PHY105_ MODULE 2
2nd Lecture

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Pearson Education, Inc. and Serway et al., 2003 are acknowledged for the figures and materials.

Text: College Physics by Serway et al

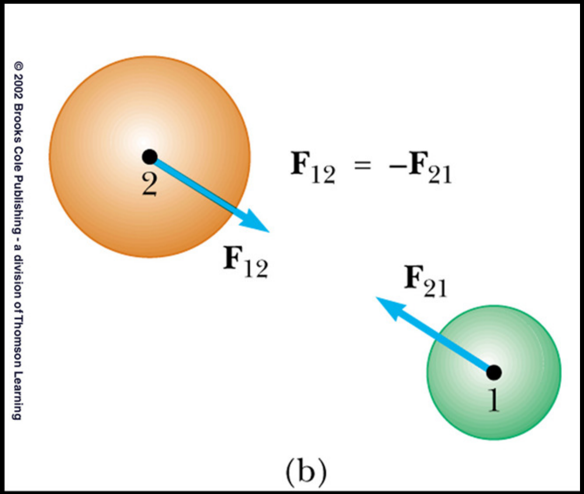
3 Newton's 3rd Law

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

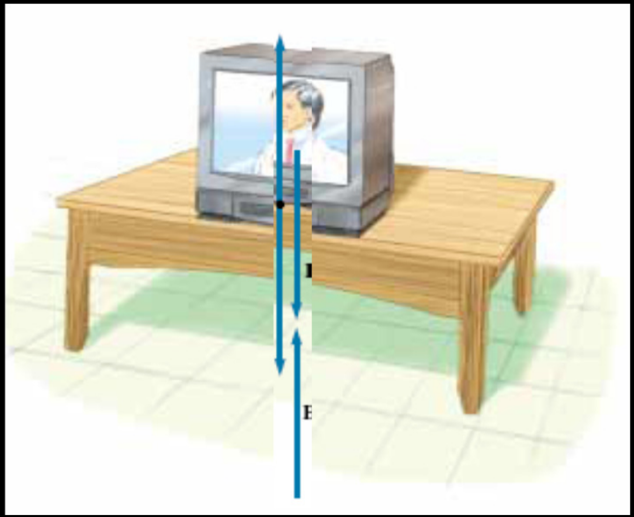
$$\boxed{\vec{F}_{12} = -\vec{F}_{21}}$$

F_{12} may be called the *action* force and F_{21} the *reaction* force

The action and reaction forces act on **different** objects



(b)



STRATEGY

1 Make a sketch of the situation described in the problem, introduce a coordinate frame

2 Draw a free body diagram for the isolated object under consideration and label all the forces acting on it

3 Resolve the forces into x- and y-components, using a convenient coordinate system

4 Apply equations, keeping track of signs

5 Solve the resulting equations

4.1 The Gravitational Force and Weight

Gravitational Force : Mutual force of attraction between any two objects

Expressed by Newton's Law of Universal Gravitation :

$$F_g = G\frac{m_1 m_2}{r^2}\ ; \quad G = 6.67 \times 10^{-11}\ N.m^2.kg^{-2}$$

The magnitude of the gravitational force acting on an object of mass *m* near the Earth's surface is called the weight *w* of the object

w = mg is a special case of Newton's 2nd Law

$$F_g = G\frac{Mm}{r^2} = mg\ ; \qquad \boxed{g = G\frac{M}{r^2}}$$

$$g = 6.67 \times 10^{-11}\ N.m^2.kg^{-2} \times \frac{6.0 \times 10^{24}\ kg}{6.4 \times 10^6\ m} =$$

4.2 Equilibrium

An object either at rest or moving with a constant velocity is said to be in *equilibrium*

The net force acting on the object is zero

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

$$\sum F_x = 0$$

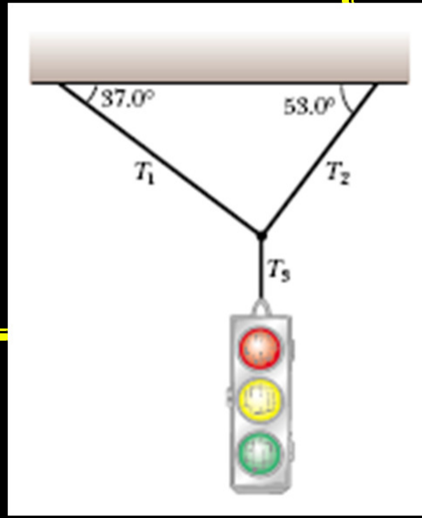
$$\sum F_y = 0$$

Easier to work with the equation in terms of its components

EXAMPLE

A traffic light weighing 125 N hangs from a cable tied to two other cables fastened to a support. The upper cables make angles of 37.0° and 53.0° with the horizontal.

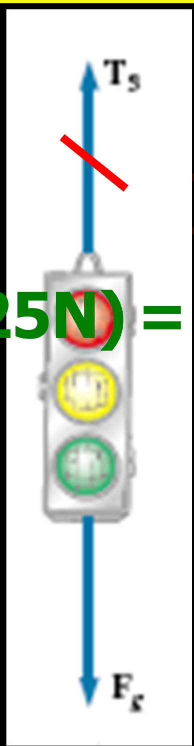
(a) Find the tension in the three cables.

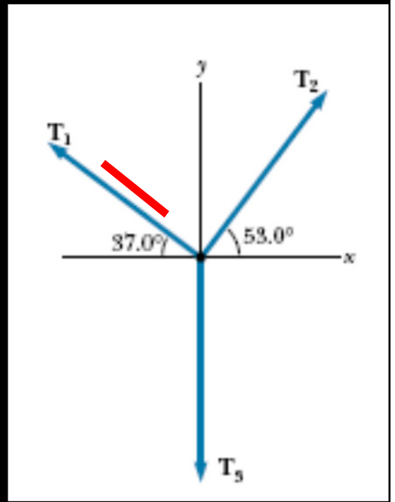


(a) $T_3 = F_g = 125\ N$

(1) $\sum F_X = -T_1 \cos 37.0^0 + T_2 \cos 53.0^0 = 0$

(2) $\sum F_Y = T_1 \sin 37.0^0 + T_2 \sin 53.0^0 + (-125N) = 0$





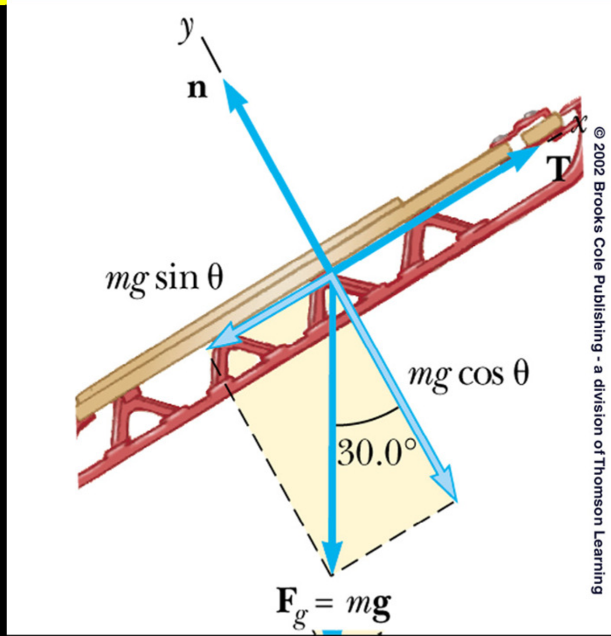
(1) $\rightarrow$ $T_2 = 1.33 T_1$

(2) $\rightarrow$ $T_1 = 75.1\ N$

(1) $\rightarrow$ $T_2 = 99.9\ N$

EXAMPLE

A child holds a sled at rest on frictionless, snow-covered hill, as shown in figure. If the sled weights 77.0 N, find the force T exerted by the rope on the sled and the force n exerted by the hill on the sled.



Given:

angle: $\alpha = 30°$
weight: $w = 77.0$ N

Find:

Tension T =?
Normal n =?

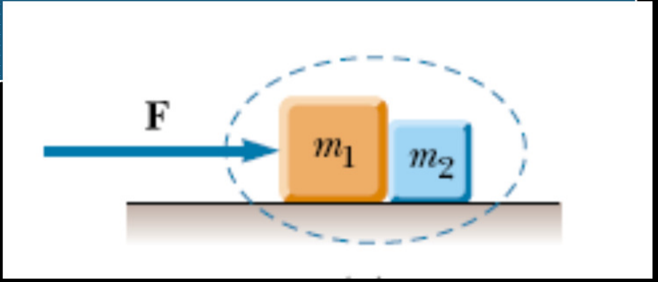
- **Choose the coordinate system with x along the incline and y perpendicular to the incline**
- **Replace the force of gravity with its components**

Introduce coordinate frame:
Oy: y is directed perp. to incline
Ox: x is directed right, along incline

PROBLEM

Two blocks of masses m_1 and m_2 are placed in contact with each other on a frictionless horizontal surface. A constant horizontal force F is applied to the block of mass m_1.

(a) Determine the magnitude of the acceleration of the two-block system.



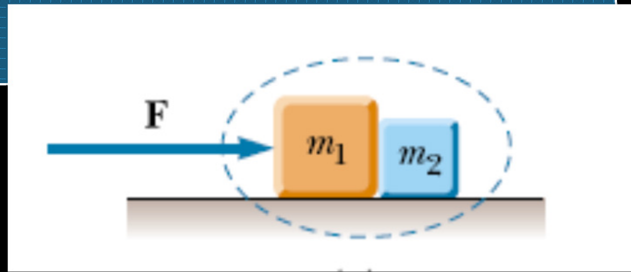
SOLUTION (a)

$$\sum F_x = F = (m_1 + m_2)a_x \; ; \; a_x = \frac{F}{m_1 + m_2}$$

EXAMLE

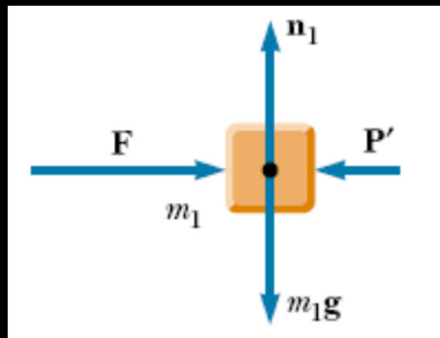
Two blocks of masses m_1 and m_2 are placed in contact with each other on a frictionless horizontal surface. A constant horizontal force F is applied to the block of mass m_1 .

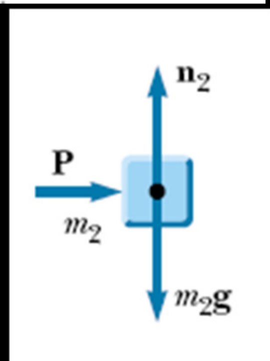
(b) Determine the magnitude of the contact force between the two blocks.



SOLUTION (b)

Treat each block separately with its own free-body diagram





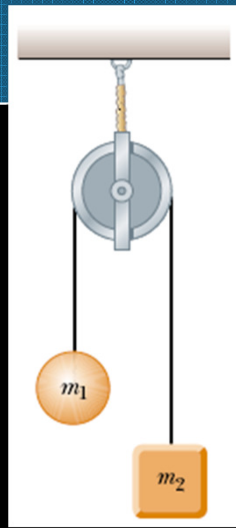
For m_2 : $$\sum F_x = P = m_2 a_x = \frac{m_2 F}{m_1 + m_2}$$

For m_1 : $$\sum F_x = F - P' = m_1 a_x$$

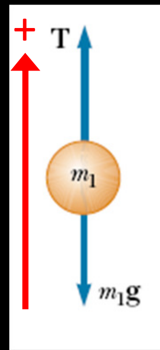
$$P' = F - m_1 a_x = F - \frac{m_1 F}{m_1 + m_2} = \frac{m_2 F}{m_1 + m_2} \longrightarrow P' = P$$

EXAMPLE

Two objects of unequal mass are hung vertically over a frictionless pulley of negligible mass (figure), the arrangement is called an *Atwood machine*. Determine the magnitude of the acceleration of the two objects and the tension in the lightweight cord.



SOLUTION



For m_1 : $\sum F_y = T - m_1 g = m_1 a_y$ (1)

For m_2 : $\sum F_y = m_2 g - T = m_2 a_y$ (2)

(1) + (2) $\longrightarrow$ $a_y = \dfrac{m_2 - m_1}{m_1 + m_2} g$

(1) $\longrightarrow$ $T = \dfrac{2 m_1 m_2}{m_1 + m_2} g$