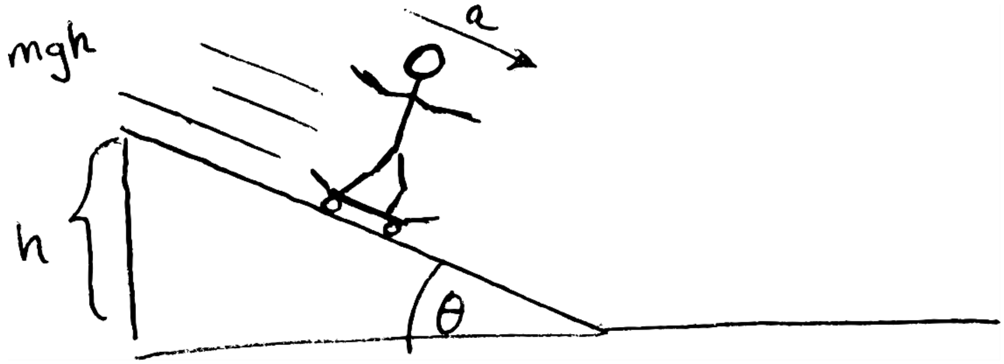
Energy and Action Sports



Overview:

Students will design and 3D print their own custom fingerboards, and then use their fingerboards to experimentally observe the law of conservation of energy.

Grade Levels: Middle school

Standards*:

NGSS: MS-PS3-2 Energy: *Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.*

CCSS: CCSS.Math.Content.5.MD.A.1: *Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.*

CCSS.Math.Content.6.EE.A.2: *Write, read, and evaluate expressions in which letters stand for numbers.*

CCSS.ELA-Literacy.SL.6.1: *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.*

CCSS.ELA-Literacy.SL.7.1: *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.*

CCSS.ELA-Literacy.SL.8.1: *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse* *partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.*

**It is assumed that teachers will tweak the lesson plan as needed to better suit their students.*

Learning objectives:

1) Students will understand how to apply theory to make predictions about the energy in a moving object.
2) Students will understand how to perform an experiment to test their predictions.
3) Students will develop an intuitive sense of the law of conservation of energy.
4) Students will become curious about 3D modeling, printing, and how the law of conservation of energy pertains to every day systems and activities, like action sports.

Lesson outcome:

1) Students will create a hypothesis to be tested in an experiment.
2) Students will collect data and discuss the data, arriving at a conclusion.
3) Students will use parametric modeling to design their own custom fingerboard.

Materials:

- Fingerboard trucks (2 per student)*
- Fingerboard wheels (4 per student)*
- Miniature screws (8 per student)*
- Miniature nuts (4 per student)*
- 3D printer
- 3D printer filament such as PLA
- Laptops/computers with internet access (1 per student)
- Scale or triple-beam balance
- Notebooks and pencils/pens
- Mini Philips head screwdriver
- Mini socket wrench (2.5 mm)*
- Rulers, tape measures, meter sticks
- Ramps of varying height (rise) and length (run) – these can be made from books, cardboard, wood, etc.
- Stopwatches

Fingerboard kits (trucks, wheels, hardware, and tool) may be ordered individually or in bulk from www.opensourceboards.com/shop.html.

Instructions:

Day 1 [50 minutes]**:**

1) [10 minutes] **Overview/warmup**: Instructor explains how understanding physics plays a critical roll on action sports, particularly with the design of ramps and obstacles.

   Video: https://youtu.be/MqoKvULSTyo (1.5 min)

2) [10 minutes] Instructor gives class brief tutorial on fingerboard design tool:

   https://www.opensourceboards.com/CAD/fingerboard-simple.html

   Instructor provides constraints to students for each parameter (for example, the maximum width is 1.25”, the maximum wheelbase is 2.5”, etc.)

3) [30 minutes] Students design their fingerboards. They can use pencil and paper to sketch their ideas.

   When finished, students download an STL file of their board.

   Instructor collects, prepares, and prints STL files in batches after class.

Day 2 [50 minutes]**:**

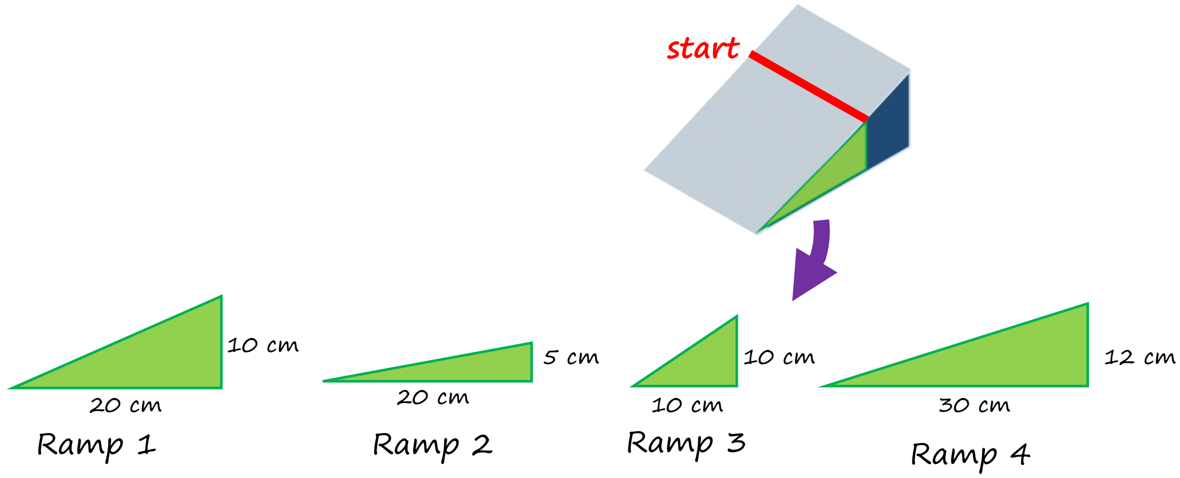
1) [15 minutes] Students assemble* their fingerboards with trucks, wheels, nuts and bolts. Students weigh their fingerboards and record the mass. Convert the units of measurement to kilograms.

   **Depending on print quality, fingerboard holes may need to be re-drilled with a 1/16” drill bit.*

   While students assemble, instructor sets up different stations around the classroom. Each station has a ramp at a different angle and length, measuring devices, and a stop watch. Each ramp needs to have a marked starting line, far enough down from the edge of the ramp to fit the longest fingerboard.

   Instructor also draws the ramps on the chalkboard/whiteboard, displaying the height (rise) and length (run) from the base of the ramp to the starting line.

Example:

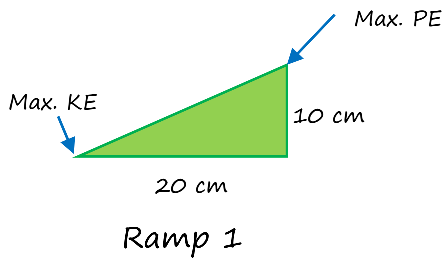


2) [5 minutes] For each ramp the instructor drew, students identify:

   a) Point of maximum potential energy (PE)

   b) Point of maximum kinetic energy (KE)

Example:



Students rank the ramps according to the potential energy (PE) they provide (i.e., the first ramp in their list provides the largest PE, and the last ramp provides the least PE)

Students also rank the ramps according to how fast they expect the skateboard to go. Instructor reminds students of the law of conservation of energy (the ramps that provide the fingerboards the greatest potential energy will also provide the greatest kinetic energy).

3) [5 minutes] Students independently calculate the potential energy for their fingerboard for each ramp:

$$PE = mgh$$

PE: potential energy (Joule)
m: mass (kg)
g: acceleration due to gravity (9.81 m/s²)
h: rise (m)

Extension option:

Students then calculate the expected velocity of their fingerboard for each ramp, observing the law of conservation of energy:

$$PE = KE$$

$$KE = \frac{1}{2}mv^2$$

KE: kinetic energy (Joule)
m: mass (kg)
v: velocity (m/s)

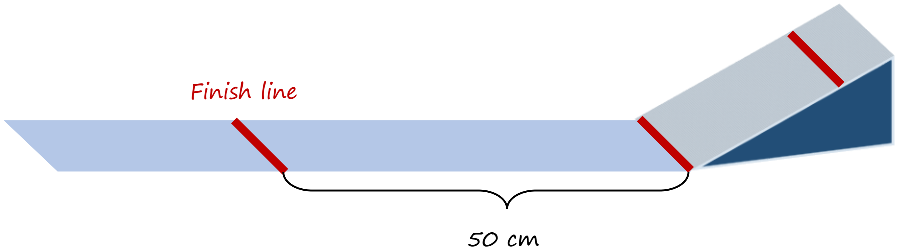
4) [20 minutes] Students pair-up or form small teams, and each team goes to a station. Students measure the slope of the ramp (rise over run) to determine which ramp they are using. Students place their fingerboards at the top of the ramp one at a time, with the front wheels of their skateboard right behind the starting line. They let go of the board and measure the distance the board travels from the bottom of the ramp until it stops. Each student performs 3 trials per station, and records their data.

Example of data set for two stations:

				Distance traveled		
Station	Rise (cm)	Run (cm)	Slope	Trial 1 (m)	Trial 2 (m)	Trial 3 (m)
1	10	20	0.5	2.11	2.12	2.09
2	4	40	0.1	0.59	0.59	0.60

Extension option:

Students will also record the time it takes for their fingerboard to travel a specific distance immediately after the ramp, and calculate the velocity for each recorded time (each student performs 3 trials). Make a marking a set distance from the ramp to use as a finish line.



5) [5 minutes] Students get together as a class and discuss their findings:

   1) Was the students' listing of ramps in the correct order, based on the data?

   2) Why didn't the fingerboards roll on forever? (Why did they eventually stop?)

   3) If you have a ramp with a slope angle of 45° and height of 5 cm, and another ramp with a slope angle of 5° and height of 6 cm, which ramp would make your fingerboard go faster?