# Work-Energy Theorem and Conservation of Energy

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| **Lesson Plan for Grades:** High school physics<br>**Length of Lesson:** 90 minutes |
| **Authored by:** Environmental Science Institute, University of Texas at Austin<br>**Date created:** 04/01/2021 |
| **Subject area/course:**<br>• Physics |
| **Materials:**<br>• Projector<br>• Laptop<br>• Handout |
| **TEKS:**<br>***§112.39***<br><br>***Process:***<br>(3) The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:<br>(E) express, manipulate, and interpret relationships symbolically in accordance with accepted theories to make predictions and solve problems mathematically.<br><br>***Content***<br>(6) Science concepts:<br>(A) investigate and calculate quantities using the work-energy theorem in various situations;<br><br>(B) investigate examples of kinetic and potential energy and their transformations;<br><br>(C) calculate the mechanical energy of, power generated within, impulse applied to, and momentum of a physical system;<br><br>(D) demonstrate and apply the laws of conservation of energy and conservation of momentum in one dimension. |
| **Lesson objective(s):**<br>• Students will be able to explain physics using work-energy theorem and energy transformations.<br>• Students will be able to set up governing equations from real-world problems.<br>• Students will be able to solve the problems mathematically. |
| **Differentiation strategies to meet diverse learner needs:**<br>• The lesson plan will include oral, written, and visual explanations to accompany the different learning styles.<br>• The students can also receive help from each other in discussion and exploration.<br>• The teacher is available to guide the students through difficult tasks. |
| **ENGAGEMENT (10 minutes)**<br>• Teacher explains to the class that superheroes like Avengers do a great job showcasing the bodies of engineering and math. 5 highlights to do it well: observe (read the problem carefully); create (think and set up the governing equation); teamwork (work and get help from team members); repeat (use same the concept to solve a similar problem); and fun (enjoy working through the solution and coming up with other things to investigate). |

**Work-Energy Theorem and Conservation of Energy**

- Watch the Dr. Raychelle Burks *Hot Science At Home* "Science & The Avengers" from 01:50-5:00: https://youtu.be/eSSywdZyBr0.

**EXPLORATION (40 minutes)**

- Teacher explains the concept of work-energy theorem and energy conservation. The theorem is explained in videos included in the *Sources and Resources* section.
- Divide students into appropriate number of groups.
- Students will work together in groups to complete the *Part 1* of the *Exploration Student Worksheet* below to the best of their skill.
- Based on what the students have learned from *Part 1* by teamwork, keep working on *Part 2* individually as a repeat (use the same concept to solve a similar problem) and check answers with team members.

**EXPLANATION (30 minutes)**

- Volunteers from each group will present their solutions of either *Part 1* or *Part 2* of the *Exploration Student Worksheet*.
- If the group did not get the correct answer or made some partial mistakes, they still receive 1 credit for partial answer. Other groups have a chance to steal the 1 credit by raising their hand and giving the correct answer.
- After 3 tries, including from the original group, if the students still do not have the correct answer, the teacher will pause the game and go over the problem as a class.

**ELABORATION (10 minutes)**

- Each group comes up with a conservation of energy example in real life (see the *Elaboration Teacher Handout).*
- Teacher will summarize what the students learned today and answer any questions students might have.

**EVALUATION (throughout entire lesson)**

- Teacher will conduct formative assessments during the lesson by walking around and leading discussions with each group.
- Each group will present and turn in a packet with their answers to the physics problems.

**SOURCES AND RESOURCES**

- Hot Science At Home with Dr. Raychelle Burks's "*Science & the Avengers"*: https://youtu.be/eSSywdZyBr0
- Work-energy theorem: https://youtu.be/zVRH9d5PW8g
- Conservation of energy: https://youtu.be/OTK9JrKC6EY

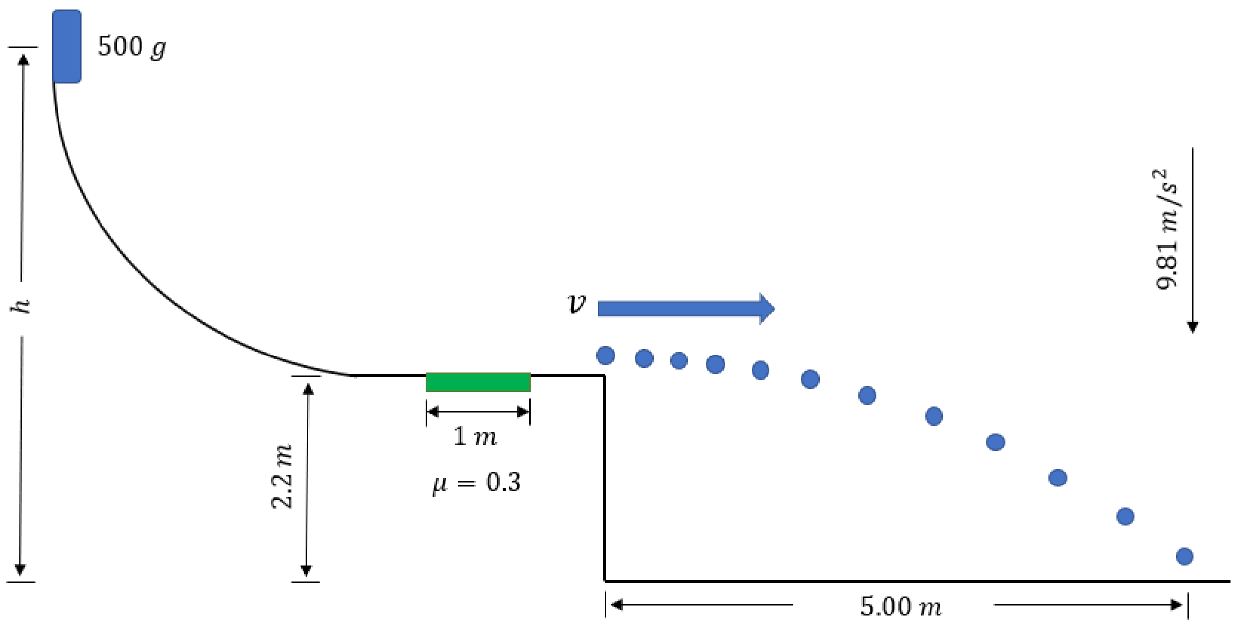
# Work-Energy Theorem and Conservation of Energy

**EXPLORATION STUDENT WORKSHEET (40 min)**

Student's name: Group's name:

**Part I. Use work-energy theorem and conservation of energy to solve the physics problem.**

A block at rest slides downs a frictionless track except for a small rough area on a horizontal section of the track (shown in the figure below). It leaves the track horizontally, flies through the air (assume no air resistance), and subsequently strikes the ground. At what height h above the ground is the block released?

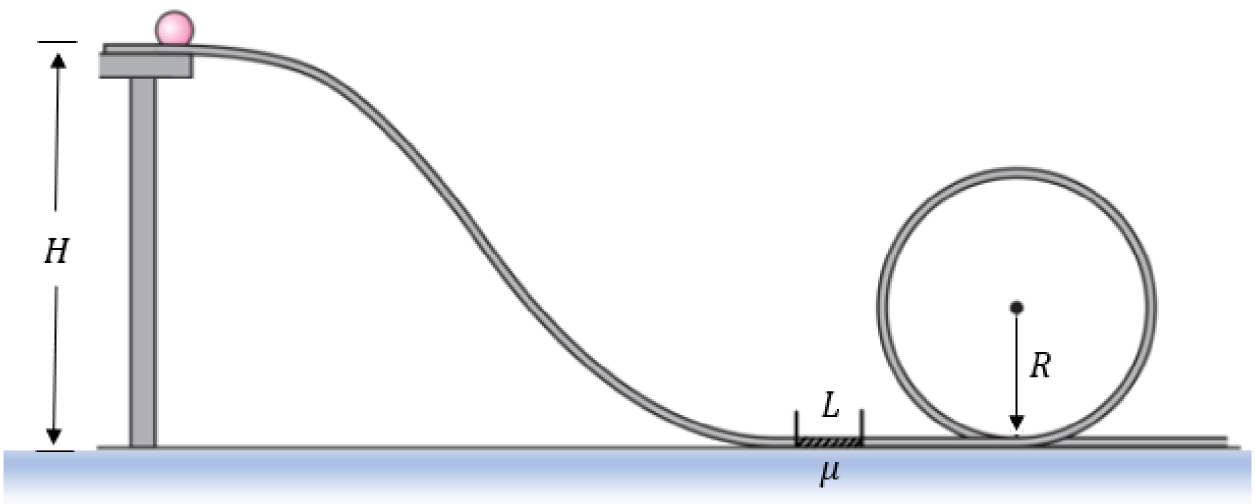


**Work-Energy Theorem and Conservation of Energy**

**EXPLORATION STUDENT WORKSHEET (continued)**

**Part II. Repeat what you learnt from Part I and solve below physics problem.**

A rest solid ball (mass m) starts from the top of a hill with height H and rolls down without slipping on the loop-the-loop track in the following figure. At the horizontal part of the track (before the loop) there was a rough floor whose length is L = 0.2 m, and its kinetic friction coefficient with the ball is 0.3. Assume there is no friction at any other part of the track. The loop has a radius of R = 1 m. If the ball exerts a normal force to the track with the same magnitude of its weight, when it is at the top of the loop, what's the value of height H?

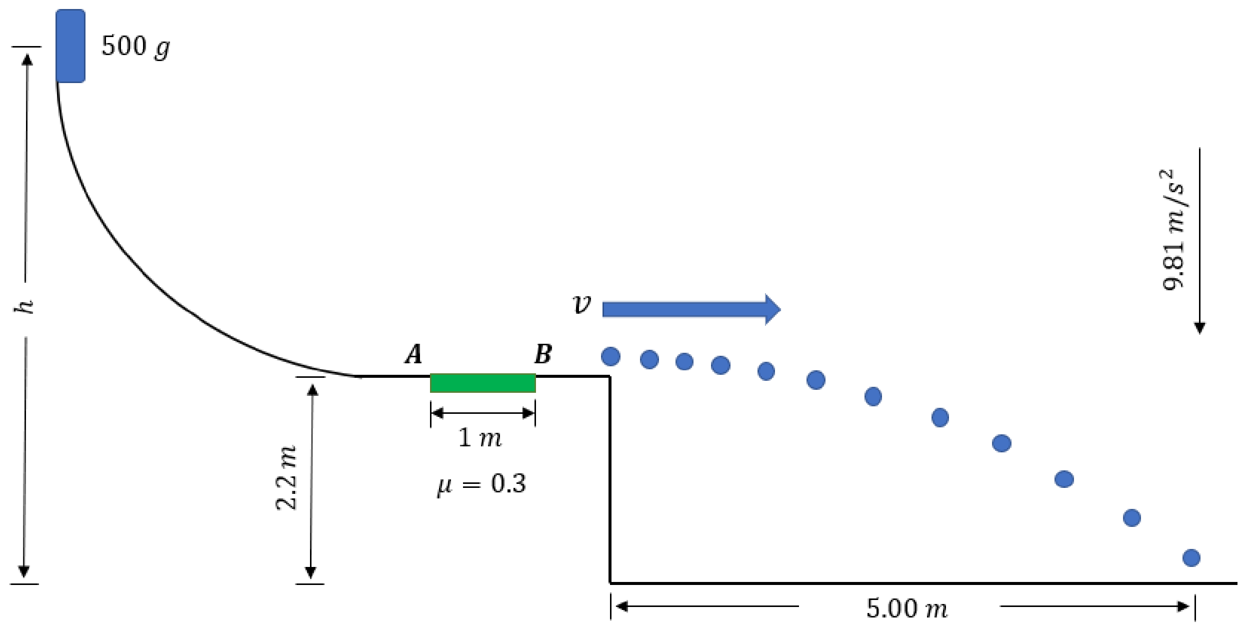


**Work-Energy Theorem and Conservation of Energy**

**EXPLORATION STUDENT WORKSHEET ANSWERS**

**Part I. Use work-energy theorem and conservation of energy to solve the physics problem.**

A block at rest slides downs a frictionless track except for a small rough area on a horizontal section of the track (shown in the figure below). It leaves the track horizontally, flies through the air (assume no air resistance), and subsequently strikes the ground. At what height h above the ground is the block released?




As the block slides down to horizontal section A before the small rough area, there is no friction, so energy is conserved.

Set the ground as the reference: $mgh = \frac{1}{2}mv_A^2 + mg * 2.2$

Solve for $h$: $h = \frac{v_A^2}{2g} + 2.2$ ...... (1)

As the block slides from A to B, due to friction and work-energy theorem:

$$\begin{cases} f_k = \mu mg \\ f_k * 1 * cos180^\circ = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 \end{cases} \rightarrow \quad v_A^2 = v_B^2 + 2\mu g \quad ......(2)$$

As the block flies through the air:

In the horizontal direction, it is constant velocity motion: $v_B * t = 5 \rightarrow t = \frac{5}{v_B}$ ...... (3)

**Work-Energy Theorem and Conservation of Energy**

In the vertical direction, it is free fall with no initial velocity: $2.2 = \frac{1}{2}gt^2$ $\quad \ldots \ldots (4)$

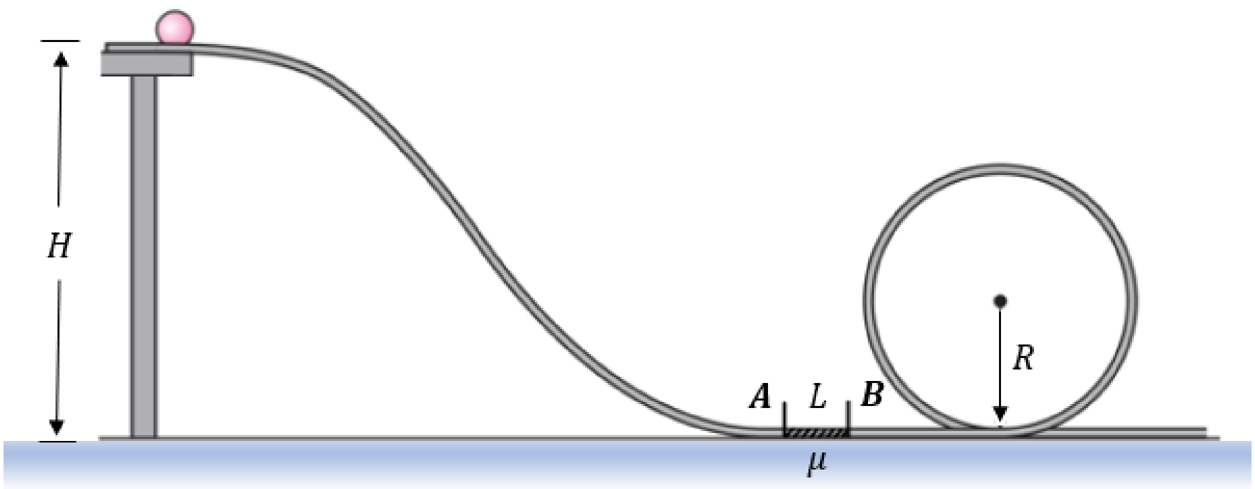
Plug (3) into (4): $2.2 = \frac{1}{2} * 9.81 * \frac{5^2}{v_B^2}$ $\quad \rightarrow \quad$ $v_B^2 = \frac{9.81*5^2}{2*2.2} = 55.74$ $\quad \ldots \ldots (5)$

Plug (5) into (2): $v_A^2 = 55.74 + 2 * 0.3 * 9.81 = 61.63$ $\quad \ldots \ldots (6)$

Plug (6) into (1): $h = \frac{61.63}{2*9.81} + 2.2 = 5.34\ m$

**Part II. Repeat what you learnt from Part I and solve below physics problem.**

A rest solid ball (mass m) starts from the top of a hill with height H and rolls down without slipping on the loop-the-loop track in the following figure. At the horizontal part of the track (before the loop) there was a rough floor whose length is L = 0.3 m, and its kinetic friction coefficient with the ball is 0.4. Assume there is no friction at any other part of the track. The loop has a radius of R = 1 m. If the ball exerts a normal force to the track with the same magnitude of its weight, when it is at the top of the loop, what's the value of height H?




By description, when the ball is at C (the top of the loop), $N = mg$. And both forces are downward.

Then $F_{centripetal} = N + mg = 2mg = m\frac{v_C^2}{R}$ $\quad \rightarrow \quad$ $v_C^2 = 2gR$ $\quad \ldots \ldots (1)$

As the ball rolls from the top of the hill to A, there is no friction, so energy is conserved.

Set the ground as the reference: $mgH = \frac{1}{2}mv_A^2$ $\quad \ldots \ldots (2)$

As the ball rolls from A to B, due to friction and work-energy theorem:

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$$\begin{cases} f_k = \mu mg \\ f_k * L * cos180^{\circ} = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 \end{cases} \rightarrow -\mu mgL = \frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 \quad \ldots\ldots(3)$$

As the ball rolls from B to C, there is no friction, so energy is conserved.

Set the ground as the reference: $mg * 2R + \frac{1}{2}mv_C^2 = \frac{1}{2}mv_B^2 \quad \ldots\ldots(4)$

Plug (1) into (4): $\frac{1}{2}mv_B^2 = 2mgR + \frac{2mgR}{2} = 3mgR \quad \ldots\ldots(5)$

Plug (5) and (2) into (3): $-\mu mgL = 3mgR - mgH \quad \rightarrow \quad H = 3R + \mu L = 3 * 1 + 0.4 * 0.3 = 3.12$

# Work-Energy Theorem and Conservation of Energy

**ELABORATION TEACHER HANDOUT (10 min)**

1. Each group comes up with a conservation of energy example in real life. Here are some examples.

- Example 1: As object falls, potential energy is converted into kinetic energy, but the sum of kinetic and potential energy of the object will be the same during the free fall.
- Example 2: A car engine converts chemical energy stored in gasoline through a series of steps to eventually produce the kinetic energy to move the car.
- Example 3: When we eat food, we are converting chemical energy within the food into the chemical energy in ATP which can then be used as kinetic energy to move our bodies around.
- Example 4: When we slap our hand down the table, all the kinetic energy is transformed into thermal energy by heating up the table slightly, as well as acoustic energy which is the sound we will hear.

2. Teacher wrap up what the students learned today and answer any questions students might have.