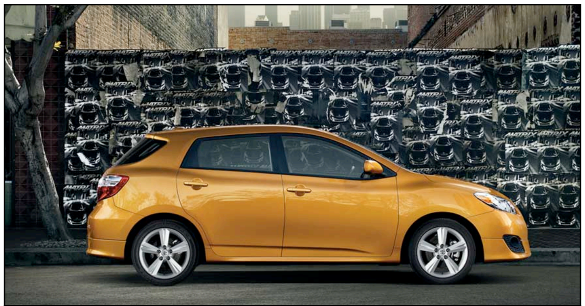
Human Horsepower



158 horses under the hood, which sounds like a lot until you realize that Indy cars have about 650 hp.

Introduction

We all know what power is, right? You probably know how much power your car engine delivers, because it's a widely advertised feature. But when you are told that your Toyota Matrix has a 2.4-liter DOHC 16-valve VVT-i 4-cylinder engine that produces 158 hp @ 6000 rpm, what does that even mean? What is horsepower? Firstly, power is defined as the amount of work done per unit time. The idea of horsepower is actually literal: How much work can a horse do in a given amount of time? Now, not all horses are equally capable, so this is somewhat akin to defining a foot as the length from heel to toe of the current king of the realm. Lucky for us that the unit of horsepower was standardized in the 1700s.

How many calories are you burning?

As much fun as it would be to compare our cars by drag racing in the parking lot, that would be a dangerous and irresponsible lab exercise. Lucky for us, a person climbing up a flight of stairs at a constant velocity does work against gravity. Work is the product of the force times the parallel distance. In this case, the force is the person's weight and the vertical height climbed by the person is the distance:

$$\text{work} = \text{weight} \times \text{height}$$

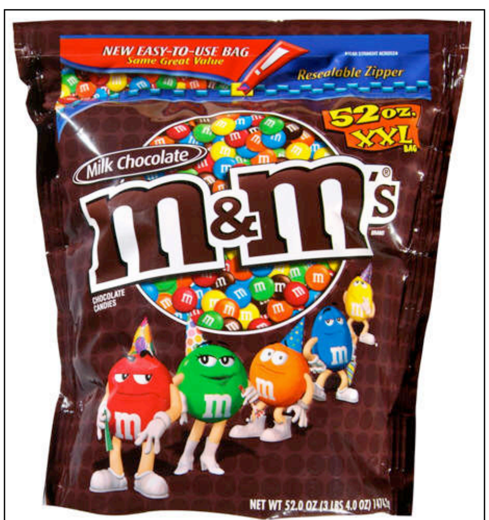
$$W = (mg)h$$

where $g = 9.8\ \text{m/s}^2$. If t is the time it takes the person to climb the flight of stairs, then the power P expended is:

$$\text{power} = \frac{\text{work}}{\text{time}}$$

$$P = \frac{W}{t} = \frac{(mgh)}{t}$$

In SI units, distance is measured in meters (m), work is measured in joules (J) and the power in watts (W = J/s). One horsepower (hp) is equal to 746 W.



How many M&Ms can you eat to make up those calories you burned on the stairs? Prepare to be disappointed.

Objectives

- Distinguish between the concepts of work and power
- Determine the work done and the power expended (in watts and horsepower) by a person in running up a flight of stairs
- Practice unit conversions
- Compare the work done in climbing a flight of stairs to the energy gained by eating a packet of M&Ms

Equipment

- Stopwatch
- Meterstick
- Kilogram weight scale
- M&Ms (optional, but delicious)

Experimental Procedure

- This activity will be done in the spectator seating area at the Farris Center.
- Each group will consist of two members. One of the team members will be responsible for climbing up the stairs while the other will keep time.
- Measure and record the mass (in kg) and weight (in Newtons) of the person who will be climbing the flight of stairs.
- Determine the total height of the flight of stairs in meters. For example, measure the heights of three different pairs of steps, then determine the average height of a pair of steps. The total height of the flight of stairs will be the number of steps times the average height.
- Determine the time it takes the person to climb up the flight of stairs. Make sure the stairs are climbed at a fast but steady pace. Be careful while climbing the stairs.

Data & Analysis

If you have not already, create a neat and complete table for your information.

Step Height (m)			Average Step (m)	Total Number of Steps N	Flight Height h =avg·N (m)
Step 1	Step 2	Step 3			

Runner's Mass m (kg)	Runner's Weight mg (N)	Time to Climb (s)

Nutrition Facts

Serving Size 1.0 package (1.69 oz)

Amount Per Serving

Calories 236 Calories from Fat 91

	% Daily Value *
Total Fat 10g	16%
Saturated Fat 6g	31%
Polyunsaturated Fat 0g	
Monounsaturated Fat 2g	
Cholesterol 7mg	2%
Sodium 29mg	1%
Total Carbohydrate 34g	11%
Dietary Fiber 1g	5%
Sugars 31g	
Protein 2g	

Vitamin A 0% • Vitamin C 0%

Calcium 5% • Iron 4%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs:

		Calories: 2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram:
Fat 9 • Carbohydrate 4 • Protein 4

If you eat the entire packet, how many times do you have to run the stairs? Prepare to be disappointed.

1. Calculate the amount of work done (in Joules) by the Runner climbing the stairs:

$$W = (mg)h$$

2. Calculate the power expended (in Watts) by dividing the work done by the time it took:

$$P = \frac{W}{t} = \frac{(mgh)}{t}$$

3. Convert the power in Watts (J/s) to horsepower:

$$\text{hp} = \frac{\text{power in Watts}}{\left(746\,\frac{\text{Watts}}{\text{hp}}\right)}$$

4. Compare the Runner's horsepower to that Toyota Matrix. In order for the Runner to develop 150hp, how fast would she have to run the stairs?

If you look at any packaged food item that you buy from a store, you will notice it carries an information table titled Nutrition Facts. One of the items in this table is the total number of Calories per serving. On the left is the label from a snack-size packet of plain M&Ms. Calories are a unit of energy which tells you how much energy is gained by a person ingesting a specific quantity of the food in question:

$$1 \text{ food calorie} = 1 \text{ Calorie} = 4200\text{J}$$

5. The work done by a person climbing a flight of stairs is the energy lost by that person in climbing the flight of stairs. How many calories did the Runner burn by climbing the stairs? (Convert your answer to Question 1 from Joules to Calories).

$$\text{Calories burned} = \frac{W}{4200\,\frac{\text{J}}{\text{Cal}}} = \frac{(mgh)}{4200\,\frac{\text{J}}{\text{Cal}}}$$

6. What is the total energy in Joules of the packet of M&M candies?
7. There are approximately 55 M&Ms in a packet. What is the energy contained in a single piece of M&M candy (in Joules)?
8. How many M&Ms would the Runner have to eat to gain the energy that she lost in climbing the flight of stairs?
9. If the Runner were to eat an entire packet of M&M candies, how many times would she have to repeat the climbing to use up all the energy gained from the M&Ms?
10. This answer may sound unreasonable. That is because we are assuming that your body is able to store all the energy gained from the M&Ms. The human body is not that efficient. Assume instead your body stores only 25% of the energy gained from the M&Ms. How does this change your answer to the previous question?