Assignment #4

Chapter 5 Questions:

5.2 Third law force pairs act on different systems. Only one member of each third law force pair ever is used in Newton's second law.

5.3 Because of the rotation of the earth, the surface of the earth is only approximately an inertial reference frame.

5.5 The reading of the scale on the incline will be less than when the scale is on level ground. The scale measures the magnitude of the normal force of you on its surface.

5.10 There may be forces acting on the system, but the vector sum of the forces will be zero since the system is moving at constant velocity or is at rest.

5.18 No, the total force is parallel to the acceleration.

5.32 The magnitude of the force you exert on the earth is 600 N and the force is directed vertically upward at your location.

Chapter 5 Problems:

5.6

a) The acceleration of the system is in the same direction as the total force. Since the given force has both x and y components, while the acceleration has only an x component, there must be another force on the system.

b) Let $\vec{\mathbf{F}}$ be the other force on the system. Then from Newton's second law,

$$\vec{\mathbf{F}}_{\text{total}} = m\vec{a}$$

$$\implies \vec{\mathbf{F}} + (3.00\text{ N})\hat{\mathbf{i}} - (6.00\text{ N})\hat{\mathbf{j}} = (2.50\text{ kg})(4.00\text{ m/s}^2)\hat{\mathbf{i}} = (10.00\text{ N})\hat{\mathbf{i}}$$

$$\implies \vec{\mathbf{F}} = (10.00\text{ N})\hat{\mathbf{i}} - \Big((3.00\text{ N})\hat{\mathbf{i}} - (6.00\text{ N})\hat{\mathbf{j}}\Big) = (7.00\text{ N})\hat{\mathbf{i}} + (6.00\text{ N})\hat{\mathbf{j}}.$$

5.8 Choose $\hat{\mathbf{i}}$ to point in the direction the sprinter runs, and let the origin be at the starting line. Then

$$x_0 = 0\text{ m} \qquad \text{and} \qquad v_{x0} = 0\text{ m/s},$$

so during the interval of constant acceleration,

$$x(t) = a_x\frac{t^2}{2}.$$

Now let t be the time that the acceleration ceases. At this time, the sprinter has covered 10.0 m, so $10.0\text{ m} = a_x\frac{t^2}{2}$, hence

$$a_x = \frac{20.0\text{ m}}{t^2}. \tag{1}$$

Since $v_{x0} = 0$ m/s, the velocity component at time t is

$$v_x = a_x t = \frac{20.0 \text{ m}}{t^2} t = \frac{20.0 \text{ m}}{t}.$$

The remaining 90.0 m of the track are run with this constant velocity component, over the remaining time 10.0 s $- t$. Hence

$$90.0 \text{ m} = \frac{20.0 \text{ m}}{t}(10.0 \text{ s} - t) = \frac{(20.0 \text{ m})(10.0 \text{ s})}{t} - 20.0 \text{ m}.$$

So, solving for t,

$$t = \frac{(20.0 \text{ m})(10.0 \text{ s})}{90.0 \text{ m} + 20.0 \text{ m}} = 1.82 \text{ s}.$$

Use this value of t in equation (1) to find a_x.

$$\frac{20.0 \text{ m}}{(1.82 \text{ s})^2} = 6.04 \text{ m/s}^2.$$

Therefore, the magnitude of the total force on the sprinter during the interval of constant acceleration is

$$F_{\text{total}} = ma = (60.0 \text{ kg})(6.04 \text{ m/s}^2) = 362 \text{ N}.$$

5.10

a) Choose $\hat{\mathbf{i}}$ to point in the direction of travel of the incoming ball and let $t = 0$ s be the time that the ball hits the player's head. Then

$$v_{x0} = 15.0 \text{ m/s}, \qquad \text{and} \quad v_x = -18.0 \text{ m/s} \quad \text{when } t = 0.100 \text{ s}.$$

Therefore, since the acceleration is constant over this 0.100 s interval,

$$-18.0 \text{ m/s} = 15.0 \text{ m/s} + a_x(0.100 \text{ s}) \implies a_x = -330 \text{ m/s}^2.$$

The magnitude of the acceleration is the absolute value of this single acceleration component.

$$a = 330 \text{ m/s}^2.$$

b) The magnitude of the total force on the ball is

$$F_{\text{total}} = ma = (0.430 \text{ kg})(330 \text{ m/s}^2) = 142 \text{ N}.$$

5.12

a) If the scalar product of two vectors is zero, then they are perpendicular. Hence, to show the forces are perpendicular to one another, take their scalar products with one another.

$$\vec{\mathbf{F}}_1 \bullet \vec{\mathbf{F}}_2 = \Big((3.0 \text{ N})\hat{\mathbf{i}} + (2.0 \text{ N})\hat{\mathbf{j}}\Big) \bullet (2.0 \text{ N})\hat{\mathbf{k}} = 0 \text{ N}^2.$$

$$\vec{\mathbf{F}}_1 \bullet \vec{\mathbf{F}}_3 = \Big((3.0 \text{ N})\hat{\mathbf{i}} + (2.0 \text{ N})\hat{\mathbf{j}}\Big) \bullet \Big((2.0 \text{ N})\hat{\mathbf{i}} - (3.0 \text{ N})\hat{\mathbf{j}}\Big) = 6.0 \text{ N}^2 - 6.0 \text{ N}^2 = 0 \text{ N}^2.$$

$$\vec{\mathbf{F}}_2 \bullet \vec{\mathbf{F}}_3 = (2.0 \text{ N})\hat{\mathbf{k}} \bullet \Big((2.0 \text{ N})\hat{\mathbf{i}} - (3.0 \text{ N})\hat{\mathbf{j}}\Big) = 0 \text{ N}^2.$$

b) First find the acceleration of the system from Newton's second law.

$$\vec{\mathbf{F}}_{\text{total}} = m\vec{\mathbf{a}}$$

$$\implies \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \vec{\mathbf{F}}_3 = m\vec{\mathbf{a}}$$

$$\implies \Big((3.0 \text{ N})\hat{\mathbf{i}} + (2.0 \text{ N})\hat{\mathbf{j}}\Big) + (2.0 \text{ N})\hat{\mathbf{k}} + \Big((2.0 \text{ N})\hat{\mathbf{i}} - (3.0 \text{ N})\hat{\mathbf{j}}\Big) = (20 \text{ kg})\vec{\mathbf{a}}$$

$$\implies \vec{\mathbf{a}} = (0.25 \text{ m/s}^2)\hat{\mathbf{i}} - (0.050 \text{ m/s}^2)\hat{\mathbf{j}} + (0.10 \text{ m/s}^2)\hat{\mathbf{k}}.$$

This is a constant acceleration. The velocity components are found from the one-dimensional kinematic equations

$$v_x(t) = v_{x0} + a_x t, \qquad v_y(t) = v_{y0} + a_y t, \qquad \text{and} \quad v_z(t) = v_{z0} + a_z t.$$

The initial velocity components v_{x0}, v_{y0}, and v_{z0} are all zero. Hence, when $t = 3.0\,\text{s}\,(\text{s})$,

$$v_x = 0.75\,\text{m/s}\,, \qquad v_y = -0.15\,\text{m/s}\,, \qquad \text{and} \quad v_z = 0.30\,\text{m/s}\,,$$

so

$$\vec{\mathbf{v}} = (0.75\,\text{m/s})\hat{\mathbf{i}} - (0.15\,\text{m/s})\hat{\mathbf{j}} + (0.30\,\text{m/s})\hat{\mathbf{k}}.$$

The speed is the magnitude of the velocity vector, so

$$v = \sqrt{(0.75\,\text{m/s})^2 + (-0.15\,\text{m/s})^2 + (0.30\,\text{m/s})^2} = 0.82\,\text{m/s}\,.$$

5.26 Refer to Figure P.26 on page 219 of the text.

a) The magnitude of the total force on the crate is

$$F_{\text{total}} = ma = (51.0\,\text{kg})(0.100\,\text{m/s}^2) = 5.10\,\text{N}\,.$$

The direction of the total force is in the same direction as the acceleration — along and up the inclined plane.

b) The magnitude of the weight of the crate is

$$w = mg = (51.0\,\text{kg})(9.81\,\text{m/s}^2) = 500\,\text{N}\,.$$

c) Let $\vec{\mathbf{F}}_{\text{h}}$ be the horizontal force applied. Use a coordinate system with $\hat{\mathbf{i}}$ in the direction of motion of the crate, and $\hat{\mathbf{j}}$ perpendicular to the plane, so that $\hat{\mathbf{j}}$ makes a $20.0°$ angle with the straight upwards direction. Then in this coordinate system the normal force of the plane is entirely in the $\hat{\mathbf{j}}$ direction, so the only forces with non-zero x components are $\vec{\mathbf{F}}_{\text{h}}$, with $F_{x\,\text{h}} = F_{\text{h}}\cos 20.0°$, and $\vec{\mathbf{w}}$, with $w_x = -mg\sin 20.0°$. Hence

$$\begin{aligned} F_{x\ \text{total}} = ma_x \implies\ & F_{\text{h}}\cos 20.0° - mg\sin 20.0° = ma_x \\ \implies\ & F_{\text{h}} = \frac{m(a_x + g\sin 20.0°)}{\cos 20.0°} = \frac{(51.0\,\text{kg})[(0.100\,\text{m/s}^2) + (9.81\,\text{m/s}^2)\sin 20.0°]}{\cos 20.0°} = 188\,\text{N}\,. \end{aligned}$$

d) Note that all three forces $\vec{\mathbf{F}}_{\text{h}}$, $\vec{\mathbf{w}}$, and $\vec{\mathbf{N}}$, have non-zero y components. These components are $F_{\text{h}}\sin 20.0°$, $-mg\cos 20.0°$, and N respectively. Since the acceleration is zero in the y direction, we have

$$\begin{aligned} & F_{y\ \text{total}} = ma_y \\ & \implies -F_{\text{h}}\sin 20.0° - mg\cos 20.0° + N = m(0\,\text{m/s}^2) = 0\,\text{N} \\ & \implies N = mg\cos 20.0° + F_{\text{h}}\sin 20.0° = (51.0\,\text{kg})(9.81\,\text{m/s}^2)\cos 20.0° + (188\,\text{N})\sin 20.0° = 534\,\text{N}\,. \end{aligned}$$

5.35

a) The forces on the meteorite system are:

1. its weight $\vec{\mathbf{w}}$, of magnitude mg, directed down;
2. the force $\vec{\mathbf{T}}_1$ of the horizontal cable on the meteorite directed along the cable and toward the wall;
3. the force $\vec{\mathbf{T}}_2$ of the other cable on the meteorite, directed along the cable towards the point where it is fastened to the ceiling.