<u>Projectile motion</u>

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Students of class X have always experienced projectile motion in their lifetime. This experiment is set up to formalize this experience using simple tools (low cost) so that students can understand this very important physics concept. This aim is achieved by using very simple equipment which includes spring and steel ball.

The Apparatus: The equipment required for carrying out this experiment includes plastic vials which can be purchased from medical store, a protector to measure the angles, a tooth-pick to point out the angles on protector, a spring, a syringe piston which can be locked and help in release of the steel ball-bearing. A measuring tape, a plastic tray filled with fine sand, few more tooth picks to be used as marker on the sand.

The launcher was assembled in-house and can be described as follows. A vial labelled ‘A’, which is around 1.1 cm in outer diameter and 0.9 cm in inner diameter, available commercially is used as the ‘muzzle’ from where the projectile is launched. A shift of syringe ‘B’ is used as the piston to launch the projectile which is a steel ball bearing ball weighing around 1.7 g.

Spring ‘C’ with a known spring constant is used trapped between the shaft end and the threaded top of the vial ‘A’. Vial ‘A’ is fitted in a bigger vial ‘F’ attached to the protector ‘E’ and a wooden strip ‘G’. The wooden strip is around 1 cm thick so that it can be glued to a flat plastic sheet ‘K’. The whole arrangement can be seen in Figure1.

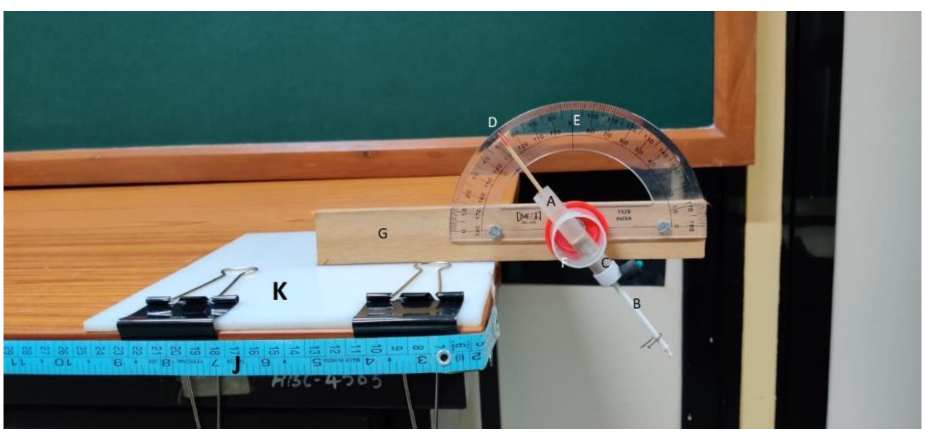
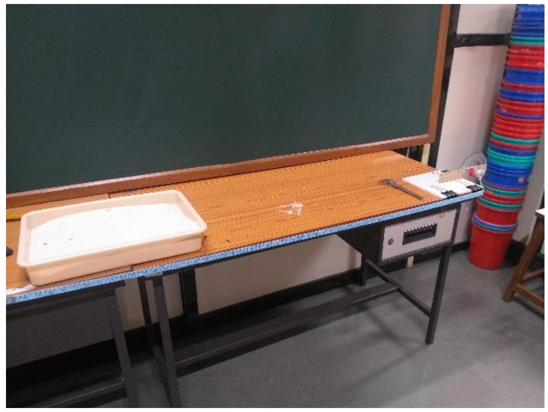


Figure 1. The picture of launcher of the projectile attached to a table top.

The whole setup connected to 'K' is attached to the table top with file clips. A steel ball is inserted in the muzzle 'A' and then the shaft 'B' is withdrawn outwards



compressing spring 'C'. The shaft 'B' has a small hole across the

Figure 2 & 3. Set up from different angles.

shaft so that a pin can be inserted to lock the shaft in its extended position. Upon removal of the pin, the spring is allowed to expand and launch the ball out of the muzzle.

The arrangement can be seen in Figure 2 and 3 which show the arrangement from a different perspective.

A measuring tape 'J', is attached on the table top to measure the range of the ball. On the other end of the table, as seen in Figure 2 and 3, is a tray with a sand bath. The ball is caught in the sand without a bounce and a marker can be placed to record the location where ball touches the 'ground level' after its flight. The arrangement of the launcher, top view, can be seen in Figure 4.

Figure 4. Top view of the launching arrangement.

A long rod with a bar magnet attached to it is very handy. It is not part of the experiment but in the case of ball overshoots the sand filled tray, it can be very useful in picking up the ball quickly from corners it can seep into.

Theory:

When an object is projected under gravitational force with velocity “v”, called muzzle velocity, at various angle of projection, its trajectory is nearly a parabola. In the process it acquires different heights, ranges, time of flight and so on, ignoring air resistance and other retarding forces. The small range over which the ball is in connection with the spring, it accelerates from zero to “release” velocity (or muzzle velocity) “v”. It becomes a projectile motion after the release from spring contact. In this small range the repulsive forces of different format are important and hence the “release” velocity v is not same at different angles.

Related formulae:

Time of flight $T = \frac{2v\sin\theta}{g}$ **;**

Range of the projectile $R = \frac{v^2}{g}\sin 2\theta$

Hence by measuring the range at any given angle the velocity v can be calculated.

When a spring is either compressed or stretched, a restoring force is set up within the spring which is proportional to the compression/ elongation (x) of the spring. When the spring is released, this force linearly decreases with the compression/ elongation till the compression/ elongation is zero. Thus the average force is $\frac{1}{2} kx^2$. This force will be acting on any external body against which the spring is released.

When the piston is pulled back to release the ball, the force acting on the ball is due to the spring and earth’s gravity. This force and subsequent acceleration results in the velocity of the projectile deduced/calculated by you for each projection angle. This v can be obtained from the following relationship

$$v^2 = \frac{2k(x/2)^2}{m} - 2(\frac{x}{2})g\ sin\theta$$

Procedure:

1. It is essential to get a feel of the range over which the ball will fly before hitting the ground/table, before taking readings.
2. Attach a bar magnet to given long rod. This is useful whenever steel ball shoots off in an uncontrollable fashion. The magnet is used to quickly retrieve it.
3. Spring should be compressed to the same extent every time, throughout the experiment.
4. Note the arrangement given to ensure the same extent of compression and same posture for shooting the ball. Insert the pin till black rubber cork touches the muzzle. Ensure that the pin is released in the same format every time. This can be practiced without inserting the ball.

   [Note: If the spring is released in different formats/style then the "release" velocity will be slightly different every time.]
5. Pull the spring with shaft and lock it with the given pin arrangement. Then insert the given steel ball.

   [Note: If the steel ball is inserted in shaft and then the spring is pulled, an accidental slip can send the ball flying in air in an uncontrolled fashion.]
6. Arrange the position of the tray with sand in such a manner that the ball lands in the tray. For this you need to carry out few trials. This will happen when you adopt the removal of pin in the same way every time.
7. Now start the experiment aiming the "muzzle" at angle 30˚ with the horizontal. The angle measurement is carried out by matching the pointer with the correct angle mark on the protractor. Shoot the ball and capture it in the sand tray. Put a tooth-pick in the sand to lock the point of landing of the ball in the sand tray. Measure this range using string and scale or the cloth tape. This is the range of the projectile.

   [Note: teachers should observe the students to see how they decide the points between which the range is to be measured. One end of the measurement is where the ball has landed in the tray. This should be the point where ball contacted the sand surface for the first time and not after bouncing. The other point is the point where ball was at rest JUST BEFORE the release of the spring. Many a times students measure it from the point of fulcrum of the shaft which is incorrect.]

8. Repeat the measurement five times and note them down in the Table 1 in the answer sheet. Calculate the average range.

9. Repeat steps 6 & 7 for angles of projections 40˚, 50˚, 60˚ and 70˚. [Note: at 30˚, the ball will hit the wall of the tray, unless the tray is filled with sand all the way to the brim, but then it requires lot of sand.

10. Draw a graph of average range vs angle of projection.

11. From the graph estimate the angle at which range measured, will be maximum.

    [stepts 10 and 11 can be replaced by simply calculating the mass of ball using the given equations. Where v is calculated from the range and then the velocity of v is used to calculate the mass of the ball.]

12. Calculate the velocity of projection for each angle of projection from the range measured for each angle of projection. Note them in Table No 3 of the answer sheet.

13. Now plot v^2 vs *sin θ*.

14. From the relevant intercept of graph calculate the mass of the ball. The spring constant is (typical value) 176.4 N/m and g = 9.8 m/s^2.

    [student have to find the k value of the spring that they use]

15. Using a vernier caliper, measure the normal length (x_1) and the compressed length (x_2) of the spring. Note down the same in the answer sheet. Hence calculate the length (x) through which the spring can be compressed.

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Answer Sheet

Table 1: [10 Marks]

Obs. No.	□	R_1 /cm.	R_2 /cm.	R_3 /cm.	R_4 /cm.	R_5 /cm.	Avg R /cm
	30						
	40						

	50						
	60						
	70						

Graph of range vs angle of projection
[3 Marks]

Range is maximum at angle ___________ [0.5 Marks]

Table No. 3: [5 marks]

Obs. No.	θ	*Sin* θ	Velocity υ/cm	υ^2/cm^2
1	30			
2	40			
3	50			
4	60			
5	70			

Graph of υ^2 against *Sin* θ [3 marks]

Uncompressed length of the spring x_1 = ________ cm

Compressed length of the spring x_2 = _________ cm

Length through which the spring is compressed x = ________ cm [1 Mark]

Intercept of the graph = __________ [0.5 marks]

Mass of the ball =_______________ [0.5 mark]