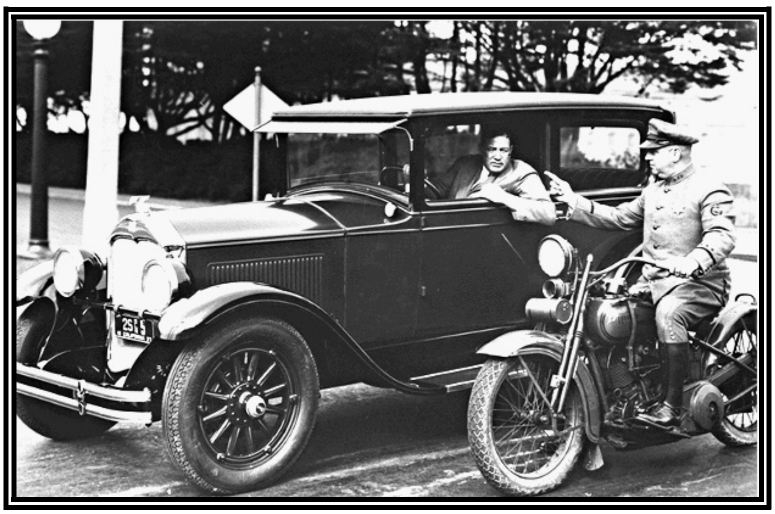
INQUIRY PHYSICS

A Modified Learning Cycle Curriculum
by Granger Meador

Unit 1: Motion

Student Papers



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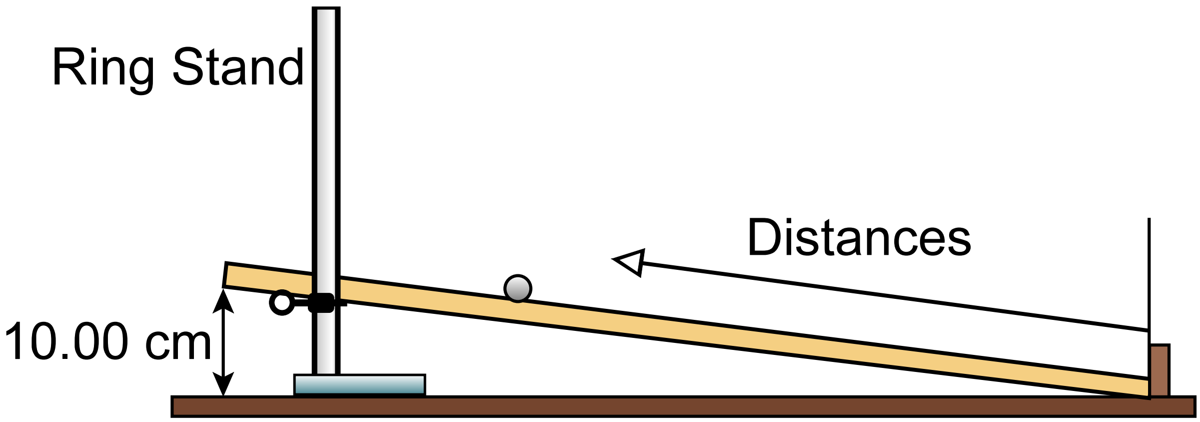
1: Motion

Lab: Galilean Ramp

Name______________________________

There are fundamental principles governing the motion of all objects, from supersonic aircraft to glaciers. This lab is similar to experiments conducted by Galileo Galilei several hundred years ago which laid the foundations for modern-day physics.

Set up the equipment as shown in the diagram below:



Use the ring stand and ring to raise one end of the track until the distance between the bottom of the track and the tabletop is 10.00 cm.

You will be varying distance. If necessary, mark off on masking tape the following distances from the lower end of the track: 25.00 cm, 50.00 cm, 75.00 cm, 100.00 cm, 125.00 cm, 150.00 cm, and 175.00 cm. Be sure the tape will not interfere with the motion of the ball or cart. You will measure the time required for the ball/cart to travel each of those seven distances.

1. Begin taking data by placing the ball/cart at the 175.00 cm mark. To start the ball/cart the same way each time, keep it at the mark on the incline with a pencil until you are ready to release it and begin timing. Don't push or spin the ball/cart when you pull the pencil away! Start a stopwatch as the ball/cart is released and stop the watch when it reaches the stop. Make **three** measurements of time to as many decimal places as possible, ensuring that the difference between the highest and lowest measurements is no more than 0.10 s. Record those values in the table on the reverse.

2. Gather the same data as before, but start the ball/cart at the mark that will make the distance equal to 150.00 cm. Make three measurements of time and record them in the table.

3. Repeat the data gathering process for each of the other distances. Record the data in the table.

Distance (cm)	Time (s)	Average Time (s)	
175.00			
150.00			
125.00			
100.00			
75.00			
50.00			
25.00			

The Idea ANSWER ALL QUESTIONS IN COMPLETE SENTENCES

1. Identify the independent and dependent variables in this experiment.

____

____

Create a graph of distance traveled along the incline versus **average** time. Graphs involving time always plot time horizontally on the x-axis and the other variable vertically on the y-axis. This can violate the usual practice of placing the independent variable on the x-axis and the dependent on the y-axis.

You need to decide if (0,0) is a valid point to include. Make sure each member of the group has a graph.

2. What is the shape of the line on your graph? (Is it straight or is it curved? If it is curved, state whether it looks parabolic or hyperbolic, etc.)

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3. The shape of a graph illustrates the mathematical relationship between the independent and dependent variables. What does your graph specifically show you about the relationship between distance and time?

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4. Express the relationship you described in question 3 as a proportionality: ____________________

5. According to the graph, what was the ball/cart doing as it went down the track?

____

6. Apply a best-fit curve to your graph. What type of fit did you perform, or instruct the computer or calculator to perform (linear, quadratic, inverse, etc.)?

____

7. In question 4, you expressed the basic proportionality between the independent and dependent variables. Your best-fit curve allows you to now express the precise equation for your group's data. Use your graph to fill in the missing values in this equation. **Round off the values to the appropriate number of significant figures.**

$d =$ ________ + ________ t + ________ t^2

Soon we will examine *how* the speed of the ball/cart was changing.

ANSWER ALL QUESTIONS IN COMPLETE SENTENCES, EXCEPT FOR MATH FORMULAS

8. What kind of fit (linear, quadratic, inverse, etc.) did you perform on the speed vs. time graph?

____

9. What does this graph indicate about the relationship between speed and time?

____

____

10. Express the relationship you described in question 9 as a proportionality: ____________________

11. How was the speed changing as the ball/cart went down the track?

____

____

12. Your graph allows you to formulate an equation that fits your data. Write that equation below, substituting the appropriate variable letters for x and y, and rounding off the numbers to the proper significant figures.

____

Types of Laboratory Error

Type	Examples	Prevention	Discussion
personal error (mistakes)	mis-reading a scale or incorrectly rearranging an equation or calculating a figure	check against lab partners' work; redo parts of lab as needed when error discovered	**none**; should be corrected before lab is submitted
systematic error	miscalibration or uncontrolled variables (e.g. friction); includes unavoidable timing errors	calibrate equipment when possible; think through procedures to minimize error	**identify any uncontrollable variables** (do not include variables causing random error)
random error	estimating the last digit on a scale reading; minor variations in temperature or air pressure	eliminate when possible; can never be completely eliminated	**none**

13. In a few sentences, discuss the systematic error in this laboratory.

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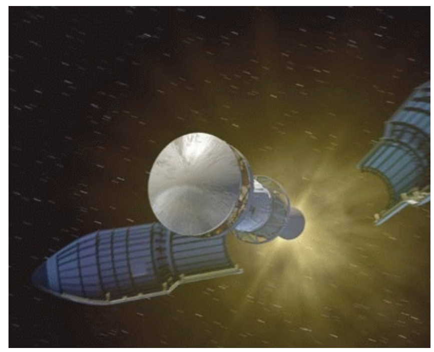
1: Motion

Name______________________________

Worksheet A: Calculating Motion

1. The Spirit and Opportunity robot rovers landed on Mars in 2004 and explored its surface for years. The rovers' spacecraft and the rovers themselves travelled at wildly different speeds.

   a. The Spirit rover could move across the Martian landscape at a maximum of 2.68 m/min. How many minutes would it take for it to travel 10.4 m, the length of a typical classroom?



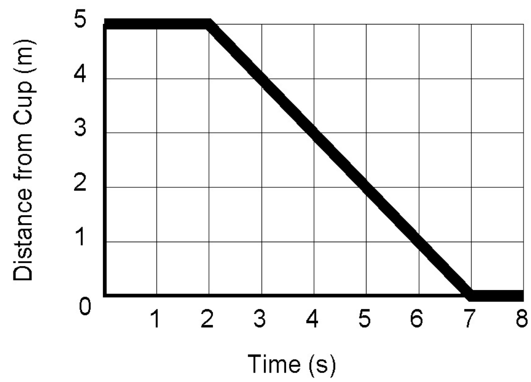
   2. Spirit journeyed to Mars in a spacecraft that traveled about 487 gigameters (487×10^9 m or 303 million miles) from Earth to Mars, averaging about 27,100 m/s (60,600 mi/h). Use the SI units to calculate how many Earth **days** it took for the spacecraft to complete its journey.

2. A runner in a 1.00×10^2 meter race passes the 40.0 meter mark with a speed of 5.00 m/s.

   a. If she maintains that speed, ***how far from the starting line*** will she be 3.00 seconds later?

   b. If 5.00 m/s was her top speed, what is the shortest possible time for her entire 1.00×10^2 m run?

CONTINUED…



3. The graph above describes the motion of a golf ball. Note that it graphs *distance from a position*, **not** *distance traveled.* The ball is placed on the green at 5 meters from the cup at t=0 seconds.

a. How far from the cup was the ball at t = 1 second?

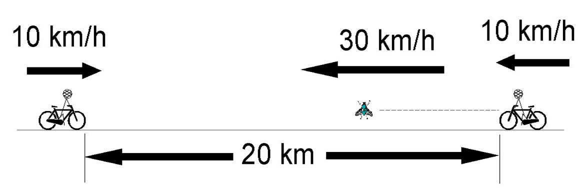
b. What was the speed of the ball at t = 1 second?

c. How far from the cup was the ball at t = 5 seconds?

d. What was the speed of the ball as it moved towards the cup?

e. What happened at t = 7 seconds?

4. Two bicyclists are riding toward each other, and each has an average speed of 10.0 km/h. When their bikes are 20.0 km apart, a pesky fly begins flying from one wheel to the other at a steady speed of 30.0 km/h. When the fly gets to the wheel, it abruptly turns around and flies back to touch the first wheel, then turns around and keeps repeating the back-and-forth trip until the bikes meet, and the fly meets an unfortunate end.



How many kilometers did the fly travel in its total back-and-forth trips?

1: Motion

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Worksheet B: Interpreting Motion Graphs

ANSWER QUESTIONS 1 AND 2 IN COMPLETE SENTENCES

1. What does the slope of a distance vs. time graph indicate about an object's motion?

____

2. What does the slope of a speed vs. time graph indicate about an object's motion?

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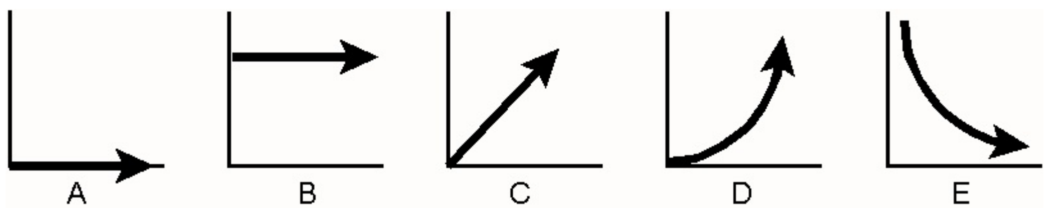
Questions 3 - 8 refer to the following generic graph shapes. Write the letter corresponding to the appropriate graph in the blank at the left of each question.



_______ 3. Which shape fits a **distance** vs. time graph of an object moving at constant (non-zero) speed?

_______ 4. Which shape fits a **speed** vs. time graph of an object moving at constant (non-zero) speed?

___ ___ 5. Which *two* shapes fit a **distance** vs. time graph of a motionless object?

_______ 6. Which shape fits a **speed** vs. time graph of a motionless object?

_______ 7. Which shape fits a **distance** vs. time graph of an object that is speeding up at a steady rate?

_______ 8. Which shape fits a **speed** vs. time graph of an object that is speeding up at a steady rate?

_______ 9. Which of the following units is equivalent to (meters per second) per second?
a) m b) m/s c) m/s^2 d) m/s^3

_______ 10. Which of the following units correspond to the slope of a distance vs. time graph?
a) m b) s c) m/s d) m/s^2

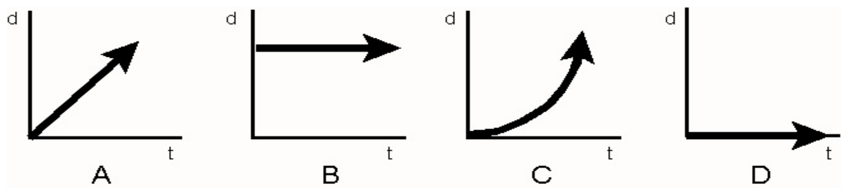
_______ 11. Which of the following units correspond to the slope of a speed vs. time graph?
a) m/s b) m•s c) m/s^2 d) m^2/s^2

CONTINUED . . .

The table below gives distance and time data for a moving object. Notice the varying size of the time intervals as the distance rises in 20 cm increments.

Distance (m)	Time (s)
0	0
20	4.5
40	6.3
60	7.7
80	8.9
100	10

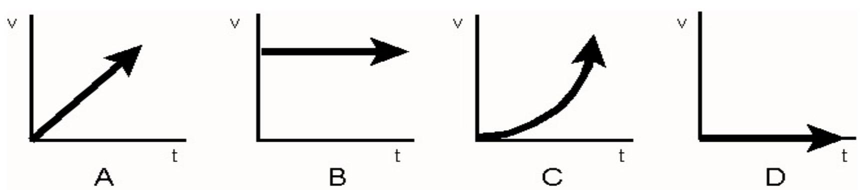
_______ 12. Which of the following **distance** vs. time graphs corresponds to the table data?



_______ 13. Which of the following descriptions matches the graph you selected in question 12?

a) A motionless object.
b) An object moving at a constant speed.
c) An object undergoing constant, positive acceleration.
d) An object undergoing constant, negative acceleration.

_______ 14. Which of the following **speed** vs. time graphs corresponds to the table data?

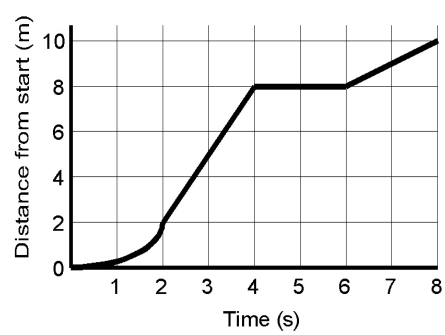


_______ 15. Which of the following descriptions matches the graph you selected in question 14?

a) A motionless object.
b) An object moving at a constant speed.
c) An object undergoing constant, positive acceleration.
d) An object undergoing constant, negative acceleration.

BEWARE: If your answers to questions 13 and 15 are different from each other, you are claiming that the same object can have two distinct motions simultaneously. Ask yourself, "Is that reasonable?"

16. A woman walks away from a starting point in a straight line. A distance vs. time graph for her motion is shown at right.



a. Describe the woman's motion between 0 and 2 seconds.

____

____

b. Fill out the table below.

Time Interval	Woman's Speed (m/s)
2 to 4 seconds	____________
4 to 6 seconds	____________
6 to 8 seconds	____________

1: Motion

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Worksheet C: Combining the Variables of Motion

We have already developed three equations for velocity and acceleration:

$$\bar{v} = \frac{d}{t} \qquad \bar{v} = \frac{v_i + v_f}{2} \qquad a = \frac{v_f - v_i}{t}$$

Using these equations, figure out ways to combine them algebraically to make five other equations that would enable you to:

1. Solve for v_f when you know v_i, a, and t.

2. Solve for d when you know v_i, a, and t.

3. Solve for a when you know v_i, d, and t.

4. Solve for t when you know d and a, and v_i=0.

5. Solve for v_f when you know v_i, a, and d.

1: Motion

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Worksheet D: 1-Dimensional Motion Problems

1. The head of a rattlesnake can accelerate 50.0 m/s^2 in striking a victim. If a car could do as well, how long would it take for it to reach a speed 24.6 m/s (which is about 55 mi/h) from rest?

0.492 s

2. The speed limit on an 86.0 mile highway was changed from 55.0 mi/h to 75.0 mi/h. How much time was saved on the trip for someone traveling at the speed limit?

0.417 h

3. In an emergency, a driver brings a car to a full stop in 5.00 seconds. The car is traveling along a highway at a rate of 24.6 m/s when braking begins.

   a. At what rate is the car accelerated? *– 4.92 m/s^2*

   b. How far does it travel before stopping?

4. A supersonic jet flying at 200. m/s is accelerated uniformly at the rate of 23.1 m/s^2 for 20.0 seconds.

   a. What is its final speed?

   b. Physicist Ernst Mach studied the effects of motion faster than sound, and the ratio of a speed to that of sound is called its "Mach number". The speed of sound itself is 331 m/s (approx. 740 mi/h) at supersonic airplane altitudes. "Mach 1.00" is the ratio 331/331, or the speed of sound. One of the fastest planes was the SR-71 Blackbird. It flew at 1059 m/s, so 1059/331 = 3.20; we say it flew at "Mach 3.20." What is the Mach speed of our jet?

5. If a bullet leaves the muzzle of a rifle with a speed of 600. m/s, and the barrel of the rifle is 0.800 m long, at what rate is the bullet accelerated while in the barrel?

225,000 m/s^2

6. What is the acceleration of a racing car if its speed is increased uniformly from 44.0 m/s to 66.0 m/s over an 11.0 s period?

7. An engineer is to design a runway to accommodate airplanes that must gain a ground speed of 360. km/h (approx. 225 mi/h) before they can take off. These planes are capable of being accelerated uniformly at the rate of 3.60×10^4 km/h^2.

   a. How many kilometers long must the runway be?

   b. How many **seconds** will a plane need to accelerate to take-off speed?

8. A plane flying at the speed of 150. m/s is accelerated uniformly at a rate of 5.00 m/s^2.

   a. What is the plane's speed at the end of 10.0 seconds?

   b. What distance has it traveled?

9. A Tokyo express train is accelerated from rest at a constant rate of 1.00 m/s^2 for 1.00 **minute**. How far does it travel during this time?

10. In a vacuum tube, an electron is accelerated uniformly from rest to a speed of 2.60×10^5 m/s during a time period of 6.50×10^{-2} seconds. Calculate the acceleration of the electron.

4.00×10^6 m/s^2

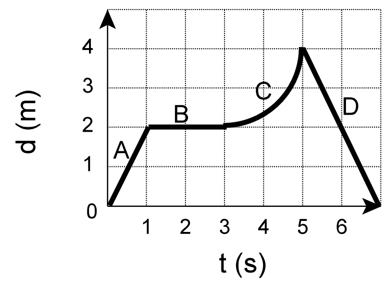
1 Motion

Name______________________________

Worksheet E: Quiz Practice Problems

1. A fly takes off with an acceleration of 0.700 m/s^2 from a wall. How many seconds will it take the fly to reach a speed of 12.6 km/h?

2. In the graph:
   a. What is the speed and acceleration from 0 to 1 seconds?
   b. What is the speed and acceleration from 1 to 3 seconds?
   c. What is the acceleration from 3 to 5 seconds? (assume it is constant)
   d. What is the object doing from 5 to 7 seconds?



3. The evil Victor Vector has tied poor Velma Velocity to a train track. He is aboard a train which is moving at 5.00 m/s when it is 175 m from the struggling Velma. If the train is accelerating at 3.00 m/s^2, how much time does she have to make her escape?

4. The Hanson brothers are backstage after a concert, sauntering at 0.500 m/s, when a horde of screaming fans gives chase. The musicians are 12.0 m away from the safety of their dressing room. If they accelerate steadily and reach the room in 3.20 s, how fast are they traveling as they pass its doorway?

5. Mr. M is a human cannonball in his spare time. If the cannon he uses is 1.75 meters long and he exits the cannon at a speed of 20.0 m/s, what acceleration does the cannon impart to Mr. M?

Answers:
1) 5.00 s
2) a. 2 m/s; 0 m/s^2
b. 0 m/s; 0 m/s^2
c. 1 m/s^2 (use $a=2d/t^2$ since $v_i=0$)
d. moving backward at a constant speed
3) 9.26 s
4) 7.00 m/s
5) 114 m/s^2