Lesson 9
Power

Recall from Physics 2204 that $P = \frac{E}{T}$.

In an electric circuit, power is defined as the rate at which electrical energy is passed on to various circuit loads.

Recall: $E = VIt$

Thus:

$$P = \frac{VIt}{t}$$

or

$$P = VI$$

where,
P = power (Watts)
V = voltage (Volts)
I = current (Amps)

Power is measured in Watts where,

$$1W = 1V \times 1A$$

$$1W = 1\frac{J}{C} \times 1\frac{C}{s}$$

$$1W = 1\frac{J}{s}$$

Example:
A small color television connected to a 120 V outlet draws 1400 mA of current. Calculate its power rating.

We can also derive other power formulas using Ohm's law.

$P = VI$

$but\ V = IR$

so

$P = (IR)I$

$P = I^2R$

Also,

$P = VI$

$but\ I = \frac{V}{R}$

so

$P = V\left(\frac{V}{R}\right)$

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

Example:
Calculate the resistance of a 40.0 W automobile headlight designed for 12.0 V.

*Note that this is the resistance when the bulb is burning brightly at 40.0 W. When the bulb is cold, the resistance is much lower. Since the current is high when the resistance is low, lightbulbs burn out most often when first turned on.

Example:
Calculate the resistance in a 1000.0 W hairdryer connected to a 120 V line. What happens if it is connected to a 240 V line in Britain?

*When connected to a 240 V line, more current would flow and the resistance would change with the increased temperature. But if we make an estimate based on the resistance calculated previously, we see that the power is four times the dryer's power rating. This would melt the heating element or the wire coils of the motor.

Example:
Determine the total current drawn by all the devices connected in parallel as shown. Will the fuse blow?

Electricity in the Home

Note that in your home, it is energy, not power, that you pay for on the electric bill.

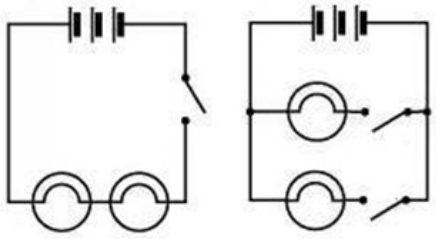
Since $P = \frac{E}{t}$ *then* $E = Pt$

Energy is normally calculated in Joules, but this is such a small unit that it is not practical for billing purposes. In NL we use kilowatt hours. (1 kW·h = 3.6 MJ)

Example:
At 9.63 cents per kilowatt hour, what is the cost of operating a 1500 W hairdryer for 5.0 min a day for 365 days?

Example:
An electric heater draws 15.0 A on a 120 V line. How much power does it use and how much does it cost per month (30 days) if it operates for 3.0 h per day and the rate is 10.5 cents/kilowatt hour?

Example:
The lightbulbs shown are identical and have resistance R. Which configuration produces more light? Which way do you think the headlights of a car are wired?



Solution:
The parallel combination has lower resistance (R/2) than the series combination (2R). There will be more total current in the parallel configuration. The total power consumed, which is proportional to the light produced, is P=IV, so the greater current in the parallel combination means more light.
Headlights are wired in parallel because if one goes out the other can stay lit.

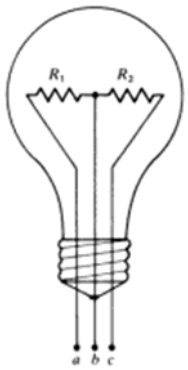
Example:
The circuit shown has three identical bulbs of resistance R.

a) When the switch is closed, how will the brightness of bulbs A and B compare with that of bulb C?
b) What happens when the switch is opened?

Solution:

a) When the switch is closed, the current that passes through bulb C must then split into two equal parts when it reaches the junction leading to bulbs A and B. It splits into equal parts because the resistances are the same. Thus, bulbs A and B receive half the current and will be less bright than bulb C.
b) When the switch is opened, we have a simple one loop series circuit and we expect bulbs C and B to be equally bright. However the equivalent resistance of this circuit (=R+R) is greater than that of the circuit with the switch closed (=R + R/2). So when we open the switch, we increase the resistance and reduce the current leaving the battery. Thus, compared to before, bulb C will dim when we open the switch. But bulb B gets more current when the switch is open, and so it will brighten somewhat (compared to before) when the switch is opened.

Example:
A three way light bulb contains two filaments that are connected to three wires as shown. By turning the socket switch, 120 V is put across either ab, bc or ac.
a) If R_1=144 Ω and R_2=216 Ω, what are the three possible power dissipations of the light bulb?
b) A different three way light bulb can operate at 300, 100 and 75 W. What are the resistances of its two filaments?



Solution:

(a) Case *ab*:
$$P_1 = \frac{V^2}{R_1} = \frac{(120\,V)^2}{144\,\Omega} = 100\,\text{W}$$

Case *bc*:
$$P_2 = \frac{V^2}{R_2} = \frac{(120\,\text{V})^2}{216\,\Omega} = 67\,\text{W}$$

Case *ac*:
$$P_3 = \frac{V^2}{R_1 + R_2} = \frac{(120\,\text{v})^2}{360\,\Omega} = 40\,\text{W}$$

(b) The highest wattage occurs for the smallest resistance, so

Case *ab*:
$$R_1 = \frac{V^2}{P_1} = \frac{(120\,\text{V})^2}{300\,\text{W}} = 48\,\Omega$$

Case *bc*:
$$R_2 = \frac{V^2}{P_2} = \frac{(120\,\text{V})^2}{100\,\text{W}} = 144\,\Omega$$

Check:

Case *ac*:
$$R_3 = \frac{V^2}{P_3} = \frac{(120\,\text{V})^2}{75\,\text{W}} = 192\,\Omega = R_1 + R_2$$