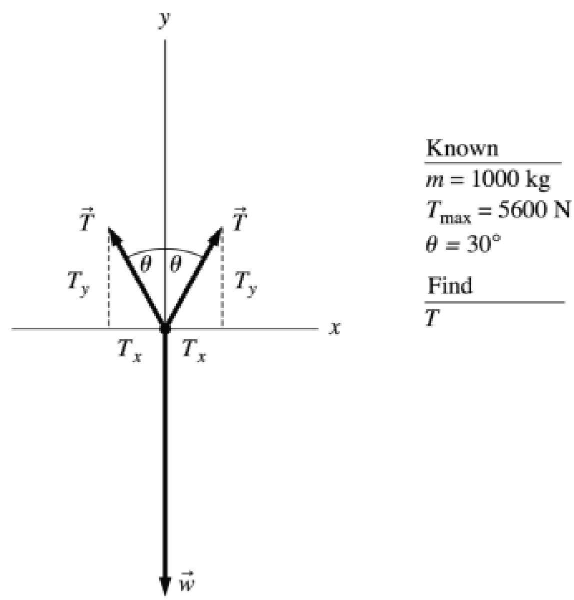
P5.4. Strategize: This problem involves forces in two dimensions. We separate the forces into components and use Newton's second law.

Prepare: The forces acting on the beam are shown on a free-body diagram below. You can model the beam as a particle and assume $\vec{F}_{\text{net}} = 0$ N to calculate the tensions in the suspension ropes.



Solve: The beam attached to the ropes will remain in static equilibrium only if $T < T_{\text{max}}$, where T_{max} is the maximum sustained tension. The equilibrium equations in vector and component form are

$$\vec{F}_{\text{net}} = \vec{T} + \vec{T} + \vec{w} = \vec{0}\text{ N}$$
$$(F_{\text{net}})_x = T_x + T_x = 0\text{ N}$$
$$(F_{\text{net}})_y = T_y + T_y + w_y = 0\text{ N}$$

Using the free-body diagram and $w = mg$ yields:

$$2T\cos\theta - w = 0\text{ N} \Rightarrow T = \frac{mg}{2\cos\theta} = \frac{(1000\text{ kg})(9.8\text{ m/s}^2)}{2\cos 30°} = 5660\text{ N}$$

So the ropes break.

Assess: The above approach and result seem reasonable.

P5.9. Strategize: We are told the force along the direction of motion and the mass, such that we can determine the acceleration. Given the initial and final speeds, this becomes a simple kinematics problem.
Prepare: The sum of all forces in this case is very simple, with only friction acting to slow the stone. Let us call the direction in which the stone is initially pushed the $+x$ direction. We determine the acceleration and use the kinematic equation $(v_f)_x^2 = (v_i)_x^2 + 2a_x\Delta x.$

Solve: From Newton's second law, we see $a_x = \frac{(F_{net})_x}{m} = \frac{-2.0\text{ N}}{20\text{ kg}} = -0.10\text{ m/s}^2$. Inserting this and given values into the kinematic equation we selected, we find

$$(v_i)_x^2 = (v_f)_x^2 - 2a_x\Delta x = (0)^2 - 2(-0.10\text{ m/s})(27.9\text{ m})$$
$$(v_i)_x = \sqrt{-2(-0.10\text{ m/s})(27.9\text{ m})} = 2.4\text{ m/s}$$

Assess: Our answer is of a reasonable order of magnitude and has the correct direction.

P5.11. Strategize: This is a straightforward application of Newton's second law, in two dimensions. There is no need to consider components, since all forces lie along x- or y-axes.
Prepare: The free-body diagram shows five forces acting on an object whose mass is 2.0 kg. We will first find the net force along the x- and the y-axes and then divide these forces by the object's mass to obtain the x- and y-components of the object's acceleration.
Solve: Applying Newton's second law:

$$a_x = \frac{(F_{net})_x}{m} = \frac{4\text{ N} - 2\text{ N}}{2\text{ kg}} = 1.0\text{ m/s}^2 \quad a_y = \frac{(F_{net})_y}{m} = \frac{3\text{ N} - 1\text{ N} - 2\text{ N}}{2\text{ kg}} = 0.0\text{ m/s}^2$$

Assess: The object's acceleration is only along the x-axis.

P5.17. Strategize: We are told the acceleration of the astronauts, and we are given information about forces acting on them. We can determine what the necessary contact force between the floor of the spacecraft and their bodies would be (which is the apparent weight).
Prepare: We will use Newton's second law in the vertical direction (calling vertically upward from the surface of the moon $+y$.
Solve: We have, for the sum of all forces on the astronauts $\sum(F_{\text{on astro}})_y = n - mg = ma_y$. Here g refers to the acceleration due to gravity on the moon. Thus $n = m(a_y + g) = (75\text{ kg})((3.4\text{m/s}^2) + (1.6\text{m/s}^2)) = 3.8\times10^2\text{ N}$. This normal force between the floor and the astronaut is the apparent weight.

Assess: Note that on Earth the weight of a 75 kg astronaut would be about 740 N. It is reasonable that the apparent weight taking off from the moon is still smaller than this since gravity is so weak there and the acceleration of the spacecraft was also small compared to Earth's 9.8m/s^2 acceleration due to gravity.

P5.23. Strategize: This problem deals with apparent weight, which is the contact force between the passenger and the surface on which he/she is resting. We will use the sum of all forces in the direction of motion (here the y direction) to determine the unknown contact force.

Prepare: The passenger is acted on by only two vertical forces: the downward pull of gravity and the upward force of the elevator floor. Referring to Figure P5.23, the graph has three segments corresponding to different conditions: (1) increasing velocity, meaning an upward acceleration, (2) a period of constant upward velocity, and (3) decreasing velocity, indicating a period of deceleration (negative acceleration). Given the assumptions of our model, we can calculate the acceleration for each segment of the graph.
Solve: The acceleration for the first segment is

$$a_y = \frac{v_f - v_i}{t_f - t_i} = \frac{8\text{ m/s} - 0\text{ m/s}}{2\text{ s} - 0\text{ s}} = 4\text{ m/s}^2 \Rightarrow w_{app} = w\left(1 + \frac{a_y}{g}\right) = (mg)\left(1 + \frac{4\text{ m/s}^2}{9.80\text{ m/s}^2}\right)$$
$$= (75\text{ kg})(9.80\text{ m/s}^2)\left(1 + \frac{4}{9.8}\right) = 1000\text{ N}$$

For the second segment, $a_y = 0\text{ m/s}^2$ and the apparent weight is

$$w_{app} = w\left(1 + \frac{0\text{ m/s}^2}{g}\right) = mg = (75\text{ kg})(9.80\text{ m/s}^2) = 740\text{ N}$$

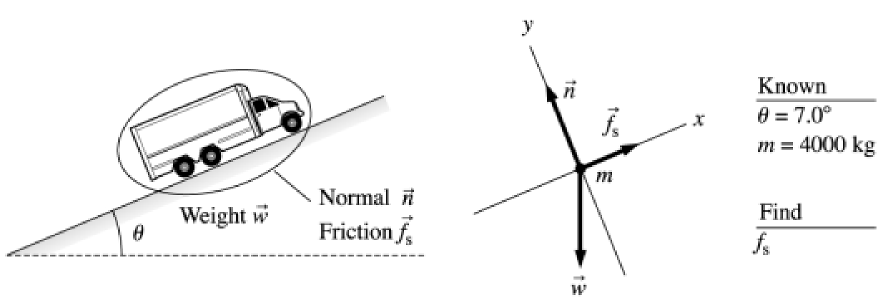
For the third segment,

$$a_y = \frac{v_3 - v_2}{t_3 - t_2} = \frac{0\text{ m/s} - 8\text{ m/s}}{10\text{ s} - 6\text{ s}} = -2\text{ m/s}^2$$
$$\Rightarrow w_{app} = w\left(1 + \frac{-2\text{ m/s}^2}{9.80\text{ m/s}^2}\right) = (75\text{ kg})(9.80\text{ m/s}^2)(1 - 0.2) = 590\text{ N}$$

Assess: As expected, the apparent weight is greater than normal when the elevator is accelerating upward and lower than normal when the acceleration is downward. When there is no acceleration the weight is normal. In all three cases the magnitudes are reasonable, given the mass of the passenger and the accelerations of the elevator.

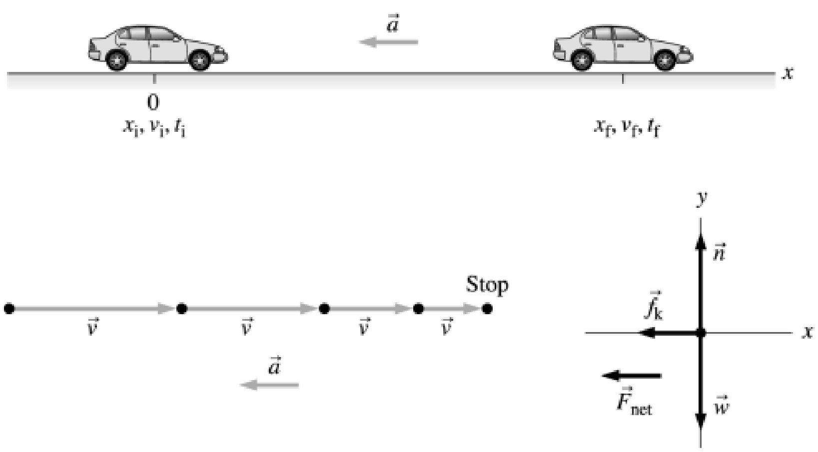
P5.28. Strategize: The truck is in static equilibrium. We can apply Newton's second law to determine the unknown force of friction.
Prepare: Below we identify the forces acting on the truck and construct a free-body diagram.
Solve: The truck is not accelerating, so it is in equilibrium, and we can apply Newton's first law. The normal force has no component in the x-direction, so we can ignore it here. For the other two forces

$$(F_{net})_x = \Sigma F_x = f_s - w_x = 0\text{ N} \Rightarrow f_s = w_x = mg\sin\theta = (4000\text{ kg})(9.80\text{ m/s}^2)(\sin 7.0°) = 4800\text{N}$$



Assess: The truck's weight (mg) is roughly 40,000 N. A friction force that is $\approx 12\%$ of the truck's weight seems reasonable.

P5.29. Strategize: We can determine the acceleration of the car through a straightforward application of Newton's second law. Assuming the acceleration is constant, we can then use kinematics to determine over what distance the car came to a stop.
Prepare: The car is undergoing skidding, so it is decelerating and the force of kinetic friction acts to the left. We give below an overview of the pictorial representation, a motion diagram, a free-body diagram, and a list of values. We will first apply Newton's second law to find the deceleration and then use kinematics to obtain the length of the skid marks.



Known	
$x_i = 0$	$v_i = 40$ m/s
$t_i = 0$	$m = 1000$ kg
$v_f = 0$	$\mu_k = 0.6$

Find
x_f

Solve: We begin with Newton's second law. Although the motion is one-dimensional, we need to consider forces in both the x- and y-directions. However, we know that $a_y = 0 \text{ m/s}^2$. We have

$$a_x = \frac{(F_{net})_x}{m} = \frac{-f_k}{m} \qquad a_y = 0\,\text{m/s}^2 = \frac{(F_{net})_y}{m} = \frac{n-w}{m} = \frac{n-mg}{m}$$

We used $(f_k)_x = -f_k$ because the free-body diagram tells us that $\vec{f}_k$ points to the left. The force of kinetic friction relates $\vec{f}_k$ to $\vec{n}$ with the equation $f_k = \mu_k n$. The y-equation is solved to give $n = mg$. Thus, the kinetic friction force is $f_k = \mu_k mg$.
Substituting this into the x-equation yields

$$a_x = \frac{-\mu_k mg}{m} = -\mu_k g = -(0.6)(9.80\text{ m/s}^2) = -5.88\text{ m/s}^2$$

The acceleration is negative because the acceleration vector points to the left as the car slows. Now we have a constant-acceleration kinematics problem. Δt isn't known, so use

$$v_f^2 = 0\text{ m}^2/\text{s}^2 = v_i^2 + 2a_x\Delta x \Rightarrow \Delta x = -\frac{(40\text{ m/s})^2}{2(-5.88\text{ m/s}^2)} = 140\text{ m}$$

Assess: The skid marks are 140 m long. This is ≈ 430 feet, reasonable for a car traveling at ≈ 80 mph. It is worth noting that an algebraic solution led to the m canceling out.

P5.38. Strategize: We can find the drag force using Equation 5.12 from the text.
Prepare: From Example 5.15 we'll assume the cross section area of the runner is 0.72 m^2. Table 5.4 gives the drag coefficient of a running person as $C_D = 1.2$. Converting 18 min to SI units gives 1080 s.
Solve: Using Equation 5.12, $D = \frac{1}{2}C_D\rho A v^2$ with $\rho = 1.22\,\text{kg/m}^3$. We need to compute the speed of the runner from the data given. $v = \dfrac{5000\text{ m}}{1080\text{ s}} = 4.63\text{ m/s}.$

$$D = \tfrac{1}{2}C_D\rho Av^2 = \tfrac{1}{2}(1.2)(1.22\text{ kg/m}^3)(0.72\text{ m}^2)(4.63\text{ m/s})^2 = 1.1\times10^2\text{ N}$$

This is a fairly small fraction of the weight of the runner, but is non-negligible: $D/w = (11\text{ N})/(590\text{ N}) = 1.9\%$.

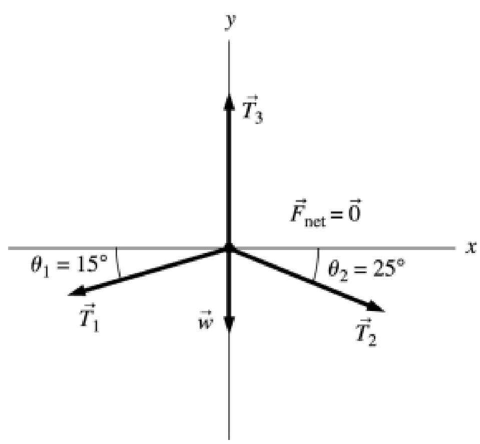
Assess: The drag force is fairly small because the speed of the runner is small.

P5.45. Strategize: This is a straightforward application of Newton's second law.
Prepare: If we take our "object" to be the painter and the chair combined, the rope is connected to this object at two points. The tension acting upward at each of those connections is equal. Let us call the vertically upward direction $+y$. We will write the sum of all forces in the vertical direction and solve for the tension. We will use m to refer to the total 80 kg mass of the object.

Solve: We have $\sum F_y = 2T - mg = ma_y = 0 \Rightarrow T = \dfrac{mg}{2} = \dfrac{(80\text{ kg})(9.8\text{ m/s}^2)}{2} = 3.9\times10^2\text{ N}.$

Assess: This may seem strange that the tension is less than the weight of the object. But the fact that tension acts at each end of a taut rope is one reason why we use pulley systems.

P5.49. Strategize: This problem involves Newton's second law in two dimensions. Because the piano is to descend at a steady speed, it is in dynamic equilibrium.
Prepare: The following shows a free-body diagram of the piano and a list of values.



Known
$m = 500$ kg
$T_1 = 500$ N
$\theta_1 = 15°$
$\theta_2 = 25°$

Find
T_2

Solve: (a) Based on the free-body diagram, Newton's second law is

$$(F_{net})_x = 0\text{ N} = T_{1x} + T_{2x} = T_2\cos\theta - T_1\cos\theta_1$$
$$(F_{net})_y = 0\text{ N} = T_{1y} + T_{2y} + T_{3y} + w_y = T_3 - T_1\sin\theta_1 - T_2\sin\theta_2 - mg$$

Notice how the force components all appear in the second law with *plus* signs because we are *adding* vector forces. The negative signs appear only when we *evaluate* the various components. These are two simultaneous equations in the two unknowns T_2 and T_3. From the x-equation we find

$$T_2 = \frac{T_1\cos\theta_1}{\cos\theta_2} = \frac{(500\text{ N})\cos 15°}{\cos 25°} = 530\text{ N}$$

(b) Now we can use the y-equation to find

$$T_3 = T_1\sin\theta_1 + T_2\sin\theta_2 + mg = 5300\text{ N}$$