Module #4: Motion in Two Dimensions

Navigation in Two Dimensions

* (p.105) Example 4.1: A man walks at a constant speed of 1.2 m/sec with a direction of 45°. What will be his displacement in 301 seconds?
* (p.106) Example 4.2: An explorer follows directions on a map. She first travels at a constant 0.92 m/sec in a direction of 113° for 2.3 hours. She then turns to a heading of 220° and travels at a constant 0.56 m/sec for 1.2 hours. What is the explorer’s final displacement?
* OYO p.109
  + #4.1

Projectile Motion in Two Dimensions

* When a projectile is fired at an angle relative to the ground, its motion is called parabolic because it follows the curved path of a parabola.
  + Motion is not in a straight line
  + One-dimensional motion is found in the x- and y- components of the vectors
    - Look at how the components change
* Ex: canon fired (Fig4.1 p.109)
  + Once the cannonball leaves the barrel, the only thing acting on it is gravity
    - Air resistance is neglected
  + Gravity only acts in the y-component of the cannonball’s velocity
    - Since gravity is constantly pulling the cannonball down, the y-component of the velocity changes.
    - At first, Vy is pointed up because the cannon is shooting the ball up in the air, but since gravity is pulling it down the upwards velocity is decreasing.
    - In the middle of the cannonball’s trip, gravity has reduced the y-component of the ball’s velocity to zero.
    - Gravity continues to pull down, so the y-component of its velocity continues to change and now starts to point down resulting in the cannonball falling.
    - Since the velocity and gravity are pointed in the same direction (down) the y-component of velocity increases, making it fall faster.
  + Gravity does not affect the x-component; therefore the x-component of the velocity never changes.
    - The x-component stays exactly the same length and points in exactly the same direction
    - From the time it leaves the cannon to the time it hits the ground, the x-component of its velocity is always the same
* Parabolic motion = motion that occurs when an object moves in two dimensions but has zero acceleration in one of those dimensions and a constant, non-zero acceleration in the other.
* Summary
  + When a projectile is fired or thrown near the surface of the earth, its path is parabolic.
  + The x- and y-components of a projectile’s motion can be treated as two separate one-dimensional situations. The x-component of the projectile’s velocity will never change once it has been launched. The y-component of the velocity will be affected by gravity, so it will decrease until it reaches zero, at which point it will get more and more negative.
  + A projectile’s maximum height will be reached when the y-component of its velocity is zero.
  + If the projectile lands at the height from which it was launched, it will reach its maximum height at the midpoint of the journey. The final value of Vf will be the negative of the initial value of Vy. This makes the final speed the same as its initial speed.
* Example 4.3 p.113
* OYO p.115
  + #4.3-4.4

The Range Equation

* When we calculate the distance that the projectile travels in the x-dimension, we are calculating the range of the projectile.
* In order to calculate the range of a projectile, you need the total time it takes for the projectile to reach its destination
  + Calculated from the y-dimension
* Deriving a general equation for the range of a projectile
  + Assume that the initial velocity is known (vo) and the angle (Ө)
  + We can determine the y-component of the initial velocity
    - Voy = vo \* sin(Ө)
  + We can calculate the time it takes for the projectile to reach its maximum height
    - V= vo + at
    - Substitute in what we know
    - 0 = [vo \* sin(Ө)] + (-g)t
    - T = [vo \* sin(Ө)] / g
  + Now we can calculate the total time
    - Total time = 2 \* (time it takes to reach max. height)
    - Total time = 2 \* [vo \* sin(Ө)] / g
  + Now that we know the total time we can figure out the distance the projectile travels in the x-dimension.
  + First we need to calculate the x-component of the initial velocity.
    - Vox = vo \* cos(Ө)
  + We need to calculate displacement. Remember: in the x-dimension acceleration is zero.
    - ∆x = vot + ½ at2
    - Substitute in the things we know
    - ∆x = [vo \* cos(Ө)] \* {2[vo \* sin(Ө)] / g} + ½ (0) t2
    - ∆x = [vo \* cos(Ө)] \* {2[vo \* sin(Ө)] / g}
    - ∆x = [2vo2 \* cos(Ө) sin(Ө)] / g
  + Condensing the equation
    - Trig: cos(Ө) sin(Ө) = sin(2Ө) / 2
    - Therefore
      * ∆x = [2vo2 \* (sin(2Ө) / 2)] / g
    - **Range = [vo2 \* sin(2Ө)] / g**
  + This equation does not apply to all two-dimensional projectiles
    - Applies only to projectiles that land at the same height from which they are launched.
    - Valid only for angles between 0° and 90°
    - Gravitational acceleration is always positive in this equation!
* Example 4.4 p.119
* OYO p.120 #4.5-4.7
* Experiment 4.1 p.121
  + Materials = rubber band, timer, goggles
  + CD and Solutions Guide (experiment answer)

Two-Dimensional Situations in Which You Cannot Use the Range Equation

* Example 4.5 p.122
  + A cannon shoots horizontally (Ө = 0°) off of a cliff. If the cannon can shoot with an initial speed of 150.0m/s and is 100.0m above the ground, how far will the cannonball be from the cliff when it finally hits the ground?
  + Draw the picture on the board
* Experiment 4.2 p.124
  + Materials : toy car/ping pong ball, meter stick, goggles
* Example 4.6 p.125
* OYO p.126-127
  + #4.8-4.10