Physics 16 Problem Set 3 Solutions

3.29. **IDENTIFY:** Apply Eq. (3.30).
SET UP: $T = 24\text{ h}$.
EXECUTE: **(a)** $a_{\text{rad}} = \dfrac{4\pi^2(6.38\times10^6\text{ m})}{((24\text{ h})(3600\text{ s/h}))^2} = 0.034\text{ m/s}^2 = 3.4\times10^{-3}g.$

(b) Solving Eq. (3.30) for the period T with $a_{\text{rad}} = g$, $T = \sqrt{\dfrac{4\pi^2(6.38\times10^6\text{m})}{9.80\text{ m/s}^2}} = 5070\text{ s} = 1.4\text{ h}.$

EVALUATE: a_{rad} is proportional to $1/T^2$, so to increase a_{rad} by a factor of $\dfrac{1}{3.4\times10^{-3}} = 294$ requires that T be multiplied by a factor of $\dfrac{1}{\sqrt{294}}$. $\dfrac{24\text{ h}}{\sqrt{294}} = 1.4\text{ h}$.

3.34. **IDENTIFY:** The acceleration is the vector sum of the two perpendicular components, a_{rad} and $a_{\tan}$.
SET UP: $a_{\tan}$ is parallel to $\vec{v}$ and hence is associated with the change in speed; $a_{\tan} = 0.500\text{ m/s}^2$.
EXECUTE: **(a)** $a_{\text{rad}} = v^2/R = (3\text{ m/s})^2/(14\text{ m}) = 0.643\text{ m/s}^2$.
$a = ((0.643\text{ m/s}^2)^2 + (0.5\text{ m/s}^2)^2)^{1/2} = 0.814\text{ m/s}^2,\ 37.9°$ to the right of vertical.
(b) The sketch is given in Figure 3.34.

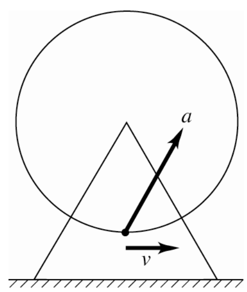


Figure 3.34

3.38. **IDENTIFY:** Calculate the rower's speed relative to the shore for each segment of the round trip.
SET UP: The boat's speed relative to the shore is 6.8 km/h downstream and 1.2 km/h upstream.
EXECUTE: The walker moves a total distance of 3.0 km at a speed of 4.0 km/h, and takes a time of three fourths of an hour (45.0 min).
The total time the rower takes is $\dfrac{1.5\text{ km}}{6.8\text{ km/h}} + \dfrac{1.5\text{ km}}{1.2\text{ km/h}} = 1.47\text{ h} = 88.2\text{ min}.$
EVALUATE: It takes the rower longer, even though for half the distance his speed is greater than 4.0 km/h. The rower spends more time at the slower speed.

3.86. **IDENTIFY:** **(a)** The ball moves in projectile motion. When it is moving horizontally, $v_y = 0$.
SET UP: Let $+x$ be to the right and let $+y$ be upward. $a_x = 0$, $a_y = -g$.
EXECUTE: **(a)** $v_{0y} = \sqrt{2gh} = \sqrt{2(9.80\text{ m/s}^2)(4.90\text{ m})} = 9.80\text{ m/s}.$
(b) $v_{0y}/g = 1.00\text{ s}$.
(c) The horizontal component of the velocity of the ball relative to the man is $\sqrt{(10.8\text{ m/s})^2 - (9.80\text{ m/s})^2} = 4.54\text{ m/s}$, the horizontal component of the velocity relative to the hoop is $4.54\text{ m/s} + 9.10\text{ m/s} = 13.6\text{ m/s}$, and the man must be 13.6 m in front of the hoop at release.

(d) Relative to the flat car, the ball is projected at an angle $\theta = \tan^{-1}\left(\dfrac{9.80\text{ m/s}}{4.54\text{ m/s}}\right) = 65°$. Relative to the ground the angle is $\theta = \tan^{-1}\left(\dfrac{9.80\text{ m/s}}{4.54\text{ m/s} + 9.10\text{ m/s}}\right) = 35.7°$.

EVALUATE: In both frames of reference the ball moves in a parabolic path with $a_x = 0$ and $a_y = -g$. The only difference between the description of the motion in the two frames is the horizontal component of the ball's velocity.

4.24. **IDENTIFY:** The reaction forces in Newton's third law are always between a pair of objects. In Newton's second law all the forces act on a single object.

SET UP: Let $+y$ be downward. $m = w/g$.

EXECUTE: The reaction to the upward normal force on the passenger is the downward normal force, also of magnitude 620 N, that the passenger exerts on the floor. The reaction to the passenger's weight is the gravitational force that the passenger exerts on the earth, upward and also of magnitude 650 N. $\dfrac{\sum F_y}{m} = a_y$ gives $a_y = \dfrac{650\text{ N} - 620\text{ N}}{(650\text{ N})/(9.80\text{ m/s}^2)} = 0.452\text{ m/s}^2$. The passenger's acceleration is 0.452 m/s^2, downward.

EVALUATE: There is a net downward force on the passenger and the passenger has a downward acceleration.

4.27. **IDENTIFY:** Identify the forces on each object.

SET UP: In each case the forces are the noncontact force of gravity (the weight) and the forces applied by objects that are in contact with each crate. Each crate touches the floor and the other crate, and some object applies $\vec{F}$ to crate *A*.

EXECUTE: **(a)** The free-body diagrams for each crate are given in Figure 4.27.

F_{AB} (the force on m_A due to m_B) and F_{BA} (the force on m_B due to m_A) form an action-reaction pair.

(b) Since there is no horizontal force opposing *F*, any value of *F*, no matter how small, will cause the crates to accelerate to the right. The weight of the two crates acts at a right angle to the horizontal, and is in any case balanced by the upward force of the surface on them.

EVALUATE: Crate *B* is accelerated by F_{BA} and crate *A* is accelerated by the net force $F - F_{AB}$. The greater the total weight of the two crates, the greater their total mass and the smaller will be their acceleration.

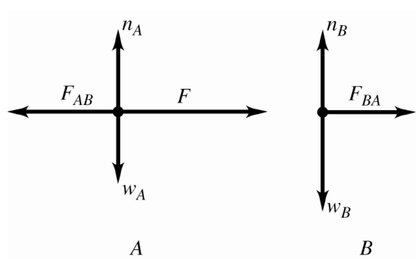
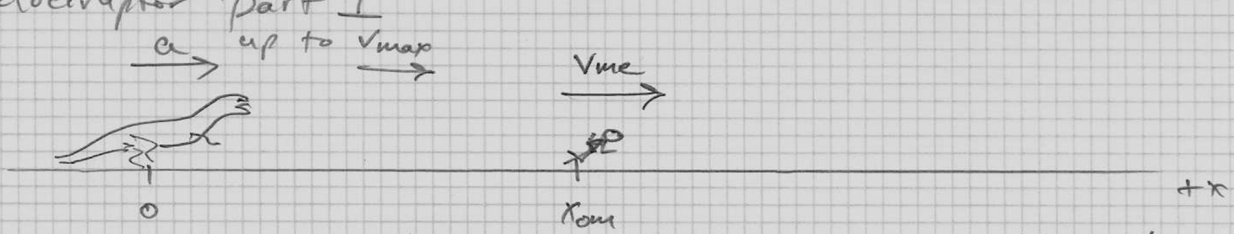


Figure 4.27

Accelerometer question:

1. After about 40s, the acceleration looks kind of constant (except for quite a bit of noise). Averaging from 40s until I started braking (at around 116s) I get $\langle a_y \rangle = 1.8\text{ m/s}^2$. From Google Earth, I measure the diameter of the circle to be 72 m. (Google maps works too, or you can *even* go out behind the library and pace it off). From the formula for centripetal acceleration $a=v^2/R$, we know that $v = \sqrt{aR}$, giving v = 8 m/s or 18 mph. (I actually tried to drive at 20 mph) .
2. Since the acceleration is to the left (out the driver's side window), the center of the circle must be to the left: that is, I was turning leftward the whole time.

Velociraptor Part 1

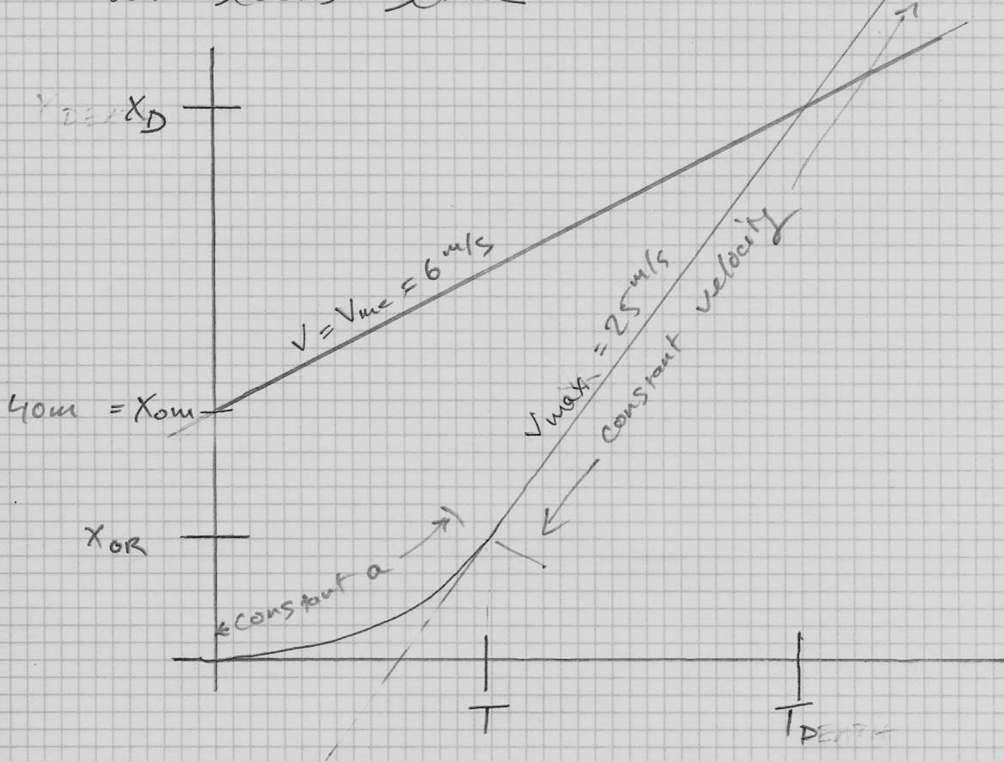


$X_{om} = 40\,m$
$V_{me} = 6\,m/s$
$a = 4\,m/s^2$
$V_{max} = 25\,m/s$

$$x_{me}(t) = X_{om} + V_{me}\,t$$

$$X_R(t) = \begin{cases} \frac{1}{2} a t^2 & \text{until } T \\ X_{oR} + V_{max}(t-T) & \text{afterwards} \end{cases}$$

This looks like



During constant accⁿ $V_R = at$; so $V_R = V_{max}$ when $aT = V_{max} \longrightarrow \boxed{T = V_{max}/a}$. This is the time of the changeover from constant a to constant V motion. It occurs at a distance $X_{OR} = \frac{1}{2} a T^2 = \frac{1}{2} a \left(\frac{V_{max}}{a}\right)^2 = \frac{1}{2}\frac{V_{max}^2}{a}$

$$\boxed{X_{OR} = \frac{1}{2}\frac{V_{max}^2}{a}}$$

After the changeover,

$$x_R(t) = x_{0R} + v_{max}(t - T)$$

$$= \frac{1}{2}\frac{v_{max}^2}{a} + v_{max}\left(t - \frac{v_{max}}{a}\right) = -\frac{1}{2}\frac{v_{max}^2}{a} + v_{max}t.$$

Comparing this to $x_{me}(t)$, death occurs when

$$x_R(T_D) = x_{me}(T_D)$$

$$-\frac{1}{2}\frac{v_{max}^2}{a} + v_{max}T_D = x_{0m} + v_{me}T_D$$

$$(v_{max} - v_{me})T_D = x_{0m} + \frac{1}{2}\frac{v_{max}^2}{a}$$

$$T_D = \frac{x_{0m} + \frac{1}{2}\frac{v_{max}^2}{a}}{v_{max} - v_{me}}$$

$$= \frac{(40.0\,m) + \frac{1}{2}(25\,m/s)^2/(4\,m/s^2)}{(25-6)\,m/s}$$

$$\boxed{T_D = 6.22\,s}$$

In this time I will have run $v_{me} \cdot T_D = \left(6\frac{m}{s}\right)(6.22\,s) = \boxed{37\,m}$