Designing Safer Roadways

Grade Level:	**Total Time Required:**
4	four 30-minute periods

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Lesson Objectives:

In this lesson, students will be able to:

1. Describe the basic forces that act on a moving system and influence its motion
2. Design a structure to change the forces acting on a moving transportation system

Indiana Standards:

4.PS.1 Investigate transportation systems and devices that operate on or in land, water, air and space and recognize the forces (lift, drag, friction, thrust and gravity) that affect their motion.

4.PS.2 Investigate the relationship of the speed of an object to the energy of that object.

Next Generation Science Standards

Discipline Core Ideas

3-5.ETS1-1 Identify a simple problem with the design of an object that reflects a need or a want. Include criteria for success and constraints on materials, time, or cost.

Science/Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence

Crosscutting Concepts
2. Cause and effect: Mechanism and explanation.

Concepts and Vocabulary

Term	***Defined by a scientist or engineer***	***Defined by a student***
Force	Interaction between physical bodies that create a pushing or pulling on the bodies.	A push or a pull
Work	The product of force and motion.	When a force moves an object
Gravity	The force exerted by celestial bodies that acts to pull objects to their centers.	The force that keeps us on earth; prevents us from flying into space
Friction	An force opposing relative motion between objects.	A force that holds back the movement of an object (ex, skating on an ice rink vs. skating on carpet)
Transportation System	A system that can change the location of an object in space or time.	A system to take people or objects to other places (ex, car, bus, bike)
Motion	Any movement or change in position or time of an object.	The act of moving or changing places
Direction	The relative position of one point with respect to another point, without considering the distance between the points.	The way in which something travels or faces (ex, right vs. left, north vs. south)
Speed	The magnitude of its velocity (the rate of change of its position), typically calculated as the distance travelled divided by the time required (average velocity).	How fast or slow an object moves during a unit of time (ex, 25 miles per hour)
Distance	A numerical description of how far apart objects are.	Measure of space between things or places (ex, meter, inch)
Wheel	Circular component that is intended to rotate on an axial bearing.	A round object that turns in circles and allows for things to move
Weight	The product of the mass of an object and the magnitude of the local gravitational acceleration.	How heavy or light an object is
Mass	Composed of the number and type of atoms or molecules that an object contains.	The amount of matter something contains
Texture	The local deviations of a surface from a perfectly flat plane.	The feel or look of a surface

Equipment, Materials, and Tools

Materials		
3-ring binder (3 inch)	Bubble wrap	Yellow and red construction paper
Marbles, arranged in a shallow tray	Paper towel	Index cards
Sand, arranged in a shallow tray	Textured fabric (ex, terry cloth towel)	Regular paper
Tape		

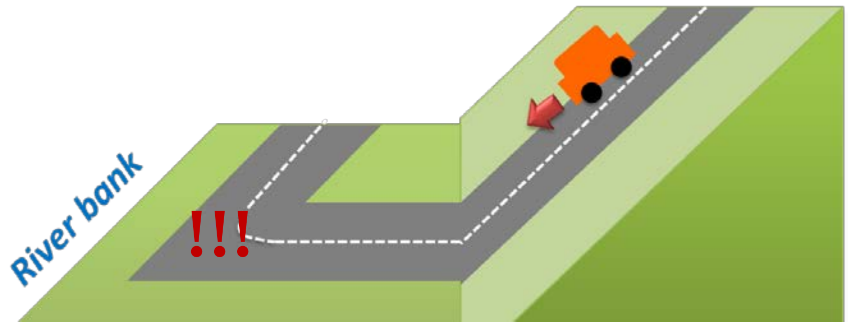
Tools		
Scissors	Rulers	Lab notebook

Special materials (purchase ahead of time):

- Large soup can and small soup can: to be used as model vehicles (purchase at local grocery store)
- Three different sizes of model vehicles: small die cast cars, medium, and large size (purchase at a dollar store or similar)

Synopsis of Engineering Design Activity

Synopsis of the Design Activity:

Problem:	A road going down a hill makes a sharp right turn near a riverbank at the base of the hill. This road is a high-risk site for car accidents. 
Goal:	Improve the safety of the road system by designing a way to keep vehicles from crashing into the river if the drivers do not make the right turn successfully.
Who is the client:	The State of Indiana's Transportation Department
End-User:	People driving their vehicles on this road.
What is the design:	Designing a way to keep vehicles from crashing into the river if the drivers do not make the right turn successfully.
Criteria:	• Design a way to safely prevent vehicles from going into the river. • The design should include a zone to slow the vehicles and a zone to stop the vehicles. • The design should work for a range of vehicles (small car and large school bus).
Constraints:	• Classroom materials will be provided for construction purposes. • Design space: the distance between the road and river bank is the size of two sheets of construction paper, one (yellow) for the "slow down" zone and one (red) for the "stop" zone. • In the classroom, the hill will be modeled with a 3'' binder and the small and large vehicles will be modeled with small and large soup cans. • Allotted time for construction in the classroom.

Lesson Plan #1: Introduction and Background

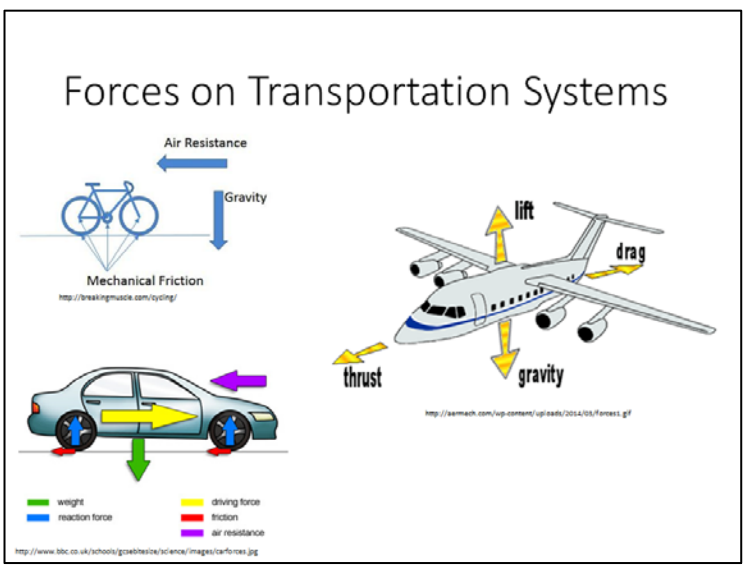
Time: one 30-minute session

Objective: Introduce the students to the concepts of work and force, the different types of transportation systems that are used in different environments, and how the surface of a road directly influences the motion of a land vehicle (which is directly related to the Inquiry and Design Activity).

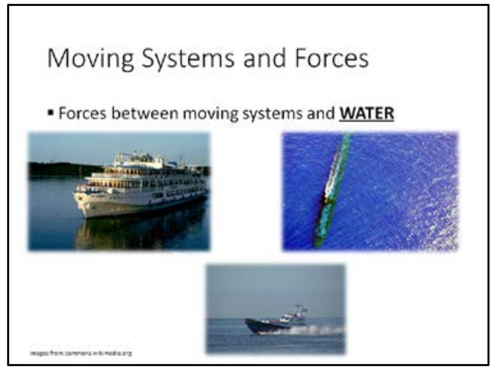
Teacher Notes

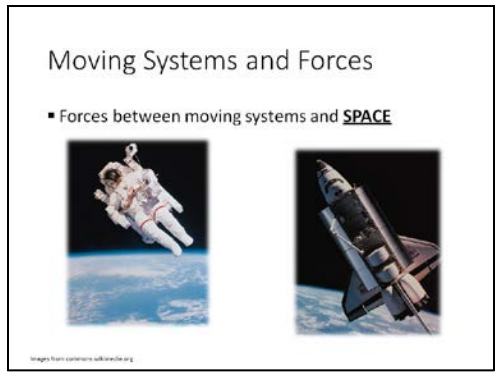
- Introduction structured in three parts
  - ✓ General introduction to transportation systems
    - Land, water, air, space
      - Manmade and examples from nature
  - ✓ Expansion of land-based examples
    - Examples of different vehicles designed for different applications and land surfaces
      - Emphasizes how the vehicle interacts with different surfaces to produce forces to move and turn the vehicles
  - ✓ Transition to inquiry based background
    - More specific examples of surface profiles and forces on those surfaces

- Forces acts on transportation system to influence motion and change direction. For a vehicle on a road, the main forces are the driving force (from the engine turning the axel and wheels), the friction force from the road on the tires, the weight of the car and the drag/air resistance.

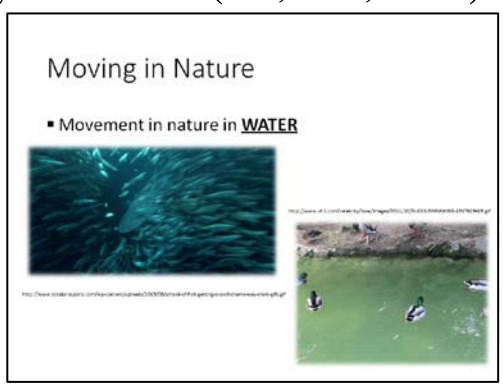


- What are the common environments where we see vehicles in motion?



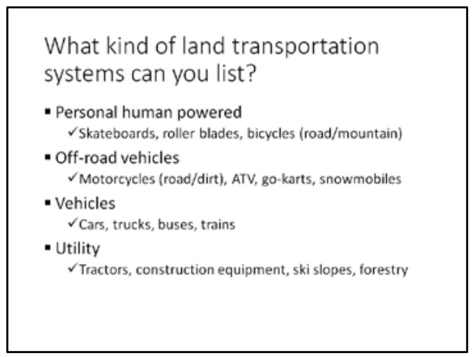


- What are some examples of transportation systems in nature (land, water, and air)?

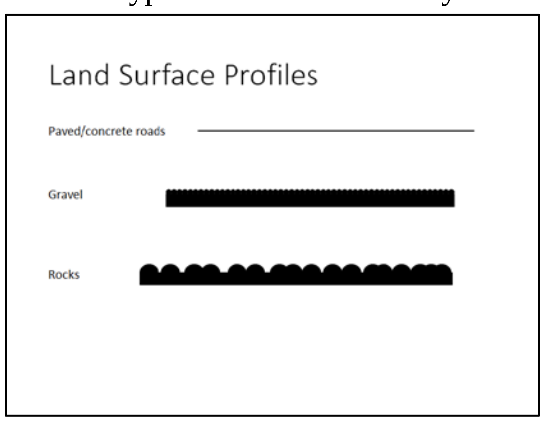


- Are there some transportation systems that work on land, water and air?

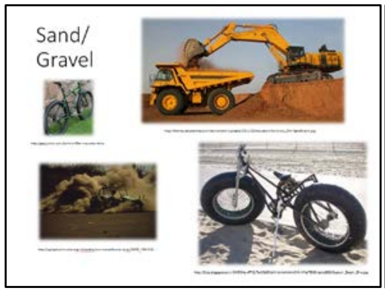
- Thinking about land vehicles, what are some different types of surfaces that these vehicles travel over?

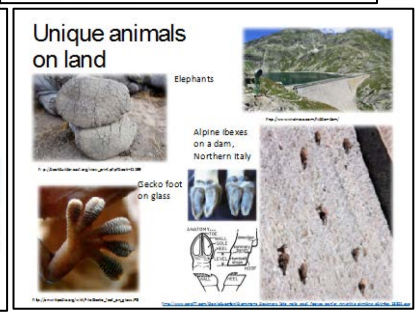


- How can we sketch the different types of land surfaces? By cross-sections (side-views).



- What kind of transportation system would you pick for these different surfaces? Why? What does the cross-section (side-view) of each surface look like?





- Now that we know how the surface of road directly affects the motion of a land vehicle, why might we **intentionally design a road surface** to produce forces on a vehicle?

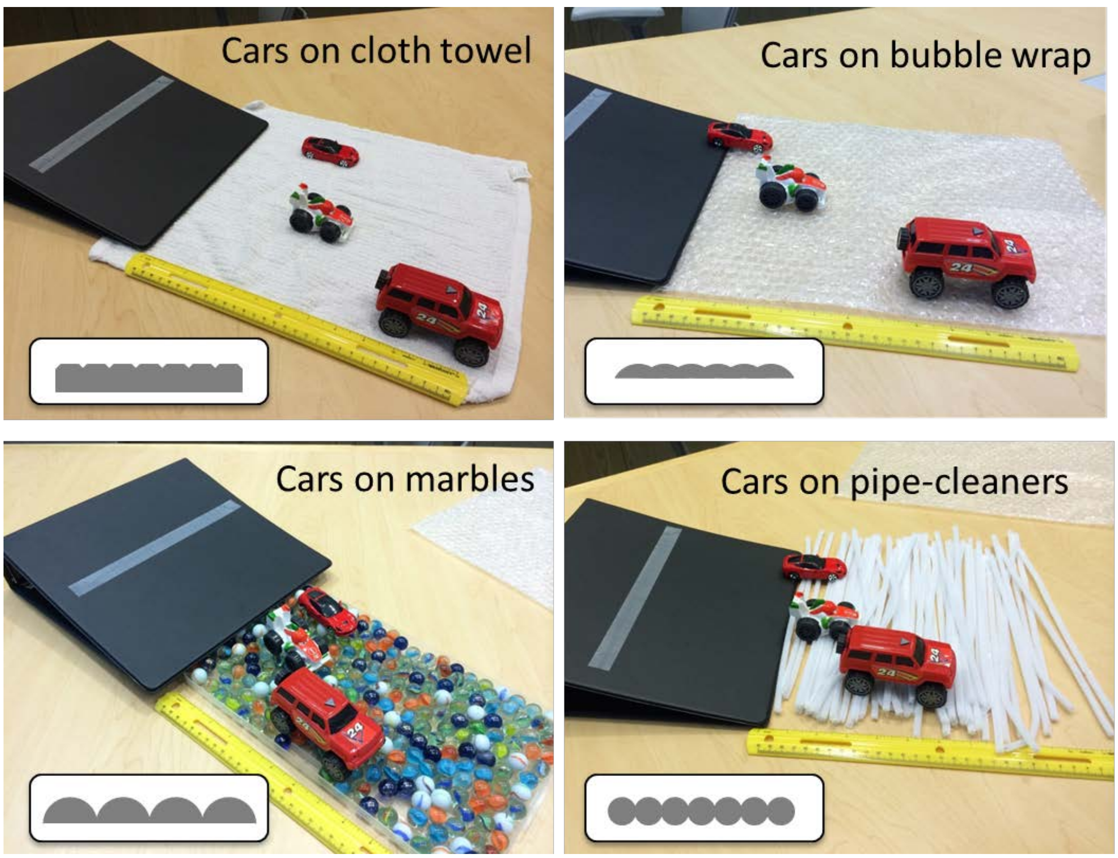
Introduction to Inquiry

- Why might we intentionally design a surface to produce forces on a vehicle?
  - ✓Can you think of some examples?
  - ✓Hint: when we don't want cars to hit each other or go someplace that is dangerous.
- Two common ways:
  - ✓Designing a surface
  - ✓Design a barrier

Lesson Plan #2: Inquiry Activity
Motion on Different Surfaces

Time: one 30-minute session

Objective and Introduction:
Students will visit a series of stations to observe and record how various surfaces affect distance traveled and directional changes of a moving car and a truck. At each station, a 3” binder will simulate a downhill grade and the flat surface at the bottom will vary at each station. Students will place the car or truck at the top of the ramp (binder) and let go. Then, they will observe how the vehicle’s motion is affected by the surface. Students will measure the distance traveled from the end of the binder to the front of the vehicle and record on the chart. Students will also note whether the surface caused the vehicle to change directions.



Images of three different sized cars traveling on four different surfaces. The distance traveled in each case is directly affected by the surface. The insets show the approximate cross-section (side-view) of the surfaces, illustrating the different texture (smooth to bumpy) of the different surfaces.

Instructor Notes: A variety of different materials could be used for this activity, including felt, cotton balls, sand paper, aluminum foil a tray of sand, a piece of flat smooth plastic, a carpet square, a layer of adhesive contact paper. Additionally, a single car can be used with and without a small weight taped to it, in order to illustrate the effect of car mass on the distance travelled.

Student Directions: Place the car at the 'starting line' on the hill and let go without pushing the car. Watch the car move down the ramp and onto the flat surface. When the car stops, measure the distance from the end of the ramp to the front of the car. Record the distance on the chart (see next page). Did the car change directions after it hit the flat surface? Circle Yes or No on the chart. Repeat with the truck and record your measurements and observations. Did the car behave the same or differently from the truck? Why?

Data table for use by the students to record the measured distances for each car (e.g., small car, large truck) moving across each surface (e.g., carpet, foam, marbles, sand, towel).

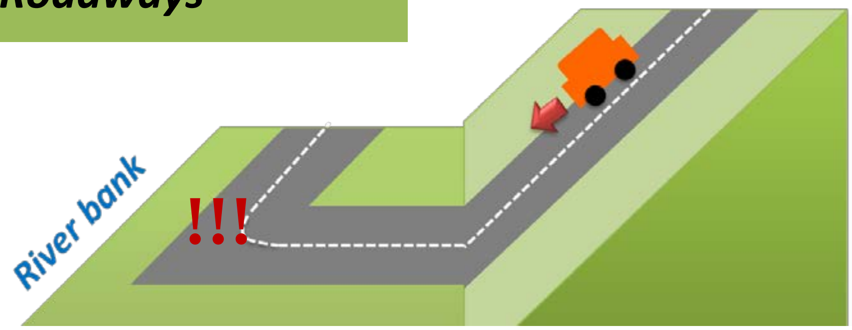
Surface & Vehicle	Distance (cm)	Direction Change
Carpet – Car		Y N
Carpet - Truck		Y N
Foam – Car		Y N
Foam – Truck		Y N
Marbles – Car		Y N
Marbles – Truck		Y N
Sand – Car		Y N
Sand – Truck		Y N
Table – Car		Y N
Table – Truck		Y N
Towel – Car		Y N
Towel - Truck		Y N

Post-activity discussion questions:

1. What did you notice as you were performing the inquiry activity?
2. Which materials allowed the car to go the greatest distance? What about the truck? Why do you think this happened?
3. Which materials did not allow the vehicles to travel very far? Why do you think this happened?
4. Which materials changed the direction of motion of the car? What about the truck? Why do you think this happened?
5. Which materials did not change the direction of the vehicles? Why do you think this happened?
6. What are some other materials that we could have used? What do you think would have happened to the distance traveled and direction change if we used these materials?

Design Activity

Designing Safer Roadways



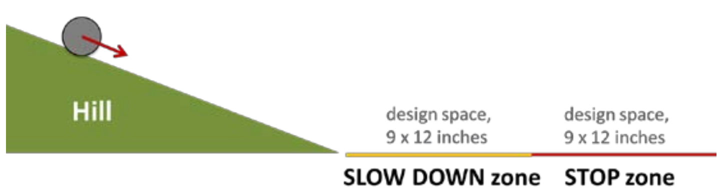
The State of Indiana's Department of Transportation recently had a new road built by "Wile E. Coyote Construction, Inc." This road travels down a steep hill and then turns sharply to the right when it comes to Wabash river. Unfortunately, drivers have nearly crashed their vehicles at the base of this hill when trying to make the right turn while going too quickly!

To fix this dangerous problem, the Department of Transportation has hired you to design a way to safely prevent vehicles from crashing into the river if they fail to make the turn properly. If your design works well, the Department of Transportation will hire you to install your design on other dangerous roads in the area as well.

Your design should keep the people in the vehicle and their cargo safe (no hurt passengers or squished cargo from stopping too quickly!). To do this, your design should include a zone where the vehicle will slow down (but not stop) and a zone where the vehicle will come to a complete stop. Your design should work for small cars and large school buses.

Constraints

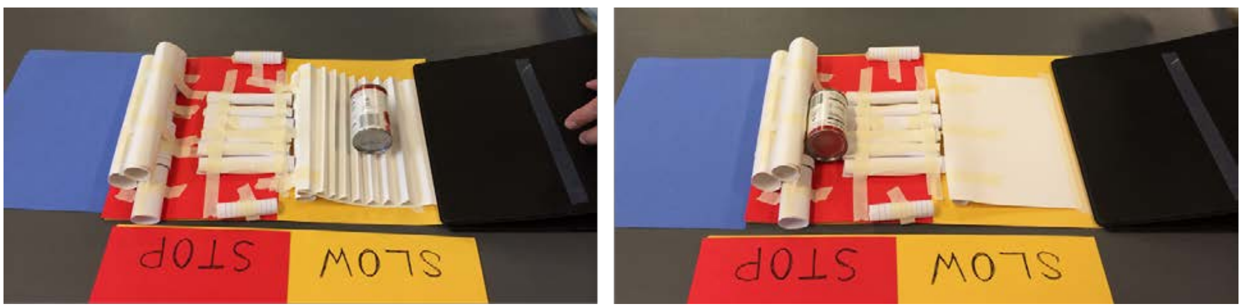
- Classroom materials will be provided for construction purposes
- Design space: the distance between the road and river bank is the size of two sheets of construction paper, a yellow sheet for the "slow down" zone and a red sheet for the "stop" zone (see below figure).
- The hill will be modeled with a 3'' binder and the small car and large school bus will be modeled with small and large soup cans.



Instructor Notes

The following images show the testing set-up with the 3” binder, the two design spaces for the “slow down” and “stop” zones, and the large and small “vehicles”. Only one testing set-up is needed per classroom, as each student group can carry their designs to the set-up for testing. It is a good idea to label the yellow and red zones.

This image shows the 3” binder with “starting line” for the small soup can, the yellow “slow down” zone and the red “stop” zone (without any road safety design yet). The blue paper represents the river. The small and large soup cans are used to represent a small car and a large school bus.



These images show a student’s design for the slow and stop zone during testing with the small “car”. For the design in the left image, the car stopped in the “slow down” zone and thus this design did not meet the specified criteria (not a good design). For the design shown in the right image, the car successfully stopped in the “stop” zone, which meets the criteria and is thus a good design.

To help the student’s sketch their individual and group designs, one of the following worksheets can be used. In the first one, the students can sketch the side-view of their design, illustrating the different surface textures and features that they want to create. In the second one (more advanced), the students can sketch the side-view and the top-view, which are typically both included in real-world engineering design plans.

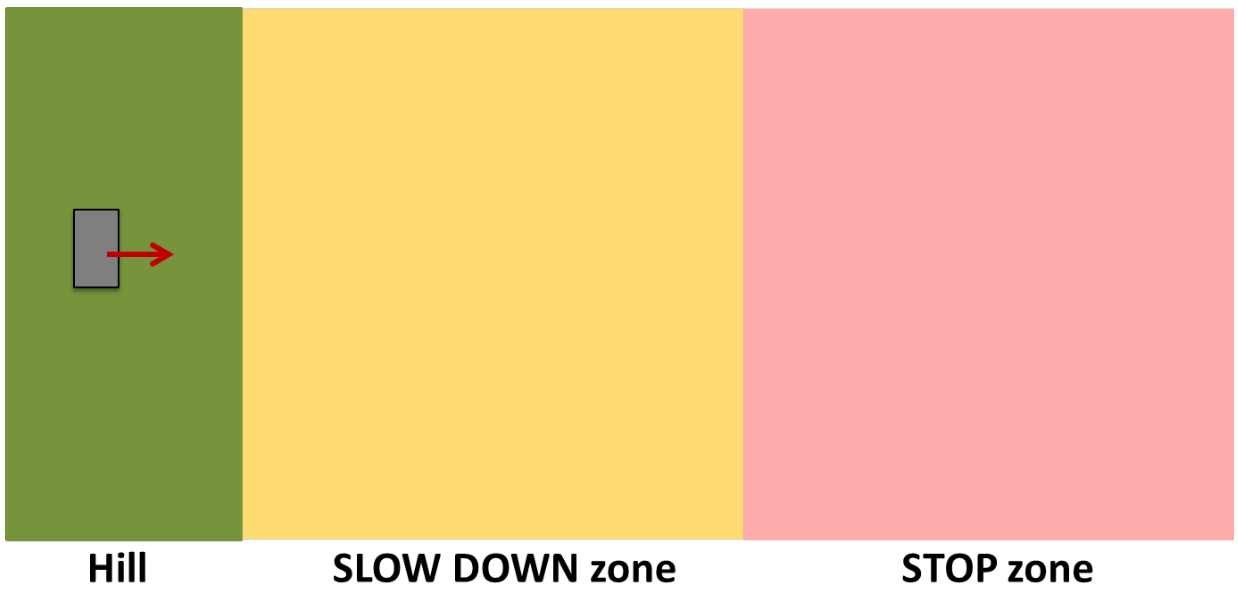
Movies of example designs being tested are available on the SLED hub. In the “Successful Design” movie, a design was created that works for both the small and large vehicles: both were slowed down in the “slow down” zone and both came to a complete stop in the “stop” zone. In the “Unsuccessful Design” movie, a design was crated that worked for the small vehicle but not the large vehicle: the small vehicle was slowed in the “slow down” zone and came to a full stop in the “stop” zone, however the large vehicle came to an abrupt stop in the “slow down” zone which does not meet the specified criteria of the design brief (the large vehicle was so heavy that it caused the paper ramp in the “slow down” zone to buckle).

WORKSHEET: Side-view sketch of you road safety design

Instructions: Sketch your design for the "slow down" zone and "stop" zone as you would see it from looking at the side.

WORKSHEET: Side-view and top-view sketch of you road safety design

Instructions: Sketch your design for the "slow down" zone and "stop" zone as you would see them from looking at the side and from looking at the top.



Lesson Plan #3: Design Activity
Designing Safer Roadways

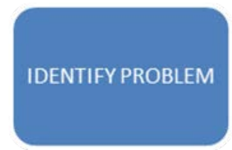
Time: two 30-minute sessions

Objective: for the students to discover how different surfaces and objects affect the speed and direction of a moving system

Procedure:

1. (5 minutes) Distribute, read aloud, and discuss the roadway safety design activity brief.
   Ask the students:

   What is the problem?
   Who is the client?
   Who is the user?
   What are the criteria?
   What are the constraints?
   What materials and tools have been provided?

   Have students respond to the above questions in their notebooks. Discuss responses with class and write answers on the board.

2. (5 minutes) Review with the students:
   a. Show students the materials that are available for the roadway safety design activity.
      i. Describe how the 3'' binder represents the hill and the large and small soup cans represent the large and small vehicles.
      ii. Explain to the students that the design space for the "slow down" zone is represented by the yellow construction paper and the design space for the "stop" zone is represented by the red construction paper.
      iii. Show students the materials that are available for construction of their design, which must be built in the allotted design space of the two sheets of construction paper.
   b. Briefly summarize the discoveries learned from the <u>inquiry activity</u> and remind students to use these discoveries and observations to help them solve the problem.

3. (10 minutes) Have students sketch their <u>individual</u> roadway safety design to solve the problem. Remind students that sketches should be large, neatly drawn, and clearly labeled showing dimensions and materials. It may be helpful to have the students make a separate design/sketch for the "slow down" zone and the "stop" zone and use one of the provided worksheets.

4. (10 minutes) Students should then meet with their team and share plans, explaining how they expect their design to solve the problem. Each team should decide on a 'final' <u>group</u> roadway safety design, which can be a combination of ideas or a specific design from an individual within the group. Have each team member sketch the final design in their lab notebook. Each of the students' sketches should be detailed to allow anyone else to construct the design by looking at the drawing.

5. (20 minutes) Student teams will then gather materials and construct their roadway safety designs with the materials provided and space allotted for the "slow down" and "stop" zones.
   OPTION: After 10 minutes, allow the students to test their design with the small car (small soup can) to see how the design performs. From the results of the test, they should be able to predict how the large car (large soup can) would perform – but do not allow them to test their design with the large soup can. Allow the students to slightly modify their design if they choose based on their test with the small soup can.
   OPTION: The students could also measure the distance travelled in the "slow down" zone and "stop" zone and record the results in their lab notebook using the following data table:

CREATE AND TEST

Description of Design	Size of Vehicle (small/large)	Design Version (#1, #2…)	Distance travelled in "slow down" zone (cm)	Distance travelled in "stop" zone (cm)	Did vehicle come to a complete stop in the "stop" zone?
					Yes No
					Yes No
					Yes No
					Yes No
					Yes No

6. (5 minutes) When construction is complete, each team will present their roadway safety design to the whole class. Then the team will test their design with the small and large vehicles. The results of the tests should be recorded in their lab notebook.

COMMUNICATE RESULTS

GATHER FEEDBACK

7. (5 minutes) After all groups have finished testing their roadway safety designs, each student will answer the following questions in their notebook:
   - *How effective (good) was your design? How do you know?*
   - *What would you change in your design? Why?*

8. If time permits, encourage students to redesign based on test results. If time does not permit, instruct students to sketch a new design in notebook based on change mentioned above. Remind students to note any changes if the design was modified from the original sketch.

IMPROVE AND RETEST

Assessment

The following are possible sources of formative and summative assessment:

From Lesson Plan #3, use a simple rubric to assess student notebooks for the following Design Process Standards:

- Identify a need or problem to be solved.
- Document the design throughout the entire design process. (individual, group, redesign sketches)
- Create the solution through a prototype.
- Evaluate and test the design.
- Communicate how to improve the solution.

Individual participation within group

- Note level of engagement
- Ability to work well with other team members during design process
- Contribution during team presentation

Examples of potential self-assessments and grading rubrics are provided below and on the following page:

Did I include all of these things?
How did I do?

Problem	☺	☹
Goal	☺	☹
Client	☺	☹
User	☺	☹
Criteria	☺	☹
Constraints	☺	☹
Individual Design	☺	☹
Group Design	☺	☹
Sketch	☺	☹
Reflection	☺	☹

	Includes a few details. 1	Includes some details. 2	Includes many details. 3
Problem			
Goal			
Client			
User			
Criteria			
Constraints			
Individual Design			
Group Design			
Sketch			
Reflection			

Name ____________________Design Task __________________Teacher ______________ Date________

	5	4	3	2	1
Identified each step of the design process (problem, goal, client, user, criteria, constraints)	Correctly identified 6 steps of the design process	Correctly identified 5 steps of the design process	Correctly identified 4 steps of the design process	Correctly identified 3 steps of the design process	Correctly identified 1 or 2 steps of the design process
Individual Design (sketch includes measurements, labels, different viewpoints, materials)	Individual design fully explained	Individual design includes 4 or 5 of the requirements	Individual design includes 2 or 3 of the requirements	Individual design includes only 1 of the requirements	Individual design not included
Group Design (sketch includes measurements, labels, different viewpoints, materials)	Group design fully explained	Group design includes 4 or 5 of the requirements	Group design includes 2 or 3 of the requirements	Group design includes only 1 of the requirements	Group design not included
Applied Knowledge	Applied what was learned to a successful design	Considered many ideas that were learned to make a successful design	Considered some ideas that were learned to make a successful design	Considered few ideas that were learned to make a successful design	Did not consider ideas that were learned to make a success design
Reflection What I did, What worked well, What didn't work well, What I would change, What I learned	Reflection answered all questions	Reflection answered 4 of the questions	Reflection answered 3 of the questions	Reflection answered 2 of the questions	Reflection answered only 1 of the questions

	3	2	1
Participation	I participated in all parts of the design process with my group	I participated in most of the design process with my group	I did not help my group much with the design process
Cooperation	I respectfully cooperated with all members of my group	I was cooperative part of the time	I did not cooperate well with my group members
Presentation	My presentation was clear and showed what I know about the design process	My presentation was somewhat clear or did not fully explain the design process	My presentation was not clear or did not show an understanding of the design process

Lesson Extensions and Resources

Activities:

Could tie the lesson plan with the Indianapolis 500 race

Video clips or movies:

See the power-point slides available on SLED hub for all the video links.

Books:

- *Making Tracks*, by Steve Parker (J 629.049 Par), Describes how different kinds of vehicles and their wheels have developed throughout history, from chariots to trucks to the Bullet Train.
- *On A Bike*, By Nikki Bundey (J 796.6 Bun), Introduces basic physics concepts such as force, resistance, and friction while describing bicycling skills, techniques, events, and safety issues.
- *On The Road*, by Steve Parker (J 629.2 Par), Covers a wide selection of machines used on the road, from motorcycles to snow plows, outlining how they work and what they are used for.
- *The Berenstain Bears Ride the Thunderbolt*. Jan and Stan Berenstain. (1998). Readers will love spending a day at the Bear Country Amusement Park, where they'll experience the stomach-dropping, heart-stopping thrills of a giant roller coaster right along with the Berenstain Bears.
- *The Magic School Bus Plays Ball: A Book about Forces.* Joanna Cole. Scholastic (1998). On a field trip inside a physics book, Ms. Frizzle's class plays baseball in a world without friction and learns all about friction and forces.
- *Sheep in a Jeep.* Nancy E. Shaw. Houghton Mifflin Company (1997). Five foolish sheep cram into one jeep, their high spirits and occasional lack of foresight combine to make a outrageous road trip. This cute rhyming book is ideal for simplifying the topic of force and motion.