Body Energy

Pillar(s): Healthy Eating and Active Living
Division IV
Grades: 10-12
Core Curriculum Connections: Physics 20 Unit C: Circular Motion, Work and Energy

I. Rationale:

Students have done many examples of **work**, **energy** and **power** in physics class. Most of these examples are made up word problems about hypothetical examples. One aspect of energy that is rarely considered is that humans require energy to power our body. Just like a light bulb needs electricity, humans must consume food in order to live. This exercise will try to relate the two subjects of nutrition and energy.

II. Activity Objectives:

Students will learn how the body can convert food energy into muscular work. The human body requires energy to perform all body functions. This energy is derived from the food we eat. In this exercise, students will see how much of the food that is consumed can be converted into mechanical energy.

III. Curriculum Outcomes: Physics 20

Unit C: Circular Motion, Work, and Energy
General Outcome 2: *Students will* explain that work is a transfer of energy and that conservation of energy in an isolated system is a fundamental physical concept.

Specific Outcomes for Knowledge
Students will:
20–C2.1k define mechanical energy as the sum of kinetic and potential energy
20–C2.2k determine, quantitatively, the relationships among the kinetic, gravitational potential and total mechanical energies of a mass at any point between maximum potential energy and maximum kinetic energy
20–C2.3k analyze, quantitatively, kinematics and dynamics problems that relate to the conservation of mechanical energy in an isolated system
20–C2.4k recall work as a measure of the mechanical energy transferred and power as the rate of doing work
20–C2.5k describe power qualitatively and quantitatively
20–C2.6k describe, qualitatively, the change in mechanical energy in a system that is not isolated

IV. Teacher Background

Energy
The chemical energy contained in the food we eat serves many functions. It is used to maintain body temperature, to drive bodily metabolic processes, some is used for growth and replacing worn-out tissue, and the energy that is no longer available to us is excreted. Most importantly, food energy is used to perform **mechanical work**. This includes running, pulling, lifting, hauling, and many other tasks. But just how much of the food we eat can be converted to muscular activity?

Conversion
All of the processes described above require a great deal of energy. Because there are so many of them, the fraction of the food energy converted to mechanical work must be fairly small. To prove that point, think about what you did this morning. Whether you sat in class all day or ran all morning in gym class, you were still hungry at lunchtime. This is because a large fraction of the **caloric intake** you ingest is used for maintenance and is not available for muscular work. In the following examples, a 15% conversion for food to muscular work will be used.

V. Materials

- Copy of exercise the Body Energy exercise

VI. Procedure

- See activity description below

Body Energy

Consider how far a person can climb after consuming a specific food substance.

We will use the formula : Work $= m\,g\,h$ where h = height
g = gravity
m = mass

Example 1 - Milk

For a liter of milk, the energy content is about 2.4×10^6 Joules. Using a conversion efficiency labeled ϵ, the amount of work that can be performed is related to the food energy input, Q, by $W = \epsilon Q$
If the person weighs 50 kg, we know the conversion of milk calories to muscular work is about 15%, and the force of gravity ($g = 9.8$ m/sec^2). Ignoring all the other possible complicating factors, what is the height a person could climb on a liter of milk?

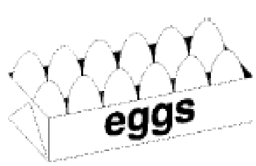
Solution

$$h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{(.15)(2.4 \times 10^6)(\text{kgm}^2/\text{sec}^2)}{(50\text{ kg})(9.8\text{ m/sec}^2)}$$

$$= 700\text{ m}$$

Example 2 - Eggs

a) A serving of two large eggs provides 149 kilocalories of energy. What is the height a person could climb after eating two eggs for breakfast? Use the same values as the previous problem with milk. Given: 1 Joule = 0.2390 calories



Body Energy

Solution

- First convert kcals into Joules $149 \text{ kcal} \times \frac{1000 \text{ cal}}{1 \text{ Kcal}} \times \frac{1 \text{ J}}{0.2390 \text{ cal}} = 623{,}430.96 \text{ J}$

- now solve $h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{(.15)(623{,}430.96)(kgm^2/sec^2)}{(50kg)(9.8m/sec^2)}$

$$= \frac{93{,}514.64}{490} = 190.85 \text{ m}$$

b) How high will a person weighing 250 pounds be able to climb? Given: 1kg = 2.2 lbs

Solution:

- first convert pounds into kilograms $\frac{250 \text{ lbs} \times 1kg}{2.2 \text{ lbs}} = 113.64 \text{ kg}$

- solve $h = \frac{(\text{conversion efficiency})(Q)}{mg} = \frac{93{,}514.64}{(113.64kg)(9.8m/sec2)}$

$$= 83.97 \text{ m}$$

c) This time use the same factors from the first problem. If two large eggs provide 149 Kcal of energy, how many eggs would a person have to eat in order to climb a mountain that was 500 meters high. Round up to find the exact number of eggs.

Body Energy

Solution

- find the amount of energy required to climb the mountain (E)

$$h = \frac{(\text{conversion factor})(Q)}{mg}$$

$$500m = \frac{(0.15)(E)(kgm2/sec2)}{(50kg)(9.8m/sec2)}$$

$$(500)(490) = 0.15(E)$$

$$E = 1{,}633{,}333.33 \text{ Joules}$$

- convert joules to kilocalories $1{,}633{,}333.33J \times \frac{0.2390 \text{ cal}}{1J} \times \frac{1kcal}{1000cal} = 390.37 \text{ kcal}$

149 kcal divided by 2 = 74.5 kcal for every egg

$$390.37 \text{ kcal} \times \frac{1 \text{ egg}}{74.5 \text{ kcal}} = 5.24 \text{ eggs}$$

This person would have to eat about 6 eggs to be able to climb the 500 meter mountain