Newton's Laws II: 2-Body Problems

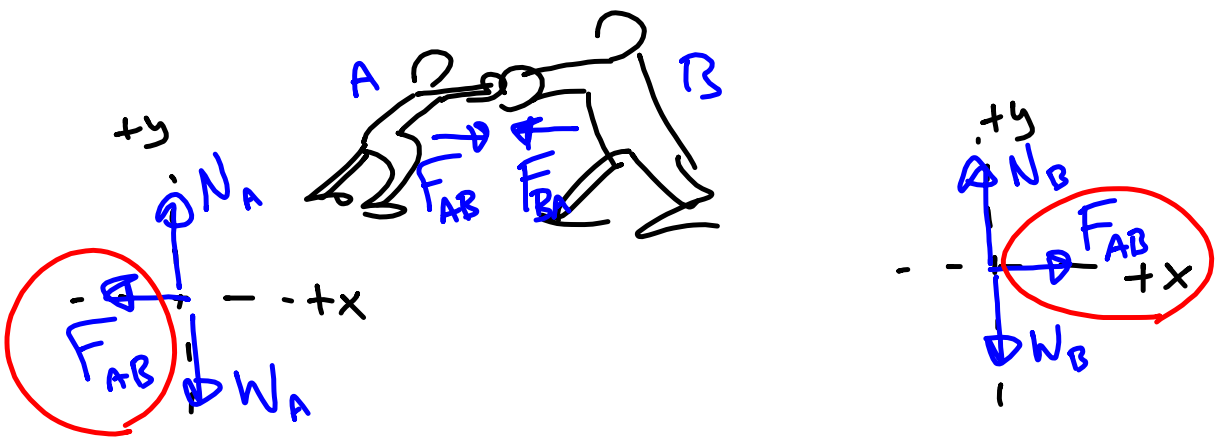
1. Newton's 3rd Law
2. Pairs: Frictions, Normals & Tensions
3. Friction - which Normal??
4. The whole and the parts
5. Sample Problems

1. The Third Law of Motion

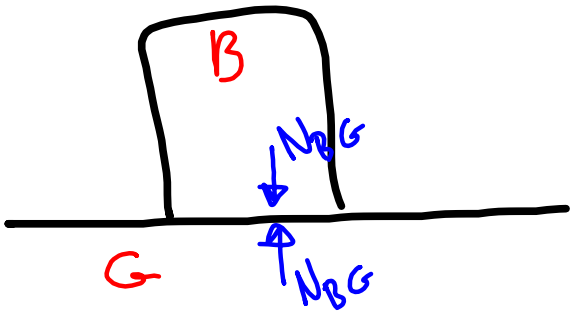
When one object exerts a force on second object, the second exerts an identical force back on the first object in the opposite direction.

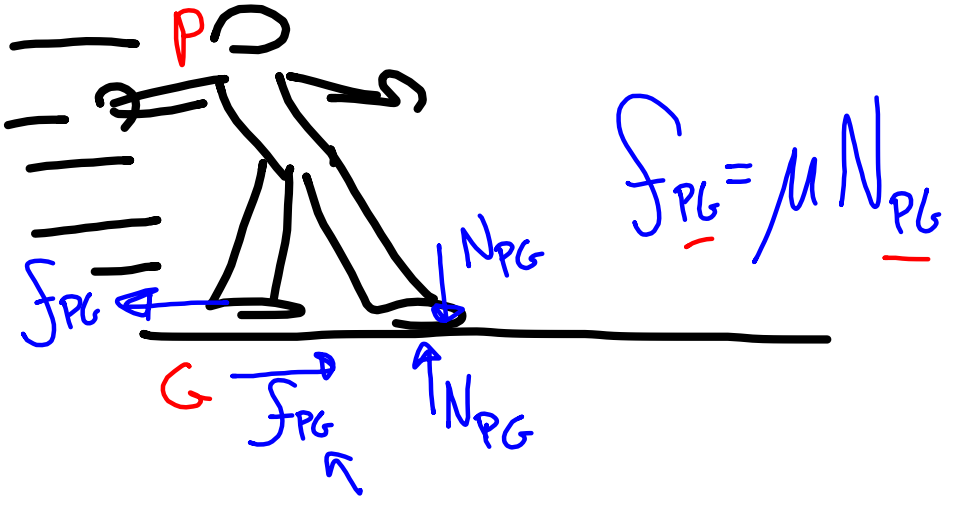
"force pairs"

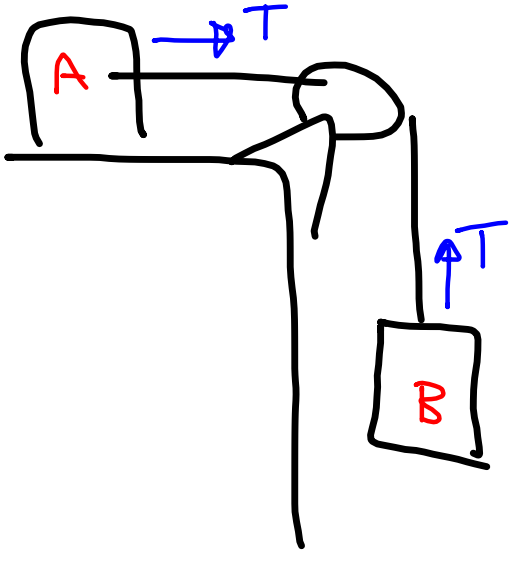
$F_{ab} = -F_{ba}$

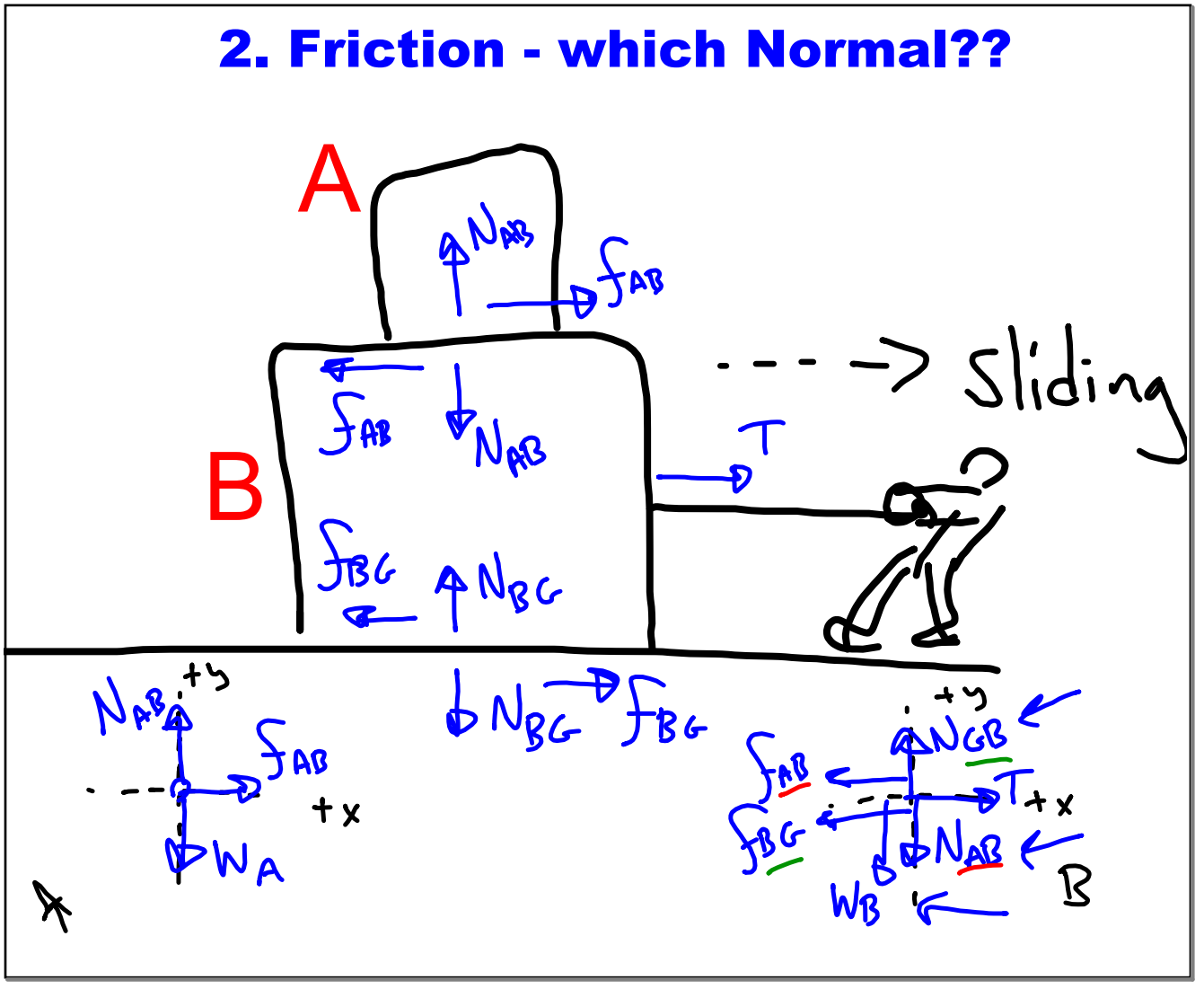


1. Pairs: Frictions, Normals & Tensions

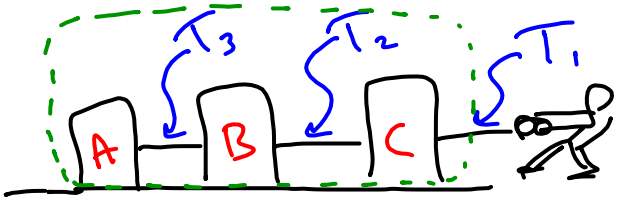






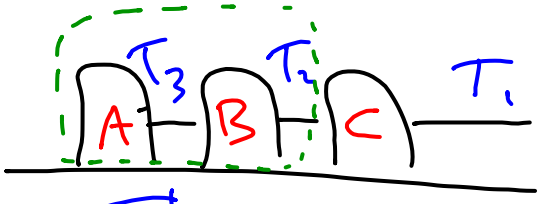

2. Friction - which Normal??
A
B
N_{AB}
f_{AB}
f_{AB}
N_{AB}
T
f_{BG}
N_{BG}
sliding
N_{BG}
f_{BG}
N_{AB}
+y
f_{AB}
+x
W_A
A
N_{GB}
+y
f_{AB}
T
+x
f_{BG}
N_{AB}
W_B
B

3. The Whole and the Parts



$$\sum F_{ext} = m_{system}\, a$$

$$\rightarrow T_1 = (m_A + m_B + m_C)\, a \leftarrow$$

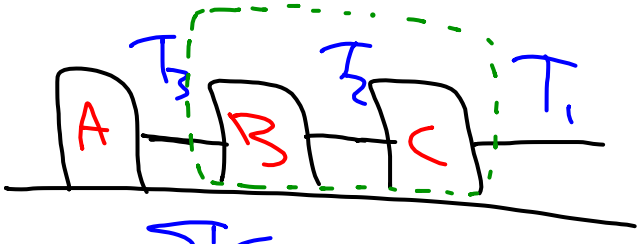


$$\sum F_{ext} = m_{system}\, a$$

$$T_2 = (m_A + m_B)\, a$$

$$\sum F_{ext} = m_{system}\, a$$

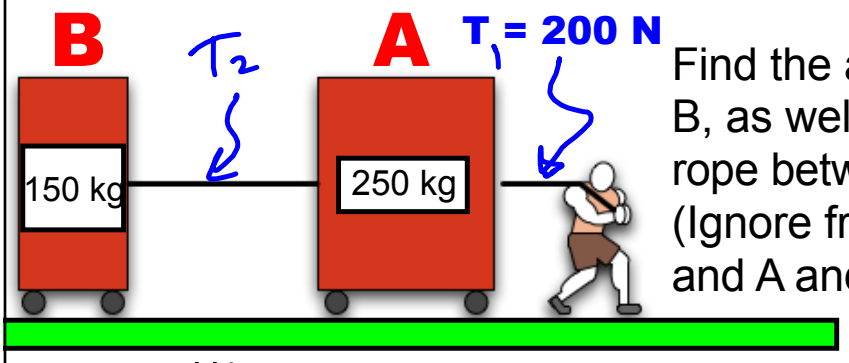
$$T_3 = m_A\, a$$



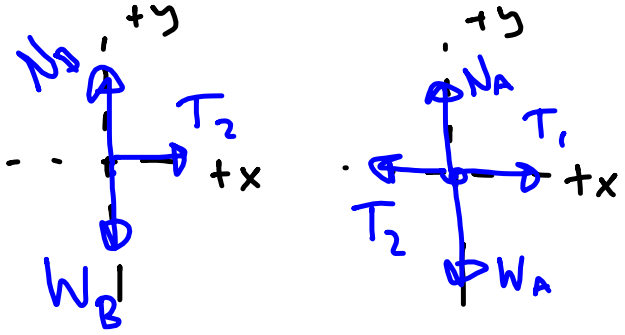
$$\sum F_{ext} = m_{system}\, a$$

$$T_1 - T_3 = (m_B + m_C)\, a$$

a. horizontal, roped objects



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



$\sum F_B = m_B a$ $\sum F_A = m_A a$

$T_2 = m_B a$ $T_1 - T_2 = m_A a$

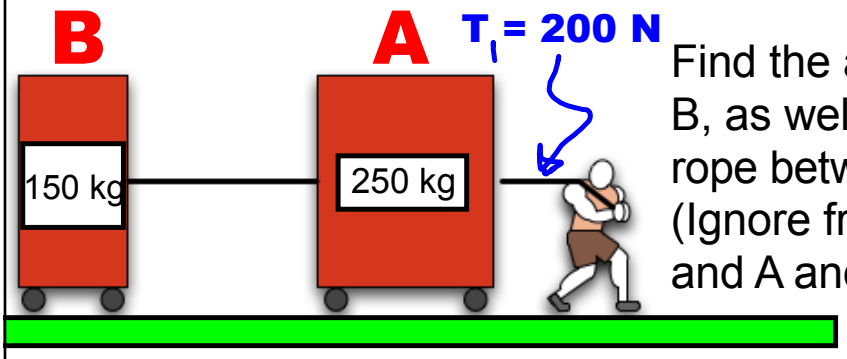
$T_2 = 150a$ $200 - T_2 = 250a$

$T_2 = 150(0.5)$ $200 - 150a = 250a$

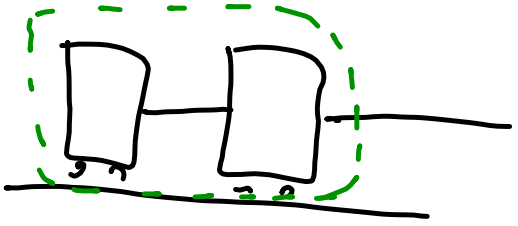
$T_2 = 75\ N$ $200 = 400a$

$0.5 \frac{m}{s^2} = a$

a. horizontal, roped objects (more thinking, less algebra)



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



$$\sum F_{ext} = m_{tot}\, a$$

$$T_1 = (m_A + m_B)\, a$$

$$200 = (150 + 250)\, a$$

$$200 = 400\, a$$

$$0.5 \tfrac{m}{s^2} = a$$

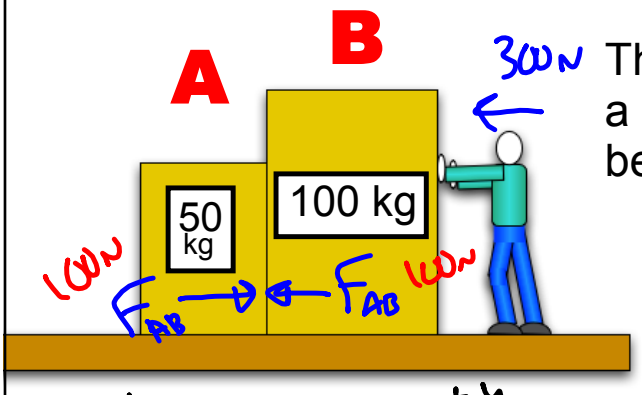
$$\sum F_{ext} = m_{tot}\, a$$

$$T_2 = m_B\, a$$

$$T_2 = (150)\left(0.5 \tfrac{m}{s^2}\right)$$

$$T_2 = 75\ N$$

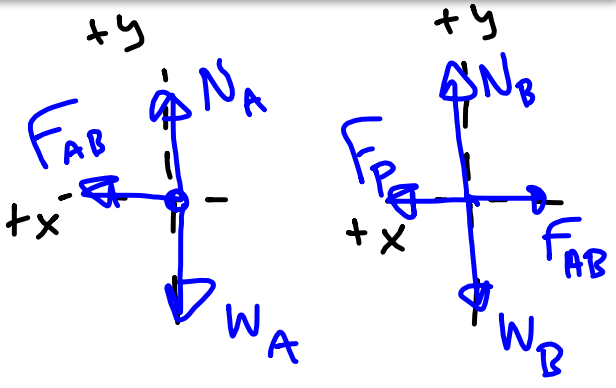
b. Blocks pushed horizontally



The person pushes to the left with a force of 300 N. Ignore friction between the boxes and the ground.

a) What is the acceleration of the boxes?

b) What is the magnitude of the contact force between box A and box B?



$\sum F_A = m_A a$ $\quad$ $\sum F_B = m_B a$

$F_{AB} = m_A a$ $\quad$ $F_P - F_{AB} = m_B a$

$F_{AB} = 50a$ $\quad$ $300 - F_{AB} = 100a$

$F_{AB} = (50)(2)$

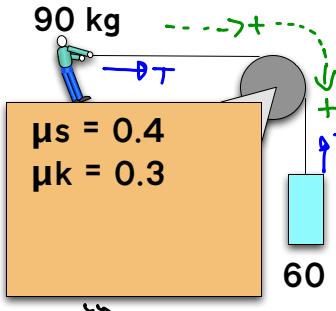
$F_{AB} = 100\,N$

$300 - 50a = 100a$

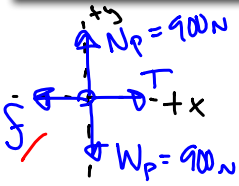
$300 = 150a$

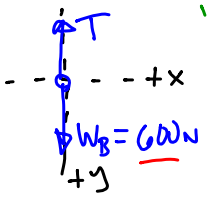
$2\,\frac{m}{s^2} = a$

c. flat surface, hanging mass



Given the coefficients of friction, determine the acceleration of the system. Also, determine the Tension in the rope.





$f_{s(max)} = \mu_s N$

$= (0.4)(90)$

$= 360N$

$T = 360N$

$W_B > T$

$a \neq 0$

$\therefore f_k$

$\sum F_P = m_P a$

$T - f = m_P a$

$T - f_k = 90a$

$\sum F_B = m_B a$

$W_B - T = m_B a$

$60 - T = 60a$

$T - \mu_k N_P = 90a$

$T - (0.3)(90) = 90a$

$T - 270 = 90a$

$T = 90a + 270$

$60 - (90a + 270) = 60a$

$60 - 90a - 270 = 60a$

$330 = 150a$

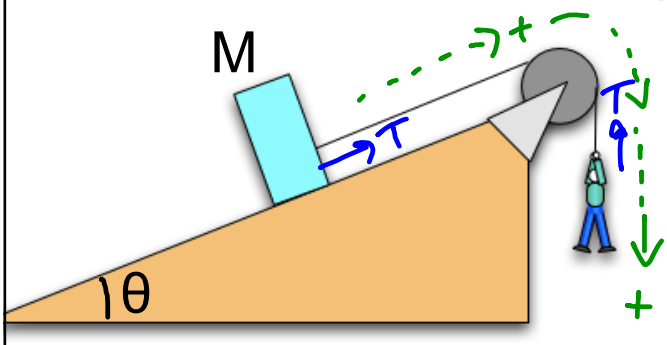
$2.2 \frac{m}{s^2} = a$

$T = 90(2.2) + 270$

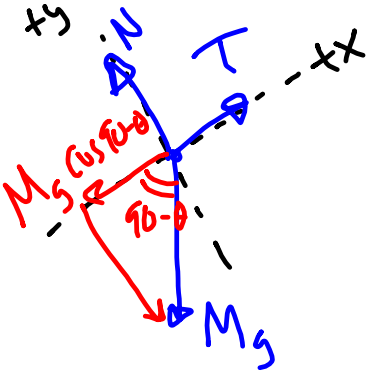
$= 198 + 270$

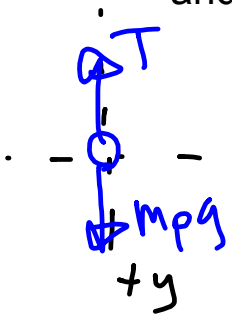
$T = 468N$

d. incline, hanging mass



The person has an acceleration **a** toward the ground. Find the mass of the person in terms of **a**, **M**, **θ**, and fundamental constants. Ignore friction between the box and the incline.





$\sum F_B = m_B a$

$T - M_g \cos(90-\theta) = M a$

$T - M_g \sin\theta = M a$

$T = M a + M_g \sin\theta$

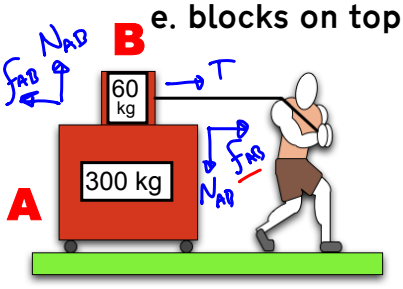
$m_p g - T = m_p a$

$m_p g - m_p a = T$

$m_p = \dfrac{T}{g-a}$

$$m_p = \frac{M a + M_g \sin\theta}{g-a}$$

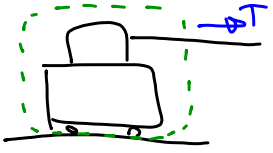
e. blocks on top of one another

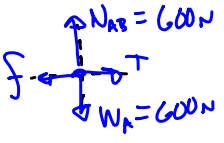


Between B and A:
$\mu_s = 0.2$
$\mu_k = 0.1$

Between A and ground:
$\mu = 0$

Find the acceleration of A if the Tension in the rope is 240 N.





$\sum F_{ext} = m_{total}\, a$

$T = (m_A + m_B)\, a$

$240 = (360)\, a$

$0.67 \frac{m}{s^2} = a$

$\sum F_{ext} = m_A a$

$f_{s_{AB}} = (300)(0.67)$

$f_{s_{AB}} = 200N$

is $f_{s(max)}$ enough?

$f_{s(max)} = \mu_s N$ ← AB

$= (0.2)(600)$

$= 120N$

NOPE! ∴ f_k

$\sum F_{ext} = m_A a$

$f_{AB} = m_A a$

$\mu_k N_{AB} = m_A a$

$(0.1)(600) = 300a$

$60 = 300a$

$0.2 \frac{m}{s^2} = a$