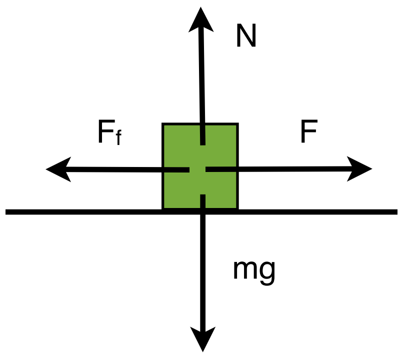
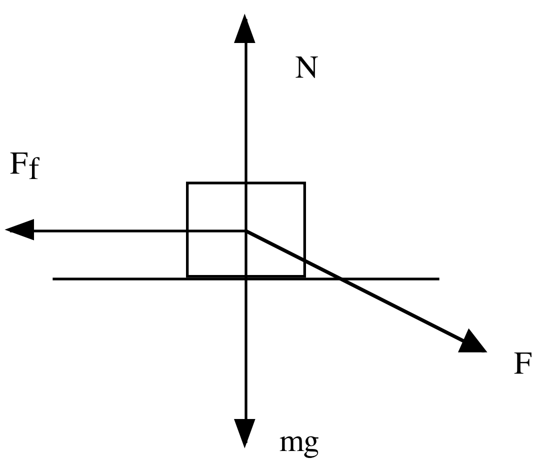
Problems from Chapter 6

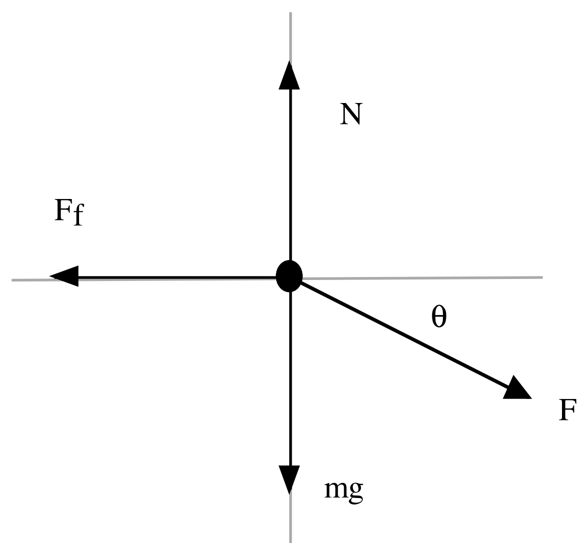
6.3 A person pushes horizontally with a force of 220 N on a 55 kg crate to move it across a level floor. The coefficient of kinetic friction is 0.35. What is the magnitude of (a) the frictional force and (b) the crate's acceleration.



$$ma_y = 0 = N - mg$$
$$N = mg$$
$$F_f = \mu N = \mu mg = 0.35 \cdot 55kg \cdot 9.8m/s^2 = 188.65N$$
$$ma_x = F - F_f$$
$$a_x = \frac{F - F_f}{m} = \frac{220N - 188.65N}{55kg} = 0.57m/s^2$$

6.7. A 3.5 kg block is pushed along a horizontal floor by a force F of magnitude 15N at an angle of 40 degrees with the horizontal. The coefficient of kinetic friction between the block and the floor is 0.25. Calculate the magnitudes of (a) The frictional force on the block from the floor and (b) the acceleration of the block.





We can now write the forces in the vertical and horizontal directions:

Vertical

$$0 = N - mg - F\sin\theta$$
$$N = mg + F\sin\theta$$

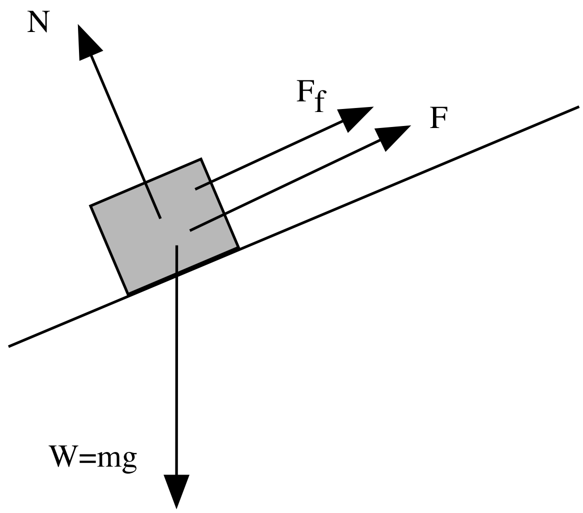
Horizontal

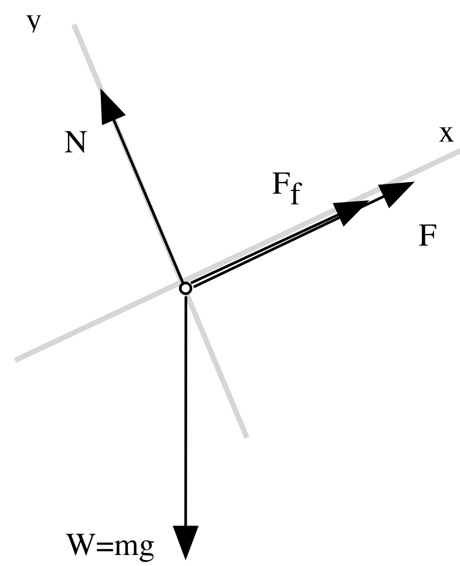
$$ma = F\cos\theta - F_f = F\cos\theta - \mu N$$
$$a = \frac{F\cos\theta - \mu(mg + F\sin\theta)}{m}$$

$$
\begin{aligned}
F_f &= \mu(mg + F\sin\theta) \\
&= 0.25 \cdot (3.5kg \cdot 9.8m/s^2 + 15N\sin 40°) \\
&= 10.99N \\
a &= \frac{F\cos\theta - \mu(mg + F\sin\theta)}{m} \\
&= \frac{15N\cos 40° - 10.99N}{3.5kg} \\
&= 0.143m/s^2
\end{aligned}
$$

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.



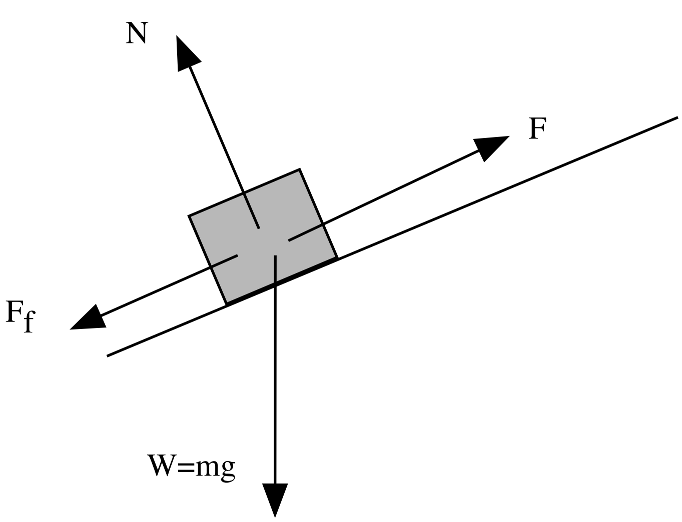


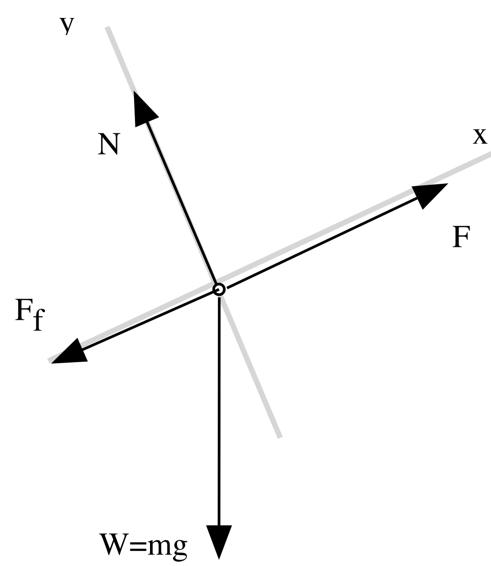
We now write the forces in component form. Since the sled is not to move, the net force will be zero.

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

$$
\begin{aligned}
&y-direction\\
0 &= N - mg\cos\theta\\
N &= mg\cos\theta
\end{aligned}
$$

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





$$
\begin{aligned}
&x-direction\\
0 &= F - F_f - mg\sin\theta\\
F &= mg\sin\theta + F_f\\
&= mg\sin\theta + \mu N\\
&= mg\sin\theta + \mu_s mg\cos\theta\\
&= 80N\sin 20 + 0.25\cdot 80N\cdot\cos 20\\
&= 46.2N
\end{aligned}
$$

$$
\begin{aligned}
&y-direction\\
0 &= N - mg\cos\theta\\
N &= mg\cos\theta
\end{aligned}
$$

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.

$x-direction$

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

$$\begin{aligned}F&=mg\sin\theta+F_f\\&=mg\sin\theta+\mu N\\&=mg\sin\theta+\mu_k\,mg\cos\theta\\&=80N\sin 20+0.15\cdot 80N\cdot\cos 20\\&=38.6N\end{aligned}$$

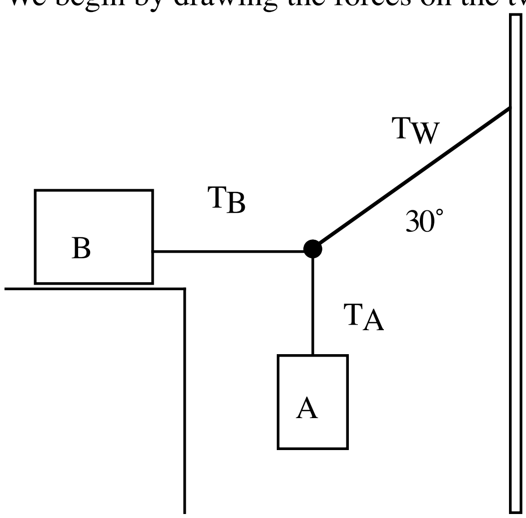
$y-direction$

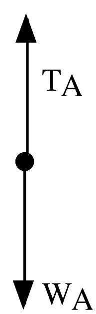
$$0=N-mg\cos\theta$$

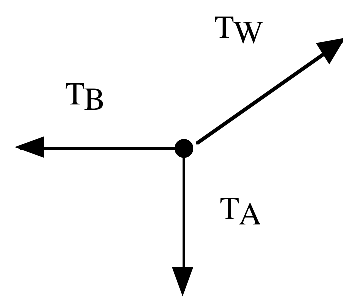
$$N=mg\cos\theta$$

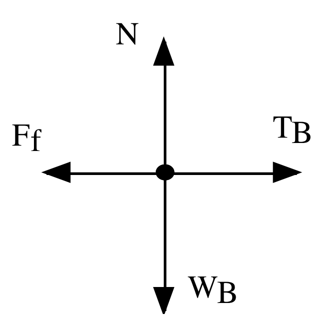
6.23 Block B in Fig. 6-31 weights 711N. The coefficient of static friction between block and horizontal surface is 0.25. Find the maximum weight block A for which the system will be stationary.

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

$$0 = T_W \sin 30 - T_A$$
$$T_W = \frac{T_A}{\sin 30} = \frac{W_A}{\sin 30}$$
$$0 = T_W \cos 30 - T_B$$
$$T_B = T_W \cos 30$$
$$= \frac{W_A}{\sin 30} \cdot \cos 30$$
$$T_B = W_A \cot 30$$

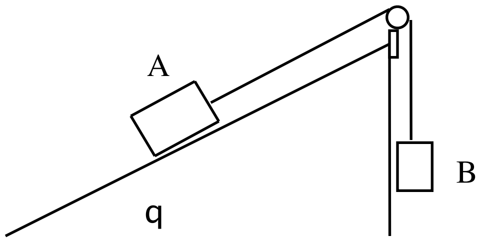
and on B. We then substitute and solve for the weight of A.

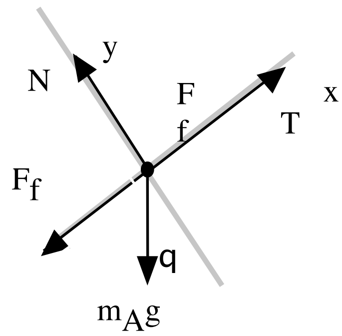
$$0 = N - W_B$$
$$N = W_B$$
$$0 = T_B - F_f$$
$$T_B = F_f$$
$$W_A \cot 30 = \mu N$$
$$W_A = \frac{\mu N}{\cot 30}$$
$$= \mu W_B \tan 30$$
$$= 0.25 \cdot 711N \cdot \tan 30$$
$$= 102.6N$$

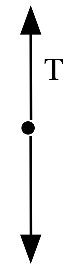
6.29 Body A in Fig 6-36 weights 102 N and body B weights 32N. The coefficients of friction between A and the include are $\mu_s = 0.56$ and $\mu_k = 0.25$. The angle is 40 degrees. Find the acceleration of A if (a) A is initially at rest, (b) A is initially moving up the incline, and (b) A is initially 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.

Mass A

$$0 = N - m_A\, g\cos\theta$$
$$N = m_A\, g\cos\theta$$

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

Mass B

$$m_B a = m_B g - T$$

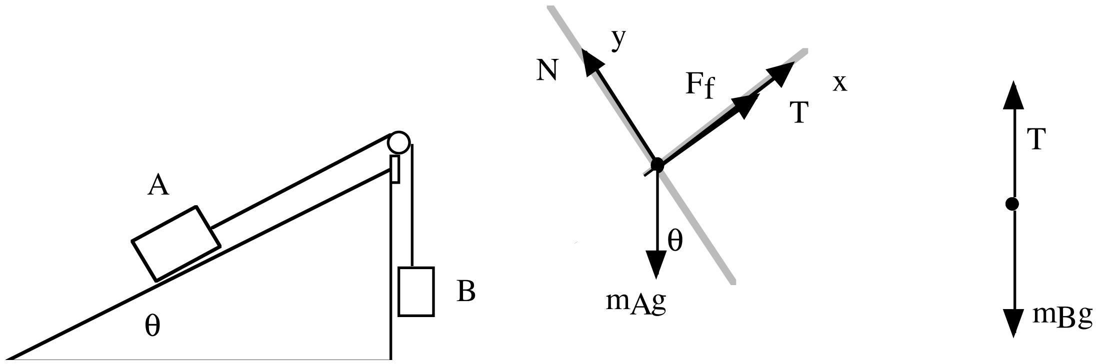
We now solve for T and plug in to find a.

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

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.



For a mass that is sliding downward

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

6.36. The terminal speed of a sky diver in the spread-eagle position is 160 km/h. In the nosedive position, the terminal speed is 310 km/hr. Assuming that C does not change from one position to another, find the ration of the effective cross-sectional area A in the slower position to that in the faster position.

Terminal velocity occurs when the drag force equals the weight. In both positions, the drag -force equals the weight of the sky diver. This means that the Drag forces in both positions equal each other.

$$
\begin{aligned}
D_s &= D_n \\
\frac{1}{2}C\rho A_s {v_s}^2 &= \frac{1}{2}C\rho A_n {v_n}^2 \\
A_s {v_s}^2 &= A_n {v_n}^2 \\
\frac{A_s}{A_n} &= \frac{{v_n}^2}{{v_s}^2} = \frac{(310km/h)^2}{(160km/h)^2} \\
&= 3.76
\end{aligned}
$$

6.41 What is the smallest radius of an unbanked (flat) track around which a bicyclist can travel if her speed is 29 km/h and the coefficient of static friction is 0.32.

This is a centripetal force problem. The net inward force is the centripetal force. In this case, only friction contributes to the centripetal force. The normal force is just the biker's weight.

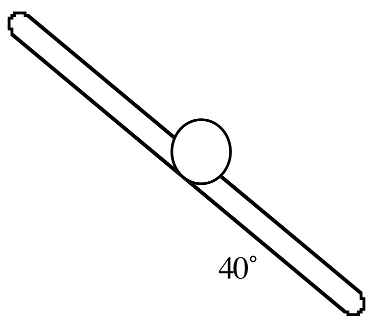
$$v = \frac{29km}{h} \cdot \frac{1000m}{1km} \cdot \frac{1h}{3600s} = 8.06 m/s$$

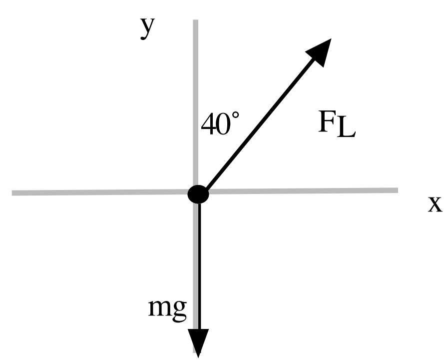
$$\frac{mv^2}{r} = \mu N$$

$$\frac{mv^2}{r} = \mu m g$$

$$r = \frac{v^2}{\mu g} = \frac{(8.06 m/s)^2}{0.32 \cdot 9.8 m/s^2} = 20.7m$$

6.53. 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 km/h=133.3m/s.

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

$$F_L \cos 40 = mg$$

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

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

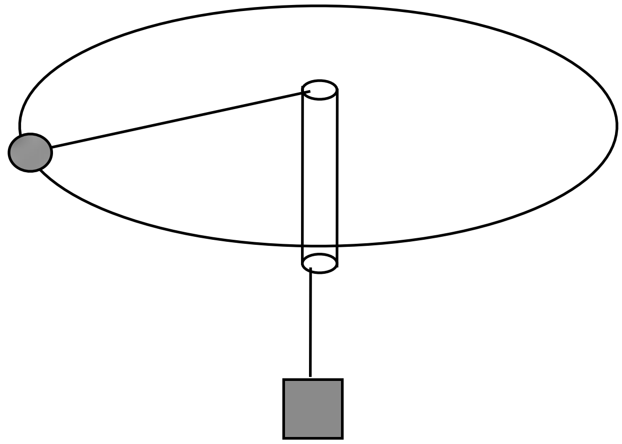
$$m\frac{v^2}{r} = \left(\frac{mg}{\cos 40}\right) \cdot \sin 40$$

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

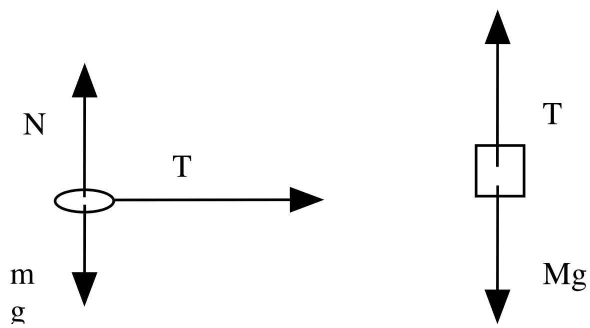
$$r = \frac{v^2}{g \tan 40} = \frac{(133.3 m/s)^2}{9.8 m/s^2 \cdot \tan 40}$$

$$= 2160.8m$$

6.55 A puck of mass $m = 1.50\,kg$ slides in a circle of radius $r = 20.0\,cm$ on a frictionless table while attached to a hanging cylinder of mass $M = 2.50\,kg$ by a cord through a hole in the table (Fig 6-41) What speed keeps the cylinder at rest.



We write out the forces on each mass. The hanging mass does not accelerate. The orbiting mass experiences a net inward force that is the centripetal force.



We write out the forces and solve for v.

$$\frac{mv^2}{r} = T$$

$$v = \sqrt{\frac{rT}{m}} \qquad 0 = T - Mg \qquad v = \sqrt{\frac{rT}{m}} = \sqrt{\frac{r\,Mg}{m}} = \sqrt{\frac{0.2 \cdot 2.5 \cdot 9.8}{1.5}}$$

$$T = Mg \qquad = 1.81 m/s$$

6.98. See your notes on banked curves.