Lesson 42: Efficiency

Efficiency is a very popular topic in our modern world.

- Many companies selling a wide range of products, from light bulbs to cars, advertise the efficiency of their products.
- Increasing energy costs are making efficiency an important factor to consider when purchasing a product.
  - In the past, when energy costs were lower, people focused more on the immediate "up-front" cost of a product.
  - Many people are now willing to pay extra for a product at the start with the knowledge they will save money in the long run on energy cost.
- People still don't necessarily understand what efficiency really means.

> **Did You Know?**
> Compact fluorescent lamps (CFLs) and Light Emitting Diodes (LEDs) are a much better choice that incandescent bulbs. Although you must pay more for them at the store, you will save money in the long run on the cost of the electricity they use (less than ¼ of what regular bulbs use).

Efficiency can be measured in terms of either energy or power.

- In either case it is a measurement of how much useful stuff comes out (**output**) compared to what was originally put in (**input**).

$$efficiency = \frac{Energy\ Output\ (E_{out})}{Energy\ Input\ (E_{in})} \qquad efficiency = \frac{Power\ Output\ (P_{out})}{Power\ Input\ (P_{in})}$$

- No matter what device you are examining, there is no such thing as a 100% efficient device (where all the **input** turns into useful **output**). The output is always less than the input. There is always some waste.
- This does not mean energy, for example, has been destroyed. Rather, some of the energy was just wasted in forms you didn't want.
- An incandescent light bulb is a fantastic example of this...

Example 1: A 100W incandescent bulb gives off about 1600 lumens of light, but has an efficiency of only 2.0% (ugg!). **Determine** the rate at which electricity is actually being turned into light.

The rate at which electricity changes to light is **power**. The reason 2.0% efficiency is "ugg" is because it means that only 2.0% of the power being used is actually usefully being changed into light. The other 98.0% is being turned into heat coming off the bulb. If an alien ever landed on Earth and looked at regular incandescent light bulbs, he would declare that they must be heating devices!

$$efficiency = \frac{P_{out}}{P_{in}}$$
$$P_{out} = efficiency\,(P_{in})$$
$$P_{out} = 0.020\,(100)$$
$$P_{out} = 2.0\,W$$

Remember that power in Watts is just a measurement of how many Joules are used per second. The calculation shown here shows us that of the 100 Joules used every second by the bulb, only

2.0 Joules per second actually becomes light. The other 98.0 Joules per second are released as heat. Ugg. Also consider that most incandescent bulbs have a lifespan of only about 1000 hours of use.

In comparison, a CFL uses only a quarter the power for the same light, in part because it also runs at an efficiency close to 8%. Add in their lifespan of about 10 000 hours and then you see how superior they are to incandescent bulbs.

Example 2: For a CFL to produce about the same amount of light as the incandescent bulb in the previous example it would also need to release about 2.0 W of light. If CFLs have an 8.0% efficiency, **determine** the wattage of the CFL you should buy that would replace a 100 W incandescent.

$$efficiency=\frac{Power\ Output\,(P_{out})}{Power\ Input\,(P_{in})}$$

$$P_{in}=\frac{P_{out}}{eff}$$

$$P_{in}=\frac{2.0}{0.080}$$

$$P_{in}=25\,W$$

So you would be looking to buy a bulb with about 25W input. In reality you could probably get buy with even as low as about a 23W bulb, since many CFLs give off light that is more spread across the visible light spectrum, so they are more effective at creating light you can see.

Example 3: I am buying an LED bulb that also produces 1600 lumens, or about 2.0W of light. I read on the package that the LED bulb I am buying actually uses 20W. Determine the efficiency of the bulb.

$$efficiency=\frac{Power\ Output\,(P_{out})}{Power\ Input\,(P_{in})}$$

$$efficiency=\frac{2.0}{20}$$

$$efficiency=0.10=10\%$$

A small improvement over CFLs, but when you factor in the longer life span of LEDs the savings will add up. Also, most CFLs have at least a small amount of mercury in them (as well as some other nasty chemicals) that make their proper disposal a problem. LEDs win out there also.

Example 4: A crane is lifting a 380 kg load at a constant velocity of 3.8 m/s. Determine its efficiency if the motor on the crane is rated as 22 kW.

Just like in the last lesson, we know that an object moving at a constant velocity has zero net force acting on it...

$$F_{NET}=F_a+F_g$$

$$0=F_a+F_g$$

$$F_a=-F_g$$

$$F_a=-mg$$

$$F_a=-380(-9.81)=3727.8\,N$$

So we can figure out the power **output** based on what the crane **actually did** with the load.

$$P=\frac{W}{t}=\frac{Fd}{t}=Fv$$
$$P=3727.8(3.8)$$
$$P=14165.64\,W$$

So the efficiency will be based on this output and the input (22 000 W) given in the question.

$$efficiency=\frac{P_{out}}{P_{\text{in}}}$$
$$efficiency=\frac{14165.64}{22000}$$
$$efficiency=0.64=64\%$$

We can say that the crane has an efficiency of 64%. (*Two sig digs because of the velocity*.)