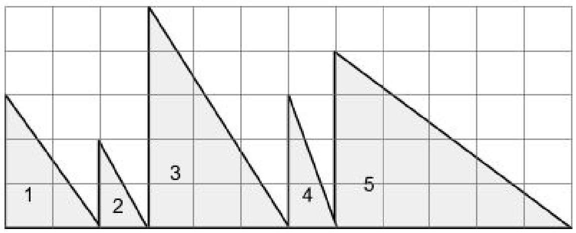
Cw 10-24

Do Now: Your research team investigated the five ramps shown in the drawing shown to the right. You released the marble from rest at the top of each ramp and measured the marble's speed at the bottom. Which ramp will make the marble fastest at the bottom? Explain



1. What does it mean for something to be "conserved"? Give an example of something that YOU conserve, or try to conserve.

2. Record our Physics definition of the "Law of Conservation of Energy" here:

3. What does it mean for a system to be "closed"? What would cause a system to be "open"? Do you think the image we analyzed describing an OPEN or CLOSED system? What makes you think that?

Part 2: Equations and Word Problems

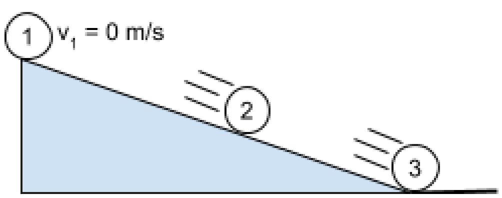
1. As we learned yesterday, GPE and KE are in play when a marble rolls down a ramp. For a marble released from rest, consider locations 1, 2, and 3 as you respond to the following. **EXPLAIN your answers!**

   a. Which choice correctly ranks the locations by GPE?

      i. 1 = 2 = 3
      ii. 1 > 2 > 3
      iii. 1 > 2 = 3
      iv. 3 > 2 > 1

   b. Which choice correctly ranks the locations by KE?

      i. 1 = 2 = 3
      ii. 1 > 2 > 3
      iii. 1 > 2 = 3
      iv. 3 > 2 > 1



   c. Where does the marble's KE come from?

   d. Which choice correctly compares total mechanical energy at 1 and 3 if the **system is isolated**?

      i. $E_1 < E_3$
      ii. $E_1 = E_3$
      iii. $E_1 > E_3$

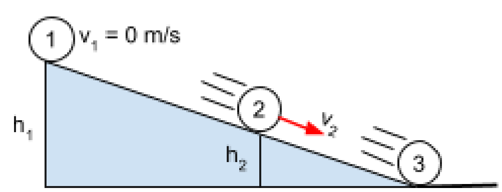
   e. Which choice correctly compares GPE_1 and KE_3 if the **system is isolated**?

      i. $GPE_1 < KE_3$
      ii. $GPE_1 = KE_3$
      iii. $GPE_1 > KE_3$

   f. Which choice correctly compares GPE_1 and KE_3 if the **system is not isolated**? *Note:* Continue to assume no wind.

      i. $GPE_1 < KE_3$
      ii. $GPE_1 = KE_3$
      iii. $GPE_1 > KE_3$

2. (DYGIT?) Assuming an isolated system, which of the following choices correctly models the marble's speed at point 2 (v_2)? Support your response with the same process used in #5c.



   a. $v_2 = \sqrt{2gh_1}$
   b. $v_2 = \sqrt{2gh_1 - 2gh_2}$
   d. $v_2 = \sqrt{2gh_2}$
   e. $v_2 = \sqrt{2gh_1 + 2gh_2}$

c. $v_2 = \sqrt{2gh_2 - 2gh_1}$

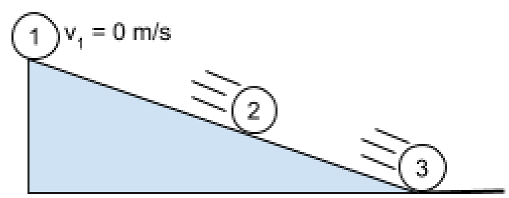
Reading

<u>**Conservation of Energy**</u> **(version #1) Energy can neither be created nor be destroyed: it can be transformed from one form to another or transferred from one place to another.**

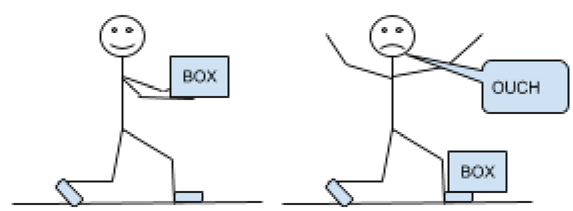
So, how does this idea relate to the ramps?
In the systems discussed above – the sun, plants, people – the systems took in energy and and then transferred it out of the system. However, what would happen if we looked at a **closed (or isolated) system, or one that did not allow energy to be transferred in or out**? In this case the total energy in the system would remain constant. Let's rephrase energy conservation for this case:

<u>**Conservation of Energy**</u> **(version #2) – The energy in a closed system can change forms but the total remains constant.**

Assume the marble/ramp system shown in the drawing is a closed system. In this situation, there are two types of energy, **gravitational potential energy (GPE)** and **kinetic energy (KE)**. Let's first look at GPE.



As stated at the beginning of this reading, energy is the ability to produce change. How does the height of the drop affect how much damage you do to your foot? Of course, the higher the height, the more it will hurt. **So, the higher the height the more GPE.**



Now consider the box being full of heavy physics books. As you would guess, when it hits your foot, the box will hurt even more. Hence, the amount of the box's GPE also depends on its mass.

Height and mass can be combined to form the following mathematical model:

Gravitational Potential Energy Model

$$GPE = m\,g\,h \quad \begin{bmatrix} \text{m = mass} \\ \text{g = gravity field strength} \\ \text{h = height} \end{bmatrix}$$

The "*g*" in this equation relates to the strength of the gravitational field. Generally, the more massive the planet, the higher the *g*.

Let's now look at kinetic energy (KE). The amount of an object's KE depends on its mass (*m*) and its speed (*v*). The more massive the object, the more damage it can do. The faster an object is moving, the more damage it can do. In the mid 18th century, William 's Gravende (1688 – 1742) dropped masses into soft clay and found that when he doubled the speed, it fell 4 times the depth into the clay. When he tripled the speed, it fell 9 times further into the clay.[1] These results helped the following KE model become widely accepted by the scientific community.

Kinetic Energy Model

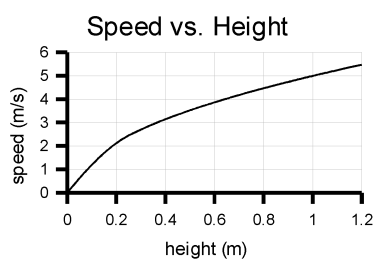
$$KE = \frac{1}{2} m v^2 \quad \begin{bmatrix} \text{m = mass} \\ \text{v = speed} \end{bmatrix}$$

Energy Transformations down the Ramp

Since GPE depends on height, the marble possesses the most GPE at point 1 in the drawing above. As the marble goes down the ramp, its GPE decreases. Where does it go? It actually becomes KE, since the marble's speed increases as it goes down the ramp. At the bottom of the ramp, the height is zero, so the marble no longer has any GPE. It all became KE. Energy conservation ($E_1 = E_3$) can be used to show that the speed of the marble for a closed system, depends on the height of the ramp as shown in the box to the right.

$$E_1 = E_3$$
$$GPE_1 = KE_3$$
$$mgh_1 = \tfrac{1}{2} m {v_3}^2$$
$$gh_1 = \tfrac{1}{2} v_3^2$$
$$v_3^2 = 2gh_1$$
$$v_3 = \sqrt{2gh_1}$$

Plotting the equation for v_3 yields the graph shown to the right, matching many of the results you and your classmates found experimentally. Notice how the **data is not linear**, but the slope decreases as the height increases, following a square root relationship as shown in the equation ($v_3 = \sqrt{2gh_1}$).



C. Key Terms

energy, gravitational potential energy (GPE), kinetic energy (KE), conservation of energy

D. Review:

- Energy is the quantifiable ability to produce change.
- Energy cannot be destroyed but can change forms and/or location.
- In a closed system, the total energy remains constant but may change forms.
- $GPE = m\,g\,h$
- $KE = \frac{1}{2} mv^2$
- Energy conservation model (total energy remains constant): $E_1 = E_2$

Reading Questions

[1] http://www.scientific-web.com/en/Biographies/WillemsGravesande.html

3. What is an isolated system?

4. How is conservation of energy applied to isolated systems?

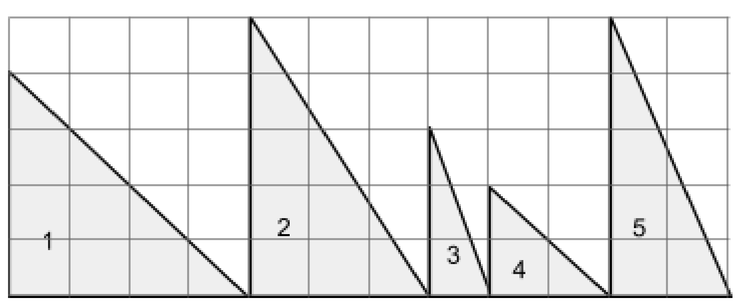
5. How is conservation of energy applied to non-isolated systems?

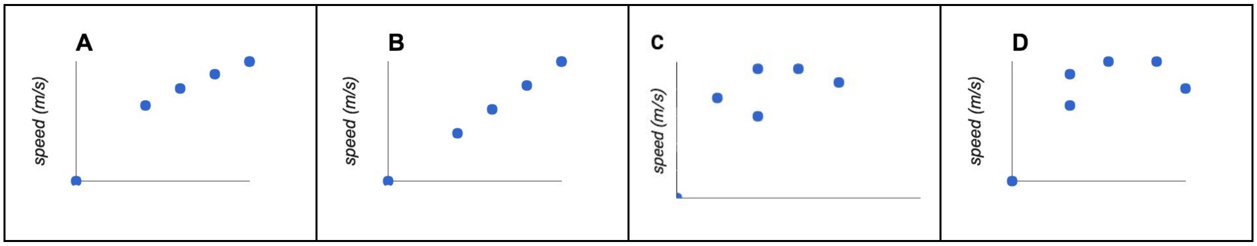
6. For a marble rolling down a ramp, is the relationship between the speed at the bottom and the height of the ramp linear? Explain.

Conceptual Exercises

7. L2: A marble at the top of a ramp rolls down isolated from the environment. Which of the following does NOT impact the speed of the marble at the bottom of the ramp? Justify your answer.
   a. marble mass (*m*)
   b. strength of gravity (*g*)
   c. ramp height (*h*)
   d. It depends on all of the choices.
   e. It does not depend on any of the choices.

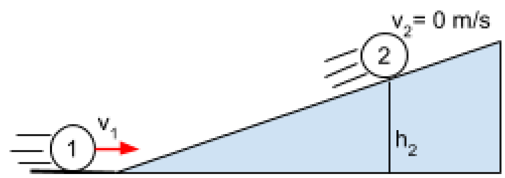
8. (Difficult): You investigate the five ramps below, measuring marble speed as they roll off each ramp. Select the graph that exhibits the speed at the bottom of the ramp vs. the variable indicated.
   a. Speed vs. Height
   b. Speed vs. Slope
   c. Speed vs. Base



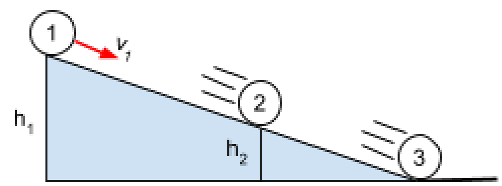


Practice Problems- Show your work! Start with E1 = E2 for every problem

9. L3: You roll a marble up a ramp as shown to the right. Develop an equation for the h_2 in terms of v_1 and g.



10. L3: You push a marble at the top of a ramp so it is moving with speed v_1 at point 1. Develop an equation for v_3 in terms of h_1, v_1, and g.



11. (L4) Determine h_4 in terms of h_1 if you want v_5 to be twice the speed of v_3 (i.e. $v_5 = 2v_3$).