

How efficient is your body?

A laboratory experiment
from the
Little Shop of Physics at
Colorado State University



Overview

We get our energy from the food we eat. Our bodies use the chemical energy stored in food to move, grow, and live.

How efficient is your body at doing this? If you eat a certain number of calories, how many can your body actually use?

We'll consider the following question: How many times must you climb a set of stairs to burn off the energy stored in a small bag of candy?

Theory

As you get higher up in elevation, your potential energy increases:

$$\text{Change in Potential Energy (in joules)} = \text{mass (in kilograms)} \times \text{gravity} \times \text{change in height (in meters)}$$

In this equation, “mass” is how much stuff you’re made up of—you have to carry yourself up the stairs, which means some people require more energy than others because we come in different sizes!

To calculate your mass in kilograms, divide your weight in pounds by 2.2:

$$(\text{_____ lbs}) / (2.2) = \text{_____ kilograms}$$

The “gravity” in this equation is a constant. Due to the size and mass of the earth, gravity is 9.8 N/kg, meaning it pulls you (and everything else) with a force of 9.8 Newtons on every kilogram of mass.

The “change in height” is the distance you traveled up. An average household set of stairs is 8 ft in height, which we’ll need to convert to meters:

$$\text{_____ ft} \times .305 = \text{_____ meters}$$

Your potential energy increases as you climb stairs. This energy came from food, which is measured in Calories. A Calorie is another measure of energy. The unit on a nutrition label is “Calories”; but 1 Calorie (with a capital C) is 1000 calories (with a lowercase c).

The unit that we use for energy in Physics is joules. To convert, approximately:

$$1 \text{ calorie} = 4 \text{ joules}$$

But your body is only 25% efficient, so for 1 calorie input, instead of getting 4 joules out, you get only 1. We can therefore make the following approximation:

$$\mathbf{1 \text{ calorie of energy in food} \Rightarrow 1 \text{ joule of energy output}}$$

Necessary materials:

Activity 1

- Fun-size bag of M&Ms
- Ruler
- Bathroom scale

Activity 2

- Stopwatch
- Tennis shoes

the energy stored in a fun-size bag of M&Ms.

Have each student individually calculate how many joules of energy they gain in potential energy by climbing the stairs by using the formula:

$$\text{Change in Potential Energy (in joules)} = \text{mass (in kilograms)} \times \text{gravity} \times \text{change in height (in meters)}$$

Because of the students' different sizes, they should have different answers!

Now they'll compare the energy they expend climbing the stairs to the amount of energy stored in a fun sized bag of M&Ms.

Recall that 1 Calorie = 1000 calories, and that, due to the body's 25% efficiency:

$$\mathbf{1 \text{ calorie of energy in food} \Rightarrow 1 \text{ joule of energy output}}$$

Then, have your students make the following calculations—or simply give them the desired final outcome, and have them fill in the intermediate steps.

- Determine the energy in the bag of M&Ms, then convert to calories.
- Compute the possible energy output in joules.
- Compute how many sets of stairs could be climbed with this energy.

Doing the Experiment - Activity 2

Another way to measure energy output is to look at power—the rate of energy conversion.

The useful output of climbing the stairs is an increase in potential energy. If you measure the time for this, you can compute the power:

$$\text{Power (in watts)} = \text{Energy used (in joules)} / \text{time elapsed (in seconds)}$$

Your students know the energy to climb the stairs—now have them measure their power output!

Summing Up

Your students will be surprised by how many flights of stairs you can climb with the energy in a small bag of candy. They will also be surprised by how modest their power output is.

Here's another thing to consider: If your body only converts 25% of the energy in food into potential energy, where does the rest go? Nearly all goes to thermal energy—which is why you warm up when you exercise!

For More Information

CMMAP, the Center for Multiscale Modeling of Atmospheric Processes: <http://cmmmap.colostate.edu>

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

