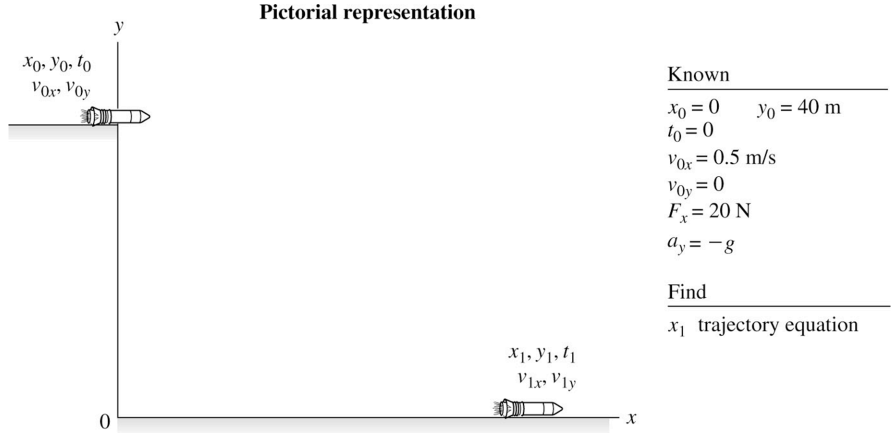
Solutions to HW14, Chapter 8

NOTE! The problems in masteringphysics.com had their numbers altered slightly for each individual student. The solutions below use the same numbers as those used in the book for that problem!

8.37. Model: The model rocket is treated as a particle and its motion is determined by constant-acceleration kinematic equations.
Visualize:

Pictorial representation



Solve: As the rocket is accidentally bumped $v_{0x} = 0.5$ m/s and $v_{0y} = 0$ m/s. On the other hand, when the engine is fired

$$F_x = ma_x \Rightarrow a_x = \frac{F_x}{m} = \frac{20\ \text{N}}{0.500\ \text{kg}} = 40\ \text{m/s}^2$$

(a) Using $y_1 = y_0 + v_{0y}(t_1 - t_0) + \frac{1}{2}a_y(t_1 - t_0)^2$,

$$0\ \text{m} = 40\ \text{m} + 0\ \text{m} + \tfrac{1}{2}(-9.8\ \text{m/s}^2)t_1^2 \Rightarrow t_1 = 2.857\ \text{s}$$

The distance from the base of the wall is

$$x_1 = x_0 + v_{0x}(t_1 - t_0) + \tfrac{1}{2}a_x(t_1 - t_0)^2 = 0\ \text{m} + (0.5\ \text{m/s})(2.857\ \text{s}) + \tfrac{1}{2}(40\ \text{m/s}^2)(2.857\ \text{s})^2 = 165\ \text{m}$$

(b) The *x*- and *y*-equations are

$$y = y_0 + v_{0y}(t - t_0) + \tfrac{1}{2}a_y(t - t_0)^2 = 40 - 4.9t^2$$

$$x = x_0 + v_{0x}(t - t_0) + \tfrac{1}{2}a_x(t - t_0)^2 = 0.5t + 20t^2$$

Except for a brief interval near $t = 0$, $20t^2$? $0.5t$. Thus $x \approx 20t^2$, or $t^2 = x/20$. Substituting this into the *y*-equation gives

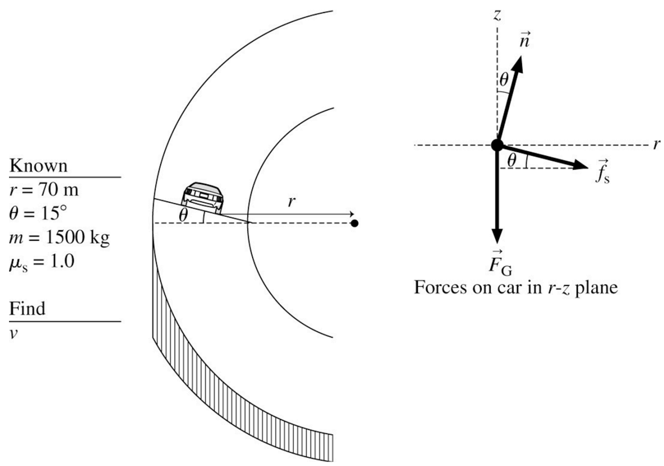
$$y = 40 - 0.245x$$

This is the equation of a straight line, so the rocket follows a linear trajectory to the ground.

8.40. Model: We will use the particle model for the car, which is undergoing uniform circular motion on a banked highway, and the model of static friction.

Visualize:

Pictorial representation



Note that we need to use the coefficient of static friction μ_s, which is 1.0 for rubber on concrete.

Solve: Newton's second law for the car is

$$\sum F_r = f_s \cos\theta + n\sin\theta = \frac{mv^2}{r} \quad \sum F_z = n\cos\theta - f_s \sin\theta - F_G = 0 \text{ N}$$

Maximum speed is when the static friction force reaches its maximum value $(f_s)_{max} = \mu_s n$. Then

$$n(\mu_s \cos 15° + \sin 15°) = \frac{mv^2}{r} \quad n(\cos 15° - \mu_s \sin 15°) = mg$$

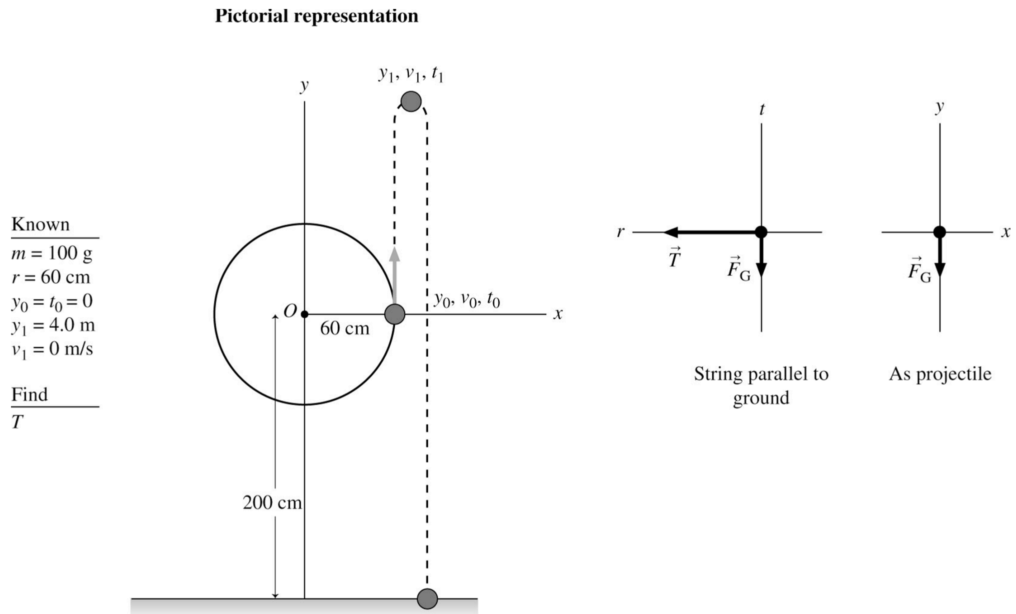
Dividing these two equations and simplifying, we get

$$\frac{\mu_s + \tan 15°}{1 - \mu_s \tan 15°} = \frac{v^2}{gr} \Rightarrow v = \sqrt{gr\frac{\mu_s + \tan 15°}{1 - \mu_s \tan 15°}}$$

$$= \sqrt{(9.80 \text{ m/s}^2)(70 \text{ m})\frac{(1.0 + 0.268)}{(1 - 0.268)}} = 34 \text{ m/s}$$

Assess: The above value of $34 \text{ m/s} \approx 70 \text{ mph}$ is reasonable.

8.59. Model: Model the ball as a particle undergoing circular motion in a vertical circle.
Visualize:



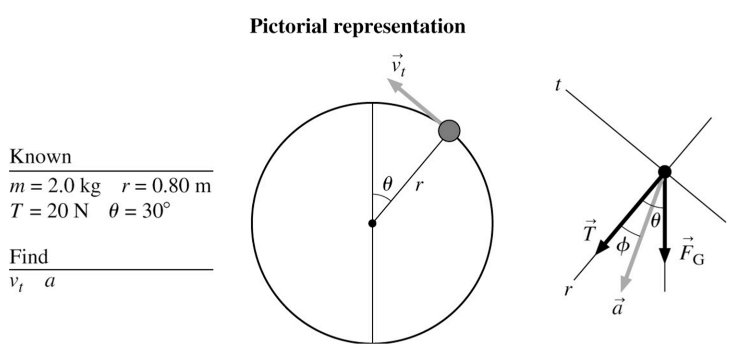
Solve: Initially, the ball is moving in circular motion. Once the string breaks, it becomes a projectile. The final circular-motion velocity is the initial velocity for the projectile, which we can find by using the kinematic equation

$$v_1^2 = v_0^2 + 2a_y(y_1 - y_0) \Rightarrow 0\ \text{m}^2/\text{s}^2 = (v_0)^2 + 2(-9.8\ \text{m/s}^2)(4.0\ \text{m} - 0\ \text{m}) \Rightarrow v_0 = 8.85\ \text{m/s}$$

This is the speed of the ball as the string broke. The tension in the string at that instant can be found by using the r-component of the net force on the ball:

$$\sum F_r = T = m\left(\frac{v_{0y}^2}{r}\right) \Rightarrow T = (0.100\ \text{kg})\frac{(8.85\ \text{m/s})^2}{0.60\ \text{m}} = 13\ \text{N}$$

8.63. Model: Assume the particle model for a ball in vertical circular motion.
Visualize:



Solve: (a) Newton's second law in the r- and t-directions is

$$(F_{\text{net}})_r = T + mg\cos\theta = ma_r = \frac{mv_t^2}{r} \quad (F_{\text{net}})_t = -mg\sin\theta = ma_t$$

Substituting into the r-component,

$$(20\ \text{N}) + (2.0\ \text{kg})(9.8\ \text{m/s}^2)\cos 30° = (2.0\ \text{kg})\frac{v_t^2}{(0.80\ \text{m})} \Rightarrow v_t = 3.85\ \text{m/s}$$

The tangential velocity is 3.8 m/s.

(b) Substituting into the t-component,

$$-(9.8\text{ m/s}^2)\sin 30° = a_t \Rightarrow a_t = -4.9\text{ m/s}^2$$

The radial acceleration is

$$a_r = \frac{v_t^2}{r} = \frac{(3.85\text{ m/s})^2}{0.80\text{ m}} = 18.5\text{ m/s}^2$$

Thus, the magnitude of the acceleration is

$$a = \sqrt{a_r^2 + a_t^2} = \sqrt{(18.5\text{ m/s}^2)^2 + (-4.9\text{ m/s}^2)^2} = 19.1\text{ m/s}^2 \approx 19\text{ m/s}^2$$

The angle of the acceleration vector from the r-axis is

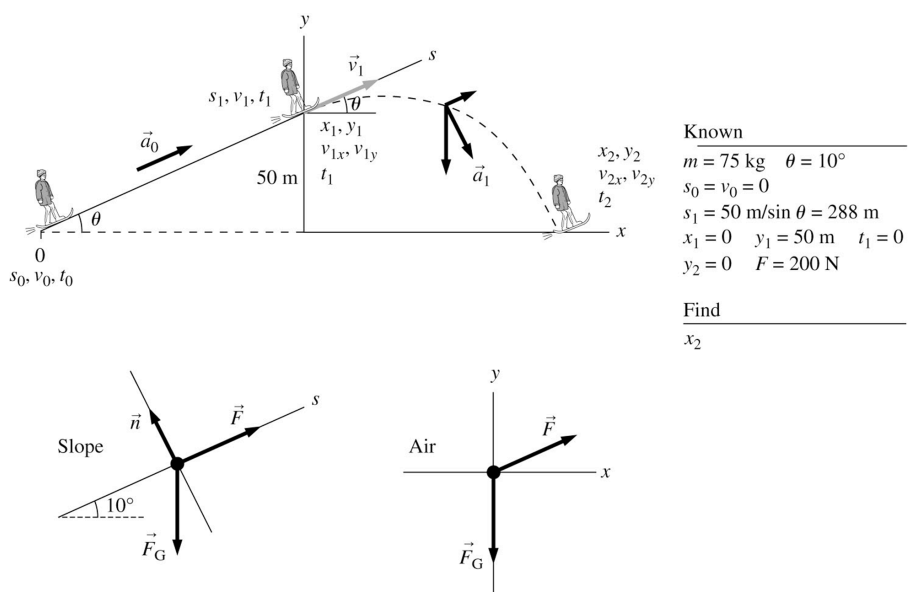
$$\theta = \tan^{-1}\frac{|a_t|}{a_r} = \tan^{-1}\frac{4.9}{18.5} = 14.8° \approx 15°$$

The angle is below the r-axis.

8.66. Model: Treat Sam as a particle.

Visualize: This is a two-part problem. Use an s-axis parallel to the slope for the first part, regular xy-coordinates for the second. Sam's final velocity at the top of the slope is his initial velocity as he becomes airborne.

Pictorial representation



Solve: Sam's acceleration up the slope is given by Newton's second law:

$$(F_{net})_s = F - mg\sin 10° = ma_0$$

$$a_0 = \frac{F}{m} - g\sin 10° = \frac{200\text{ N}}{75\text{ kg}} - (9.8\text{ m/s}^2)\sin 10° = 0.965\text{ m/s}^2$$

The length of the slope is $s_1 = (50\text{ m})/\sin 10° = 288\text{ m}$. His velocity at the top of the slope is

$$v_1^2 = v_0^2 + 2a_0(s_1 - s_0) = 2a_0 s_1 \Rightarrow v_1 = \sqrt{2(0.965\text{ m/s}^2)(288\text{ m})} = 23.6\text{ m/s}$$

This is Sam's initial speed into the air, giving him velocity components $v_{1x} = v_1\cos 10° = 23.2\text{ m/s}$ and $v_{1y} = v_1\sin 10° = 410\text{ m/s}$. This is not projectile motion because Sam experiences both the force of gravity *and* the thrust of his skis. Newton's second law for Sam's acceleration is

$$a_{1x} = \frac{(F_{\text{net}})_x}{m} = \frac{(200 \text{ N})\cos 10°}{75 \text{ kg}} = 2.63 \text{ m/s}^2$$

$$a_{1y} = \frac{(F_{\text{net}})_y}{m} = \frac{(200 \text{ N})\sin 10° - (75 \text{ kg})(9.80 \text{ m/s}^2)}{75 \text{ kg}} = -9.34 \text{ m/s}^2$$

The y-equation of motion allows us to find out how long it takes Sam to reach the ground:

$$y_2 = 0 \text{ m} = y_1 + v_{1y}t_2 + \tfrac{1}{2}a_{1y}t_2^2 = 50 \text{ m} + (4.10 \text{ m/s})t_2 - (4.67 \text{ m/s}^2)t_2^2$$

This quadratic equation has roots $t_2 = -2.86$ s (unphysical) and $t_2 = 3.74$ s. The x-equation of motion—this time with an acceleration—is

$$x_2 = x_1 + v_{1x}t_2 + \tfrac{1}{2}a_{1x}t_2^2 = 0 \text{ m} + (23.2 \text{ m/s})t_2 - \tfrac{1}{2}(2.63 \text{ m/s}^2)t_2^2 = 105 \text{ m}$$

Sam lands 105 m from the base of the cliff.