MND Physics

Comprehensive Motion Lab

You will explore the motion of different objects by applying the concepts of distance, speed, and acceleration. You will draw d vs. t and v vs. t graphs and explain what the graphs tell you about the motion observed. Both constant velocity and accelerated motion will be explored.

EQUIPMENT: Meter stick, stopwatch, battery-powered bulldozer, masking tape, incline ramp, ball bearing, and wood blocks.

PART I

Constant motion (velocity)

1. You will have your bulldozer travel in a straight line for a distance of 3 meters.

2. Mark the floor with 7 small pieces of tape, each spaced 0.5 meter apart.

3. Start the bulldozer 10-20 cm <u>behind the first mark</u> (your starting line) so that you can get an accurate starting time.

4. You will time the bulldozer beginning when the front part crosses the starting tape and ending when the front crosses the 0.5 meter mark.

5. Repeat this process extending the next runs to 1 meter, then 1.5 meters, then to 2 meters, etc. (start every run at the first mark).

6. Collect the time data for each of the 6 trial runs and record the data in your book (you should create a table in your book similar to the example illustrated in this handout).

7. Remove the tape from the floor.

8. Calculate the average velocity of the bulldozer in meters/second. For each run, v = d/t where "d" is distance and "t" is time. The average velocity should be calculated as:

$$\overline{V} = \frac{v_1 + v_2 + v_3 + v_4 + v_5 + v_6}{6}$$

9. Prepare a graph of d vs. t (meters vs. seconds). Plot each run point and draw a line/curve that best represents the data. Explain the results.

PART II

Acceleration of a ball bearing down an incline ramp

1. Set up a ramp with the angle of the incline exactly 10 degrees to the horizontal. Calculate the required angle using trig relationships. (see diagram below)

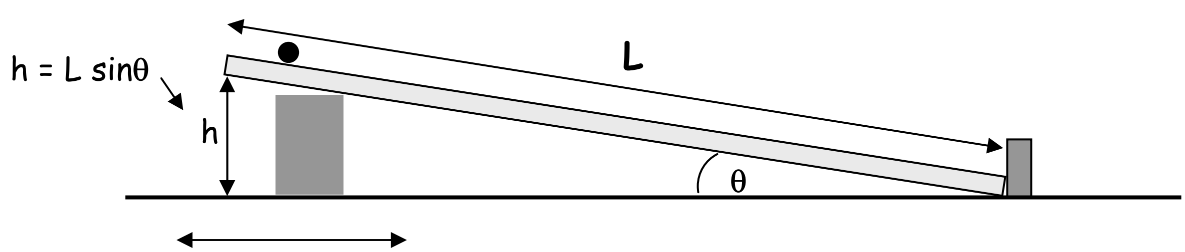
2. Divide the ramp's length into 6 equal parts and mark the 6 positions on the board with a small piece of tape. These positions will be your release points. IMPORTANT: Make sure your marks are placed off the side of the ramp… you do not want the ball to roll over the marks! (the bump and friction will effect your data).

3. Place a stopping block at the bottom; this will allow you to hear when the ball bearing reaches the end point.

4. Use a stopwatch to measure the time it takes to roll down the ramp from each tape mark. Make 3 timing runs from each position and record your data in a Table. Calculate the average time for each distance. DO NOT LET THE BALL ROLL OVER THE TAPE!

5. Graph your data, plotting distance (y-axis) vs. average time (x-axis). Plot a line/curve that best represents your data.

6. Now repeat steps 4 and 5 using an incline of 15 degrees.

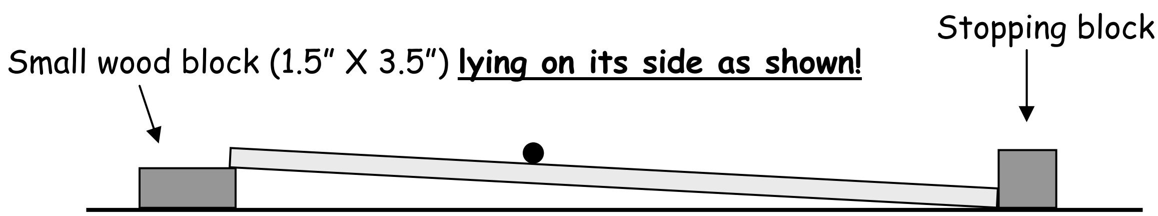


Move the block back and forth to achieve the correct angle.
"h" is measured from the floor to the BOTTOM edge of the board.

PART III

Prove that the Galileo's relationship $d \propto t^2$ holds true for a ball bearing accelerating down an inclined plane.

1. Remove the tape marks from the part II experiment and place them at 10 cm, 40 cm, and 90 cm from the stopping block. Set up the incline as shown.



2. Measure the time it takes for the ball to roll down the ramp from each mark (3 trial runs per mark). Calculate the average time. Then round the average time to the nearest integer and record the result in the Data Table.

3. Graph your data plotting distance (y-axis) vs. average time (x-axis)

4. Galileo, in his famous experiments with inclined planes, discovered the distance traveled for an accelerating object was proportional to the square of time, or:

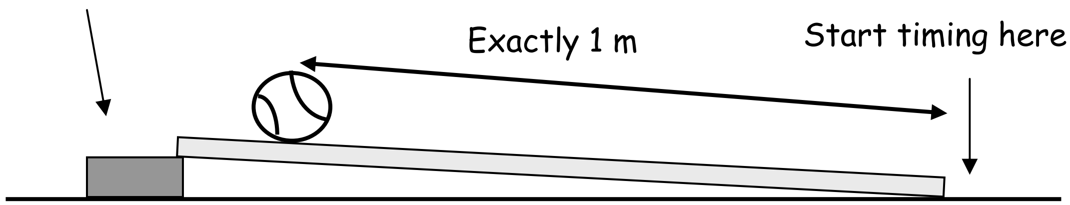
   $d \propto t^2$, where the symbol $\propto$ denotes "is proportional to".

PART IV

Deceleration of a tennis ball.

1. Set up the incline as shown. Make sure the ball is exactly 1 m from the edge of the ramp (measure from ball's the center of mass). Given this setup, assume the balls velocity at the end of the ramp is V = 0.92 m/s. (The velocity at the end of the ramp was determined using an energy analysis which you will learn later on in the year). Since we are timing the motion of the ball starting at the moment the ball hits the floor, we will call 0.92 m/s our initial velocity (i.e. Vi = 0.92 m/s).

1.5" X 3.5" block **lying on its side as shown!**



2. Release the ball. At the moment the ball hits the floor, start timing the motion; measure the time it takes the ball to roll to a complete stop. Calculate the ball's deceleration in meters per second squared. Average deceleration: $\overline{a} = (V_f - V_i) / t$, where Vi = 0.92 m/s and $V_f = 0$.

DATA:

DATA TABLE **PART I: Constant motion of a bulldozer**

TAPE MARK	DISTANCE (m)	TIME (s)
1		
2		
3		
4		
5		
6		

DATA TABLE **PART II: ANGLE = 10 DEGREE SLOPE**

TAPE MARK	DISTANCE (m)	TIME (s) TRIAL 1	TIME (s) TRIAL 2	TIME (s) TRIAL 3	AVERAGE TIME (s)
1					
2					
3					
4					
5					
6					

DATA TABLE **PART II: ANGLE = 15 DEGREE SLOPE**

TAPE MARK	DISTANCE (m)	TIME (s) TRIAL 1	TIME (s) TRIAL 2	TIME (s) TRIAL 3	AVERAGE TIME (s)
1					
2					
3					
4					
5					
6					

DATA TABLE **PART III: Galileo Experiment Incremental Slope**

DISTANCE TRAVELED (m)	ROLLING TIME (s)				Ave Time to the closest INTEGER
	TRIAL 1	TRIAL 2	TRIAL 3	Ave. Time	
0.10					
0.40					
0.90					

DATA TABLE **PART IV: Negative acceleration of a tennis ball**

TRIAL	VELOCITY AT BOTTOM OF RAMP (Vi)	ROLLING TIME ON FLOOR (t)	ACCELERATION ($\bar{a}$)
1	0.92 m/s		
2	0.92 m/s		
3	0.92 m/s		
		Average acceleration	- **m/s^2**

Average acceleration: $\bar{a} = (V_f - Vi) / t$, where Vi = 0.92 m/s and $V_f = 0$.

PART I ANALYSIS:

- What factors detracted from the constant motion of the bulldozer?
- What mathematical relationship between “d” and “t”?
- What does the slope of your graph represent?

PART II ANALYSIS:

- What is acceleration?
- Does the ball accelerate down the ramp? Cite evidence to defend your answer.
- What happened to the acceleration when the angle of the ramp increased?
- What mathematical relationship between “d” and “t”?
- What does the slope of your graphs represent?

PART III ANALYSIS:

- Compare the distance to the time in integers. Explain your results.
- Can you prove Galileo’s relationship using your experimental data?

PART IV ANALYSIS:

- Calculate the balls average acceleration.
- Explain the significance of the minus sign. What are the possible causes for the tennis ball to slow to a stop?
- Would your results be different if the floor was made of rough concrete? Why?