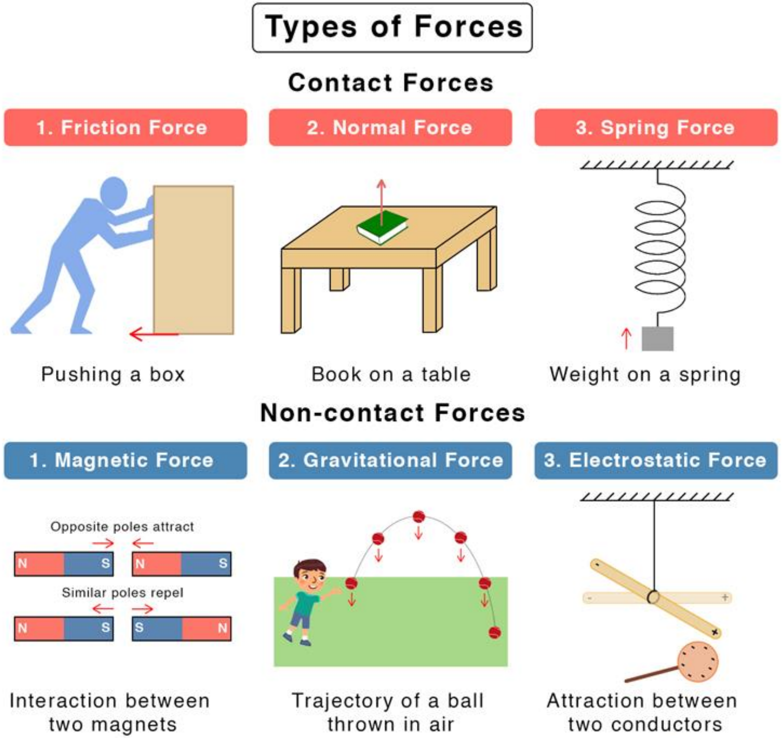
# Forces

# What is a force?

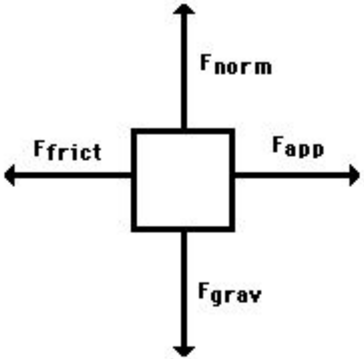
- A push or pull on an object that causes it to move
  - Units: Newtons (N)
  - Forces cause acceleration!!
- Common types of forces:
  - **Applied**
  - **Friction**
  - **Normal** (stops objects from going through each other)
  - **Tension**: string
  - **Gravity**
  - **Restoring** (spring)
  - **Drag** (air resistance)



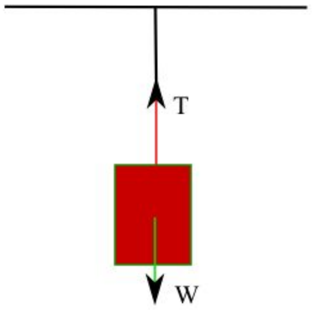
# Newton's Laws

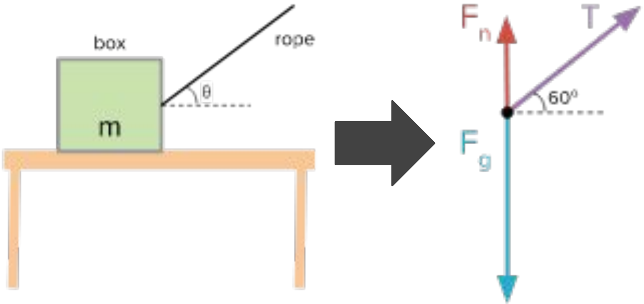
| Newton's laws of motion in physics | |
|---|---|
| LAW #1 | A body at rest will remain at rest, and a body in motion will remain in motion unless it is acted upon by an external force. |
| LAW #2 | The force acting on an object is equal to the mass of that object times its acceleration, F = ma. |
| LAW #3 | For every action, there is an equal and opposite reaction. |

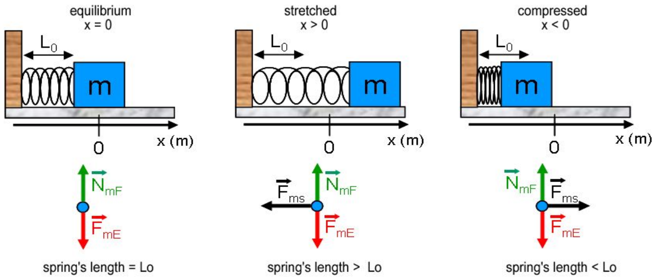
# Free Body Diagrams

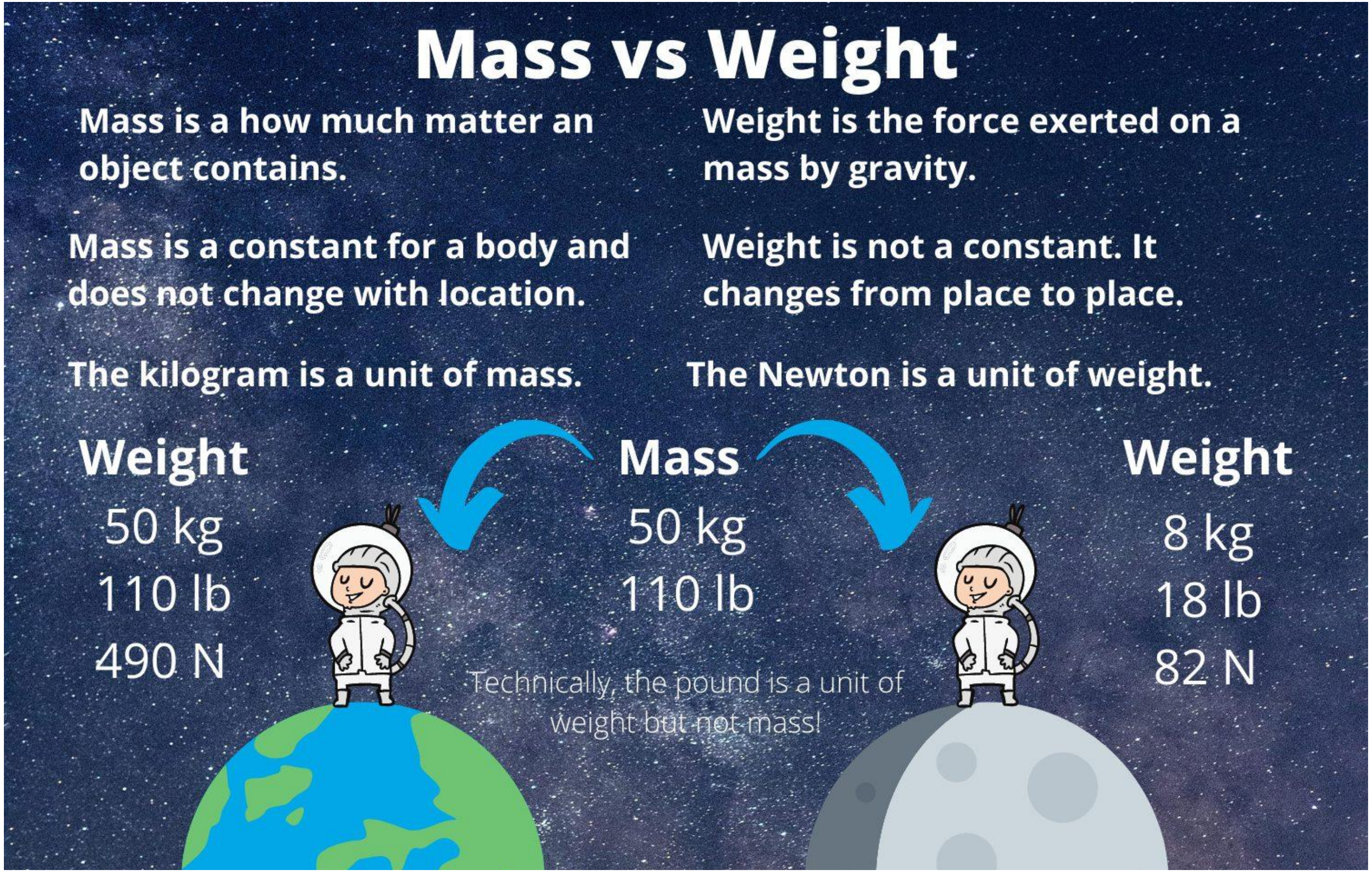



- Helps visualize forces on an object
- Indicate **magnitude** and **direction** of a force on an object with arrows + labels
- Net force = sum of all the forces on an object
- It is helpful to split the forces into x and y components (like what we did with velocity in kinematics)



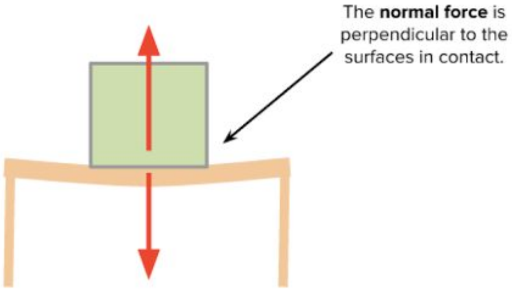




Mass vs Weight
Mass is a how much matter an object contains.
Weight is the force exerted on a mass by gravity.
Mass is a constant for a body and does not change with location.
Weight is not a constant. It changes from place to place.
The kilogram is a unit of mass.
The Newton is a unit of weight.
Weight
50 kg
110 lb
490 N
Mass
50 kg
110 lb
Weight
8 kg
18 lb
82 N
Technically, the pound is a unit of weight but not mass!

# Other important forces

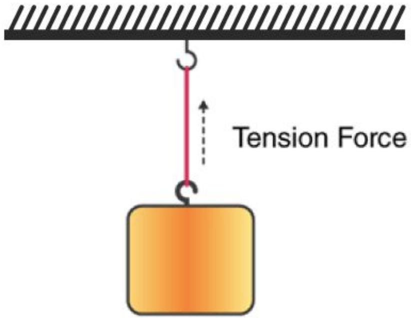
## Normal Force:

- There MUST BE CONTACT
- Every solid deforms slightly
  - Spring force “restores”



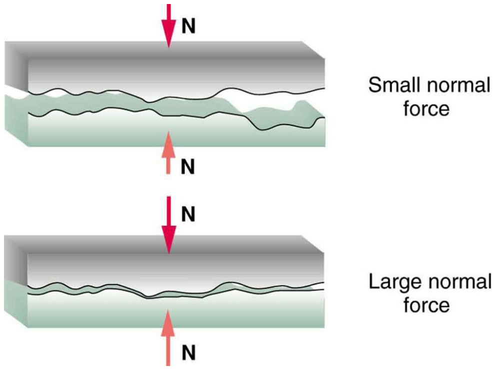

## Tension:

- Only PULLS
- Strings ~ tiny masses connected by springs



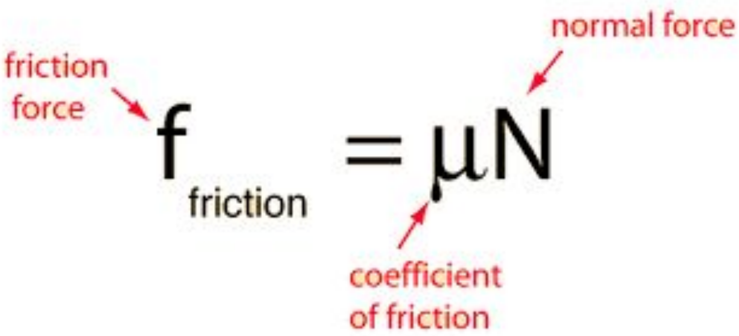

## Friction:

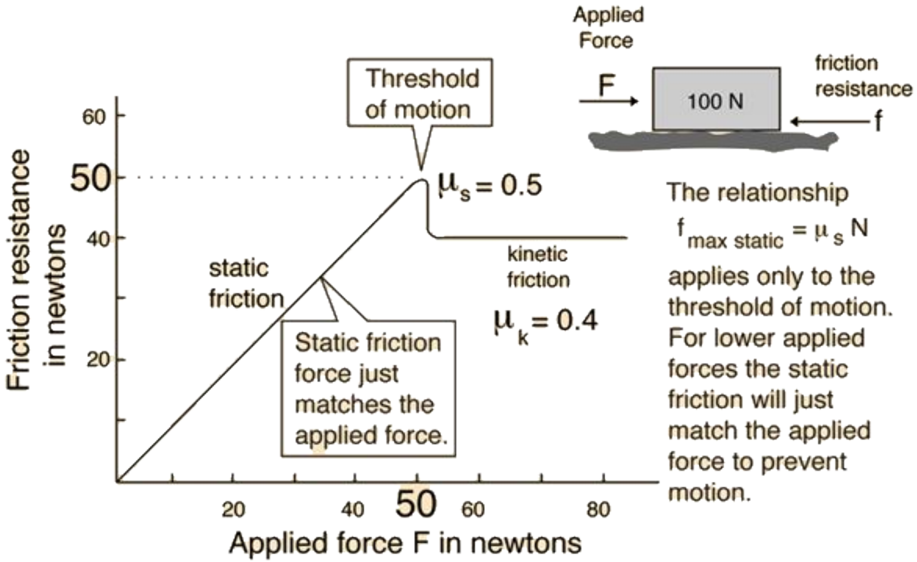
- Tiny bumps in any surface



# Types of Friction

- Kinetic - moving
- Static - not moving



# Example 1: Block on plane

- Perfectly Smooth surface

At Rest:

Moving Right:

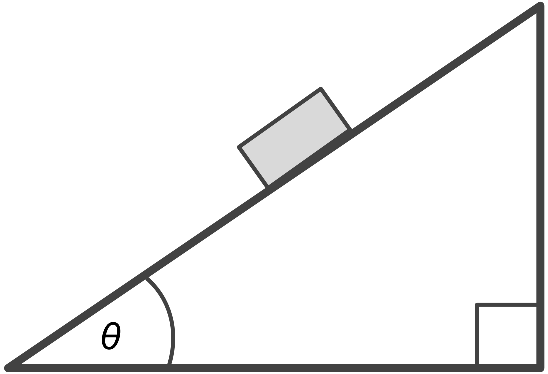
- Rough surface

At Rest:

Moving Right:

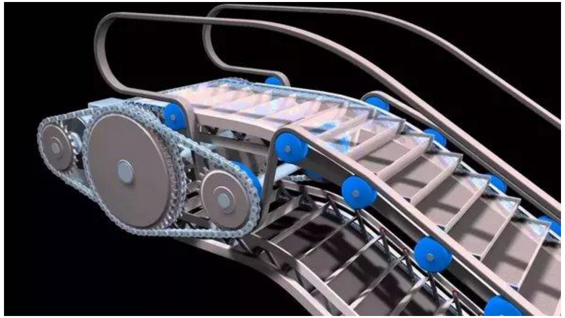
# Example 2: Block on rough, inclined plane

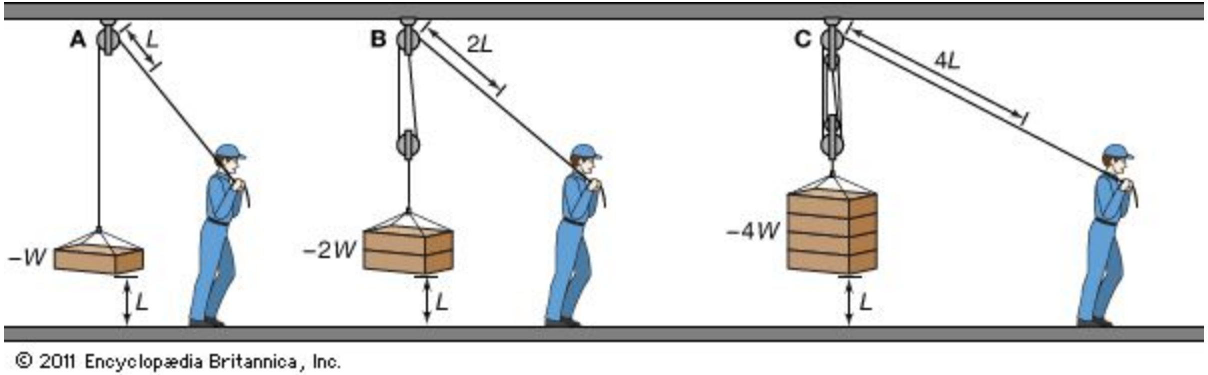
- Draw a FBD for the gray block

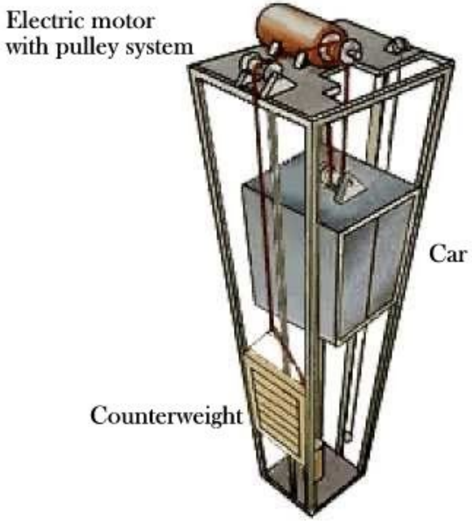


# Pulley

- Make life easier - can you think of examples?



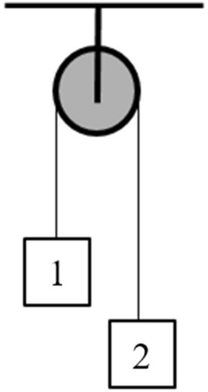


# Atwood Machines

- Negligible mass/friction in pulley
- mass of block 2 (m2) > mass of block 1 (m1)
- the blocks move with the same speed/acceleration

1. Draw free body diagrams for blocks 1 and 2
2. Write net force equations (2nd Law) for both blocks
3. Algebraically manipulate to solve for acceleration



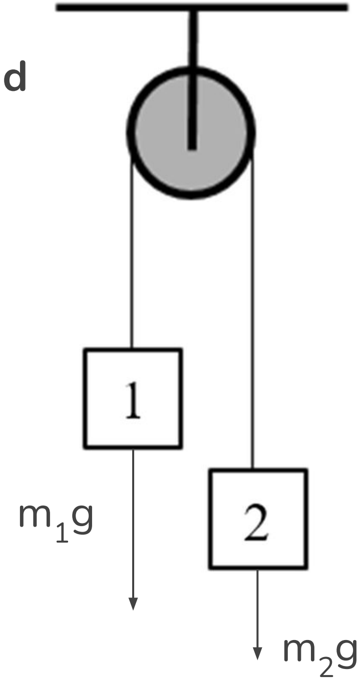

# Atwood Machines (but the shortcut way)

- Notice how the tensions will always cancel out because the **pulley is massless (we will see why this matters when we get to rotation) and both blocks are connected to the same string**
- So we can just "skip" the part where the tensions cancel
- Think of the gravitational forces as two forces that are pulling on the string in opposite directions

$$F_{net} = F_1 - F_2 = m_1 g - m_2 g = (m_1 - m_2)g$$

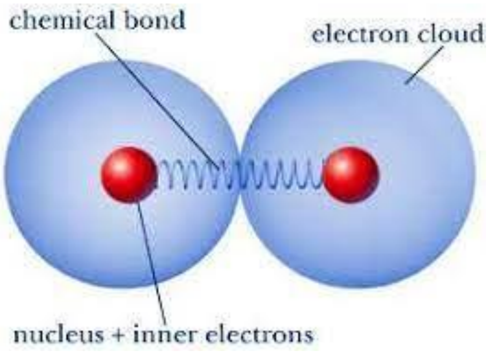
$$F_{net} = m_{total} a = (m_1 + m_2)a$$

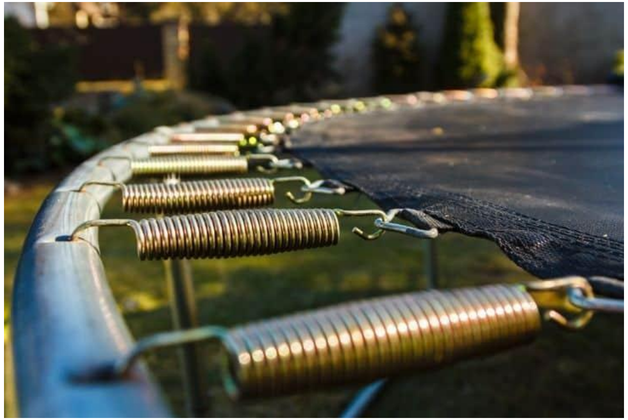
$$\Rightarrow a = (m_1 - m_2)g/(m_1 + m_2)$$



# Springs

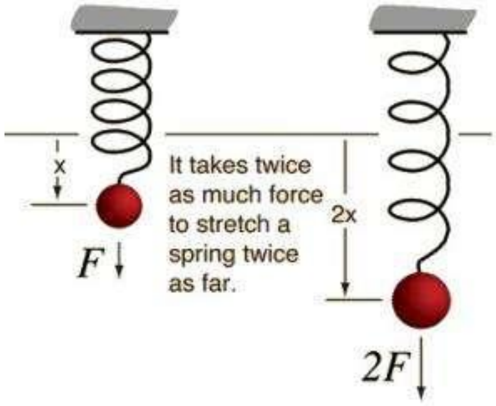
- Sometimes make life easier
- Spring force responsible for NORMAL force
- Chemical bonds often modeled as springs



# Hooke's Law

- $F = -kx$
- k = spring constant (a larger spring constant means the spring is more stiff → for the same displacement, you need a bigger force)
- x = how far the spring is pushed or pulled
- Notice the negative sign!
  - Sometimes you won't see this ($F = kx$ is the magnitude of the force)
- Then why is it negative?
  - A spring always resists the force you apply
  - If you pull down, the spring will try to pull up because that's just how springs work → spring force is always opposite of the applied force F

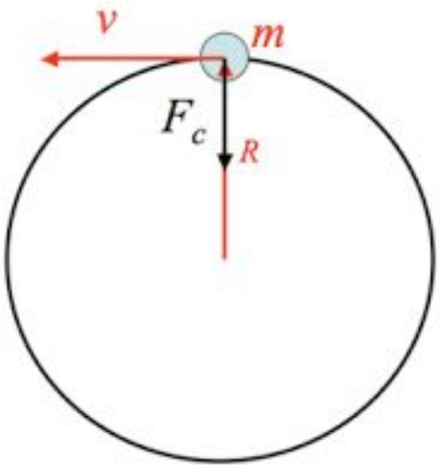


# Example: Hanging Spring

Luke decides to go bungee jumping at the Del Mar Fair from 150 m off the ground. Luke weighs 60 kg and the bungee cords can be modeled as a spring with an unstretched length of 32 m and spring constant 5 N/m. Does he die?

# Centripetal Force

- Force pointing towards center
- $F_c = mv^2/r$
  - $F_c$ = Centripetal Force
  - m = mass
  - v = velocity
- Common causes of centripetal force:
  - Tension
  - Gravity (Orbits)
  - Normal Force

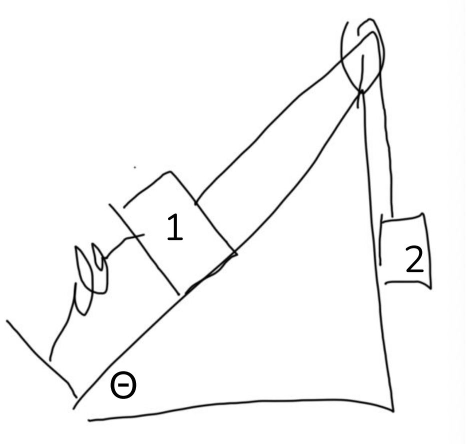



# Practice problem

A block is hung from a rope on a pulley which is connected to a block on a rough inclined plane connected to a spring... you know what you should just look at the drawing:

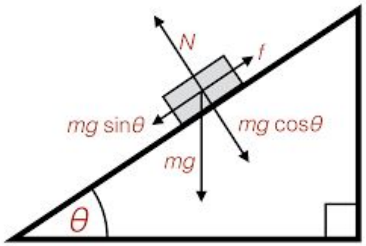
$$\sum F = ma$$

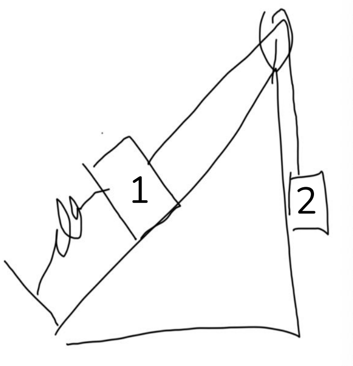
$$F_s = -kx$$



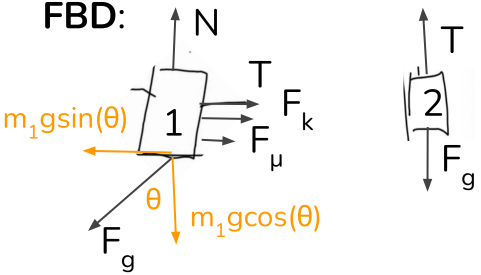

$m_2 < m_1\sin(\text{theta})$, and the system is at rest.

How much does the spring compress?






**FBD:**




**Equations:**

Block 2: $F_y = 0 = T - F_g$

$F_x = 0$

Block 1: $F_y = N - m_1 g\cos(\theta) = 0$

$F_x = T + F_\mu + F_k - m_1 g\sin(\theta) = 0$

**Algebra:**

$T = F_g = m_2 g$

$T = m_1 g\sin(\theta) - F_k - F_\mu$

$F_k = kx$

$F_\mu = \mu N$

$N = m_1 g\cos(\theta)$

$F_\mu = \mu m_1 g\cos(\theta)$

$m_2 g = m_1 g\sin(\theta) - kx - \mu m_1 g\cos(\theta)$

$kx = m_1 g\sin(\theta) - \mu m_1 g\cos(\theta) - m_2 g$

$x = (m_1 g\sin(\theta) - \mu m_1 g\cos(\theta) - m_2 g)/k$

**$x = g(m_1\sin(\theta) - m_1\cos(\theta) - m_2)/k$**

# Fictitious Forces

- We need to worry about fictitious forces when we are in **noninertial (accelerating) reference frames**
- It's a "force" that we feel from the movement of the reference frame
- It's fictitious because there isn't actually a force on you, but you feel a force because of the reference frame
  - You feel a force in the **opposite direction** of the acceleration of the frame
- Example: centrifugal force