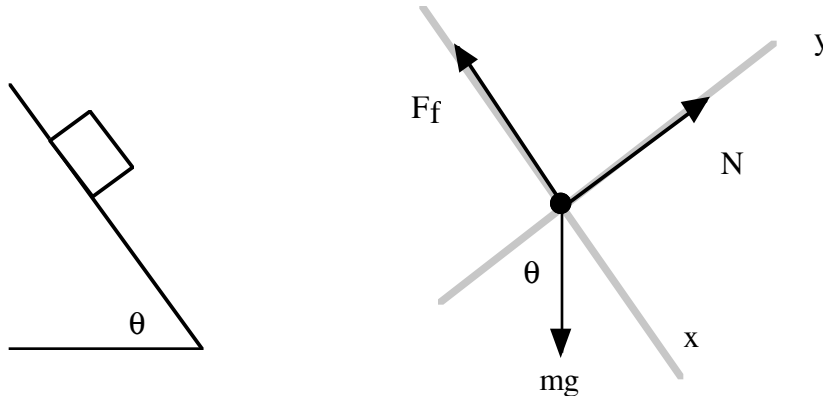


Problems from Chapter 6

6.1 The coefficient of static friction between Teflon and scrambled eggs is about 0.04. What is the smallest angle from the horizontal that will cause the eggs to slide across the bottom.

This problem is really about finding the maximum angle where the egg will *not* slide. We begin by drawing the force diagram. You may notice that this is the same drawing as problem 6.11. It is fundamentally the same problem.



$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

$$0 = mg \sin \theta - F_f$$

$$= mg \sin \theta - \mu N$$

$$= mg \sin \theta - \mu mg \cos \theta$$

$$mg \sin \theta = \mu mg \cos \theta$$

$$\tan \theta = \mu$$

$$\theta = \tan^{-1}(\mu) = 2.29^\circ$$

6.4. The mysterious sliding stones. Along the remote Racetrack Playa in Death Valley California, stones sometimes gouge out prominent trails in the desert floor, as if they had been migrating. For years, curiosity mounted about why the stones moved. One explanation was that strong winds during the occasional rainstorms would drag the rough stones over ground softened by rain. When the desert dried out, the trails behind the stones were hard-baked in place. According to measurements, the coefficient of kinetic friction between the stones and the wet playa ground is about 0.80. What horizontal force is needed on a stone of typical mass 20kg to maintain the stones motion once a gust has started it moving?.

The force of the wind must at least equal the force of friction. In this problem, the Normal force is equal to the weight, as in the previous problem.

$$F_{wind} = \mu N$$

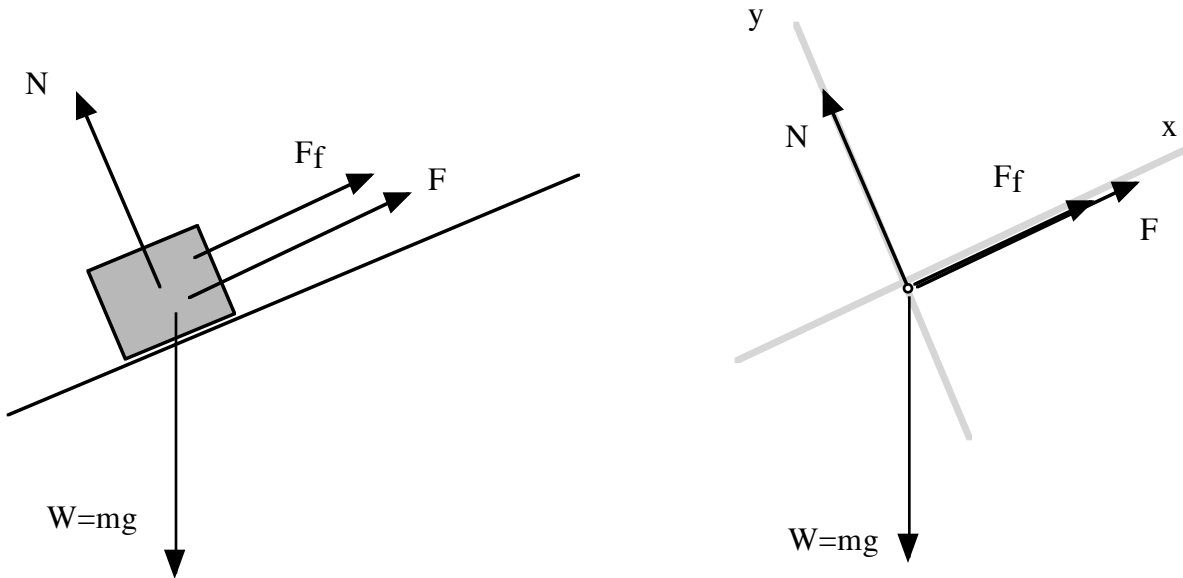
$$= \mu mg$$

$$= 0.80 \cdot 20\text{kg} \cdot 9.8\text{m/s}^2$$

$$= 156.8\text{N}$$

6.20 A loaded penguin sled weight 80N rests on a plane inclined at 20 degrees to the horizontal. Between the sled and the plane, the coefficient of static friction is 0.25, and the coefficient of kinetic friction is 0.15. (a) What is the minimum magnitude of the force F , parallel to the plane, that will prevent the sled from slipping down the plane. (b) What is the minimum magnitude F that will start the sled moving up the plane? (c) What value F is required to move the sled with constant velocity up the incline.

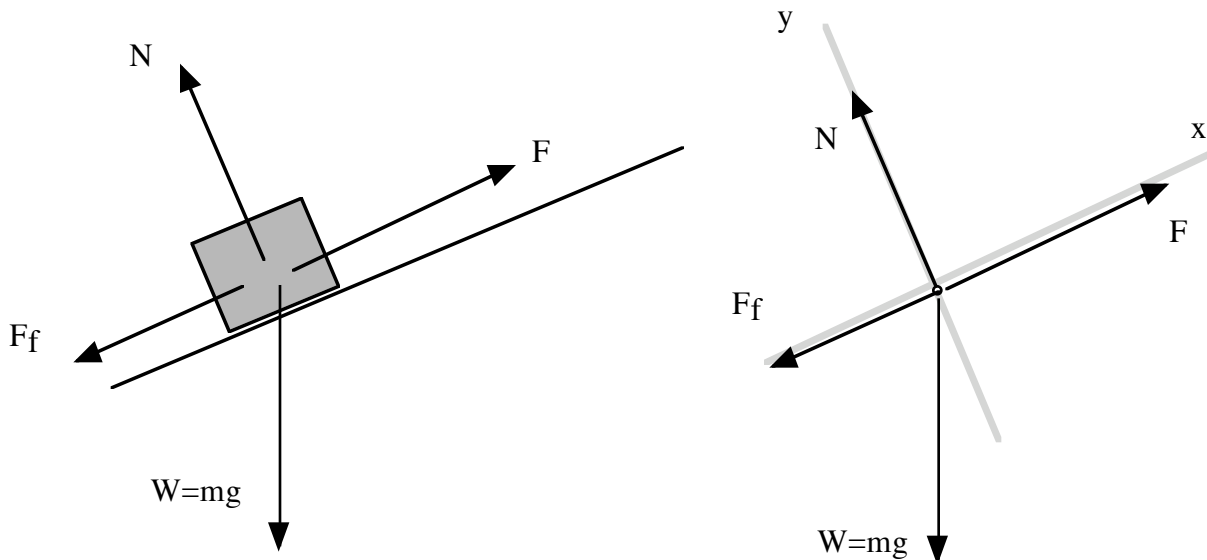
a) We begin by drawing the forces. Since the motion would be downward if F is too small, we draw Friction as pointing UP the incline for part a.



We now write the forces in component form. Since the sled is not to move, the net force will be zero.

$$\begin{aligned}
 & \text{y-direction} \\
 & 0 = N - mg \cos \theta \\
 & N = mg \cos \theta \\
 & \text{x-direction} \\
 & 0 = F + F_f - mg \sin \theta \\
 & F = mg \sin \theta - F_f \\
 & = mg \sin \theta - \mu N \\
 & = mg \sin \theta - \mu_s mg \cos \theta \\
 & = 80N \sin 20 - 0.25 \cdot 80N \cdot \cos 20 \\
 & = 8.57N
 \end{aligned}$$

b) In this section, we wish to get the block moving. The drawing will change, because the frictional force acts downward as it opposes the upward motion



y - direction

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

x - direction

$$0 = F - F_f - mg \sin \theta$$

$$F = mg \sin \theta + F_f$$

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

$$= mg \sin \theta + \mu_s mg \cos \theta$$

$$= 80N \sin 20 + 0.25 \cdot 80N \cdot \cos 20$$

$$= 46.2N$$

c) The drawing for c is the same as for b), but since the sled is now moving with constant speed (not just starting) we need use the kinetic coefficient of friction.

y - direction

$$0 = N - mg \cos \theta$$

$$N = mg \cos \theta$$

x - direction

$$0 = F - F_f - mg \sin \theta$$

$$F = mg \sin \theta + F_f$$

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

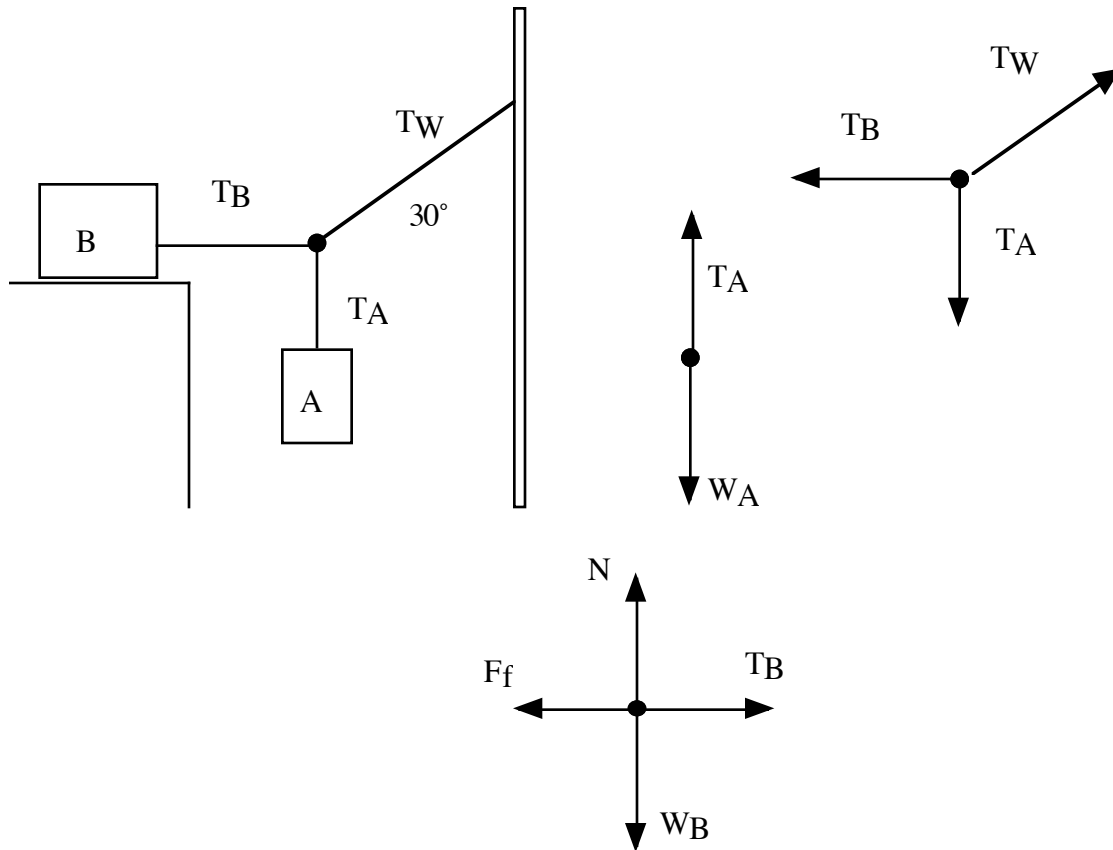
$$= mg \sin \theta + \mu_k mg \cos \theta$$

$$= 80N \sin 20 + 0.15 \cdot 80N \cdot \cos 20$$

$$= 38.6N$$

6.21. Block B in Fig. 6-30 weights 711N. The coefficient of static friction between block and horizontal surface is 0.25. Find the maximum weight block A for which the system will be stationary.

This problem is a classic “statics” problem where the net force on the two blocks and the knot. We begin by drawing the forces on the two blocks and on the knot.



The forces on A allow us to find the tension T_A .

$$0 = T_A - W_A$$

$$T_A = W_A$$

Now we write forces on the knot

$$0 = T_w \sin 30 - T_A$$

$$T_w = \frac{T_A}{\sin 30} = \frac{W_A}{\sin 30}$$

$$0 = T_w \cos 30 - T_B$$

$$T_B = T_w \cos 30$$

$$= \frac{W_A}{\sin 30} \cdot \cos 30$$

$$T_B = W_A \cot 30$$

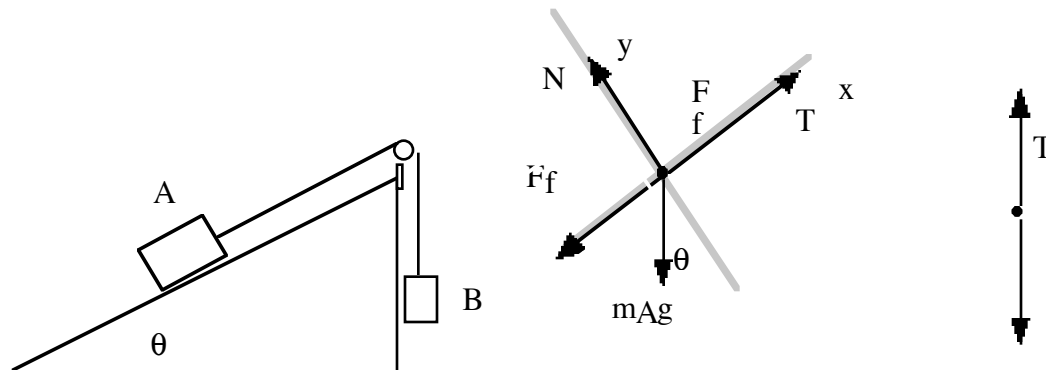
and on B. We then substitute and solve for the weight of A.

$$\begin{aligned}
0 &= N - W_B \\
N &= W_B \\
0 &= T_B - F_f \\
T_B &= F_f \\
W_A \cot 30 &= \mu N \\
W_A &= \frac{\mu N}{\cot 30} \\
&= \mu W_B \tan 30 \\
&= 0.25 \cdot 711 \text{ N} \cdot \tan 30 \\
&= 102.6 \text{ N}
\end{aligned}$$

6.27 Body A in Fig 6-34 weighs 102 N and body B weighs 32 N. The coefficients of friction between A and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. The angle is 40 degrees. Find the acceleration of A if (a) A is initially at rest, (b) A is initially moving up the incline, and (c) A is initially moving down the incline.

We begin, as always by drawing the forces. Lets assume that the static friction is keeping A from sliding down.

a) If A is initially at rest, it has no acceleration.



b) For a mass sliding upward.

$$\begin{aligned}
0 &= N - m_A g \cos \theta \\
N &= m_A g \cos \theta
\end{aligned}$$

Mass A

$$\begin{aligned}
m_A a &= T - F_f - m_A g \sin \theta \\
&= T - \mu N - m_A g \sin \theta \\
&= T - \mu m_A g \cos \theta - m_A g \sin \theta
\end{aligned}$$

Mass B

$$m_B a = m_B g - T$$

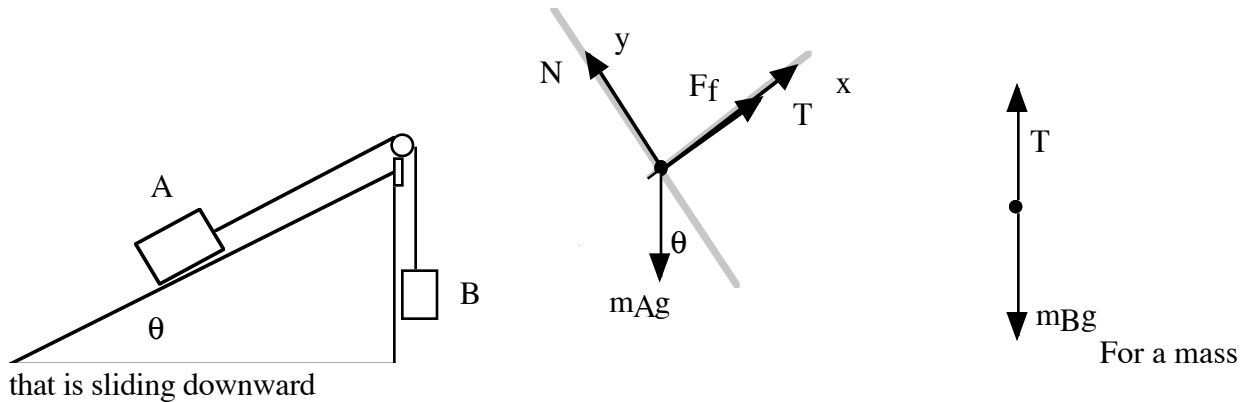
We now solve for T and plug in to find a.

$$\begin{aligned}
 T &= m_B g - m_B a \\
 m_A a &= T - \mu m_A g \cos \theta - m_A g \sin \theta \\
 m_A a &= m_B g - m_B a - \mu m_A g \cos \theta - m_A g \sin \theta \\
 a &= \frac{m_B g - \mu m_A g \cos \theta - m_A g \sin \theta}{m_A + m_B}
 \end{aligned}$$

If the mass is sliding up initially, we find a using the coefficient of kinetic friction

$$\begin{aligned}
 a &= \frac{m_B g - \mu m_A g \cos \theta - m_A g \sin \theta}{m_A + m_B} \\
 &= \frac{32N - 0.25 \cdot 102N \cdot \cos 40 - 102N \sin 40}{(32N + 102N) / 9.8m / s^2} \\
 &= -3.89m / s^2
 \end{aligned}$$

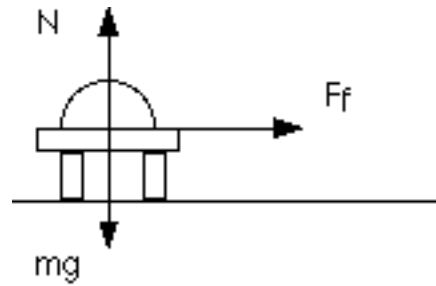
If the mass is sliding downward, we simply reverse the frictional piece of the expression.



$$\begin{aligned}
 a &= \frac{m_B g + \mu m_A g \cos \theta - m_A g \sin \theta}{m_A + m_B} \\
 &= \frac{32N + 0.25 \cdot 102N \cdot \cos 40 - 102N \sin 40}{(32N + 102N) / 9.8m / s^2} \\
 &= -1.03m / s^2
 \end{aligned}$$

6.36 Suppose the coefficient of static friction between the road and the tires on a car is 0.6 and the

care has no negative lift. What speed will put the care on the verge of sliding as it rounds a level curve of 30.5 m radius.



$$\frac{mv^2}{r} = \mu N$$

$$N = mg$$

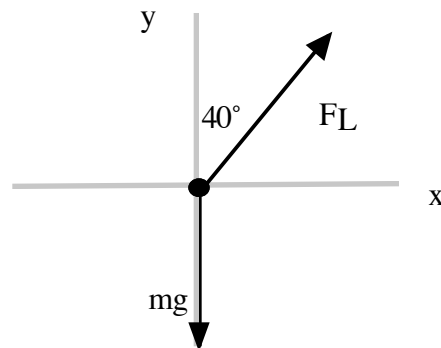
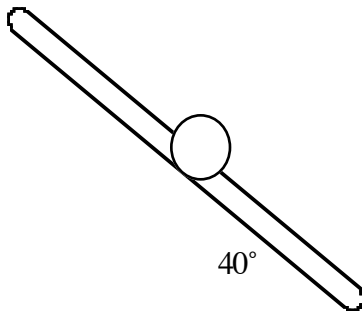
$$\frac{mv^2}{r} = \mu mg$$

$$v^2 = rg$$

$$v = \sqrt{rg} = \sqrt{30.5 \cdot 9.8}$$

$$= 17.28 \text{ m/s}$$

6.45. An airplane is flying in a horizontal circle at a speed of 480 km/h. If the wings of the plane are tilted 40° to the horizontal, what is the radius of the circle in which the plane is flying. Assume that the required force is provided entirely by an aerodynamic lift that is perpendicular to the wing surface.



We write the forces and set the net inward force equal to the centripetal force. $480 \text{ km/h} = 133.3 \text{ m/s}$.

$$0 = F_L \cos 40 - mg$$

$$F_L \cos 40 = mg$$

$$F_L = \frac{mg}{\cos 40}$$

$$F_{net-in} = ma = m \frac{v^2}{r} = F_L \sin 40$$

$$m \frac{v^2}{r} = \left(\frac{mg}{\cos 40} \right) \cdot \sin 40$$

$$\frac{v^2}{r} = g \tan 40$$

$$r = \frac{v^2}{g \tan 40} = \frac{(133.3 \text{ m/s})^2}{9.8 \text{ m/s}^2 \cdot \tan 40}$$
$$= 2160.8 \text{ m}$$