8.5: Using PhET to explore the Work-Energy Theorem and Energy Diagrams

Consider a skater who can skate on a frictionless parabolic surface as shown in the PhET simulation below. Choose the "Graphs" tab. If you place the skater at the top of the ramp, they will accelerate down the ramp due to their gravitational potential energy. When they pass the lowest point, we consider the gravitational potential energy to be zero. The skater will continue in the same direction and decelerate until they stop at some height on the ramp and turn around. They will then accelerate again towards the rest position of the ramp ($y = 0\mathrm{m}$), and then decelerate once the skater starts up the ramp again. This motion will repeat endlessly in the absence of non-conservative external forces.

We can describe the motion of the skater in terms of their total mechanical energy, E.

$$E = \frac{1}{2}mv^2 + mgh \tag{8.5.1}$$

In the simulation is an Energy Diagram for the skater, which allows us to examine how their total energy, E. Without friction, the energy is divided between kinetic and potential energy depending on the position of the skater on the ramp. The vertical axis corresponds to energy and the horizontal axis corresponds to the position of the skater.

Exercise 8.5.1

Check the box for the Grid to show. How much potential energy would the skater have at the top of the ramp (Their mass is listed on the right.)? Where would you predict the skater's turning point will be on the opposite side of the ramp? Place the skater at the top of the ramp. Is your prediction correct?

Answer

Since there is no friction, the skater will return to a height they began with on the other side of the ramp. The starting height at the top of the ramp corresponds to turning points at 0 and 10 meters.

Exercise 8.5.2

Suppose you add friction. What will happen to the total energy? What will happen to the turning points?

Answer

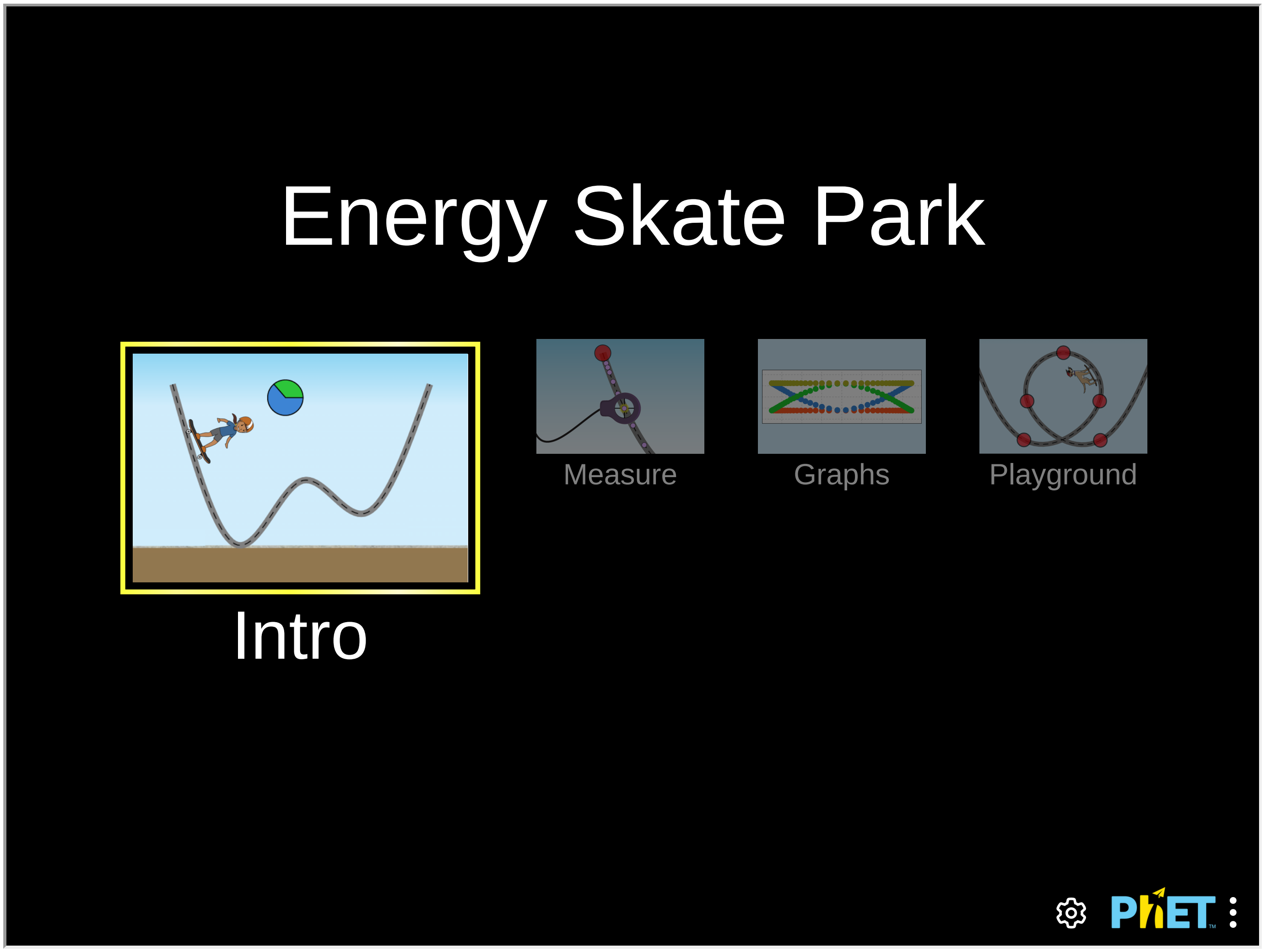
Friction is a non-conservative force. There will be thermal energy that reduces the total energy of the skater. The turning points will get closer and closer together as total energy decreases. Eventually, the skater will be at rest at the lowest point on the ramp, where their mechanical energy is zero.

Exercise 8.5.3

Turn off the friction, and adjust the reference height to about halfway up the ramp. Release the skater from the top of the ramp. The graph now shows the total energy is a smaller number than the kinetic energy for some regions of the graph. Is this a violation of conservation of energy?

Answer

No. The new reference height makes some of the potential energy negative. Since energy (coordinate systems) can reference any point, these negative energies are possible. However, kinetic energy can never be negative. The total energy is still the sum of kinetic and potential energy. It is simply shifted due to adding negatives to positives. The skater still has the same speeds (kinetic energies) along the ramp. This can be seen by using the speed measuring tool.


Energy Skate Park
Intro
Measure
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PhET