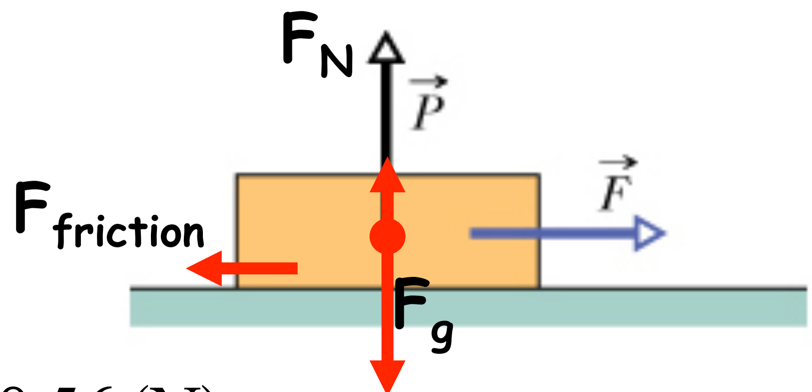
Homework: 5, 9, 19, 25, 31, 34, 39 (p 130-134)

5. A 3.0 kg block is initially at rest on a horizontal surface. A force F of magnitude 6.0 N and a vertical force P are then applied to the block. The coefficients of friction for the block and surface are μ_s=0.40 and μ_k=0.25. Determine the magnitude of the frictional force acting on the block if the magnitude of P is (a) 8.0 N, (b) 10 N, and (c) 15 N (12N, textbook) .

$$F_{s,max} = k_s F_N$$

$$F_N = F_g - P$$

$$F_g = mg = 3.0 \times 9.8 = 29.4 \text{ (N)}$$



(a) P=8.0 N, F_N=21.4 N:

$$F_{s,max} = k_s F_N = 0.4 \times 21.4 = 8.56 \text{ (N)}$$

$$F_{s,max} > F \Rightarrow \text{the block is stationary, therefore}: F_{friction} = F = 6.0 \text{ (N)}$$

(b) P=10.0 N, F_N=19.4 N:

$$F_{s,max} = 0.4 \times 19.4 = 7.76 \text{ (N)}$$

$$F_{s,max} > F \Rightarrow \text{the block does not move, therefore}:$$

$$F_{friction} = F = 6.0 \text{ (N)}$$

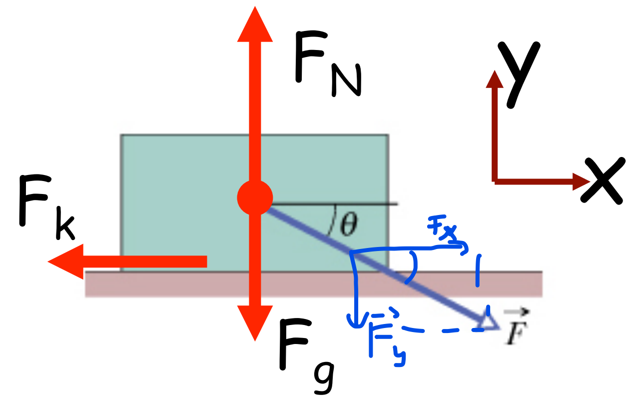
(c) P=15 N, F_N=14.4 N:

$$F_{s,max} = 0.4 \times 14.4 = 5.76 \text{ (N)}$$

$F_{s,max}$ < F $\Rightarrow$ the block moves:

$$F_{friction} = F_k = \mu_k F_N = 0.25 \times 14.4 \approx 3.6 \text{ (N)}$$

9. A 3.5 kg block is pushed along a horizontal floor by a force $\vec{F}$ of magnitude 15 N at an angle $\theta=40^0$ with the horizontal force. The coefficient of kinetic friction between the block and the floor is 0.25. calculate the magnitude of (a) the frictional force on the block from the floor and (b) the block's acceleration.



$$F_k = k\,F_N = \mu N$$

$$F_N = F_g + F\sin\theta \approx 43.9\,(\mathrm{N})$$

$$F_N - F_g - F\sin\theta = 0$$

$$F_k = k\,F_N = 0.25\times 43.9 \approx 11\,(\mathrm{N})$$

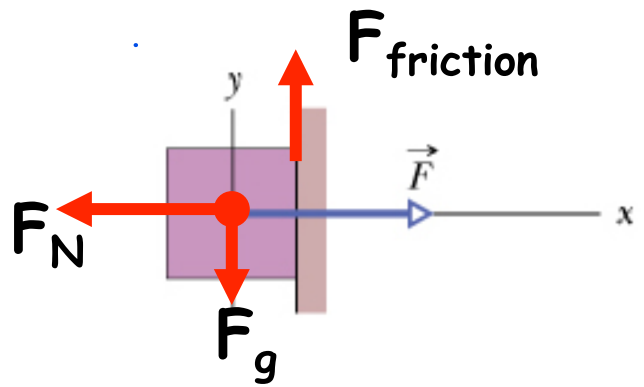
$$F\cos\theta - F_k = ma \Rightarrow a = \frac{F\cos\theta - F_k}{m} = 0.14\,(\mathrm{m/s^2})$$

19. A 12 N horizontal force F pushes a block weighing 5.0 N against a vertical wall. The coefficient of static friction between the wall and the block is 0.6, and the coefficient of kinetic friction is 0.4. Assume that the block is not moving initially. (a) Will the block move? (b) In unit-vector notation, what is the force on the block from the wall?

$$F_N = F$$

$$F_{s,max} = k_s F_N = 0.6 \times 12 = 7.2\,(N)$$

$$F_g = 5\,(N)$$



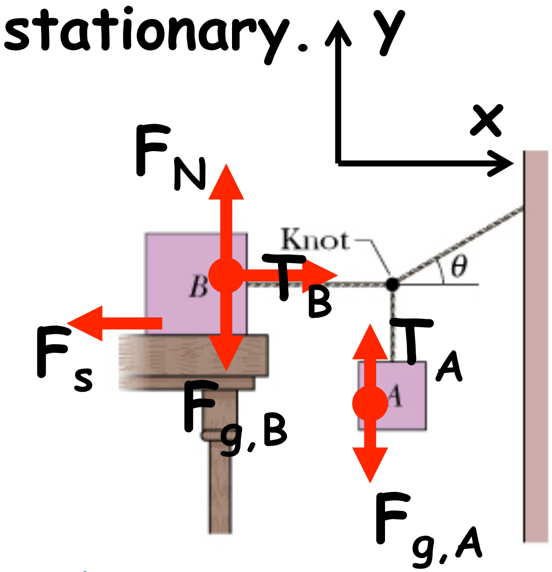
(a) 5 7.2

$$F_g < F_{s,max} \Rightarrow \text{the block does not move, } F_s = F_g = 5\,(N)$$

(b) $$\vec{F}_{wall} = \vec{F}_N + \vec{F}_s = (F_{N,x} + F_{s,x})\hat{i} + (F_{N,y} + F_{s,y})\hat{j}$$

$$\vec{F}_{wall} = (-12+0)\hat{i} + (5+0)\hat{j} = (-12N)\hat{i} + (5N)\hat{j}$$

25. Block B in the figure below weighs 750 N. The coefficient of static friction between block and table is 0.25; angle θ is 30^0; assume that the cord between B and the knot is horizontal. Find the maximum weight of block A for which the system will be stationary.



Here, we need to find the maximum value of $F_{g,A}$. If the system is stationary:

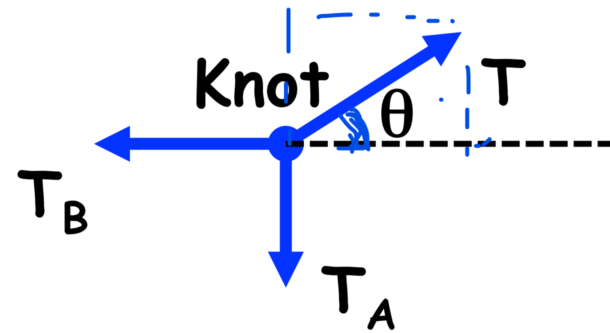
For block A: $F_{g,A} = T_A$ $\quad T_A - F_{g,A} = 0$

For block B: $T_B = F_s$;

$F_N - F_{gB} = 0$ $\quad F_N = F_{g,B}$; $F_{s,max} = k_s F_N$

For Knot K: $T_B = T\cos\theta$

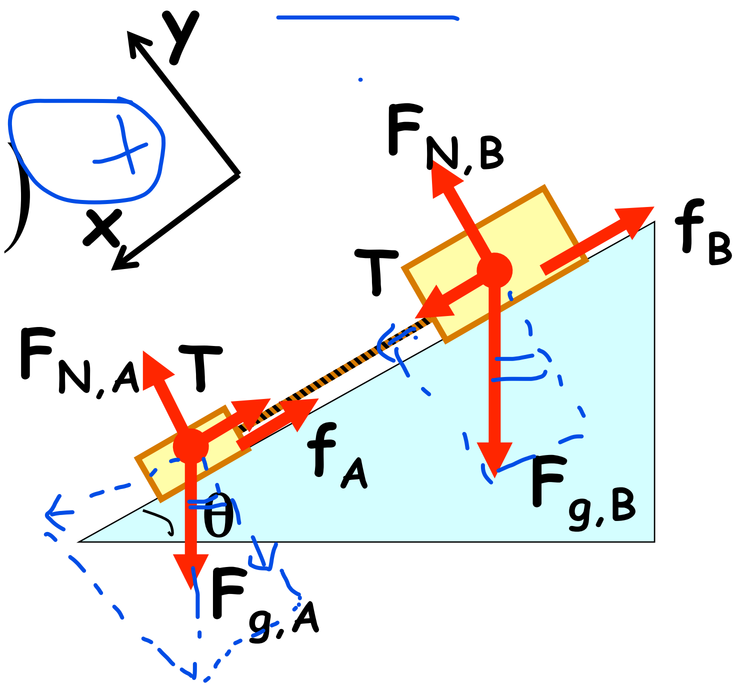
$T_A = T\sin\theta$



$F_{g,A}$ is maxima when F_s=$F_{s,max}$: $T_B = F_{s,max} = 0.25 \times 750 \approx 187.5\ (N)$

$$F_{g,A} = T_A = T_B \tan(\theta) = 187.5 \times \tan(30^0) \approx 108.3\ (N)$$

31. Two blocks of weights 3.6 N and 7.2 N, are connected by a massless string and slide down a 30^0 inclined plane. The coefficient of kinetic friction between the lighter block and the plane is 0.10; that between the heavier block and the plane is 0.20. Assuming that the lighter block leads, find (a) the magnitude of the acceleration of the blocks and (b) the tension in the string.



For block A:

$$F_{g,A}\sin\theta - T - f_A = m_A a \ (1)$$

$$f_A = k_A F_{g,A}\cos\theta$$

For block B:

$$F_{g,B}\sin\theta + T - f_B = m_B a \ (2)$$

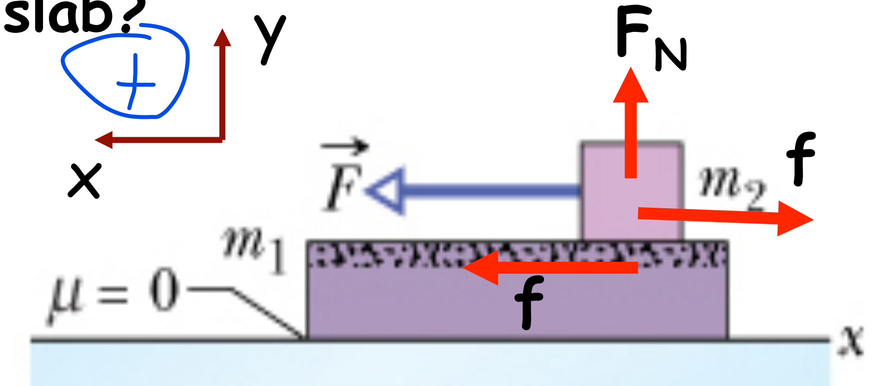
$$f_B = k_B F_{g,B}\cos\theta$$

$$(1)\,\&\,(2) \Rightarrow a = \frac{(F_{g,A} + F_{g,B})\sin\theta - (f_A + f_B)}{m_A + m_B}$$

$$a \approx 3.5\,(m/s^2);\ T \approx 0.2\,(N)$$

$$\frac{F_{gA}\sin\theta - T - f_A}{m_A} = \frac{F_{gB}\sin\_}{m_B}$$

34. A slab of mass m_1 = 40 kg rests on a frictionless floor, and a block of mass m_2=12 kg rests on top of the slab. Between block and slab, the coefficient of static friction is 0.60, and the coefficient of kinetic friction is 0.40. The block is pulled by a horizontal force F of magnitude 120 N. In unit-vector notation, what are the resulting accelerations of (a) the block and (b) the slab?



For the slab, along Ox: $f = m_1 a_1$

For the block, Ox: $F - f = m_2 a_2$

$$f_{s,max} = \mu_s F_N = \mu_s m_2 g = 0.6 \times 12 \times 9.8 = 70.6\,(N)$$ – static

$\boxed{f_{s,max} < F}$ ➔ therefore the block does slide on the slab

kinetic $$a_2 = \frac{F - \mu_k m_2 g}{m_2} = \frac{120 - 0.4 \times 12 \times 9.8}{12} \approx 6.1\,(m/s^2);\ \vec{a}_2 = (6.1\,m/s^2)\hat{i}$$

$$a_1 = \frac{\mu_k m_2 g}{m_1} = \frac{0.4 \times 12 \times 9.8}{40} \approx 1.2\,(m/s^2);\ \vec{a}_1 = (1.2\,m/s^2)\hat{i}$$

39. Calculate the ratio of the drag force on a jet flying at 1200 km/h at an altitude of 15 km to the drag force on a prop-driven transport flying at half that speed and altitude. The density of air is 0.38 kg/m³ at 15 km and 0.67 kg/m³ at 7.5 km. Assume that the airplanes have the same effective cross-sectional area and drag coefficient C.

$$D = \frac{1}{2} C \rho A v^2$$

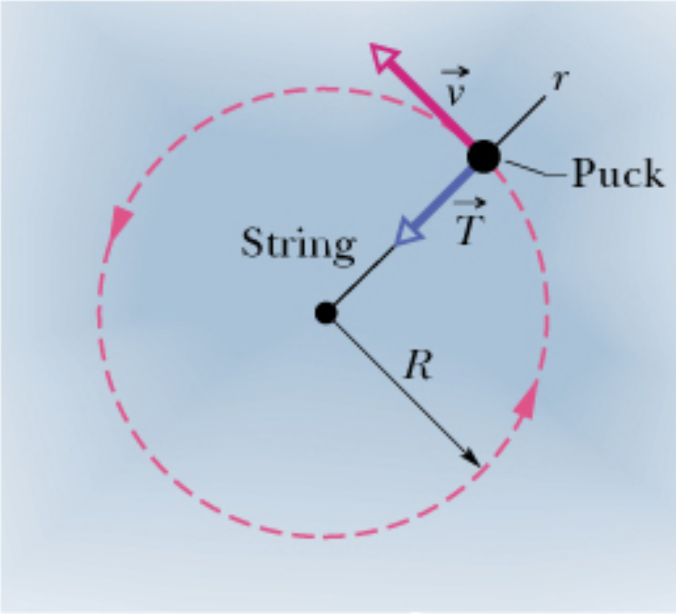
$$R = \frac{D_{jet}}{D_{propeller}} = \frac{\rho_{15km} v_{jet}^2}{\rho_{7.5km} v_{prop}^2} = \frac{0.38 \times 1200^2}{0.67 \times 600^2} \approx 2.3$$

Chapter 2 Force and Motion

2.1. Newton's First Law and Inertial Frames
2.2. Newton's Second Law
2.3. Some Particular Forces. The Gravitational Force and Weight
2.4. Newton's Third Law
2.5. Friction and Properties of Friction.
    Motion in the Presence of Resistive Forces
2.6. Uniform Circular Motion and Non-uniform Circular Motion
2.5. Motion in Accelerated Frames

2.6. Uniform Circular Motion and Non-uniform Circular Motion

Uniform circular motion



Centripetal (radial) acceleration:

$$a = \frac{v^2}{R}$$

Centripetal (radial) force:

$$F = ma = m\frac{v^2}{R}$$

$$T = m\frac{v^2}{R}$$

Note: A centripetal force accelerates an object by changing its velocity direction without changing its speed.

Non-uniform circular motion

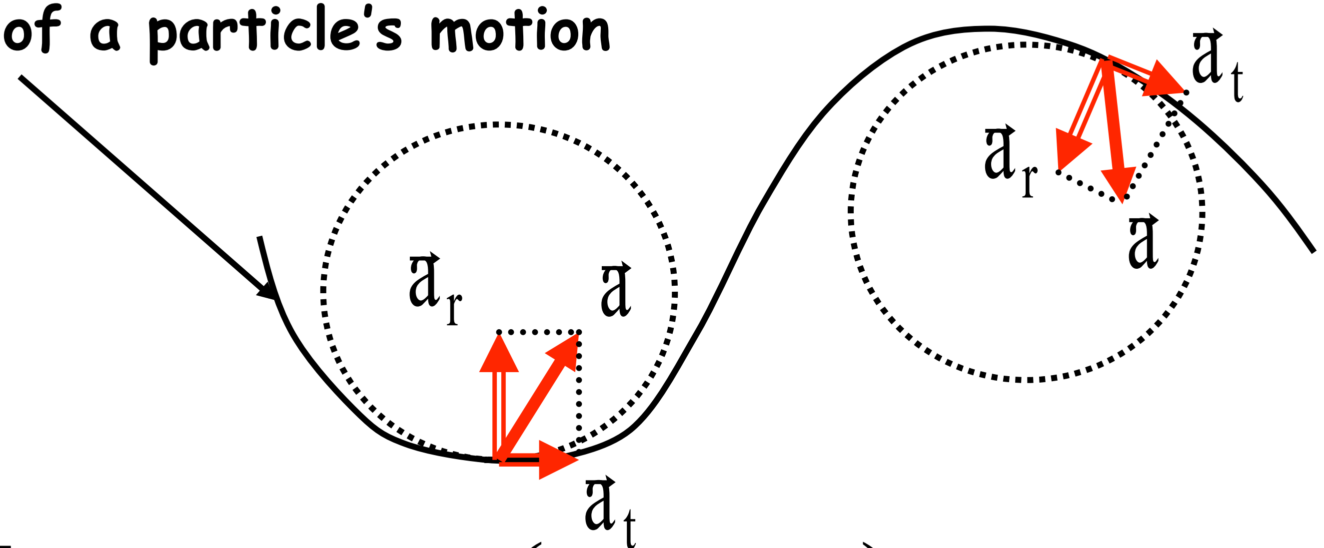
$$\boxed{\vec{a} = \vec{a}_r + \vec{a}_t}$$

$\frac{dv}{dt}$

Radial (centripetal) acceleration

Tangential acceleration

The path of a particle's motion



$$\vec{F} = m\vec{a} = m(\vec{a}_r + \vec{a}_t) = m\vec{a}_r + m\vec{a}_t$$

$$\vec{F}_r = m\vec{a}_r ; \vec{F}_t = m\vec{a}_t$$

$$\boxed{F_r = m\frac{v^2}{R} ; F_t = m\frac{dv}{dt}}$$

Sample Problem (p. 125)

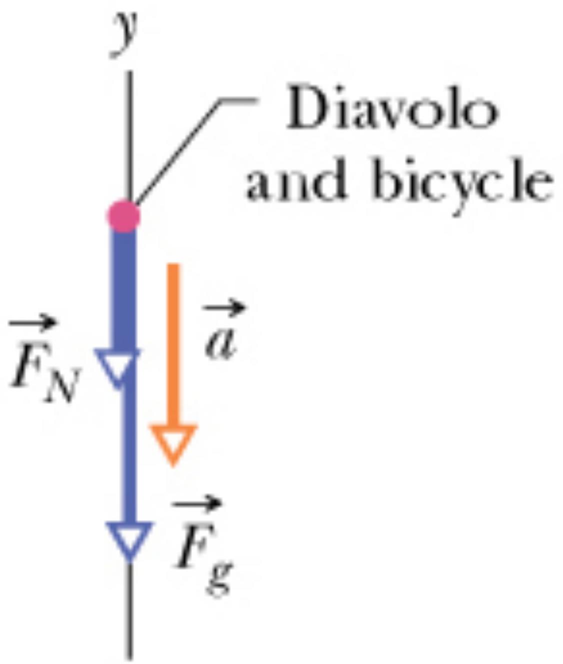
Diavolo is riding a bike in a loop, assuming the loop is a circle with R = 2.7 m, what is the least speed v Diavolo can have at the top of the loop to remain in contact with it there?

$$-F_N - F_g = m(-a) = -m\frac{v^2}{R}$$

$$F_N + mg = m\frac{v^2}{R}$$

To remain in contact with the loop:

$$F_N \geq 0$$



the least speed needed for the Diavolo and his bike:

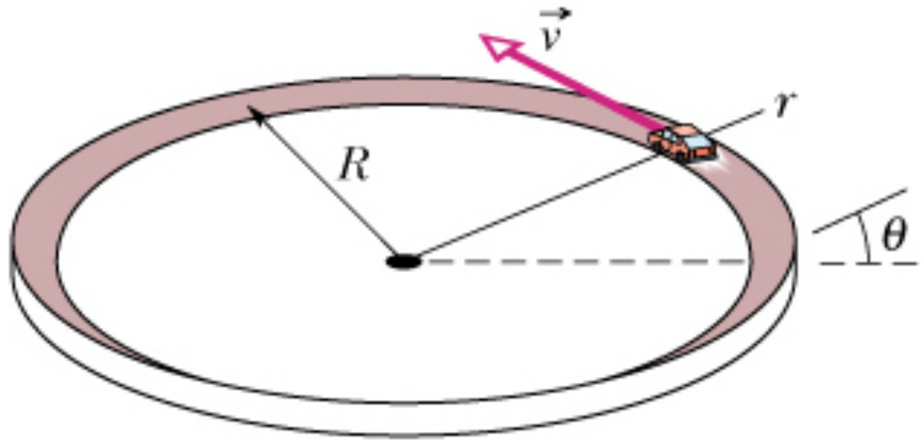
$$F_N = 0 \Rightarrow v_{min} = \sqrt{gR}$$

$$v_{min} = \sqrt{9.8 \times 2.7} = 5.1(m/s)$$

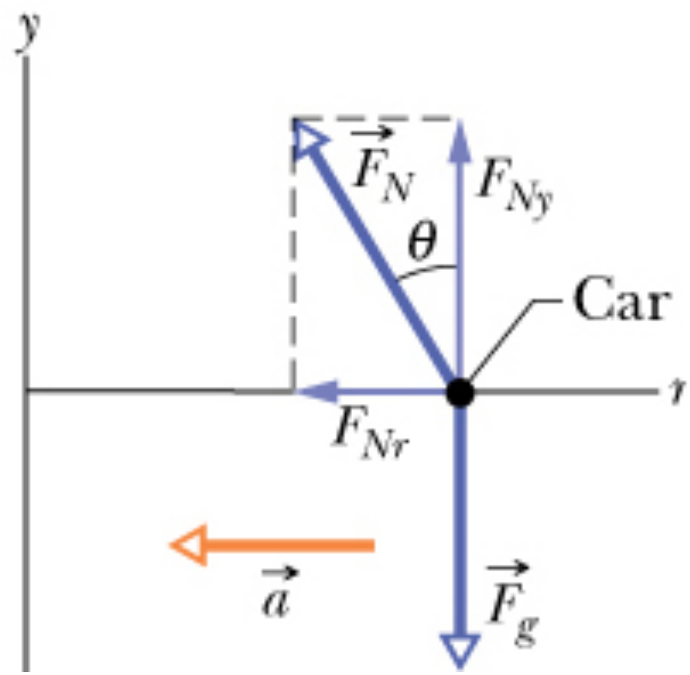
A free-body diagram

Sample Problem (p. 128)

Curved portions of highways are tilted to prevent cars from sliding off the highways. If the highways are wet, the frictional force from the track is negligible. What bank angle θ prevents sliding?



To prevent sliding, the component F_{Nr} of the normal force along the radial axis r provides the necessary centripetal force and radial acceleration:



$$F_{Nr} = -F_N \sin\theta = m\left(-\frac{v^2}{R}\right)$$

$$F_N \cos\theta = mg$$

$$\theta = \tan^{-1}\frac{v^2}{gR}$$ ➔ to prevent sliding

[Car on a level track]

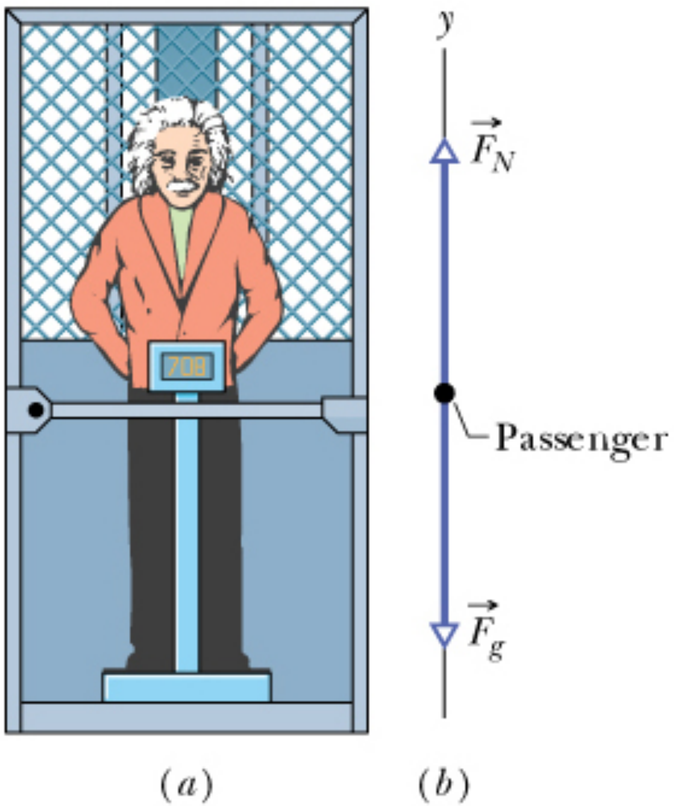
[Car on a banked frictionless track]

2.5. Motion in Accelerated Frames

Accelerated (noninertial) reference frames: in which Newton's laws of motion do not hold.

Example: An elevator cab is moving with an acceleration $\vec{a}_0$ ➔ the cab is not an inertial frame.

+ We choose the ground to be our inertial frame (stationary), so using Newton's second law for the passenger with a mass m :



$$\vec{F}_N + \vec{F}_g = m\vec{a}_0$$

+ However, if we choose the cab (noninertial frame, accelerated with $\vec{a}_0$) to be our frame, the passenger's acceleration is zero in this frame, so

$$\cancel{\vec{F}_N + \vec{F}_g} = 0$$

In this case, to use Newton's second law, we must add an inertial (fictitious) force:

$$\vec{F}_{fictitious} = -m\vec{a}_0$$

$$\vec{F} + \vec{F}_g - m\vec{a}_0 = 0$$

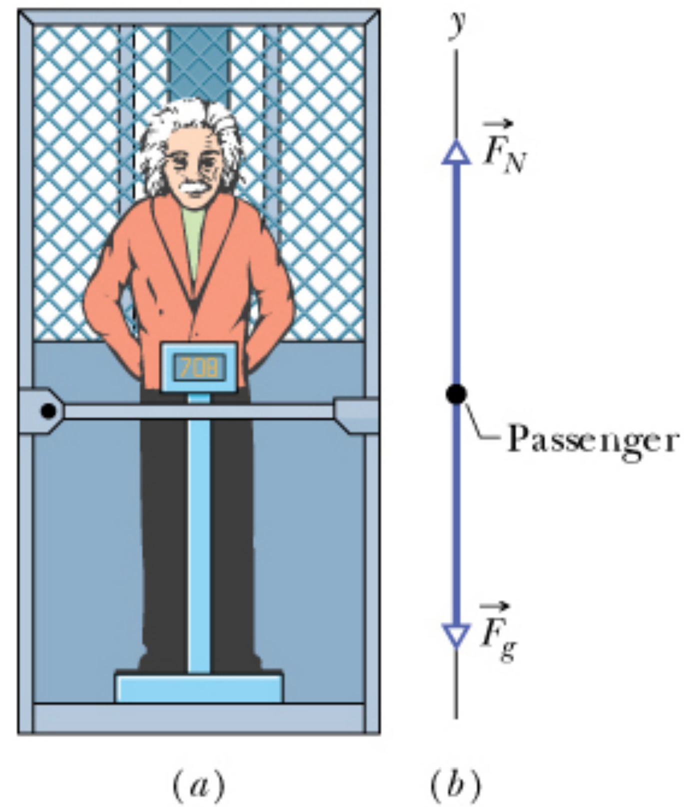
If the passenger moves with an acceleration $\vec{a}$ in the cab:

$$\vec{F} + \vec{F}_g - m\vec{a}_0 = m\vec{a}$$

In a noninertial frame, Newton's second law is:

$$\boxed{\sum \vec{F} - m\vec{a}_0 = m\vec{a}}$$

Sample Problem (p. 103): **In the figure below, a passenger of mass m=72.2 kg stands on a platform scale in an elevator cab. We are concerned with the scale readings when the cab is stationary and when it is moving up or down.**



(a) Find a general solution for the scale reading, whatever the vertical motion of the cab.

The scale reading is equal to the magnitude of the normal force F_N acting on the passenger.

$$F_N - mg = ma \Rightarrow F_N = m(g + a)$$

(b) What does the scale read if the cab is stationary or moving upward at a constant 0.50 m/s?

$$a = 0 \Rightarrow F_N = m(g + a) = 72.2 \times 9.8 \approx 708\,(N)$$

(c) What does the scale read if the cab accelerates upward at 3.20 m/s^2 and downward at 3.20 m/s^2?

$$F_N = m(g + a) = 72.2 \times (9.8 + 3.2) \approx 939\,(N)$$

$$F_N = m(g + a) = 72.2 \times (9.8 - 3.2) \approx 477\,(N)$$

(d) During the upward acceleration in part (c), what is the magnitude F_{net} of the net force on the passenger, and what is the magnitude $a_{p,cab}$ of his acceleration as measured in the frame of the cab? Does $F_{net} = m\vec{a}_{p,cab}$?

$$F_{net} = F_N - F_g = 939 - 708 = 231(N)$$

The passenger is stationary in the elevator, so: $a_{p,cab} = 0$

The cab is not an inertial frame, hence Newton's second law is not applicable in the frame of the cab:

$$F_{net} \neq m a_{p,cab}$$

If we want to use Newton's second law, we need to include a fictitious force:

$$\mathrm{F}_{\text{net}} + F_{\text{fictitious}} = \underbrace{\mathrm{F}_{\text{net}} - ma_{\text{cab,ground}}}_{=\,0} = \underbrace{ma_{\text{p,cap}}}_{=\,0}$$

Homework: 49, 51, 70 (p. 134-137)