Workshop Tutorials for Introductory Physics

MI3: **Motion in a Plane**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
resistance, constant, constant velocity, constant acceleration, projectile, zero, velocity, idealised, trajectory

Projectile motion

A _____ is any body that is given an initial velocity and then follows a path determined by the effects of gravitational acceleration. A batted cricket ball, a thrown football, a package dropped from an airplane, and a bullet shot from a rifle are all projectiles. The path followed by a projectile is its _____.

To analyse this common type of motion, we start with an _____ model, representing the projectile as a single particle with an acceleration (due to gravity) that is constant in both magnitude and direction. We neglect the effects of air _____ and the curvature and rotation of the earth. Like all models, this one has limitations. Nevertheless, we can learn a lot from analysis of this simple model.

Notice that projectile motion is always described within a vertical plane determined by the direction of the initial _____ and acceleration, g. We will call this plane the *xy*-coordinate plane, with the *x*-axis horizontal and the *y*-axis vertically upward. The key to analysis of projectile motion is the fact that we can treat motion in the *x* and *y* directions separately. The *x*-component of acceleration is _____, and the *y*-component is _____ and equal to -*g*. So we can think of projectile motion as a combination of horizontal motion with _____ _____ and vertical motion with _____ _____. The actual motion is the superposition of these separate motions.

Discussion questions:
1. Identify an example where the above model fails because air resistance can't be ignored.
2. Identify an example where the above model fails because the curvature and rotation of the earth can't be ignored.
3. The third paragraph talks of "vertical plane", "*x*-axis horizontal" and "*y*-axis vertically upward". Identify the above physical descriptions for an eraser thrown across your table (projectile). Throw the eraser in different directions, what happens to the physical descriptions?

B. Activity Questions:

1. Projectile Launcher

Use the Projectile Launcher to answer the following questions.
What is the angle of launch corresponding to maximum range?
What is the angle of launch corresponding to maximum vertical height?
Explain your results qualitatively.

2. Marble ejecting trolley

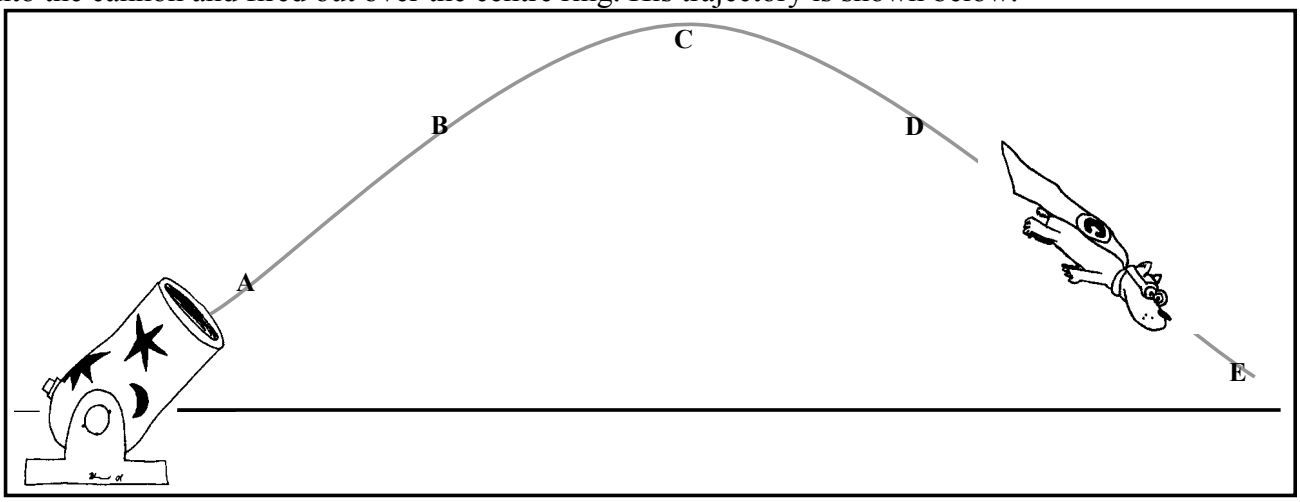
This system is designed such that the trolley is travelling with uniform velocity during the process of ejecting and catching the marble. What can you deduce about the horizontal and vertical components of the velocity of the marble after it has been ejected?
How could you repeat this experiment while traveling on a train?

3. Drop and Horizontal Throw

Examine the apparatus.
Predict which ball will hit the ground first when the balls are released.
What are the initial velocities of the two balls?
Which ball hit the ground first? Why?

C. Qualitative Questions:

1. Chuck the Canine Cannonball is the star dog of the Sirius Circus. As the circus's finale he is loaded into the cannon and fired out over the centre ring. His trajectory is shown below.



a. At which point(s) is Chuck's speed the greatest?
b. At which point(s) is his speed the lowest?
c. At which points is his the speed the same? Is the velocity the same at these points?
d. What is the direction of the acceleration at point B?
e. What is the direction of the acceleration at point D?

2. Brent drops a ball while running and at the same time Rebecca, who is standing still, also drops a ball.
a. If the two balls are dropped at the same time and from the same height which ball, if either, will hit the ground first?
b. The ball Rebecca drops will hit the ground next to her. Where will the ball Brent dropped land?
c. If Brent (who is still running) wishes to drop the ball so that it falls into a bucket on the floor as he runs past, should he drop it before he reaches the bucket, when he reaches the bucket or after he passes the bucket? Why?

D. Quantitative Question:

Chuck the Canine Cannonball is fired from his cannon which is angled at 45^{o} to the horizontal. He has a speed of 20 $m.s^{-1}$ as he leaves the barrel of the cannon. Chuck wears a special low-friction suit and a streamlined bike helmet to minimise air resistance (drag).
a. What height does Chuck reach (neglecting air resistance)?
b. How long is Chuck in the air?
c. How far from the cannon does Chuck land?