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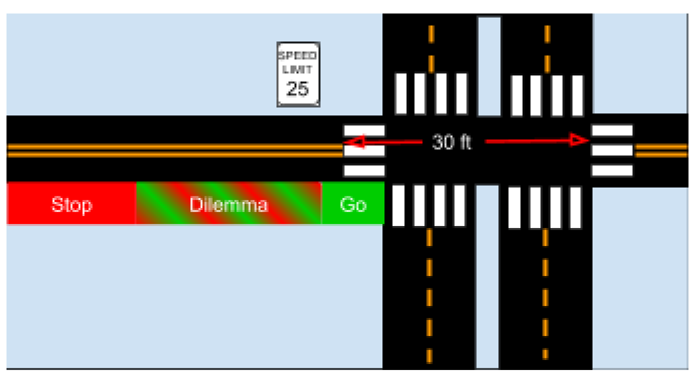
YUNG KOPROWSKI

Engineering Traffic to Become a Great Engineer

STEM Lesson Plan for Grades 6-8

Helping all students, especially girls, to be interested in engineering as a possible future can be challenging. Research suggests that role models are important for helping students to see themselves in jobs where they have been underrepresented. In addition, having challenging and fun engineering experiences help students to want to become engineers.

Many engineering projects though are focused on competitions, but that isn't the essence of engineering. The cycle of determining a problem, identifying what's needed to solve the problem, trying and testing possible solutions, and optimizing and iterating to find an adequate solution is what makes an engineering project.



In this lesson plan, students will watch a video where Yung Koprowski explains how she became a successful engineer. After figuring out what she says are some key factors to being a great engineer, they will investigate an intersection to see if the yellow light is the right length of time. Later they will compare their work with what is accepted in the field. Finally, they will look back at their work habits to determine how closely they matched skills that the engineer suggested were important.

NGSS Standards
CCC: Constructing Explanations and Designing Solutions

CCC: Using Mathematics and Computational Thinking

PS2.A: Forces and Motion
Newton's second law accurately predicts changes in the motion of macroscopic objects.

Part I: Watching the Yung Koprowski Video

Before the students watch the video, the teacher should explain that in this video an engineer will explain what makes her a successful engineer. The teacher should ask students to record what personality traits, desires, and behaviors are important to becoming an engineer.

For younger students, you may need to use sentence starters like

Yung Koprowski said that she had to overcome the obstacles of _________
Yung Koprowski said that she wants to _______

The video has on-screen icons that will help students when she is saying key components of her success. For some students, pausing the video at those moments will help them better record what is going on.

In small groups have the students summarize what they saw and then make sure that the entire class has all of the points. While they may have more than these, they should at least note:

- Yung Koprowski is an engineer because she wants to help people.
- Yung Koprowski works with others as a team.

Making a Great Engineer Checklist

Students now should now make a checklist of things for themselves to do if they want to be a good engineer. Then when they do something on the checklist, they should mark it off. For example,

Activity	
I helped someone	𝍸 I
I didn't give up when something didn't go the way I planned	𝍸 III

Students will use this checklist several times in the following projects. Don't assign points or give too much praise, otherwise students will just game the system. We just want them noting when they are doing something a good engineer does, helping them to internalize that they can be an engineer. Alternatively, you can make it the task of one of the members of the group to note when their groupmates are being good engineers.

Part II: Traffic Engineering

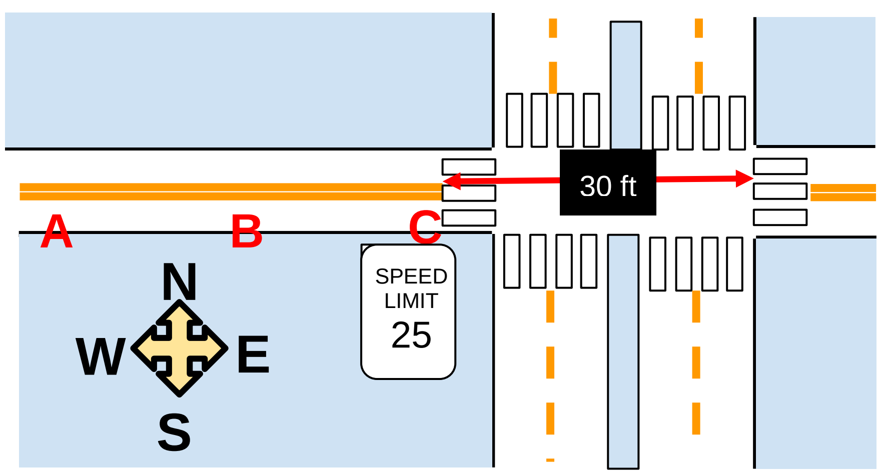
Red means stop. Green means go. What does a yellow light mean? According to the Institute of Transportation Engineers, yellow lights are a warning that right of way is about to change. The time should be long enough for traffic move at posted speeds to clear the intersection or stop before entering the intersection. Are yellow lights the right length of time near your schools?

Determining the Problem: Figuring What It Means to Stop Safely

Although the guideline -- yellow lights should be long enough so that vehicles won't stop in the intersection -- is straightforward enough, some students have trouble figuring out what to do next.

To help them along, you might give them an example like the drawing similar to the one below and ask a few questions.

Imagine a car is driving from west to east on the road above at the speed limit. When the light turns yellow, the driver has essentially two choices: stop before the crosswalk or go through the intersection before the light turns red. (See note at the end for some particulars about state laws.)



Ask students, *What should drivers do if they are far away from the intersection (Point A)?* Most students will say that the car should stop.

What should drivers do if they are right at the crosswalk (Point C)? Most students say the car should go through.

How about at some point in between (Point B)? That depends. If they can safely stop before the crosswalk they should do that. Alternatively, if they can drive through the intersection at or below the speed limit, they can do that. If they can do both, they can chose. The trouble happens when they can do neither. Then something about the intersection's signal has to change.

Collecting data

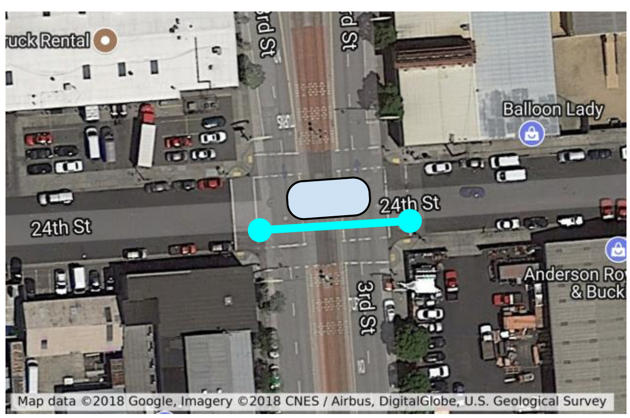
Have groups select an individual traffic light near their school or home. You may consider having all students select the same light as it may make examining their data easier for you, but students tend to have more buy in if they pick what seems like a problematic light of their own.

Ask the groups what data they think they will need to know. Have the groups share with the class what they think they will need. Typically, they figure out that they'll need

- Dimensions of the intersection
- Legal speed limit of the road approaching the intersection
- Maximum safe deceleration
- Reaction time of drivers
- Current yellow light time
- Grade of the road

Dimensions Most states require cars to stop before a posted crosswalk or to clear the corner on the other side of the intersection. For smaller intersections, laser tape measures can be used to find their size, but for larger intersections, students could use a measuring wheel. These are frequently used to measure and lay out athletic fields. However, students should only do this under the close supervision of a teacher.

The distance can also be determined by Google Maps or similar applications. For Google Maps, find the location, turn on imagery, and then zoom in. Right click on the image, and then select "Measure Distance". Left click on the starting and finishing locations to show the distance on the screen. It is possible to adjust the starting and end points. The screen displays the distance in meters or feet.



Speed Limit The speed limit on many streets is displayed on a sign, but many cities have a default speed for unposted streets. Actual speeds may be significantly higher.

Maximum Safe Deceleration Car advertisements often tout a variety of different values for decelerations, but they come from professional drivers on closed courses that are in perfect conditions. Actual traffic engineers know that drivers and cars have a variety of capabilities and are maintained in a variety of conditions. To figure out what is the actual drivers can do, traffic engineers examine the behavior of drivers in real road conditions. The assumptions about drivers can often be found in state road standards and are often available for free online. The National Academy of Sciences, Engineering, and Medicine has published a summary of findings of various transportation engineering organizations in terms of setting the times for yellow and red traffic signals in *Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections.* Most drivers can safely decelerate at 3.0 m/s^2 (10 ft/s^2).

Reaction Time Drivers have to see the change in the light and then decide what to do. While human reaction time can sometimes be lower than 0.2 seconds, this generally only happens in situations where the person is posed to react to some trigger without considering any complicating factors, like starting a runner starting a race on the sound of "Go!" If a person has to first see or hear the trigger, interpret it, and then decide what to do, most people's reaction time is much slower. That time depends on how many bits of information do they have to consider and whether or not they were primed to make a decision. For example, in yellow light situation, the correct reaction isn't necessarily to brake. If braking would leave the car in the intersection, then the driver should continue through and stop on the other side. The *Guidelines* suggests in these situations that most drivers take from 1 s to 1.5 s to decide what to do. Students can try simulation that compares simple reaction to choice reaction time here: https://www.psytoolkit.org/lessons/simple_choice_rts.html

Current Yellow Light Time Students can measure this in person. Some lights have different red and green light times depending on the time of day, but relatively few change the yellow light time.

Computing the Distance Necessary to Slow Down Safely

Advanced students can probably compute the rest of the problem at this point, but newer students will probably need scaffolding to help them compute what they need.

Initially, the groups might want to determine how much time it would take cars moving at the speed limit to stop at their maximum safe deceleration. Since acceleration (*a*) is the change in velocity (*v*) divided by the time (*t*),

$$a = \frac{\Delta v}{\Delta t} \quad or \quad \Delta t = \frac{\Delta v}{a}$$

Example: A typical car moving at 11 m/s (25 mi/h) can decelerate at about 3.0 m/s^2, so it can stop in about 3.7 s.

That time, though, assumes that the drivers will react instantaneously, but real drivers take about 1 s to react. So, the minimum amount of time for a typical car to stop is about 4.7 s. For yellow lights shorter than 4.7 s, drivers will not be able to slow to a stop before the light changes to red.

Next, the groups may want to determine how far the cars will go while coming to a stop. This is a bit tricky since it has two parts. First, they need to figure out how far cars go before the drivers start braking, and add to that the distance that the cars travel while braking. Using kinematic formulas, students can figure out what the minimum distance necessary to slow done safely.

$$d = v_i t + \frac{1}{2} a t^2$$

where d is the distance that is traveled, v_i is the velocity initially in the time interval t, and a is the acceleration or deceleration of the car during that time.

For our typical car starting at 11 m/s, it moves 11 meters before the car starts to brake, and it travels another

$$d = (11\frac{m}{s})\,(3.7s) + \frac{1}{2}(-3.0\ \frac{m}{s^2})\,(3.7\ s)^2 = 20\ m$$

So, a total of 31 m. As long as the car is farther than 31 m from the crosswalk, the car can stop safely.

Should the cars go through?

For the example above, if cars are closer than 31 m, then they must go through the intersection. Assuming that they continue at the speed limit, how far will they go before the light changes to red? Of course, that depends on how long the yellow light is. For many places, the yellow light is 3.5 s.

We can use the same kinematic formula as before, but cars aren't slowing down.

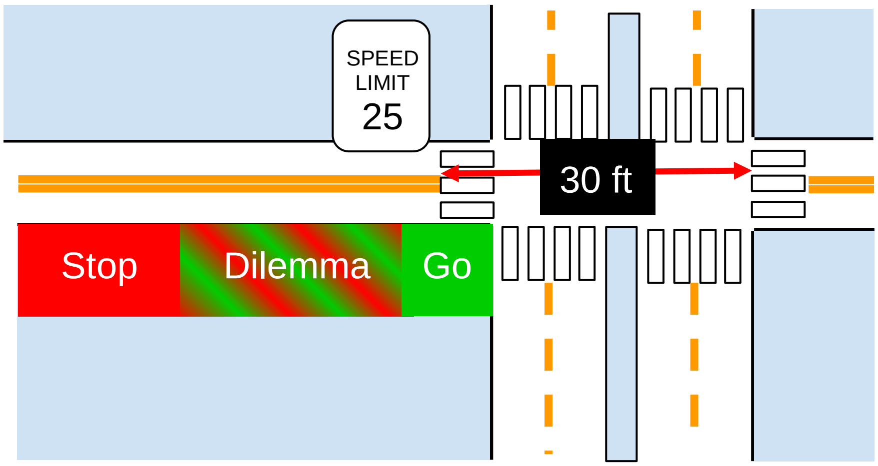
$$d = v_i t + \tfrac{1}{2} a t^2$$

$$d = (11\frac{m}{s})\,(3.5s) + \frac{1}{2}(0\ \frac{m}{s^2})\,(3.5\ s)^2 = 38.5\ m$$

Imagine an intersection that is 30 m across. If cars are farther than 8.5 m from the near crosswalk, then they can't across the intersection before the light changes to red.

Dilemma Zone

These two situations in the example suggest a zone of 8.5 m to 31 m from the near crosswalk where the driver can't get all the across before the light changes to red and where they can't stop without going into the intersection. A driver who is in this zone when the light changes to yellow has no good choices.



Engineering Changes

Should students find an intersection that poses a dilemma for drivers, each group can try to decide how to change the signaling. Ask each group to come up with a plan to fix the problem and to explain why it works. Have the groups create a short presentation.

Most of the groups will settle by extending the length of yellow lights. In our example, if the yellow light were 10 s long, then a car moving at 11 m/s could go as far as 110 m during a yellow light, easily far enough so that the car could always either stop before the crosswalk or make it through.

After the groups have made their presentations, you can mention some additional concerns.

- Long yellow lights reduce traffic flow by having less time when the light is green.
- Long yellow lights might cause people not respect the yellow.
- Reducing the speed limit can also reduce the size of the dilemma zone.
- Adding a median can reduce the size of the intersection.
- For many states, adding an interval when the all the lights are red before the other direction turns green can also reduce the dilemma zone by allowing cars to complete their trip through the intersection when no other cars have started.

Have the groups return and reconsider their decisions, trying to balance needs of getting traffic through but reducing the dilemma zone. Have groups create a presentation that defends their choices.

Finally, you might have your students compare their suggestions to what actual traffic engineers suggest. The *Guidelines* suggest these two formulas (converted into metric) for determining how long a yellow light should be in states with permissive yellow light laws (see below). For states with restrictive laws, the *Guidelines* suggest adding the two times together.

$$Y = t + \frac{v}{2a} \text{ and } R = \frac{W+L}{v} - 1$$

Where:

Y is the length of the yellow light
t is the reaction time
v is the velocity (in m/s) of the vehicle
a is the maximum comfortable deceleration (in m/s^2)
R is the time of the all red condition
W is the width of the intersection
L is the length of a typical car

The subtraction of 1 from the red light time is from the reaction time of the cross traffic drivers.

Note on State Laws

State laws about yellow lights fall into two major categories: restrictive or permissive. Four states -- Louisiana, Rhode Island, Tennessee, and West Virginia -- have restrictive laws that prohibit cars from being in the intersection during a red light for any reason. Other states have more permissive laws that allow cars to be in the intersection during a red light if they entered while it the light was yellow or if stopping would be unsafe. Permissiveness notwithstanding, being in the intersection when cars are coming from the other direction is still dangerous and is to be avoided.

Part III: Evaluation

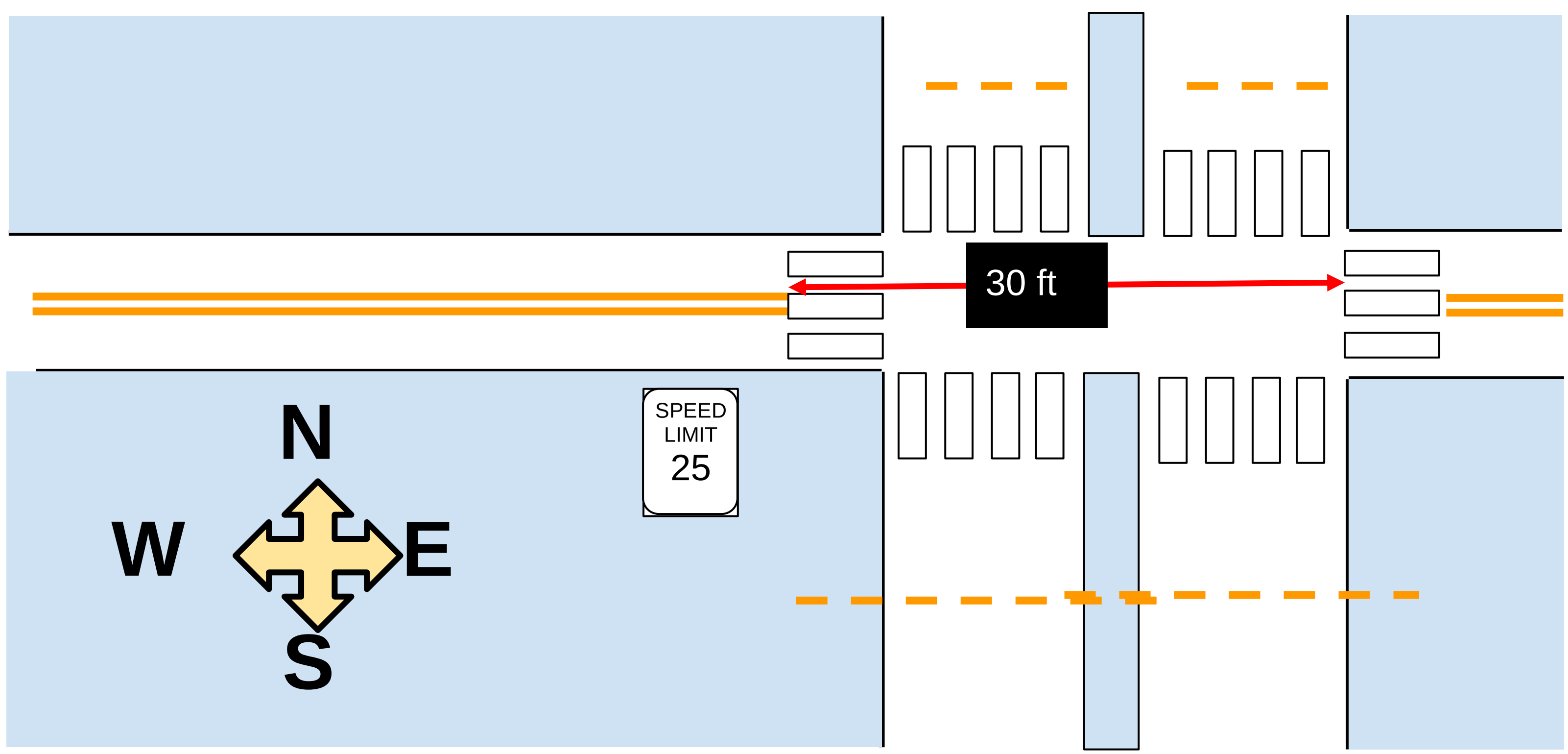
Groups should report out how they have improved their intersection or explained a method for examining other intersections should theirs be fine.

In addition, each group should report out on how well they worked together. Even for classes that didn't have time for the groups to work on their own project, having the students briefly present their work to their classmates tends to give the best opportunity to figure out what happened in their group. They should explain

- What their problem/goal was
- What they tried
- Whether or not it was successful
- How they could tell if it was working
- What they did if they didn't all agree on what to do

- How often did they get to put a mark on their checklists

National Academies of Sciences, Engineering, and Medicine. 2012. *Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections.* Washington, DC: The National Academies Press. https://doi.org/10.17226/22700 Available as a free download at https://www.nap.edu.



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