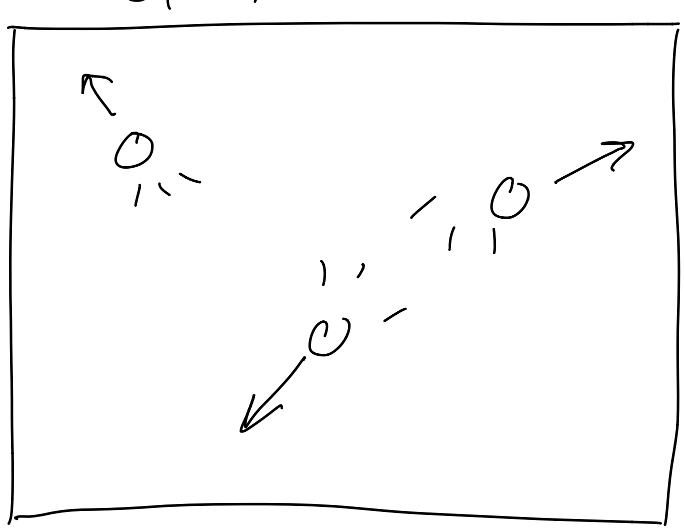
Think about the air in this room

What is air?

A bunch of atoms, mostly nitrogen & oxygen, moving around randomly

At room temp, $v \sim 500$ m/s (1100 mph)

Not like solids



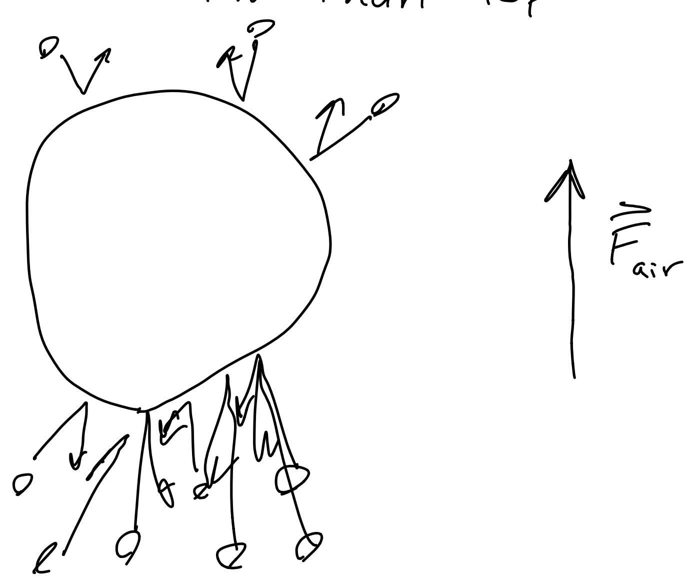
On average, $\vec{v} = 0$ (no preferred direction)

- Air molecules are constantly bombarding you from every direction

- Each time they collide, they exert a force on you (very small, since mass of a molecule is very small (2×10^{-23} g))

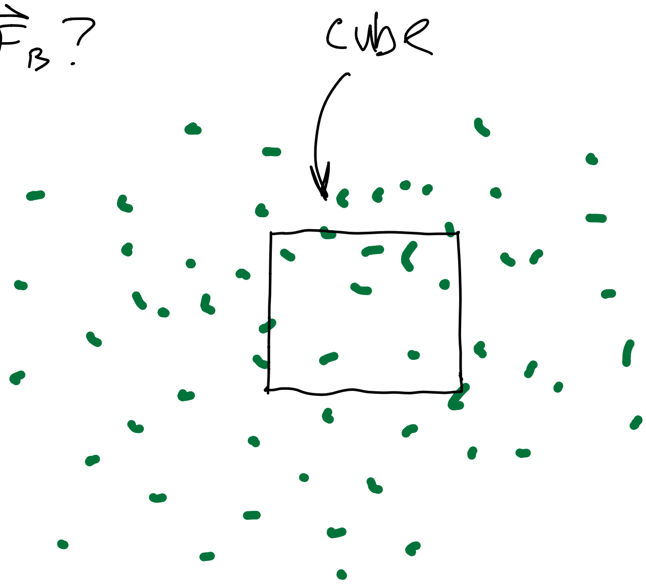
- But air gets less dense w/ altitude (due to gravity)

- more collisions on bottom than top



This is the buoyant force $\vec{F}_B$

What is $\vec{F}_B$?



molecules are always entering & exiting the box, but on average, the air density in the box is the same as everywhere around it

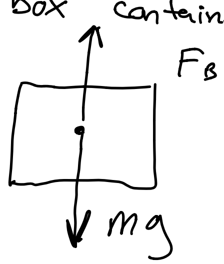
- the box is not moving ($p = 0$)

If it were moving, we would feel a rush of air

This means that $\vec{F}_{net} = 0$ on the box

What are the forces?

The box contains air, which has mass

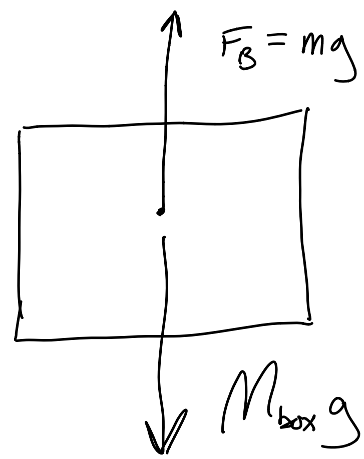


m is the total mass of air in the box

$F_B - mg = 0 \Rightarrow F_B = mg$

- Now, remove the box of air & replace it with an actual box filled with something (mass $= M_{box}$)

sum forces:



$$|\vec{F}_{net}| = mg - M_{box}\,g$$

Upward force equal to the weight of the air displaced by the object

if box has a volume V, the

$$m = (\text{air density} \left[\tfrac{kg}{m^3}\right] \times V \left[m^3\right]$$

$$m = \rho_{air} V$$

$$F_B = \rho_{air} V g$$

$$F_{net} = \rho_{air} V g - M g$$

$$F_{net} = (\rho_{air} - \rho_{box}) V g$$

$$F_{net} = (\rho_{air} - \rho_{obj}) V_{obj}\, g$$

Object is:

- less dense than air?
  float upward
- as dense as air?
  not move
- denser than air?
  sink

Same principle applies to water:

$$F_B = \rho_{water} V_{obj}\, g$$

$$F_{net} = (\rho_{water} - \rho_{obj}) V_{obj}\, g$$

This is why an 800 million lb aircraft carrier floats

Why you sink in water when you exhale all air

That's it for Ch. 4

We will learn nothing new in Chapter 5.

Basic principles

Momentum:

$\Delta\vec{p} = \vec{F}_{net}\Delta t$

$\frac{d\vec{p}}{dt} = \vec{F}_{net}$

Cons of momentum: $\Delta\vec{p}_{sys} + \Delta\vec{p}_{sur} = \vec{0}$

We've learned how to calculate forces & predict how a system will respond

Ex: const force $(\vec{F} = \langle 0, -mg, 0\rangle)$

Ex: spring force

$F = kx \qquad x(t) = A\cos(\omega t)$

- In Ch 5, we simply want to reverse this process

If I know the momentum (+ $\frac{d\vec{p}}{dt}$) I can deduce the force

$\frac{d\vec{p}}{dt} = \vec{F}_{net}$

Know want

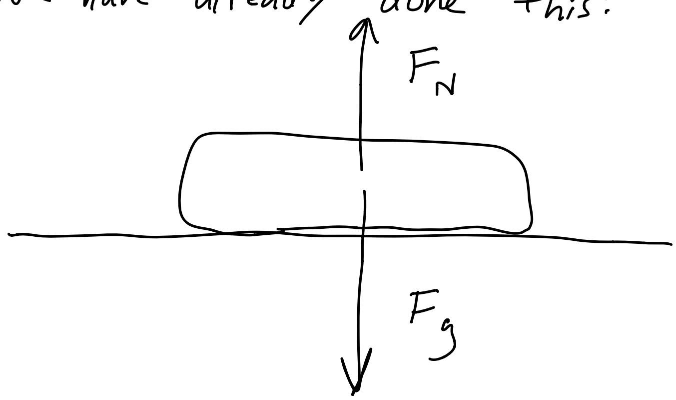
Usually, our system is subject to several forces.

Some we know, some we do not.

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}, \quad \text{solve for } \vec{F}_2$$

- We have already done this!

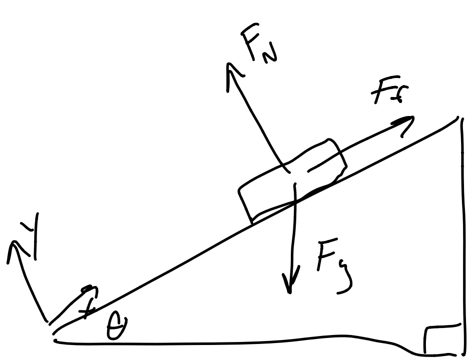


Since $\frac{dp_y}{dt} = 0$, $F_{net,y} = 0$

$$F_N - F_g = 0 \implies F_N = F_g$$

$$F_N = mg$$

Ex:



Know $\frac{dp_y}{dt} = 0$

Know F_g, find F_N

Two possibilities for $\frac{d\vec{p}}{dt}$

$$\frac{d\vec{p}}{dt} = \vec{0} \qquad \text{(statics)}$$

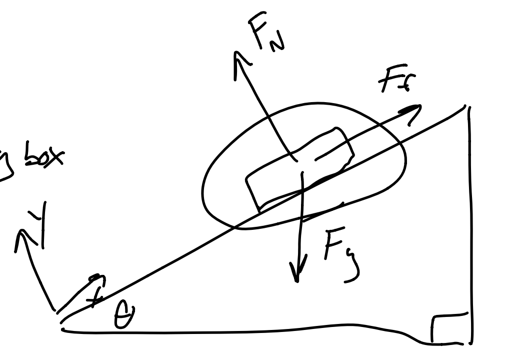
$$\frac{d\vec{p}}{dt} \neq \vec{0} \qquad \text{(dynamics)}$$

A systematic approach

① Choose a system

- The object whose motion you are interested in

Ex:
System: Sliding box
Surr: Earth, ramp



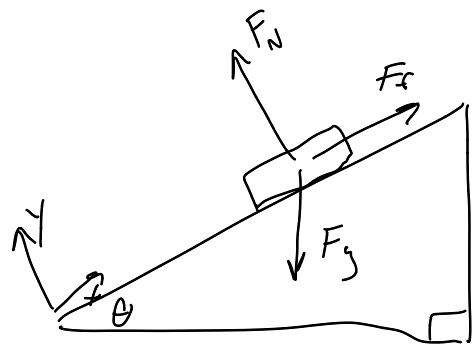
- Can choose anything, but be consistent

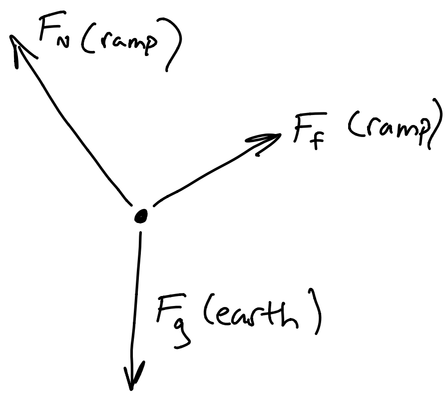
② List all forces acting on the system

- distance forces (grav, e+m)
- contact force (normal, Friction, tension)

Free body diagrams

- Draw the system as a dot
- Draw all forces as arrows
- Label each force



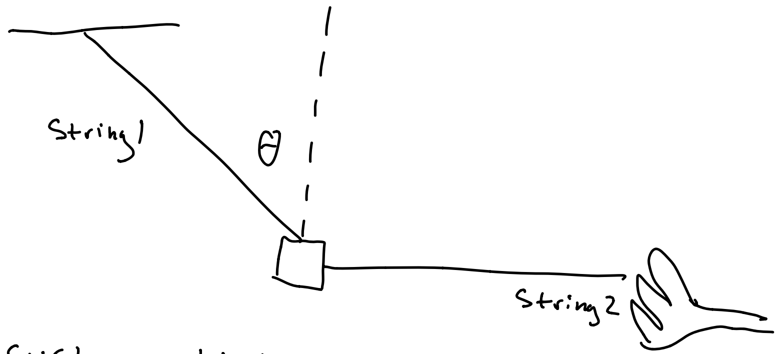


Label: a symbol to use in equations + identify object causing the force

This is very important!

- Don't need to draw arrows to scale (you don't know the magnitude of all forces yet)

CQ 5.4.a



① System: block

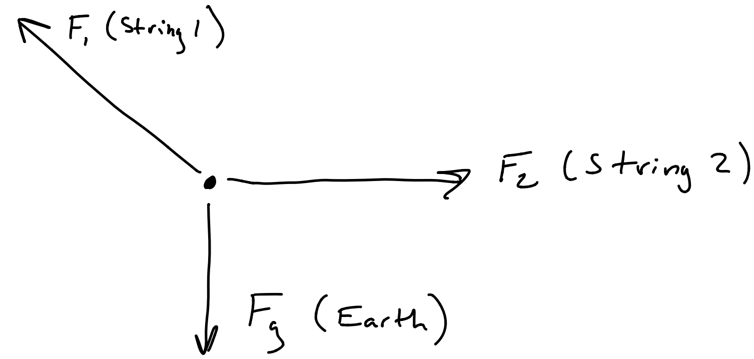
Earth, String 1, String 2

Block is the system

- Ceiling + hand aren't touching block
- Block isn't charged (no F_{elec})
- grav force between block + hand/ceiling is ignorable
- Ceiling + hand can't exert a force on the block

- Ceiling + hand exert force on String 1 + String 2
- String 1 + String 2 exert forces on block

FBD



Now we've identified all forces

- Find an expression for $\vec{F}_{net}$
- Find $\frac{d\vec{p}}{dt}$
- Solve

To find $\vec{F}_{net}$, we need x, y, z components of every force

$$\vec{F}_1 = \langle F_{1x}, F_{1y}, F_{1z} \rangle$$

$$\vec{F}_2 = \langle F_{2x}, F_{2y}, F_{2z} \rangle$$

$$\vec{F}_{net} = = \langle F_{1x} + F_{2x}, F_{1y} + F_{2y}, F_{1z} + F_{2z} \rangle$$

3 Pick a coordinate system

- can be anything
- default to