Foothold ideas: Dimensions and units

- Each measurement is a counting of something. It matters what kind of thing we are counting.
- The kind of counting we are doing is expressed in terms of basic types: dimensions (M, L, T).
- Only measurements of the same dimensionality can be added or equated since the dimensionality tells how the measurement changes when the scale is changed. (cf., length [L], area [L^2], volume [L^3])
- The specific scale chosen for a measurement is the unit.

Foothold ideas: Velocity

- Velocity is the rate of change of position
- Average velocity

  = (how far did you go?)/(how long did it take you?)

$$\langle v \rangle = \frac{\Delta x}{\Delta t}$$

- Instantaneous velocity = same (but for short Δt)

$$v = \frac{dx}{dt}$$

Foothold ideas: Vector velocity

- A displacement – a change in position – has a direction. This means

  velocity = displacement/time interval

  has one too.

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$v_x\hat{i} + v_y\hat{j} = \frac{d}{dt}\left(x\hat{i} + y\hat{j}\right) = \left(\frac{dx}{dt}\right)\hat{i} + \left(\frac{dy}{dt}\right)\hat{j}$$

Foothold ideas: Acceleration

- Average acceleration is defined by

$$\langle \vec{a} \rangle = \frac{\Delta \vec{v}}{\Delta t} = \frac{\text{change in velocity}}{\text{time it took to do it}}$$

Note: an average acceleration goes witha <u>time interval</u>.

- Instantaneous acceleration is what we get when we consider a very small time interval (compared to times we care about)

$$\vec{a} = \frac{d\vec{v}}{dt}$$

Note: an instantaneous acceleration goes with a <u>specific time</u>.

What have we learned? ☑

- Position $\hat{r} = x\hat{i} + y\hat{j}$
  (where *x* and *y* are signed lengths)
- Velocity $\langle \vec{v} \rangle = \dfrac{\Delta \vec{r}}{\Delta t}$ $\vec{v} = \dfrac{d\vec{r}}{dt}$
- Acceleration $\langle \vec{a} \rangle = \dfrac{\Delta \vec{v}}{\Delta t}$ $\vec{a} = \dfrac{d\vec{v}}{dt}$
- Seeing from the motion
- Seeing consistency (graphs & equations)

Newton's Laws: Version 1.0

- Newton 0:
  - An object responds to the forces it feels when it feels them.
- Newton 1:
  - An object that feels a net force of 0 keeps moving with the same velocity (which may = 0).
- Newton 2:
  - An object that is acted upon by other objects changes its velocity according to the rule

$$\vec{a}_A = \vec{F}_A^{net} / m_A$$

- Newton 3:
  - When two objects interact the forces they exert on each other are equal and opposite.

$$\vec{F}_{A\to B}^{type} = -\vec{F}_{B\to A}^{type}$$

Kinds of pForces

- pForces are what objects do to each other when they touch.
- If a pForce is a
  - Normal pForce N
  - Tension pForce T
  - Friction pForce f
  - Weight pForce W
  - Electric pForce F^E
  - Magnetic pForce F^M
- Notation convention.

$$\vec{F}^{\text{ type of force}}_{(\text{object causing force})\rightarrow(\text{object feeling force})}$$

Tension:
The Spring

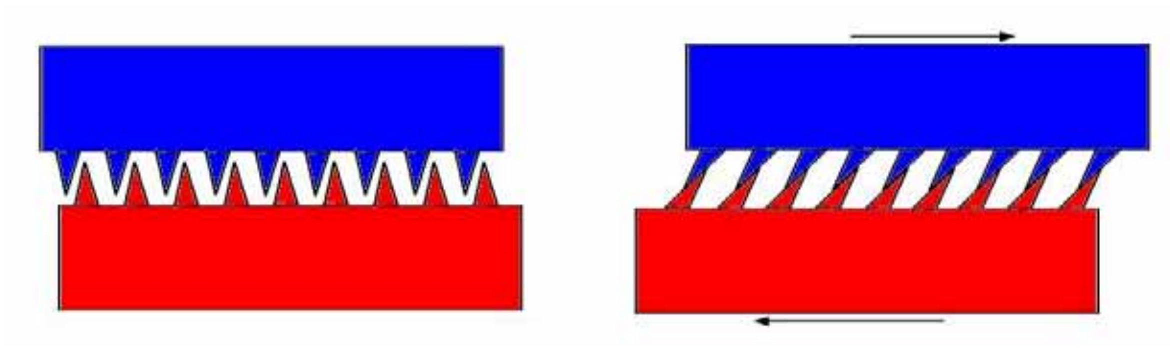
- Recall what we have learned about a spring.
- A spring changes its length in response to pulls (or pushes) from opposite directions.

$$T = k\,\Delta l$$

Friction

- When the surfaces are not sliding on each other, the friction force may take any value up to a maximum. $f_{A\to B} \leq f_{A\to B}^{\max} = \mu_{AB}^{static} N_{A\to B}$
- When the surfaces are sliding on each other, the friction force is a constant value (usually less than the maximum possible).

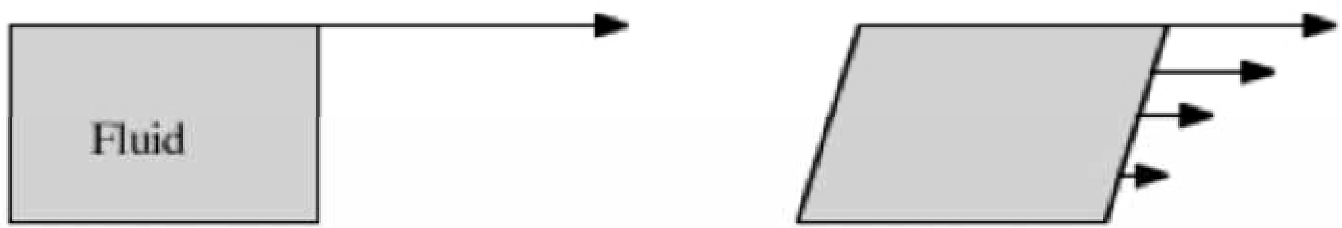
$$f_{A\to B} = \mu_{AB}^{kinetic} N_{A\to B} \qquad \mu_{AB}^{kinetic} \leq \mu_{AB}^{static}$$



Viscosity

- When sheets of fluid move over each other there is an "internal friction" that resists the sliding – but it's proportional to the relative speed.
- When a solid moves through a fluid it drags the fluid with it – which drags the fluid over fluid leading to a resistive force.
- For a sphere moving through a liquid

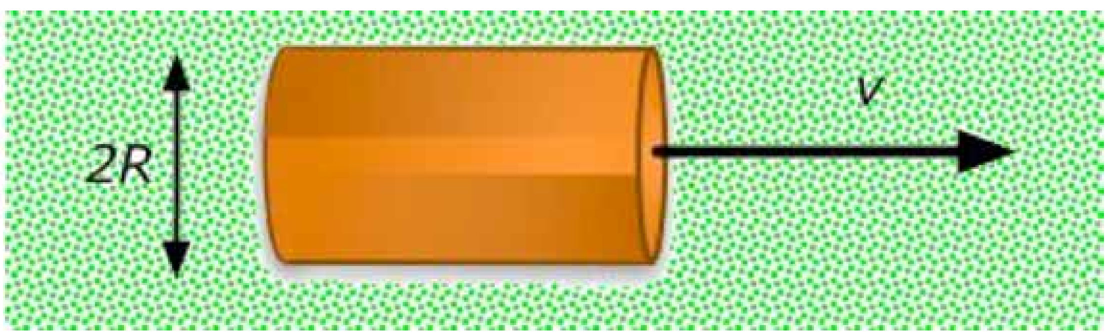
$$F^{viscous}_{liquid \to sphere} = -6\pi\mu R v$$



Drag

- When a solid object moves through a fluid it has to speed up the fluid in front of it.
- It has to exert a force on the bits of the fluid in front of it to bring it up to the object's speed. By N3, the fluid exerts a force back on the object.
- For a sphere moving through a fluid

$$F^{drag}_{fluid \rightarrow sphere} = -CdAv^2$$



The Gravitational Field Strength

- We find that, when we can ignore the effects of other objects (the air), that all objects accelerate the same in free fall (only *W* acting).

$$\vec{a}_A = \frac{\vec{W}_{E\to A}}{m_A} = \vec{g} \qquad \text{(independent of A!)}$$

- Experimentally, this is a constant independent of the object. Therefore:

$$\vec{W}_{E\to A} = m_A \vec{g}$$

- Define the constant g as the *gravitational field strength*. (Units of N/kg)

Foothold Ideas: Gravity

- Every object (near the surface of the earth) feels a downward pull proportional to its mass:

$$\vec{W}_{E\to m} = m\vec{g}$$

where $\vec{g}$ is referred to as *the gravitational field.*

What object causes *W*?

- This is a pForce even though nothing touching the object is responsible for it.
- The gravitational field has the same magnitude for all objects irrespective of their motion and at all points.
- The gravitational field always points down.
- It is measured to be $g \approx 9.8$ N/kg

Why N/kg instead of m/s^2?

Response to Gravity: Free Fall

- After an object has been released,
  - if it is dense enough so the forces from the air can be ignored
  - if nothing else is touching it

  the only force acting on it is gravity.

$$\vec{a} = \vec{F}^{net}/m = \vec{W}_{E \to m}/m = m\vec{g}/m = \vec{g}$$

“How we think” Icons

- Cat television
- Measurement
- Consistency
- Making sense
- Multiple representations
- Shopping for ideas
- Foothold ideas
- The implications game