PHYSICS 102N
Spring 2022

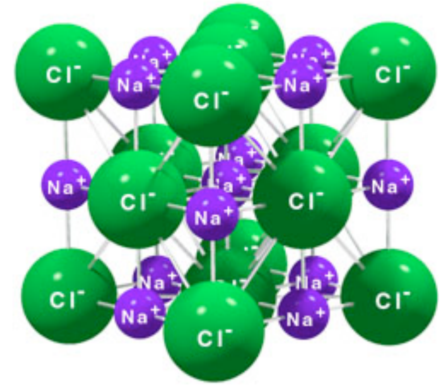
Week 2

Solids and Liquids

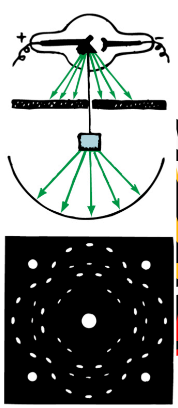
Condensed Matter

- Common feature: Atoms/molecules are tightly packed together (equilibrium distance)
  – Any closer: Repulsion due to electromagnetic interaction and quantum mechanics
  – Any further apart: Attraction due to residual electromagnetic forces ("Van-der-Waals" forces, ionic, metallic binding)
- Solids: Atoms arranged in a rigid pattern
  – Crystal: regular pattern
  – Amorphous solid: random pattern
- Liquids: Individual atoms free to roam

Crystals



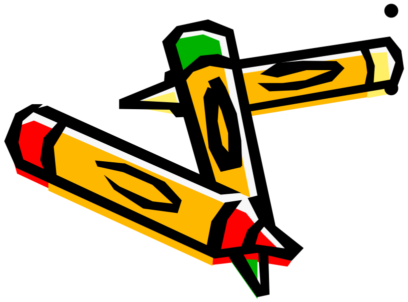
- Regular arrangement of atoms in a repeating pattern
  - elemental metals: all atoms of the same kind (gold, iron, lead…)
  - ionic compounds: two or more different species alternate
- Important feature: Symmetry!
- Revealed by micrographs, x-ray scattering, neutron scattering, electron microscopy…



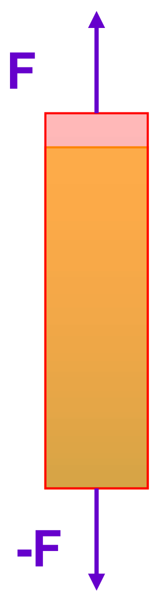
=> Image patterns show regularities

Deformation of Solids

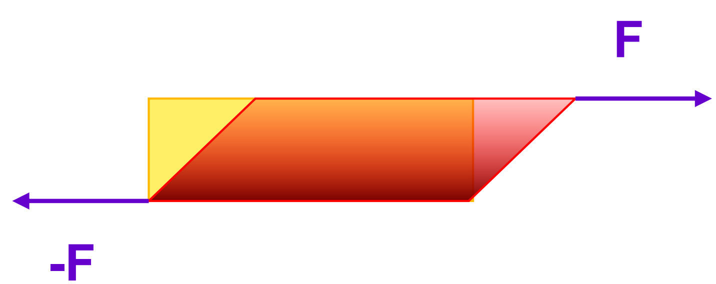
- Solids can be rotated and moved without any change to internal structure
- Solids can also be deformed by external forces
  - elastic:
    - deformation proportional to force
    - Object returns to original shape afterwards
  - Inelastic (plastic):
    - Deformation is permanent (shape change)
    - Examples: Putty, metal forming (blacksmith)
    - All elastic deformations become inelastic if limit exceeded



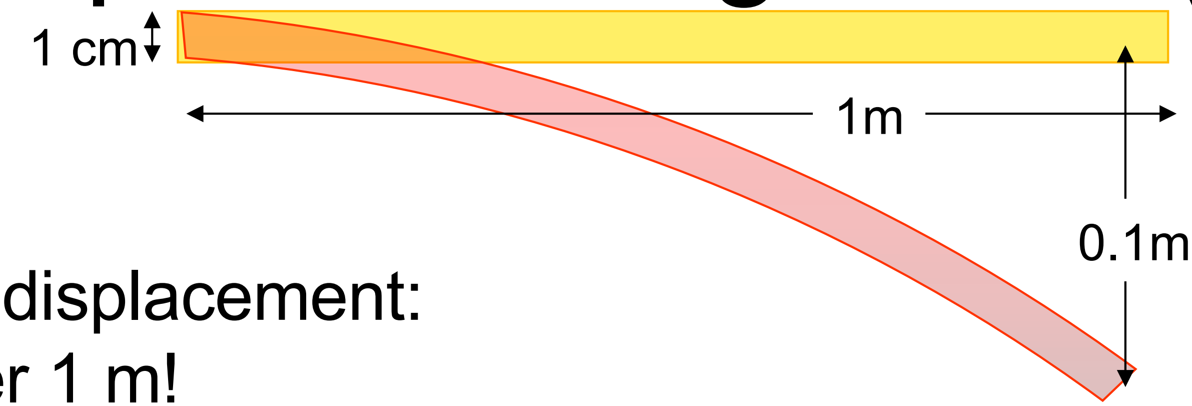
Elastic deformation of Solids



- Compression and expansion
  - Compression: External “pushing” (or pressure)
  - Expansion: Opposing forces at opposite ends (tension)
  - Change in linear dimension: $\Delta L/L \propto F$
  - Proportionality constant: inverse of Young’s modulus x cross sectional area
    - Strong resistance: Small deformation (steel, carbon fiber…)
    - Soft material: Larger deformation (Aluminum…)
  - Springs $\rightarrow$ Hooke’s law: $F = -kx$
  - Volume change: Pressure from all sides
- Shear
  - “sideways” displacement
  - Force pair offset sideways



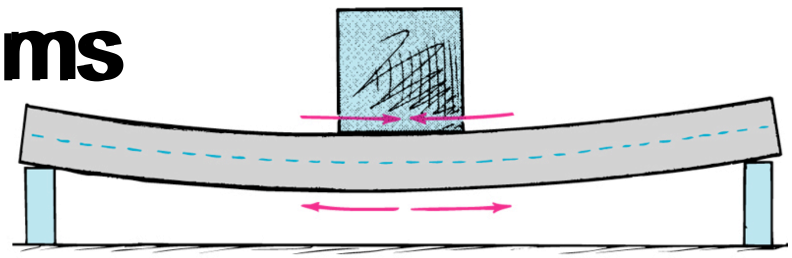
Example: Bending



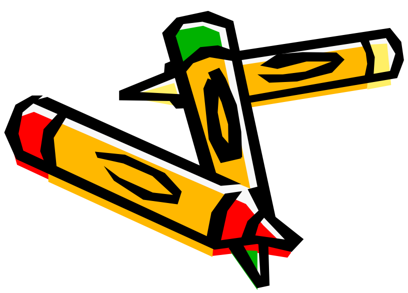
- Shear?
  - Sideways displacement:
    10 cm over 1 m!
- Compression/Expansion?
  - Length change: topmost layer stretched by 1 mm, bottommost layer extended by 1 mm
    => **much less** deformation!
  - Middle (“neutral”) layer unchanged in length

Examples

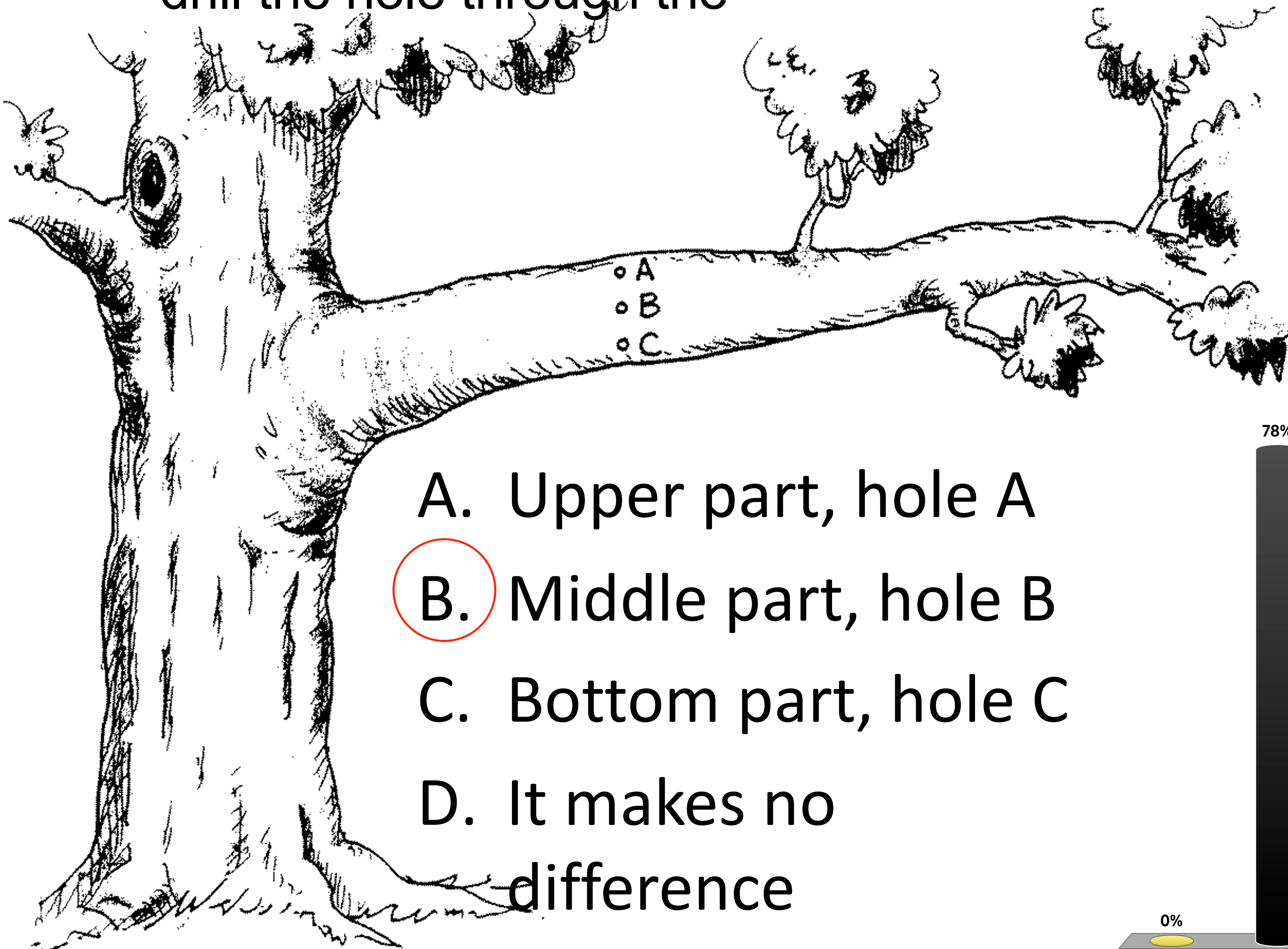
- Extended beams
  - Skywalk Grand Canyon
- Doubly supported beams



- Arches



Q1 If you drill a hole horizontally through the branch of a tree, you risk weakening the branch. For minimum weakening, drill the hole through the

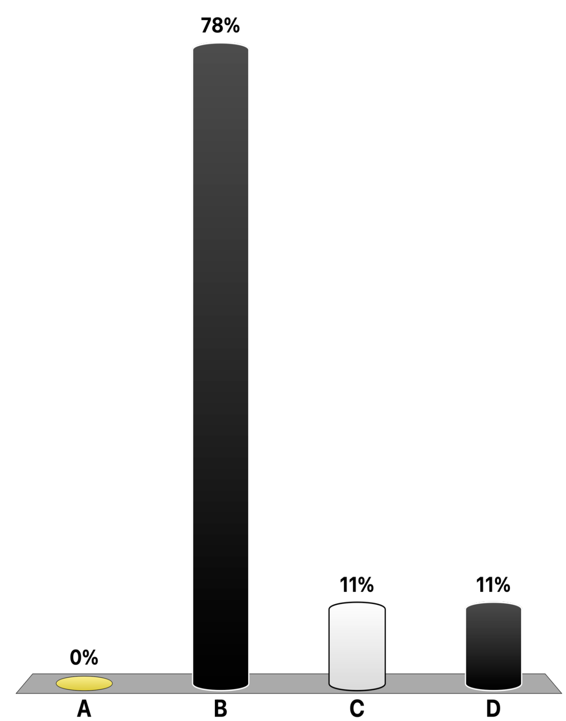


A. Upper part, hole A

B. Middle part, hole B

C. Bottom part, hole C

D. It makes no difference



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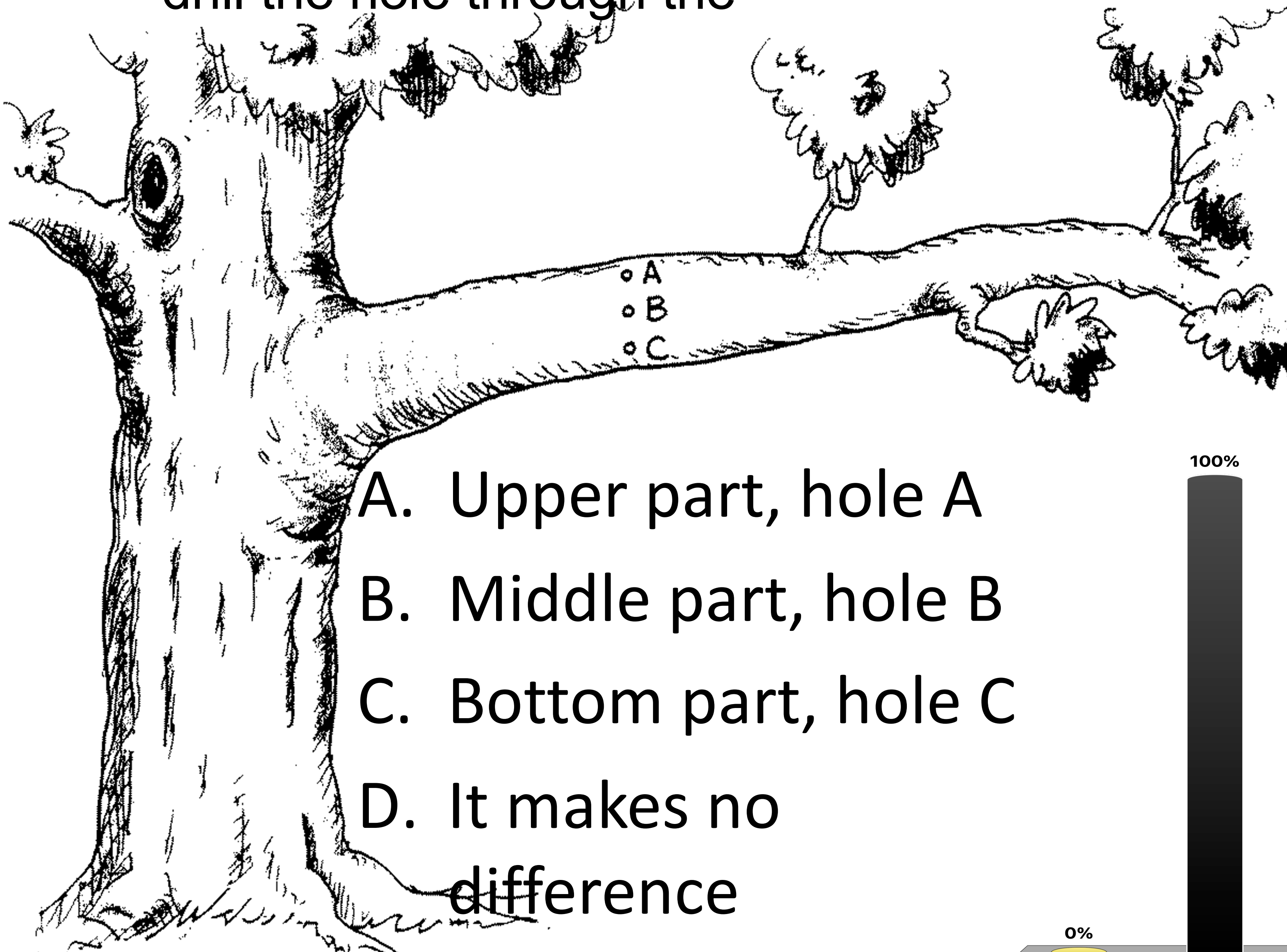

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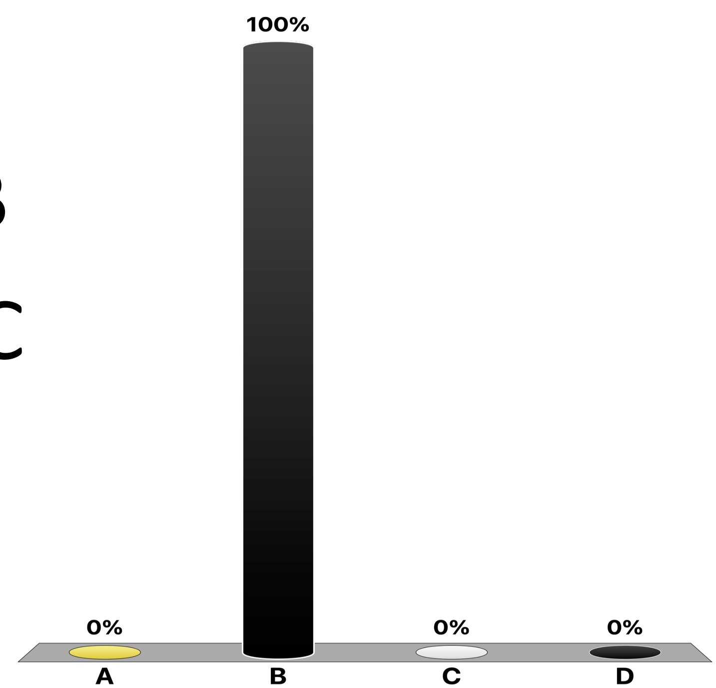


From now on:
more convenient to think of matter as "continuous"

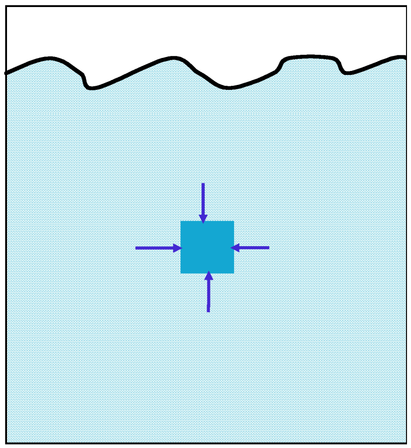
- Blur atomic structure (de-focus, "smearing out")
- Matter described by continuous, "smooth" ("intensive") variables
- Example: Density ρ
  - Amount of mass per unit volume
  - Unit kg/m^3
  - Mass of object = Volume x density
    - Examples:
      Oxygen at normal atmospheric conditions - 1.33
      Water - 1,000 (ice a little bit less)
      Wood - ≈ 900…1000
      Iron - 7,874
      Gold - 19,320
      Iridium - 22,650

Pressure

- Definition: Force per surface area:
  - More force: Increase weight, density,…
  - smaller surface area: nails, block standing on end…
- Unit: $N/m^2 = 1$ Pa (Pascal) *)
- Pressure can
  - squeeze objects (refer to deformation of solids)
  - change physical state of objects (solid $\leftrightarrow$ liquid)
  - do work (break windows, …)

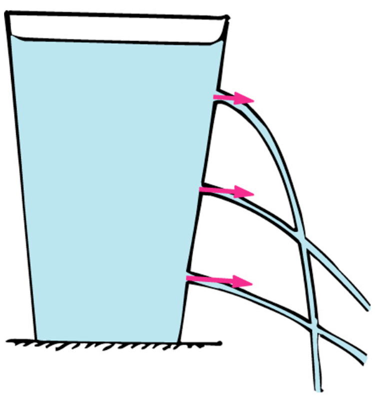
*) (1 atmosphere $\approx$ 100 kPa) => Force on 1 cm^2 is equivalent to Weight of 1 kg mass (10 N)

Pressure in fluids*)



- Isotropic: same in all directions, given by a single number *p* for each position within the fluid
- For fluid at rest, depends only on amount of fluid above:

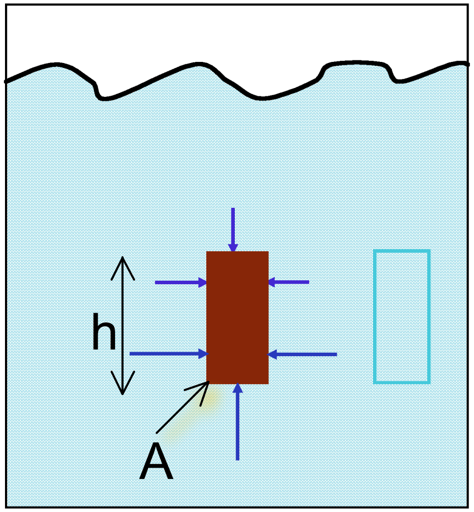
$$\Delta p = \rho g \left(-\Delta h\right)$$



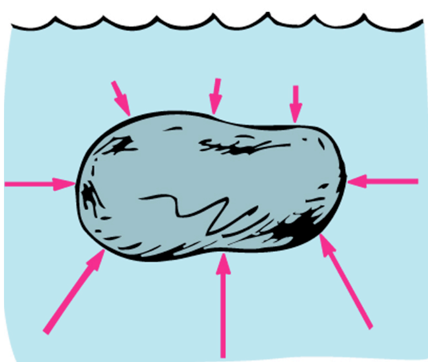
- Many consequences:
  - air pressure, “ear” pressure under water,…
  - independent of shape and volume of vessel
  - buoyancy, Archimedes’ Principle, flotation
  - connecting tubes (hoses, water mains,siphons)
  - hydraulic actuators, Pascal’s principle

*) “Fluid” = anything that can flow; “Liquid” = fluid at densest possible packing

Buoyancy



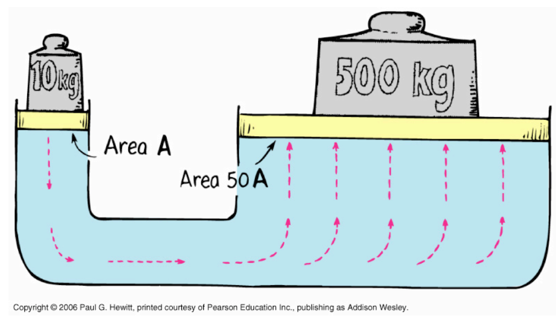
- For a LARGER volume, pressure **does** vary from top to bottom by $\Delta p = \rho_{fluid} g h$ => net upwards force!
- Size of force:
  Cross sectional area A times p = $\rho_{fluid} h A g = \rho_{fluid} V g = m_{fluid} g$ =
  Weight of displaced fluid



- Flotation: displace fluid with more mass than one's own mass ("be less dense than water"; have more volume than an equally massive amount of fluid)
- Only submerged part creates buoyancy

Pascal's Principle

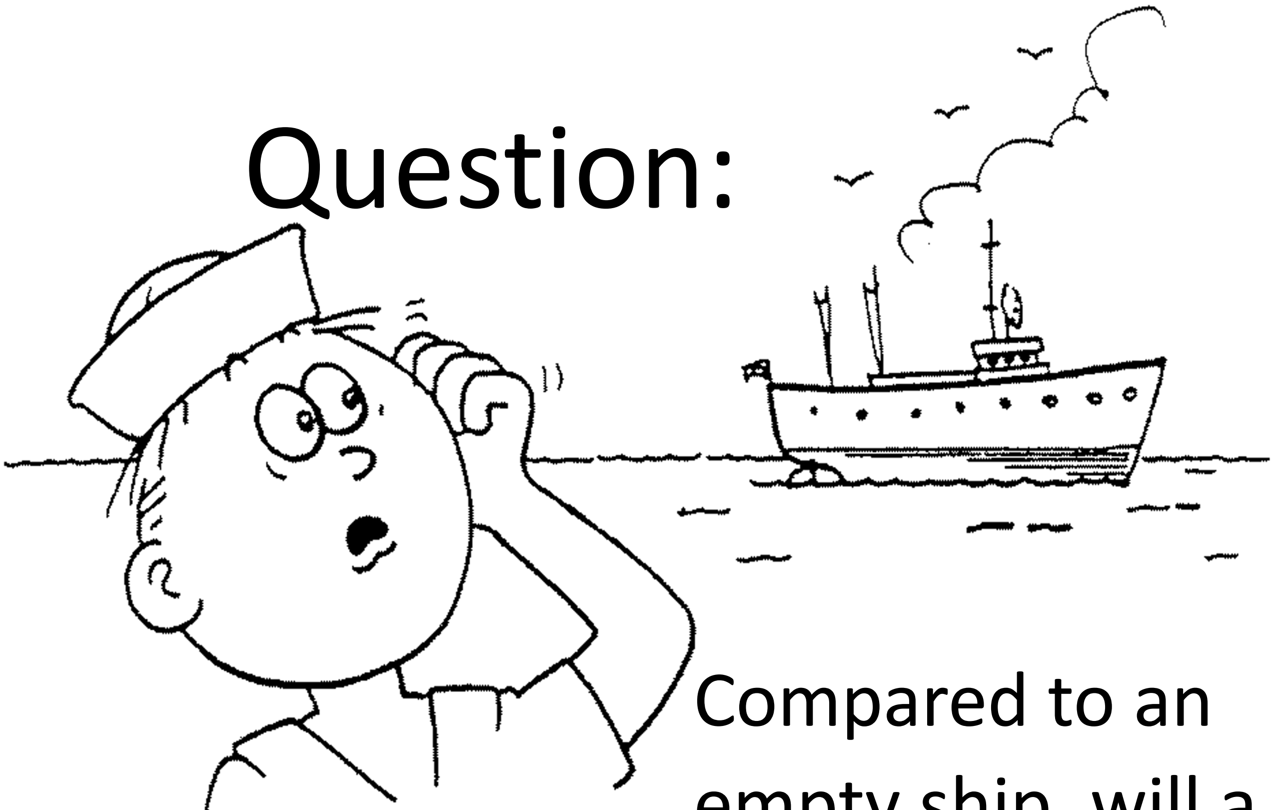
- Change pressure on one part of a **Liquid** – => pressure change gets transmitted to all other parts
- Hydraulics



Surface Tension of a Liquid

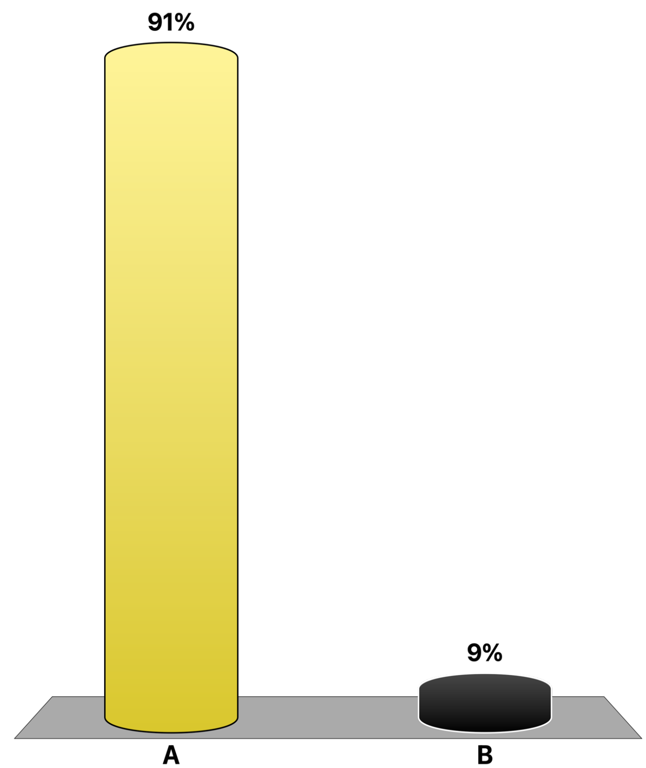
- Intermolecular forces try to minimize surface ("tension")
- Drop shape, bubbles, "floating" needles and water runners,…

Question:



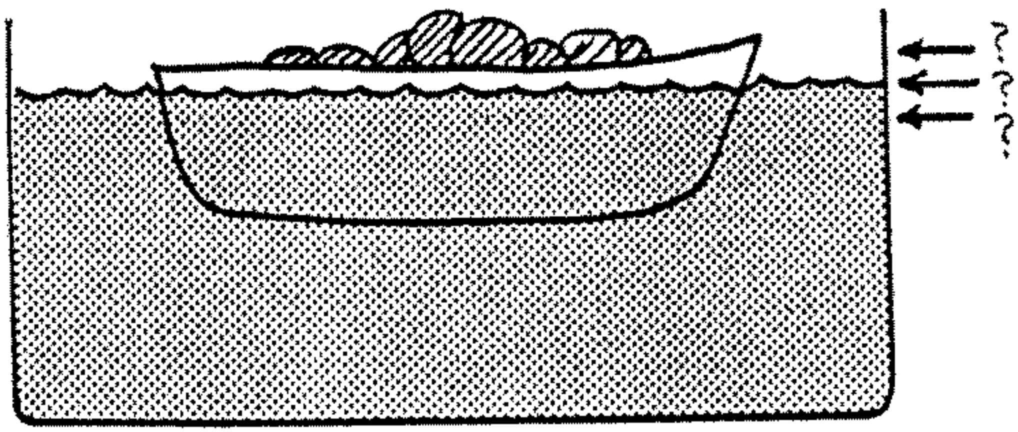
Compared to an empty ship, will a ship loaded with a cargo of Styrofoam float lower in water or higher in water?

A. Lower in the water
B. Higher in the Water



Q2

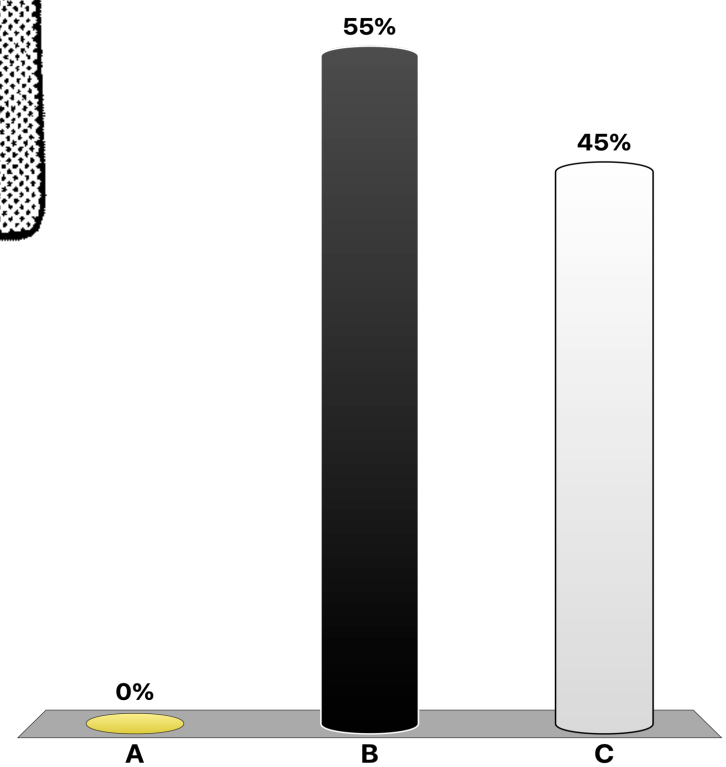
Consider a boat loaded with scrap iron in a swimming pool. If the iron is thrown overboard into the pool, will the water level at the edge of the pool rise, fall, or remain unchanged?



A. Rise

B. Fall

C. Remain unchanged



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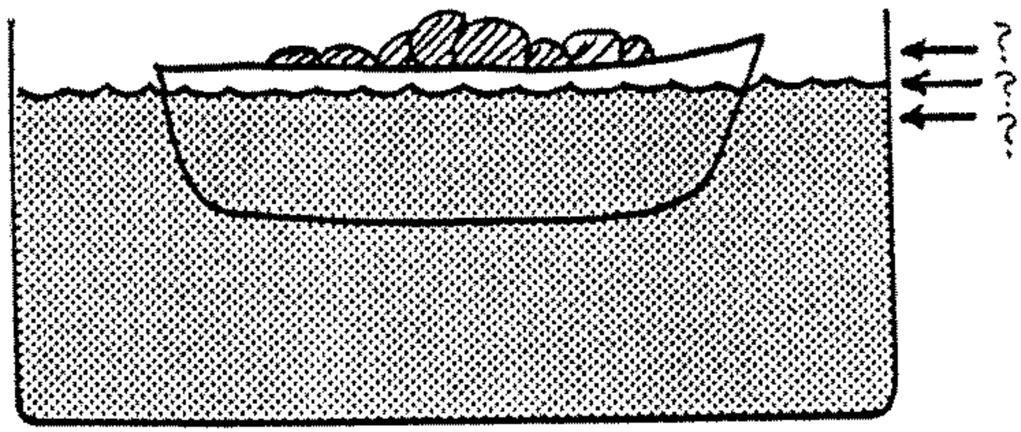

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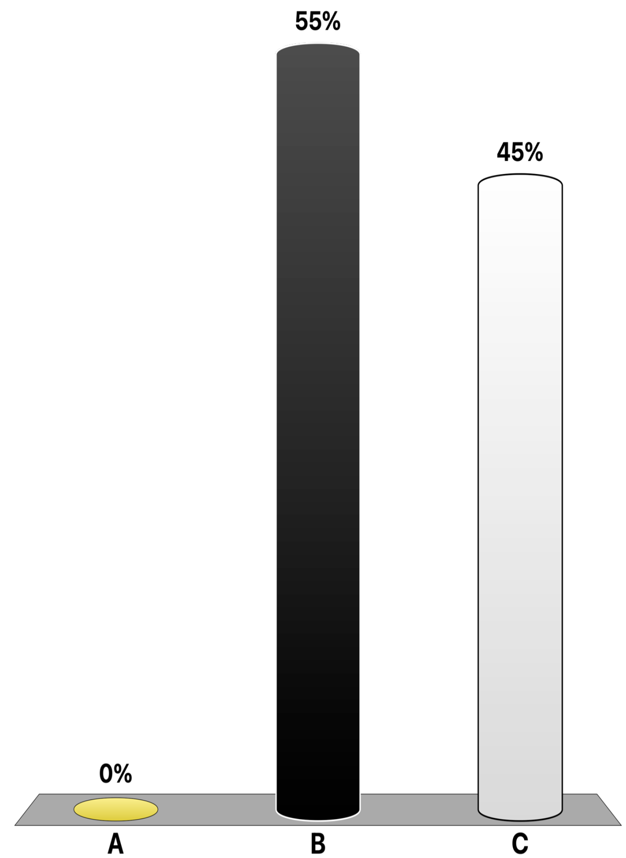
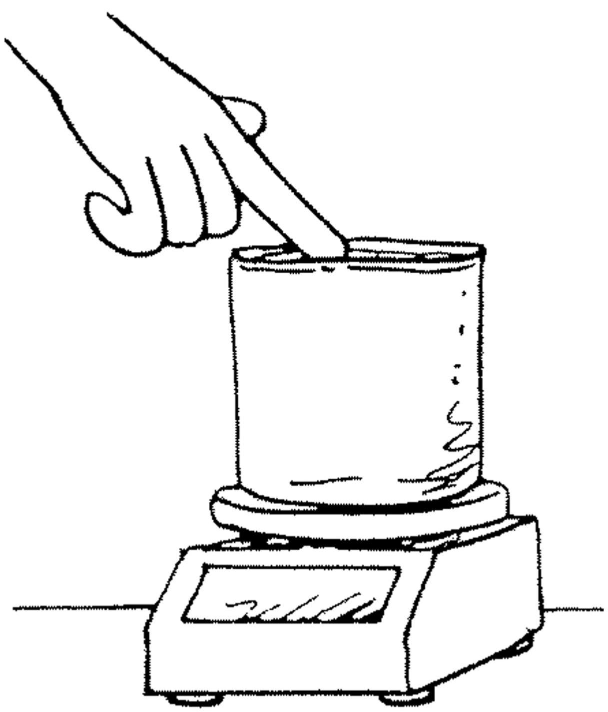
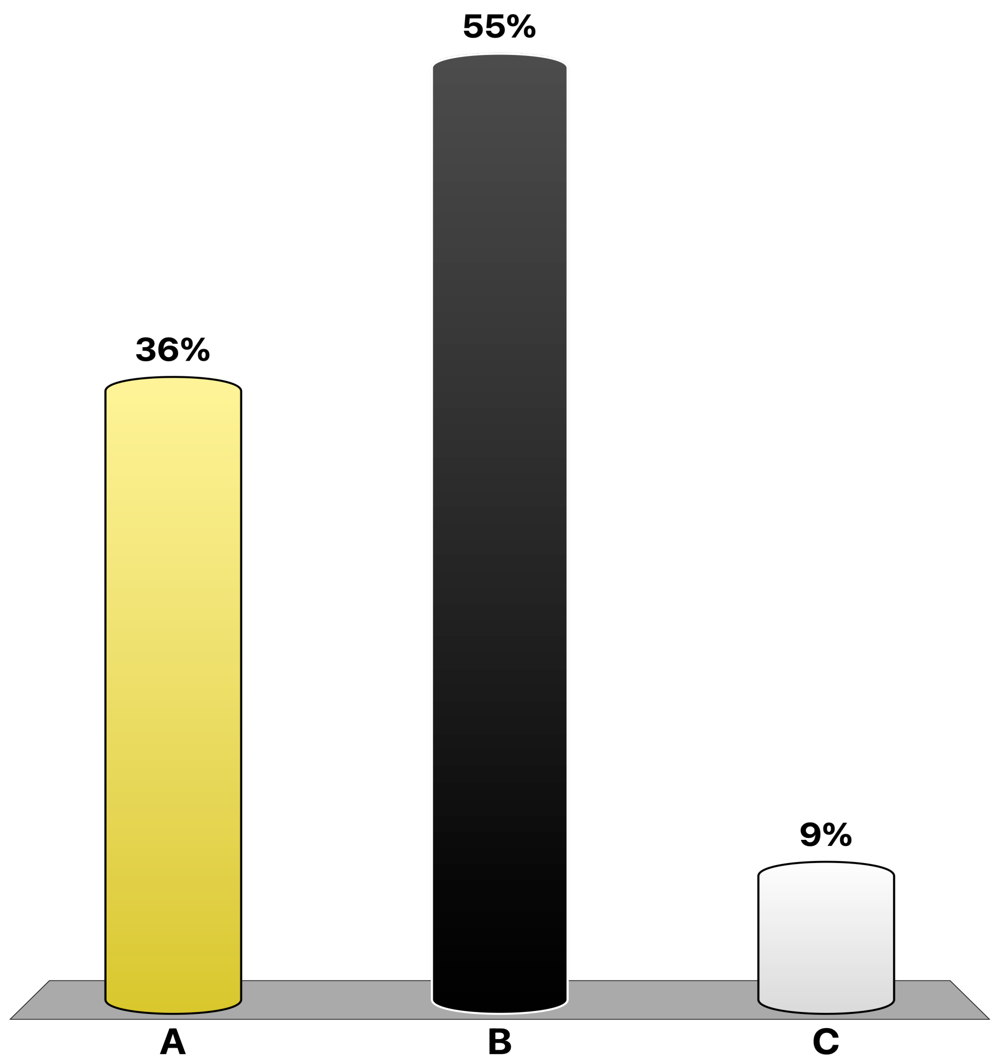


Q3 Gently push down on the pan of the scale and the display shows an increase in force. Likewise if you do the same on the rim of the beaker. But what if you immerse your fingertip in the water, without touching the beaker? Then the scale reading

A. Doesn't change
B. Shows an increase
C. Shows a decrease





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