PHYS 1200 Physics of Everyday Experience

Review questions and exercises for Lecture 4 (M-3)

1. Does a falling object fall the same distance during each second that it if falling?
2. How does air resistance affect a falling object?
3. What are the proper units for acceleration?
4. A car accelerates from rest to 100 m/s in 20 s. What is its acceleration?
5. What is the relationship between the velocity of an object at time t, if its velocity at t = 0 was v_0 and experienced a constant acceleration a?
6. An object falls from rest from the top of a tall building. How far will it fall and what will its velocity be after 5 s?
7. An object is thrown vertically up from the ground with a velocity of 30 m/s. When will it reach its highest point and when will it return to the ground?
8. A car moving at 10 m/s begins to accelerate at a = 5 m/s^2. What will its velocity be in 7 s?
9. A car is moving at 30 m/s when the brakes are applied. If the brakes provide a constant deceleration of 5 m/s^2 when will the car come to rest?
10. A basketball player makes a jump shot. If he can jump straight up with a speed of 3 m/s, (a) when will be reach his highest point above the ground, and (b) what is the total time that he is in the air?

Answers and Solutions (Try to do the problems before reading the solutions)

1. No, a falling object is accelerating downward at 10 m/s^2. When an object accelerates, it does not move the same distance for each second of motion. The distance that an object falls, starting from rest, in a time t, is given by $y(t) = ½ g t^2$. In the first second it falls $y(1) = ½ (10)(1)^2 = 5$ m. At t = 2 s, it will reach $y(2) = ½ (10) (2)^2 = 5 (4) = 20$ m. So from t = 1 s to t = 2 s, it fell 20 m – 5 m = 15 m.

2. Air resistance or drag always opposes the motion of an object. The force of air resistance depends on how fast the object is moving. When an object starts to fall, its speed is low and so the force of air resistance is smaller the force of gravity, so the object accelerates. As its speed increases, so does the air resistance force, and at some point the air resistance becomes as large as the force of gravity. When that happens, the acceleration of the object is zero, and it then continues to fall at a constant speed, that is called the terminal speed.

3. Acceleration is the change in velocity with time, so it is measured in velocity units divided by time units. In the SI system of units, acceleration is given in $m/s/s = m/s^2$.

4. a = change in velocity / time = 100 m/s / 20 s = 5 m/s^2.

5. If the initial velocity of an object is v_0 at t = 0, and accelerates with an acceleration a, then its velocity at a later time t is $v(t) = v_0 + a t$. The symbol v(t) means the velocity at time t.

6. An object falling from rest, and in the absence of air resistance, falls a distance $y(t) = ½ gt^2$, at time t, and will have acquired a velocity v(t) = gt.

   → $y(5 s) = ½ (10) (5)^2 = 5 (25) = 125$ m; $v(5 s) = 10 (5) = 50$ m/s.

7. An object that is thrown upward reaches a maximum height where it is instantaneous at rest, before it begins to fall back down. The relationship between velocity at time t, and the initial velocity is $v(t) = v_0 + a t$, where a is its acceleration. As the object rises, gravity slows it down, until at the top $v(t_{top}) = 0$, where t_{top} is the time when it reaches its highest point. As it rises, its acceleration is downward so that $a = - g = -10 m/s^2$. → $v(t_{top}) = 0 = v_0 – g t_{top}$, so that $t_{top} = v_0 / g = 30 / 10 = 3$ s. The time for an object to reach its highest point is the same as the time it takes to fall back to the ground, so that the total time that it is in the air is 6 s.

8. $v(t) = v_0 + a t$ → $v(7s) = 10 + 5 (7) = 10 + 35 = 45$ m/s.

9. $v(t) = v_0 + a t$ → When it stops, v(t) = 0. Deceleration means that the velocity and acceleration are in opposite directions, so that $0 = 30 m/s + (-5) t$ → t = 6 s.

10. When you jump straight up with a speed v_0, it takes a time $t_{top} = v_0 / g$ to reach the highest point. (a) $t_{top} = 3 / 10 = 0.3$ s. (b) It takes the same amount of time to fall back down to the ground, so the total time you are in the air is $t_{total} = 2t_{top} = 2 (0.3 s) = 0.6$ s.