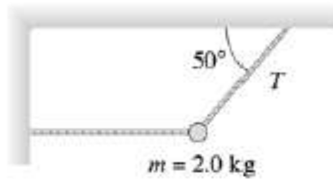
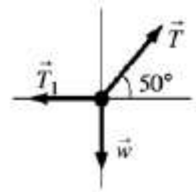
pp. 154 – 156: problem # 23, 25, 31, 7, 13, 19, 39, 43

Q5.23. Reason: The ball is in equilibrium. We will use Equation 5.1.
See the free-body diagram below.





In the vertical direction we have

$$T\sin(50°) - w = T\sin(50°) - mg = 0$$

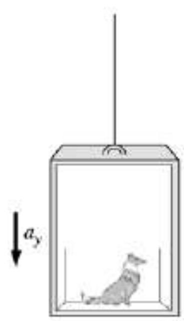
Solving for T, we obtain

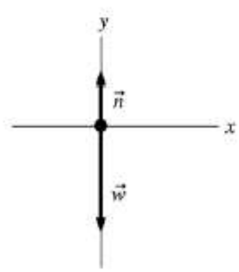
$$T = \frac{mg}{\sin(50°)} = \frac{(2.0\text{ kg})(9.80\text{ m/s}^2)}{\sin(50°)} = 26\text{ N}$$

The correct choice is D.
Assess: Note that we did not need to use the horizontal components of the forces.

Q5.25. Reason: We will use Equation 5.2 since neither the dog nor the floor is in equilibrium.

(a)



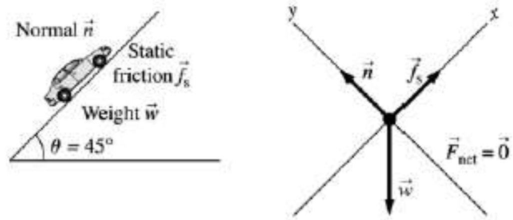


From the free-body diagram above, we have $n - w = ma_y$.
Solving for the normal force,

$$n = w + ma_y = mg + ma_y = (5.0\text{ kg})(9.80\text{ m/s}^2) + (5.0\text{ kg})(-1.20\text{ m/s}^2) = 43\text{ N}$$

The correct choice is B.
(b) The normal force on the dog is the force of the floor of the elevator on the dog. The force of the dog on the elevator floor is the reaction force to this. The correct choice is D.
Assess: This result makes sense; the normal force will be less than the weight of the dog, which is 49 N.

Q5.31. Reason: For the Land Rover claim to be true, the vehicle must be able to at least sit on the hill motionless without slipping. So we'll draw a free-body diagram with the vehicle stationary. We use tilted axes with the *x*-axis running up the slope.



First apply $F_{net} = ma$ in the *y*-direction.

$$n - w\cos\theta = 0$$

Then apply $F_{net} = ma$ in the *x*-direction.

$$f_s - w\sin\theta = 0$$

With $f_s = \mu_s n$ we rearrange the pair of equations into

$$\mu_s n = w\sin\theta$$
$$n = w\cos\theta$$

Now the key is to divide the top equation by the bottom one. (This is mathematically legal, because the two sides of the bottom equation are equal to each other, then we are really dividing both sides of the top equation by the same thing.) Remember that $\frac{\sin\theta}{\cos\theta} = \tan\theta$.

$$\mu_s = \tan\theta$$

P5.7. Prepare: The tension in the more vertical of the two angled ropes (the right one) will have a greater tension, so we apply Newton's second law and set $T_{right} = 1500\text{ N}$ and solve for m. T_{left} will be less than 1500 N and will not break.
Solve:

$$\Sigma F_x = T_{right}\cos 45° - T_{left}\cos 30° = 0$$
$$\Sigma F_y = T_{right}\sin 45° + T_{left}\sin 30° - mg = 0$$

There are various strategies to solve such a system of linear equations. One is to put the two T_{left} terms on the left side and then divide the two equations.

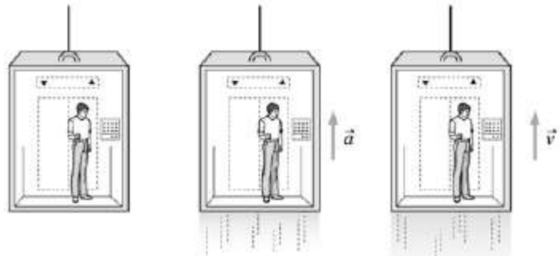
$$T_{left}\sin 30° = mg - T_{right}\sin 45°$$
$$T_{left}\cos 30° = T_{right}\cos 45°$$

Now dividing these two equations cancels T_{left} on the left (since we don't need T_{left}) and leaves $\tan 30°$.

$$\tan 30° = \frac{mg - T_{right}\sin 45°}{T_{right}\cos 45°}$$

P5.13. Prepare: The force of friction between the crate and the horizontal floor surface is proportional to the crate's mass. Specifically, $f_{s\,max} = \mu_s n = \mu_s mg = ma_x$. That is, the acceleration as the crate slows down is unchanged. We can now use kinematics equations to find the stopping distance.
Solve: (a) The block will slide the same distance *d*. The acceleration is the same as before and the velocity is the same as before, so from Equation 2.13 the distance traveled *d* remains the same.
(b) The block will slide a distance of 4*d*. Because the acceleration is unchanged, but the velocity is doubled, Equation 2.13 yields a stopping distance of 4*d*.

P5.19. Prepare: The passenger is subject to two vertical forces: the downward pull of gravity and the upward push of the elevator floor. We can use one-dimensional kinematics for the three situations.



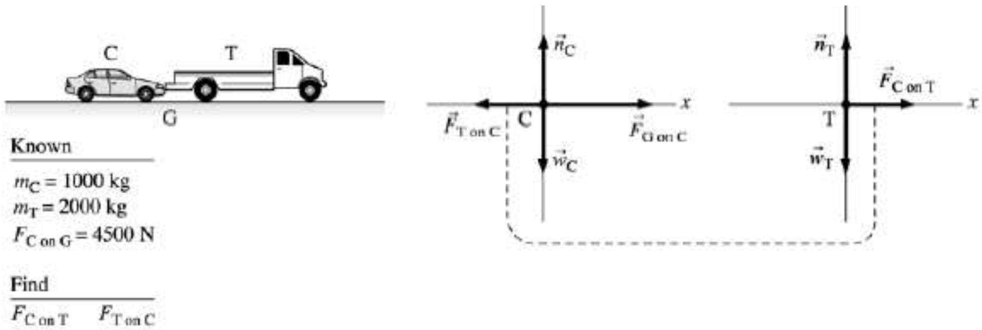
Solve: **(a)** The apparent weight is

$$w_{app} = w\left(1+\frac{a_y}{g}\right) = w\left(1+\frac{0}{g}\right) = mg = (60\ \text{kg})(9.80\ \text{m/s}^2) = 590\ \text{N}$$

(b) The elevator speeds up from $v_{0y} = 0\ \text{m/s}$ to its cruising speed at $v_y = 10\ \text{m/s}$. We need its acceleration before we can find the apparent weight:

$$a_y = \frac{\Delta v}{\Delta t} = \frac{10\ \text{m/s} - 0\ \text{m/s}}{4.0\ \text{s}} = 2.5\ \text{m/s}^2$$

P5.39. Prepare: The car and the truck will be denoted by the symbols C and T, respectively. The ground will be denoted by the symbol G. A visual overview shows a pictorial representation, a list of known and unknown values, and a free-body diagram for both the car and the truck. Since the car and the truck move together in the positive x-direction, they have the same acceleration.



Solve: **(a)** The x-component of Newton's second law for the car is

$$\Sigma(F_{\text{on C}})_x = F_{\text{G on C}} - F_{\text{T on C}} = m_C a_C$$

The x-component of Newton's second law for the truck is

$$\Sigma(F_{\text{on T}})_x = F_{\text{C on T}} = m_T a_T$$

Using $a_C = a_T = a$ and $F_{\text{T on C}} = F_{\text{C on T}}$, we get

$$(F_{\text{C on G}} - F_{\text{C on T}})\left(\frac{1}{m_C}\right) = a \quad (F_{\text{C on T}})\left(\frac{1}{m_T}\right) = a$$

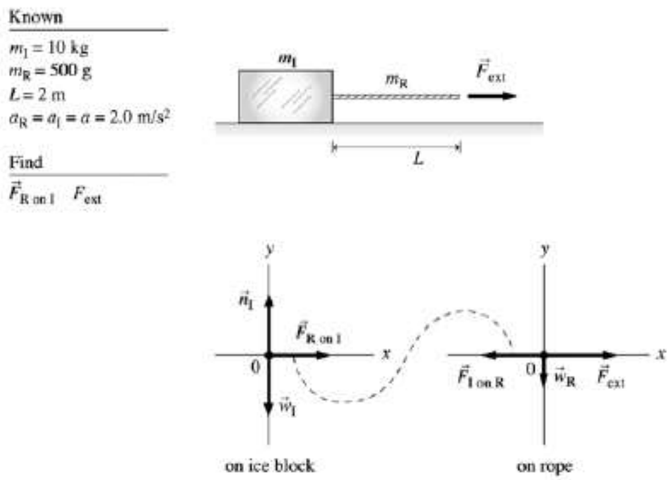
Combining these two equations,

$$(F_{\text{C on G}} - F_{\text{C on T}})\left(\frac{1}{m_C}\right) = (F_{\text{C on T}})\left(\frac{1}{m_T}\right) \Rightarrow F_{\text{C on T}}\left(\frac{1}{m_C} + \frac{1}{m_T}\right) = (F_{\text{C on G}})\left(\frac{1}{m_C}\right)$$

$$\Rightarrow F_{\text{C on T}} = (F_{\text{C on G}})\left(\frac{m_T}{m_C + m_T}\right) = (4500\text{ N})\left(\frac{2000\text{ kg}}{1000\text{ kg} + 2000\text{ kg}}\right) = 3000\text{ N}$$

(b) Due to Newton's third law, $F_{\text{T on C}} = 3000$ N.

P5.43. Prepare: A visual overview shows below a pictorial representation, a list of known and unknown values, and a free-body diagram for both the ice (I) and the rope (R). The force $\vec{F}_{ext}$ acts only on the rope. Since the rope and the ice block move together, they have the same acceleration. Also because the rope has mass, F_{ext} on the front end of the rope is not the same as $F_{I\ on\ R}$ that acts on the rear end of the rope.



Solve: **(a)** Newton's second law along the x-axis for the ice block is

$$\Sigma(F_{on\ I})_x = F_{R\ on\ I} = m_I a = (10\ \text{kg})(2.0\ \text{m/s}^2) = 20\ \text{N}$$

(b) Newton's second law along the x-axis for the rope is

$$\Sigma(F_{on\ R})_x = F_{ext} - F_{I\ on\ R} = m_R a \Rightarrow F_{ext} - F_{R\ on\ I} = m_R a \Rightarrow F_{ext} = F_{R\ on\ I} + m_R a = 20\ \text{N} + (0.5\ \text{kg})(2.0\ \text{m/s}^2) = 21\ \text{N}$$

Assess: We see that the massless rope approximation is really an aproximation that may not always be good.