Theme 2: Around Town

Introduction:

This theme examines the fictional region of Adela Valley. Students will select the route of a new highway that passes through the region, the signage that gives important information to drivers, and model the navigational devices that predict travel times. Activities 1 and 2 should be done in-order. Activity 4 can, if desired, last several class sessions. Activity 5 could last two sessions.

Objectives:

- Design a highway route that minimizes impact on culture and the environment.
- Use geometry to calculate the monetary cost of highway construction.
- Compare and evaluate competing construction plans.
- Model the calculations performed by navigational devices when they predict travel times.
- Design and implement a test to determine the visibility of highway signs.
- Determine the roles of speed and banking on a car's ability to safely negotiate a curve.

Standards:

- CCSS.Math.Content.7.G.1 Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing.

- CCSS.Math.Content.7.RP.A.1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. http://www.corestandards.org/Math/Content/7/RP/#CCSS.Math.Content.7.RP.A.
- CCSS.Math.Content.7.RP.A.2b Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships. http://www.corestandards.org/Math/Content/7/RP/A/2/b/

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. https://www.nextgenscience.org/pe/ms-ets1-2-engineering-design

- MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. https://www.nextgenscience.org/pe/ms-ess3-3-earth-and-human-activity

Activity 1: Adela Valley Highway

Objective:

Design a highway route that minimizes impact on culture and the environment.

Background Information:

If you ask a longtime resident of your neighborhood what the town was like 30 or 40 years ago, they will tell you that there were a lot of empty spaces or fields. Ask them if they are happy with the numerous homes, businesses, roads, and industries that now exist. They may say that they lost part of their community. At the same time, they gained jobs, property value, and infrastructure improvements.

Whether to build more roads through a town is not an easy decision. There has to be a clear implementation plan, local or state funding, city code agreement, an environmental assessment, and the consideration of social responsibility. A local government is responsible for the wellbeing of the population, not just the economic impact. For example, a bridge could be the best solution for a town. It could bring more revenue for the town, less traffic, more business, and higher property value. On the other hand, the bridge can cause the deforestation of some of the forest preserves, the elimination of cornfields, or the demolition of a 60-year-old church. The question is, "Is it worth it?" The answer will depend on who you ask but data should provide a guide to a good solution.

Materials for a class of 24:

- 12 Adela Valley Maps
- Student pages

Advanced Preparation:

- Print student pages.
- Print maps, 1 for every group of 2-3 students.

Implementation:

Begin by asking students:

- How long does it take you to get home from school?

- Imagine if you could take a bulldozer and demolish everything that stands in a direct line between the school and your home. How long would it take to get home on that new path?

- What problems might this plan cause? Who might object to it?

- When a local government decides to build a new road, what responsibilities do they have to the people in the community?

Have students form groups of 2-3. Distribute the student handouts and maps. Read and discuss the scenario. Answer any questions students have about the task.

Assist groups as needed and allow ample time for groups to discuss and plan a route. Encourage them to consider several options before making a decision. The plan they develop in this activity will be needed again in the following activity. Emphasize that they need to save their work in a safe place.

Debrief Questions:

- Why might some citizens of Adela Valley agree with your plan?
- Why might other citizens disagree with your plan?
- What other information would have been helpful to know when you were planning the location of the highway?

Extensions:

(1) If you wish to address the cultural impacts of building a highway through a city or town, show the following 4-minute video:
https://www.youtube.com/watch?v=odF4GSX1y3c

The concepts are advanced and narration moves quickly, so be prepared to host a discussion based on students' questions.

(2) Students may apply their knowledge of a pros and cons analysis to an actual project in Illinois closer to home. Chicago area Shared Streets Program, https://www.chicago.gov/city/en/depts/cdot/supp_info/openstreets.html. Students assume the role of a resident in a city or town that participates in this program. The goal of the activity is to decide what streets should be part of the Shared Streets Program.

Career Connections:

- Urban and Regional Planners

- Public Relations Specialists
- Surveyors

Adela Valley Highway - Student Handout

Welcome to Adela

Cosumel is a thriving city that has grown tremendously over the last 15 years. The transportation of people and goods between Cosumel and Interstate Highway 87 is essential for the region's economy. A new highway to connect them is needed. This new connecting highway will have to run through Adela Valley. The valley contains rich farmland and the small town of Adela. The new highway will bring many changes.

Problem: You are the owners of a construction company. Your job is to create a plan for a new highway to connect Cosumel to Interstate Highway 87. Consider the financial, environmental, and cultural costs in your plan.

Considerations:

- The highway will begin in Cosumel at (14, 2) and end at I-87 at either (2, 18) or (5, 20).
- You will model the highway as a series of connected line segments.
- The scale of the map is 1 cm = ¼ mile.
- The longer the highway, the more it will cost.
- There are no "empty" areas in the valley. What look like blank, white spaces on the map are actually valuable farmlands. These must be purchased from their owners.
- The highway may not cross over Blue Lake or through the Forest Preserve.
- Building through wetlands is expensive. Water must be drained. Dirt must be brought in to fill low areas. Because they are important to a healthy environment, new wetlands must be created to replace any that are lost to construction. Building through wetlands costs twice as much as building through farmlands.
- Building through the town of Adela requires many buildings to be demolished. Building through the town costs twice as much as building through farmlands.

Business owners may welcome a highway into the town. Why? What might other residents think about a highway through town?

People living in the eastern half of Adela tend to have less money than the people living in the western half. Being poor, they might be less able to sustain a protest against demolition. Is it ok to make use of that difference? A highway built through the center of town will further separate the wealthy and poorer communities. What consequences might that have?

- Building through mountains is difficult and costs twice as much as building through farmlands.

- Highway curves require careful design and construction to keep drivers safe. Every time your highway changes direction between line segments adds an additional cost.

Procedure:

1. Look at the map of Adela Valley. Discuss possible routes that the highway might follow.
2. With your partner, come to consensus on the location of the highway. Describe each segment in the Planning Table on the next page.

Planning Table

Highway Segment	Starting location	Ending location	Potential impacts on local people and the environment	Potential Advantages
1	(14,2)			

In the next activity, you will calculate the total cost of your highway. You will need to use this plan in that activity. Don't lose your paper.

Activity 2: Cost Analysis

Objective:

- Use geometry to calculate the monetary cost of highway construction.
- Compare and evaluate competing construction plans.

Background Information:

The unit cost of highway construction varies tremendously, but state departments of transportation often publish estimates. For this activity, we assume that a four-lane divided highway will cost $5 million per mile across flat farmland.

Materials for a class of 24:

- Student handouts (for each student)
- Completed student handouts from previous activity
- Rulers with centimeter markings
- Calculators (although this math can be done by hand if you prefer)

Implementation:

Help students complete the calculations on their handout. If you see students using rulers to measure segment lengths, challenge them to try finding lengths using only the starting and ending coordinates. Their map grid is in 1 cm squares. Of course, using rulers is good practice, too. They will need rulers for measuring diagonal segments unless they also know the Pythagorean Theorem.

Hold a county board meeting. Groups will take turns presenting their plans. The rest of the students will act as the county board. The role of the presenters is to share their plan and convince the board to accept the idea. The role of the board is to ask the presenting group questions about their plans. Suggested questions may include:

- What are the advantages of your plan? Disadvantages?
- Are there ways to lessen the effects of the highway construction?
- How well does the plan achieve its purpose?
- How will your plan positively affect Adela Valley?

Note: You may wish to have the entire class develop and come to consensus on a set of questions that the county board will ask each of the groups. These questions may be shared with groups as they plan their presentations.

Debrief Questions:

- Who do you think pays for new highways?
- Who benefits from new highways?
- Who should get to decide the route of a new highway?

Extension:

If students are ready, you might use this opportunity to teach them the Pythagorean Theorem: $a^2 + b^2 = c^2$. This will allow them to calculate the length of diagonal segments without using a ruler.

Career Connections:

- Accountants and Auditors
- Budget Analysts
- Cost Estimators

Cost Analysis - Student Handout

Problems:

- Estimate the cost of building a highway according to your plan
- Compare competing plans

Procedure:

Complete the table below, examining each segment of your highway route. The estimated cost of building a highway is $5 million per mile across flat farmland. Building in some areas cost $10 million per mile (mountains, wetlands, and the town of Adela).

Remember that each centimeter on your map represents ¼ mile.

Every time your highway changes direction adds an additional $1 million cost for designing and building the curve.

Highway Segment	Starting location	Ending location	length (in miles)	estimated cost
1	(14,2)			

In the space below, calculate the <u>total</u> estimated cost.

Your plan will be competing with plans developed by other construction companies. Can you think of a way to reduce the cost of your plan without making it worse in some other way? If so, feel free to revise your plan now.

Prepare a presentation to the County Board. You will be presenting your final plan as the best possible choice. Use the space below to record any ideas you have about how you will convince the County Board that your plan is the best.

Activity 3: Navigation

Objective:

Model the calculations performed by navigational devices when they predict travel times.

Background Information:

Highways of the future will be more than ribbons of concrete and asphalt. They will have an information infrastructure that includes sensors, computers, and wireless connection with the computers in every moving vehicle. In the same way that people are connected by the internet, vehicles will be connected with each other through the highway's network. This will enable drivers using navigation software to get real-time updates and suggestions. It will also increase the safety and efficiency of driverless vehicles.

In this activity, students will use mathematics to examine the types of calculations that navigational computers use to redirect drivers to the most efficient routes.

Materials for a class of 24:

- 12 City maps
- 12 Sets of cards
- 12 Pairs of scissors (If groups are cutting the cards apart)
- 12 Calculators or access to online calculator
- 24 Student handouts

Advanced Preparation:

- Print maps (single sided)
- Print cards (double sided) and cut (or let students do it)
- Print Student Handouts
- Decide which teaching option to use for this activity:
    1. Teams working at their own pace, or
    2. Whole-class competition between teams

Implementation:

Have students work in pairs. Distribute a map to each pair. Allow students time to make and share observations about the map. Explain that they will be modeling the calculations done by navigation computers to find the driving time between two intersections.

Distribute cards for students (along with scissors if they need to cut).

Projecting from your laptop, show students how to use Mapquest, Google Maps, or any other online mapping site to find the driving time between your school and some other nearby location (let the students pick it).

Point out that if an accident has blocked any of those roads, you would probably not know it until you got stuck in traffic. It can take 20 minutes for an electronic map to be updated. Engineers are experimenting with highways that have their own sensors and computers to communicate with every car on the road. The goal is to get updates faster.

Distribute the Student Handout. Work together as a class, do Scenario Card #1 as an example. Show students how to do the calculations and use the data table. Discus how the hazard cards might change which route is the best (fastest).

Option #1 (Teams working at their own pace):

Each team selects another scenario to solve. They need not go in order. After finding what they think is the best route, they can check their answer with the teacher. Next, they ask another group to apply a hazard card to their map. Then the work to find the new best route. Teams do as many scenarios as time allows. Assist groups as necessary while they proceed through their calculations.

Option #2 (Whole-class competition between teams):

The teacher selects the next scenario. Every team races to find the best route. When finished, a team writes their time on the board. The first team to get the correct answer wins. The winners explain their solution to the class. The winners now select and apply a hazard card. They will referee and judge this contest. The winners of the second race will select the next scenario card and be the next referees, etc.

Debrief Questions:

- What strategies did you find to be effective?
- How many alternate routes did you examine before selecting what you thought to be the best?
- Why do we use computers for doing tasks like this?
- What might be the advantages of a highway that instantly reports hazard conditions to every vehicle in the area?

Career Connections:

- Mathematicians and Statisticians
- Software Developers, Quality Assurance Analysts, and Testers
- Computer Programmers

Navigation - Student Handout

Problem: How do navigational devices calculate the time it will take to get from point A to point B?

Procedure:

1. Read the Scenario card.
2. Identify what looks like the quickest route from the starting point to the destination. You may draw on the map, but use pencil so you can erase.
3. Calculate the total time for that route. Show you work in the Data Table.
4. Examine some alternates to be sure you have selected the best route.
5. Have someone apply a Hazard card to your map. Repeat the process for this new condition.
6. Continue with the next Scenario card.

Things to remember:

Speed is the distance an object travels in a given amount of time.

$$speed = \frac{distance}{time}$$

Which is why units for speed include $\frac{miles}{hour}$ and $\frac{meters}{second}$

To find the time it takes to cover some distance, that equation is rearranged into:

$$time = \frac{distance}{speed}$$

That is how to calculate times in your data table.

There are 60 minutes in every hour. You can calculate a time in minutes by multiplying the number of hours by 60.

Navigation Data Table

Scenario	distance along highway (miles)	time on highway (hours) t = d/s	distance on secondary roads (miles)	time on secondary roads (hours) t = d/s	total time (hours)	total time (minutes) min = hrs x 60

Activity 4: High Visibility Signs

Objective:

Design and implement a test to evaluate the visibility and legibility of highway signs.

Background Information:

Highway signage has evolved over time in response to driving habits and advances in automotive technology and materials science. Although most informational signs have a nondescript appearance, the microscopic structure of their surfaces is complex. Many competing designs attempt to provide advantages when illuminated by headlights.

It is often true that designing a test to evaluate different items is as important and challenging as designing the items themselves. In this activity, students will design both highway signs and a reliable procedure for testing them.

Materials for a class of 24:

- 12 Rulers
- 12 pair of Scissors
- 1 flashlight (if you want to simulate headlights)
- Tape Measures (at least one, more is better)
- Blank paper
- Colored markers
- Tape and glue for assembling sign models
- Art supplies to make sign models highly visible

Advanced Preparation:

Decide how much time you want to allocate to this activity. Students will be:

- designing the tests
- making model signs
- evaluating the signs

There are many options listed on the Student Handout. Doing them all would take several class sessions. If you plan to do this lesson in a single session, select only one aspect of the sign's performance to test, and evaluate it under only one lighting condition.

- Print student Handouts
- Print and cut-out the four tiny signs below. Tape one on each wall in your classroom. Locate them in places that are visible, but not immediately obvious. “Hidden in plain sight” is the idea.

Adela
Next 3 Exits

EXIT 15
6th AVE

Adela 15
Cosumel 30

EXIT 17
2nd AVE

Implementation:

Begin by asking students if they notice anything new about the classroom. If they don’t notice, tell them that new signs have been added to the walls.

Once they have spotted all four signs, see who in the room can read them and who can’t. Try to establish that students sitting closer can do better than those sitting farther from the sign.

Then ask:

- What could be done to make those signs more noticeable?
- What could be done to make them easier to read?

Distribute the Student Handout. Read the problem statement together.

Help students form groups of two or three.

Part 1: Planning the test

Moderate a class discussion for the purpose of reaching consensus on what to test. Consider the time and resources available.

Then moderate a class discussion for the purpose of reaching consensus on how to test. Encourage students to create and record a detailed procedure.

Part 2: Creating model signs

Show students what materials are available for making signs. Various types of paper and markers should be made available. Some might wish to experiment with aluminum foil or wax paper. Craft stores sell glitter, sequins, fluorescent paints, and sheets of sparkly and reflective paper.

Part 3: Testing the model signs

Help students test their signs and decide which are the most effective. Discuss what features seem to work best. If time allows, let them modify and retest their signs.

Debrief Questions:

- Why is it important to have a detailed test procedure before you start testing?
- What design elements made the most effective signs?

Career Connections:

- Mechanical Engineers
- Health and Safety Engineers

High Visibility Signs - Student Handout

Problems:

How can highway signs be made more visible and easier to read? How can these features be tested?

The Adela Valley Highway needs six new signs. They must contain the following information:

As a class, you will develop a method to test and measure the performance of road signs. Then, in teams, you will create model signs and apply your test to see which works best.

Procedure (Part 1 - Planning the Test):

You will be testing small models of highway signs. They will measure 8 cm x 5 cm.

You will need a method to assign a numerical score for a sign's performance in one or more of these areas:

1. Visibility - How easy it is to spot a sign and recognize it as something important that you should read once you are close enough?
2. Legibility - How easy it is to read at a distance? From what distance can it be read?
3. Aesthetic Appeal - How does it look? Highway signs don't need to be pretty, but should not be too ugly. People in the area will have to see it from their window every day.

Visibility and Legibility could be tested under conditions simulating one or more of the following:

- full sunlight

- dim light
- night time with headlights

As a class, decide which of these tests you will perform.

With your partner, discuss how the class might be able to do the tests. How could you measure the results? How can you ensure the tests are fair? Record your thoughts below:

Now share your thoughts with the class. Ultimately, the entire class will need a procedure on which all can agree. Details matter. Be specific! Once the class has reached agreement, explain the procedure below:

Procedure (Part 2 - Creating Model Signs):

Using paper, markers, and any other material available, make one or more model signs. They must measure 8 cm x 5 cm. The information on the sign must be as given in the examples, but may be formatted differently. Consider the following options:

- All capital letters, or not?
- Abbreviations, or not?
- Numbers given as numerals (5) or spelled-out (five).

Procedure (Part 3 - Testing the Model Signs):

As a class, test all the signs. Decide which are the best. If time allows, modify your signs to make them better.

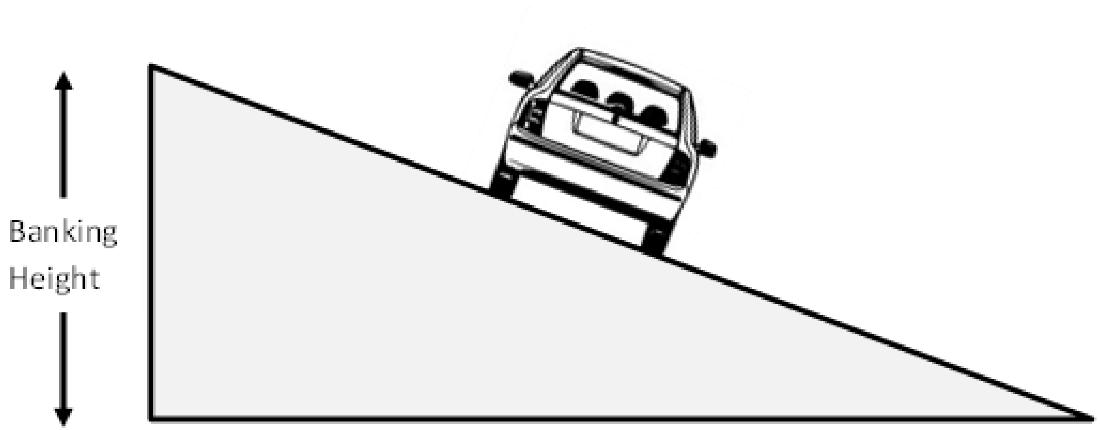
Activity 5: Slow Down, Curves Ahead

Objective:

Determine the roles of speed and banking on a car's ability to safely negotiate a curve.

Background Information:

Highway curves are banked so the outside edge of the roadway is elevated above the inside edge. This provides additional centripetal force to keep the car on the road and following the proper path. The faster a car is moving, the more banking it will need.



Materials for a class of 24:

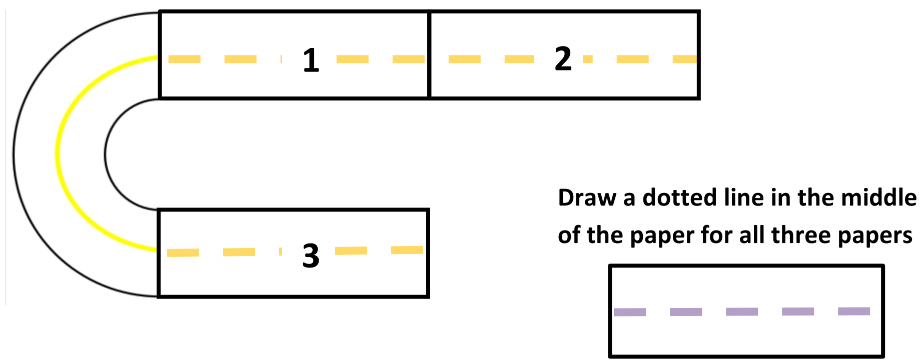
- 12 Curve Templates (each template is several pages)
- Paper (cardstock will work better than regular copy paper)
- Scissors
- Tape (any kind)
- Stack of books or other objects to elevate curve
- Markers
- 12 Marbles
- 12 Rulers
- Student Handout

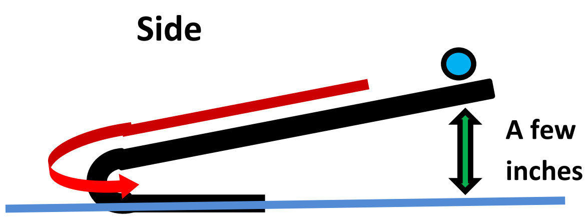
Advanced Preparation:

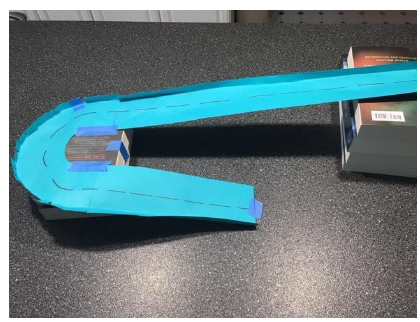
- Print the curve template for each group of 2-3 students.
- If students are to cut and assemble their tracks, it may take two class periods to complete the entire activity. Decide how to schedule this activity and where assembled tracks will be stored between sessions.

Implementation:

Put students into groups of 2-3. Each group will build a road curve model to test. They should cut out the curve on the template and divide 2 pieces of paper lengthwise for their track. Have the students cut the curve template along the dotted line and clip the curve so that they can fold up the outer edge to form a safety barrier.







Ask the students to draw a line through the center of the paper and attach the paper in sections for the roadway. Finally, raise the paper road model curve 3 inches from the ground level by utilizing a container, stack of books, or clay. Elevate the starting position with another stack of books or a container. You can suggest a starting height of 4 inches. Tape down the curve on the support structure. Have students hypothesize about the motion of the marble down the ramp.

The main challenge for students is to roll the marble from the top of the road downhill and for the marble to follow the curve and exit the model on the other side of the curve.

Ideally, the marble should <u>not</u> be in contact with the guardrail while negotiating the curve. Your car would require expensive repairs if it needed to run along the guardrail!

An even greater challenge is to keep the marble in the right-hand lane.

Students will investigate two variables of the curved model:

1. The starting height of the marble (which will determine its speed through the curve)
2. The banking height of the curve (elevation of the outside edge above the inside edge)

Students will explore how these two variables effect the marble's ability to make it around the curve safely.

Stress that experiments work best when only one variable at a time is being changed. Challenge students to explain why this is so.

Allow as much time as possible for the students to try different situations with the model, to analyze their findings and share their results.

Debrief Questions:

- How did the initial height of the marble effect its ability to make it around the curve safely? Explain why.
- How did the banking height of the curve effect the marble's ability to make it around the curve safely? Explain why.
- Why might some roads be built with a greater banking height than others?
- If you had to post a speed limit for a curved section of the road, what factors might you consider?

Extension

Students may try different "cars" on the model to see if items such as in a ping pong ball behave any differently. Students could research the way tires impact the traction of the vehicles making it easier or worse to drive through curves.

Career Connections:

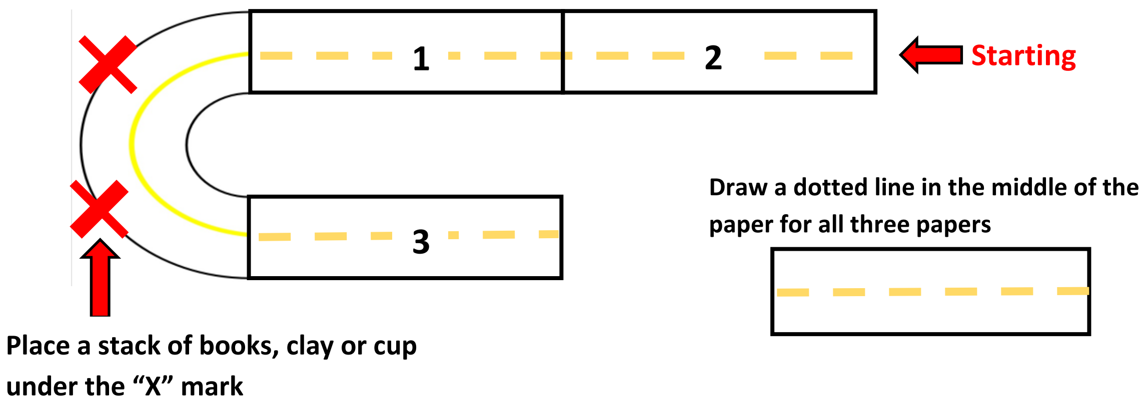
- Civil Engineers
- Health and Safety Engineers

Slow Down, Curves Ahead - Student Handout

You will construct a model of a road with a curve.

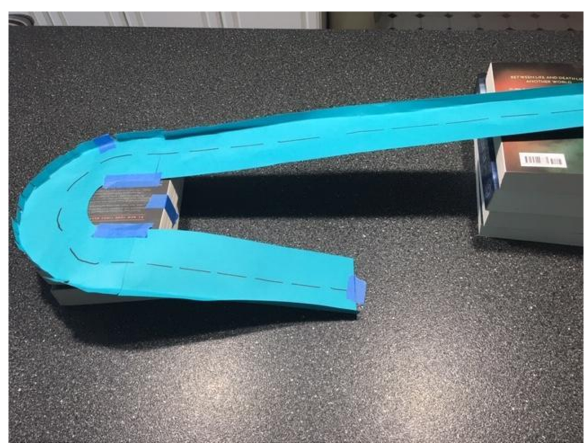
Cut the curve template along the dotted line and clip around the curve so that you can fold up the edge to create a guard rail. A marble that is released at the top of the ramp should travel along your road.

Cut 2 pieces of paper lengthwise. Draw a line down the center of each section of your road. Attach three sections of paper to the curve template (2 on one side and another on the opposite side similar to the diagram below.



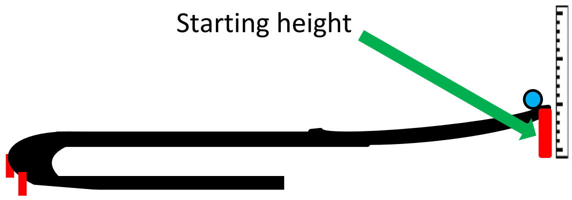
Raise the outside of the curve by about 3 inches by playing pieces of clay or books under the "X" marks.

Attach the starting point to a stack of books and measure the height of the starting point from the ground level.

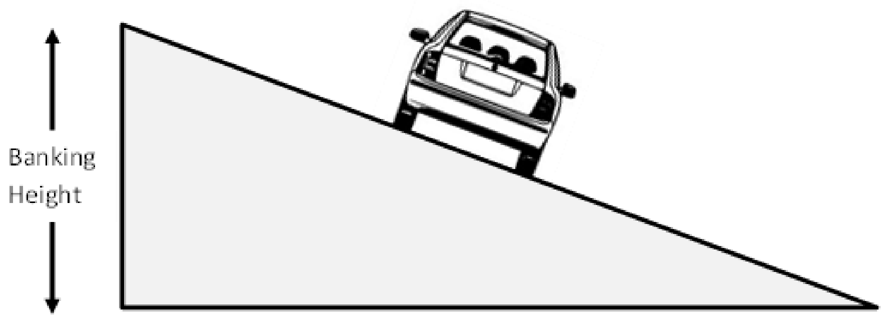


You will investigate how two variables effect the ability of your marble to get around the curve safely:

1. The starting height of the marble (which will determine its speed through the curve).



2. The banking height of the curve. (height of the outside edge above the inside edge)



Rules of the road:

- The marble must stay on the road.
- Don't move the model while the marble is traveling.
- Don't fold the model as a tunnel or "U" shape. Imagine real cars on your road, not marbles.
- For the first experiment, you will change the height of the starting point but not any part of the rest of the model.
- For the second experiment, you will change the banking height of the curved section but keep the starting height the same.
- For an extra challenge:
    - Try to keep the marble off the guard rail.
    - Try to keep the marble in the correct lane (right side)

Problem 1: How does the starting height of a marble change its speed and its ability to go around the curve safely? Record your measurements and observations in the box below:

Record your conclusions below:

Problem 2: How does the banking height of the curve effect the marble's ability to go around the curve safely? Record your measurements and observations in the box below:

Record your conclusions below: