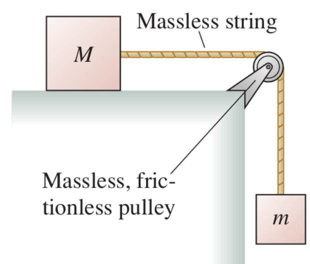
Homework 4
Due Friday, 24 February

NOTE: For all problems, in order to receive credit, you must draw force diagrams for all relevant objects. These diagrams must be at least two inches tall to receive full credit. This is for your benefit, not mine; carefully drawing clear diagrams will help you with these problems more than anything else.

1. An object of mass M sits on a frictionless table; it is connected by a light string to a hanging mass m. (See figure.)



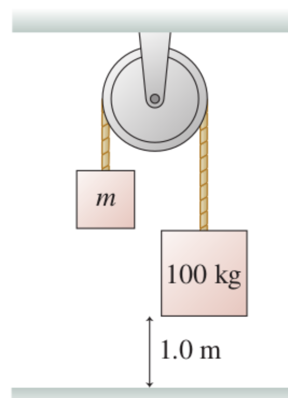
   (a) Find an expression for the tension in the string in terms of M, m, and g.

   (b) Find the acceleration of the masses in terms of M, m, and g.

   (c) What is the tension in the limit where $M \gg m$ (that is, the mass on the table is very heavy)? Is this what you expect it to be?

   (d) What is the acceleration in the limit where $m \gg M$ (that is, the hanging mass is very heavy)? Is this what you expect it to be?

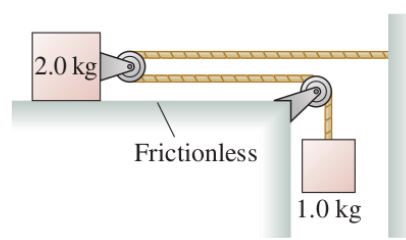
2. Two masses are connected by a light string and draped over a light, frictionless pulley. One has mass m, which you will find; the other has mass $M = 100$ kg. (See figure.)



   (a) Find an expression for the acceleration of the mass M in terms of M, m, and g.

   (b) If it takes a time $\tau = 6$ s to hit the ground after it is released, what is the value of m?

3. A rope-and-pulley system is set up as shown. What is the acceleration of the 2 kg block sitting on the table?



Hint: Think very carefully about how the acceleration of the two blocks relates. If the hanging mass moves downward by one meter, how far does the block on the table move?

4. A block of mass $m_1 = 5$ kg rests on a table. Two ropes connect that block to two masses: one hangs off the left side of the table, and the other hangs off the right side. The coefficient of static friction μ_s between the block and the table is 0.2.

   If one of the hanging masses has mass $m_2 = 3$ kg, for what range of values of the other block's mass m_3 will the system not move?

   HINT 1: What happens if m_3 is very small? What happens if it is very big? Does this affect your force diagram in any way? How do you know what direction static friction will point? Does this depend on the sizes of the masses? HINT 2: If you use the same variable a for acceleration in all your equations, make sure that it has the same value for all the objects! This may require careful choice of your coordinate axes.

5. Two blocks slide down an incline angled at 30° above the horizontal, connected by a cable. The top block has a mass of $m_1 = 1$ kg, and the bottom one has a mass of $m_2 = 2$ kg. The coefficients of kinetic friction are $\mu_{k_1} = 0.2$ (top block) and $\mu_{k_2} = 0.1$ (bottom block). What is the tension in the cable that connects them?

6. A hiker with a mass of 85 kg wants to drag a 200 kg sled over snow. She does this by tying a rope to the sled (at ground level) and running it over her shoulder. The rope running between her and the sled makes a 45 degree angle with the horizontal.

   If the coefficient of friction between the sled and the snow is 0.1, what must the coefficient of friction between her boots and the ground be for her to move the sled?

7. See Problem 2 on the first practice exam, at `https://walterfreeman.github.io/phy211/practice-exam-1-all.pdf`.

   - In this problem, is the car experiencing static or kinetic friction while on the snow? Is it experiencing static or kinetic friction on the ice?
   - If the hill has a slope of 15°, determine the coefficient of friction on the snow, and on the ice. (I wound up making up nice and simple numbers for you to do this problem; it turns out this car has some very nice snow tires!)

8. I drive a small sedan (a 2009 Toyota Yaris) that is front wheel drive. This means that the engine is linked only to the front wheels, so only the static friction coming from the front wheels can provide traction to help me move forward.

However, it has brakes on all four wheels, so static friction from both the front and the back wheels can provide traction to help me stop.

Since the engine is the heaviest part of the car, the front wheels bear most of the car's weight. For this problem, assume that the front wheels supply 2/3 of the normal force and the rear wheels supply the other 1/3.

In the summer of 2018, I was driving this car on some steep and dusty mountain roads ($\mu_s = 0.7$) in the mountains in Colorado. When I was climbing up the mountains, I was confident that I could make it safely back down any slope that I could climb up. However, I knew the reverse wasn't true, and was very reluctant to drive *down* a steep slope since I didn't know if I could make it back up.

- What is the steepest slope that my car can drive up (at a constant velocity)?
- What is the steepest slope that my car can travel down safely (without sliding down the slope)?
- Will four wheel drive help you avoid a car accident on icy roads in Syracuse? Will it help you avoid getting your car stuck?