Problem 1. The impact between the block *A* and pan *B* must be treated separately; the solution is therefore divided into three parts.

Part 1. Let v_A be the velocity with which the block *A* hits the pan *B*. From the conservation of energy,

$$\Delta T + \Delta V_g = 0$$

$$\Rightarrow \qquad m_A g h = \frac{1}{2} m_A v_A^2$$

$$\Rightarrow \qquad v_A = 6.26 \text{ m/s} \quad \downarrow$$

Part 2. For the impact between block *A* and pan *B*, linear momentum is conserved. Let *v* be the common velocity of the block and pan after impact. Then

$$m_A v_A + m_B v_B = (m_A + m_B) v$$

$$\Rightarrow \qquad 30(6.26) = (30 + 10) v$$

$$\Rightarrow \qquad v = 4.70 \text{ m/s} \quad \downarrow$$

Part 3. Denote by *x* the maximum deflection of the pan, measured from its static equilibrium position. Initially the spring supports the weight of the pan, thus the spring has a static compression of $\delta = m_B g / k = 4.91 \times 10^{-3}$ m. When the pan reaches the position of maximum deflection, the spring has a total compression of $x + \delta$. From the conservation of energy,

$$\Delta T + \Delta V_g + \Delta V_e = 0$$

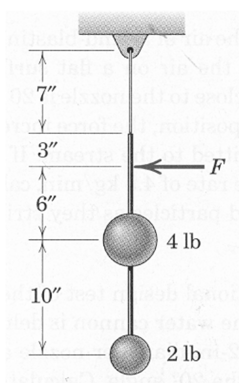
$$\Rightarrow \qquad \frac{1}{2}(m_A + m_B) v^2 + \frac{1}{2} k \delta^2 = -(m_A + m_B) g x + \frac{1}{2} k (x + \delta)^2$$

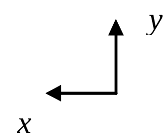
$$\Rightarrow \qquad k x^2 + 2(k\delta - 392) x - 884 = 0$$

$$\Rightarrow \qquad x = 0.225 \text{ or } -0.196$$

Thus the maximum deflection of the pan is $x = 0.225$ m

Problem 2.





Let *G* be the center of mass of the system. Upon application of the horizontal force *F*, *G* will move with an acceleration a_G in the direction of *F*. From the generalized equation of motion,

$$\sum F_x = m a_G$$

$$\Rightarrow \qquad 12 = \left(\frac{4 + 2}{32.2} \right) a_G$$

$$\Rightarrow \qquad a_G = 64.4\ \text{ft/sec}^2 \qquad \longleftarrow$$

In order to determine the angular momentum of the system about *G*, it is necessary to find its position. Let *G* be located at a distance *d* from the 2-lb ball along the rigid rod. By moment balance,

$$4(10 - d) = 2d$$

$$\Rightarrow \qquad d = \frac{20}{3} = 6.67\ \text{in}$$

Let the angular position of the rigid rod be specified by an angle θ measured from any convenient fixed direction. Each ball moves in a circle relative to *G*. For the entire system,

$$H_G = \sum \rho_i (m_i \dot{\rho}_i) = \sum m_i \rho_i^2 \dot{\theta}$$

$$= \frac{4}{32.2}\left(\frac{3.33}{12}\right)^2 \dot{\theta} + \frac{2}{32.2}\left(\frac{6.67}{12}\right)^2 \dot{\theta} = 0.0288\dot{\theta}\ \text{lb-ft-sec}$$

With respect to the mass center *G*,

$$\sum M_G = \dot{H}_G$$

$$\Rightarrow \qquad 12\left(\frac{6 + 3.33}{12}\right) = 0.0288\ddot{\theta}$$

$$\Rightarrow \qquad \ddot{\theta} = 325\ \text{rad/sec}^2 \qquad \circlearrowleft$$

Problem 3.

(a) $\mathbf{V_a} = 0.5\mathbf{i}$ m/s . Because the engine rests on the driver axles, the engine must share the same velocity as the center of the axles: point A on the driver.

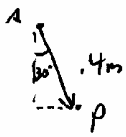
(b)

$$\vec{V}_S = \vec{V}_A + \vec{\omega}_{dr} \times \vec{r}_{S/A} = 0.5\hat{i}\ \tfrac{m}{s} + \left(-2.2\hat{k}\ \tfrac{rad}{s}\right) \times \left(-0.95\hat{j}\ m\right)$$

$$\boxed{\vec{V}_S = -1.59\hat{i}\ \tfrac{m}{s}}$$

This velocity proves that the driver is slipping on the rail. Otherwise $\mathbf{V_s}$ would be equal to zero.

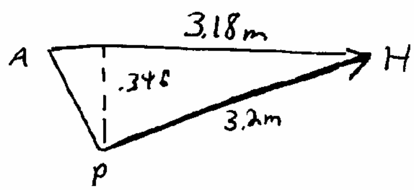
(c)



$$\vec{r}_{P/A} = (.2\hat{i} - .346\hat{j})\,m, \quad \vec{V}_P = \vec{V}_A + \vec{\omega}_{dr} \times \vec{r}_{P/A}$$

$$\vec{V}_P = 0.5\hat{i}\ \tfrac{m}{s} + \left(-2.2k\ \tfrac{rad}{s}\right) \times (.2\hat{i} - .346\hat{j})\,m$$

$$\vec{V}_P = (-.261\hat{i} - .44\hat{j})\ \tfrac{m}{s}$$



$$\vec{r}_{H/P} = (3.18\hat{i} + .346\hat{j})\,m$$

$$\vec{V}_H = \vec{V}_P + \vec{\omega}_{mr} \times \vec{r}_{H/P}$$

$$V_H\hat{i} = (-.261\hat{i} - .44\hat{j})\ \tfrac{m}{s} + \dot{\theta}_{mr}\vec{k} \times (3.18\hat{i} + .346\hat{j})\,m$$

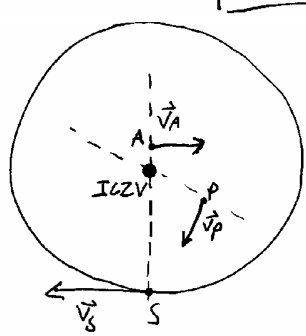
j component: $0 = -.44\ \tfrac{m}{s} + (3.18\,m)(\dot{\theta}_{mr})$

$$\dot{\theta}_{mr} = .138\ \tfrac{rad}{s}$$

i component: $V_H = -.261\ \tfrac{m}{s} - (.346\,m)\dot{\theta}_{mr}$

$$\boxed{\vec{V}_H = -.309\hat{i}\ \tfrac{m}{s}}$$

(d)



(e) The angular velocity of the Side Rod is always zero because the drivers all rotate at the same speed and the Side Rod only translates and does not rotate.