Chapter 03: Energy *Physical Science*, Tillery, 13th ed.

Lab 05: Work and Energy DUE: 22 Feb 2024

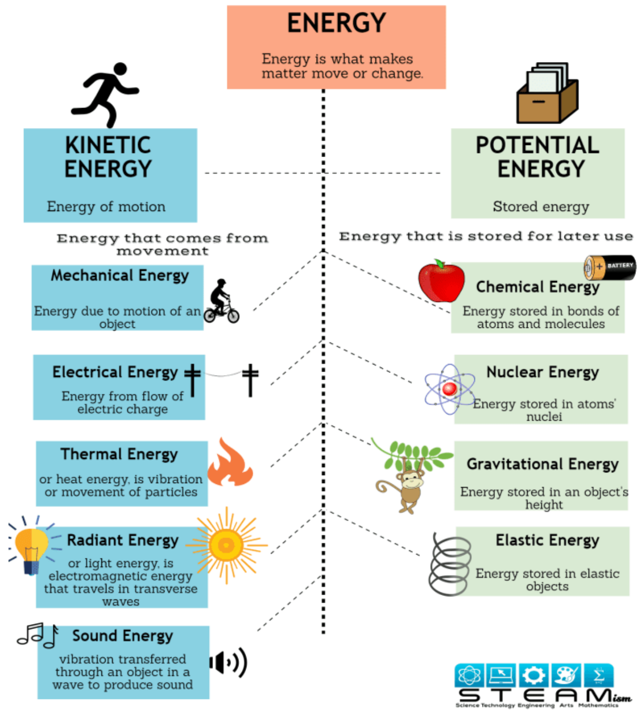
Introduction

Did you know how many different types of energy exist? Did you know that some of those types of energy are actually the same phenomenon?

For example, heat (or thermal energy) and sound are both the consequence of the motion of atoms or molecules. And when you move electrical charges, the result is electrical energy. All forms of kinetic energy are fundamentally the same: something must be moving.

Now look at potential energy: the different types of PE exist for different reasons. Gravitational PE is completely different from chemical or nuclear PE. But the thing is, you can convert energy from one form to another, and you can exchange energy from kinetic to potential (and vice-versa).

Work is the process that changes an object's energy. By doing work on an object, you can increase or decrease an object's energy. Let's look at these ideas, and see how they fit with what we already understand about forces and motion.

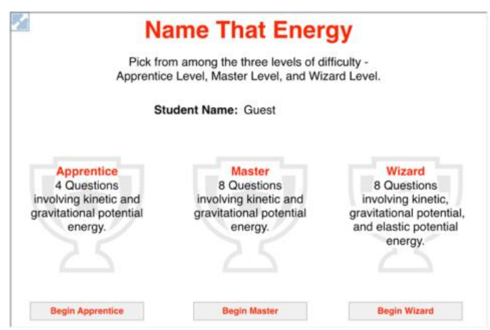


Objectives

- Recognize different forms of energy
- Identify conversions between forms of energy
- Observe the process of work and describe the resulting energy transformation
- Develop a relationship between the energy of an object and the work done on it

Equipment

- Internet-connected device capable of running a browser
- Paper and pen or pencil (you're always going to need these)
- Scientific Calculator



Procedure

1. Read this handout completely before you try to dive in. It will save you time and frustration later. If you are able to print it, you will not have to tab between windows—you can look at this and the simulation at the same time.
2. Do you have paper and pencil handy? Don't forget your calculator.
3. In a browser window, navigate to the Name That Energy Concept Builder. Don't try to start doing the lab yet! Just verify that when you click LAUNCH the interactive opens properly.

Kinetic Energy and Potential Energy

You should proceed with the Name That Energy exercise as GUEST. No need to log in. There are three separate exercises, each with a few situations to resolve. You should begin at APPRENTICE and work your way through WIZARD. Once you have, you should be able to answer the questions below easily. (Hint: Clicking the HELP ME! button is always really useful.)

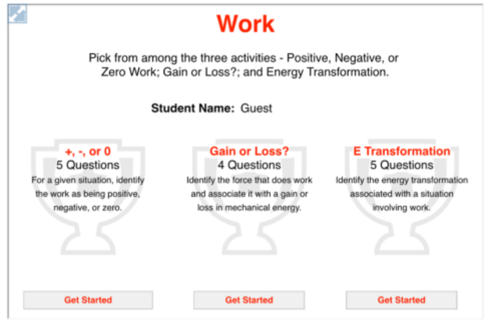
1. True or false: An object may only possess kinetic energy or potential energy. It may not possess both.

For the scenarios in Questions 2–7 below, use the following multiple choices:

Kinetic energy:	☐ Object possesses KE	☐ Object does not possess KE
Potential energy:	☐ Object possesses PE	☐ Object does not possess PE

2. A toy car is at rest at the top of a toy racetrack ramp.
3. The toy car, released from the top of a toy ramp, is at the half-way point along its path to the floor below.
4. The toy car rolls across the playroom floor.
5. A gymnast stands in the middle of the bed of a trampoline, three feet above the ground.
6. At the instant just before it rebounds upwards from a hardwood floor, a stationary bouncy ball is compressed from its spherical shape.
7. A rubberband is used to secure a child's ponytail. Her head is 1m above the ground.

All About Work



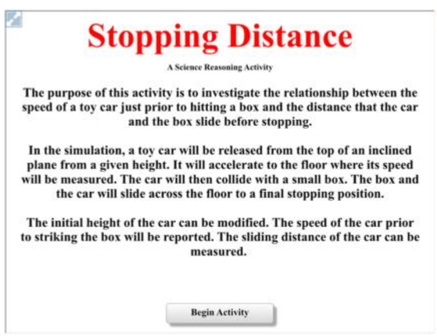
Return to your browser window and launch the Work Concept Builder. Like last time, continue as a GUEST. Also like the previous simulation, there are three sets of exercises to complete. Each one practices a different skill, so don't skip any! Once you have worked through all three, you should be able to answer the following questions easily. (Hint: Clicking the HELP ME! button is always really useful.)

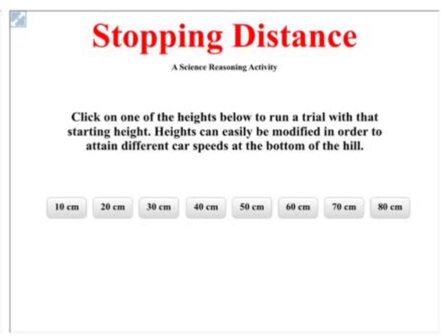
For the scenarios in Questions 8–10 below, use the following multiple choices:

A) Negative work is done on the object.
B) Positive work is done on the object.
C) Zero work is done on the object.

8. A lineman pushes a weighted sled across the practice field during football practice.
9. A softball player slows to a stop while sliding into second base.
10. A weightlifter stands motionless with a 100-kg barbell over their head several seconds.
11. A car with locked wheels skids to a stop while moving across a level highway. Work is done on the car by
    A) the normal force of the road pushing upwards on the car.
    B) the torque due to the spinning axles of the car.
    C) the force of friction between the tires and the road.
    D) the force of gravity pulling down on the car.
12. True or false: As a result, the mechanical energy of the car increases.
13. A 90-mph fastball is stopped by a catcher with his mitt. Work is done on the baseball by
    A) the force of gravity on the ball.
    B) the force of the pitcher who threw the ball.
    C) the force of the baseball pushing the mitt forward.
    D) the force of the catcher's mitt pushing against the baseball.
14. A runner accelerates up a hill. Categorize the energy transformations.
    A) Chemical potential energy is transformed into both kinetic and gravitational potential energy.
    B) Gravitational potential energy is transformed into kinetic energy and chemical potential energy.
    C) Kinetic energy is transformed into gravitational potential energy and chemical potential energy.
    D) Gravitational potential and chemical potential energies are transformed into kinetic energy.

Work and Energy: Stopping Distance





Return to your browser window and switch to the Stopping Distance Physics Interactive. We are going to analyze the energy of an object and the mechanical work done on it.

When you click BEGIN ACTIVITY, you will get the option to select a release height for a toy car which will be released from rest on a ramp. Start by choosing the 10cm release height, and we'll analyze it together. Then you can complete the analysis with the remaining release heights!

First, let's define our variables so that we're using the symbols consistently:

m = mass of the toy car (we are going to ignore the mass of the box, and assume it's negligible compared to the car)

h = initial release height of the toy car, measured in centimeters with respect to the floor

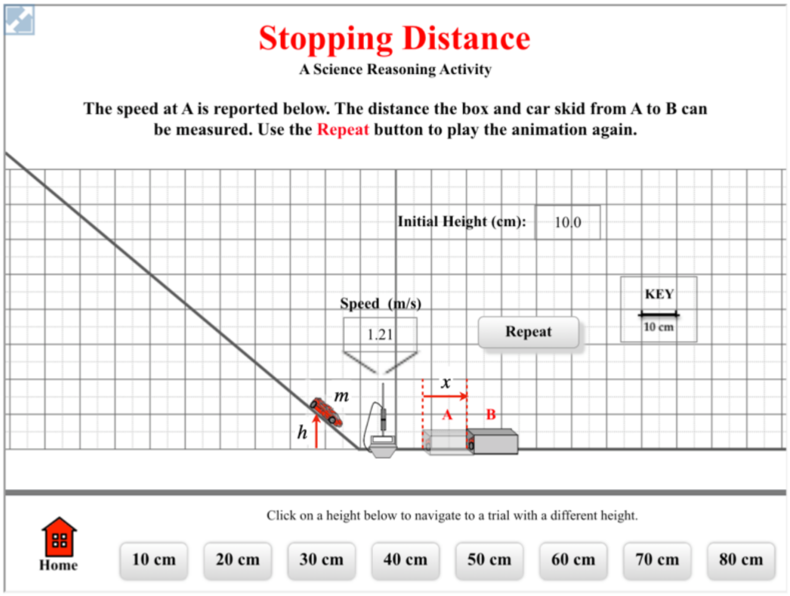
v = velocity of the toy car at the instant it reaches the bottom of the ramp (the final velocity will be zero!)

x = the horizontal distance the toy car travels before stopping (again, let's ignore that little distance before the car gets to the box; it's not exactly negligible, but it will be the same distance for each trial we run, so as long as we know it's there, we can safely leave it out of our analysis, and it won't affect our results)

f = the force of friction between the box and the floor, which is proportional to the weight of the object in this case

μ = the coefficient of friction between the two surfaces in contact; the greater the friction, the larger the coefficient (if the surfaces are rough, more friction means larger μ, and smoother surfaces will have a lower μ)

Now let's work (pun intended!) through the process step-by step and follow what happens to the energy of the cart from the instant it's released to the point where it comes to rest.



STEP 1: Potential energy is transformed to kinetic:

$$PE = KE$$
$$mgh = \frac{1}{2}mv^2$$

STEP 2: Friction does negative work to dissipate the kinetic energy:

$$KE + W = KE_f$$
$$\frac{1}{2}mv^2 - fx = 0$$
$$\frac{1}{2}mv^2 = fx$$

STEP 3: Math! Substitute the expression for the PE into the work-energy equation for the KE:

$$mgh = fx$$

STEP 4: Friction is proportional to the weight w:

$$w = mg$$
$$f = \mu(mg)$$

STEP 5: Math! Substitute Step 4 into Step 3:

$$mgh = fx = [\mu(mg)]x$$
$$h = \mu x$$

Now what? Well, now you see that the horizontal distance x is proportional to the release height h! The proportionality constant μ is related to the friction in an obvious way: the rougher the surface, the greater the friction. The greater the friction, the smaller the distance the car will travel before stopping. That means the bigger the value of μ, the rougher the surface and greater the friction!

We will test this by increasing the release height, measuring the stopping distance, and finding the ratio.

HEIGHT (CM)	DISTANCE (CM)	RATIO $\mu = \frac{h}{x}$
10	12.5	0.80
20		
30		
40		
50		
60		
70		
80		

Complete the table for the remaining release heights. When you measure the stopping distance x, be sure to be consistent: always measure from the back edge of the box as shown in the figure above!

15. For a release height $h = 30\text{cm}$, what is the car's velocity v at the bottom of the ramp?
    A) $v = 1.21\frac{\text{m}}{\text{s}}$ C) $v = 2.1\frac{\text{m}}{\text{s}}$ E) $v = 2.71\frac{\text{m}}{\text{s}}$
    B) $v = 1.71\frac{\text{m}}{\text{s}}$ D) $v = 2.42\frac{\text{m}}{\text{s}}$ F) $v = 2.97\frac{\text{m}}{\text{s}}$
16. For a release height $h = 30\text{cm}$, what is the stopping distance x?
    A) $x = 26\text{cm}$ C) $x = 48\text{cm}$ E) $x = 85\text{cm}$
    B) $x = 36\text{cm}$ D) $x = 73\text{cm}$ F) $x = 97.5\text{cm}$
17. For a release height $h = 30\text{cm}$, what is the ratio μ?
    A) $\mu = 0.76$ C) $\mu = 0.80$ E) $\mu = 0.82$
    B) $\mu = 0.77$ D) $\mu = 0.81$ F) $\mu = 0.83$
18. For which release height h is the stopping distance $x = 60\text{cm}$?
    A) $h = 40\text{cm}$ C) $h = 60\text{cm}$ E) $h = 80\text{cm}$
    B) $h = 50\text{cm}$ D) $h = 70\text{cm}$ F) $h = 90\text{cm}$
19. What is the average ratio μ for all of the trials? (You *have* to complete all the trials to calculate this!)
    A) $\mu_{avg} = 0.769$ C) $\mu_{avg} = 0.817$ E) $\mu_{avg} = 0.824$
    B) $\mu_{avg} = 0.800$ D) $\mu_{avg} = 0.821$ F) $\mu_{avg} = 0.833$
20. You were not able to measure a stopping distance for a release height $h = 100\text{cm}$, but based on your data you should be able to predict it. What is your best prediction for the stopping distance x for a release height of 100cm?
    A) $x = 100\text{cm}$ C) $x = 110\text{cm}$ E) $x = 120\text{cm}$
    B) $x = 105\text{cm}$ D) $x = 115\text{cm}$ F) Impossible to predict!
21. Are your results for the ratio μ consistent with the table on the right?

MATERIALS	COEFFICIENT OF KINETIC FRICTION μ
Rubber on concrete	0.80
Wood on snow	0.20
Ice on ice	0.03

22. In this experiment, let's say the box was in contact with a concrete floor. If we performed the same experiment, but placed the box on an ice rink, how would our results change?
    A) They wouldn't. If we use the same car, then we will get exactly the same results for stopping distances and ratio μ.
    B) If we use the same car and box, the stopping distances will decrease. This will make the ratio μ increase.
    C) The ice will have less friction, which means the stopping distances will increase. That will decrease the ratio μ.
    D) There is no way to predict what will happen, because the stopping distance has nothing to do with whether the ice has greater or less friction than a concrete floor.