CSD2301 Practice Solutions

6. Application of Newton's Laws Part 2

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Practice Question 1

A stone with mass 0.80 kg is attached to one end of a string 0.90 m long. The string will break if its tension exceeds 600 N. The stone is whirled in a horizontal circle on a frictionless tabletop; the other end of the string remains fixed. Find the maximum speed the stone can attain without breaking the string.

$$v = \sqrt{\frac{F_{\text{net}} R}{m}} = \sqrt{\frac{(600\,\text{N})(0.90\,\text{m})}{(0.80\,\text{kg})}} = 26.0\,\text{m/s},$$

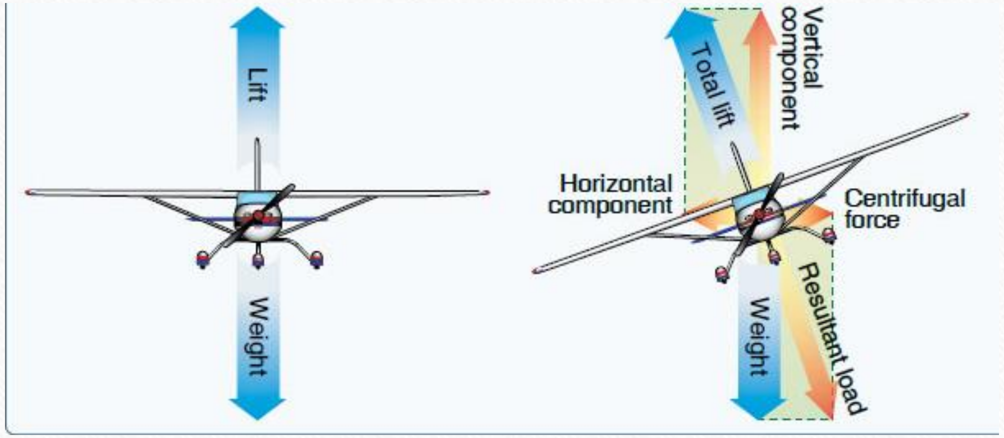
Practice Question 2

A flat (unbanked) curve on a highway has a radius of 220 m. A car rounds the curve at a speed of 25.0 m/s. What is the minimum coefficient of friction that will prevent sliding?

$$\mu_s = \frac{v^2}{Rg} = \frac{(25.0\,\mathrm{m/s})^2}{(220\,\mathrm{m})(9.80\,\mathrm{m/s^2})} = 0.290.$$

Practice Question 3

Aircraft experience a lift force (due to the air) that is perpendicular to the plane of the wings and to the direction of the flight. A small airplane is flying at a constant speed of 240 km/h. At what angle from the horizontal must the wings of the airplane be tilted for the plane to execute a horizontal turn with a turning radius of 1200 m?



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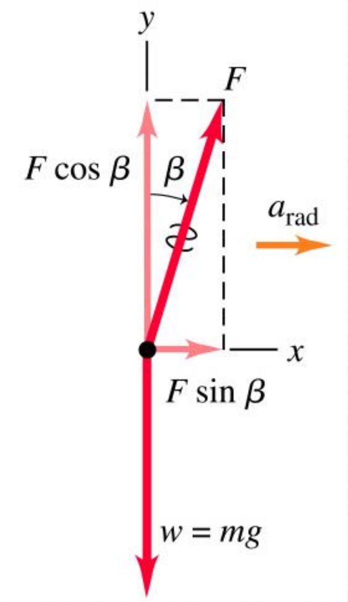
$$\sum F_x = F\sin\beta = ma_{\text{rad}} = m\frac{v^2}{R}$$

$$\sum F_y = F\cos\beta + (-mg) = 0$$

$$\tan\beta = \frac{v^2}{Rg}$$

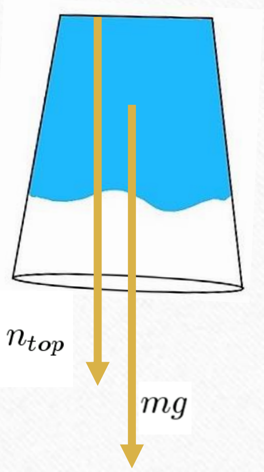
$$\beta = \arctan\left(\frac{v^2}{gR}\right) = \arctan\left(\frac{(240\,\text{km/h}\times((1\text{m/s})/(3.6\,\text{km/h})))^2}{(9.80\,\text{m/s}^2)(1200\,\text{m})}\right) = 20.7°.$$



Practice Question 4

You tie a cord to a pail of water, and you swing the pail in a vertical circle of radius 0.600 m. What minimum speed must you give the pail at the highest point of the circle if no water is to spill from it?

$$n_{top} + mg = m\frac{v^2}{r}$$



To ensure the water stays in the pail, normal contact force must be > 0.

$$v > \sqrt{gR} = \sqrt{(9.80\,\mathrm{m/s^2})(0.600\,\mathrm{m})} = 2.42\,\mathrm{m/s}.$$

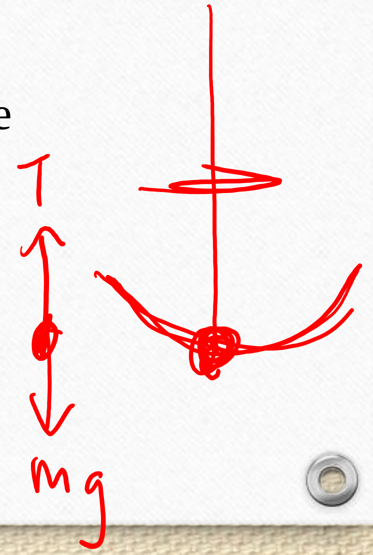
Practice Question 5

A bowling ball weighing 71.2 N is attached to the ceiling by a 3.80 m rope. The ball is pulled to one side and released. It swings back and forth as a pendulum. As the rope swings through the lowest point, the speed of the ball is 4.20 m/s. a) What is the acceleration of the bowling ball, in magnitude and direction, at this instant? b) What is the tension in the rope at this instant?

a) The inward (upward, radial) acceleration will be $\frac{v^2}{R} = \frac{(4.2\,\text{m/s})^2}{(3.80\,\text{m})} = 4.64\,\text{m/s}^2$. At the bottom of the circle, the inward direction is upward.

b) The forces on the ball are tension and gravity, so $T - mg = ma$,

$$T = m(a+g) = w\left(\frac{a}{g} + 1\right) = (71.2\ \text{N})\left(\frac{4.64\,\text{m/s}^2}{9.80\,\text{m/s}^2} + 1\right) = 105\ \text{N}.$$



Practice Question 6

One problem for humans living in outer space is that they are apparently weightless. One way around this problem is to design a space station that spins about its center at a constant rate. This creates "artificial gravity" at the outside rim of the station. a) If the diameter of the space station is 800 m, how many revolutions per minute are needed in order for the "artificial gravity" acceleration to be 9.80 m/s^2? b) How many revolutions per minute are needed to simulate the acceleration due to gravity on Mars (3.70 m/s^2) instead?

$v = \frac{2\pi R}{T}$

$$a_{rad} = \frac{v^2}{R} = \frac{4\pi^2 R}{T^2}$$

For (a), we need centripetal acceleration = g = 9.80 m/s^2

$$T = 2\pi\sqrt{\frac{R}{g}} = 2\pi\sqrt{\frac{400\,\text{m}}{9.80\,\text{m/s}^2}} = 40.1\,\text{s},$$

so the number of revolutions per minute is $(60\,\text{s/min})/(40.1\,\text{s}) = 1.5\,\text{rev/min}$.

b) The lower acceleration corresponds to a longer period, and hence a lower rotation rate, by a factor of the square root of the ratio of the accelerations,

$T' = (1.5\,\text{rev/min}) \times \sqrt{3.70/9.8} = 0.92\,\text{rev/min.}$.

The End