Measuring Energy and Power

Overview

You can use a wattmeter to measure the power (rate of energy use) and energy for household appliances.

Theory

A wattmeter plugs into a normal electric outlet, and then you plug devices into the wattmeter. This lets you measure the energy and power used by the device you plug in.

Necessary materials:

- Wattmeter
- Lots of stuff to plug into the wattmeter.

Energy is a basic physical quantity—it's basically the currency for doing things. Walk up a flight of stairs? It's going to cost you some energy. Need to heat your food on the stove? It's going to cost you some energy.

The basic unit of energy is the joule (J). A joule isn't very much energy. When I climb the two flights of stairs to my office, it costs me about 25,000 J.

Power is the rate at which energy is used. Right now, as I type this, my body is using about 150 J every second. 1 J/s is a watt (W), so I am using energy at a rate of 150 W. The amount of energy used depends on the power and the time:

$$\text{Energy used (in J)} = \text{Power (in W)} \times \text{time (in s)}$$

So, over the course of an hour, if I am using energy at 150 W, I use:

$$540{,}000\ \text{J} = (150\ \text{W}) \times (3600\ \text{s})$$

Household appliances are often rated in terms of the power they consume. My microwave oven has a rated power of 1100 W; this is the rate at which it pulls energy from the wall socket. It converts about 700 W of that input energy into microwaves; the other 400 W are lost as heat in the microwave generator.

Rather than measure your energy use in joules—which would be a very large number—the utility company measures your energy use in kilowatt-hours. A kilowatt hour is the amount of energy used by a device that uses 1000 W for a time of 1 hour. Generally, the energy used is:

$$\text{Energy used (in kWh)} = \text{Power (in kW)} \times \text{time (in h)}$$

If I ran my microwave oven for two hours, it would use:

$$2.2\ \text{kWh} = (1.1\ \text{kW}) \times (2.0\ \text{h})$$

Doing the experiment

Plug different devices into the wattmeter and measure how much power they are using, or how much energy they use over a period of time—both are possible.

There are some surprises here. If you plug in a lamp, the power will vary, dramatically, with the type of bulb you use. Incandescent bulbs are very inefficient, converting only about 4% of the input energy into light; LED bulbs might be 25% efficient—not great, but much better! So, for the same brightness, an LED bulb will use a lot less energy.

The big energy users in your house are things that run all the time. Your refrigerator doesn't use that much power, but the motor runs a good fraction of the day. It's likley the largest user of energy in your home.

Another interesting thing to look for are shadow loads—devices that use power even when they aren't running. Your television is often a culprit, as are many electronic devices. They might not be off—they are just in a low-power mode. I have a stereo that uses the exact same amount of energy whether it is playing music or not—it's always warmed up, ready to go.

When we've used this with classes, the students have been ruthless at finding things in the classroom that use energy and can be turned off. It's a fun activity.

Summing up

This device is a great tool for exploring energy and power use in your home, school, or office.

For more information

Colorado State University College of Natural Sciences: http://www.natsci.colostate.edu

Little Shop of Physics: http://littleshop.physics.colostate.edu