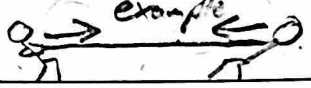
Physics 200 (Stapleton) Name: Key

Notes, Ch. 4.5: Normal, Tension, and Other Examples of Forces - Part 2

1. What is tension? The action/reaction pair of pulling forces acting at each end* of a stretched* object.

2. In our physics problems, almost all of the ropes, chains, wires, cables, or strings will be massless. In massless objects such as these the force of tension at every point is equal. We know this because of Newton's 3rd law.



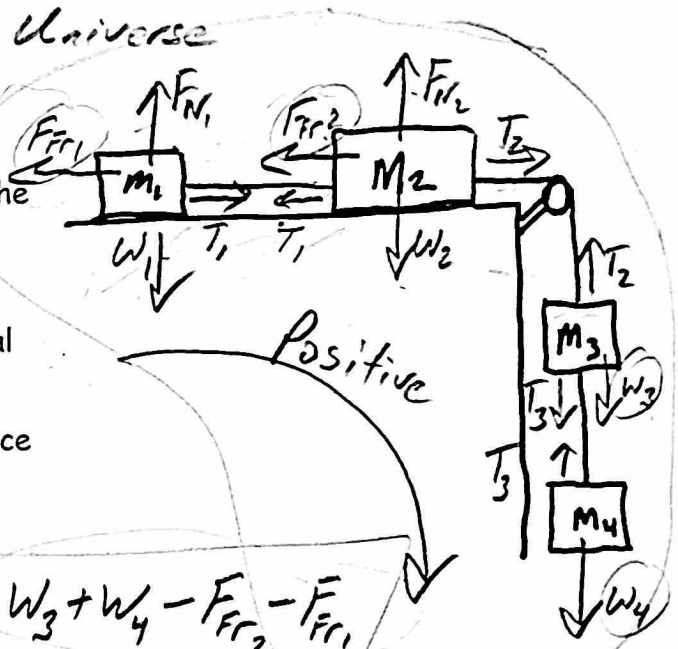
Analyzing Multibody Systems (and writing net force equations for those systems)

3. What is a "system" in Physics?

Whatever portion of the Universe you choose to analyze

4. The diagram on the right represents blocks of matter that are connected by a massless string. The pulley and the air are frictionless, but there is friction between the surface and the blocks.

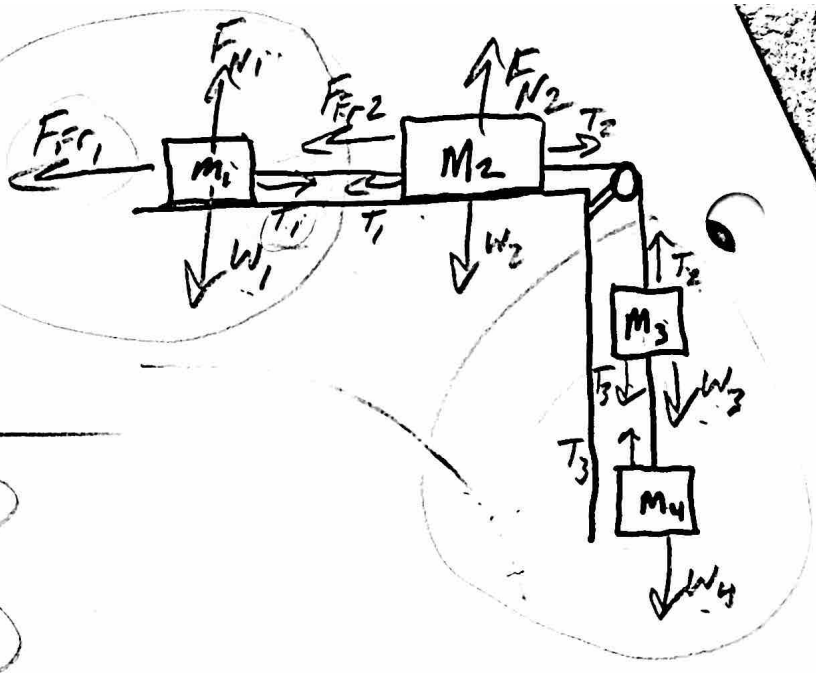
- Draw several (or possibly all) of the individual **systems** that you can find in the diagram.
- For each system, write equations for net force in terms of:
  - The sum of individual forces
  - Newton's 2nd Law



$$\sum F_{All} = W_3 + W_4 - F_{Fr_2} - F_{Fr_1}$$

$$\sum F_{All} = (m_1 + m_2 + m_3 + m_4)\,a$$

Continue...



$$\sum F_{M_1} = (M_1)(a)$$

$$\sum F_{M_1} = T_1 - F_{Fr1}$$

$$\sum F_{m_3+m_4} = (m_3+m_4)\,a$$

$$\sum F_{m_3+m_4} = T_2 - W_3 - W_4$$

$$\sum F_{M_3} = M_3(a)$$

$$\sum F_{M_3} = T_2 - T_3 - W_3$$

$$\sum F_{M_2+M_3} = (M_2+M_3)\,a$$

$$\sum F_{M_2+M_3} = T_3 + W_3 - T_1 - F_{Fr2}$$

Assuming clockwise = positive

$\sum F_{All} \Rightarrow$ See previous page

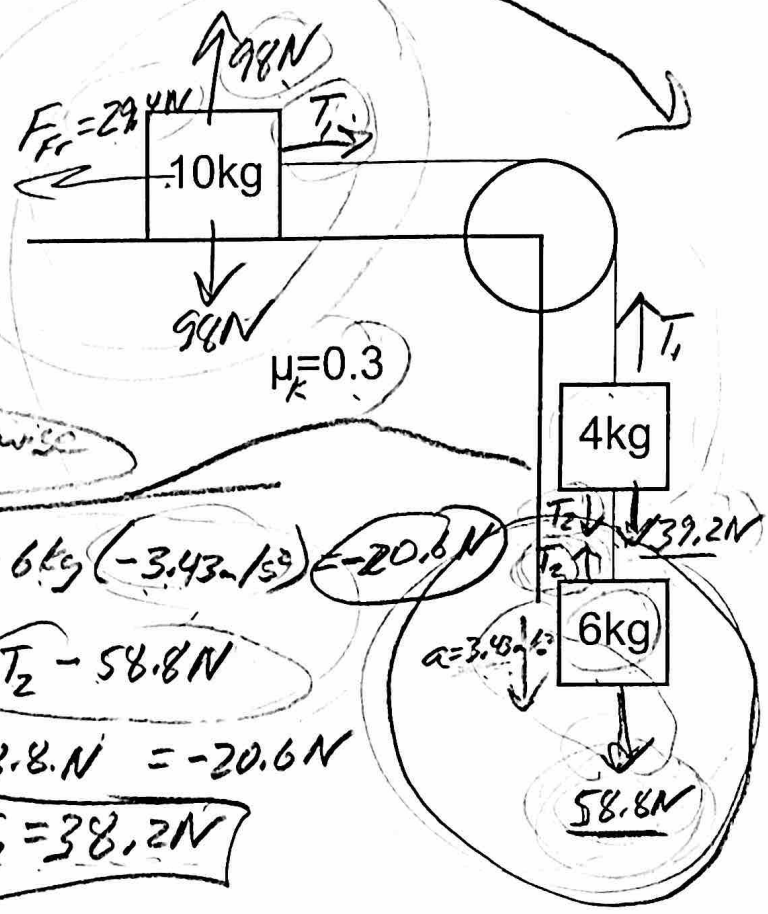
$$\sum F_{m_2+m_3+m_4} = (m_2+m_3+m_4)\,a$$

$$\sum F_{m_2+m_3+m_4} = W_4 + W_3 - F_{Fr2} - T_1$$

Multibody Drill A

Pos.

Practice) Find the accelerations and tensions of the ropes on the right.



$\Sigma F_{20} = 20kg(a)$

$\Sigma F_{20} = 58.8N + 39.2N - 29.4N$

$20kg(a) = 68.6N$

$a = 3.43 m/s^2$ Clockwise

$\Sigma F_{10} = 10kg(3.43 m/s^2) = 34.3N$

$\Sigma F = T_1 - 29.4N$

$T_1 - 29.4N = 34.3N$

$T_1 = 63.7N$

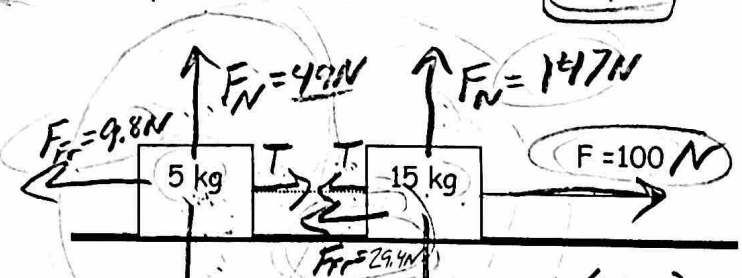
$\Sigma F_6 = 6kg(-3.43 m/s^2) = -20.6N$

$\Sigma F_6 = T_2 - 58.8N$

$T_2 - 58.8N = -20.6N$

$T_2 = 38.2N$

1) Find the acceleration and the tension in the rope between the 2 masses. Assume $\mu = 0$



$\Sigma F_{20kg} = 20kg(a)$

$\Sigma F_{20kg} = 100N$

$20kg(a) = 100N$

$a = 5 m/s^2$

$\Sigma F_{5kg} = 5kg(5 m/s^2) = 25N$

$\Sigma F_{5kg} = T$ $\quad T = 25N$

2) Repeat if $\mu = 0.2$.

$F_{Fr\,5kg} = 0.2(49N) = 9.8N$

$\Sigma F_{20kg} = 20kg(a)$

$\Sigma F_{20kg} = 100N - 29.4N - 9.8N = 60.8N$

$20kg(a) = 60.8N$

$a = 3.04 m/s^2$

$\Sigma F_{5k} = 5kg(3.04 m/s^2) = 15.2N$

$\Sigma F_{5kg} = T - 9.8N$

$T - 9.8N = 15.2N$

$T = 25N$

3) Find the acceleration and the tension in the rope between the 2 masses.

$\Sigma F_{4kg} = 4kg\,(a)$

$\Sigma F_{4kg} = 30N - 29.4N - 9.8N = -9.2N$

$4kg\,(a) = -9.2N$

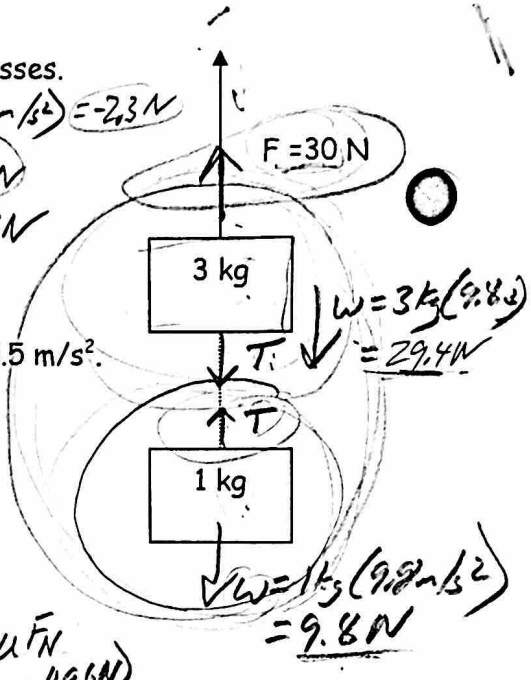
$a = -2.3\,m/s^2$

$\Sigma F_{1kg} = 1kg\,(-2.3\,m/s^2) = -2.3N$

$\Sigma F_{1kg} = T - 9.8N$

$T - 9.8N = -2.3N$

$T = 7.5N$



4) Find the force required to accelerate the 2 masses at a rate of +2.5 m/s².

$\Sigma F_{4kg} = 4kg\,(2.5\,m/s^2) = 10N$

$\Sigma F = F - 29.4N - 9.8N$

$F - 39.2N = 10N$

$F = 49.2N$

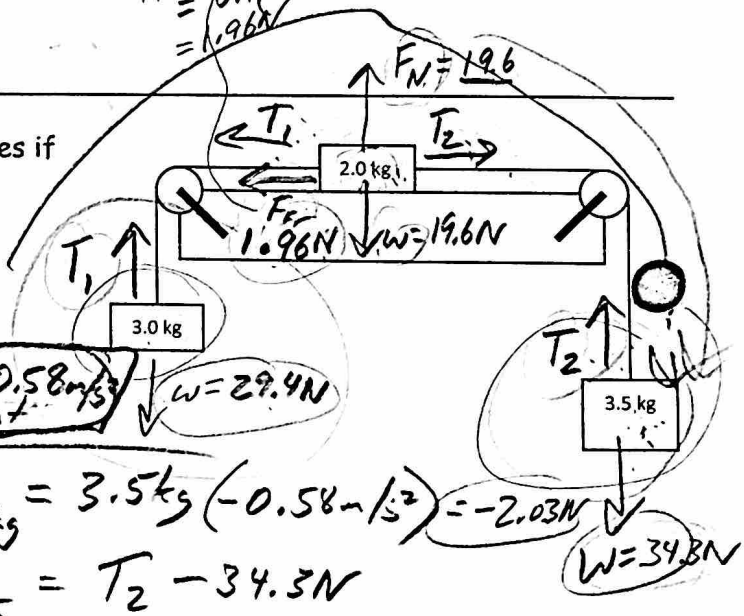
---

5) Find the acceleration and the tension in the 2 ropes if the surface is frictionless.

$F_{Fr} = \mu F_N$

$= 0.1\,(19.6N)$

$= 1.96N$



$\Sigma F_{8.5} = 8.5kg\,(a)$

$\Sigma F_{8.5} = 34.3N - 29.4N = 4.9N$

$8.5kg\,(a) = 4.9N \Rightarrow a = 0.58\,m/s^2$ right

$\Sigma F_3 = 3kg\,(0.58\,m/s^2) = 1.73N$

$\Sigma F_3 = T_1 - 29.4N$

$T_1 - 29.4N = 1.73N$

$T_1 = 31.1N$

$\Sigma F_{3.5kg} = 3.5kg\,(-0.58\,m/s^2) = -2.03N$

$\Sigma F_{3.5} = T_2 - 34.3N$

$T_2 - 34.3 = -2.03$

$T_2 = 32.3N$

---

6) Repeat if the coefficient of kinetic friction is 0.10

$\Sigma F_{8.5} = 8.5kg\,(a)$

$\Sigma F_{8.5} = 34.3N - 29.4N - 1.96N = 2.94N$

$8.5kg\,(a) = 2.94N$

$a = 0.35\,m/s^2$ Clockwise

$\Sigma F_{3.5kg} = 3.5kg\,(-0.35\,m/s^2)$

$= -1.21N$

$\Sigma F = T_2 - 34.3N$

$T_2 - 34.3N = -1.21N$

$T_2 = 33.1N$

$\Sigma F_2 = 2kg\,(0.35\,m/s^2)$

$= 0.7N$

$\Sigma F_2 = 33.1N - T_1 - 1.96N = 0.7N$

$-T_1 = -30.4N \Rightarrow T_1 = 30.4N$