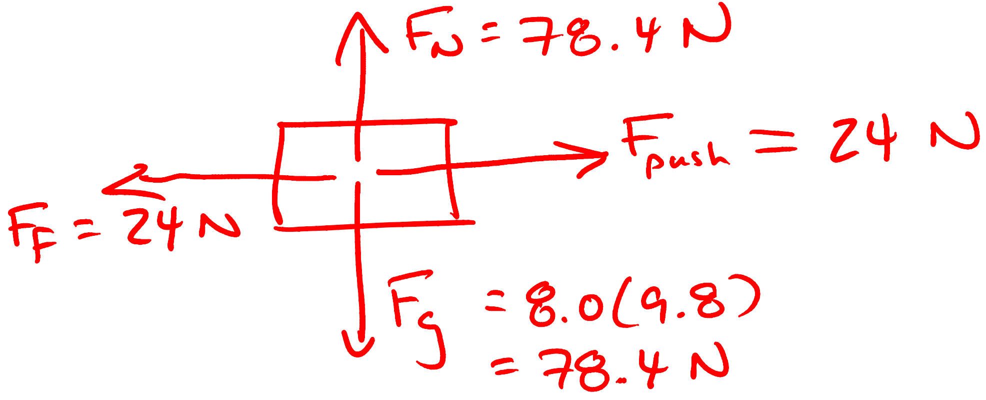
Example #1. **An 8.0 kg mass is pushed along a horizontal surface at constant speed with a force of 24 N.**

- **a) Draw a f.b.d. showing all forces that act on the mass. Include the value for each force drawn.**
- **b) The same 8.0 kg mass is now pushed with a force of 37 N. Find the acceleration of the mass.**

a)



→ all forces cancel out ($F_{Net} = 0$)

b) ignoring vert. forces (no change):

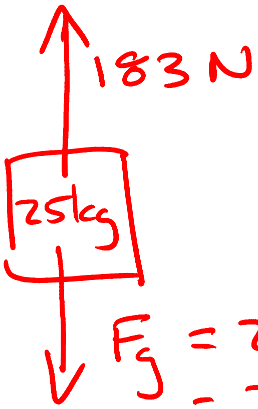
$F_{Net} = 37 - 24 = 13$ N

$F_{Net} = ma$

$13 = 8.0a$

$$\boxed{a = 1.6 \text{ m/s}^2}$$

Example #2. **A 25.0 kg mass is pulled upward vertically by a force of 183 N. Find the acceleration of the mass.**



$F_g = 25(9.8)$

$= 245$ N

F_{net}, a are both down

$F_{net} = 245 - 183$

$= 62$ N down

$F_{net} = ma$

$62 = 25a$

$$\boxed{a = 2.5 m/s^2}$$

Example #3. What is the tension of the cable of an elevator of mass 550 kg that is accelerating upwards at the rate of 4.5 m/s^2?

$\uparrow a = 4.5\ m/s^2 \Rightarrow F_T > F_g$

$F_g = 550(9.8)$
$= 5390\ N$

$F_{Net} = ma$
$= 550(4.5)$
$= 2475\ N$

$\rightarrow F_{Net} = F_T - F_g$

$2475 = F_T - 5390$

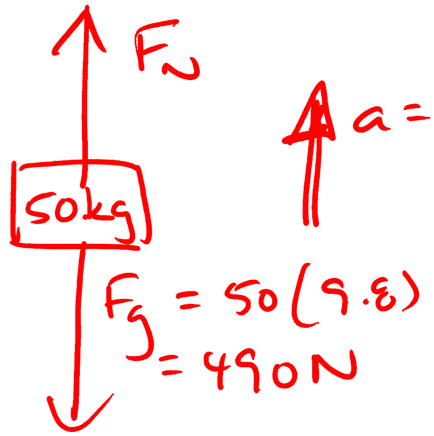
$$\boxed{F_T = 7.9 \times 10^3\ N}$$

Example. #4. A 50.0 kg student is riding an elevator while standing on a bathroom type scale. Find the scale reading when the elevator is:

a) accelerating upwards at 0.50 m/s^2.
b) traveling upwards, but decelerating at 1.0 m/s^2.
c) accelerating downwards at 0.75m/s^2.

$\rightarrow$ scale reading is F_N

a)



$\uparrow a = .50\ m/s^2 \Rightarrow F_{Net} = 50(.50)$
$= 25N$

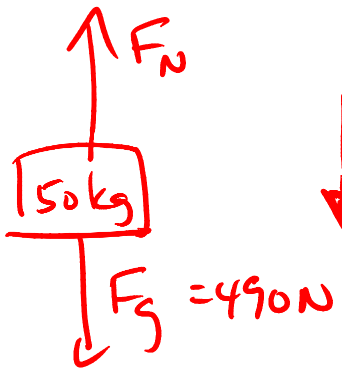
$F_N > F_g$, so

$F_{Net} = F_N - F_g$

$25 = F_N - 490$

$\boxed{F_N = 5.1 \times 10^2 N}$

b)



$\downarrow a = 1.0\ m/s^2 \Rightarrow F_{Net} = 50(1)$
$= 50\ N$ (down)

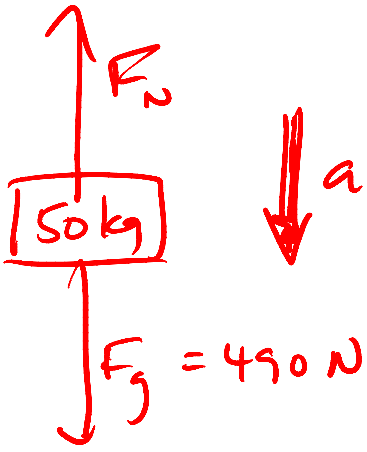
$F_g > F_N$, so

$F_{Net} = F_g - F_N$

$50 = 490 - F_N$

$\boxed{F_N = 4.4 \times 10^2 N}$

c)



$a = .75\,m/s^2 \Rightarrow F_{net} = 50(.75)$

$= 37.5\,N$ (down)

$F_g > F_N$, so

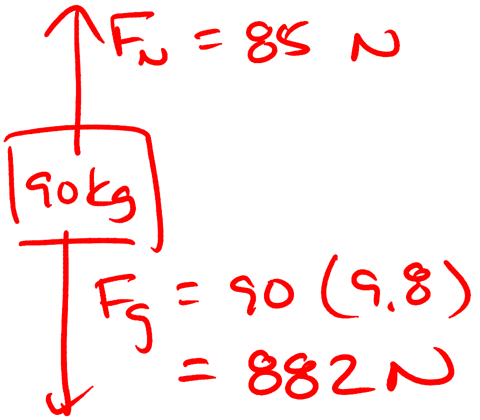
$$F_{net} = F_g - F_N$$

$$37.5 = 490 - F_N$$

$$\boxed{F_N = 4.5 \times 10^2\,N}$$

Example. #5. **A 90 kg person stands on a bathroom type scale in an elevator as it accelerates downwards. If the scale reads 85 N, at what rate is the elevator accelerating?**

→ $F_N = 85\text{ N}$ (scale reading)



$F_N = 85\text{ N}$

$F_g = 90(9.8)$

$= 882\text{N}$

$F_{net} = 882 - 85$

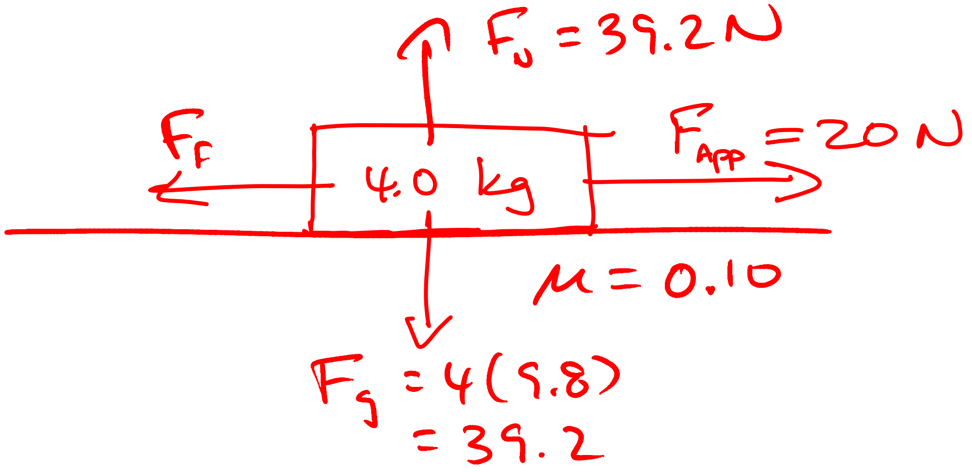
$= 797\text{ N}$

$F_{net} = ma$

$797 = 90a$

$$\boxed{a = 8.9\text{ m/s}^2\ \underline{\text{down}}}$$

Example #6. Find the acceleration of a 4.0 kg mass when a 20 N force is applied and the coefficient of friction between mass and surface is 0.10.



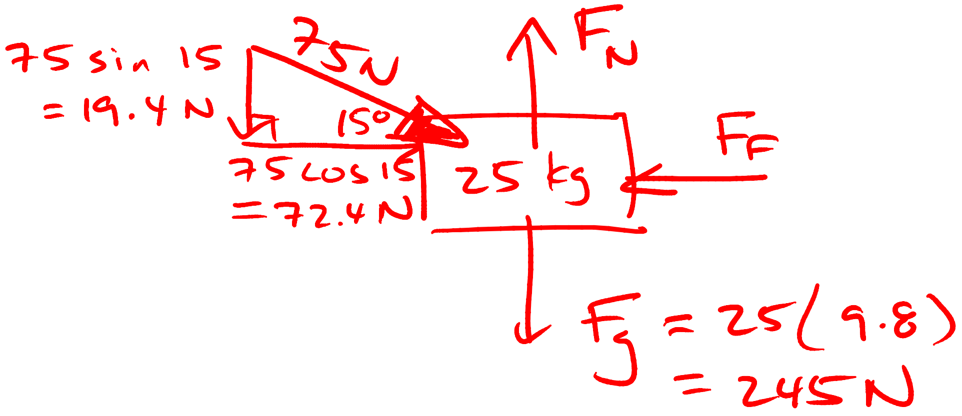
$$F_f = \mu F_N = .10(39.2) = 3.92 N$$

$$F_{Net} = 20 - 3.92 = 16.1 N$$

$$F_{Net} = ma \qquad 16.1 = 4a$$

$$\boxed{a = 4.0 m/s^2}$$

Example #7. A force of 75 N pushes down at an angle of 15° on a mass of 25 kg. If the coefficient of friction is 0.15, find the acceleration.



→ find F_N: $19.4 + 245 = F_N$

$$F_N = 264.4 \text{ N}$$

→ find F_f: $F_f = \mu F_N = .15(264.4)$

$$F_f = 39.66 \text{ N}$$

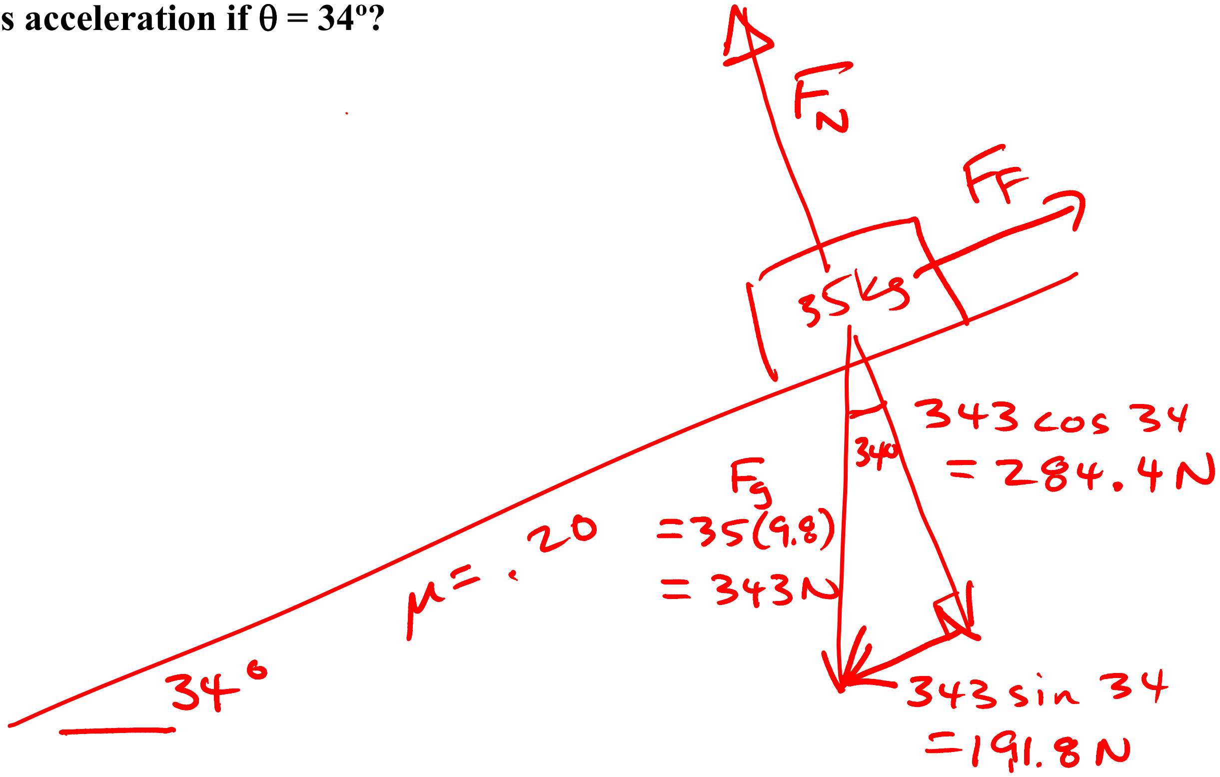
← see diagram

→ $F_{net} = 72.4 - 39.66 = 32.7$

$F_{net} = ma \qquad 32.7 = 25a$

$$\boxed{a = 1.3 \text{ m/s}^2}$$

Example #8. A 35 kg mass is set on a smooth inclined surface of μ=0.20. What is its acceleration if θ = 34°?



→ analyze ⊥ forces to find F_N:

$$F_N = 284.4 \text{ N}$$

→ $F_f = \mu F_N = .20(284.4) = 56.9 \text{ N}$

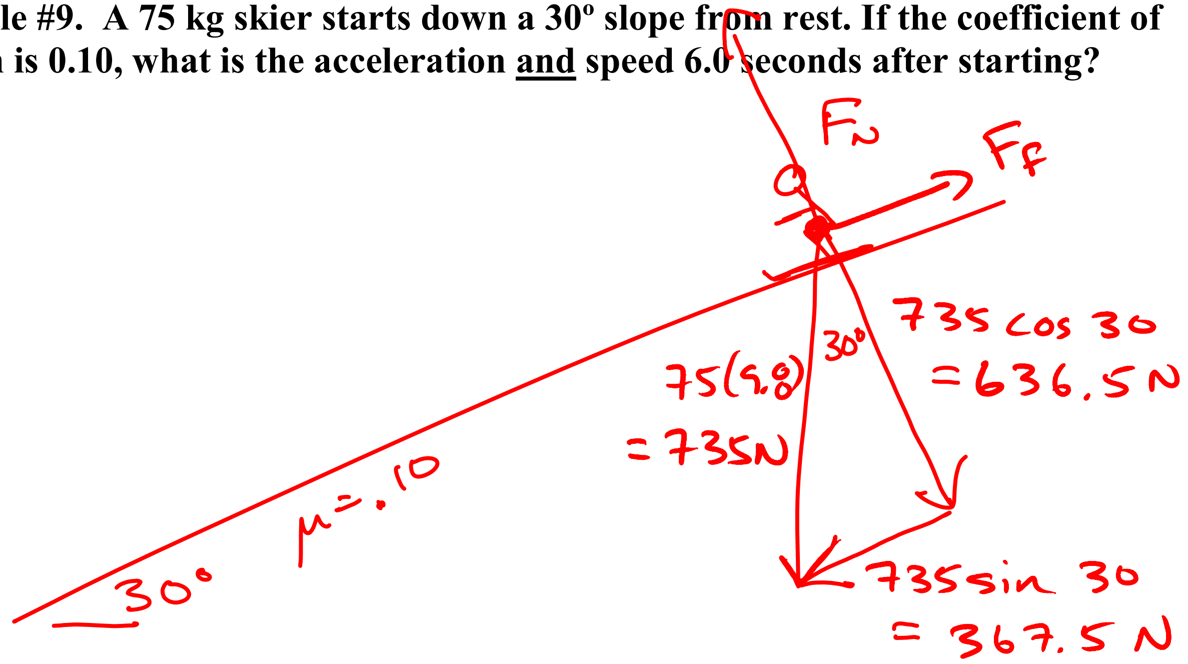
→ analyze // forces to find F_{Net} + a:

$$F_{Net} = 191.8 - 56.9 = 134.9 \text{ N}$$

$$F_{Net} = ma \qquad 134.9 = 35a$$

$$\boxed{a = 3.9 \text{ m/s}^2}$$

Example #9. **A 75 kg skier starts down a 30° slope from rest. If the coefficient of friction is 0.10, what is the acceleration <u>and</u> speed 6.0 seconds after starting?**



→ analyzing ⊥ forces : $F_N = 636.5 N$

→ $F_f = \mu F_N = .10(636.5) = 63.65 N$

→ $F_{Net} = 367.5 - 63.7 = 303.8 N$

→ $F_{Net} = ma \quad 303.8 = 75a$

$$\boxed{a = 4.0 \quad m/s^2} \quad (4.05)$$

$V_0 = 0 \qquad t = 6.0 s.$

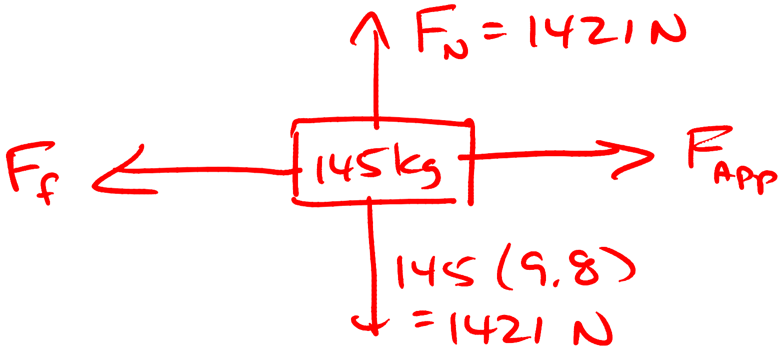
→ $V = V_0 + at = 4.05(6)$

$$\boxed{V = 24 \; m/s}$$

Example #10. **A muscular physics student needs to move a 145 kg crate across the room over a floor where $\mu_s = 0.370$ and $\mu_k = 0.210$.**

a) **What minimum horizontal force is required to *just* start the crate sliding?**

b) **If this force continues to be applied, what will be the rate of acceleration?**



a) $F_{App} = F_{f\,(static)} = \mu_s F_N$

$= .370(1421)$

$F_{App} = 526$ N

b) When moving, $F_f = \mu_k F_N$

$= .210(1421)$

$= 298$ N

$F_{Net} = 526 - 298 = 228$ N

$F_{Net} = ma$

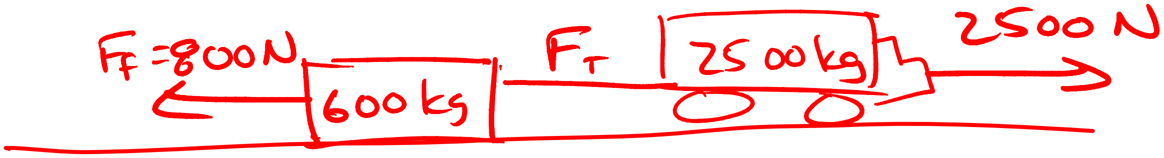
$228 = 145a$

$\boxed{a = 1.57\ m/s^2}$

Example #11. **A Truck pulls a log with a force of 2500 N. The log drags back with a 800 N force of friction. The mass of the truck is 2500 kg, the mass of the log is 600 kg. Find:**

a) the acceleration of the truck & log system.

b) the tension in the rope.



a) f.b.d. of the system:

(vertical forces aren't needed)

$F_{Net} = 2500 - 800 = 1700\ N$

$F_{Net} = m_T a \qquad 1700 = 3100a$

$$\boxed{a = 0.55\ m/s^2}$$

b) f.b.d. of the log:

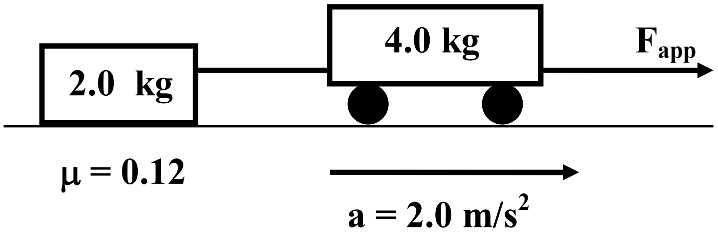
$\overrightarrow{a = .55}\ m/s^2 \Rightarrow F_{Net} = 600(.55)$
$= 330N$

$F_{Net} = F_T - 800 \Rightarrow F_T = 330 + 800$

$$\boxed{F_T = 1.1 \times 10^3\ N}$$

Note: F_T could also be found by analyzing the truck.

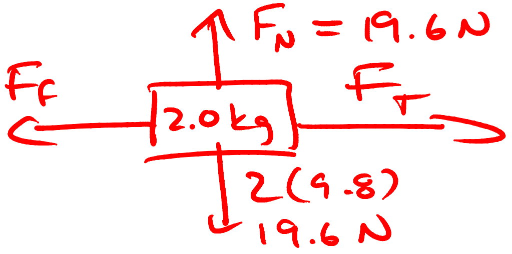
Example #12. Two masses shown below are connected together and pulled by an applied force to the right, causing an acceleration of 2.0 m/s^2. There is a coefficient of friction between the 2.0 kg mass and the floor, while the friction between the cart and the floor is negligible. Find:



a) the tension in the string attaching the two masses.

b) the applied force used to pull the system.

a) We can draw a f.b.d. of either the cart or the mass in order to find F_T. The mass is the only f.b.d. with <u>one</u> unknown value, so analyze it:



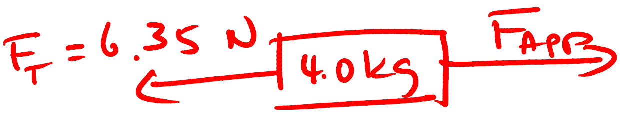
$\Rightarrow F_f = \mu F_N$
$= .12(19.6)$
$= 2.35N$

$\overrightarrow{a = 2.0\ m/s^2} \Rightarrow F_{Net} = 2(2)$
$= 4.0N$

$\rightarrow F_{Net} = F_T - F_f \qquad 4.0 = F_T - 2.35$

$\boxed{F_T = 6.4\ N}$ (6.35)

b) f.b.d. of the cart:



$\Rightarrow$ no friction, so F_g, F_N not needed.

$\overrightarrow{a = 2.0m/s^2}$

$F_{Net} = 4(2) = 8.0\ N$

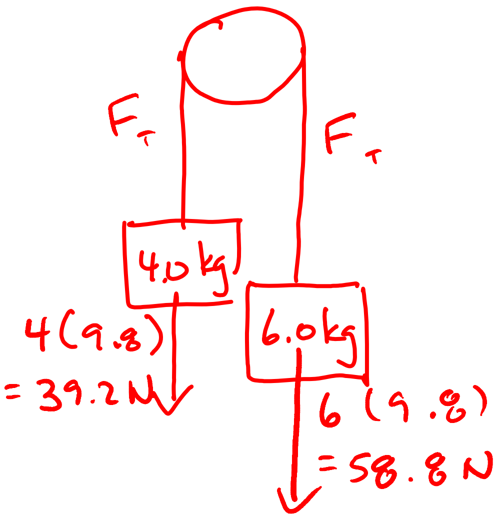
$\Rightarrow F_{net} = F_{App} - F_T \qquad 8.0 = F_{App} - 6.35$

$$\boxed{F_{App} = 14\ \text{N}}$$

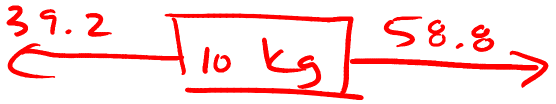
The value of F_{App} could also be found by analyzing a f. b. d. of the whole system.

Example #13. **Two masses are suspended by a single pulley, and hang on each side of it. One mass is 4.0 kg and the other is 6.0 kg. Find:**

- **a) the acceleration of the system.**
- **b) the tension in the rope.**



a) f.b.d. of the whole system:



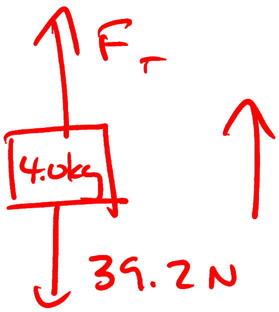
$F_{Net} = 58.8 - 39.2 = 19.6 N$

$F_{Net} = m_T a$

$19.6 = 10 a$ $\boxed{a = 2.0 m/s^2}$

(1.96)

b) f.b.d. of 4.0 kg mass:



$\uparrow a = 1.96 m/s^2 \Rightarrow F_{Net} = 4(1.96)$

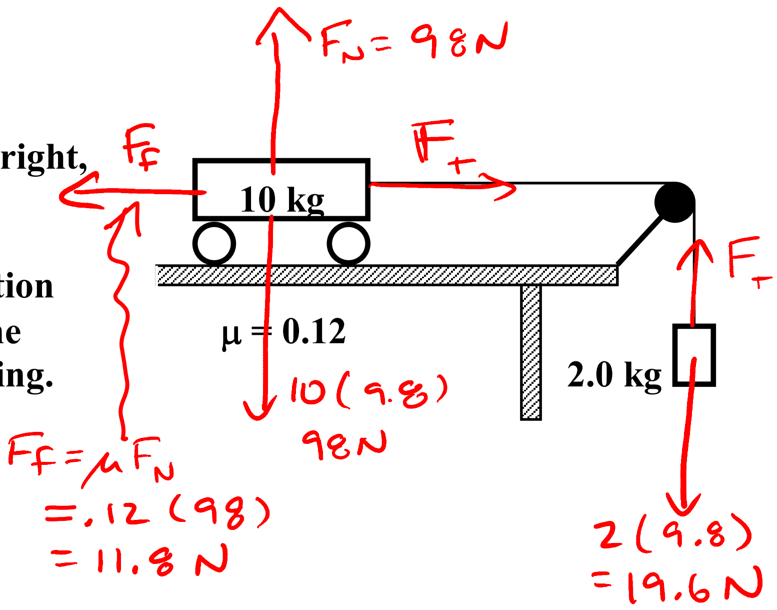
$= 7.8 N$

$F_T > 39.2$

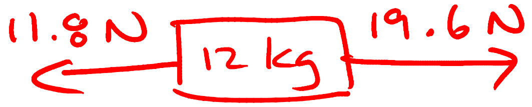
so $F_{Net} = F_T - 39,2$

$F_T = 39.2 + 7.8$ $\boxed{F_T = 47 N}$

Example #14. In the diagram to the right, the weight of the 2.0 kg mass exerts a force on the system causing both masses to move. Given the information listed, find: (a) the acceleration of the system and (b) the tension in the string.



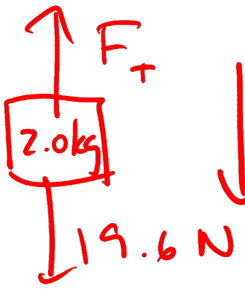
a) f.b.d of system:



$F_{Net} = 19.6 - 11.8 = 7.8 N$

$F_{Net} = m_T a \qquad 7.8 = 12a \qquad \boxed{a = 0.65 m/s^2}$

b) f. b. d. of hanging mass (easiest)



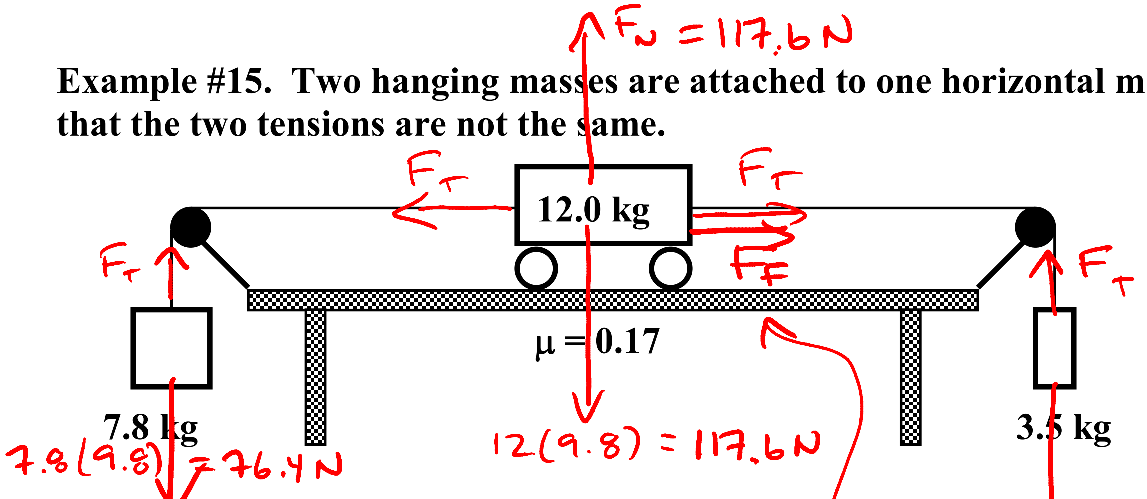
$\downarrow a = 0.65 m/s^2 \Rightarrow F_{Net} = 2(.65)$
$= 1.3 N$

$19.6 > F_T$, so

$F_{Net} = 19.6 - F_T$

$F_T = 19.6 - 1.3 \qquad \boxed{F_T = 18 N}$

Example #15. Two hanging masses are attached to one horizontal mass. Note that the two tensions are not the same.

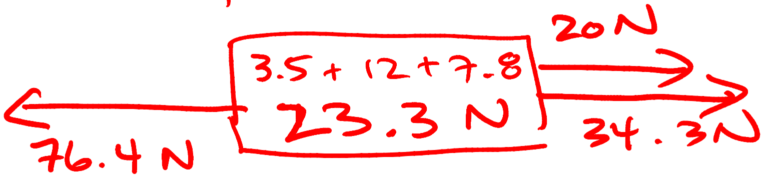


a) What is the unbalanced or net force?
b) What is the acceleration of the system?
c) What is the tension in each rope?

3.5(9.8)
= 34.3 N

$F_F = \mu F_N$
$= .17(117.6)$
$= 20$ N (to the right, opposing motion)

a) f.b.d of system:



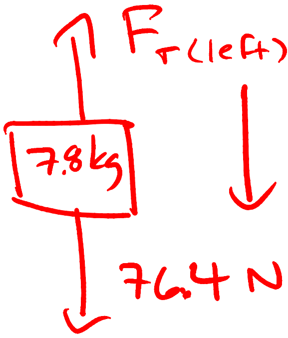
$F_{net} = 76.4 - (34.3 + 20)$ $\boxed{F_{net} = 22 N}$ (22.1)

b) $F_{net} = m_T a$ $22.1 = 23.3a$ $\boxed{a = 0.95 m/s^2}$

c)

next page

→ f.b.d of 7.8 kg mass:



$a = .95\ m/s^2 \Rightarrow F_{Net} = 7.8(.95)$

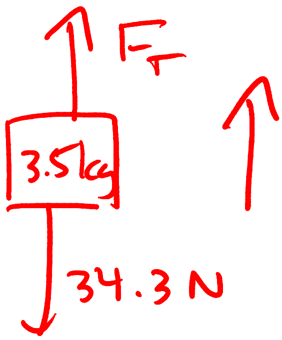
$= 7.4\ N$

→ $76.4 > F_T$, so

$F_{Net} = 76.4 - F_{T(left)}$

$F_T = 76.4 - 7.4$ $\boxed{F_T = 69\ N}$

→ f.b.d. of 3.5 kg mass:



$a = .95\ m/s^2 \Rightarrow F_{Net} = 3.5(.95)$

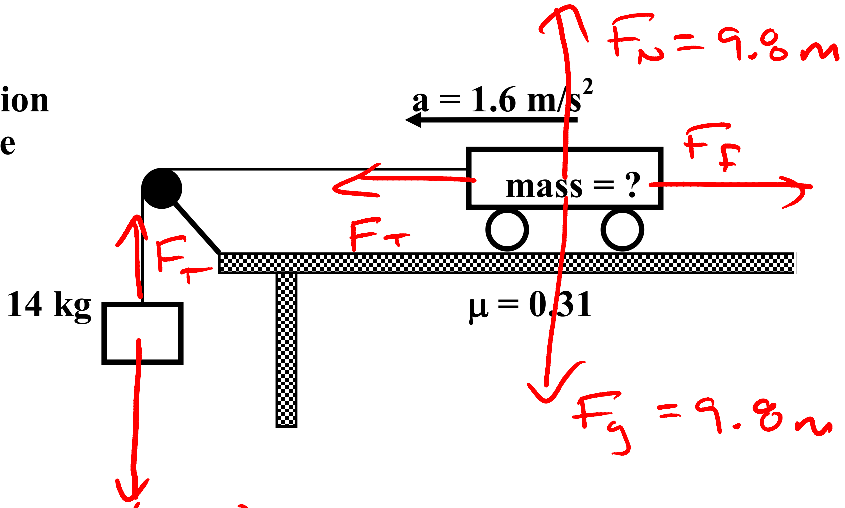
$= 3.3\ N$

→ $F_T > 34.3$, so

$F_{Net} = F_T - 34.3$

$F_T = 34.3 + 3.3$ $\boxed{F_T = 38\ N}$

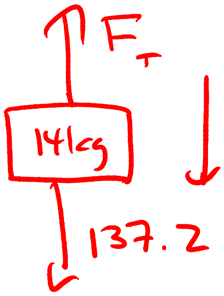
Example #16. Given the information in the diagram to the right, find the unknown mass of the cart.



Hint: start by isolating the known mass to find tension $\mathbf{F_T}$ in the string.

$14(9.8)$

$= 137.2N$



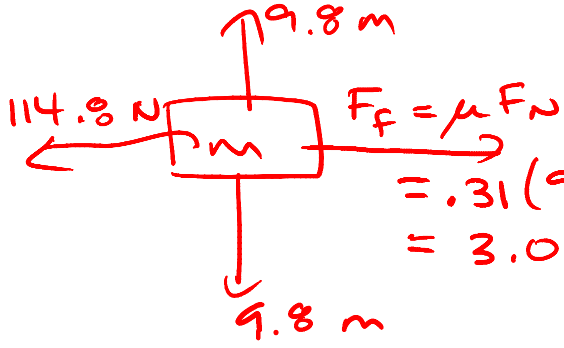
$a = 1.6\ m/s^2 \Rightarrow F_{Net} = 14(1.6) = 22.4\ N$

$\rightarrow 137.2 > F_T$, so

$F_{Net} = 137.2 - F_T$

$F_T = 137.2 - 22.4 = 114.8\ N$

→ f.b.d. of cart:



$= .31(9.8)m$

$= 3.04m$

$a = 1.6\ m/s^2$

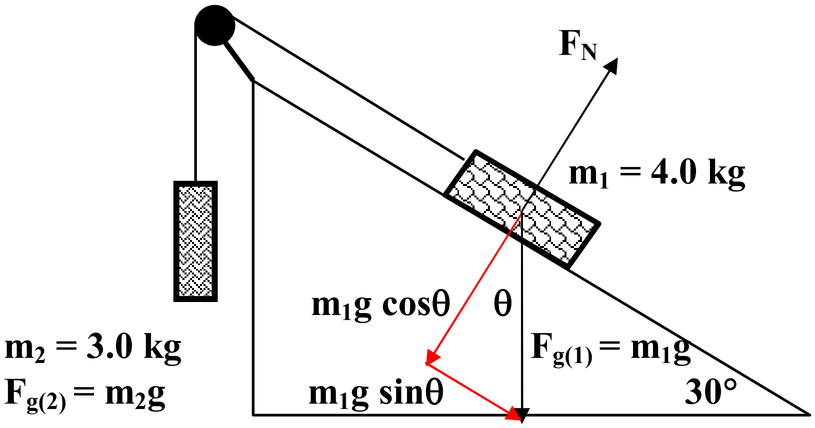
$F_{Net} = 1.6m$

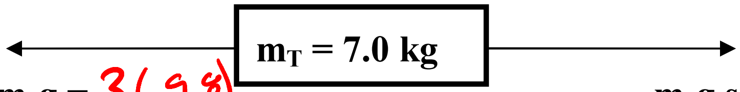
$\rightarrow 114.8 > F_f$, so $F_{Net} = 114.8 - F_f$

$1.6m = 114.8 - 3.04m$

$$\boxed{m = 25\ kg}$$

Example #17. In the diagram below, a 4.0 kg mass rests on a 30° frictionless slope and is pulled by a 3.0 kg mass connected to it over a pulley by a cord. What is the acceleration of the system and the tension in the cord?





$m_2g = 3(9.8)$
$= 29.4\text{ N}$

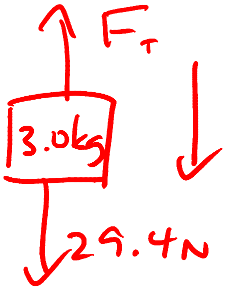
$m_1g\sin\theta = 4(9.8)\sin 30$
$= 19.6\text{ N}$

$F_{Net} = 29.4 - 19.6 = 9.8\text{ N}$

$F_{Net} = m_T a \qquad 9.8 = 7.0a \qquad \boxed{a = 1.4\text{ m/s}^2}$

(upslope)

→ f.b.d. of hanging mass

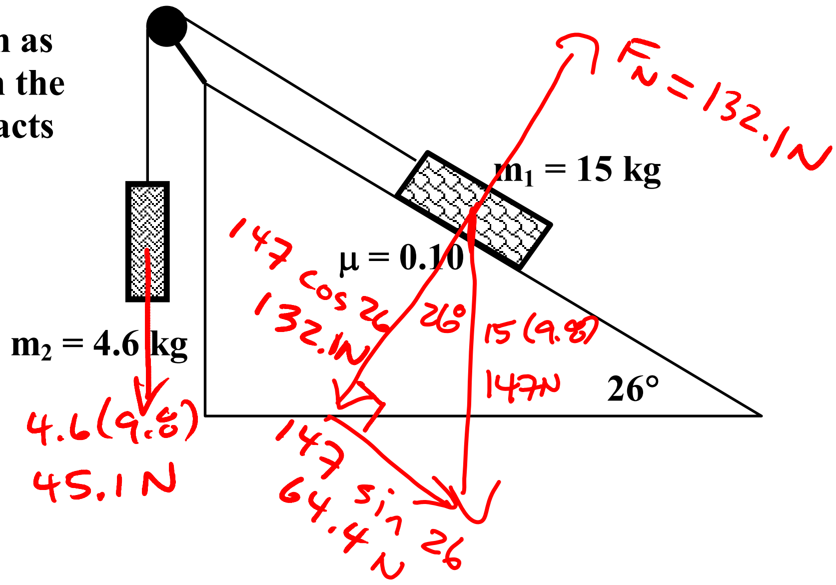


$a = 1.4\text{ m/s}^2 \Rightarrow F_{Net} = 3(1.4) = 4.2\text{ N}$

→ $29.4 > F_T$, so $F_{Net} = 29.4 - F_T$

$F_T = 29.4 - 4.2 \qquad \boxed{F_T = 25\text{ N}}$

Example #18. Similar problem as #17, but with friction acting on the 15 kg mass. Note that friction acts in the *opposite* direction to the largest force. Find the acceleration by <u>first determining the direction of motion</u>.



→ by inspection of the calculations above, friction will act upslope, because 64.4 > 45.1

→ $F_F = \mu F_N = .10(132.1) = 13.2N$

→ f.b.d of the system:

$$F_{net} = 64.4 - (45.1 + 13.2) = 6.1 \text{ N}$$

$$F_{net} = m_T a \qquad 6.1 = 19.6a$$

$$\boxed{a = 0.31 \text{ m/s}^2}$$