43. The magnitude of the acceleration of the cyclist as it rounds the curve is given by $v^2/R$, where $v$ is the speed of the cyclist and $R$ is the radius of the curve. Since the road is horizontal, only the frictional force of the road on the tires makes this acceleration possible. The horizontal component of Newton's second law is $f = mv^2/R$. If $F_N$ is the normal force of the road on the bicycle and $m$ is the mass of the bicycle and rider, the vertical component of Newton's second law leads to $F_N = mg$. Thus, using Eq. 6-1, the maximum value of static friction is

$$f_{s,\max} = \mu_s F_N = \mu_s mg.$$

If the bicycle does not slip, $f \le \mu_s mg$. This means

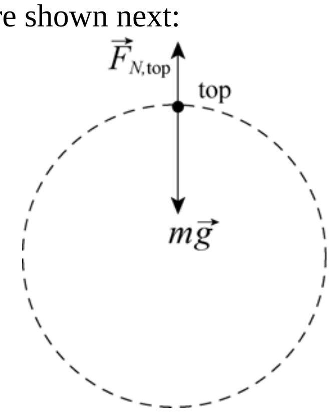
$$\frac{v^2}{R} \le \mu_s g \quad \Rightarrow \quad R \ge \frac{v^2}{\mu_s g}.$$

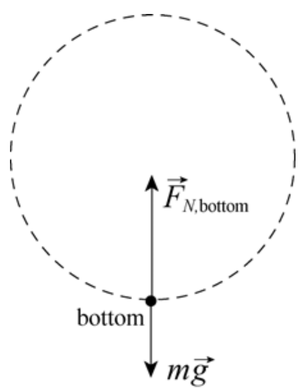
Consequently, the minimum radius with which a cyclist moving at 29 km/h = 8.1 m/s can round the curve without slipping is

$$R_{\min} = \frac{v^2}{\mu_s g} = \frac{(8.1\text{ m/s})^2}{(0.32)(9.8\text{ m/s}^2)} = 21\text{ m}.$$

45. **THINK** Ferris wheel ride is a vertical circular motion. The apparent weight of the rider varies with his position.

**EXPRESS** The free-body diagrams of the student at the top and bottom of the Ferris wheel are shown next:




At the top (the highest point in the circular motion) the seat pushes up on the student with a force of magnitude $F_{N,\text{top}}$, while the Earth pulls down with a force of magnitude $mg$. Newton's second law for the radial direction gives

$$mg - F_{N,\text{top}} = \frac{mv^2}{R}.$$

At the bottom of the ride, $F_{N,\text{bottom}}$ is the magnitude of the upward force exerted by the seat. The net force toward the center of the circle is (choosing upward as the positive direction):

$$F_{N,\text{bottom}} - mg = \frac{mv^2}{R}.$$

The Ferris wheel is "steadily rotating" so the value $F_c = mv^2 / R$ is the same everywhere. The apparent weight of the student is given by $F_N$.

**ANALYZE** (a) At the top, we are told that $F_{N,\text{top}}$ = 556 N and $mg$ = 667 N. This means that the seat is pushing up with a force that is smaller than the student's weight, and we say the student experiences a decrease in his "apparent weight" at the highest point. Thus, he feels "light."

(b) From (a), we find the centripetal force to be

$$F_c = \frac{mv^2}{R} = mg - F_{N,\text{top}} = 667\text{ N} - 556\text{ N} = 111\text{ N}.$$

Thus, the normal force at the bottom is

$$F_{N,\text{bottom}} = \frac{mv^2}{R} + mg = F_c + mg = 111\text{ N} + 667\text{ N} = 778\text{ N}.$$

(c) If the speed is doubled,

$$F_c' = \frac{m(2v)^2}{R} = 4(111\text{ N}) = 444\text{ N}.$$

Therefore, at the highest point we have

$$F'_{N,\text{top}} = mg - F_c' = 667\text{ N} - 444\text{ N} = 223\text{ N}.$$

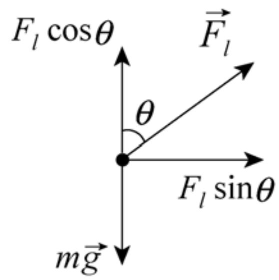
(d) Similarly, the normal force at the lowest point is now found to be

$$F'_{N,\text{bottom}} = F_c' + mg = 444\text{ N} + 667\text{ N} = 1111\text{ N}.$$

**LEARN** The apparent weight of the student is the greatest at the bottom and smallest at the top of the ride. The speed $v = \sqrt{gR}$ would result in $F_{N,\text{top}} = 0$, giving the student a sudden sensation of "weightlessness" at the top of the ride.

51. **THINK** An airplane with its wings tilted at an angle is in a circular motion. Centripetal force is involved in this problem.

**EXPRESS** The free-body diagram for the airplane of mass $m$ is shown to the right. We note that $\vec{F}_l$ is the force of aerodynamic lift and $\vec{a}$ points rightwards in the figure. We also note that $|\vec{a}| = v^2 / R$. Applying Newton's law to the axes of the problem (+$x$ rightward and +$y$ upward) we obtain




$$F_l \sin\theta = m\frac{v^2}{R}$$
$$F_l \cos\theta = mg$$

Eliminating mass from these equations leads to $\tan\theta = \frac{v^2}{gR}$. The equation allows us to solve for the radius $R$.

**ANALYZE** With $v$ = 480 km/h = 133 m/s and $\theta$ = 40°, we find

$$R = \frac{v^2}{g\tan\theta} = \frac{(133\,\text{m/s})^2}{(9.8\,\text{m/s}^2)\tan 40°} = 2151\text{ m} \approx 2.2\times 10^3\text{ m}.$$

**LEARN** Our approach to solving this problem is identical to that discussed in the Sample Problem – "Car in banked circular turn." Do you see the similarities?

56. We refer the reader to Sample Problem – "Car in banked circular turn," and use the result Eq. 6-26:

$$\theta = \tan^{-1}\left(\frac{v^2}{gR}\right)$$

with $v$ = 60(1000/3600) = 17 m/s and $R$ = 200 m. The banking angle is therefore $\theta$ = 8.1°. Now we consider a vehicle taking this banked curve at $v'$ = 40(1000/3600) = 11 m/s. Its (horizontal) acceleration is $a' = v'^2/R$, which has components parallel the incline and perpendicular to it:

$$a_{||} = a'\cos\theta = \frac{v'^2\cos\theta}{R}$$
$$a_{\perp} = a'\sin\theta = \frac{v'^2\sin\theta}{R}.$$

These enter Newton's second law as follows (choosing downhill as the +$x$ direction and away-from-incline as +$y$):

$$mg\sin\theta - f_s = ma_{||}$$
$$F_N - mg\cos\theta = ma_{\perp}$$

and we are led to

$$\frac{f_s}{F_N} = \frac{mg\sin\theta - mv'^2\cos\theta/R}{mg\cos\theta + mv'^2\sin\theta/R}.$$

We cancel the mass and plug in, obtaining $f_s/F_N$ = 0.078. The problem implies we should set $f_s = f_{s,\max}$ so that, by Eq. 6-1, we have $\mu_s$ = 0.078.

57. For the puck to remain at rest the magnitude of the tension force $T$ of the cord must equal the gravitational force $Mg$ on the cylinder. The tension force supplies the centripetal force that keeps the puck in its circular orbit, so $T = mv^2/r$. Thus $Mg = mv^2/r$. We solve for the speed:

$$v = \sqrt{\frac{Mgr}{m}} = \sqrt{\frac{(2.50\ \text{kg})(9.80\ \text{m/s}^2)(0.200\ \text{m})}{1.50\ \text{kg}}} = 1.81\ \text{m/s}.$$