SLE123 Physics for the Life Sciences

1.6 Free Fall - ANSWERS

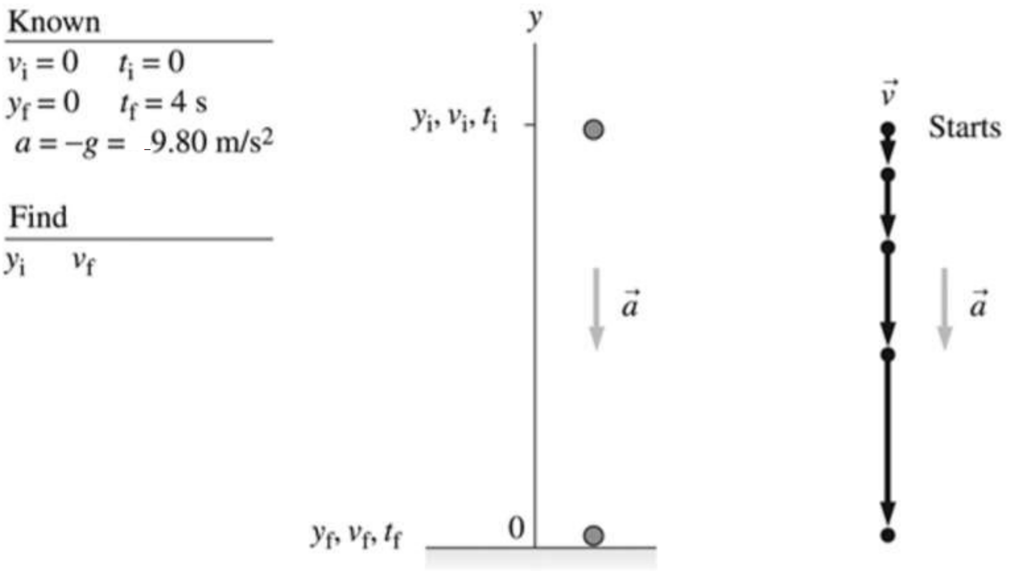
1. The upward and downward velocity vectors are of equal magnitude but opposite direction. Answer is D.

2. During the entire motion after the ball has left the hand to just before it hits the ground, the acceleration is that of free fall. Despite the name, free fall is not restricted to objects that are literally falling. Any object moving under the influence of gravity only, and no other forces, is in free fall. This includes objects falling straight down and objects that have been tossed or shot straight up. Acceleration of free fall equals -g. The negative indicates that the acceleration due to gravity is always pointing down.

3. Both balls are in free fall (neglecting air resistance) once they leave the hand, and so they will have the same acceleration. Therefore, the slopes of their velocity-versus-time graphs must be the same (i.e., the graphs must be parallel). That eliminates choices B and C. Ball 1 has positive velocity on the way up, while ball 2 never goes up or has positive velocity; therefore, choice A is correct.

   Examine the other choices. In choice B ball 1 is going up faster and faster while ball 2 is going down faster and faster. In choice C ball 1 is going up the whole time but speeding up during the first part and slowing down during the last part; ball 2 is going down faster and faster. In choice D ball 2 is released from rest (as in choice A), but ball 1 is thrown down so that its velocity at $t = 0$ is already some non-zero value down; thereafter both balls have the same acceleration and are in free fall.

4. A visual overview of a ball bearing's motion that includes a pictorial representation, a motion diagram, and a list of values is shown below. We label the bearing's motion along the y-axis. The bearing is under free fall, so kinematic equations hold.



The shot is in free fall, so we can use free fall kinematics with a = –g = + 9.8 m/s^s. The height must be such that the shot takes 4 s to fall, so we choose t_f = 4 s. From the given information it is easy to see that we need to use Equation 3 from Module 1.4 (y instead of x for displacement because we are using the y-axis, and g instead of a for acceleration).

Down is positive. The displacement is

$$y_f = y_i + v_i\,(t_f - t_i) + \tfrac{1}{2}\,a\,(t_f - t_i)^2$$

$$y_i = 0 \text{ m}$$

$$v_i = 0 \text{ m/s}$$

$$t_i = 0 \text{ s}$$

$$t_f = 4 \text{ s}$$

$$y_f = \tfrac{1}{2}\,(9.8 \text{ m/s}^2)\,(4 \text{ s})^2 = 78 \text{ m}$$

The distance travelled = the (downward) displacement = 78 m.

The impact velocity is

$$v_f = v_i + a\,(t_f - t_i)$$

$$v_f = (9.8 \text{ m/s}^2)\,(4 \text{ s}) = 39 \text{ m/s}$$

5. Use kinematic equation 4 from Module 1.4 for constant acceleration. Assume the gannet is in free fall during the dive.

$$\left(v_y\right)_f^2 = \left(v_y\right)_i^2 + 2g\Delta y$$

$$\Delta y = \frac{\left(v_y\right)_f^2}{2g} = \frac{(32\,m/s)^2}{2(9.8\,m/s^2)} = 52m$$

6. If we ignore air resistance then the only force acting on both balls after they leave the hand (before they land) is gravity; they are therefore in free fall. Think about ball A's velocity. It decreases until it reaches the top of its trajectory and then increases in the downward direction as it descends. When it gets back to the level of the student's hand it will have the same speed downward that it had initially going upward; it is therefore now just like ball B (only later).
   a. Because both balls are in free fall they must have the same acceleration, both magnitude and direction, 9.8 m/s2, down.
   b. Because ball B has the same downward speed when it gets back to the level of the student that ball A had, they will have the same speed when they hit the ground.

7. Assume the trajectory is symmetric (i.e., the ball leaves the ground) so half of the total time is the upward portion and half downward. Put the origin at the ground. Assume no air resistance.
   a. On the way down, initial velocity and final position are zero, and time = 2.6 s. Solve for y_i.

$$0 = y_i + \frac{1}{2} g(\Delta t)^2$$

$$y_i = -\frac{1}{2} g(\Delta t)^2 = -\frac{1}{2}(-9.8\, m/s^2)(2.6s)^2 = 33.1m$$

   b. On the way up, final velocity equals zero.

$$\left(v_y\right)_f^2 = \left(v_y\right)_i^2 + 2g\Delta y$$

$$\left(v_y\right)_i = \sqrt{-2(-9.8\, m/s^2)(33.1m)} = 25\, m/s$$

8. Assume the jumper is in free fall after leaving the ground, so use the kinematic equations. Since the trajectory is symmetric we'll compute the time it takes to come down from 1.1 m to the floor and then double it.

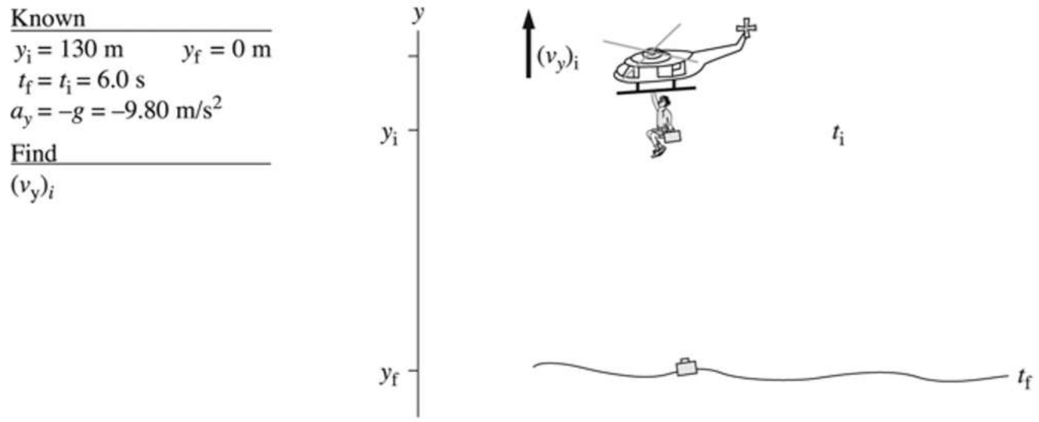
$$\left(y_f - y_i\right) = -\frac{1}{2} g(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2\left(y_f - y_i\right)}{g} = \sqrt{\frac{2(-1.1m)}{-9.8\, m/s^2}} = 0.47s}$$

   The whole "hang time" will be double this, or 0.95 s.

9. You may be thinking down because all these questions have been about free fall and the acceleration for anything in free fall is pointing down. However, Mike is *not* in free fall. He is touching a trampoline that is very stretched and forcing him back up. So Mike's acceleration is upward.

10. Since the villain is hanging on to the ladder as the helicopter is ascending, he and the briefcase are moving with the same upward velocity as the helicopter. We can calculate the initial velocity of the briefcase, which is equal to the upward velocity of the helicopter. See the following figure:



We can use Kinematic Equation 3 here. We know the time it takes the briefcase to fall, its acceleration, and the distance it falls. Solving for initial velocity.

$$(y_f - y_i) = v_i(t_f - t_i) + \frac{1}{2}g(t_f - t_1)^2$$

$$(0m - 130m) = v_i(6.0s - 0s) + \frac{1}{2}(-9.8\,m/s^2)(6.0s - 0s)^2$$

$$v_i = \frac{-130\text{m} - \left[\frac{1}{2}(-9.8m/s^2)(6.0s)^2\right]}{6.0s} = 7.7\,m/s$$

Note the placement of negative signs in the calculation. The initial velocity is positive, as expected for a helicopter ascending