipe:

No change in GPE of water from one side to the other, so no flow of charge.

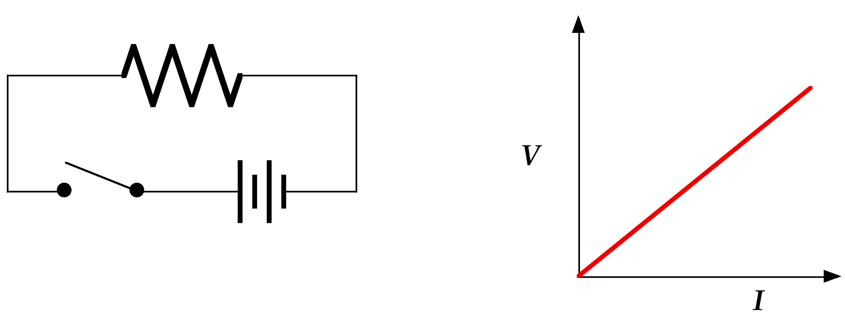


Small change in GPE of water from one side to the other, so small flow of charge.



Bigger change in GPE of water from one side to the other, so bigger flow of charge.

Ohm's Law



$$V = IR$$

Voltage (Volts) Current (Amps) Resistance (Ohms, Ω)

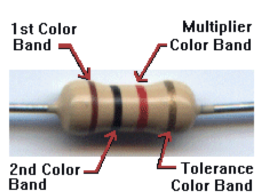
Example 1

The video projector here uses a $120V_{rms}$ potential, and "draws" 2.7 Amps of current.

a. What is its resistance?

b. What would be the current if the Voltage used to run the machine was only 12 V?

Secret Resistor Code



Secret Resistor Code

Color	Number	Multiplier	Tolerance
Black	0	10^0	
Brown	1	10^1	
Red	2	10^2	+/- 2%
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^-1	+/- 5%
Silver		10^-2	+/- 10%
No Color			+/- 20%

Example 2

You have an LED with essentially no resistance, that takes 300 mA of current to light. You have a 9 Volt battery that you'd like to use to light the LED.

a. What will your circuit look like?

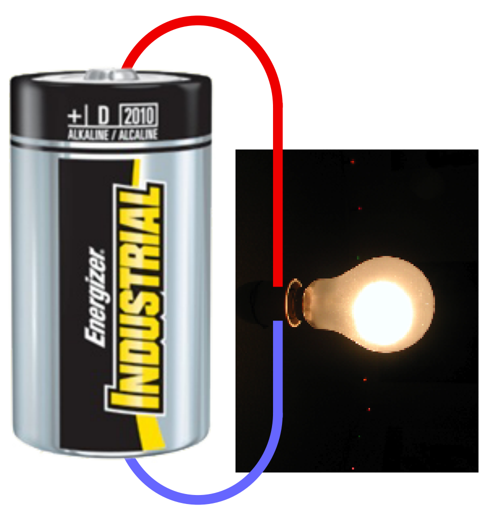
b. How large a resistor should you use to make sure that the LED doesn't blow out?

c. What color code should you look for on your resistor?

Summary of Ohm's Law

Electrical Energy

$$\Delta U = q\Delta V$$



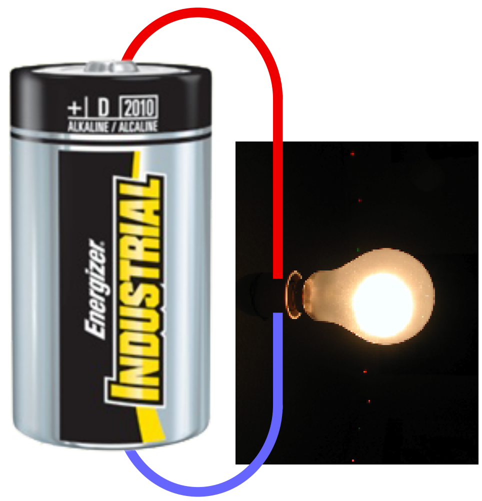
Electrical Power

$$\Delta U = q\Delta V$$

$$\frac{dU}{dt} = \frac{d(q\Delta V)}{dt}$$

$$P = IV$$

$$P = I^2 R = \frac{V^2}{R}$$



Example 3

A lightbulb is rated at 120V, 75W. If the bulb is powered by a 120V AC power supply, find...

a. the current in the bulb

b. its resistance.

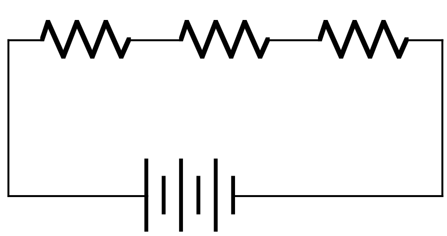
Example 4

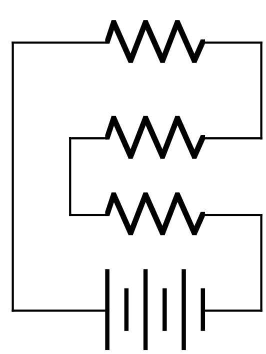
An electric heater draws 15 Amps on a 120 Volt line. It operates 3 hours/day, for 30 days/month. P.G.&E charges 8¢ per kWh.

a. How much Power does the heater draw?

b. How much does it cost to run the heater for a month?

Resistors in series

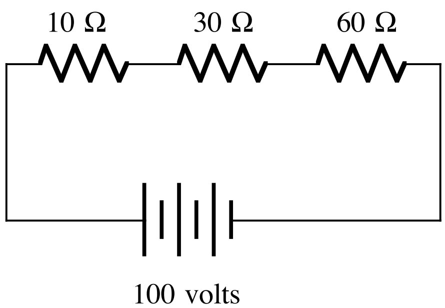




Resistors in series

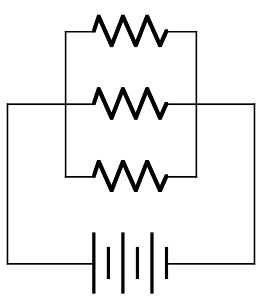
What is the current flow in this model?
What is the voltage drop across each resistor?

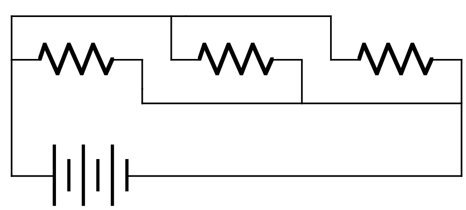
(Look at "series movie" in "Richard's stuff")



$$R_{equivalent} = R_1 + R_2 + R_3 + \ldots \text{ (for resistors in series)}$$

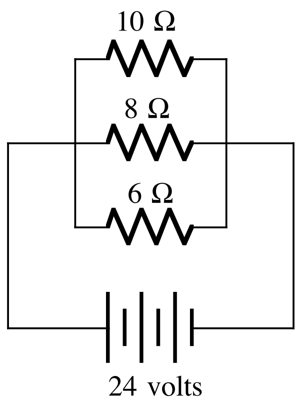
Resistors in parallel





Resistors in parallel

What is the voltage drop over each resistor in this model?
What is the current through each resistor?

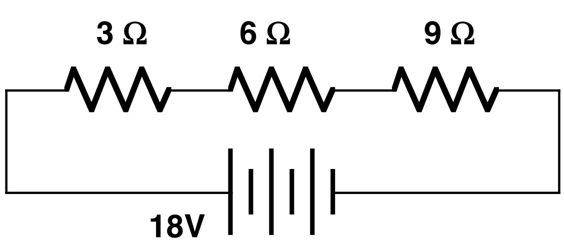


(Look at "parallel movie" in "Richard's stuff")

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \text{ (for resistors in parallel)}$$

Example 5

Examine the circuit here.



a. What is the equivalent resistance?

b. Find the current flowing throughout the circuit.

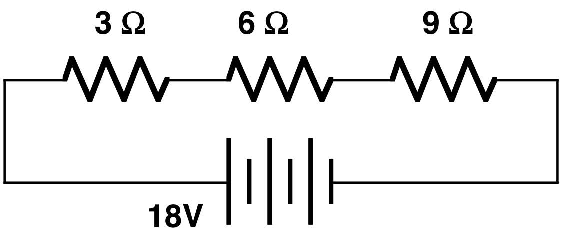
c. What is the potential at every point in the circuit.

d. What is the Power delivered by the battery?

e. What is the Power consumed by each resistor?

Example 5

Examine the circuit here.



a. What is the equivalent resistance?

R_{equiv}=3W+6W+9W=18W

b. Find the current flowing throughout the circuit.

I=V/R=18V/18W =1.0A

c. What is the potential at every point in the circuit.

V_3=IR=(1A)(3W)=3V; V_6=6V; V_9=9V

d. What is the Power delivered by the battery?

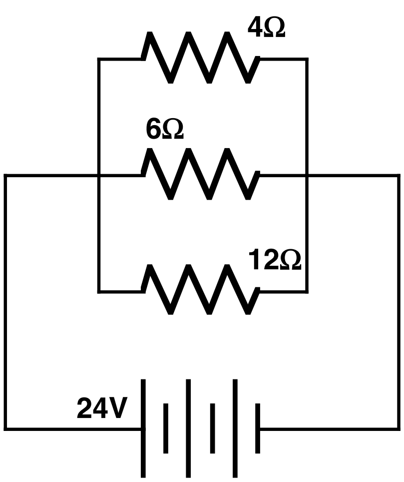
P=IV=(1.0A)(18V)=18W

e. What is the Power consumed by each resistor?

P_3=IV=(1.0A)(3V)=3W; or use $P_3=I^2R$=(1A)(3W)=3W; or use $P_3=V^2/R=(3V)^2/3A$=3W; P_6=6W; P_9=9W

Example 6

Examine the circuit here.



a. What is the equivalent resistance?

b. Find the current flowing throughout the circuit.

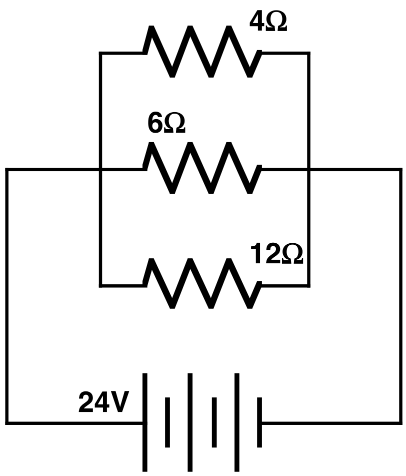
c. What is the potential at every point in the circuit.

d. What is the Power delivered by the battery?

e. What is the Power consumed by each resistor?

Example 6

Examine the circuit here.



a. What is the equivalent resistance?

$1/R_{equiv}$=1/4W+1/6W+1/12W; R_{equiv}=2W

b. Find the current flowing throughout the circuit.

V drop identical for each resistor=24V

c. What is the potential at every point in the circuit.

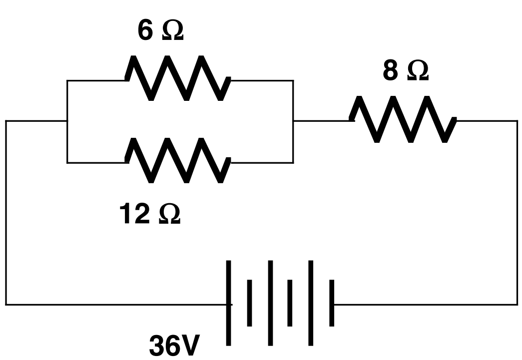
I from battery = V/R_{equiv}= 24V/2W =12A; I_4=V/R= (24V)/(4W)=6A; I_6=4A; I_{12}=2A

d. What is the Power delivered by the battery?

e. What is the Power consumed by each resistor?

Example 7

Examine the circuit here.



a. What is the equivalent resistance?

b. Find the current flowing throughout the circuit.

c. What is the potential at every point in the circuit.

d. What is the Power delivered by the battery?

e. What is the Power consumed by each resistor?