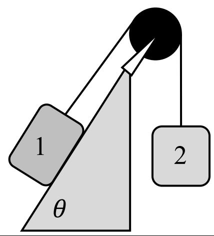
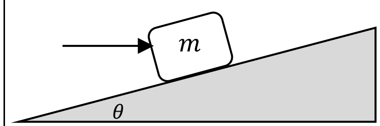
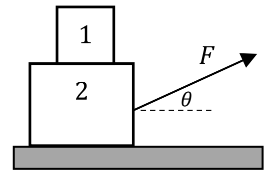
Coding Options for PHYS 161 Oral Presentation 2

Option 1 (details page 3)	Option 2 (details page 6)	Option 3 (details page 8)
		

Your ultimate goal is to create a simulation which correctly animates the motion of objects for a wide range of masses, angles, applied force magnitudes, and frictional coefficients. In addition, your code must display a correct FBD for each mass and with labeled arrows. Your code must also display numerical values (formatted without excessive sig figs) for all forces and acceleration.

Trust me: the animation and drawing everything will be easy compared to understanding the force equations and `if` statements. The hard part is using FBDs and force equations to derive a correct set of `if` statements. **Ignore animation and the visual aspects of the code for the time being.**

For all codes you might first make a list of initial parameters similar to the one shown below.
Not all codes will use all parameters. Some codes may require additional parameters.

```
m_1=1.00       #in units of kg
m_2=2.00       #in units of kg
mu_s12=0.5
mu_k12=0.3
g=9.8    #in units of m/s^2
theta=radians(60.0) #use radians to correctly compute trig functions
friction_direction=vec(0,0,0)
friction_magnitude=0          #in units of N
normal_direction=vec(0,0,0)
normal_magnitude=0            #in units of N
tension_magnitude=vec(0,0,0)        #in units of N
weight_1 = vec(0, -1*m_1*g, 0)  #in units of N
weight_2 = vec(0, -1*m_2*g, 0)  #in units of N
tension_1 = vec(0,0,0)              #in units of N
tension_2 = vec(0,0,0)              #in units of N
```

Your first sub-goal is to correctly compute all the forces and the accelerations as both magnitudes and vectors for the initial set of conditions. Then verify your code still produces correct outputs with the additional test cases shown later in the document. Once this is done, start doing the visuals and the animation.

In order to correctly compute the forces, each code must use a set of if statements to select an appropriate set of equations based on the FBD and applicable friction conditions. These equations and conditions will be based on force magnitudes. Later, to animate the motion, the code should convert these force magnitudes to vectors.

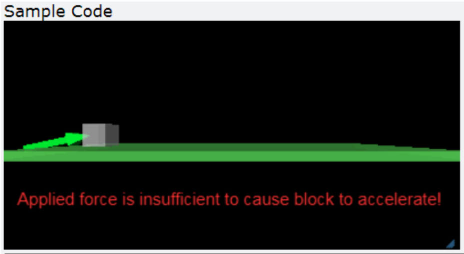
Note: one could handle acceleration in one of two ways. One could define `acceleration_direction` & `acceleration_magnitude` similarly to the work shown above. You could use force equations and solve them for `acceleration_magnitude`. This work can be checked in code using $\Sigma\vec{F} = m\vec{a}$.

Before plunging into your own codes let me give you an example of a code I wrote.
I deliberately over-engineered this code since everyone immediately copies my code then tries to modify it.
Hopefully the style I chose will make it easier for you to modify.
I also included a second code which will be useful if you need to rotate the incline or use a pulley with strings.

A word of caution: Each code has wildly different conditional statements.
Yours will *not* look like mine. In fact, there are many different possible correct sets of conditional statements.
You must analyze *your* FBDs and *your* force equations to get *your* conditional statements.

https://www.glowscript.org/#/user/robjorstadahc/folder/ForceSims/program/box.with.friction

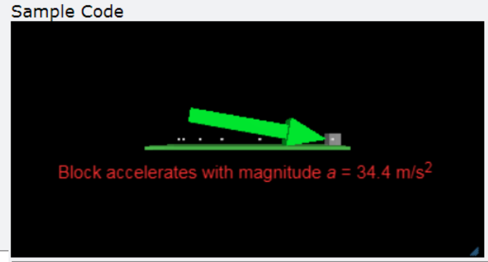
Sample Code




```
weight_1 = < 0, -98, 0 > N
F_applied = < 9.78148, 2.07912, 0 > N
F_applied.mag = 10 N
F_applied at angle 12 degrees from the horizontal.
normal = < 0, 95.9209, 0 > N
friction = < -9.78148, 0, 0 > N
acceleration = < 0, 0, 0 >  m/s^2

The following value is a check on the acceleration.
NOTE: sometimes you will get numbers like 1.25648E-15 when you expect a zero.
This is not a problem...you are simply seeing the rounding errors associated with
the computer converting number to binary but only carrying out the operation to 14
decimal places.
F_NET/block_1.m = < 0, -3.10862e-16, 0 >  m/s^2
```

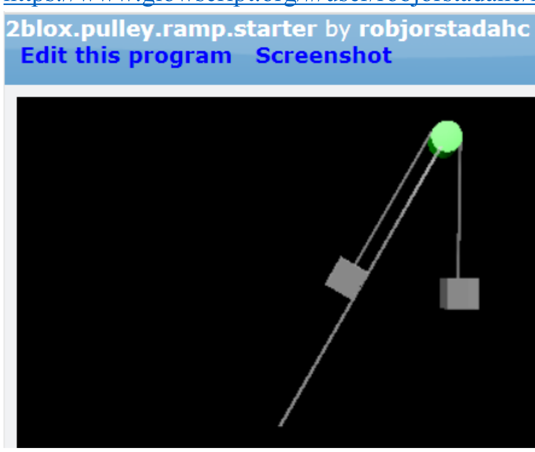
Sample Code



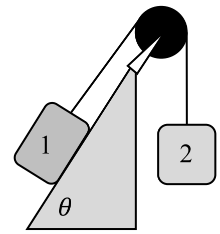

```
weight_1 = < 0, -9.8, 0 > N
F_applied = < 39.3923, -6.94593, 0 > N
F_applied.mag = 39.99999999999999 N
F_applied at angle -10 degrees from the horizontal.
normal = < 0, 16.7459, 0 > N
friction = < -5.02378, 0, 0 > N
acceleration = < 34.3685, 0, 0 >  m/s^2

The following value is a check on the acceleration.
NOTE: sometimes you will get numbers like 1.25648E-15 when you expect a zero.
This is not a problem...you are simply seeing the rounding errors associated with
the computer converting number to binary but only carrying out the operation to
14 decimal places.
F_NET/block_1.m = < 34.3685, 8.88178e-16, 0 >  m/s^2
```

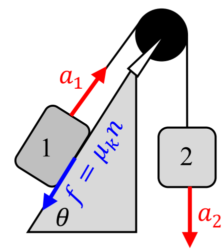
https://www.glowscript.org/#/user/robjorstadahc/folder/phys161/program/2blox.pulley.ramp.starter



Option 1: A two block system is designed as shown. Block 1 has mass m_1 and experiences coefficients of friction μ_s and μ_k. The ramp has fixed angle θ. The system is released from rest.



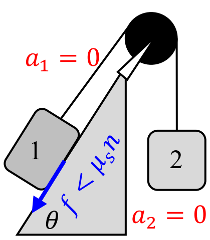
Conditional statement for friction *direction*?
First consider the frictionless case. Draw an FBD *assuming acceleration is zero*!
Solve this equation for m_2 in terms of m_1 and θ.
If $m_2 > m_1 \sin\theta$, friction points up the plane. Otherwise friction points down the plane.
We don't yet know if the blocks will actually *move*, but this tells us the direction friction points.
Note: a vector pointing up the plane is given by `up_plane=vec(cos(theta),sin(theta),0)`.
Create an `if` statement in the code which assigns `friction_direction` correctly based on the condition.



Case 1: Now assume friction is present but m_2 is large enough to make m_1 slides *up* the ramp.
Draw a correct FBD and write a correct set of force equations for each block *with friction present*.
Show that when if $m_2 g > f_{max\ possible} + m_1 g \sin\theta$ it makes m_1 slides *up* the ramp.
Tip: determine n and plug it into $f_{max\ possible} = \mu_s n$.
Solve the inequality for m_2 to determine a conditional statement for your code!
Expect non-zero acceleration up the plane and use $f = \mu_k n$.
Combine the force equations & eliminate the unknown forces to find

$$a_{up\ the\ plane} = g\frac{m_2 - m_1(\sin\theta + \mu_k\cos\theta)}{m_{total}}$$

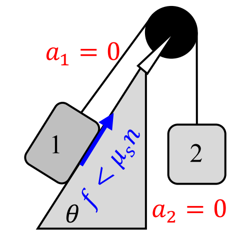
You can then use this acceleration to solve algebraically for tension magnitude!



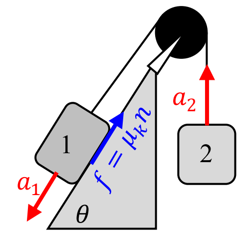
Case 2: There is enough friction to prevent the block from sliding even though you m_2 is large (compared to $m_1 \sin\theta$). In this case tension parallel to the plane should balance with the component of weight down the plane & friction *down* the plane. No sliding should occur. We expect $a = 0$ in this particular scenario. Note: it is not sliding due to static friction between m_1 and the ramp.
WATCH OUT! It is not sliding: do not use $f = \mu_k n$.
It is not on the verge of slipping: do not use $f = \mu_s n$.
Get f by solving for it in the force equation parallel to the plane!
I hope it is obvious why $T = m_2 g$ and $a = 0$.

Discussion continues on the next page…

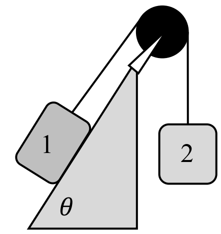
Case 3: Now assume $m_2 < m_1 \sin\theta$ but there is enough friction to prevent the block from sliding. In this case tension parallel to the plane should balance with the component of weight down the plane & friction *up* the plane. No sliding should occur. We expect $a = 0$ in this particular scenario. Note: it is not sliding due to static friction between m_1 and the ramp.
WATCH OUT! It is not sliding: do not use $f = \mu_k n$.
It is not on the verge of slipping: do not use $f = \mu_s n$.
Get f by solving for it in the force equation parallel to the plane!



Case 4: Now assume m_2 is too small to prevent m_1 from sliding *down* the ramp.
Show that when if $m_2 g + f_{max\ possible} < m_1 g \sin\theta$ it makes m_1 slides *up* the ramp.
Solve the inequality for m_2 to determine a conditional statement for your code!
Expect non-zero acceleration up the plane and use $f = \mu_k n$.
Combine the force equations & eliminate the unknown forces to find $a_{down\ the\ plane}$.
Note: $a_{down\ the\ plane}$ is similar to but not exactly the same as $a_{up\ the\ plane}$.
I think some minus signs get flipped.
You can then use $a_{up\ the\ plane}$ to solve algebraically for tension magnitude!



A set of test cases is shown on the nest page.



Using $m_1 = 1.00$ kg, $\mu_s = 0.5$, $\mu_k = 0.3$, $g = 9.8\frac{\text{m}}{\text{s}^2}$, and $\theta = 60°$ one expects the following code behavior. I was rounding all the time to get this done; expect errors in third digit.

Anytime $m_2 \geq 0.866$ kg friction should point *down* the plane.

- Block 1 should slide (move) *up* the plane whenever $m_2 > 1.116$ kg.
- I found $m_2 = 1.117$ kg produced $a = 0.45\frac{\text{m}}{\text{s}^2}$ while $m_2 = 1.5$ kg produced $a = 1.88\frac{\text{m}}{\text{s}^2}$.
- While block 1 slides up-plane we expect $f = 1.47$ N and $\vec{f} =< -0.735, -1.27, 0 >$ N.
- Anytime mass 2 is in the range $0.866 \text{ kg} < m_2 < 1.116$ kg we expect $f < 2.45$ N.
- Normal force has magnitude $n = 4.9$ N and vector $\vec{n} =< -4.24, 2.45, 0 >$ N.

Anytime $m_2 < 0.866$ kg friction should point *up* the plane.

- Block 1 should slide (move) *down* the plane $m_2 < 0.616$ kg.
- I found $m_2 = 0.60$ kg produced $a = 0.71\frac{\text{m}}{\text{s}^2}$ while $m_2 = 0.40$ kg produced $a = 2.21\frac{\text{m}}{\text{s}^2}$.
- While block 1 slides down-plane we expect $f = 1.47$ N and $\vec{f} =< 0.735, 1.27, 0 >$ N.
- Anytime mass 2 is in the range $0.616 \text{ kg} < m_2 < 0.866$ kg we expect $f < 2.45$ N.

If you set $m_2 = 0$:

- Friction points up the plane with magnitude $f = 1.47$ N giving vector $\vec{f} =< 0.735, 1.27, 0 >$ N.
- Acceleration down the plane has magnitude $a = 7.02\frac{\text{m}}{\text{s}^2}$ giving vector $\vec{a} =< -3.51, -6.08, 0 > \frac{\text{m}}{\text{s}^2}$.
- Tension in the cable should be zero.

If you set $m_2 = 1$ kg and $m_1 = 0$ kg:

- Acceleration should have magnitude $a = 9.8\frac{\text{m}}{\text{s}^2}$ directed up the plane.
- Tension in the cable and friction should be zero.

If you set $m_1 = 1$ kg and $\theta = 0°$:

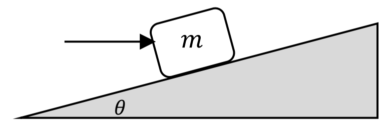
- Blocks should move whenever $m_2 > 0.5$ kg.
- When $m_2 < 0.5$ kg expect $f < 4.9$ N.
- When $m_2 > 0.5$ kg expect $f = 2.94$ N.
- When $m_2 = 1$ expect $a = 2.45\frac{\text{m}}{\text{s}^2}$ and $T = 7.35$ N.
- As $m_2 \to \infty$ we expect $a \to g$ and $T \to 12.74$ N.

OPTION 2: We expect 4 significant *possible* cases for the simulation. For choices of F & θ, only a subset of these possible cases will occur. For example, for small θ case 4 will likely NOT occur.

Pay close attention to the subscripts when looking at the frictional force.
Note: $f_{max\ possible} = \mu_s n$ is never the actual friction force used in the simulation.
It is used to help determine the conditional statements in your code (`if` statements).
WATCH OUT! Normal force n is not mg due to the component of F perpendicular to the plane!

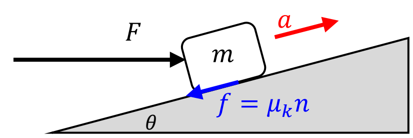
Conditional statement for friction *direction*?
Assume the ramp is frictionless to show the block slides *up-plane* if $F\cos\theta > mg\sin\theta$. This doesn't tell us if **Case 1** or **Case 2** applies, but you know friction points *down* the plane when $F\cos\theta > mg\sin\theta$. Note: a vector pointing up the plane is given by

```
up_plane=vec(cos(theta),sin(theta),0)
```

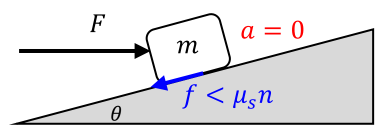


Create an `if` statement in the code which assigns `friction_direction` correctly based on the condition.

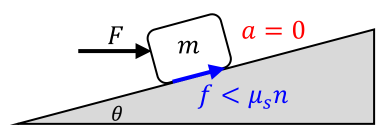
Case 1: You push really hard on the block and it should slide *up* the ramp.
Any time $F\cos\theta > f_{max\ possible} + mg\sin\theta$ the block slides up the plane.
Tip: determine n and plug it into $f_{max\ possible} = \mu_s n$.
WATCH OUT! Notice $F\sin\theta$ will appear in n!!!
Solve the inequality for F to determine a conditional statement for your code!
Expect non-zero acceleration up the plane and use $f = \mu_k n$.



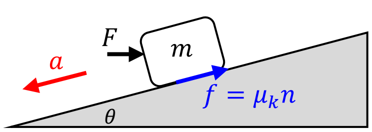
Case 2: There is enough friction to prevent the block from sliding even though you push pretty hard up the hill. In this case the component of $\vec{F}$ parallel to the plane should balance with the component of weight down the plane & friction *down* the plane. No sliding should occur. We expect $a = 0$ in this particular scenario. Note, because it is not sliding, there is static friction between m and the ramp.
WATCH OUT! **It is not sliding:** do not use $f = \mu_k n$.
It is not on the verge of slipping: do not use $f = \mu_s n$.
Get f by solving for it in the force equation parallel to the plane!



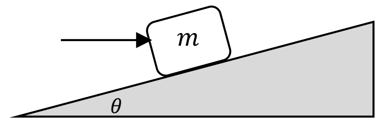
Case 3: You push on the block but not that hard. Friction points *up* the plane and helps keep the block in place. In this case the component of $\vec{F}$ parallel to the plane should balance with the component of weight down the plane & friction up the plane. No sliding should occur. We expect $a = 0$ in this particular scenario. Note, because it is not sliding, there is static friction between m and the ramp.
WATCH OUT! **It is not sliding:** do not use $f = \mu_k n$.
It is not on the verge of slipping: do not use $f = \mu_s n$.
Get f by solving for it in the force equation parallel to the plane!



Case 4: You barely push on the block at all.
Any time $F\cos\theta + f_{max\ possible} < mg\sin\theta$ the block slides *down* the plane.
Tip: determine n and plug it into $f_{max\ possible} = \mu_s n$.
WATCH OUT! Notice $F\sin\theta$ will appear in n!!!
Solve the inequality for F to determine a conditional statement for your code!
Expect non-zero acceleration up the plane and use $f = \mu_k n$.
Test cases with numbers on the next page…

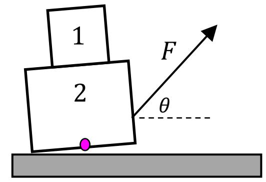


Using $m = 1.00$ kg, $\mu_s = 0.5$, $\mu_k = 0.3$, and $g = 9.8\,\frac{\text{m}}{\text{s}^2}$ one expects the following code behavior. I was rounding all the time to get this done; expect errors in third digit.

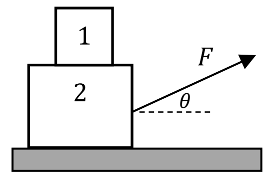


$\theta = 0°$ & $F = 4.8$ N	$n = 9.8$ N $a = 0\,\frac{\text{m}}{\text{s}^2}$ $f = 4.8$ N	$\vec{n} =< 0, 9.8, 0 >$ N $\vec{a} =< 0, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -4.8, 0, 0 >$ N
$\theta = 0°$ & $F = 4.91$ N	$n = 9.8$ N $a = 1.97\,\frac{\text{m}}{\text{s}^2}$ $f = 2.94$ N	$\vec{n} =< 0, 9.8, 0 >$ N $\vec{a} =< 1.97, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -2.94, 0, 0 >$ N
$\theta = 20°$ & $F = 10$ N	$n = 12.63$ N $a = 0\,\frac{\text{m}}{\text{s}^2}$ $f = 6.05$ N	$\vec{n} =< -4.32, 11.87, 0 >$ N $\vec{a} =< 0, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -5.69, -2.07, 0 >$ N
$\theta = 20°$ & $F = 10.5$ N	$n = 12.80$ N $a = 2.67\,\frac{\text{m}}{\text{s}^2}$ $f = 3.84$ N	$\vec{n} =< -4.37, 12.03, 0 >$ N $\vec{a} =< 2.51, 0.915, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -3.61, -1.31, 0 >$ N
$\theta = 26.4°$ & $F = 0$ N	$n = 8.78$ N $a = 0\,\frac{\text{m}}{\text{s}^2}$ $f = 4.35$ N	$\vec{n} =< -3.90, 7.86, 0 >$ N $\vec{a} =< 0, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< 3.90, 1.94, 0 >$ N
$\theta = 26.6°$ & $F = 0$ N	$n = 8.77$ N $a = 1.76\,\frac{\text{m}}{\text{s}^2}$ $f = 2.63$ N	$\vec{n} =< -3.92, 7.84, 0 >$ N $\vec{a} =< -1.57, -0.79, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< 2.35, 1.18, 0 >$ N
$\theta = 40°$ & $F = 2.3$ N	$n = 8.99$ N $a = 1.84\,\frac{\text{m}}{\text{s}^2}$ $f = 2.70$ N	$\vec{n} =< -5.78, 6.89, 0 >$ N $\vec{a} =< -1.41, -1.18, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< 2.07, 1.74, 0 >$ N
$\theta = 40°$ & $F = 2.4$ N	$n = 9.05$ N $a = 0\,\frac{\text{m}}{\text{s}^2}$ $f = 4.46$ N	$\vec{n} =< -5.82, 6.93, 0 >$ N $\vec{a} =< 0, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< 3.42, 2.87, 0 >$ N
$\theta = 40°$ & $F = 22.0$ N	$n = 21.6$ N $a = 0\,\frac{\text{m}}{\text{s}^2}$ $f = 10.55$ N	$\vec{n} =< -13.9, 16.6, 0 >$ N $\vec{a} =< 0, 0, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -8.08, -6.78, 0 >$ N
$\theta = 40°$ & $F = 22.7$ N	$n = 22.1$ N $a = 4.46\,\frac{\text{m}}{\text{s}^2}$ $f = 6.63$ N	$\vec{n} =< -14.21, 16.93, 0 >$ N $\vec{a} =< 3.42, 2.87, 0 > \frac{\text{m}}{\text{s}^2}$ $\vec{f} =< -5.07, -4.26, 0 >$ N
If $\theta = 63.4°$ you should be able to accelerate upwards (but only if $F = HUGE$).		
If $\theta > 63.5°$, it should be impossible to make the block accelerate *up* the plane.		

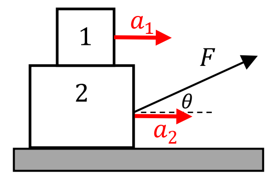
OPTION 3: With the system shown at right we expect 4 significant cases for the simulation.



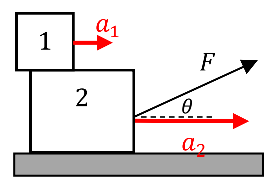
Case 1: Any time $F \sin\theta > (m_1 + m_2)g$ your code should produce an error message. Think: when this condition is met the vertical component of tension is larger than the total weight. The blocks would lift off the table and start to twist. This is beyond the scope of our class during Chapter 6 work. Note: partial lift-off can be avoided by connecting the string at the pink dot.



Case 2: There is enough friction to prevent the blocks from sliding even though you pull on them. In this case the horizontal component of $\vec{F}$ should balance with friction and no sliding should occur. We expect $a_1 = a_2 = 0$ in this particular scenario. Note, because it is not sliding, no friction is required between m_1 & m_2! There is static friction between m_2 and the floor.
WATCH OUT! **It is not sliding:** do not use $f_{2floor} = \mu_k n_{2floor}$.
It is not on the verge of slipping: do not use $f_{2floor} = \mu_s n_{2floor}$.
Get f_{2floor} by solving for it using the system horizontal force equation.

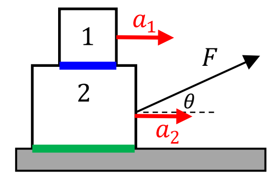


Case 3: There is insufficient friction to prevent the m_2 from sliding.
HOWEVER, there is sufficient friction to keep m_1 moving in unison with m_2.
We expect $a_1 = a_2 = a = \frac{F\cos\theta - f_{2floor}}{m_{total}}$ in this particular scenario.
Friction between the floor and m_2 is kinetic using $f_{2floor} = \mu_k n_{2floor}$.
WATCH OUT! Normal force n_{2floor} is not $m_{total}g$ due to the vertical component of F!
WATCH OUT! **Block $\boldsymbol{m_1}$ is not sliding relative to $\boldsymbol{m_2}$:** do not use $f_{12} = \mu_{k\,12} n_{12}$.
It is not on the verge of slipping: do not use $f_{12} = \mu_{s\,12} n_{12}$.
Get f_{12} by solving for it using the horizontal force equation for block m_1.
I haven't thought this through completely, but perhaps this scenario can only occurs when $\mu_{s\,12} > \mu_{s\,2floor}$???



Case 4: There is insufficient friction to prevent the m_2 from sliding.
In addition, there is insufficient friction to keep m_1 moving in unison with m_2.
WATCH OUT! The system FBD is no longer valid so we can no longer use $a = \frac{F\cos\theta - f_{2floor}}{m_{total}}$!
We use kinetic friction at both interfaces: $f_{12} = \mu_{k\,12} n_{12}$ and $f_{2floor} = \mu_k n_{2floor}$.
WATCH OUT! Normal force n_{2floor} is not $m_{total}g$ due to the vertical component of F!
Do each FBD separately to get two force equations. Solve one for a_1 and the other for a_2.
We expect $a_1 < a_2$ when all is said and done.

Test cases with numbers on the next page…



I set my parameters to $m_1 = 1.00$ kg, $m_2 = 4.00$ kg, $\mu_{s12} = 0.7$, $\mu_{k12} = 0.6$, $\mu_{s2floor} = 0.5$, $\mu_{k2floor} = 0.4$, and $g = 9.8\,\frac{\text{m}}{\text{s}^2}$. With these values I expect the following code behavior. I was rounding all the time to get this done; expect errors in third digit.

Expect lift-off error when $T > 143.3$ N at $\theta = 20°$.	
Expect lift-off error when $T > 56.6$ N at $\theta = 60°$.	
$\theta = 0°$ & $F = 24.0$ N	$n_{2floor} = 49$ N $a_1 = a_2 = 0\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 0$ N $f_{2floor} = 24.0$ N
$\theta = 0°$ & $F = 24.6$ N	$n_{2floor} = 49$ N $a_1 = a_2 = 1\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 1$ N $f_{2floor} = 19.6$ N
$\theta = 0°$ & $F = 34.2$ N	$n_{2floor} = 49$ N $a_1 = a_2 = 2.92\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 2.92$ N $f_{2floor} = 19.6$ N
$\theta = 0°$ & $F = 53.8$ N	$n_{2floor} = 49$ N $a_1 = a_2 = 6.84\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 6.84$ N $f_{2floor} = 19.6$ N
$\theta = 0°$ & $F = 54.0$ N	$n_{2floor} = 49$ N $a_1 = 5.88\,\frac{\text{m}}{\text{s}^2}$ & $a_2 = 7.13\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 5.88$ N $f_{2floor} = 19.6$ N
$\theta = 15°$ & $F = 50.2$ N	$n_{2floor} = 36.0$ N $a_1 = a_2 = 6.82\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 6.82$ N $f_{2floor} = 14.4$ N
$\theta = 15°$ & $F = 50.5$ N	$n_{2floor} = 35.9$ N $a_1 = 5.88\,\frac{\text{m}}{\text{s}^2}$ & $a_2 = 7.13\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 5.88$ N $f_{2floor} = 14.37$ N
$\theta = 10°$ & $F = 20.0$ N	$n_{2floor} = 45.5$ N $a_1 = a_2 = 0\,\frac{\text{m}}{\text{s}^2}$ $f_{12} = 0$ N $f_{2floor} = 19.7$ N