

Note on Posted Slides

- These are the slides that I intended to show in class on Wed. Feb. 6, 2013.
- They contain important ideas and questions from your reading.
- Due to time constraints, I was probably not able to show all the slides during class.
- They are all posted here for completeness.

PHY205H1S Physics of Everyday Life Class 9: **Liquids**

- Pressure
- Buoyancy in a Liquid
- Archimedes' Principle
- What Makes an Object Sink or Float
- Pascal's Principle
- Surface Tension
- Capillarity



[Image retrieved Jan. 17 2013 from <http://en.wikipedia.org/wiki/File:RubberDuck.jpg>]

Pre-class reading question

What is the approximate density of water?

- A. 10^{-5} kg/m^3
- B. 0.01 kg/m^3
- C. 0.1 kg/m^3
- D. 1 kg/m^3
- E. 1000 kg/m^3



Pre-class reading question

What is Archimedes' Principle?

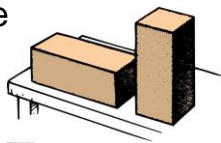
- A. A change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.
- B. An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.
- C. Energy can be neither created nor destroyed, only transformed from one form to another.
- D. Where the speed of a fluid increases, internal pressure in the fluid decreases.

Pressure

- **Pressure** is the force per unit area that one object exerts on another
- In equation form:

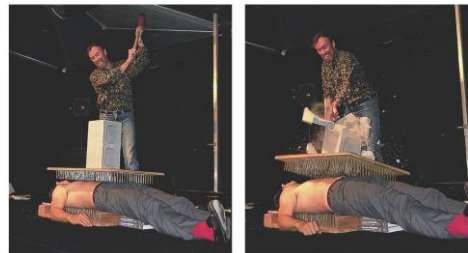
$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

- Depends on area over which force is distributed
- Units: N/m^2 , or Pa (Pascals)



Bed of Nails

Example: The teacher between nails is unharmed because force is applied over many nails. Combined surface area of the nails results in a tolerable pressure that does not puncture the skin.



Pressure
CHECK YOUR NEIGHBOR

When you stand on one foot instead of two, the **force** you exert on the floor is

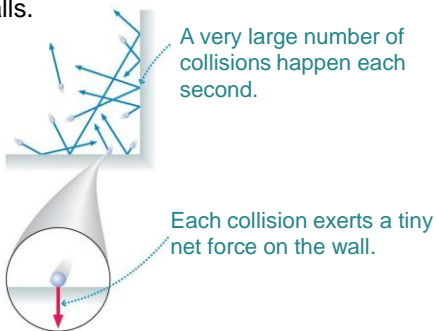
- A. less.
- B. the same.
- C. more.

Pressure
CHECK YOUR NEIGHBOR

When you stand on one foot instead of two, the **pressure** you exert on the floor is

- A. less.
- B. the same.
- C. more.

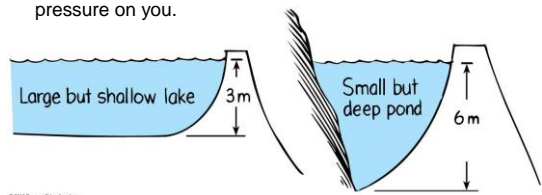
Pressure in a fluid is due to the net force of the molecules in a fluid colliding with the walls.



Pressure in a Liquid

- Force per unit area that a liquid exerts on an object
- Depth dependent and not volume dependent

Example: Swim twice as deep, then twice as much weight of water above you produces **twice as much** pressure on you.



Pressure in a Liquid



- Acts equally in all directions

Examples:

- Your ears feel the same amount of pressure under water no matter how you tip your head.
- Bottom of a boat is pushed upward by water pressure.
- Pressure acts upward when pushing a beach ball under water.

Pressure in a Liquid

- Independent of shape of container:
Whatever the shape of a container, pressure at any particular depth is the same.
- In equation form:

$$\text{Liquid pressure} = \text{weight density} \times \text{depth}$$

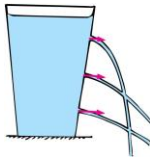
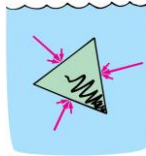


[Image retrieved Jan 17 2013 from <http://www.peterson.ac.nz/secondary/science/insophysicscur50commentary.htm>]

Pressure in a Liquid

Effects of water pressure

- Acts perpendicular to surfaces of a container
- Liquid spurts at right angles from a hole in the surface.
 - The greater the depth, the greater the exiting speed.



Pressure in a Liquid CHECK YOUR NEIGHBOR

Water pressure provided by a water tower is greater if the tower

- is taller.
- holds more water.
- Both A and B.
- None of the above.

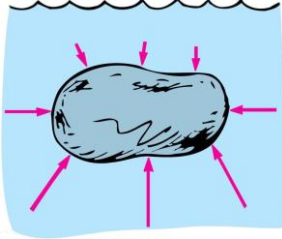


[image from <http://www.flickr.com/photos/76774188/N62430015189/lightbox/>]

Buoyancy in a Liquid

Buoyancy

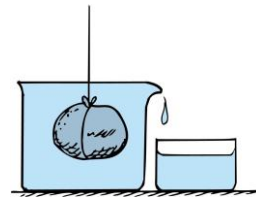
- Apparent loss of weight of a submerged object
- Amount equals the weight of water displaced



• Displacement rule:

A completely submerged object always displaces a volume of liquid equal to its own volume.

Example: Place a stone in a container that is brimful of water, and the amount of water overflow equals the volume of the stone.



<http://www.dairygoodness.ca/butter/butter-tips-tricks/how-to-measure-butter>



butter



- When butter is in **hard**, irregular shaped pieces, fill a 2-cup liquid measuring cup with water to the 1 cup mark.
- Add enough butter pieces until the level reaches 1-1/4 cups.
- Drain off the water and you're left with 1/4 cup of butter!

Buoyancy in a Liquid CHECK YOUR NEIGHBOR

A cook who measures a specific amount of butter by placing it in a measuring cup with water in it is using the

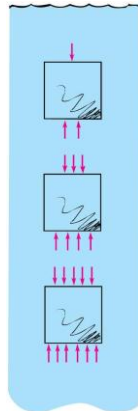
- principle of buoyancy.
- displacement rule.
- concept of density.
- All of the above.



Buoyant force

- Net upward force that a fluid exerts on an immersed object = weight of water displaced

Example: The difference in the upward and downward forces acting on the submerged block is the same at any depth

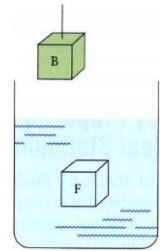


Buoyancy: Archimedes Principle

- Let's do a "thought experiment" (Gedanken).
- Imagine a beaker with a fluid and a block, B, hanging near it.
- There is a fluid element F with the same shape and volume as the block B.
- The fluid element F is in mechanical equilibrium:

$$F_{\text{up}} - F_{\text{down}} - W_F = 0$$

- where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of fluid F.

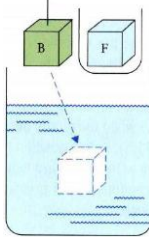


Buoyancy: Archimedes Principle

- **Step 1:** Remove F from the beaker and place it in a small container, leaving an empty bubble of the same size in the beaker.
- The bubble is not in mechanical equilibrium, since its weight is much less than that of the removed fluid, but the pressure forces are the same.:

$$F_{\text{up}} - F_{\text{down}} = W_F > 0$$

- where F_{up} is the pressure force on the bottom surface, F_{down} is the pressure force on the top surface, and W_F is the weight of the removed fluid F.



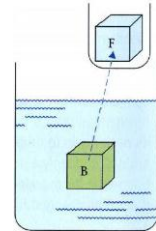
Buoyancy: Archimedes Principle

- **Step 2:** Block B, with weight W_B , is placed in the bubble.
- There is a net force on Block B:

$$F_{\text{net}} = F_{\text{up}} - F_{\text{down}} - W_B = W_F - W_B$$

- where W_F is the weight of the removed fluid F, and W_B is the weight of the block B.
- This is equal to the force of gravity, $-W_B$, plus a new force called "Buoyancy", which is due to the pressure gradient in the fluid.

Archimedes' principle: When an object is immersed in a fluid, the fluid exerts an upward force on the object equal to the weight of the fluid displaced by the object.



Archimedes' Principle

- Discovered by Greek scientist Archimedes in 250 BC.
- Relates buoyancy to displaced liquid.
- States that an immersed body (completely or partially) is buoyed up by a force equal to the weight of the fluid it displaces.
- Applies to gases and liquids.



Demonstration Prediction

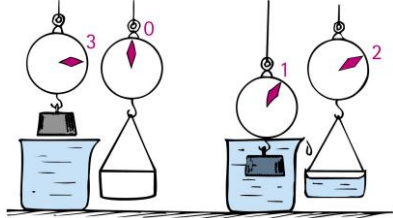
- A steel mass of 0.75 kg hangs from a spring scale.
 - When it is not accelerating, the spring scale reads 7.5 N.
 - If Harlow dips the mass into an open container of water, then stops the motion and lets the scale settle, what will be the reading on the scale?
- A. Less than 7.5 N, but not zero
 B. More than 7.5 N
 C. About 7.5 N
 D. zero

[image retrieved Jan 17 2013 from <http://personal.maths.unsw.edu.au/~ic31/Buoy/AMM/Archimedes.html>]

Archimedes' Principle

Apparent weight of a submerged object
= Weight out of water minus buoyant force

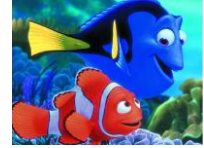
Example: If a 3 N block submerged in water apparently weighs 1 N, then the buoyant force or weight of water displaced is 2 N.



Archimedes' Principle CHECK YOUR NEIGHBOR

When a fish expands its air bladder, the density of the fish

- A. decreases.
- B. increases.
- C. remains the same.



Archimedes' Principle CHECK YOUR NEIGHBOR

When a fish makes itself less dense, the buoyant force on it

- A. decreases.
- B. increases.
- C. remains the same.

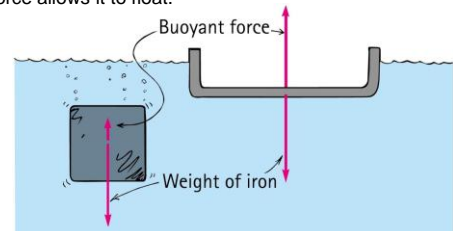


Flotation

- Principle of flotation:

– A floating object displaces a weight of fluid equal to its own weight.

Example: A solid iron 1-ton block may displace 1/8 ton of water and sink. The same 1 ton of iron in a bowl shape displaces a greater volume of water—the greater buoyant force allows it to float.

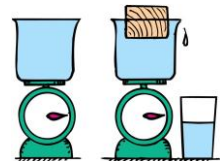


Ch.13 Problem 8

- Your friend of mass 100 kg can just barely float in fresh-water. Calculate her approximate volume.
- $W = mg$
- Buoyancy = (density)(V)(g)
- $W = \text{Buoyancy}$
- $mg = \text{density}(V)(g)$
- $V = m/\text{density} = 100 \text{ kg}/1000 \text{ kg/m}^3$
- $V = 0.1 \text{ m}^3$

Flotation CHECK YOUR NEIGHBOR

You place an object in a container that is full to the brim with water on a scale. The object floats, but some water spills out. How does the weight of the object compare with the weight of the water displaced?



- A. Weight of object is greater than weight of water displaced.
- B. Weight of object is less than weight of water displaced.
- C. Weight of object is equal to weight of water displaced.
- D. There is not enough information to decide.



The Falkirk Wheel's two caisson are brimful of water and the same weight, regardless of whether there are boats in them. This makes rotation and lifting almost effortless.

[image from http://en.wikipedia.org/wiki/File:FalkirkWheel04_2004_SawmillsCaisson.jpg]



The Falkirk Wheel's two caisson are brimful of water and the same weight, regardless of whether there are boats in them. This makes rotation and lifting almost effortless.

[image from http://en.wikipedia.org/wiki/File:Falkirk_half_wheel_round.jpg]

Archimedes' Principle

Denser fluids will exert a greater buoyant force on a body than less dense fluids of the same volume.

Example: Objects will float higher in saltwater (density = 1.03 g/cm^3) than in freshwater (density = 1.00 g/cm^3).



[image retrieved Jan. 17, 2013 from <http://www.ck12.org/wiki/File:ArchimedesPrinciple.jpg>]

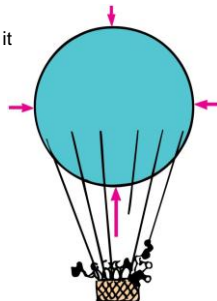
Archimedes' Principle CHECK YOUR NEIGHBOR

The buoyant force on an object submerged in a liquid depends on

- A. the object's mass.
- B. the object's volume.
- C. the density of the liquid.
- D. both A and B.
- E. both B and C.

Archimedes' Principle

- Applies in air!
 - The more air an object displaces, the greater the buoyant force on it.
 - If an object displaces its weight, it hovers at a constant altitude.
 - If an object displaces less air, it descends.



What Makes an Object Float or Sink?

Whether an object floats or sinks depends upon the

- Weight of the object.
- Weight of the fluid displaced.



The weight of the fluid displaced depends on volume.

So what really counts is the weight of the object per volume.

This is related to the average **density** of the object.

[image retrieved Jan. 17, 2013 from <http://en.wikipedia.org/wiki/File:RubberDuck.jpg>]

What sinks? What floats?

1. An object **more** dense than the fluid in which it is immersed will sink.
2. An object **less** dense than the fluid in which it is immersed will float.
3. An object having a density **equal to** the density of the fluid in which it is immersed will neither sink nor float.



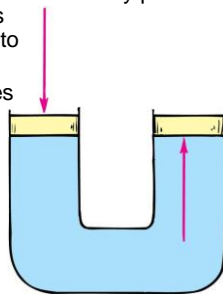
What Makes an Object Float or Sink? CHECK YOUR NEIGHBOR

Two solid blocks of identical size are submerged in water. One block is lead and the other is aluminum. Upon which is the buoyant force greater?

- A. On the lead block
- B. On the aluminum block
- C. Same on both blocks
- D. There is not enough information to decide.

Pascal's principle:

- Discovered by Blaise Pascal, a scientist and theologian in the 17th century
- States that a change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid
- Applies to all fluids—gases and liquids

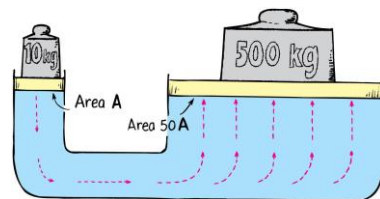


Pascal's Principle

- Application in hydraulic press

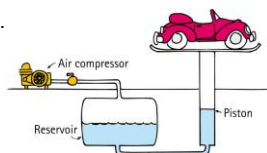
Example:

- Pressure applied to the left piston is transmitted to the right piston.
- A 10-kg load on small piston (left) lifts a load of 500 kg on large piston (right).



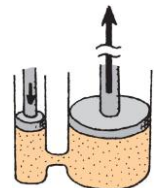
Pascal's Principle

- Application for gases and liquids:
 - Seen in everyday hydraulic devices used in construction
 - In auto lifts in service stations
 - Increased air pressure produced by an air compressor is transmitted through the air to the surface of oil in an underground reservoir. The oil transmits the pressure to the piston, which lifts the auto.



Ch.13 Problem 7

- In the sketch, the small hydraulic piston has a diameter of 2 cm.
- The large piston has a diameter of 6 cm.
- If 1 N of downward force is applied to the small piston, how much force is exerted by the large piston?



Surface Tension

The tendency of the surface of a liquid to contract in area and thus to behave like a stretched elastic membrane.

Examples:

- Insects can stand on the surface of water, even if they are more dense than water.
- In a small droplet of water, the surface will contract until it forms the shape with the smallest surface area for its volume: a sphere

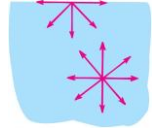


[image from <http://www.dailymail.co.uk/news/article-1371418/Photographer-Adam-Goorty-captures-ant-trapped-airdrop.html#ixzz22014z02F>]

[image from <http://www.ck12.org/physics/surface-tension-1.14-1484861838101/>]

Surface Tension

- Surface tension is caused by molecular attractions.
- Beneath the surface, each molecule is attracted in every direction by neighboring molecules.
- A molecule on the surface of a liquid is pulled only by neighbors on each side and downward from below; there is no pull upward.
- These molecular attractions tend to pull the molecule from the surface into the liquid, causing surface tension.



What Makes an Object Float or Sink? CHECK YOUR NEIGHBOR

What causes surface tension?

- Bernoulli's principle.
- Cohesive forces between molecules in a liquid.
- Adhesive forces between molecules in a liquid and a solid surface.
- Archimedes' principle
- Viscosity.

Surface Tension

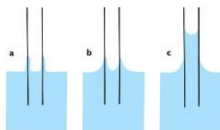
Factors affecting surface tension:

- The type of liquid
 - Water has greater surface tension than oil.
- What is mixed with the liquid
 - Soapy water has lower surface tension than water without soap.
- Temperature of the liquid
 - The molecules in a hot liquid have higher energy and are not bound tightly as in a cooler liquid.

Capillarity

The rise of a liquid in a fine, hollow tube or in a narrow space is called **capillarity**.

- Adhesion between the molecules of the glass and water draws the surface of water into the tube.
- Surface tension causes the water to be pulled upward.
- This raises the liquid from below to rise into the tube.
- When the force of the surface tension balances out the weight of the liquid, the liquid stops rising.



Capillarity

Examples:

- Oil rises in a wick.
- Hair let loose in a bathtub causes the scalp to get wet.
- Water is drawn up from the roots of trees



[image retrieved Jan 17 2013 from <http://think-hiker/facts.blogspot.ca/2012/02/06-used-to-figh-god-temp.html>]

Test 1 has been marked

Average was 73%

Find your mark under "My Grades" on the portal page for this course.

Your test will be returned to you by your TA in your next tutorial

Bubble sheets can be viewed in MP129 by request

Please have a look over the marking; bring any concerns to me by Feb.15

Before Class 10 on Monday



- Please read Chapter 14, or at least watch the 10-minute pre-class video for class 10
- Some things to think about:
 - Is it possible to have a region of absolute nothingness (ie empty space)?
 - If space is empty, why doesn't the Earth's atmosphere leak away?

