

# Lesson Plans for Conservation of Energy Module

**Prior Knowledge:** Basic kinematics ( $v = \Delta x/t$ ), how to measure distance and time.

## 1. Work Stations

### Objective

Students will derive the essential components of work.

### Engage and Explore

1. Are asked to write the answers to these questions...
  - a. What do you think physical work is?
  - b. What factors do you think go in to making more or less physical work?
  - c. If you could guess at what a work equation would equal, what would it be?  $W =$
2. Students rotate around 4 pre-arranged stations (There could be more or fewer. There could be two sets of stations to lower the number of students at each station, so that the students on the right side of the class rotate through the four stations on the right and vice-versa for the left.)

### Explain

3. At each station, the students answer these questions...
  - a. How is this a demonstration of work being done?
  - b. What could be changed so that more work is done?

### Elaborate

4. Teacher debriefs with students and guides them to the answer that work increases with greater force and work is also increased with greater distance.  $W = F\Delta x$

### Evaluate

5. Teacher should give a problem set on  $W = F\Delta x$

\*Student Handout is meant to support this process and guide students through the Explore and Explain phases. Teacher is responsible for the scaffolding of content within the Elaborate Phase and the building of prior knowledge leading into the Engage and Explore piece of the Conservation of Energy.

## 2. Pinning It! (Nailing It! for those with bowling balls)

### Objective:

Students will derive the essential components of work and potential energy.

### Engage

1. Have students write down what they think the definition of energy is.

2. Announce that today we will drive a push pin into a block of wood by dropping a ping-pong ball and a golf ball on it. Have students write a prediction about what will happen.

### Explore and Explain

3. Have students try driving the push pin in with the balls. Have them explain...
  - a. How the activity shows connection to work.
  - b. What is needed to get more work done?

### Elaborate

4. Teacher helps guide students to an understanding that work was done by dropping the ball on the push pin. The ball had energy (the ability to do work), potential energy, and it started to move and gain kinetic energy as it fell. The kinetic energy of the ball went into doing work on the push pin.  $PE = mgh$  and  $\Delta PE = W$
5. Have students draw a diagram of the activity and illustrate the energy transfers and work being done.

### Evaluate

6. Teacher should give a problem set on  $PE = mgh$  and  $\Delta PE = W$

## 3. Ramp Race

### Objective:

Students will be able to construct 2 ramps to explore the Conservation of Energy.

### Engage & Explore

1. Students are informed that they will make a Chain Reaction machine as a culminating activity. But not yet, at this point in time, they are going to build ramps.
2. Students watch the OK GO Music video “This Too Shall Pass”, and/or Honda’s “Cog” commercial
  - a. Inspiration and engagement into the idea behind the chain reaction machine (evaluation piece).
  - b. Can be found for free via YouTube
3. Students use the scientific process to respond to a question
  - a. Students make a prediction (hypothesis) in response
    - i. “Which ramp would come in first place?”
    - ii. “Which ramp produces the greater final velocity? Why?”
  - b. Students construct 2 ramps at the same height
    - i. Different paths must be assembled.
    - ii. Remember to stifle creativity at this point (keep designs simple).
  - c. Students test their hypothesis using their ramps.
    - i. Students create data tables to organize data to support their hypothesis.
    - ii. Students will then perform their experiment and collect data
    - iii. To get final velocity, students will generally need to measure the velocity from ramp end to a point 1-2 meters away, unless some kind of velocity

meter is available. Stopwatches are the most “hands on” measuring method, but imprecise. Photogate devices or video analysis can be more accurate, however, they can consume more time to calculate the data.

- d. Students analyze their data
  - i. Students will draw conclusions from their findings to determine evidence for or against their hypothesis.
  - ii. Was your hypothesis correct? What is your evidence?

## Explain

### 4. The Big Picture

- a. Teacher can facilitate a discussion based on students’ data.
  - i. “Which ramp produces the greater final velocity?”
  - ii. Teacher may have to discuss, error, significant figures, and rounding
    - 1. “Is 3.9 roughly the same as 4.0 or 3.93?”
    - 2. “Why do the ramps have approximately the same velocities?”
  - iii. Teacher and class conclusion
    - 1. Conservation of Energy
    - 2. Since both ramps began at the same height, their velocities are the same
    - 3. Link to Potential and Kinetic Energy.
      - a. More accurately, for a rolling solid sphere...  
Translational kinetic energy due to velocity =  $\frac{1}{2}mv^2$   
Rotational kinetic energy  $E_r = \frac{1}{2}I\omega^2$   
But, for a solid sphere,  $I = \frac{2}{5}mR^2$  and  $\omega = v / R$   
Substituting,  
 $E_r = \frac{1}{2} * \frac{2}{5}mR^2 * (v/R)^2 = \frac{1}{5}mv^2$   
The rotational energy of a solid sphere without slipping is  $\frac{2}{5}$  of the kinetic energy.  
So, in terms of percentage, for a rolling solid sphere like a marble or a bowling ball:  
 $KE_{total} = 71.4\%$  in translational KE and  $28.6\%$  in rotational KE  
For a hollow sphere like a ping-pong or tennis ball, it becomes  $60\%$   $KE_t$  and  $40\%$   $KE_r$
      - b. This needs to be addressed at the discretion of the instructor. Or, students could use carts or Hot Wheels.

## Evaluate

- 5. Students are evaluated based on their ability to follow scientific practices.
  - a. Hypothesis development
  - b. Ability to test hypothesis
  - c. Collect and analyze data
  - d. Draw conclusions

\*Student Handout is meant to support this process and guide students through the exploration phase. Teacher is responsible for the scaffolding of content within the Explain Phase and the building of prior knowledge leading into the Engage and Explore piece of the Conservation of Energy.

## 4. Energy of Motion

### Objective

Students will take data and model  $KE = \frac{1}{2} mv^2$

### Engage

1. Teacher asks students, “What if we lowered the height of your ramp from yesterday. What effect would that have?”

### Explore

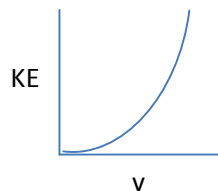
2. Have students take data, at least 5 data points, for different heights of the ramp and the corresponding velocities at the bottom of the ramp.

### Explain

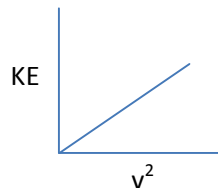
3. Have students graph the data in a way that makes sense to them and have them explain what knowledge they can get from the data.

### Elaborate

4. Guide students to connect the ideas that we have learned so far;  $PE = mgh$  and  $\Delta PE = KE$ . So instead of graphing height vs velocity, let's graph KE vs v.



5. After getting graphs that look like the one above, ask students, “How does v change with KE? Exponential? OK, let's square v and graph it again.”



6. Students should get a graph that looks like the one above. To students, “So this is a line! And lines have linear equations! Can we find the slope and figure out what that is?” It should come out to be about  $\frac{1}{2}$  mass of the ball.
  - a. “So what is the linear equation?”
$$y = mx + b$$
$$KE = (\frac{1}{2}m) v^2 + 0$$
  - b. Therefore, we have modeled that  $KE = \frac{1}{2} m v^2$ . Reminder: some energy “lost” to rotation.

### Evaluate

7. Teacher should give a problem set on  $KE = \frac{1}{2} m v^2$

## 5. Simple Machine Stations

### Objective

Students familiarize themselves with simple machines and other concepts in order to prepare for the Chain-Reaction recycling project.

### Engage

1. Inform students that the point of the Simple Machines Stations is to spark ideas and inspire creative connections for the chain reaction machine. They are going to take the ramps that they made and connect them into a whole-class chain reaction machine.

### Explore & Explain

1. Students rotate around stations and explore each concept
  - a. Students identify the labeled station
  - b. From their experience with the station or prior knowledge describe the concept
    - i. What does it do?
    - ii. How does it work.
  - c. Students brainstorm ways in which this machine may assist with their recycling project.
2. Teacher facilitates student learning
  - a. Monitors station timing
    - i. Based on classroom dynamics – you know your students.
  - b. Circles around classroom
    - i. Asks guiding and supporting questions – deepen student understanding
    - ii. Provides examples of the use of the machine in real-world scenarios
      1. Making real-world connections
      2. Students can provide real-world connections
    - iii. Answers student questions

### Elaborate

3. Students “apply” simple machine
  - a. Students sketch a possible transition to another ramp
    - i. Students make connections from lab to project outcome
    - ii. Students participate in engineering practices

\*Students should be given the simple machines table hand-out to support this process.

### 3. Culminating Activity: Chain-Reaction Recycling Machine

#### Objective

Students connect ramps to create one continual recycling machine that sorts paper and plastic by knocking them into the correct container.

#### Engage & Elaborate

1. Replay the OK GO – This Too Shall Pass video, and/or Honda’s “Cog” commercial.
  - a. Re-engage students in the Chain Reaction Machine Process
  - b. Provide ideas for students.
2. Students construct recycling machine
  - a. Teacher may have to set supporting guidelines for classroom management
    - i. Delegate roles, provide guidelines on which group communicates to who. The order of which group follows which needs to be clearly defined, so groups can decide how to transition between their elements
    - ii. Support students at tool station – safety
  - b. Students take part in Engineering practices
    - i. Communicate amongst peers and plan
    - ii. Construct and problem solve
    - iii. Design, Expand and Elaborate on ideas
3. Students Explain Conservation of Energy concepts
  - a. Articulate in writing
    - i. Work, Gravitational Potential Energy, Kinetic Energy
    - ii. Possibly Elastic Potential Energy etc.
  - b. Students effectively use academic language and concepts.
  - c. Students sketch their connection
    - i. Label points
    - ii. Identify energy at that point
4. Students develop a procedure to collect and analyze data
  - a. Identify energy at each point
  - b. Calculate the respective energy using the correct formula
  - c. Explain their data collection process
  - d. Articulate areas of trouble to demonstrate deep understanding of content and its application.
5. Students should record in a daily log
  - a. Serves as reflection and collection of the evolution of their thinking process
  - b. Students ought to think deeper about content and its application to engineering and real-world phenomenon.
  - c. Teacher should scaffold the logs to make them appropriate to their class and can be used as a method of assessment (pre and post)
6. Teacher facilitates
  - a. Probes students for conceptual understanding
  - b. Models for students when necessary
  - c. Evaluates and Suggests
  - d. Provides constructive feedback

**Evaluate**

7. Teacher evaluates student progress in each of the following areas (rubric created by instructor)
  - a. Construction of transition
  - b. Explanation and application of content
    - i. Calculations and conceptual understanding
  - c. Application of the scientific method in respect to the collecting and analyzing of data

\*During all activities teacher serves as a facilitator of student learning (i.e. student centered instruction). Most tasks should be completed by students after simple directions, or facilitated questions to enhance student learning.

\*\*Use of student handouts serves as guidelines for students.

**Accommodations**

All individual accommodations for students should be met with respect to your particular students and classroom dynamics and will vary from class to class and group to group. Facilitator should always differentiate instruction by providing the necessary blend of guidance and exploration for each student group and their specific needs.