Physics 115
General Physics II

Session 3

Buoyancy
Archimedes' Principle

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Lecture Schedule (up to exam 1)

Date	Day	Lect.	Topic	readings in Walker
31-Mar	Mon	1	Introduction, Preview	
1-Apr	Tues	2	Density & Pressure	15.1-15.3
3-Apr	Thurs	3	Static Fluids, Buoyancy	15.4-15.5
4-Apr	Fri	4	Fluid Flow, Bernoulli	15.6-15.8
7-Apr	Mon	5	Viscosity, Flow, Capillaries	15.9
8-Apr	Tues	6	Temperature, expansion	16.1-16.3
10-Apr	Thurs	7	Heat, Conduction	16.4-16.6
11-Apr	Fri	8	Ideal gas	17.1-17.2
14-Apr	Mon	9	Heat, Evaporation	17.4-17.5
15-Apr	Tues	10	Phase change	17.6
17-Apr	Thurs	11	First Law Thermodynamics	18.1-18.3
18-Apr	**Fri**		**EXAM 1 Ch 15,16,17**	

Just joined the class? See course home page

courses.washington.edu/phy115a/

for course info, and slides from previous sessions

Today

Announcements

- You must log in to WebAssign to get your name onto the class roster for grades
  - Done automatically when you first log in, no other action required
- Clicker registration is open - Follow link on course home page: https://catalyst.uw.edu/webq/survey/wilkes/231214

Q: please post slides *before* class

A: No. Usually not finished updating/revising until just before class!

Disability Resources for Students is looking for at least two notetakers; a primary who would be able to upload their notes every day, and an alternate who would be on standby as a back-up notetaker.
If you take accurate and legible notes, please see me at the end of the class.

Topics for this week

- ✓ Fluids overview
- ✓ Density
- ✓ Pressure
- ✓ Static equilibrium in fluids
- ✓ Pressure vs depth
- Archimedes' Principle and buoyancy
- Continuity and fluid flow
- Bernoulli's equation

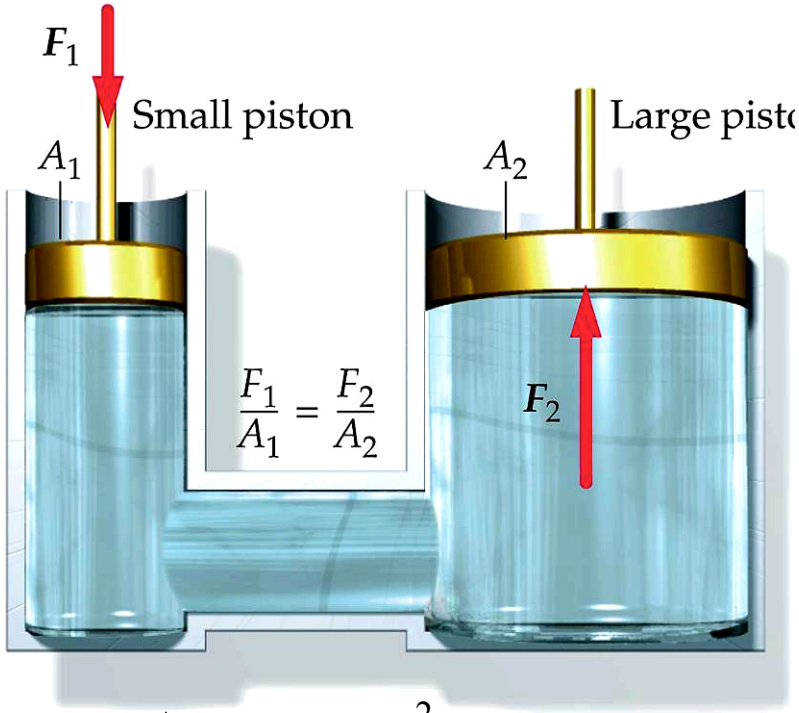
Read each day's assigned text sections before class

Applying Pascal's principle: hydraulic lift

The large piston of a hydraulic lift has a radius of 20 cm.

What force must be applied to the small piston of radius 2.0 cm to raise a car of mass 1,500 kg?

(***weight*** = mg = 14,700 N)



$$PA_2 = mg \quad \text{so} \quad P = \frac{mg}{A_2}$$

Last time:

$$F_1 = PA_1 = mg\frac{A_1}{A_2} = mg\frac{\pi r_1^2}{\pi r_2^2} = mg(r_1 / r_2)^2$$

$$= (1500\ \text{kg})(9.81\ \text{N/kg})(2.0\ \text{cm} / 20\ \text{cm})^2$$

$$= \boxed{147\ \text{N}}$$

$F_2 = 100\ F_1$

Hydraulic lift: did we get something for nothing?

(Basic rule of physics: there is no free lunch!)

- Hydraulic lift is just another form of lever
  - Force produced on the big piston is 100X force applied to small one, but
    - Volume of water moved, to push large piston 1 cm up:

$$V_2 = d_2 \pi r_2^2 = (1cm)\left(3.14\right)\left(20cm\right)^2 = 1256cm^2$$

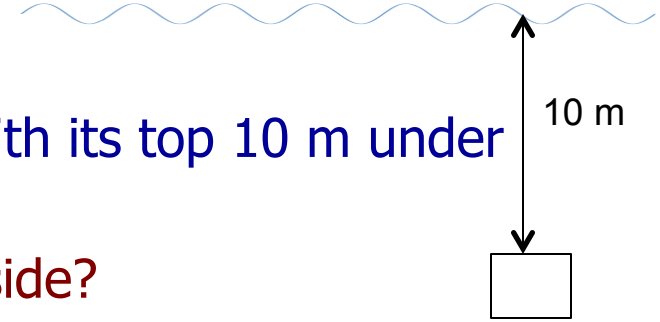
    - Distance small piston has to be moved, to push same V

$$V_1 = V_2 \rightarrow d_1 \pi r_1^2 = 1256cm^2 \rightarrow d_1 = \frac{1256cm^2}{\left(3.14\right)\left(2cm\right)^2} = 100cm$$

  - Small piston has to be pushed 100X farther than large one
    - Notice: work done (W=Fd) is the **same** on both sides

Last time:

Empty box underwater



- An empty box 1 m on each side is located with its top 10 m under the surface of a freshwater lake.
  - What is the (gauge) pressure on its top side?
    - "gauge" – so, subtract the atmospheric pressure and consider only pressure due to the water column

$$P_{TOP} = \rho g h = \left(1000\text{kg/m}^3\right)\left(9.8\text{m/s}^2\right)\left(10\text{m}\right) = 98kPa$$

  - What is the gauge pressure on its bottom side?

$$P_{BOTTOM} = \rho g h = \left(1000\text{kg/m}^3\right)\left(9.8\text{m/s}^2\right)\left(11\text{m}\right) = 107.8kPa$$

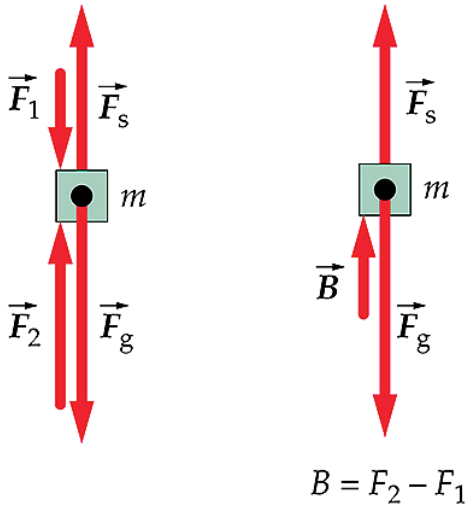
  - What does the 10 kPa pressure *difference* between top and bottom imply...?

Force on each side = P A: F_{TOP} = 98kPa(1m^2)=98 kN; F_{BOTTOM} = 108 kN
10 kN difference = net force upward on box .... but notice,
10 kN = weight of 1 m^3 of water = weight of water displaced by box

Buoyancy and Archimedes: phys 114 application

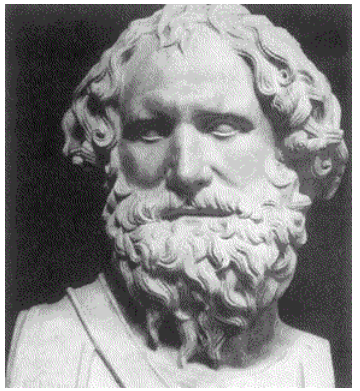
Difference in pressure means a net upward force on the box

Suspend object from scale.
Submerge in water.
Forces acting:
mg down, scale acts upward,
B= P_{bottom} A – P_{top} A
"Buoyant force" (BF) upward



Archimedes Principle:

A body wholly or partially submerged in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

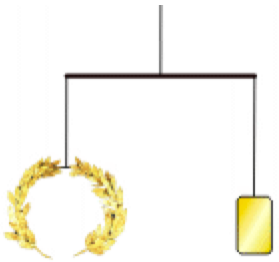


Archimedes

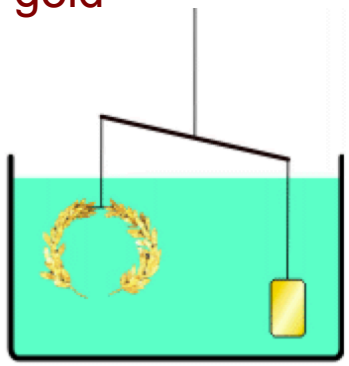
(287 BC – 212 BC)

First recorded Eureka Moment

- Archimedes' famous insight (c. 200 BCE):
  - King paid for new crown of pure gold
  - Asked Archimedes (wisest man in Sicily) to check if goldsmith had cheated by adding silver
    - Density of gold 19.3 kg/m^3, silver = 10.5 kg/m^3
  - Easy to get weight, but how to get V of crown? (Can't melt it down and make an easily-measured cube!) Archimedes puzzled over this problem...
  - Noticed the water rise in his bathtub as he got in
  - Realized BF could be used to measure density of complicated shapes
    - Anecdote: too excited to dress, A. ran naked to king's palace crying "Eureka!" (="I found it!")
    - Performed the measurement: density too low! (Goldsmith was executed...)



In air: crown is balanced by equal weight of known pure gold



In water: less dense crown displaces *more* water than pure gold: B is larger

Modern example calculation

Your friend wonders if a ring she bought is really pure gold – consults you, as a physics student.

You weigh the ring in air and find F_g = 0.158 N.

Then using a (massless) thread, you weigh the ring while submerged in water and get 0.150 N. Is the ring pure gold?

Buoyant force B will be = weight of water of same volume of ring:

$$F_{\text{g air}} = \rho_{\text{R}} V g \qquad B = \rho_{\text{W}} V g$$

Use ratios to simplify the calculation:
V and g are same for both cases, so cancel

$$\frac{\rho_{\text{R}} V g}{\rho_{\text{W}} V g} = \frac{\rho_{\text{R}}}{\rho_{\text{W}}} = \frac{F_{\text{g air}}}{B} = \frac{F_{\text{g air}}}{\left(F_{\text{g air}} - F_{\text{g water}}\right)} = \frac{0.158\ \text{N}}{0.158\ \text{N-}0.150\ \text{N}} = \frac{0.158\ \text{N}}{0.008\ \text{N}} = 20$$

$$\rho_{\text{Au}} = 19.3\times10^{3}\ \text{kg/m}^3 \quad \rho_{\text{Ag}} = 10.5\times10^{3}\ \text{kg/m}^3 \quad \rho_{\text{Water}} = 1.00\times10^{3}\ \text{kg/m}^3$$

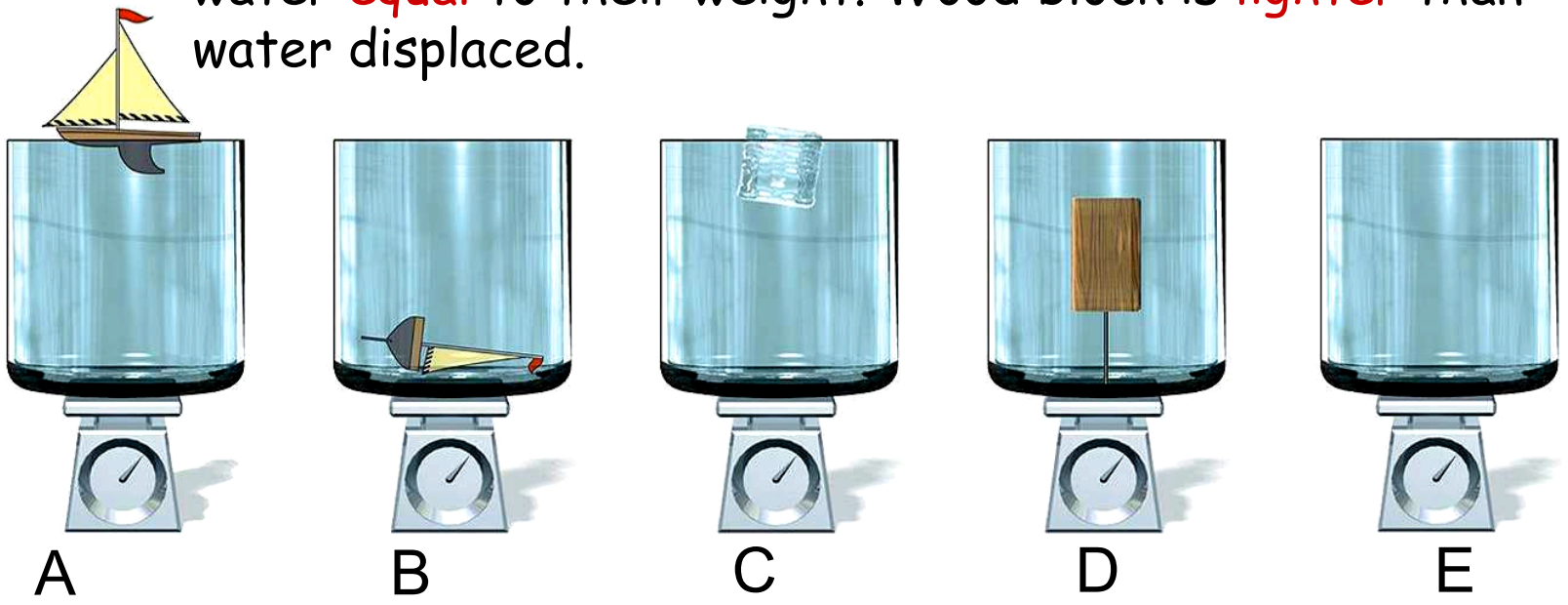
Conclusion: the result is consistent with gold, very inconsistent with silver: Ring is likely nearly pure gold. No need to execute anyone!
(exercise: if weight was measured to ± 0.001 N, what is *uncertainty* of this density estimate?)

Buoyancy: Which weighs the most?

- The boat, wood block, and ice cube all have equal masses, and the beakers are all full to the brim. Case E = just water.
- In case A the boat is air-filled and floats, in case B the boat sank.
- Rank the readings of the scales, from lowest to highest weight

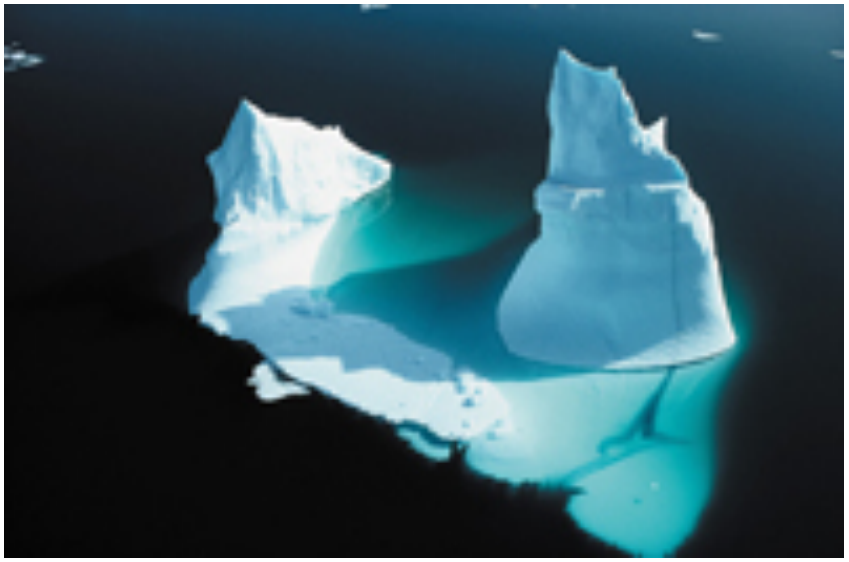
Weight readings: B>A=C=E>D

The sunken boat must be denser than water, so its weight is greater than water displaced. Floating objects displace water equal to their weight. Wood block is lighter than water displaced.



Example: The Tip of the Iceberg

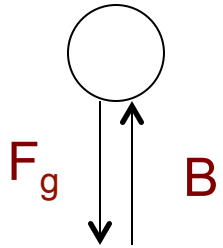
Find the fraction of the volume of an iceberg that is below the water line. (Iceberg = freshwater ice, ocean = saltwater)



http://www.ec.gc.ca/glaces-ice/

Iceberg is in equilibrium, so $F_{net}=0$

$$F_g = B$$



$$\rho_{\text{ice}} V g = \rho_{\text{sea water}} V_{\text{sub}} g$$

$$f = \frac{V_{\text{sub}}}{V} = \frac{\rho_{\text{ice}}}{\rho_{\text{sea water}}} = \frac{(0.92\times10^3\ \text{kg/m}^3)}{(1.025\times10^3\ \text{kg/m}^3)} = 0.898 = 90\%$$

Clicker quizzes

- First we'll program clickers to this rooms channel (01)
- Then, we'll have an example of a quiz question (but answers NOT COUNTED)

If you haven't done so already, please register:

- Go to ("Clicker registration" link on course home page)

  https://catalyst.uw.edu/webq/survey/wilkes/231214
- Follow instructions there carefully – do not click "submit" until you are SURE all info is entered in the format requested
  - You may register a 3-character personal alias which will be displayed on the projector screen to confirm your answer has been recorded
  - If you leave that space blank when registering, your screen code will just be the last 3 digits of your clicker serial number

Find your clicker's serial number

- Look on the back to find your clicker's unique serial number, and write it down for later.
  - Your answers are recorded against this number
  - If you have the colorful model, you have to open the battery compartment

Setting the RF channel

- Let's program your clickers to this room's RF channel = 01

  (zero one)

1. Press and hold the ↓ button **until** the LED turns red
2. Press the J/0 button once.
3. Press the A/1 button once.
4. Press the ↓ button again. The LED will flash green a few times and then turn off.

You're done!

Your clicker may get deprogrammed by random keying when carried in a backpack: **just repeat these steps before use**

Clicker Practice Quiz

Choose the best answer to the question.

Once the screen shows clock running down, press the corresponding letter's button on your clicker.

- The clicker receiver **does not accept answers until I start it.**
- As you enter your response, watch for your clicker ID icon to appear on the screen
  - It will always be in the same spot on the screen
- Today, it will just be the last 3 digits of your clicker's serial #, unless you registered before noon today.

If you change your mind you can re-enter your answer twice (3rd response received is your last chance) – a number will appear next to your icon

Clicker quiz for today's class

- This is the kind of pop quiz you can expect: if you paid attention during class, it is easy…

1. A cup of water is filled to the brim, with an ice cube in it. The top of the ice cube sticks out of the surface. As the ice melts, you observe that

A) the cup overflows.
B) the cup might overflow but it depends on the actual mass of the ice cube.
C) the water level remains the same.
D) the water level actually goes down.
E) Not enough information to answer this question.