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.

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 60W incandescent bulb has an efficiency of only 2.0% (ugg!). **Determine** the amount of power actually turned into light.

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!

$$efficiency = \frac{P_{out}}{P_{in}}$$
$$P_{out} = efficiency\ (P_{in})$$
$$P_{out} = 0.020\ (60)$$
$$P_{out} = 1.2W$$

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 60 Joules used every second by the bulb, only 1.2 Joules per second actually becomes light. The other 58.8 Joules per second are released as heat. Ugg.

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%.

Example 2: A 13W CFL produces the same amount of light as the incandescent bulb in the previous example. At 8.0% efficiency, **determine** the amount of energy turned into light, and compare it to the answer from Example 1.

$$efficiency = \frac{Power\,Output\,(P_{out})}{Power\,Input\,(P_{in})}$$
$$P_{out} = efficiency\,(P_{in})$$
$$P_{out} = 0.080(13)$$
$$P_{out} = 1.0W$$

"Oy! Look at that!" you say. "We only used 1.0W of power usefully in the CFL, but we used 1.2W on the incandescent bulb. You're wrong Mr.C!"

Take a second look. It's true, less power became light, but that's because the CFL runs on so much less power overall. We only wasted 12W with the CFL, compared to 58.8W on the incandescent. We wasted about five times more with power with the incandescent bulb.

Example 3: 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 22 000 W.

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

$$F_{NET} = F_a + F_g$$
$$0 = F_a + F_g$$
$$F_a = -F_g$$
$$F_a = -mg$$
$$F_a = -380(-9.81) = 3727.8N$$

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

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

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

$$efficiency = \frac{P_{out}}{P_{in}}$$
$$efficiency = \frac{14165.64}{220000}$$
$$efficiency = 0.64$$

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