Spring 2014

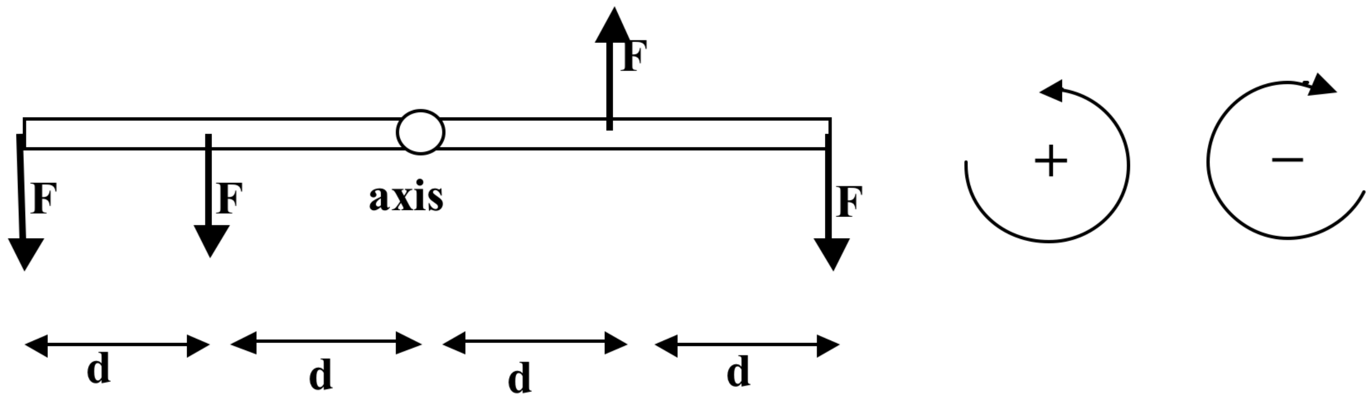
PHYS-2010

Lecture 38

Clicker Question

Room Frequency BA

A bar has four forces, all of the same magnitude, exerted on it, as shown. What is the sign of the net torque about the axis of rotation? Use the sign convention shown.



A) torque is zero B) positive (+) C) negative (–)

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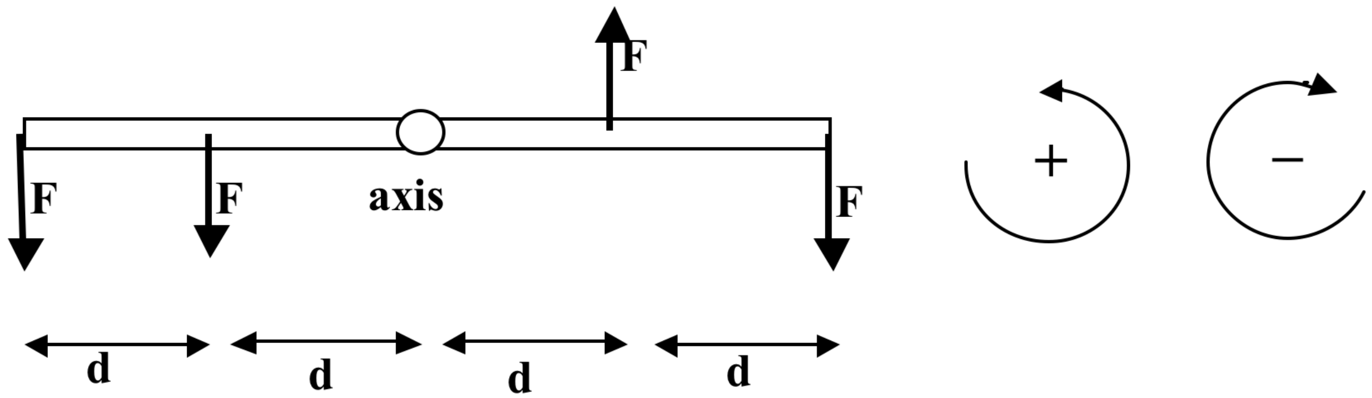


A) torque is zero

B) positive (+)

C) negative (–)

Answer: The net torque causes a CCW rotation, so the net torque is positive. The two forces on the ends (far right and far left) cause torques that exactly cancel. The two forces near the axis both cause torques that produce CCW rotation, both positive torques.

Announcements

- Finish Giancoli **Chapter 9, start Chapter 10.**
- **CAPA # 13** due next Tuesday, April 22.
- **Written Homework # 9** due today, April 18, at 4 pm.

FLUIDS

The Phases of Matter

Solids: Shape independent of "container".

Liquids: Shape depends on "container" and surface.

Gases: Shape only depends on "container".

Plasmas: Shape depends on "container", surface, electrodes, plasma itself, magnetic fields,….

Atomic View of the Phases of Matter

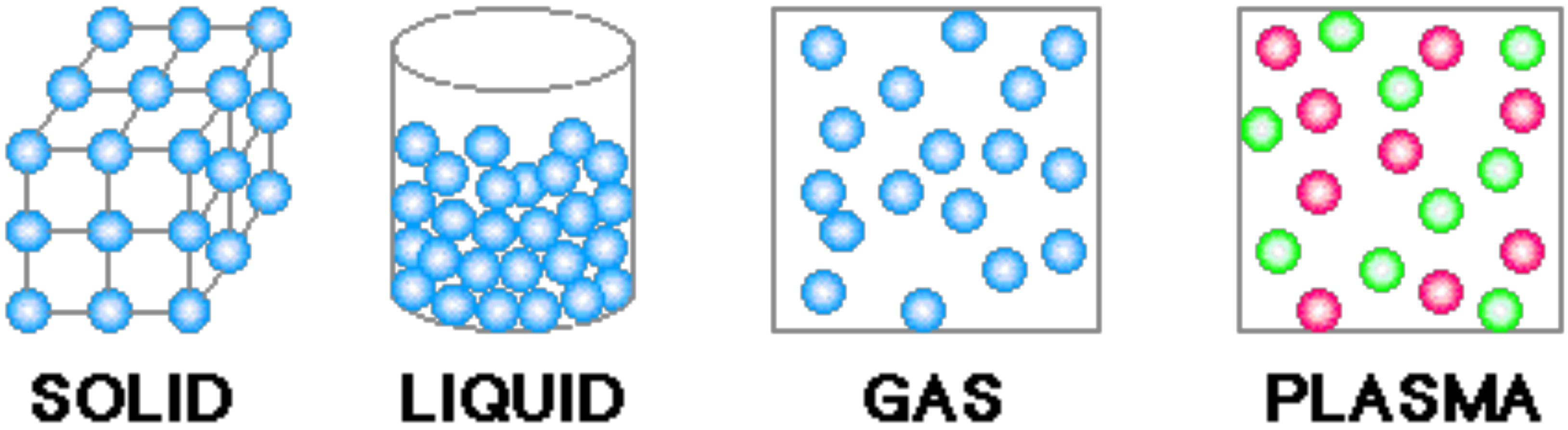
Solids: Atoms locked together, close and rigidly. Number of atoms per volume high.

Liquids: Atoms close together, but free to move individually. Attraction strong enough to keep them from flying apart. Number of atoms per volume high, similar to solids.

Gases: Atoms only interact weakly, mostly just fly around hitting the container walls or each other. Number of atoms per volume low.

Plasmas: Atoms broken apart into electrons and ions which have strong electric forces acting on them. Number of Atoms per volume low.

Atomic KE Low → Atomic KE High

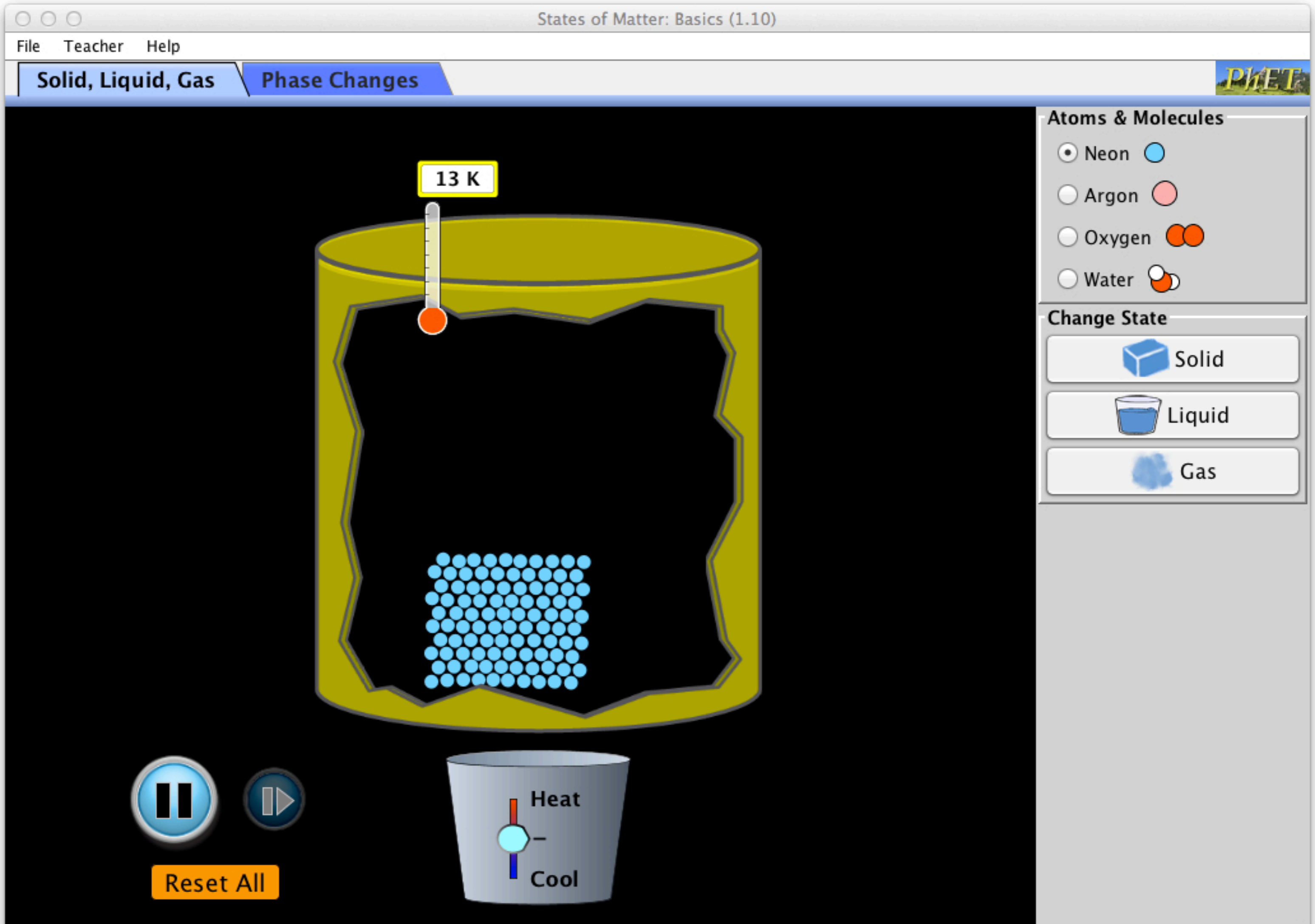


# of Atoms/Volume High ← # of Atoms/Volume Low

Counter examples exist!!!

PHET SIMULATION:

States of Matter



Simplest Case: Static Fluids

Static fluids have no flow.

Uhh,… what's flow?

There is flow when "large" numbers of atoms all move in the same direction.

Are static fluids really "static"?

On the atomic level no! But on the "large" number level yes!

Critical Point: In a static fluid, any small volume of liquid is at rest, hence the net force on this small volume is zero, by Newton's 2nd Law!

<u>How large is a "large" number?</u>

In volume 1cm x 1cm x 1cm we have about 3×10^{22} atoms of water.

In volume 1 μm x 1 μm x 1 μm we have about 3×10^{10} = 30 billion atoms of water (1 μm = 1 micrometer = 10^{-6} meter – the size of a cell).

In volume 1 nm x 1 nm x 1 nm we have about 30 atoms of water.
(1 nm = 1 nanometer = 10^{-9} meter).

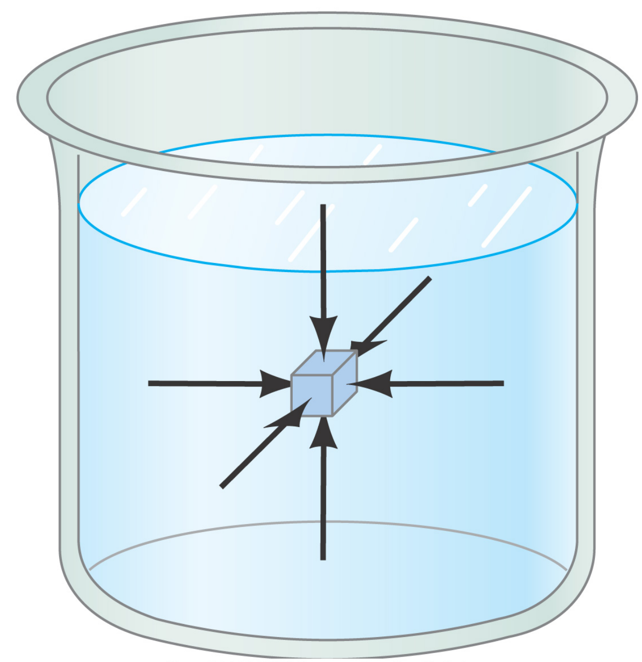
If we are working with volumes larger than a few nm^3, we don't need to worry about individual atoms.

Back to square 1: Fluid "Mass"

When we try to apply Newton's Laws to Fluids what do we use for the mass?

We always consider a "small" imaginary volume inside the body of fluid! Usually a cube or cylinder is easiest. We call it a ***"fluid element"****.*

To find the mass of fluid m inside the imaginary volume V, we use the concept of ***mass density***.



Fluid Density

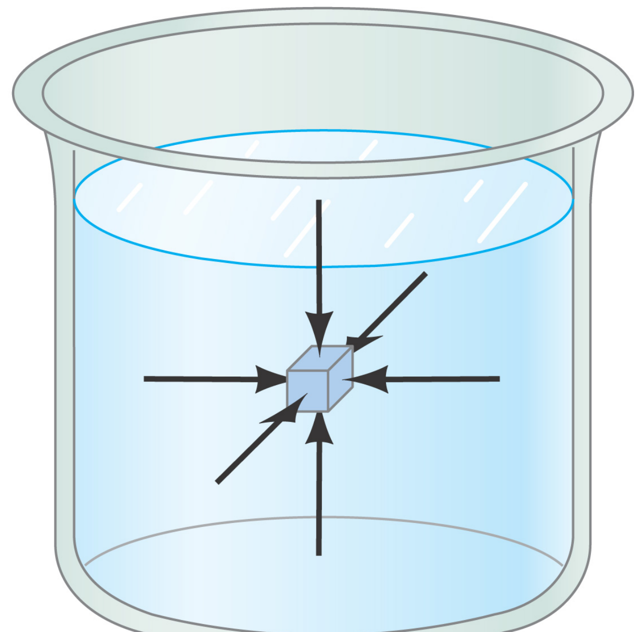
We imagine that the volume *V* is completely filled with some "continuous" substance. If we measure the mass *m* and the volume *V*, then calculate the mass density:

$$\rho_{mass} = \frac{m}{V}$$

In words, we say *mass density* is defined as the mass of material per unit volume.

There are other types of densities; another common one is *number density,* defined as the number of atoms *N* per volume *V*:

$$\rho_{number} = N / V$$



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What are the units of mass density?

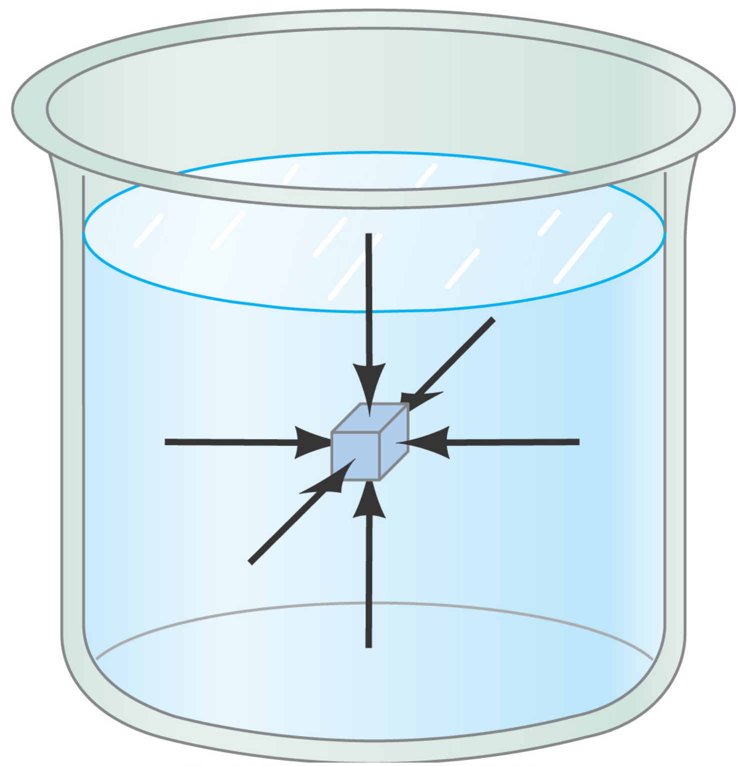
A) kg/m

B) kg/m^2

C) kg/m^3

D) kg

E) None of the above



For mass density, it's mass/volume!

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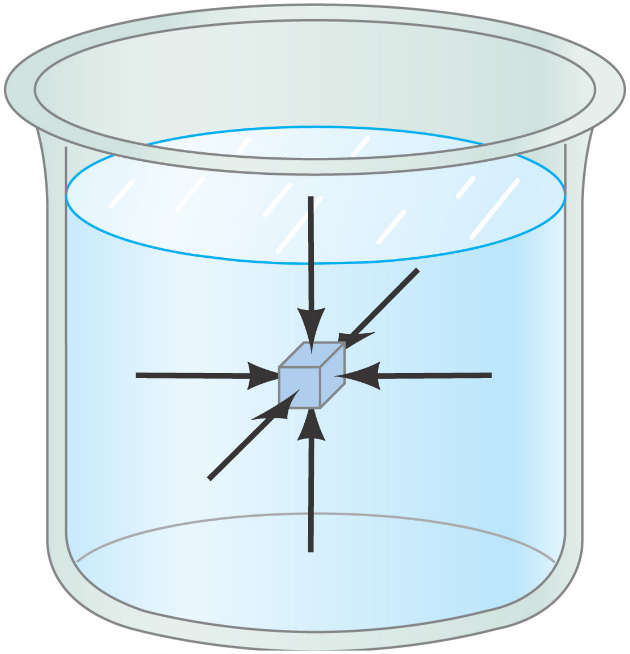
Often mass densities are given in units of g/cm^3. What is the factor to multiply a density of 1 g/cm^3 to get SI units of kg/m^3?

A) 0.1
B) 1
C) 100
D) 1000
E) 1,000,000



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Both mass and volume units have to be converted!

$$1\frac{\text{g}}{\text{cm}^3} = 1\frac{\text{g}}{\text{cm}^3}\bullet\frac{1\text{ kg}}{1000\text{ g}}\bullet\left(\frac{100\text{ cm}}{1\text{ m}}\right)^3 = 1000\frac{\text{kg}}{\text{m}^3}$$

- density of H_2O !!!

Clicker Question

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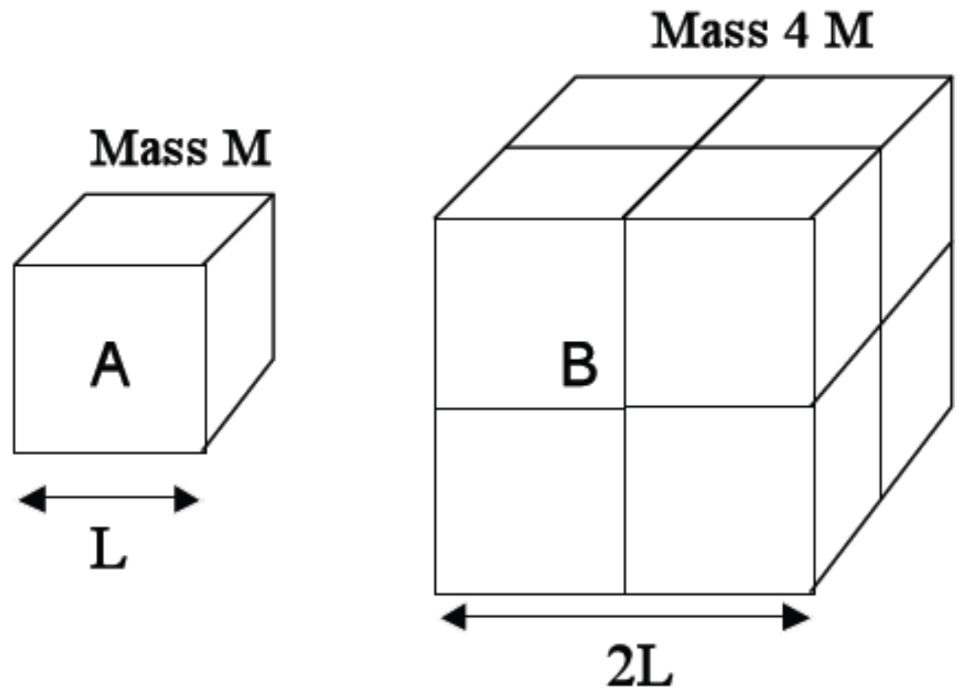
Cube A has edge length L and mass M. Cube B has edge length 2L and mass 4M. Which has greater density?

A) A has larger density
B) B has larger density
C) A and B have the same density.



Cube A has larger density. $\rho_A = M/L^3$, $\rho_B = (4M)/(2L)^3 = (1/2)M/L^3$ so object A has twice the density of object B.

Changing Density

Is the density the same everywhere in the fluid?

Not necessarily! If a fluid can have its density changed it is called *compressible;* if not it is incompressible.

Gases: Compressible (expand or compress)

Liquids: Often nearly incompressible (water!)

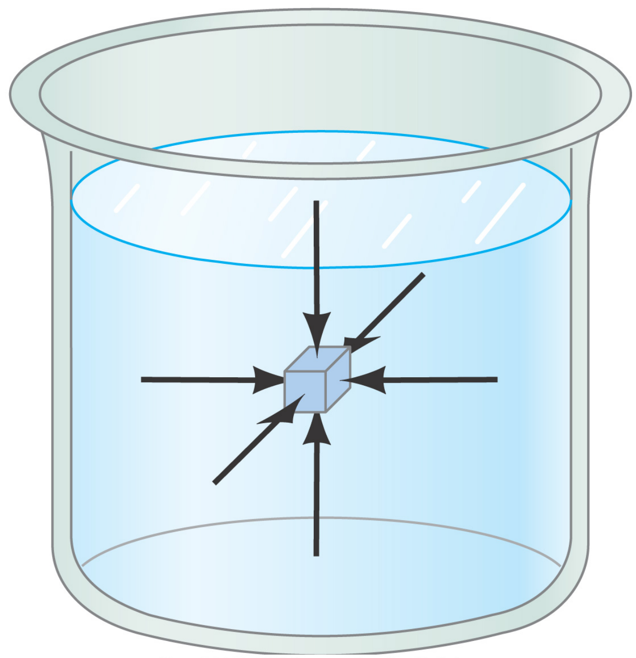
We'll stick to incompressible liquids for now; we'll return to gases later in the semester. So for a given substance, the mass density is the same everywhere in side the liquid!

Fluid Density

We imagine that the volume *V* is completely filled with some "continuous" substance. We measure the mass *m* and the volume *V* then calculate the mass density ρ_{mass} as m/V.

Gases: Compressible (expand or compress)
Liquids: Often nearly incompressible

We'll typically assume, for a given substance, that the mass density is the same everywhere in side the fluid! This is a good assumption for statics.



Specific Gravity

SI Units of density are kg/m^3 = 0.001 g/cm^3

Another common and useful measure of density is the *specific gravity (SG).*

$$\text{Specific Gravity (SG) of substance X} \equiv \frac{\rho_X}{\rho_{Water}}$$

$SG_{Water} = 1$

$SG_{Iron} = 7.9$

$SG_{Pb} = 11.9$

$SG_{Ice} = 0.92$

$SG_{Alcohol} = 0.79$

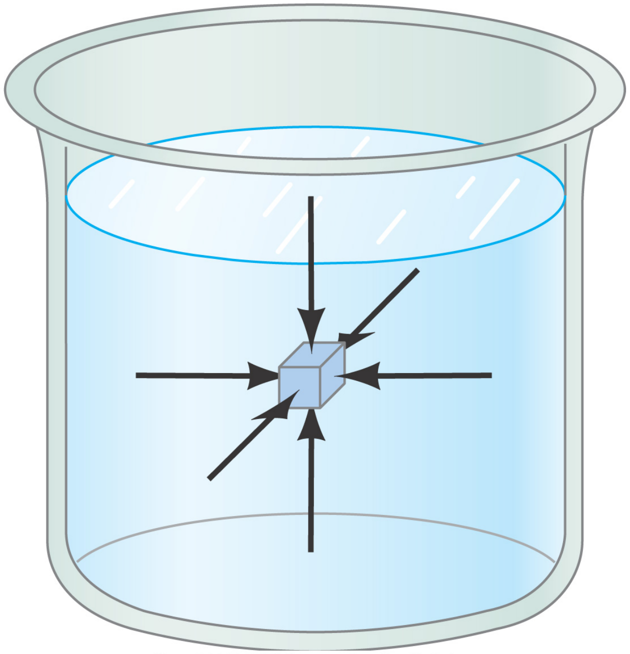
No "visible" units because it is a ratio!

Back to square 2: Fluid "Forces"

When we try to apply Newton's Laws to Fluids what do we use for the force?

Again we consider a "small" imaginary volume or box inside the body of fluid.

To find the force on the imaginary volume *V*, we use the concept of *pressure.* We find the force F on each side of the volume V and divide the magnitude of that force by the *area* A of that side. The pressure P is then F/A



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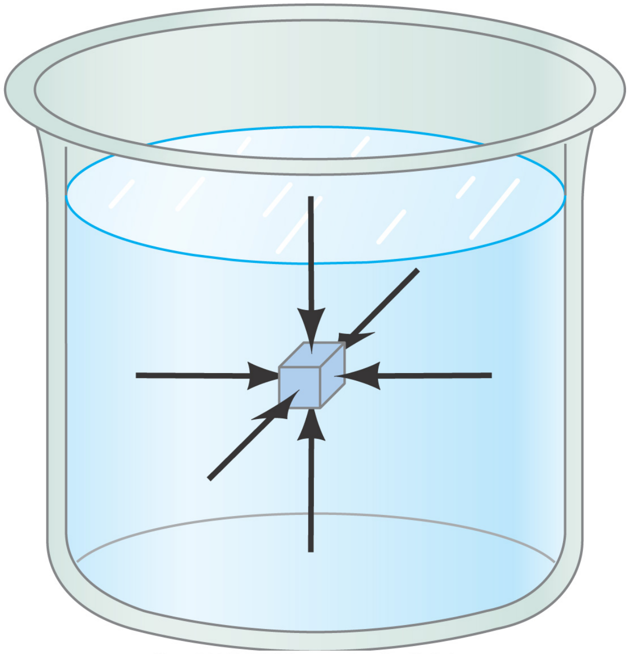
$$P_{\text{at side of V}} = \frac{\left|\vec{F}_{\text{on side of V}}\right|}{A_{\text{of side V}}}$$

Direction of Fluid Forces

Newton's law deals with forces which are *vectors!* What is the direction of the force from fluid pressure?

For static fluids (no flow) the force is perpendicular to the surface of the side.

In the figure you see arrows for the force on each side of an imaginary cube of volume *V.*



Critical point: Pressure does not have any direction; the direction of the force from pressure depends on the orientation of the surface the pressure acts on.