

**Time:** 1 day (6 hours)

**Class Size:** 32 students, paired into 8 groups of 4 for activities

**Lesson Overview & Objectives:**

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| **Lesson** | | **Objective** | **Time** |
| 1 | Slope | * Students will learn about the concept of slope through a series of running activities and apply their observations to real world scenarios involving car performance on road surfaces. * Students will understand the correlation between slope and a vehicle’s speed and required effort. * Students will recognize the challenge of hilly landscapes in roadway design. | 1 hr |
| 2 | Horizontal Curve | * Students will learn about the concept of horizontal curve through a running activity and apply their observations to real world scenarios involving car performance navigating bends/curves in the road. * Students will understand the correlation between horizontal curve and a vehicle’s speed/control around road bends. * Students will recognize the challenges of curves and turns in roadway design. | 1 hr |
| 3 | Road Cut & Fill | * Students will learn about the concept of cutting a road through a hill and filling a hole for road building through visual examples and class discussion * Students will understand the correlation between flat roads and the time and cost to construct a road * Students will recognize the challenge of constructing flat roads. | ½ hr |
| 4 | Culvert Flow | * Students will learn about water flow and the role of culverts in allowing flow through filled in portions of roads. * Students will understand the correlation between water flow and the diameter of culverts. * Students will understand why culverts are used in roadway design, and how they are properly used to handle a river’s flow and support road weight. | ½ hr |
| 5 | Road Building | * Students will work in small groups to design and build a road surface through hilly terrain with waterways. * Students will apply newly acquired skills with slope, horizontal curve, cut and fill, and flow, to create an efficient road design. | 3 hr |

**Materials Needed:**

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| **Material** | **Quantity** |
| Cones/tape (or other trail marking items) | Varies |
| Clipboards | 10 |
| Stopwatches | 10 |
| Google Slides Presentation: Road Building | 1 |
| Slope Data Collection Sheets | 10 |
| Road Building Challenge Cards | 10 |
| Horizontal Curve Data Collection Sheets | 10 |
| Sandbox with sand | 2 |
| Shovels | 4 |
| Mini RC Cars | 2 |
| Set of culvert flow water jugs | 1 |
| 5-Gallon Buckets | 2 |
| 2-Gallon Buckets | 2 |
| Water |  |
| Butcher Paper cut to 2’ x 4’ | 10 |
| Yard Sticks/rulers | 10 |
| Pencils | 30 |
| Scissors | 10 |
| Plastic Drinking straws | 20 |
| Assorted Culvert Pipes | Many |
| Blocks (for setting tables on) | 8 |

**Key Vocabulary:**

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| * Horizontal Curve * Centrifugal Force | * Grade * Slope * Flow | * Diameter * Culvert |

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# Lesson 1: Slope

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| Time Needed: | 1 hour |
| Objectives: | * Students will learn about the concept of slope through a series of running activities and apply their observations to real world scenarios involving car performance on road surfaces. * Students will understand the correlation between slope and a vehicle’s speed and required effort. * Students will recognize the challenge of hilly landscapes in roadway design. |
| Setup: | **Slope Running Paths:** prior to activity, determine 3 different locations where students will be able to conduct timed running experiments, including one flat surface and two sloped surfaces (one more extreme than the other). Mark off a start and finish line at all 3 locations. It is important that every route be the same distance.  **Sandboxes:** Use the provided map to set up both sand tables, including the indicated steep hill, river, structures, and trees. |

**Warm-up Activity (45 min)**

* Explain to students that we’re going to begin our road building activity with a bit of an experiment. Students will need to be collecting data and making observations about their team’s running performance under different conditions.
* **Assign Groups:** Assign students to groups of three and have them decide on roles: runner, timer, and scribe.
* **Hand Out Materials:** each group should receive 1 clipboard, 1 data collection worksheet, and 1 timer. Review the data students will be collecting and ensure they understand what they will be recording.
* **Timed Runs:** Bring students to each of the 3 running paths and have each group time their runner. Depending on the width of the route, runners may go all at once or take turns. Provide time after each run for groups to collaborate to document run time and make observations.
* **Compile Data:** Teacher collects student data sheets and insert data into the table provided on powerpoint. Note: it’s possible for any number of outside influences to taint the data (overly competitive students, exhaustion, slippery surface, etc.) It is recommended to skip this step if data does not clearly support the key takeaway that the an increase in slope leads to an increase in time and effort from the runner.

**Instruction (15 min)**

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| **Powerpoint Slide** | **Discussion Questions** |
| Activity Reflection Questions | On which running surface did your team get the fastest running time? And the slowest?  Which running surface took the most amount of effort to run up? Why do you think that is? |
| Crazy Running Slopes | Raise your hand if you think you could run up these surfaces. At what point do you think it becomes impossible for you to run up the surface? |
| Running Data Graph | What can conclusions can we make based on our experience running on these different surfaces? |
| Slope | Use provided images to explain the concept of slope to students. |

**Introduce Road Building Challenge (15 min)**

Bring the students to the challenge sandboxes and present their road challenge to them, facilitating a discussion using questions such as the following:

* *You will be working with teams to design and build a road that begins here and ends here. Your final road design will be tested using this mini RC car.*
* *What do you think is the most direct way to get from point A to point B?*
* *What do you notice about the landscape? What challenges do you see?*
* *Do you think it is possible for the RC car to go straight over the hill? Why or why not?*
* *What are some possible solutions to this mountain problem?*

Guide students to the conclusion that they will have to design a road that goes around the mountain.

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# Lesson 2: Horizontal Curve

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| Time Needed: | 1 hour |
| Objectives: | * Students will learn about the concept of horizontal curve through a running activity and apply their observations to real world scenarios involving car performance navigating bends/curves in the road. * Students will understand the correlation between horizontal curve and a vehicle’s speed/control around road bends. * Students will recognize the challenges of curves and turns in roadway design. |
| Setup: | **Running Paths:** prior to activity, establish two running routes of equal distance, both on flat surfaces. Path A should take a sharp turn (perhaps around a post or other object anchoring a corner) while Path B takes a gradual curve. See example:  **Sandbox Setup:** Sandboxes should remain set up from previous activity. Make sure that the setup remains consistent with the included map. |

**Warm-up Activity (45 min)**

* Explain to students that we have a few more experiments to run and data to collect.
* **Groups:** Students should work in groups of three with designated roles: runner, timer, and scribe.
* **Hand Out Materials:** each group should receive 1 clipboard, 1 Horizontal Curve data collection worksheet, and 1 timer. Review the data students will be collecting and ensure they understand what they will be recording.
* **Timed Runs:** Bring students to the two running paths and have each group time their runner. Teams will likely need to take turns running these routes or going in small heats. Provide time after each run for groups to collaborate to document run time and make observations. Examples students might make include:
  + *Our runner had to stop at the corner and turn*
  + *Our runner ran fast on the straight parts, but slow on the turn*
  + *Our runner ran too fast and went far past the corner before turning*
* **Compile Data:** Teacher collects student horizontal curve data sheets from students and insert data into the table provided on powerpoint. Note: it’s possible for any number of outside influences to taint the data (overly competitive students, exhaustion, slippery surface, etc.) It is recommended to skip this step if data does not clearly support the key takeaway that the short horizontal curve leads to an lack of control around corners, or the need to slow down drastically to go around the curve.

**Instruction (15 min)**

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| **Powerpoint Slide** | **Discussion Questions** |
| Activity Reflection Questions | On which path was your team fastest?  Why do you think that was?  What observations did you make about each path?  Which path did you prefer? Why? |
| Crazy Running Curves | What do you think of these roads and paths? Would you want to run around those? What do you think would happen if a car was going on these paths? What would happen if the road was wet or icy? |
| Running Data Graph | What conclusions can we make based on our experience running these two paths? |
| Horizontal curve | Use provided images to explain the concept of horizontal slope to students. |
| Crazy curves | Display images of crazy looking roads |

**Connections: Road Building Challenge (15 min)**

Bring the students to the challenge sandboxes and review where the previous session left off: the group concluded that our roads should go around the mountain due to slope challenges.

* *What challenges does horizontal curve create for us?*
* *If our path goes around the mountain, how does that impact the road’s horizontal curve?*
* *What risks does that create for vehicles?*
* *How could we create a solution that doesn’t result in a steep road or a tight curve?*

Guide students in the direction of concluding that they can cut away portions of the mountain so they can make a curved road rather than making it turn tightly.

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# Lesson 3: Road Cut and Fill

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| Time Needed: | ½ hour |
| Objectives: | * Students will learn about the concept of cutting a road through a hill and filling a hole for road building through visual examples and class discussion * Students will understand the correlation between flat roads and the time and cost to construct a road * Students will recognize the challenge of constructing flat roads. |
| Setup: | **Sandbox Setup:** Sandboxes should remain set up from previous activity. Make sure that the setup remains consistent with the included map. |

**Warm-up Activity (15 min)**

Dig in dirt?

**Instruction (15 min)**

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| **Powerpoint Slide** | **Discussion Questions** |
| Images of Road Cuts | How many dump trucks would it take to remove that dirt? How many football stadiums is that? |
| Images of Road Fill | How many dump trucks would it take to remove that dirt? How many football stadiums is that? |

**Connections: Road Building Challenge (15 min)**

Bring the students to the challenge sandboxes and review where the previous session left off: the group concluded that they could away portions of the mountain so that the turn is not too tight and the car can go faster.

* *What challenges does cutting through the mountain present?*
* *How far down into the mountain should you cut?*
* *What should the sides of the road cut look like?*
* *What effect does cutting deep into the mountain have on the amount of material you have left?*
* *How will the road get over the ravine?*
* *If you want to fill the ravine, what materials will you use?*

Guide students in the direction of concluding that a deeper cut will take more time and create more fill. If fill and cut are balanced, there is no need to bring in or remove material.

# Lesson 4: Culverts

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| Time Needed: | ½ hour |
| Objectives: | * Students will learn about water flow and the role of culverts in allowing flow through filled in portions of roads. * Students will understand the correlation between water flow and the diameter of culverts. * Students will understand why culverts are used in roadway design, and how they are properly used to handle a river’s flow and support road weight. |
| Setup: | **Water Flow Jugs:** Set up two water flow buckets outside or in another area where water mess will not be a concern. Have 2 full buckets of water available for pouring, as well as 2 empty buckets for collecting water.  **Sandboxes:** Use the provided map to set up both sand tables, including the indicated steep hill, river, structures, and trees. |

**Instruction (15 min)**

Bring students to the water flow demonstration station. Begin with bucket A (larger diameter hole), positioning an empty water collection bucket beneath it. Ask students:

* *What do you think will happen when I pour water into this bucket?*
* *Do you think it will overflow? Why or why not?*

Pour water at a steady rate, keeping a steady flow through the large hole in bucket A. Display bucket B to students (smaller diameter hole), and ask:

* *What do you think will happen when I pour water in to this bucket?*
* *Do you think it will overflow? Why or why not?*

Pour water at the same rate as was used to pour into Bucket B, which should result in water building up and eventually overflowing over the sides of bucket B. Ask students:

* *Why did one bucket overflow and the other didn’t?*
* *What could we do to bucket B to make sure it doesn’t overflow? (possible responses: pour slower, make hole bigger, add more holes)*

Guide students to the conclusion that, depending on the water flow rate, a hole that allows water through must be the right diameter to keep up with the flow. This can be done by increasing the diameter of the hole and/or increasing the number of holes.

**Culvert construction tip:** Use straws to demonstrate to students that culverts, on their own, can withstand very little direct pressure without collapsing. Demonstrate burying a straw under packed sand and applying the same amount of pressure. Explain to the students that the sand allows the pressure to be distributed, preventing culvert collapse. For this reason, during the road building challenge, all culverts must be covered completely by sand.

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# Lesson 5: Road Building Activity

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| Time Needed: | 3 hours |
| Objectives: | * Students will work in small groups to design and build a road surface through hilly terrain with waterways. * Students will apply newly acquired skills with slope, horizontal curve, cut and fill, and flow, to create an efficient road design. |
| Setup: | * Set the two sandboxes up with the correct configuration used in previous activities. Bring students to the sandboxes. |

**Instruction: 20 minutes**

Provide students with Road Building Challenge outline. Review challenge parameters and allow time for question and answer.

Provide the students with 24” wide construction paper that is cut to 48” long. Instruct them to draw in important features including ravine, tunnel entrances, trees and building.

Show culvert options.

**Work Time:**

Students should draw their roadway design directly onto the 24” by 48” piece of paper, which is then a to-scale drawing of their final road design. Once they have designed the route of their roadway, students cut paper roadway out of the paper to act as both a template and a road surface.

Allow students time to practice setting up their challenge, from cut and fill to laying the road surface. It is not recommended to allow testing of culvert flow until the final competition.

**Competition:**

Each group will construct their road, including culvert, cut/fill, and road surface. Use the following 3 assessments to determine an overall and category winners:

* **Construction time:** Time the team from start to finish of construction (including cut and fill, culvert installation, road surface, etc).
* **Drive Time:** Once complete, the teacher will drive the car on the road to determine how fast it is. Use the same driver for each group to reduce the number of variables.
* **Culvert Test:** Pour water through the ravine at a steady rate. Determine if the road is overtopped.

Scoring: Rank construction time from fastest to longest, and assign points to each team (10 points for 1st place, 9 for 2nd, etc.) Follow the same procedure for drive time. Teams whose road surface was dampened by water due to water flowing over the road are disqualified. The team with the highest combined scores wins.