Problem Set 3 (Due 3/20/2025 before class)

Late homework will NOT be accepted, unless you have notified the course instructor 3 days BEFORE deadline.

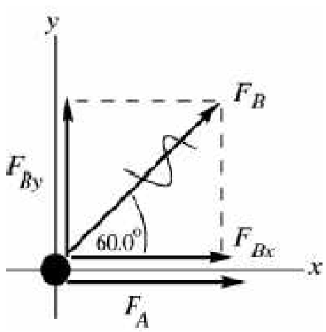
Part I (60%)

4.5 •• Two dogs pull horizontally on ropes attached to a post; the angle between the ropes is 60.0°. If dog *A* exerts a force of 270 N and dog *B* exerts a force of 300 N, find the magnitude of the resultant force and the angle it makes with dog *A*'s rope.

IDENTIFY: Vector addition.

SET UP: Use a coordinate system where the $+x$-axis is in the direction of $\vec{F}_A$, the force applied by dog A. The forces are sketched in Figure 4.5.

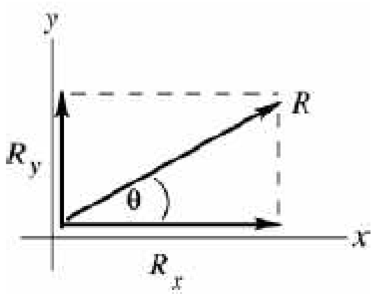
EXECUTE:



$$F_{Ax} = +270\text{ N},\quad F_{Ay} = 0$$
$$F_{Bx} = F_B\cos 60.0° = (300\text{ N})\cos 60.0° = +150\text{ N}$$
$$F_{By} = F_B\sin 60.0° = (300\text{ N})\sin 60.0° = +260\text{ N}$$

Figure 4.5a

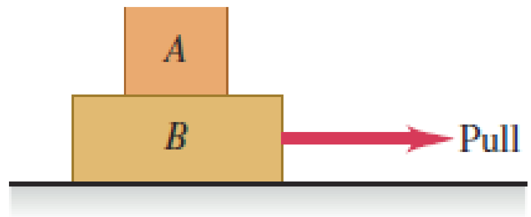
$$\vec{R} = \vec{F}_A + \vec{F}_B$$
$$R_x = F_{Ax} + F_{Bx} = +270\text{ N} + 150\text{ N} = +420\text{ N}$$
$$R_y = F_{Ay} + F_{By} = 0 + 260\text{ N} = +260\text{ N}$$



$$R = \sqrt{R_x^2 + R_y^2}$$
$$R = \sqrt{(420\text{ N})^2 + (260\text{ N})^2} = 494\text{ N}$$
$$\tan\theta = \frac{R_y}{R_x} = 0.619$$
$$\theta = 31.8°$$

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**



Horizontal table

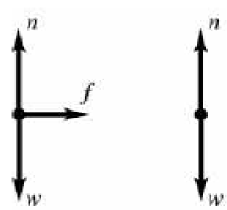
IDENTIFY: The surface of block B can exert both a friction force and a normal force on block A. The friction force is directed so as to oppose relative motion between blocks B and A. Gravity exerts a downward force w on block A.

SET UP: The pull is a force on B not on A.

EXECUTE: **(a)** If the table is frictionless there is a net horizontal force on the combined object of the two blocks, and block B accelerates in the direction of the pull. The friction force that B exerts on A is to the right, to try to prevent A from slipping relative to B as B accelerates to the right. The free-body diagram is sketched in Figure 4.28a. f is the friction force that B exerts on A and n is the normal force that B exerts on A.

(b) The pull and the friction force exerted on B by the table cancel and the net force on the system of two blocks is zero. The blocks move with the same constant speed and B exerts no friction force on A. The free-body diagram is sketched in Figure 4.28b.

EVALUATE: If in part (b) the pull force is decreased, block B will slow down, with an acceleration directed to the left. In this case the friction force on A would be to the left, to prevent relative motion between the two blocks by giving A an acceleration equal to that of B.



(a) (b)

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?

IDENTIFY: The reaction forces in Newton's third law are always between a pair of objects. In Newton's second law all the forces act on a single object.

SET UP: Let $+y$ be downward. $m = w/g$.

EXECUTE: The reaction to the upward normal force on the passenger is the downward normal force, also of magnitude 620 N, that the passenger exerts on the floor. The reaction to the passenger's weight is the gravitational force that the passenger exerts on the earth, upward and also of magnitude 650 N. $\dfrac{\sum F_y}{m} = a_y$ gives $a_y = \dfrac{650\text{ N} - 620\text{ N}}{(650\text{ N})/(9.80\text{ m/s}^2)} = 0.452\text{ m/s}^2$. The passenger's acceleration is 0.452 m/s^2, downward.

EVALUATE: There is a net downward force on the passenger and the passenger has a downward

Part II (40%)

1. A 1-kg object accelerated at a constant 5 m/s^2. Estimate the net force needed to accelerate the object.

Known :	Solution :
Mass (m) = 1 kg	We use Newton's second law to get the net force.
Acceleration (a) = 5 m/s^2	$\sum F = m\,a$
Wanted : net force ($\sum F$)	$\sum F = (1\text{ kg})(5\text{ m/s}^2) = 5\text{ kg m/s}^2 = 5$ Newton

2. Object's mass = 2 kg, F = 5 Newton, F = 3 Newton. What are the magnitude and direction of the acceleration?

Solution :

net force :

$\sum F = F_1 - F_2 = 5 - 3 = 2$ Newton

The magnitude of the acceleration :

$a = \sum F / m$

$a = 2 / 2$

$a = 1\ m/s^2$

Known :

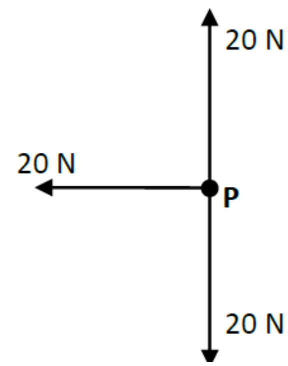
Mass (m) = 2 kg

$F_1 = 5$ Newton

$F_2 = 3$ Newton

Direction of the acceleration = direction of the net force = direction of F_1

3. Three forces of magnitude 20 N each act on object P as shown below. What is the magnitude and direction of the resultant force? (1.4)



Answer: 20 N to the left. The vector sum of the 20 N upward and 20 N downward is 0.

4. Two forces of magnitudes 15 N and 20 N act at a point on an object. Which one of the following magnitudes CANNOT be the resultant of these forces? (1.5)

A. 35 N
B. 10 N
C. 4 N
D. 18 N

Answer: C. In a vector sum, magnitude of the resultant R must fall in to the range |F1-F2| < R < |F1+F2|

5. 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?

IDENTIFY: Friction is the only horizontal force acting on the skater, so it must be the one causing the acceleration. Newton's second law applies.
SET UP: Take $+x$ to be the direction in which the skater is moving initially. The final velocity is $v_x = 0$, since the skater comes to rest. First use the kinematics formula $v_x = v_{0x} + a_x t$ to find the acceleration, then apply $\sum F_x = 5.00\text{ N}$ to the skater.

EXECUTE: $v_x = v_{0x} + a_x t$ so $a_x = \dfrac{v_x - v_{0x}}{t} = \dfrac{0 - 2.40\text{ m/s}}{3.52\text{ s}} = -0.682\text{ m/s}^2$. The only horizontal force on the skater is the friction force, so $f_x = ma_x = (68.5\text{ kg})(-0.682\text{ m/s}^2) = -46.7\text{ N}$. The force is 46.7 N, directed opposite to the motion of the skater.
EVALUATE: Although other forces are acting on the skater (gravity and the upward force of the ice), they are vertical and therefore do not affect the horizontal motion.

6. A box rests on a frozen pond, which serves as a frictionless horizontal surface. If a fisherman applies a horizontal force with magnitude 48.0 N to the box and produces an acceleration of 3.00 m/s^2, magnitude what is the mass of the box?

IDENTIFY: Apply $\sum \vec{F} = m\vec{a}$ to the box.
SET UP: Let $+x$ be the direction of the force and acceleration. $\sum F_x = 48.0\text{ N}$.
EXECUTE: $\sum F_x = ma_x$ gives $m = \dfrac{\sum F_x}{a_x} = \dfrac{48.0\text{ N}}{3.00\text{ m/s}^2} = 16.0\text{ kg}$.
EVALUATE: The vertical forces sum to zero and there is no motion in that direction.

For Problems 7-8: A ball is hanging from a long string that is tied to the ceiling of a train car traveling eastward on horizontal tracks. An observer inside the train car sees the ball hang motionless.

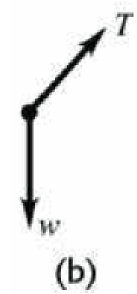
7. Draw a clearly labeled free-body diagram for the ball if the train has a uniform velocity.

IDENTIFY: Since the observer in the train sees the ball hang motionless, the ball must have the same acceleration as the train car. By Newton's second law, there must be a net force on the ball in the same direction as its acceleration.
SET UP: The forces on the ball are gravity, which is w, downward, and the tension $\vec{T}$ in the string, which is directed along the string.
EXECUTE: **(a)** The acceleration of the train is zero, so the acceleration of the ball is zero. There is no net horizontal force on the ball and the string must hang vertically. The free-body diagram is sketched in Figure 4.29a.

(a)

8. Draw a clearly labeled free-body diagram for the ball if the train is speeding up uniformly.

(b) The train has a constant acceleration directed east so the ball must have a constant eastward acceleration. There must be a net horizontal force on the ball, directed to the east. This net force must come from an eastward component of $\vec{T}$ and the ball hangs with the string displaced west of vertical. The free-body diagram is sketched in Figure 4.29b.

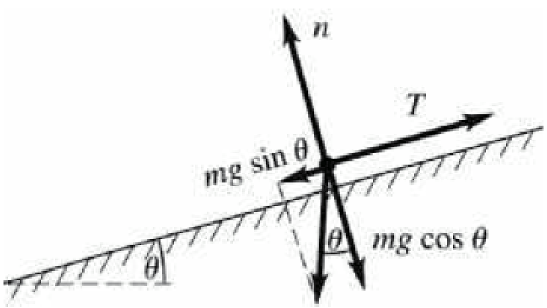


Is the net force on the ball zero in either case? Explain.

When the motion of an object is described in an inertial frame, there must be a net force in the direction of the acceleration.

For problem 9-10: A skier of mass 65.0 kg is pulled up a snow-covered slope at constant speed by a tow rope that is parallel to the ground. The ground slopes upward at a constant angle of 26 degrees above the horizontal, and you can ignore friction.

9. Draw a clearly labeled free-body diagram for the skier.



10. Calculate the tension in the tow rope.

IDENTIFY: Identify the forces on the skier and apply $\sum \vec{F} = m\vec{a}$. Constant speed means $a = 0$.
SET UP: Use coordinates that are parallel and perpendicular to the slope.
EXECUTE: **(a)** The free-body diagram for the skier is given in Figure 4.32.
(b) $\sum F_x = ma_x$ with $a_x = 0$ gives $T = mg\sin\theta = (65.0\text{ kg})(9.80\text{ m/s}^2)\sin 26.0° = 279\text{ N}$.
EVALUATE: T is less than the weight of the skier. It is equal to the component of the weight that is parallel to the incline.