RICHMOND HILL HIGH SCHOOL

89-30 114 Street

Richmond Hill New York 11418

Physics

Semester 1 LABORATORY ACTIVITIES

NAME\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ TEACHER\_\_\_\_\_\_\_\_\_\_\_\_\_

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| --- | --- | --- | --- | --- |
| DATE | LAB # | PAGES | TITLE OF LAB ACTIVITY | GRADE |
|  | 1 | 1-3 | Safety |  |
|  | 2 | 4-7 | Metric Measurements |  |
|  | 3 | 8-13 | Graphing Analysis |  |
|  | 4 | 14-18 | 2D Kinematics: Vectors |  |
|  | 5 & 6 | 19-21 | Graph Matching |  |
|  | 7 & 8 | 22-24 | Acceleration due to Gravity |  |
|  | 9 & 10 | 25-28 | Force & Acceleration |  |
|  | 11 & 12 | 29-31 | 2D Kinematics: Projectile Motion |  |
|  | 13 | 32-34 | Projectile Motion (virtual lab) |  |
|  | 13a | 35-37 | Projectile Motion Simulator (virtual lab) |  |
|  | 14 & 15 | 38-39 | Centripetal Motion |  |
|  | 16 & 17 | 40-41 | Frictional Force |  |
|  | 18 & 19 | 42-44 | Momentum & Mass |  |

TOTAL LABS = \_\_\_\_\_\_\_\_\_\_\_

**Lab Requirement**- Section 207 of Education Law states that ALL students in a Regents science course must complete the laboratory requirement of 1200 minutes prior to entry into a Regents examination in science. If the lab requirements have not been met by a particular student, they MAY NOT sit for the Regents exam. Labs will be completed, collected, reviewed and then filed for state review as deemed necessary. All students who have missed, failed to turn in, or have incomplete labs will be given a deadline of completion by May 31st. After this time, the student has forfeited the opportunity to take the June Regents Exam.

**LAB #1: Recognizing Laboratory Safety**

**Introduction**

An important part of your study of biology will be working in a laboratory. In the laboratory, you and your classmates will learn biology by actively conducting and observing experiments. Working directly with living things will provide opportunities for you to better understand the principles of biology discussed in your textbook or talked about in class.

Most of the laboratory work you will do is quite safe. However, some laboratory equipment, chemicals, and specimens can be dangerous if handled improperly. Laboratory accidents do not just happen. They are caused by carelessness, improper handling of equipment and specimens, or inappropriate behavior.

In this investigation, you will learn how to prevent accidents and thus work safely in a laboratory. You will review some safety guidelines and become acquainted with the location and proper use of safety equipment in your classroom laboratory.

**Problem**

What are the proper practices for working safely in a biology laboratory?

**Pre-Lab Discussion**

Read the entire investigation. Then, work with a partner to answer the following questions.

**1.** Why might eating or drinking in the laboratory be dangerous?

**2.** How can reading through the entire investigation before beginning the Procedure help prevent accidents?

**3.** Look around the room. What safety equipment do you recognize?

**4.** What safety procedures should you follow when cleaning up at the end of an investigation?

**5.** Can minor safety procedures be skipped in order to finish the investigation before the bell rings?

**Materials** *(per group)*

Textbook

Laboratory safety equipment (for demonstration)

**Procedure**

**1.** Carefully read the list of laboratory safety rules

**2.** Special symbols are used throughout this laboratory manual to call attention to investigations that require extra caution. Use Appendix B in your textbook as a reference to describe what each symbol printed below means.

**1.**

**2.**

**3.**

**4.**

**5.**

**6.**

**7.**

**8.**

**3.** Your teacher will point out the location of the safety equipment in your classroom laboratory. Pay special attention to instructions for using such equipment as fire extinguishers, eyewash fountains, emergency blankets, emergency showers, and items in first-aid kits. Use the space provided below to list the location of all safety equipment in your laboratory.

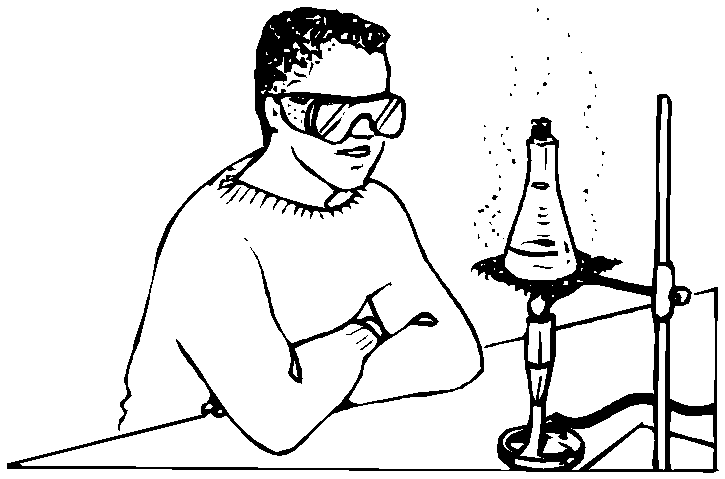
**Analysis and Conclusions**

**Observing:** Look at each of the following drawings and explain why the laboratory activities pictured are unsafe.

 **1.**

 **2.**

**3.**



**4.**



**Going Further**

Many houseplants and some plants found in biology laboratories are poisonous. Use appropriate library resources to do research on several common poisonous plants. Share your research with your classmates. You may prepare a booklet describing common poisonous plants. Use drawings or photographs to illustrate your booklet.

**LAB #2: Metric Measurement Lab**

This laboratory exercise is designed as a review of the metric system and will provide practice in manipulating units.

The metric system is based on standard units of length, mass and volume.

*Standard units:*

Length – meter

Mass – gram

Volume (liquid) – liter

Volume (solid) – cm3

1 mL = 1 cm3

These standard metric units can be modified by the addition of various prefixes.

*Metric prefixes:*

Kilo- 1,000 (103) Deci- 0.1 (10-1) Centi- 0.01 (10-2) Milli- 0.001 (10-3)

Micro- 0.000001 (10-6) Nano- 0.000000001 (10-9)

Various instruments are used to make metric measurements.

*Metric instruments:*

Length – metric ruler

Mass – metric scale (triple beam balance) Volume – graduated cylinder, pipettes

You will use all these instruments to complete the following metric measurement exercise.

**Metric Table**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Quantity** | **Numerical Value** | **English**  **Equivalent** | **Convert English to**  **Metric** |
| **Length** | kilometer (km)  *meter (m)* decimeter (dm) centimeter (cm) millimeter (mm) micrometer (µm) nanometer (nm) | 1,000 m  0.1 m  0.01 m  0.001 m  0.000001 m  0.000000001 m | 1 km= 0.62 mile  1 m= 1.09 yards= 3.28 ft  1 cm= 0.394 inch  1 mm= 0.039 inch | 1 mile= 1.609 km  1 yard= 0.914 m  1 foot= 0.305 m  1 foot= 30.5 cm  1 inch= 2.54 cm |
| **Mass** | kilogram (kg)  *gram (g)*  milligram (mg)  microgram (µg) | 1,000 g  0.001 g  0.000001 g | 1 kg= 2.205 pounds (lb)  1 g= 0.0353 ounce (oz) | 1 pound= 0.45 kg  1 ounce= 28.35 g |
| **Volume**  **(liquid)** | kiloliter (kL)  liter (L)  milliliter (mL)  microliter (µL) | 1,000 L  0.001 L  0.000001 L | 1 kL= 264.17 gallons  1 L= 1.06 quarts (qt)  1 mL= 0.034 oz | 1 gallon = 3.785 L  1 quart =0.94 L  1 pint =0.47 L  1 oz =29.57 mL |
| **Time** | second (sec)  millisecond microsecond | 0.001 second  0.000001 second |  |  |

*Standard units*

1 meter = 100 cm = 1000 mm = 1x106 µm (1000000 µm)

1 gram = 100 cg = 1000 mg = 1x106 µg (1000000 µg)

1 liter = 100 cL = 1000 mL = 1x106 µL (1000000 µL)

1 second = 1000 milliseconds

--------------------------------------------------------------------------------------

Temperature Conversion:

Record all measurements and do the calculations on this sheet of paper to be handed in to instructor. Record all measurements in this lab to the nearest tenth of a unit. Calculations are significant only to the same number of decimal places as measurements, so round off calculations to the nearest tenth unit. All answers must have proper units!

A. 1. Measure and record the length (L), height (H) and width (W) of a block in cm.

Length: Height: Width:

2. Calculate its volume =

3. Convert the length, height and width of this block to mm.

Length: Height: Width:

4. What is the volume in cubic mm?

5. Determine the mass of the block to the nearest tenth gram using the weigh balance.

B. 1. Measure and record the length (L) and inside diameter (D) of a test tube in cm.

Length: Diameter:

2. Calculate its volume (V) in cubic cm (cc).

Calculated Volume:

3. Fill the test tube to the lip with water. Carefully pour the water into a 50 ml graduated cylinder. Place the cylinder on the table and view at eye level to read the volume at the bottom of the meniscus (curved surface of the water). Record this measured volume.

Measured Volume:

4. How does your measured volume compare with your calculated volume? If there is a discrepancy, give an explanation.

C. 1. Weigh an empty small beaker and record its weight to the nearest tenth gram.

Weight of beaker:

2. Measure 20 mL of water with a serological pipette into the previously weighed beaker and then weigh again.

Weight of beaker plus water:

3. Calculate the weight of the water from these 2 measurements.

Weight of water:

4. How much would 1 mL of water weigh?

Weight of 1 mL of water:

D. 1. Fill a 250 mL graduated cylinder to 200 mL with water. Record the volume. Carefully place a solid rubber stopper into the water. Record the volume.

Volume of water:

Volume of water + rubber stopper:

2. Calculate the volume of the rubber stopper.

E. 1. Temperature measurement. Record the temperature (°C) of the water in the instructor’s beaker.

Temperature:

2. Convert to °F.

1. What do the following prefixes mean in relation to the standard unit?

a. kilo- c. deci- b. centi- d. milli-

2. What do the following abbreviations mean?

a. lb = e. µg = i. sec = b. g = f. oz = j. gal = c. cc = g. km = k. cm = d. mL = h. L = l. qt =

3. Which is greater (larger)?

a. 1 m or 1 yd? g. 1 µg or 1 cg?

b. 1 L or 1 qt? h. 1 L or 1 dL?

c. 1 lb or 1 kg? i. 1 mm or 1 km? d. 1 oz or 1 g? j. 1 cL or 1 mL? e. 1 m or 1 km? k. 1 kg or 1 g?

f. 1 cm or 1 in? l. 1 dm or 1 cm?

4. Complete: (use decimals)

a. g = 1 dg f. cm = 5 m b. km = 1 m g. L = 3 mL c. c. cL = 1 L h. dg = 7 g

d. mg = 1 cg i. mm = 6 m e. dL = 1 mL j. cL = 4 mL

5. Problems:

a. Add 5.0 m + 6.25 m + 3.1 m = m

(hint: use proper significant figures)

b. Add 1.2 g + 3 dg + 2.6 g + 90 cg =

same unit)

hint: convert all numbers to the

c. A box measures 1 cm x 6 cm x 5 cm. What is its volume?

**LAB #3: GRAPH ANALYSIS**



INTRODUCTION: Constructing and interpreting graphs are integral parts

of any earth science course. This section presents a review of graphing with emphasis on the rate of change.

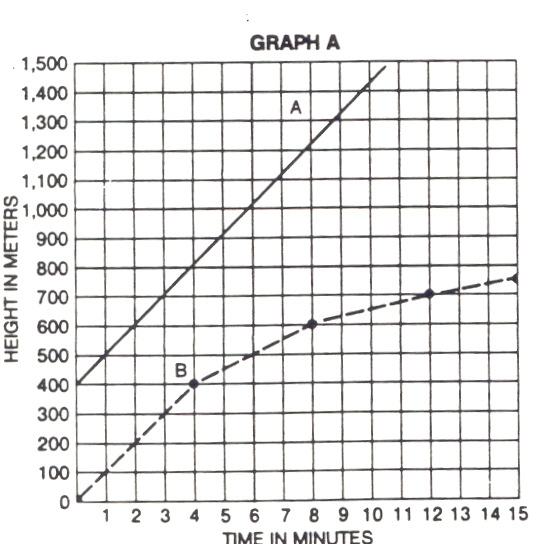
OBJECTIVE: You will review graph construction and interpretation in this lab.

Part A: Graph Interpretation

• Answer the following questions based on the graph below.

• Be sure to label all answers whenever appropriate.

1. Is the altitude of the balloons increasing or decreasing as shown by lines A and B?



2. During the first four (4) minutes, how many meters did A rise?

3. During the first four (4) minutes, how many meters did B rise?

4. During the first four (4) minutes, what was the rate of increase for the balloon A? Hint: you can find the equation on page 1 of the ESRT

5. During the first four (4) minutes, what was the rate of increase for the balloon B?

6. Do lines A and B show a direct or an indirect (inverse) relationship between altitude and time?

PART B: A cup of hot water was left standing on a lab table. Temperature was measured and recorded at one-minute intervals. Plot the given data on Graph B. Be sure to completely label each axis. Answer the questions that follow.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Time  (minutes) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Temp. (0C) | 36.0 | 32.5 | 30.5 | 29.0 | 28.0 | 27.0 | 26.0 | 25.5 | 24.5 | 24.0 | 23.5 | 23.2 | 23.0 | 23.0 | 23.0 | 23.0 |

Graph B

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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1. Did temperature increase or decrease with time?

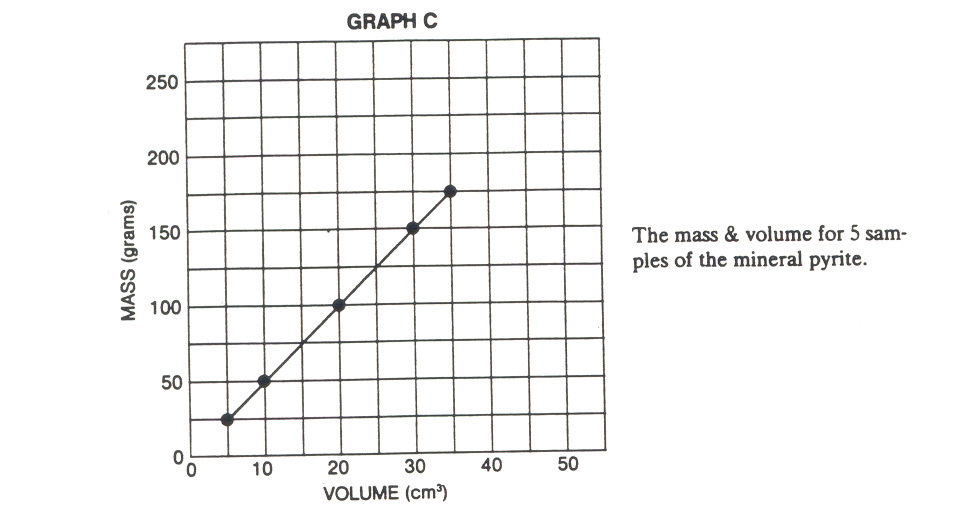
2. Calculate the rate of temperature change from time 0 to time 4.

3. Calculate the rate of temperature change from time 4 to time 8.

4. Does this graph show a direct or inverse relationship?

5. Is time or temperature the independent variable?

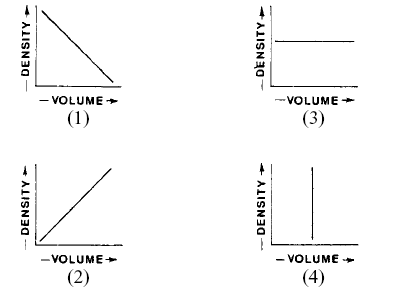
**Part C**: Base your answers to the following questions on Graph C and your knowledge of density.



1. According to the graph, what is the density of pyrite?

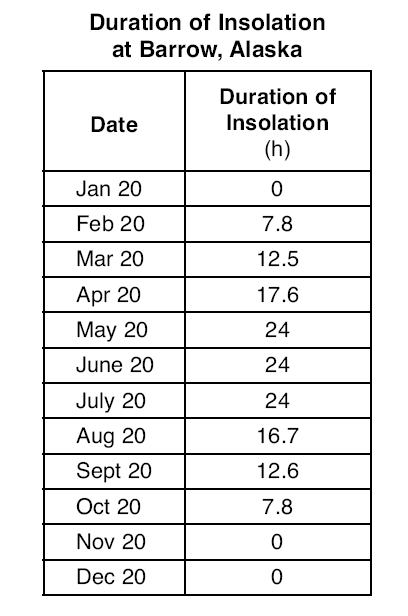
2. If a sample of pyrite has a volume of 50 cm3, what would its mass be?

3. A student calculates the densities of five different pieces of aluminum, each having a different volume. Which graph best represents this relationship?



Analysis & Conclusion:

*answer some of the questions)*

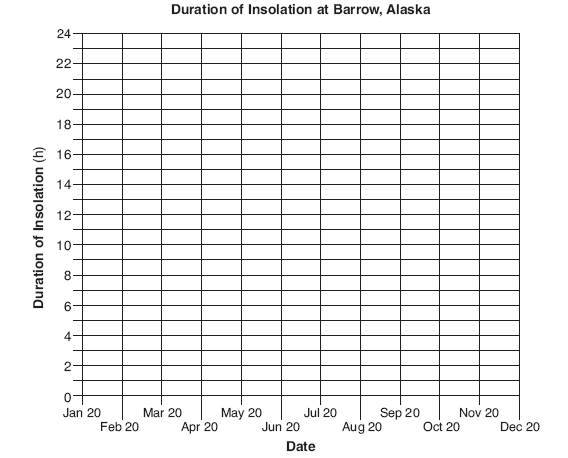


Ana ys s and Conc us ons: *(You will need your ESRT to*

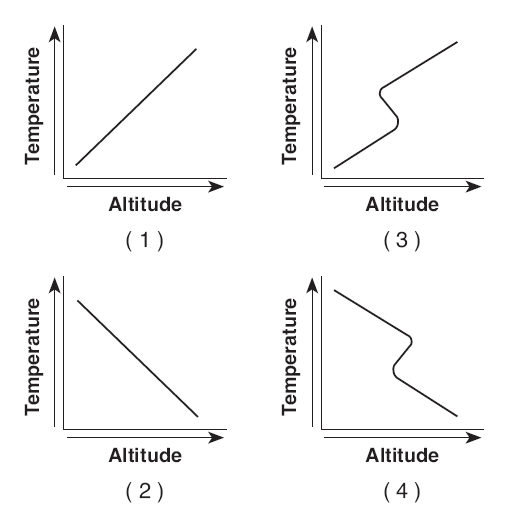
1. The table shows the duration of insolation, in hours, at Barrow, Alaska, on the twentieth day of each month during

2008.

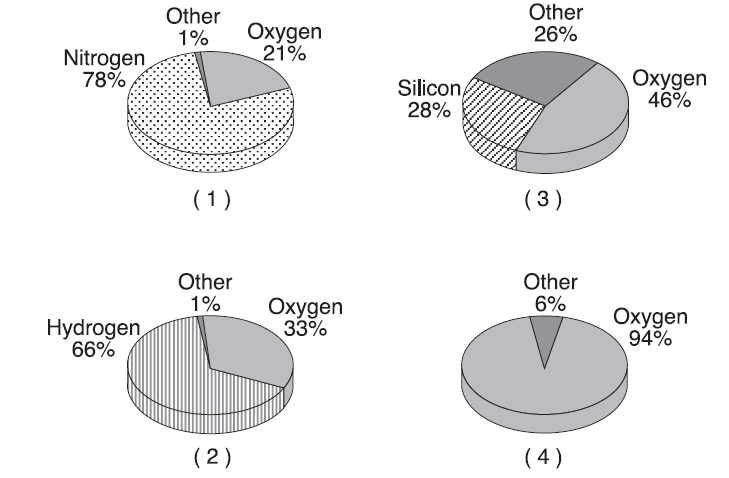
On the grid *below,* construct a line graph by plotting the data for the duration of insolation at Barrow for *each* date shown on the data table. Connect the plots with a line.



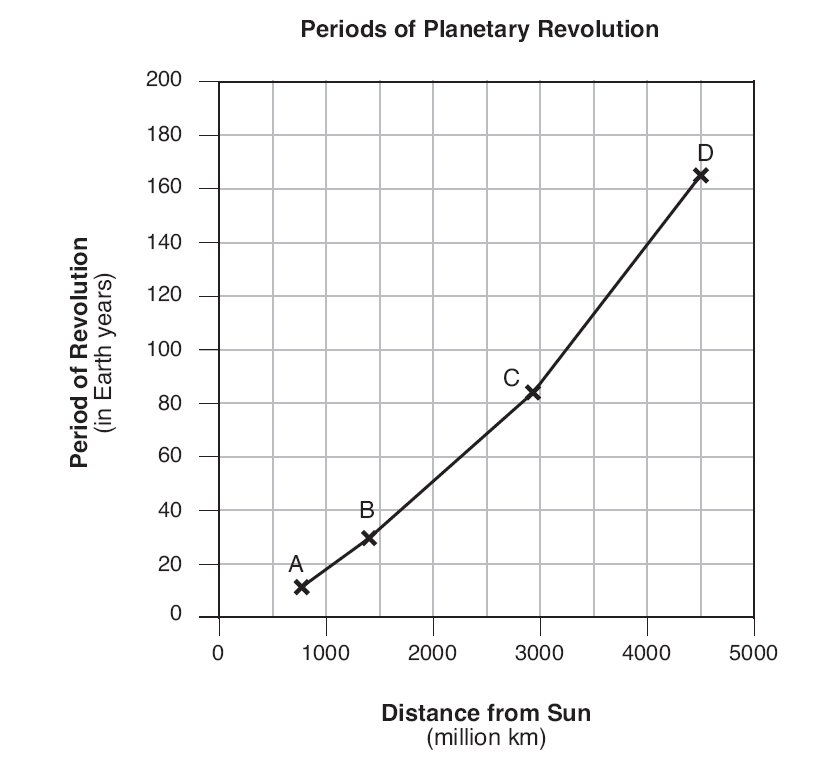
2. Which graph best shows the general relationship between altitude and temperature in the troposphere?



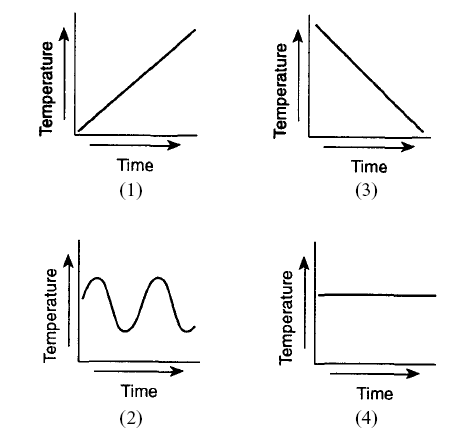
3. Which pie graph correctly shows the percentage of elements by volume in Earth’s troposphere?



4. Describe the relationship between the distance from the Sun and the period of revolution for these four planets.



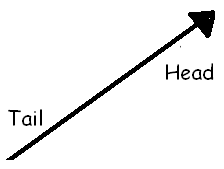
5. Which graph on the right most



likely illustrates a cyclic change?

**(Virtual) LAB #4: 2D Kinematics: *Vectors***

**Setup**

1. Make sure your calculator is set to degrees and not radians. Logon to computer.
2. Do a Google search for “PhET” and then go to the PhET website.
3. From the menu at the left, click “Math Tools” and then select the **Vector Addition** simulation.
4. Once you get to the **Vector Addition** page, there should be a green button below the picture that says “Run Now!” Click this button.
5. In the basket at the top right, you can drag out a vector arrow. If you ever want to get rid of a vector, drag it to the trash can at the bottom right. If you want to start over, click “Clear All.”
6. You can adjust the direction and length of the arrow by click-dragging the arrow head. Play with this until you are comfortable.
7. Click the “Show Grid” button. This will make it easier to adjust the arrow lengths.

**Part A: 3-4-5 Triangle**

1. Drag out a vector, and move it until the tail is located at the origin. Click on the head of the vector, and drag it until it is completely horizontal, points to the right, and has a magnitude (|R|) of 40.
2. Look at the chart at the top of the page. Here is an explanation of what each number represents:
   1. **|R|** represents the length of the arrow. This is usually called the **magnitude** of the vector.
   2. **Θ** represents the direction the arrow points. This is simply called the **direction** of the vector. The magnitude AND direction will completely define a vector.
   3. **Rx** is called the **X-component** of the vector. This is the length of the vector in the X-direction only.

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | Θ | Rx | Ry |
|  |  |  |  |

* 1. **Ry** is called the **Y-component** of the vector. This is the length of the vector in the Y-direction only.

1. For the first vector you dragged out, fill in the chart at right.



|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. Now, drag out a second vector and place its tail at the head of the first, as shown at right. Adjust this second vector until it points vertically upward and has a length of 30. Fill in the table for this vector here:
2. As you saw in the previous activity, if you were to walk this path, at the end you would be 50 units away from the origin. You can show this by clicking the button that says **Show Sum**. A green vector should pop up. This represents the vector sum, or **resultant,** of the first two arrows.

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. Drag this vector over so that the tail is at the origin, and use it to form the hypotenuse of a right triangle. Notice that the head of this vector ends exactly where the second vector ends. Click on the green vector and fill in the chart for this vector here:
2. ۞ Compare the Rx and Ry values for the green vector to the |R| values from the first two red vectors. What do you notice about these values?

**Part B: Single Vector, Magnitude 50**

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | Θ | Rx | Ry |
|  |  |  |  |

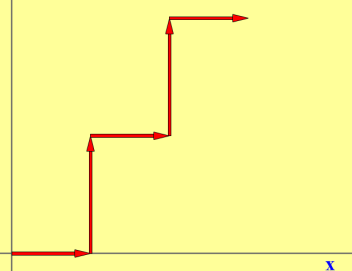
1. Hit the **Clear All** button to erase the screen. Next, create a vector with an Rx of 40 and an Ry of 30. Fill in the chart for this vector here:
2. ۞ Compare the chart values of this vector to those of the green resultant vector from #13. How do these values compare?
3. Next, click the **Style 2** button on the “Component Display” menu. This is a way to visualize any vector as a sum of horizontal and vertical components.

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. Adjust this vector until it has an Rx value of 30 and an Ry value of 40. Fill in the chart for this vector:
2. ۞ Has the **magnitude** (that is, |R| ) of this vector changed, compared #15? If so, how?
3. ۞ Has the **direction** (that is, θ) of this vector changed, compared to #15? If so, how?
4. ۝ Figure out a way to adjust the magnitude and direction of this vector until it has a magnitude of 50, just like before, but points in a different direction from the first 2. Fill in the chart for this vector, and **show your vector to your instructor**.

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. Looking at this vector, it is easy to imagine a right triangle, made from Rx, Ry and |R|. In this case, |R| would be the hypotenuse, and Rx & Ry would be the legs.
   1. Show, using the Pythagorean Theorem, that |R|2 = Rx2 + Ry2.
   2. Show, using SOHCAHTOA, that Rx = |R| cos θ.
   3. Show, using SOHCAHTOA, that Ry = |R| sin θ.
2. Clear All. Imagine a vector with magnitude |R| = 28 and angle θ = 45o.
   1. ۝ Use SOHCAHTOA to determine the X- And Y- components (that is, find Rx and Ry). Show your work to your instructor.
   2. Check your answer by constructing this vector.

**Part C – Several Vectors**

1. Create 5 vectors, as shown at right. The length of each of the horizontal vectors should be 10, and the length of the vertical vectors should be 15.
2. Click on the “Show Sum” button. Fill in the chart for this resultant.

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. ۝ A useful way to keep track of vector sums is to create a chart. Complete the chart below, using the 5 vectors you’ve constructed, and then add the columns to get the sums. Show your instructor when finished.

|  |  |  |
| --- | --- | --- |
| Vector # | Rx | Ry |
| 1 | 10 | 0 |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| 5 |  |  |
| SUM |  |  |

1. ۞ How do the Rx and Ry sums from the previous chart compare to the Rx and Ry values from question #25?
2. ۝ Using the Pythagorean Theorem, determine the resultant |R| value. Compare this number to the |R| value from #25. Show instructor when finished.
3. Clear All. Construct the following 4 vectors:

* |R| = 20, θ = 0o
* |R| = 20, θ = 90o
* |R| = 20, θ = 180o (or -180o)
* |R| = 20, θ = 270o (or -90o)

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. What is the sum (or resultant) of these vectors?

|  |  |  |  |
| --- | --- | --- | --- |
| |R| | θ | Rx | Ry |
|  |  |  |  |

1. What is the sum of these vectors if the first vector is 10 units long rather than 20?
2. When finished, close all Explorer windows. You can leave the laptop on and plugged in.

**Extension Questions**

1. A student, following instructions on her treasure map, starts at the origin and walks the following routes:

🡪36 meters North (θ = 90o)

🡪15 meters West (θ = 180o)

🡪20 meters South (θ = 270o or -90o)

🡪27 meters East (θ = 0o)

* 1. Fill in the chart below, which represents the horizontal and vertical components of the routes. Also determine the X and Y sums.

|  |  |  |
| --- | --- | --- |
| Vector # | Rx | Ry |
| 1 | 0 | 36 |
| 2 |  |  |
| 3 |  |  |
| 4 |  |  |
| SUM |  |  |

* 1. After the student has finished walking, what is her horizontal displacement? (Rx sum)
  2. What is her vertical displacement? (Ry sum)
  3. Using the Pythagorean Theorem, and your answers from (b) and (c), how far is she from the origin? (In other words, what is her resultant |R|?)
  4. Using SOHCAHTOA, what is her direction, as measured from the origin? (In other words, what is θ?)

1. A helicopter flies 25 km North, then 35 km East, then 5 km South, then 15 km West.
   1. What is the resultant displacement (|R|) of the helicopter, measured from the origin?
   2. What is the direction (θ) of the helicopter, measured from the origin?
2. An airplane is flying North with a velocity of 200 m/s. A strong wind is blowing East at 50 m/s. What is the airplane’s resultant velocity (magnitude and direction)?

Lab 5 & 6: Graph Matching

One of the most effective methods of describing motion is to plot graphs of position, velocity, and acceleration *vs*. time. From such a graphical representation, it is possible to determine in what direction an object is going, how fast it is moving, how far it traveled, and whether it is speeding up or slowing down. In this experiment, we will use a Motion Detector to determine this information by plotting a real time graph of *your* motion as you move across the classroom.

The Motion Detector measures the time it takes for a high frequency sound pulse to travel from the detector to an object and back. Using this round-trip time and the speed of sound, you can determine the position of the object. Logger *Pro* will perform this calculation for you. It can then use the change in position to calculate the object’s velocity and acceleration. All of this information can be displayed either as a table or a graph. A qualitative analysis of the graphs of your motion will help you develop an understanding of the concepts of **kinematics** (**study of motion of objects without consideration of the causes leading to the motion**).



objectives

1. Analyze the motion of a student walking across the room.
2. Predict, sketch, and test position *vs*. time kinematics graphs.
3. Predict, sketch, and test velocity *vs*. time kinematics graphs.

Materials

|  |  |
| --- | --- |
| Computer | Vernier Motion Detector |
| Vernier computer interface | meter stick |
| Logger *Pro* | masking tape |

VOCABULARY WORDS

**Kinematics**: see above

**Speed**: of an object (denoted **v**) is the magnitude rate of change of its position. The **average speed** of an object in an interval of time **is** the **distance trav**eled by the object **divided by the duration of the interval** **(time)**. Speed has the dimensions of a **length divided by a time**; the SI **unit** of speed **is** the **meter per second**, but the most usual unit of speed in **everyday usage is** the **kilometer per hour** or, in certain countries, the **mile per hour**.

The **fastest possible speed** at which energy or information can travel, according to special relativity, **is** the **speed of light** in vacuum c = **299,792,458 meters per second**, approximately 1079 million kilometers (671 million miles) per hour. Matter cannot quite reach the speed of light, as this would require an infinite amount of energy.

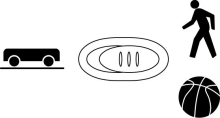
**Velocity**: is the **rate of change of position**; both speed and direction are required to define it. It is **measured in meters per second**: (m/s). For example, "5 meters per second" is a speed and not a velocity, whereas "5 meters per second east" is a velocity.

**Acceleration**: the rate of change of velocity – how an **object's speed or direction changes over time**, and how it is changing at a particular point in time.

Preliminary questions

1. CREATE 4 GRAPHS: Use a coordinate system with the origin at far left and positive positions increasing up. Sketch the position *vs*. time graph for each of the following situations:
2. An object at rest
3. An object moving in the positive direction with a constant speed
4. An object moving in the negative direction with a constant speed
5. An object that is accelerating in the positive direction, starting from rest
6. Sketch the velocity *vs*. time graph for each of the situations described above.

Procedure

Part l Preliminary Experiments

1. Connect the Motion Detector to the DIG/SONIC 1 channel of the interface. If the Motion Detector has a sensitivity switch, set it to Normal.
2. Place the Motion Detector so that it points toward an open space at least 4 m long. Use short strips of masking tape on the floor to mark the 1 m, 2 m, 3 m, and 4 m positions from the Motion Detector.
3. Open the file “01a Graph Matching” from the *Physics with Vernier* folder.
4. Using Logger *Pro*, produce a graph of your motion when you walk away from the detector with constant velocity. To do this, stand about 1 m from the Motion Detector and have your lab partner click CollectNew. Walk slowly away from the Motion Detector when you hear it begin to click.
5. Sketch what the position *vs.* time graph will look like if you walk faster. Check your prediction with the Motion Detector.
6. Try to match the shape of the position *vs*. time graphs that you sketched in the Preliminary Questions section by walking in front of the Motion Detector.

Part Il Position *vs*. Time Graph Matching

1. Open the experiment file “01b Graph Matching.” A position *vs*. time graph will appear.
2. Describe how you would walk to produce this target graph.
3. To test your prediction, choose a starting position and stand at that point. Start data collection by clicking CollectNew. When you hear the Motion Detector begin to click, walk in such a way that the graph of your motion matches the target graph on the computer screen.

10. If you were not successful, repeat the process until your motion closely matches the graph on the screen. If a printer is attached, print the graph with your best attempt.

11. Open the experiment file “01c Graph Matching” and repeat Steps 8–10, using a new target graph.

12. Answer the Analysis questions for Part II before proceeding to Part III.

Part IIl Velocity *vs*. Time Graph Matching

13. Open the experiment file “01d Graph Matching.” A velocity *vs*. time graph will appear.

14. Describe how you would walk to produce this target graph.

15. To test your prediction, choose a starting position and stand at that point. Start by clicking CollectNew. When you hear the Motion Detector begin to click, walk in such a way that the graph of your motion matches the target graph on the screen. It will be more difficult to match the velocity graph than it was for the position graph.

16. Open the experiment file “01e Graph Matching.” Repeat Steps 14–15 to match this graph.

17. Remove the masking tape strips from the floor.

Analysis

Part II Position *vs*. Time Graph Matching

1. Describe how you walked for each of the graphs that you matched.
2. Explain the significance of the slope of a position *vs*. time graph. Include a discussion of positive and negative slope.
3. What type of motion is occurring when the slope of a position *vs*. time graph is zero?
4. What type of motion is occurring when the slope of a position *vs*. time graph is constant?
5. What type of motion is occurring when the slope of a position *vs*. time graph is changing? Test your answer to this question using the Motion Detector.
6. Return to the procedure and complete Part III.

Part III Velocity *vs*. Time Graph Matching

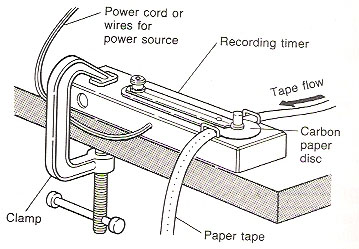
1. Describe how you walked for each of the graphs that you matched.
2. What type of motion is occurring when the slope of a velocity *vs*. time graph is zero?

9. What type of motion is occurring when the slope of a velocity *vs*. time graph is not zero? Test your answer using the Motion Detector.

**LAB 7 & 8: Acceleration Due to Gravity**

Small variations in the acceleration due to gravity, ***g***, occur at different places on Earth. This is because ***g*** varies with distance from the center of the Earth and is influenced by the subsurface (underground) geology. In addition, ***g*** varies with latitude due to Earth’s rotation.

For motion with constant acceleration, the displacement is **df – di = vi (tf – ti) + ½ a (tf – ti)2**. On our Physics Reference Table we see that equation as **.**

If di (starting position) = 0 (starting from rest) and ti (starting time) = 0, then displacement is . Dividing both sides of the equation by tf yields the following: The ***slope of a graph*** of **** versus**,** is equal to **½ a**. The initial velocity, , is determined by the **y-intercept**. In this activity, you will be using a recording timer to collect ***free-fall*** data and use it to determine the acceleration due to gravity, ***g***.

**OBJECTIVES**

* Measure free-fall data
* Make and use graphs of velocity versus time
* Compare and contrast values of g for different locations

**MATERIALS**

Spark timer

Timer tape

1-kg mass

C-clamp

Stack of newspapers

Masking tape

**VOCABULARY WORDS**

**Free-fall**: The motion of a body when air resistance is negligible and the motion can be considered due to the force of gravity alone.

**Acceleration due to gravity**: The acceleration of an object in free fall, resulting from the influence of Earth’s gravity; acceleration due to gravity on Earth, ***g***, is 9.80 m/s2 toward the center of Earth.

**PROCECURE**

Attach the spark timer to the edge of the lab table with the C-clamp.

1. Place the stack of newspapers on the floor, directly below the timer so the mass, when released, will not damage the floor.
2. Cut a piece of time tape approximately 70 cm (28 inches) in length (**about the length of your arm from fingertips to shoulder**) and slide it into the spark timer.
3. Attach the timer tape to the 1-kg mass with a small piece of masking tape. Hold the mass next to the spark timer, over the edge of the table so that it is above the newspaper stack.
4. Turn on the spark timer and release the mass.
5. Inspect the timer tape to make sure that there are dots marked on it. If your timer tape is defective, repeat with another piece of timer tape.
6. Have each member of your group perform the experiment and collect his or her own data.
7. Choose a dot near the beginning of the timer tape, a few centimeters from the point where the timer began to record dots and label it 0. Label the dots after that 1, 2, 3, 4, 5, etc. until you get near the end.
8. Measure the total distance to each numbered dot from zero dots, to the nearest 1/10 of a centimeter and record it on the data table below. Using the timer period (1/60 s), record the total time associated with each distance measurement and record it in your data table.

|  |  |  |  |
| --- | --- | --- | --- |
| **DATA TABLE** | | | |
| **Spark Timer Period (#/s) = 60/s (60 dots per second)** | | | |
| Interval | Distance (cm) | Time (s) | Speed (cm/s) |
| **1** |  | **1/60** |  |
| **2** |  | **2/60** |  |
| **3** |  | **3/60** |  |
| **4** |  | **4/60** |  |
| **5** |  | **5/60** |  |
| **6** |  | **6/60** |  |
| **7** |  | **7/60** |  |
| **8** |  | **8/60** |  |
| **9** |  | **9/60** |  |
| **10** |  | **10/60** |  |
| **11** |  | **11/60** |  |
| **12** |  | **12/60** |  |
| **13** |  | **13/60** |  |

**ANALYSIS**

1. **Use Numbers**. Calculate the values for speed (cm/s) by dividing distance (cm) by time (s) and record them in the third column of the data table.
2. **Make and Use Graphs**. Draw a graph of speed versus time. Draw the best-fit straight line for your data.
3. Calculate the slope of the line. Convert your result to m/s2.

250

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 200 |  |  |  |  |
| ***d/t (cm/s)***  150 |  |  |  |  |
| 100 |  |  |  |  |
| 50 |  |  |  |  |
| 0 |  |  | 0.20 |  |

0.25

0.15

0.10

0.05

0.00

***Time (s)***

**CONCLUDE AND APPLY**

1. Recall from the first paragraph on page 1 of this lab that the slope is equal to ½ a. What is the acceleration due to gravity? (you must take the number you calculated for slope and multiply it by 2).
2. Find your relative error for your experimental value of ***g*** by comparing it to the accepted value.

Relative Error =

1. What was the mass’s velocity, vi, when you began measuring distance and time? (this number will be the y-intercept of your graph i.e. where your line would pass through y-axis).
2. Explain why the slope of your line is (should be) a straight line.

**LAB 9 & 10: Force and Acceleration**

**PROBLEM**

How does an **unbalanced force** acting on a body moving in a straight line affect its **speed** and its **acceleration**?

When no **net force** is acting on a body such as a cart, the cart either **remains at rest or continues to move in the same straight line at a constant speed** (Newton’s 1st Law).

When an unbalanced force acts upon such a cart, **the unbalanced force changes the carts speed**.

**OBJECTIVES**

1. Determine the nature of the changes in speed that the unbalanced force produces
2. Compare the relationship between the **magnitude of force** and the **change in speed (acceleration)** that the various unbalanced forces produce in the cart.
3. Make and use graphs of time distance versus time.

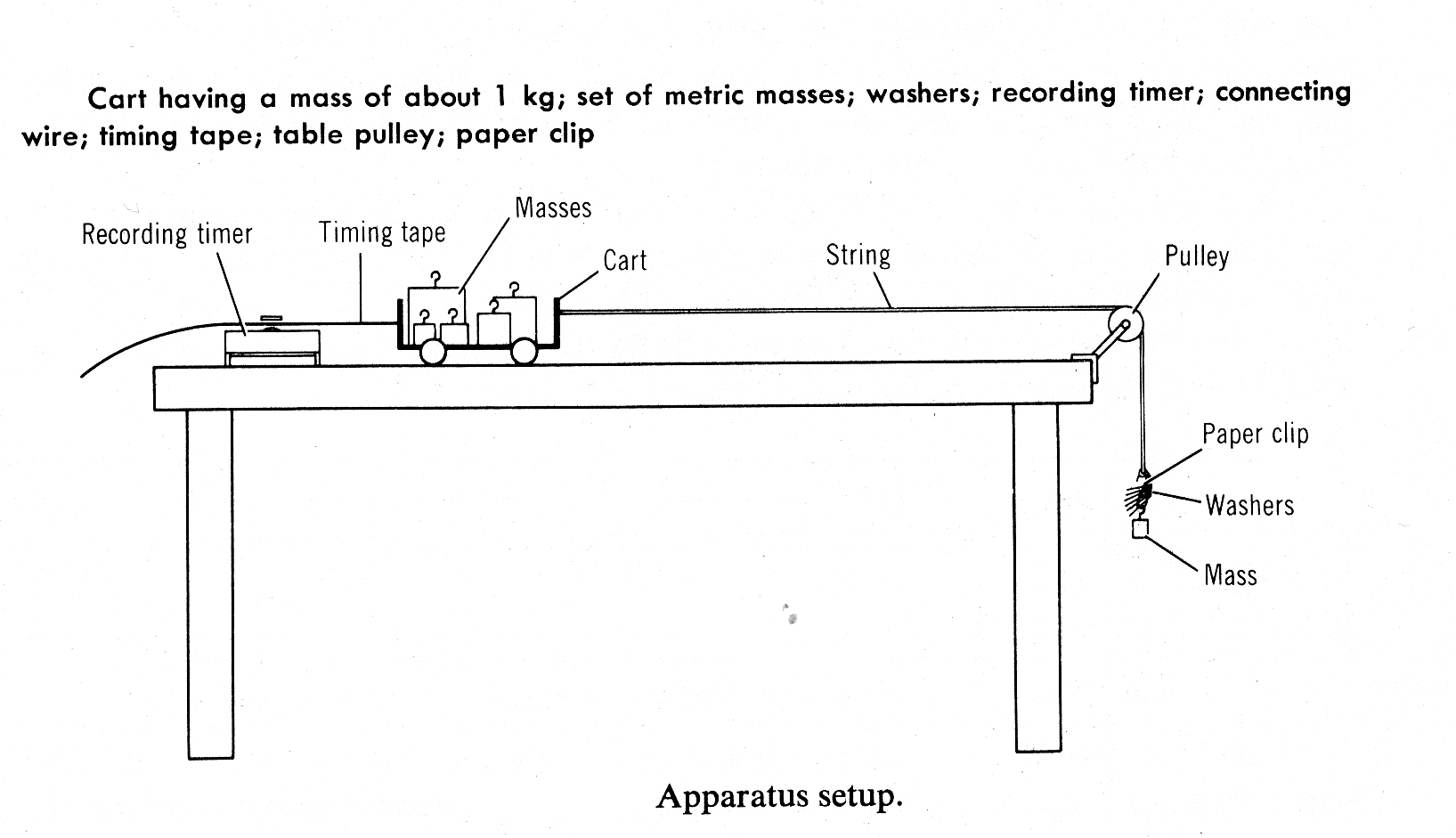
**Cart; set of metric masses; washers; recording timer; string; timing tape, paper clip.**

**MATERIALS**

Recording timer

Cart

Timer tape

Set of metric masses

Washers

String

Paperclip

Tape

**VOCABULARY WORDS**

**Newton’s 2nd Law**: The acceleration **a** of a body is parallel and directly proportional to the net force **F** and inversely proportional to the mass **m**, i.e., F = ma.

**PROCECURE**

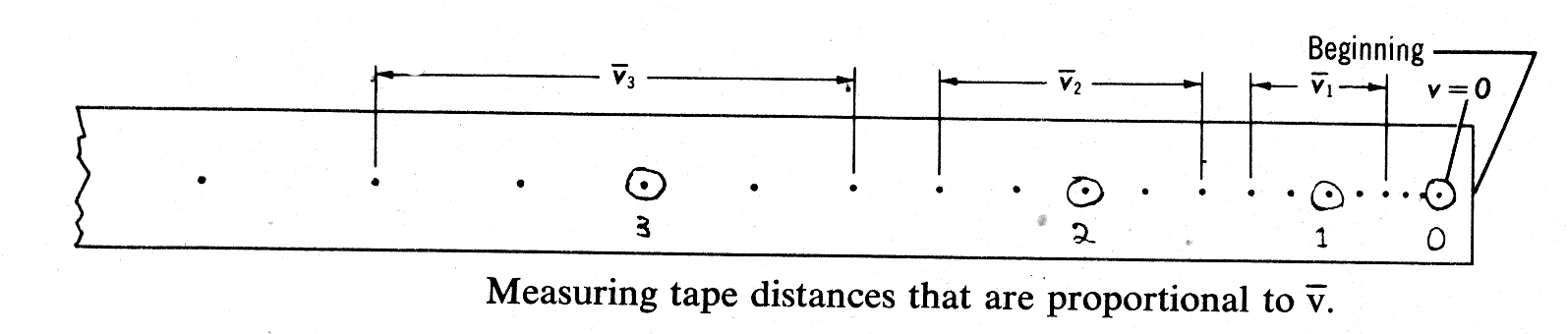
**Setup**

1. Set up your equipment as shown in the image above. We do not have clamps to hold the recording timer in place so you’ll have to have one group member hold it down. Also we do not table pulleys so the string will just rub on the table. This increase in friction will slow down the cart somewhat but since the friction will be consistent for each mass measured your results should still be valid.
2. Load the cart with 5 different masses of 10, 20, 50, 100 & 200 g.
3. Give the cart a slight push. It stops after a little while because the **force of friction** opposes its motion.
4. You will need to **eliminate** the effect of friction from your experiment.
5. To do this tie a string through the hole in one end of the cart and hang the string with a paperclip tied to the other end over the end of the table as shown in image above.
6. Hang washers one by one to the paperclip until the cart, **given a small initial push**, continues to move **slowly** across the table.
7. When this condition is reached the force of friction is just balanced by the force coming from the **weight of the washers**.
8. You have now **balanced out the effect of friction.** Once the number of washers has been found they should remain on the string throughout the experiment.
9. You are now prepared to allows a set of **increasing forces** **(masses)** to pull the cart across the table and to **measure the rate** at which each **mass** changes the speed of the cart **(accelerates)**.

**GATHERING THE DATA**

1. Place the 1kg mass or a book in front of the cart to keep it from rolling.
2. Cut a piece of time tape approximately 70 cm (28 inches) in length (**about the length of your arm from fingertips to shoulder**) and slide it into the spark timer.
3. Attach the timer tape to the cart with a small piece of tape.
4. **Remove the 20-g mass from the cart** and hang it on the paperclip.
5. The **Law of Conservation of Mass** of the experiment (cart, paperclip, string, masses) remains valid as the total mass before and after you move the mass from the cart to the paperclip is the same.
   1. However NOW the forces are **UNBALANCED**.
6. Turn on the spark timer and release the cart and stop it after it has moved the length of the table.
7. **Detach the tape** and label it **20g** for future reference.
8. Return the 20g mass to the cart and remove the 50g mass and hang it from the paperclip.
9. Repeat the experiment and label the tape obtained 50g.
10. Continue in this fashion letting the 100g and 200g masses pull the cart.
11. In each case, collect the tape and label it 100g and 200g for future reference.
12. You should now have 4 recording tapes labeled 20, 50, 100 & 200g.

**INSPECTING THE TAPE AND RECORDING YOUR MEASUREMENTS**

1. You are now prepared to study the motion on the recording tapes.
2. Since the mass falls a distance of about 2 feet, only the first 2 feet or less of each tape corresponds to the motion.
3. Analyze about the first 1.5 feet of tape.
4. Label the **first dot 0** and **every 5th dot after that** 1, 2, 3, etc.
5. The speed corresponding to dot 0 is ZERO.
6. To find the speed for each remaining dot you will **mark off a distance to two intervals (dots) to the left and two intervals (dots) to the right** as shown above.
7. Each of these 5-dot intervals represents the distance covered by the cart during the time period.
8. You will use the 5-dot interval as a measure of average speed of the cart around that dot.
9. For each tape, measure the distances and enter them into the table below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **DATA TABLE** | | | |
|  | **Distance covered during 5-dot intervals for each mass (y-axis)** | | | |
| **Time Interval**  **(x-axis)** | **20g** | **50g** | **100g** | **200g** |
| **0** | **0** | **0** | **0** | **0** |
| **1** |  |  |  |  |
| **2** |  |  |  |  |
| **3** |  |  |  |  |
| **4** |  |  |  |  |
| **5** |  |  |  |  |
| **6** |  |  |  |  |
| **7** |  |  |  |  |
| **8** |  |  |  |  |
| **9** |  |  |  |  |
| **10** |  |  |  |  |
| **11** |  |  |  |  |
| **12** |  |  |  |  |
| **13** |  |  |  |  |
| **14** |  |  |  |  |
| **15** |  |  |  |  |
| **16** |  |  |  |  |
| **17** |  |  |  |  |
| **18** |  |  |  |  |
| **19** |  |  |  |  |
| **20** |  |  |  |  |

**ANALYSIS**

**Make and Use Graphs**. For each of your 4 recording tapes (20, 50, 100 & 200g) plot the **distance**s in centimeters (cm) covered for each time period (**y-axis**) against the **time** interval (**x-axis**).

1. Your graph **should have 4 lines** labeled 20g, 50g, 100g, & 200g.
2. **Calculate the slope** of each line using either graph or data table above and enter it in the data table below.

|  |  |
| --- | --- |
| **DATA TABLE** | |
| **Force Supplied by Weight of** | **Slope of Graph (Acceleration)** |
| **0** | **0** |
| **20g** |  |
| **50g** |  |
| **100g** |  |
| **200g** |  |

1. **Make and Use Graphs**. Make a graph plotting the values of the suspended masses (**whose weights provided the forces pulling the cart**) as y-axis and **accelerations they produce** as x-axis.

**CONCLUDE AND APPLY**

1. Looking at your first graph which line has steepest slope?
2. How would you explain the reason for the steep slope?
3. Using the words “distance”, “mass” and “acceleration” explain what is happening to make the slope so “steep”.
4. What is the relationship between the steep slope and the flattest (shallow) slope?
5. Looking at your 2nd graph describe the line (increasing or decreasing; is the line constant (straight) or increasing (curved)?
6. What is the relationship between mass and acceleration?
7. While thinking about Newton’s 2nd Law (f=ma) explain why your 2nd graph is a straight line (constant)?

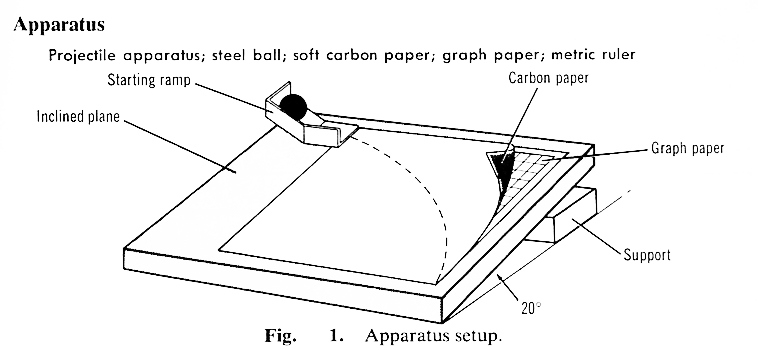
**LAB 11 & 12: 2D Kinematics: Projectile Motion**

**PROBLEM**

What **effect** does the force of **gravity** have **on** the motion of a **projectile**?

When a **projectile** is **fired** **horizontally**, **gravity** acts on it, **pulling it downward** with a constant force equal to its weight. To slow down the resultant downward motion of the projectile for purposes of this lab, you are going to “dilute” the effect of gravity. You will **fire a projectile horizontally** over the **surface of an inclined plane** (a board on a book). Only the component of gravity acting *parallel to the incline* will affect the motion of the projectile. The effect of this component of the projectile is similar to the effect that the entire force of gravity would have on a projectile moving through space in the vertical plane.

**OBJECTIVES**

1. Using graphed data, describe the motion of a projectile launched horizontally in terms of the horizontal and vertical components of the motion.
2. Explain Galileo’s description of uniformed accelerated motion.
3. Make and use graphs of time distance versus time.

**MATERIALS**

Projectile apparatus

Steel ball

Carbon paper

Graph paper

Metric ruler Protractor

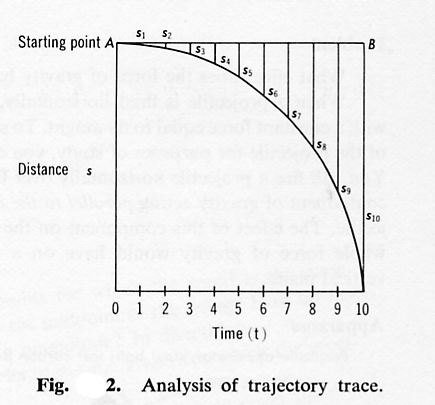
**VOCABULARY WORDS**

* **Horizontal component**: The component of something (generally a force) that acts in a horizontal direction.
* **Projectile motion**: The arced trajectory of an object projected into the air at a given initial speed and angle.
* **Projectile**: An object propelled through the air, esp. one thrown as a weapon.
* **Vertical component**: The component of something (generally a force) that acts in a vertical direction.

**PROCECURE**

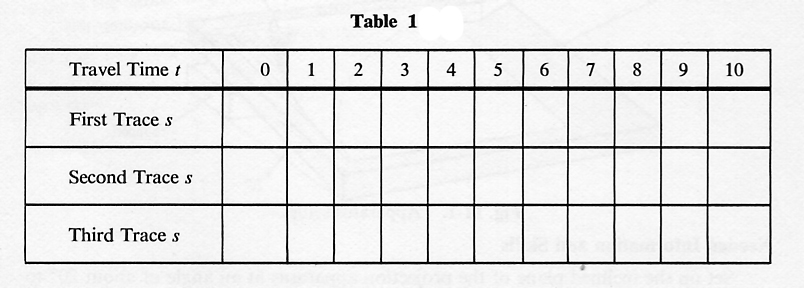
**Setup**

1. Set up the inclined plane of the projection apparatus at an angle of about 20° (1 or 2 textbooks under board) to the horizontal as shown in Fig. 1.
2. Start the steel ball at a point high enough on the steel ramp so that, when released, it rolls horizontally onto the upper right-hand corner of the board and then moves over the inclined plane to the lower left-hand corner.
3. Try this a few times to obtain a repeating path for the ball.
4. To make a record of this path, put a sheet of graph paper on the inclined plane and cover it with a sheet of carbon paper with the **carbon side face down**.
5. Now let the **ball roll down the inclined plane**. As it rolls, the ball **presses against the carbon paper** and **traces its motion** on the graph paper.
6. Next, **mark the edge** of the starting **ramp** **on the graph paper** to indicate the starting point of the trajectory.
7. To study **trajectory**, not that except for friction (**very small so neglect it**), **no horizontal force** acts on the ball after is leaves the ramp.
8. The **horizontal component** (**x-axis**) of the balls’ velocity remains **constant**.
9. This means that the **ball moves forward** (to the left)in **equal time intervals**.
10. You will use this fact to **divide the trajectory** into **equal time intervals**.



**GATHERING THE DATA**

1. **Obtain** (get/collect) **several** (a few) **trajectories** by the method described above.
2. **Analyze** (look at/study) **one** of the **trajectories** made on your graph paper.
3. **Divide it into 10** equal vertical **sections** as shown in Fig 2.
4. The width of each vertical section represents and equal time interval.
5. Mark the lines beginning each time interval from 0 to 10 as shown in Fig. 11-2.
6. Measure the distances (vertically) from lines S1 to S10.
7. Enter your data in Table 1 below.



**ANALYSIS**

1. **Make and Use Graphs**. Make a distance-time graph plotting the **distance** **s** as the **y-axis** and the **time** **t** as the **x-axis**.
   1. Is this uniform or accelerated motion?
   2. How do you know?
2. From your graph, **determine the speed of the ball at** t = 0, 2, 4, 6, and 8, by drawing a tangent to the curve at each of these points and measuring its slope.
   1. What is happening to the slope of the velocity of the ball as it rolls down the incline?
   2. What kind of motion is this?
3. Galileo showed that **when acceleration** of an object **is constant**, **s should be** proportional to **t2**.
4. **Make a graph** of **s** and **t2** for the trajectory.
   1. Is this uniformly accelerated motion?
5. Repeat the experiment with different angles on the incline.

**CONCLUDE AND APPLY**

1. If the angle of incline of the board is increased, what change can be expected in the acceleration of the ball?
   1. Predict the acceleration when the angle of incline is 90°.
2. If the initial horizontal velocity of the ball is increased what effect will this have on:
   1. It forward motion
   2. Its motion down the slop?
3. What additional information is needed in this experiment to obtain the actual numerical value of the acceleration?

**(Virtual) LAB 13: Projectile Motion Simulator**

Go to the projectile motion simulator at <http://phet.colorado.edu/sims/projectile-motion/projectile-motion.swf>

1. Starting with the pumpkin as your projectile, gather data and answer the following questions.

a. With an initial speed of 18m/s and no air resistance, what angle must the cannon be at to hit the bull’s eye?

b. Clear your results from part a. Now add air resistance and answer the same question.

c. Clear your results from part b and remove the air resistance. Collect data to figure out how the angle must be changed to hit the bull’s eye as the initial speed increases.

|  |  |
| --- | --- |
| **Initial speed** | **Angle** |
| 14m/s |  |
| 18m/s |  |
| 22m/s |  |
| 26m/s |  |

**Conclusion:** As the speed increases the angle \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

2. Now, using different projectiles, collect data to figure out how the angle must be changed as the mass of the projectile changes. Use 18m/s as your speed.

|  |  |  |
| --- | --- | --- |
| **Projectile** | **Mass** | **Angle** |
| Football |  |  |
| Bowling ball |  |  |
| Adult human |  |  |
| Piano |  |  |
| Buick |  |  |

**Conclusion:** As the mass of the object increases, the angle

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as long as the speed is constant.

3. Now, repeat the experiment in #2, only keep the angle constant at 65, and determine what happens to the initial speed needed to hit the bull’s eye as the mass of the projectile changes.

|  |  |  |
| --- | --- | --- |
| **Projectile** | **Mass** | **Initial speed** |
| Football |  |  |
| Bowling ball |  |  |
| Adult human |  |  |
| Piano |  |  |
| Buick |  |  |

**Conclusion:** As the mass of the object increases, the initial speed \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as long as the angle is constant.

1. Repeat the experiment in #3, except set the speed based on your results in #3, add air resistance and record the drag coefficient and whether the object hits the bull’s eye or not.

|  |  |  |  |
| --- | --- | --- | --- |
| **Projectile** | **Initial speed (from #3)** | **Drag coefficient** | **Hit bull’s eye?** |
| Football |  |  |  |
| Bowling ball |  |  |  |
| Adult human |  |  |  |
| Piano |  |  |  |
| Buick |  |  |  |

**Conclusion:** Explain how the air resistance relates to whether the object could still hit the bull’s eye or not?

5. Finally, choose an object and analyze its motion without air resistance.  Fill in the data table below by first choosing an initial speed and angle.  As the object is in motion record the remaining data.  After collecting all the data, prove that the simulator is accurate by using the mathematical formulas from Physics Reference Table and showing that the height, distance and time that the object traveled are accurate.  Show your work. (Hint:  you have to watch for the maximum height as the object is moving)

|  |  |
| --- | --- |
| Object: | Football |
| Angle: |  |
| Initial Speed: |  |
| Max. height: |  |
| Range: |  |
| Time: |  |

Calculations for time, height and range:

1. First we need to calculate the **x** (initial horizontal **velocity**) and **y** (initial vertical velocity) vectors of 18m/s resultant.

y =

18m/s

x =

1. Solve for TIME first by using vf = vi + at (Remember: vf (final velocity) is 0 since object has hit the ground and come to rest).
2. To calculate maximum height use d = vit + ½ at2 (Remember: when we calculate height the **time (t)** is ½ of the TIME calculated in step one since the **MAX Height** represents ½ of the parabolic flight of the object).

Max Height

0 TIME 50 100

1. To calculate RANGE (how far object traveled) we use: d = vt.

**(Virtual) LAB 13a: Projectile Motion Simulator**

**Introduction:**

Projectiles travel with two components of motion, X any Y. The acceleration and velocity in the Y direction is independent of the acceleration (if any) and velocity in the X direction. In this module, you will investigate the motion of a simple projectile. Realize that while gravity (acceleration) acts on the projectile in the \_\_\_\_\_\_\_\_\_\_\_\_ direction, it does not affect the velocity of the projectile in the \_\_\_\_\_\_\_\_\_\_\_\_ direction.

**Procedure:** *(we will be ignoring air resistance during this lab)*

* Run the PhET Simulations 🡪 Play 🡪 Motion 🡪 Projectile Motion 
* The cannon can be moved to add or remove initial Y position and X position.
* The cannon can be pivoted to change the firing angle, θ.
* The tape measure can be moved and dragged to measure range to target.
* To fire the cannon, .
* To erase the projectile’s path, .

Be sure **air resistance is off** and spend some time firing various projectiles.

* Set the initial speed to a value between 10-15m/s. Choose your favorite projectile.
* Find the range of the projectile at various angles.

θ = \_30\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_40\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_50\_\_ Range (dx) = \_\_\_\_\_\_\_ m

Add two more 🡪

θ = \_60\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_70\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_80\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_\_\_\_\_ Range (dx) = \_\_\_\_\_\_\_ m

θ = \_\_\_\_\_ Range (dx) = \_\_\_\_\_\_\_ m

* Measure the distance from the cannon to the target using the tape measure.
* Move the target to 21.0 m from the cannon. Attempt to hit the target with three different angles by changing the firing angle and initial velocity.

Range (dx) = 21.0m θ = \_\_\_\_\_\_\_\_\_\_ Vi = \_\_\_\_\_\_\_\_\_\_\_

**Vy**

**V**

**V**

Range (dx) = 21.0m θ = \_\_\_\_\_\_\_\_\_\_ Vi = \_\_\_\_\_\_\_\_\_\_\_

**θ**

Range (dx) = 21.0m θ = \_\_\_\_\_\_\_\_\_\_ Vi = \_\_\_\_\_\_\_\_\_\_\_

**Vx**

**θ**

VERY IMPORTANT



* A projectile’s velocity (v) has an X component (vx) and a Y component (vy). The X component (vx) is found by multiplying the magnitude of the velocity by the ***cosine*** of the angle, θ.



* Similarity, the Y component of velocity is found by multiplying the magnitude of the velocity by the ***sine*** of the angle, θ.

So, a projectile fired at **20 m/s** at **65o** has an X-velocity of  or **8.5** m/s.

The projectile would have a Y-velocity of  or **18** m/s.

So, the projectile would fire as far as one fired horizontally at 8.5 m/s and as high as one fired straight up at 18 m/s.

A projectile fired at 30 degrees with a velocity of 15 m/s would have an x-velocity component of \_\_\_\_\_\_\_\_ m/s and a y-velocity component of \_\_\_\_\_\_\_\_ m/s.

Calculate the components of the following projectile’s velocities:

1. v = 35 m/s θ = 15o vx =\_\_\_\_ vy = \_\_\_\_
2. v = 35 m/s θ = 30o vx =\_\_\_\_ vy = \_\_\_\_
3. v = 35 m/s θ = 45o vx =\_\_\_\_ vy = \_\_\_\_
4. v = 35 m/s θ = 60o vx =\_\_\_\_\_ vy = \_\_\_\_
5. v = 35 m/s θ = 75o vx =\_\_\_\_\_ vy = \_\_\_\_
6. v = 35 m/s θ = 90o vx =\_\_\_\_\_ vy = \_\_\_\_

* We can reverse the process and combine the two components of velocity back into one velocity fired at an angle.
* The magnitude of velocity is found using the Pythagorean Theorem with vx and vy as the legs of a right triangle. For instance, the velocity of a projectile with an x-component of 7.2 and a y-component of 4.8 is m/s.
* The angle above the horizontal is found using the inverse tangent (tan-1) of the legs vy/vx. For instance, the angle of the projectile described above would be = 34o.

Calculate the velocity magnitude and angle of the projectiles listed below:

1. vx = 5.6 vy = 6.4 v =\_\_\_\_\_ θ = \_\_\_\_\_\_
2. vx = 2.8 vy = 4.9 v =\_\_\_\_\_ θ = \_\_\_\_\_\_
3. vx = 8.1 vy = -7.2 v =\_\_\_\_\_ θ = \_\_\_\_\_
4. vx = -1.3 vy = -5.2 v = \_\_\_\_ θ = \_\_\_\_\_

**Conclusion Questions:**

1. Without air resistance, the piano travels *further / the same distance* as the football. (circle)
2. This is due to the fact that velocity in the X-direction *increases / is constant / decreases* as projectiles travel.
3. The Y-component of velocity *increases / is constant / decreases* as projectiles travel.
4. The answers to #2 and #3 are due to the fact that gravity acts *only in the Y / both the X any Y* direction.
5. The path of a projectile is a *linear curve / round curve / parabolic curve*.
6. This is due to the fact that the time component in the free fall equation (dy) is \_\_\_\_\_\_\_\_\_\_\_\_\_.
7. Without air resistance, maximum range of a projectile is obtained with an angle of\_\_\_\_\_\_\_\_\_ .
8. The same range can be obtained with angles of \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_.
9. Firing a projectile at 25 m/s at an angle of 35o is similar to firing a projectile with a speed of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ straight up and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ horizontally.
10. A projectile with a horizontal component of 13 m/s and a vertical component of 18 m/s would have an overall velocity of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m/s at an angle of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ above the horizontal.

**LAB 14 & 15: Centripetal Force**

**PROBLEM**

What is the relationship between centripetal force acting on an object moving in a circle of constant radius and the frequency of revolution of the object?

As long as **no resultant force** acts upon an object in motion it will move in a straight path (**Newton’s 1st Law**). To make the object move in a circular path, a **force acting towards the center of the circle** must be applied to it. This force is called ***centripetal* force**. **To keep** an **object moving in a circle** of fixed radius, the **centripetal force must change** **with** the **velocity** of the object. In this experiment you are going to study the **quantitative relationship between** the centripetal **force** acting on an object and its **frequency** **of revolution**.

**OBJECTIVES**

1. Determine the change in force and its affect on centripetal motion.
2. Compare the relationship between the **centripetal force** on an object and its **frequency of revolution**.
3. Make and use graphs of force versus frequency.

**MATERIALS**

15cm tube

#4 2-hole rubber stopper

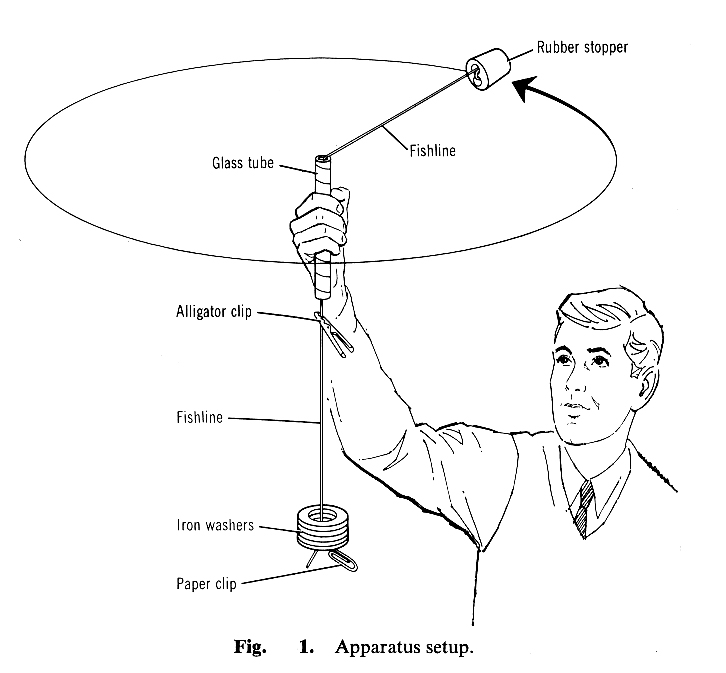
(24) 6g washers

Graph paper

stop watch

alligator clip

1.5m fishline



**VOCABULARY WORDS**

**Centripetal Motion**: Any motion in a curved path represents accelerated motion, and requires a force directed toward the center of curvature of the path. This force is called the centripetal force which means **"center seeking"** force. The force has the magnitude.

**PROCECURE**

**Setup**

1. Securely tie one end of the fishline to the rubber stopper. Pass the line through the tube and attach a bent paper clip to the other end so that iron washers can be slipped on at the other end of the string as shown in Fig. 1 above.
2. **Attach the alligator clip** to the line so as to **limit the radius** **of** the circular path of the stopper **from 80 to 100 cm**.
3. Now add about 5 or 6 washers to the line.
4. Whirl the stopper over your head in a horizontal circular path at such a rate that the **alligator clip is just pulled up to, but not touching, the lower and of the tube**.
5. Adjust your rate of revolution so that the radius of the circular path remains at constant.
6. The **centripetal force furnished by** the weight of the **washers** is now **keeping** the **stopper moving in** a **fixed radius**.
7. Have your partner **determine how long** it takes for the stopper **to make 30 revolutions**.
8. Find the **frequency of revolution** by dividing 30 by the time it takes to spin stopper 30 times.

**GATHERING THE DATA**

1. **Adjust the alligator clip** to allow the stopper to move in a circle of **radius about 80cm**.
2. The clip will indicate when the radius of revolution is at the selected fixed value.
3. Keep the stopper revolving overhead and adjust the rate until the alligator clip is just raised to the bottom of the tube and remains motionless there.
4. Measure the time for 30 revolutions and enter it in Table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| **TABLE 1** | | | |
| **Number of Washers** | **Time for 30 Revolutions (sec)** | **Frequency of Revolution** | **Square of Frequency** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

**ANALYSIS**

1. For each trial recorded in Table 1 calculate the frequency of revolution and also the square of the frequency .
2. **Create graph** **1** plotting **number of washers** as the **x-axis** and the frequency as the **y-axis**.
3. **Create graph 2** plotting the washers against .

What relationship do these graphs reveal between the centripetal force and the frequency for a body moving in a circle of fixed radius?

**CONCLUDE AND APPLY**

1. The speed *v* of a body moving in a circle at a fixed radius *r* at a frequency *f* is equal to . If *r* is kept constant, what is the relationship between *v* and *f*?
2. If *r* is kept constant, what does the experiment indicate to be the relationship between the centripetal force and speed *v*?

**EXTENSION**

1. How would you modify this experiment to learn the relationship between *f* and *r* when the centripetal force and the mass are kept constant?

**39**

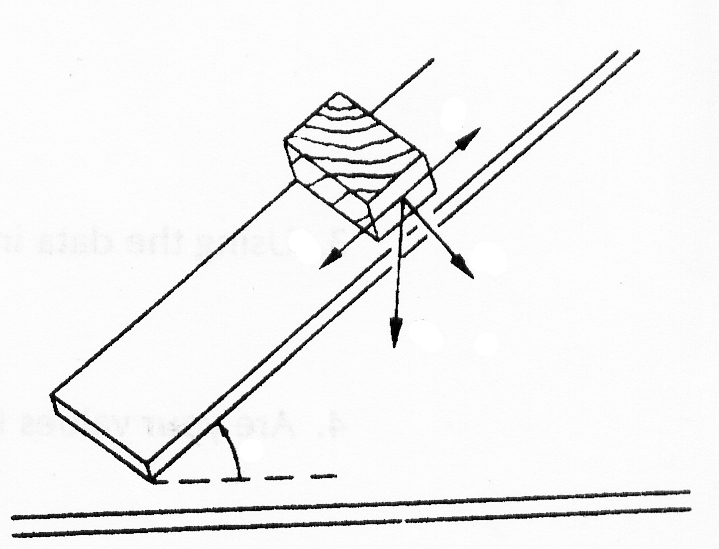
**LAB 16 & 17: Coefficient of Friction**

**PROBLEM**

What is friction and how do we measure its coefficients?

An object placed on an inclined plane may or may not slide. If the object is a rest, the **force of friction is opposing** the tendency of the object to slide down the plane. When the plane has been **tilted at a certain angle θ** with the horizontal, the object **begins to slide** down the inclined plane. If the object **slides down the inclined plane** **at a constant speed**, then the **force of friction** **Ff** is **equal to** the **force down the plane** **FII**. The **force down the plane** **is** the **same as** the component of the **object’s weight parallel to the plane**, as shown in the figure. The **parallel component** of weight is described as **FII = Fw sin θ**. The perpendicular component of weight is described as **F = Fw cos θ**. When **slide just begins** and object is moving at a constant speed, the **coefficient of friction μ is** given by:

**=**

**OBJECTIVES**

1. Investigate friction.

**Ff**

1. Calculate the coefficients of friction.
2. Make and use graphs of force versus frequency.

**FII**

**MATERIALS**

**F**

**Fw**

Spring scale

Object: book, dry erase board eraser

**Θ**

2x4 block

Flat board

String (1m)

Masking tape

Protractor

**VOCABULARY WORDS**

* **Friction**: the rubbing of the surface of one body against that of another.
* **Coefficient of Friction**: the force required to move two sliding surfaces over each other, divided by the force holding them together. It is reduced once the motion has started.

1. Select an object and a flat board. **Describe the object** **and** the surface of the **board** in Table.

|  |  |
| --- | --- |
|  | **Description Table 1** |
| **Object** |  |
| **Surface** |  |

1. **Tape the string to** the end of the **object**. **Hang the object** by the string **from** the spring **scale**. **Measure the weight** of the object. Record this value in Table. 2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weight of object (N)** |  |  |  | **Table 2** |
|  | **1** | **2** | **3** | **Average** |
| **Force of sliding friction (N)** |  |  |  |  |

1. Place the flat board on a horizontal surface. Hold the spring scale and, with the string held **parallel** **to** the level **board**, **pull the object** along at a constant speed. With the spring scale, measure the amount of force required to keep the object moving at a constant rate. Repeat this procedure 3 times, **average your results**, and **record the average** in Table 2 as the **force of sliding friction** between the surface of the board and the surface of the object.
2. **Detach the string** from the object. Place the object on the flat board. **Slowly lift one end of** the **board**. Continue **increasing the angle** of the board with the horizontal **until the object starts to slide**. Use the protractor to **measure this angle**. Record this angle in Table 3 as the angle for static friction. The tangent of this angle is the coefficient of static friction.

**40**

|  |  |  |
| --- | --- | --- |
| **Motion** | **Angle (degrees)** | **μ = tan θ Table 3** |
| **Static** |  |  |
| **Sliding** |  |  |

1. Move the object to one end of the board. Again, **slowly lift this end of the board** while your lab partner lightly **taps the object**. **Adjust** the **angle of** the **board** **until** the **object slides** at a constant speed after it has received an initial light tap. Use the protractor to **measure this angle** and record it in Table 3 as the angle for sliding friction. The tangent of this angle is the coefficient of sliding friction.
2. Repeat the experiment with a different object so that each lab partner has data to analyze.

**ANALYSIS**

1. From the data in Table 3, calculate the coefficients of **static and sliding friction** for the object used. Record these values in Table 3.
2. Explain any difference between the values for the coefficients of static and sliding friction.
3. Using the data in Table 2, calculate the coefficient of **sliding friction**. **SHOW YOUR WORK!!!**
4. A brick is positioned first with its largest surface in contact with an inclined plane. The plane is tilted at an angle to the horizontal until the brick just begins to slide and the angle is measured. Then the brick is turned on one of its narrow edges, the plane is tilted and the angle is measured. Predict whether there will be a difference in the measured angles. Is the coefficient of static friction affected by the area of contact between the surfaces?
5. A brick is placed on an inclined plane, which is tilted until the brick just begins to slide. The angle is measured. Then the brick is wrapped in wax paper and placed on a plane. The plane is tilted and the angle is again measured. Predict whether there will be a difference in these measured angles. Explain.

**EXTENSION**

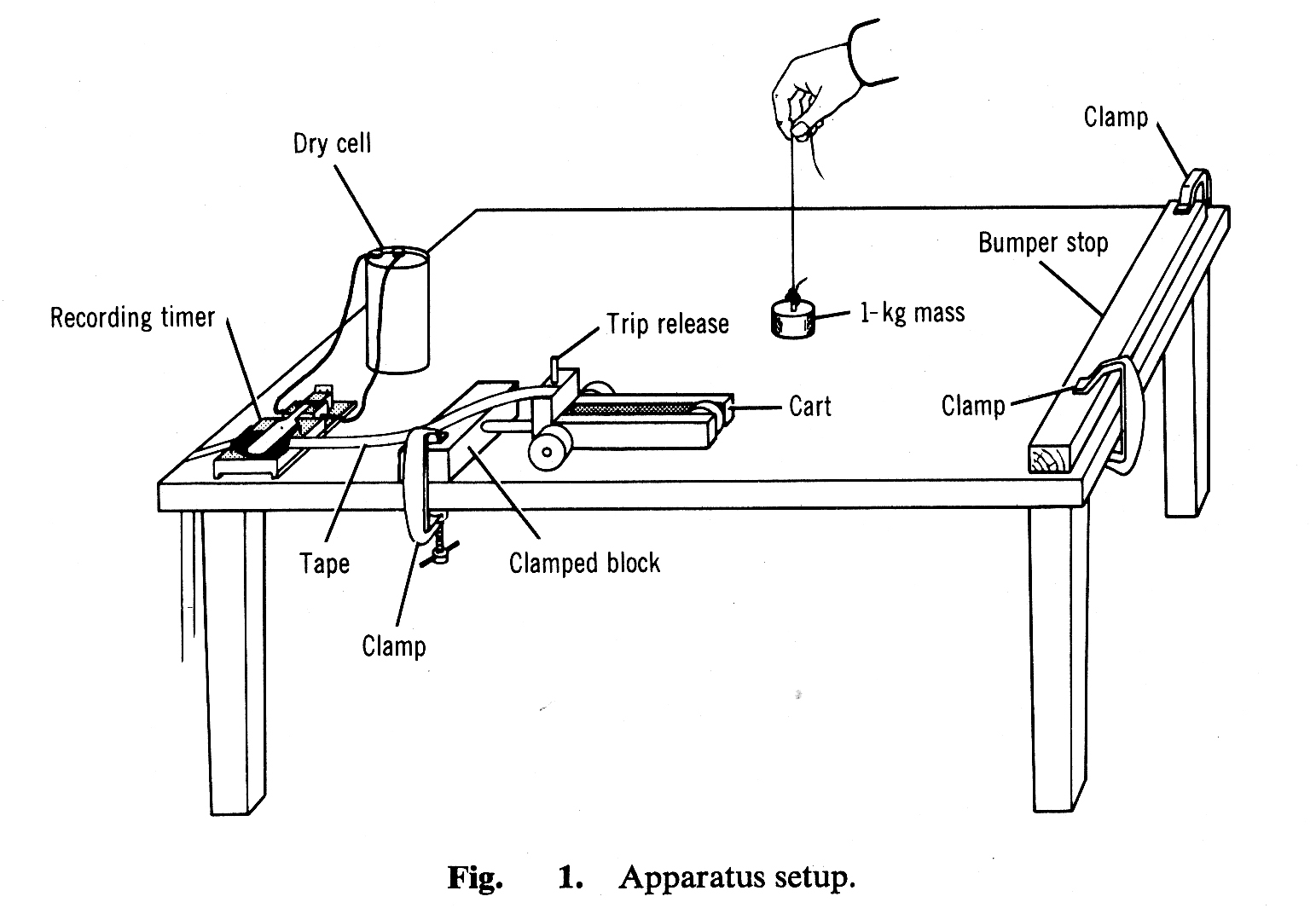
While looking for a set of new tires for your car, you find an advertisement that offers two brands of tires, brand **X** and brand **Y**, at the same price. Brand **X** has a coefficient of friction on dry pavement of 0.90 and on wet pavement of 0.15. Brand **Y** has a coefficient of friction on dry pavement of 0.88 and on wet pavement of 0.45. If you live in an area with high levels of precipitation, which tire would give you better service? Explain.

**41**

**LAB 18 & 19: Momentum & Mass**

**PROBLEM**

How does an increase in the mass of a moving cart affect its speed?

The law of ***conservation of momentum*** states that when no outside forces act upon a body its momentum remains constant. In this experiment, you are going to use this law to predict the velocity which a moving cart acquires when a mass is suddenly added to it. You will also measure this velocity and compare the predicted and measured values.

**OBJECTIVES**

1. Investigate momentum.
2. Calculate the initial and final momentum
3. Compare computed value with measured value
4. Calculate percent error

**MATERIALS**

Recording timer

Timing tape

Cart with spring mechanism

Electronic balance

Set of metric masses

1-kg mass

Blocks

Clamps

String

**VOCABULARY WORDS**

**Momentum:** Quantity or amount of motion; product of mass and velocity (momentum = mass x velocity).

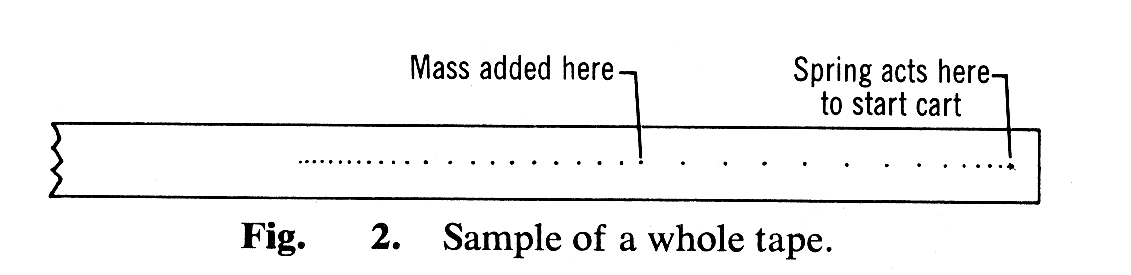
**Velocity**: Rate of change of position; speed AND direction.

**Mass**: The amount of matter in an object

**429**

**PROCECURE**

You are going to measure the velocity of a cart **before** and **after** a mass has been added to it by using the apparatus shown in Figure 1. The cart, with its spring “**loaded**” is placed near the end of a table against a clamped block. A strip of timing tape is attached to the rear of the cart and passed through the recording timer. To set the cart in motion the spring release is rapped sharply with a ruler. The cart **accelerates** during the time that the spring acts on it. However, as soon as the cart moves away from the clamped block and no longer is in contact with it, the spring no longer exerts a force on the cart. The cart then continues to move with almost constant velocity.



A **mass of 1kg**, held over its path as shown in Fig. 1, is **gently dropped** into the cart a short time after the cart has begun moving with constant velocity. The velocity of the cart **before** and **after** the mass has been added to it is obtained from an analysis of the tape.

To predict the velocity ***vf*** of the cart after the mass ***m*** has been added to it, you must measure the mass of the empty cart ***mc***and the velocity of the empty cart ***vi***. The momentum of the empty cart is ***mc vi***. The momentum of the cart with the added mass is (***mc*** + ***m***) ***vf***. **According to the law of conservation of momentum, these two momenta MUST BE EQUAL**. Setting ***mc vi*** = (***mc*** + ***m***) ***vf*** and solving for ***vf*** yields

Therefore, once *mc, m,* and *vi* are known, you can compute and predict *vf*.

**Setup**

1. With the electronic balance, **determine the mass of the cart**, *mc.* Enter this and the value of the mass *m* in Table 1.
2. To measure the velocity of the cart before and after the mass *m* has been added to it, **put the cart at the starting point**. Arrange the apparatus as shown in Fig.1. **Start the recording** and **strike the trip release**. After the cart has moved a short distance with constant velocity, gently drop the 1-kg mass onto the cart. Allow the cart to complete its run.
3. **Examine the first section of the tape** and find the part where the dots are evenly spaced as shown in Fig. 2. **Here the empty cart was moving at constant velocity**. **Examine the second section of tape** to find the part where the dots are also evenly spaced but closer than before as shown in Fig. 2. **In this part of the motion, the cart had the added mass in it**.
4. Determine T, the **period of the recording-timer**, by pulling a length of tape through the timer for 3 seconds and **dividing 3 seconds by the number of dots** on the tape. **Record the measured value** for the period of the timer T in second in Table 1.
5. Find the velocity ***vi*** corresponding to the first part of the tape by **dividing the distance** ***s1*** **over 10 equal spaces** in this part of the tape **by** **10T**. If the distance is measured in centimeters and the time in seconds, the velocity will be in cm/sec. Record the value ***vi*** in Table 1.
6. In a similar fashion, find the velocity ***vf*** corresponding to the second part of the tape and record the value in the table.

**43**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Table 1** | | | | | | |
| **Recording Timer Period = T** | | | | | | |
| **Trial** | **Mass of Cart**  **MC** | **Added Mass**  **M (g)** | **Initial Velocity**  **Vi**  **(cm/sec)** | **Final Velocity**  **Vf**  **(c,/sec)** | **Initial Momentum**  **Pi**  **(Mc · Vi)** | **Final**  **Momentum**  **Pf**  **(Mc + M)· Vf** |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |

**ANALYSIS**

Compute the value of ***vf*** from the relationship

1. Compare the computed value of ***vf*** with the measured value of ***vf***. Calculate the **percent difference** between your measured value and your computed value of ***vf*** using the formula below.

Percent Difference: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Compute the momentum of the empty cart, ***mc vi*** and the momentum of the loaded cart, (***mc*** + ***m***) ***vf*** and enter these values in Table 1. Do these values agree with the prediction of the law of conservation of momentum? Explain any difference between them.
2. Are your values for μsliding from Questions 1 and 3 equal? Explain any differ
3. How would the final velocity of the cart be affected if a 2-kg mass were used instead of the 1-kg mass?
4. The law of the conservation of momentum holds only when there is no external force acting on the system. What is the **effect on the velocity** of the cart, both before and after the mass added, **of the** **external force of friction**?

**EXTENSION**

Miles Tugo and Ben Travlun are riding in a bus at highway speed on a nice summer day when an unlucky bug splatters onto the windshield. Miles and Ben begin discussing the physics of the situation. Miles suggests that the momentum change of the bug is much greater than that of the bus. After all, argues Miles, there was no noticeable change in the speed of the bus compared to the obvious change in the speed of the bug. Ben disagrees entirely, arguing that that both bug and bus encounter the same force, momentum change, and impulse. Who do you agree with? Support your answer.

**44**