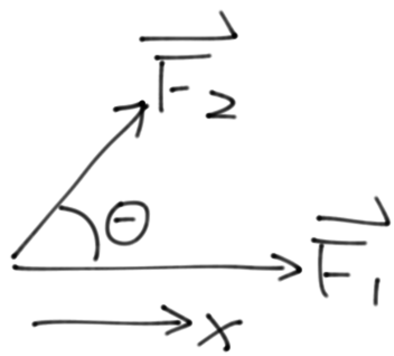
Section 4.1 Force and Interactions

4.1 • Two forces have the same magnitude F. What is the angle between the two vectors if their sum has a magnitude of (a) $2F$? (b) $\sqrt{2}F$? (c) zero? Sketch the three vectors in each case.

Figure **E4.2**

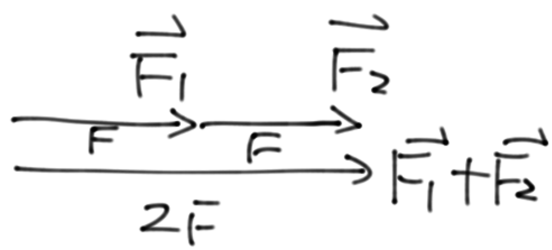
$$|\vec{F_1}| = |\vec{F_2}| = F$$

Choose arbitrarily $\vec{F_1} = F \cdot \hat{i}$ (in $+x$)



$$\vec{F_2} = F \cdot \cos\theta \cdot \hat{i} + F \cdot \sin\theta \cdot \hat{j}$$

(a) is simple:



$\theta = 0$

(b)

$$\vec{R} = \vec{F_1} + \vec{F_2} = F(1+\cos\theta)\hat{i} + F \cdot \sin\theta \cdot \hat{j}$$

$$|\vec{R}|^2 = F^2(1+\cos\theta)^2 + F^2 \cdot \sin^2\theta)$$

$$= (2 + 2\cos\theta) \cdot F^2$$

(b) for $R = \sqrt{2}F$ $\qquad R^2 = 2F^2 =$

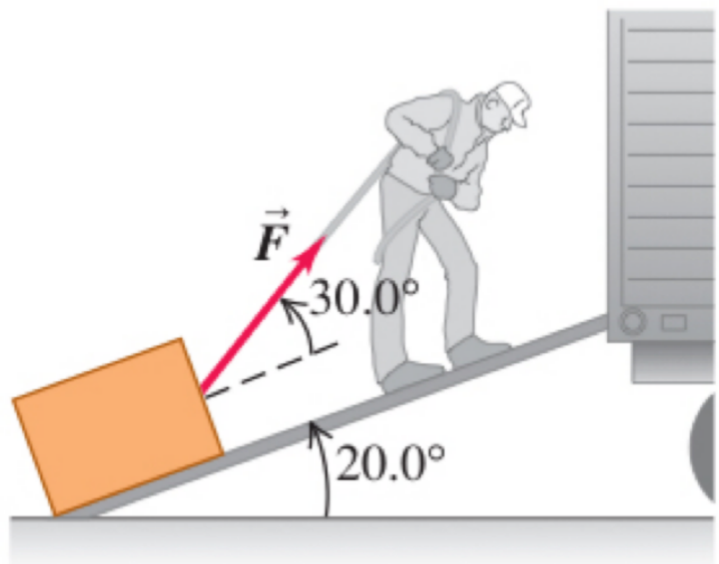
$$\cos\theta = 0 \Rightarrow \theta = \pm 90^\circ$$

(c)

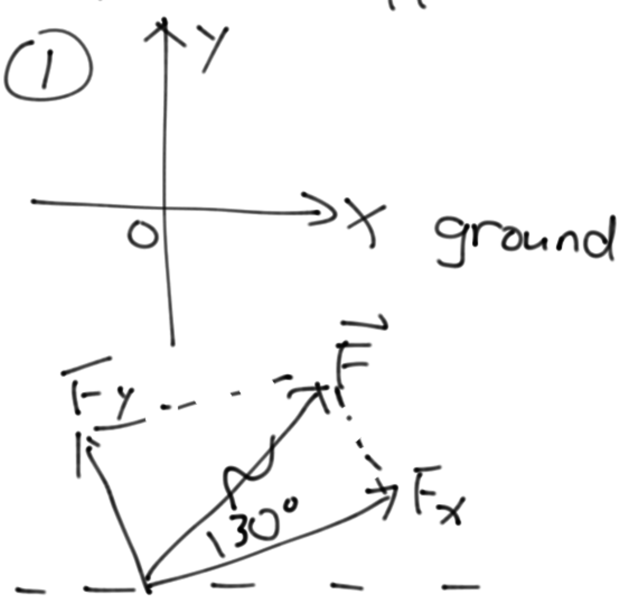
$$\left.\begin{array}{l} \sin\theta = 0 \\ \cos\theta + 1 = 0 \end{array}\right] \rightarrow \theta = 180^\circ$$

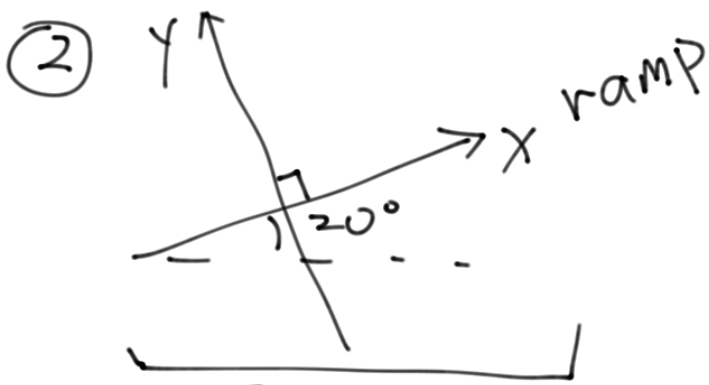
4.4 • A man is dragging a trunk up the loading ramp of a mover's truck. The ramp has a slope angle of 20.0°, and the man pulls upward with a force $\vec{F}$ whose direction makes an angle of 30.0° with the ramp (Fig. E4.4). (a) How large a force $\vec{F}$ is necessary for the component F_x parallel to the ramp to be 60.0 N? (b) How large will the component F_y perpendicular to the ramp then be?

Figure **E4.4**



Two different ways to set up coordinate





This problem

$$F_x = |\vec{F}| \cdot \cos 30^\circ \qquad |\vec{F}| = \frac{F_x}{\cos 30^\circ} = 69.3\,N$$

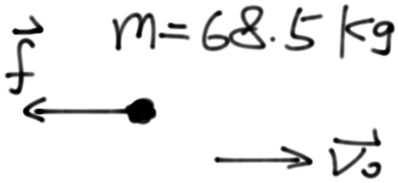
$$F_y = |\vec{F}| \cdot \sin 30^\circ = 34.6\,N$$

Section 4.3 Newton's Second Law

4.7 •• A 68.5-kg skater moving initially at 2.40 m/s on rough horizontal ice comes to rest uniformly in 3.52 s due to friction from the ice. What force does friction exert on the skater?

Assume $\vec{f}$ is constant

$m = 68.5\,\text{kg}$



$t_0 = 0,\ v_0 = 2.4\,\text{m/s} \longrightarrow t_1 = 3.52\,\text{s} \quad v_1 = 0$

Equations $\vec{F} = m\vec{a} \overset{1D}{\Longrightarrow} f = ma$

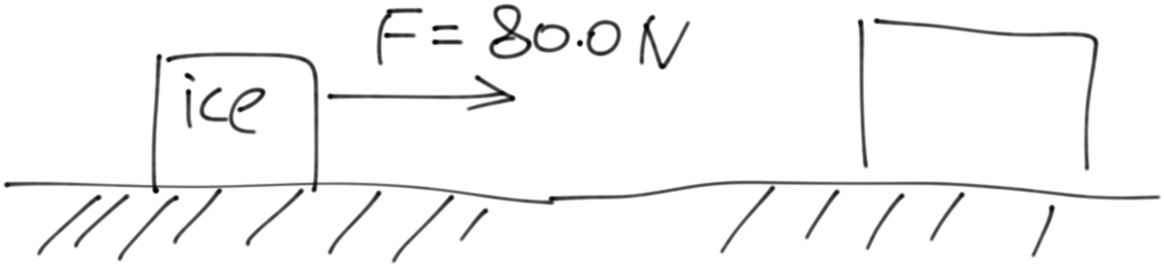
Kinematics $\Delta\vec{v} = \vec{a}\cdot\Delta t \overset{1D}{\Longrightarrow} a = \dfrac{\Delta v}{\Delta t} = \dfrac{v_1 - v_0}{t_1 - t_0}$

$$f = m \cdot \frac{v_1 - v_0}{\Delta t} = 68.5\,\text{kg} \times \frac{0 - 2.4\,\text{m/s}}{3.52\,\text{s}}$$

$$= -46.7\,\text{N}$$

where $+x$ is the direction of initial motion

4.10 •• A dockworker applies a constant horizontal force of 80.0 N to a block of ice on a smooth horizontal floor. The frictional force is negligible. The block starts from rest and moves 11.0 m in 5.00 s. (a) What is the mass of the block of ice? (b) If the worker stops pushing at the end of 5.00 s, how far does the block move in the next 5.00 s?



$t_0 = 0$ $\qquad$ $t_1 = 5\,s$

$x_0 = 0$ $\qquad$ $x_1 = 11\,m$

Recall kinematics in 1D $\quad x = x_0 + v_0\Delta t + \frac{1}{2}a\Delta t^2$

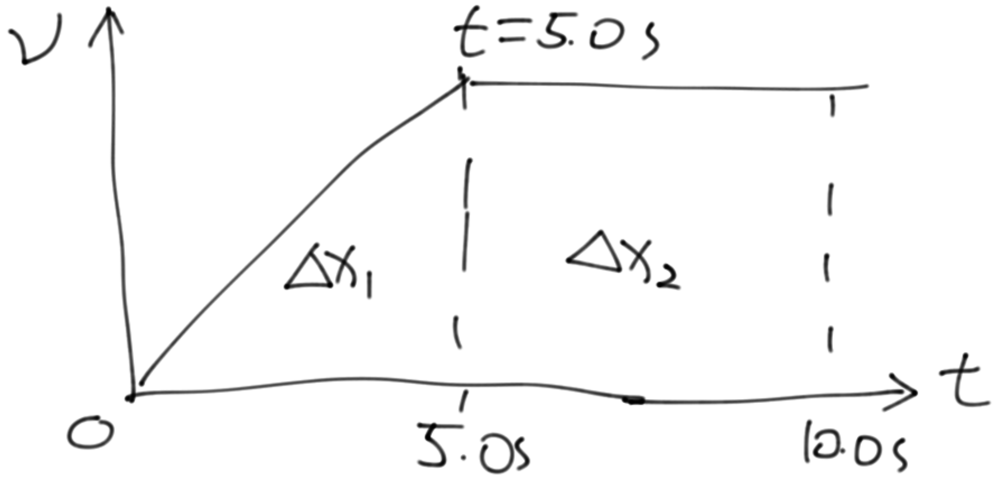
$$\Delta x = \frac{1}{2} a \Delta t^2$$

$$a = \frac{2\Delta x}{\Delta t^2} = \frac{2 \times 11.0\,m}{(5.0\,s)^2} = 0.88\,m/s^2$$

(a) $F = m \cdot a \Rightarrow m = \frac{F}{a} = 90.9\,kg$

(b) $v_1 = a(t_1 - t_0) = 4.4\,m/s$

$$\Delta x_2 = v_1 \cdot \Delta t_2 = 22.0\,m/s$$


v
t=5.0s
ΔX1
ΔX2
t
0
5.0s
10.0s

4.20 • An astronaut's pack weighs 17.5 N when she is on earth but only 3.24 N when she is at the surface of an asteroid. (a) What is the acceleration due to gravity on this asteroid? (b) What is the mass of the pack on the asteroid?

(b) Mass does not change!

On earth $W = mg = 17.5\,N$

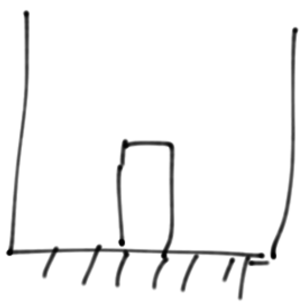
$$m = \frac{W}{g} = \frac{17.5\,N}{9.8\,m/s^2}$$

$$= 1.79\,kg$$

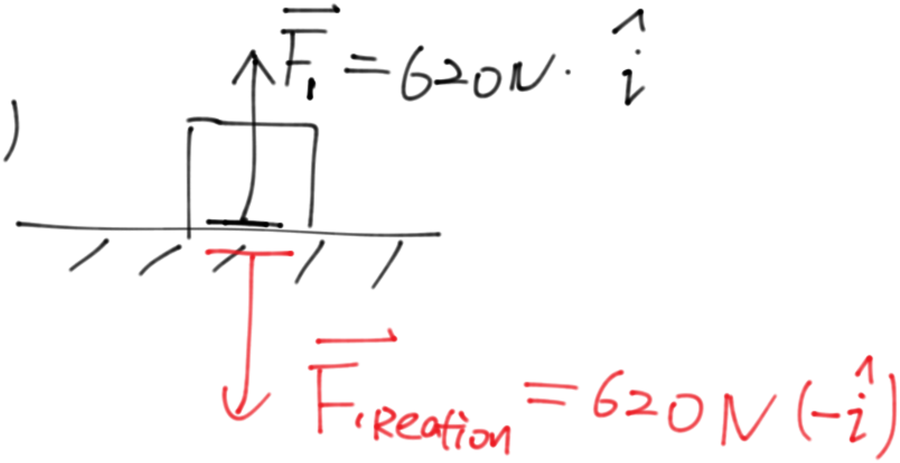
(a) $w' = mg'$

So $g' = \frac{W'}{m} = \frac{3.24\,N}{1.79\,kg} = 1.81\ m/s^2$

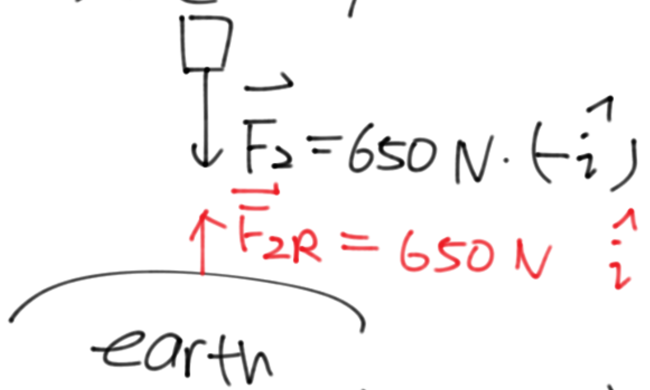
4.24 •• The upward normal force exerted by the floor is 620 N on an elevator passenger who weighs 650 N. What are the reaction forces to these two forces? Is the passenger accelerating? If so, what are the magnitude and direction of the acceleration?

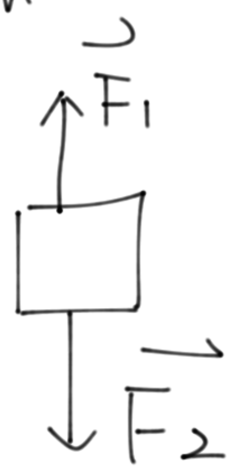


(1)



(2) The key is to identify which objects are interacting.



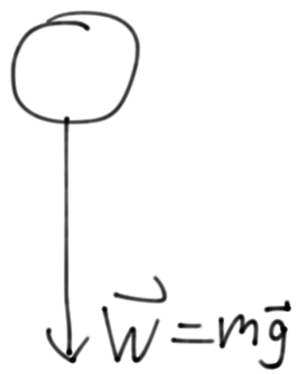


$$\vec{F}_{total} = \vec{F}_1 + \vec{F}_2$$
$$= 620N \cdot \hat{i} - 650N \cdot \hat{i}$$
$$= -30N \cdot \hat{i}$$
$$m = \frac{W}{g} = \frac{|F_2|}{g} = 66.3\,kg$$
$$\vec{a} = \frac{\vec{F}_{total}}{m} = -\frac{30N}{66.3kg} \cdot \hat{i} = -0.45\,m/s^2 \cdot \hat{i}$$

Section 4.6 Free-Body Diagrams

4.26 • An athlete throws a ball of mass m directly upward, and it feels no appreciable air resistance. Draw a free-body diagram of this ball while it is free of the athlete's hand and (a) moving upward; (b) at its highest point; (c) moving downward. (d) Repeat parts (a), (b), and (c) if the athlete throws the ball at a 60° angle above the horizontal instead of directly upward.

(a)



(b) Does anything change?

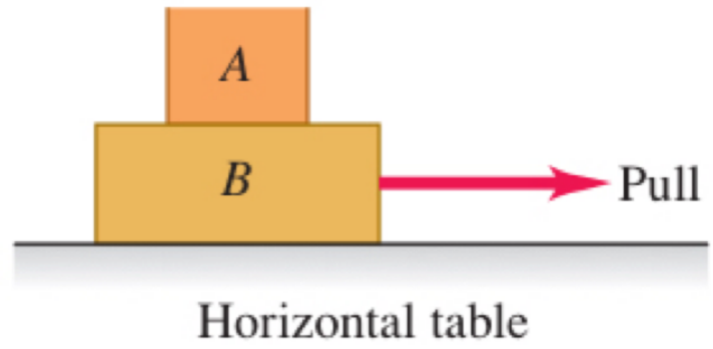
Free body diagrams is only about forces and acceleration!

* Thoughts: answer could differ if we consider air resistance

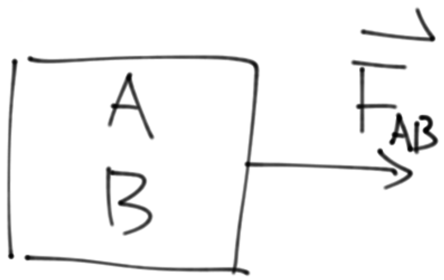
$\vec{F} \propto \vec{v}$

4.28 •• A person pulls horizontally on block B in Fig. E4.28, causing both blocks to move together as a unit. While this system is moving, make a carefully labeled free-body diagram of block A if (a) the table is frictionless and (b) there is friction between block B and the table and the pull is equal to the friction force on block B due to the table.

Figure **E4.28**

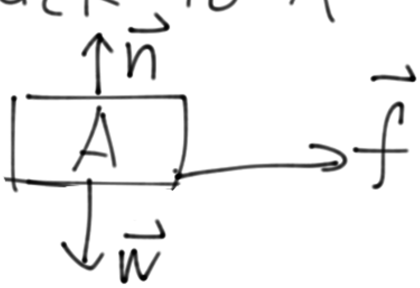


(a)



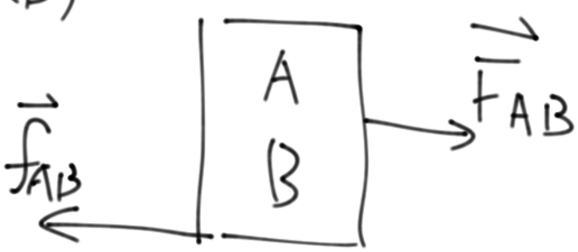
$|F_{AB}| > 0$ AB are both accelerating!

Back to A



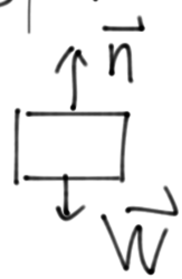
to make A accelerate.

(b)



$|\vec{F}_{AB}| = |\vec{f}_{AB}|$ no acceleration

So A



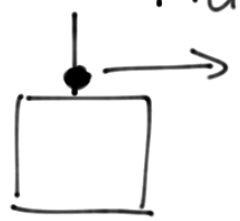
EXERCISES

Section 5.1 Using Newton's First Law: Particles in Equilibrium

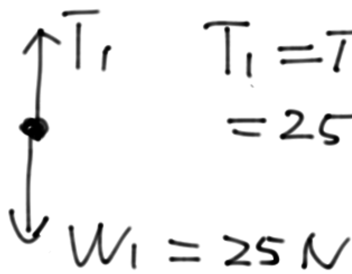
5.1 • Two 25.0-N weights are suspended at opposite ends of a rope that passes over a light, frictionless pulley. The pulley is attached to a chain that goes to the ceiling. (a) What is the tension in the rope? (b) What is the tension in the chain?

"light"
no weight

(a) rope: same tension magnitude



free body diagram



$T_1 = T_2$
$= 25N.$

(b)

free body diagram.

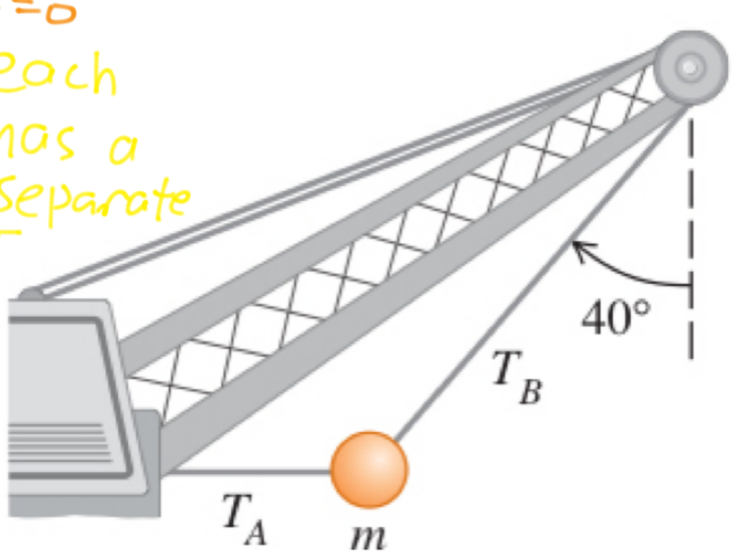
$T = T_1 + T_2 = 50N.$

5.6 •• A large wrecking ball is held in place by two light steel cables (Fig. E5.6). If the mass m of the wrecking ball is 4090 kg, what are (a) the tension T_B in the cable that makes an angle of 40° with the vertical and (b) the tension T_A in the horizontal cable?

$m=0$

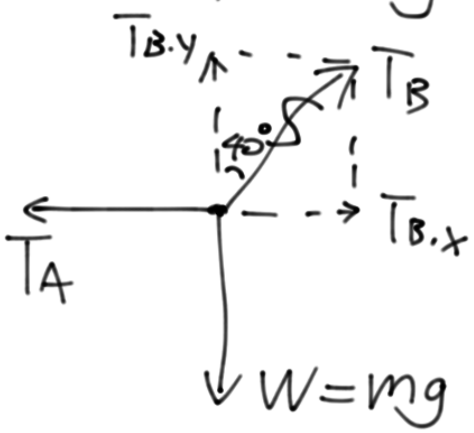
each has a separate T

Figure **E5.6**



5.7 •• Find the tension in

For both (a) and (b), we need the free body diagram



In equilibrium

$$\sum \vec{F} = 0$$

in x: $T_{Bx} = T_A$

in y: $T_{B.y} = W$

In y: $\left.\begin{aligned} T_{B.y} &= T_B \cdot \cos 40^\circ \\ W &= m\cdot g \end{aligned}\right\} \Rightarrow T_B = \dfrac{m\cdot g}{\cos 40^\circ}$

$$= \frac{4090\ kg \cdot 9.8\ m/s^2}{0.766}$$

$$= 5.23\times 10^4\ N$$

$T_{B,x} = T_A \Rightarrow T_A = T_B \cdot \sin 40^\circ$

$$= 5.23 \times 10^4 N \cdot 0.64$$

$$= 3.35 \times 10^4 N$$