September 30, 2016 Physics 131 Prof. E. F. Redish

- **Theme Music: Tom Petty**
  Free Fallin'
- **Cartoon: Bob Thaves**
  Frank & Ernest

Exam next week!

- What will it look like?
- How will I choose questions?
- Writing your answers
- Regrades

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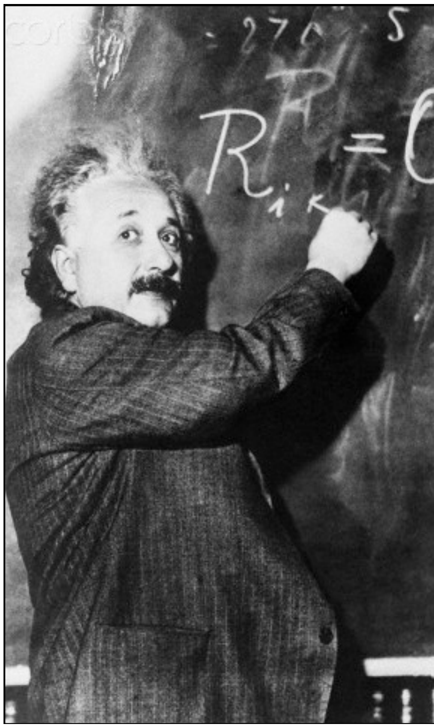

The Equation of the Day

Weight and mass

$$\vec{F}_A^{grav} = \vec{W}_A = m_A\vec{g}$$

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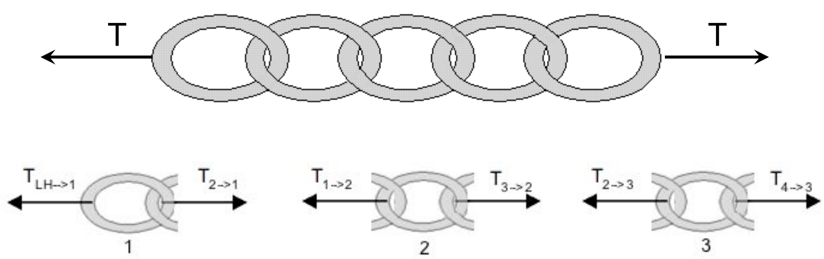
Scalar vs. Vector Tension: The Chain

- Consider a series of links of chain being pulled from opposite directions.
  What are the forces on each link?



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Alternating N2 and N3!

Tension: Scalar vs. Vector

- Note we are using the word "tension" in two distinct ways!
- The "tension" in a spring, chain, or string has no direction (or rather, both directions at once). It is a tension scalar.
- When tension appears at the end of a spring, chain, or string, the choice of end gives us a direction and lets us create a tension force.

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Foothold ideas: Models of resistive forces

- Resistive forces are contact forces acting between two touching surfaces that are parallel to the surface and tend to oppose the surfaces from sliding over each other.
- There are three common models:
  - – Friction (independent of velocity)
  - – Viscosity (proportional to velocity)
  - – Drag (proportional to the square of velocity)

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Foothold Ideas: Friction

- Friction is our name for the interaction between two touching solid surfaces that is parallel to the surface.
- It acts to oppose the relative motion of the surfaces. It acts as if the two surfaces stick together a bit.
- Normal forces adjust themselves in response to external forces. So does friction – up to a point.

Static

$$f_{A\to B} \le f^{\max}_{A\to B} = \mu^{static}_{AB} N_{A\to B}$$

Sliding

$$f_{A\to B} = \mu^{kinetic}_{AB} N_{A\to B}$$

$$\mu^{kinetic}_{AB} \le \mu^{static}_{AB}$$

- Friction is independent of velocity and only depends on how hard the two surfaces are being squeezed together.
- Friction can oppose motion or cause it.

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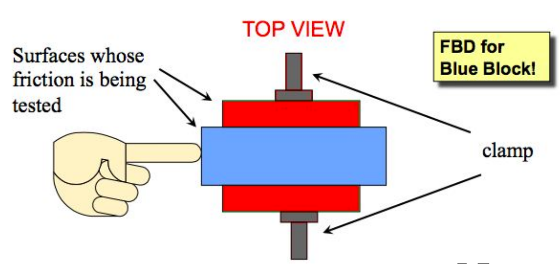
Dangerous bend!

- We deal with unsupported objects resting on something so often that we tend to think of friction as associated with gravity. That's can get you into trouble! Friction is determined by whatever force is squeezing the two surfaces together.

  Sometimes that's gravity, but often it's not.



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Foothold Ideas: Viscosity

- An object moving through a fluid (air or water) drags the fluid along with it. The fluid sticks to th side of the object. This means that the fluid next to the object is moving with respect to the fluid a bit farther away.
- The internal friction of the fluid layers sliding over themselves creates a resistive force that is proportional to velocity. $\vec{F}^{visc.}_{fluid \to A} = -b\vec{v}$
- For a small sphere of radius R moving without turbulence $b = 6\pi\mu R$ where μ is a property of the fluid.

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Foothold Ideas: Inertial Drag

- An object moving through a fluid (air or water) pushes the fluid in front of it, speeding it up. Since the object is exerting a force on the fluid, the fluid exerts a (resistive) force back on the object.
- The drag force an object feels from pushing fluid away in front of it is proportional to the square of the velocity:

$$\vec{F}^{inertial\,drag}_{fluid \to A} = -cv\vec{v} \quad \text{(vector)}$$

$$F^{inertial\,drag}_{fluid \to A} = cv^2 \quad \text{(magnitude)}$$

- For a sphere of radius R,

$$c \sim \tfrac{1}{2}\pi R^2 \rho_{fluid}$$

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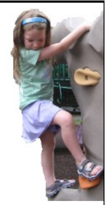
Foothold Ideas: Reynold's Number



- For objects moving in a fluid,
  they experience both viscous and drag forces.
  (And the forces can become much more complicated if there is turbulence.)
- The ratio of the drag to viscous forces is called the *Reynold's number*.

$$\mathrm{Re} = \frac{\rho_{fluid} R^2 v^2}{\mu_{fluid} R v} = \left(\frac{\rho_{fluid}}{\mu_{fluid}} \right) R v$$

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