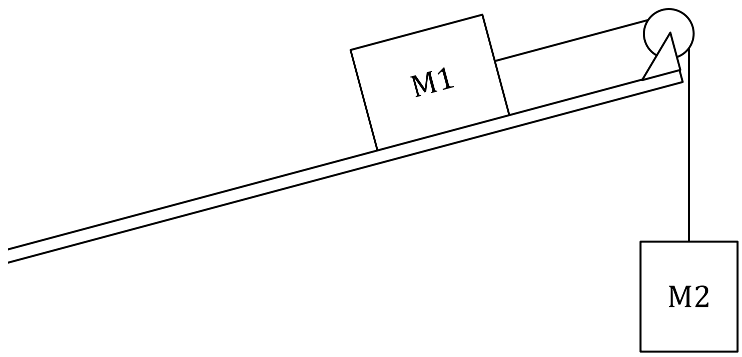
# GUIDE to Question #1: Whacky Friction

## 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 at its axel—in other words, it changes the direction of the string & thus of the force of tension, without absorbing any of that force. In short, the force of tension on M1 is equal & opposite 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 table 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 a system schema for this situation. (You need not include the string or the pulley wheel in your SS. Connect M1 directly to M2.)

C. Draw a pure & a component FBD of M1.
   - Your PFBD will contain FOUR arrows.
   - Your CFBD will contain FIVE arrows.
   - As always, your X-Axis should line up with the direction of acceleration. What acceleration? The acceleration of M1. If this system moves, which way will M1 accelerate?
   - NOTE: M1 will move at a totally different angle from M2. Therefore, the coordinate system you use for M1 will be DIFFERENT from the coordinate system you use for M2. That's OK.

D. Compute the magnitude of the normal force on M1.
   - Write down Newton's Second Law.
   - Apply it to the axis that contains the normal force.

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

F. Compute force with which gravity pulls M1 down the ramp.
   - You know total the force of gravity on M1: that's easy.
   - You are being asked to find the portion (component) of that force that is pulling M1 down the ramp (as opposed to into the ramp).

G. Create an NII equation for M1 in the x direction, leaving $a$, $f$, 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. Create an NII equation for M2, leaving $a$ 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 the force of tension on M1 will be enough to make it 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, right?
   - Assuming the system does not move will allow you to plug in a number for one of those unknown variables.
   - You will then be able to solve one of the NII equations to find another of the unknown variables.
   - You will then be able to solve the remaining NII equation to find the magnitude of $f$.
   - You can then determine whether this magnitude is possible, given what you know about friction.

K. Calculate the force of kinetic friction on M1.

L. Solve the system of equations to find the acceleration of the system and the tension on the string.
   - 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 don't know what T is either.
   - 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.