Physics 2010 Chapter 2 Quiz Solutions

Multiple Choice (2 points each):

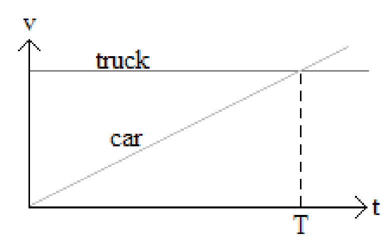
1. A motorcycle accelerates from +6.0 m/s to +22.2 m/s at an acceleration of +3.1 m/s^2. How far did it travel during this interval?
   a. 5.2 m
   b. 31 m
   c. 74 m
   d. 120 m

Given a constant acceleration, initial and final velocities. We are looking for a distance, so the velocity-displacement equation will give it to us:

$$v_f^2 = v_i^2 + 2a_x(\Delta x)$$

$$\Delta x = \frac{v_f^2 - v_i^2}{2a_x} = \frac{(22.2\ \mathrm{m/s})^2 - (6.0\ \mathrm{m/s})^2}{2 \cdot (3.1\ \mathrm{m/s^2})} = \boxed{\mathbf{74\ m}}$$

2. The motions of a car and a truck along a straight road are shown in the velocity graph below. The two vehicles are initially alongside each other at time t=0. At time t=T, what is true of the distances traveled by the vehicles since time t=0?
   a. They will have traveled the same distance.
   b. The truck will not have moved.
   c. The car will have traveled farther than the truck.
   d. The truck will have traveled farther than the car.



Note that this is a velocity graph, not a position graph. The truck and car both start at the same position; however, the car starts from rest (its line is at v=0 when t=0) while the truck is initially moving with a positive, constant speed the entire time (its line is horizontal). The car only reaches the same speed as the truck at time T, but by now (since the truck has always been traveling at a higher speed than the car) the truck will have traveled a farther distance. Note also that displacement is the area under the velocity graph: the truck's displacement consists of the entire rectangle between t=0 and t=T, while the car's displacement is only the triangle, which is half as big.

3. A tennis ball moving to the right strikes a wall with an initial speed of 32 m/s and rebounds in the opposite direction with a speed of 25 m/s. The collision with the wall takes 21 ms. What is the acceleration during the collision (assuming it's constant)?
   a. 300 m/s^2, directed to the left
   b. 2700 m/s^2, directed to the left
   c. 300 m/s^2, directed to the right
   d. 2700 m/s^2, directed to the right

Here the difference between speed and velocity is important. Taking moving to the right as the positive direction, then our initial and final velocities are:

$$v_i = +32 \text{ m/s}$$

$$v_f = -25 \text{ m/s}$$

The time interval is the duration of the collision: $\Delta t = 21 \text{ ms} = 21 \times 10^{-3}\text{s} = 0.021 \text{ s}$

By the definition of acceleration (or the velocity equation):

$$a = \frac{v_f - v_i}{\Delta t} = \frac{-25 \text{ m/s} - 32 \text{ m/s}}{0.021 \text{ s}} = \boxed{\mathbf{-2700 \text{ m/s}^2}}$$

Thus, the acceleration must be to the left (it stops its right-motion, and begins its left-motion). Partial credit was given for getting just the direction correct (answer a.) or getting just the magnitude correct (answer d.).

Show your work, and clearly designate your answer. Partial credit may be given. (4 points)

4. A penny is dropped (from rest) from the top of the Willis Tower in Chicago (442 m high). Assume free-fall (no air resistance).
   a. How long does it take the penny to hit the street below? $\boxed{\mathbf{9.49 \text{ s}}}$
   b. With what speed is the penny traveling immediately before it hits the ground? $\boxed{\mathbf{93.1 \text{ m/s}}}$
   c. Suppose instead the penny is given an initial velocity of 31 m/s downwards. What would its speed be immediately before hitting the ground in this case? $\boxed{\mathbf{98.1 \text{ m/s}}}$

Taking ground level as y=0 and upward as the positive direction, our variables are:

$$y_i = +442 \text{ m}$$

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

$$v_{yi} = 0 \text{ m/s}$$

$$a_y = -g$$

a. *To find the time, we can use the position equation:*

$$y_f = y_i + v_{yi}\Delta t + \frac{1}{2}a_y(\Delta t)^2$$

$$0 = 442 \text{ m} - \frac{1}{2}(9.81 \text{ m/s}^2)(\Delta t)^2$$

$$\Delta t = \sqrt{\frac{2 \cdot 442 \text{ m}}{9.81 \text{ m/s}^2}} = \boxed{\mathbf{9.49 \text{ s}}}$$

b. *To find the impact speed, we can either use the velocity-displacement equation just with our initial information, or the velocity equation and the time we found in part a.*

$$v_{yf}^2 = v_{yi}^2 + 2a_y(\Delta y)$$

$$v_{yf}^2 = 2 \cdot (-9.81 \text{ m/s}^2) \cdot (0 - 442 \text{ m}) = 2 \cdot (9.81 \text{ m/s}^2) \cdot (442 \text{ m})$$

$$v_{yf} = \pm\sqrt{2 \cdot (9.81 \text{ m/s}^2) \cdot (442 \text{ m})} = \pm 93.1 \text{ m/s}$$

Note, mathematically, we have both solutions, and if we were asked to find the impact velocity, we'd have to take the negative solution, since the penny is moving downwards at the point of impact. However, since we're only asked to find the speed, it doesn't matter:

$$|v_{yf}| = \boxed{\mathbf{93.1\ m/s}}$$

Credit was still given if you gave the velocity instead of the speed.

To see that using the velocity equation and the time from part a. gives the same solution:

$$v_{yf} = v_{yi} + a_y \Delta t = 0 \text{ m/s} - (9.81 \text{ m/s}^2) \cdot \sqrt{\frac{2 \cdot 442 \text{ m}}{9.81 \text{ m/s}^2}}$$

$$v_{yf} = -\sqrt{(9.81 \text{ m/s}^2)^2 \cdot \frac{2 \cdot 442 \text{ m}}{9.81 \text{ m/s}^2}} = -\sqrt{2 \cdot (9.81 \text{ m/s}^2) \cdot (442 \text{ m})} = -93.1 \text{ m/s}$$

*By bringing the factor of g inside the square root, we see that not only do we get approximately the same answer, we get **exactly** the same answer. Plus we get the sign correct.*

c. *Here we are asking for a final speed, but with a different initial velocity. Note that the time it takes for the penny to get the ground is **not** the time we computed in part a -- it take a shorter time to reach the ground since we are initially throwing it downward. Instead, we can use the velocity-displacement equation in the same way we did in part b.:*

$$v_{yi} = -31 \text{ m/s}$$

$$v_{yf}^2 = v_{yi}^2 + 2a_y(\Delta y)$$

$$v_{yf}^2 = (-31 \text{ m/s})^2 + 2 \cdot (-9.81 \text{ m/s}^2) \cdot (0 - 442 \text{ m})$$

$$v_{yf}^2 = (31 \text{ m/s})^2 + 2 \cdot (9.81 \text{ m/s}^2) \cdot (442 \text{ m})$$

$$v_{yf} = \pm\sqrt{(31 \text{ m/s})^2 + 2 \cdot (9.81 \text{ m/s}^2) \cdot (442 \text{ m})} = \pm 98.1 \text{ m/s}$$

$$|v_{yf}| = \boxed{\mathbf{98.1\ m/s}}$$

Note that since $(-31 \text{ m/s})^2 = (31 \text{ m/s})^2$, it would hit the ground at the same speed whether we threw it upwards or downwards (though it would take different amounts of time to hit the ground in that case). The reason behind this is the conservation of energy, which we learn about in Ch. 10.