Discovery Ride
Energy Worksheet

This paper will walk you through the concepts and calculations we will use in our unit on work, energy, and simple machines. It is designed to give you an introduction to a variety of concepts through the eyes of the Discovery Ride, a bicycle journey Mr. Flint completed during the summer of 2002.

Directions

Complete all calculations using SI (metric system) units and follow all significant digit rules. Place your answers in a box.

Chemical Potential Energy

Food energy is measured in joules in the SI system. The standard energy unit used by nutritionists in the United States is the Calorie. One Calorie (with a capital "C") is also known as a kilocalorie and is equal to 1000 calories (lower case "c"). One calorie is equal to 4.184 joules.

1.) Calculate the total amount of food energy consumed by Mr. Flint over the course of the 70 day journey. The average amount of energy consumed each day was 18.3 million Joules (4380 Calories).

2.) Calculate the total amount of energy contained in the stored fat that Mr. Flint consumed over the course of the trip. He used up a total of 3.6 kg (8.0 lbs) of fat and each gram of fat has the energy equivalent of 37,700 Joules.

3.) Add the energy consumed in the daily diet (answer to problem #1) to the energy contained in fat (answer to problem #2). This is the total amount of energy available for use for the entire summer.

Basal and Active Metabolism

Basal Metabolism is the energy consumed by the body to take care of essential body functions. These include digestion, neurological requirements (brain and nerves) and cardiopulmonary requirements (circulation and respiration). Every person requires a particular minimum amount of energy to maintain these functions. Any activity above and beyond basal metabolism requires additional energy.

For this exercise we will assume that Mr. Flint had three modes of activity during each day:

Sleep, sedentary activity:	16.5 hours
Moderate activity (setting up camp, walking):	2.0 hours
Heavy activity (biking):	5.5 hours

The energy use rates for each activity follow. These are specific to Mr. Flint and will be different for you.

Sleep, sedentary:	331,000 Joules per hour (79 Calories per hour)
Moderate activity:	439,000 Joules per hour (105 Calories per hour)
Heavy activity:	1,970,000 Joules per hour (470 Calories per hour)

4.) Calculate the amount of energy consumed during each of the three stages of activity per day then come up with a total daily energy requirement.

5.) Calculate the total amount of energy required for the entire summer by multiplying the answer from #4 by 70 days. Compare the amount of energy consumed in problem #3 to the amount of energy required for the entire trip. If they are the same then his energy "budget" is balanced. If they are different then come up with a reasonable explanation as to the difference in energy.

Gravitational Potential Energy

Gravitational potential energy is a measurement of how much mechanical energy an object has when it has the potential to fall while being accelerated by gravity. The object does not necessarily have to be lifted straight upward and dropped straight down. Sometimes there is a machine involved.

On the Discovery Ride, Mr. Flint increased his potential energy by riding up hills (inclined planes). Riding back down the hills decreases his potential energy while raising the kinetic energy (that's why you go fast when riding down hill on a bike.)

Gravitational potential energy is measured using the following formula:

$$PE = mgh$$

Where PE is potential energy in joules (J), m is mass in kilograms (kg), g is acceleration due to gravity (9.80 m/s^2 on the Earth's surface), and h is the difference in height in meters (m).

6.) The tallest continuous climb on this journey was between Hartsell, Colorado and the top of Hoosier Pass just south of Breckenridge, Colorado. Hartsell, Colorado is at an elevation of 2661 meters (8733 ft.) and Hoosier Pass is at an elevation of 3514 m (11529 ft.). Mr. Flint's mass is 77.3 kg (170 lbs.) and the mass of his bicycle and gear was 43 kg (95 lbs.). Calculate the change in potential energy for Mr. Flint and his gear for this climb.

Work

Work is defined as the product of force that is applied to an object and the distance it travels. The formula for work is given as

$$W = Fd$$

where W is work in joules (J), F is the force applied to the object in Newtons (N), and d is distance in meters (m).

You will notice that the unit for work and the unit for energy are the same. The work–energy theorem states that the amount of work done to an object is equal to its change in energy. This can be written as

$$W = \Delta E$$

If we compare the formulas for work and potential energy, you will see that they are essentially the same. Both formulas have distance in them (height of the hill). The product mg in the potential energy formula and force in the work formula are both equal to the weight of the rider and the bike. This work–energy theorem will be a very important concept as we continue to study energy and machines.

Power

Power defines how much work can be done in a particular amount of time. It is given by the formula:

$$P = W/t$$

Where P is power in Watts (W), W is work in Joules (J), and t is time in seconds (s).

7.) Mr. Flint was able to ride from Hartsell, Colorado to the top of Hoosier Pass as described in problem number six in a time of 4 hours and 16 minutes. Convert the time into seconds for use in the formula. This is a very important step that you must remember when doing power problems!

Sidebar – Usually a bicyclist has to do work to overcome rolling resistance and air resistance. While climbing steep hills the rider usually moves slowly. This reduces air resistance dramatically since it is dependent on the square of the speed of the rider. All in all, we are able to neglect these forces and focus on the change in gravitational potential energy

8.) Calculate the power Mr. Flint was able to produce for this climb. Remember that work is equal to the change in potential energy.

9.) Another unit of energy that is commonly used in the United States is horsepower. One horsepower is equal to 746 Watts. Convert Mr. Flint's average energy output in problem #8 into horsepower.

Kinetic Energy

Kinetic energy is a form of mechanical energy that is sometimes called the "energy of motion." The formula for kinetic energy is:

$$KE = {}^{1}/_{2}\, mv^2$$

Where *KE* is kinetic energy in joules (J), *m* is mass in kilograms (kg), and *v* is speed in meters per second (m/s).

Mr. Flint's top speed on the Discovery Ride was 75.5 km/hr (46.8 mph). This occurred in northern Colorado near the town of Walden just south of the Colorado/Wyoming border.

10.) Convert this speed in kilometers per hour in to meters per second.

11.) Calculate the amount of kinetic energy Mr. Flint had at that point. Mr. Flint's mass is 77.3 kg (170 lbs.) and the mass of his bicycle and gear was 43 kg (95 lbs.).