Free Response Problems

1. A toy boat moves on the surface of a pond. The position as a function of time is given by the following formulas: \(x(t) = 2.6 \text{ (m/s)} \ t\) and \(y(t) = 5 \text{ m} - 1.4 \text{ (m/s}^2\)\(t^2\).

   a. Sketch the path of the toy between \(t = 0\) and \(t = 4\) s.
   b. Calculate the velocity and acceleration of the toy as functions of time.
   c. Calculate the magnitude and direction of the toy’s velocity and acceleration at \(t = 3\) s.
   d. What is the angle between two vectors – velocity and acceleration at \(t = 3\) s.

2. A boy dives off a cliff with a running horizontal velocity of 8.6 m/s. The distance from the edge of the cliff to the surface of the lake is 12 m.

   a. How much time will it take the boy to fall from the edge of the cliff to the surface of water?
   b. How far from the cliff will he strike the surface of water?
   c. What is the landing velocity?
   d. Graph the horizontal and vertical components of the velocity.

3. An airplane flies at a constant horizontal speed of 170 m/s. When the airplane is 1150 m above the ground level a pilot drops a package.

   a. How long will it take the package to reach the ground?
   b. How far horizontally will the package fly until it strikes the ground?
   c. What is the velocity of the package just before it strikes the ground?
   d. How would you compare the velocity of the package and the velocity of an object dropped from the same height 1150 m.
4. A projectile is fired from the ground with the initial velocity \( v_0 = 45 \text{ m/s}, \) 53° above the horizontal.
   a. How long will it take the projectile to return back to the ground level?
   b. What is the maximum horizontal range?
   c. What is the maximum height the projectile reaches?
   d. What is the projectile’s velocity at the highest point?
   e. Which angle will give the projectile the same horizontal range? Does the projectile reach the same height at this angle?

5. A cannon ball is fired from a cannon located at the edge of 34-m–tall cliff. The initial velocity of the cannon ball has a magnitude of 540 m/s and an angle 42° above the horizontal.
   a. How much time is required for the cannon ball to reach the ground?
   b. How far from the cliff will the cannon ball strike the ground?
   c. What is the maximum height reached by the cannon ball?
   d. What is the landing velocity of the cannon ball (magnitude and direction)?
   e. Draw \( x(t), y(t), v_x(t), v_y(t), a_x(t), a_y(t) \) for the motion of the cannon ball.

6. A fire fighter is trying to shoot water straight to the window located at the second floor of a house 6 m above the ground. The distance between the fire fighter and the house is 8 m and he holds the fire hose 1.8 m above the ground. The water leaves the hose with a constant speed of 12.5 m/s. Initially, the fire fighter aims the hose at 53° above the horizontal and misses the window. (we can assume that the hose and the window are in the same vertical plane)
   a. How much time it will take for the water flow to reach the house?
   b. How far above the window does the water go?
   c. What is the magnitude of the velocity of water when it strikes the house?
   d. What must be the minimum angle and speed of the flow in order to get water right into the window?
Answer Key:

1. A. v_x = 2.6 m/sec, v_y = -2.8t, a = -2.8\text{m/s}^2

B. v_x = 2.6 m/sec, v_y = -2.8t, a = -2.8\text{m/s}^2

C. v = 8.55 m/s & \theta = 287.2^\circ, a = 2.8 \text{m/s}^2 & \theta = 270^\circ

D. 17.2^\circ

2. A. 1.56 s

B. 13.42 m

C. 17.55 m/s

D. v_x

3. A. 15.32 s

B. 2604.4 m

C. 226.81 m/s

D. The package has greater velocity.
4. A. 7.33s  
   B. 198.51m  
   C. 65.9m  
   D. 27m/s  
   E. 37°, No

5. A. 72.3s  
   B. 29615.81m  
   C. 6695.21m  
   D. 530.66m/s, -40.87°

6. A. 1.063s  
   B. .875m  
   C. 7.56m/s  
   D. 12.6m/s, 50°