

Physics 107 HOMEWORK ASSIGNMENT #5

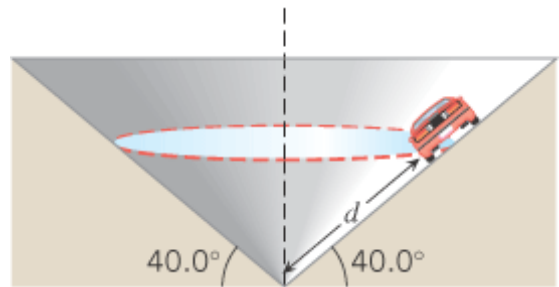
Cutnell & Johnson, 7th edition

Chapter 5: Problems 18, 23, 24, 32, 38

***18** A block is hung by a string from the inside roof of a van. When the van goes straight ahead at a speed of 28 m/s, the block hangs vertically down. But when the van maintains this same speed around an unbanked curve (radius = 150 m), the block swings toward the outside of the curve. Then the string makes an angle θ with the vertical. Find θ .

23 Before attempting this problem, review Examples 7 and 8. Two curves on a highway have the same radii. However, one is unbanked and the other is banked at an angle θ . A car can safely travel along the unbanked curve at a maximum speed v_0 under conditions when the coefficient of static friction between the tires and the road is μ_s . The banked curve is frictionless, and the car can negotiate it at the same maximum speed v_0 . Find the angle θ of the banked curve.

***24** As an aid in working this problem, first consult [Interactive Solution 5.24](#). A racetrack has the shape of an inverted cone, as the drawing shows. On this surface the cars race in circles that are parallel to the ground. For a speed of 34.0 m/s, at what value of the distance d should a driver locate his car if he wishes to stay on a circular path without depending on friction?



***32** The earth orbits the sun once per year at the distance of 1.50×10^{11} m. Venus orbits the sun at a distance of 1.08×10^{11} m. These distances are between the centers of the planets and the sun. How long (in earth days) does it take for Venus to make one orbit around the sun?

38 Pilots of high-performance fighter planes can be subjected to large centripetal accelerations during high-speed turns. Because of these accelerations, the pilots are subjected to forces that can be much greater than their body weight, leading to an accumulation of blood in the abdomen and legs. As a result, the brain becomes starved for blood, and the pilot can lose consciousness (“black out”). The pilots wear “anti-G suits” to help keep the blood from draining out of the brain. To appreciate the forces that a fighter pilot must endure, consider the magnitude F_N of the normal force that the pilot’s seat exerts on him at the bottom of a dive. The magnitude of the pilot’s weight is W . The plane is traveling at 230 m/s on a vertical circle of radius 690 m. Determine the ratio F_N/W . For comparison, note that black-out can occur for values of F_N/W as small as 2 if the pilot is not wearing an anti-G suit.

18. **REASONING AND SOLUTION** The centripetal acceleration of the block is

$$a_c = v^2/r = (28 \text{ m/s})^2/(150 \text{ m}) = 5.2 \text{ m/s}^2$$

The angle θ can be obtained from

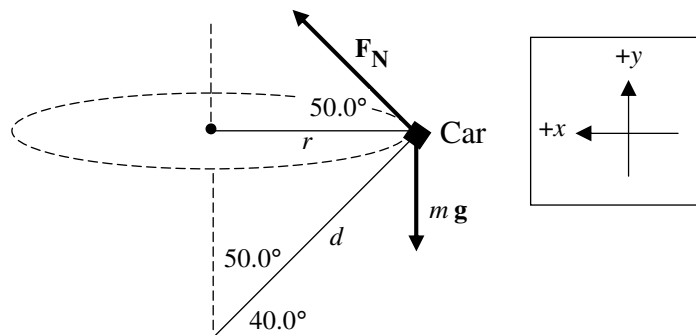
$$\theta = \tan^{-1}\left(\frac{a_c}{g}\right) = \tan^{-1}\left(\frac{5.2 \text{ m/s}^2}{9.80 \text{ m/s}^2}\right) = \boxed{28^\circ}$$

23. **REASONING** From the discussion on banked curves in Section 5.4, we know that a car can safely round a banked curve without the aid of static friction if the angle θ of the banked curve is given by $\tan \theta = v_0^2/(rg)$, where v_0 is the speed of the car and r is the radius of the curve (see Equation 5.4). The maximum speed that a car can have when rounding an unbanked curve is $v_0 = \sqrt{\mu_s g r}$ (see Example 7). By combining these two relations, we can find the angle θ .

SOLUTION The angle of the banked curve is $\theta = \tan^{-1}[v_0^2/(rg)]$. Substituting the expression $v_0 = \sqrt{\mu_s g r}$ into this equation gives

$$\theta = \tan^{-1}\left(\frac{v_0^2}{rg}\right) = \tan^{-1}\left(\frac{\mu_s g r}{rg}\right) = \tan^{-1}(\mu_s) = \tan^{-1}(0.81) = \boxed{39^\circ}$$

24. **REASONING** The distance d is related to the radius r of the circle on which the car travels by $d = r/\sin 50.0^\circ$ (see the drawing).



We can obtain the radius by noting that the car experiences a centripetal force that is directed toward the center of the circular path. This force is provided by the component, $F_N \cos 50.0^\circ$, of the normal force that is parallel to the radius. Setting this force equal to the mass m of the car times the centripetal acceleration ($a_c = v^2/r$) gives $F_N \cos 50.0^\circ = ma_c = mv^2/r$. Solving for the radius r and substituting it into the relation $d = r/\sin 50.0^\circ$ gives

$$d = \frac{r}{\sin 50.0^\circ} = \frac{\frac{mv^2}{F_N \cos 50.0^\circ}}{\sin 50.0^\circ} = \frac{mv^2}{(F_N \cos 50.0^\circ)(\sin 50.0^\circ)} \quad (1)$$

The magnitude F_N of the normal force can be obtained by observing that the car has no vertical acceleration, so the net force in the vertical direction must be zero, $\sum F_y = 0$. The net force consists of the upward vertical component of the normal force and the downward weight of the car. The vertical component of the normal force is $+F_N \sin 50.0^\circ$, and the weight is $-mg$, where we have chosen the “up” direction as the + direction. Thus, we have that

$$\underbrace{+F_N \sin 50.0^\circ - mg}_{\sum F_y} = 0 \quad (2)$$

Solving this equation for F_N and substituting it into the equation above will yield the distance d .

SOLUTION Solving Equation (2) for F_N and substituting the result into Equation (1) gives

$$\begin{aligned} d &= \frac{mv^2}{(F_N \cos 50.0^\circ)(\sin 50.0^\circ)} = \frac{mv^2}{\left(\frac{mg}{\sin 50.0^\circ}\right)(\cos 50.0^\circ)(\sin 50.0^\circ)} \\ &= \frac{v^2}{g \cos 50.0^\circ} = \frac{(34.0 \text{ m/s})^2}{(9.80 \text{ m/s}^2) \cos 50.0^\circ} = \boxed{184 \text{ m}} \end{aligned}$$

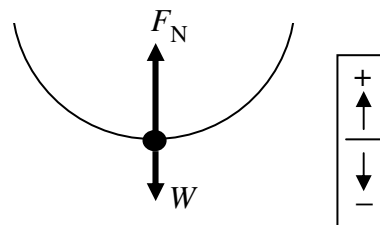
- 32. REASONING AND SOLUTION** The period of rotation is given by $T^2 = 4\pi^2 r^3 / GM$. Comparing the orbital periods for Earth and Venus yields

$$(T_V / T_E)^2 = (r_V / r_E)^3 \quad \text{so that } T_V / T_E = 0.611$$

The earth's orbital period is 365 days so

$$T_V = (0.611)(365 \text{ days}) = \boxed{223 \text{ days}}$$

38. REASONING The normal force (magnitude F_N) that the pilot's seat exerts on him is part of the centripetal force that keeps him on the vertical circular path. However, there is another contribution to the centripetal force, as the drawing at the right shows. This additional contribution is the pilot's weight (magnitude W). To obtain the ratio F_N/W , we will apply Equation 5.3, which specifies the centripetal force as $F_c = mv^2 / r$.



SOLUTION Noting that the direction upward (toward the center of the circular path) is positive in the drawing, we see that the centripetal force is $F_c = F_N - W$. Thus, from Equation 5.3 we have

$$F_c = F_N - W = \frac{mv^2}{r}$$

The weight is given by $W = mg$ (Equation 4.5), so we can divide the expression for the centripetal force by the expression for the weight and obtain that

$$F_c = \frac{F_N - W}{W} = \frac{mv^2}{mgr} \quad \text{or} \quad \frac{F_N}{W} - 1 = \frac{v^2}{gr}$$

Solving for the ratio F_N/W , we find that

$$\frac{F_N}{W} = 1 + \frac{v^2}{gr} = 1 + \frac{(230 \text{ m/s})^2}{(9.80 \text{ m/s}^2)(690 \text{ m})} = \boxed{8.8}$$
