SECTION 6

Using Models: Intersections with a Yellow Light

Section Overview

This section investigates the dilemma a driver faces when encountering a yellow light at an intersection. A mathematical model demonstrates the interplay of different factors that determine whether a driver can safely make it through the intersection. The factors relevant to the driver's decision include reaction time, width of the intersection, speed of the car, and the rate of negative acceleration. The quantitative data for these factors are recorded on a spreadsheet. This data is then inserted into the equations for reaction and braking distance to calculate the actual distance the automobile will cover during the length of the yellow-light time. The equations are then used to determine whether an automobile will be able to go safely through an intersection before the light turns red.

Background Information

While you are driving at a constant speed, you need a certain length of time to react to a stimulus (such as the neighbor's cat running on the road), interpret the stimulus, then tell your muscles to perform an action (push the brake pedal). During the time it takes to react to a yellow light, your vehicle will continue to move with the original speed. It will cover a distance $\left(d = vt\right)$.
This distance will be added to the distance that is required to stop once the brakes are applied $\left(d = v^2/2a\right)$. Because the acceleration rate is not known for each vehicle, there will be an arbitrary rate chosen to reflect an average. It is usually based on an average car, with good brakes, on clean, dry pavement. The stopping distance, then, is the distance that is required to come to a stop, after the stimulus (the cat) is presented. Therefore, total distance, $d = vt + \dfrac{v^2}{2a}$.

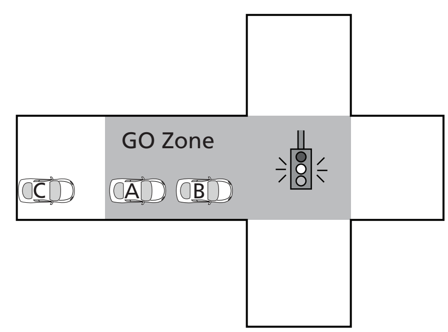
Computing the GO Zone

Determining the GO Zone is an application of distance = velocity × time. While the yellow light is illuminated, the automobile must be able to go through the intersection. The total distance traveled is the distance from the intersection plus the width of the intersection.

GO Zone + width =
velocity × yellow-light time

$GZ + w = vt_y$

$GZ = vt_y - w$



The GO Zone actually includes a range of possible distances. If automobile A goes through the intersection, as shown above, then any automobile closer than automobile A can also make it through the intersection. The correct equation for the GO Zone is $GZ \le vt_y - w$. It can be shown in a sketch with a shaded area.

Computing the STOP Zone

Determining the STOP Zone requires one to realize that the stopping distance is the sum of the coasting distance (the distance you travel during the reaction time) and the braking distance. These factors were investigated in *Sections 3* and *5*. The coasting distance is an application once again of the equation: distance = velocity × time.

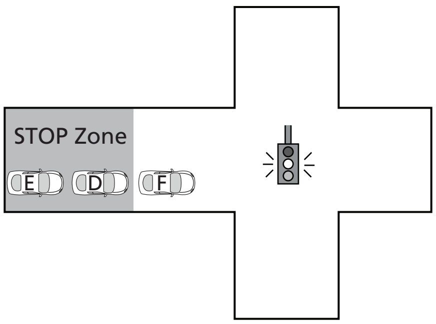
Because time is the reaction time, $d = vt_r$.

The braking distance is an application of the kinematics equation which relates velocity, acceleration, and distance given by $v^2 = 2ad$.

STOP Zone = velocity × reaction time + velocity squared/(2 × negative acceleration rate).

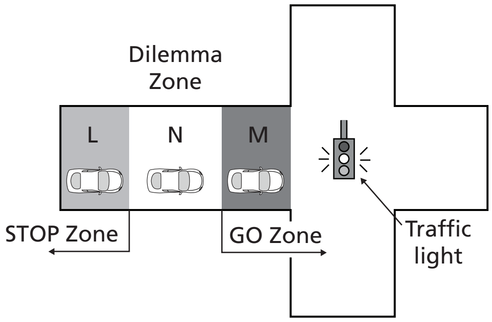
In symbols,

$$SZ = vt_r + \frac{v^2}{2a}.$$



The STOP Zone actually includes a range of possible distances (shown in the shaded area in the diagram above). If automobile D is able to stop before the intersection, as shown above, then any vehicle further than automobile D can also stop before the intersection. The correct equation for the STOP Zone is

$$SZ \geq vt_r + \frac{v^2}{2a}.$$



The GO Zone (where it is safe to continue when the light changes), and the STOP Zone (where it is safe to stop) are easily understood. The Dilemma Zone, however, introduces the area or region where the driver must make the more difficult decision of whether to stop or go. Automobile N is in the Dilemma Zone, shown in the diagram above. To calculate the Dilemma Zone, the five input variables must be examined separately.

The sample data below gives a good representation of the Dilemma Zone increasing as the speed of the vehicle increases. This zone is too dangerous to stop (not enough room to stop) and too dangerous to go through—when the light changes to red. There is a good possibility you will either be in the intersection or approaching it at the high speed at which you were initially driving or come to a stop in the intersection after the light has changed.

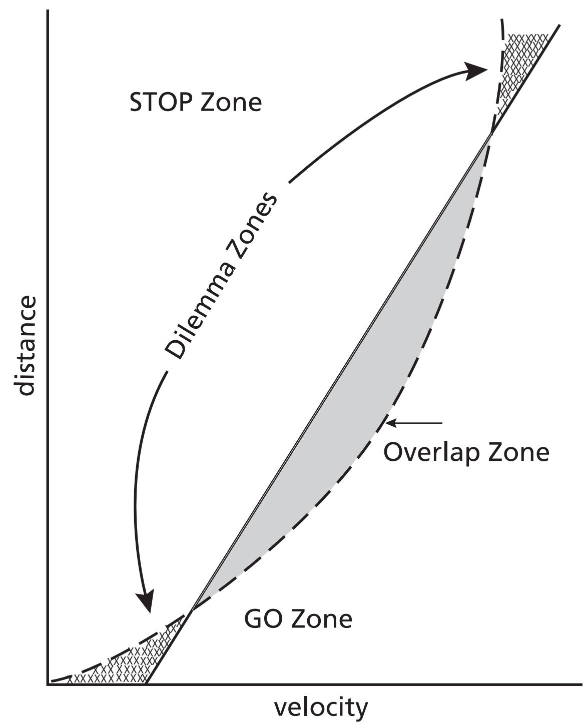
Intersection data	Velocity	STOP Zone	GO Zone	Dilemma Zone
Yellow-light time = 3 s	10 m/s	20 m	20 m	none
Reaction time = 1 s	15 m/s	37.5 m	35 m	2.5 m
Negative acceleration = 5 m/s²	20 m/s	60 m	50 m	10 m
Insertion width = 10 m				

The intersection will be unsafe if the GO Zone is smaller than the STOP Zone. The Overlap Zone provides a buffer, an area where it is safe to either go or stop. Because there is always some latitude in the way people drive, it is important to provide this Overlap Zone. An Overlap Zone appears when the GO Zone is larger that the STOP Zone, giving the driver time to decide whether to stop before the intersection or proceed through it.

The physics of the GO Zone and the STOP Zone could probably be made clearer if both functions were graphed. In the graph shown, the distances for the corresponding GO Zone and STOP Zone are displayed as a function of velocity.

The GO Zone is a linear graph $\left(GZ = vt_y - w\right)$. Its y-intercept changes with the width of the intersection and its slope changes with the yellow-light time. Either change can alter the Overlap and Dilemma Zones.

The STOP Zone is a parabola $\left(SZ = vt_r + v^2/2a\right)$. Its shape can be altered by varying the reaction time or the negative acceleration rate. The change in the shape or position of the parabola can alter the Overlap and Dilemma Zones. In the graph at the bottom of the next page, the STOP Zone is any distance above the straight line (the solid line), the GO Zone is any distance beneath the parabola (the dotted line), and the Overlap Zone is the area between the parabola and the straight line (shaded area). The Dilemma Zones (cross-hatched area) show where the driver is too close to the intersection to stop safely before the light turns from yellow to red, but does not have enough time to do so.



Even though any of the variables can eliminate a Dilemma Zone, it is fairly obvious that a change in the width of an intersection would be an expensive approach. Changing human reaction times, or assuming that people will be more alert, is hardly a worthwhile strategy. Likewise, the negative acceleration rate of cars is so dependent on individual cars and drivers that this is also a poor strategy. This leaves us with lengthening yellow-light time (which can be adjusted easily) or lowering the speed limit.

Crucial Physics

- Models can be used to describe mathematically what happens at a yellow light.
- An intersection with a yellow has a STOP Zone and a GO Zone.
- A safe intersection has an overlap between the GO and STOP Zones.
- An unsafe intersection has positions that are neither in the STOP Zone nor the GO Zone.

Learning Outcomes	Location in the Section	Evidence of Understanding
Investigate the factors that affect the STOP and GO Zones at intersections with traffic lights.	***Investigate*** Part A: Steps 1-9	Students should be able to determine the size of the STOP and GO Zones by using a spreadsheet.
Investigate the factors that result in an Overlap Zone or a Dilemma Zone at intersections with traffic lights.	***Investigate*** Part B: Steps 1-9	Students will be able to define an Overlap and a Dilemma Zone.
Use a computer simulation to mathematically model the situations that can occur at an intersection with traffic lights.	***Investigate*** Part A: Steps 5-9 Part B: Steps 1-9	After using the computer simulations, students will be able to determine the STOP, GO, Overlap, and Dilemma Zones.

Section 6 Materials, Preparation, and Safety

Materials and Equipment

PLAN A		
Materials and Equipment	**Group (4 students)**	**Class**
Multimedia DVD/CD Set		1 per class
Computer, station or calculator, CBL or equivalent system*	1 per group	

*Additional items needed not supplied

PLAN B		
Materials and Equipment	**Group (4 students)**	**Class**
Multimedia DVD/CD Set		1 per class
Computer, station or calculator, CBL or equivalent system*	1 per group	

*Additional items needed not supplied

Note: Time, Preparation, and Safety requirements are based on Plan A, if using Plan B, please adjust accordingly.

Time Requirement

This *Investigate* should take two class periods or 80 minutes.

Teacher Preparation

- Preview the video and note the automobiles that should have stopped for the yellow light and those that did not need to stop.
- A previously prepared spreadsheet is available, but you can easily make your own.
- Input the spreadsheet model into your spreadsheet software. Test your spreadsheet by changing the yellow-light time and see if your samples match those in the text.
- If you are using a local area network, simply download each spreadsheet to the workstations that the student groups will be using, or load the software on the individual stations.
- You need to make sure that specific jobs are assigned to each student in the group and rotate the jobs periodically. If the groups need to share or compare information, assign a communicator to represent each group.
- If you are using a low-tech alternative to this *Investigate*, you will need to copy a set of spreadsheets for each group of students.

Safety Requirements

- If you are in an urban environment, and choose to have the students observe an actual intersection, take the appropriate precautions. Obtain permission from your school administrator prior to taking the class outside the building.
- Follow safe usage for the computers.

Meeting the Needs of All Students

Differentiated Instruction: Augmentation and Accommodations

Learning Issue	Reference	Augmentation and Accommodations
Copying tables	***Investigate*** Part A: Step 5.b)	**Augmentation** • For students with visual-motor, graphomotor, and focus issues, copying tables is a tedious and time-consuming task. Model how to draw a table with 4 columns and 5 rows without any data in it first. Then students can fill in the data from the table in a sequential way (top to bottom or left to right). **Accommodation** • Provide students with a blank table to fill in and tape into their logs.
Tracking information on a spreadsheet	***Investigate*** Part A: Steps 6-9	**Augmentation** • Students with visual integration and focus issues struggle to track and differentiate numbers that are close together in a spreadsheet. Provide students with a ruler or index card to assist in tracking the desired data. **Accommodation** • Provide students with an enlarged copy of the spreadsheet.
Finding patterns in numbers	***Investigate*** Part A: Steps 7.c) and 9	**Augmentation** • Students with math and visual-spatial issues struggle to see patterns in groups of numbers. Limit the amount of numbers in the list to allow students to find the pattern amongst three numbers instead of ten. Give three choices for the pattern and allow students time to find the correct pattern. **Accommodation** • Give students the pattern/formula and ask them to prove why that formula works, given the data in the spreadsheet.
Understanding the differentiation of the four zones	***Investigate*** Part B ***Physics Talk*** Yellow-Light Model ***Physics Essential Questions***	**Augmentation** • Students with reading comprehension issues may be confused by the introduction of two more zones in this section. Draw a diagram to show the GO and STOP Zones with an Overlap Zone and another diagram to show the GO and STOP Zones with a Dilemma Zone. • As a class, create a list of factors that affect and do not affect the size of the zones. This list will help students answer the *Physics Essential Questions.*
Completing a series of calculations	***Physics to Go*** Question 5	**Augmentation** • Remind students to use *Physics to Go,* Question 1, to assist them in performing these calculations. • Students have difficulty switching back and forth between equations. Encourage students to compute all of the GO Zones first and then compute the STOP Zones. **Accommodation** • Limit the number of computations by asking students with more learning issues to complete Questions 5.a), 5.b), and 5.c) only.

Strategies for Students with Limited English-Language Proficiency

Learning Issue	Reference	Augmentation and Accommodations
Vocabulary comprehension	***Investigate*** Introduction	Check students' understanding of "computer simulation." They should know that it is a model of a real-world system by a computer for the purposes of study.
Vocabulary comprehension	***Investigate*** Part A: Step 2.a)	Ask an ELL student to interpret *Step 2.a)* in his or her own words. Listen to be sure the student has correctly interpreted "cutoff" in context as a point on the road behind which a vehicle cannot safely make it through the intersection before the light turns red.
Understanding charts Vocabulary comprehension	***Investigate*** Part A: Step 5	Explain to students that an input-output chart is really just a cause-and-effect chart. A change to any of the input variables (the cause) can affect the size of a safe GO Zone or the STOP Zone (the effect). For example, an increase in speed (a cause) requires a larger GO Zone (the effect) for an automobile to proceed safely through the intersection while the light is yellow. The "boundaries" (real or imaginary lines that mark off an area) need to be moved accordingly.
Comprehension	***Investigate*** Part B: Step 4.d)	To comprehend "Overlap Zone" and "Dilemma Zone," students must have some understanding of the words "overlap," "dilemma," and "zone." An overlap is a space, or zone, held in common by two side-by-side areas. The Overlap Zone, then, is an area from which a vehicle can either safely proceed through the yellow light or stop safely before the light turns red. A dilemma is a situation in which you have a choice between two undesirable options. So, a Dilemma Zone is an area from which a vehicle can neither safely proceed through the yellow light nor stop safely before the light turns red.
Paraphrasing	***Physics Talk*** Checking Up	Have students answer the *Checking Up* questions in writing, so you can assess their ability to express in their own words what they have learned.
Understanding slang	***Active Physics Plus*** Steps 7 and 8	ELL students may not understand the phrase "step on it." Explain that it means press your foot more forcefully on the accelerator pedal to make the vehicle go faster. "Beat the light" means speeding up to try to get through the intersection before the light turns red, even if you were not in the GO Zone when the light turned yellow.

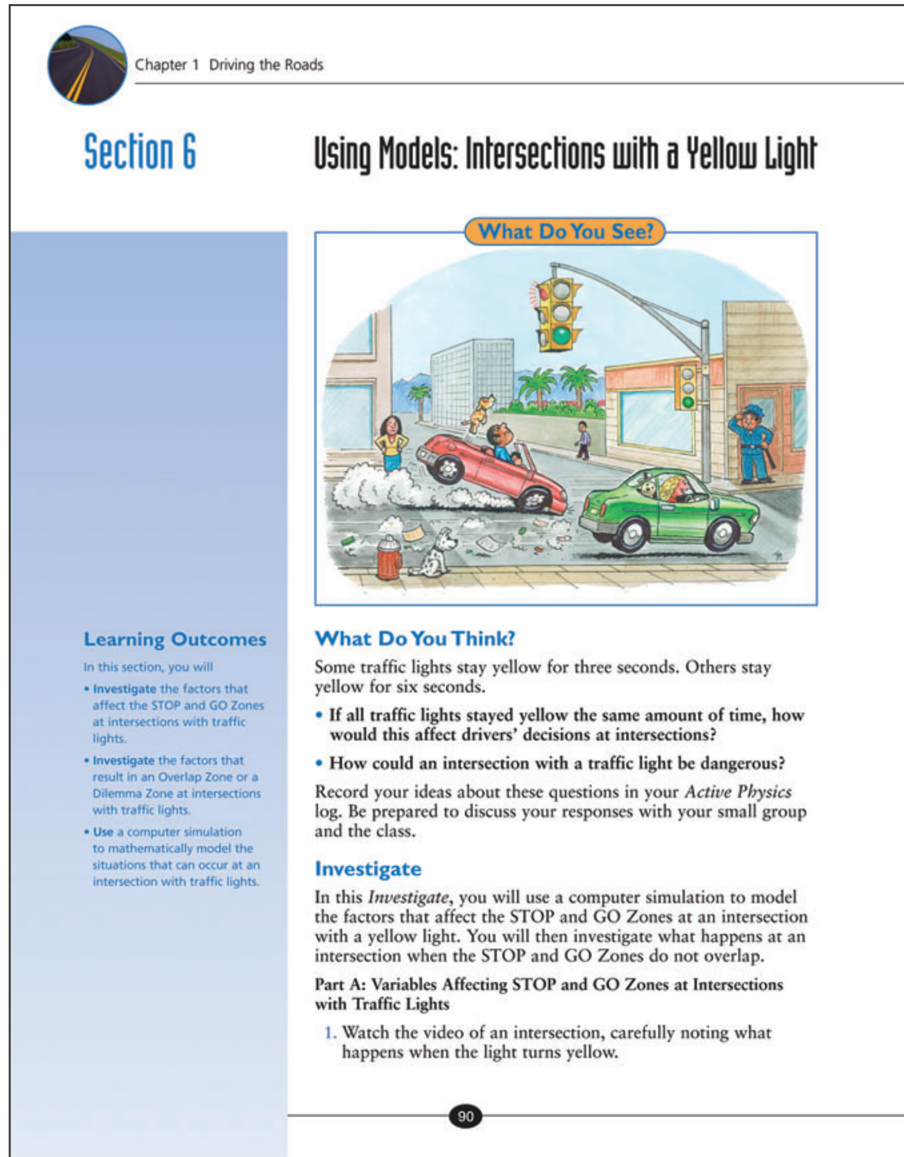
SECTION 6

Teaching Suggestions and Sample Answers

What Do You See?

The function of the *What Do You See?* illustration is to set the stage for further student inquiry. The automobile screeching to a halt or the automobile zooming though the intersection will most likely draw the student's attention. The vivid illustration is designed to stimulate student's curiosity about yellow-light time at traffic intersections.

As students respond in a discussion, direct their attention to different aspects of the visuals. You might want to ask them how the colors that the artist has used also contribute to the meaning of each visual. Ask them if the artist employs an element of humor to convey the main purpose of this illustration.



Chapter 1 Driving the Roads

Section 6 Using Models: Intersections with a Yellow Light

Learning Outcomes

In this section, you will

- **Investigate** the factors that affect the STOP and GO Zones at intersections with traffic lights.
- **Investigate** the factors that result in an Overlap Zone or a Dilemma Zone at intersections with traffic lights.
- **Use** a computer simulation to mathematically model the situations that can occur at an intersection with traffic lights.

What Do You Think?

Some traffic lights stay yellow for three seconds. Others stay yellow for six seconds.

- **If all traffic lights stayed yellow the same amount of time, how would this affect drivers' decisions at intersections?**
- **How could an intersection with a traffic light be dangerous?**

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.

Investigate

In this *Investigate*, you will use a computer simulation to model the factors that affect the STOP and GO Zones at an intersection with a yellow light. You will then investigate what happens at an intersection when the STOP and GO Zones do not overlap.

Part A: Variables Affecting STOP and GO Zones at Intersections with Traffic Lights

1. Watch the video of an intersection, carefully noting what happens when the light turns yellow.

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Students' Prior Conceptions

The student preconceptions identified in *Sections 1-6* may still persist, and is vital for the teacher to try to identify prior knowledge that may still not correlate with accepted theory. The prior conceptions focusing on inertia, forces, and friction are pertinent in *Section 6*. Because they were discussed previously, they will not be mentioned again. Students develop new analytical skills as they investigate the factors that result in an Overlap Zone or a Dilemma Zone at intersections with traffic lights. The use of computer simulations to mathematically model the situations addresses different styles of learning.

All seven stages of the 7E Learning Model apply to this section. One student prior conception dealing with friction should be emphasized.

1. **Friction always hinders motion; you always want to eliminate friction.** Frictional forces act to enable a vehicle to travel along the road as well as to enable a vehicle to stop. These forces allow vehicles to move forward, to back up, to negotiate curves, in addition to stopping motion. This phenomenon perplexes students who may consider friction as something that only impedes motion.

Encourage students to ponder the illustration with the title of the section in mind. Remind then that their impressions of the visuals will carry through to what they will be reading subsequently in the section.

What Do You Think?

These are questions that will have varied answers. Do not expect them to be correct. The purpose of these *What Do You Think?* questions is to make students reflect on how the length of the yellow-light time affects a driver's decision. Students should be encouraged to engage in discussing all the factors that drivers might consider when approaching a yellow light at an intersection.

What Do You Think?

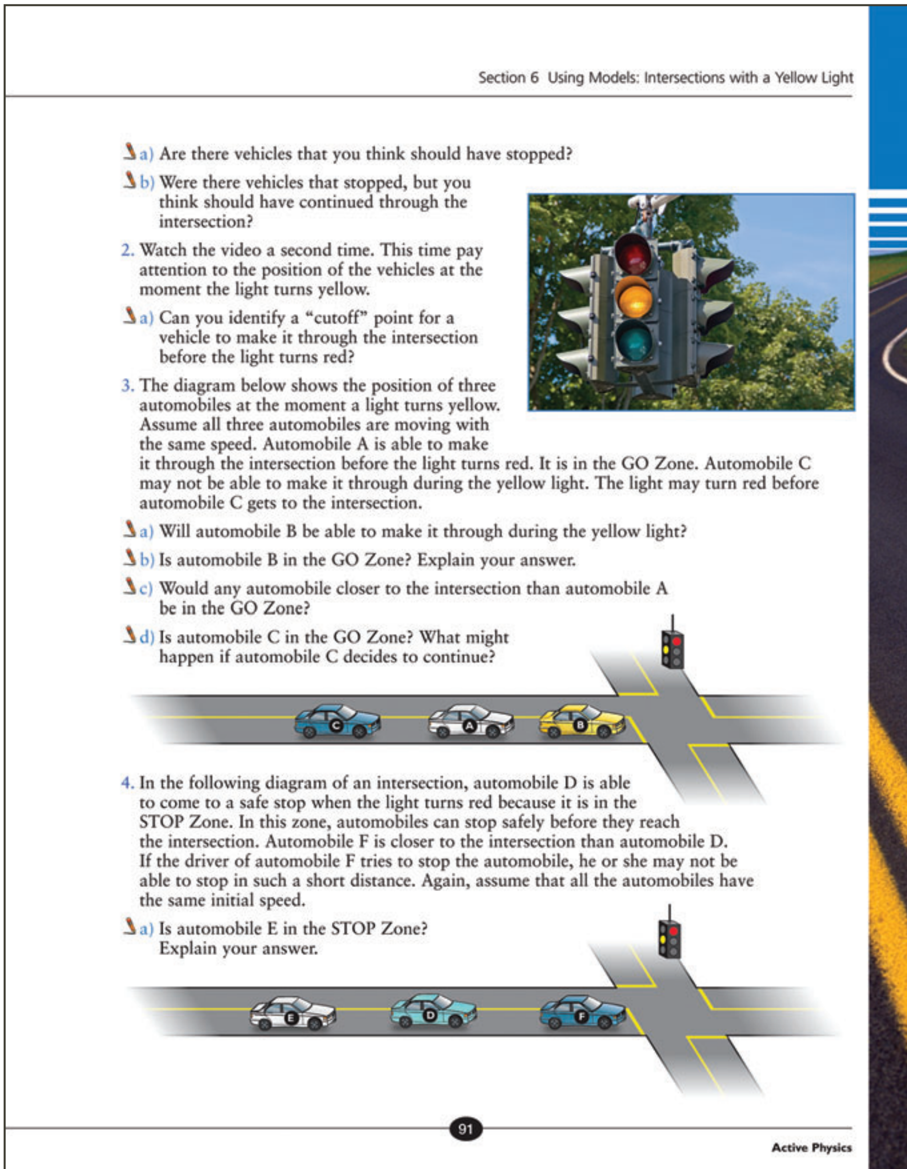
A Physicist's Response

If all traffic lights stayed yellow for the same amount of time, numerous problems could develop. For vehicles traveling across very wide intersections, or in areas with a low speed limit, there might not be sufficient time to clear the intersection before the light changed to red. For areas with a higher speed limit, vehicles might not have enough time to stop prior to the intersection if the yellow-light time were short. The advantage would be that drivers would know how long the light would be yellow, and might be able to plan accordingly.

Intersections with traffic lights could be dangerous because an automobile that did not clear the intersection before the light turned red might be struck by another vehicle that is starting to enter the intersection when the light turned green.

As students explore factors that affect the STOP and GO Zones at intersections with traffic lights, it is instructive to guide them to identify all forces acting on the vehicle, the direction in which these forces act, and their magnitude. The focus on reaction time or the time to stop, as implemented by braking (friction) or other interactions in the Dilemma Zone, is important to the student evaluation of the crash worthiness of a situation. What happens to the motion of the vehicle and to the state of the vehicle and its passengers when the interaction time with stopping forces is larger or smaller? How does friction affect the forward motion of the vehicle?

NOTES


Section 6 Using Models: Intersections with a Yellow Light

a) Are there vehicles that you think should have stopped?

b) Were there vehicles that stopped, but you think should have continued through the intersection?

2. Watch the video a second time. This time pay attention to the position of the vehicles at the moment the light turns yellow.

a) Can you identify a "cutoff" point for a vehicle to make it through the intersection before the light turns red?

3. The diagram below shows the position of three automobiles at the moment a light turns yellow. Assume all three automobiles are moving with the same speed. Automobile A is able to make it through the intersection before the light turns red. It is in the GO Zone. Automobile C may not be able to make it through during the yellow light. The light may turn red before automobile C gets to the intersection.

a) Will automobile B be able to make it through during the yellow light?

b) Is automobile B in the GO Zone? Explain your answer.

c) Would any automobile closer to the intersection than automobile A be in the GO Zone?

d) Is automobile C in the GO Zone? What might happen if automobile C decides to continue?

4. In the following diagram of an intersection, automobile D is able to come to a safe stop when the light turns red because it is in the STOP Zone. In this zone, automobiles can stop safely before they reach the intersection. Automobile F is closer to the intersection than automobile D. If the driver of automobile F tries to stop the automobile, he or she may not be able to stop in such a short distance. Again, assume that all the automobiles have the same initial speed.

a) Is automobile E in the STOP Zone? Explain your answer.

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Active Physics

Investigate

Part A: Variables Affecting STOP and GO Zones at Intersections with Traffic Lights

1.a)-b)

Student observations and responses will vary.

Teaching Tip

Have students record their responses to the questions before viewing the video a second time. You may wish to work through the first few examples with the entire class, so you can be sure that the students understand the concept of the STOP and GO Zones.

2.a)

Student observations and responses will vary.

3.a)

Yes.

3.b)

Yes. Because automobile B is closer to the intersection than automobile A, it must be in the GO Zone.

3.c)

Yes.

3.d)

Not sure. It could be, but you can't tell from the data provided. It probably is not. It would be dangerous for the automobile to try.

4.a)

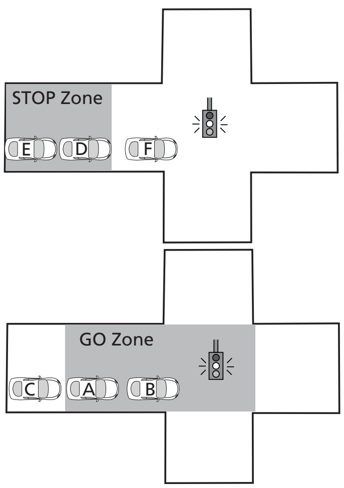
Yes. It is farther away from the intersection than automobile D, and if automobile D can stop, so should automobile E.

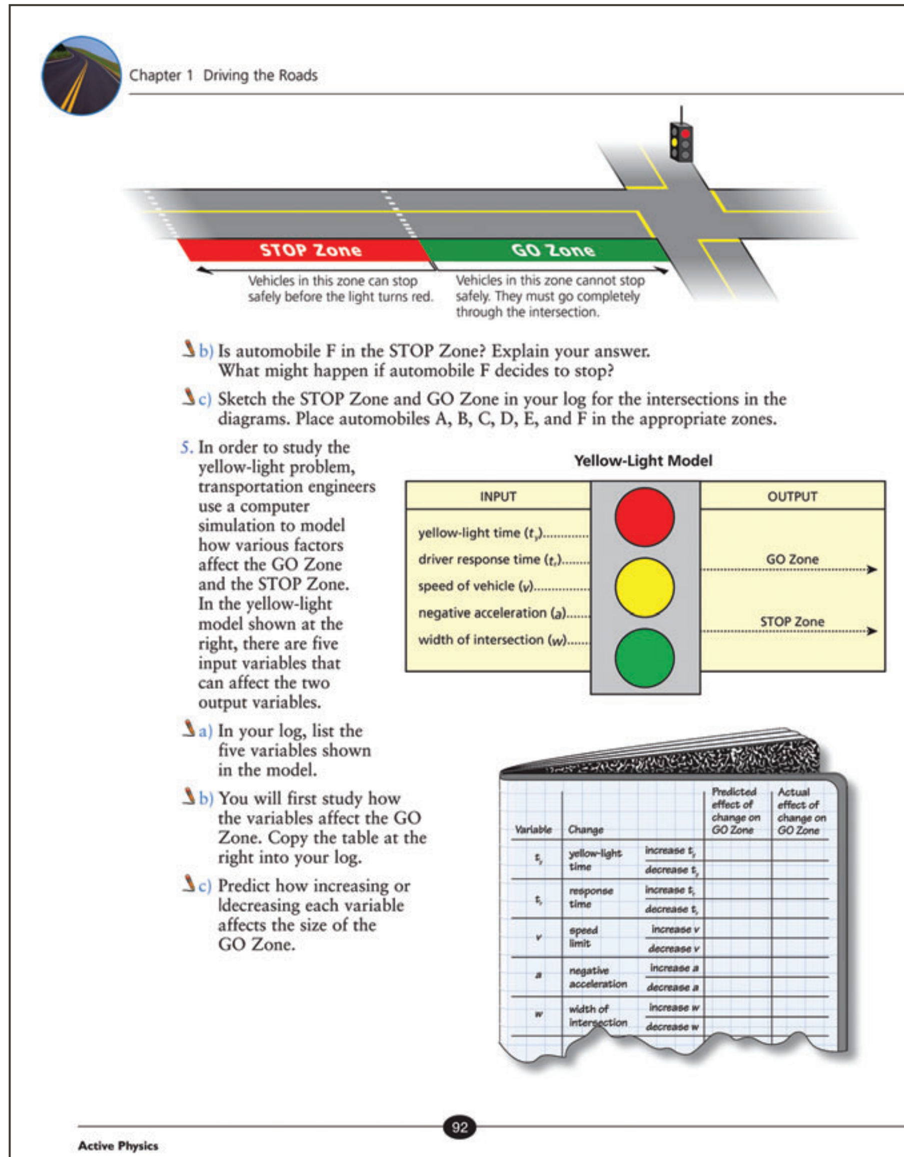
4.b)

Not sure. It could be, but you can't tell from the data provided. It appears to be too close to the intersection to stop safely.

4.c)

Student sketches should resemble the diagrams below.




Chapter 1 Driving the Roads

STOP Zone

GO Zone

Vehicles in this zone can stop safely before the light turns red.

Vehicles in this zone cannot stop safely. They must go completely through the intersection.

b) Is automobile F in the STOP Zone? Explain your answer. What might happen if automobile F decides to stop?

c) Sketch the STOP Zone and GO Zone in your log for the intersections in the diagrams. Place automobiles A, B, C, D, E, and F in the appropriate zones.

5. In order to study the yellow-light problem, transportation engineers use a computer simulation to model how various factors affect the GO Zone and the STOP Zone. In the yellow-light model shown at the right, there are five input variables that can affect the two output variables.

Yellow-Light Model

INPUT	OUTPUT
yellow-light time (t_y)	GO Zone
driver response time (t_r)	
speed of vehicle (v)	
negative acceleration (a)	STOP Zone
width of intersection (w)	

a) In your log, list the five variables shown in the model.

b) You will first study how the variables affect the GO Zone. Copy the table at the right into your log.

c) Predict how increasing or ldecreasing each variable affects the size of the GO Zone.

Variable	Change		Predicted effect of change on GO Zone	Actual effect of change on GO Zone
t_y	yellow-light time	increase t_y		
		decrease t_y		
t_r	response time	increase t_r		
		decrease t_r		
v	speed limit	increase v		
		decrease v		
a	negative acceleration	increase a		
		decrease a		
w	width of intersection	increase w		
		decrease w		

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Active Physics

5.a)

Yellow-light time, driver reaction time, speed of vehicle, negative acceleration rate, width of intersection.

5.b)

Students copy table.

5.c)

Student predictions will vary. The predictions should include the following:

Variable	Change	Predicted Effect of the change on the GO Zone	Actual Effect of the change on the GO Zone
yellow light time (t_y)	increase t_y decrease t_y	Student prediction	Increase Decrease
response time (t_r)	increase t_r decrease t_r	Student prediction	No change No change
speed (v)	increase v decrease v	Student prediction	Increase Decrease
negative acceleration rate (a)	increase a decrease a	Student prediction	No change No change
width of intersection (w)	increase w decrease w	Student prediction	Decrease Increase

Remember to consider one variable at a time. The other four variables will stay constant. For example, if the time the light is yellow increases from 3 s to 3.5 s, how will the boundaries and size of the GO Zone change? Will the zone increase or decrease? Record your predictions.

6. Look at the copies of the following spreadsheets.

	A	B	C	D	E	F	G
1	INPUT VARIABLES					OUTPUT	
2							
3	yellow-light time (t_y)	3	seconds				
4	human-response time (t_r)	1	seconds	YELLOW	53	meters	GO Zone
5	speed of vehicle (v)	20	m/s	LIGHT	60	meters	STOP Zone
6	negative acceleration rate (a)	5	m/s/s	MODEL			
7	width of intersection (w)	7	meters				
8							
9							

	A	B	C	D	E	F	G
1	INPUT VARIABLES					OUTPUT	
2							
3	yellow-light time (t_y)	3.5	seconds				
4	human-response time (t_r)	1	seconds	YELLOW	63	meters	GO Zone
5	speed of vehicle (v)	20	m/s	LIGHT	60	meters	STOP Zone
6	negative acceleration rate (a)	5	m/s/s	MODEL			
7	width of intersection (w)	7	meters				
8							
9							

a) What is the distance of the GO Zone if the yellow-light time is 3 s?

b) What happens to the GO Zone when the yellow-light time is increased to 3.5 s?

c) Would increasing the yellow-light time allow you to get through the intersection from a further distance away? Explain your answer in your log.

d) Record the effect of changing the yellow-light time in your log.

7. Use a computer spreadsheet program to obtain quantitative data (numbers you can use to test your predictions). Remember to change only one variable at a time. For each variable you investigate, record the following:

a) Did the effect of the change of the variable make sense to you? Explain your answer.

b) Record the effect of changing each variable in your *Active Physics* log. How did the actual effect compare with your predictions in *Step 5.c*)?

6.a)

53 m.

6.b)

The GO Zone increases to 63 m.

6.c)

Yes, increasing the yellow-light time will allow more time to get through the intersection, so the driver will have a larger GO Zone.

6.d)

The students will see from the spreadsheet that increasing the yellow-light time increases the GO Zone.

7.a)

Students record their response.

7.b)

Students will respond either in agreement with their predictions, or with a correction of an incorrect prediction.

CHAPTER 1

7.c)

GO Zone = $vt_y - w$ =
(speed of car × yellow-light time)
– width of intersection

7.d)

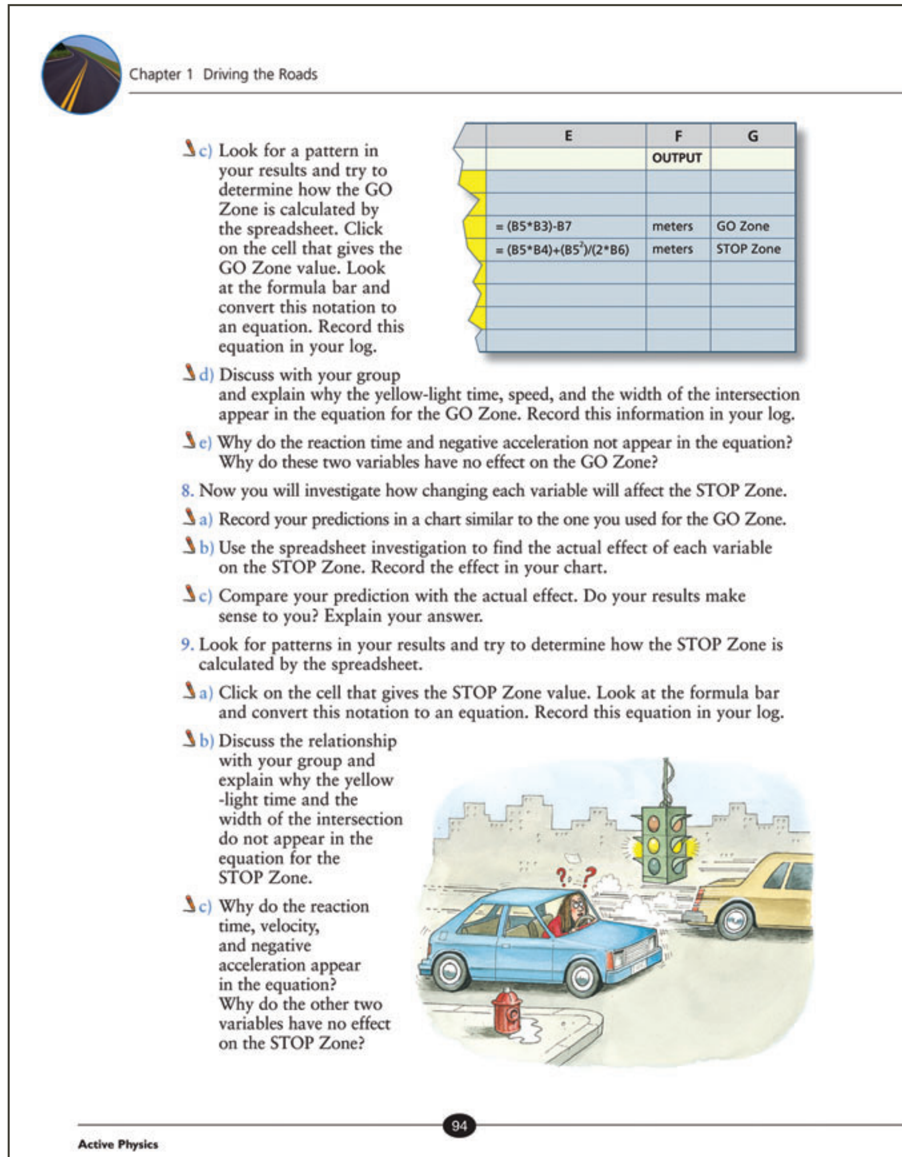
By increasing the yellow-light time, there is more time to get through the yellow light safely. If there is more time, then at the same speed, you can cover a greater distance. Thus, the GO Zone increases. By increasing the speed, you can cover a greater distance in a shorter time; therefore, the GO Zone increases. The wider the intersection, the greater the distance that needs to be covered; therefore, the GO Zone is smaller.

7.e)

For the GO Zone, the driver does not have a reaction time because it is associated with how long it takes the driver to react to the yellow light and apply the brakes. Likewise, braking (negative acceleration) doesn't occur when the driver is in the GO Zone.

8.a)

Student predictions should be recorded in the STOP Zone chart below.



Chapter 1 Driving the Roads

c) Look for a pattern in your results and try to determine how the GO Zone is calculated by the spreadsheet. Click on the cell that gives the GO Zone value. Look at the formula bar and convert this notation to an equation. Record this equation in your log.

E	F	G
	OUTPUT	
= (B5*B3)-B7	meters	GO Zone
= (B5*B4)+(B5²)/(2*B6)	meters	STOP Zone

d) Discuss with your group and explain why the yellow-light time, speed, and the width of the intersection appear in the equation for the GO Zone. Record this information in your log.

e) Why do the reaction time and negative acceleration not appear in the equation? Why do these two variables have no effect on the GO Zone?

8. Now you will investigate how changing each variable will affect the STOP Zone.

a) Record your predictions in a chart similar to the one you used for the GO Zone.

b) Use the spreadsheet investigation to find the actual effect of each variable on the STOP Zone. Record the effect in your chart.

c) Compare your prediction with the actual effect. Do your results make sense to you? Explain your answer.

9. Look for patterns in your results and try to determine how the STOP Zone is calculated by the spreadsheet.

a) Click on the cell that gives the STOP Zone value. Look at the formula bar and convert this notation to an equation. Record this equation in your log.

b) Discuss the relationship with your group and explain why the yellow -light time and the width of the intersection do not appear in the equation for the STOP Zone.

c) Why do the reaction time, velocity, and negative acceleration appear in the equation? Why do the other two variables have no effect on the STOP Zone?

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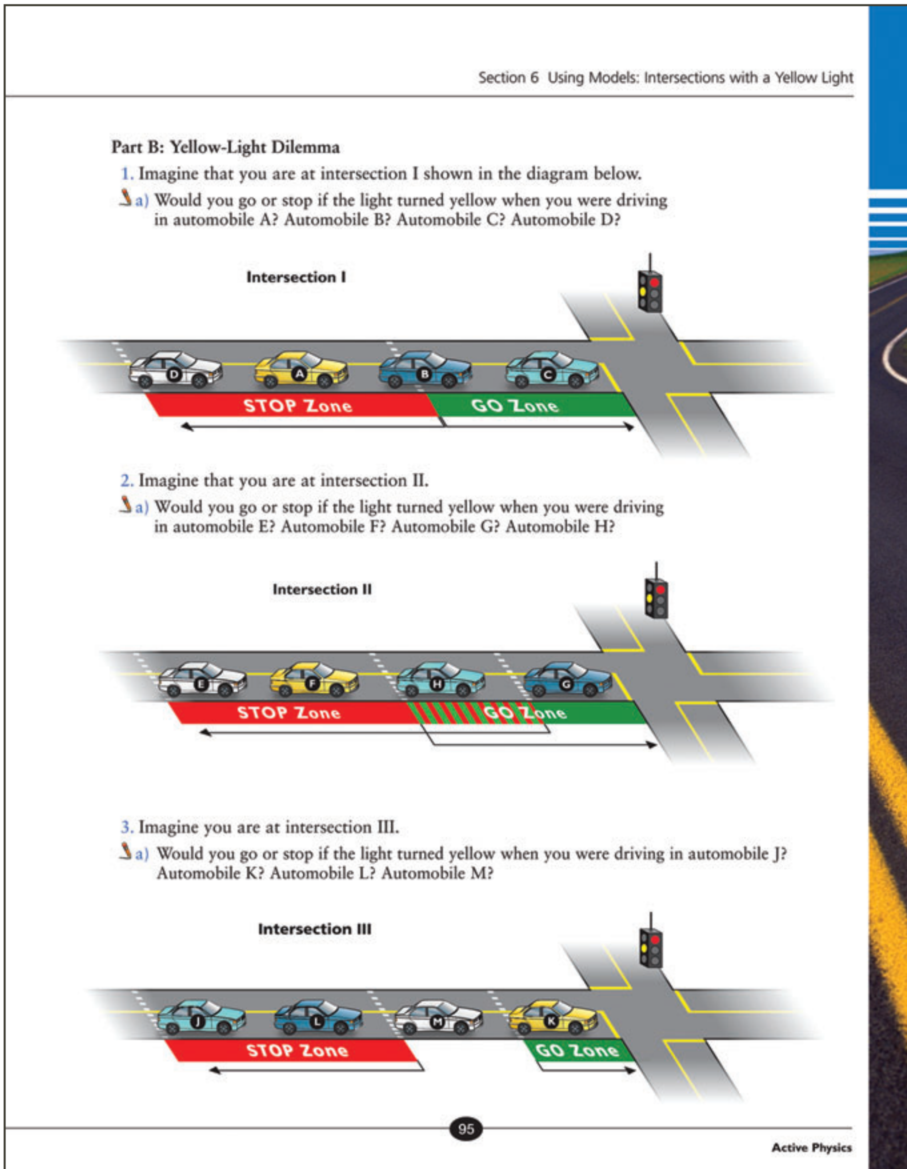
Variable	Change	Predicted Effect of change on the STOP Zone	Actual Effect of the change on the STOP Zone
yellow light time (t_y)	increase t_y decrease t_y	Student prediction	No change No change
response time (t_r)	increase t_r decrease t_r	Student prediction	Increase Decrease
speed (v)	increase v decrease v	Student prediction	Increase Decrease
negative acceleration rate (a)	increase a decrease a	Student prediction	Decrease Increase
width of intersection (w)	increase w decrease w	Student prediction	No change No change

8.b)

Students will use the spreadsheet to verify their answers and record them in the column for "Actual Effect of the Change on the STOP Zone."

8.c)

While responding, students should look for understanding of why the width of the intersection and the yellow-light time do not affect the STOP Zone.


Section 6 Using Models: Intersections with a Yellow Light

Part B: Yellow-Light Dilemma

1. Imagine that you are at intersection I shown in the diagram below.

a) Would you go or stop if the light turned yellow when you were driving in automobile A? Automobile B? Automobile C? Automobile D?

2. Imagine that you are at intersection II.

a) Would you go or stop if the light turned yellow when you were driving in automobile E? Automobile F? Automobile G? Automobile H?

3. Imagine you are at intersection III.

a) Would you go or stop if the light turned yellow when you were driving in automobile J? Automobile K? Automobile L? Automobile M?

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9.a)

Students record equations from spreadsheet.

9.b)

Students should recognize that the formula for stopping distance is the distance traveled during the reaction time plus the braking distance as shown in the equation below.

(speed of car × reaction time) +
(speed × speed) ÷
(2 × negative accleration)

9.c)

The reaction time and automobile speed determine how far an automobile travels toward the intersection before the brakes are applied, and the speed and the negative acceleration determine the braking distance. The length of time the light stays yellow does not affect the distance in which you can stop. Also, the width of the intersection has no effect on the distance required to stop.

Part B: Yellow-Light Dilemma

1.a)

The driver would stop in automobile A, would go in automobile B, would go in automobile C, and would stop in automobile D.

2.a)

The driver would stop in automobile E, would stop in automobile F, would go in automobile G, and would stop or go in automobile H.

3.a)

The driver would stop in automobile J, would go in automobile K, would stop in automobile L, and would not be able to stop or go safely in automobile M.

4.a)

In Intersection II, the GO Zone and the STOP Zone overlap. In Intersection III, there is a gap between the two zones.

4.b)

The choice would be either to stop or to go. Both choices are safe because the car is in both the STOP and GO Zones.

4.c)

The choice would be either to stop or to go. Neither choice would be safe because the car is in neither the STOP nor the GO Zone.

4.d)

Intersection II has an Overlap Zone, and Intersection III has a Dilemma Zone.

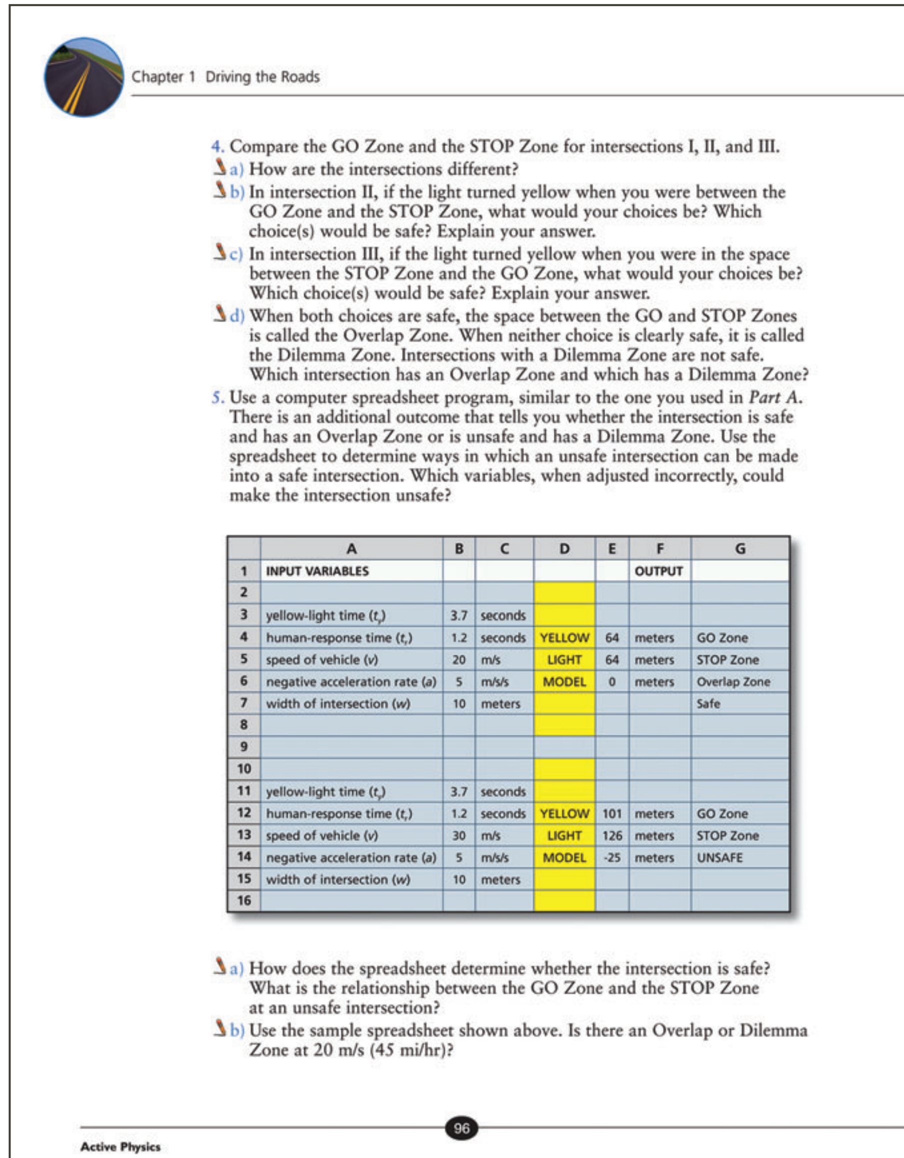
5.a)

The spreadsheet calculates the difference between the GO and STOP Zones. If there is a negative value between the STOP and GO Zones, the intersection is unsafe.

5.b)

No, there is no Overlap or Dilemma Zone at 20 m/s (45 mi/h).

1-6a Blackline Master



Chapter 1 Driving the Roads

4. Compare the GO Zone and the STOP Zone for intersections I, II, and III.
   a) How are the intersections different?
   b) In intersection II, if the light turned yellow when you were between the GO Zone and the STOP Zone, what would your choices be? Which choice(s) would be safe? Explain your answer.
   c) In intersection III, if the light turned yellow when you were in the space between the STOP Zone and the GO Zone, what would your choices be? Which choice(s) would be safe? Explain your answer.
   d) When both choices are safe, the space between the GO and STOP Zones is called the Overlap Zone. When neither choice is clearly safe, it is called the Dilemma Zone. Intersections with a Dilemma Zone are not safe. Which intersection has an Overlap Zone and which has a Dilemma Zone?
5. Use a computer spreadsheet program, similar to the one you used in *Part A*. There is an additional outcome that tells you whether the intersection is safe and has an Overlap Zone or is unsafe and has a Dilemma Zone. Use the spreadsheet to determine ways in which an unsafe intersection can be made into a safe intersection. Which variables, when adjusted incorrectly, could make the intersection unsafe?

	A	B	C	D	E	F	G
1	INPUT VARIABLES					OUTPUT	
2							
3	yellow-light time (t_y)	3.7	seconds				
4	human-response time (t_r)	1.2	seconds	YELLOW	64	meters	GO Zone
5	speed of vehicle (v)	20	m/s	LIGHT	64	meters	STOP Zone
6	negative acceleration rate (a)	5	m/s/s	MODEL	0	meters	Overlap Zone
7	width of intersection (w)	10	meters				Safe
8							
9							
10							
11	yellow-light time (t_y)	3.7	seconds				
12	human-response time (t_r)	1.2	seconds	YELLOW	101	meters	GO Zone
13	speed of vehicle (v)	30	m/s	LIGHT	126	meters	STOP Zone
14	negative acceleration rate (a)	5	m/s/s	MODEL	-25	meters	UNSAFE
15	width of intersection (w)	10	meters				
16							

   a) How does the spreadsheet determine whether the intersection is safe? What is the relationship between the GO Zone and the STOP Zone at an unsafe intersection?
   b) Use the sample spreadsheet shown above. Is there an Overlap or Dilemma Zone at 20 m/s (45 mi/hr)?

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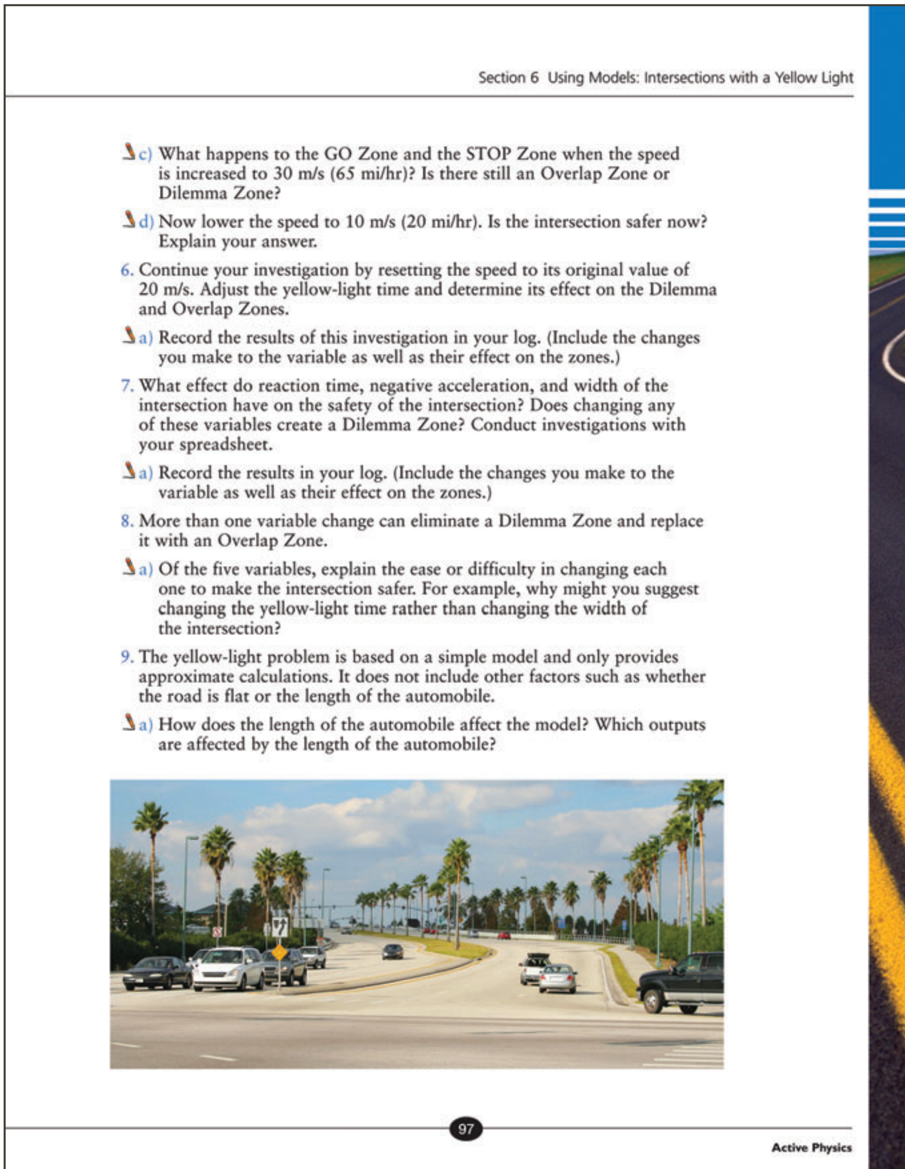

Section 6 Using Models: Intersections with a Yellow Light

c) What happens to the GO Zone and the STOP Zone when the speed is increased to 30 m/s (65 mi/hr)? Is there still an Overlap Zone or Dilemma Zone?

d) Now lower the speed to 10 m/s (20 mi/hr). Is the intersection safer now? Explain your answer.

6. Continue your investigation by resetting the speed to its original value of 20 m/s. Adjust the yellow-light time and determine its effect on the Dilemma and Overlap Zones.

a) Record the results of this investigation in your log. (Include the changes you make to the variable as well as their effect on the zones.)

7. What effect do reaction time, negative acceleration, and width of the intersection have on the safety of the intersection? Does changing any of these variables create a Dilemma Zone? Conduct investigations with your spreadsheet.

a) Record the results in your log. (Include the changes you make to the variable as well as their effect on the zones.)

8. More than one variable change can eliminate a Dilemma Zone and replace it with an Overlap Zone.

a) Of the five variables, explain the ease or difficulty in changing each one to make the intersection safer. For example, why might you suggest changing the yellow-light time rather than changing the width of the intersection?

9. The yellow-light problem is based on a simple model and only provides approximate calculations. It does not include other factors such as whether the road is flat or the length of the automobile.

a) How does the length of the automobile affect the model? Which outputs are affected by the length of the automobile?

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5.c)

Both the GO Zone and the STOP Zone increase. There is a Dilemma Zone.

5.d)

The GO Zone becomes 27 m and the STOP Zone is 22 m. The Overlap Zone is 5 m, so the intersection is safer.

6.

Students record their observations. Changing the yellow-light time changes the GO Zone, so when it overlaps the STOP Zone the intersection is safe, but it creates a Dilemma Zone, which is unsafe.

7.a)

Students record the results in their logs. They need to see that increasing the GO Zone to at least the STOP Zone will eliminate the Dilemma Zone. Therefore, decreasing width, decreasing reaction time, and increasing the negative acceleration rate will make the intersection safer by eliminating the Dilemma Zone.

8.a)

Reaction time is hard to change. The width of an intersection is very difficult to change, as it involves rebuilding the road. The speed limit on the road could be changed, but it is difficult to enforce it at all intersections. The negative acceleration rate of vehicles is very difficult to change because different vehicles have different deceleration rates, plus the rate changes depending on the weather, road surface, hills, temperature of tires and road, etc. The easiest variable to change would be the yellow-light time. This might involve only changing a timer or, at a central location, reprogramming a computer.

9.a)

The length of the automobile is affected by the width of the intersection as it takes a longer period to clear the intersection. Therefore, the output which is affected would be the GO Zone.

CHAPTER 1

Physics Talk

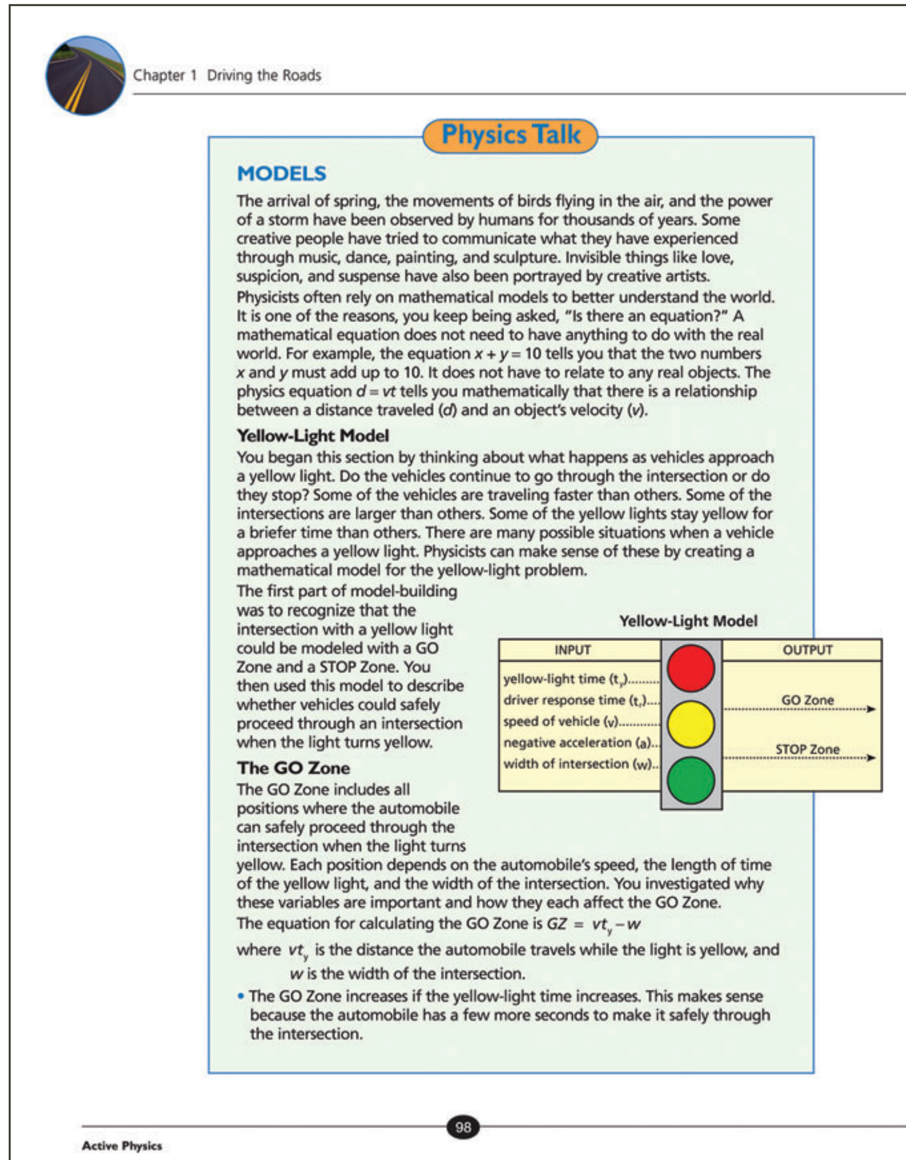
The *Physics Talk* highlights the importance of models. Ask students to give you some examples of scientific models that have helped them understand their world. Write up a list of their responses on the board. It is important that they discuss how these models serve to explain scientific ideas. Highlight the significance of the yellow-light model to demonstrate how automobiles can safely pass through an intersection and how engineers use this model to determine if an intersection is safe or how it could be made safer.

Revisit the variables that affect the GO Zone, discuss each variable listed in the *Physics Talk*, and ask students to record how these variables affect the GO Zone in their *Active Physics* logs. Discuss why braking acceleration and a driver's reaction time are variables that don't affect the GO Zone. Determine if students understand the effect of intersection width on the GO Zone.

When discussing the STOP Zone, refer to the spreadsheet model and have students assess which variables would affect the STOP Zone. Ask them to explain why the width of the intersection and the yellow-light time have no effect on the STOP Zone. Consider giving a quiz with different features of the STOP Zone and GO Zone. Make sure they are also aware of the variables that do not affect the STOP Zone.

For Overlap and Dilemma Zones, consider inviting a student to draw a diagram of an Overlap Zone on the board. Then ask each student in the class to draw a diagram that shows an intersection with a Dilemma Zone. Allow students time to focus on the difference between a Dilemma Zone and an Overlap Zone by giving them assignments that require a detailed description of an Overlap Zone and a Dilemma Zone. You could ask them why an Overlap Zone makes an intersection safer, while a Dilemma Zone makes an intersection unsafe. Students will benefit by summarizing the meaning of a Dilemma Zone and an Overlap Zone in their *Active Physics* logs.

While analyzing models, ask students to explain why they developed a yellow-light model and how this model helps traffic engineers. Discuss the limitations of a yellow-light model and have students consider situations in which the yellow-light model is limited in its use. Emphasize that a model is not the same as an actual event; a model describes and analyzes an event.


Chapter 1 Driving the Roads

Physics Talk

MODELS

The arrival of spring, the movements of birds flying in the air, and the power of a storm have been observed by humans for thousands of years. Some creative people have tried to communicate what they have experienced through music, dance, painting, and sculpture. Invisible things like love, suspicion, and suspense have also been portrayed by creative artists.

Physicists often rely on mathematical models to better understand the world. It is one of the reasons, you keep being asked, "Is there an equation?" A mathematical equation does not need to have anything to do with the real world. For example, the equation $x + y = 10$ tells you that the two numbers x and y must add up to 10. It does not have to relate to any real objects. The physics equation $d = vt$ tells you mathematically that there is a relationship between a distance traveled (d) and an object's velocity (v).

Yellow-Light Model

You began this section by thinking about what happens as vehicles approach a yellow light. Do the vehicles continue to go through the intersection or do they stop? Some of the vehicles are traveling faster than others. Some of the intersections are larger than others. Some of the yellow lights stay yellow for a briefer time than others. There are many possible situations when a vehicle approaches a yellow light. Physicists can make sense of these by creating a mathematical model for the yellow-light problem.

The first part of model-building was to recognize that the intersection with a yellow light could be modeled with a GO Zone and a STOP Zone. You then used this model to describe whether vehicles could safely proceed through an intersection when the light turns yellow.

The GO Zone

The GO Zone includes all positions where the automobile can safely proceed through the intersection when the light turns yellow. Each position depends on the automobile's speed, the length of time of the yellow light, and the width of the intersection. You investigated why these variables are important and how they each affect the GO Zone.

The equation for calculating the GO Zone is $GZ = vt_y - w$

where vt_y is the distance the automobile travels while the light is yellow, and w is the width of the intersection.

- The GO Zone increases if the yellow-light time increases. This makes sense because the automobile has a few more seconds to make it safely through the intersection.

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- The GO Zone decreases if the width of the intersection increases because the vehicle has to travel a greater distance to safely go through the intersection at the same speed.
- The GO Zone increases with an increase in speed because the vehicle can travel a greater distance during the time that the light is yellow.
- The braking acceleration does not affect the GO Zone because vehicles trying to go through the intersection do not use the brakes.
- The driver's reaction time is also not important because a driver who is going to continue through the intersection does not have to decide to use the brakes and move from the gas to the brake.

The STOP Zone

The STOP Zone includes all positions where the car can safely stop before reaching the intersection. Each position depends on the vehicle's speed, the braking acceleration, and the driver's reaction time. You investigated why these variables are important and how they each affect the STOP Zone.

The equation for calculating the STOP Zone is $SZ = vt_r + \frac{v^2}{2a}$

where vt_r is the distance the vehicle travels as the driver decides to stop (the reaction distance), and

$\frac{v^2}{2a}$ is the braking distance.

- The STOP Zone decreases if the speed decreases. A slower-moving vehicle can be closer to the intersection and still stop safely.
- The STOP Zone decreases if the braking acceleration increases. Better brakes means that a vehicle can stop in a shorter distance.
- The STOP Zone decreases if the human reaction time decreases. The faster someone can react and move the foot from the gas to the brake, the smaller the distance required to stop.
- The width of the intersection does not affect the STOP Zone. Because vehicles in the STOP Zone do not enter the intersection, the size of the intersection does not matter.
- The yellow-light time does not affect the STOP Zone. Because you are stopping your vehicle, it does not matter how long the light stays yellow.

Overlap Zone and Dilemma Zone

A properly designed yellow-light intersection must be safe for drivers when they are obeying the posted speed limits. For this reason, the STOP and GO Zones are adjusted so that a driver can either safely stop the vehicle before the intersection when the light turns yellow, or safely proceed through the intersection before the light turns red. The STOP and GO Zones must form an Overlap Zone. In the Overlap Zone, when the light turns yellow, the driver of the vehicle has the choice of either stopping or going through the intersection safely before the light turns red.

CHAPTER 1

Checking Up

1.

The spreadsheet is referred to as a model because it is used to represent the STOP and GO Zones of an intersection with a yellow light.

2.

The GO Zone is an area in an intersection which includes all positions through which a vehicle can pass safely.

3.

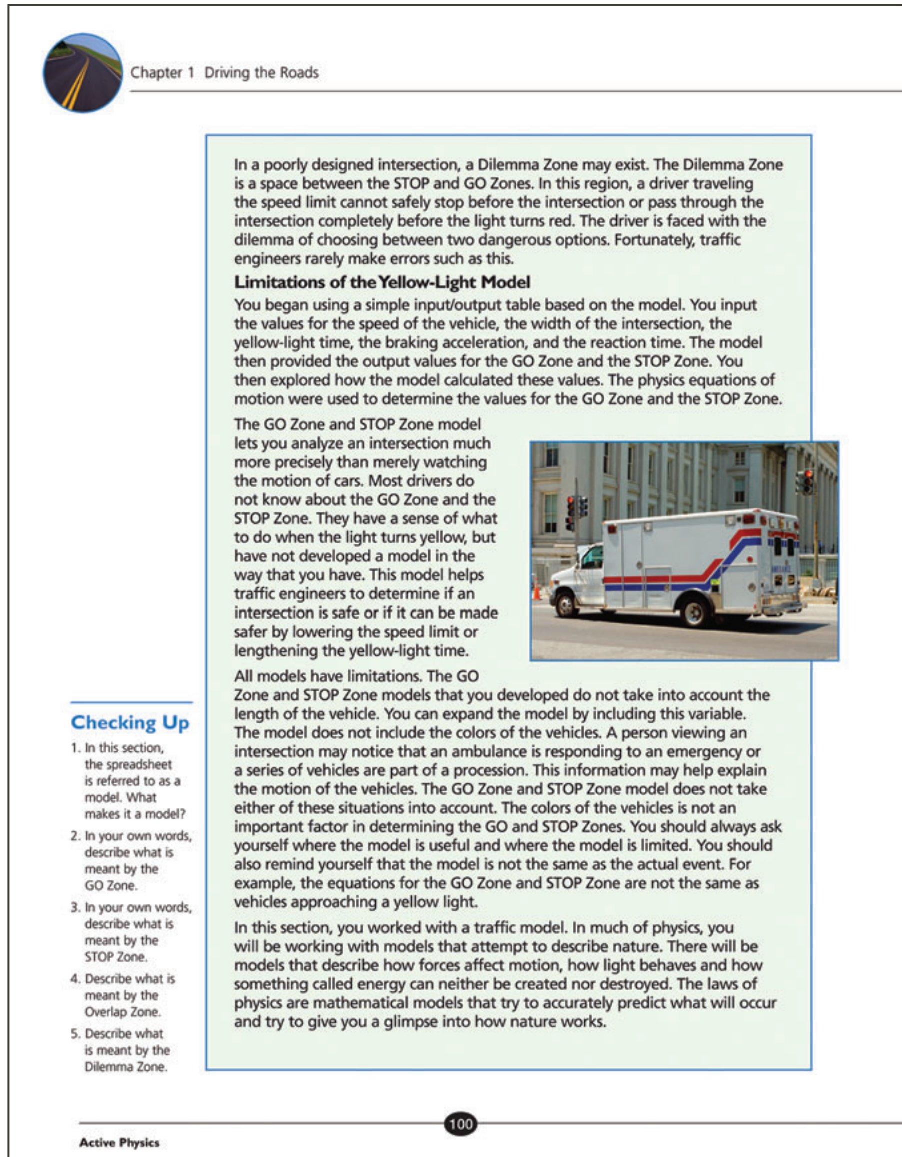
The STOP Zone is an area in an intersection where the automobile can safely stop before reaching the intersection.

4.

The Overlap Zone is an area where the STOP and GO Zones overlap, and the driver has the safe choice of either making it through the intersection or stopping before a red light.

5.

When the STOP and GO Zones are separated by a space, the space represents an area where it is unsafe for vehicles to pass through if the light turns yellow. This zone poses a dilemma between two dangerous choices: to pass through or stop before the light turns red.



Chapter 1 Driving the Roads

In a poorly designed intersection, a Dilemma Zone may exist. The Dilemma Zone is a space between the STOP and GO Zones. In this region, a driver traveling the speed limit cannot safely stop before the intersection or pass through the intersection completely before the light turns red. The driver is faced with the dilemma of choosing between two dangerous options. Fortunately, traffic engineers rarely make errors such as this.

Limitations of the Yellow-Light Model

You began using a simple input/output table based on the model. You input the values for the speed of the vehicle, the width of the intersection, the yellow-light time, the braking acceleration, and the reaction time. The model then provided the output values for the GO Zone and the STOP Zone. You then explored how the model calculated these values. The physics equations of motion were used to determine the values for the GO Zone and the STOP Zone.

The GO Zone and STOP Zone model lets you analyze an intersection much more precisely than merely watching the motion of cars. Most drivers do not know about the GO Zone and the STOP Zone. They have a sense of what to do when the light turns yellow, but have not developed a model in the way that you have. This model helps traffic engineers to determine if an intersection is safe or if it can be made safer by lowering the speed limit or lengthening the yellow-light time.

All models have limitations. The GO Zone and STOP Zone models that you developed do not take into account the length of the vehicle. You can expand the model by including this variable. The model does not include the colors of the vehicles. A person viewing an intersection may notice that an ambulance is responding to an emergency or a series of vehicles are part of a procession. This information may help explain the motion of the vehicles. The GO Zone and STOP Zone model does not take either of these situations into account. The colors of the vehicles is not an important factor in determining the GO and STOP Zones. You should always ask yourself where the model is useful and where the model is limited. You should also remind yourself that the model is not the same as the actual event. For example, the equations for the GO Zone and STOP Zone are not the same as vehicles approaching a yellow light.

In this section, you worked with a traffic model. In much of physics, you will be working with models that attempt to describe nature. There will be models that describe how forces affect motion, how light behaves and how something called energy can neither be created nor destroyed. The laws of physics are mathematical models that try to accurately predict what will occur and try to give you a glimpse into how nature works.

Checking Up

1. In this section, the spreadsheet is referred to as a model. What makes it a model?
2. In your own words, describe what is meant by the GO Zone.
3. In your own words, describe what is meant by the STOP Zone.
4. Describe what is meant by the Overlap Zone.
5. Describe what is meant by the Dilemma Zone.

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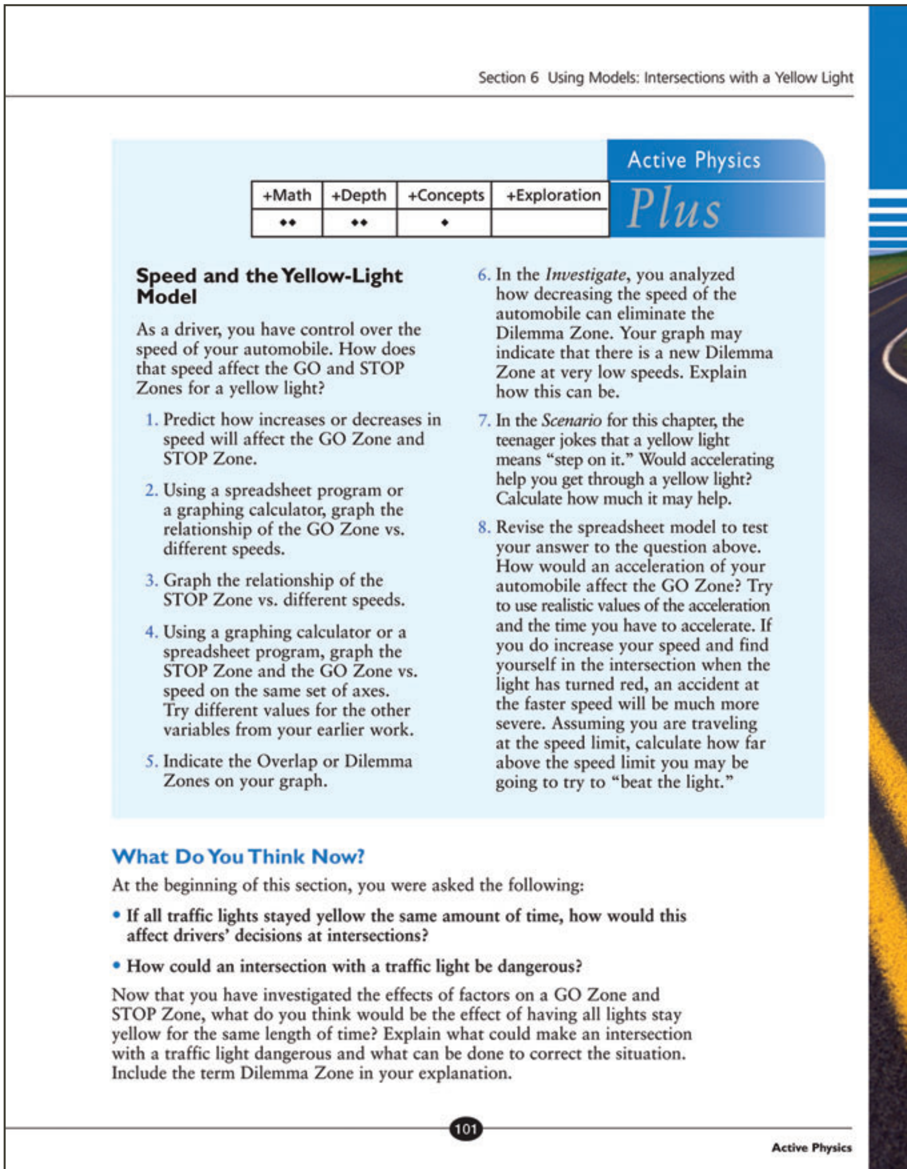


Active Physics *Plus*

+Math	+Depth	+Concepts	+Exploration
••	••	•	

Speed and the Yellow-Light Model

As a driver, you have control over the speed of your automobile. How does that speed affect the GO and STOP Zones for a yellow light?

1. Predict how increases or decreases in speed will affect the GO Zone and STOP Zone.
2. Using a spreadsheet program or a graphing calculator, graph the relationship of the GO Zone vs. different speeds.
3. Graph the relationship of the STOP Zone vs. different speeds.
4. Using a graphing calculator or a spreadsheet program, graph the STOP Zone and the GO Zone vs. speed on the same set of axes. Try different values for the other variables from your earlier work.
5. Indicate the Overlap or Dilemma Zones on your graph.
6. In the *Investigate*, you analyzed how decreasing the speed of the automobile can eliminate the Dilemma Zone. Your graph may indicate that there is a new Dilemma Zone at very low speeds. Explain how this can be.
7. In the *Scenario* for this chapter, the teenager jokes that a yellow light means "step on it." Would accelerating help you get through a yellow light? Calculate how much it may help.
8. Revise the spreadsheet model to test your answer to the question above. How would an acceleration of your automobile affect the GO Zone? Try to use realistic values of the acceleration and the time you have to accelerate. If you do increase your speed and find yourself in the intersection when the light has turned red, an accident at the faster speed will be much more severe. Assuming you are traveling at the speed limit, calculate how far above the speed limit you may be going to try to "beat the light."

What Do You Think Now?

At the beginning of this section, you were asked the following:

- **If all traffic lights stayed yellow the same amount of time, how would this affect drivers' decisions at intersections?**
- **How could an intersection with a traffic light be dangerous?**

Now that you have investigated the effects of factors on a GO Zone and STOP Zone, what do you think would be the effect of having all lights stay yellow for the same length of time? Explain what could make an intersection with a traffic light dangerous and what can be done to correct the situation. Include the term Dilemma Zone in your explanation.

Active Physics Plus

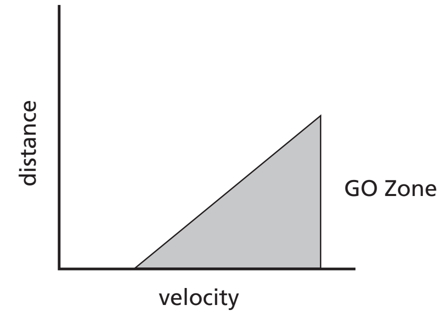
Students answer questions posed in *Active Physics Plus* by predicting the effect on STOP and GO Zones and using a spreadsheet program to graph the relationship of the STOP and GO Zones vs. different speeds. Drawing graphs provides a visual understanding of the Overlap and Dilemma Zones. Encourage students to share their graphs with others, and ask them to explain how Dilemma Zones can be changed into Overlap Zones or GO Zones can increase with an increase in acceleration.

1.

As speed increases, the GO Zone also increases in direct proportion, since $GZ \le vt_y - w$. Likewise, the STOP Zone is given by $SZ \ge vt_r + v^2/2a$ and also increases with velocity, but at a faster rate than the GO Zone.

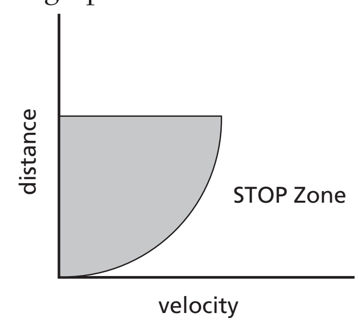
2.

The GO Zone should resemble the graph below.



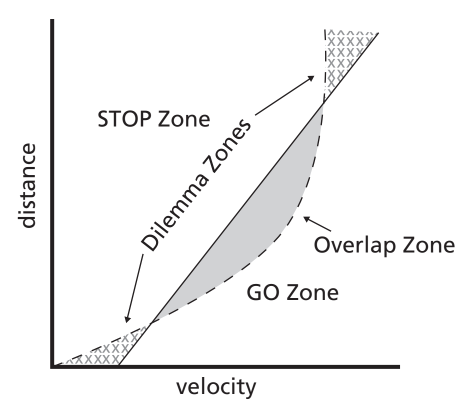
3.

The STOP Zone should resemble the graph below.



4.

The STOP Zone and GO Zone graphs should be the overlap of the preceding two graphs, and appear like the graph below.



5.

In the graph above, the Overlap Zone is shown by the shaded region, and the Dilemma Zone by the cross-hatched region of the graph.

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6.

At very low speeds, the width of the intersection becomes important in determining how long it takes to safely pass through. At low speeds, it may be possible that an automobile is too close to the intersection to stop before entering it, and still the intersection might be too wide for the car to get across before the yellow light turns red.

7.

Yes, accelerating the automobile may help in expanding the size of the GO Zone, possibly enough to eliminate the Dilemma Zone for a driver. How much it will help will depend upon the amount of acceleration.

8.

The speed above the speed limit can be calculated from the formula $v_f = v_i + at$. Here, v_i will be the speed limit, a will be the vehicle's acceleration, and v_f will be the speed above the speed limit.

What Do You Think Now?

Students should reflect on their responses to the *What Do You Think?* section and decide how their original answers could be modified. The effects of various factors on the driver's decision to stop or go through an intersection when approaching a yellow light can be more thoroughly examined at this stage.

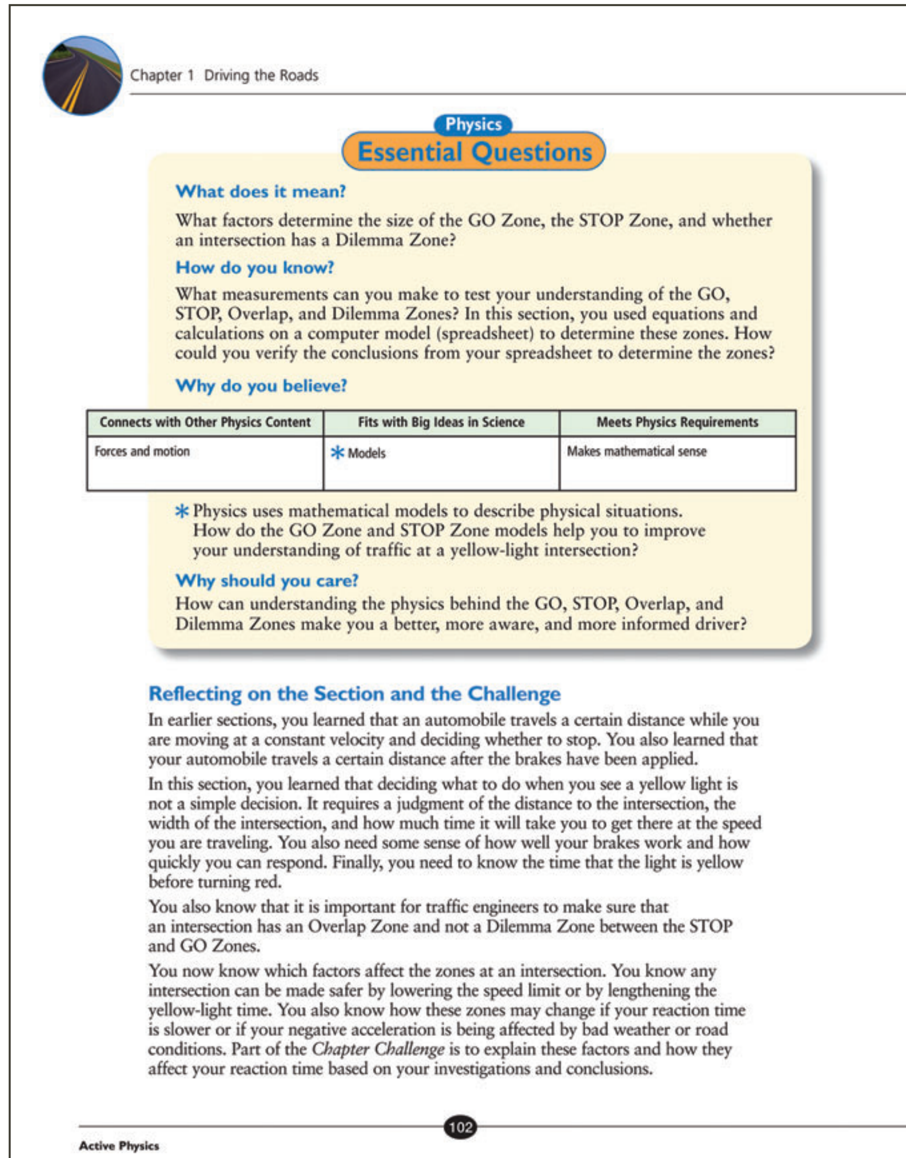
You could share the answers found in *A Physicist's Response* and discuss students' opinions. Revisiting prior questions can prompt other queries that you should encourage in order to build a platform that leads to a stimulating discussion. Yellow-light dilemmas and decisions are critical to human safety. Ensure that your students understand why intersections at traffic lights could be dangerous.

NOTES

NOTES

Reflecting on the Section and the Challenge

Reflecting on the *Investigate* and *Physics Talk* can help students make important connections between reaction time, length of yellow-light time, stopping distance, width of an intersection, and rate of deceleration while approaching a yellow light. All these factors that contribute to a driver's decision can be incorporated into the challenge. Students should read the *Reflecting on the Section and the Challenge* to help them compose and present their *Chapter Challenge* project.



Physics **Essential Questions**

What does it mean?

What factors determine the size of the GO Zone, the STOP Zone, and whether an intersection has a Dilemma Zone?

How do you know?

What measurements can you make to test your understanding of the GO, STOP, Overlap, and Dilemma Zones? In this section, you used equations and calculations on a computer model (spreadsheet) to determine these zones. How could you verify the conclusions from your spreadsheet to determine the zones?

Why do you believe?

Connects with Other Physics Content	Fits with Big Ideas in Science	Meets Physics Requirements
Forces and motion	* Models	Makes mathematical sense

* Physics uses mathematical models to describe physical situations. How do the GO Zone and STOP Zone models help you to improve your understanding of traffic at a yellow-light intersection?

Why should you care?

How can understanding the physics behind the GO, STOP, Overlap, and Dilemma Zones make you a better, more aware, and more informed driver?

Reflecting on the Section and the Challenge

In earlier sections, you learned that an automobile travels a certain distance while you are moving at a constant velocity and deciding whether to stop. You also learned that your automobile travels a certain distance after the brakes have been applied.

In this section, you learned that deciding what to do when you see a yellow light is not a simple decision. It requires a judgment of the distance to the intersection, the width of the intersection, and how much time it will take you to get there at the speed you are traveling. You also need some sense of how well your brakes work and how quickly you can respond. Finally, you need to know the time that the light is yellow before turning red.

You also know that it is important for traffic engineers to make sure that an intersection has an Overlap Zone and not a Dilemma Zone between the STOP and GO Zones.

You now know which factors affect the zones at an intersection. You know any intersection can be made safer by lowering the speed limit or by lengthening the yellow-light time. You also know how these zones may change if your reaction time is slower or if your negative acceleration is being affected by bad weather or road conditions. Part of the *Chapter Challenge* is to explain these factors and how they affect your reaction time based on your investigations and conclusions.

Physics Essential Questions

What does it mean?

The GO Zone is dependent on the speed of the car, the yellow-light time, and the width of the intersection. The STOP Zone is dependent on the speed of the car, the braking acceleration, and the reaction time. The intersection has a Dilemma Zone if there is a gap between the GO Zone and the STOP Zone.

How do you know?

You can measure the width of an intersection, the speed of cars, and the yellow-light time. You can use an approximate value for the braking acceleration and reaction time of drivers. Using motion equations, you can determine the zones, as well as see if cars in the calculated zones travel through or stop at the intersections.

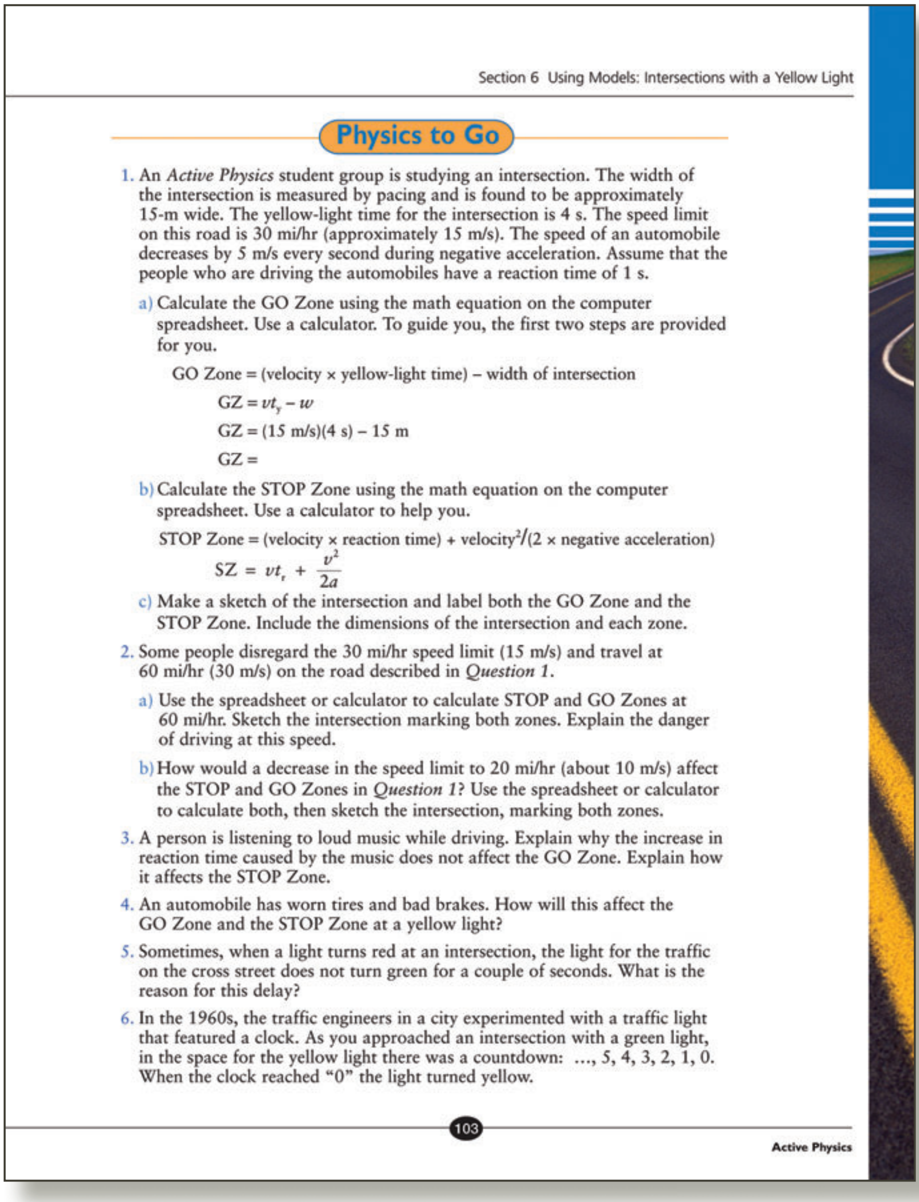
Why do you believe?

The GO and STOP Zones provide a new way to look at the intersection. Without this model, people just guess as to whether they should go or stop at the yellow light.

Why should you care?

Understanding how the speed of your car affects the GO and STOP Zones will encourage you to be more aware of your speed as you approach intersections. You can also conclude that speeding up to make it through a yellow light is particularly dangerous.

CHAPTER 1


Section 6 Using Models: Intersections with a Yellow Light

Physics to Go

1. An *Active Physics* student group is studying an intersection. The width of the intersection is measured by pacing and is found to be approximately 15-m wide. The yellow-light time for the intersection is 4 s. The speed limit on this road is 30 mi/hr (approximately 15 m/s). The speed of an automobile decreases by 5 m/s every second during negative acceleration. Assume that the people who are driving the automobiles have a reaction time of 1 s.

a) Calculate the GO Zone using the math equation on the computer spreadsheet. Use a calculator. To guide you, the first two steps are provided for you.

GO Zone = (velocity × yellow-light time) − width of intersection

$GZ = vt_y - w$

$GZ = (15\text{ m/s})(4\text{ s}) - 15\text{ m}$

GZ =

b) Calculate the STOP Zone using the math equation on the computer spreadsheet. Use a calculator to help you.

STOP Zone = (velocity × reaction time) + velocity²/(2 × negative acceleration)

$$SZ = vt_r + \frac{v^2}{2a}$$

c) Make a sketch of the intersection and label both the GO Zone and the STOP Zone. Include the dimensions of the intersection and each zone.

2. Some people disregard the 30 mi/hr speed limit (15 m/s) and travel at 60 mi/hr (30 m/s) on the road described in *Question 1*.

a) Use the spreadsheet or calculator to calculate STOP and GO Zones at 60 mi/hr. Sketch the intersection marking both zones. Explain the danger of driving at this speed.

b) How would a decrease in the speed limit to 20 mi/hr (about 10 m/s) affect the STOP and GO Zones in *Question 1*? Use the spreadsheet or calculator to calculate both, then sketch the intersection, marking both zones.

3. A person is listening to loud music while driving. Explain why the increase in reaction time caused by the music does not affect the GO Zone. Explain how it affects the STOP Zone.

4. An automobile has worn tires and bad brakes. How will this affect the GO Zone and the STOP Zone at a yellow light?

5. Sometimes, when a light turns red at an intersection, the light for the traffic on the cross street does not turn green for a couple of seconds. What is the reason for this delay?

6. In the 1960s, the traffic engineers in a city experimented with a traffic light that featured a clock. As you approached an intersection with a green light, in the space for the yellow light there was a countdown: ..., 5, 4, 3, 2, 1, 0. When the clock reached "0" the light turned yellow.

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1.a)

$GZ = vt_y - w$

$GZ = (15\text{ m/s})(4.0\text{ s}) - 15\text{ m} =$ 45 m.

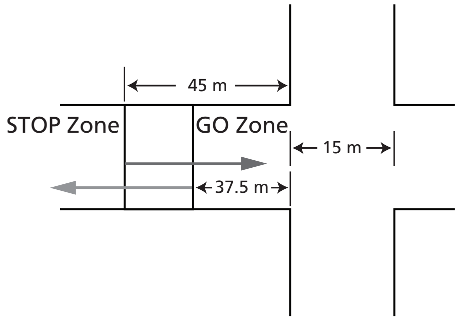
1.b)

$$SZ = vt_r + \frac{v^2}{2a}$$

$$SZ = (15\text{ m/s})(1.0\text{ s}) + \frac{(15\text{ m/s})^2}{2(5\text{ m/s}^2)} = 37.5\text{ m.}$$

1.c)

Student sketch. Check that the students include the correct units in the sketch, similar to the one below.



2.a)

Using the same equation provided in *Question 1* gives

$GZ = vt_y - w$

$GZ = (30\text{ m/s})(4.0\text{ s}) - 15\text{ m} =$ 105 m

$$SZ = vt_y + \frac{v^2}{2a}$$

$$SZ = (30\text{ m/s})(1.0\text{ s}) + \frac{(30\text{ m/s})^2}{2(5\text{ m/s}^2)} =$$

120 m.

Driving at this speed is dangerous because it leaves a Dilemma Zone between 105 m and 120 m where the automobile is too far away to go through the intersection safely, but too near to stop safely.

2. b)

Reducing the speed limit to 10 m/s would give the following GO and STOP Zones.

$GZ = vt_y - w$

$GZ = (10\ \text{m/s})(4.0\ \text{s}) - 15\ \text{m} =$ 25 m.

$SZ = vt_r + \dfrac{v^2}{2a}$

$SZ = (10\ \text{m/s})(1.0\ \text{s}) + \dfrac{(10\ \text{m/s})^2}{2(5\ \text{m/s}^2)} =$ 20 m.

This would yield an Overlap Zone of 5 m, making the intersection safer.

3.

The STOP Zone includes all positions where the vehicle can safely stop before reaching the intersection. Therefore, the stopping distance is affected by the reaction time, which can be affected by the music. The GO Zone is the area through which you can pass safely in an intersection; therefore, there is no reaction time necessary.

4.

Worn tires and bad brakes will have no effect on the GO Zone because the automobile does not need to stop. However, the STOP Zone will be affected because the worn tires and bad brakes will increase the braking distance, thus increasing the STOP Zone.

5.

Having the intersection light turn green a few seconds after the yellow light turns red for the crossing street, provides an additional safety margin (in effect increasing the yellow-light time). Automobiles that might be in a Dilemma Zone might be able to go through the intersection safely with the extra time.

6.

The countdown was intended to provide extra warning when the light would turn yellow, and possibly increase the STOP Zone. Traffic engineers decided this was not a good idea because the extra warning might tempt drivers to increase their speed and they might still not be able to cross the GO Zone. The countdown would make the intersection more dangerous due to higher traffic speeds.

NOTES

NOTES

7.

Intersection **A**

$GZ = vt_y - w$

$SZ = vt_r + \dfrac{v^2}{2a}$

$GZ = (20 \text{ m/s})(3.0 \text{ s}) - 12 \text{ m} =$
48 m

$SZ = (20 \text{ m/s})(1.2 \text{ s}) + \dfrac{(20 \text{ m/s})^2}{2(7 \text{ m/s}^2)}$

53 m

This intersection is unsafe, because there is a Dilemma Zone between 48 m and 53 m.

Intersection **B**

$GZ = (20 \text{ m/s})(4.0 \text{ s}) - 8 \text{ m} = 72 \text{ m}$

$SZ = (20 \text{ m/s})(1.2 \text{ s}) + \dfrac{(20 \text{ m/s})^2}{2(7 \text{ m/s}^2)} \approx$

53 m

This intersection is safe. There is an Overlap Zone between 53 m and 72 m.

Intersection **C**

$GZ = (20 \text{ m/s})(3.0 \text{ s}) - 12 \text{ m} =$
48 m

$SZ = (20 \text{ m/s})(1.0 \text{ s}) +$
$\dfrac{(20 \text{ m/s})^2}{2(7 \text{ m/s}^2)} \approx 49 \text{ m}$

This intersection is unsafe, with a small Dilemma Zone.

Intersection **D**

$GZ = (20 \text{ m/s})(3.0 \text{ s}) - 12 \text{ m} =$
48 m

$SZ = (20 \text{ m/s})(1.8 \text{ s}) +$
$(20 \text{ m/s})^2 / (2 \times 7 \text{ m/s}^2) \approx$
65 m

This intersection is unsafe, with a large Dilemma Zone.

Intersection **E**

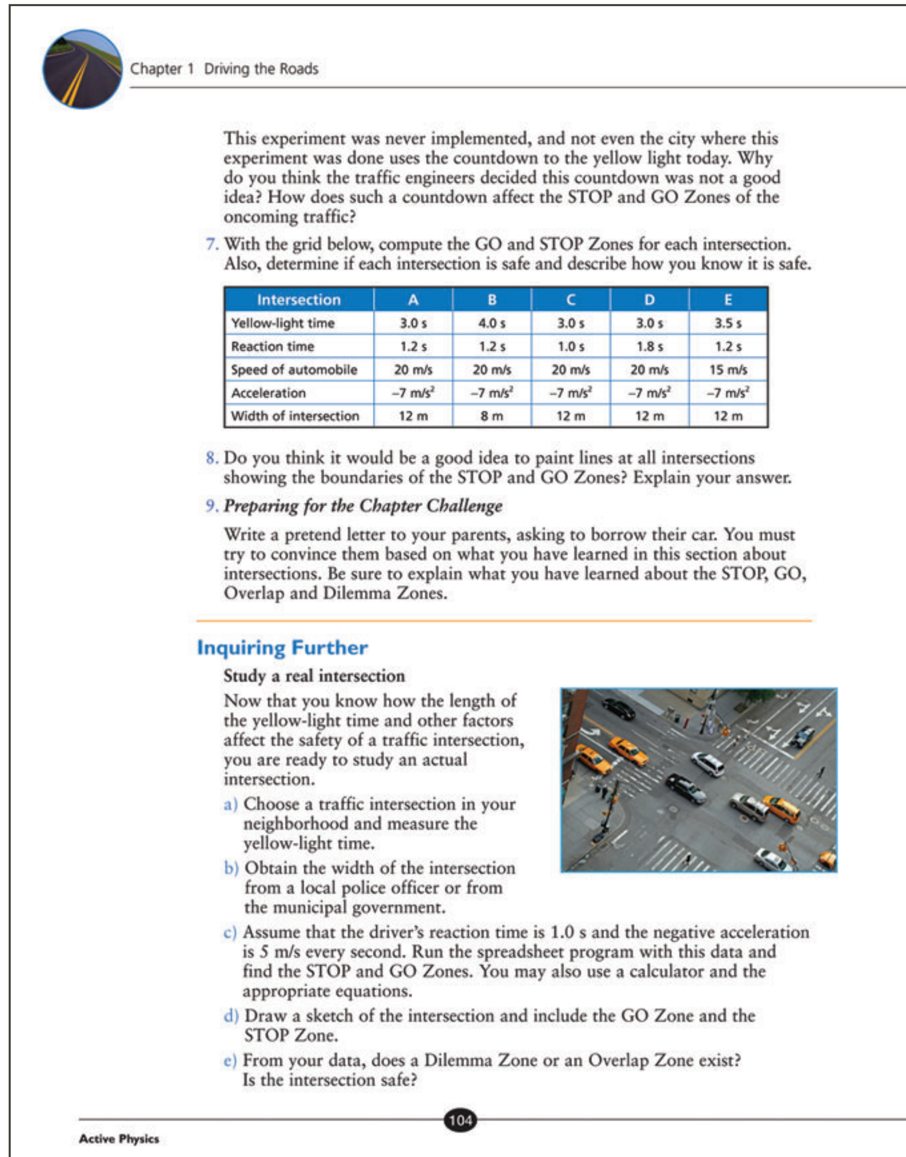
$GZ = (15 \text{ m/s})(3.5 \text{ s}) - 12 \text{ m} =$
41 m

$SZ = (15 \text{ m/s})(1.2 \text{ s}) +$
$(15 \text{ m/s})^2 / (2 \times 7 \text{ m/s}^2) \approx 34 \text{ m}$

This intersection is safe, with an Overlap Zone from 34–41 m.

8.

Some students might think it is a good idea, while others might find that they are looking at the painted lines, and not at the stoplight, thus changing their reaction time and increasing the STOP Zone.



Chapter 1 Driving the Roads

This experiment was never implemented, and not even the city where this experiment was done uses the countdown to the yellow light today. Why do you think the traffic engineers decided this countdown was not a good idea? How does such a countdown affect the STOP and GO Zones of the oncoming traffic?

7. With the grid below, compute the GO and STOP Zones for each intersection. Also, determine if each intersection is safe and describe how you know it is safe.

Intersection	A	B	C	D	E
Yellow-light time	3.0 s	4.0 s	3.0 s	3.0 s	3.5 s
Reaction time	1.2 s	1.2 s	1.0 s	1.8 s	1.2 s
Speed of automobile	20 m/s	20 m/s	20 m/s	20 m/s	15 m/s
Acceleration	–7 m/s²	–7 m/s²	–7 m/s²	–7 m/s²	–7 m/s²
Width of intersection	12 m	8 m	12 m	12 m	12 m

8. Do you think it would be a good idea to paint lines at all intersections showing the boundaries of the STOP and GO Zones? Explain your answer.

9. ***Preparing for the Chapter Challenge***

Write a pretend letter to your parents, asking to borrow their car. You must try to convince them based on what you have learned in this section about intersections. Be sure to explain what you have learned about the STOP, GO, Overlap and Dilemma Zones.

Inquiring Further

Study a real intersection

Now that you know how the length of the yellow-light time and other factors affect the safety of a traffic intersection, you are ready to study an actual intersection.

a) Choose a traffic intersection in your neighborhood and measure the yellow-light time.

b) Obtain the width of the intersection from a local police officer or from the municipal government.

c) Assume that the driver's reaction time is 1.0 s and the negative acceleration is 5 m/s every second. Run the spreadsheet program with this data and find the STOP and GO Zones. You may also use a calculator and the appropriate equations.

d) Draw a sketch of the intersection and include the GO Zone and the STOP Zone.

e) From your data, does a Dilemma Zone or an Overlap Zone exist? Is the intersection safe?

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9.

Preparing for the Chapter Challenge

Students write letters that show what they have learned about intersections, including the STOP, GO, Overlap, and Dilemma Zones. Be certain that students respond to all four sections of the question, including a description of why the Dilemma Zone is dangerous for drivers. The discussion of the GO Zone should include why reaction time and braking distances are not important in this region, as well as what determines the size of the GO Zone.

Students' responses should include a discussion of how the braking distance depends upon the velocity squared and reaction time to determine the STOP Zone, and how the condition of the car and their concentration on driving will determine these factors. They might also wish to include what they intend to do to ensure these two factors are optimal when they are driving.

Students should discuss the Overlap and Dilemma Zones in their presentation, so that their parents are aware that they understand these regions. The discussion about the Overlap and Dilemma Zones should also include why the Overlap Zone helps them to drive safely, and how the realization of the existence of a Dilemma Zone for a red light will make them even more cautious when they are driving.

Inquiring Further

Depending upon your school's policy, you may wish to determine the yellow-light time and then give it to the students, rather than have them measure it themselves. If the intersection width is not readily available from the police, you or the students may measure it by "pacing off" the distance from curb to curb as you cross the street.

Students' calculations for the GO Zone will depend upon the intersection width, local speed limit, and yellow-light time. The calculations for the STOP Zone can be done from the given values for reaction time, negative acceleration, and the local speed limit.

The drawings for the STOP and GO Zones will be similar to the ones in the *Investigate*, and the location of any Overlap or Dilemma Zones as determined from their calculations, should be clearly marked on their diagrams.

If there are no intersections with a stop light in your local area, you may substitute values from another area without changing the value of the exercise.

SECTION 6 QUIZ

1-6b **Blackline Master**

1. Which of the following is an important consideration in determining the width of the GO Zone for a yellow light?

   a) The negative acceleration rate of an automobile.

   b) The width of an intersection.

   c) The driver's reaction time.

   d) The condition of an automobile's brakes.

2. An automobile is approaching an intersection with a yellow light. The automobile is traveling with a velocity of 20 m/s, and goes a distance of 15 m before the driver starts to apply the brakes. The automobile stops at a distance of 50 m. What is the driver's reaction time?

   a) 0.75 s   b) 2.00 s

   c) 0.30 s   d) 0.40 s

3. For *Question 2*, what would be the automobile's rate of negative acceleration if it comes to a stop in 50 m?

   a) $-5.7\ \text{m/s}^2$ b) $-8.0\ \text{m/s}^2$

   c) $-13.3\ \text{m/s}^2$ d) $-4.0\ \text{m/s}^2$

4. Which statement below best describes what occurs when the yellow-light time at an intersection is increased while all the other variables remain constant?

   a) The GO Zone decreases, and the STOP Zone remains the same.

   b) The GO Zone decreases, and the STOP Zone decreases.

   c) The GO Zone increases, and the STOP Zone decreases.

   d) The GO Zone increases, and the STOP Zone remains the same.

5. An intersection has an improperly timed yellow light, resulting in a Dilemma Zone for drivers. For automobiles traveling at the legal speed limit, which of the following changes can alter the STOP and GO Zones so that the Dilemma Zone can be eliminated?

   a) Increasing the speed limit.   b) Increasing the width of the intersection.

   c) Increasing the yellow-light time.   d) Increasing the driver's reaction time.

SECTION 6 QUIZ ANSWERS

1. b) The GO Zone is determined by the speed of an automobile, the yellow-light time, and the intersection width only. Reaction time, and the negative acceleration rate of an automobile, determine the size of the STOP Zone. The condition of an automobile's brakes determines the negative acceleration rate.

2. a) The distance traveled during the reaction time of the driver is given by $d = vt_r$. To obtain t_r, the distance traveled is divided by the automobile's speed, giving $(15 \text{ m})/(20 \text{ m/s}) = 0.75 \text{ s}$. If the total distance (50 m) is used, the student would get choice *d)*, and if the braking distance is used rather than the reaction distance, choice *c)* is obtained.

3. a) To obtain the automobile's negative acceleration, one needs to know the braking distance. The braking distance is the difference between the stopping distance and the reaction distance, or $50 \text{ m} - 15 \text{ m} = 35 \text{ m}$. Using the formula for braking distance, $v^2 = -2ad$ and solving for a gives
$a = \frac{-v^2}{2d} = \frac{-(20 \text{ m/s})^2}{2(35 \text{ m})} = -5.7 \text{ m/s}^2$. Using the total distance for d (50 m), gives choice *d)*.

4. d) The GO Zone is determined by the speed of the automobile, the yellow-light time and the intersection width only. Reaction time, and the negative acceleration rate of the car determine the size of the STOP Zone. An increase in the yellow-light time increases the GO Zone too. The STOP Zone is not affected by yellow-light time.

5. c) Increasing the yellow-light time will increase the GO Zone, but has no effect on the STOP Zone, so the two zones will eventually overlap, eliminating the Dilemma Zone. Increasing the speed limit increases both the STOP and GO Zones, but the STOP Zone increases faster than the GO Zone because the STOP Zone depends upon the velocity squared. Increasing the width of the intersection decreases the GO Zone, without decreasing the STOP Zone, widening the gap, and increasing the driver's reaction time will increase the STOP Zone while leaving the GO Zone unchanged.