Homework 2 solutions

Problem 10. *A 50.0 g super-ball traveling at 25.0 m/s bounces off a brick wall and rebounds at 22.0 m/s. A high-speed camera records this event. If the ball is in contact with the wall for 3.50 ms, what is the magnitude of the average acceleration of the ball during this time interval. (Note: 1 ms = 10^{-3} s.)*

Pick a coordinate system (e.g. rebound direction is positive). Then $v_0 = -25.0$ m/s and $v_1 = 22.0$ m/s.

$$a \equiv \frac{\Delta v}{\Delta t} = \frac{v_1 - v_0}{\Delta t} = \frac{[22.0 - (-25.0)][\text{m/s}]}{3.50 \text{ ms} \cdot \frac{1\text{s}}{10^3 \text{ ms}}} = \frac{47.0\text{m/s}}{3.5 \cdot 10^{-3} \text{ s}} = 13400 \text{ m/s}^2 \tag{1}$$

Problem 16. *Draw motion diagrams...*

Look at Figure 2.11 on page 50 of the text. For question parts (e) and (f), draw figures (b) and (c) respectively but with the x-axis reversed.

Note the different spacing in the figure because the 'strobe' is going off at a constant frequency (same time between pictures). If you didn't vary the spacing when the velocity changed, you'd need to point out somewhere that your time intervals were not constant.

I also accepted plots of velocity or position vs time.

Problem 40. *A woman is reported to have fallen 144 ft from the 17th floor of a building, landing on a metal ventilator box that she crushed to a depth of 18.0 in. She suffered only minor injuries. Ignoring air resistance, calculate (a) the speed of the woman just before she collided with the box and (b) her average acceleration while in contact with the box. (c) Modeling her acceleration as constant, calculate the time interval it took to crush the box.*

(a)
First deal with the portion from the top (point P_0) to the point of collision with the box (point P_1). Pick a coordinate system pointing down, with $x_0 = 0$ m. Converting the distance into meters:

$$x_1 = 144 \text{ ft} \cdot \frac{1 \text{ m}}{3.28 \text{ ft}} = 43.9 \text{ m} \tag{2}$$

So

	P_0	P_1
a	9.8 m/s^2	
v	0 m/s	?
x	0 m	43.9 m
t	0 s	?

We want v_1 and we don't know t_1 so we use

$$v_1^2 = v_0^2 + 2a\Delta x_{01} \tag{3}$$
$$v_1 = \sqrt{2a(x_1 - x_0)} = \sqrt{2 \cdot 9.8 \text{ m/s} \cdot 43.9 \text{ m}} = 29.3 \text{ m/s} \tag{4}$$

Some people wanted to leave Δx in ft, and this works if you also use a in ft/s^2. You run into trouble if you use ft for one and m for the other...

(b)
Converting the change in x over the box into m we have

$$\Delta x_{12} = 18\text{in} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \cdot \frac{1 \text{ m}}{3.28 \text{ m}} = 0.457 \text{ m} \tag{5}$$

Calling the point just after she crushed the box P_2, we have

$$v_2^2 = v_1^2 + 2a_{12}\Delta x_{12} \tag{6}$$
$$a_{12} = \frac{-v_1^2}{2\Delta x_{12}} = \frac{-(29.3 \text{ m/s})^2}{2 \cdot 0.457 \text{ m}} = -941 \text{ m/s}^2 \tag{7}$$

(c)

$$v_2 = a_{12}t_{12} + v_1 \tag{8}$$
$$t_{12} = -v_1/a_{12} = \frac{-29.3 \text{ m/s}}{-941 \text{ m/s}^2} = 31.2 \text{ ms} \tag{9}$$

Problem 49. *Setting a world record in a 100 m race, Maggie and Judy cross the finish line in a dead heat, both taking 10.2 s. Accelerating uniformly, Maggie took 2.00 s and Judy 3.00 s to attain maximum speed, which they maintained for the rest of the race. (a) What was the acceleration of each sprinter? (b) What were their respective maximum speeds? (c) Which sprinter was ahead at the 6.00 s mark and by how much?*

(a,b)

Consider Maggie first. Let P_0 be the Maggie leaving the starting line, P_1 be Maggie finishing her acceleration phase, and P_2 be Maggie finishing the race.

	P_0	P_1	P_2
a	?	0 m/s^2	
v	0 m/s	?	
x	0 m	?	100 m
t	0 s	2.00 s	10.2 s

Using the 2nd equation from Table 2.2 on page 53 on the first leg:

$$x_1 = 0.5(v_0 + v_1)t_1 + x_0 = 0.5 v_1 t_1 \tag{10}$$

And again on the second leg:

$$x_2 = 0.5(v_2 + v_1)(t_2 - t_1) + x_1 = 0.5(v_1 + v_1)(t_2 - t_1) + 0.5 v_1 t_1 = v_1(t_2 - t_1 + 0.5 t_1) = v_1(t_2 - 0.5 t_1) \tag{11}$$

$$v_1 = \frac{x_2}{t_2 - 0.5 t_1} = \frac{100 \text{ m}}{10.2 \text{ s} - 0.5 \cdot 2.00 \text{ s}} = 10.9 \text{ m/s} \tag{12}$$

Which is the answer for Maggie in part (b). So

$$v_1 = a_1 2 t_1 + v_0 \tag{13}$$

$$a_1 2 = v_1 / t_1 = \frac{10.9 \text{ m/s}}{2.00 \text{ s}} = 5.43 \text{ m/s}^2 \tag{14}$$

Which answers Maggie in part (a).

Applying the formulas to Judy,

$$v_1 = \frac{x_2}{t_2 - 0.5 t_1} = \frac{100 \text{ m}}{10.2 \text{ s} - 0.5 \cdot 3.00 \text{ s}} = 11.5 \text{ m/s} \tag{15}$$

$$a_1 2 = v_1 / t_1 = \frac{11.5 \text{ m/s}}{3.00 \text{ s}} = 3.83 \text{ m/s}^2 \tag{16}$$

(c)

$$x_M(t) = v_{M1}(t - t_{M1}) + x_{M1} \tag{17}$$
$$x_J(t) = v_{J1}(t - t_{J1}) + x_{J1} \tag{18}$$
$$\Delta x = x_M(6 \text{ s}) - x_J(6 \text{ s}) = 10.9 \text{ m/s} \cdot 4.00 \text{ s} + 0.5 \cdot 10.9 \text{ m/s} \cdot 2.00 \text{ s} - 11.5 \text{ m/s} \cdot 3.00 \text{ s} - 0.5 \cdot 11.5 \text{ m/s} \cdot 3.00 \text{ s} = 2.62 \text{ m} \tag{19}$$