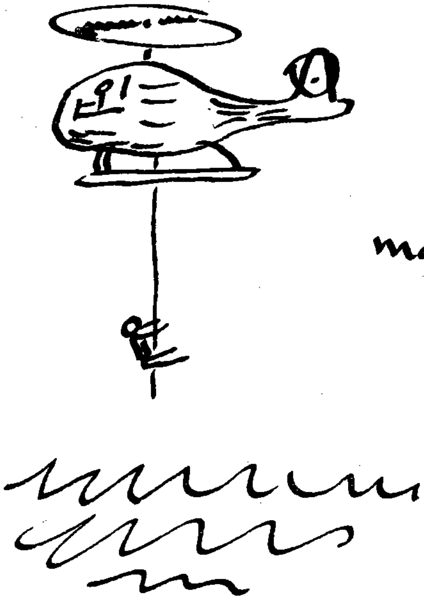
Newton's Laws

Example 1

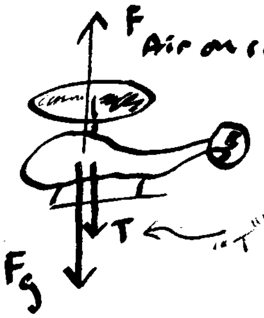


man w/ mass 70 kg dangles at end of rope during daring sea rescue by Helicopter.

Helicopter accelerates upward at $4\ m/s^2$. What tension must rope withstand?

Free body diagrams

Helicopter



Man

Man + Helicopter both accelerate upward at $4\ m/s^2$

So, for man

x direction

$\sum F = 0 = m_{man} a_x$

$a_x = 0$

sign of g

$\sum_i F_i = T - mg = m a_y$

$T - (70\ kg)(9.8\ m/s^2) = (70\ kg)(4\ m/s^2)$

$T = (70\ kg)(13.8\ m/s^2)$

$T = 966\ N$

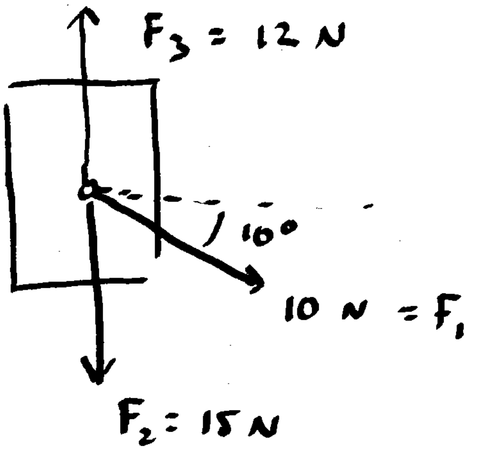
Check units ✓

0 Accel
∞ Accel } Limits

Do they make sense?

Newton's Laws – Example 2

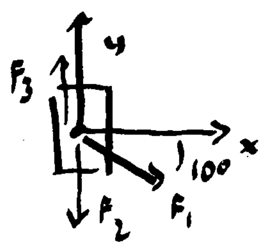
Hyenas pulling on an Antelope carcass

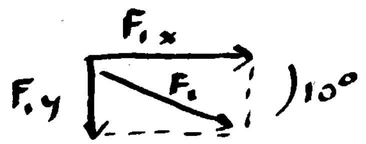


$M_{antelope} = 300\ kg$

Assume NO friction in this Example

Which way does the carcass move?
What is $|\vec{a}|$?





$F_{1x} = F_1 \cos 10$

$F_{1y} = -F_1 \sin 10$

$\sum F_x = (m_{Antelope}) a_x = F_1 \cos 10$

$\sum F_y = (m_{Ant}) a_y = \overset{+F_3}{\cancel{+12N}}\ \overset{-F_2}{\cancel{-15N}} - F_1 \sin 10$

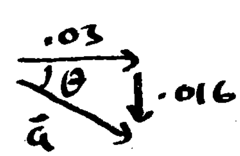
x eqn $(300\ kg)\, a_x = 10 \cos 10$ Newtons

$a_x = 0.03\ m/s^2$

y eqn $(300 kg)\, a_y = 12 - 15 - 10 \sin 10$

$a_y = -0.016\ m/s^2$

$|\vec{a}| = \sqrt{a_x^2 + a_y^2} = 0.034\ m/s^2$

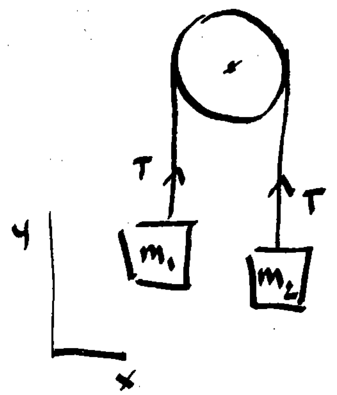


$\tan\theta = \frac{.016}{.03}$

$\theta = 28°$

Newton's laws

Example 3



$m_1 = 6$ kg

$M_2 = 10$ kg

Pulley is frictionless

What is acceleration of the system?
What is the tension on the rope?

MASS 1

$\Sigma F_x = 0$

$a_x = 0$

$\Sigma F_y = T - m_1 g = m_1 a_y$

MASS 2

$\Sigma F_x = 0$

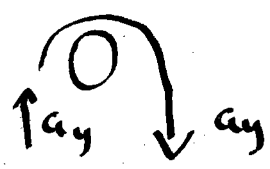
$a_x = 0$

$\Sigma F_y = T - M_2 g = M_2 a_y$

but <u>Need</u> <u>consistency</u>

a_y is related in two cases

T is related in two cases



MASS 1

a_y + ↑

T + ↑

MASS 2

a_y + ↓

F + ↓

$T - M_1 g = M_1 a_y$

$-T + M_2 g = M_2 a_y$

Mass 1

$$T = m_1 a_y + m_1 g = m_1 (a_y + g)$$

Mass 2

$$T = m_2 (g - a_y)$$

$\therefore$

$$m_1 (a_y + g) = m_2 (g - a_y)$$

$$m_1 a_y + m_1 g = m_2 g - m_2 a_y$$

$$a_y (m_1 + m_2) = g (m_2 - m_1)$$

$$a_y = \frac{g (m_2 - m_1)}{(m_1 + m_2)} = \frac{9.8\ \text{m/s}^2 (4\ \text{kg})}{16\ \text{kg}} = 2.45\ \text{m/s}^2$$

What is T ?

$$T = m_1 (a_y + g) = \cancel{\text{kg}}\ 6\ \text{kg} (2.45\ \text{m/s}^2 + 9.8\ \text{m/s}^2)$$

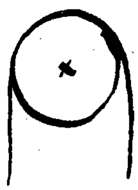
$$= 73.5\ \text{N}\ !$$

This used eqn from Mass I

Same as that for mass 2 ?

$$T = m_2 (g - a_y) = 10\ \text{kg} (9.8\ \text{m/s}^2 - 2.45\ \text{m/s}^2)$$

$$= 73.5\ \text{N}\ !$$



~ string just transfers force if pulley is frictionless

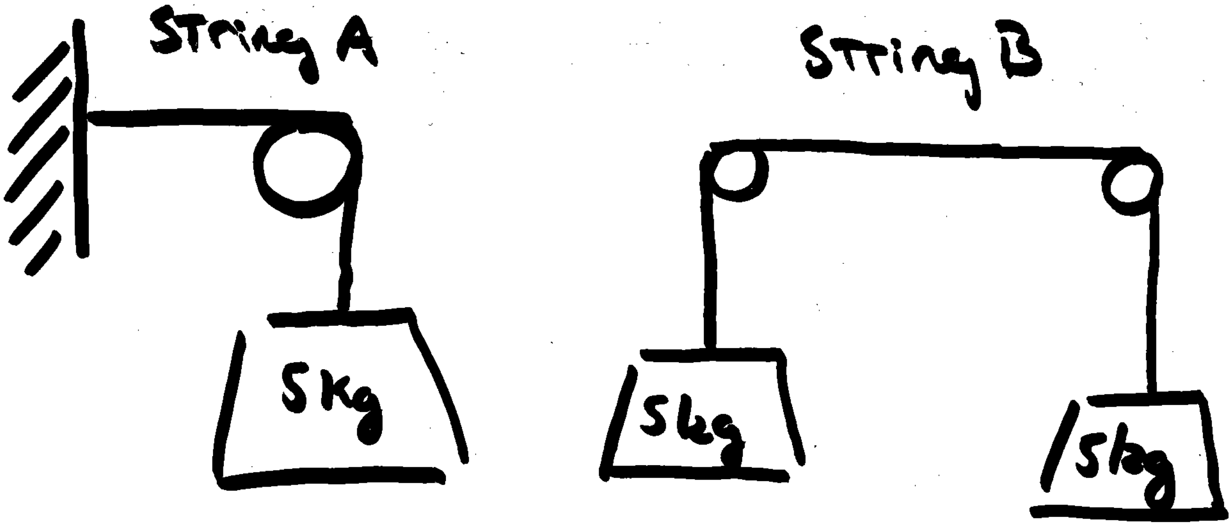
Limiting cases: if $m_1 = m_2$ $a_y = 0$ ✓

$m_2 \gg m_1$ a_y big + positive

$m_2 \ll m_1$ a_y big + negative

✓

Two identical Strings are used to Support Weight(s)



Which String is More likely to Break?

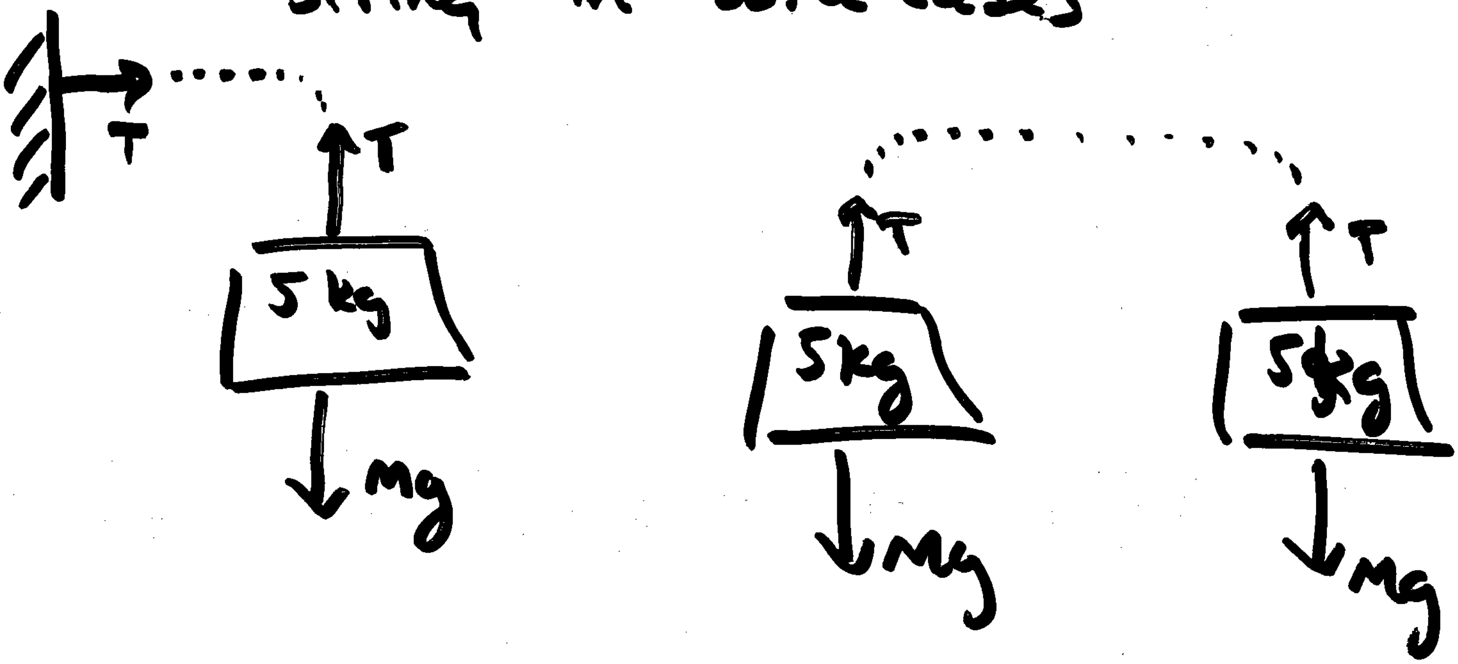
① String A

② String B

③ Both have equal probability of Breaking.

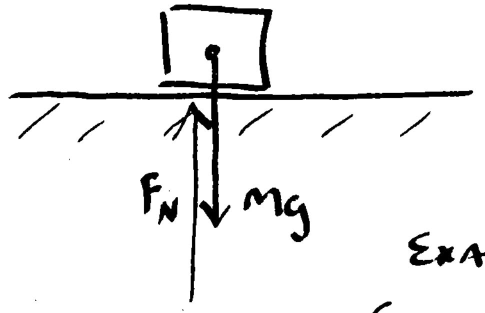
⇒ 3 Both have equal probability of Breaking

The tension is the same in the string in both cases



Earth exerts a grav. force on you downward right ?

What keeps you from falling thru the floor ?



$F_N \equiv$ Normal Force

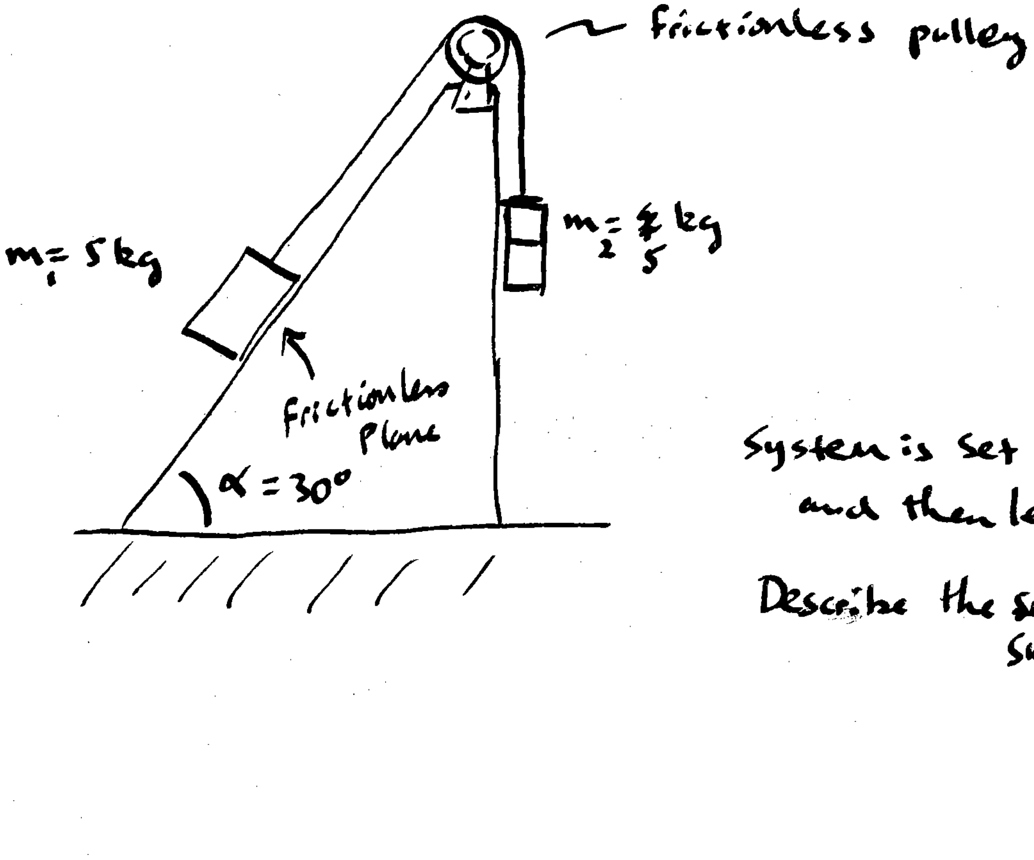
Example of a Contact force

force is exerted normal to the surface making contact

due to "Material integrity"

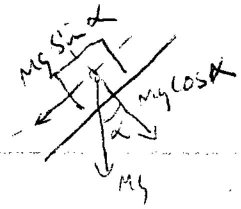
comes out of Newton's 3rd law "Action - reaction"

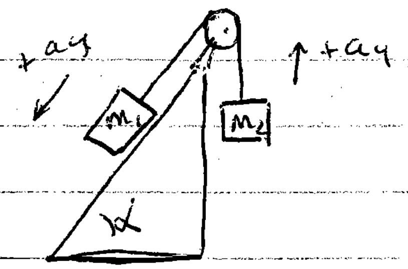
Newton's Laws Example 4



System is set in place and then let go.

Describe the ~~subsequent~~ subsequent Motion





I $\quad N - m_1 g\cos\alpha = 0$

II $\quad T - m_2 g = m_2 a_y$

III $\quad m_1 g\sin\alpha - T = m_1 a_y$

I $\rightarrow \quad N = m_1 g\cos\alpha = (5\text{ kg})(9.8\text{ m/s}^2)\cos 30 = 42.4\text{ N}$

II $\rightarrow \quad T = m_2 a_y + m_2 g$

sub in III

$$m_1 g\sin\alpha - m_2 a_y - m_2 g = m_1 a_y$$

$$m_1 g\sin\alpha - m_2 g = a_y (m_1 + m_2)$$

$$\boxed{\frac{m_1 g\sin\alpha - m_2 g}{m_1 + m_2} = a_y}$$

units ok

Big $M_2 \rightarrow a_y$ is neg

Big $M_1 \rightarrow a_y$ is +

$\alpha = 90 \rightarrow a_y = \frac{M_1 - M_2}{M_1 + M_2}$

solve for T

$$T = m_2 g + \frac{m_2 m_1 g\sin\alpha - m_2^2 g}{m_1 + m_2}$$

$$T = \frac{m_1 m_2 g + \cancel{m_2^2 g} + m_1 m_2 g\sin\alpha - \cancel{m_2^2 g}}{m_1 + m_2}$$

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