Activity 3: Setting Yellow Light Time

Activity Summary	
Instructor Prep Time	10 minutes
Class Time	30 minutes
Grade/Class	9 - 12 Beginner
Suggested Activity Grouping	Individual
Technology	Low Tech
National Science Education Standards	Appropriate tools Technology & mathematics Think Critically Motion & forces Standard 8 Standard 9 Standard 10

Introduction

In this activity, students will learn about the design calculations of traffic signals, or more specifically, they will learn how to calculate the duration of a yellow light. Students will learn the variables involved in this calculation, study examples, and then apply what they have learned to solve a problem.

Objective

In this activity, students will:

- Learn about the factors that affect yellow light time (such as reaction time from Activity 1)
- Determine the optimal time for a yellow light using the yellow light timing equation.

Activity Expansion Ideas

Students could delve into the dangers of intersections. This would be a good opportunity for students to research the conflict points (or possible collision points of vehicles) in a regular 4-way intersection and compare it to the conflict points of a roundabout. Encourage them to research ways other than roundabouts that transportation and traffic engineers either are or could make intersections safer. Keep in mind that some of the solutions – including roundabouts – don't include a traffic signal at all.

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Questions

1) How long does the yellow light last? (Round answer to one decimal place)

$$Y(v) = T_{pr} + \frac{1.47v}{2d_r + 2Gg} = 1s + \frac{1.47 * 30\ mph}{2(10\ ^{ft}/_{s^2}) + 2(0.03)(32.2\ ^{ft}/_{s^2})} = 3.0s$$

2) How long does it take for the police officer to come to a stop? (Round answer to one decimal place)

$$Y(v) = T_{pr} + \frac{1.47v}{2d_r + 2Gg} = 1.5s + \frac{1.47 * 30\ mph}{2(14\ ^{ft}/_{s^2}) + 2(0.03)(32.2\ ^{ft}/_{s^2})} = 3.0s$$

3) Should the police officer come to a stop or proceed through the intersection? Why?

The police officer should come to a stop because even though they might react slower than the assumed design reaction time their deceleration is greater and causes their total stopping time to be within the 3.0 second yellow light duration.

4) Why do you think that the grade of a road leading up to a traffic light is a factor in what the yellow light duration should be?

If cars are traveling downhill (negative grade), gravity is accelerating the car. Therefore, the amount of time they will need to stop increases and the yellow light duration will need to be longer. Opposite of this, if a car is traveling uphill (positive grade), gravity is decelerating the car. Therefore, the amount of time they will need to stop decreases and the yellow light duration can be shorter.

5) What factors present on a roadway could be dangerous to drivers traveling through an intersection?

Answers may vary. A few examples would be weather conditions and sight distances. Certain weather conditions, such as snow and rain, lower the rate at which drivers are able to decelerate, which could increase the likelihood of accidents at this intersection. Additionally, intersections without proper sight lines can cause longer reactions to the approaching intersection, which could lead to the driver not stopping in time.

Discussion

As students calculate the yellow light times in the activity, talk about the criteria for selecting the ideal yellow light time and the required actions within that time. For example, some criteria that is taken into account is the volume of traffic, the patterns of traffic, and the design speed of the road. If yellow light times are too long, what might happen to drivers' response to them? In turn, what might happen if the time is too short?

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Introduction

As a car travels down a road, it approaches a traffic light. As the car nears the light, the light turns from green to yellow, and the driver is faced with a decision: are they close enough to continue through the intersection or should they prepare to stop? This decision is highly dependent on how long the light stays yellow. In this activity, the method for determining traffic light times and the impact this time has on the average driver will be explored.

Objective

In this activity, you will:

- Learn about the factors that affect yellow light time (such as reaction time from Activity 1).
- Determine the optimal time for a yellow light using the yellow light timing equation.

Background

In order to calculate the sequencing of a traffic system, several variables must be addressed and understood. These include:

- **Reaction Time**: How quickly can drivers react and put their foot on the brake?
- **Deceleration**: How quickly can the car slow down?
- **Grade**: How steep is the road leading to the intersection?
- **Velocity**: How fast is the car moving?

The changing of a traffic light can be broken down into three phases:

1. **Green**: The traffic is free to go.
2. **Yellow**: Depending on which is safer, drivers either come to a stop or continue through the yellow light. Drivers often make this decision based on the braking distance—the distance the car will travel once the driver has applied the brakes. When drivers are closer to the intersection than the required braking distance, they should continue through the light; if they don’t, then they could end up stopping in the intersection, potentially causing an accident. A yellow light should never go longer than 5 seconds. If it does, drivers tend not to "respect" it and the chance of an accident increases.
3. **All Red**: This is when the traffic lights for all the lanes are red (i.e., no one has a green or yellow light).

The Institute of Transportation Engineers (ITE) uses the following formula to calculate yellow light durations:

Yellow Light Duration Formula
$Y(v) = T_{pr} + \frac{1.47v}{2d_r + 2Gg}$
Where: d_r = deceleration (ft/s^2) g = acceleration due to gravity (32.2 ft/s^2) G = grade (expressed as a decimal) v = velocity (mph) T_{pr} = reaction time (seconds) Y = yellow light duration (seconds)

This formula can be used to set the timing of yellow lights so that there is enough time for drivers to clear the intersection if they are close to it when the light turns yellow, as well as enough time for approaching cars to safely slow to a stop. However, the timing cannot be long enough that approaching drivers choose to ignore the yellow light all together and accelerate to make it through the intersection, which creates the potential for an accident.

Not every driver has the same reaction time and not every vehicle can decelerate at the same rate, so averaged values are often selected for these variables when using this formula. Standard (averaged) values used for reaction time and deceleration are taken as 1 second and 10 ft/s^2, respectively. These standard values are often used in design, when specific data for these variables at an intersection is unknown.

Sample Problem 1:

Imagine an intersection with an approaching northbound road that has a grade of +2% and a design speed of 35 mph. The average reaction time of drivers approaching this intersection has been found to be 1.5 seconds, and the average rate of deceleration has been found to be 13 ft/s^2. What should the yellow light duration be for this northbound road? (Note: Standard values of reaction time and deceleration are not used here, as specific intersection data is available.)

To begin, we will write down what information we know:

d_r = 13 ft/s^2
g = 32.2 ft/s^2
G = +2% = 0.02
v = 35 mph
T_{pr} = 1.5 s

Put this information into the formula, it appears as shown below:

$$Y(v) = 1.5s + \frac{1.47 * (35mph)}{2 * \left(13 \, {}^{ft}/_{s^2}\right) + 2 * (0.02) * (32.2 \, {}^{ft}/_{s^2})} = 3.4s$$

According to the formula, the yellow light duration for the northbound road at this intersection should be set at 3.4 seconds.

Sample Problem 2:

Imagine that a four-way intersection is in the design phase, and you, as the engineer, are asked how long the yellow light should last. The roads that intersect both have a design speed of 40 mph. One road was built on flat ground, while the other is located on a hill with a ±5% grade. Using the standard values for reaction time and deceleration, how long would the yellow lights last for both the flat road and the one on the hill?

Recall that the standard values for reaction time and deceleration are 1 second and 10 ft/s^2, respectively. Again, we will write down what information we know:

d_r = 10 ft/s^2
g = 32.2 ft/s^2
G_{flat} = 0% = 0.00
G_{hill} = ±5% = ±0.05
v = 40 mph
T_{pr} = 1 s

You may have noticed the ± symbol in front of the 5%; this symbol stands for both plus and minus. In our example, driving on the inclined road in one direction means you are traveling uphill at a grade of +5%, while driving on the inclined road in the other direction means you are traveling downhill at a grade of -5%. When calculating yellow light durations, the goal should be to select the safest duration. In this case, the safest duration occurs when traveling downhill (resulting in a larger yellow light duration than when traveling uphill).

Calculate the yellow light duration for the road on flat ground:

$$Y(v) = 1s + \frac{1.47 * (30mph)}{2 * \left(10 {ft}/{s^2}\right) + 2 * (0.00) * (32.2 {ft}/{s^2})} = 3.2s$$

Next, calculate the yellow light duration for the road on the hill (using the -5% grade):

$$Y(v) = 1s + \frac{1.47 * (30mph)}{2 * \left(10 {ft}/{s^2}\right) + 2 * (-0.05) * (32.2 {ft}/{s^2})} = 3.6s$$

From our calculations, we can see that the yellow light should be lit for 3.2 seconds when traveling in either direction on the flat road, and should flash for 3.6 seconds when traveling either direction on the hill.

Use what you have learned to determine answers to the scenario provided in the procedure section.

Materials

Item	Quantity
Activity 1 Data	
Pencils	1 per person
Paper	As needed
Calculators	1 per person

Procedure

Imagine a police car traveling down a road with a +3% grade at 30 mph, approaching an intersection as shown in Figure 3-1. The traffic light is initially green, but as the police car gets closer to the intersection, the light suddenly turns yellow. Assuming the road designers used standard values for reaction time and decelearation (1 second and 10 ft/s^2, respectively), how long will the yellow light last?

Imagine that the police officer is scanning the area for crime, and does not react to the yellow light for 1.5 seconds. If the police car has a deceleration rate of 14 ft/s^2, how long will it take for the vehicle to reach a stop?

Based on your answers to these questions, should the police car continue through the intersection or come to a stop? Why?

Show your work and record your answers in the space provided in the *Research Notes* section.

Figure 3-1: Scenario Site Depiction

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Questions

1) How long does the yellow light last? (Round answer to one decimal place)

2) How long does it take for the police officer to come to a stop? (Round answer to one decimal place)

3) Should the police officer come to a stop or proceed through the intersection? Why?

4) Why do you think that the grade of a road leading up to a traffic light is a factor in what the yellow light duration should be?

5) What factors present on a roadway could be dangerous to drivers traveling through an intersection?

Discussion Notes