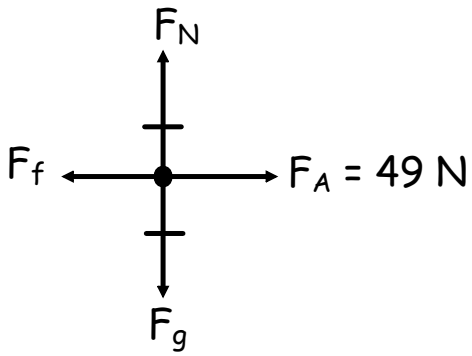
Examples - Newton's Laws and Friction

1. A 10.0 kg box is sitting on a table.
   (A) If a 49 N force is required to overcome friction and start the block moving, calculate the coefficient of static friction.



μ_s = ?

$F_{net\ x} = F_A - F_f$

$0 = F_A - \mu F_N$ But $F_N = F_g$

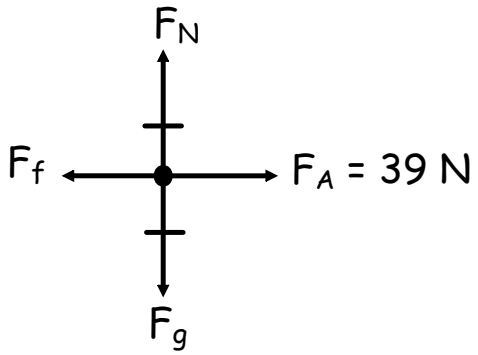
$0 = F_A - \mu mg$

$0 = 49\ N - \mu_s(10\ kg)(9.8\ m/s^2)$

$\mu_s(98\ N) = 49\ N$

$\mu_s = 0.50$

(B) Once the block is moving, it only requires a 39 N force to maintain a constant speed. What is the coefficient of kinetic friction? $F_{net_x} = 0$



$\mu_K = ?$

Fnet x = FA - Ff

$0 = F_A - \mu F_N$ But $F_N = F_g$

$0 = F_A - \mu mg$

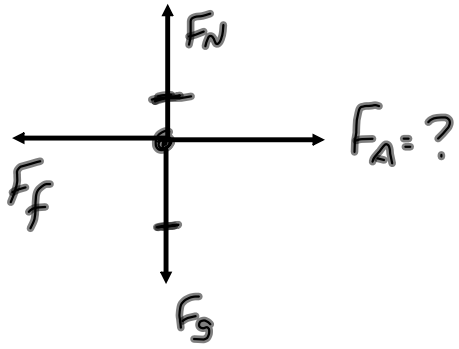
$0 = 39\ N - \mu(10\ kg)(9.8\ m/s^2)$

$\mu(98\ N) = 39\ N$

$\mu_K = 0.40$

2. A 110 kg crate is moving on a surface with a coefficient of kinetic friction of 0.600.

(A) What force is necessary to maintain a constant speed?



$\mu_K = 0.60$

$F_{Netx} = F_A - F_f$

$0 = F_A - \mu F_N \qquad F_N = F_g$

$0 = F_A - \mu mg$

$0 = F_A - (0.6)(110kg)(9.8m/s^2)$

$650N = F_A$

(B) What force is necessary to produce an acceleration of 1.5 m/s^2?

Same FBD

$F_{Netx} = F_A - F_f$

$ma = F_A - \mu mg$

$(110kg)(1.5m/s^2) = F_A - (0.6)(110kg)(9.8m/s^2)$

$810N = F_A$

NOTE: If an object is on a horizontal surface and the only forces acting in the y - direction is F_N and F_g then

$$F_N = F_g = mg$$

Therefore, $F_f = \mu F_N = \mu mg$

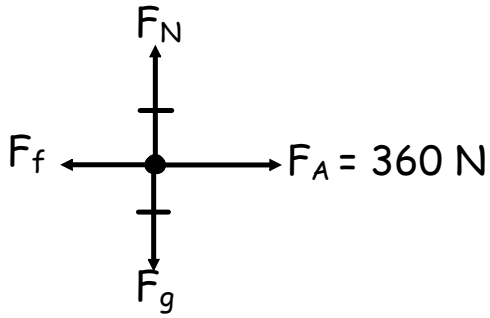
HOWEVER, if there are other forces acting in the y-direction (other than F_N and F_g) , then

if

$F_N \neq F_g$ **and**

$F_f \neq \mu mg$

3. An applied force of 360 N accelerates a 75 kg object across the floor at a rate of 2.5 m/s^2. Find the coefficient of kinetic friction.



$a = 2.5\ m/s^2$

$\mu_K = ?$

Fnet = $F_A - F_f$

$ma = F_A - \mu F_N$ But $F_N = F_g$

$\therefore\ ma = F_A - \mu mg$

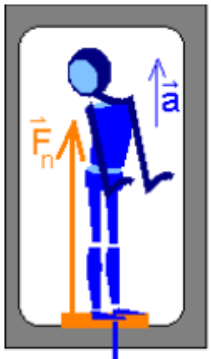
✓ $(75\ kg)(2.5\ m/s^2) = 360\ N - \mu(75\ kg)(9.8\ m/s^2)$

$187.5\ N = 360\ N - \mu(735\ N)$

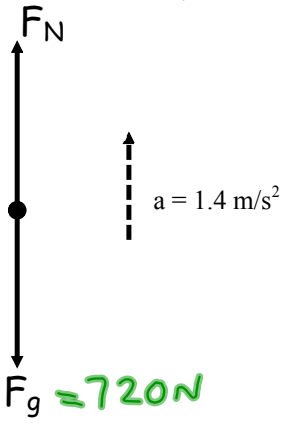
✓ $-172.5\ N = -\mu(735\ N)$

$0.23 = \mu$

4. If your bathroom scale indicates that your weight is 720 N, (F_g) what will be the reading on the scales if you stand on it in an elevator that briefly accelerates upward at 1.4 m/s^2?



F_n = ?



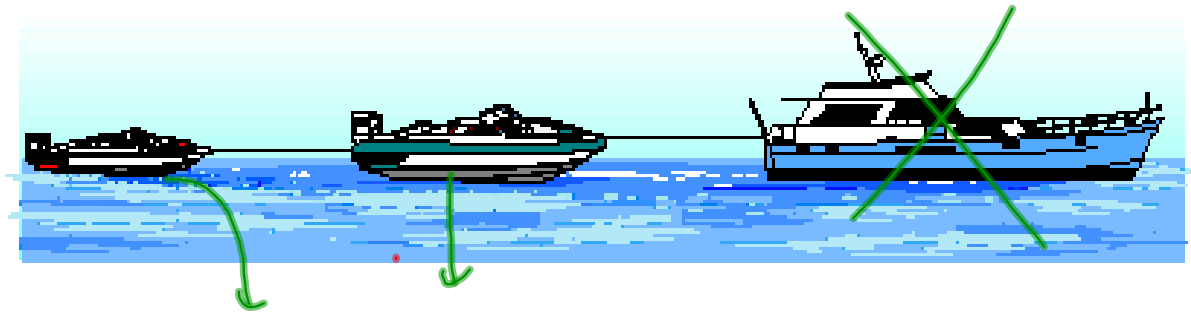
Let up be the positive direction of motion.

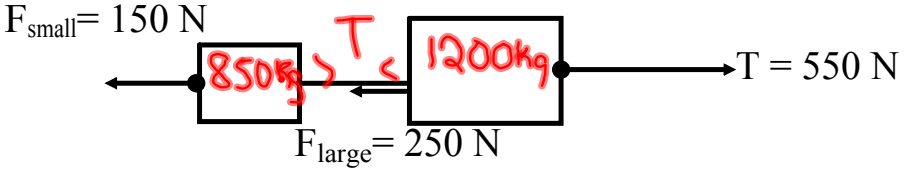
$F_g = mg$
$720\ N = m(9.8\ m/s^2)$
$73\ kg = m$

F_N - reading on the bathroom scales.

$F_{Net\ y} = F_N - F_g$
$ma = F_N - F_g$
$(73\ kg)(1.4\ m/s^2) = F_N - 720\ N$
$102.2\ N = F_N - 720\ N$
$820\ N = F_N$

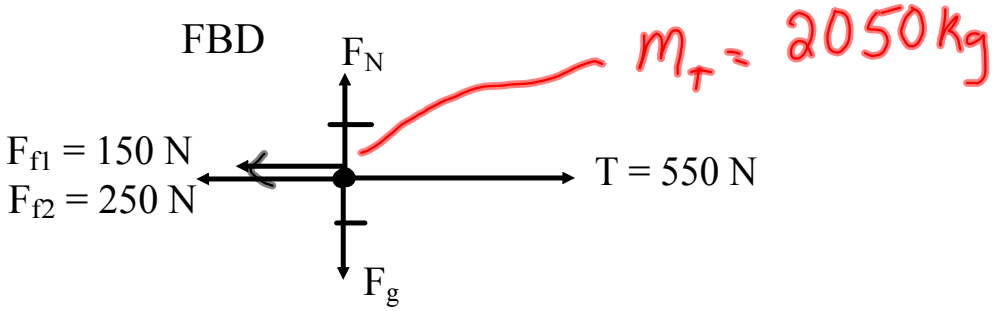
4. A yacht is towing 2 speed boats that have broken down. The mass of the larger boat is 1200 kg, while the smaller one has a mass of 850 kg. The tension in the cable to the first speed boat is 550 N. The opposing forces are 250 N on the larger speed boat and 150 N on the smaller one.
(A) What is the acceleration of the boats?





To find the acceleration of the boats, you must consider the two boats as one object.

FBD



$F_{net\ x} = T - F_{f1} - F_{f2}$
$m_t a = T - F_{f1} - F_{f2}$
(2050 kg)a = 550 N - 250 N - 150 N
(2050 kg) a = 150 N
$a = 0.073\ m/s^2$

(B) How long will it take the yacht to reach a speed of 12 km/h?

$v_1 = 0$
$v_2 = 12$ km/h = 3.33 m/s
$a = 0.073$ m/s^2
$t = ?$

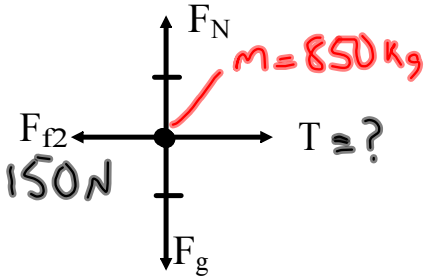
$$t = \frac{v_2 - v_1}{a}$$

$$t = \frac{3.33 m/s - 0}{0.073 m/s^2}$$

$$t = 46 s$$

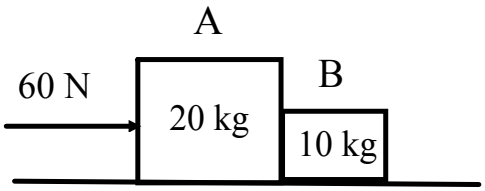
(C) What is the tension in the cable between the two speed boats?

To find the tension between the two speed boats, draw a FBD for the last or smallest boat.



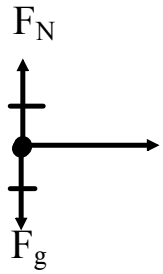
$F_{net} = T - F_{f2}$
$ma = T - F_{f2}$
$(850 \text{ kg})(0.073 \text{ m/s}^2) = T - 150 \text{ N}$
$62.05 \text{ N} = T - 150 \text{ N}$
$212.5 \text{ N} = T$
$210 \text{ N} = T$

6. A 60.0 N force acts on a combination of 2 boxes that are next to each other on a frictionless surface. Find the force of B on A.



F_{AB}

To find the force of A on B, we need to find the acceleration of the blocks. To do this we consider the two blocks as one object.



$m_T = 30kg$

$F_{Net} = F_A$

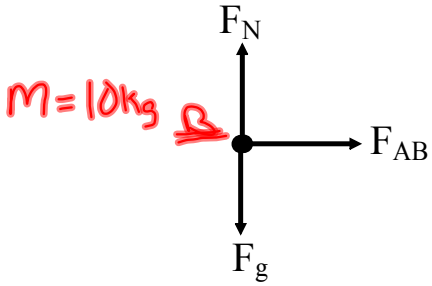
$m_T a = F_A$

$$a = \frac{F_{Net}}{m_t}$$

$$a = \frac{60N}{30kg}$$

$$a = 2m/s^2$$

To find the force of B on A (F_{BA}), you need to draw the FBD for A. But the FBD for object A has two forces: F_{BA} and $F_{Applied}$. It is easier to draw the FBD for block B and find the force of A on B (F_{AB}). Then use Newton's third law to find F_{BA}.

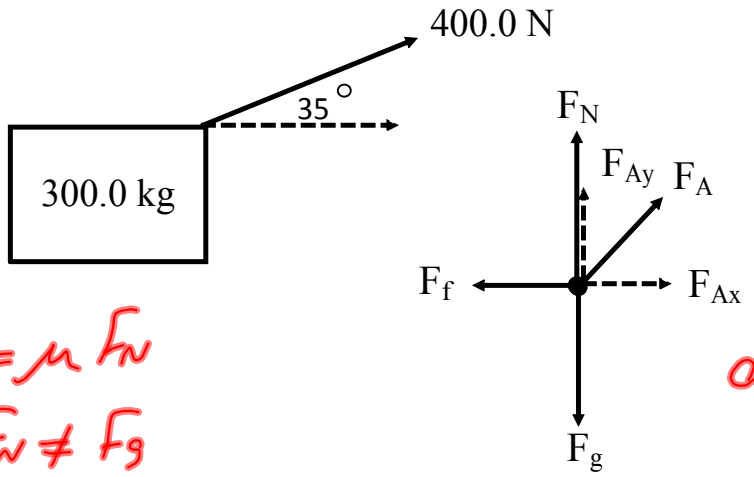


$m = 10kg$ B

$F_{Net} = F_{AB}$
$(m_B)\ a = F_{AB}$
$(10\text{ kg})\ (2\text{ m/s}^2) = F_{AB}$
$20\text{ N} = F_{AB}$

According to Newton's Third Law $F_{AB} = -F_{BA}$
Therefore, $F_{BA} = -20$ N or 20 N [West]

7. A 300.0 kg crate is pulled by a worker who exerts a force of 400.0 N at an angle of 35°with the horizontal. The coefficient of kinetic friction is 0.10. Determine the acceleration of the crate.



DOE

MC - find F_N

$a = ?$

$F_f = \mu F_N$

$F_N \neq F_g$

NOTE: There are other forces besides the normal force and the force of gravity acting in the y-direction. Therefore,

$$F_N \neq F_g$$

$F_{net\,y} = F_N + F_{Ay} - F_g$

$(0 = F_N + F_{Ay} - F_g)$

$0 = F_N + F_A \sin\theta - mg$

$0 = F_N + 400\text{ N} \sin 35 - (300\text{ kg})(9.8\text{ m/s}^2)$

$2710.6\text{ N} = F_N$

$F_{net\,x} = F_{Ax} - F_F$

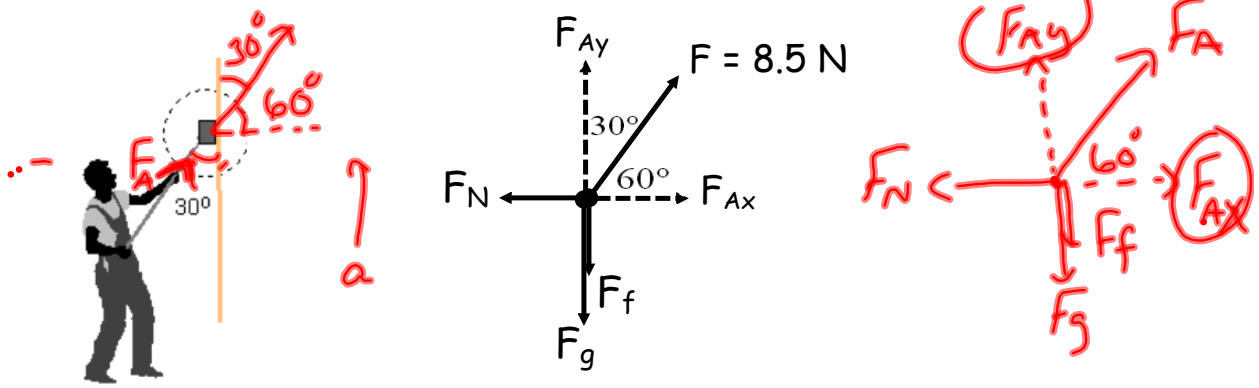
$ma = F_A \cos\theta - \mu F_N$

$(300\text{ kg})\,a = 400\text{ N} \cos 35 - (0.10)(2710.6\text{ N})$

$(300\text{ kg})\,a = 56.6\text{ N}$

$a = 0.19\text{ m/s}^2$

8. A carpenter uses a force of 8.5 N applied along a handle, which is attached to a sanding block, to slide the block up the wall at a constant speed. The angle between the handle and the wall is 30.0° and the mass of the block is 0.50 kg. What must be the coefficient of friction between the block and the wall?



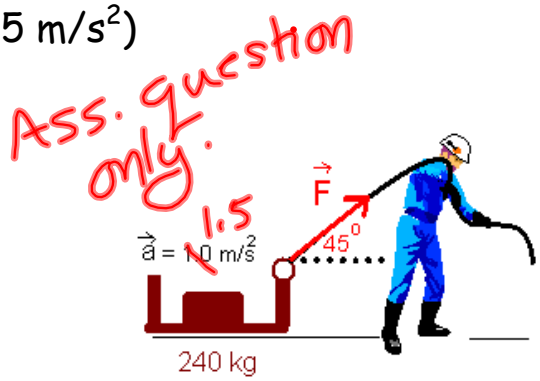
In the x-direction, Fnet = 0 since the sanding block is not moving horizontally. Use this fact to determine the normal force acting on the block.

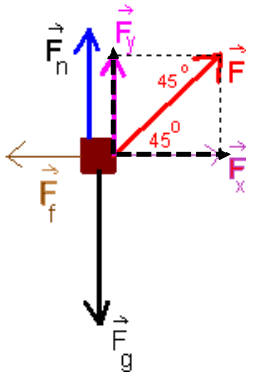
$F_{Net} = F_{Ax} + F_N$
$0 = FA \cos\theta + F_N$
$0 = 8.5\ N \cos 60 + F_N$
$-4.25\ N = F_N$

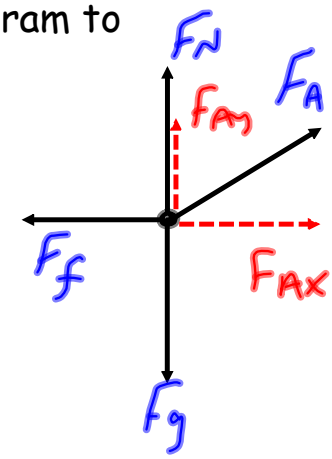
Note the negative sign means that the normal force acts to the left. To calculate the force of friction we do not use the negative sign. We only use the magnitude of the normal force.

$Fnet\ y = F_{Ay} - F_g - F_f$
$0 = FA \sin\theta - mg - \mu F_N$
$0 = 8.5N \sin 60 - (0.50\ kg)(9.8\ m/s^2) - u(4.25)$
$0 = 7.36\ N - 4.9\ N - \mu(4.25\ N)$
$-2.46\ N = -\mu(4.25\ N)$
$\mu = 0.58$

9. An off-shore-oil-worker decides to move a piece of equipment the hard way. The mass of the equipment is 240 kg and the coefficient of kinetic friction is 0.56. What force does he have to apply along the rope so that the piece of equipment will accelerate at 1.5 m/s^2? (change 1.0 m/s^2 in the diagram to 1.5 m/s^2)







$F_{Net\,y} = F_N + F_{Ay} - F_g$

$0 = F_N + F_A \sin\theta - mg$

$0 = F_N + F_A \sin 45 - (240\ kg)(9.8\ m/s^2)$

$0 = F_N + 0.7071F_A - 2352\ N$

$F_N = 2352\ N - 0.7071\ FA$

$F_{Net\,x} = F_{Ax} - F_f$

$ma = F_A \cos\theta - \mu F_N$

$(240\ Kg)\ (1.5\ m/s^2) = F_A \cos 45 - 0.56F_N$

$360\ N = (0.7071)\ F_A - 0.56F_N$

$360\ N = (0.7071)\ F_A - 0.56(2352\ N - 0.7071F_A)$

$360\ N = (0.7071)F_A - 1317.12\ N + 0.3960\ FA$

$1677.12\ N = 1.1031F_A$

$1520\ N = F_A$