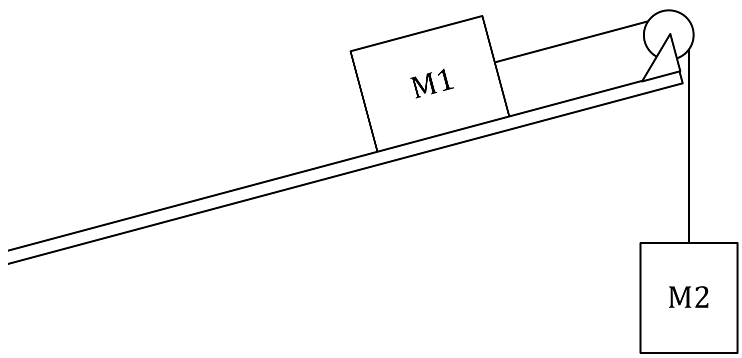
GUIDE to Question #1: Whacky Friction

1. Whacky Friction

M1 sits on a slanted desktop and is attached by a string to M2, which hangs off the edge of the desk, as shown. The string runs over a pulley wheel at the edge of the table. The string is massless and the pulley wheel is massless & has zero friction—in other words, it changes the direction of tension, without changing its magnitude. So tension on M1 is equal in magnitude (but not opposite in direction) to the force of tension on M2.

The desk is angled 20 degrees from the horizontal. The coefficients of ***static*** and ***kinetic*** friction between M1 and the desk are 0.6 and 0.4 ***respectively***. M1 and M2 both have masses of 10kg.



The ULTIMATE GOAL of this problem is to find the acceleration of the system and the tension on the string.

A. Draw your own pictorial diagram of this situation—it can look exactly like the one that's given, but it should contain ***all known and unknown quantities***.

B. Draw system schemata for each mass. (You need not include the string & pulley—you can connect M1 directly to M2.)

C. Draw a pure & a component FBD of M1.
   - Your PFBD will contain FOUR arrows.
   - Choose a coordinate system.
   - As always, your x-axis should ***line up with the direction of acceleration*** of the object of interest (i.e. M1). If this system moves, which way will M1 accelerate?
   - (NOTE: M1 will move in a totally different direction from M2. Therefore, the coordinate system you use for M1 will be ***different*** from the one you use for M2. That's OK.)
   - One force must be split into components. To do this, you will need a right triangle. DRAW this right triangle clearly. There are two ways to draw it. Either one is ok.
   - SHOW how you find the angles in this triangle.
   - Your CFBD will contain FIVE arrows.

D. Write down Newton's 2nd Law. Apply it to M1 on the y-axis.

E. Compute the magnitude of the normal force on M1.

F. Compute f_s(max), the maximum force of static friction, between M1 and the desk.

G. Write down N's 2nd Law. Apply it to M1 on the x-axis. Leave ***a***, ***f***, and ***T*** as variables.
- As always, use your CFBD to tell you which forces are on the x-axis.
- Plug in the numbers you know. Leave the variables as variables.
- There are way too many unknowns to solve. That's fine. Just write the equation.

H. Draw an FBD for M2.
- Nothing too tricky here.

I. Write down N's 2nd Law. Apply it to M2. Leave ***a*** and ***T*** as variables.
- Again, plug in any numbers you know. Leave everything else as variables. Don't worry about solving the equation yet.
- Notice the problem says to leave ***a*** as a variable. Why does it say that? Isn't ***a*** zero in the y-direction? Oh, wait. Is ***a*** zero? Do we know? Contemplate this.

J. Assume the system starts at rest. Show that it ***will*** begin to accelerate.
- We are trying to see if the system will move AT ALL.
- If the system does not move, what force(s) are ***stopping*** it from moving?
- If the system does move, what force(s) are ***making*** it move?
- What direction would it move in? (There may be multiple possible answers.)
- To show that a system will move, first assume it will NOT.
- You currently have two NII equations with THREE unknowns (steps G & I).
- But if this system is ***not*** moving, this automatically tells you the value of one variable.
- Solve one of the NII equations to find another of the unknown variables.
- Solve the other NII equation to find the magnitude of *f*.
- Is this possible? Can *f* have this magnitude?

K. Calculate the force of kinetic friction on M1.

L. Solve the system of equations to find ***a*** and ***T***.
- Since the system IS moving, you know you are dealing with ___ friction.
- Also, since the system IS moving, you no longer know what ***a*** is.
- Which means the work you did in step J to find ***T*** no longer applies. You do not know what ***T*** is yet.
- Go back to the two NII equations you found in steps G & I. Plug in for ***f***.
- What do you know about $\boldsymbol{a}_{M1}$ & $\boldsymbol{a}_{M2}$? What do you know about $\boldsymbol{T}_{M1}$ and $\boldsymbol{T}_{M2}$?
- You have TWO equations with TWO unknowns. Solve for the unknowns.