Running the Stairs Assessment

About this Assessment

This assessment can be used to assess student understanding of the concepts of work, energy, and power. Students are asked to apply their understanding of these topics both conceptually and mathematically in multiple choice and free response items.

Objectives

Students will:

- Demonstrate conceptual understanding of the terms work, power, and energy and the relationship between these
- Apply equations to new situations to determine quantities of work, power, and energy

Level

Middle Grades: Physical Science

Common Core State Standards for Science Content

LTF Science lessons will be aligned with the next generation of multi-state science standards that are currently in development. These standards are said to be developed around the anchor document, *A Framework for K–12 Science Education*, which was produced by the National Research Council. Where applicable, the LTF Science lessons are also aligned to the Common Core Standards for Mathematical Content as well as the Common Core Literacy Standards for Science and Technical Subjects.

Code	Standard	Level of Thinking	Depth of Knowledge
(MATH) 6.EE.2C	Write, read, and evaluate expressions in which letters stand for numbers. Evaluate expressions at specific values for their variables. Include expressions that arise from formulas in real-world problems. Perform arithmetic operations, including those involving whole-number exponents, in the conventional order when there are no parentheses to specify a particular order (Order of Operations). For example, use the formulas $V = s^3$ and $A = 6\ s^2$ to find the volume and surface area of a cube with sides of length s = 1/2.	Apply	II
(LITERACY) W.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and	Apply	II

Code	Standard	Level of Thinking	Depth of Knowledge
	sufficient evidence.		
(MATH) 6.RP.3d	Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations. Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.	Apply	II

Connections to AP*

AP Physics: II. Newtonian mechanics C. Work, energy, and power

**Advanced Placement and AP are registered trademarks of the College Entrance Examination Board. The College Board was not involved in the production of this product.*

Running the Stairs Assessment

Answer Key

1. (E) When the force is exerted in the direction of motion, work is defined as the product of force and displacement. The work done is (100 kg)(10m/s^2)(5.0 m) = 5000 J.
2. (B) The power is the rate at which work is done and it decreases since it takes the person twice as long to lift the object.
3. (E) When the force is exerted in the direction of motion, work is defined as the product of force and displacement. The work done is zero since there is no movement in the direction of motion. No work is done since there is no displacement.
4. (D) Power is a measure of work divided by time. Work is a measure of force multiplied by displacement. Since the box is lifted with a constant velocity, we know that the net force acting on it is zero, and so the force exerted by the teacher must be equal and opposite to the weight of the box, which equals (100kg)(10m/s^2)=1000N. From this we can calculate the power exerted by the teacher.
$$P = \frac{W}{t} = \frac{(1000N)(2m)}{4s} = 500W$$
5. (A) Power is defined as work divided by time, and work is the product of force and displacement. While the box is being held in the air, it is not displaced, so the displacement is zero. This means the teacher does no work, and thus exerts no power.
6. (D) When the book reaches the person in the window, it will have a gravitational potential energy of U = mgh=(5.0kg)(10m/s^2)(4m)=200 J.
7. (C) When the student runs up the stairs, he will have a gravitational potential energy of U = mgh= 500 J regardless of his speed.
8. (D) Power is the rate at which work is done and its units are Joules per seconds or Watts. The unit for energy is the Joule.
9. (E) Since the height was measured lower than its actual value, the work and power would appear to be lower than they actually were.
10. (D) Both do the same amount of work. Liz performs the work in less time, and therefore operates at a higher power level than Ty.

Free Response

A student weighing 500 N climbs at a constant speed to the top of a 4.0 m vertical stairway. The time is measured to be 10.0 s using a stopwatch.

A. Determine the increase in the gravitational potential energy of the student.

Rationale

1 point for recognition that the increase in the GPE of the student equals the work done
1 point for correctly finding the GPE

$$PE = W = Fd = (mg)h = (500\text{N})(4.0\text{m}) = 2000\text{J}$$

B. Determine the average power exerted by the student to overcome gravity.

Rationale

1 point for correctly finding the average power

$$P = \frac{W}{t} = \frac{2000\text{J}}{10.0s} = 200\text{W}$$

C. If the stopwatch was started too early, then the work would be less than, greater than, or equal to the actual value. Check one and justify your answer.

_____ less than _____ greater than _____equal to

Rationale

1 point for the correct answer, equal to
1 point for the correct justification
The amount of work done depends upon the force exerted and the distance through which the force acts. It does not depend upon time. Power is the rate at which work is done and is time dependent.

Running the Stairs Assessment

1. How much work does a 100 kg student do in running a vertical distance of 5.0 m to the top of the stairs? Assume g=10 m/s^2

   A. 0.5 J
   B. 5.0 J
   C. 50 J
   D. 500 J
   E. 5000 J

2. A student raises a 6.0 kg mass to a height of 1.2 m above the floor in 3.0 s. If she repeats the same task in 6.0 s, then what quantity has changed?

   I. total energy
   II. power
   III. work
   IV. gravitational potential energy

   A. II only
   B. I and IV only
   C. II and III only
   D. I, II, and III only
   E. II, III, and IV only

3. Avery, a 40 kg student pushes vigorously against a brick wall for 20.0 seconds. Bode, a 60 kg student pushes vigorously against the same wall for 10.0 seconds. Cho, a 50 kg student pushes vigorously against the brick wall for 16.0 seconds. The wall does not move. Which of the three does the most work on the brick wall? Assume g=10 m/s^2

   A. Avery
   B. Bode
   C. Cho
   D. Avery and Cho
   E. none of the students does any work on the brick wall

Questions 4 and 5 refer to the following scenario

A teacher lifts a 100 kg box to a height of 2.0 m at a constant velocity in a time of 4.0 seconds. She then holds the box in place for 10.0 seconds. Assume g=10 m/s^2

4. How much power does the teacher exert in lifting the box?

   A. 0 W
   B. 0.5 W
   C. 50 W
   D. 500 W
   E. 5000 W

5. How much power does the teacher exert while holding the box in place?

   A. 0 W
   B. 0.2 W
   C. 20 W
   D. 200 W
   E. 2000 W

6. A student standing on the street throws a 5.0 kg book to another student who is leaning out of a window that is 4.0 m above the street. How much gravitational potential energy will the book have relative to the street when it reaches the student leaning out of the window? Assume g=10 m/s^2

   A. 0 J
   B. 0.2 J
   C. 20 J
   D. 200 J
   E. 2000 J

7. A student runs up a flight of stairs. The increase in his gravitational potential energy is 500 J. If he runs up the stairs at half the speed, his increase in gravitational potential energy will be

   A. 125 J
   B. 250 J
   C. 500 J
   D. 1000 J
   E. 2000 J

8. Which of the following is NOT true of power?

   A. It is the rate at which work is done.
   B. It is measured in Joules per second.
   C. It is measured in Watts.
   D. It has the same units as energy.
   E. It is the product of force and displacement divided by time.

9. Students count 40 steps on a stairway and measure each step to be 4.0 cm in height. Later, they discover that they used the wrong side of the meter stick, so that the actual height of each step is 10.0 cm. What effect will this error have on their calculations for running the stairs?

   A. there would be no effect since 10.0 cm and 4.0 inches are equivalent
   B. the work would appear to be higher than it actually was, but there would be no effect on the power
   C. the work would appear to be lower than it actually was, but there would be no effect on the power
   D. both work and power would appear to be higher than they actually were
   E. both work and power would appear to be lower than they actually were

10. Liz lifts a 30.0 kg box onto a truck bed 1.0 meter high in 3.0 seconds. Ty lifts thirty 1.0 kg boxes onto the same truck in a time of 20.0 seconds. Which of the following statements is true?

    A. Ty does more work.
    B. Liz does more work.
    C. Ty operates at a higher power level.
    D. Liz operates at a higher power level.
    E. Ty and Liz do the same amount of work and operate at the same power level.

Free Response

A student weighing 500 N climbs at a constant speed to the top of a 4.0 m vertical stairway. The time is measured to be 10.0 s using a stopwatch.

A. Determine the increase in the gravitational potential energy of the student.

B. Determine the average power exerted by the student to overcome gravity.

C. If the stopwatch was started too early, then the work would be less than, greater than, or equal to the actual value. Check one and justify your answer.

_____ less than _____ greater than _____equal to