# ANNOUNCEMENTS

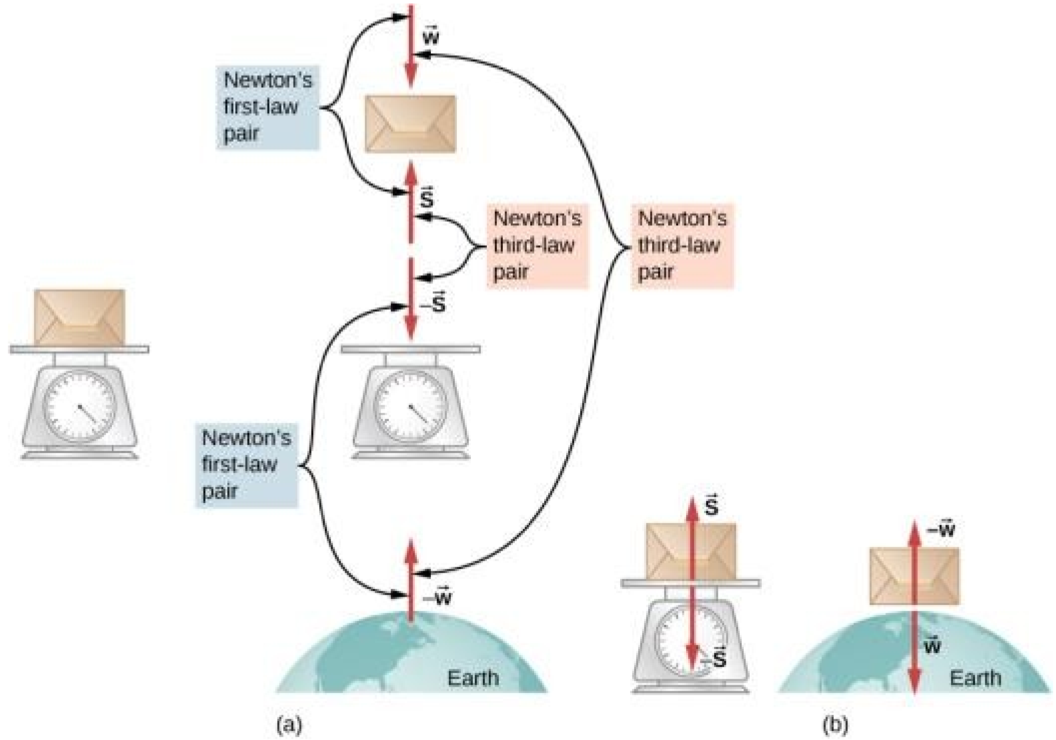
- Homework #5, due Friday, September 28

  Conceptual questions: Chapter 5, #8 and #12
  Problems: Chapter 5, #64, #88

- 5-minute quiz on Chapter 5:
  Wednesday, September 26 at beginning of class

| | |
|---|---|
| Net external force | $\vec{\mathbf{F}}_{\text{net}} = \sum \vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \cdots$ |
| Newton's first law | $\vec{\mathbf{v}} = \text{ constant when } \vec{\mathbf{F}}_{\text{net}} = \vec{\mathbf{0}}\ \text{N}$ |
| Newton's second law, vector form | $\vec{\mathbf{F}}_{\text{net}} = \sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$ |
| Newton's second law, scalar form | $F_{\text{net}} = ma$ |
| Newton's second law, component form | $\sum \vec{\mathbf{F}}_x = m\vec{\mathbf{a}}_x, \sum \vec{\mathbf{F}}_y = m\vec{\mathbf{a}}_y, \text{ and } \sum \vec{\mathbf{F}}_z = m\vec{\mathbf{a}}_z.$ |
| Newton's second law, momentum form | $\vec{\mathbf{F}}_{\text{net}} = \frac{d\vec{\mathbf{p}}}{dt}$ |
| Definition of weight, vector form | $\vec{\mathbf{w}} = m\vec{\mathbf{g}}$ |
| Definition of weight, scalar form | $w = mg$ |
| Newton's third law | $\vec{\mathbf{F}}_{\text{AB}} = -\vec{\mathbf{F}}_{\text{BA}}$ |
| Normal force on an object resting on a horizontal surface, vector form | $\vec{\mathbf{N}} = -m\vec{\mathbf{g}}$ |
| Normal force on an object resting on a horizontal surface, scalar form | $N = mg$ |
| Normal force on an object resting on an inclined plane, scalar form | $N = mg\cos\theta$ |
| Tension in a cable supporting an object of mass *m* at rest, scalar form | $T = w = mg$ |

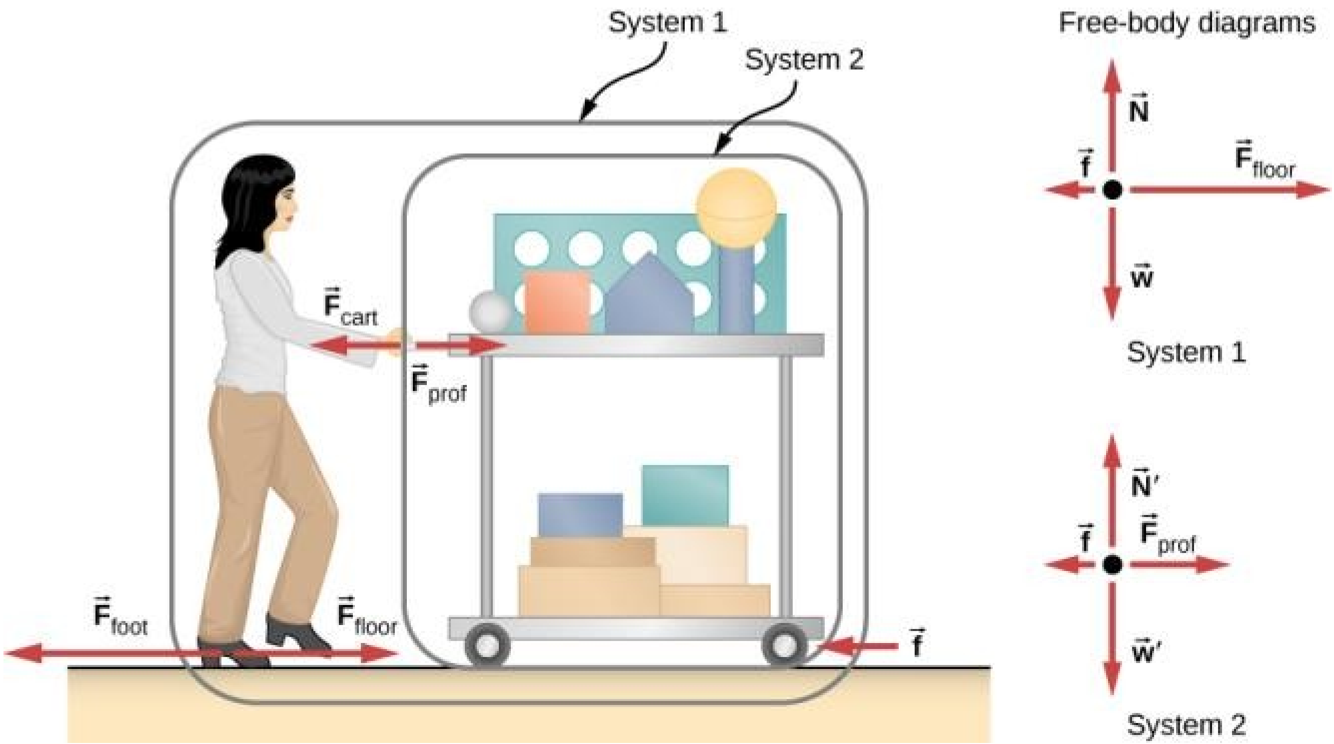
# FIDENTIFYING FORCES




(a) The forces on a package sitting on a scale, along with their reaction forces. The force $\vec{\mathbf{w}}$ is the weight of the package (the force due to Earth's gravity) and $\vec{\mathbf{S}}$ is the force of the scale on the package.

(b) Isolation of the package-scale system and the package-Earth system makes the action and reaction pairs clear.

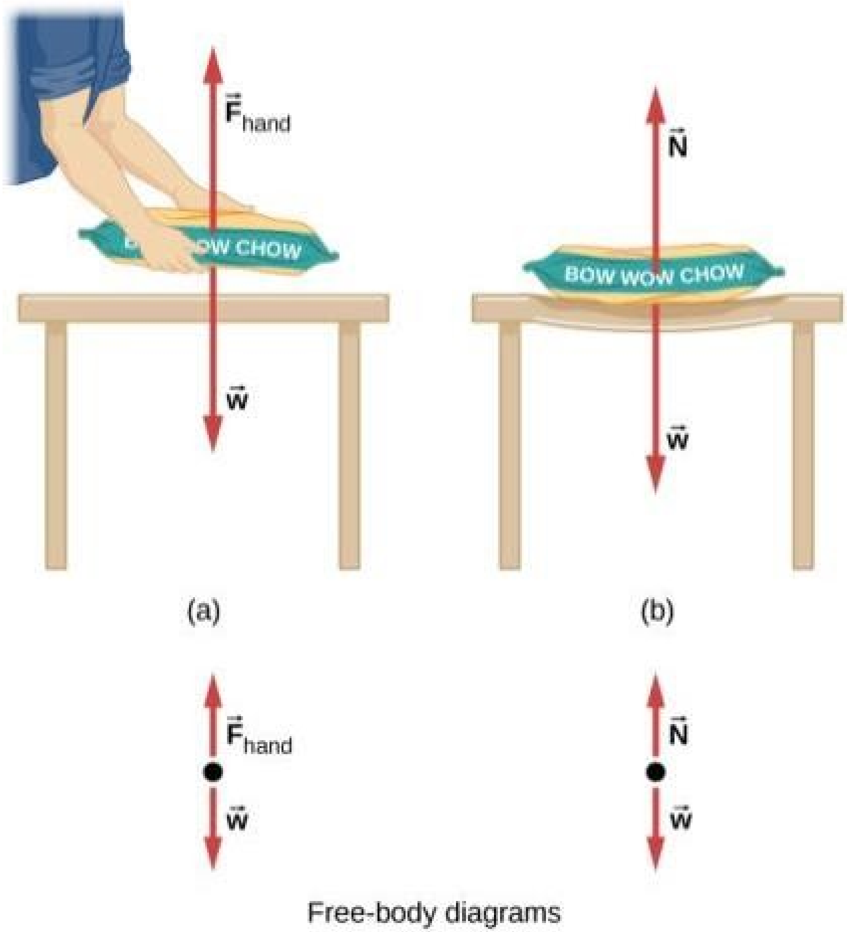
# IDENTIFYING FORCES



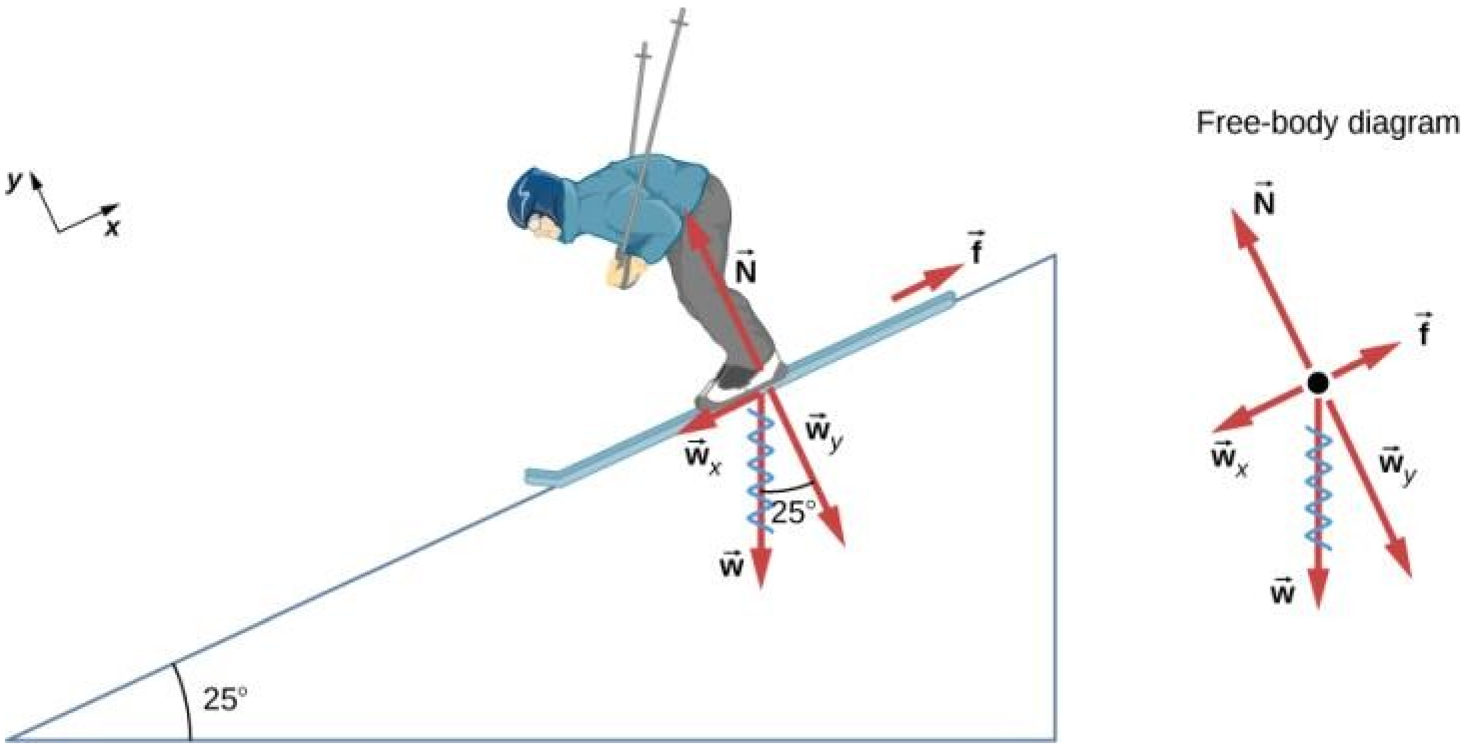

A professor pushes the cart with her demonstration equipment. The lengths of the arrows are proportional to the magnitudes of the forces (except for $\vec{\mathbf{f}}$, because it is too small to drawn to scale). System 1 is appropriate for this example, because it asks for the acceleration of the entire group of objects. Only $\vec{\mathbf{F}}_{floor}$ and $\vec{\mathbf{f}}$ are external forces acting on System 1 along the line of motion. All other forces either cancel or act on the outside world. System 2 is chosen for the next example so that $\vec{\mathbf{F}}_{prof}$ is an external force and enters into Newton's second law. The free-body diagrams, which serve as the basis for Newton's second law, vary with the system chosen.

(a) The person holding the bag of dog food must supply an upward force $\vec{\mathbf{F}}_{\text{hand}}$ equal in magnitude and opposite in direction to the weight of the food $\vec{\mathbf{w}}$ so that it doesn't drop to the ground.

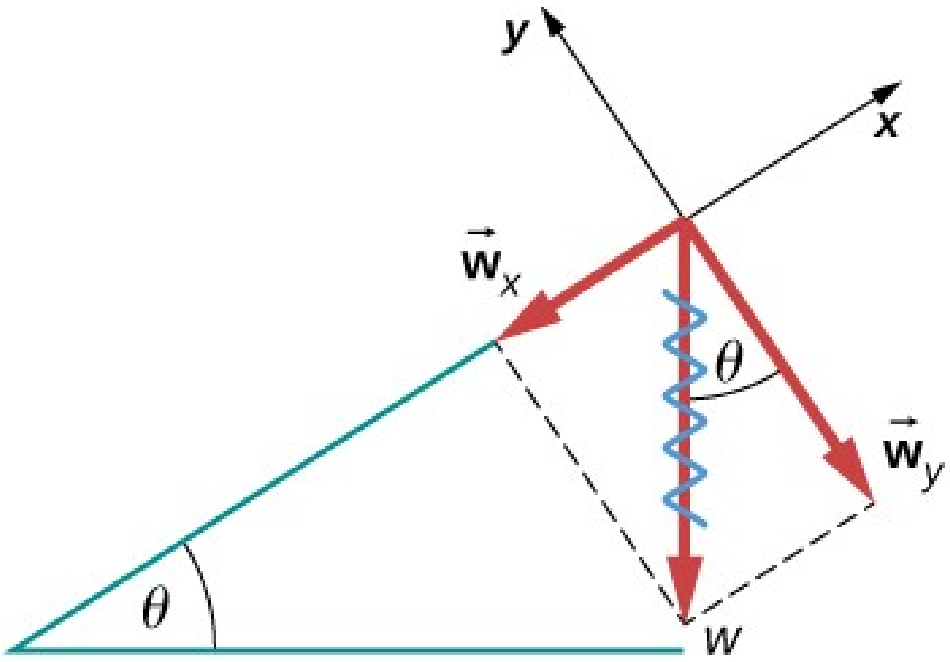
(b) The card table sags when the dog food is placed on it, much like a stiff trampoline. Elastic restoring forces in the table grow as it sags until they supply a force $\vec{\mathbf{N}}$ equal in magnitude and opposite in direction to the weight of the load.



# EXAMPLE



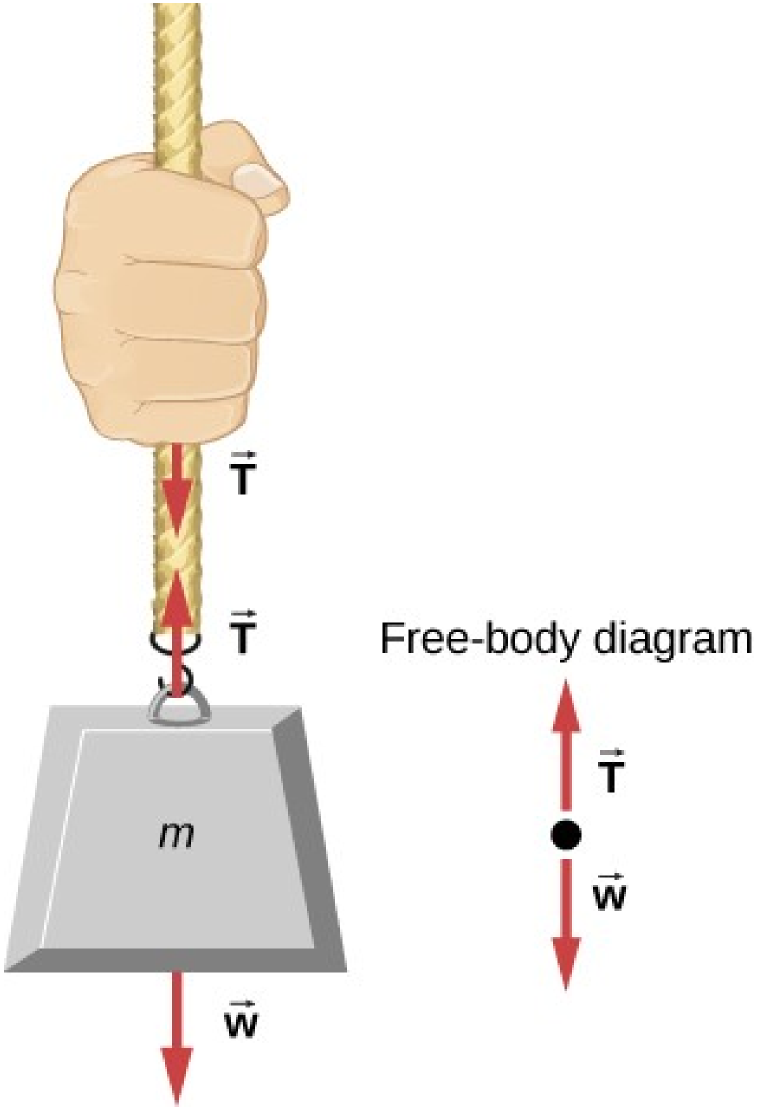

Since the acceleration is parallel to the slope and acting down the slope, it is most convenient to project all forces onto a coordinate system where one axis is parallel to the slope and the other is perpendicular to it (axes shown to the left of the skier). $\vec{\mathbf{N}}$ is perpendicular to the slope and $\vec{\mathbf{f}}$ is parallel to the slope, but $\vec{\mathbf{w}}$ has components along both axes, namely, $w_y$ and $w_x$. Here, $\vec{\mathbf{w}}$ has a squiggly line to show that it has been replaced by these components. The force $\vec{\mathbf{N}}$ is equal in magnitude to $w_y$, so there is no acceleration perpendicular to the slope, but $f$ is less than $w_x$, so there is a downslope acceleration (along the axis parallel to the slope).




$$w_x = w\sin(\theta) = mg\sin(\theta)$$
$$w_y = w\cos(\theta) = mg\cos(\theta)$$

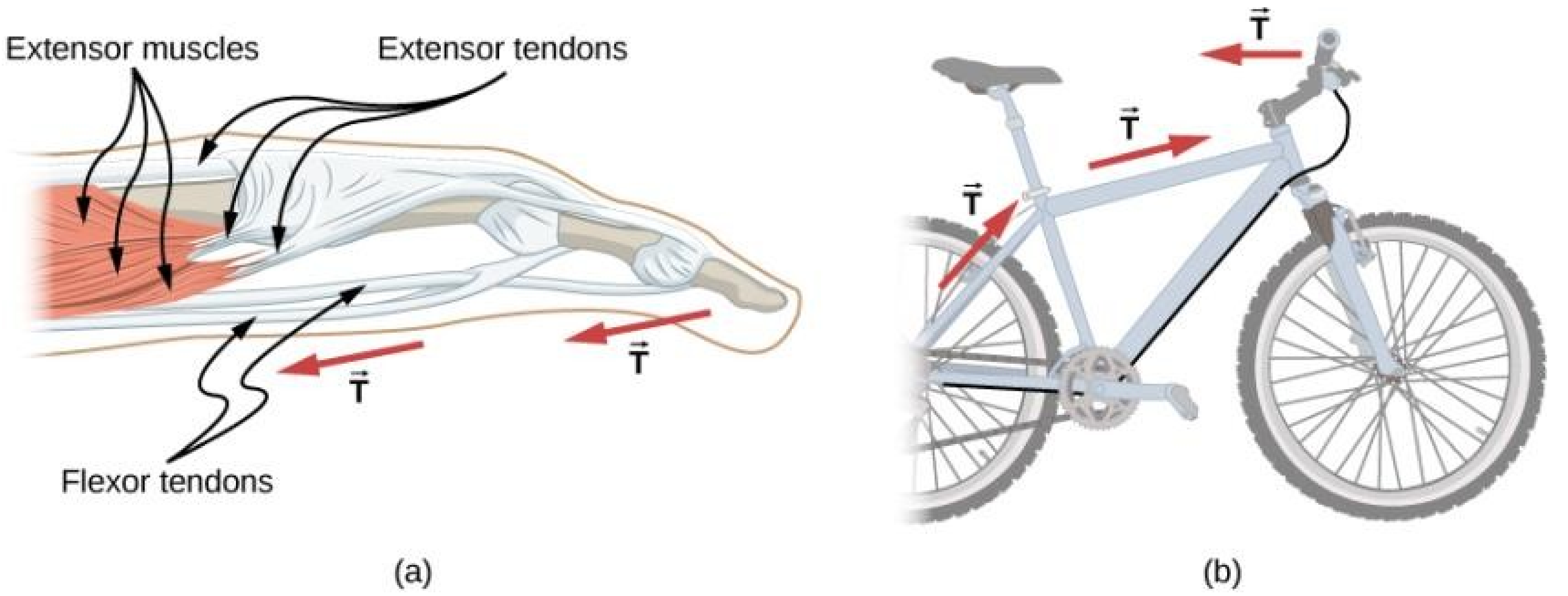
An object rests on an incline that makes an angle $\theta$ with the horizontal.

# TENSION




When a perfectly flexible connector (one requiring no force to bend it) such as this rope transmits a force $\vec{\mathbf{T}}$, that force must be parallel to the length of the rope, as shown. By Newton's third law, the rope pulls with equal force but in opposite directions on the hand and the supported mass (neglecting the weight of the rope). The rope is the medium that carries the equal and opposite forces between the two objects. The tension anywhere in the rope between the hand and the mass is equal. Once you have determined the tension in one location, you have determined the tension at all locations along the rope.

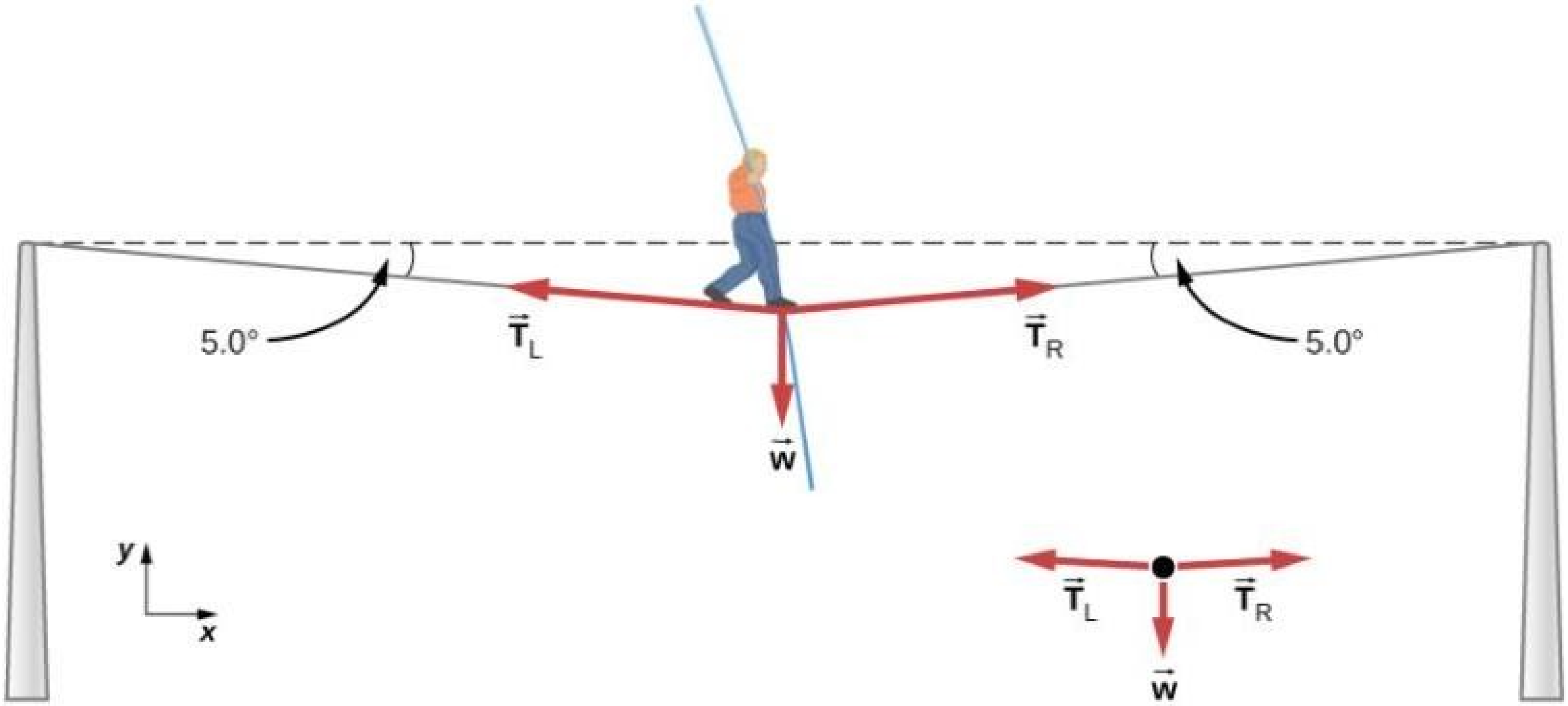
# EXAMPLE



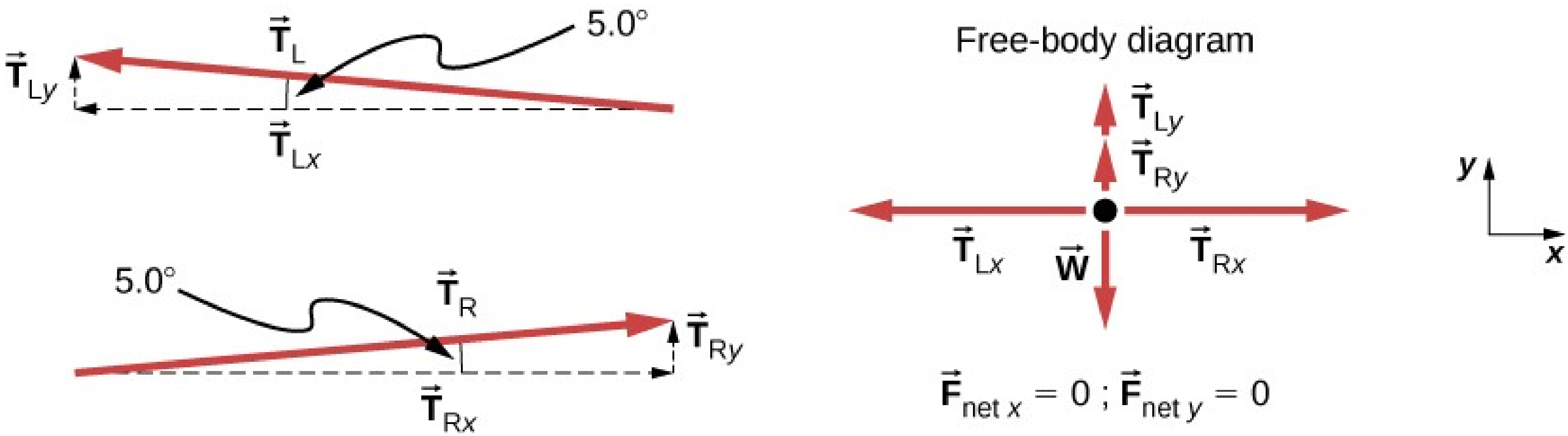

(a) Tendons in the finger carry force *T* from the muscles to other parts of the finger, usually changing the force's direction but not its magnitude (the tendons are relatively friction free).

(b) The brake cable on a bicycle carries the tension *T* from the brake lever on the handlebars to the brake mechanism. Again, the direction but not the magnitude of *T* is changed.

# EXAMPLE




The weight of a tightrope walker causes a wire to sag by 5.0°. The system of interest is the point in the wire at which the tightrope walker is standing.




When the vectors are projected onto vertical and horizontal axes, their components along these axes must add to zero, since the tightrope walker is stationary. The small angle results in *T* being much greater than *w*.

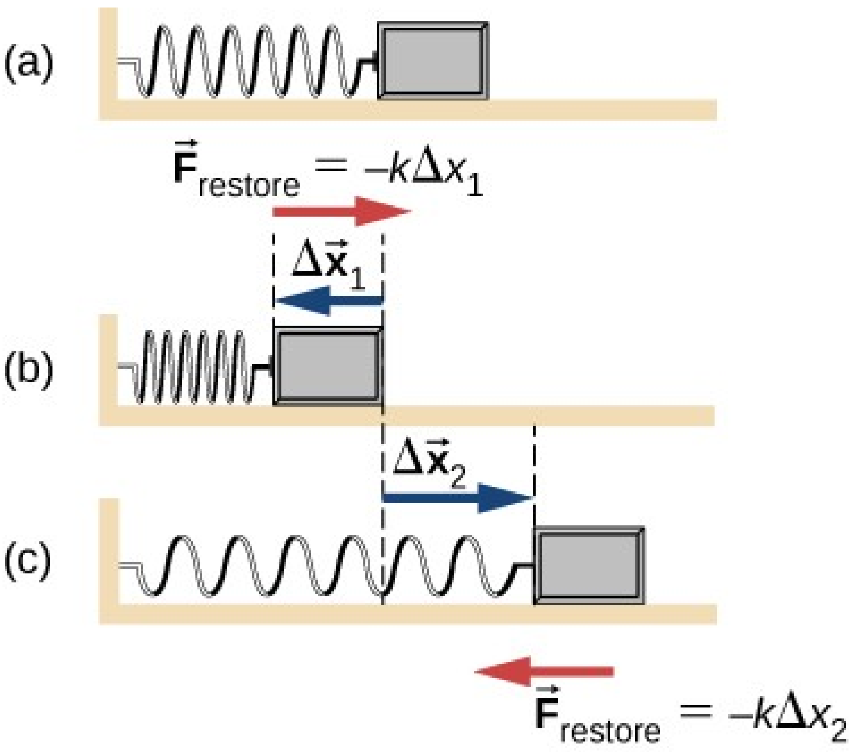
# FORCE OF A SPRING

A spring exerts its force proportional to a displacement, whether it is compressed or stretched.

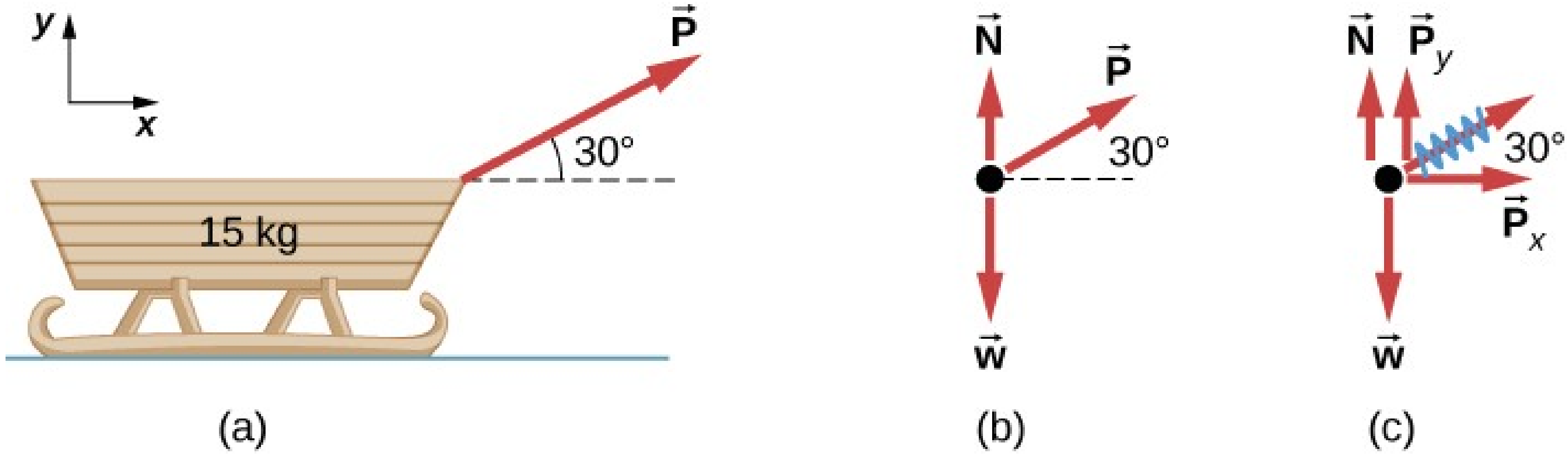
(a) The spring is in a relaxed position and exerts no force on the block.

(b) The spring is compressed by displacement $\Delta\vec{\mathbf{x}}_1$ of the object and exerts restoring force $-k\Delta\vec{\mathbf{x}}_1$.

(c) The spring is stretched by displacement $\Delta\vec{\mathbf{x}}_2$ of the object and exerts restoring force $-k\Delta\vec{\mathbf{x}}_2$.



# EXERCISE

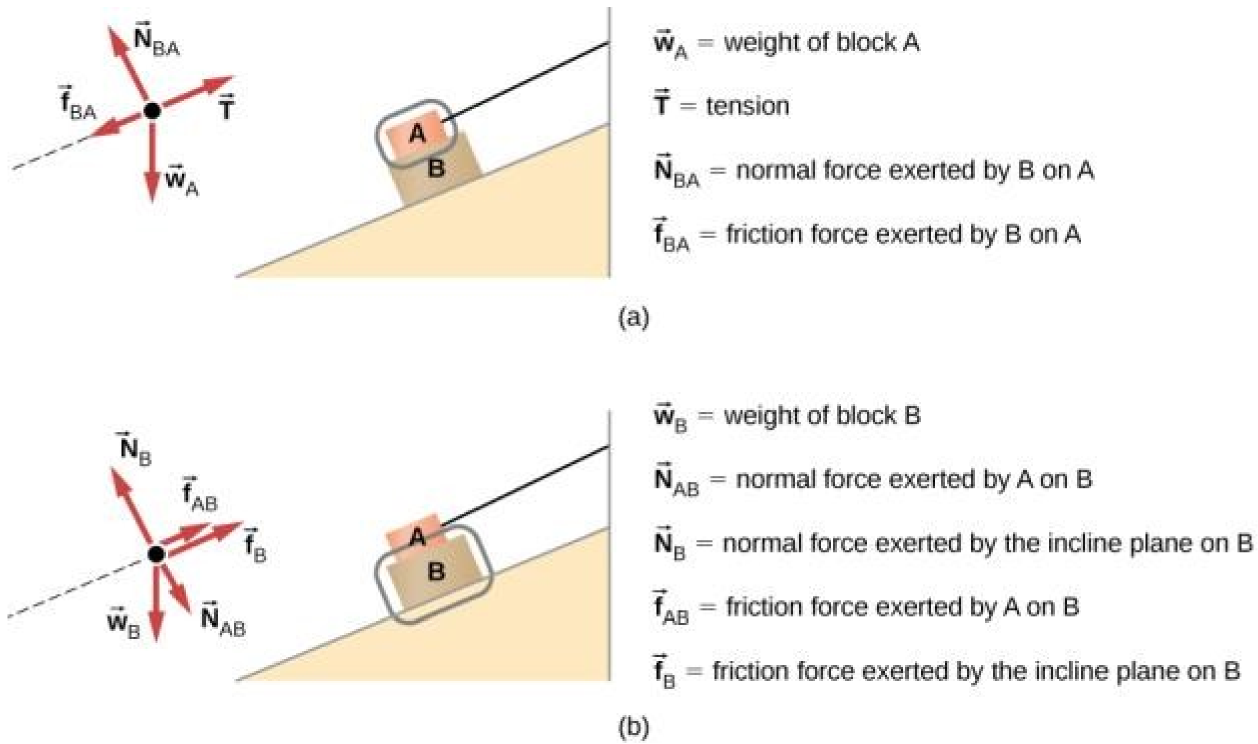



(a) A moving sled is shown as (b) a free-body diagram and (c) a free-body diagram with force components.

# EXAMPLE 5.14

## Two Blocks on an Inclined Plane

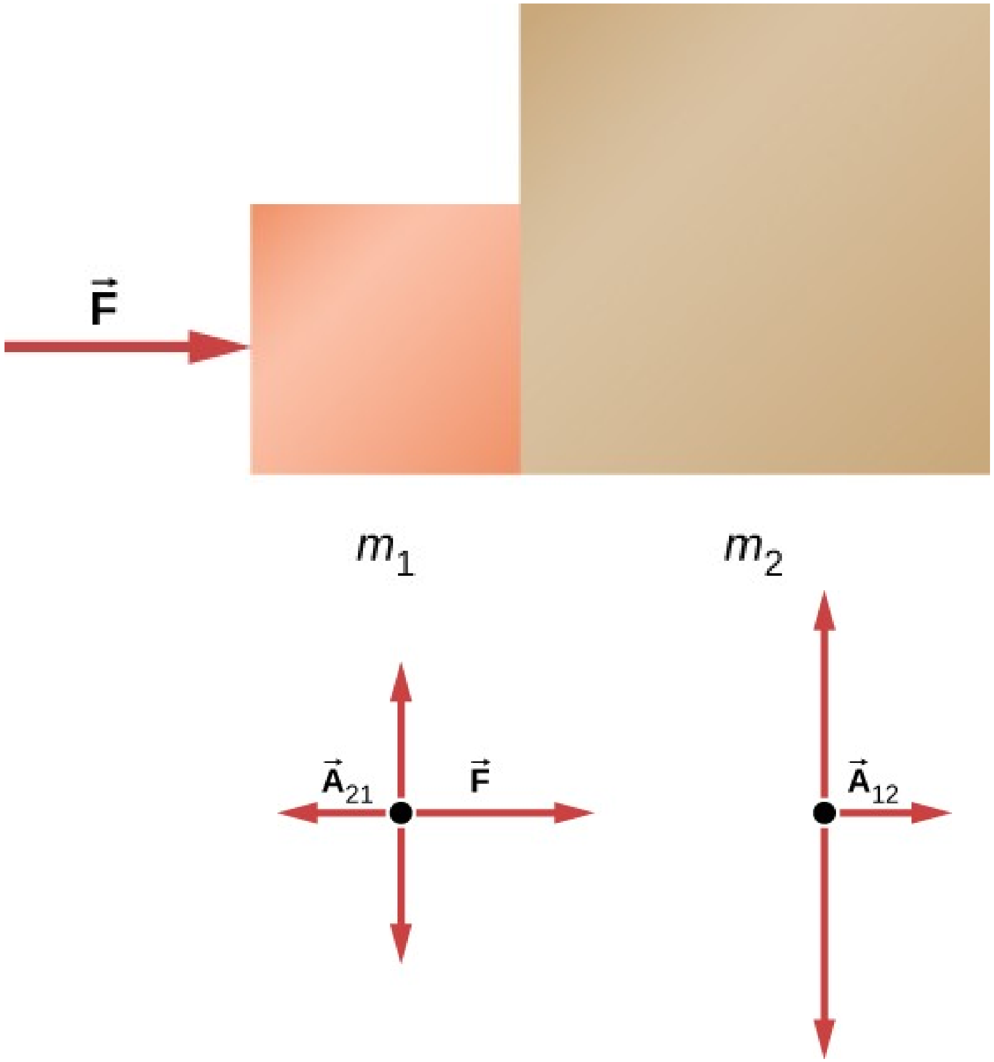
Construct the free-body diagram for object A and object B in Figure 5.32.




(a) The free-body diagram for isolated object A.

(b) The free-body diagram for isolated object B. Comparing the two drawings, we see that friction acts in the opposite direction in the two figures. Because object A experiences a force that tends to pull it to the right, friction must act to the left. Because object B experiences a component of its weight that pulls it to the left, down the incline, the friction force must oppose it and act up the ramp. Friction always acts opposite the intended direction of motion.

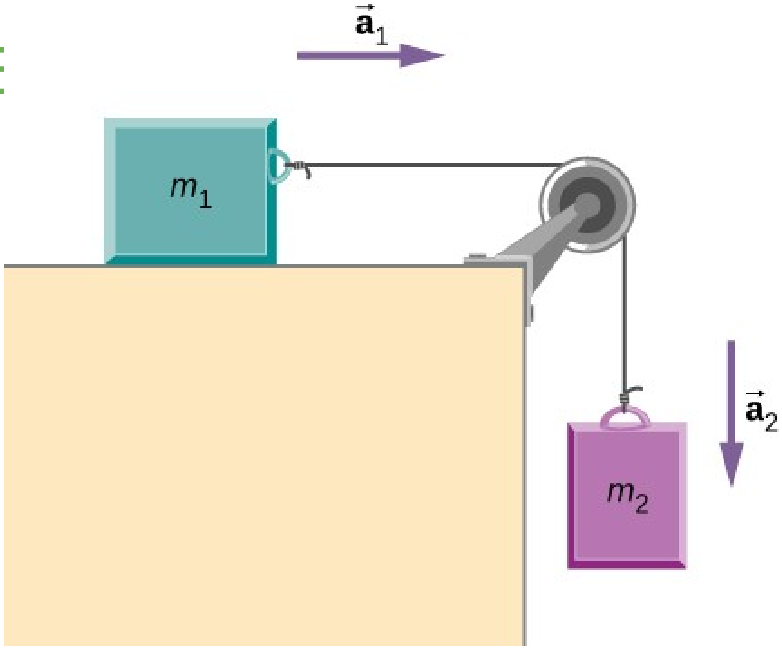
# EXAMPLE

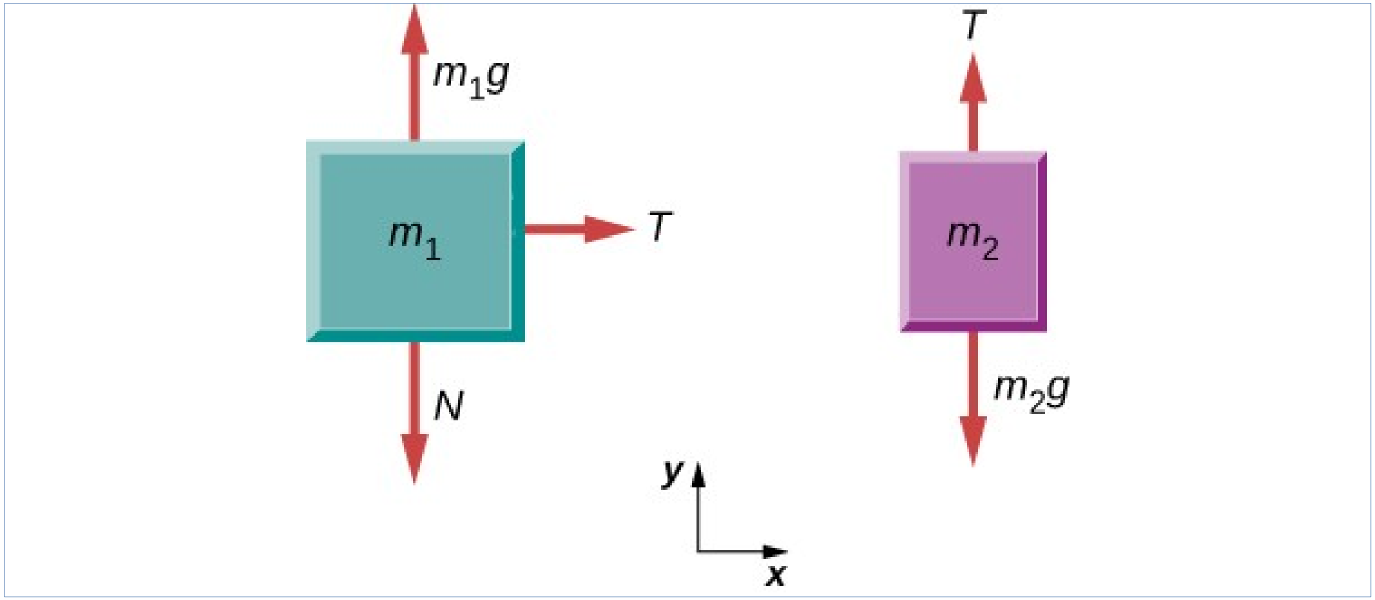



**Significance**

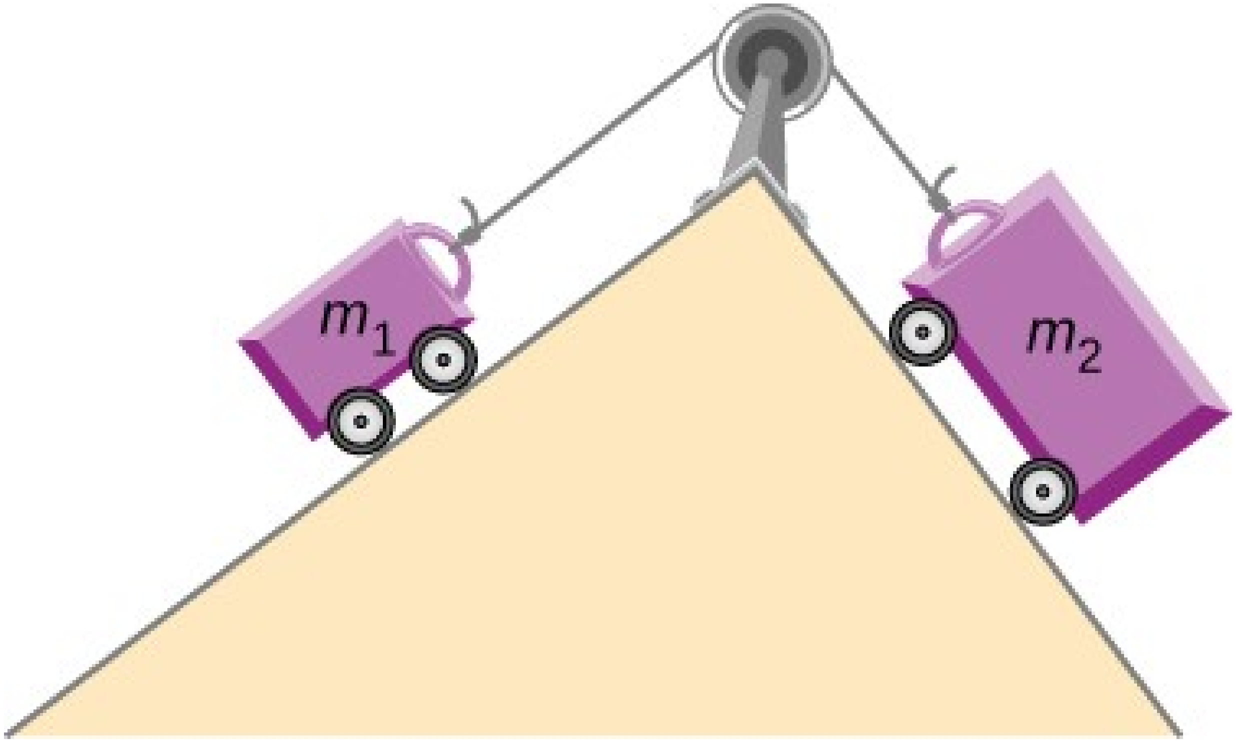
$\vec{A}_{21}$ is the action force of block 2 on block 1. $\vec{A}_{12}$ is the reaction force of block 1 on block 2. We use these free-body diagrams in Applications of Newton's Laws.

# EXAMPLE



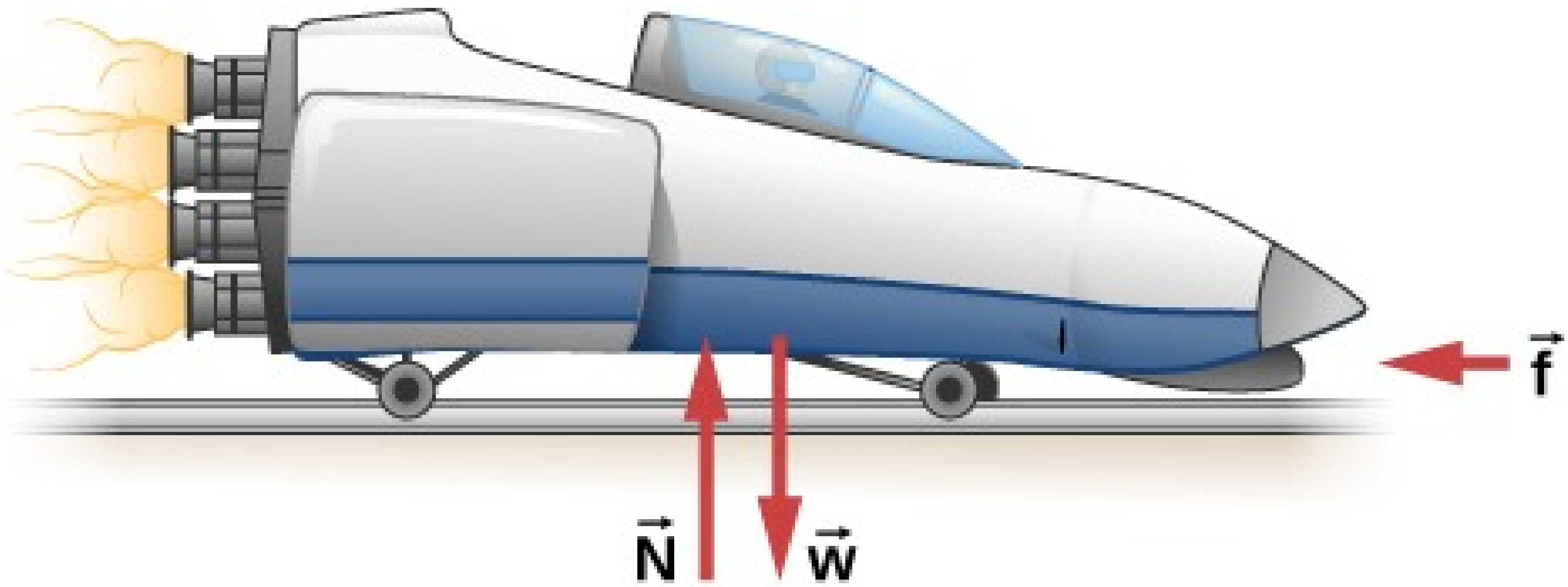



# EXAMPLE



# EXERCISE

The rocket sled shown below decelerates at a rate of $196\ \mathrm{m/s^2}$. What force is necessary to produce this deceleration? Assume that the rockets are off. The mass of the system is $2.10 \times 10^3$ kg.



# EXERCISE

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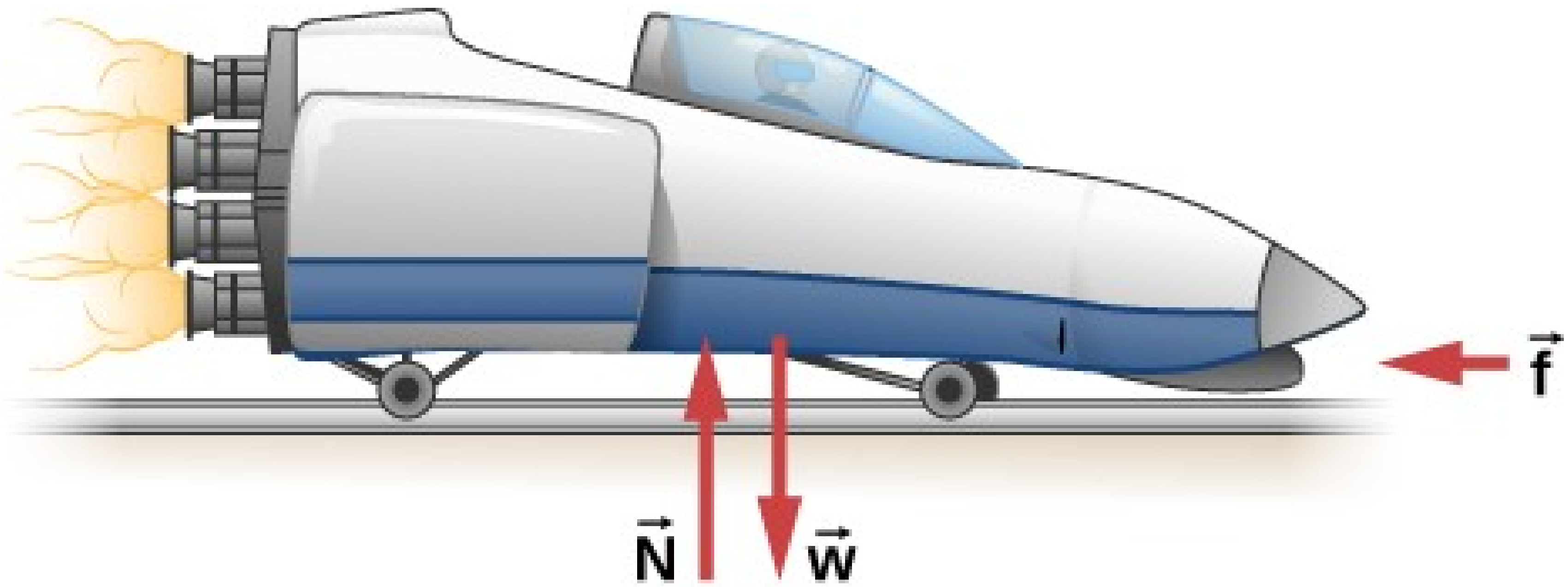
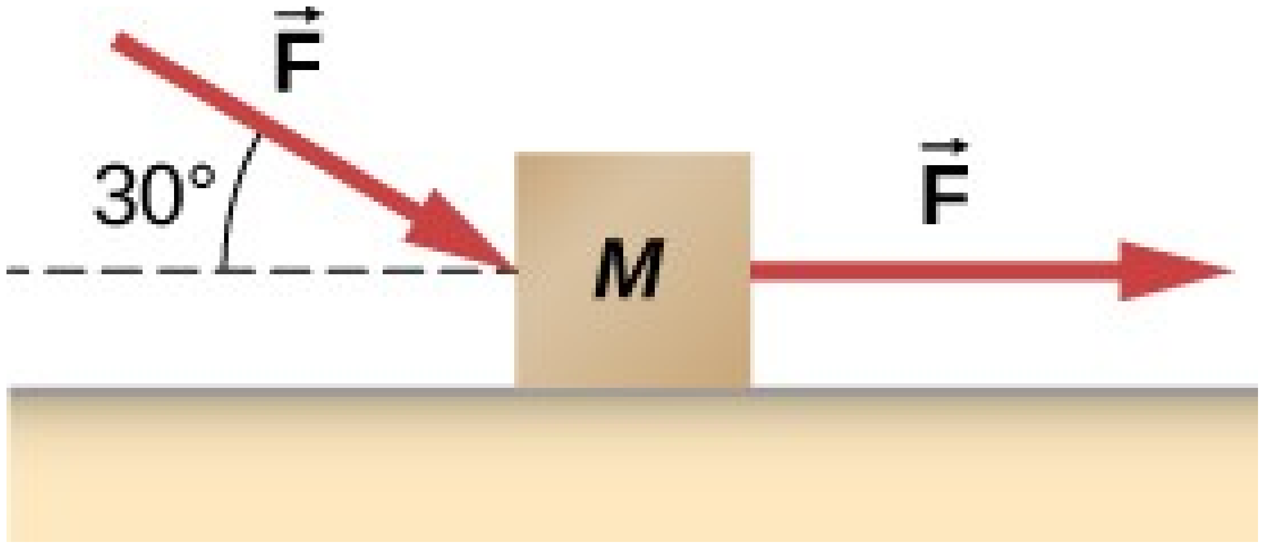



$$F = ma = 2.10 \times 10^3\ \text{kg} \cdot 196\ \text{m/s}^2 = 4.12 \times 10^5\ \text{N}$$

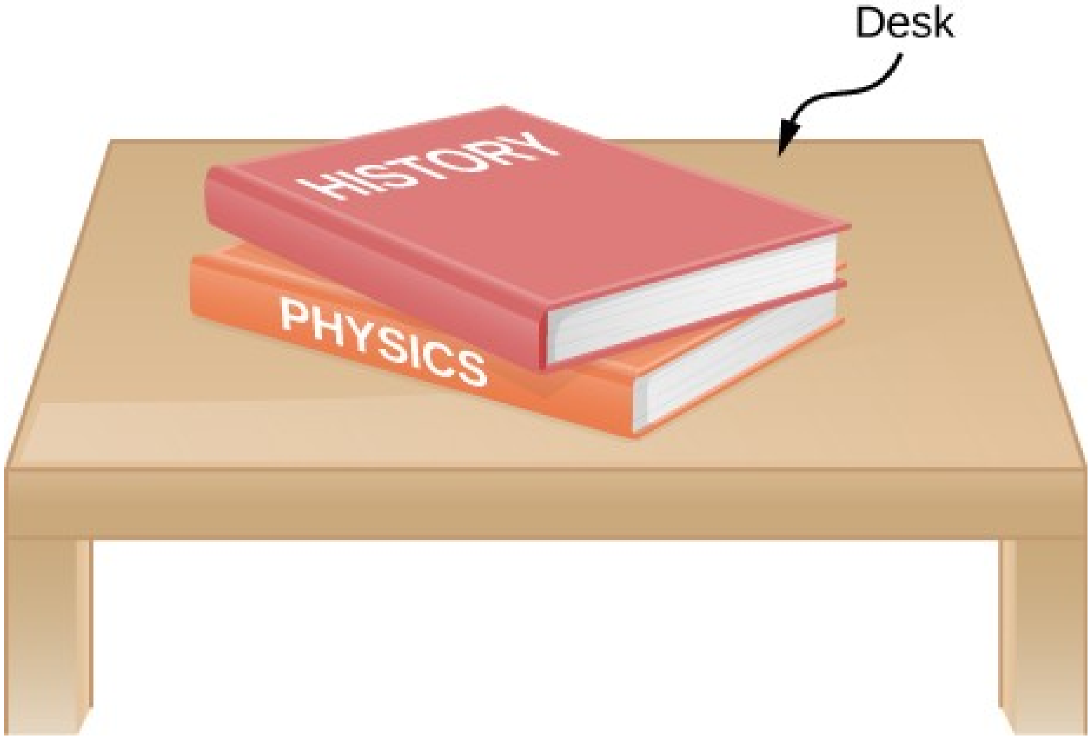
# EXERCISE

In the following figure, the horizontal surface on which this block slides is frictionless. If the two forces acting on it each have magnitude $F = 30.0 \text{ N}$ and $M = 10.0 \text{ kg}$, what is the magnitude of the resulting acceleration of the block?

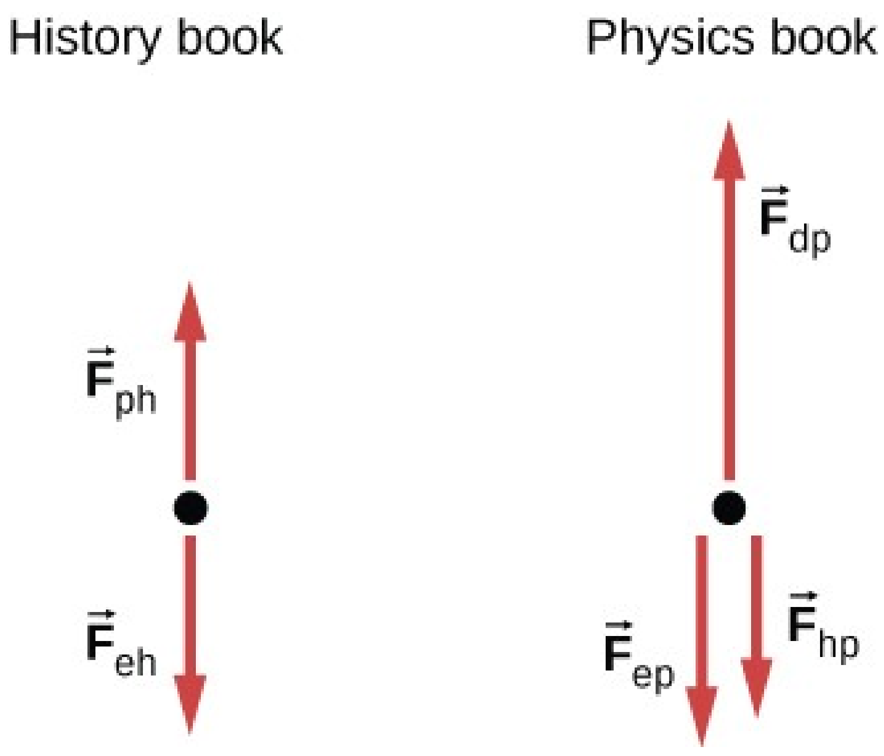


# EXERCISE

A history book is lying on top of a physics book on a desk, as shown below; a free-body diagram is also shown. The history and physics books weigh 14 N and 18 N, respectively. Identify each force on each book with a double subscript notation (for instance, the contact force of the history book pressing against physics book can be described as $\vec{\mathbf{F}}_{\mathrm{HP}}$), and determine the value of each of these forces, explaining the process used.



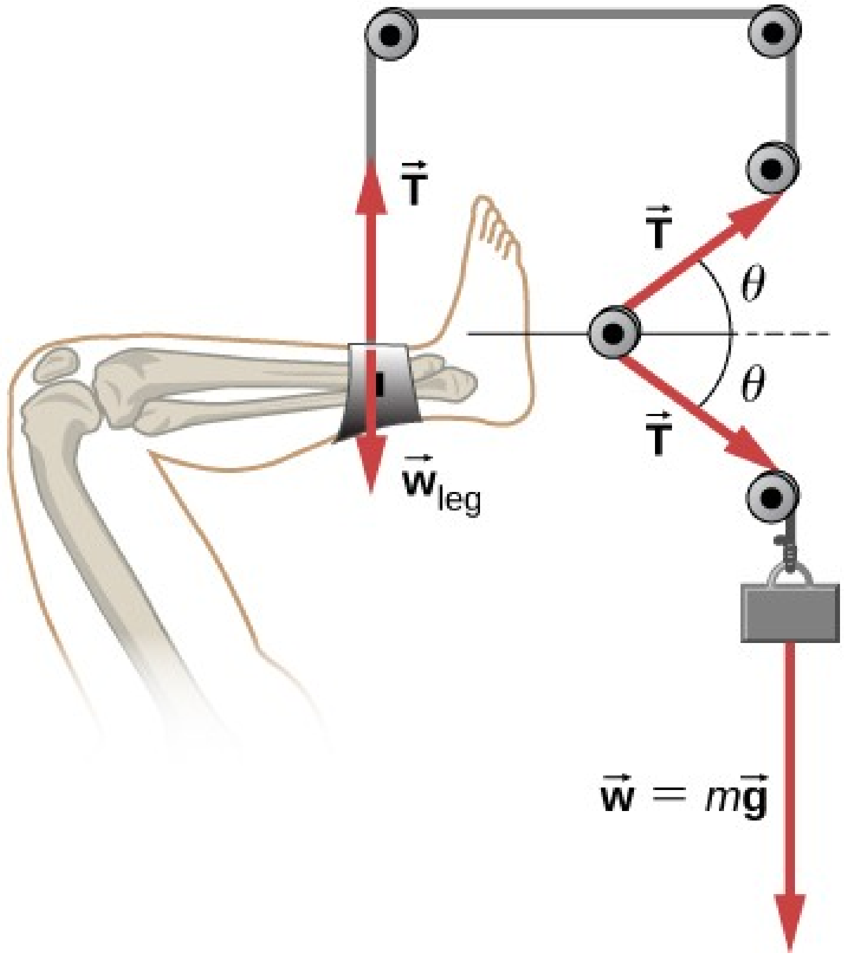
# EXERCISE



History book
Physics book
$\vec{F}_{ph}$
$\vec{F}_{eh}$
$\vec{F}_{dp}$
$\vec{F}_{ep}$
$\vec{F}_{hp}$

# EXERCISE 55

A leg is suspended in a traction system, as shown below. (a) Which pulley in the figure is used to calculate the force exerted on the foot? (b) What is the tension in the rope? Here $\vec{T}$ is the tension, $\vec{w}_{leg}$ is the weight of the leg, and $\vec{w}$ is the weight of the load that provides the tension.



# EXERCISE