Homework 5 (Solutions)
Physics 1000
Preparatory Physics
Due: Friday February 21, 1997

Reading Assignment

Basic Technical Physics, by Tippens. Chapter 6.

Written Assignment

Law of Falling Bodies

1. In the Mechanical Universe video entitled 'The Law of Falling Bodies', which scientist was credited with being the first chief advocate of the position that a combination of experiment and mathematics held the key to unlocking the secrets of the universe?

   a. Newton

   b. Leibniz

   c. Oresme

   d. Aristotle

   e. Galileo

2. In the same video as in question #1 above, who were credited as being the co-inventors of the differential calculus?

   a. Newton and Leibniz

   b. Galileo and Leibniz

   c. Galileo and Oresme

   d. Newton and Aristotle

   e. Newton and Galileo

3. Finally, in the same video mentioned in questions #1 and #2, which scientist presented the 'Compound Body Paradox' as an argument to establish that all bodies fall with the same constant acceleration unless somehow impeded?

   a. Newton

   b. Leibniz

   c. Oresme

   d. Aristotle

   e. Galileo

4. True or False. The ancient Greeks believed that all bodies fall at different different rates according to their weight.

5. Which of the following are the SI units for acceleration?

   a. km/s^2

   b. m/s^2

   c. m/s

   d. km/s

   e. miles/h.

6. Consider a car subjected to an acceleration or a deceleration. (Recall that a deceleration is simply a negative acceleration.)

   a. If the car accelerates with a constant acceleration from 5 m/s to 10 m/s, what is its average velocity?

   Answer: $v_0 = 5$ m/s, $v = 10$ m/s, $\bar{v} = (v + v_0)/2 = 7.5$ m/s.

   b. If the car accelerates (actually decelerates) with a constant acceleration from 10 m/s to 5 m/s, what is its average velocity?

   Answer: $v_0 = 10$ m/s, $v = 5$ m/s, $\bar{v} = (v + v_0)/2 = 7.5$ m/s.

7. Tippens, Ch. 6, problem #6-8 on p. 151.

8. A car initially at rest accelerates at 5 m/s^2 for 5 seconds. How far has it traveled?

   Answer: Choose the origin such that $x_0 = 0$ m. Starting from rest implies that $v_0 = 0$m/s. $a = 5$ m/s^2, $t = 5$ s. We're given (a, t) and asked for x. This is a (x, a, t) problem, which requires : $x = x_0 + v_0 t + at^2/2$. Thus, substituting in the values we are given yields: $x = (5 \text{ m/s}^2)(5 \text{ s})^2/2 = 62.5$ m.

9. Another car, initially at rest, accelerates at 5 m/s^2 for a distance of 40 m. How many seconds did it accelerate?

   Answer: Choose the origin such that $x_0 = 0$ m. Starting from rest again implies that $v_0 = 0$m/s. $a = 5$ m/s^2, $x = 40$ m. We're given (a, x) and asked for t. This is again a (x, a, t) problem, which requires: $x = x_0 + v_0 t + at^2/2$, but now we must solve for time. Setting $v_0 = 0$ we get $t = \sqrt{2(x - x_0)/a}$. Thus, substituting in the values we are given yields: $t = \sqrt{2(40)/5} = \sqrt{16} = 4$ s.

10. A ball is dropped or thrown straight down from a 10 m high cliff. (Neglect air resistance. For simplicity, you can use 10 m/s^2 for g. Be careful to choose your signs on velocities and accelerations carefully!)

a. If the ball is dropped from rest, how long after it was dropped will it hit the ground?

Answer: Choose the coordinate system at the base of the cliff with positive upward so that $x_0 = 10$ m and a = -g = -10 m/s^2. Hitting the ground will occur when $x = 0$. Starting from rest means that $v_0 = 0$ m/s. This is a falling body problem relating the variables (x, a, t) so we use: $0 = x_0 + v_0 t + at^2/2 = x_0 - gt^2/2$. Solving for time yields: $t = \sqrt{2(x_0)/g} = \sqrt{2(10)/10}$ s $= \sqrt{2}$ s ~ 1.4 s. (The symbol $\sim$ means 'approximately'.)

b. If the ball is thrown down with an initial speed of 1 m/s, how long after it was thrown will it hit the ground?

Answer: In this case $v_0 = -1$ m/s. Note the sign! So, $0 = x_0 + v_0 t - gt^2/2$. Putting this in a form where the coefficient in front of t^2 is unity yields: $t^2 - 2(v_0/g)t - 2x_0/g = 0$. Recall that for a quadratic equation of the form $At^2 + Bt + C = 0$ the quadratic formula tells us the solutions: $t = (-B/2A) \pm \sqrt{B^2 - 4AC}/2A$. Here, $A = 1$, $B = -2v_0/g$ = -2(-1)/10 = .2, $C = -2x_0/g = -2(10)/10 = -2$. Thus, $t = -.2/2 \pm \sqrt{(.4)^2 - 4(-2)}/2 \sim -.1 \pm 1.4$ s ~ 1.3 s or -1.5 s. The negative solution is physically meaningless here and the answer it $t \sim 1.3s$.

c. How much less time does it take the thrown ball to hit the ground than if the ball were simply dropped off the cliff?

Answer: About 0.1 s.