PARADISE VALLEY COMMUNITY COLLEGE

PHYSICS 101 - INTRODUCTION TO PHYSICS

LABORATORY

Human Horsepower

- **Equipment Needed:**

  Stopwatch, mass scale, and tape measure/meter stick.

- **Objective:**

  To measure human power when climbing a flight of stairs.

- **Theory:**

  Horsepower is defined as work done over time. The exact definition of one horsepower is 33,000 ft.lbs./minute. Put another way, if you were to lift 33,000 pounds one foot over a period of one minute, you would have expended one horsepower.

  The definition of horsepower was originated by James Watt (1736-1819), the inventor of the steam engine, and the man whose name has been immortalized by the definition of Watt as a unit of power.

  To help sell his steam engines, Watt needed a way of rating their capabilities. The engines were replacing horses, the usual source of industrial power of the day. The typical horse, attached to a mill that grinded corn or cut wood, walked a 24 foot diameter (about 75.4 feet circumference) circle. Watt calculated that the horse pulled with a force of 180 pounds, although how he came up with the figure is not known. Watt observed that a horse typically made 144 trips around the circle in an hour, or about 2.4 per minute. This meant that the horse traveled at a speed of 180.96 feet per minute. Watt rounded off the speed to 181 feet per minute and multiplied that by the 180 pounds

of force the horse pulled and came up with 32,580 ft.lbs./minute. That was rounded off to 33,000 ft.lbs./minute, the figure used today.

Put into perspective, a healthy human can sustain about 0.1 horsepower. Most observers familiar with horses and their capabilities estimate that Watt was a bit optimistic; few horses could maintain that effort for long.

- **Procedure:**
  - 1) When the force applied to an object is constant, the formulas below can be used to calculate work and power. For gravitational forces on Earth, units of measure corresponding to the weight of the object are commonly used.
    - W = work (N.m=J)
    - F = force (N)
    - d = distance (m)
    - t = time (s)
    - P = power (J/s=W)
    - 1 hp = 746 Watts
    - 1 lb = 0.454 kg
  - 2) Weigh yourself (convert your mass to kg).
  - 3) Go to a designated staircase and conduct this experiment to determine your horsepower. You will need to calculate the vertical height of the stairs (height of one step multiplied by total number of steps). Do not take any running starts. Have someone time you.
  - 4) Calculate your horsepower for two different methods:
    - a) one step at a time.
    - b) two steps at a time.
- **Data Analysis:**
  - 1) Calculate your horsepower when taking one step at a time.
  - 2) Calculate your horsepower when taking two steps at a time.

- 3) Make 2 bar graphs (for the single steps and the double steps) of the class data sorting from least to greatest horsepower generated.
- 4) Include in your summary how you compared to the rest of the group. (What percent above, and what percent below.)

- **Questions:**
  - 1) Suppose that a 150 pound person climbs a staircase that has a vertical height of 8 feet in 3 seconds. What is that person's horsepower? (Convert to SI units.)
  - 2) Would the horsepower change if a lighter person climbed the same flight of stairs in the same amount of time? In what way? Explain your reasoning.
  - 3) In this problem, you will use the relationship between the Joule (mechanical energy), the calorie (heat energy), and the Calorie (food energy). The relationship between the three is:

    4,186 Joules = 1,000 heat calories = 1 food Calorie.

    4,186 J = 1,000 cal = 1 Cal.

    Using the above conversions, calculate how many times (and how many flights of steps) you would have to climb the Sears Tower located in downtown Chicago if you ate a 500 Cal piece of apple pie and drank a 150 Cal soft drink. The Sears Tower is 1,450 feet high and has 110 flights of steps. Be sure to use the appropriate SI units!