Lesson Plan: Introduction to Measurements of Force, Work, and Power

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Duration
3 hours

Student Learning Objectives

1. Students will be able to define Force and its SI unit of measure, the Newton, as well as discuss a various kinds of forces. They will be able to measure gravitational force given a Newton meter or information pertaining to an objects mass as the acceleration due to gravity.
2. Students will be able to define work and its SI unit of measure, the Joule. Students will be able to calculate work given a force and a distance upon which the force acts.
3. Students will be able to define power and its SI units of measure, watts and horsepower. Students will be able to calculate power given a measure of work and the time for which the work is being carried out.

Key Terms

Energy: the capacity to do work
Force: an influence on a body or system, producing or tending to produce a change in movement or in shape or other effects
Power: work done or energy transferred per unit time
Work: force times the distance through which it acts

Units of Measure

Newton: the SI unit of force, equal to the force that produces an acceleration of one meter per second squared on a mass of one kilogram

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Newton(N) = \frac{mass(kg) \times distance(m)}{time^2(s)^2}
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Joule: the SI unit of work or energy, equal to the work done by a force of one newton when its point of application moves through a distance of one meter in the direction of the force

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Joule(J) = \frac{force(N)}{distance(m)}
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Watt: the SI unit of power, equivalent to one joule per second

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\text{Watt}(W) = \frac{\text{energy}(J)}{\text{time}(s)}
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Horsepower: a unit of power, equal to approximately 746 Watts

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\text{Horsepower}(hp) = 746 \times \text{Watts}(W)
\]

Teaching Plan

Introduction/Lecture

- Introduce force and its definition
  - \( \text{Force} = \text{mass} \times \text{acceleration} \)
  - Ask the students for examples of forces (i.e. gravity, friction, spring, pressure, etc.)
- Introduce the Newton as the unit of measure for Force
  - Measure the gravitational force of a small object using a Newton meter
  - Covert my weight in pounds-force to Newtons
    - \( 1\text{ pound, force(lbf)} = 1\text{ pound, mass(lbm)} \times 32.17 \left( \frac{\text{ft}}{\text{s}^2} \right) \)
    - \( 1\text{ kg} = 2.2\text{lbf} \)
- Introduce the Newton as the unit of measure for Force
- Introduce energy, and ask students to name a few different types of energy
- Introduce work and its definition
  - \( \text{Work} = \text{Force} \times \text{distance} \)
  - Ask students to name a few real-life examples of work being done
  - Explain the Joule as the unit of measure for work.
    - Step up on a chair and have a student measure the height of the chair. Given my weight in Newtons and the height of the chair, how much work did I do?
- Introduce power and its definition
  - \( \text{Power} = \frac{\text{Work}}{\text{Time}} \)
  - For what objects do we usually measure power?
  - Explain Watt as the unit of measure for power
    - Again step up on the chair, this time very slowly. Ask students if I produced more power the first time when I stepped up more quickly or the second time when I stepped up more slowly. Step up on the chair one final time, and this time have a student time the movement. Use this measurement to calculate power.
  - Explain Horsepower as a unit of measure for power
    - Convert my power output in Watts to Horsepower
Activity 1: Climbing Up the Stairs

**Purpose:** Force, work, and power are common terms when discussing energy and how it is used. In this activity, students will learn how to calculate force, work, and power from data obtained experimentally.

**Materials:** tape measure, stopwatch, staircase, data sheet

**Objective:** Be the student who generates the most power while climbing up the stairs.

**Procedure:**
1. Find a suitable staircase, measure it's height, and record it's height in the data sheet. This may be done by measuring the height of a step and multiplying that height by the number of steps.
2. One at a time, have a student walk or run up the stairs. Have a second student record the amount of time it takes the student to move from the bottom of the stairs to the top step using the stopwatch.
3. Record each student's time on the data sheet.
4. Using each student's weight in Newtons, calculate the amount of work required to move up the stairs.
   - Note: 1kg = 2.2 lbf
5. Using the calculated work and recorded times, calculate the power output in Watts and horsepower.
6. Each student will complete evaluation questions on data sheet and hand in.

Activity 2: Power Generation while Lifting Weights

**Purpose:** Power generation is a function of force, distance, and time. In this activity, students will be challenged to take all of these factors into account as they select a weight for which they feel like they can generate the most power.

**Materials:** tape measure or ruler, stopwatch, set of weights, data sheet

**Objective:** Be the student who generates the most power while lifting weights for 30 seconds.

**Procedure:**
1. One at a time, each student will select a weight between 5 and 30 lbs for which they believe they can generate the most power with over a 30 second time interval. The weight selected will be recorded on the data sheet.
2. The student will then curl the weight starting with the arm at a right angle on the table until the forearm is parallel with the upper arm over an interval of 30 seconds. This will make the distance over which work is being done to be the
length of the forearm. The number of repetitions will be recorded on the data sheet.

3. After each student has completed the activity, the work done per repetition will be calculated. This can be multiplied by the total number of repetitions to find the total work done. Each student will calculate their total amount of work done and share with the class.

4. The power that each student generated during the exercise can then be calculated by dividing the total amount of work done by 30 seconds. This calculation will be recorded in the data sheet.

5. Each student will complete the evaluation questions on the data sheet and hand in.

References


Measurements of Force, Work, and Power: Climbing Up The Stairs

Data Sheet

Length of a stair (inches) =
Time is took you to climb the stairs (s) =

Length of a stair (meters) =

Total Height of the Staircase (meters) =

What is your approximate weight (lbs)?
What is your approximate weight in Newtons?

How much work did you do to climb the stairs (in Joules)?

How much power did you generate while climbing the stairs (in Watts and Horsepower)?
Evaluation Questions

1. Two years from now, if you climbed up the stairs in the same amount of time but weighted less and you did now would you generate more or less power than you did today?

2. If you climbed up a staircase that was double the height in double the time, would you have generated more or less power than you did in this activity? Would you have done more or less work?

3. If you climbed up the exact same staircase in the exact same time, but on a different planet with stronger gravitational field, would you have generated more or less power than you did here on Earth?
Answers to Evaluation Questions

1. Two years from now, if you climbed up the stairs in the same amount of time but weighted less and you did now would you generate more or less power than you did today?

   You would generate less power since you would have less mass (assuming that the force do to gravity has remained unchanged). Less mass would result in less work that you would need to do in climbing up the same set of stairs.

2. If you climbed up a staircase that was double the height in double the time, would you have generated more or less power than you did in this activity? Would you have done more or less work?

   You would have generated the same amount of power. First, since the staircase is double the height, you would have to do double the amount of work as compared to climbing the original staircase. When calculating power, you divide the work (2 times the original amount of work) by the time (2 times the original amount of time). This will result in the same power output as in the original case.

3. If you climbed up the exact same staircase in the exact same time, but on a different planet with stronger gravitational field, would you have generated more or less power than you did here on Earth?

   A stronger gravitational force will result in an increasing force (weight) that must be moved up the staircase. As a result, the amount of work that you would need to do to climb the staircase increases as does the power generated since you climb the staircase in the same amount of time.
Measurements of Force, Work, and Power: Lifting Weights

Data Sheet

Length of your forearm (cm) =
Weight selected (lbs) =
Number of repetitions done in 30 s =

Length of your forearm (meters) =

What is the total distance that you lifted the weight in 30 s (meters)?

What is the weight that you selected in Newtons?

How much work did you accomplish lifting the weight during the 30 s interval (in Joules)?

How much power did you generate (in Watts and Horsepower)?
Evaluation Questions

1. What factors in this activity influence the amount of power that you are able to generate?

2. If you had to do this activity again, would you change the amount of weight that you chose to lift?
Answers to Evaluation Questions

1. What factors in this activity influence the amount of power that you are able to generate?

   The factors influencing the amount of power produced include the length of your forearm, the weight selected, and the amount of repetitions that you are able to do in the 30-second time period.

2. If you had to do this activity again, would you change the amount of weight that you chose to lift?

   This answer is subjective and meant to make the students think. They may answer that they would try to lift a larger weight since they did many repetitions at a small weight and did not generate as much power as their classmates, or they may answer that they would try a smaller weight since they were not able to lift up a larger weight enough times to generate the most power.