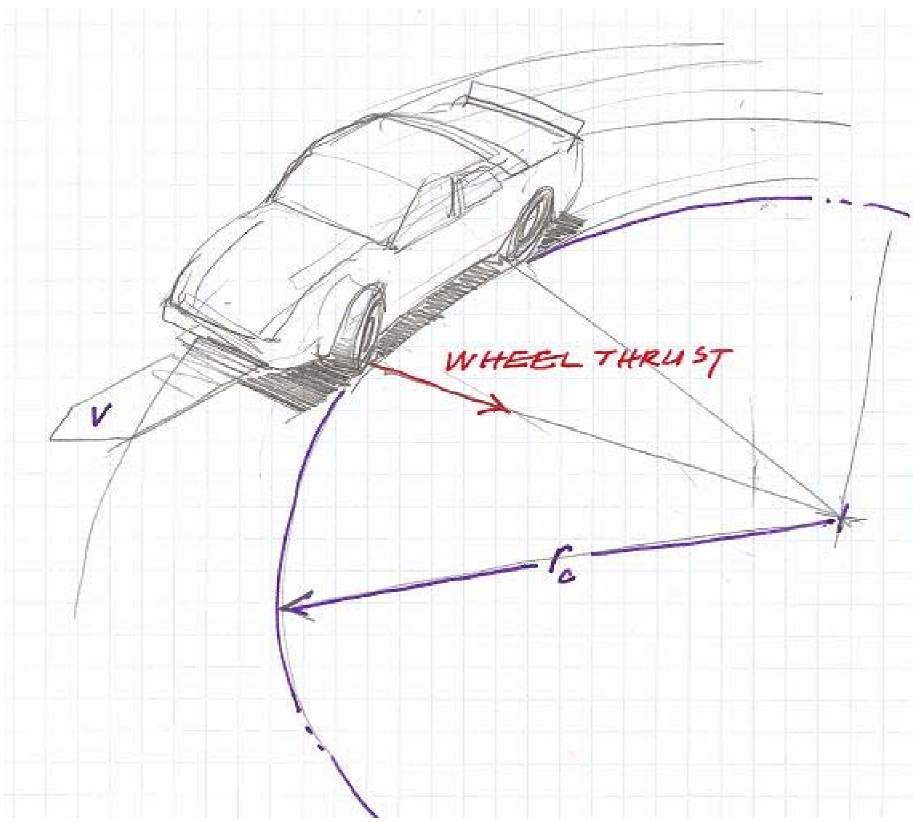
The Science of Racing Series

Activities Created by Ten80 Education
and Texas Instruments



Activity 2: Hitting the Mark

It's All About Speed

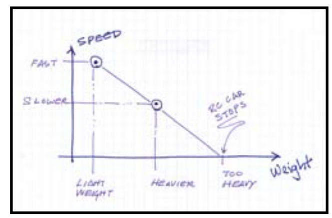
The shortest path is not always the fastest one. For example, a race car does not travel around the inside skirt of the track though this is undoubtedly the shortest path. A baseball player does not run the bases by making ninety degree turns at every base. It is very important that a race team (and any other team in the business of transporting items across some distance in the shortest amount of time) understands the relationship between speed, time and distance. Their job is to make the average time of their trip smaller than everyone else's time.

You will hear drivers say they "hit their mark". They are referring to the places on the track at which they must slow down or speed up in order to drive the fastest path. The distance driven on any lap is not really the official distance given for a track. For example, the measurement for the 1.5 mile track in Charlotte, NC is taken 20 feet inside the outside wall. When Jimmy Johnson posts a qualifying run on this track of 28.764 seconds, his speed would be calculated at 187.74 miles per hour. When the replay is watched, he was almost touching the outside walls on the straight aways and diving toward the apron of the track on the corners. He slowed down to make the corners and drove faster on the straight aways.

In these qualifying runs, the best of two laps is the posted time and the qualifying speed is an Average Speed. If you watch a speedometer you are seeing a representation of Instantaneous speed.

Since running a race car is VERY expensive, race engineers know a great deal about how speed, time and distance relate. In this activity, you will investigate the relationship between distance traveled, speed and elapsed time. You will create a picture in the form of a graph from which you can make predictions relating to these measurements.

Activity at a Glance:
Grade: 6-9
Subject: Physical Science
Subject: Math
Topic: Average Speed
Time: 45-minute periods



Visit the engineers and educators of Ten80 Education at

www.ten80education.com

Materials:

- TI-73 Explorer
- Student Handout
- Transparencies with sample data: H the Mark_2A and 2B
- Background Paper: F=ma Article: Science of Racing

Optional for collecting your own data:
- RC (radio controlled) car (1/16th or smaller is suggested)
- Scale to weigh the RC car
- Stop watches
- Tape measure (meter stick, or yard stick, etc.)

Extensions:
Technology Unit 1

The Science of Racing
Hitting the Mark

Student Investigation

Name ________________ Date __________

1. **State the Objective:**
Create a mathematical model (equation and graph) that illustrates how top-speed, distance and time are related and is useful for predicting the speed of the car at various car-weights (exclude acceleration in this activity). Examine average vs. instantaneous speeds.

2. **State the Problem:**
Create a scenario that will help you investigate these variables.

Suppose you have two cars traveling the same distance. One car travels at constant speed, carrying a single load the entire distance. The other car carries a load that changes once during the trip so that this second car travels at two different average speeds.

Both cars are to cross the finish line at the same time, meaning they travel at the same average speed over the full distance. Use the model to determine the weight of the “constant-speed car” that would make it travel the full distance of the track in the same time as the second, ”two-load car”.

3. **Plan an investigation:**
Set up the scenario in which two RC cars are traveling the same distance, but in different ways.

Set up a track divided into two segments, A and B, of unequal distance. The car should be at top speed when crossing the Start lines for segments A or B. Drive segment A carrying a heavy load. Record several times for each run (using several timers). Drive segment B carrying a lighter load. Record the times. Drive segments A and B together (A+B is the distance) and record the times. Use the data to make a mathematical model (graph) to determine the weight of a vehicle which will run the total track distance in the same total time.

4. **Make a prediction in your SCIENCE OF RACING LOG.**
Race cars or any other moving object travel at varying speeds (heavier with a full gas tank and lighter as it empties, or faster with new tires and slower as tires wear). It is important to understand the difference in average speed, constant speed and instantaneous speed.

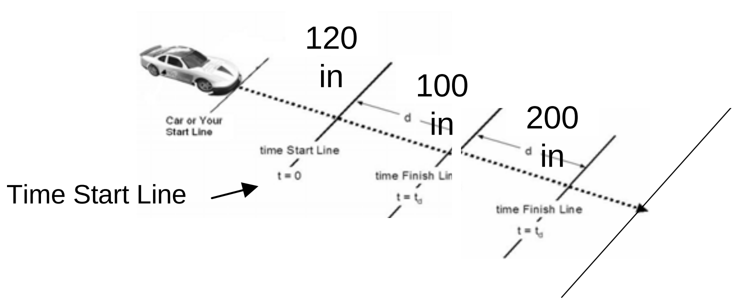
These activities are designed to be used with the TI 73 Explorer but are easily adapted to other TI calculators. Download more Math2Go lessons on the Science of Racing at www.ten80education.com

5. Set up your investigation.

- Make a plan for collecting data. Assemble materials and practice so that team members know how to read watches, scales, and tape measures and are familiar with the controls on the vehicle.
- Assign roles: Each team requires a driver, timers, a data recorder, calculator of the human kind and a crew chief who keeps track of all materials and schedules for completion of assignments.

6. Set Up the Car and Track

- From START, measure approximately 120 inches and mark with tape. This is the line at which timers start their watches. The car should be up to top speed once crossing this line.
- Mark the Finish Line#A approximately 100 inches from the Start Time Line. Mark finish Line#B 300 inches from the start line. Drivers should not slow the car until they are past the Finish Line. (These are suggested measurements and can be adjusted to meet size constraints of your classroom or hallways).
- Add weights to a radio controlled car. The weights can be washers taped to the car or soda bottles with water added.



See transparency Hitting the Mark-2A for track plan

Vocabulary:

Average speed describes speed of motion when speed is changing.

Instantaneous speed is speed at a given point of time.

Speed
Distance traveled in some amount of time or
speed = d / t

Velocity
Speed in some direction.

Constant Velocity describes motion in which neither speed or direction are changing.

Distance describes how far an object moves.

Displacement describes a change in an object relative to its starting point.

7. Collect Data

- Have three timers time each test run.
- Start car at start line and begin timing at Time Start Line.
- Record times for each run on the table below

To learn more about the Science of Racing, contact Professor Pi at ProfPi@ten80education.com

Data Table A

Distance	100 in.	200 in	300 in
Vehicle Weight in oz.	Fully loaded	Partial load	Average load
Timer # 1			
Timer # 2			
Timer # 3			
Time Totals			
Time Average in sec.			
Speed d/t	In/sec	In/sec	In/sec

Note

After collection of your own data, you may want to use Professor Pi's sample data. You can practice the steps shown here that help you to analyze and gain insight from your numbers.

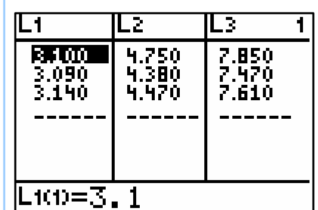
See Transparency_ Hitting the Mark_ 2A

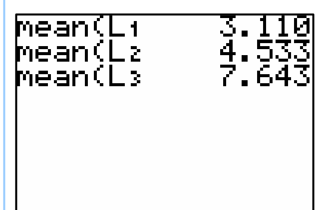
8. Calculate and store Average Times (mean) values

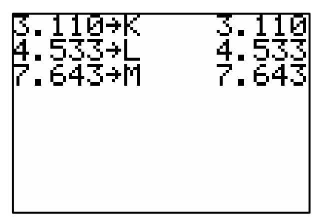
- **Create time lists in the List Editor.** [LIST]
  - Under L1, enter three times for Run # 1: the car running the first part of the course and under L2, enter three times for run # 2: the car running the second part of the course.
  - Return to the home screen [2nd][QUIT][CLEAR] and calculate the average time for each run.
  - [2nd][STAT][▶][▶]3
  - [2nd][STAT][ENTER][ENTER] for the average of run #1 times
  - [2nd][STAT][▶][▶]3
  - [2nd][STAT][▼][ENTER][ENTER] for the average of run# 2 times

- **Store these average times for later recall.**
  - On the home screen, use the up arrow keys [▲] to scroll up to previous entries and highlight the average for L1. Press enter [ENTER] to place that number at the bottom of the screen. Press [STO▶] [2nd][TEXT][ENTER][▼][▼][▼][▼][ENTER][ENTER]
  - Repeat these steps to store the averages for L2
  - The values stored for the average times for 2 runs of decreasing weights are A and B. (You may choose other variables.)

Sample Data Set







You have your own data. The following directions will use Professor Pi's sample data to demonstrate steps you might take to solve the problem.

Use Transparency Hitting the Mark_2A for Sample Data Set

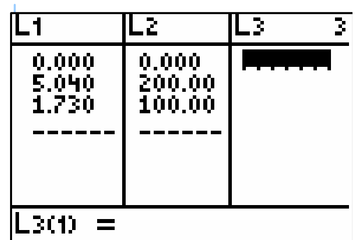
What do you know and what do you need to know?

With distance and time you have enough information to calculate speeds. Create graphs to analyze the data.

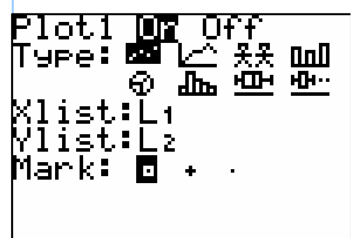
9. Graph Distance as a function of Time to find speed.

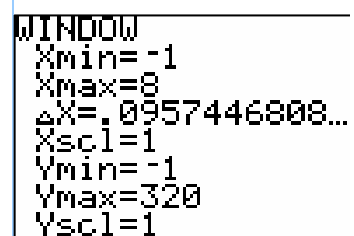
The slope of a Distance-Time graph is Speed

These directions use Professor Pi's Sample data as inputs**.**

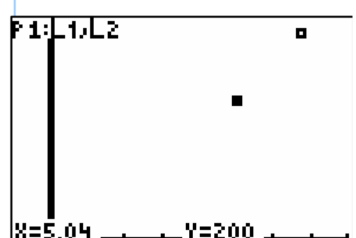


- **Clear all lists** [2nd] [MEM] 6 DONE
- **Create two lists from your data table.**
  - o Average times in L1
    [LIST] [▼] 0 [ENTER] 5.040 [ENTER] 1.73 [ENTER]
  - o Displacement in L2
    [▲][▲][▶] 0 [ENTER] 200 [ENTER]
    100 [ENTER]
  - o Note the first line contains the (X,Y) point (0 time, 0 displacement)

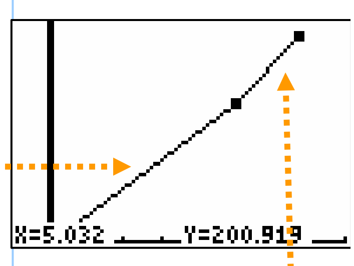




- **Define a Stats Plot for distance and time graph**
  - o [2nd][PLOT] [ENTER] Select ON for Plot 1
  - o [▼] [▶] Select the plot [ENTER]
  - o Select L1 for XList [2nd][STAT][ENTER][▼] and
  - o L2 for YList [2nd][STAT] [▼] [ENTER].
  - o Adjust Window value [WINDOW]
  - o x min =-1 x max=8 Ymin=-1 Ymax=320
  - o You will adjust window values to your minimum and maximum data values plus 5.
- [GRAPH][TRACE]



Slope = speed of 39.71 in/sec



Slope = speed of 57.88 in/sec

A quick check (divide distance by time) shows that the slopes are equal to the speeds of the cars on two parts of the track.

The Science of Racing
Hitting the Mark
Data Analysis: Use Professor Pi's Data

What do you know and what do you need to know?

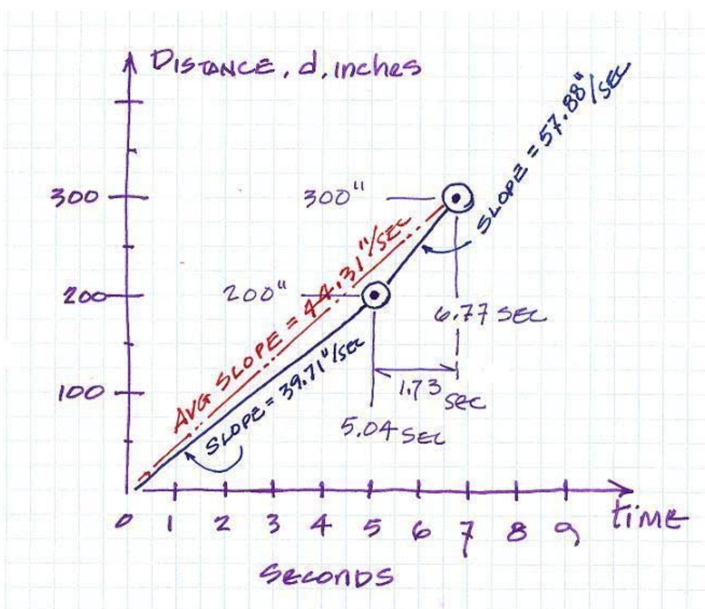
Sample
Data Set

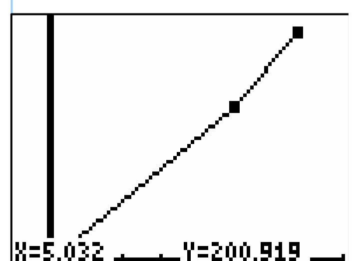
We now know the average speeds for each part of the track but still need to find the speed at which a car would travel the same distance at a constant speed in the same amount of time This speed will be the slope of the line connecting (time, distance) at the start line with (time, distance) at the finish line or (0,0) and (6.77, 300). Here are the graphs Professor Pi drew.

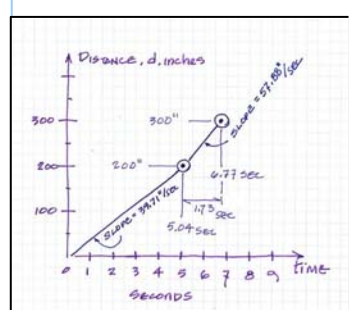
Slope = $(Y_2 - Y_1) \div (X_2 - X_1)$

The units in slope on this graph are (inches ÷ second) or inches/second

Slope = (300 – 0) inches ÷ (6.77 - 0) seconds   = 44.313 inches/second







A car traveling 44 inches per second will cross the finish line of our 300 inch course at the same time that the car traveling at our two different speeds along the course. That is, both cars require a total of 6.7 seconds to travel 300 inches.

⇒One car travels at a constant speed of 44 inches per second.

⇒One car travels at different speeds, covering 200 inches in 5.04 seconds at a speed of 39 in/sec and covering another 100 inches in 1.73 seconds at a speed of 58 in/sec.

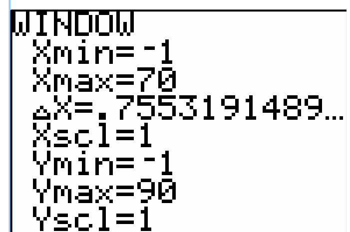
The Science of Racing
Hitting the Mark
Data Analysis: Use Professor Pi's Data

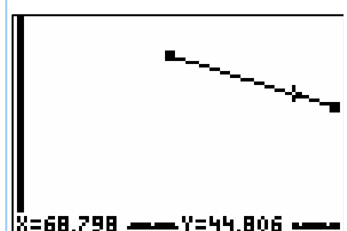
What do you know and what do you need to know?
We now know the constant speed at which a car could travel to reach the finish line at the same time as our car traveling at the two different speeds. We still need to know what weight the car should be to travel at this constant speed.

Sample Data Set

10. Create a Graph of Speed as a Function of Weight to determine the weight of the car driving the entire track. These inputs are from Professor Pi's Sample data**.**

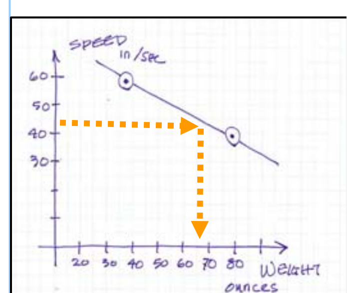
- **Clear all lists** [2nd] [MEM] 6 DONE
- **Create four lists from your data table.**
  - Average times in L1 (you may recall stored values)
    [LIST] [▼] 5.040 [ENTER] 1.73 [ENTER]
  - Distance in L2
    [▲][▲][▶] 200 [ENTER] 100 [ENTER]
  - Weights in L3
    [▲][▲][▶] 79 [ENTER] 37.7 [ENTER]
  - Speed formula in L4
    [▲][▲][▶] [ENTER] [2nd][STAT] [▼] ÷ [2nd][STAT] [ENTER][ENTER]





- **Define a Stats Plot for speed - weight graph**
  - [2nd][PLOT] [ENTER] Select ON for Plot 1
  - [▼] [▶] Select the plot [ENTER]
  - Select L3 for XList [2nd][STAT] [▼] [▼] [ENTER] [▼] and
  - L2 for YList [2nd][STAT] [▼] [▼] [▼] [ENTER].
  - Adjust Window value [WINDOW]
  - x min =-1 x max=70 Ymin=-1 Ymax=90
  - You will adjust window values to your minimum and maximum data values plus 5.
- [GRAPH] and scroll to the Y=44 in/sec speed.

Y = speed



X = weight

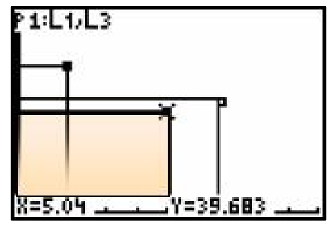
The X at this point shows a car weighing 68.7 ounces should finish in the same 6.74 seconds as the car with varying weight.

Follow Steps 8 – 10 to analyze your own data.

Sample
Data Set

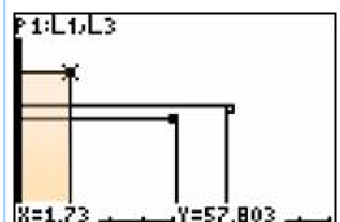
11. Check your work. Create a Speed-Time Graph. The Area under the "curve" is the distance traveled.

A speed-time graph allows you to divide the areas under the "curve", looking at each part of the course separately.

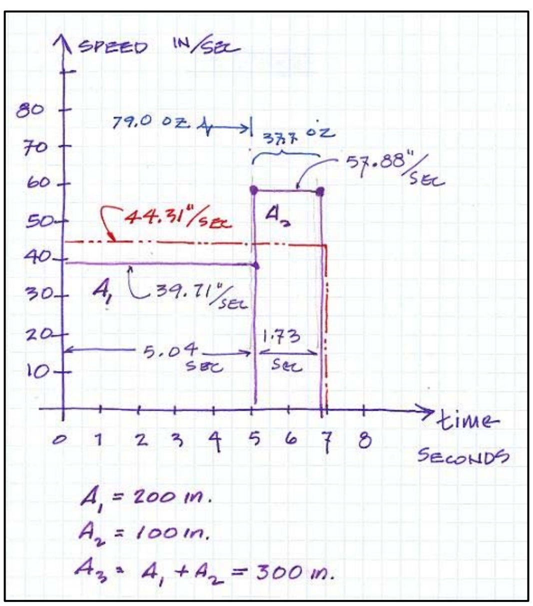


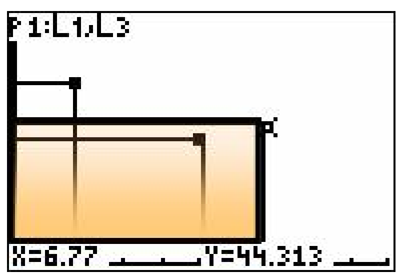
Make a rectangle of the area anchored by the (X,Y) coordinate for speed and time on that section. For instance find the area of the rectangle with side 5.04 and 39.71. It is 200 rounded to the nearest whole number.

Make a rectangle of the area anchored by (5.04,0), (6.77,0), (5.04,57.88) and (6.77,57.88). The X distance is 1.73 times the Y distance of 57.88. The area is 100 inches rounded to the nearest whole number.



Do you see the pattern? If our calculations are correct, the rectangle under the speed curve for 44.31 will equal the entire course of 300 inches. Try it!





Area under curve = distance

6.77sec x 44.31 in/sec =

299.973 which rounds to 300 inches.

The screen shots on this page are a Speed-Time graph.

Draw was used to add lines to show areas.

12. Graphs are mathematical models.

A graph is a model of what you observed, just as the radio controlled car models a real car. Scientists and engineers work with mathematical models to make them as accurate as possible so that predictions made from them are as accurate as possible.

distance = speed x times

On a speed-time graph in which speed is on the Y Axis and time is on the X Axis, the area under the "curve" is the distance.

If you revisit the Charlotte race track and graph each quarter of Jimmy Johnson's 28.764 second qualifying lap, you could form a better picture of the distance he traveled in any given amount of time. By graphing smaller and smaller segments of time, the picture of instantaneous velocity begins to take shape.

In your Science of Racing Log, create a series of hand drawn graphs representing your understanding of the relationship between speed, distance and time. You may want to look back at some of the graphs Professor Pi drew to help you get started.

The Science of Racing

Hitting the Mark

Additional Assessment:

Assessment:

- What is the difference in instantaneous velocity, constant velocity and average velocity?
- If you graph distance on the Y Axis and time on the X Axis the line connecting the points represents ____________________.
- If you graph speed on the Y Axis and time on the X Axis the area under the speed line or curve represents ____________
- How would you describe the relationship between speed, distance and time?.
- What is your understanding of a math model and how might it help you to be able to create these models?
- What is the math formula for calculating speed?
- What is the math formula for calculating distance if you know speed and time?

The Science of Racing
Hitting the Mark
Additional Assessment:

Assessment:

- What is the difference in instantaneous velocity, constant velocity and average velocity?
  - *See vocabulary*
- If you graph distance on the Y Axis and time on the X Axis the "best fit" line connecting the plotted points represents
  - *Speed : the units of the slope are distance divided by time.*
- If you graph speed on the Y Axis and time on the X Axis the area under the speed line or curve represents
  - *Distance: the units are distance per second x seconds which cancels out to leave only distance.*
- How would you describe the relationship between speed, distance and time?.
  - *Speed equals distance multiplied by time.*
- What is your understanding of a math model and how might it help you to be able to create these models?
  - *Math models allow you to predict things you have not directly measured.*
- What is the math formula for calculating speed?
  - *See Vocabulary*
- What is the math formula for calculating distance if you know speed and time?
  - *Speed times time equals distance which is again why the distance is the area under the speed-time graph.*

Vocabulary:

Average speed describes speed of motion when speed is changing.

Instantaneous speed is speed at a given point of time.

Speed Distance traveled in some amount of time or speed = d / t

Velocity Speed in some direction.

Constant Velocity describes motion in which neither speed or direction are changing.

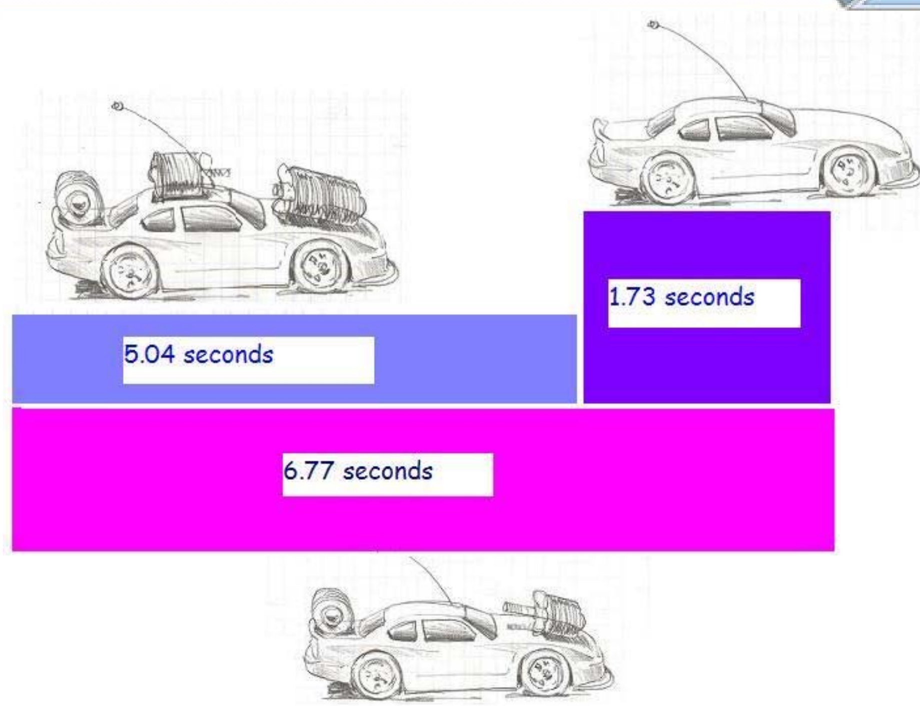
Distance describes how far an object moves.

Displacement describes a change in an object relative to its starting point.

The Science of Racing

Hitting the Mark

Transparency_Hitting the Mark_2A
Use Professor Pi's Data



Distance	200 inches	100 inches	300 inches
Vehicle Weight in oz.	Fully loaded 79	Partial load 37.7	?
Timer # 1	5.03	1.75	
Timer # 2	5.1	1.7	
Timer # 3	4.99	1.74	
Time Totals	15.12	5.19	
Time Average in sec.	5.04	1.73	6.77
Speed d/t	In/sec	In/sec	In/sec

Use Professor Pi's Data: Find Average Speed.

The professor's radio controlled car weighs 79 ounces.

It traveled 200 inches at a constant speed and completed the first part of the course in 5.04 seconds.

At this point the reduced the car's weight to 37.7 ounces.

It traveled 100 inches at a constant speed and completed this part of the course in 1.73 seconds.

Questions:

What weight vehicle should complete the entire course in the same total time?

At what Average Speed would this vehicle travel?

The Science of Racing

Transparency_Hitting the Mark_2B
Solutions

Hitting the Mark

Distance	200 inches	100 inches	300 inches
Vehicle Weight in oz.	Fully loaded 79	Partial load 37.7	68.7
Timer # 1	5.03	1.75	
Timer # 2	5.1	1.7	
Timer # 3	4.99	1.74	
Time Totals	15.12	5.19	
Time Average in sec.	5.04	1.73	6.77
Speed d/t	39.71 In/sec	57.8 In/sec	44.8 In/sec

Use Professor Pi's Data: Find Average Speed.

The professor's radio controlled car weighs 79 ounces.

It traveled 200 inches at a constant speed and completed the first part of the course in 5.04 seconds.

At this point the reduced the car's weight to 37.7 ounces.

It traveled 100 inches at a constant speed and completed this part of the course in 1.73 seconds.

Questions:

What weight vehicle should complete the entire course in the same total time?

At what Average Speed would this vehicle travel?

Science of Racing Series

Correlations to National Science Standards

Activities 01 - 06

☑ Comprehensive coverage ✓ Partial coverage

PROGRAM STANDARD C:
Mathematics is important in all aspects of scientific inquiry.

The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics.

ACTIVITIES

1	2	3	4	5	6
☑	☑	☑	☑	☑	☑

PROGRAM STANDARD B:
Properties & changes of properties in matter , Motions and forces, Transfer of energy

MOTIONS AND FORCES

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.

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.

ACTIVITIES

1	2	3	4	5	6
☑	☑	☑	☑	☑	
✓	☑	✓	✓	✓	
			☑		

TRANSFER OF ENERGY

Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers

ACTIVITIES

1	2	3	4	5	6
✓	✓	✓	✓	☑	☑
					☑
				☑	☑
					☑

CONTENT STANDARD D:

Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.

1	2	3	4	5	6
			☑		

CONTENT STANDARD G:

The introduction of historical examples will help students see the scientific enterprise as more philosophical, social, and human. Middle-school students can thereby develop a better understanding of scientific inquiry and the interactions between science and society.

1	2	3	4	5	6
☑	☑	☑	☑	☑	☑