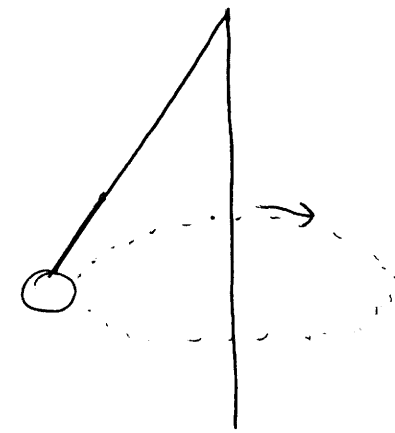
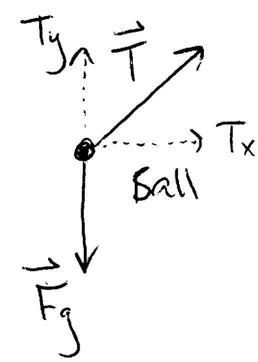
Homework #4

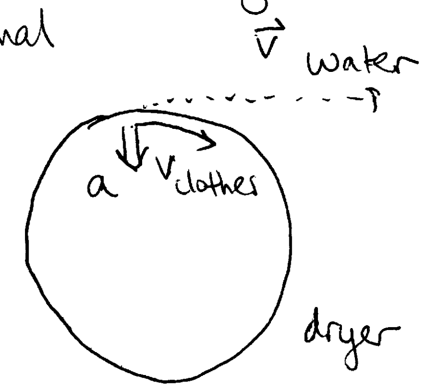
Ch5

(Q7) Since the ball is moving in a circle, a component of the acceleration must be towards the center of the circle (the pole). If the only forces acting on the ball are gravity and the tension in the rope (ie. ignore air resistance, and assume you are no longer touching it with your hand), then it is the x-component of the tension that is causing the inward acceleration





(Q9) This statement is or is not correct depending on the reference frame of the observer. If you are in the reference frame that is at rest with respect to the outer wall of the dryer (a "non-inertial", accelerating frame) then it appears that there is some outward force on the water called the centrifugal force. This force only exists in non-intertial reference frames and is sometimes called a pseudoforce. If, however, you are at rest with respect to the ground watching the dryer spin, what you see is that both the water and the clothes "want" to move in a straight line tangent to the ~~[illegible]~~ edge of the dryer. However, the clothes feel a normal force from the edge of the dryer and are accelerated toward the center of the dryer. This acceleration causes the clothes to move is a circle. The water, on the other hand, can continue on its straight line path because of holes in the edge of the dryer.

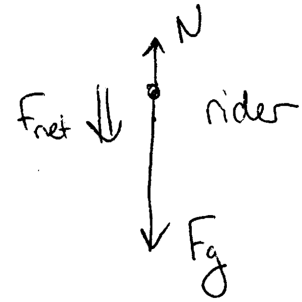


(Q10) If you are interested in the force exerted on an object in the centrifuge, you not only need to know the rotational speed, but also the distance from the center of the centrifuge. The force exerted on an object in a centrifuge is the centripetal force which depends on the mass of the object, the radius of the orbit and the rotational speed.

~~[illegible]~~ $$F_c = \frac{mv^2}{r}$$

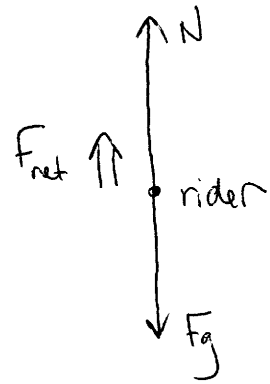
(Q12) The normal force exerted on the rider is less at the top of the circle than at the bottom. If the rider is moving in a circle, then the net force is toward the center, and if the rider has a constant speed, than the centripetal acceleration is a constant.

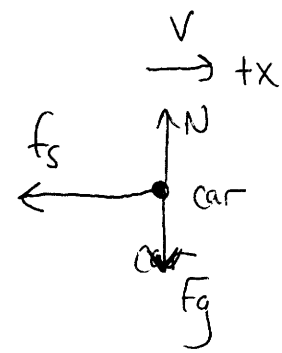
At the top



At the bottom, the normal force increases so that the net force is toward the center.
At the top, the rider's weight is already towards the center so the normal force must be smaller.

At the bottom





(P14)

(a) $\Sigma F = -f_s = ma$ (horizontal)

$-\mu_s N = ma$

(vertical) $\Sigma F = N - F_g = 0$

$N = F_g = mg$

$-\mu_s \cancel{m} g = \cancel{m} a$

$a = -\mu_s g$

Using N's 2nd and 1st law to find the maximum acceleration

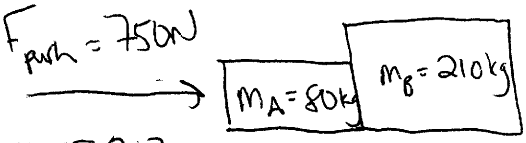
$\cancel{V_f^2}^{\,0} = V^2 + 2a\Delta x$

$V^2 - 2\mu_s g \Delta x = 0$

$\Delta x = \dfrac{V^2}{2\mu_s g}$

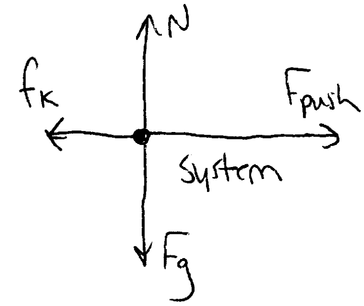
Using kinematics to find minimum stopping distance.

(P17)



$\mu_k = 0.12$

(a) To find the acceleration of the system, treat the boxes as one object of mass $M = m_A + m_B = 290 \text{ kg}$



$\hat{x}$-direction: $\Sigma F_x = F_{push} - f_k = Ma$

$\Sigma F_y = N - F_g = 0 \Rightarrow N = Mg$

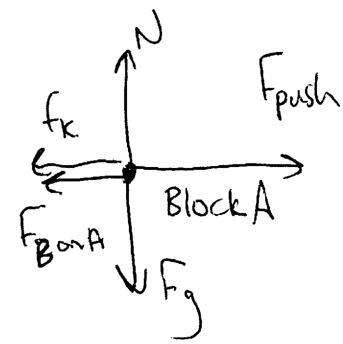
$$a_{system} = \frac{F_{push} - f_k}{M} = \frac{F_{push}}{M} - \frac{\mu_k N}{M} = \frac{F_{push}}{M} - \mu_k g$$

$$a_{system} = \frac{750\,N}{290\,kg} - (0.12)(9.8\,m/s^2) = 1.4\,m/s^2$$

The system will have an acceleration of $1.4\,m/s^2$

(b) In order to have an acceleration of $1.4\,m/s^2$, block A needs a net force of:

$\Sigma F_x = F_{push} - f_k - F_{2on1} = m_A a_{system}$

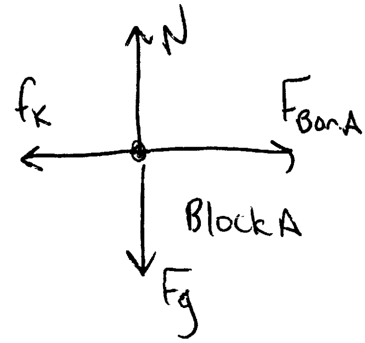


$F_{B\,on\,A} = F_{push} - f_k - m_A a_{system}$

$= 750N - (0.12)(80kg)(9.8\,m/s^2) - (80kg)(1.4\,m/s^2)$

$F_{B\,on\,A} = 540\,N \longrightarrow$ (N's 3rd Law) $F_{A\,on\,B} = 540\,N$

(C) Blocks are now reversed



$$\Sigma F_x = F_{B on A} - f_K = m_A a_{system}$$

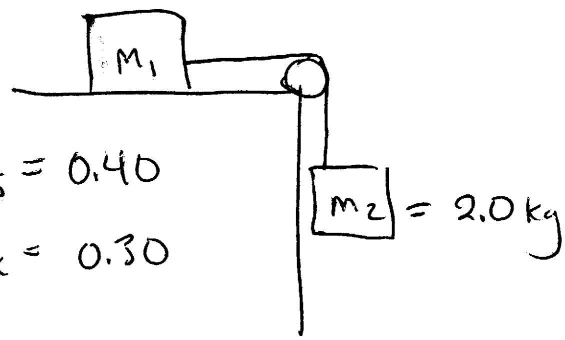
$$F_{B on A} = m_A a_{system} + f_K$$

$$= m_A (a_{system} + \mu_K g)$$

$$= 80 kg (1.4 m/s^2 + 0.12 (9.8 m/s^2))$$

$$F_{B on A} = 210 N \Rightarrow (N's\ 3^{rd}\ Law)\ F_{A on B} = 210 N$$

(P24)



$\mu_s = 0.40$

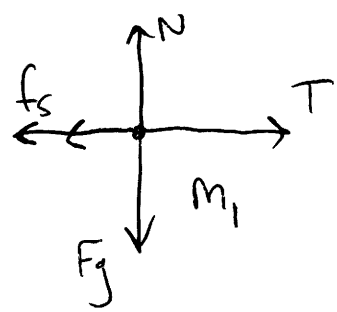
$\mu_K = 0.30$

(a) $\Sigma F_{x, m_1} = T - f_s = 0$

$$f_s = T = m_2 g$$

$$\mu_s m_1 \cancel{g} = m_2 \cancel{g}$$

$$m_1 = \frac{m_2}{\mu_s} = \frac{2.0 kg}{0.4}$$



$$m_1 = 5.0 kg$$

(b) For constant speed $\Sigma F = 0$

$$\Sigma F = T - f_k = 0$$

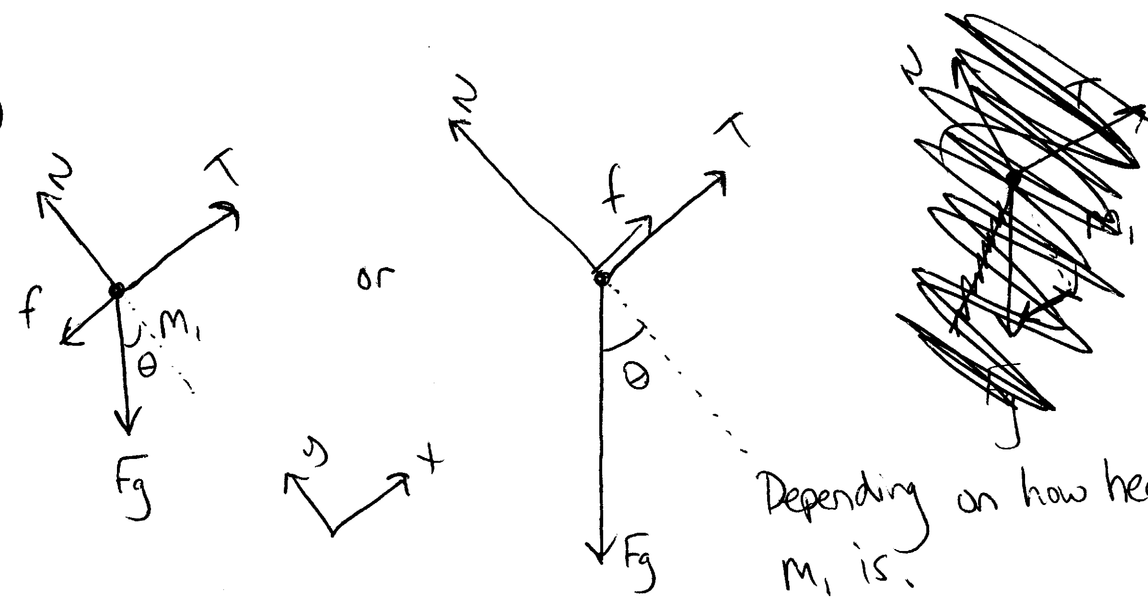
$$f_k = T = m_2 g$$

$$\mu_k m_1 \cancel{g} = m_2 \cancel{g}$$

$$m_1 = \frac{m_2}{\mu_k} = \frac{2.0\,kg}{0.3} = 6.7\,kg$$

If m_1 has a mass of 6.7 kg, the block will not accelerate.

(P28)



Depending on how heavy m_1 is.

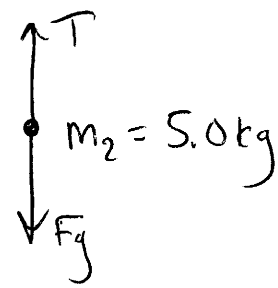
For m_1 small

$$\Sigma F_x = T - f - mg\sin\theta = 0$$

$$T = f + mg\sin\theta = \mu N + mg\sin\theta$$

$$\Sigma F_y = N - mg\cos\theta = 0 \Rightarrow N = mg\cos\theta$$

$$T = \mu m g \cos\theta + m g \sin\theta$$



$$T = m_1 g\,(\mu\cos\theta + \sin\theta)$$

$$m_1 = \frac{T}{g(\mu\cos\theta + \sin\theta)} \longleftarrow T = m_2 g$$

$$m_1 = \frac{m_2}{\mu\cos\theta + \sin\theta} = \frac{5.0\ \text{kg}}{0.5\cos 30^\circ + \sin 30^\circ}$$

$$m_1 \geq 5.4\ \text{kg}$$

For large m_1

$$\Sigma F_x = T + f - mg\sin\theta = 0$$

$$T = mg\sin\theta - f = m_1 g\sin\theta - \mu m_1 g\cos\theta$$

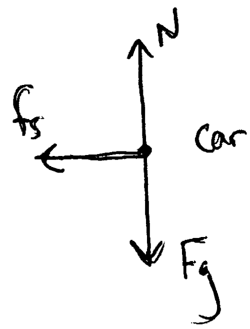
$$m_2 g = m_1 g\,(\sin\theta - \mu\cos\theta)$$

$$m_1 = \frac{m_2}{\sin\theta - \mu\cos\theta} = \frac{5.0\text{kg}}{\sin 30^\circ - 0.5\cos 30^\circ}$$

$$m_1 \leq 75\ \text{kg}$$

so $5.4\ \text{kg} \leq m_1 \leq 75\ \text{kg}$

(P35) In this case the centripetal force is provided by the friction force between the tires and the road.



$$f_s = F_c$$

$$\mu_s \cancel{m} g = \frac{\cancel{m} v^2}{r}$$

$$\Sigma F_y = N - F_g = 0$$

$$N = mg$$

$$v = \sqrt{\mu_s r g}$$

$$= \sqrt{(0.55)(80.0\,m)(9.8\,m/s^2)}$$

$$V_{max} = 21\ m/s$$

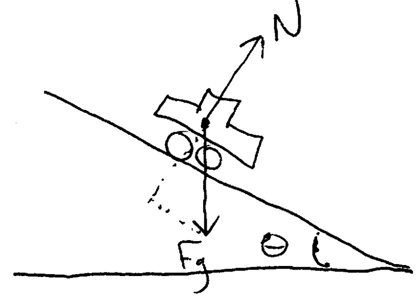
The maximum speed is 21 m/s and does not depend on the mass.

(P37)

(a) $a_c = \frac{v^2}{r} = \frac{(1.50\ m/s)^2}{9.0\,m} = 0.25\ m/s^2$

(b) $\Sigma F_{Horizontal} = F_c = m a_c = (25\,kg)(0.25\ m/s^2) = 6.3\ N$

(P42) The condition that the car stay in contact with the road means that the centripetal force is provided by the component of the gravitational force that is normal to the surface of the road.



$$F_{g\perp} = mg\cos\theta$$

$$F_{g\perp} = F_c$$

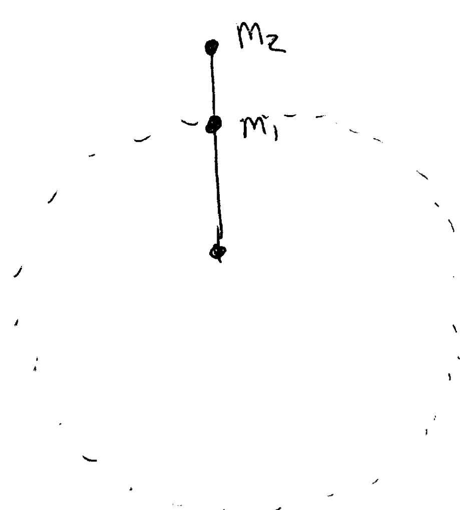
$$\cancel{m}g\cos\theta = \frac{\cancel{m}v^2}{r}$$

$$r = \frac{v^2}{g\cos\theta} = \frac{\left[(90\,\text{km/hr})\left(\frac{1000\,\text{m}}{\text{km}}\right)\left(\frac{1\,\text{hr}}{3600\,\text{s}}\right)\right]^2}{(9.8\,\text{m/s}^2)(\cos 22^\circ)}$$

$$r = 69\,\text{m}$$

(P48)

Force diagrams for each mass.



For m_2 the centripetal force is provided by T_2

$$v = \frac{2\pi r}{T} = 2\pi r f$$

$$T_2 = F_{c_2} = \frac{m_2 v_2^2}{r_2} = \frac{(2\pi r_2 f)^2 m_2}{r_2}$$

$$T_2 = 4\pi^2 f^2 r_2 m_2$$

For m_1, the centripetal force is provided by the difference between T_1 and T_2

$$\Sigma F_{m_1} = T_1 - T_2 = F_{c_1}$$

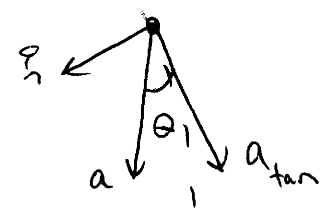
$$T_1 = F_{c_1} + T_2 = \frac{m_1 v_1^2}{r_1} + 4\pi^2 f^2 r_2 m_2$$

$$T_1 = \frac{m_1 (2\pi r_1 f)^2}{r_1} + 4\pi^2 f^2 r_2 m_2$$

$$T_1 = 4\pi^2 f^2 \left(m_1 r_1 + r_2 m_2 \right)$$

(P54)

(a) Use the radial acceleration to find the speed.



$$a_r = a \sin\theta = \frac{v^2}{r}$$

$$v = \sqrt{a r \sin\theta} = \sqrt{0.210(9.8\,m/s^2)(3.60\,m)\sin 28.0^\circ}$$

$$v = 1.86\,m/s$$

(b) Since a_{tan} = constant

$$v_f = v_i + a_{tan} t = (1.86\,m/s) + (0.210)(9.8\,m/s^2)(\cos 28.0^\circ)(2.00\,s)$$

$$v_f = 5.49\,m/s$$

(P58) The raindrop will reach its terminal velocity when the drag force balances the downward force of gravity.

(a) $\Sigma F = -F_D + F_g = 0$

$F_D = F_g$

$bv = mg$

$b = \frac{mg}{v} = \frac{(3\times10^{-5}\,kg)(9.8\,m/s^2)}{9\,m/s} = 3.3\times10^{-5}\,\frac{kg}{s}$

(b) $V_f = 0.63\,V_T = (0.63)(9\,m/s) = 6\,m/s$

Use Newton's 2nd law to find the acceleration

$\Sigma F = F_g - F_D = ma$

$a = g - \frac{bv}{m} = \frac{dv}{dt}$

$\frac{dv}{g - \frac{b}{m}v} = dt$, or $\frac{dv}{v - \frac{m}{b}g} = -\frac{b}{m}\,dt$

$\int_{v_0}^{v_f} \frac{1}{v' - \frac{m}{b}g}\,dv' = -\int_{t_0}^{t_f} \frac{b}{m}\,dt'$

$\ln\left(v - \frac{m}{b}g\right)\Big|_0^v = -\frac{bt}{m}\Big|_0^t$

$$\ln\left(v - \frac{mg}{b}\right) - \ln\left(-\frac{mg}{b}\right) = -\frac{bt}{m}$$

$$\ln\left(\frac{v - \frac{mg}{b}}{-\frac{mg}{b}}\right) = \frac{-bt}{m}$$

$$\frac{v - \frac{mg}{b}}{-\frac{mg}{b}} = \exp\left(\frac{-bt}{m}\right)$$

$$v = \frac{mg}{b} - \frac{mg}{b}\exp\left(\frac{-bt}{m}\right)$$

$$V = \frac{mg}{b}\left(1 - e^{-bt/m}\right)$$

Remember, for terminal velocity

$V_T = \frac{mg}{b}$ so we want when

$$1 - e^{-bt/m} = 0.63$$

$$e^{-bt/m} = 0.37$$

$$\frac{-bt}{m} = \ln(0.37) \approx -1$$

$$t = \frac{m}{b} = \frac{3 \times 10^{-5}\ \text{kg}}{3.3 \times 10^{-5}\ \text{kg/s}} = 0.92\ \text{s}$$

(P61) $F_D = F_{D1} + F_{D2}$

(a) $F_{D_1} \neq F_{D_1}(v) \rightarrow F_{D_1} = 4.0N$

$F_{D_2} = cv^2$

$F_D = 4.0N + cv^2$

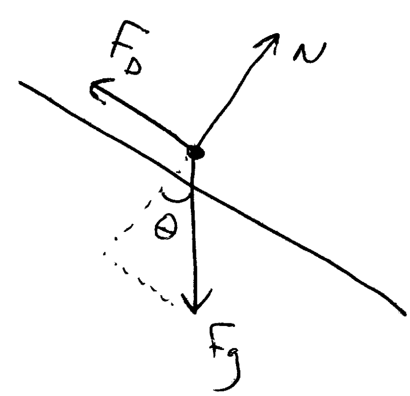
$F_D(v = 2.2 m/s) = 4.0N + c(2.2 m/s)^2 = 5.0N$

$c(4.84 m^2/s^2) = 1.0N$

$c = 0.21$

$F_D = 4.0 + 0.21v^2$

(b) To go at constant speed, the component of gravity parallel to the slope balances the drag force.



$\Sigma F_{\parallel} = mg\sin\theta - F_D = 0$

$mg\sin\theta = 4.0 + 0.21v^2$

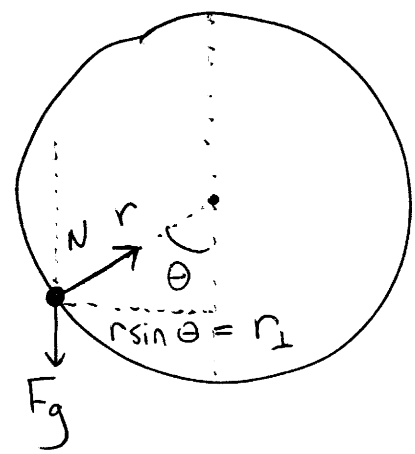
$$\theta = \sin^{-1}\left[\frac{4.0 + 0.21v^2}{mg}\right]$$

$$= \sin^{-1}\left[\frac{4.0 + 0.21\,(10\,\text{m/s})^2}{(80\,\text{kg})(9.8\,\text{m/s}^2)}\right]$$

$$\theta = 1.8^\circ$$

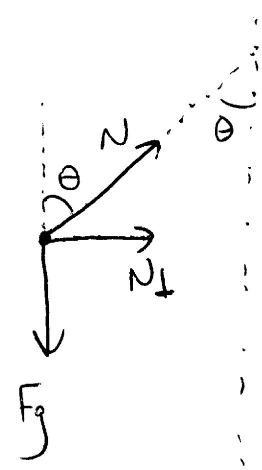
(P92) The bead will remain in equillibrium

(a) when the normal force provides the centripetal acceleration towards the axis



$$\Sigma F_{\parallel} = F_g - N\cos\theta = 0$$

$$\ast \quad \frac{mg}{\cos\theta} = N$$



$$N\sin\theta = \frac{mv^2}{r\sin\theta} = \frac{m(2\pi r_{\perp} f)^2}{r\sin\theta}$$

$$N\sin\theta = \frac{m\,4\pi^2 r^2 \sin^2\theta\, f^2}{r\sin\theta}$$

$$\ast \quad N = 4\pi^2 m r f^2$$

$$\frac{\cancel{m}g}{\cos\theta} = 4\pi^2 \cancel{m} r f^2$$

$$\cos\theta = \frac{g}{4\pi^2 r f^2}$$

(b) $$\theta = \cos^{-1}\left[\frac{9.8\,m/s^2}{4\pi^2(.20\,m)(4.0\,\frac{rev}{s})^2}\right]$$

$$\theta = 86^\circ$$

(c) No, there has to be some component of the normal force parallel to the axis of rotation to balance the downward force of gravity.