

TRAFFIC TECHNOLOGY

ABSTRACT

The Traffic Technology module covers the educational topics of basic linear motion, basic circuits and Boolean logic as taught in an intermediate school general science course or a high school physics/computer course. The understanding of these concepts is fundamental to the transportation topics of highway safety and design. Teachers may select one activity from each concept area on the basis of grade/course level and equipment availability. Additional activities are available depending on time, interest, and equipment.

There are five activities within this module. The first activity, Calculating Reaction Time, is a brief one that has students roughly calculate their reaction time using linear motion equations for use in a later activity. The second activity, Calculating Braking Distance, involves the use of photogates to determine the deceleration and stopping distance of a braking vehicle. The third activity, Setting Yellow Light Period, uses data collected from the first two activities to calculate the timing sequence of a traffic light.

The next two activities explore the topics of intelligent traffic systems. Activity 4, Traffic System Logic, uses spreadsheets to build a traffic light logic sequence. The fifth activity, Reactive Traffic Technology, is a project-type assignment, in which students look at the physics concepts used to design the mechanism to change a traffic light from red to green. The activities have been designed to meet the National Science Education Standards and the Standards for Technology Literacy.

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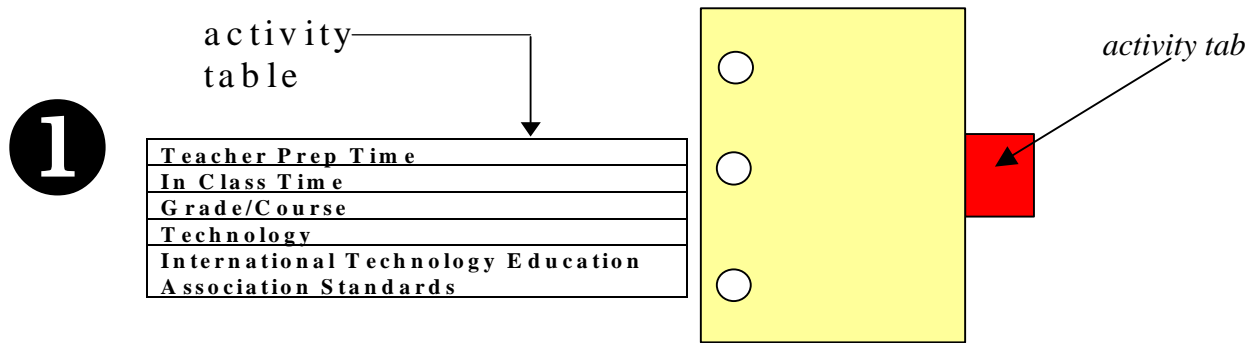
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HOW TO USE THIS MANUAL

Pick any one of the five activities (See the *Activity Table* on the page that immediately follows each activity tab).



- 2 Decide which *activity pages* you want to hand to students.
 The *first page* of each activity is an introduction for the teacher's use.
 The *last few pages* of each activity contain answers for the suggested questions.
- 3 Assign the evaluation questions you deem appropriate for homework or discussion.
- 4 If students are new to calculator based labs, then consider handing out the reference pages entitled *Using the TI-83 and Lab Pro* shown at the end of Activity 2.

ACTIVITY TABLE

Grade Level	Activity	Description	Technology Level	Standards	Transportation Background Material	Page
High School (Grades 9-12)	Calculating reaction time	Students will estimate their reaction time.	Lo- Hands on	Appropriate Tools Technology and Mathematics Think Critically	Traffic Control Systems	4
High School (Grades 9-12)	Calculating braking distance	Students will use hot wheel cars and photo gates to simulate and calculate braking distance and deceleration.	High- Hands on	Appropriate Tools Technology and Mathematics Think Critically Motion and Forces Standard 8 Standard 9 Standard 10	Traffic Control Systems	8
High School (Grades 9-12)	Setting yellow light time	Students will use data gathered in the first two activities to calculate the appropriate length of a yellow light in a traffic signal.	Lo	Appropriate Tools Technology and Mathematics Think Critically Motion and Forces Standard 8 Standard 9 Standard 10	Traffic Control Systems	17
High School (Grades 9-12)	Programming Logic for Traffic Systems	Students will apply the concept of logic in creating and testing a traffic light algorithm to control the light sequence.	Hi	Appropriate Tools Technology and Mathematics Think Critically Standard 8 Standard 9 Standard 10	Traffic Control Systems	23
High School (Grades 9-12) Middle School (Grades 6-8)	Reactive Traffic Technology	Students will construct a device that will switch a red light to a green one in the presence of a car.	Variable- Hands on	Appropriate Tools Technology and Mathematics Think Critically	Traffic Control Systems	33

NATIONAL EDUCATION STANDARDS

The activities and lab formats used in this module were geared toward meeting the National Science Education Standards. The standards have been included below for the instructor to reference.

Standards for Technology Literacy

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

National Science Education Standards

Grades 5-8 Science as Inquiry

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Use technology and mathematics to improve investigations and communications.
- Think critically and logically to make the relationships between evidence and explanations.
- Formulate and revise scientific explanations and models using logic and evidence.

Grades 9-12 Physical Science Content Standard B

Motion and Forces:

- Its position, direction of motion and speed can describe the motion of an object. That motion can be measured.
- If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

Grades 9-12 Science as Inquiry

- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Formulate and revise scientific explanations and models using logic and evidence.
- Recognize and analyze alternative explanations and models.
- Motion and forces: Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects.

ACTIVITY 1:

CALCULATING REACTION TIME

ACTIVITY TABLE

Teacher Prep Time	None
In Class Time	1 day
Out of Class Time	30 minutes
Grade/Course	9-12
Technology	Lo
NSES Standards Met	Appropriate Tools Technology and Mathematics Think Critically

OBJECTIVE

In this activity students will perform an activity using the linear motion equations to find out their reaction time. Students will also choose parameters for calculations, given a range of choices.

MATERIALS NEEDED

Meter Stick

SET-UP

None Needed

PROCEDURE

1. Hold the ruler above the students open hand
2. Release the meter stick and have the student close their hand to stop it.
3. Measure the distance that the meter stick covers
4. Repeat three times
5. Have students complete the data table and answer the questions.

ACTIVITY 1 DATA COLLECTION SHEET

Background

An important factor in designing intersections is the reaction time of drivers on the roadway; that is to say, “How quickly can a driver react to put their foot on the brake?”

Sample Problem

During this activity students use the equation,

$$x = v_o t + \frac{1}{2} a t^2,$$

a meter stick and the rate of acceleration due to gravity to calculate their reaction time. All of the variables in the equation will be known except for t, which represents the reaction time ($a = 9.81$ m/s/s, x = the length of ruler that passes through the person’s hand, $v_o = 0$). Say that the ruler falls .15m before you catch it. The reaction time could be calculated as follows:

$$x = v_o t + \frac{1}{2} a t^2$$

$$t = \sqrt{\frac{2x}{a}}$$

$$t = \sqrt{\frac{2(.15)}{9.81}} = 0.17s$$

Procedure

1. Hold the ruler above a student's open hand.
2. Release the meter stick and have the student close his or her hand to stop it.
3. Measure the distance that the meter stick covers.
4. Repeat three times.
5. Have students complete the data table and answer the questions.

Student	Distance Ruler Dropped (m)			Average Dropped Distance (m)	Reaction Time (s)
	Trial 1	Trial 2	Trial 3		
Person 1					
Person 2					
Person 3					
Person 4					

ACTIVITY 1 QUESTIONS

1. What was the average reaction time of your group?

2. Is this the best way to measure reaction time? What method would you use to get a more accurate reaction time?

3. If you were an engineer designing a traffic light, what range or calculation from the found reaction times would you use to perform the calculations in your design?

GUIDELINES FOR EVALUATING ACTIVITY 1

1. What was the average reaction time of your group?

Be sure that the students have followed the example calculation and have not made any math errors. Say that the ruler falls .15m before you catch it. The reaction time could be calculated as follows:

$$x = v_0 t + \frac{1}{2} a t^2$$
$$t = \sqrt{\frac{2x}{a}}$$
$$t = \sqrt{\frac{2(.15)}{9.81}} = 0.17s$$

2. Is this the best way to measure reaction time? What method would you use to get a more accurate reaction time?
3. If you were an engineer designing a traffic light, what range or calculation from the found reaction times would you use to perform the calculations in your design?

Questions 2 and 3 are not meant to be correct or incorrect. They are intended to be used to foster a discussion within the class. If no one mentions it, ask, "Does catching a ruler give a good estimate of the time it would take a driver to remove his or her foot from the gas and step on the brake?"

ACTIVITY 2:

CALCULATING BRAKING DISTANCE

ACTIVITY TABLE

Teacher Prep Time	30 minutes
In Class Time	1 day
Out of Class Time	30 minutes
Grade/Course	9-12
Technology	High
NSES Standards Met	Appropriate Tools Technology and Mathematics Think Critically Motion and Forces Standards 8, 9, and 10

OBJECTIVE

In this activity the student groups will design and run an experiment to calculate the safe braking distance for cars traveling at various speeds and to choose data for calculations when given a range of values.

MATERIALS NEEDED

Hot Wheels Track

Two Photo Gates

Vernier Lab Pro and T1-83 calculator or computer (see p. 15 for help loading Lab Pro on your calculator)

Hot Wheels Car

Index Card

PROCEDURE

1. Set up equipment as shown in Figures 1 and 2. The photogates need to be in the gate mode where each one operates independently of the other. If the photogates are set to record the time it takes for an object to pass between the two gates, the data collected will be incorrect.
2. Have students answer the prediction questions.
3. Release the car from the starting point.
4. Collect the time data from the two photogates.
5. From this data, calculate the initial and final velocities.
6. Using the linear motion equations, find the deceleration of the car.
7. Using the linear motion equations, find the braking distance of the car.

SET UP

The students should set up the equipment as shown in Figure 1. The distance between the photogates should be approximately .2 meters.

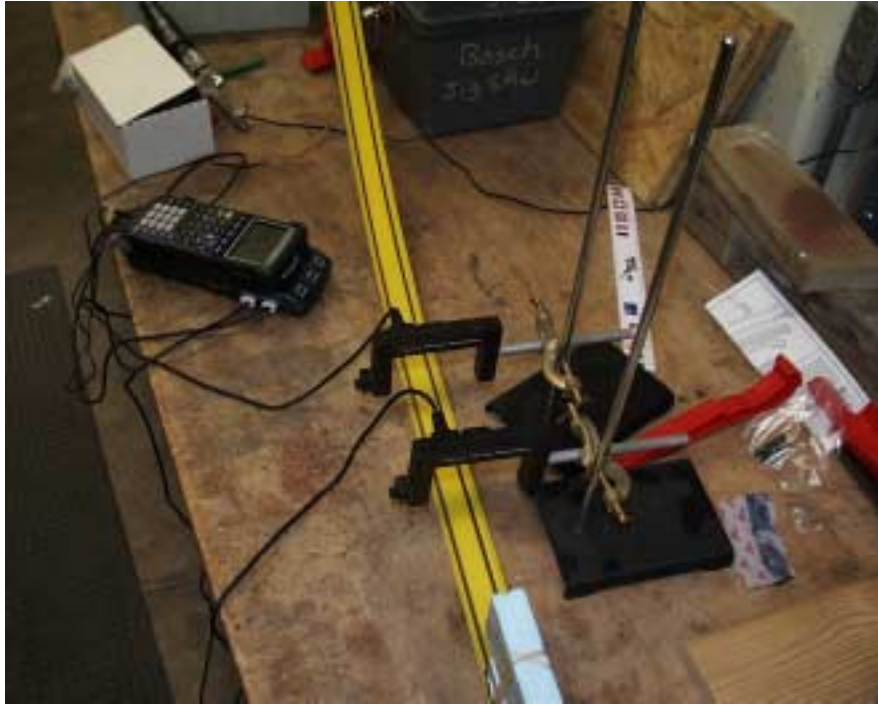


Figure 1: Equipment setup

In order to make the data collection more accurate, a foam block or note card can be fixed to the top of the car. The distance of the card will need to be recorded for use in the calculations.



Figure 2: Car setup

Launching the car will depend on what type of Hot Wheels track you are able to get. If it is a gravity-driven system, the plastic C-clamp can be attached to a ring stand to adjust the launch height. It is important when launching from different heights that the track remains taut. If there is a lot of slack in the track, it will increase friction and possibly change the results. If you are using a spring-loaded launcher, use the different settings to increase or decrease your launch speed.

NOMENCLATURE

t_o = time taken to pass through first photo gate

t_f = time taken to pass through second photo gate

V_o = velocity of the object as it passes through the first photo gate

V_f = velocity of the object as it passes through the second photo gate

a = the rate at which the car is decelerating

x = the distance between the photo gates

Length of block = the length foam block attached to the car. This is the length that will be used to calculate the initial and final velocities.

BACKGROUND

An important factor in designing intersections is the rate of deceleration for the traffic; that is to say, "How quickly can a car slow down?"

Braking Distance Calculation:

$$v_f^2 = v_o^2 + 2ax$$

$$x = \frac{v_f^2 - v_o^2}{2a} \quad (v_f \text{ is equal to zero})$$

$$\text{Braking Distance} = \frac{-v_o^2}{2a}$$

For this activity the formula $v_f^2 = v_o^2 + 2ax$ will be used to first calculate the deceleration of a braking car and then the braking distance of the car. Students will be using photogates to collect data about a braking vehicle. They will be able to calculate the velocity of the car at two points along a track and measure the distance between the two points. With this data they can rearrange the formula as shown below:

$$v_f^2 = v_o^2 + 2ax$$

$$a = \frac{v_f^2 - v_o^2}{2x}$$

$$a = \frac{v_f^2 - v_o^2}{2x}$$

Although the term is not shown in the above derivations, friction plays a major role in stopping a car. Be sure to explain to students that the friction term is taken into account by the acceleration term. If the road is wet or the tires are slick, the car will decelerate less, and the braking distance will increase. This activity could be modified to focus on the friction effect and be used to determine the coefficient of friction.

ACTIVITY 2 DATA COLLECTION SHEET

Prediction Questions

1. How will the height at which the car is released affect the deceleration of the car?
2. How does releasing the car from different heights affect the initial velocity of the car?
3. What are the different variables that are going to affect the braking distance?
4. What variable are being held constant for this experiment?
5. What variables are changing?

Procedure

1. Set up equipment as shown in Figures 1 and 2. The photogates need to be in the gate mode where each one operates independently of the other. If the photogates are set to record the time it takes for an object to pass between the two gates, the data collected will be incorrect.
2. Release the car from the starting point.
3. Collect the time data from the two photogates.
4. From this data, complete the data table below.

	Initial and Final Velocities						Average Initial and Final Velocities		Deceleration
	Trial 1		Trial 2		Average of Trials 1&2		$V = \frac{\text{length of block}}{t}$		$a = \frac{V_f^2 - V_i^2}{2x}$
	<i>t_o</i>	<i>t_f</i>	<i>t_o</i>	<i>t_f</i>	Avg (<i>t_o</i>)	Avg (<i>t_f</i>)			
Speed 1									
Speed 2									
Speed 3									

Nomenclature

t_o = time taken to pass through first photo gate

t_f = time taken to pass through second photo gate

V_o = velocity of the object as it passes through the first photo gate

V_f = velocity of the object as it passes through the second photo gate

a = the rate at which the car is decelerating. A negative value indicates that the initial velocity is greater than the final velocity and therefore the car is slowing down.

x = the distance between the photo gates

Length of block = the length foam block attached to the car. This is the length that will be used to calculate the initial and final velocities.

ACTIVITY 2 QUESTIONS

1. What was the average acceleration of the car? Did it change much as the initial velocity increased?

2. Using your acceleration value of your choice, calculate the safe breaking distance for a car traveling 5 m/s, 7 m/s, 10 m/s, and 15 m/s. In order to do this you must rearrange the formula $v_f^2 = v_o^2 + 2ax$ to a usable form. What is the relationship between an increase in initial velocity and the additional stopping distance needed?

GUIDELINES FOR EVALUATING ACTIVITY 2

1. What was the average acceleration of the car? Did it change as the initial velocity increased?

Students should find that the rate at which the car slows down is not affected by its initial velocity.

2. Using your acceleration value of your choice, calculate the safe breaking distance for a car traveling 5 m/s, 7 m/s, 10 m/s and 15 m/s. In order to do this you must rearrange the formula $v_f^2 = v_o^2 + 2ax$ to a usable form. What is the relationship between an increase in initial velocity and the additional stopping distance needed?

The braking distance equation numerator is a squared term. This causes the braking distance to jump up exponentially. If a car is traveling 5 m/s and the rate of deceleration is 4 m/s/s the braking distance will be:

$$v_f^2 = v_o^2 + 2ax$$

$$x = \frac{v_f^2 - v_o^2}{2a} \quad (v_f \text{ is equal to zero})$$

$$\text{Braking Distance} = \frac{-v_o^2}{2a}$$

$$\text{Braking Distance} = \frac{-5^2}{2(-4)} = \frac{-25}{-8} = 3.125m$$

If the same car is traveling 10 m/s the braking distance will be:

$$v_f^2 = v_o^2 + 2ax$$

$$x = \frac{v_f^2 - v_o^2}{2a} \quad (v_f \text{ is equal to zero})$$

$$\text{Braking Distance} = \frac{-v_o^2}{2a}$$

$$\text{Braking Distance} = \frac{-10^2}{2(-4)} = \frac{-100}{-8} = 12.5m$$

The initial velocity was doubled, but the braking distance increased by 4 times. If the initial velocity were tripled to 15 m/s the braking distance increases to 28.125 m, 9 times the original braking distance.

USING THE TI-83 AND LAB PRO

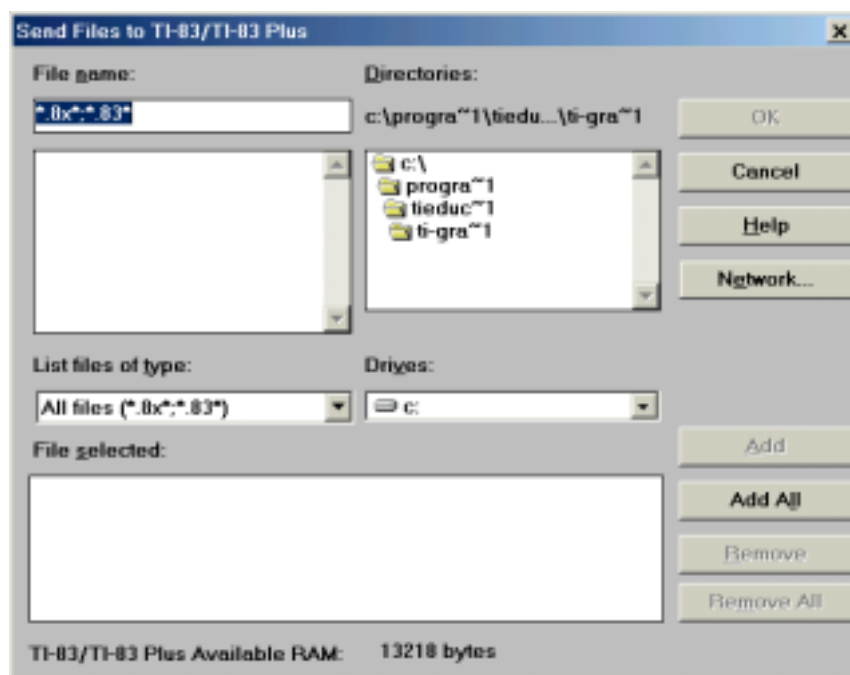
Using photogates allows you to easily collect very accurate motion data that cannot be done by hand. Trying to collect data for an experiment like in activity 2 without photogates would require the use of large distances and relatively slow moving objects so that timer error could be compensated for.

Loading the Data Gate Program Onto the TI-83

Once you get it set up, the Lab Pro is easy to use, but you may run into a few challenges while trying to use the equipment. Using this page in conjunction with the directions provided with the equipment should make the process easier.

The biggest problem most people face is getting the program needed to run the photogates onto their calculator. If you have the data gate program on your calculator, you can skip ahead to running the data gate program.

1. Install the TI Graph-link program on your computer.
2. Make sure that you have the graph link cable and that it is plugged into your computer and calculator. The calculator must be on when you attempt to load programs onto it.
3. You must have the datagate program on your computer and know where it is. You can download the datagate program from www.vernier.com (There is a copy on the accompanying CD-Rom). The program's name is datagate.8xp.
4. When you start the TI-83 Graph Link program one of the menus will be called "link." Under this menu is a command called "Send To" with a choice of either Send to Ram or Send to Archive. Select "Send to RAM." If your calculator and graph link cable are not properly connected the program will give you an error prompt. Otherwise, it will bring up a window like shown below.



5. Use the window on the top left side of the screen to locate the folder in which the datagate program is located. When you get to the correct folder, it will show up in the upper left window. Select the program with the mouse and use Add to move to the bottom window (these are the programs that will be sent to the TI-83).
6. Click on Ok, and a progress window will show the transfer status of the programs.

Running the Data Gate Program

1. Make sure the Lab Pro and calculator are connected to each other using the black linking cable.
2. Make sure the photogates are plugged into the correct sockets (Dig/Sonic 1 & 2).
3. Press PRGM (Program).
4. Select the DataGate program.
5. This should show the word pgrmDATAGATE at the top right corner of the calculator screen.
6. Press Enter.
7. After a while a menu with five options will appear.
8. Go through the setup (choice 1).
9. When you get to the screen you will see five choices, choose 2 (Gate).
10. Select the number of photogates (the activity in this module uses two).
11. The calculator will prompt you for the flag width. This is the width of the object that will be traveling through the gates. This feature is not really important for this activity, because you will be using the raw time data. However, you can put in the length of the Styrofoam block here.
12. Use start (choice 2) to start collecting data. Three lines will be shown on the collection screen: (1) Trial Number, (2) Time Gate1 and (3) Time Gate2. Run an object through the gates a few times and watch the time data appear. These will be the numbers that the students will record in their data tables.

ACTIVITY 3: SETTING YELLOW LIGHT TIME

ACTIVITY TABLE

Teacher Prep Time	10 minutes
In Class Time	1 day
Out of Class Time	30 minutes
Grade/Course	9-12
Technology	Lo-high
NSES Standards Met	Appropriate Tools Technology and Mathematics Think Critically Motion and Forces Standard 8 Standard 9 Standard 10

OBJECTIVE

Using the data collected from the first two activities, students will draw conclusions about how to time traffic lights. The question students must answer is, “What is the ideal yellow light time for a intersection with a speed limit of 40 mph?” Given the equations for yellow light time and braking distance, students should examine the yellow light time versus velocity.

MATERIALS NEEDED

Students will need data collected from the first activity. If students did not do the first activity, the data for reaction time will have to be provided.

PROCEDURE

1. Lead a brief discussion about the purpose of yellow lights in traffic signals, as covered in the background.
2. If appropriate, have students brainstorm the factors that would need to be taken into consideration when setting the yellow light time.
3. If appropriate, have students derive the yellow light time formulas or walk them through the derivation.
4. Have the students use the formulas to complete the data table for yellow light time at different velocities.
5. Direct students to graph yellow light time vs. velocity.
6. Direct students to write a report, making recommendations for their light sequence. The report will contain the following parts:

- Data Table:
- Data Graph
- Conclusion paragraph explaining the duration they would choose for the different lights in their traffic signal.

BACKGROUND

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

- Reaction Time: How quickly can drivers react to put their foot on the brake?
- Deceleration: How quickly can the car slow down?
- Intersection Length: How far must a car travel to safely clear an intersection?

These properties include the speed at which the traffic is moving, the rate at which the traffic can stop, and the reaction time of the drivers. The changing of a traffic light can be broken down into three phases:

Green: The traffic is free to go.

Yellow: Depending on which is safer, cars either slow down or drive through the yellow light. This is called the dilemma zone. The braking distance is the distance a car will travel once the driver has applied the brakes. When drivers are closer than their braking distance, they should continue through the light; otherwise, they will end up stopping in the intersection, 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.

All Red: This is when the traffic lights for all the lanes are red (i.e., no one has a green or yellow light)

An engineer who decides the sequence of a traffic signal must take all of these factors into consideration. Using the basic equations of motion, a basic traffic signal calculation can be derived.

$$\text{Velocity} = \frac{\text{Distance Traveled}}{\text{Time Taken}}$$

$$v = \frac{x}{t}$$

$$t = \frac{x}{v}$$

v = the initial speed at which the car is travelling

The challenging part of the derivation is figuring out what goes in the distance (x) part of the equation. In the last activity, students considered the braking distance for a car traveling at a given speed. If a car needs 50 meters to come to a complete stop and it is 40 meters away from

the intersection when a light turns red, the car will end up in the middle of the intersection. For this reason a yellow light is necessary. It also provides the parameters necessary to derive the yellow light time. If a car is closer than the needed stopping distance when a light turns yellow, it should continue through the yellow light. It is the engineer's job to make sure that the yellow light time is long enough to make it through the intersection safely. The distance (x) that the car must travel in the yellow light equation is given by the following:

$$x = (\text{reaction time} \cdot v_o) + \text{Braking distance} + \text{intersection length} + \text{avg. vehicle length}$$

$$\text{Yellow light time} = \frac{(\text{reaction time} \cdot v_o) + \text{Braking distance} + \text{intersection length} + \text{avg. vehicle length}}{v_o}$$

Braking Distance Calculation

$$v_f^2 = v_o^2 + 2ax$$

$$x = \frac{v_f^2 - v_o^2}{2a} \quad (v_f \text{ is equal to zero})$$

$$\text{Braking Distance} = \frac{-v_o^2}{2a}$$

Although the term is not shown in the above derivations, friction plays a major part in stopping a car. Explain to students that the friction term is taken into account by the acceleration term. If the road is wet or the tires are slick, the car will decelerate less and the braking distance will increase.

ACTIVITY 3 DATA COLLECTION SHEET

Procedure

1. Use the formulas to complete the data table for yellow light time at different velocities.
2. Graph yellow light time vs. velocity.
3. Write a report, making recommendations for their light sequence. The report will contain the following parts.

Use the formulas, information, and data table below to complete your calculations for yellow light time for each of the starting velocities.

Please note that miles per hour must be converted into m/s for use in the different equations!

The braking effect can be easily expressed as deceleration in terms of g. Values from 0.7g to 0.6g are more typical on dry surfaces. The value will drop to 0.3g to 0.4g on wet surfaces and below 0.1g on snow and ice. A design lower limit on wet ice is usually taken as 0.06g. From these given values you can decide which deceleration rate you will use in your calculations. Remember that the deceleration should be a negative number, because it indicates that the change in speed is in the opposite direction the car is moving. $g = 9.81 \text{ m/s}^2$.

Use the reaction time from the first activity, where the meter stick was used to determine reaction time.

Calculated Values					
Speed (mph)	Speed (m/s)	deceleration (m/s ²)	Braking Distance (m)	Reaction Time (s)	Yellow Light Period (s)
30					
35					
40					
45					
50					

$$\text{Yellow light time} = \frac{(\text{reaction time} \cdot v_o) + \text{Braking distance} + \text{intersection length} + \text{avg. vehicle length}}{v_o}$$

$$\text{Braking Distance} = \frac{-v_o^2}{2a}$$

1 mile = 1600 m 1 hour = 60 minutes 1 minute = 60 seconds

In a written report make your recommendation for your light sequence. The report will contain the following parts.

- Data Table.
- Data Graph.
- Conclusion paragraph explaining the duration you would choose for the different lights in your traffic signal.

DISCUSSION QUESTIONS

The following questions can be used as a guide for this conclusion section.

- What happened to the yellow light time needed as the speed increased?
- Was this a linear relationship?
- What is the sequence that you recommend for the traffic light sequence and duration?
- What are other factors that should be taken into consideration when choosing the yellow light time?

What is the criteria for selecting the ideal yellow light time?

What has to happen within that time?

What is the maximum time you can use?

What are the trade-offs of lower times?

GUIDELINES FOR EVALUATING ACTIVITY 3

Where students may have difficulty is switching between English and SI units. Having them set up their problems in the following manner may help them. If they are trying to convert 30 MPH to m/s the problem would look like:

$$\frac{30\text{miles}}{1\text{hour}} \times \frac{1\text{hour}}{60\text{min}} \times \frac{1\text{min}}{60\text{s}} \times \frac{1600\text{m}}{1\text{miles}} = 13.333\text{m/s}$$

By starting off with the value they are trying to convert and adding the conversion units when all the units cancel out, the only thing left is meters and seconds.

When the students create their graph of yellow light time vs. initial speed, make sure they use an xy graph. Many students may be tempted to use a bar graph, but because the x and y data are continuous and they are trying to determine a relationship between the two, a line graph should be used.

ACTIVITY 4: PROGRAMMING LOGIC FOR TRAFFIC SYSTEMS

ACTIVITY TABLE

Teacher Prep Time	90 minutes
In Class Time	2 days
Out of Class Time	120 minutes
Grade/Course	9-12
Technology	High
NSES Standards Met	Appropriate tools Technology and mathematics Think Critically Standards 8, 9, and 10

OBJECTIVE

During this activity students will be asked to build an algorithm that will switch a simple circuit to change a traffic light from red to green. This activity is intended to look at a problem solving/design process that engineers use.

MATERIALS NEEDED

Access to computers with Microsoft Excel
Copies of street map for each student group

SET UP

It is recommended that the teacher go through the exercise prior to assigning it to students. Teacher guidance or troubleshooting may be necessary.

PROCEDURE

1. Introduce the idea of logic and IF-THEN-ELSE statements covered in the background. On the CD there is a PowerPoint file that can be used for this activity. It contains the information covered in the background. The file is called *Logic Activity.ppt*
2. Give the students the following practice problem and circulate to check their progress.
 - a) Create a spreadsheet that will indicate if a number is a multiple of 7.
Ans: =IF(MOD(Cell Location,7)=0,"Yes","No")
 - b) Create a spreadsheet that will indicate if a number is a multiple of 3 or 5.
Ans: =IF((MOD(Cell Location,3)=0),"Yes",IF(MOD(Cell Location,5)=0,"Yes","No"))
3. Give students the street intersection assignment.
4. Have students graphically outline their solution as shown in the background.
5. Have students use a spreadsheet program to build and test their model.
6. Have students compare designs as a group and lead discussion about the need to follow good design or problem solving procedures.

BACKGROUND

Many traffic systems operate on a timing mechanism that changes the lights after a given interval. Intelligent traffic systems sense the presence or absence of vehicles and react accordingly. The idea behind intelligent traffic systems is that drivers will not spend unnecessary time waiting for the traffic signals to change. Intelligent traffic systems detect traffic in many different ways. Older systems used weight as a trigger mechanism. Many newer traffic systems react to motion or use electro-magnetic induction to trigger the light changes. Once the sensor picks up the presence of a car, a switch causes the lights to change. In order to accomplish this, algorithms are used to govern the actions of the traffic system. While there are many different programming languages today, some programming concepts are universal in Boolean Logic (the type of logic computers use). One of the most important concepts of programming is the IF-THEN-ELSE statement:

"IF a certain criteria is met THEN perform a said function, ELSE perform this other function."

Spreadsheets are able to perform logic statements. When writing a formula in a Microsoft Excel spreadsheet, the IF-THEN-ELSE statement should be written in the form IF(Logical_Test, Value_If_True, Value_If_False).

In the example below, an IF-THEN statement is used to determine whether a driver should be issued a speeding ticket. The First table shows the IF-THEN statements and the second table shows the results obtained from the calculation. The algorithm will govern whether a speeding ticket will be issued (see also Figure 3).

Speed Caught Traveling	Action To Be Taken
65	Issue Ticket
55	No Ticket

Speed Caught Traveling	Action To Be Taken
65	=IF(A11<65,"No Ticket","Issue Ticket")
55	=IF(A12<65,"No Ticket","Issue Ticket")

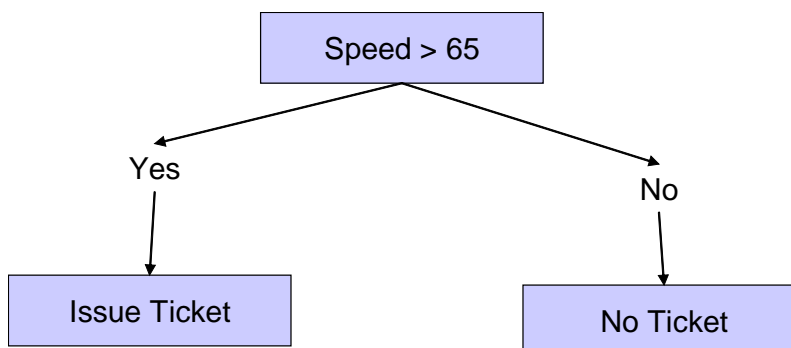


Figure 3. Flowchart illustrating IF-THEN statement.

In the second example a more complex IF-THEN statement is used. In this case the statement says, "If Condition 1 is true, then perform the first function, else perform the next IF-THEN statement." IF-THEN statements can be imbedded or nested within each other to perform very complex logic computations. In this scenario a function has been added to assign a ticket if the motorist is traveling too slowly (see also Figure 4).

Speed Caught Traveling	Action To Be Taken
65	Issue Ticket
14	Issue Ticket
22	No Ticket

Speed Caught Traveling	Action To Be Taken
65	=IF(A11>64,"Issue Ticket",IF(A11<40,"Issue Ticket","No Ticket"))
14	=IF(A12>64,"Issue Ticket",IF(A12<40,"Issue Ticket","No Ticket"))
55	=IF(A13>64,"Issue Ticket",IF(A13<40,"Issue Ticket","No Ticket"))

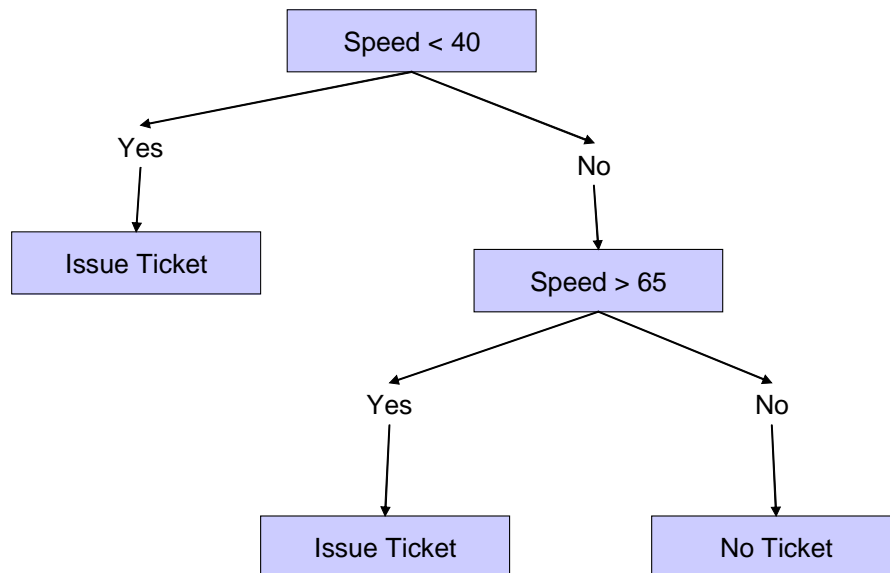
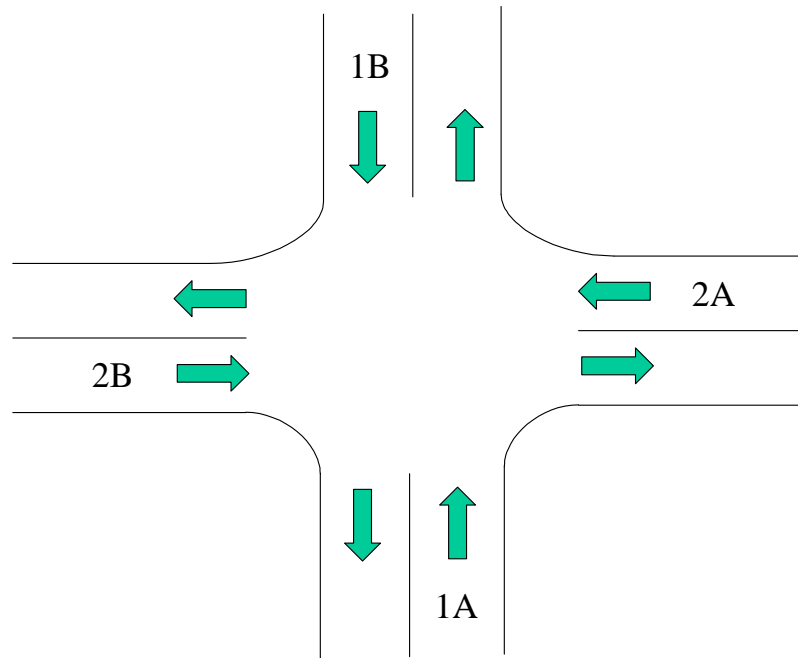


Figure 4. Expanded IF-THEN statement.

Suggested Problem Solving Methodology for This Exercise

- Break the problem into steps and verbalize what you want to do.
- Draw a flow chart that outlines your solution.
- Add columns to your spreadsheet and perform the necessary calculations in stages.

TRAFFIC CHALLENGE 1



The intersection has road sensors that will tell it how many cars are on queue when the light turns green. The first lights that turn green are for lanes 1A and 1B. Your algorithm should determine the length of the green light by looking at which lane has the most cars. The same process must be repeated for lanes 2A and 2B. Set up a spreadsheet that has the following columns. Outline the logic statements and complete the spreadsheet.

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# Of Cars	Time Needed	Time Given (s)	# of Cars Left in Lane
Lane 1A							
Lane 1B							
Lane 2A							
Lane 2B							

Turn in a brief summary of the logic of the spreadsheet, a visual flowchart of the solution, the statements from your spreadsheets and data from five different settings.

ANSWERS/GUIDANCE FOR TRAFFIC CHALLENGE 1

	A	B	C	D	E	F	G	H
1	Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# Of Cars	Time Needed	Time Given	# of Cars Left in Lane
2	Lane 1 A							
3	Lane 1 B							
4	Lane 2 A							
5	Lane 2 B							

Time needed is a function of the time it takes for a car to clear the intersection and the number of cars on queue.

Time Needed
$F2 = E2 * D2$
$F3 = E3 * D3$
$F4 = E4 * D4$
$F5 = E5 * D5$

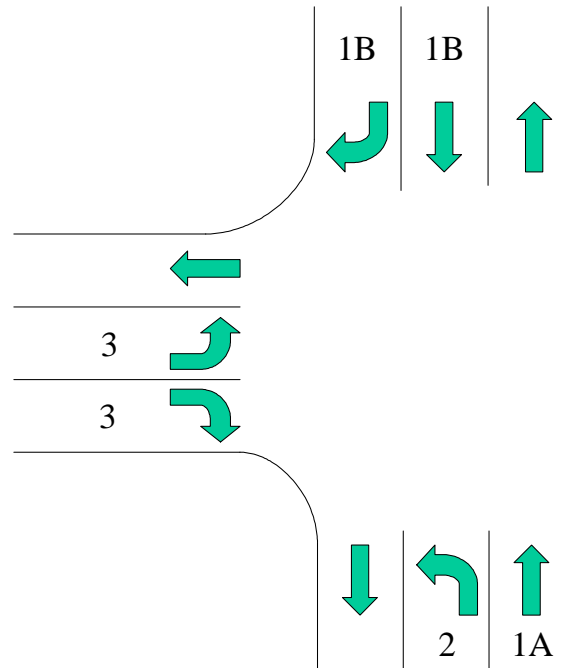
Time given compares the number of cars in each lane to determine the maximum time needed. The value from this is matched up against the maximum and minimum times to calculate how long the light will be left on.

Time Given (s)
$=IF(E2>E3,IF(E2>A2,A2,IF(E2<B2,B2,E2)),IF(E3>A3,A3,IF(E3<B3,B3,E3)))$
$=IF(E2>E3,IF(E2>A2,A2,IF(E2<B2,B2,E2)),IF(E3>A3,A3,IF(E3<B3,B3,E3)))$
$=IF(E4>E5,IF(E4>A4,A4,IF(E4<B4,B4,E4)),IF(E5>A5,A5,IF(E5<B5,B5,E5)))$
$=IF(E4>E5,IF(E4>A4,A4,IF(E4<B4,B4,E4)),IF(E5>A5,A5,IF(E5<B5,B5,E5)))$

The Number of Cars Left in Lane column is determined by comparing the Time Given and the Time Needed to determine how many cars could pass through the intersection.

of Cars Left Left in Lane
$=IF((E2-F2)/C2>0,(E2-F2)/C2,0)$
$=IF((E3-F3)/C3>0,(E3-F3)/C3,0)$
$=IF((E4-F4)/C4>0,(E4-F4)/C4,0)$
$=IF((E5-F5)/C5>0,(E5-F5)/C5,0)$

TRAFFIC CHALLENGE 2



The traffic intersection above has road sensors that will tell it how many cars are on queue when the light turns green. The first light that turns green are in lanes 1A and 1B. Cars in Lane 2 must yield to the oncoming traffic. If traffic is heavy, the cars in Lane 2 will not be able to go. The traffic system should sense this and signal a left turn arrow signal. If traffic is light and the cars in Lane 2 are able to turn during the green signal, the traffic system should not call the left turn signal. The light in Lane 1A remains green when the left turn arrow is on. After this, the traffic system will give the green light to Lane 3. The sequence then repeats itself.

Set up a spreadsheet that has the following columns. Outline the logic statements and complete the spreadsheet.

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# Of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1A							
Lane 1B							
Lane 2							
Lane 3							

Turn in a brief summary of the logic of the spreadsheet, a visual flowchart of the solution, the statements from your spreadsheets and data from five different settings.

ANSWERS/GUIDANCE FOR TRAFFIC CHALLENGE 2

The debugging of the spreadsheet will probably take students some time. It is recommended that students be given at least a couple of days to turn in their finished product. The data shown in the example table can be used as benchmark for students to try and beat. For the first three columns of data it might be good to set standard values to be used by the class. This would be ideal for comparing spreadsheets from different students.

	A	B	C	D	E	F	G	H
1	Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
2	Lane 1 A							
3	Lane 1 B							
4	Lane 2							
5	Lane 3							

Time needed is a function of the time it takes for a car to clear the intersection and the number of cars on queue.

Time Needed
F2 =E2*D2
F3 =E3*D3
F4 =E4*D4
F5 =E5*D5

The green light time for the left turn arrow is a function of the amount of traffic in Lane 1B. The light time for Lanes 1A and 1B are decided by whichever one has the greater time needed. The light time for Lane 1A also takes into account the light time of the left turn arrow. Lane 3 light time is a function of the needed time, maximum length of time, and minimum length of time.

Time Given
G2 =IF(F2>F3,IF(F2>B2,B2+G4,IF(F2<C2,C2+G4,F2+G4)),IF(F3>B3,B3+G4,IF(F3<C3,C3+G4,F3+G4)))
G3 =IF(F2>F3,IF(F2>B2,B2,IF(F2<C2,C2,F2)), IF(F3>B3,B3,IF(F3<C3,C3,F3)))
G4 =IF(F4<(G3-F3),0,IF((F4-(G3-F3))>B4,B4,IF((F4-(G3-F3))<C4,C4,IF((G3-F3)>0,F4-(G3-F3),F4))))
G5 =IF(F5>B5,B5,IF(F5<C5,C5,F5))

The Number of Cars Left in Lane column compares the Time Given and the Time Needed to determine how many cars could pass through the intersection. The calculation for Lane 2 incorporates the unused time from Lane 1B. During this “unused” time cars from Lane 2 could pass through the intersection.

of Cars Left in Lane
$H2 = IF((F2-(G3+G4))/D2>0,(F2-(G3+G4))/D2,0)$
$H3 = IF((F3-G3)/D3>0,(F3-G3)/D3,0)$
$H4 = IF((G3-F3)>0,IF((F4-(G4+(G3-F3)))/D4<0,0,(F4-(G4+(G3-F3)))/D4),IF((F4-G4)/D4<0,0,(F4-G4)/D4))$
$H5 = IF((F5-G5)/D5>0,(F5-G5)/D5,0)$

Scenario 1

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1 A	45	10	3	20	60	90	0
Lane 1 B	45	10	3	20	60	45	5
Lane 2	45	10	3	20	60	45	5
Lane 3	45	10	3	20	60	45	5

Scenario 2

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1 A	45	10	3	3	9	30	0
Lane 1 B	45	10	3	9	27	27	0
Lane 2	45	0	3	1	3	3	0
Lane 3	45	10	3	5	15	15	0

Scenario 3

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for car to clear intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1 A	45	10	3	1	3	54	0
Lane 1 B	45	10	3	12	36	36	0
Lane 2	45	10	3	6	18	18	0
Lane 3	45	10	3	7	21	21	0

Scenario 4

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1 A	45	10	3	12	36	48	0
Lane 1 B	45	10	3	20	60	45	5
Lane 2	45	10	3	1	3	3	0
Lane 3	45	10	3	20	60	45	5

Scenario 5

Traffic Lane	Max Length of Light	Minimum Length of Light	Time for Car to Clear Intersection	# of Cars	Time Needed	Time Given	# of Cars Left in Lane
Lane 1 A	45	10	3	3	9	39	0
Lane 1 B	45	10	3	3	9	10	0
Lane 2	45	0	3	10	30	29	0
Lane 3	45	10	3	1	3	10	0

Once students have turned in their spreadsheets, a discussion can be held to see who had the “most efficient” algorithm. If a computer lab is available, the teacher can have students try different scenarios to see who had the best solution.

ACTIVITY 5: REACTIVE TRAFFIC TECHNOLOGY

ACTIVITY TABLE

Teacher Prep Time	60 minutes
In Class Time	2 days
Out of Class Time	30-90 minutes
Grade/Course	6-12
Technology	Lo
NSES Standards Met	Appropriate Tools Technology and Mathematics Think Critically

OBJECTIVE

During this activity students will learn about how traffic detection systems use coils of wire to help in traffic detection. This activity will introduce students to the concept of induction.

MATERIALS NEEDED

Vernier Lab Pro Interface

Magnetic Field Sensor

A TI-83 Calculator or a computer with Logger Pro on it

A DC power source

A solenoid

Materials to affect the magnetic field (a bag with a rubber stop, galvanized bolt(round end) and stainless steel bolt(hexagonal end) are provided in the kit. Additional items may be used (brass bolts, pieces of wood or pure iron)

PROCEDURE

The teacher should go through as much of the background as necessary. Split the students into groups of two or three and have them set up the equipment as described in the setup section. Students then should work through the questions.

SET UP

This activity involves the use of need a TI-83 calculator or computer, Vernier Lab Pro, the Vernier magnetic field sensor for the Lab Pro, a solenoid, and a power source. Students can make their own solenoids using a pre-wound spool of wire. You should test the solenoid, power source, and magnetic probe set-up in advance, so you will be ready to help troubleshoot. The magnetic field sensor should be set up perpendicular to the open end of the solenoid. The side with the white dot should face the solenoid (this is the field detector and should be oriented so that the magnetic field lines pass through it). A stand and clamp should be used to hold the magnetic field sensor in place (see Figure 6). If a power source and solenoid are not available, three batteries in series and a spool of wire can be used. The wire should be wound around a spool with at least a 1-inch diameter hole. The coil of wire should be positioned so that the end the positive wire is connected to is positioned away from the magnetic field sensor.

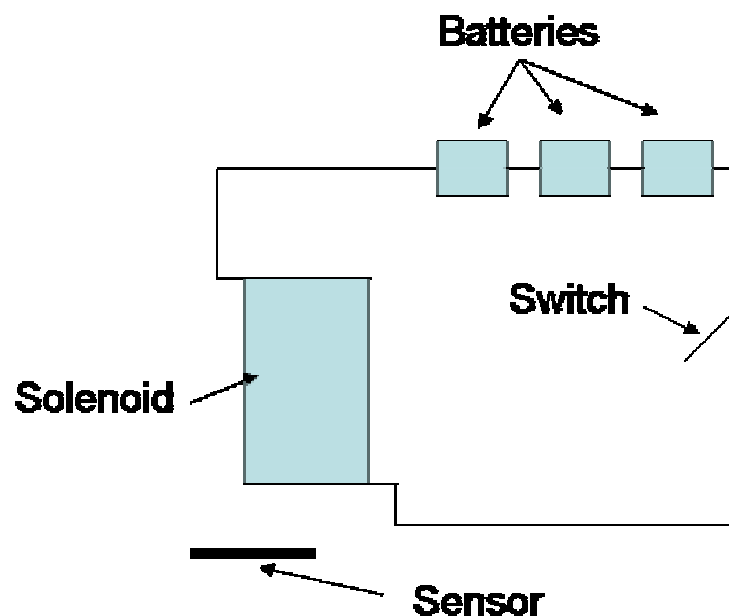


Figure 6. Reactive traffic technology activity set-up.

To use the magnetic field sensor the datamate program will be needed if the TI-83 calculators are to be used. If computers are going to be used the logger pro software should be used. If needed, consult the Lab Pro and magnetic field sensor documentation for further instruction on using this equipment (Vernier has done a great job at outlining simple, easy to follow steps in using their equipment) .

BACKGROUND

Intelligent traffic systems sense the presence or lack of presence of vehicles and react accordingly. The idea behind intelligent traffic systems is to reduce the amount of time drivers must spend unnecessarily waiting for traffic signals to change. Intelligent traffic systems detect traffic in many different ways. Older systems used weight as a trigger mechanism. Many newer traffic systems react to motion or use electro-magnetic induction to trigger the light changes. Once the sensor picks up the presence of a car the computer algorithms of the system calculate and set the appropriate signal changes.

Whenever current passes through a wire, it generates a magnetic field in a circular pattern around the wire (see Figure 7).

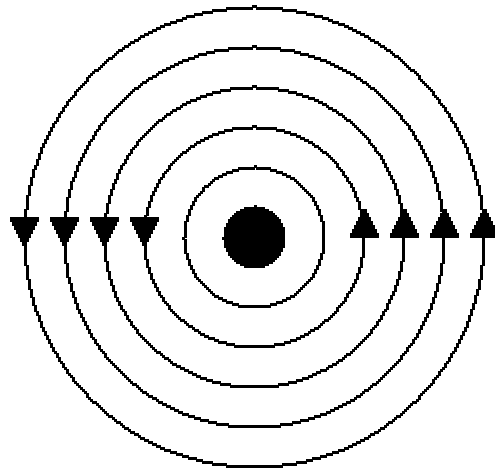


Figure 7. Model of the circular magnetic field around a wire.

Because the magnetic field around a wire is circular and perpendicular to the wire, an easy way to amplify the wire's magnetic field is to coil the wire, as shown in Figure 8.

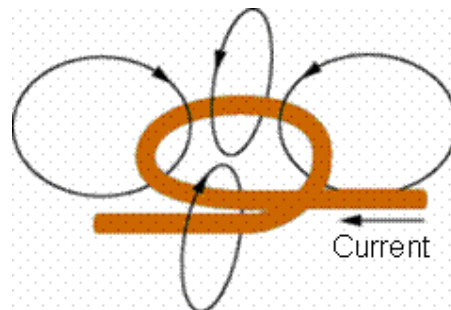


Figure 8. Model of magnetic field around coiled wire.

By making several loops and creating a coil of wire, a focused magnetic field can be created inside of the coil (see Figure 9). This is how electromagnets are created. Coils of wires are also referred to as inductors.

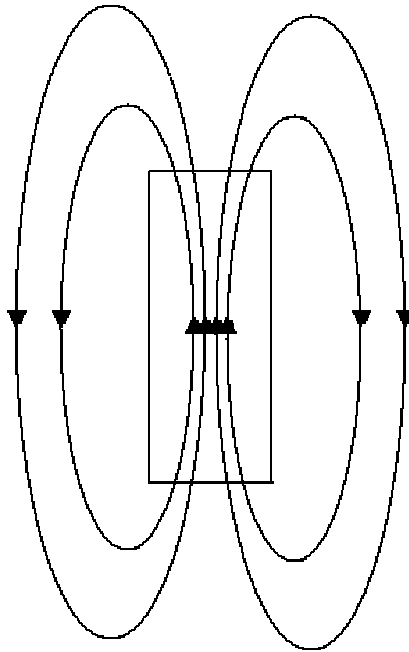


Figure 9. Model showing how a magnetic field is created inside coiled wire.

The magnetic field generated by an inductor is controlled by several factors:

1. The number of coils (N) per unit length (L).
2. The material the coils are wrapped around (μ). Putting iron in the core of an inductor gives it much more inductance than would air or any non-magnetic core.
3. The amount of current passing through the coil (I).
4. The permeability of free space (μ_0)

The strength of a magnetic field is measured in Tesla (T).

$$B = \frac{\mu_0 NI\mu}{L}$$

$$1T = 1 \frac{N}{A \cdot m}$$

The other measurement for magnetic field is Gauss.

$$1 \text{ Gauss} = 10^{-4} \text{ T}$$

Coils of wire are also referred to as inductors. The inductance of a coil is determined by the following:

1. The cross-sectional area of the coil (A).
2. The number of coils (N) per unit length (L).
3. The material that the coils are wrapped around (μ). Putting iron in the core of an inductor gives it much more inductance than would air or any non-magnetic core.
4. The amount of current passing through the coil (I).
5. The permeability of free space (μ_0)

The standard unit of inductance is the Henry (H). The equation for calculating the number of henries in an inductor is:

$$\text{Inductance} = \frac{\mu_0 N^2 A \mu}{L}$$

$$1H = \frac{T \cdot m}{A} \cdot \frac{m^2}{m} = \frac{N \cdot m}{A^2}$$

The area and length of the coil are in meters. The term μ is the permeability of the core. Air has a permeability of 1, while steel might have a permeability of 2,000. The magnetic field generated by an inductor is directly proportional to the current running through the inductor.

ACTIVITY 5 QUESTIONS

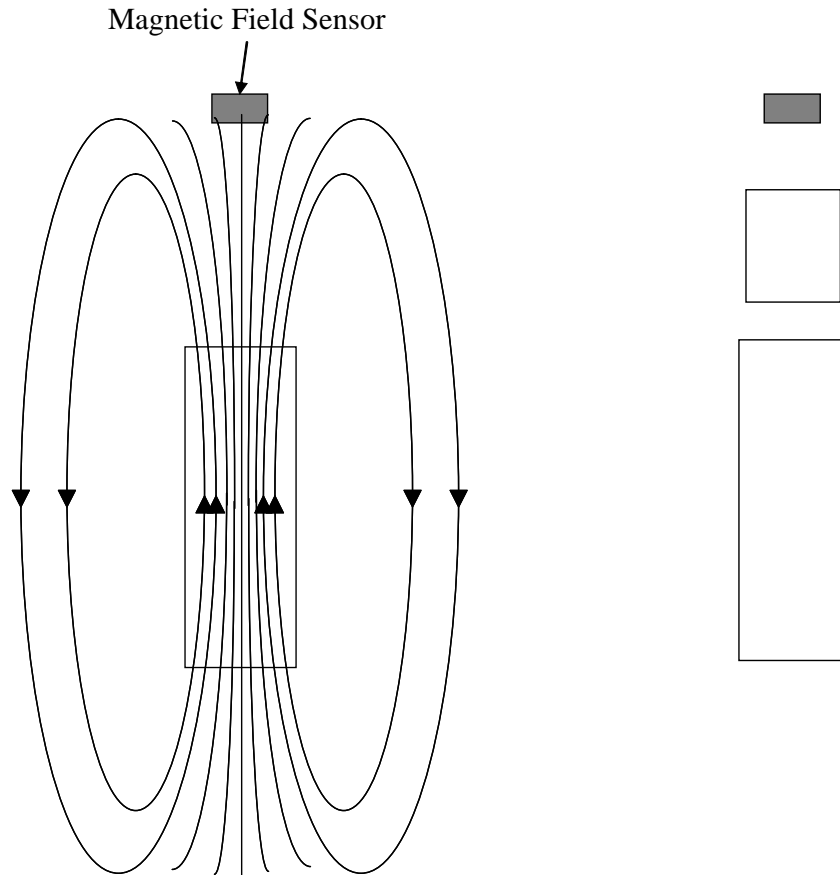
1. One at a time, pass the different pieces of material between the solenoid and the sensor. You should adjust the position of the magnetic field sensor so that there is about a half inch of space on either end of the material you are using. How did the magnetic field change for each object passed between the probe and solenoid?

2. Next place a long piece of ferrous metal between the solenoid and the sensor. First place it perpendicular to the opening of the solenoid. Next hold it parallel with the opening of the solenoid. How did the magnetic field change in each instance?

3. Compare the inductance formula and the magnetic field formula. How are they similar? How are they different? Do you change the inductance when you change the magnetic field produced by the inductor and vice versa? Under what conditions does one change the other?

$$B = \frac{\mu_o N \mu}{L} \quad \text{Inductance} = \frac{\mu_o N^2 A \mu}{L}$$

4. Placing the iron in the solenoid/inductor changes the permeability of the solenoid. The permeability of iron is much higher than air. How do you think the iron affects the field lines? Describe it and draw it on the diagram below. What do you think permeability means?



5. When a vehicle pulls up to some stoplights, the stoplight “knows” the vehicle is there, because of a buried coil of wire in the road. Based on what you observed to answer the previous questions, how does it “know”? Explain in terms of the magnetic field and inductance formulas what is happening.

SUGGESTED SOLUTIONS FOR ACTIVITY 5

1. One at a time, pass a piece of iron, wood, plastic and your hand between the solenoid and the sensor. How did the magnetic field change for each object passed between the probe and solenoid?

Students should see the magnetic field picked up by the sensor change only when iron or another ferrous material is passed between the solenoid and sensor

2. Next place a long piece of ferrous metal between the solenoid and the sensor. First place it perpendicular to the opening of the solenoid. Next hold it parallel with the opening of the solenoid. How did the magnetic field change in each instance?

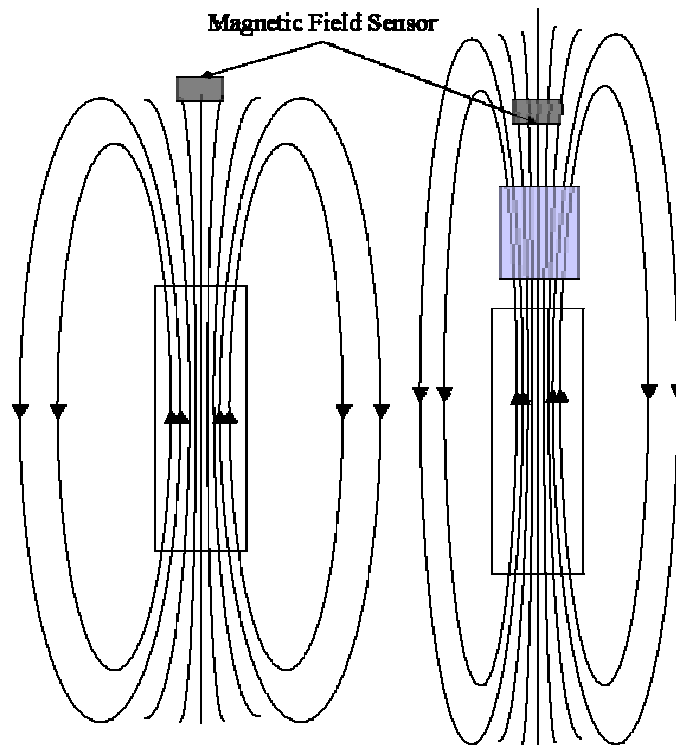
When held parallel to the opening, the change in field detected should be much greater.

3. Compare the inductance formula and the magnetic field formula. How are they similar? How are they different? Do you change the inductance when you change the magnetic field produced by the inductor and vice versa? Under what conditions does one change the other?

$$B = \frac{I\mu_o N\mu}{L} \quad \text{Inductance} = \frac{\mu_o N^2 A\mu}{L}$$

The two equations differ in that the inductance is affected by the area of the coil, while the magnetic field produced by that same inductor is also dependent on the current passing through the coil.

4. Placing the iron in solenoid/inductor changes the permeability of the solenoid. The permeability of iron is much higher than air. How do you think the iron affects the field lines? Describe it and draw it on the diagram below. What do you think permeability means?



The iron acts as a conduit for the magnetic field lines and channels them to spread out much further from the end of the solenoid. Because the field lines remain closer together, more of them will pass through the magnetic field sensor, causing a greater strength signal to be picked up. The iron squeezes the magnetic field lines together. The word permeates means to flood or saturate. Magnetic permeability means that more magnetic field lines can be crammed into a given space.

5. When a vehicle pulls up to some stoplights, the stoplight “knows” the vehicle is there, because of a buried coil of wire in the road. Based on what you observed to answer the previous questions, how does it “know”? Explain in terms of the magnetic field and inductance formulas what is happening.

When a truck, which has large amounts of ferrous materials in it, parks over the buried coil of wire, it changes the inductance of the coil and magnetic field that flows through it just as the iron placed in front of the solenoid did. This is because the truck is increasing the magnetic permeability of the coil of wire.

VOLUNTEER'S PAGE

Activity 1, 2 and 3: The first three activities deal with the design of traffic intersections. The concepts linear motion are being taught through applications of reaction time, braking distance and the factors associated with setting the length of the yellow light time in a traffic signal.

- A *traffic engineer* can discuss how far a car travels in a second and reinforce the importance of drivers not being distracted while they are driving or following the car in front of them too closely.
- The class volunteer can talk about the procedure used to test the braking distance of vehicles and how road conditions affect braking distance.
- The class volunteer can discuss the different stages of a traffic light, as well as explaining all the different elements that go into making design decisions.

Any video footage or demonstrations that the volunteer may have access to through their work with the department of transportation would also be a nice addition to these activities

Activity 4, Traffic System Programming Logic: In this activity the students will be constructing algorithms that would be used to control a light system at an intersection. The activity is designed to help build problem solving and logic skills. Talking about engineering problem solving approaches as well as design factors of intersections would add significant value to this activity.

Activity 5, Reactive Traffic Technology, is ideal for any person with an intelligent traffic systems background. Discussing the different ways induction loops are used in traffic detection would be helpful. On page 34 there is a diagram of the set up the students will be using to create a magnetic field. They will pass ferrous and non ferrous materials to see how the magnetic field and hence induction are affected.