9.4.1: Projectile Motion for an Object Launched Horizontally

Figure 4.2.1

The activity of bike jumping, like other sports that involve vector motions in perpendicular directions, requires more physical practice than mathematical analysis. The laws of physics apply to the activity, however, whether the biker is aware of them or not.

Projectile Motion for an Object Launched Horizontally

Objects that are launched into the air are called **projectiles**. The path followed by a projectile in motion is called a **trajectory**. The image of the snowboarder in the chapter introduction showed his trajectory; every object has a trajectory even when we cannot see it. **Projectile motion**, or the object's trajectory, is described in terms of position, velocity, and acceleration. Even with only an object's current location, velocity, and acceleration, we can calculate when and where the object will land. Our knowledge that perpendicular components of vectors do not affect each other allow us to easily analyze the motion of projectiles.

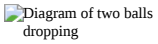

Figure 4.2.2

In the diagram, two balls (one red and one blue) are dropped at the same time. The red ball is released with no horizontal motion and the blue ball is dropped but also given a horizontal velocity of 10 m/s. As the balls fall to the floor, a photograph is taken every second so that in 5 seconds, we have 5 images of the two balls. Each vertical line on the diagram represents 5 m. Since the blue ball has a horizontal velocity of 10 m/s, you will see that for every second, the blue ball has moved horizontally 10 m. That is, in each second, the blue ball has increased its horizontal distance by 10 m. This horizontal motion is due to the ball's constant velocity.

The red ball was dropped straight down with no horizontal velocity and therefore, in each succeeding second, the red ball falls straight down with no horizontal motion. The increasing distances between seconds in the red ball's motion indicates that this motion is accelerating.

A very important point here is that the vertical motion of these two balls is identical. That is, they each fall exactly the same distance vertically in each succeeding second. The constant horizontal velocity of the blue ball has no effect on its accelerated vertical motion. Therefore, the vertical motion of the blue ball can be analyzed exactly the same as the vertical motion of the red ball.

Examples

Example 4.2.1

If an arrow is fired from a bow with a perfectly horizontal velocity of 60.0 m/s and the arrow was 2.00 m above the ground when the it was released, how far will the arrow fly horizontally before it strikes the ground?

Solution

This problem is solved by determining how long it takes the arrow to fall to the ground in exactly the same manner as if the arrow was dropped with no horizontal velocity. The time required for the arrow to fall to the ground will be the same time that the arrow flies horizontally at 60.0 m/s, so

$d=(1/2)at^2$ solved for $t=(2d/a)^{(1/2)}=((2)(2.00\ m)/9.80\ m/s^2)^{(1/2)}=0.639\ s$

The time required for the fall is multiplied by the horizontal velocity to get the horizontal distance.

$d_{horizontal}=(v_{horizontal})(time)=(60.0\ m/s)(0.639\ s)=38.3\ m$

Example 4.2.2

A rock was thrown horizontally from a 100.0 m high cliff. It strikes the ground 90.0 m from the base of the cliff. At what speed was it thrown?

Solution

We can calculate how long it takes for a rock to free fall 100.0 m and then divide this time into the horizontal distance to get the horizontal velocity.

$t=(2d/a)^{(1/2)}=((2)(100.0\ m)/9.80\ m/s^2)^{(1/2)}=4.52\ s$

$v=d/t=90.0\ m/4.52\ s=19.9\ m/s$

Use the following simulation to adjust the initial velocity and height of a launched arrow and try to predict whether or not the archer will hit her target:

Summary

- Perpendicular components of vectors do not influence each other.
- The horizontal motion of a projectile does not influence its free fall.

Review

1. If a bullet is fired from a high powered rifle at the exact time a duplicate bullet is dropped by hand near the barrel of the rifle, which bullet will hit the ground first?
    1. the one dropped straight down
    2. the one fired horizontally
    3. both will hit the ground at the same time
2. A cannon is fired from the edge of a small cliff. The height of the cliff is 80.0 m. The cannon ball is fired with a perfectly horizontal velocity of 80.0 m/s. How far will the cannon ball fly horizontally before it strikes the ground?
3. A cliff diver running 3.60 m/s dives out horizontally from the edge of a vertical cliff and reaches the water below 2.00 s later. How high is the cliff and how far from the base of the cliff did the diver hit the water?

Explore More

Use this resource to answer the questions that follow.

1. What was the problem the mythbusters had with the dropped bullet? Why was fixing this so important?
2. Why did they move the bullet being dropped to 360 ft away?
3. What was the final result?
4. What are some possible reasons that the bullets didn't hit the ground at exactly the same time?

Additional Resources

Interactive: Water Fountain

PLIX: Play, Learn, Interact, eXplore: Kicking a Gold Ball

Real World Application: Physics of Archery

Video: Horizontal Projectile Motion - Overview

Study Guide: Motion Study Guide
