Unit 3 – Newton’s Second Law Post-Lecture

A net force of 40.0 N acts on a body that has a weight of 9.00 N. What is the mass of the body? What is its acceleration?

$$w = mg \qquad \therefore\ m = \frac{w}{g} = \frac{9.00\ \text{N}}{9.80\ \text{m/s}^2} = \boxed{0.918\ \text{kg}}$$

$$F = ma \qquad \therefore\ a = \frac{F}{m} = \frac{40.0\ \text{N}}{0.918\ \text{kg}} = \boxed{43.6\ \text{m/s}^2}$$

A net force of 40.0 N also acts on a body that has a mass of 14.0 kg. What is the weight of the body? What is its acceleration?

$$w = mg = (14.0\ \text{kg})(9.80\ \text{m/s}^2) = \boxed{137\ \text{N}}$$

$$a = \frac{F}{m} = \frac{40.0\ \text{N}}{14.0\ \text{kg}} = \boxed{2.86\ \text{m/s}^2}$$

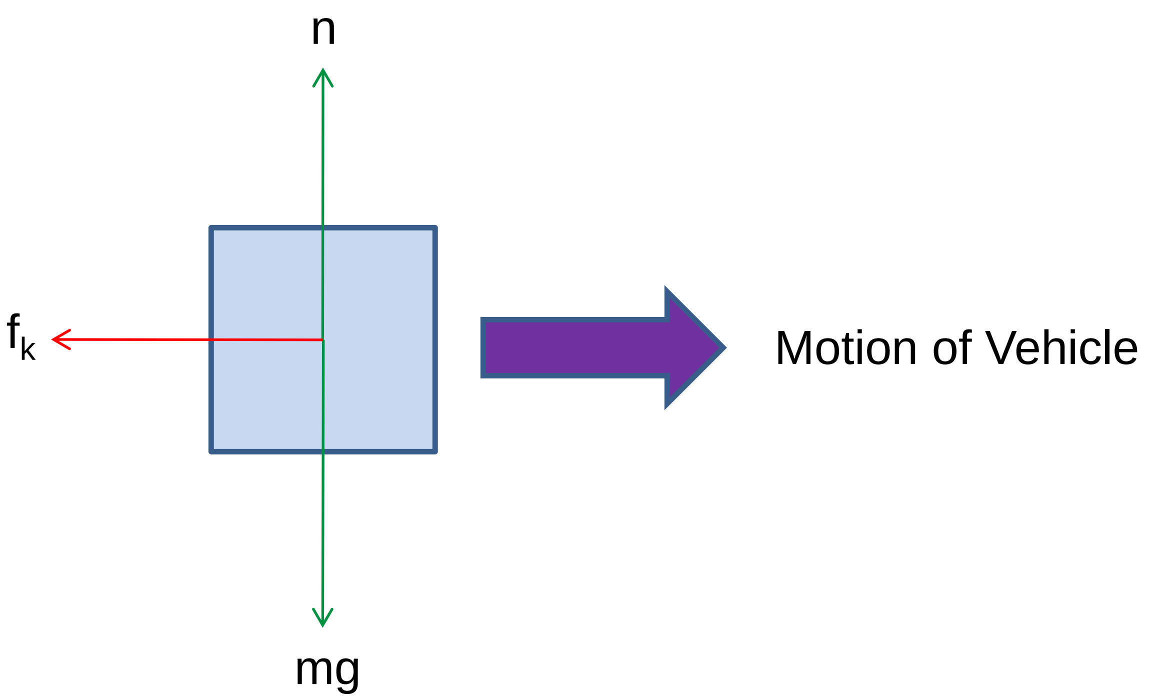
A 1000.0 kg stockcar is traveling 270.0 km/hr. What resultant force is required to stop the car in a distance of 0.750 m?

$$v_o = \left(\frac{270.0\ \cancel{\text{km}}}{\cancel{\text{hr}}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{3600\ \text{s}}\right) = 75.0\ \text{m/s}$$

$$a = \frac{v^2 - v_o^{\ 2}}{2x} = \left[\frac{(0\ \text{m/s})^2 - (75.0\ \text{m/s})^2}{2(0.750\ \text{m})}\right] = -3750\ \text{m/s}^2$$

$$F = ma = (1000.0\ \text{kg})\left(-3750\ \text{m/s}^2\right) = \boxed{-3.75 \text{ x } 10^6\ \text{N}}$$

Assuming a coefficient of friction of 0.860 for rubber on asphalt, determine the minimum stopping distance for a 1530 kg vehicle moving at 180.0 km/hr.


n
fk
mg
Motion of Vehicle

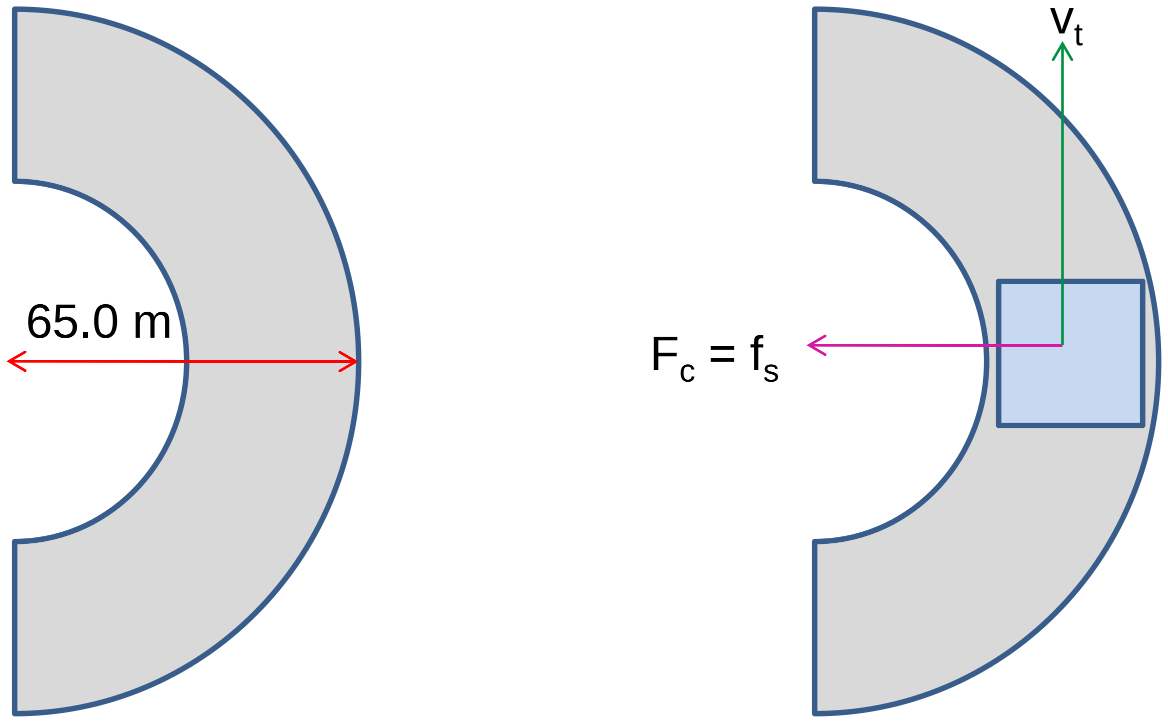
$$v_o = \left(\frac{180.0\ \cancel{\text{km}}}{\cancel{\text{hr}}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{3600\ \text{s}}\right) = 50.0\ \text{m/s}$$

$$\Sigma F_y = n - mg = 0 \qquad \therefore\ n = mg = \left(1530\ \text{kg}\right)g = 15,\bar{0}00\ \text{N}$$

$$\Sigma F_x = -f_k = ma = -\mu_k mg \qquad \therefore\ a = -\mu_k g = -\left(0.860\right)g = -8.43\ \text{m/s}^2$$

$$x = \frac{v^2 - \text{v}_o{}^2}{2a} = \left[\frac{\left(0\ \text{m/s}\right)^2 - \left(50.0\ \text{m/s}\right)^2}{2\left(-8.43\ \text{m/s}^2\right)}\right] = \boxed{148\ \text{m}}$$

Calculate the maximum speed a car can negotiate a curve of radius 65.0 m without side slipping. (Assume the μ_s is 0.750)



65.0 m
v_t
$F_c = f_s$

$$F_c = ma_c = \frac{mv^2}{r} = f_s = \mu_s n = \mu_s mg$$

$$\therefore \frac{mv^2}{r} = \mu_s mg \qquad \therefore \frac{v^2}{r} = \mu_s g$$

$$\therefore v = \sqrt{\mu_s gr} = \sqrt{(0.750)(g)(65.0 \text{ m})} = \boxed{21.9 \text{ m/s}}$$

A car can negotiate a curve of radius 65.0 m without side slipping. (Assume the μ_s is 0.750.) If the car weighs 13,500 N, calculate the centripetal force.

$$F_c = \mu_s mg = (0.750)mg = (0.750)w$$

$$\therefore\ F_c = (0.750)(13{,}500\ \text{N}) = \boxed{10{,}100\ \text{N}}$$

What coefficient of friction is required to maintain a speed of 65.0 mph around a flat curve of radius 295 ft?

$$v = \left(\frac{65.0\ \cancel{\text{mi}}}{\cancel{\text{hr}}}\right)\left(\frac{1609\ \text{m}}{1\ \cancel{\text{mi}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{3600\ \text{s}}\right) = 29.1\ \text{m/s}$$

$$r = 295\ \cancel{\text{ft}} \cdot \left(\frac{1\ \cancel{\text{mi}}}{5280\ \cancel{\text{ft}}}\right)\left(\frac{1609\ \text{m}}{1\ \cancel{\text{mi}}}\right) = 89.9\ \text{m}$$

$$F_c = \frac{mv^2}{r} = \mu_s mg \qquad \therefore\ \frac{v^2}{r} = \mu_s g$$

$$\therefore\ \mu_s = \frac{v^2}{gr} = \frac{\left(29.1\ \text{m/s}\right)^2}{g\left(89.9\ \text{m}\right)} = \boxed{0.961}$$

An airboat with mass 3.50×10^2 kg, including the passenger, has an engine that produces a net horizontal force of 7.70×10^2 N, after accounting for forces of resistance (*as in lecture Figure 4.6*).

(a) Find the acceleration of the airboat.

(b) Starting from rest, how long does it take the airboat to reach a speed of 12.0 m/s? After reaching that speed, the pilot turns off the engine and drifts to a stop over a distance of 50.0 m. **(c)** Find the resistance force, assuming it's a constant.

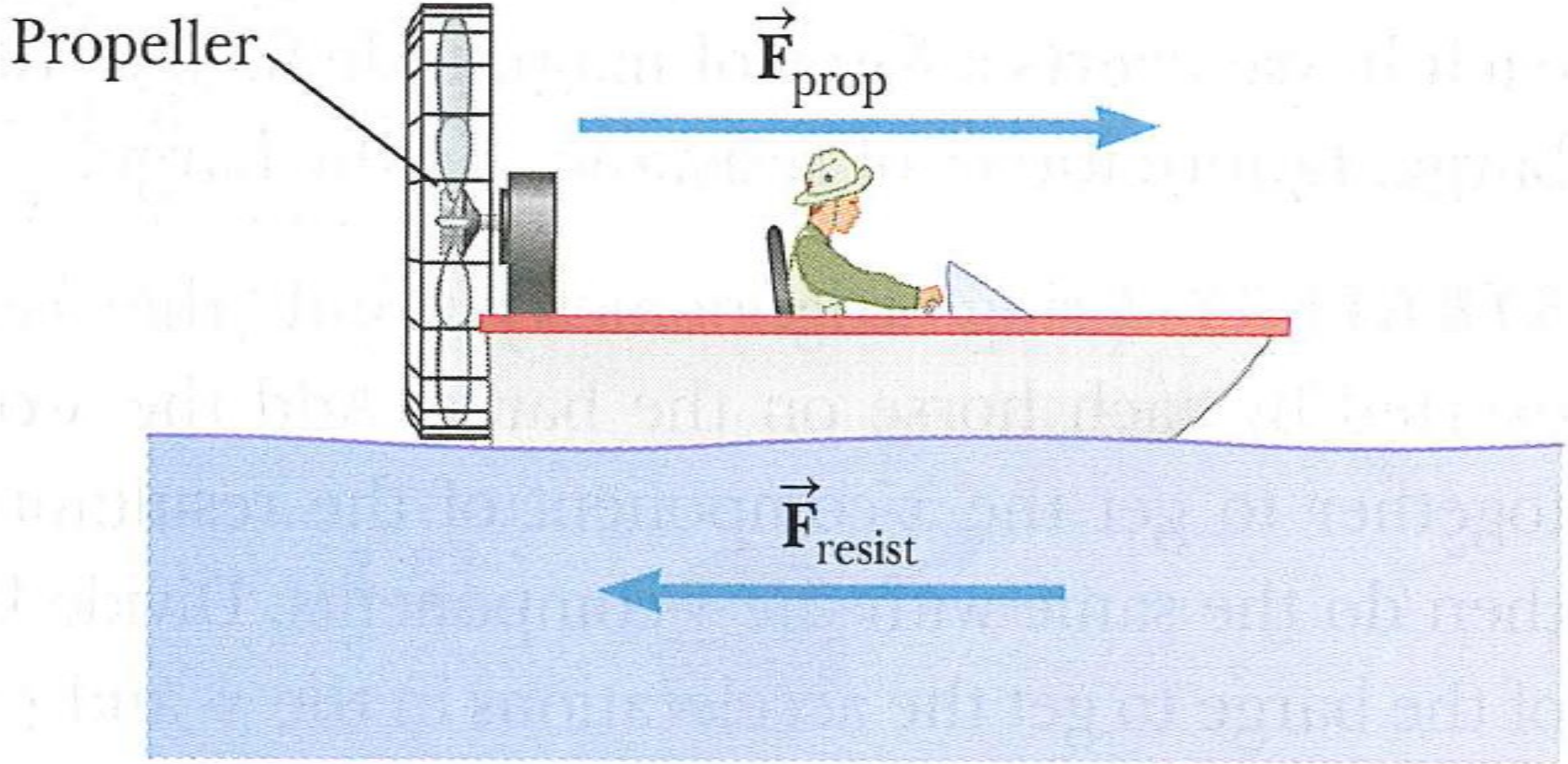


Figure 4.6

Photos/Illustrations courtesy of *College Physics*, 9th edition.

$$F_{net} = ma \qquad \therefore \quad a = \frac{F_{net}}{m} = \frac{77\bar{0}\ \text{N}}{35\bar{0}\ \text{kg}} = \boxed{2.20\ \text{m/s}^2}$$

$$v = v_0 + at = 12.0 \text{ m/s} = \left(0 \text{ m/s}\right) + \left(2.20 \text{ m/s}^2\right)\left(t\right)$$

$$\therefore \; t = \boxed{5.45 \text{ s}}$$

$$v^2 = v_0^{\ 2} + 2a\Delta x = \left(0 \text{ m/s}\right)^2 = \left(12.0 \text{ m/s}\right)^2 + 2\left(a\right)\left(50.0 \text{ m}\right)$$

$$\therefore \quad a = -1.44 \text{ m/s}^2$$

$$F_{net} = ma = \left(35\overline{0} \text{ kg}\right)\left(-1.44 \text{ m/s}^2\right) = \boxed{-504 \text{ N}}$$

Two horses are pulling a barge with mass $20\bar{0}0$ kg along a canal (*as shown similarly in lecture Figure 4.7*). The cable connected to the first horse makes an angle of θ_1 = 30.0° with respect to the direction of the canal, while the cable connected to the second horse makes an angle of θ_2 = -45.0° Find the initial acceleration of the barge [both

(a) magnitude and

(b) direction], starting from rest, if each horse exerts a force of magnitude 600. N on the barge. Ignore forces of resistance on the barge.

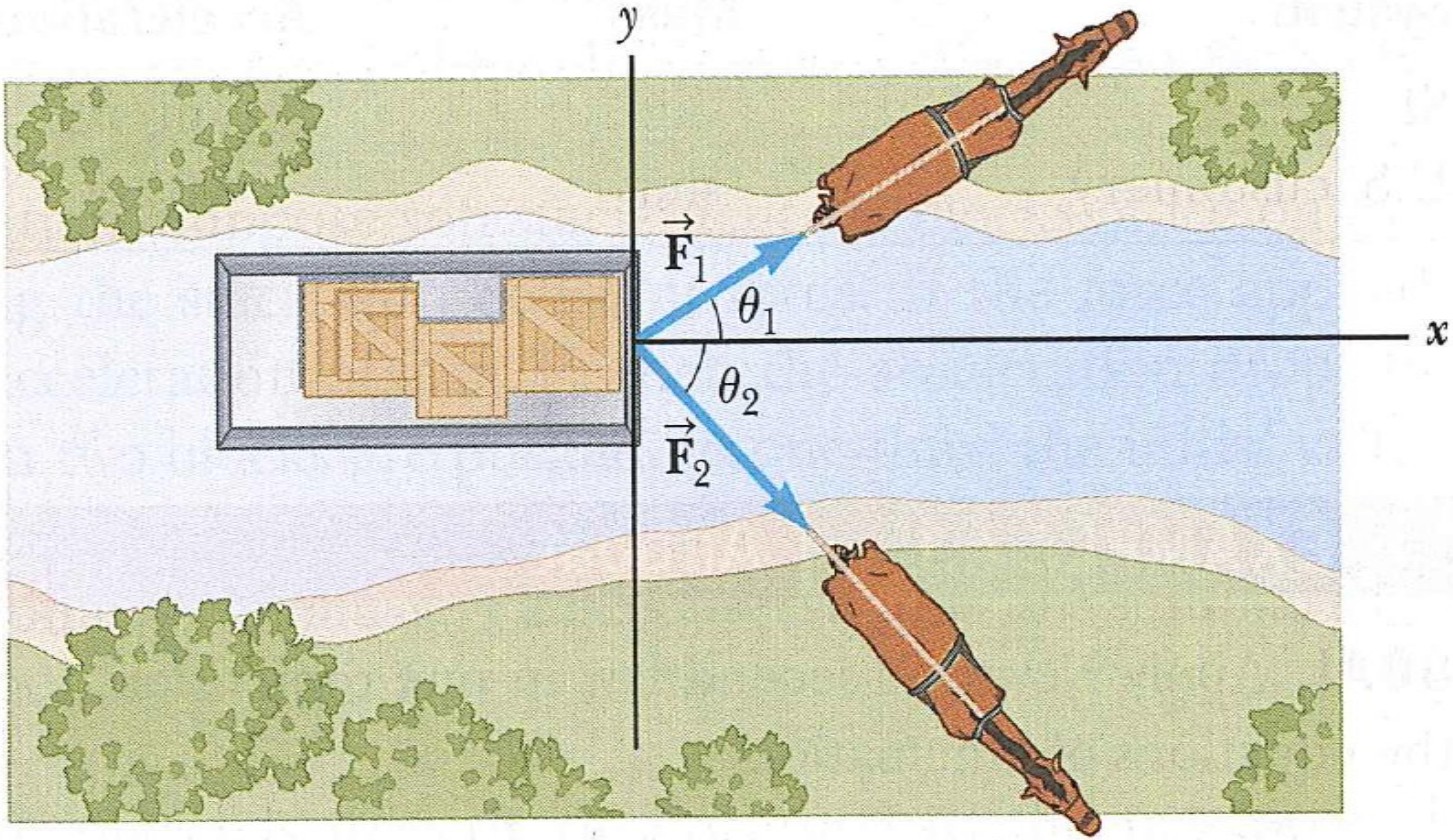


Figure 4.7

Photos/Illustrations courtesy of *College Physics*, 9th edition.

$$F_{1x} = F_1(\cos\theta_1) = (60\bar{0}\ \mathrm{N})(\cos\ 30.0°) = 52\bar{0}\ \mathrm{N}$$

$$F_{2x} = F_2(\cos\theta_2) = (60\bar{0}\ \mathrm{N})(\cos\ -45.0°) = 424\ \mathrm{N}$$

$$F_x = F_{1x} + F_{2x} = (52\bar{0}\ \mathrm{N}) + (424\ \mathrm{N}) = 944\ \mathrm{N}$$

$$F_{1y} = F_1(\sin\theta_1) = (60\bar{0}\ \mathrm{N})(\sin\ 30.0°) = 30\bar{0}\ \mathrm{N}$$

$$F_{2y} = F_2(\sin\theta_2) = (60\bar{0}\ \mathrm{N})(\sin\ -45.0°) = -424\ \mathrm{N}$$

$$F_y = F_{1y} + F_{2y} = (30\bar{0}\ \mathrm{N}) + (-424\ \mathrm{N}) = -124\ \mathrm{N}$$

$$a_x = \frac{F_x}{m} = \frac{944\ \text{N}}{20\overline{0}0\ \text{kg}} = 0.472\ \text{m/s}^2$$

$$a_y = \frac{F_y}{m} = \frac{-124\ \text{N}}{20\overline{0}0\ \text{kg}} = -0.0620\ \text{m/s}^2$$

$$a = \sqrt{a_x{}^2 + a_y{}^2} = \sqrt{\left(0.472\ \text{m/s}^2\right)^2 + \left(-0.0620\ \text{m/s}^2\right)^2} = \boxed{0.476\ \text{m/s}^2}$$

$$\tan\theta = \frac{a_y}{a_x} = \frac{-0.0620\ \text{m/s}^2}{0.472\ \text{m/s}^2} = \boxed{-7.48°}$$

A traffic light weighing 100. N hangs from a vertical cable tied to two other cables that are fastened to a support (*as shown similarly in lecture Figure 4.14*). The upper cables make angles of 37.0° (with T_1) and 53.0° (with T_2). Find the tension in

(a) T_1,
(b) T_2, and
(c) T_3.

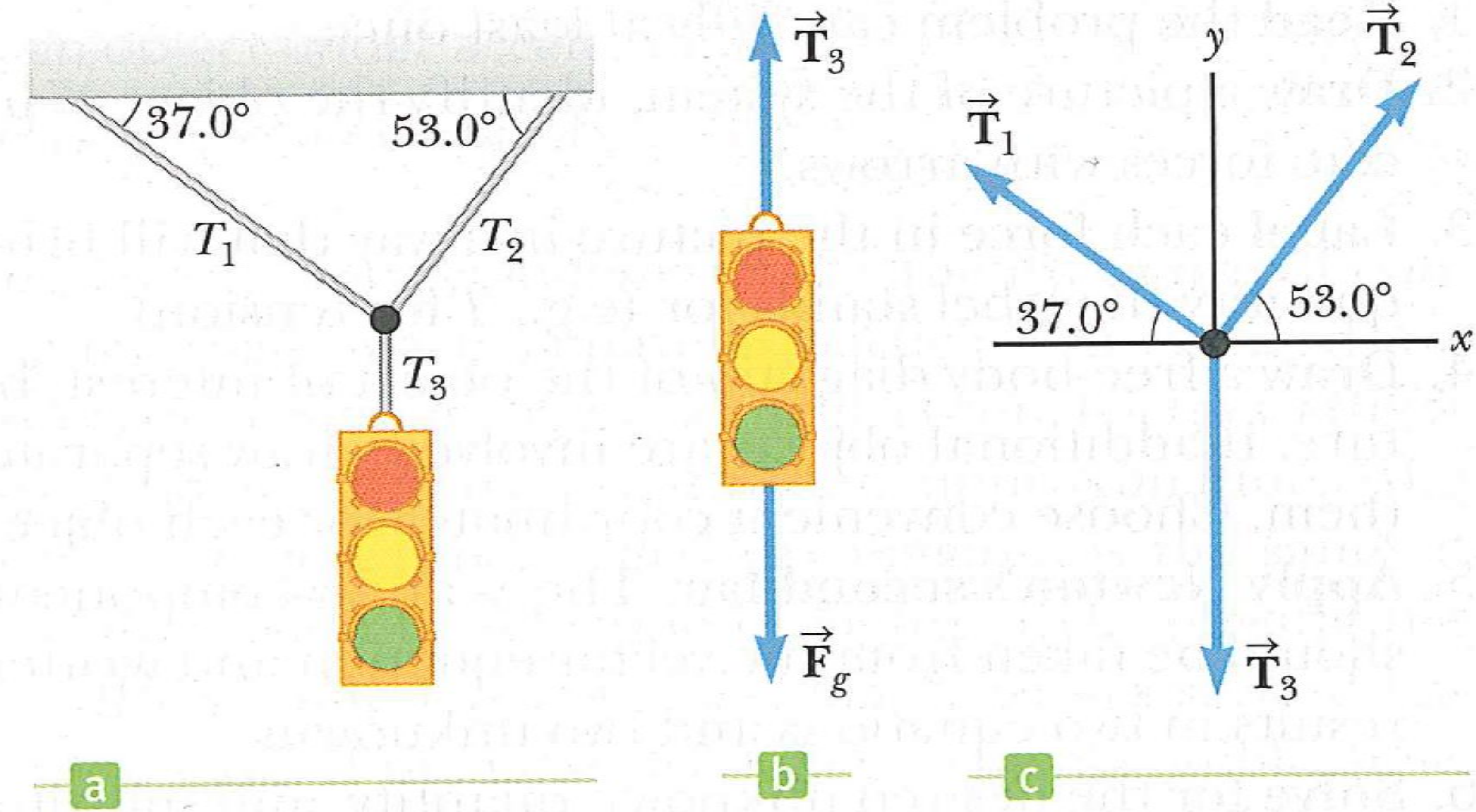


Figure 4.14

Photos/Illustrations courtesy of *College Physics*, 9th edition.

$$\Sigma F_y = 0 = T_3 - F_g \qquad \therefore \quad T_3 = F_g = \boxed{10\bar{0}\text{ N}}$$

$$\Sigma F_x = T_2\left(\cos\ 53.0°\right) - T_1\left(\cos\ 37.0°\right) = 0$$

$$T_2 = T_1\left(\frac{\cos\ 37.0°}{\cos\ 53.0°}\right) = T_1\left(1.33\right)$$

$$\Sigma F_y \;=\; T_1\left(\sin\;37.0°\right) \;+\; T_2\left(\sin 53.0°\right) - 10\bar{0}\text{ N} \;=\; 0$$

$$\Sigma F_y \;=\; T_1\left(\sin\;37.0°\right) \;+\; T_1\left(1.33\right)\left(\sin 53.0°\right) - 10\bar{0}\text{ N} \;=\; 0$$

$$\Sigma F_y \;=\; T_1\left(0.602\right) \;+\; T_1\left(1.06\right) \;=\; 10\bar{0}\text{ N}$$

$$\Sigma F_y \;=\; T_1\left(1.66\right) \;=\; 10\bar{0}\text{ N}$$

$$\therefore \quad T_1 \;=\; \boxed{60.2\text{ N}}$$

$$T_2 \;=\; T_1\left(1.33\right) \;=\; \left(60.2\text{ N}\right)\left(1.33\right) \;=\; \boxed{80.1\text{ N}}$$

A car travels at a constant speed of 30.0 mi/h on a level circular turn of radius 50.0 m, as shown in the bird's eye view (*as in lecture Figure 7.13*).

(a) What minimum coefficient of static friction, μ_s, between the tires and roadway will allow the car to make the circular turn without sliding?

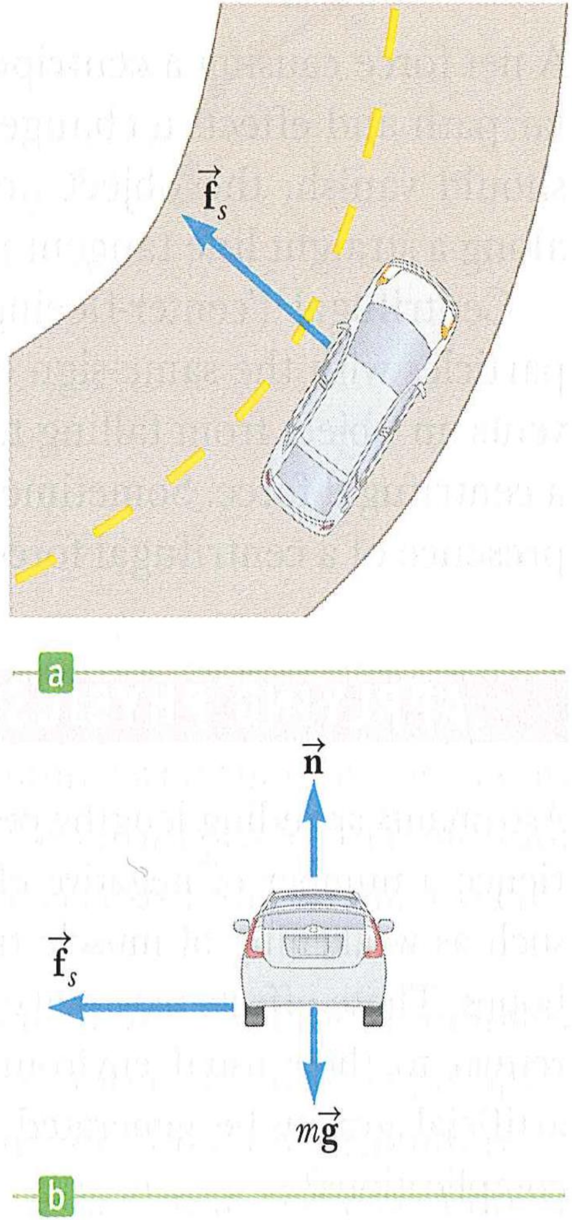


Figure 7.13

Photos/Illustrations courtesy of *College Physics*, 9th edition.

$$F_c = \frac{mv^2}{r} = f_s = \mu_s n \qquad n - mg = 0 \qquad \therefore \ n = mg$$

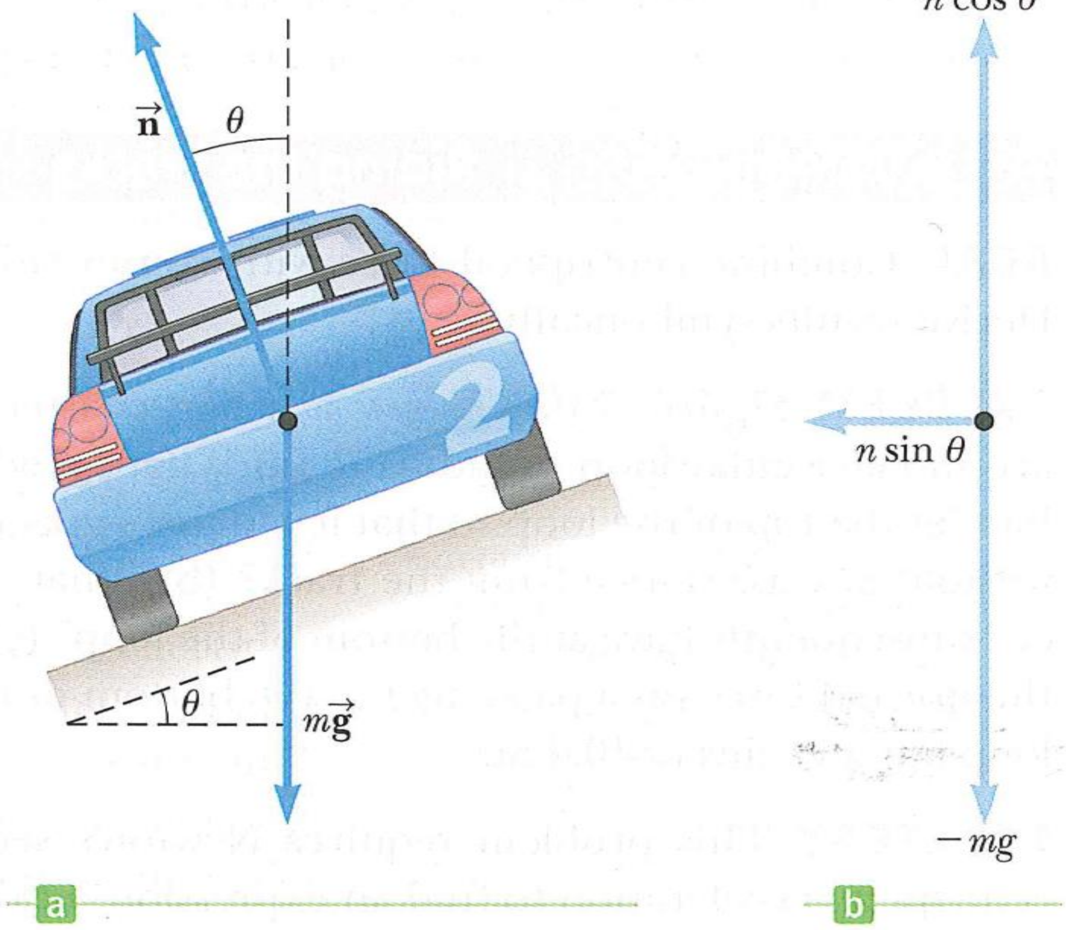
$$\therefore \ \frac{mv^2}{r} = f_s = \mu_s mg \qquad \therefore \ \frac{\cancel{m}v^2}{r} = \mu_s \cancel{m}g \qquad \therefore \ \mu_s = \frac{v^2}{rg}$$

$$\therefore \ \mu_s = \frac{v^2}{rg} = \frac{\left[\left(\frac{30.0\ \cancel{\text{mi}}}{\cancel{\text{hr}}}\right)\left(\frac{1609\ \text{m}}{1\ \cancel{\text{mi}}}\right)\left(\frac{1\ \cancel{\text{hr}}}{3600\ \text{s}}\right)\right]^2}{(50.0\ \text{m})(9.80\ \text{m/s}^2)} = \boxed{0.367}$$

The Daytona International Speedway is famous for its high banked, high speed races. The track features 31.0 ° banked curves with a maximum radius of 316 m. If a pace car negotiates the curve too slowly, it tends to slip down the incline of the turn, whereas if it's going too fast, it may begin to slide up the incline (*as in lecture Figure 7.14*).

(a) Find the necessary centripetal acceleration so the pace car won't slip down or slide up the incline.
(b) Calculate the speed of the car (in mph).

Figure 7.14



Photos/Illustrations courtesy of *College Physics*, 9th edition.

$$ma = \Sigma F = n + mg$$

$$n(\cos\theta) - mg = 0 \qquad \therefore \; n = \frac{mg}{(\cos\theta)}$$

$$F_c = n(\sin\theta) = \frac{mg(\sin\theta)}{(\cos\theta)} = mg(\tan\theta)$$

$$F_c = ma_c \qquad \therefore \; a_c = \frac{F_c}{m} = \frac{\cancel{m}g(\tan\theta)}{\cancel{m}} = g(\tan\theta)$$

$$a_c = \left(9.80 \text{ m/s}^2\right)\left(\tan\ 31.0°\right) = \boxed{5.89 \text{ m/s}^2}$$

$$a_c = \frac{v^2}{r}$$

$$\therefore \quad v = \sqrt{r a_c} = \sqrt{(316\text{ m})(5.89\text{ m/s}^2)} = 43.1\text{ m/s}$$

$$?\text{ mph} = \left(\frac{43.1\text{ m}}{\text{s}}\right)\left(\frac{1\text{ mi}}{1609\text{ m}}\right)\left(\frac{3600\text{ s}}{1\text{ hr}}\right) = \boxed{96.4\text{ mph}}$$