3.18 Let $\mathcal{I} = (O, \mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3)$ be an inertial reference frame and frame $\mathcal{A} = (O', \mathbf{a}_1, \mathbf{a}_2, \mathbf{a}_3)$ be aligned with $\mathcal{I}$ and translating with velocity ${}^{\mathcal{I}}\mathbf{v}_{O'/O} = v_0\mathbf{e}_1$. Frame $\mathcal{B} = (O', \mathbf{b}_1, \mathbf{b}_2, \mathbf{b}_3)$ is a polar frame with angular velocity ${}^{\mathcal{I}}\boldsymbol{\omega}^{\mathcal{B}} = \dot{\theta}\mathbf{b}_3$. ($P$ is free to move in $\mathcal{A}$.) Derive the following using the coordinates shown in Figure 3.43:

a. The transformation table between $\mathcal{A}$ and $\mathcal{B}$.
b. The position $\mathbf{r}_{P/O'}$ of P with respect to O' expressed as components in $\mathcal{B}$.
c. The position $\mathbf{r}_{P/O}$ of P with respect to O expressed as components in $\mathcal{B}$.
d. The velocity ${}^{\mathcal{B}}\mathbf{v}_{P/O'}$ and acceleration ${}^{\mathcal{B}}\mathbf{a}_{P/O'}$ of P with respect to O' in $\mathcal{B}$ expressed as components in $\mathcal{B}$.
e. The velocity ${}^{\mathcal{A}}\mathbf{v}_{P/O}$ and acceleration ${}^{\mathcal{A}}\mathbf{a}_{P/O}$ of P with respect to O in $\mathcal{A}$ expressed as components in $\mathcal{B}$.

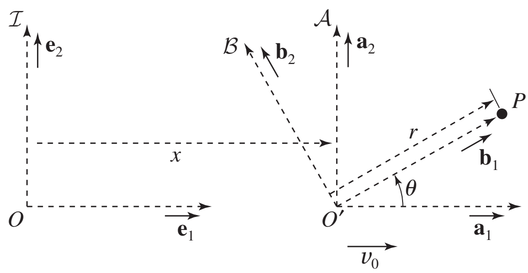

Figure 3.43 Problem 3.18.

3.24 Solve the equations of motion for the spring-pendulum system in the previous problem using MATLAB `ODE45` and plot the pendulum angle $\theta(t)$ and pendulum length $r(t)$ versus time. Assume that the pendulum is released with initial conditions $\theta(0) = \pi/4$, $\dot{\theta}(0) = 0$, $r(0) = l_0$, and $\dot{r}(0) = 0$, where l_0 is the rest length of the spring. Let $m = 1$ kg, $l_0 = 0.1$ m, and $k = 2$ N/m. Be sure to label your plots with units and include a legend.

3.28 Suppose a rocket with mass 10^4 kg propels itself at an angle of 30° above the horizontal using a thrust force of 2×10^7 N, as shown in Figure 3.46. Use a path frame to compute the magnitude of the tangential and normal components of the rocket's acceleration at the instant shown in the figure.

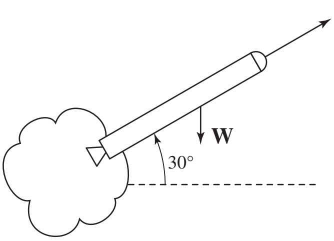

Figure 3.46 Problem 3.28.

3.32 Consider a race car being transported in a moving trailer, as shown in Figure 3.48. Suppose the trailer is traveling at 30 mph when it hits a bump that jostles the race car off of its blocks and opens the trailer ramp. The race car starts to accelerate down the trailer ramp, which is 1 m tall and 5 m long. What

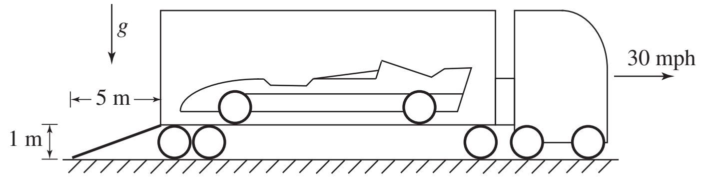

Figure 3.48 Problem 3.32.

is the inertial velocity of the car when it hits the ground? In what direction does it roll (left or right)? [HINT: Model the car as a point mass.]

3.36 Suppose a batter hits a fly ball that leaves his bat with speed v_0 at angle θ_0 with the horizontal (Figure 3.52). Assuming that the ball is initially at a height of h_0 above the ground and there is no air resistance, how high, h, does it go? How far, d, does it go?

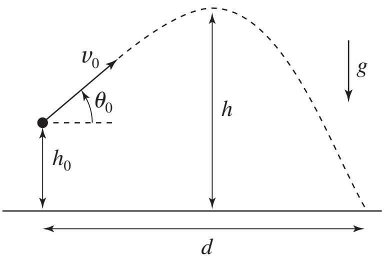

Figure 3.52 Problem 3.36.