

October 10, 2013

Physics 131

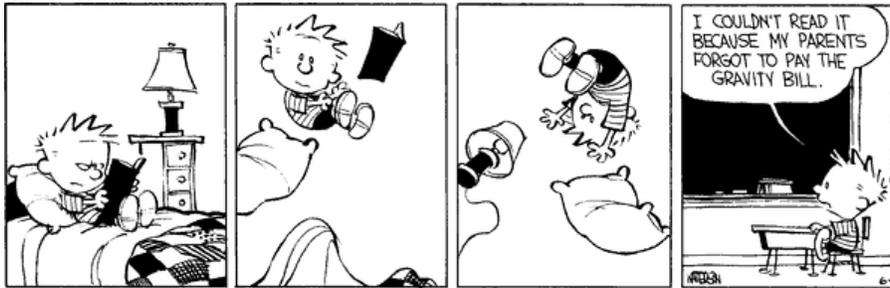
Prof. E. F. Redish

■ **Theme Music: Gravity**

John Mayer

■ **Cartoon: Bil Watterson**

Calvin & Hobbes



10/10/13

Physics 131

1

Kinds of Forces

- Forces are what objects do to each other when they interact.
- Some Forces are touching, some at a distance
 - Normal Force N
 - Tension Force T
 - Resistive Forces f, F^D, F^V
 - Weight Force W
 - Electric Force F^E
 - Magnetic Force F^M
- Notation convention.

\vec{F} type of force
 (object causing force) → (object feeling force)

10/10/13

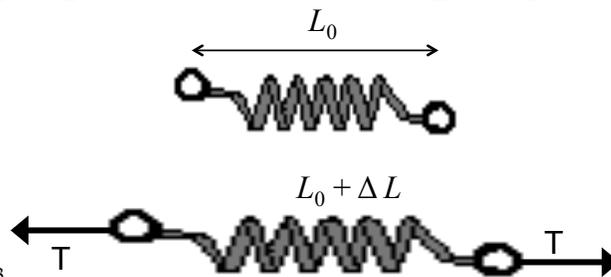
Physics 131

5

The spring as a model



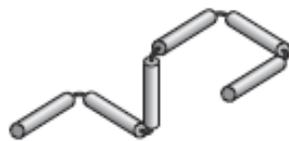
- What are the characteristics that make something “spring like”?
- What are some biological systems/properties that are “spring like”?



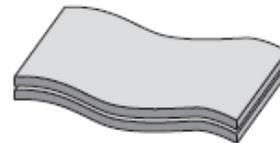
10/10/13

6

Springs in biology



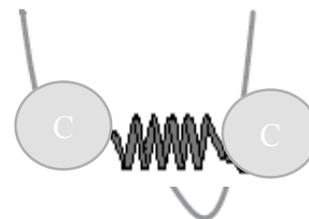
DNA polymer wiggling in solution



cell membrane fluctuating



flagellum beating on a swimming sperm



Connected Atoms in molecules

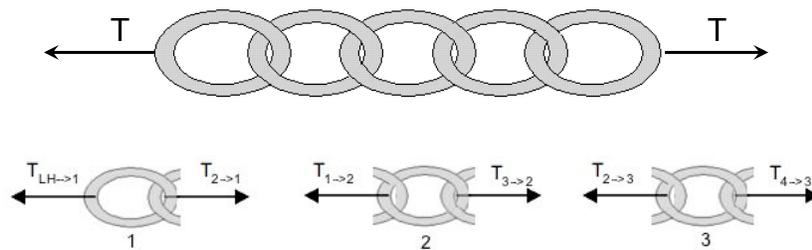
10/10/13

Physics 131

7

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?



10/10/13

Physics 131

9

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.

10/10/13

Physics 131

10

Foothold ideas: 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.
- How they behave depends on the interacting materials.
- There are three types:
 - Friction (solid-solid: independent of velocity)
 - Viscosity (solid-fluid: or fluid-fluid: proportion to velocity)
 - Drag (solid-fluid: proportional to the square of velocity)

10/10/13

Physics 131

11

Foothold ideas: Friction – solid/solid



- 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. That is, 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.

$$f_{A \rightarrow B} \leq f_{A \rightarrow B}^{\max} = \overset{\text{Static}}{\mu_{AB}^{\text{static}}} N_{A \rightarrow B} \quad \overset{\text{Sliding}}{f_{A \rightarrow B} = \mu_{AB}^{\text{kinetic}}} N_{A \rightarrow B} \quad \mu_{AB}^{\text{kinetic}} \leq \mu_{AB}^{\text{static}}$$

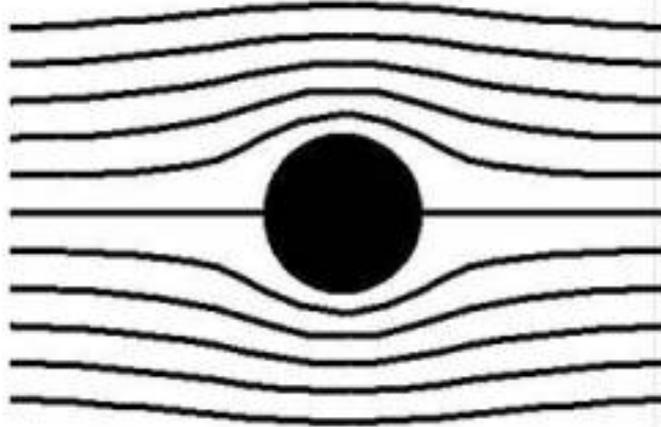
- Friction can oppose motion or cause it.

10/10/13

Physics 131

12

Objects in fluids



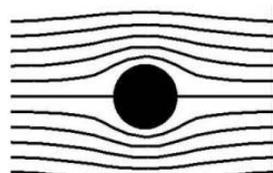
10/10/13

Physics 131

13

National Aeronautics and Space Administration

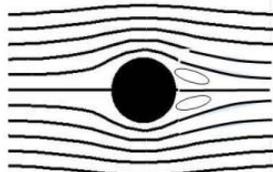
Flow Past a Cylinder



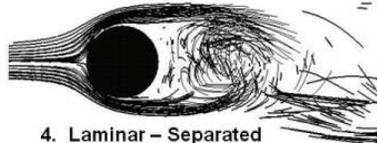
1. Ideal - Flow Attached



3. Unsteady - Oscillating



2. Separated - Steady



4. Laminar - Separated



5. Turbulent - Separated

www.nasa.gov

10/10/13

Physics 131

14

Foothold ideas: Drag force – solid/liquid



- The drag (“Newtonian drag”) is a resistive force felt by an object moving through a fluid. It arises because the object is pushing fluid in front of it, bringing it up to the same speed it’s going.
- The result is a force proportional to the density of the fluid, the area of the object, and the square of the object’s velocity.

$$F_{fluid \rightarrow object}^{drag} = C d_{fluid} A_{object} v^2$$

10/10/13

Physics 131

15

Foothold ideas: Viscosity – liquid/liquid



- Viscosity is a resistive force that an object feels when it moves through a fluid as a result of the fluid sticking to the object’s surface. This layer of fluid tries to slide over the next layer of fluid and the friction between the speeds that layer up and so on.
- The result is a force proportional to the velocity of the object.

$$\vec{F}_{fluid \rightarrow object}^{viscous} = -6\pi\mu R_{object} \vec{v}$$

10/10/13

Physics 131

16

Reynolds' Number

- Generally, for an object moving in a fluid both drag and viscosity are present. However, often, one is much more important.
- The ratio of the two forces (drag / viscosity) is called the Reynolds' Number (leaving out a few dimensionless constants)

$$Re = \frac{dvR}{\mu}$$

- Small objects in water (v , R small) are generally dominated by viscosity; larger objects in air (v , R large) tend to be dominated by drag.

10/10/13

Physics 131

17