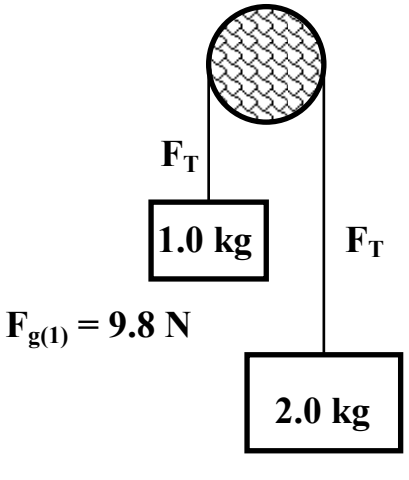
Connected Masses and Pulleys

For these problems we need a sign convention; let the direction of movement (in this case, the direction of the **net force**) be positive.

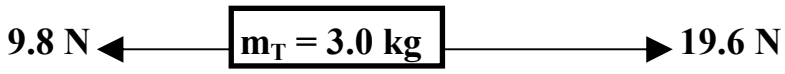
Here is a standard Physics 11 problem (with a wrinkle): two connected masses hang over a pulley, as shown below. Determine the tension in the rope.



Recall: a frictionless pulley can only change the direction of a force; the tension F_T in the rope connecting the masses is the same on either side of the pulley.

- Ignore tension for now; first, find what unbalanced force and acceleration acts on the whole system.

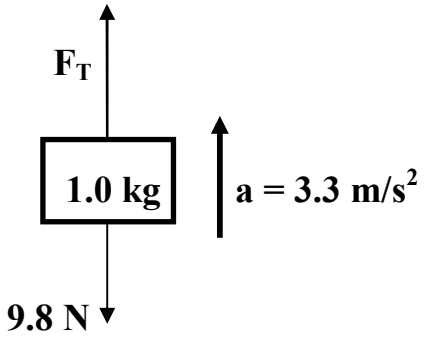
→examine the f.b.d. of the system:



→$F_{Net} = 19.6 - 9.8 = 9.8$ N

→ $F_{Net} = m_T a$ →$9.8 = 3.0a$ →$a = 3.3$ m/s^2

- Now find the tension in the string by examining a f.b. diagram of only one of the two masses. If we choose the 1.0 kg mass, we must recognize its upward acceleration and net force, which means:



→$F_{Net} = ma = 1.0(3.3) = 3.3$ N

→$F_{Net} = F_T - 9.8$

→$3.3 = F_T - 9.8$ → $F_T = 13$ N

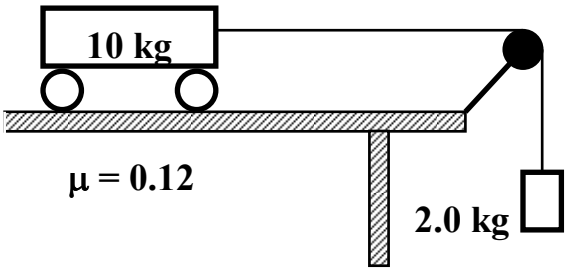
Note that the same answer would result from analyzing only the 2.0 kg mass. In this case, the acceleration is downward, so $\mathbf{F_{Net} = 19.6 - F_T}$. I'll leave this one for you to prove.

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.**

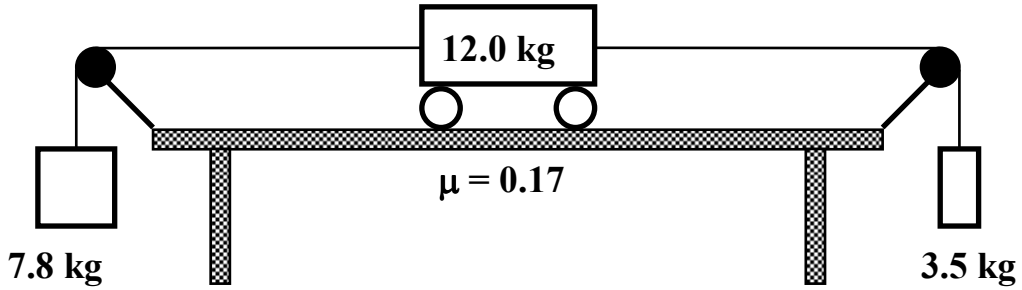
(see Dynamics Ex 13 for answer)

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.



(see Dynamics Ex 14 for answer)

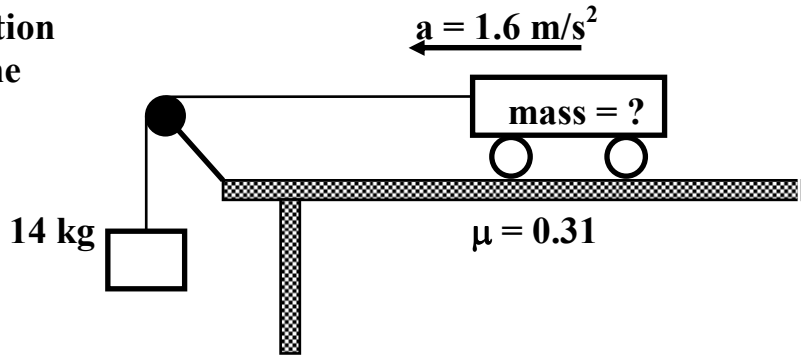
Example #15. Two hanging masses are attached to one horizontal mass. Note that the two tensions are not the same.



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

(see Dynamics Ex 15 for answer)

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

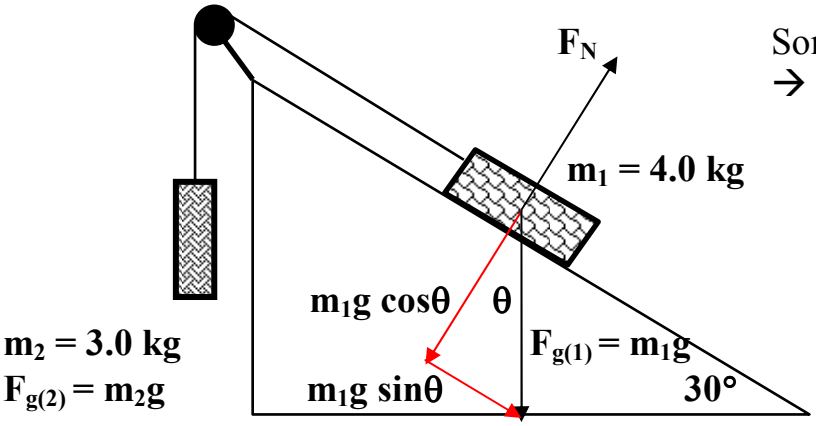


Hint: start by isolating the known mass to find tension $\mathbf{F_T}$ in the string.

(see Dynamics Ex 16 for answer)

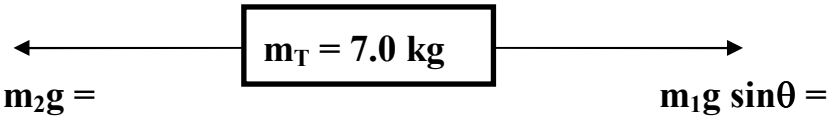
Finally, consider a coupled mass system, one on an incline and one hanging.

Example #17. In the diagram below, a 4.0 kg mass rests on a 30° <u>frictionless</u> 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?



Some helpful hints:
→ first, calculate all forces that affect motion; this includes taking components of $\mathbf{F_g}$ on the right mass, as shown.

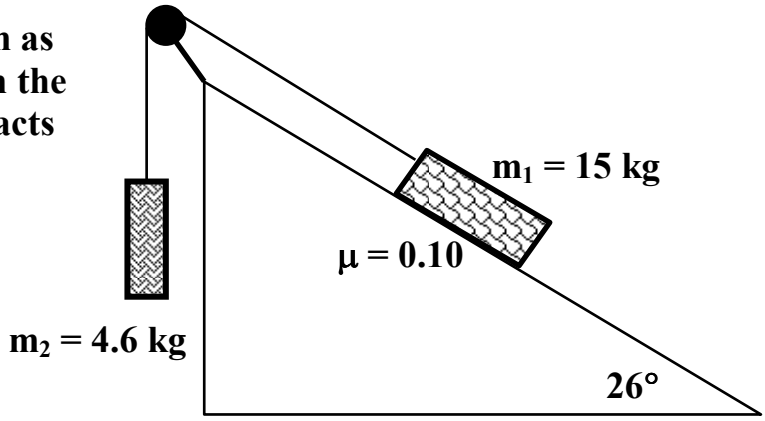
→Next step: to find the acceleration, consider the ***whole system***. Note which force is greater; that will be the direction of the net force and the acceleration.



→Finally, to find the **tension**, analyze just one mass. Try **mass 2** (3.0 kg); it has fewer forces acting on it so is probably easier to work with.

(see Dynamics Ex 17 for answer)

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>.



(see Dynamics Ex 18 for answer)