Announcements

- Homework
  - Video Homework 3 due by midnight tonight
  - WebWorK 7 due on Wednesday
- Hoping to start Ch 5 on Wednesday.
- Polling: `rembold-class.ddns.net`

Review Question

Mystery material A has a Young's modulus of 132 GPa whereas mystery material B has a Young's modulus of 110 GPa. Without knowing anything else about the materials, what could you deduce about the intermolecular spring strengths for each of the materials?

A) A's spring constant is 1.2 times greater than material B's.

B) A's spring constant is greater than material B's, but less than 1.2 times as much.

C) B's spring constant is greater than material A's.

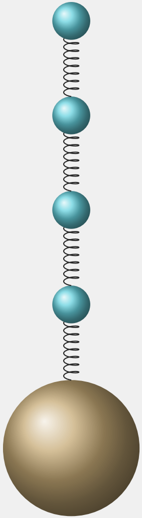
D) There is not enough information to determine which material's intermolecular spring constant will be greater.

Upcoming:

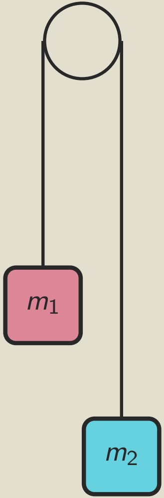
Relations to Macroscopic Forces

Tension

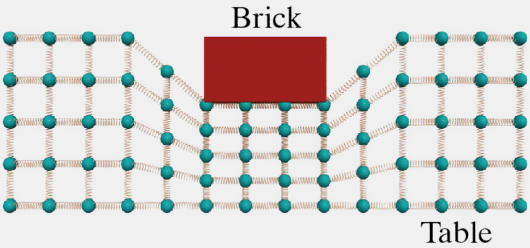
- Force exerted by wires or strings
- Propagates up the sequence of atomic springs
- If atomic masses small compared to the end mass, then force equal along entire length
    - In this situation, tension just redirects forces



An Attwood machine consists of a pulley over which a rope hangs with two masses attached to each end. Suppose the mass of the rope and pulley are tiny compared to the masses. If $m_1 = 10\,\mathrm{kg}$ and $m_2 = 14\,\mathrm{kg}$ and both start from rest, how quickly are they moving $0.5\,\mathrm{s}$ later?



Normal Forces

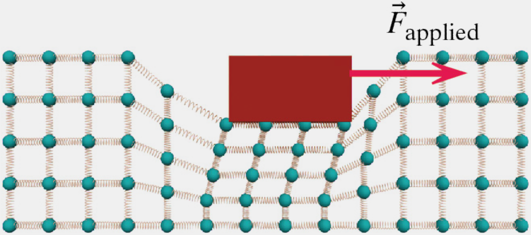


$\vec{\mathbf{F}}_N$

- When a solid object is placed atop another, they influence the atomic springs
- "Table" compresses until spring forces counteract gravity
- Force due to compression of the table atoms
- Points perpendicular to the surface
  - Hence called the normal force

Friction

- Movement of brick moving across table forces down new atoms
- Can also visualize the sideways atomic springs pushing back
- "Depth" that it has sunk plays a role
  - Related to the normal force in some fashion
- Springs left behind will bounce back and jiggle, raising temperature
- Force is parallel to the surface!



$$\left|\vec{\mathbf{F}}_{friction}\right| \approx \mu \left|\vec{\mathbf{F}}_N\right|$$

A Tale of Two Frictions

- In general, friction will not depend on the velocity
- One large exception: if the velocity is zero
  - Static Friction: friction on a non-moving object

$$F_{friction} \leq \mu_s F_N$$

  - Kinetic Friction: friction on objects moving at any other speed

$$F_{friction} \approx \mu_k F_N$$

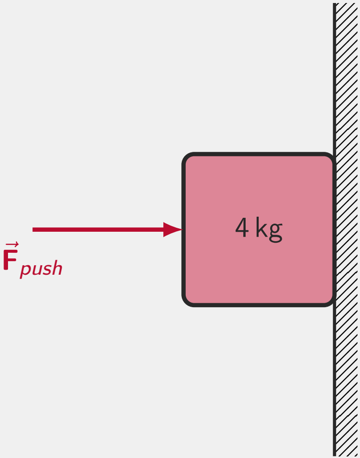
Sliding Block

Say I pull a 10 kg block across a level surface at a constant speed. If I pull with a constant force of 80 N, what is the coefficient of kinetic friction?

Understanding Check

Suppose you are pressing a 4 kg block against a wall. If the coefficient of static friction between the block and wall is 0.7, how hard must you press to ensure the block doesn't begin to slide?

A) 5.71 N
B) 27.4 N
C) 39.2 N
D) 56 N



Upcoming:

Understanding Analytic Springs

Analytic Springs

- Can write the momentum principle in differential form:

$$\Delta\vec{\mathbf{p}} = \vec{\mathbf{F}}_{net}\Delta t \quad \Rightarrow \quad \frac{d\vec{\mathbf{p}}}{dt} = \vec{\mathbf{F}}_{net}$$

- Want to find an expression for the location of a mass on a spring at any time
- Assumptions:
  - No friction or air resistance
  - Only force of the spring present
  - Mass of the spring is negligible compared to the attached masses
  - Origin is located at the relaxed length
- Implies that:

$$\frac{d\vec{\mathbf{p}}}{dt} = \vec{\mathbf{F}}_{net} \quad \Rightarrow \quad \frac{d(mv_x)}{dt} = -k_s x$$

$$m\frac{d^2x}{dt^2} = -k_s x$$

Trig Functions to the Rescue

- Need a function which is it's own double derivative
  - sin or cos will fit the bill!
- Add in some constants to generalize things:

$$x(t) = A\cos(\omega t)$$

where

$$A = \text{amplitude}$$

$$\omega = \sqrt{\frac{k_s}{m}} = \text{angular frequency}$$

- Can also talk about

$$\text{Period:} \quad T = \frac{2\pi}{\omega}$$

$$\text{Frequency:} \quad f = \frac{1}{T} = \frac{\omega}{2\pi}$$

Atomic Periods

We previously found that lead had an atomic weight of $207.2\,\mathrm{g/mol}$ and an atomic spring constant of about $4.98\,\mathrm{N/m}$. How long does it take a displaced atom to oscillate back to the same position?

Analytic vs Iterative

Now that we've returned for a bit of analytic equations, let's return to some pros and cons between the analytic and iterative methods of doing things

Analytic

- Let's us easily see general features about solutions
  - Period does not depend on amplitude
  - Increasing mass increases period
  - Increasing k_s decreases period
  - etc
- Only works for particular assumptions

Iterative

- Easy to express in three dimensions
- Can easily add new variations
  - Adding in friction or air resistance
  - Springs with non-negligible mass
  - Springs with non-ideal spring behavior
  - etc

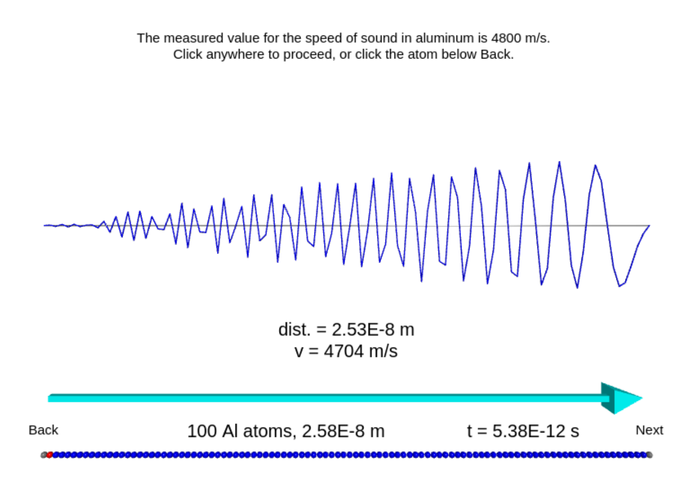
Upcoming:

The Speed of Information

Sound Propagation

- One side of a solid object doesn't react instantly to what is happening on the other side
- Information has to get transmitted through the atomic springs
- Stiffer springs oscillate quicker
- Materials with stiffer atomic springs "react" faster to effects on the far side
- Sound is a principle example of these displacements

Spring and Glowscript Demo

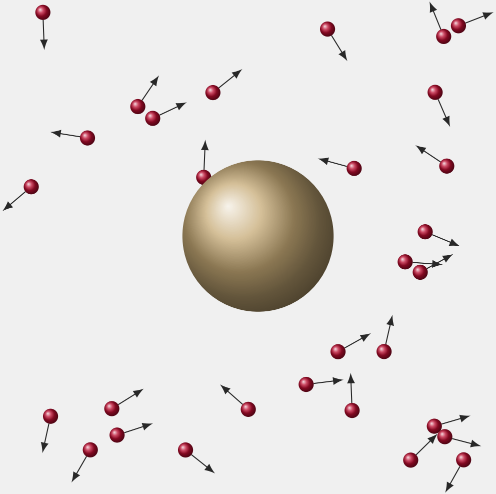


Upcoming:

Fluid Contact Forces

Bouncy Forces

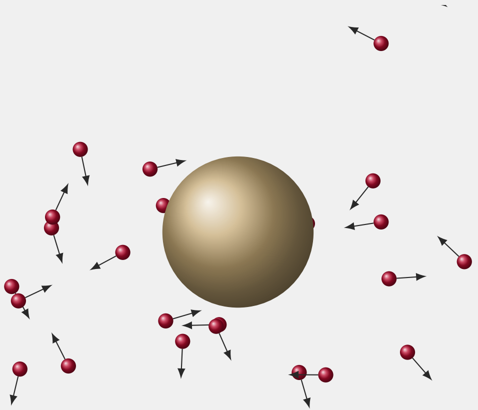
- Contact Forces can take different forms
- Approximated solids with springs because of crystal-like structure
- Fluids (including gases) operate in a more free fashion
- Apply a contact force by bombarding a surface
  - Atoms/Molecules bounce back $\Rightarrow$ change in momentum



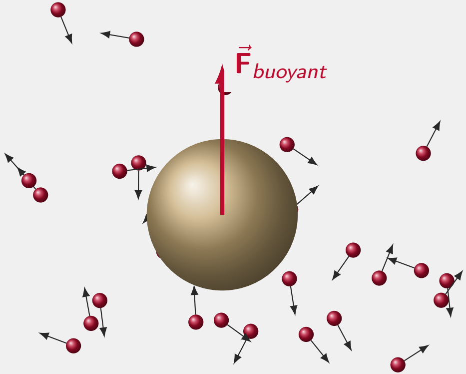
- Total force applied depends on the area being struck by the atoms
- Define pressure as

$$P = \frac{F}{A}$$

  where A is the area being bombarded
- Standard unit is a $\mathrm{N/m^2}$ or a Pascal (Pa)
- Can determine force due to pressure by multiplying the pressure by the area



- In practice, gravity pushes more things towards the bottom
- More atoms $\Rightarrow$ more bombardments $\Rightarrow$ more pressure $\Rightarrow$ greater force
- Bottom of object feels a greater force due to pressure than top
- Gives a net push upwards, called the buoyant force
- Magnitude of buoyant force equals the *weight* (mg) of the displaced fluid



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I'm on a BOAT

Suppose we have the (somewhat boring) rectangular boat below. The boat has a total mass of 800 kg and has a 2 m by 1 m bottom cross-section and sidewalls 50 cm high. Assuming we place the boat in water with a density of $1000\,\mathrm{kg/m^3}$, will the boat stay dry or fill with water?