Energy
Energy Conservation
Applications 1

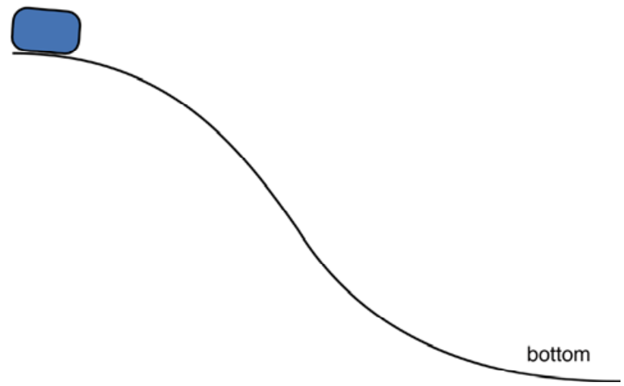
CONCEPT EXPLORATION

In this lesson you will be exploring the idea of conservation of energy. What happens to the energy of a falling object? If you were diving off of a diving board, what kind of energy would you lose and what kind of energy would you gain?

Engagement Questions

1. What kind of energy does a falling object gain as it accelerates downwards under the influence of gravity? Explain how you know this.

A large block of ice is started from rest at the top of a uniform slope.



2. Where is a good place to call the zero-gravitational-energy level (base level)? Explain why you think that this is a good choice.

3. What kind of energy does the ice have at the top of the slope before it begins to move? How do you know this?

4. How much gravitational potential energy does the ice have when it reaches the bottom of the slope? How do you know this?

5. What kind of energy does the ice have when it reaches the bottom of the slope? Explain how you know this. Where did this energy come from?

6. Evaluate the following student statements about the questions that you have just answered. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.

Student A

"As the block of ice slid down the slope it lost the gravitational potential energy that it had at the top of the slope. It had lost all off its energy when it got to the bottom of the slope."

Student B

"I think that the gravitational potential energy that the ice lost was turned into kinetic energy as the ice kept going faster down the slope. I think that the ice had just as much energy at the bottom of the slope as it did at the top of the slope, it was just a different kind of energy."

Check your work with your teacher ☐

Work was done on the ice (discussed in the preceding questions) as it slid down the slope.
7. What did work on the ice as it slid down the slope? What force was acting on the ice causing it to accelerate down the slope?

When the ice slid down the slope it lost gravitational potential energy, but it gained kinetic energy as it went faster down the slope. Since it is the pull of gravity that caused the ice to go faster down the slope, the kinetic energy it gained came from the gravitational potential energy that it lost. The energy of the block of ice was simply transformed from one kind of energy into another kind of energy.
The kind of energy that the ice had changed, but the total amount of energy of the ice, <u>never</u> changed as long as the system remained "isolated". The idea that the total amount of energy of an isolated system is always constant and doesn't change is known as **conservation of energy**. When you say that energy is conserved, you are also saying that energy cannot be created (it has to come from somewhere) and it can't be destroyed (it has to go somewhere).

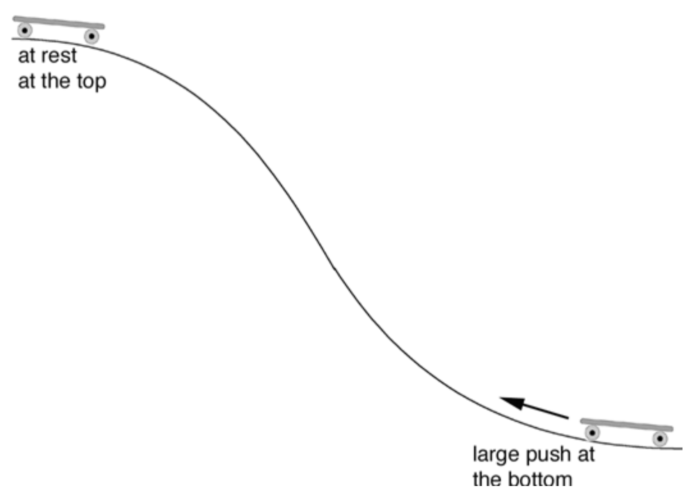
8. What kind of energy does the ice have when it is halfway down the slope? Explain how you know this.

9. Compared to the amount of gravitational potential energy that the ice had at the top of the slope, how much gravitational potential energy did the ice have at the halfway point on the slope? Was it half as much? . . . the same amount? . . . twice as much? Explain how you know. Hint: PE = mgh.

Assume that energy was conserved for this block of ice as it slid down the slope. Therefore the total amount of energy that the ice had at the top of the slope was equal to the total amount of energy that the ice had at the halfway point.

10. How does the amount of kinetic energy that the ice has at the halfway point compare to the amount of gravitational potential energy that it has at the halfway point? Explain how you know this.

A skateboard is given a large push at the bottom of a slope so that it rolls up the slope and just comes to rest at the top of the curved slope.



11. Where is a good place to call the zero-gravitational-potential-energy level (base level)? Explain why you think this is a good location.

12. How much gravitational potential energy does the skateboard have at the bottom of the slope? How do you know this?

13. What kind of energy does the skateboard have at the bottom of the slope when it first begins to move up the slope after the push? How do you know this?

14. What kind of energy does the skateboard have when it reaches the top of the slope and comes to rest? Explain how you know this. Where did this energy come from?

15. Evaluate the following student statements about the questions that you just answered. Identify ideas that are consistent with your answers and others that are not consistent with your answers.

Student A
"At the bottom of the slope the skateboard had a lot of kinetic energy. The skateboard lost all of its energy when it stopped moving at the top of the slope."

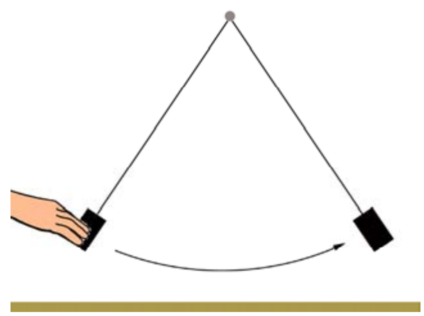
Student B
"The skateboard lost its kinetic energy as it slowed down while it went up the slope. The kinetic energy it lost was converted into gravitational potential energy as it went higher up the slope. I think energy was conserved since there weren't any forces other than gravity acting on the skateboard to slow it down. That would mean that the skateboard never lost its energy, it just changed the kind of energy that it had."

Check your work with your teacher

The Challenge
You will investigate what happens to an objects total energy as it rises upwards under the influence of gravity.

Your Ideas about the Challenge
A mass at the end of a string is pulled back and then released so that it swings back and forth.

16. During the time that the mass is swinging back and forth, what vertical position do you think would be the best position to call the zero gravitational potential energy level (base level)? Label this position on the diagram to the right.



17. What kind of energy does the mass have at the lowest position? How do you know this?

18. Compared to the initial vertical position of the mass, how high do you think that it will swing when it reaches its highest position on the other side?

Check your work with your teacher

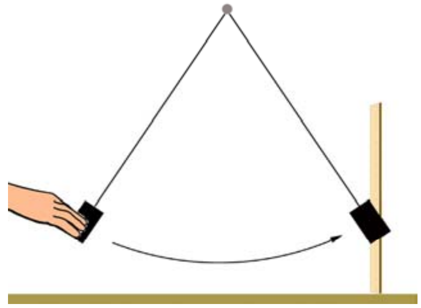
At each lab station you will find the following:
a pendulum arrangement with two vertically-oriented meter sticks positioned on each side

The Investigation
a. Pull the mass at the end of the string back so that the center of this mass is 5 cm above the table top.
b. Position one of the vertical meter sticks so that the bottom of this meter stick is an equal distance from the pivot point of the meter stick as the horizontal distance that you pulled your mass back. You should be able to read the height attained by the swinging mass when it reaches the opposite side.
c. One student should release the mass while another student attempts to read the height attained by the center of this mass when it reaches the other side.
d. Repeat this procedure to see if you are consistently reaching the same height each time. Record this height in the data table that follows.
e. Repeat steps "a" through "d" using release heights of 10 cm, 15 cm, and 20 cm.

Data Table

Release Position (cm)	Height on Opposite Side (cm)

5	
10	
15	
20	



19. How did the two heights compare for each trial? Were they roughly the same each time or was one value always slightly higher each time? How do you explain this?

Check your work with your teacher

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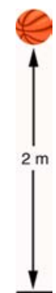
CONCEPT DEVELOPMENT

During the exploration activity you considered how the gravitational potential energy that a falling object loses is converted into kinetic energy as the falling object picks up speed.

The total energy that a falling object has remains constant. The sum of the gravitational potential energy and the kinetic energy for a falling object is a constant value. This is what is known as **conservation of energy**.

The reverse is true for an object that rises into the air. The kinetic energy that a rising object loses, as it slows down, is equal to the gravitational potential energy that it gains as it rises to a higher position. The total amount of energy that the object has still remains the same.

Engagement Activity and Questions



A basketball with a mass of 0.8 kg is held in a position that is 2 meters above the floor.

1. Calculate how much gravitational potential energy that this basketball has with respect to the floor (PE = mgh).

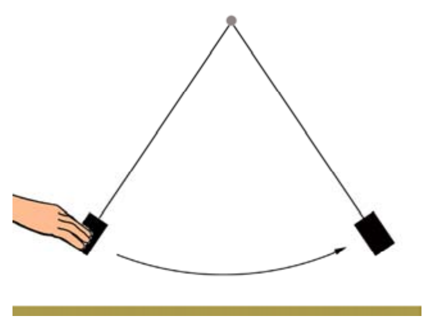
2. The basketball is now released from rest. Assuming that energy is conserved, how much kinetic energy will this basketball have just before it strikes the floor? Explain how you know.

The Challenge

You will investigate what happens to an objects total energy as it falls under the influence of gravity.

Your Ideas about the Challenge

A mass at the end of a string is released from rest so that it swings back and forth like a pendulum.



3. While this pendulum swings back and forth, what vertical position do you think would be the best position to call the zero gravitational potential energy level (base level)? Label this position on the diagram shown to the right.

4. What kind of energy does the mass have at its highest positions? Explain how you know.

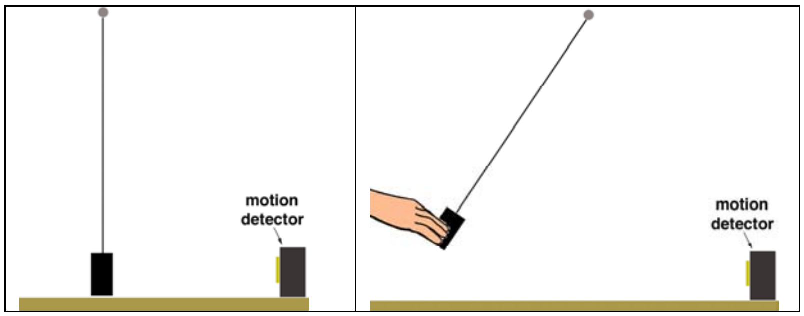
5. At what position would the mass have the most amount of kinetic energy? Explain why you think this. Label this position on the diagram shown to the right.

Check your work with your teacher

At each lab station you should find the following materials:
a motion detector with a computer and an interface, a pendulum arrangement, and a meter stick

The Investigation

a. Place the motion detector on the table top so that it will read the velocity of the pendulum mass at its lowest position. You should have a velocity time graph on your computer display.
b. Pull the mass at the end of the string back so that its center of mass is 5 cm above the table top.
c. Start the computer program.
d. Release the mass so that it swings down and towards the motion detector. Read the maximum velocity achieved by the pendulum mass. Repeat this procedure to make sure you are getting about the same maximum-velocity value each time. Record the value in the data table that follows.
e. Repeat steps "b" through "d" for the mass pulled back to 10 cm, 15 cm, and 20 cm.
f. Use the electronic balance to determine the mass of the pendulum mass. Record this value, expressed in kilograms in the data table that follows.



Data

Pendulum mass (kg)

Release Height (cm)	5	10	15	20
Maximum Velocity (m/s)				

6. Calculate the gravitational potential energy of the pendulum mass when it was held at each of the vertical positions. Be sure to show all of your calculations and to use appropriate units.

Vertical Positions (cm)	Gravitational Potential Energy
5	
10	
15	
20	

7. Calculate the maximum kinetic energy that your mass had. Use the maximum velocity from your data table in your calculations. Be sure to show all of your calculations and use appropriate units.

Release Height (cm)	Kinetic Energy
5	
10	
15	
20	

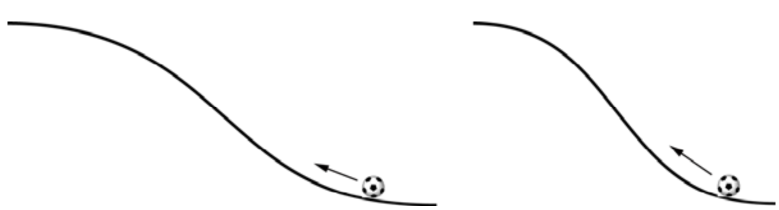
8. How did each of the gravitational potential energies (table 6) compare to each of the corresponding kinetic energies (table 7) for the pendulum mass? Were they about the same or was one quantity always larger than the other? What do you think happened?

9. Evaluate the following student statement about the work that you have done. Identify ideas that are consistent with your ideas and others that are not consistent with your ideas.
"The amount of kinetic energy that the mass had at the lowest position was almost the same as the amount of gravitational potential energy that the mass had at the highest position. I think that energy should have been conserved during this experiment but we didn't get exactly the same amounts of energy because of experimental error."

Check your work with your teacher ☐

The Challenge
You will investigate how the steepness of a slope determines the transformation of energy for an object rolling up the slope.

Your Ideas about the Challenge
A student kicks a soccer ball so that it rolls up a ramp and comes to a halt. The same student then kicks the same ball with the same force so that the ball goes up a steeper ramp.



10. On which ramp will the soccer ball reach a higher vertical position, the first ramp or the steeper ramp? Explain why you think that your answer is correct.

At each lab station you will find a ramp, a ball bearing, and a ball bearing launcher.

The Investigation (continued)

a. Tilt your ramp so that it is inclined at an angle of approximately 20^0 with respect to horizontal.
b. Pull back the spring-loaded part of the launcher so that the line, inscribed on the side, lines up with the end of the outer tube.
c. Place the ball bearing inside the holder.
d. Position the launcher so that the back part of the launcher lines up with the bottom of the ramp and so that you will be able to launch the ball bearing up the ramp.
e. Release the launcher so that the ball bearing is sent rolling up the ramp.
f. Mark the highest position on the ramp that the ball bearing reaches. Measure the distance in centimeters that this mark is above the surface of your table. Record this value in the data table that follows.
g. Repeat this procedure 4 more times.
h. Tilt the ramp so that it is inclined at a much greater angle.
i. Repeat the procedure outlined in b – g with this greater angle of inclination.

Data Tables

20^0 ramp

Launch #	Vertical height above the table top (cm)
1	
2	
3	
4	
5	

Steeper ramp

Launch #	Vertical height above the table top (cm)
1	
2	
3	
4	
5	

11. Calculate the average vertical height that the ball bearing reached with the 20^0 ramp.

12. Calculate the average vertical height that the ball bearing reached with the steeper ramp.

13. Was one average vertical height much greater than the other one or were they almost the same value? Why do you think that this happened?

14. What determines how high objects with equal initial velocities will roll up a ramp, the steepness of the ramp or the vertical height attained?

Check your work with your teacher

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CONCEPT REFINEMENT

Review

If an object is falling, under the influence of gravity, it will lose gravitational potential energy. The gravitational potential energy that it loses will be converted into kinetic energy as it accelerates downwards. Likewise, if an object is thrown into the air it loses kinetic energy as it slows down on the way up. The kinetic energy that it loses is converted into gravitational potential energy as it rises to a higher vertical position (h).

The total energy that an object has never changes as long as that object doesn't give up some of its energy to another object or to the surrounding environment. As long as the object remains a part of an "isolated system", energy is conserved within that isolated system. An **isolated system** is a system in which the objects within the system don't interact with anything outside of the system.

If energy is conserved then the total amount of energy within the system doesn't change. An equation that you can use for conservation of energy is shown below. This equation, stated in English, is the total energy of an isolated system before a change occurs is equal to the total energy after a change occurs.

total energy before = total energy after

1. What kinds of energy might an object have?

Our conservation of energy equation may be rewritten in terms of gravitational potential energy and kinetic energy as shown below. The energy before the change occurs may be written with a "zero" (0) subscript to show that this is initial energy. The energy after the change occurs may be written without any subscript to show that this is final energy.

$$PE_0 + KE_0 = PE + KE$$

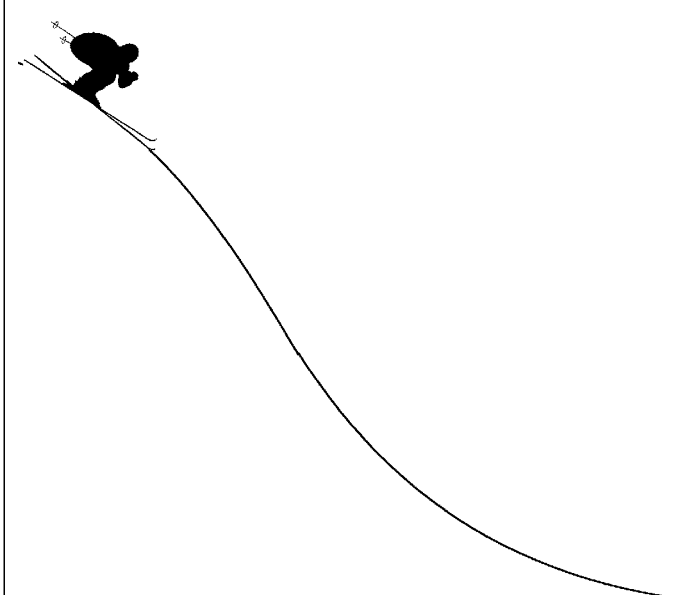
Shown to the right is a skier at the top of a hill.
You will be asked to solve for the speed of this skier at the bottom of the hill.

2. Where would be a good place for the zero gravitational potential energy level (base level)?

3. How much kinetic energy does this skier have at the top of the hill if he starts from rest?

4. What kind of energy does this skier have at the top of this hill?

5. The total energy of this "system" before the skier starts down the hill is just the initial gravitational potential energy (PE_0) that the skier has at the top of the hill.
What kind of energy does this skier have at the bottom of the hill?



6. How much gravitational potential energy does this skier have at the bottom of the hill?

Since the bottom of the hill is the best location to call the zero-gravitational potential energy level, the total energy of this "system" at the bottom of the hill is just the final kinetic energy (KE) due to the speed that the skier has at the bottom.

Since the total amount of energy within this system is constant, the initial gravitational potential energy that the skier has at the top of the hill must be equal to the final kinetic energy that the skier has at the bottom of the hill. Using this idea, you can rewrite the conservation of energy equation, for this situation, as you see below.

$$PE_0 = KE$$

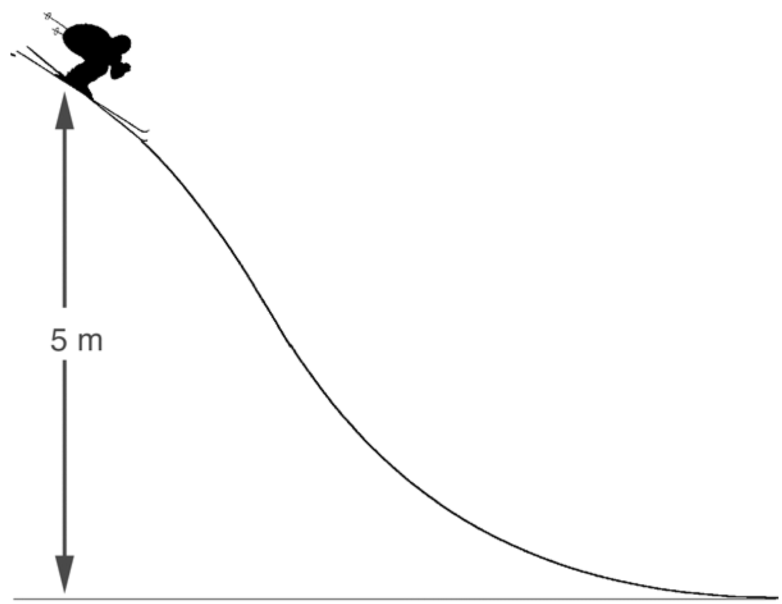
7. Rewrite this equation by substituting the mathematical expressions for gravitational potential energy and kinetic energy into this equation. Be sure to label the height "h" with a zero subscript (h_0) to show that this is the initial height.

8. Simplify this equation by dividing through by the quantity that appears on both sides of the equation. Rewrite this simplified equation below.

9. Solve the equation that you wrote above for the velocity (v). Write this new equation below.

The hill is 5 meters tall.

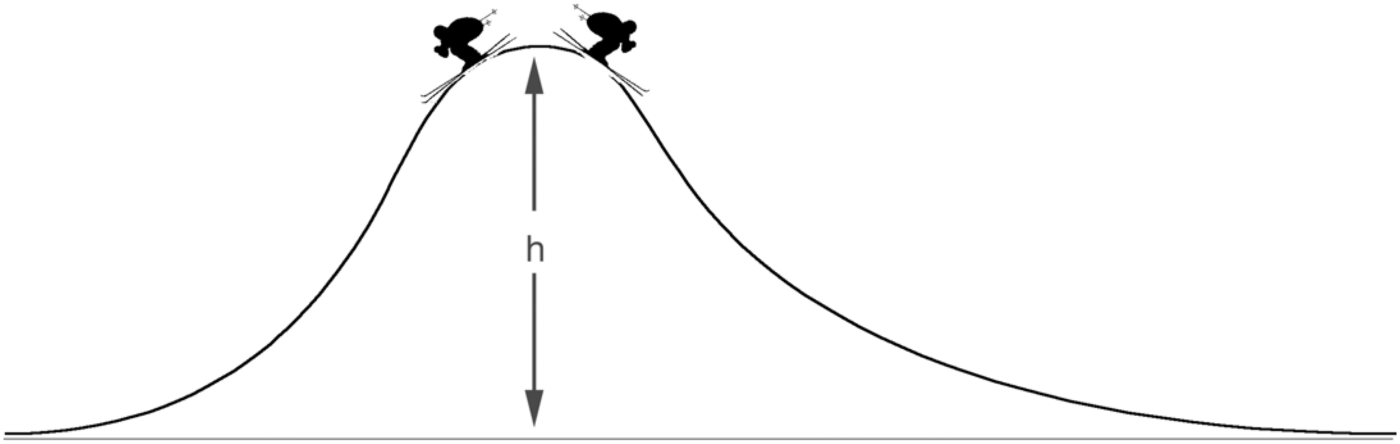
10. Calculate the speed of the skier at the bottom of the hill. Be sure to include the appropriate units in your calculations as well as for your final answer.



11. Would a heavier skier get to the bottom of this same hill faster than the skier shown above? Explain how you know the answer to this question.

Check your work with your teacher.

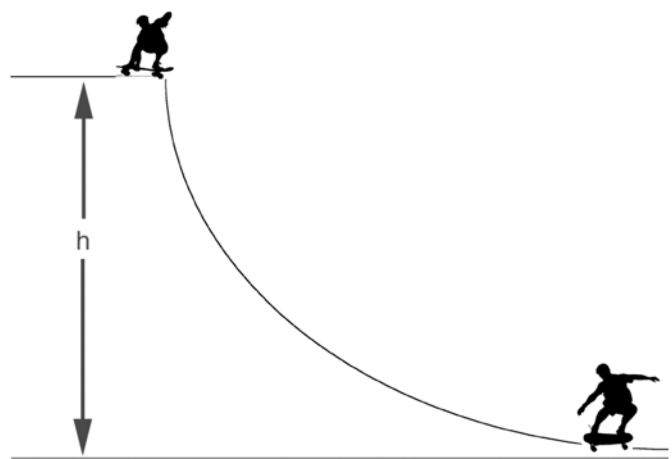
Two identical skiers are going to go down opposite sides of a hill that have unequal slopes. On one side of the hill is a steep slope. On the other side is a not-so-steep slope.



12. Which skier, if either, will be going the fastest at the bottom of the hills? Explain how you know the answer to this question.

A skateboarder starts at the bottom of a half pipe and rolls up the incline so that he just comes to rest at the top lip of the half pipe.

13. What kind of energy does the skateboarder have at the bottom of the half pipe? Explain how you know this.



14. What kind of energy does the skateboarder have at the top of the half pipe when he comes to rest? Explain how you know this.

15. Assume that energy was conserved in this situation. Write the equation for this particular situation using the concept of conservation of energy. Be sure to use the mathematical expressions for kinetic energy ($1/2mv^2$) and gravitational potential energy (mgh).

16. Solve the equation you wrote above for the height of the half pipe. Write this new form of your equation below.

17. If the skateboarder was going 12 m/s at the bottom of the half pipe, how tall must this half pipe have been?

Check your work with your teacher.