

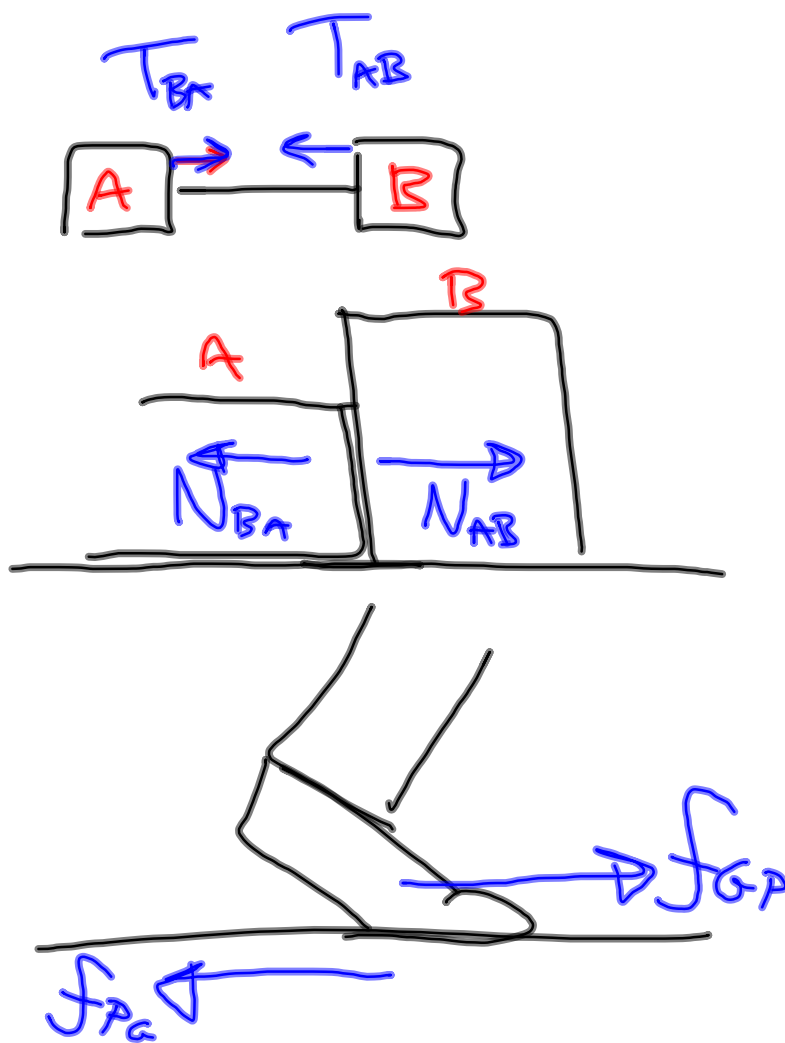
## **Newton's Laws - 2-Body Problems**

**1. Pairs: Frictions, Normals & Tensions**

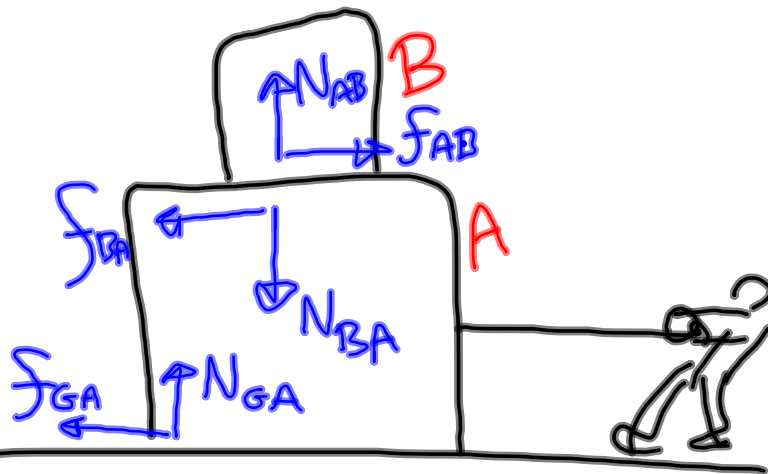
**2. Friction - which Normal??**

**3. Sample Problems**

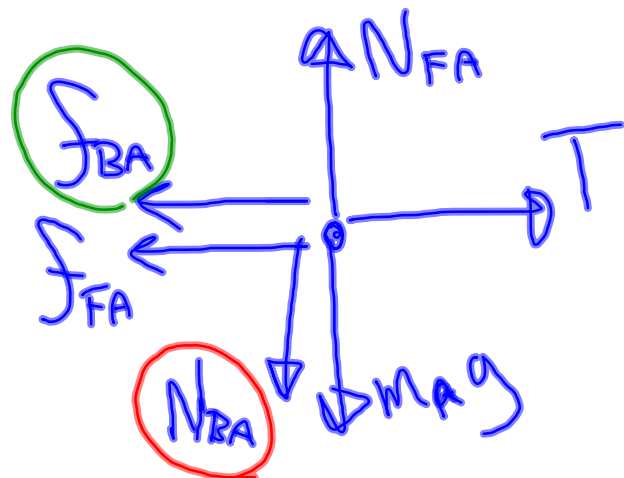
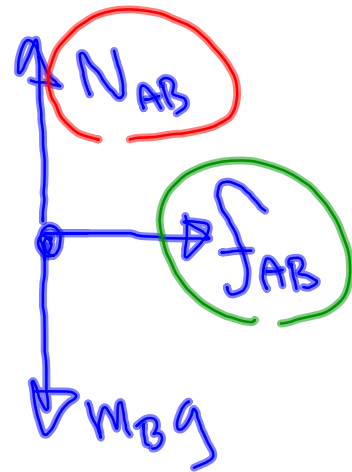
# 1. Pairs: Frictions, Normals & Tensions



## 2. Friction - which Normal??



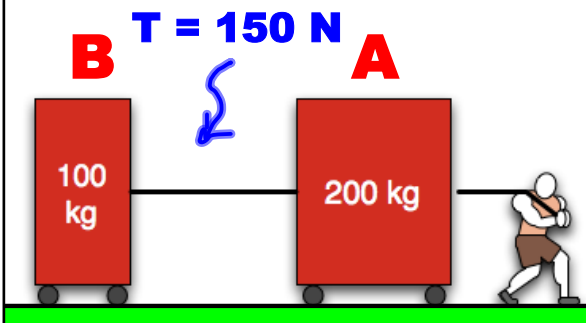
---  $\rightarrow$  sliding



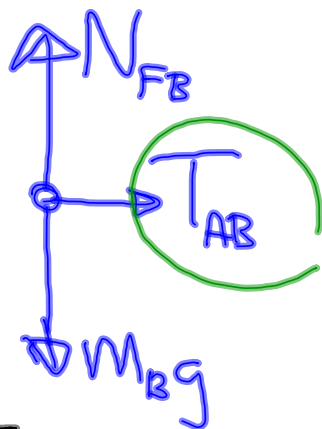
### **3. Sample Problems**

- a. horizontal, roped objects
- b. flat surface, hanging mass
- c. incline, hanging mass
- d. blocks on top of one another

## a. horizontal, roped objects



Find the acceleration of A and B, as well as the Tension in the rope between the person and A. (Ignore friction for A and B.)

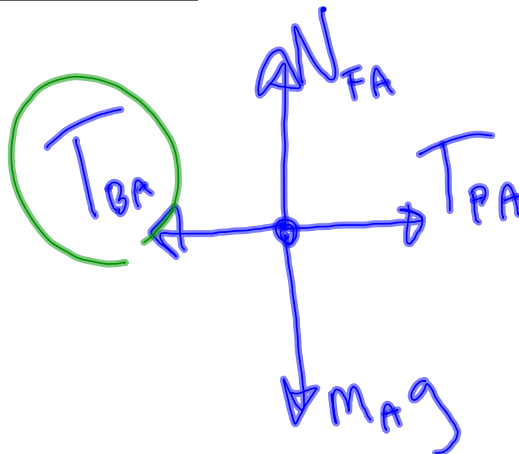


$$\sum_i F = ma$$

$$T_{AB} = m_B a$$

$$150 = 100a$$

$$1.5 \text{ m/s}^2 = a$$



$$\sum_i F = ma$$

$$T_{PA} - T_{BA} = m_B a$$

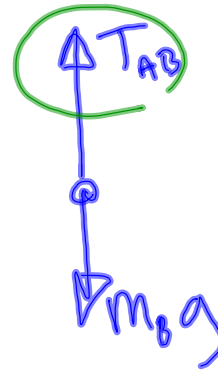
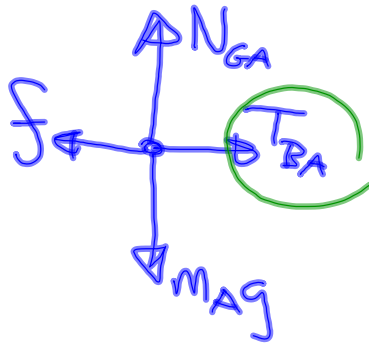
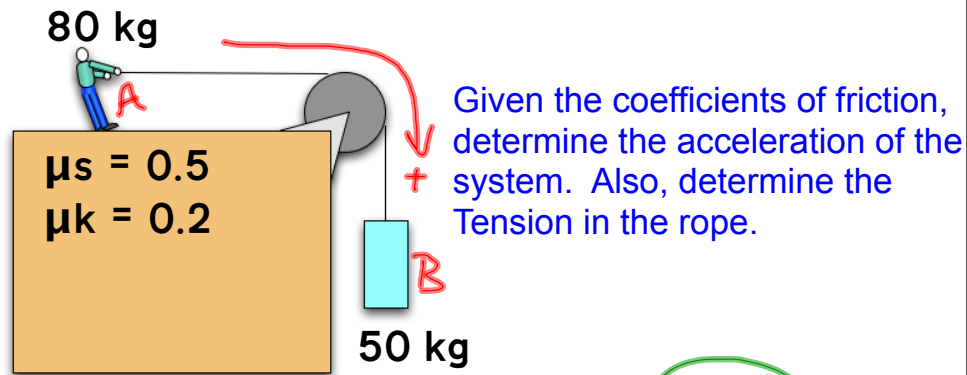
$$T_{PA} - 150 = 200a$$

$$T_{PA} - 150 = 200(1.5)$$

$$T_{PA} - 150 = 300$$

$$T_{PA} = 450 \text{ N}$$

## b. flat surface, hanging mass

**FRICITION TEST**

We must first determine whether static friction or kinetic friction is acting.

If static friction is acting, the entire system is at rest.

If the system is at rest, then the Tension is equal to  $m_B g$ , which is  $(50 \text{ kg})(10 \text{ m/s}^2) = 500 \text{ N}$

That same Tension is also acting on the person. If the person is at rest, then the person's static friction must equal the Tension

The person's max static friction is

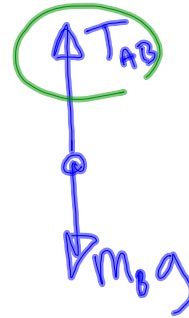
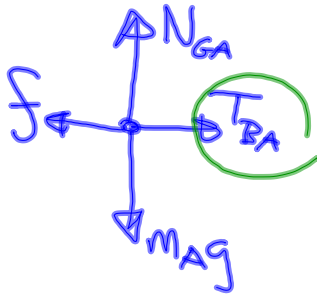
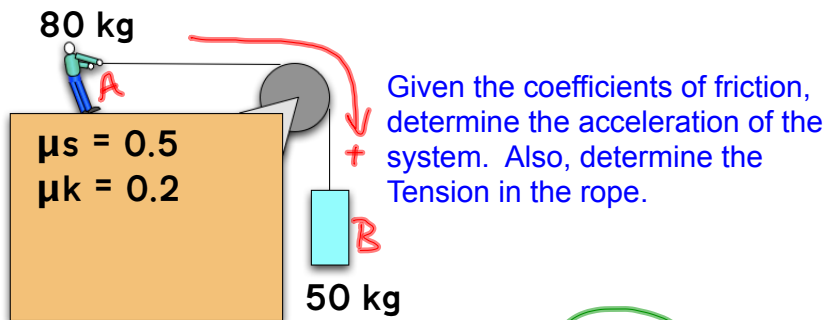
$$\begin{aligned} f_s &= \mu_s N \\ &= (0.5)(80 \text{ kg})(10 \text{ m/s}^2) \\ &= 400 \text{ N} \end{aligned}$$

(note that the person's Normal Force is equal to  $m_A g$ )

The max static friction is not enough to hold the person at rest

**Therefore, the person is sliding. Switch to kinetic friction**

## b. flat surface, hanging mass



$$\sum_i F_y = 0$$

$$N_{GA} - m_A g = 0$$

$$N_{GA} = m_A g$$

$$= (80)(10)$$

$$= 800 \text{ N}$$

$$\sum_i F_x = m a$$

$$T_{BA} - f_k = m_A a$$

$$T_{BA} - \mu_k N_{GA} = m_A a$$

$$T_{BA} - (0.2)(800) = 80 a$$

$$T_{BA} - 160 = 80 a$$

$$T_{BA} = 80 a + 160$$

$$= 80(2.9) + 160$$

$$= 392 \text{ N}$$

$$\sum_i F_y = -m a$$

$$m_B g - T_{AB} = m_B a$$

$$(50)(10) - T_{AB} = 50 a$$

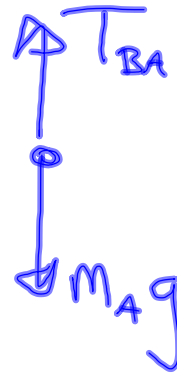
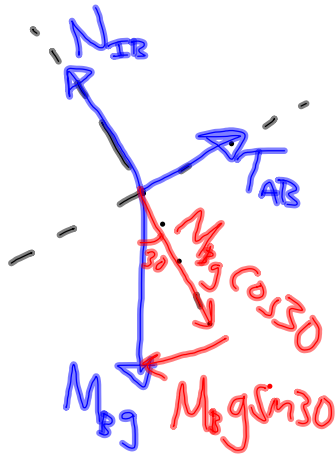
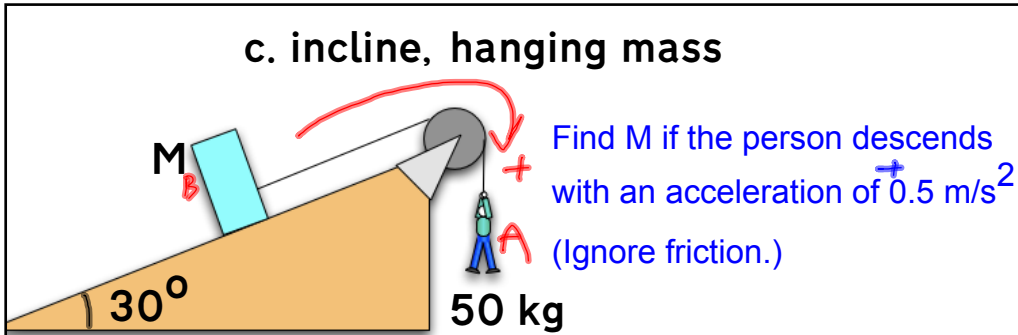
$$500 - T_{AB} = 50 a$$

$$500 - (80 a + 160) = 50 a$$

$$340 = 130 a$$

$$2.9 \text{ m/s}^2 = a$$

## c. incline, hanging mass



$$T_{AB} - M_B g \sin 30 = M_B a$$

$$T_{AB} - 5M_B = M_B(0.5)$$

$$T_{AB} = 5.5M_B$$

$$\sum F = ma$$

$$M_A g - T_{BA} = M_A a$$

$$(50)(10) - T_{BA} = 50(0.5)$$

$$500 - T_{BA} = 25$$

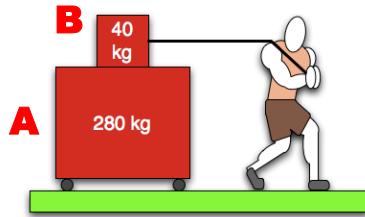
$$500 - 5.5M_B = 25$$

$$-5.5M_B = -475$$

$$M_B = \frac{475}{5.5}$$

$$M_B = 86 \text{ kg}$$

## d. blocks on top of one another



Between B and A:

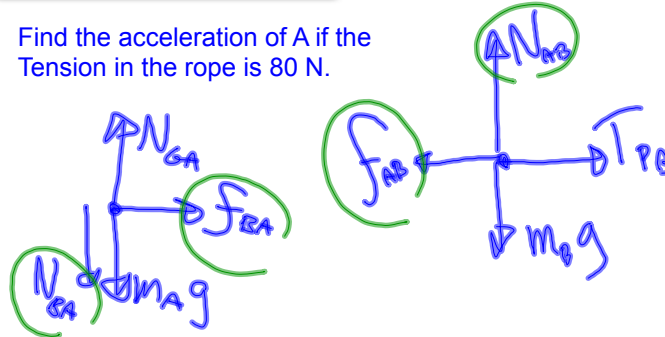
$\mu_s = 0.15$

$\mu_k = 0.1$

Between A and ground:

$\mu = 0$

Find the acceleration of A if the Tension in the rope is 80 N.

**FRICION TEST**

Determine whether static friction or kinetic friction is acting between A and B

If static friction is acting, block A and B move together as one object.

If they move as one object, we can determine the acceleration of the system by using the shortcut: the sum of the external forces equals the total mass of the system times the acceleration of the system

$$\begin{aligned}\Sigma F_{\text{ext}} &= M_{\text{total}} a_{\text{system}} \\ 80 \text{ N} &= (280 \text{ kg} + 40 \text{ kg}) a \\ 80 &= 320a \\ 0.25 \text{ m/s}^2 &= a\end{aligned}$$

The only force that could give B that acceleration would be static friction from A. Would the max static friction from A be enough?

$f_s$	?	$m_A a$
$\mu_s N_{AB}$	<	$(280)(0.25)$
$\mu_s m_B g$	>	70 N

note that the friction is due to the Normal Force between A and B, which is equal to the weight of B.

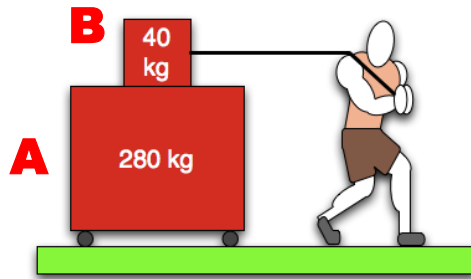
$(0.15)(40)(10)$

60 N

That's less than the 70 N required.

**That means that A slides over B and kinetic friction is acting**

## d. blocks on top of one another



Between B and A:

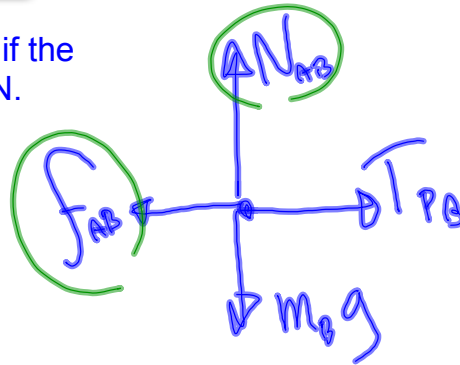
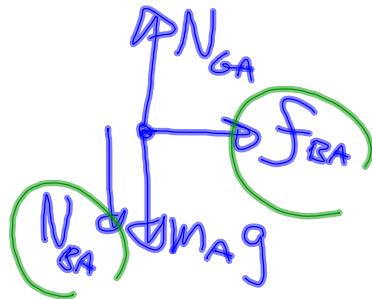
$$\mu_s = 0.15$$

$$\mu_k = 0.1$$

Between A and ground:

$$\mu = 0$$

Find the acceleration of A if the Tension in the rope is 80 N.



$$\uparrow \rightarrow \sum F = 0$$

$$N_{AB} = m_B g$$

$$= (40)(10)$$

$$= 400 \text{ N}$$

$$\sum F = m a$$

$$F_{BA} = m_B a$$

$$\mu_k N_{BA} = m_B a$$

$$(0.1)(400) = 280 a$$

$$40 = 280 a$$

$$\frac{40}{280} = a$$

$$0.14 \frac{m}{s^2} = a$$