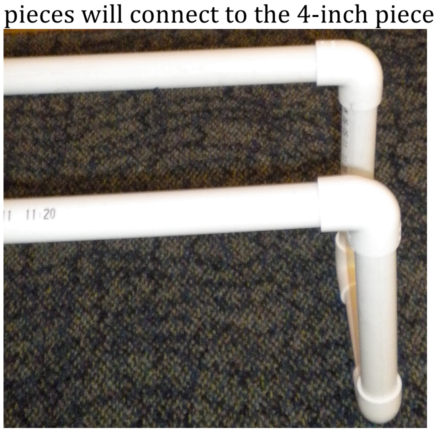
Downhill Racer - Slow Acceleration

Introduction
Slow acceleration can be studied by rolling an object down a gently ramp/inclined plane.

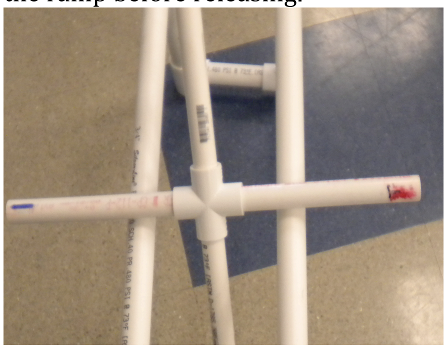
Materials
PVC cutters, stopwatch, tape measure, masking tape, markers
15 ft (5 meters) Schedule 40- ¾ in PVC
6 – ¾inch elbows, 2- ¾ inch T's, 1- ¾ inch cross

Ramp – Assembly
Cut:
2 – 5 ft pieces for the length of the ramp
2-8 inch pieces for the high end of the ramp
2-7 inch pieces for the low end of the ramp
2 – 4 inch pieces as connectors
Connect the two T's as shown in the diagram above to each 8- inch PVC piece. Use the 4-inch PVC piece to connect them. Attach each elbow to the opposite ends Attach each 5 ft PVC piece to one of the elbows. Attach the two elbows to the end of the 5 ft PVC. Turn the elbows, so that the 7-inch PVC pieces will connect to the 4-inch piece as in the diagram.



Making the device (roller)

Using the ¾ inch cross, cut 2 pieces of PVC about 4 inches in length and place in the two ends of the cross this will serve as the axle. The axles should be long enough so if the device drifts to one side the axle will not fall off the ramp.
Cut 2 more pieces of the exact same length. If they are not the same length the device might refuse the roll or roll up instead of down. Attach to the other ends of the cross. Try to balance the device on the ramp before releasing.



To Do and Notice:

1. Measure the length of the ramp. This is L1- let's say 48 inches or 122cm.
Start the roller at the high end of the ramp and start the stopwatch.
Measure how long it takes the roller device to reach the bottom of the ramp.
Repeat several times and take the average. We will use T1- 9.O seconds as our average. Record on data on table 1.
2. Measure to the center of the ramp; this is L2- 24inches or 61 cm. Start the roller device from the high end and measure the time to the center or to the ½ ramp mark.
Repeat several times and take the average. We will use T2 - 6.5 seconds. Record on table 1.
3. Measure to the ¼ of the ramp is L4 -12 inches or 30 cm. Start the roller device from the high end and measure the time to the ¼ mark. Repeat several times and take an average. We will use T4- 4.5 seconds. Record on table 1.

Table 1

Measure Length of Ramp in m	Time in Seconds Trial 1	Trial 2	Trial 3	Average time in Seconds
L1 – 1.22				T1 – 9.0 s
L2 – .61				T2 – 6.5 s
L3 – .30				T3 – 4.5s

What is the relationship between the length of the ramp and time?

Take the ratio of the time for the length of the ramp L1. This is T1 and the time for the ½ ramp L2 this is T2.

T1/T2 = 9.0/6.5 = 1.4

Take the ratio of the time for ½ the ramp T2 to the time of the ¼ ramp T4

T2/T4 = 6.5/4.5 = 1.4

Notice that the ratios remain the same.
Also, 1.4 is close to the square root of 2.
The ratio of the times is the square root of the distances.
L1/L2 = 2
T1/T2 = 1.4 = square root of 2
So, L1/L2 = (T1/T2)^2

Or L=k T^2, the length traveled from rest is proportional to the timed squared.

THIS IS A FUNDAMENTAL RULE FOR CONSTANT ACCELERATION

What's Going On?

Objects accelerating down an inclined plane accelerate slower than the acceleration of gravity for a dropped object. Galileo knew this and used it to find the mathematics of objects undergoing constant acceleration. The basic equation for relating distance traveled from rest to (d) to the constant acceleration (a) and the time (t) is d=1/2 a t^2.
Solving for the acceleration in Table 1,
a =2d/t^2 = 2
a = 2(1.22m)/ (9.0 s)^2 = 0.0578 or 0.06 m/s^2
This is 0.006 g or less than 1% of the acceleration of gravity in freefall.
We have achieved a low acceleration indeed.

So What?

The same rule is followed for objects in freefall, when friction can be ignored with a much larger acceleration of 9.8 m/s^2.

Going Further

Start the object from rest and have teachers mark the position at constant time intervals. It's easiest to use every 2 seconds. Example below;

2s	0.12 m	1
4s	0.48 m	4
6s	1.1 m	9.2
8s	1.9 m	16

The last column shows the distance traveled in units of the first measurement, 0.12 m. Notice that the distance traveled is proportional to the square of the number of intervals of time traveled. The sequence 1,4,9, 16 is the sequence of the squares of the integers.

Galileo measure this and saw that the distance traveled under constant acceleration was proportional to the square of the time.

Adapted from Paul Doherty – Scientific Explorations 2011
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