Lesson 13j: Power

Remember from earlier in the course we had a formula for relating electricity to energy changing forms...

$$V = \frac{\Delta E}{q} \rightarrow \Delta E = qV \quad \textbf{(equation 1)}$$

- But from way back in Science 10 and Physics 20 we had a formula to determine the power as energy is changed from one form to another over a period of time...

$$P = \frac{W}{t} = \frac{\Delta E}{t} \quad \textbf{(equation 2)}$$

P = Power measured in Watts (W), the equivalent of J/s
W = ΔE = change in energy measured in Joules (J)
t = time measured in seconds (s)

- This formula tells you that power is the rate at which energy is changed from one form to another.
  - For example, a 60W bulb changes electrical energy into light and thermal energy at a rate of 60 Joules per second.

We can now play around a bit with these two formulas to get...

$$P = \frac{\Delta E}{t} = \frac{qV}{t} \quad \textbf{(equation 3)}$$

- Recall that we have a formula for the current flowing through a circuit...

$$I = \frac{q}{t} \quad \textbf{(equation 4)}$$

- So we can simplify the equation 3 by subbing out the parts of equation 4...

$$P = \frac{qV}{t} = IV$$

P = IV

- This will be one of the ***main formulas*** you will use when calculating power in an electrical circuit.

Example 1: A household appliance draws a 0.50A current. **Determine** the power rating of this appliance.

Household power lines run at 120 V, so we can use that in our calculation.

P = I V = (0.5A)(120V) = 60W

The appliance runs at 60 W.

There are two other commonly used formulas for power that you need to be ready to use.

- They are both based on substituting V = I R into the P = IV formula. Try it out and you should be able to get...

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

Example 2: A portable fridge in the back of a van has a power rating of 5.0 W. Since it is plugged into the van's electrical system, it runs off of 12 V. **Determine** the resistance of the fridge.

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

$$R = \frac{V^2}{P} = \frac{12^2}{5.0} = 28.8 = 29\,\Omega$$

Power Costs

Most household run off of electricity obtained from a electricity generating station.

- Just like any other business they have to keep track of how much of their product you use, so they can figure out how much to charge you.
- Power companies could measure your electrical energy use in Joules, which would make perfect sense to a physicist.
  - Unfortunately this would mean you, the consumer, would get bills charging you for using millions of Joules of energy each month.
  - Most people don't like to see numbers that big on bills, no matter what they have to pay.
- Power companies devised a system that lets people know how much energy they use, in a much more compact, easy to understand number called **kilowatt hour** (kWh).
  - It is still a unit of energy, just like Joules.
  - It's based on the formula $\Delta E = P\,t$
  - If you measure the power an appliance uses in kilowatts, and measure how long it runs for in hours, you would get units...

$\Delta E = P\,t$
$= \text{kilowatt (hours)}$
$\Delta E = \text{kilowatt hours}$

Notice that if we had simplified stuff down to watts and seconds, we would have the standard SI unit for energy, Joules.

$\Delta E = P\,t$
$= 1 \text{ kilowatt (1 hour)}$
$= 1000\text{W (3600s)}$
$\Delta E = 3.6\text{e}6 \text{ J}$

- So one kilowatt hour equals 3.6e6 J of energy.

Your power bill is based on the cost of 1 kW h of electricity.

- Here in Alberta that number usually bounces around from about 7.5¢ to 12¢ per kWh.

Example 3: Based on the following common devices in a home running for the times shown, determine the cost of electricity for one year if the current rate is 8.9¢ / kWh.

Device	Power Consumption (W)	Time in Use Each Day (hours)
42 inch LCD TV	235	5.00
Xbox 360	135	2.00
Home Theatre System	250	5.00
Microwave Oven	1000	0.250
Oven	6000	1.00
10 Light Bulbs (60W each)	600	5.00

To solve this, we should first convert the power measurements into kilowatts, then multiply by the time to get kWh...

Device	Power Consumption (kW)	Time in Use Each Day (hours)	Energy Use (kWh)
42 inch LCD TV	0.235	5.00	1.175
Xbox 360	0.135	2.00	0.270
Home Theatre System	0.250	5.00	1.25
Microwave Oven	1.000	0.250	0.250
Oven	6.000	1.00	6.00
10 Light Bulbs (60W each)	0.600	5.00	0.300

Add the energy use of each device to find the total energy use in a day...

$1.175 + 0.270 + 1.25 + 0.250 + 6.00 + 0.300 =$ **9.245 kWh / day**

In one year this would mean that we would use...

$$\left(365\,\frac{\cancel{days}}{year}\right)\left(9.245\,\frac{kWh}{\cancel{day}}\right)=3374.425\,\frac{kWh}{year}$$

At a cost of...

$$\left(3374.425\,\frac{\cancel{kWh}}{year}\right)\left(8.9\,\frac{¢}{\cancel{kWh}}\right)=30032\,\frac{¢}{year}=\$300.32\ per\ year$$