Physics 122 Projectile Motion Unit

In your assigned group of students (3-4 students) you will be responsible for researching the concepts, teaching each other, discussing questions and checking problems. You will be responsible for designing and constructing a projectile launcher to be tested near the end of the unit. The material is based up Chapter 11, pp. 530-550.

I. Learning Objectives

By the end of this unit you will be able to

1. identify and explain the properties of projectiles, such as acceleration due to gravity, range, maximum height and trajectory.
2. determine the location and velocity of a projectile at different points in its trajectory (including final velocity with angle).
3. be able to discuss a projectile in terms of its potential and kinetic energies.
4. apply the principle of independence of motion (x- and y-direction) to solve projectile motion problems.
5. solve problems related to military, sports, historical and other applications.

II. Concepts

1. Review 1-D kinematics, including equations of motion.
2. Review force diagrams and free-body diagrams.
3. Review conservation of energy, potential, kinetic energies.
4. Independence of motion in perpendicular directions (x- and y-),
5. Terminology: Range and height, muzzle velocity,
6. Horizontal (air-to-ground) projectiles,
7. Symmetrical (ground-to-ground) projectiles.
8. Asymmetrical projectiles.

III. Questions for discussion

1-D Questions

1. A baseball player hits a foul ball straight up into the air. It leaves the bat with a speed of 120 km/h. In the absence of air resistance how fast will the ball be travelling when the catch catches it (at the same height)? If air resistance exists, what would happen to the speed (justify your answer)?
2. How would you estimate the maximum height you could throw a ball vertically upward? How would you estimate the maximum speed you could give it?
3. Can an object have zero acceleration and a non-zero velocity? If so, give an example. If not, explain.
4. Can an object have zero velocity and a non-zero acceleration? If so, give an example. If not, explain.

Projectiles

5. In archery, should the arrow be aimed directly at the target? How should your angle of aim depend upon the distance to the target?
6. When a projectile is launched horizontally with a velocity of 10 m/s, how does the horizontal component of the velocity compare 1.0 s after launch with the horizontal component 2.0 s after launch? What about the vertical components at the same times?
7. Show that the range of a symmetrical projectile launched at an angle θ to the ground is the same as one launched at an angle of $90° - \theta$.

8. A teacher, during a demonstration, places two coins on the edge of a lab bench. She then flicks one of the coins off the table, simultaneously nudging the other over the edge. Describe the subsequent motion of the two coins, in particular when the hit the ground.
9. A student wishes to design an experiment to show that the acceleration of an object is independent of the object's velocity. To do this, ball A is launched horizontally with some initial speed at an elevation 1.5 meters above the ground, ball B is dropped from rest 1.5 meters above the ground, and ball C is launched vertically with some initial speed at an elevation 1.5 meters above the ground. What information would the student need to collect about each ball in order to test the hypothesis?
10. Describe the motion of an asymmetrical projectile in terms of its potential and kinetic energies. Relate the energies to its velocity at launch, maximum height above the ground and at the ground.

IV. Problems

1-D Questions

1. A student standing on the roof of a building that is 88.5 m tall (about 30 floors) drops a stone over the edge. How long does it take for the stone to reach the ground? (4.25 s)
2. Another student standing on the roof of the 88.5 m tall building throws a stone, with a speed of 5.00 $\frac{m}{s}$, straight down off the edge of the roof. Now, how long does it take for the stone to reach the ground? (3.77 s)
3. A cannon, aimed vertically, fires a cannonball into the air. If the muzzle velocity is 38.0 $\frac{m}{s}$, calculate:
   (a) how high the cannonball rises. (73.7 m)
   (b) how long it is in the air. (7.76 s)
   (c) the final velocity before it hits the ground (-38.0 m/s)
4. A ball player throws a baseball straight up to a height of 20.0 m.
   (a) With what velocity did he throw the ball? (+19.8 m/s)
   (b) How much time elapses from the time he throws it until he catches it? Assume he catches it at the same level it was released. (4.04 s)
   (c) What is the velocity of the ball 2.50 s after it was released? (-4.70 m/s)

Horizontal (Air to Ground) Projectiles

5. Questions 1-8 pp 536-537 in your text.
6. A baseball is thrown horizontally from a hot air balloon at 108 km/h. The balloon is 600 m above the ground. Find:
   (a) the time it takes to hit the ground and the range. (11.1 s, 332 m)
   (b) the resultant velocity of the ball as it his the ground. (112 $\frac{m}{s}$ 74.5° to the ground)
   (c) the resultant velocity of the ball 7.00 s after it was thrown. (74.9 $\frac{m}{s}$ 66° to ground)

Symmetrical (Ground to Ground) Projectiles

7. Questions 13-14 p.549 in your textbook.
8. A ball is thrown so that it has a horizontal velocity of 50 m/s and an upward initial vertical velocity of 9.8 m/s. How long will it stay in the air? (2.0 s)
9. A ball is thrown into the air with a horizontal component of its velocity being 18.0 m/s and its vertical component being 29.4 m/s.
   (a) How long before the ball reaches its maximum height? (3.00 s)
   (b) How far upward does it travel? (44.1 m)
   (c) What is its range? (108 m)

10. A cannonball is fired at an angle of 45° with the horizontal. The muzzle velocity is 200 m/s.
    (a) How long does the cannonball remain in the air? (28.8 s)
    (b) What is its maximum height? (1.01×10^3 m)
    (c) What is its range? (4.06×10^3 m)
11. A ball is thrown from centre field to home plate, ground to ground. It takes only 3.00 s to travel the horizontal distance of 60.0 m.
    (a) What was the initial horizontal component of the ball's velocity? (20.0 m/s)
    (b) How far into the air did the ball rise? (11.0 m)
12. The muzzle velocity of a cannon has an upward component of 490 m/s and a horizontal component of 600 m/s.
    (a) How far upward will it shoot a cannonball? (1.23×10^4 m)
    (b) How far forward will the cannonball go? (6.00×10^4 m)
13. A boy threw a rock at an angle upward and it returned to the ground in 2.2 seconds, 26.0 m away from the boy.
    (a) What was the initial speed of the rock? (16 m/s)
    (b) At what angle was it thrown? (43° to the ground)
    (c) What were the vertical and horizontal components of the velocity 2.0 seconds after it was thrown? (-8.6 m/s, 12 m/s)

Asymmetrical Projectiles

14. Questions 9-11 p. 543 in your text
15. A pitcher throws a baseball horizontally, letting it go when it is 2.0 m above the ground. It passes the batter when it is 0.50 m above the ground. If the distance from the pitcher to the batter is 20 m, with what speed is the baseball thrown? (36 m/s)
16. A projectile is shot from the edge of the roof of a building which is 50.0 m high. The muzzle velocity is 80.0 m/s at an angle of 40° to the horizontal roof. Calculate:
    (a) the range of the projectile. (699 m)
    (b) the velocity of the projectile as it hits the ground. (85.9 m/s 44° to the ground)
17. A cannon is placed 100 m from the edge of a cliff that drops 150 m to a canyon floor. Exactly 4.0 s after being fired the cannonball just misses the edge of the cliff on its trajectory to the canyon floor. For the cannonball find:
    (a) the muzzle velocity. (32 m/s 39° to the ground)
    (b) the maximum height measured from the top of the cliff. (20 m)
    (c) the total time in the air. (7.9 s)
    (d) the distance it lands from the base of the cliff. (98 m)

V. TBL (Tennis Ball Launcher) Project

1. See attached form and rubric.

VI. Assessments

1. Homework: You will be expected to submit individual solutions (showing all steps in an organized fashion) on looseleaf to all problems (not questions for discussion) on each of the following dates for evaluation and feedback:
   Horizontal projectiles (9): _______________
   Symmetrical projectiles (8): _______________
   Asymmetrical projectiles (6): _______________
2. Quiz: You will have a quiz on _______________ covering up to the end of symmetrical projectiles
3. Test: There will be a comprehensive test at the end of the unit.
4. Projectile lab.

Projectile Lab

Your study group will build, borrow or purchase a projectile launcher that launches at a consistent velocity. On a class day (near the end of the unit) we will launch in class, in the pit, or outside (depending on the size of your launcher). Your *purpose* is to find the initial velocity, $\vec{v}_i$, of the projectile, so it is IMPORTANT that the initial velocity be consistent. Your lab should include multiple launches at the same angle (remember direction is included in velocity)

You will submit a formal lab (1 per group) as outlined in the "Formal Lab Format", including a detailed procedure, including your controls (how you ensure it is launched consistently, the variables you keep constant). It will be due one week and one day after launch date.