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BOCES Science Laboratory Investigation

MECHANICAL WORK AND POWER

**Introduction**

 We already know that the English language is a rather annoying thing. To make it even more aggravating, we often take words from science and twist them around to mean something completely different when it is used in everyday life. For example, you might say that the “power went out” if your house has no electricity. Sure, electricity has power, but not in the same way that we mean in science. Indeed, you might be sitting at your desk, doing a lot of “work,” but if you haven’t moved, then you’re not doing work as science sees it.

 Don’t worry too much about trying to figure out these differences; rather, worry about discovering what these terms really mean in science. Further, try and see how these next couple of concepts connect to what you already know. For example, you know that a rock that is sitting in your hand isn’t going to do a whole lot of damage. But that same rock, when thrown at your forehead, can cause you some issues. The only difference in the two situations is that the rock in the second situation was traveling a lot faster. So from that, you can tell that if something is moving faster, it has more energy.

 Energy, however, is another one of those terms that we toss around in our daily lives without really considering what it means. You might be “low on energy” if you’re hungry, or perhaps you want to be “energy-efficient.” In this case, having the scientific definition of energy can be really helpful.

Energy (n.) – The ability to do work.

So energy isn’t a “thing;” you can’t have a ball of energy or a handful of energy. It’s a measurable property of an object. There are also many forms of energy, from electrical to gravitational and mechanical to thermal. One particular form of energy that we are concerned with is kinetic energy (KE). KE is defined as the energy that an object has because of its motion. The formula for KE is:

KE = ½ mv2

So you can see that kinetic energy depends on the mass of an object, as well as how fast it is going. Something that is more massive or traveling faster will have more energy.

 We can connect the concept of energy with force, as well. You know that if a car hits a wall going at 2 km/h it will do a lot less damage than a car going 50 km/h. That’s because the faster car has more energy and can therefore impart more force to the wall. So force and energy are directly related: as one increases so does the other. Indeed, there is a way to calculate with what force, say, a bus traveling at 100 km/h would hit a wall, assuming you know the mass of the bus and how long the bus takes to come to a complete stop.

 Another term that is commonly brought up with energy is work. Work is another term whose scientific definition it is helpful to know. Work is a force exerted over a distance. Or, if put into the form of an equation:

W = Fd

So if you push and push on the side of the Empire State building, even though your muscles are converting a lot of chemical energy from your food to mechanical energy and heat in your muscles, if you don’t move the building, you haven’t done any work. Consider the units for work: force is measured in newtons and distance is measured in meter. So the unit is the newton-meter, but scientists now call it the joule, named after James Prescott Joule.

 It’s also true that some people or machines can do work at a faster or slower pace than others. So you might think of this as doing more work in a given amount of time. We in the science business have a name for that, and we call it power. The formula for power is:

P = W/t

Power is measured in watts, named after James Watt. One watt is equal to one joule of work per second. There are, of course, other ways to measure power, including horsepower. One horsepower is equal to 745.699872 watts, so one watt of power isn’t all that much. We can easily calculate how many watts of power an engine has by multiplying its horsepower rating by 745.699872. Consider a standard, 60-watt light bulb. The wattage tells us that it takes 60 joules of electrical work every second to make it run.

 So all these concepts can come together to show us that we can figure out how much work a machine or person can do, and how much power they can generate. Today, you’ll explore this concept even further.

**Purpose**

 The purpose of this investigation is for you to get a better understanding of the concepts of energy, work and power, and how they all relate to force and Newton’s laws. You’ll also understand the difference between the colloquial and scientific uses of the words power, work and energy.

**Materials**

 PENCIL Structure at least a meter tall

 Stopwatch

**Procedures**

 1. Find something that you can easily walk or otherwise move up, such as a set of stairs, a ladder, slide, etc. You will need to be able to safely and quickly move up whatever you select a few times.

 2. Measure the total height of whatever you choose to use. That is, find the distance, in meters, from the lowest point to the highest point.

 3. Move up the structure SLOWLY. Have your partner time how long it takes you to complete the task. Record your data in table 1.

 4. Move up the structure QUICKLY but carefully. Have your partner time how long it takes you to complete the task. Record your data in table 1.

 5. Find the force with which you will move up the structure by finding the force that you put on the ground. You can do this using Newton’s Second Law: F = ma. Simply find your mass in kilograms (there are about 2.2 lbs in one kg), and multiply by 9.81 m/s/s, which is the acceleration due to gravity. Your answer will be in newtons.

 6. Determine the work that you did for each trial and record it in table 2.

 7. Determine the power that you needed for each trial and record it in table 2.

QUESTION 1: What is your force, in newtons? Use the formula F = ma to figure this out.

|  |  |  |  |
| --- | --- | --- | --- |
| **Trial** | **Height Difference (m)** | **Force Required (N)** | **Time (s)** |
| Slowly |  |  |  |
| Quickly |  |  |  |

Table 1. Data for moving up your structure slowly and quickly.

QUESTION 2: Calculate the amount of work that you did in each trial using the formula

W = Fd. Show your calculations in the space below.

QUESTION 3: Calculate the power that was needed in each trial using the formula P = W/t. Show your calculations in the space below.

|  |  |  |
| --- | --- | --- |
| **Trial** | **Work (J)** | **Power (W)** |
| Slowly |  |  |
| Quickly |  |  |

Table 2. Calculated work and power for each trial.

QUESTION 4: Which trial (quickly or slowly) took the most work?

QUESTION 5: Which trial (quickly or slowly) needed the most power?

**Analysis**

QUESTION 6: Aside from watts, the other common unit used to measure the amount of power that is needed for a task is horsepower. Using the information in the “background information” section at the beginning of this lab, determine how much horsepower you were developing while moving up or down in this lab.

QUESTION 7: Horsepower, strangely, didn’t start out as a way to measure horses. It was used to measure how many horses the (then) newly-invented steam engine could replace. If a steam engine could replace one horse, then it was said to have 1 hp of power. Nowadays, the unit of hp is used to measure the power of everything from cars to helicopters. How many horses would be needed to power a lighthouse light bulb that needed 4,500 watts of power?

QUESTION 8: Can you be doing no work but still be using energy? Explain and give an example.

QUESTION 9: Light bulbs are rated in watts. One watt is equivalent to using one joule of energy every second. If you have a 60 watt bulb, then each second it uses 60 joules of energy. How much energy would this bulb use if you left it on for three hours?

QUESTION 10: We know that work is measured in joules, but one joule is equivalent to one newton-meter. That is, one joule of work can exert a force of one newton over a distance of one meter. So how much work are you doing if you lift a 10 kg box up a flight of stairs that is 30 m tall? If it takes you 2 minutes to do it, how much power are you developing?