PHYSICS FOR ENGINEERING I

(PHYS 1210)

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Chapter 5:

Laws of Motion

Newton's First Law

✓ **If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration.**

Or,

✓ **In the absence of external forces and when viewed from an inertial reference frame, an object at rest remains at rest and an object in motion continues in motion with a constant velocity (that is, with a constant speed in a straight line).**

Simply,

✓ ***when no force acts on an object, the acceleration of the object is zero.***

Newton's Second Law

When viewed from an inertial reference frame, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass:

$$\vec{\mathbf{a}} \propto \frac{\sum \vec{\mathbf{F}}}{m}$$

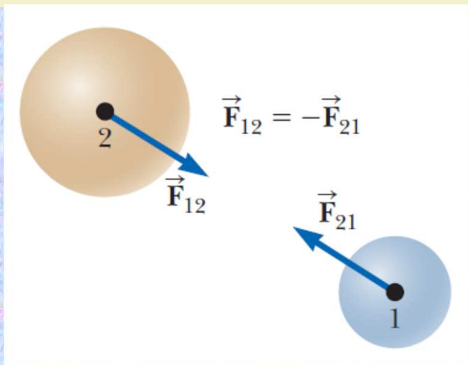
$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

✓ **Gravitational Force** $\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$

Newton's Third Law

If two objects interact, the force $\vec{\mathbf{F}}_{12}$ exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force $\vec{\mathbf{F}}_{21}$ exerted by object 2 on object 1:

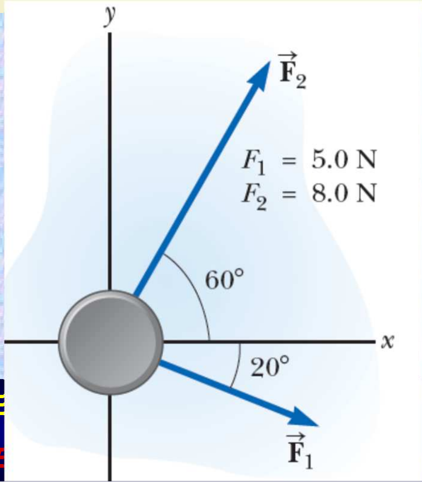
$$\vec{\mathbf{F}}_{12} = -\vec{\mathbf{F}}_{21} \quad \textbf{(5.7)}$$



Applied Mechanical Engineering Program
PHYSICS FOR ENGINEERING I
Chapter 5
LAWS OF MOTION

Example:

A hockey puck having a mass of 0.30 kg slides on the frictionless, horizontal surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in Figure 5.4. The force $\vec{\mathbf{F}}_1$ has a magnitude of 5.0 N, and is directed at $\theta = 20°$ below the x axis. The force $\vec{\mathbf{F}}_2$ has a magnitude of 8.0 N and its direction is $\phi = 60°$ above the x axis. Determine both the magnitude and the direction of the puck's acceleration.



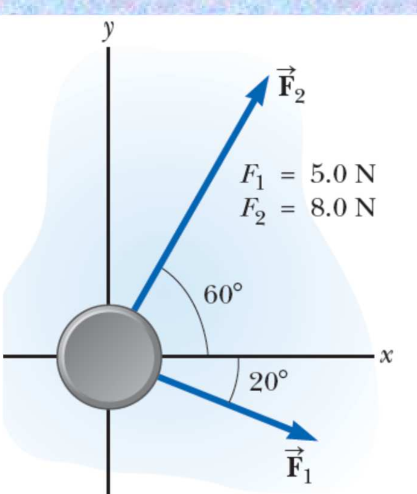
Solution:

$$\sum F_x = F_{1x} + F_{2x} = F_1 \cos\theta + F_2 \cos\phi$$

$$\sum F_y = F_{1y} + F_{2y} = F_1 \sin\theta + F_2 \sin\phi$$

$$a_x = \frac{\sum F_x}{m} = \frac{F_1\cos\theta + F_2\cos\phi}{m}$$

$$a_y = \frac{\sum F_y}{m} = \frac{F_1\sin\theta + F_2\sin\phi}{m}$$



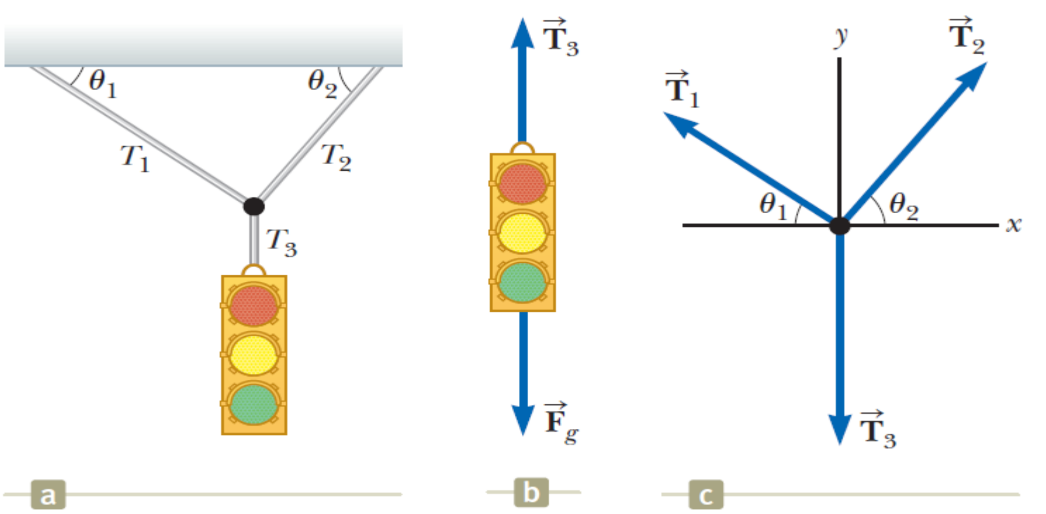
$$a_x = \frac{(5.0\text{ N})\cos(-20°) + (8.0\text{ N})\cos(60°)}{0.30\text{ kg}} = 29\text{ m/s}^2$$

$$a_y = \frac{(5.0\text{ N})\sin(-20°) + (8.0\text{ N})\sin(60°)}{0.30\text{ kg}} = 17\text{ m/s}^2$$

$$a = \sqrt{(29\text{ m/s}^2)^2 + (17\text{ m/s}^2)^2} = 34\text{ m/s}^2$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = 31°$$

Example: A traffic light weighing 122 N hangs from a cable tied to two other cables fastened to a support as in Figure 5.10a. The upper cables make angles of $\theta_1 = 37.0°$ and $\theta_2 = 53.0°$ with the horizontal. These upper cables are not as strong as the vertical cable and will break if the tension in them exceeds 100 N. Does the traffic light remain hanging in this situation, or will one of the cables break?

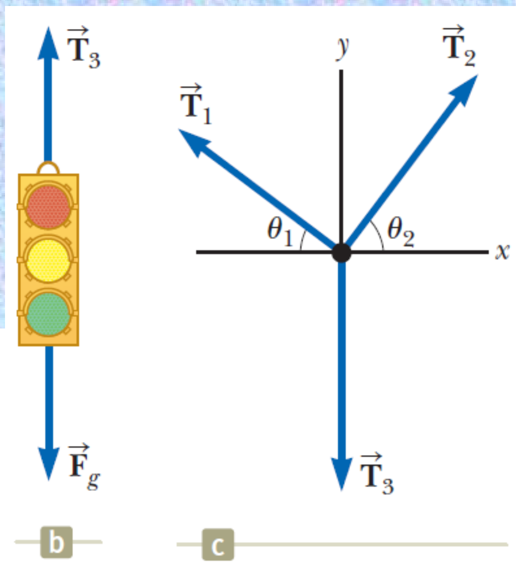


Solution:

$$\sum F_y = 0 \rightarrow T_3 - F_g = 0$$

$$T_3 = F_g$$

Force	x Component	y Component
$\vec{\mathbf{T}}_1$	$-T_1 \cos\theta_1$	$T_1 \sin\theta_1$
$\vec{\mathbf{T}}_2$	$T_2 \cos\theta_2$	$T_2 \sin\theta_2$
$\vec{\mathbf{T}}_3$	0	$-F_g$



$$(1) \quad \sum F_x = -T_1 \cos\theta_1 + T_2 \cos\theta_2 = 0$$

$$(2) \quad \sum F_y = T_1 \sin\theta_1 + T_2 \sin\theta_2 + (-F_g) = 0$$

$$(3) \quad T_2 = T_1\left(\frac{\cos\theta_1}{\cos\theta_2}\right)$$

Solution:

$$\sum F_y = 0 \;\rightarrow\; T_3 - F_g = 0$$
$$T_3 = F_g$$

Force	x Component	y Component
$\vec{T}_1$	$-T_1 \cos \theta_1$	$T_1 \sin \theta_1$
$\vec{T}_2$	$T_2 \cos \theta_2$	$T_2 \sin \theta_2$
$\vec{T}_3$	0	$-F_g$

(1) $\sum F_x = -T_1 \cos \theta_1 + T_2 \cos \theta_2 = 0$

(2) $\sum F_y = T_1 \sin \theta_1 + T_2 \sin \theta_2 + (-F_g) = 0$

(3) $T_2 = T_1\left(\frac{\cos \theta_1}{\cos \theta_2}\right)$

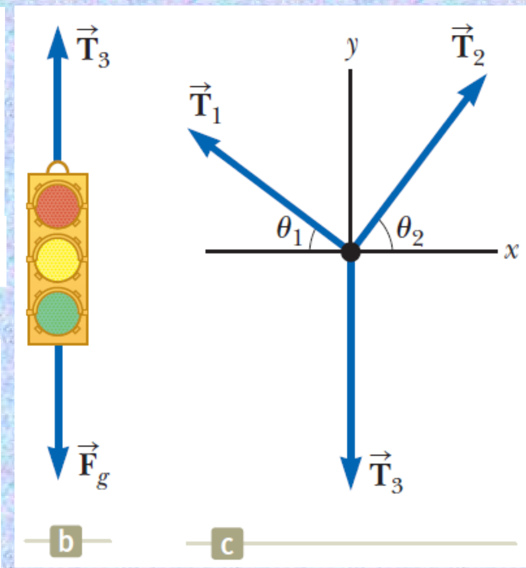
$$T_1 \sin \theta_1 + T_1\left(\frac{\cos \theta_1}{\cos \theta_2}\right)(\sin \theta_2) - F_g = 0$$

$$T_1 = \frac{F_g}{\sin \theta_1 + \cos \theta_1 \tan \theta_2}$$

$$T_1 = \frac{122 \text{ N}}{\sin 37.0° + \cos 37.0° \tan 53.0°} = 73.4 \text{ N}$$

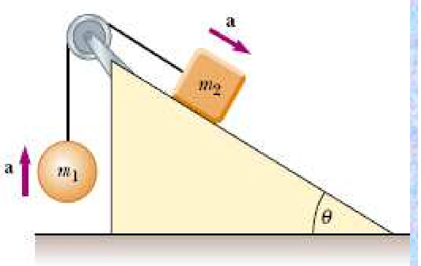
$$T_2 = (73.4 \text{ N})\left(\frac{\cos 37.0°}{\cos 53.0°}\right) = 97.4 \text{ N}$$

$$T_2 = T_1\left(\frac{\cos \theta}{\cos \theta}\right) = T_1$$



Example:

A ball of mass m_1 and a block of mass m_2 are attached by a lightweight cord that passes over a frictionless pulley of negligible mass, as in Figure 5.15a. The block lies on a frictionless incline of angle θ. Find the magnitude of the acceleration of the two objects and the tension in the cord.



(a)

Solution:

(1) $\sum F_x = 0$

(2) $\sum F_y = T - m_1 g = m_1 a_y = m_1 a$

(3) $\sum F_{x'} = m_2 g \sin \theta - T = m_2 a_{x'} = m_2 a$

(4) $\sum F_{y'} = n - m_2 g \cos \theta = 0$

(5) $$a = \frac{m_2 g \sin \theta - m_1 g}{m_1 + m_2}$$

(6) $$T = \frac{m_1 m_2 g(\sin \theta + 1)}{m_1 + m_2}$$