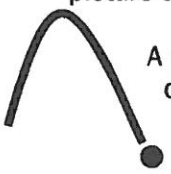
Physics **Name:**

Projectile Motion – practice problems #1 **Date:**

Projectile: An object that moves through space acted upon only by the earth's gravity.

A projectile may start at a given height and move toward the ground in an arc. For example, picture the path a rock makes when it is tossed straight out from a cliff.



A projectile may also start at a given level and then move upward and downward again as does a football that has been thrown.

Regardless of its path, a projectile will always follow these rules:

1. Projectiles always maintain a constant horizontal velocity (neglecting air resistance).
2. Projectiles always experience a constant vertical acceleration of 9.8 (or 10) m/s^2 downward (*as assumed in ideal conditions - neglecting air resistance*).
3. Horizontal and vertical motions are completely independent of each other. Therefore, the velocity of a projectile can be separated into components.
4. For a projectile beginning and ending at the same height, the time it takes to rise to its highest point equals the time it takes to fall from the highest point back to the original position.
5. Objects dropped from a moving vehicle have the same velocity as the moving vehicle.

In order to solve projectile exercise, you *must* consider horizontal (x) and vertical (y) motion separately. All of the equations for linear motion can be used for projectile motion as well. You don't need to learn any new equations! Subscripts do become more descriptive in 2D.

To simplify calculations, the term for initial vertical velocity, v_{yo}, will be left out of all equations in which an object is projected horizontally. For example,

$\Delta x_y = v_{yo}\Delta t + (1/2)g\Delta t^2$ will be written as $\Delta x_y = (1/2)g\Delta t^2$

$\Delta x = 1/2\ (v_1+v_o)t$	x – position in meters *either horizontal or vertical direction*
$\Delta x = v_o t + 1/2at^2$	v - velocity (initial or final)
$v_1^2 = v_o^2 + 2a(\Delta x)$	a – acceleration (due to gravity in the vertical)
$v_1 = v_o + at$	t – time (in seconds)

***Practice Problems #1-4 are horizontal launches and #5-8 are angled launches**

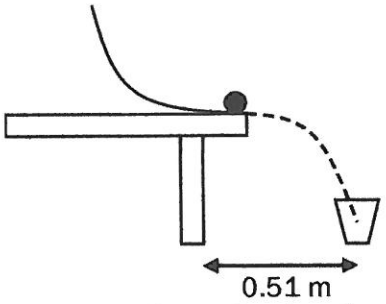
Solved Examples

Ex. 1: In her physics lab, Amanda rolls a 10 g marble down a ramp and off the table with a horizontal velocity of 1.2 m/s. The marble falls in a cup placed on the floor 0.51 m from the table's edge. How high is the table from the floor?

Solution: The first thing you should notice about projectile exercises is that you do not need to consider the mass of the object projected. Remember, if you ignore air resistance, all bodies fall at exactly the same rate regardless of their mass.

Before you can find the height of the table, you must first determine how long the marble is in the air. The horizontal distance traveled equals the constant horizontal velocity times the travel time.

Sketch:



Given:
$\Delta x_x = 0.51$ m
$v_x = 1.2$ m/s
$\Delta t = ?$

Solve:
$v_x = \Delta x_x / \Delta t$
$\Delta t = \Delta x_x / v_x$
$\Delta t = (0.51 \text{ m}) / (1.2 \text{ m/s})$
$\Delta t = 0.43$ s

Now that you know the time the marble takes to fall, you can find the vertical distance it traveled.

Given:
$a = g = 10.0$ m/s^2
$\Delta t = 0.43$ s
$\Delta x_y = ?$

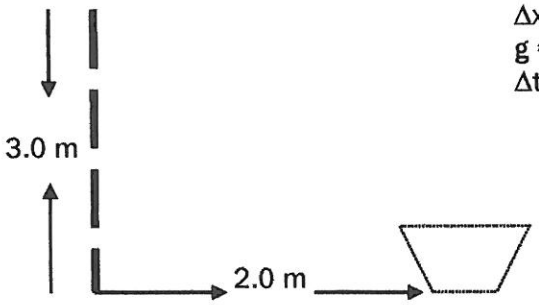
Solve:
$\Delta x_y = (1/2)\, g\, \Delta t^2$
$\Delta x_y = (1/2)(10.0 \text{ m/s}^2)(0.43 \text{ s})^2$
$\Delta x_y = 0.92$ m

Ex. 2: Emmet is standing on a ladder picking apples in his grandfather's orchard. As he pulls each apple off the tree, he tosses it into a basket that sits on the ground 3.0 m below at a horizontal distance of 2.0 m from Emmet. How fast must Emmet throw the apples (horizontally) in order for them to land in the basket?

Solution: Before you can find the horizontal component of the velocity, you must first find the time that the apple is in the air.

Strategy: treat apple as if in free fall

Sketch:



Given:	Solve:
$\Delta x_y = 3.0$ m	$\Delta x_y = (1/2)g\Delta t^2$
$g = 10.0$ m/s^2	$t = \sqrt{[(2\Delta d_y)/g]}$
$\Delta t = ?$	$t = \sqrt{[2(3.0\text{ m})/10.0\text{ m/s}^2]}$
	$t = 0.77$ s

Now that we know the time, use it to find the horizontal component of the velocity.

Given:	Solve:
$\Delta x_x = 2.0$ m	$\Delta x_x = v_x\Delta t$
$\Delta t = 0.77$ s	$v_x = \Delta x_x/\Delta t$
$v_x = ?$	**$v_x = 2.6$ m/s**

Ex. 3: On May 20, 1999, 37-year old Robbie Kneivel, son of famed daredevil Evel Knievel, successfully jumped 69.5 m over a Grand Canyon gorge using a motorbike traveling at almost 50 m/s (100 mi./hr off a ramp. Assuming that he started and landed at the same level and was airborne for 3.66 s, what height from his starting point did this daredevil achieve?

Solution: Because 3.66 s is the time for the entire travel through the air, Robbie spent half of this time reaching the height of the jump. The motorcycle took 1.83 s. to go up, and another 1.83 s to come down. To find the height of the motorcycle achieved, look only at it's downward motion as measured from the highest point.

Sketch:

Given:
$\Delta t = 1.83$ s
$a = g = 10.0$ m/s^2

$\Delta x_y = ?$

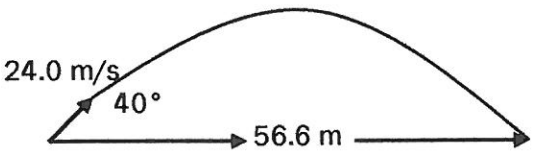
Solve:
$\Delta x_y = (1/2)\, g\, \Delta t^2$
$\Delta x_y = (1/2)\,(10.0 \text{ m/s}^2)\,(1.83 \text{ s})^2$
$\Delta x_y = 16.7$ m

ANGLED LAUNCHES

Ex. 4: Zacchini, the famous human cannonball of the Ringling Bros. and Barnum & Bailey Circus, was fired out of a cannon with a speed of 24.0 m/s at an angle of 40.0° to the horizontal. If he landed in a net 56.6 m away at the same height from which he was fired, how long was Zacchini in the air?

Solution: Because Zacchini was in the air for the same amount of time vertically that he was horizontally, you can find his horizontal time and this will be the answer. First, you need the horizontal velocity component.

Sketch:



$\cos\theta = \text{adj} / \text{hyp}$
$\cos\theta = v_x / v$
$v_x = v \cos\theta$
$v_x = (24.0 \text{ m/s}) \cos 40.0°$
$v_x = 18.4$ m/s

Now you have the horizontal velocity component and the horizontal displacement, so you can find the time.

Given:
$v_x = 18.4$ m/s
$\Delta x_x = 56.6$ m
$\Delta t = ?$

Solve:
$v = x/t$
$\Delta x_x = v_x \Delta t$
$\Delta t = \Delta x_x / v_x$
$\Delta t = 56.6 \text{ m} / 18.4 \text{ m/s}$
$\Delta t = 3.08$ s

Practice Exercises

1) Tycho stands on the Talahatchee Bridge kicking stones into the water below.

a) If Tycho kicks a stone with a horizontal velocity of 3.50 m/s, and it lands in the water a horizontal distance of 5.40 m from where Tycho is standing, what is the height of the bridge?

b) If the stone had been kicked harder, how would this affect the time of fall?

Sketch: **Given:** **Solve:**

Answer: a. _____

Answer: b. _____

2) The movie "The Gods Must Be Crazy" begins with a pilot dropping a bottle out of an airplane. It is recovered by a surprised native below, who thinks it is a message from the gods. If the plane from which the bottle was dropped was flying at an altitude of 500 m, and bottle lands 600 m horizontally from the initial dropping point,

a) how fast was the plane flying when the bottle was released?

b) how does this compare to a 100 mile per hour fast pitch baseball?

Sketch: **Given:** **Solve:**

Answer: _____

Answer: _____

3) At a meeting of physics teachers in Montana, the teachers were asked to calculate where a sack of meter sticks would land if dropped from a moving airplane. The plane would be moving horizontally at a constant speed of 60.0 m/s at an altitude of 300 m. If one of the physics teachers neglected air resistance while making his calculation,

a) how far horizontally from the dropping point would he predict the landing?

b) about how many football fields is this? (a football field is 100 yds)

Sketch: **Given:** **Solve:**

Answer: a) _____

Answer: b) _____

4) Todd drops a cherry pit out the car window 1.0 m above the ground while traveling down the road at 18 m/s.

a) How far, horizontally, from the dropping point will the pit hit the ground?

b) If the car continues to travel at the same speed, where will the car be in relation to the pit when it lands?

Sketch: **Given:** **Solve:**

Answer: a. _____

Answer. b. _____

5) At her wedding, Tracy lines up all the single females in a straight line away from her in preparation for the tossing of the bridal bouquet. She stands Beth at 1.0 m, Adrianne at 1.5 m, and Shannon at 2.0 m, Kristin at 2.5 m, and Marcy at 3.0 m. Tracy turns around and tosses the bouquet behind her with a speed of 3.9 m/s at an angle of 50.0° to the horizontal, and it is caught at the same height 0.60 s later.

Who catches the bridal bouquet?

Sketch: **Given:** **Solve:**

Answer: _____

6) Jack be nimble, Jack be quick, Jack jumped over the candlestick... with a velocity of 5.0 m/s at an angle of 30.0° to the horizontal. Did Jack burn his feet on the candle if it is 0.25 m-high? In other words – what is Jack's maximum jump height?

Sketch: **Given:** **Solve:**

Answer: _____

7) Superman is said to be able to "leap tall buildings in a single bound." How high a building could Superman jump over if he were to jump from (not fly from) the ground with a speed of 60.0 m/s at an angle of 75.0° to the horizontal?

Sketch: **Given:** **Solve:**

Answer: _____

8) Ferdinand the frog is hopping from lily pad to lily pad in search of a good fly for lunch. If the lily pads are spaced 2.4 m apart, and Ferdinand jumps with a speed of 5.0 m/s, taking 0.60 s to go from lily pad to lily pad, at what angle must Ferdinand make each of his jumps?

Sketch: **Given:** **Solve:**

Answer: _____

Additional Exercises (Horizontal Launches)

A-1: In many locations, old abandoned stone quarries have become filled with water once excavating has been completed. While standing on a 10.0-m-high quarry wall, Blake tosses a piece of granite into the water below. If Blake throws the rock horizontally with a velocity of 3.0 m/s, how far out from the edge of the cliff will it hit the water?

A-2: While skiing, Jasmine encounters an unexpected icy bump, which she leaves horizontally at 12.0 m/s. How far out, horizontally, from her starting point will Jasmine land if she drops a distance of 7.00 m during the fall?

A-3: The Essex county sheriff is trying to determine the speed of a car that slid off a small bridge on a snowy New England night and landed in a snow pile 4.00 m below the level of the road. The tire tracks in the snow show that the car landed 12.0 m measured horizontally from the bridge. How fast was the car going when it left the road?

Additional Exercises (Angled Launches)

B-1: Aaron is running to school and leaping over puddles as he goes. From the edge of a 1.5-m-long puddle, Len jumps 0.20 m high off the ground with a horizontal velocity component of 3.0 m/s in an attempt to clear it. Determine whether or not Len sits in school all day with wet socks on.

B-2: Julio jumps and shoots a field goal from the far end of the court into the basket at the other end, a distance of 27.6 m. The ball is given an initial velocity of 17.1 m/s at an angle of 40.0° to the horizontal from a height of 2.00 m above the ground. What is its velocity as it hits the basket 3.00 m off the ground?

B-3: Drew claims that he can throw a dart at a dartboard from a distance of 2.0 m and hit the 5.0-cm-wide bulls-eye if he throws the dart horizontally with a speed of 15 rn/s. He starts the throw at the same height as the top of the bulls-eye. See if Drew is able to hit the bulls-eye by calculating how far his shot falls from the bulls-eye's lower edge.

B-23: LeBron jumps and shoots a field goal from the far end of the court into the basket at the other end, a distance of 27.6 m. The ball is given an initial velocity of 17.1 m/s at an angle of 40.0° to the horizontal from a height of 2.00 m above the ground. What is its velocity as it hits the basket 3.00 m off the ground?

Possible Answers (if one of the below seems wrong – *challenge with evidence*):

1. *a. 11meters b. no effect*
2. *59 m/s*
3. *a. 9 meters b. same point*
4. *37 degrees*
5. *Adrianne*
6. *468 meters*
7. *Not burned 0.3 m*
8. *37 degrees*