PHY101: Introduction to Physics I

Monsoon Semester 2024
Lecture 9

Department of Physics, School of Natural Sciences,
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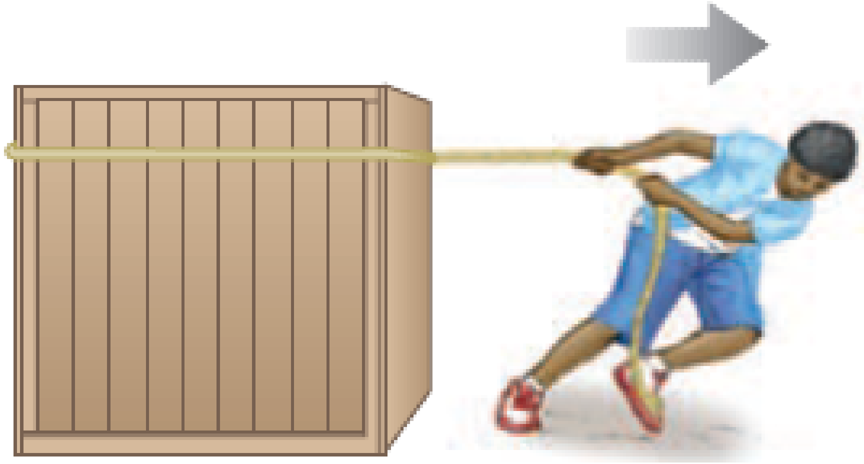
Previous Lecture

Newton's laws of motion

This Lecture

Tension
Problem solving

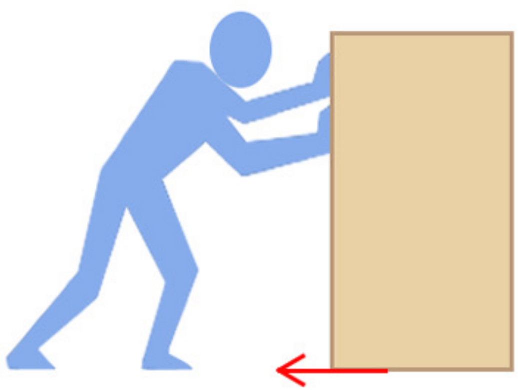


Contact Forces

<u>Contact force</u> is a force that acts at the points of contact between two objects. Microscopically this force is transmitted between two bodies by short-range atomic or molecular interactions.

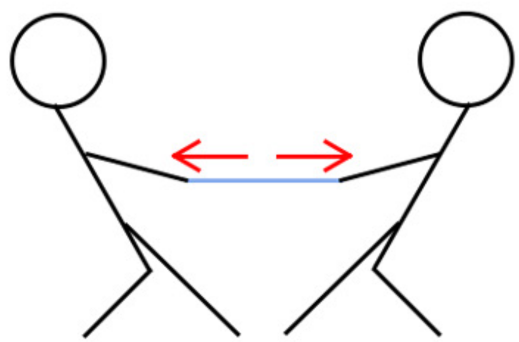
Friction Force

A man pushing a box



Tension Force

Two men pulling a rope



Viscous force

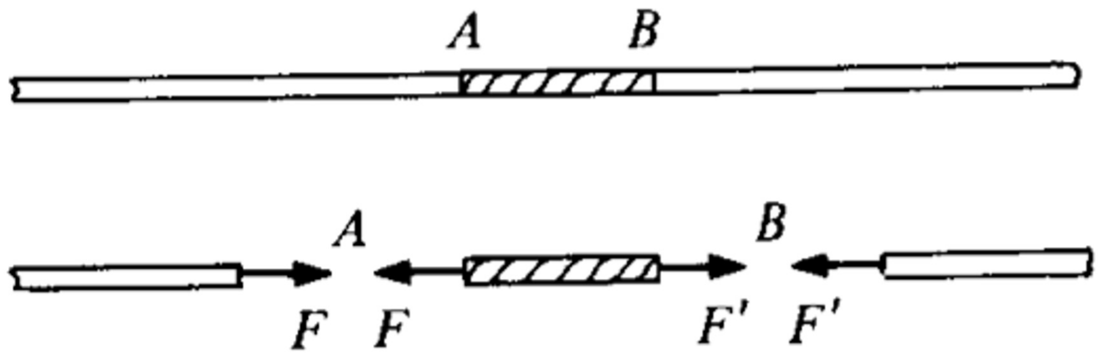
Nature of honey

Examples: **Friction force**, **tension force**, **viscous force** etc.

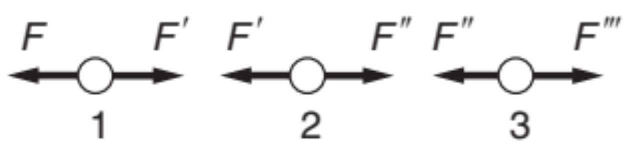
Image Sources:
https://www.sciencefacts.net/contact-and-non-contact-forces.html
https://sciencenotes.org/viscosity-definition-and-examples/

Tension

If one pulls each section of a short rope to either side of it, by Newton's third law it is pulled by the adjacent sections. The magnitude of this force acting between the adjacent sections of the rope is called the **tension**.

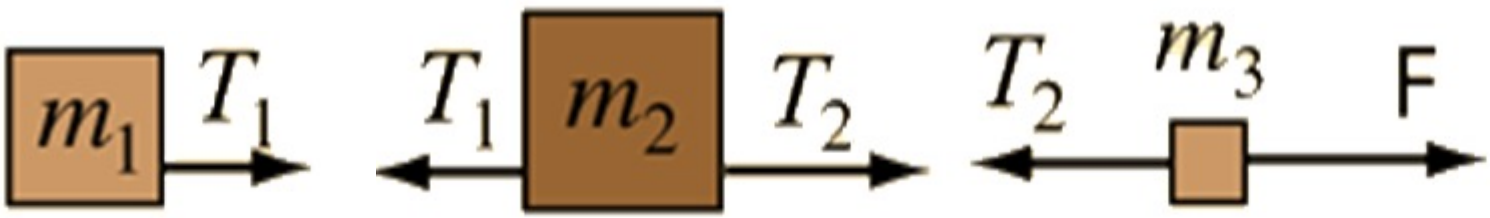


For such systems we can not associate a fixed direction to the tension.
It will depend on which object/part is exerting the force on which!



Ref.: http://parabolaonline.tripod.com/sitebuildercontent/sitebuilderpictures/compression.gif

Similarly, for the systems of masses below, a force (F) is applied and T is tension between the masses. Find the expression for acceleration of the system:



$F - T_2 = m_3 a$ gives T_2

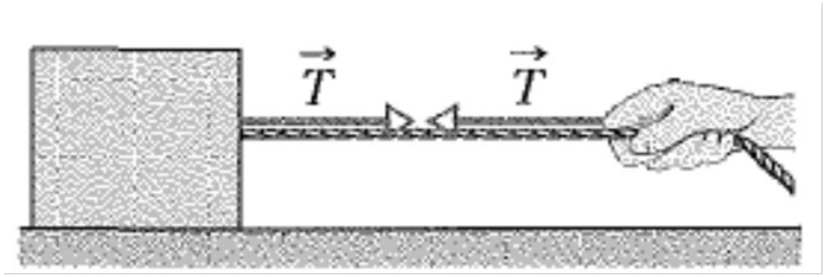
$T_1 = m_1 a$ gives T_1

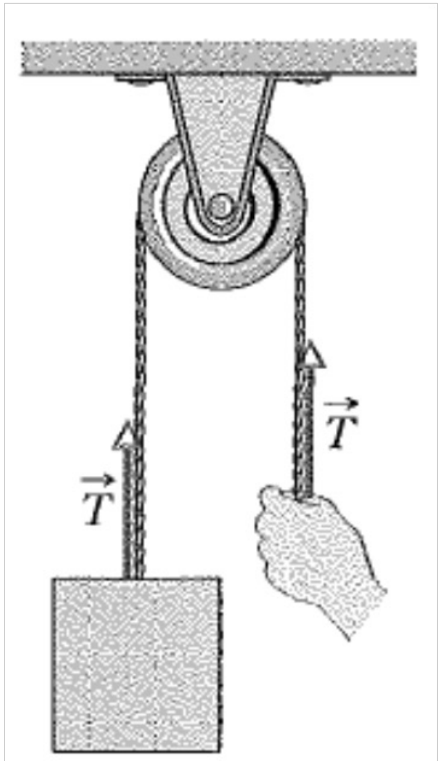
$T_2 - T_1 = m_2 a$ gives a check

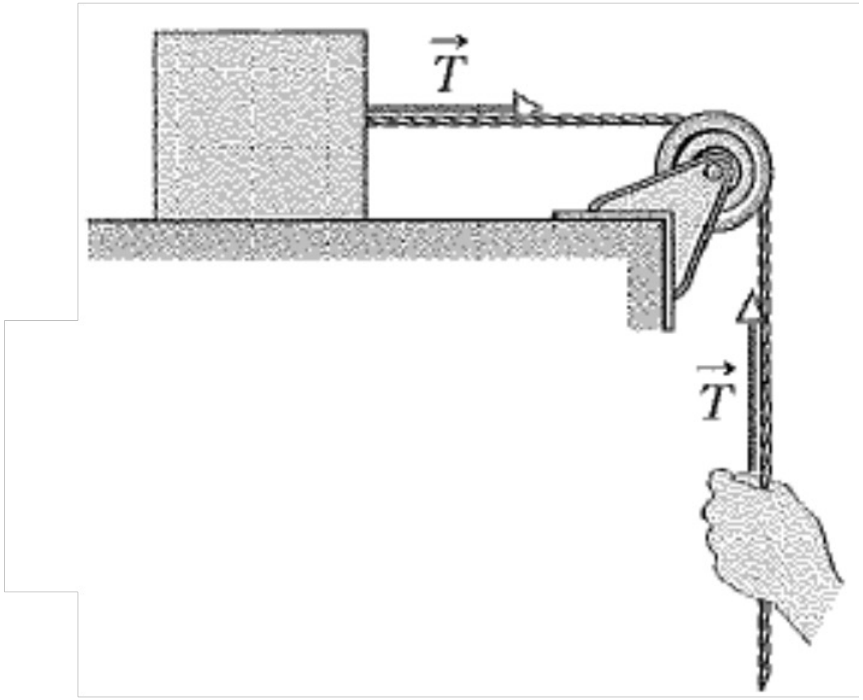
$$a = \frac{F}{m_1 + m_2 + m_3}$$

Tension

few more examples: Pulleys



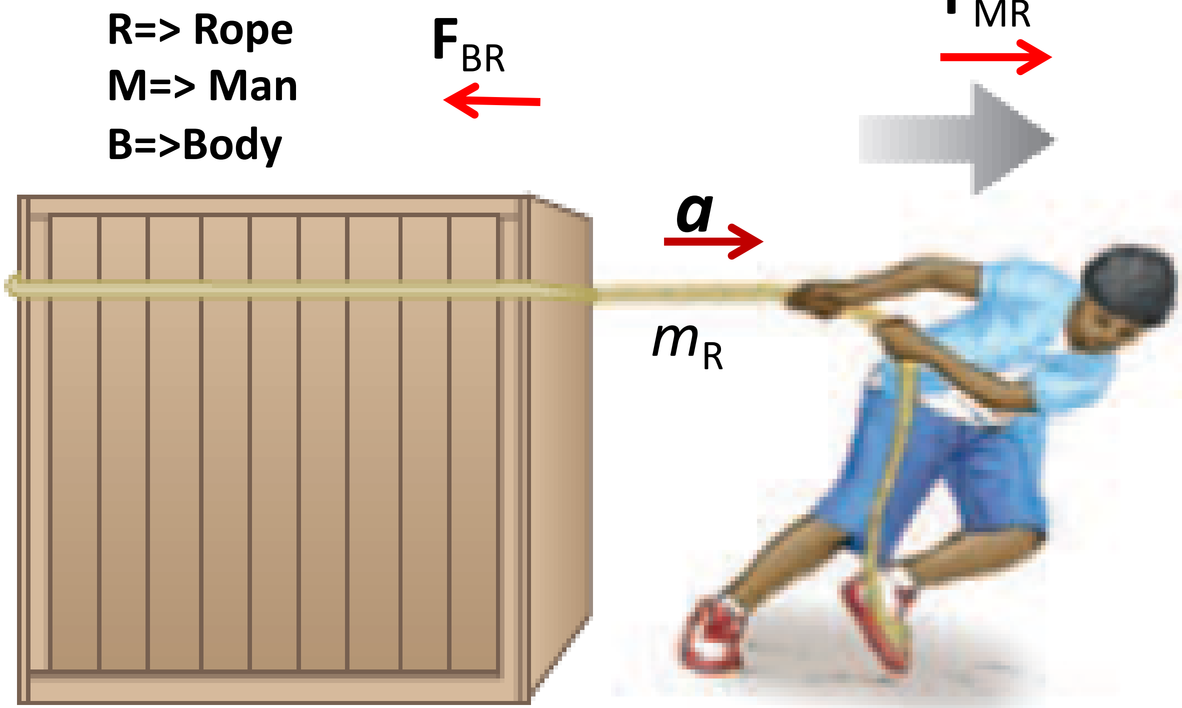




Tension

few more examples: pulling a box

R=> Rope
M=> Man
B=>Body



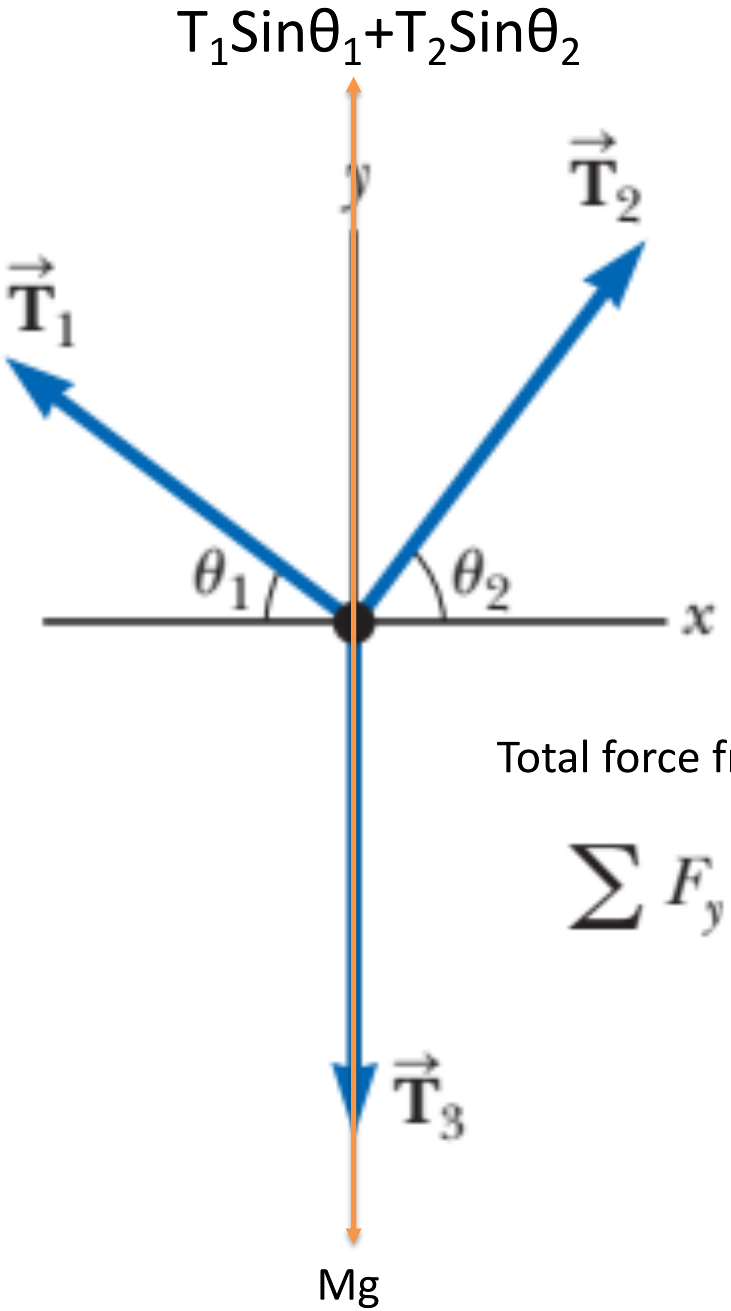
Mathematical tools for problem solving

$$\overrightarrow{F_{MR}} + \overrightarrow{F_{BR}} = m_R \vec{a}$$

$$\left|\overrightarrow{F_{MR}}\right| - \left|\overrightarrow{F_{BR}}\right| = m_R a$$

$$\left|\overrightarrow{F_{MR}}\right| \neq \left|\overrightarrow{F_{BR}}\right|$$

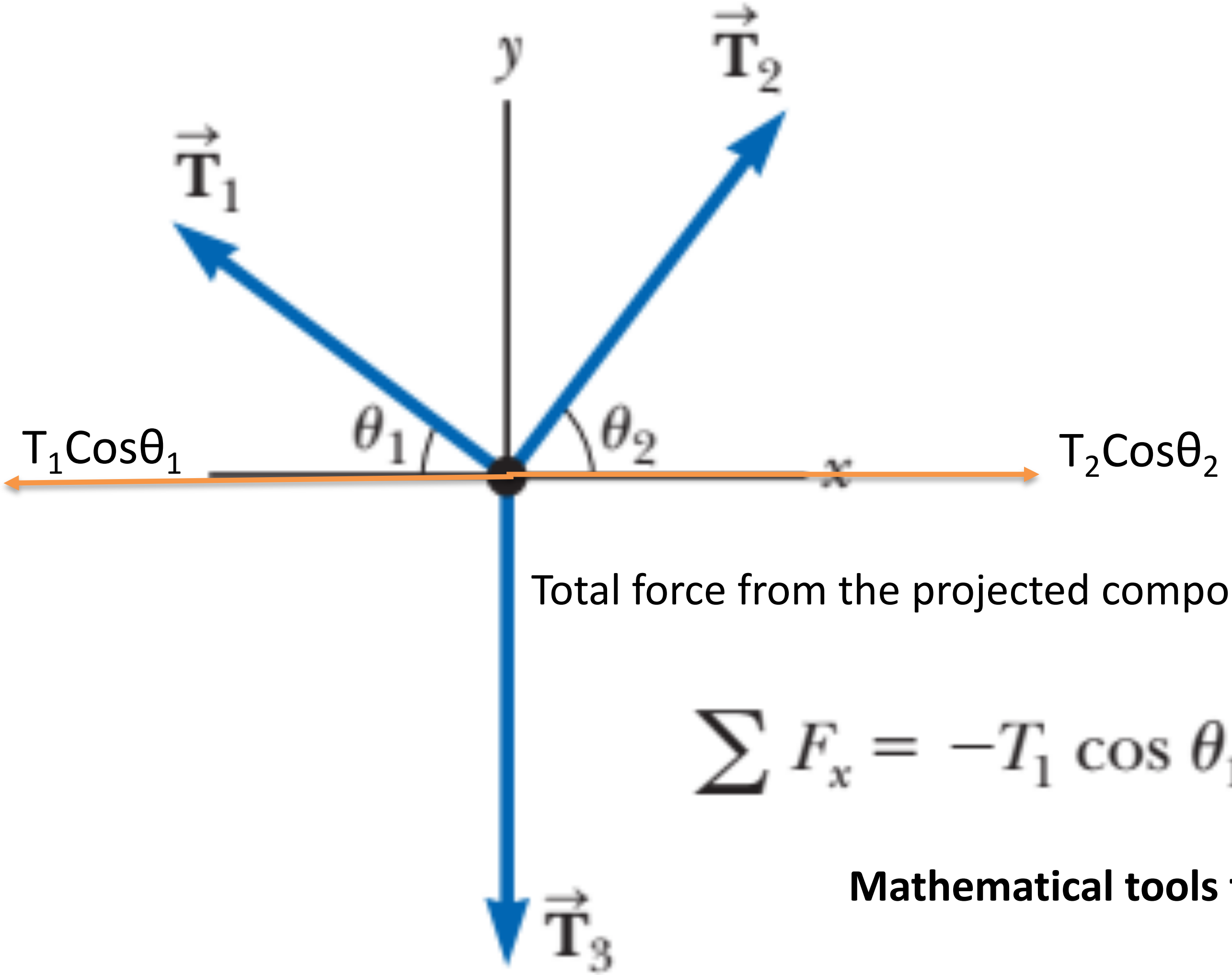
Rope can transmit a force where the force at any point on the rope is called Tension



Mathematical tools for problem solving

Total force from the projected components of tension (Y direction)

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

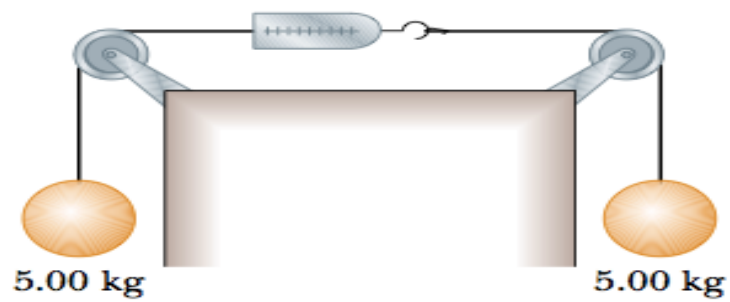


Total force from the projected components of tension (X direction)

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

Mathematical tools for problem solving

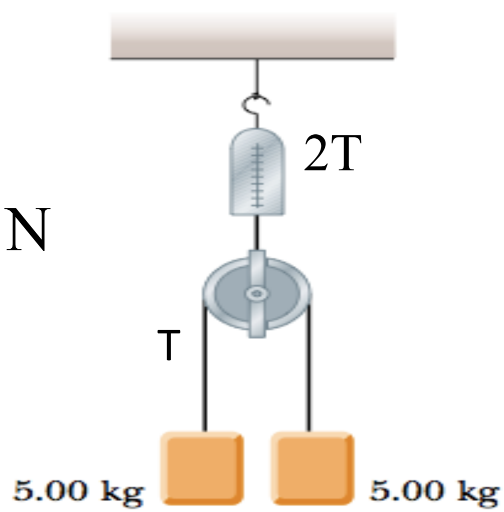
Problem 1: The systems shown in figure below are in equilibrium. If the spring scales are calibrated in Newtons, what do they read? Ignore the masses of the pulleys and strings and assume the pulleys and the incline in figures are **frictionless**. [g is referred to as the acceleration of gravity. Its value is 9.8 m/s^2 on Earth]



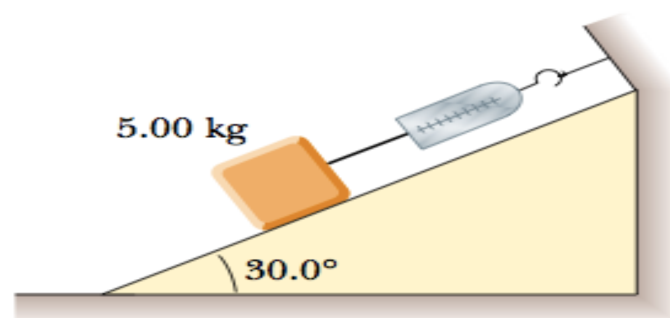
$\Rightarrow T = mg = 49\ N$

(a)

=> 2* 49 N



(b)



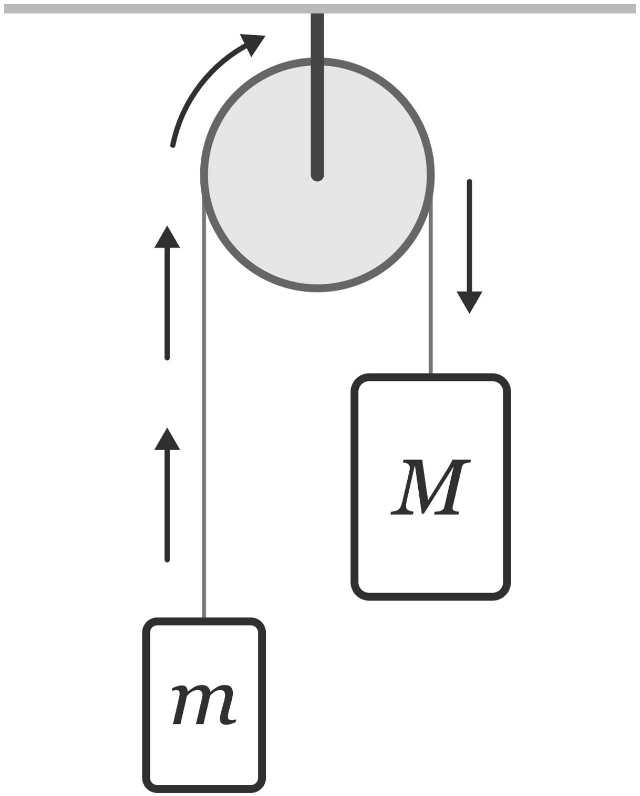
(c)

$\Rightarrow T = mg \sin 30^{o}$

$\Rightarrow 24.5\ N$

Problem 2:

Two masses of $80\ \mathrm{kg}$ and $140\ \mathrm{kg}$ hang from a rope that runs over a pulley. You can assume that the rope is massless and inextensible, and that the pulley is frictionless. Find the upward acceleration of the smaller mass and the tension in the rope.

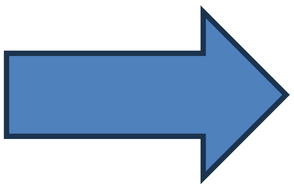


The smaller mass is subject to 2 forces:

- the upward tension, $\mathbf{T}$
- and the force of gravity, $m\mathbf{g}$

The larger mass is also subject to 2 forces:

- the upward tension, $\mathbf{T}$
- and the force of gravity, $M\mathbf{g}$



We know

$m = 80\ \mathrm{kg}$

$M = 140\ \mathrm{kg}$

We want to know

$a = ?$

$T = ?$

Continued…

Applying **Newton's 2nd Law**, the magnitudes of the two resultant forces can be expressed as

$$\boxed{\begin{aligned} r &= T - mg \\ R &= Mg - T \\ &\downarrow \\ ma &= T - mg \\ Ma &= Mg - T \end{aligned}}$$

$$r = ma$$

$$R = Ma$$

$$\Rightarrow \boxed{T = ma + mg} \Rightarrow \boxed{Ma = Mg - ma - mg}$$

$$\boxed{\begin{aligned} a &= \frac{M - m}{M + m} g \\ a &= \frac{140\text{ kg} - 80\text{ kg}}{140\text{ kg} + 80\text{ kg}} (9.8\text{ m/s}^2) \\ a &= \frac{60\text{ kg}}{220\text{ kg}} (9.8\text{ m/s}^2) \\ a &= 2.7\text{ m/s}^2 \end{aligned}}$$

$$\boxed{\begin{aligned} T &= ma + mg \\ T &= m\,(a + g) \\ T &= (80\text{ kg})\,(2.7\text{ m/s}^2 + 9.8\text{ m/s}^2) \\ T &= 1.0 \times 10^3\text{ N} \end{aligned}}$$

Answer:
Upward acceleration of the rope: 2.7 m/s2
& tension of the rope: 1000 N

<u>Next</u>

Friction

Projectile motion