

Chapter 3

Inertia

Natural Motion – Galileo

CLASS ACTIVITY:

Galileo's Thought Experiment—Page 25

This activity was attempted with three different mini-Vs. The tracks for the mini-Vs were placed along two boards, one forming the downward sloping ramp, and the second forming the upward sloping ramp. The tracks were taped to the boards to limit their motion as the car passed. The cars were released from a point A, 100 cm from the lower end of the down ramp. The vertical height to the point A was 56 cm.

Point B was marked along the upward sloping ramp. It was the point at which the car stopped moving and reversed its direction. The angle of the upward sloping ramp was measured. The distance to point B from the bottom of the upward sloping ramp was measured. The vertical height from the table to point B was also measured.

Theoretically, the car should travel up the upward sloping ramp to point B and reach the same vertical height as the point of release, A. Due to friction and the loss of energy to other forms, the cars never reached the same height as point A (i.e., 56 cm). The best that could be achieved was about 35 cm in height to point B.

The three vehicles being used were slightly different in shape and mass. The lightest (vehicle A), a sports car, performed the worst. The one with the most mass (vehicle C), a van, performed the best.



Typical Results

- The point of release in all trials was 100 cm from the lower end of the downward sloping ramp and the vertical height was always 56 cm.

Table 1

Angle of upward sloping ramp	Vehicle	Average distance traveled up the upward sloping ramp (cm)	Average vertical distance vehicle to which the vehicle rose (cm)
30°	A	65	28
30°	B	68	30
30°	C	77	35
25°	A	79	30
25°	B	82	32
25°	C	89	34
17°	A	103	28
17°	B	118	31
17°	C	125	34
10°	A	141	25
10°	B	162	31
10°	C	169	33

- Ideally, the height from which you release the car above the floor and the height to which the car rises above the floor on the other ramp should be the same. However, due to friction and the loss of energy to other forms, the height to which the vehicle will rise is always less than the height from which it was released.

3. Distance from which car is released up the ramp = 90 cm.

Distance car travels up the up ramp will be less than 90 cm if the angles the ramps make with the floor are equal, or if the angle for the upward sloping ramp is greater than for the downward sloping ramp.

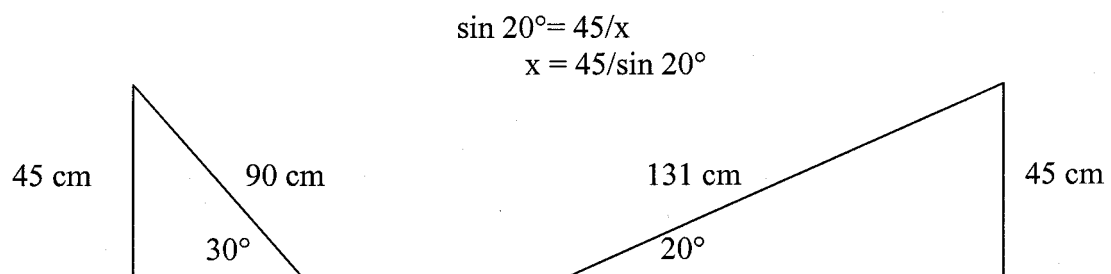
If the angle for the downward sloping ramp is less than for the upward sloping ramp, at a certain angle the vehicle will travel farther up the upward sloping ramp than 90 cm.

4. After decreasing the angle of the up ramp:

Distance from which car is released up the ramp = 90 cm.

Height above the floor to point of release = 45 cm.

Distance car moves up the up ramp = 131 cm.



Vertical distance car rises = 45 cm

The distances calculated above are for the ideal case, with no friction. The distances in real life will be less. The car will not rise to a height of 45 cm and will not travel up the slope to 131 cm.

Alternate Activity

If long movable lab tables are available, a similar activity can be done using these tables and a steel ball bearing. Butt the ends of two tables together. Raise the other ends by resting the legs on three or four textbooks. The ball bearing is released on one table from a point 1 m from the end that abuts the second table. Measure the height of the point of release above the floor. The ball then rolls down the first table and up the second table. Record the distance up the ramp the ball bearing rolls and the height it reaches above the floor.

Remove one set of textbooks from below the legs of the upward sloping table. Repeat the procedure. Repeat the procedure a third time. The ball bearing should roll almost to the end of the upward sloping table or completely off the table. If the final set of books is removed, the ball bearing rolls right off the table.

If the ball bearing is released onto a smooth, level floor as in a long hallway, the ball bearing will roll with a fairly constant velocity for a great distance. A ball released down a ramp elevated by 15 cm at one end rolled 40 m across a tiled floor and was still going when it hit the wall.

Typical Results

Table 2

Number of books under legs of upward sloping table	Point of release from end of table (cm)	Height of point of release above lowest point on the table (cm)	Distance ball travels up the upward sloping table (cm)	Height of point ball comes to rest above the lowest point on the table (cm)
3	100	3.5	89	3.0
2	100	3.5	134	3.2
1	100	3.5	>265	76.6
0	100	15 (see above)	>4000	


Think About IT!
Think About IT!—Page 25

- As the angle decreases for the up ramp, the car travels a further distance along the up ramp. The car must rise to the same height. Since the angle of the track is less, it takes a longer distance along the track to reach the same height.
- If the angle of inclination is 0° , the car would roll along forever.

PRACTICE—PAGE 26

- For initial motion, the object has uniform velocity.

Van with equal spacing at equal time intervals

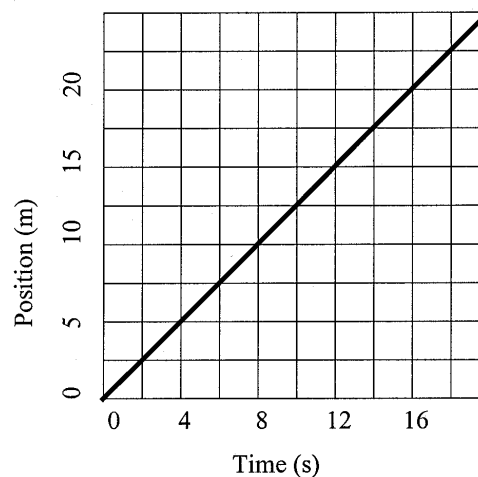
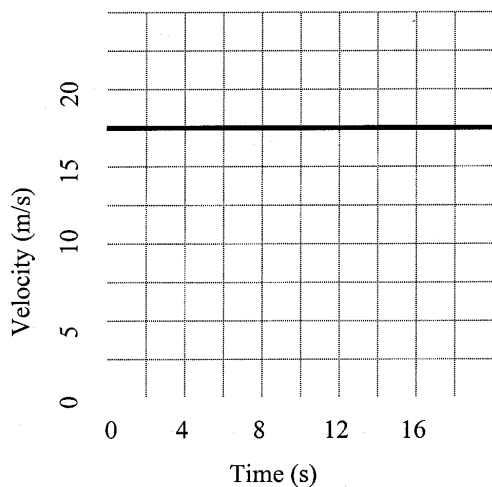


2. This table of data reflects inertial motion.

Table 3

Time (s)	Position (m)
0	0
1	2
2	4
3	6
4	8
5	10

3. This graph reflects inertial motion—motion with constant velocity.



4. An unbalanced force is any force that is acting on an object that is not cancelled out by another force of the same size acting in the opposite direction.
5. Aristotle did not use any kinds of measurements to verify his ideas about motion. He did not account for friction. To overcome friction, objects had to be pushed in order to continue to move.
6. Galileo reasoned things out in “thought experiments.” While his reasoning was correct, it was not verified by measurement.

The Velocity of a Car on an Inclined Plane

**Think
About
IT!**

Think About IT!—Page 30

- The calibration ratios should follow the pattern 1, 4, 9, 15, 25.

Sample Data

Table 4

Release point— distance up the ramp (cm)	Horizontal distance object travels before hitting the floor (cm)	Relative velocity	Actual calibration ratio	Ideal calibration ratios
5.0	17.4	1	1	1
18.5	34.8	2	4	4
34.0	52.2	3	7	9
61.5	69.6	4	12	16
100.0	87.0	5	20	25

Calibration ratio = Release point distance / First release point distance

Note to Teacher: The ramp was set at 30° from the horizontal. The track used was a plastic toy-car track nailed to the ramp. The track was quite bumpy. The object used was a marble. Better results could be obtained with a smoother track and a heavier object, such as a steel ball bearing.

The experiment was repeated using a smooth track consisting of a 1.5-m fenceboard with two smaller boards forming a channel wide enough for a Mini-V, and a steel ball bearing.

Table 5

Release point— distance up the ramp (cm)	Horizontal distance object travels before hitting the floor (cm)	Relative velocity	Actual calibration ratio	Ideal calibration ratios
5.0	21	1	1	1
22	42	2	4.4	4
45	63	3	9	9
82	84	4	16.4	16
121	105	5	24.2	25

These results closely match the ideal calibration ratios.

The angle for the calibration of the track does not matter as long as it is kept constant. In later activities, the calibrated track is used again. Be sure the students have the correct angle for the slope. A convenient way to do this is to put a mark at 100 cm from the end of the track and rest the track on three or four identical books.

2. The mathematical significance of the pattern 1, 4, 9, 16, 25 is that these numbers each represent the squares of a number.

$$1 = 1^2$$

$$4 = 2^2$$

$$9 = 3^2$$

$$16 = 4^2$$

$$25 = 5^2$$

Investigation # 2 INERTIA AND THE UNRESTRAINED OCCUPANT

Note to Teacher: Students using toy cars had difficulty with their passengers. If the passengers were too large or too lifelike (i.e., with arms and legs), they had difficulty remaining on the vehicle as it rode down the ramp. Also, the passengers with arms and legs tended to travel inconsistent distances after leaving the vehicle.

The car tended to skip over the barrier, a metrestick, when the velocity was 4 or 5. A good height for the barrier is about 1 cm. This barrier will stop the car at all speeds and allow the passenger to travel over it.

Typically, the results, when graphed, all followed the curve of an exponential relationship with an exponent of 2.

Distance traveled is proportional to velocity squared.

Some examples can reinforce this idea. For example, if a passenger is thrown a distance of 4 m at 20 km/h, then at 80 km/h, 4x the velocity, the passenger is thrown $4(4)^2 = 4(16) = 64$ m.

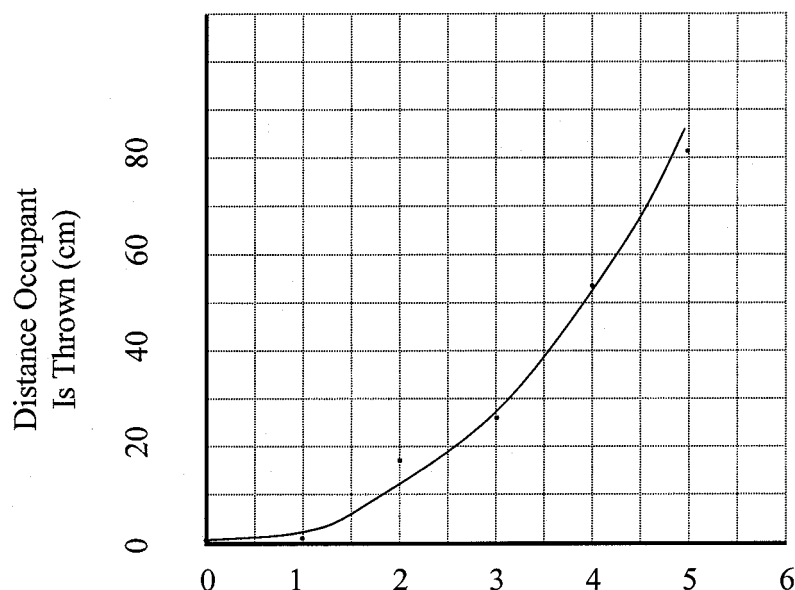
Table 6

Speed	Trial #1	Trial #2	Trial #3	Average distance occupant is thrown (cm)
0	0	0	0	0
1	0	2	0	0.7
2	19	15	18	17.3
3	30	19	29.5	26.2
4	37.5	76.5	46.5	53.5
5	86	63	94	81

Think
About
IT!

Think About IT!—Page 31

1.



2. As the speed increases, the distance the occupant is thrown also increases.

The distance the occupant is thrown increases more rapidly than the velocity of the vehicle. This is an exponential relationship. The graph is a curve. This curve was mentioned in exponential population growth as a “J” curve.

3. Other factors that affect the distance the occupant is thrown are:

- the shape of the occupant (does it have arms? Legs? Is it round? Flat?)
- how it moves after landing (sliding, rolling)
- size of occupant
- angle of contact with the ground

Challenge—Page 32

“Idealize” the inertia and the unrestricted occupant activity.

1. How will the velocity be controlled?

Students can launch the vehicle at varying velocities, using different means. For example, elastics can be attached to a dynamics cart. The elastic can propel the cart. This would be done by attaching the elastic to the cart and to a fixed point. The cart would be pulled back, stretching the elastic. Once released, the cart would accelerate to a certain velocity before smashing into the barrier.

The elastic can be stretched to double the original distance. This will double the force and should result in a velocity that is twice as great as the original. This can be repeated for other amounts of stretch of the elastic.

2. How can the passenger be modified to come to rest in a regular fashion?

If solid objects are used, these should have a regular shape. The less sharp the corners, the better. A die could be used, but a dodecahedron might be better. Board games come with regularly shaped solid objects with many sides. The more sides the object has, the better.

If plasticine or clay is used, it can be moulded into a cube, then the corners can be flattened. This would make the object roll in a more regular fashion.



**Think
About
IT!**

Think About IT!—Page 32

1. The real relationship between the distance an unrestrained object is thrown and the speed of the car is an exponential relationship.

distance \propto velocity squared

$$d \propto v^2$$

If speed doubles, distance increases by 22 or 4 times.

If speed triples, then distance increases by 32 or 9 times.