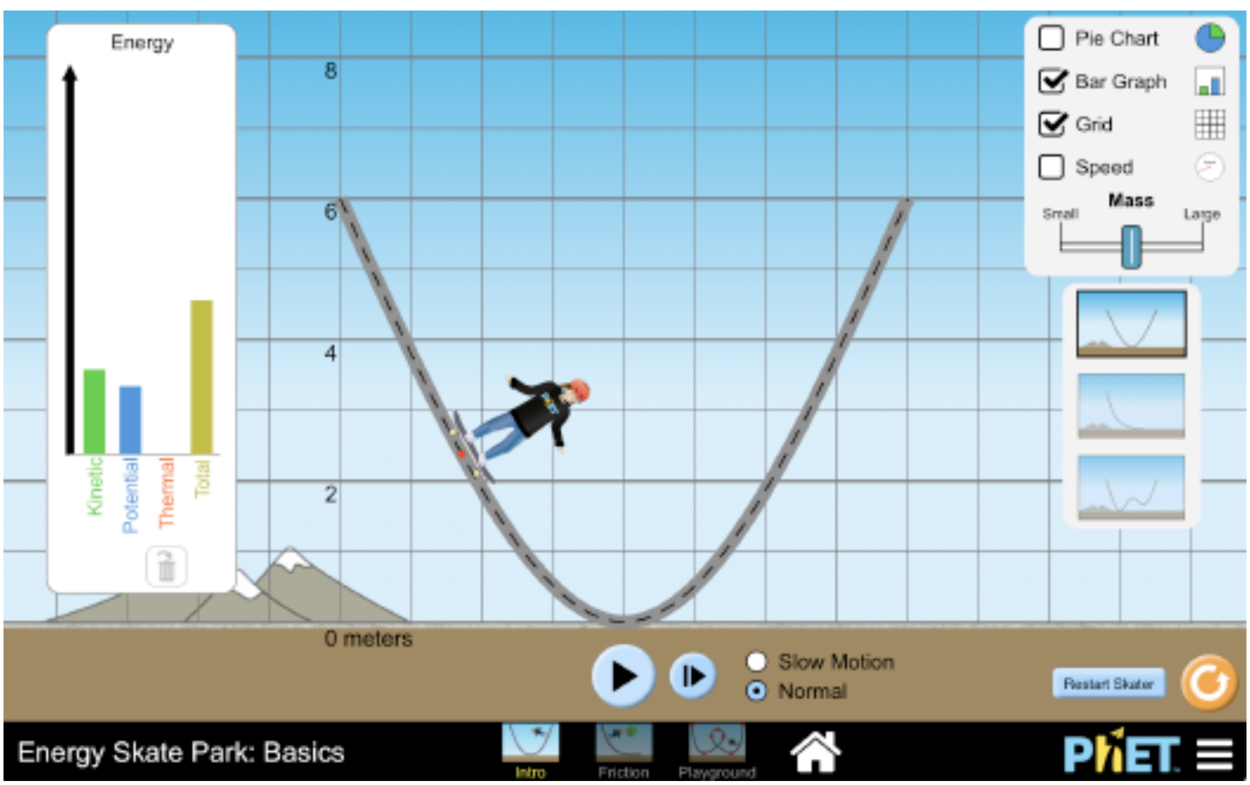
Lab: Skate Park (PhET)   A.P. Physics

Background
The law of Conservation of Mechanical Energy states that the total mechanical energy in a closed system—kinetic plus potential energies— remains constant over time. The more general law, Conservation of Energy, states that the total energy of a system remains constant as long as one accounts for Work being done on the system and/or energy leaving the system in other forms.

Objectives
To use a computer model to develop an intuitive understanding of Conservation of Energy, and to practice solving energy-based problems.
Equipment
- Computer
- Internet connection (to access PhET website)

Procedure
In this online-based experiment you'll be running a series of simulations involving a skateboarder at an idealized skate park, and looking at the interplay between various types of energies.



Part A. Familiarize yourself with the software

1. Go to https://phet.colorado.edu/sims/html/energy-skate-park-basics/latest/energy-skate-park-basics_en.html and select the “Intro” scenario. (If you are unable to load the page from the PhET website, you can get the simulation at https://www.crashwhite.com/apphysics/materials/assignments/lab-dl/lab-dl7/index.html

2. Try choosing different track layouts, activating the various display options and watching how the skater’s energies change over time.

3. Once you’ve had a chance to look at the basics, switch to the “Friction” scenario available at the bottom of the screen. You can now adjust the amount of friction acting on the skater which will obviously affect her energy over time.

4. Finally, switch to the “Playground” scenario in which you can build your own track. Experiment with some different configurations briefly before moving on to the next section.

Part B. Some experiments

1. You’re probably aware of the relationship $KE_{initial} + U_{initial} = KE_{final} + U_{final}$ which describes Conservation of Mechanical Energy. In the context of our skate park, the potential energy will only be gravitation-related. In the “Intro” scenario, there is no friction, so the relationship stated above is the one being modeled.

2. In this “Intro” scenario, does changing the skater’s mass change the amount of energy in the system? Does it change the skater’s velocity at the bottom of the ramp, or maximum height reached on the sides of the ramp?

3. Based on the Conservation of Mechanical Energy, derive the relationship between maximum height and maximum speed for the skater. Is this relationship a function of mass? Does this match up with your observations in #2?

4. Can we collect some experimental evidence to support the relationship between U and K? Using the “Intro” scenario, design an experiment and record information that will allow you to identify the relationship between potential energy (related to height) and kinetic energy (related to speed). Describe the data that you observe, and/or include screenshots of your experiment, and support your conclusion with logical reasoning. (Hint: If, ignoring friction, the kinetic energy at the bottom of the ramp—a function of v^2–and the potential energy at the top of the run—a function of y—are equal, then the graph of v^2 vs. y for various y’s should be linear.)

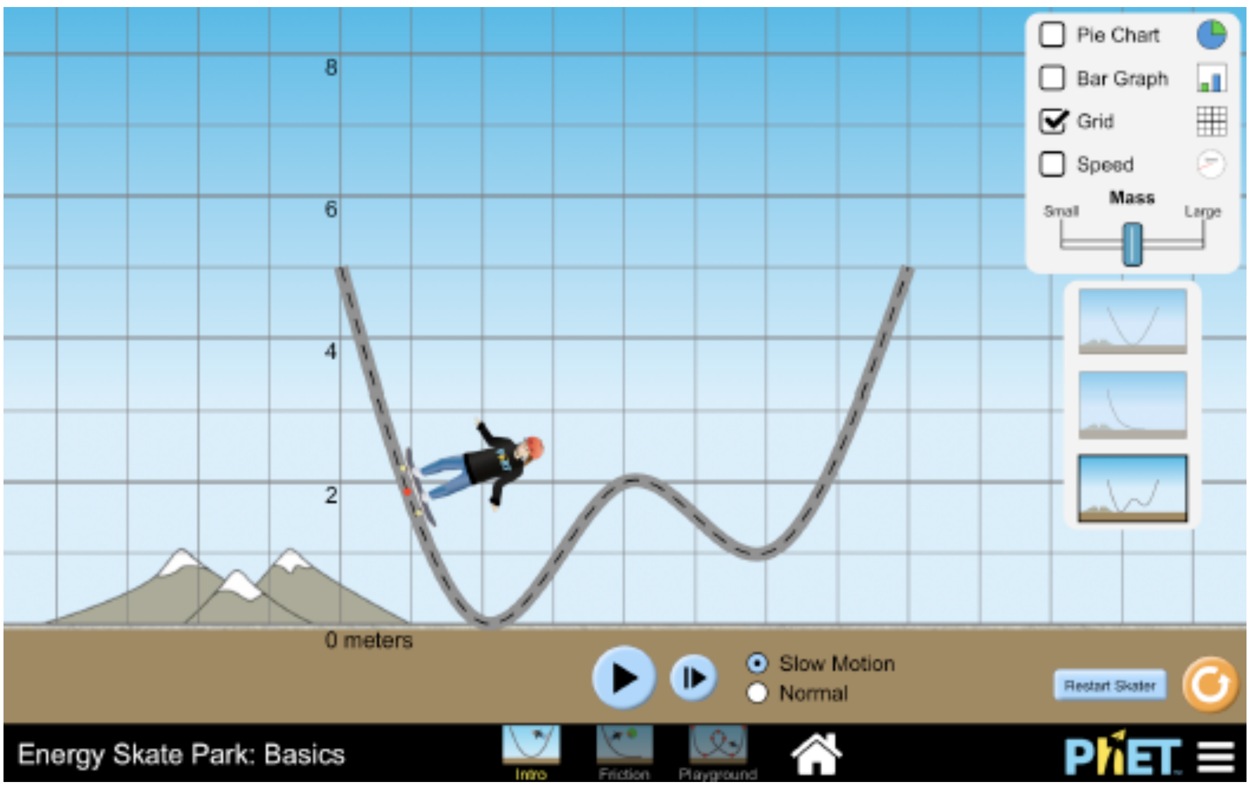
5. Use the “Playground” scenario to construct a loop that the skater can complete while Friction is set to a non-zero value. Run the simulation with the Bar Graph option activated so you can see how kinetic energy, potential energy, and thermal energy all change

throughout the course of the skater's run. Then explain why physics teachers are reluctant to say "energy was lost to friction."

6. You can hit the Pause button to halt the skater mid-run, and you can use the "trash can" icon to reset the thermal energy to zero mid-run. Using these controls, compare the amount of thermal energy that appears in the lower half of your loop to the thermal energy lost in the upper half of your loop. Are they the same? Different? Explain your how observations are consistent with real-world factors.

Potential Energy Diagrams (Optional).

1. Near the surface of the earth, gravitational potential energy (mgy) is associated with the gravitational force function $mg\left(-\hat{j}\right)$. It is not outside the realm of possibility that another potential energy function associated with gravity might be had.



Consider the ramp set-up shown above. Not only will the skater be accelerated in the y-direction by gravity, the skater will also be accelerated along the x-axis due to a normal force produced by the ramp.

Because it is possible to identify the skater's gravitational potential energy at various x-coordinates as she moves along the ramp, it is also possible to generate a function that identifies her gravitational potential energy *as a function of her x-coordinate position*, or $U\left(x\right)$.

In that case, the actual shape of the ramp reflects the potential energy diagram for the system (U(x)) plotting potential energy on the y-axis and position along the x-axis.

2. With this in mind, is the potential energy of the system greater when the skater is higher on the graph or lower on the graph?

3. At what positions does the graph suggest an equilibrium position?

4. Which of the positions identified in #3 are associated with stable equilibrium? Which is unstable equilibrium?

5. The relationship between a potential energy function and position is described by the equation $\vec{F} = -\left(\frac{dU}{dx}\hat{i}\right)$. Keep this relationship in mind as you answer the following four questions:

   a.) Consider the skater as positioned in the sketch (i.e., at y = 1.9 m). Is the slope of the ramp/potential-energy-diagram positive or negative at that point?
   b.) Again, assuming the ramp models the body's potential energy U(x), what would the slope of the graph tell you about the forces acting on the skater? In fact, WHAT forces would it be referring to?
   c.) According to the sketch, the skater's initial x-coordinate is x = 1. When the skater is at x = 3, what is the ramp/functions slope, what is the direction of the force on the skater, and what (as a consequence) would you expect the skater's motion be doing at that point.
   d.) What does $\vec{F} = -\left(\frac{dU}{dx}\hat{i}\right)$ suggest is happening at the equilibrium position?

6. Assuming no friction, the skater accelerates from rest down the ramp from an initial height of y = 1.9 m. How fast is she traveling at the lowest position on the ramp?

7. The skater's inertia carries her past the lowest position on the ramp. Will she be able to make it over the hump at x = 4.1 meters? How do you know?