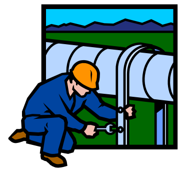
Pipelines and Oil Spills



NOTES

Target Audience:

Class age/size: 6th – 8th grade, 30 students working in pairs

Materials:

Each student will need:

- 1 copy of the Student Pages
- 1 sheet of graph paper

Each group will need the following:

- 2 containers to hold a few ounces of water (disposable cups or lab beakers are fine)
- 6 sheets of paper towel
- 4 flexible plastic straws (the type with a bendable elbow)
- 1 medicine dropper or disposable pipette
- 1 felt tip marker
- 1 ruler with centimeter scale
- 1 calculator

The teacher should also have ready:

- 1 quart of water (roughly), and a bucket if no sink is available
- 1 bottle of food coloring (blue or green are best)
- 1 pair of scissors

Resources:

- ***Time:*** Students who are familiar with the concepts might do the activity in 45 minutes. Those who need explicit instruction might require as much as 90 minutes. This activity can easily be broken into smaller segments to complete on separate days.
- ***Facilities:*** Although having a sink would be very handy, this activity can be done in any room with tables or desks.
- ***Safety:*** There are no safety concerns in this activity.

Objectives/Standards

This activity gives students practice with calculating areas, graphing, and analyzing proportional relationships. It begins with a simple engineering design challenge.

NOTES

This activity addresses the following Common Core Math Standards:

7.RP - Ratios and Proportional Relationships: Analyze proportional relationships and use them to solve real-world and mathematical problems.

> 2. Recognize and represent proportional relationships between quantities.
>
> a. Decide whether two quantities are in a proportional relationship, e.g., by testing for equivalent ratios in a table or graphing on a coordinate plane and observing whether the graph is a straight line through the origin.
>
> b. Identify the constant of proportionality (unit rate) in tables, graphs, equations, diagrams, and verbal descriptions of proportional relationships.
>
> c. Represent proportional relationships by equations. For example, if total cost t is proportional to the number n of items purchased at a constant price p, the relationship between the total cost and the number of items can be expressed as t = pn.
>
> d. Explain what a point (x, y) on the graph of a proportional relationship means in terms of the situation, with special attention to the points (0, 0) and (1, r) where r is the unit rate.

7.G - Geometry: Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

> 4. Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.
>
> 6. Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

Although the primary targets are the math standards listed above, this activity also exercises skills from the following Next Generation Science Standards:

> MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
>
> MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Obvious extensions could include standards in environmental science, energy, and natural resources.

NOTES

Opportunities:

- ***Talk about how crude oil forms.***
- ***Explain what a refinery does.***
- ***What pipelines and refineries are near your town?***

Introduction

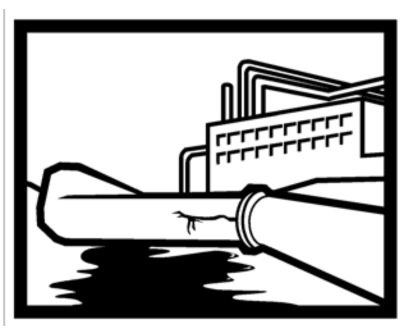
The US is currently dependent on fossil fuels such as crude oil. Crude oil is needed to create products such as gasoline, plastics, and electricity. Oil must be transported from where it has naturally formed to where it is needed. Pipelines, rail cars, trucks, and ships are all used for this purpose. Each method of transport carries some risk of accidentally spilling the oil. Any sizeable spill has the potential to devastate the local environment. Those who respond to such emergencies need to know how much oil was spilled. Determining that amount is not difficult if all the oil came from a single truck or railcar. Determining the size of a leak from a pipeline is not so easy.

Guiding Questions:

How can the amount of oil spilled from a pipeline be determined by examining the scene of the accident?

Inquiry Overview:

In this activity students will build a model pipeline to carry simulated oil from a drilling field to a refinery. They will measure the size of a spill created by a leak in the pipeline. They will conduct an experiment to create a mathematical model showing the relationship between the amount of oil spilled and the area of the pooled oil. This relationship will be used to assess the amount of oil that spilled.

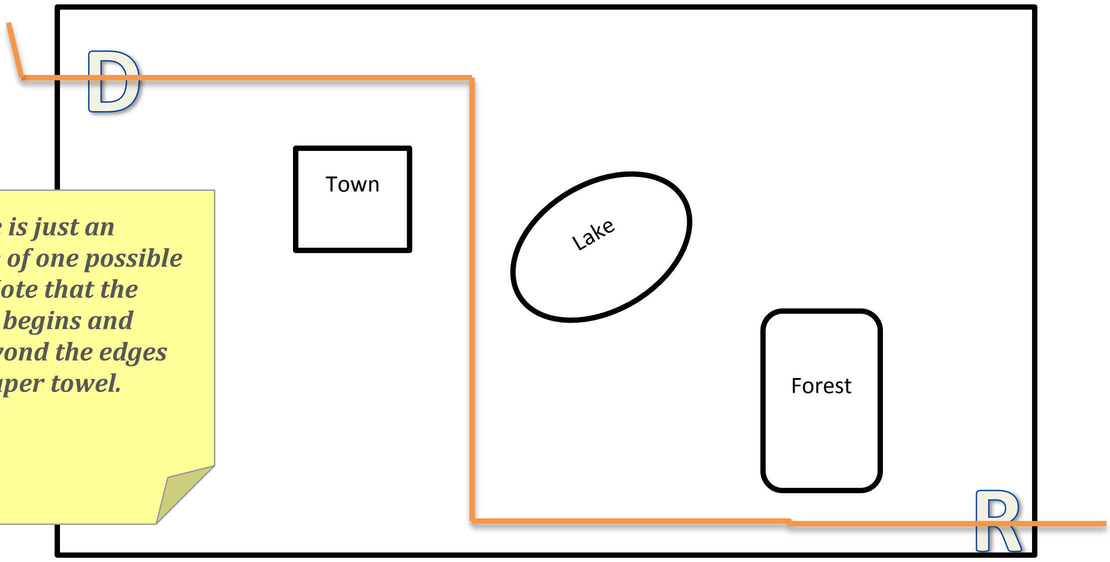


1. Place two connected sheets of paper towel flat on the table. Using a felt tip pen, write a "**D**" in one corner to represent the drilling field. In the opposite corner write an "**R**" to represent your oil refinery.

NOTES

2. Between the drilling field and refinery draw three obstacles which your pipeline must avoid.
   - A town
   - A lake which provides drinking water to the town
   - A forest preserve, home to endangered wildlife

Customize the city and the other obstacles to fit your location. They <u>don't</u> have to be positioned exactly as shown. Let students be creative!



This line is just an example of one possible route. Note that the pipeline begins and ends beyond the edges of the paper towel.

3. Use your straws to create a pipeline that passes through **D** and then **R**. Straws may be connected together by pushing one end into another. You may use scissors to shorten a straw if you wish. When placed on the table your pipeline should lay flat except for the end near **D** which should be bent to point upward. This is where you will add your simulated oil. Both ends of the pipeline should extend a little beyond the edges of the paper towel.

4. Look at all of the pipelines created in your class and discuss which design would be the most cost efficient to build and maintain.

Step 4: Consider the amount of pipe needed and the number of joints.

5. Slide your paper towel and pipeline toward the edge of your table so that the end of the pipeline extends beyond the table's edge. Have a student hold an empty cup below the pipeline's end to catch the water we are about to add.

NOTES

6. Using a dropper, add water to your pipeline near **D**. It will take several full droppers before the water reaches the end. Keep adding water until the first drop makes it all the way through and falls into the cup. Stop adding water as soon as that happens.

7. Examine your pipeline for leaks. Look for spills located at the joints between straws. If you see a spill on the paper towel, use a felt tip marker to carefully trace the perimeter of the spill before it evaporates and becomes invisible.

8. Look at all of the pipelines created in your class and discuss which designs worked best and why.

A well-constructed pipeline will not leak. But we want to measure a spill so use a push pin to puncture the straw (straight through both sides) in <u>one</u> location near the middle of the line. Only do this if the pipeline did not have a leak already!

9. If you had no leaks, congratulations! Now carefully empty your pipe into the cup without spilling on your paper towel. Since we want to study a spill you may have to **<u>make</u>** a leak in your pipeline. Use a push pin to punch a hole straight down through your pipeline some place near the center of your paper towel. Repeat steps 5, 6, and 7.

10. Do you know much oil leaked from your pipeline? Estimate how many drops were spilled into your paper towel. Place your paper towel in a safe, dry place. You will need it again, later.

11. Place a new, dry paper towel on the table. Using a dropper, squeeze a single drop of water onto the paper towel. Wait one or two minutes until the spill has reached its maximum size. Before it evaporates, use a felt tip pen to trace the perimeter of the spill. What geometric shape best describes the spill you have created? What formula is used to calculate the area of that shape?

(Most likely a circle. $A = \pi r^2$ *)*

NOTES

12. Use a ruler to measure the diameter of the one-drop spill and record your data in the table below. Measure to the nearest tenth of a centimeter.

13. Now calculate the area of the one-drop spill. Record your work and answer in the data table.

Number of drops	**Diameter of spill (cm)**	**Area of spill (cm^2)** ***Show your work below:***
1		
2		
3		
4		
5		

14. Predict the diameter and area of a spill caused by two drops of water.

15. Using the dropper create a two-drop spill. Wait one or two minutes until the spill has reached its maximum size. Before it evaporates, use a felt tip pen to trace the perimeter of the spill. Use a ruler to measure the diameter of the two-drop spill and record your data in the table. Calculate and record the area. Were your predictions close?

16. Using the same procedure, create and measure spills from 3, 4, and 5 drops.

NOTES

17. We will create a line graph to show the relationship between the number of drops and the area of the spill. Before creating the graph, discuss the following:

    Which is the independent variable? *(N)* Which is the dependent variable? *(Area)*

    Which variable will be represented on the horizontal axis? Which on the vertical axis?

    (The independent variable, The dependent variable)

    How many data points will be plotted?

    (5, although 0,0 may be used as a sixth)

    After plotting data points we usually draw a line through them. What is the purpose of this line? *(See the sticky note on next page.)*

18. Construct your graph and plot your data points. Is there a pattern to your data points or do they seem to be scattered randomly?

    (The pattern will probably be a straight line, or at least a portion of it will be straight. See the sticky note below.)

19. Draw a smooth, simple line on your graph which shows the pattern. Is your line straight?

    (Probably, but if the data suggests a smooth curve, go with the data.)

20. Is the area of the spill directly proportional to the number of drops? How do you know?

    (A straight line indicates a direct proportion.)

21. Use your line to determine the area of a spill caused by 2.5 drops of water.

22. Use your line to determine the area of a spill caused by 7 drops of water.

23. Use your line to determine how many drops of water would be needed to create a spill of exactly 25 cm^2.

Sketching a line through data points is not an exercise in "connecting the dots". The line my hit some, none, or all of the points. The important thing is that the line shows the apparent pattern, or trend of the data. It is a representation of the relationship between the two variables, not a chain of line segments.

NOTES

24. Try to describe your line with a simple mathematical equation. Let **A** represent the area of the spill and **N** represent the number of drops.

    (If the line is straight then $\boldsymbol{A = pN}$ *where* $\boldsymbol{p}$ *is a constant of proportionality.* $\boldsymbol{p}$ *would also be the slope of the line.)*

Now we will use your graph and your equation to determine how many drops of "oil" leaked from your pipeline.

25. Measure and calculate the total area of all the spills from your pipeline.

26. Use your graph or your equation to determine how many drops escaped from your pipeline.

DEBRIEF:

- *What is the difference between a calculation and an estimate?*
- *Give an example of a calculation you made in this activity.*
- *Give an example of an estimate you made in this activity.*
- *Is there any uncertainty in your answer (#26)?*
- *How could you best express that uncertainty in a written report?*
- *Could the method you used today be used for a real pipeline leak?*
- *What additional challenges would you face estimating the spill from a real pipeline leak?*
- *Research topic: You know who responds when a building is on fire or a bank is robbed. Who responds when the failure of a pipeline or tanker is damaging the environment?*

Student Pages

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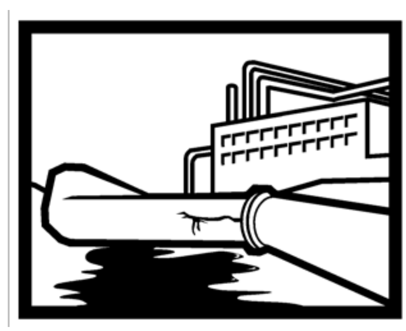
Problem: How can we determine the amount of oil spilled from a pipeline by examining the scene of the accident?



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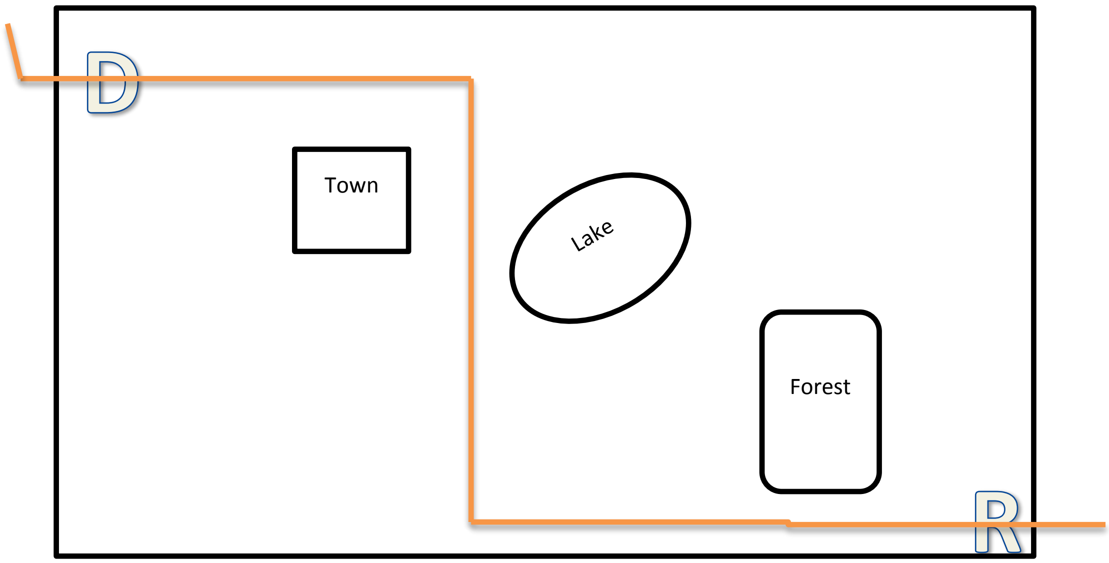

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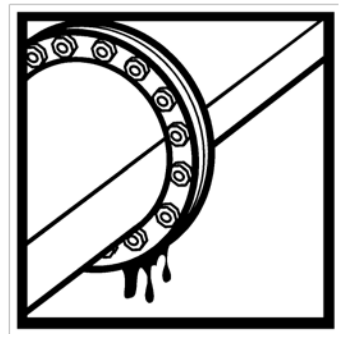

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