

Assignment 4:

Centripetal Force. Concept of Work

Assigned: Oct 5 12:00 Due: October 12 10:00 sharp!

1 A coin placed 30.0 cm from the center of a rotating, horizontal turntable slips when its speed is 50.0 cm/s. (a) What force causes the centripetal acceleration when the coin is stationary relative to the turntable? (b) What is the coefficient of static friction between coin and turntable?

(a) static friction (b) $\sum F_y = 0 = n - mg$ thus $n = mg$ and $\sum F_r = m \frac{v^2}{r} = f = \mu n = \mu mg$.

Then $\mu = \frac{v^2}{rg} = \frac{(50.0 \text{ cm/s})^2}{(30.0 \text{ cm})(980 \text{ cm/s}^2)} = \boxed{0.0850}$.

2 A 4.00-kg object is attached to a vertical rod by two strings, as in Figure P6.11. The object rotates in a horizontal circle at constant speed 6.00 m/s. Find the tension in (a) the upper string and (b) the lower string.

Solution

$F_g = mg = (4 \text{ kg})(9.8 \text{ m/s}^2) = 39.2 \text{ N}$

$\sin \theta = \frac{1.5 \text{ m}}{2 \text{ m}}$

$\theta = 48.6^\circ$

$r = (2 \text{ m}) \cos 48.6^\circ = 1.32 \text{ m}$

$\sum F_x = ma_x = \frac{mv^2}{r}$

$T_a \cos 48.6^\circ + T_b \cos 48.6^\circ = \frac{(4 \text{ kg})(6 \text{ m/s})^2}{1.32 \text{ m}}$

$T_a + T_b = \frac{109 \text{ N}}{\cos 48.6^\circ} = 165 \text{ N}$

$\sum F_y = ma_y$

$+T_a \sin 48.6^\circ - T_b \sin 48.6^\circ - 39.2 \text{ N} = 0$

$T_a - T_b = \frac{39.2 \text{ N}}{\sin 48.6^\circ} = 52.3 \text{ N}$

(a) To solve simultaneously, we add the equations in T_a and T_b :

$T_a + T_b + T_a - T_b = 165 \text{ N} + 52.3 \text{ N}$ so that: $T_a = \frac{217 \text{ N}}{2} = \boxed{108 \text{ N}}$

(b) $T_b = 165 \text{ N} - T_a = 165 \text{ N} - 108 \text{ N} = \boxed{56.2 \text{ N}}$

3 A crate of eggs is located in the middle of the flat bed of a pickup truck as the truck negotiates an unbanked curve in the road. The curve may be regarded as an arc of a circle of radius 35.0 m. If the coefficient of static friction between crate and truck is 0.600, how fast can the truck be moving without the crate sliding?

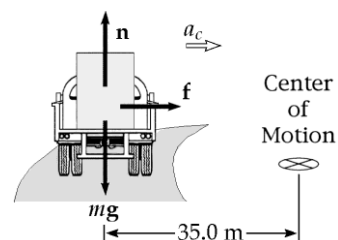
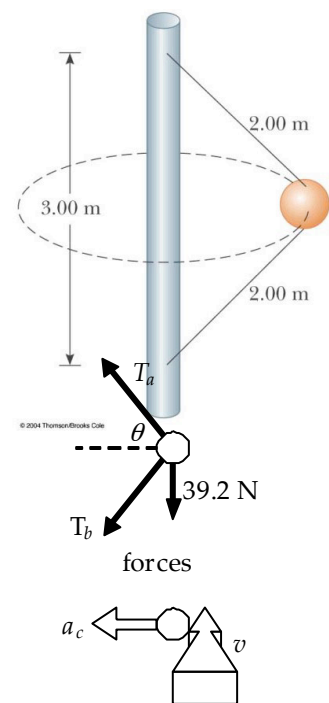
$n = mg$ since $a_y = 0$

The force causing the centripetal acceleration is the frictional force f .

From Newton's second law $f = ma_c = \frac{mv^2}{r}$.

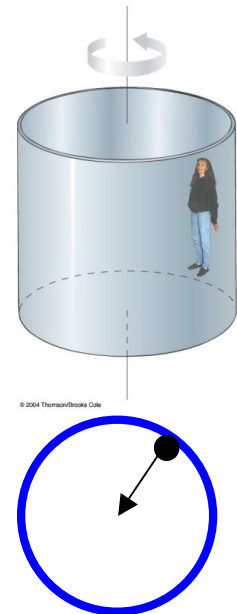
But the friction condition is $f \leq \mu_s n$ i.e., $\frac{mv^2}{r} \leq \mu_s mg$

$v \leq \sqrt{\mu_s rg} = \sqrt{0.600(35.0 \text{ m})(9.80 \text{ m/s}^2)}$ $v \leq \boxed{14.3 \text{ m/s}}$



Assignment 4 Cont.

4 An amusement park ride consists of a large vertical cylinder that spins about its axis fast enough that any person inside is held up against the wall when the floor drops away (Fig. P6.65). The coefficient of static friction between person and wall is μ_s , and the radius of the cylinder is R . (a) Show that the maximum period of revolution necessary to keep the person from falling is $T = (4\pi^2 R \mu_s / g)^{1/2}$. (b) Obtain a numerical value for T if $R = 4.00$ m and $\mu_s = 0.400$. How many revolutions per minute does the cylinder make?



$$(a) \quad n = \frac{mv^2}{R}; f - mg = 0; f = \mu_s n; v = \frac{2\pi R}{T} \quad T = \sqrt{\frac{4\pi^2 R \mu_s}{g}}$$

$$(b) \quad T = \boxed{2.54 \text{ s}} \# \frac{\text{rev}}{\text{min}} = \frac{1 \text{ rev}}{2.54 \text{ s}} \left(\frac{60 \text{ s}}{\text{min}} \right) = \boxed{23.6 \frac{\text{rev}}{\text{min}}}$$

5 A 15.0-kg block is dragged over a rough, horizontal surface by a 70.0-N force acting at 20.0° above the horizontal. The block is displaced 5.00 m, and the coefficient of kinetic friction is 0.300. Find the work done on the block by (a) the 70-N force, (b) the normal force, and (c) the gravitational force. (d) What is the increase in internal energy of the block-surface system owing to friction? (e) Find the total change in the block's kinetic energy.

$$\begin{aligned} n + Fy - mg &= 0 \\ \sum F_y = ma_y: \quad n + 70 \text{ N} \sin 20^\circ - 147 \text{ N} &= 0 \\ n &= 123 \text{ N} \end{aligned}$$

$$f_k = \mu n = 0.30 \cdot 123 \text{ N} = 36.9 \text{ N}$$

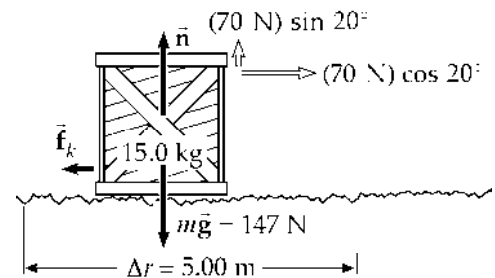
$$(a) \quad W = F \Delta r \cos 20^\circ = (70 \text{ N})(5 \text{ m}) \cos 20^\circ = 329 \text{ J}$$

$$(b) \quad W = F \Delta r \cos 90^\circ = (123 \text{ N})(5 \text{ m}) \cos 90^\circ = 0 \text{ J}$$

$$(c) \quad W = F \Delta r \cos 90^\circ = (147 \text{ N})(5 \text{ m}) \cos 90^\circ = 0 \text{ J}$$

$$(d) \quad \Delta E_{\text{int}} = f_k d \cos 0^\circ = (36.9 \text{ N})(5 \text{ m}) \cos 0^\circ = 185 \text{ J}$$

$$(e) \quad \Delta K = K_f - K_i = \sum W - \Delta E_{\text{int}} = 329 \text{ J} - 185 \text{ J} = \boxed{+144 \text{ J}}$$



6 A skier of mass 70.0 kg is pulled up a slope by a motor-driven cable. (a) How much work is required to pull him a distance of 60.0 m up a 30.0° slope (assumed frictionless) at a constant speed of 2.00 m/s? (b) A motor of what power is required to perform this task?

(a) $\sum W = \Delta K$, but $\Delta K = 0$ because he moves at constant speed. The skier rises a vertical distance of $(60.0 \text{ m}) \sin 30.0^\circ = 30.0 \text{ m}$. Thus,

$$W_{\text{in}} = -W_g = (70.0 \text{ kg})(9.8 \text{ m/s}^2)(30.0 \text{ m}) = \boxed{2.06 \times 10^4 \text{ J}} = \boxed{20.6 \text{ kJ}}$$

(b) The time to travel 60.0 m at a constant speed of 2.00 m/s is 30.0 s. Thus,

$$P_{\text{input}} = \frac{W}{\Delta t} = \frac{2.06 \times 10^4 \text{ J}}{30.0 \text{ s}} = \boxed{686 \text{ W}} = 0.919 \text{ hp}$$