POGIL: Work, Power, and Kinetic Energy

Purpose

To become familiar with work, power, and kinetic energy and the relationship between each of them.

Part 1: Work and Power

Let's define two quantities, *work* and *power*, that will be useful for explaining the motion of objects. We will define work done by a force as:

work done by a force = amount of force along direction of motion × distance moved.

Using algebraic symbols, we will write this equation as:

$$W = Fd\,.$$

Note the following regarding the sign of the work done:

- if the force is along the direction of motion, the work done by the force is *positive*
- if the force is opposite the direction of motion, the work done by the force is *negative*
- if the force is perpendicular to the direction of motion, the force does *zero* work.

If the force is in Newtons and the distance is in meters, then the unit of work is *Joules* (abbreviated J).

Power is the rate at which work is done. We can define the average power as:

average power = work/time required to do the work,

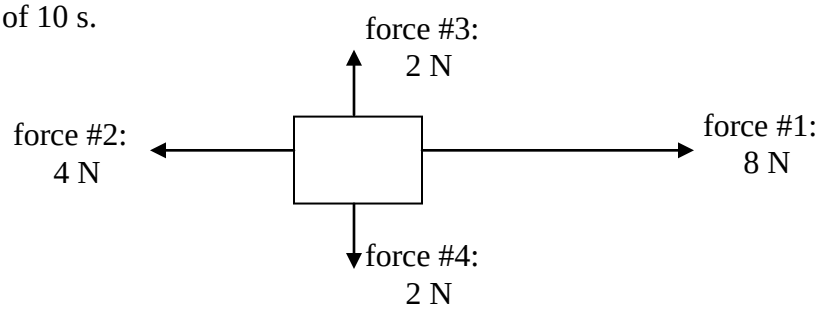
or, using algebraic symbols:

$$P = \frac{W}{t},$$

If work is measured in Joules and the time is measured in seconds, then we can use the unit *Watts* (abbreviated W) for power.

Critical Thinking Questions, part 1

1. In the diagram below, several forces are acting on the box as it moves 5 m to the right in a time of 10 s.



a. Calculate the amount of work done by each of the forces shown in the diagram. Include the correct units

work done by force #1 _____ work done by force #2 _____

work done by force #3 _____ work done by force #4 _____

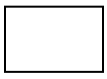
b. Calculate the power of each force shown in the diagram. Include the correct units.

power of force #1 _____ power of force #2 _____

power of force #3 _____ power of force #4 _____

2. Now imagine a person dragging a 50 kg box along the ground with a rope, as shown in the drawing below. The person exerts 50 N of force while moving the box 20 m in 10 s. Suppose also that friction is acting with 30 N of force between the box and the ground.

a. Draw a force diagram of the box below. Don't forget to label the forces.



b. Determine the amount of work done by each of the forces in the force diagram in a.

c. Determine the power of the person.

Part 2: Kinetic Energy

The *kinetic energy* of an object is the measure of an object's energy associated with its motion. We will define the kinetic energy of an object as:

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{speed})^2,$$

or, in terms of algebraic symbols:

$$KE = \tfrac{1}{2} mv^2 .$$

If the mass is in kilograms and the speed is in meters per second, then kinetic energy is measured in Joules, the same as the unit of work.

Critical Thinking Questions, part 2

3. Calculate the kinetic energy of a 1000 kg car traveling at 30 m/s, a typical speed on a highway.

4. Suppose a moving object has a kinetic energy of 100 J. What will the object's kinetic energy be if:
    a. its speed is doubled?

    b. its speed is tripled?

    c. its mass is doubled?

    d. its mass is tripled?

Part 3: The Work-Energy Theorem

It turns out that the total work done on an object is equal to the change in its kinetic energy. That's what makes work and kinetic energy such useful concepts; it shows that the effect of doing work on an object is to change its kinetic energy. We can write this as the following equation:

$$\text{total work} = \tfrac{1}{2} \times \text{mass} \times (\text{final speed})^2 - \tfrac{1}{2} \times \text{mass} \times (\text{initial speed})^2,$$

or, in terms of algebraic symbols:

$$W_{total} = \tfrac{1}{2} m v_{final}^2 - \tfrac{1}{2} m v_{initial}^2 .$$

Critical Thinking Questions, part 3

5. If a force does a positive amount of work on an object, does the object's speed increase, decrease, or remain the same? Justify your answer.

6. If a force does a negative amount of work on an object, does the object's speed increase, decrease, or remain the same? Justify your answer.

7. If a force does zero work on an object, does the object's speed increase, decrease, or remain the same? Justify your answer.

8. For the box in question #1 above, determine:
    a. the total work done on the box

    b. the change in the box's kinetic energy

c. the speed of the box at the end of its 5 m trip if its mass is 40 kg and it started from rest.

9. For the box in question #2 above, determine:
    a. the total work done on the box

    b. the change in the box's kinetic energy

    c. the speed of the box at the end of its 20 m trip if it started from rest.

10. Use the work-energy theorem to explain why, if you double the speed of a car, the distance required to stop the car will be four times as much.

Conclusions

Write a paragraph in clear, complete sentences that addresses the following questions:

- If two people do the same amount of work on an object, does this mean they are equally as powerful? Why or why not?
- In terms of work and kinetic energy:
    - why does a force in the same direction as an object's velocity increase the object's speed?
    - why does a force in the direction opposite an object's velocity decrease the object's speed?
    - why does a force perpendicular to an object's velocity change the direction of the velocity but not its magnitude?
- Suppose you do work on an object from rest to a certain speed v. Why does it take four times the amount of work to increase its speed from rest to a speed of $2v$?