

1 Theory

Mechanical energy is the sum of the potential and kinetic energies in a system. The principle of the conservation of mechanical energy states that the total mechanical energy in a system (i.e., the sum of the potential plus kinetic energies) remains constant as long as the only forces acting are conservative forces. Normally, all forces acting on our system are conservative as long as there is no friction.

1.1 Types of mechanical energy

In mechanics problems, we are likely to encounter systems

containing kinetic energy^[SEP] $KE = \frac{1}{2} mV^2$, (1)

^[SEP]where m is the mass of our object and V is its speed (disregarding of the direction). Generally speaking,

the kinetic energy is the energy of the motion and it disappears if the speed of our object is zero. We will also often encounter gravitational potential energy

$$PE_g = mgh, (2)$$

where h is the elevation of our object from a fixed zero level. Only the vertical component, or the height of our object contributed to its gravitational potential energy, not its horizontal position.

We might also need to account for the elastic—spring—potential energy of a compressed or stretched spring with spring constant k

$$PE_s = \frac{1}{2} kx^2, (3)$$

where x is the displacement of the end of the spring from its equilibrium position.

There might be a few other exotic types of potential energy, such as the energy of an electromagnetic field, or the potential energy due to a buoyant forces if such fields and forces are present, which will not be the case for our lab.

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1.2 Conservation of the mechanical energy

As we mentioned above, the mechanical energy is conserved if the friction forces acting on our system are negligible. Let us consider a cart moving along a frictionless track, as shown at Fig. 1

Figure 1: Conservation of mechanical energy (potential + kinetic) on a track. The bar charts show the amount of the potential and kinetic energies in different points of the track.

Its potential energy $PE = mgh$ depends only on its vertical position h along the track. If the total energy is conserved

$PE(h) + KE(v) = E_{\text{tot}} = \text{const}$, (4) the kinetic of the cart could be found as

$KE = E_{\text{tot}} - mgh$, (5) where the total energy of the cart is equal to its potential energy at the highest point, where the cart

is not moving and, therefore, its kinetic energy is zero. $E_{\text{tot}} = P$
 $E(h_{\text{max}}) = mgh_{\text{max}}$. (6)

Once the kinetic energy KE of our cart is known, its speed could be found from the definition of kinetic energy (1) as

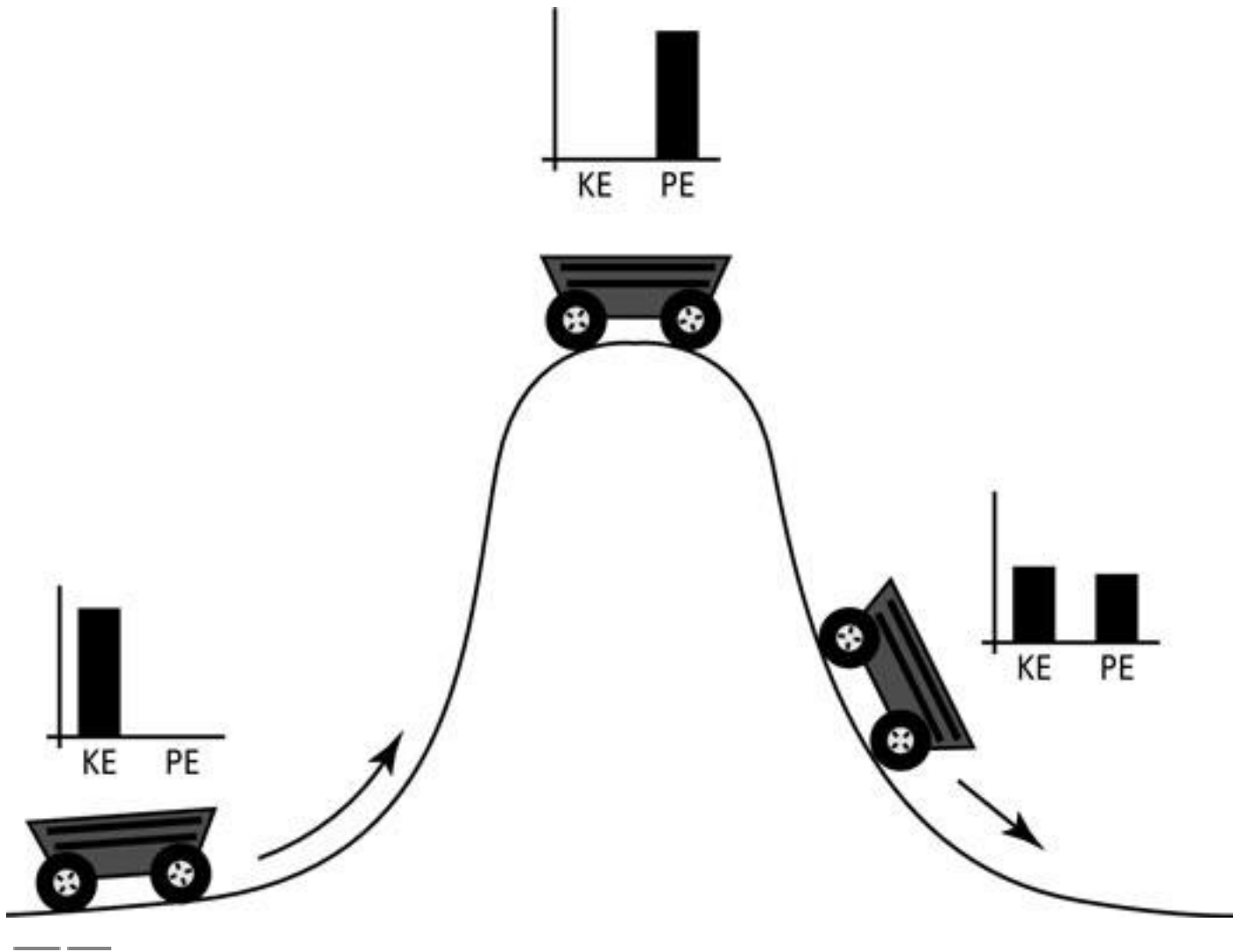
$$V = \sqrt{\frac{2KE}{m}}. \quad (7)$$

If the energy is conserved, the potential energy is transferred to the kinetic and back so that the potential energy in the lowest point of the track is zero, and the total energy is equal to the potential one. If the friction force is present, the work of friction is negative and proportional to the distance which

our cart has traveled along the track

$$W_f = f d \cos \hat{f} = f d, \quad (8)$$

where f is the friction force. The total energy keeps constantly decreasing while our cart is moving along the track until it comes to a full stop.



2

2 2.1

2.2

Useful resources Educational websites

<https://www.siyavula.com/read/science/grade-10/mechanical-energy/22-mechanical-energy-05>

https://en.wikipedia.org/wiki/Conservation_of_energy

https://cnx.org/contents/MymQBhVV@175.5:N-ly1_0_@2/Conservation-of-mechanical-energy

YouTube videos

<https://www.youtube.com/watch?v=AnuLW0ZX7-Q>

<https://www.youtube.com/watch?v=hce4pncZII4&t=445s>

<https://www.youtube.com/watch?v=AzXb63GEMss>

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and many-many others available online.

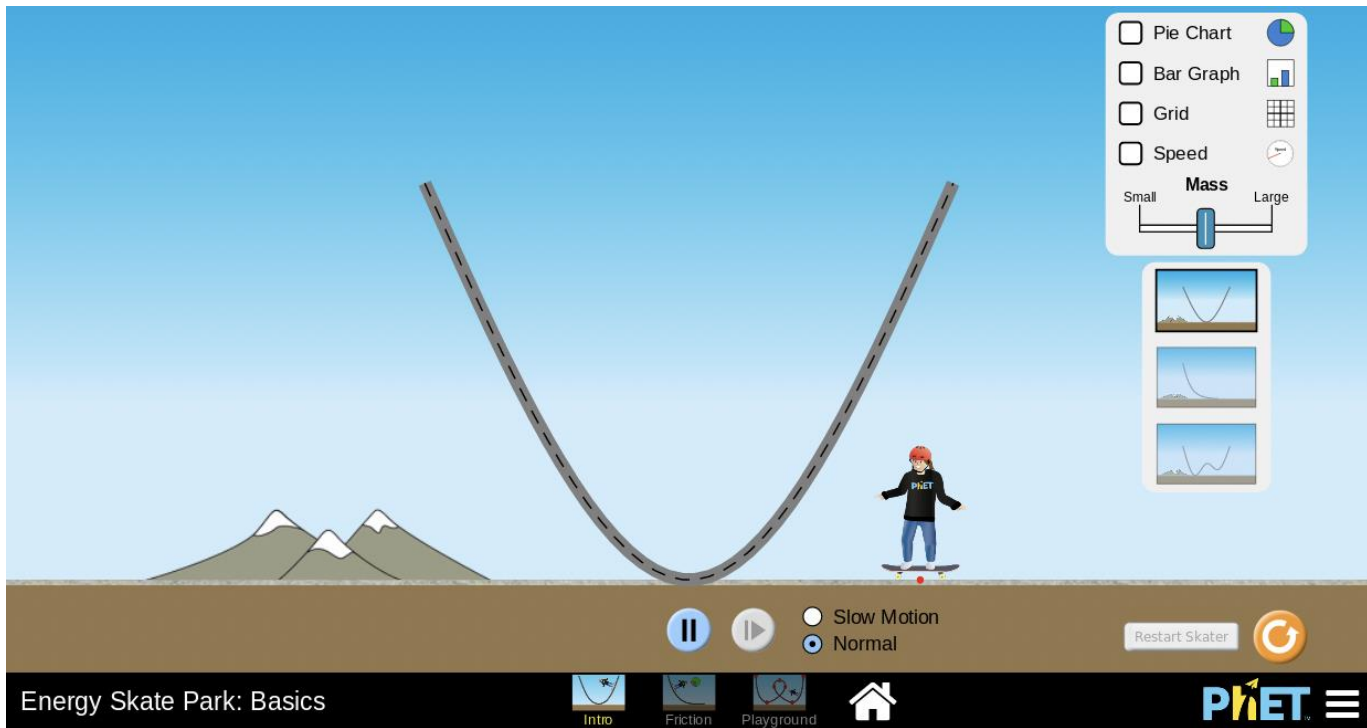
3 Procedure

1. Open our present online lab by clicking on

<https://phet.colorado.edu/sims/html/energy-skate-park-basics/latest/energy-skate-park-ba-en.html>.

Choose Intro window on the left.^[SEP]Now, your screen should look in the following way

Figure 2: (Color online) To be used for Step 1.



3

s

2. You should see a skater standing on the ground next to the track. To begin our experiment, drag the skater onto the top left part of the track and release him. The skater will demonstrate periodic motion along the track, up and down, and so forth. ^[L]_[SEP]
3. Make your prediction for the following ^[L]_[SEP] How does the potential energy $PE(h)$ and kinetic energy $KE(h)$ change from the highest to ^[L]_[SEP] the lowest point of the skater's trajectory? ^[L]_[SEP]
4. Enable all the checkmarks Pie Chart, Bar Chart, Grid and Speed (☒ Speed , and ☒ Pie Chart ) in the top right corner of your screen, which will now look as ^[L]_[SEP] Figure 3: (Color online) To be used for Step 4. ^[L]_[SEP]
5. Based on your observation, answer the following questions: How does mechanical energy change with time? ^[L]_[SEP] How you

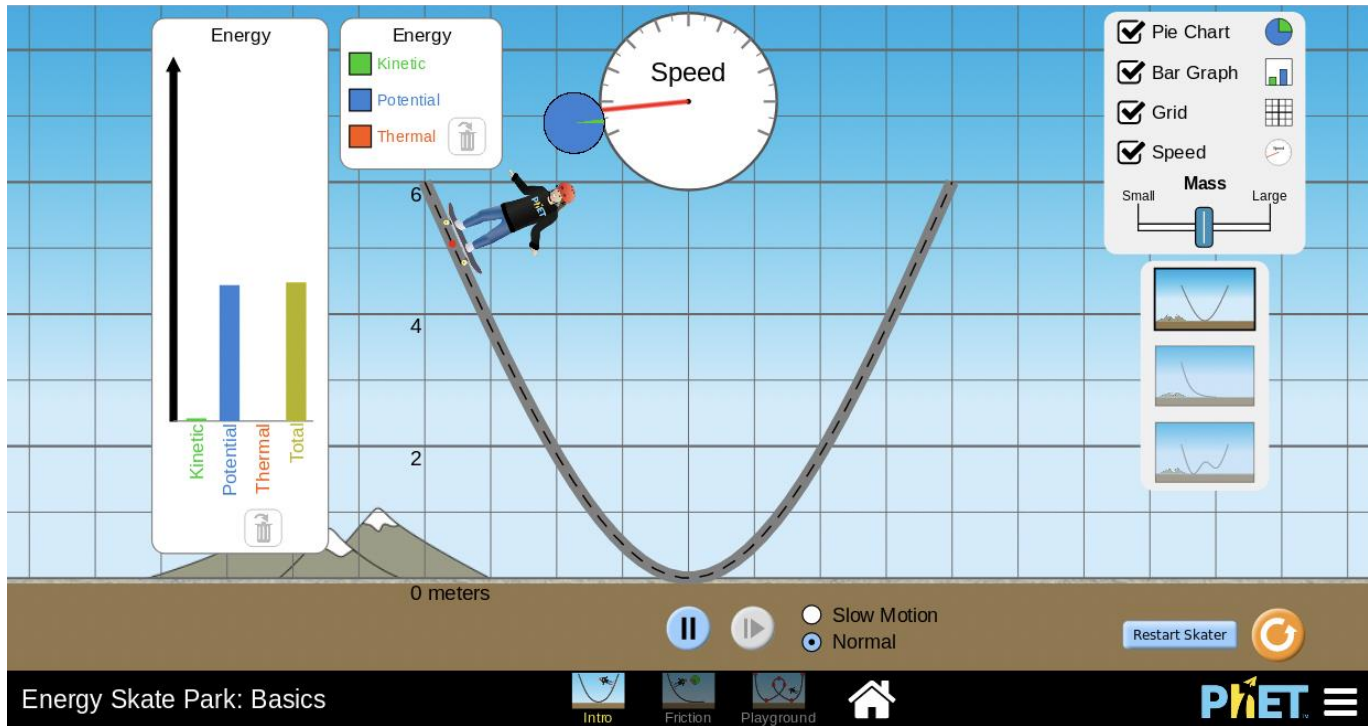
determine the kinetic energy KE? ^[1]_{SEP}

How does mechanical energy change with time.

The mechanical energy interchanges from potential energy to kinetic energy depending on the position it is located on. At max height potential energy is at its highest while kinetic energy is zero. While going down the slope the kinetic energy increases while potential energy reduces up to zero at the lowest point.

6. Consider the mass of a skater to be $m_1 = 30 \text{ kg}$, calculate its potential energy at $h = 6 \text{ m}$, 5 m , 4 m , ^[1]_{SEP} 3 m , 2 m , 1 m and 0 using Eq. 2. Record your results in Table 1 ^[1]_{SEP}Table 1. Potential energy of the skater as a function of his/her height on the track. ^[1]_{SEP}
7. Using Eq. (6), calculate the total energy of the skater equal to their potential energy at the initial point with $h = 6 \text{ m}$. ^[1]_{SEP}

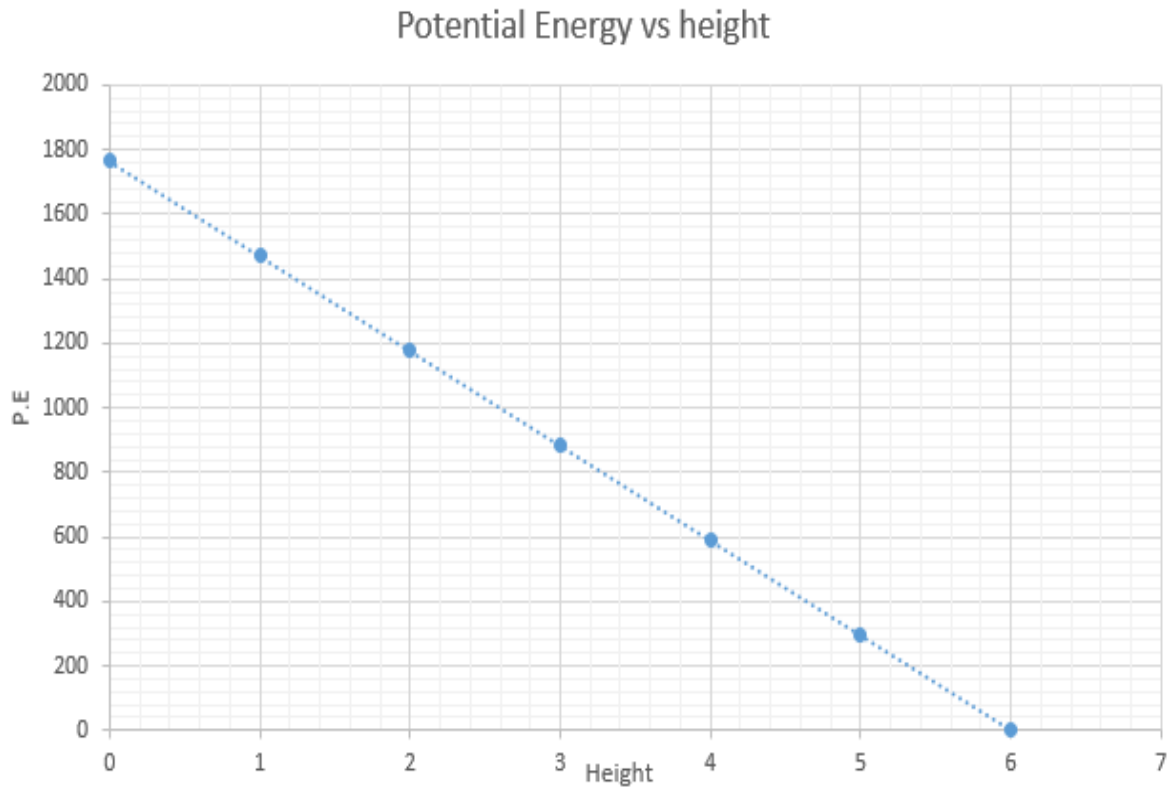
2. ☒ Bar Graph 



Height h , m	6	5	4	3	2	1	0
PE(h), J	1764	1470	1176	882	588	294	0

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8. Based on the conservation of mechanical energy expressed in Eq. (5), calculate the kinetic energy of the skater at points $h = 6\text{m}, 5\text{m}, 4\text{m}, 3\text{m}, 2\text{m}, 1\text{m}$ and 0. Calculate the speed of the skater from its known kinetic energy KE by Eq. 7. Add your results to Table 2. Kinetic energy and velocity of the skater as a function of his/her height on the track.
9. Based on the data from Table 2, prepare a graph for the kinetic energy KE for the skater at various positions. Make sure it is large and legible.



10. Press Restart skater button in the lower right corner of your screen to release them from their initial ^[L]_[SEP]position. Use the Mass slider  on the right to choose a relatively small (close to the left margin) mass of the skater. ^[L]_[SEP]Use the speedometer to experimentally determine the speed of the skater at the previously considered positions. Add your results to Table 3 ^[L]_[SEP]Table 3. Experimentally determined speed of the skater as a function of his/her height on the track. ^[L]_[SEP]
11. Compare your theoretical results for the skater's speed obtained in Step 8 with the corresponding experimental data from the previous Step 10. For three points with $h = 5\text{m}$, $h = 3\text{m}$ and $h = 2\text{m}$, calculate the percent error as

$$\%error = 2 \frac{|V_{exp} - V|}{V_{exp} + V} \cdot 100\% \quad (9)$$

Calculation of % error

For h = 5

$$\frac{4 - 4.27}{4.27} \times 100\%$$

-6.323%

For h = 3

$$\frac{8 - 7.67}{7.67} \times 100\%$$

4.30%

For h = 2

$$\frac{9 - 8.85}{8.85} \times 100\%$$

1.69%

12. Choose a larger value of mass of the skater as $m_2 = 75$ kg and repeat all your theoretical Steps 6-9. Choose a larger mass of a skater by moving the Mass slider to the right and repeat your experimental Step 10 and analysis in Step 11.

Table for P.E compared to height.

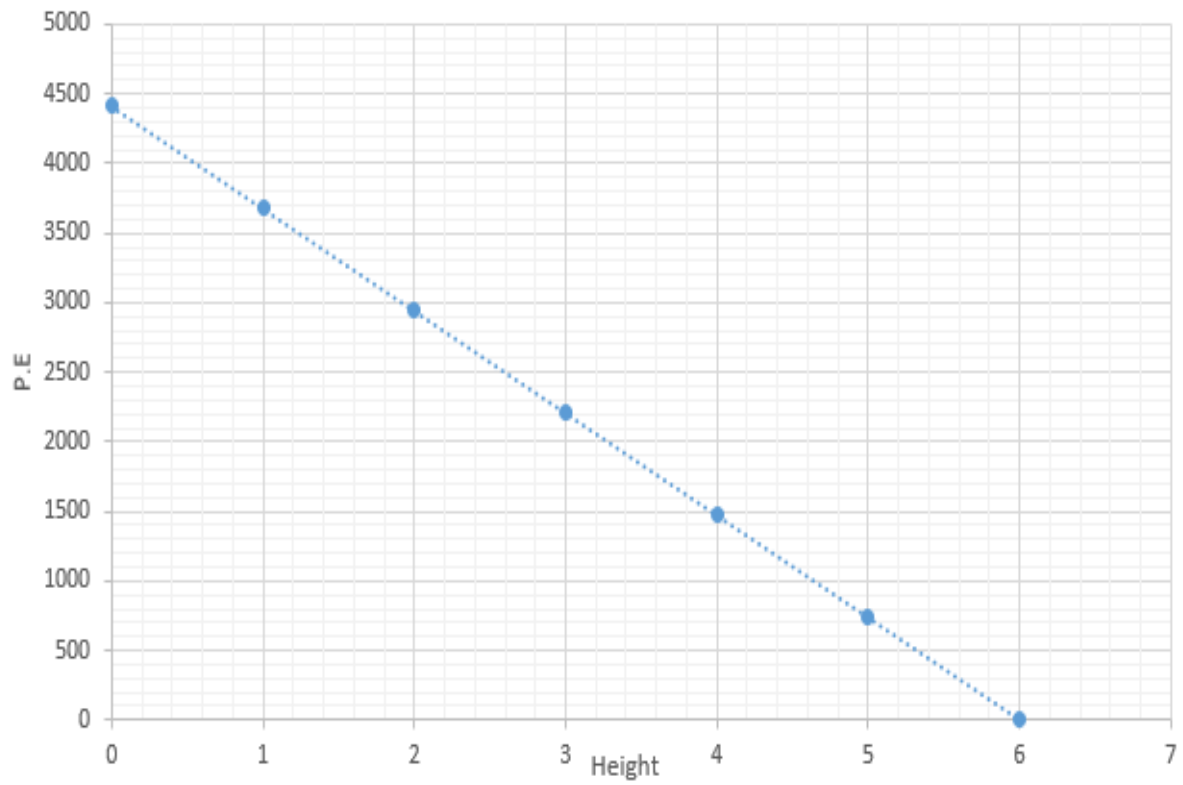
Height h, m	6	5	4	3	2	1	0
PE(h), J	4410	3675	2940	2205	1470	735	0

Table for K.E and velocity compared to height.

(Theoretical)

Height h, m	6	5	4	3	2	1	0
KE, J	0	735	1470	2205	2940	3675	4410
V , m/s	0	4.427	6.26	7.668	8.853	9.899	10.84

Potential Energy vs height



Velocity compared to height

(Experimental values)

Height h , m	6	5	4	3	2	1	0
V_{exp} , m/s	0	4	6	8	9	10	11

Calculation of % error

For $h = 5$

$$\frac{4 - 4.27}{4.27} \times 100\%$$

-6.323%

For $h = 3$

$$\frac{8 - 7.67}{7.67} \times 100\%$$

4.30%

For $h = 2$

$$\frac{9 - 8.85}{8.85} \times 100\%$$

1.69%

13. Next, choose the bottom track at the lower right part of your screen and repeat Steps 6-12 at the six points indicated in Fig. 4. Obtain the potential, kinetic and the total energies, as well as the speeds. L
SEP

Height h , m	6	5	4	3	2	1	0
KE, J	0	294	588	882	1176	1470	1764
V , m/s	0	4.427	6.26	7.668	8.853	9.899	10.84

8.



Height h , m	6	5	4	3	2	1	0
V_{exp} , m/s	0	4	6	8	9	10	11

8.

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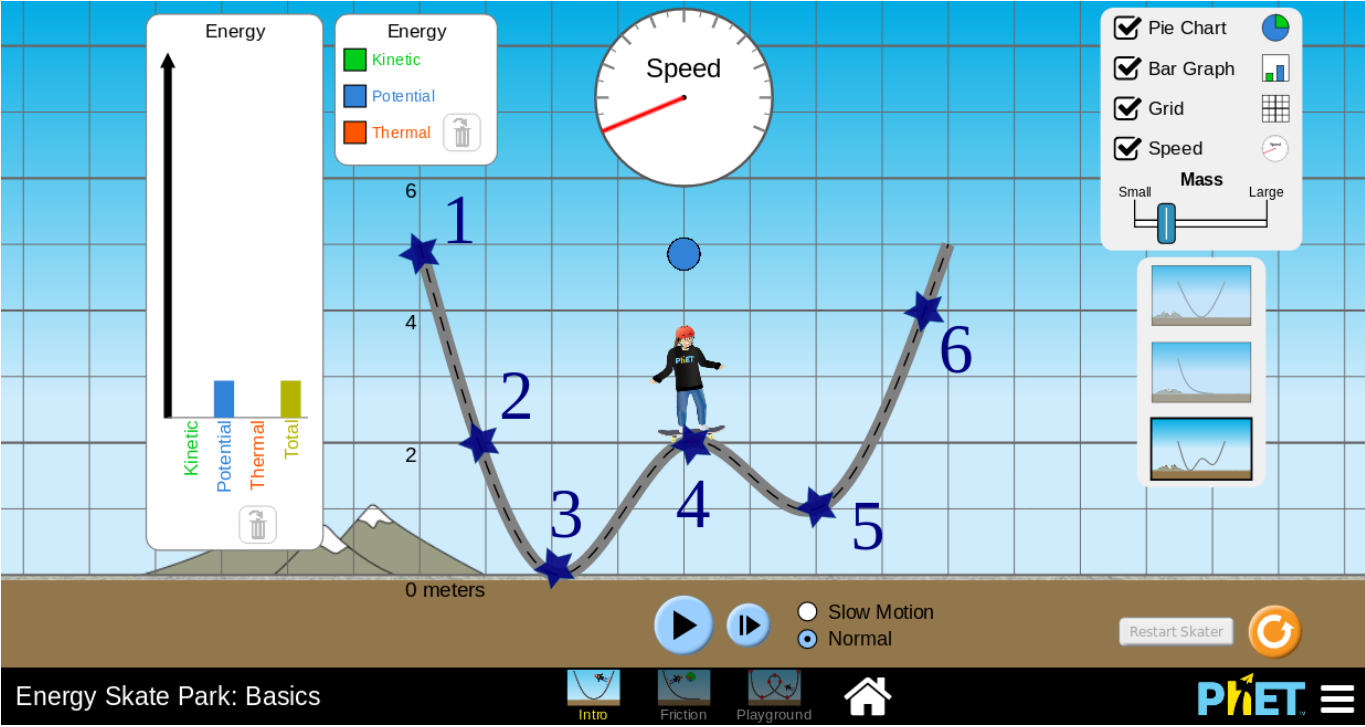


Figure 4: To be used for Step 13.^[SEP]**Important.** Please use the proper values of the coordinates for the points indicated in Fig. 4 for calculating the potential, kinetic and the total energies.

