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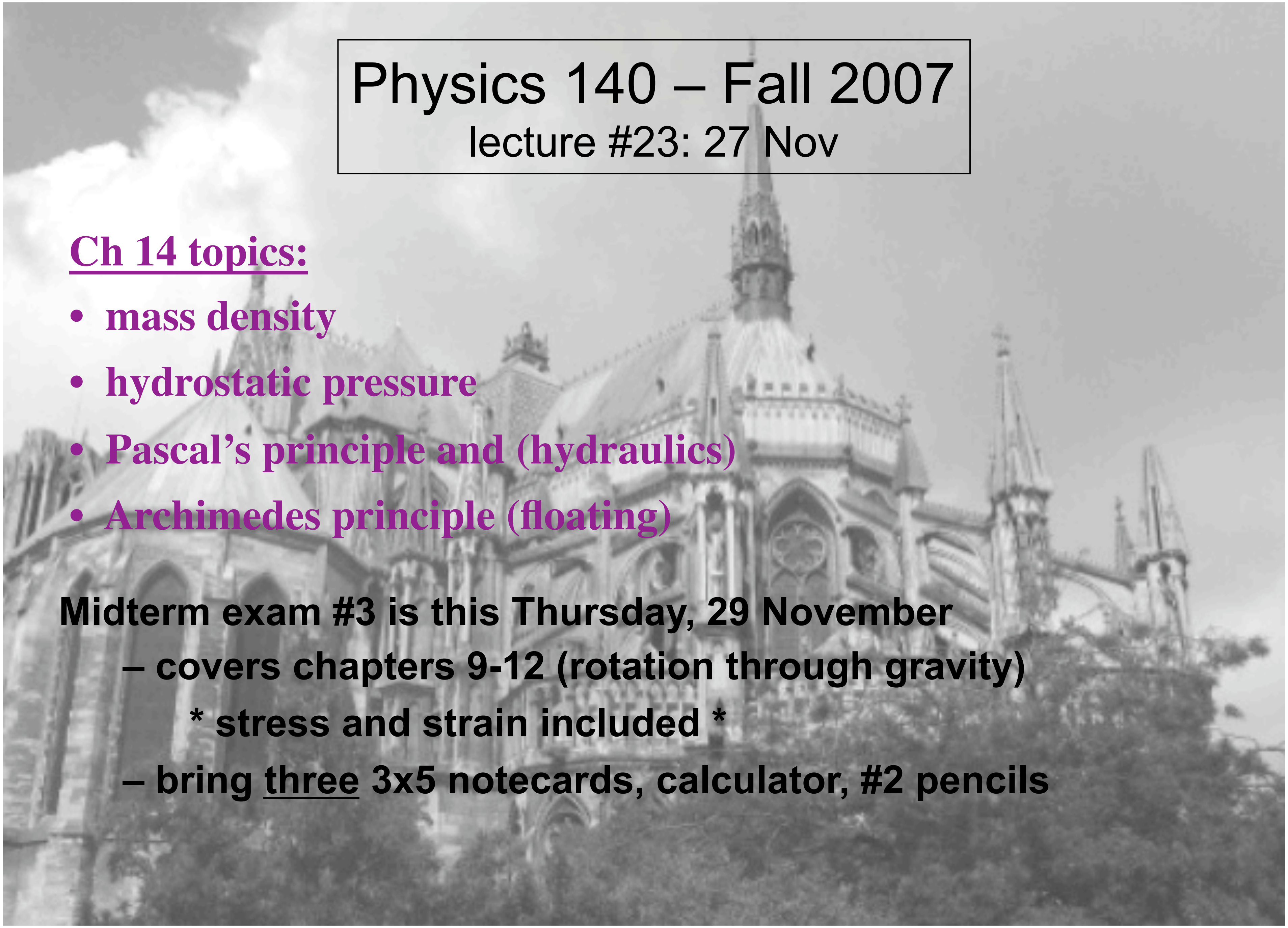


Physics 140 – Fall 2007
lecture #23: 27 Nov

<u>Ch 14 topics:</u>
- **mass density**
- **hydrostatic pressure**
- **Pascal's principle and (hydraulics)**
- **Archimedes principle (floating)**

Midterm exam #3 is this Thursday, 29 November
- **– covers chapters 9-12 (rotation through gravity)**
  - *** stress and strain included ***
- **– bring <u>three</u> 3x5 notecards, calculator, #2 pencils**

mass density

A small, continuous piece of a substance (solid, liquid or gas) of mass ΔM occupies a volume ΔV. Its ***mass density*** ρ is given by the quotient

$$\rho = \Delta M \,/\, \Delta V\,.$$

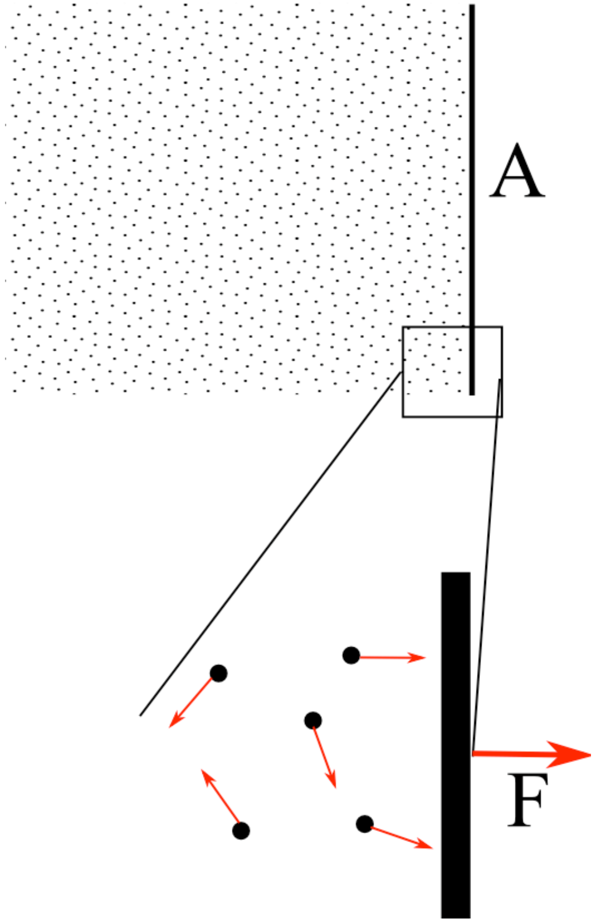
A dimensionless measure of density, the ***specific gravity***, is the ratio of the density of an object or substance (labeled X) with respect to water ρ_X / ρ_{water}.

Material	Density (kg/m^3)
Interstellar space	10^{-20}
Best laboratory vacuum	10^{-17}
Air: 20°C and 1 atm	1.21
Air: 20°C and 50 atm	60.5
Water: 20°C and 1 atm	0.998×10^3
Water: 20°C and 50 atm	1.000×10^3
Seawater: 20°C and 1 atm	1.024×10^3
Styrofoam	10^2
Whole blood	1.060×10^3
Ice	0.917×10^3
Iron	7.9×10^3
Mercury	13.6×10^3
Earth: crust	2.8×10^3
Earth: core	9.5×10^3
Earth: average	5.5×10^3
Sun: core	9.5×10^3
Sun: average	1.4×10^3
White dwarf star	10^{10}
Uranium nucleus	3×10^{17}
Neutron star	10^{18}
Black hole (1 $M_\odot$)	10^{19}

Source: Undetermined

pressure

Collisions of particles (molecules or atoms) within a gas or liquid generate a force against a surface that is in contact with it.



Fun Facts about air molecules:

(77% nitrogen, 21% oxygen, 1-2%water, 1% other)

- typical speed v = 450m/s (1000 mi/hr!)
- travel $8x10^{-8}$ m between collisions with another molecule
- 6 billion collisions per second on each square inch of your skin

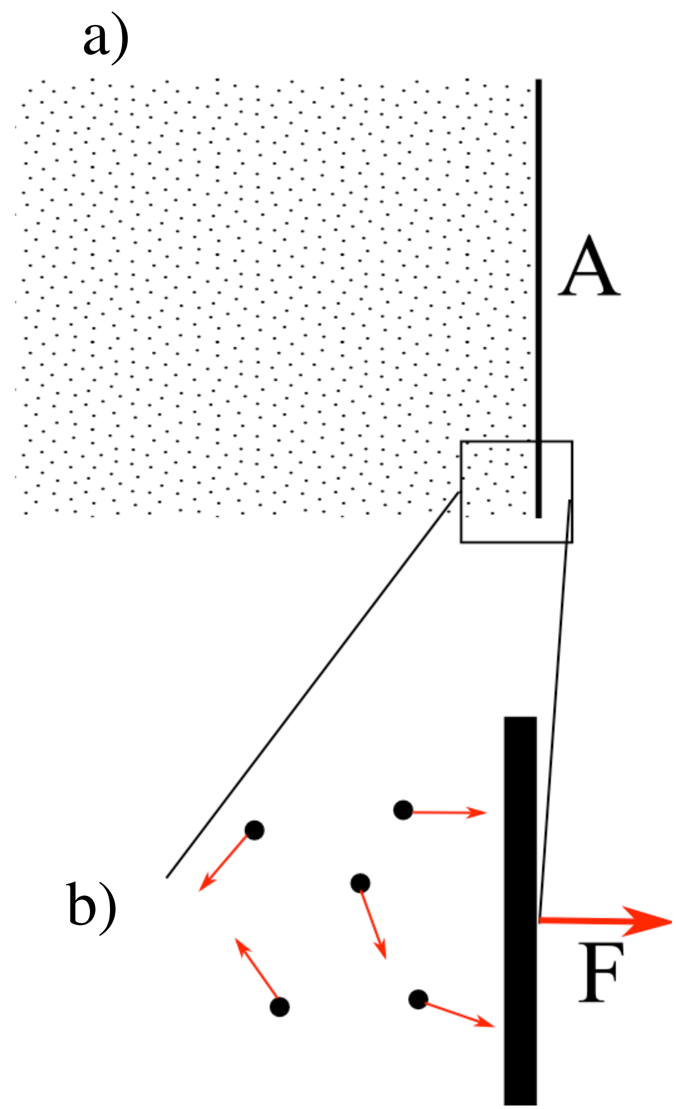
pressure

Imagine a very small section of the wall of a container (b) in a container with air or liquid (a).   Particles colliding with the outside of the plug transfer momentum, leading to a force ΔF acting across the plug's area ΔA. The force-per-area defines the ***pressure***

$$P = \Delta F / \Delta A .$$

UNIT: 1 PASCAL (Pa) = 1N/m^2

Fluid pressure is spatially *isotropic.* At a given location, the force that acts on the plug is independent of its orientation (down, up, sideways, etc.).



hydrostatic pressure and gravity

Gravity is the ultimate cause of ***hydrostatic pressure***. *Hydrostatic* refers to non-accelerating fluids, particularly fluids at rest.

Just as a stack of bricks must be strong enough to support its own weight, so the pressure in a fluid must vary with depth, so that the fluid below can support the weight of the fluid above.

A distance h below the surface of a liquid with density ρ, the pressure is increased from the surface value by an amount

$$\Delta P = \rho\, g\, h\ .$$

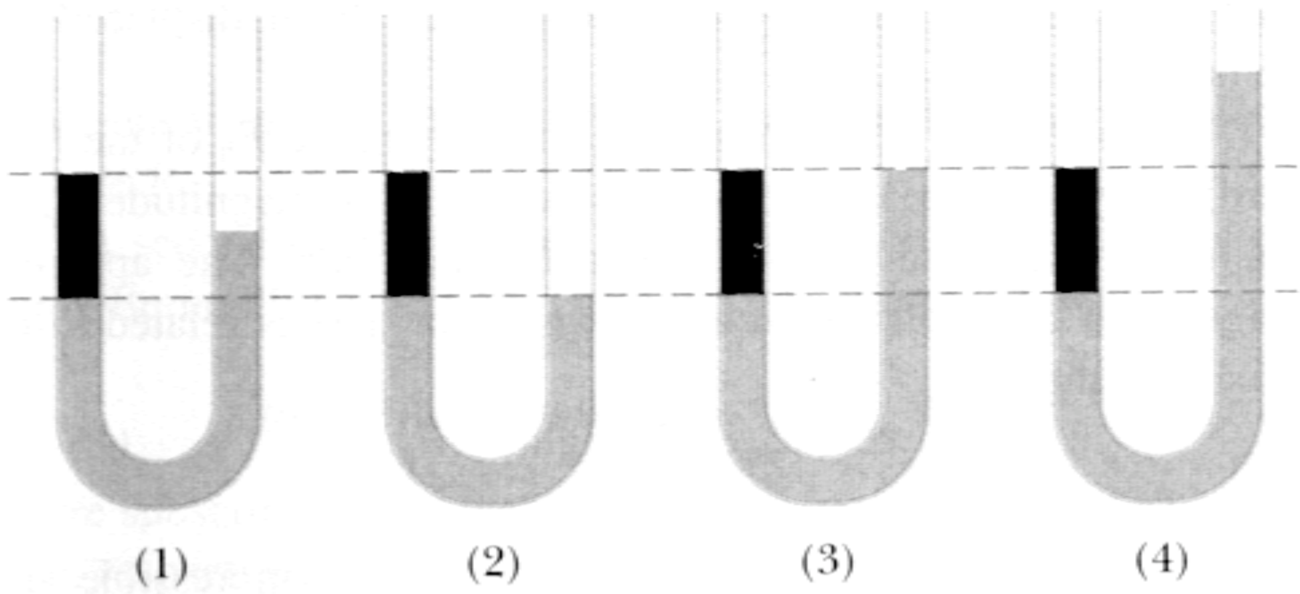
What we measure as *atmospheric pressure* is merely the weight per unit area of the column of atmosphere extending upward from the Earth's surface. It is often quoted in terms of the *equivalent height of a column of mercury* (specific gravity =13.6)

1 atmosphere = 101 kPa = 760 mm (29.92 in)

Otto von Guericke completed, around 1655, a pump which could extract the air from air-tight containers. With this new instrument, von Guericke was able to perform, at Magdeburg, in 1657, a spectacular experiment with the aid of a large number of his townsfolk. He demonstrated that the weight of air pushed together two perfectly sealed hemispheres, which had a vacuum created between them by the pneumatic pump, with such force that it needed two teams of 16 horses to separate them. Von Guericke understood that the weight of air was a force which could be put to work, to lift weights, for example. He thus initiated a line of research which led to the steam engine of James Watt (1736-1819)

Source: Gaspar Schott, Mechanica hydraulico-pneumatica, Würzburg 1657

For a description of historical experiments on pressure and fluids, see http://galileo.imss.firenze.it/vuoto/eesper.html



A U-shaped container is open on both ends and holds two fluids of different densities. If the darker fluid is *more* dense than the lighter fluid, which configuration above is correct?

1)

2)

3)

4)

Pascal's Principle

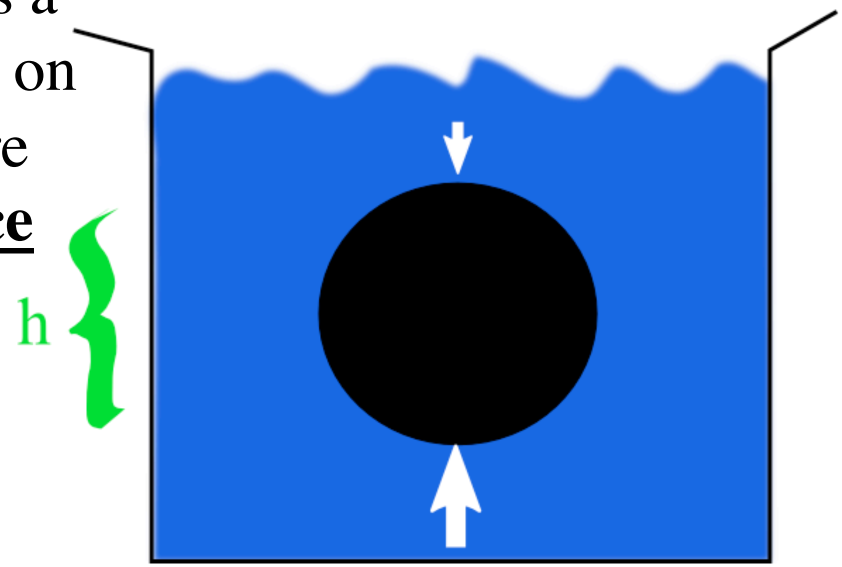
An external pressure applied to a fluid within a closed container is transmitted undiminished throughout the entire fluid.

This concept is the basic operating principle of all hydraulic equipment.

Archimedes' Principle

Objects immersed in a fluid at rest experience a *buoyant force* F_b *directed against gravity* with magnitude *equal to* ***the weight of the fluid displaced by the object.***

A small section within a fluid feels a higher pressure on its bottom than on its top. This difference in pressure produces an upward **bouyant force**



- $F_b = \Delta P\, A$
- $\quad = (\rho\, g\, h)\ A\ = \rho\, V\, g$
- $\quad = m_f\, g$

(m_f is the mass of the displaced fluid)

The magnitude of the buoyant force depends only on the mass of displaced fluid m_f and is *independent of the object's geometry*.

When I pour oil on top of the ball in the tube, what happens to the location of the ball?

1) It rises.
2) It sinks.
3) It stays at the same height.

You sit in a boat on a man-made lake filled with a fixed volume of water. Accompanying you is the pair of large rocks from the momentum chapter. This time, instead of throwing the rocks sideways, you drop them over the side and let them sink into the water. What happens to the water level of the lake after the rocks have sunk to the bottom?

1) It goes up.
2) It goes down.
3) It stays the same.

You place a small beaker of water on a scale and notice that its weight is 300g. If you now push your finger into the water, what happens to the reading on the scale?

1) It increases.
2) It decreases.
3) It stays the same.

You are in a boat holding a light rope attached to a stationary iron anchor of mass *m* that is submerged but is not touching the bottom of the lake. What is the tension in the rope?

1) mg
2) $mg(1-\rho_{water}/\rho_{iron})$
3) $mg(1+\rho_{water}/\rho_{iron})$
4) depends on the depth of the anchor.