Chapter 5

Laws of motion

Laws of motion

- Newton's laws are the most used and basic laws in mechanics.
- Newton 1st Law (inertia 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.

In the absence of external forces, 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).

- Newton's 2nd Law: (note that F and a are vectors and should deal with them accordingly).

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

- Newton's 3rd Law:

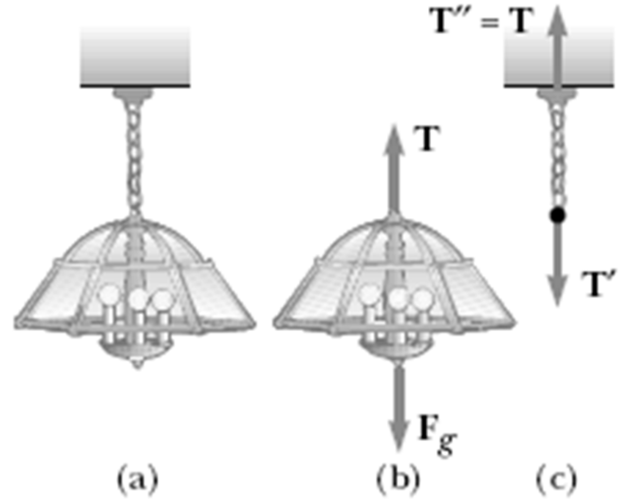
If two objects interact, the force $\mathbf{F}_{12}$ exerted by object 1 on object 2 is equal in magnitude and opposite in direction to the force $\mathbf{F}_{21}$ exerted by object 2 on object 1:

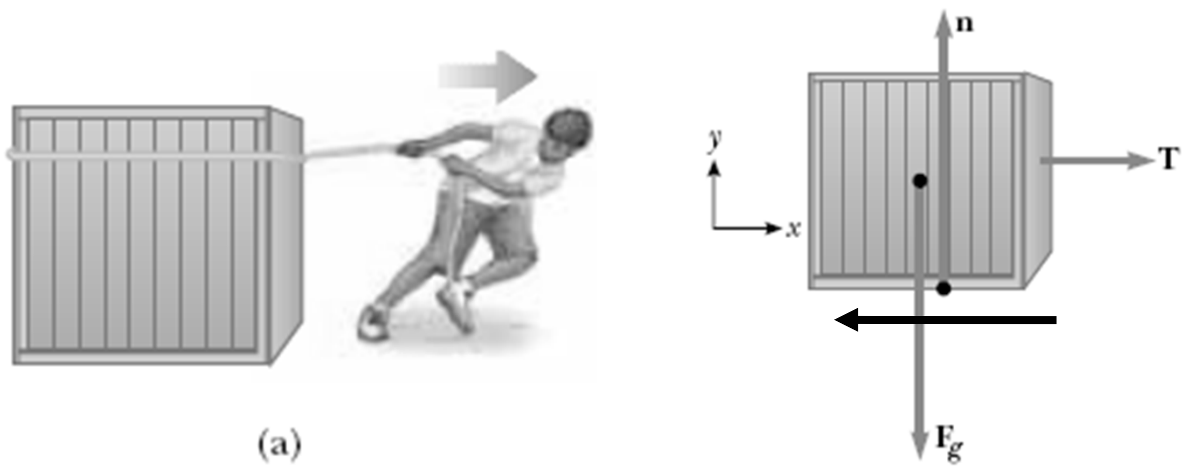
$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

Application of Newton's Laws

•Objects in equilibrium

•Objects experiencing a net force.





Example

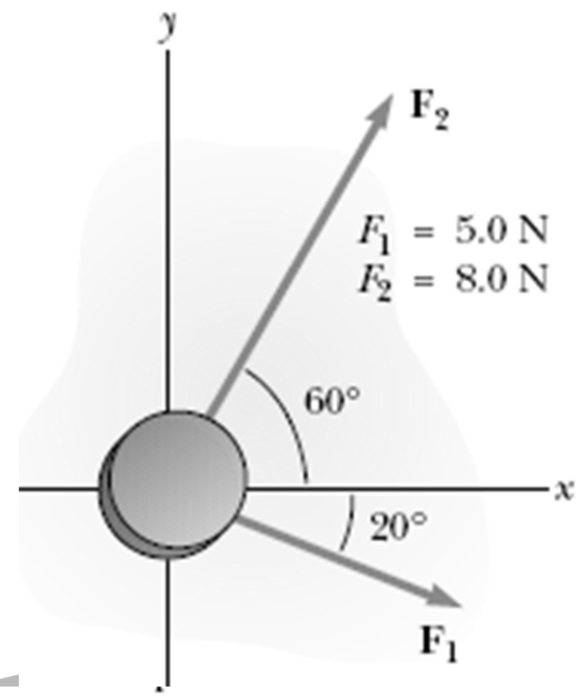
A hockey puck having a mass of 0.30 kg slides on the horizontal, frictionless surface of an ice rink. Two hockey sticks strike the puck simultaneously, exerting the forces on the puck shown in Figure 5.4. The force $\mathbf{F}_1$ has a magnitude of 5.0 N, and the force $\mathbf{F}_2$ has a magnitude of 8.0 N. Determine both the magnitude and the direction of the puck's acceleration.

$$\sum F_x = F_{1x} + F_{2x} = F_1 \cos(-20°) + F_2 \cos 60°$$
$$= (5.0\text{ N})(0.940) + (8.0\text{ N})(0.500) = 8.7\text{ N}$$

$$\sum F_y = F_{1y} + F_{2y} = F_1 \sin(-20°) + F_2 \sin 60°$$
$$= (5.0\text{ N})(-0.342) + (8.0\text{ N})(0.866) = 5.2\text{ N}$$

$$a_x = \frac{\Sigma F_x}{m} = \frac{8.7\text{ N}}{0.30\text{ kg}} = 29\text{ m/s}^2$$

$$a_y = \frac{\Sigma F_y}{m} = \frac{5.2\text{ N}}{0.30\text{ kg}} = 17\text{ m/s}^2$$

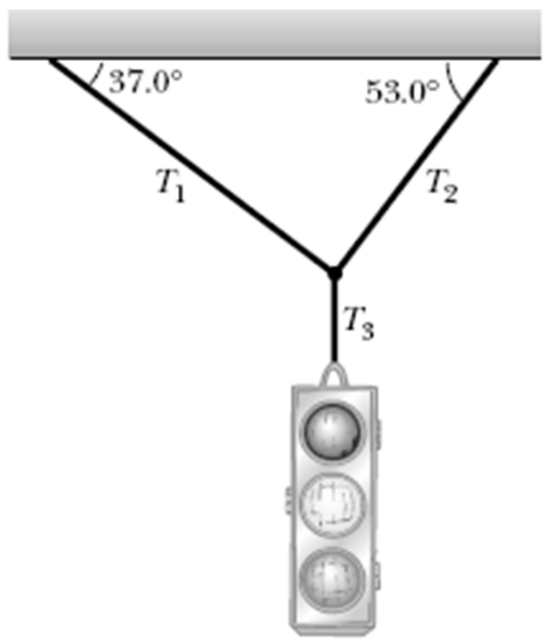


$$a = \sqrt{(29)^2 + (17)^2}\text{ m/s}^2 = 34\text{ m/s}^2$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = 30°$$

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 37.0° and 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. Will the traffic light remain hanging in this situation, or will one of the cables break?



(a)

Example

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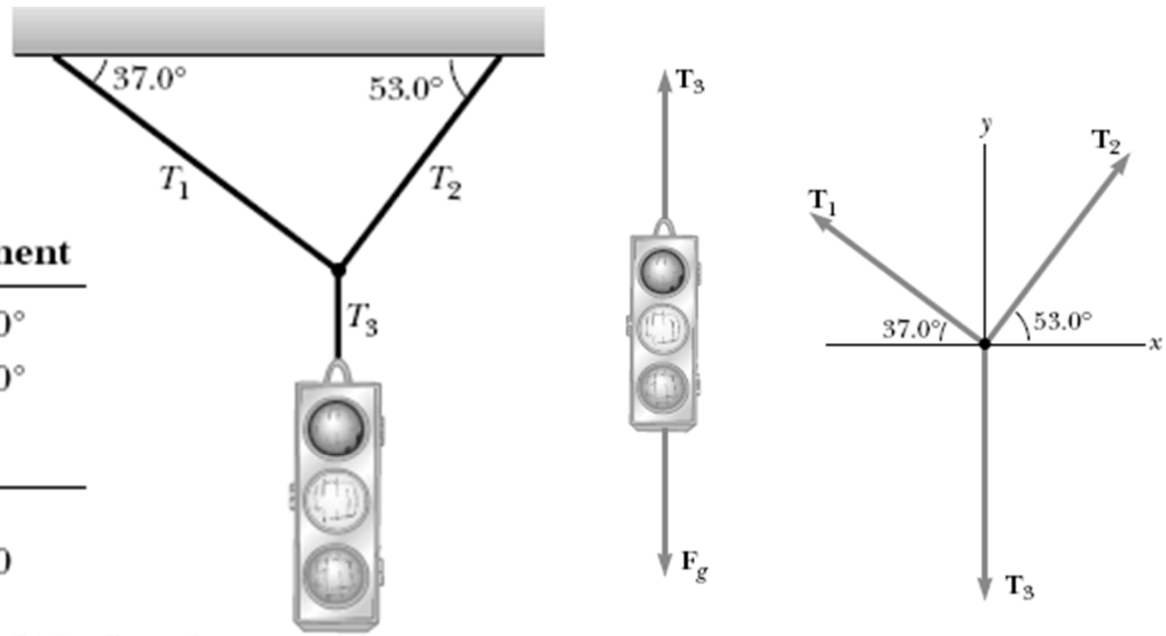
$$\sum F_y = 0 \rightarrow T_3 - F_g = 0.$$

$$T_3 = F_g = 122 \text{ N}$$

Force	x Component	y Component
$\mathbf{T}_1$	$-T_1 \cos 37.0°$	$T_1 \sin 37.0°$
$\mathbf{T}_2$	$T_2 \cos 53.0°$	$T_2 \sin 53.0°$
$\mathbf{T}_3$	0	-122 N



(a)

$$\sum F_x = -T_1 \cos 37.0° + T_2 \cos 53.0° = 0$$

$$\sum F_y = T_1 \sin 37.0° + T_2 \sin 53.0° + (-122 \text{ N}) = 0$$

$$T_2 = T_1\left(\frac{\cos 37.0°}{\cos 53.0°}\right) = 1.33 T_1$$

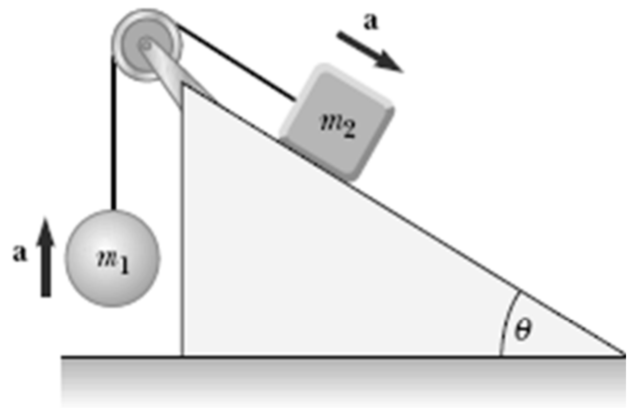
$$T_1 \sin 37.0° + (1.33 T_1)(\sin 53.0°) - 122 \text{ N} = 0$$

$$T_1 = 73.4 \text{ N}$$

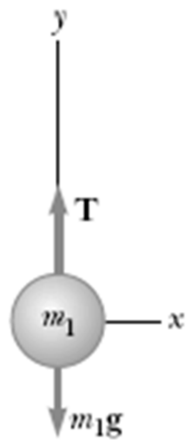
$$T_2 = 1.33 T_1 = 97.4 \text{ N}$$

Example

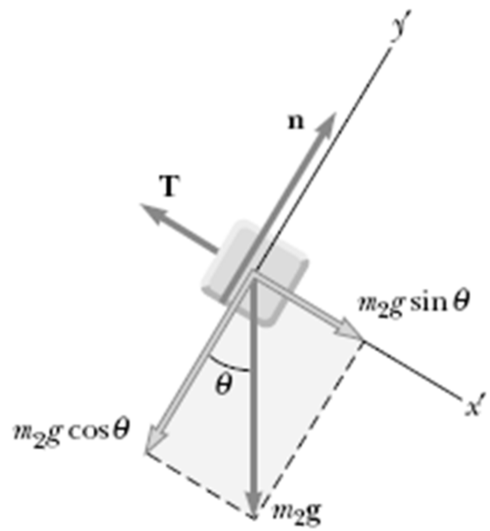
A ball of mass m_1 and a block of mass m_2 are attached by a lightweight cord that passes over a frictionless pulley of negligible mass, as in Figure 5.15a. The block lies on a frictionless incline of angle θ. Find the magnitude of the acceleration of the two objects and the tension in the cord.



(a)



(b)



(c)

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