Halliday ♦ Resnick ♦Walker

FUNDAMENTALS OF PHYSICS
SIXTH EDITION

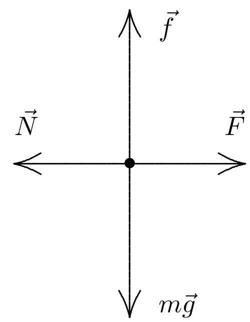
Selected Solutions

Chapter 6

6.9
6.21
6.27
6.43

9. (a) The free-body diagram for the block is shown below. $\vec{F}$ is the applied force, $\vec{N}$ is the normal force of the wall on the block, $\vec{f}$ is the force of friction, and $m\vec{g}$ is the force of gravity. To determine if the block falls, we find the magnitude f of the force of friction required to hold it without accelerating and also find the normal force of the wall on the block.

We compare f and $\mu_s N$. If $f < \mu_s N$, the block does not slide on the wall but if $f > \mu_s N$, the block does slide. The horizontal component of Newton's second law is $F - N = 0$, so $N = F = 12\,\text{N}$ and $\mu_s N = (0.60)(12\,\text{N}) = 7.2\,\text{N}$. The vertical component is $f - mg = 0$, so $f = mg = 5.0\,\text{N}$. Since $f < \mu_s N$ the block does not slide.

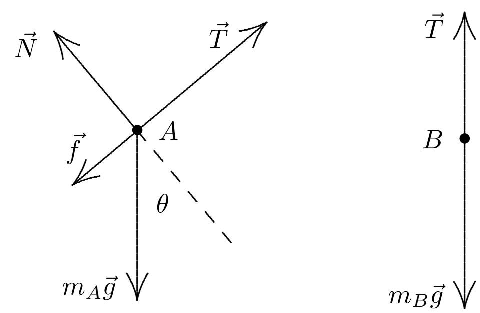


(b) Since the block does not move $f = 5.0\,\text{N}$ and $N = 12\,\text{N}$. The force of the wall on the block is

$$\vec{F}_w = -N\,\hat{\mathrm{i}} + f\,\hat{\mathrm{j}} = -(12\,\text{N})\,\hat{\mathrm{i}} + (5.0\,\text{N})\,\hat{\mathrm{j}}$$

where the axes are as shown on Fig. 6-21 of the text.

21. First, we check to see if the bodies start to move. We assume they remain at rest and compute the force of (static) friction which holds them there, and compare its magnitude with the maximum value $\mu_s N$. The free-body diagrams are shown below. T is the magnitude of the tension force of the string, f is the magnitude of the force of friction on body A, N is the magnitude of the normal force of the plane on body A, $m_A\vec{g}$ is the force of gravity on body A (with magnitude $W_A = 102$ N), and $m_B\vec{g}$ is the force of gravity on body B (with magnitude $W_B = 32$ N). $\theta = 40°$ is the angle of incline. We are not told the direction of $\vec{f}$ but we assume it is downhill. If we obtain a negative result for f, then we know the force is actually up the plane.



(a) For A we take the $+x$ to be uphill and $+y$ to be in the direction of the normal force. The x and y components of Newton's second law become

$$\begin{aligned} T - f - W_A \sin\theta &= 0 \\ N - W_A \cos\theta &= 0\ . \end{aligned}$$

Taking the positive direction to be *downward* for body B, Newton's second law leads to

$$W_B - T = 0\ .$$

Solving these three equations leads to

$$f = W_B - W_A \sin\theta = 32 - 102 \sin 40° = -34 \text{ N}$$

(indicating that the force of friction is *uphill*) and to

$$N = W_A \cos\theta = 102 \cos 40° = 78 \text{ N}$$

which means that $f_{s,\max} = \mu_s N = (0.56)(78) = 44$ N. Since the magnitude f of the force of friction that holds the bodies motionless is less than $f_{s,\max}$ the bodies remain at rest. The acceleration is zero.

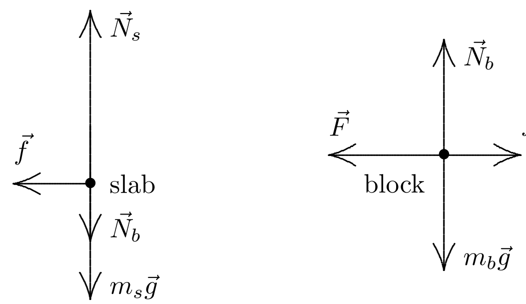
(b) Since A is moving up the incline, the force of friction is downhill with magnitude $f_k = \mu_k N$. Newton's second law, using the same coordinates as in part (a), leads to

$$\begin{aligned} T - f_k - W_A \sin\theta &= m_A\, a \\ N - W_A \cos\theta &= 0 \\ W_B - T &= m_B\, a \end{aligned}$$

for the two bodies. We solve for the acceleration:

$$\begin{aligned} a &= \frac{W_B - W_A \sin\theta - \mu_k W_A \cos\theta}{m_B + m_A} \\ &= \frac{32\,\text{N} - (102\,\text{N}) \sin 40° - (0.25)(102\,\text{N}) \cos 40°}{(32\,\text{N} + 102\,\text{N}) \,/\, \left(9.8\,\text{m/s}^2\right)} \\ &= -3.9 \text{ m/s}^2\ . \end{aligned}$$

27. The free-body diagrams for the slab and block are shown below. $\vec{F}$ is the 100 N force applied to the block, $\vec{N}_s$ is the normal force of the floor on the slab, N_b is the magnitude of the normal force between the slab and the block, $\vec{f}$ is the force of friction between the slab and the block, m_s is the mass of the slab, and m_b is the mass of the block. For both objects, we take the $+x$ direction to be to the left and the $+y$ direction to be up.



Applying Newton's second law for the x and y axes for (first) the slab and (second) the block results in four equations:

$$\begin{aligned} f &= m_s a_s \\ N_s - N_b - m_s g &= 0 \\ F - f &= m_b a_b \\ N_b - m_b g &= 0 \end{aligned}$$

from which we note that the maximum possible static friction magnitude would be

$$\mu_s N_b = \mu_s m_b g = (0.60)(10\,\text{kg})(9.8\,\text{m/s}^2) = 59 \text{ N} .$$

We check to see if the block slides on the slab. Assuming it does not, then $a_s = a_b$ (which we denote simply as a) and we solve for f:

$$f = \frac{m_s F}{m_s + m_b} = \frac{(40\,\text{kg})(100\,\text{N})}{40\,\text{kg} + 10\,\text{kg}} = 80 \text{ N}$$

which is greater than $f_{s,\max}$ so that we conclude the block is sliding across the slab (their accelerations are different).

(a) Using $f = \mu_k N_b$ the above equations yield

$$a_b = \frac{F - \mu_k m_b g}{m_b} = \frac{100\,\text{N} - (0.40)(10\,\text{kg})(9.8\,\text{m/s}^2)}{10\,\text{kg}} = 6.1 \text{ m/s}^2 .$$

The result is positive which means (recalling our choice of $+x$ direction) that it accelerates leftward.

(b) We also obtain

$$a_s = \frac{\mu_k m_b g}{m_s} = \frac{(0.40)(10\,\text{kg})(9.8\,\text{m/s}^2)}{40\,\text{kg}} = 0.98 \text{ m/s}^2 .$$

As mentioned above, this means it accelerates to the left.

43. (a) At the top (the highest point in the circular motion) the seat pushes up on the student with a force of magnitude $N = 556\,\text{N}$. Earth pulls down with a force of magnitude $W = 667\,\text{N}$. The seat is pushing up with a force that is smaller than the student's weight, and we say the student experiences a decrease in his "apparent weight" at the highest point.

(b) When the student is at the highest point, the net force toward the center of the circular orbit is $W - F_t$ (note that we are choosing downward as the positive direction). According to Newton's second law, this must equal mv^2/R, where v is the speed of the student and R is the radius of the orbit. Thus

$$mv^2/R = W - N = 667\,\text{N} - 556\,\text{N} = 111\ \text{N}\ .$$

(c) Now N is the magnitude of the upward force exerted by the seat when the student is at the lowest point. The net force toward the center of the circle is $F_b - W = mv^2/R$ (note that we are now choosing upward as the positive direction). The Ferris wheel is "steadily rotating" so the value mv^2/R is the same as in part (a). Thus,

$$N = \frac{mv^2}{R} + W = 111\,\text{N} + 667\,\text{N} = 778\ \text{N}\ .$$

(d) If the speed is doubled, mv^2/R increases by a factor of 4, to $444\,\text{N}$. Therefore, at the highest point we have $W - N = mv^2/R$, which leads to

$$N = 667\,\text{N} - 444\,\text{N} = 223\ \text{N}\ .$$

Similarly, the normal force at the lowest point is now found to be $N = 667 + 444 \approx 1.1$ kN.