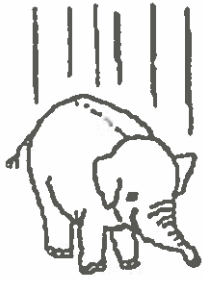


$\Sigma = \text{sigma} = \text{sum}$

Notes:

PHYSICS 12

NEWTON'S SECOND LAW



$$\frac{\mathbf{F}}{m} = \frac{m}{m}$$

1000 times the force acting on 1000 times the mass results in the same acceleration. That's a fact.



Newton's First Law says that a nonzero acceleration is a result of a nonzero net force.

Newton's Second Law explains how the acceleration and net force are related. Newton's Second Law also explains the relationship between the acceleration of an object and the object's mass.

Newton's Second Law

Acceleration of an object is directly proportional to the magnitude of the net force and inversely proportional to the object's mass. The acceleration is always in the same direction as the direction of the net force.

$$\vec{a} = \frac{\Sigma \vec{F}}{m}$$

$$\Sigma \vec{F} = m \cdot \vec{a}$$

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m}$$

$$\vec{F}_{\text{net}} = m \cdot \vec{a}$$

> One Newton is defined as a unit of force necessary for an object with mass 1.0 kg to accelerate by 1.0 m/s².

> $\mathbf{N} = \text{kg} \cdot \frac{\text{m}}{\text{s}^2}$

1. Find the acceleration of an 8.0-kg object that is being pulled with force 120 N ^{Left} 30° above horizontal and pushed with a horizontal force 80 N left. Include a free-body diagram. Assume that the object is moving along a strictly horizontal surface and frictional forces are negligible.



$$\vec{F}_g = [0, -mg] = [0, -78.4] \text{ N}$$

$$\vec{F}_{\text{push}} = [-80, 0] \text{ N}$$

$$\vec{F}_{\text{pull}} = [-120 \cos 30^\circ, 120 \sin 30^\circ] = [-103.9230, 60] \text{ N}$$

$$\vec{F}_N = [0, mg - F_{\text{pull}y}] = [0, 78.4 - 60] = [0, 18.4] \text{ N}$$

$$\begin{aligned} \vec{F}_{\text{net}} &= \vec{F}_g + \vec{F}_{\text{push}} + \vec{F}_{\text{pull}} + \vec{F}_N \\ &= [0, -78.4] + [-80, 0] + [-103.92, 60] + [0, 18.4] \\ &= [-183.9230, 0] \text{ N} \end{aligned}$$

$$\vec{a} = \frac{[-183.9230, 0]}{8.0}$$

$$\vec{a} = [-23, 0] \text{ m/s}^2$$

∴ The object accelerates 23 m/s² [L].

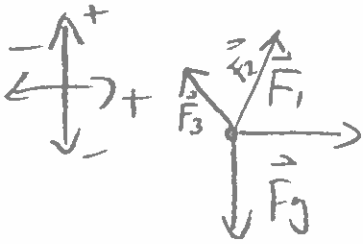
$$\theta = 62^\circ$$



$$\theta = 82^\circ$$



2. Find the magnitude and direction of an acceleration of a 10.0-kg object. The object experiences three pulling forces and a force of gravity. $F_1 = 30$ N right, $F_2 = 45$ N [Up 28° Left] and $F_3 = 85$ N [Up 8° right]. Include a free body diagram.



$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{F}_1 + \vec{F}_2 + \vec{F}_3$$

$$= [0, -(10)(9.8)] + [30, 0] + [-45 \cdot \cos 62^\circ, 45 \cdot \sin 62^\circ] + [85 \cdot \cos 82^\circ, 85 \cdot \sin 82^\circ]$$

$$= [20.7035, 25.9054] \text{ N}$$

$$\vec{a} = \frac{\vec{F}_{\text{net}}}{m} = \frac{1}{10} [20.7035, 25.9054]$$

$$= [2.0704, 2.5905] \text{ m/s}^2 \quad (*)$$

$$(*) \quad \|\vec{a}\| = \sqrt{10.9972} \\ = 3.3 \text{ m/s}^2$$

$$\theta = \tan^{-1} \left(\frac{2.5905}{2.0704} \right)$$

$$\theta \approx 51^\circ$$

\therefore The acceleration is 3.3 m/s^2
[R 51° U].

3. How much force and what direction needs to be applied to accelerate a 50.0-kg object by 4.0 m/s^2 left if the object is initially moving left at constant velocity along a horizontal surface and the coefficient of kinetic friction is 0.03? Include a FBD.

$$\vec{F}_{\text{net}} = [0, 0] \text{ N}$$

$$\begin{aligned} \vec{F}_{\text{net}} &= m\vec{a} \\ &= (50.0)(4.0) \\ &= 200 \text{ N [L]} \\ &= [-200, 0] \text{ N} \end{aligned}$$

$$\vec{F}_g = [0, -490] \text{ N}$$

$$\vec{F}_N = [0, 490] \text{ N}$$

$$\vec{F}_a = [F_x, 0] \text{ N}$$

$$\begin{aligned} \vec{F}_f &= [F_N \mu, 0] \text{ N} \\ &= [14.7, 0] \text{ N} \end{aligned}$$

$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{F}_N + \vec{F}_f + \vec{F}_a$$

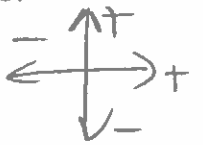
$$[-200, 0] = [0, -490] + [0, 490] + [14.7, 0] + [F_x, 0]$$

$$\Rightarrow \vec{F}_x = -200 - 14.7$$

$$= -214.7 \text{ N}$$

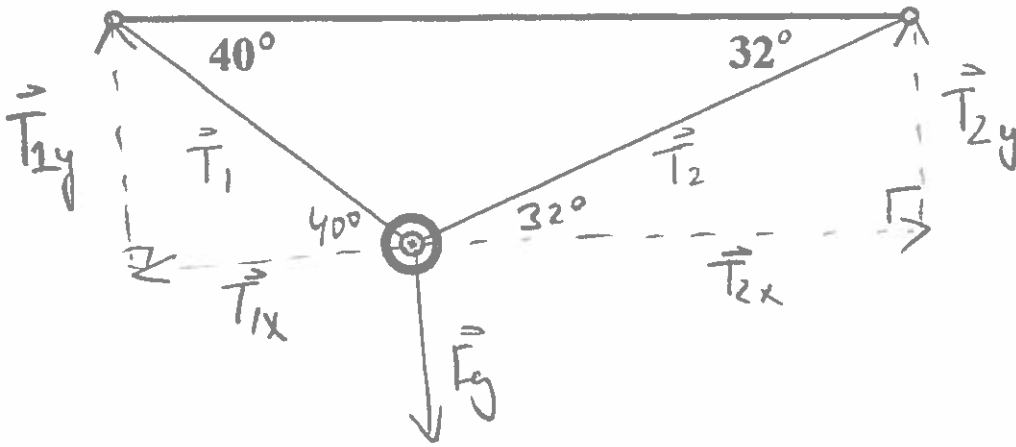
$$= 214.7 \text{ N [L]}$$

$\therefore 2.1 \times 10^2 \text{ N [L]}$ must be applied to accelerate the object 4.0 m/s^2 [L].



$$\vec{F}_{\text{net}} = [0, 0] \text{ N}$$

4. Find the magnitude and direction of the force of tension in each of the ropes given that the object tied to the ropes has mass 8.0 kg and is at rest. Include a free-body diagram.



$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{T}_1 + \vec{T}_2$$

$$[0, 0] = [0, -mg] + [-T_1 \cos 40^\circ, T_1 \sin 40^\circ] + [T_2 \cos 32^\circ, T_2 \sin 32^\circ]$$

$$0 = 0 - T_1 \cos 40^\circ + T_2 \cos 32^\circ \quad \bullet \quad 0 = -mg + T_1 \sin 40^\circ + T_2 \sin 32^\circ$$

$$T_1 = \frac{T_2 \cos 32^\circ}{\cos 40^\circ}$$

$$T_1 = 1.1070 T_2$$

$$0 = -78.4 + (1.1070 T_2)(0.6428) + 0.5299 T_2$$

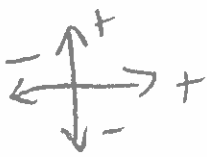
$$78.4 = 1.2415 T_2$$

$$T_2 = 63.1495 \text{ N}$$

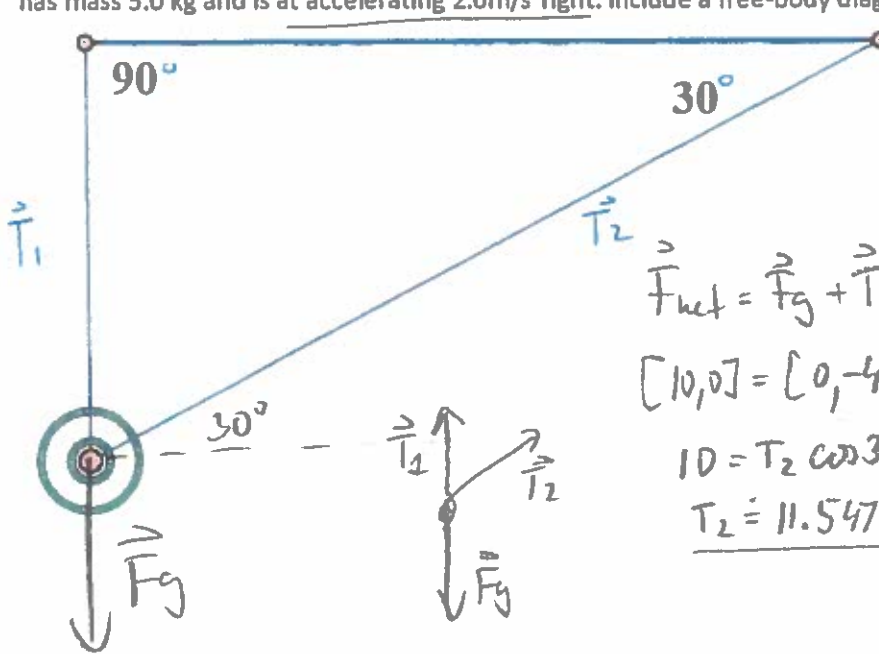
$$T_1 = (1.1070)(63.1495)$$

$$T_1 = 69.9065 \text{ N}$$

\therefore Tension in the left rope is $7.0 \times 10^1 \text{ N}$ [L 40° U]
and Tension in the right rope is 63 N [R 32° U].



5. Find the magnitude and direction of the force of tension in each of the ropes given that the object tied to the ropes has mass 5.0 kg and is accelerating 2.0 m/s^2 right. Include a free-body diagram.



$$\vec{F}_{\text{net}} = m\vec{a}$$

$$= (5.0)(2.0)$$

$$= 10.0 \text{ m/s}^2 [\text{R}]$$

$$= [10, 0] \text{ m/s}^2$$

$$\vec{F}_g = [0, -49]$$

$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{T}_1 + \vec{T}_2$$

$$[10, 0] = [0, -49] + [T_2 \cos 30^\circ, T_2 \sin 30^\circ] + [0, T_1]$$

$$10 = T_2 \cos 30^\circ$$

$$T_2 = 11.5470 \text{ N}$$

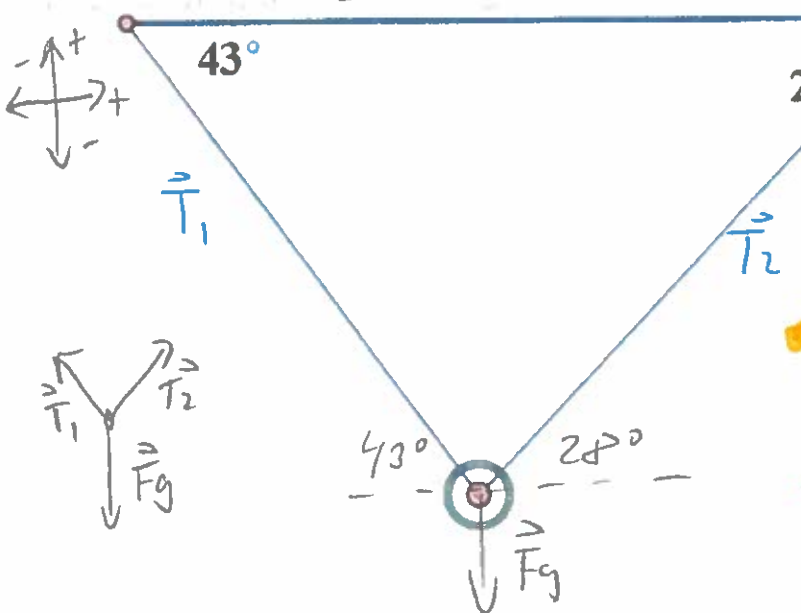
$$0 = -49 + T_2 \sin 30^\circ + T_1$$

$$T_1 = 49 - 5.7735$$

$$T_1 = 43.2265 \text{ N}$$

\therefore Tension in rope 1 is 43 N [U] and in rope 2 $T = 12 \text{ N}$ [R 30° U].

6. Find the magnitude and direction of the force of tension in each of the ropes given that the object tied to the ropes has mass 2.0 kg and is at rest. Include a free-body diagram.



$$\vec{F}_{\text{net}} = [0, 0] \text{ N}$$

$$\vec{F}_g = [0, -19.6] \text{ N}$$

$$\vec{F}_{\text{net}} = \vec{F}_g + \vec{T}_1 + \vec{T}_2 (*)$$

$$T_1 = T_2 (1.2073)$$

$$= (15.1603)(1.2073)$$

$$T_1 = 18 \text{ N} [\text{L } 43^\circ \text{ U}]$$

$$(*) [0, 0] = [0, -19.6] + [-T_1 \cos 43^\circ, T_1 \sin 43^\circ] + [T_2 \cos 28^\circ, T_2 \sin 28^\circ]$$

$$0 = -T_1 \cos 43^\circ + T_2 \cos 28^\circ$$

$$T_1 = \frac{T_2 \cos 28^\circ}{\cos 43^\circ} = T_2 (1.2073)$$

$$0 = -19.6 + T_1 \sin 43^\circ + T_2 \sin 28^\circ$$

$$19.6 = T_2 (1.2073)(0.6820) + T_2 (0.4695)$$

$$T_2 = \frac{19.6}{1.2929} = 15 \text{ N}$$