Topic: Fluids

PHYSICS 231
Key Concepts

• Density, Volume, Mass – density as material property
• Pressure – units, how to measure, direction
• Hydrostatic pressure in liquid on earth
• Buoyancy and Archimedes Principle
  – How to calculate buoyancy force
  – Floating and sinking
• Continuity equation for incompressible liquid
  – Sets fluid speed for a given flow
• Bernoulli equation for flowing fluid
  – Pressure changes drive velocity changes and compensate gravity to maintain flow.
Key Equations

• Note that these are only useful once you understood the concepts and can derive equations that apply to a specific problem

• Pressure: \( p = \frac{F}{A} \)

• Hydrostatic pressure

\[ p = p_0 + \rho gd \]

• Buoyancy force: (upward)

\[ F_B = \rho_f V_f g \]

• Bernoulli equation:

\[ p + \frac{1}{2} \rho v^2 + \rho gh = \text{constant} \]
Density

\[ \rho = \frac{m}{V} \]

Mass density of an object of mass \( m \) and volume \( V \)

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \rho ) (kg/m(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium gas (20°C)</td>
<td>0.166</td>
</tr>
<tr>
<td>Air (20°C)</td>
<td>1.20</td>
</tr>
<tr>
<td>Air (0°C)</td>
<td>1.28</td>
</tr>
<tr>
<td>Gasoline</td>
<td>680</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>790</td>
</tr>
<tr>
<td>Oil (typical)</td>
<td>900</td>
</tr>
<tr>
<td>Water</td>
<td>1000</td>
</tr>
<tr>
<td>Seawater</td>
<td>1030</td>
</tr>
<tr>
<td>Blood (whole)</td>
<td>1060</td>
</tr>
<tr>
<td>Glycerin</td>
<td>1260</td>
</tr>
<tr>
<td>Mercury</td>
<td>13,600</td>
</tr>
</tbody>
</table>
These balls are sorted by increasing weight. Which has the smallest density?

- A: small ball of gold
- B: large ball of aluminum
- C: large ball of gold
These balls are sorted by increasing weight. Which has the smallest volume?

A: small ball of gold

B: large ball of aluminum

C: large ball of gold
Clicker quiz

All objects made of the same material have:

A: The same density regardless of their weight and volume
B: The same volume, regardless of their density and mass
C: The same mass, regardless of their density and volume
Atmospheric Pressure

1. The air’s density and pressure are greatest at the earth’s surface.

2. Because of gravity, the density and pressure decrease with increasing height.

3. The density and pressure approach zero in outer space.

$p_{\text{atmos}} = 1 \text{ atm} = 103,000 \text{ Pa}$
Otto von Guericke (1602-1686)
German scientist and mayor of Magdeburg

World’s first vacuum pump
Extra Credit Project

• Crush a soda can at home using normal air pressure (see for example): [http://scifun.chem.wisc.edu/homeexpts/COLLAPSE.html](http://scifun.chem.wisc.edu/homeexpts/COLLAPSE.html)

• Bring the crushed can to class before April 25

• Provide an estimate of the force that crushed the can (in Newton)

• Extra credit: 4% added to quiz score (worth ~ 1 missed lecture)
Example for pressure meter

(a) Piston attached to spring

1. The fluid exerts force $\vec{F}$ on a piston with surface area $A$.

2. The force compresses the spring. Because the spring constant $k$ is known, we can use the spring’s compression to find $F$.

3. Because $A$ is known, we can find the pressure from $p = F/A$. 
Clicker Quiz

- Which force meter shows the largest pressure?

![Force Meters Diagram]

E
Clicker Quiz

• Which force meter shows the largest pressure?

A

B

same
Clicker Quiz

Which force meter shows the largest pressure?

A B C

same
**TACTICS BOX 13.1  Hydrostatics**

1. **Draw a picture.** Show open surfaces, pistons, boundaries, and other features that affect pressure. Include height and area measurements and fluid densities. Identify the points at which you need to find the pressure.

2. **Determine the pressure \( p_0 \) at surfaces.**
   - Surface open to the air: \( p_0 = p_{\text{atmos}} \), usually 1 atm.
   - Surface in contact with a gas: \( p_0 = p_{\text{gas}} \).
   - Closed surface: \( p_0 = F/A \), where \( F \) is the force that the surface, such as a piston, exerts on the fluid.

3. **Use horizontal lines.** The pressure in a connected fluid (of one kind) is the same at any point along a horizontal line.

4. **Allow for gauge pressure.** Pressure gauges read \( p_g = p - 1 \) atm.

5. **Use the hydrostatic pressure equation:** \( p = p_0 + \rho gd \).

Exercises 5–7
As object is immersed deeper

The volume of displaced fluid:

A: Decreases
B: Stays the same
C: Increases
As object is immersed deeper
The volume of displaced fluid:

A: Decreases
B: Stays the same (Correct)
C: Increases

NOTE: because of string
B and C are correct!!
Clicker Quiz

• What will happen to force meter (apparent weight) when object begins to be immersed in fluid?

A: Force displayed by scale decreases
B: Force displayed by scale stays the same
C: Force displayed by scale increases
Clicker Quiz

• Once object is fully immersed, what will happen to force meter (apparent weight) when object is immersed deeper?

A: Force displayed by scale decreases
B: Force displayed by scale stays the same
C: Force displayed by scale increases
Clicker quiz

Blocks A, B have same size

How do buoyancies compare:

A: A has larger buoyancy
B: they have the same buoyancy
C: B has larger buoyancy

Reason: A displaces more volume and has therefore larger buoyancy force
Blocks have different mass with 1 being the lightest and 5 the heaviest. All of them are released in the middle of the pool. Final locations of 2 and 5 are given. Sketch the final locations of 1, 3, 4:
Solution
(3 could stay where it is if accidentally its density equals that of water exactly)
A princess sits in a boat on a pond. She throws a wooden ball into the water, which floats next to the boat.

Water level in the pond:

A: rises
B: stays the same
C: decreases
A princess sits in a boat on a pond. She throws a golden ball into the water, which sinks to the bottom.

Water level:

A: rises
B: stays the same
C: decreases

Reason: a floating golden ball in the boat displaces more volume (its weight worth of water) than a sinking one (its volume).
Laminar Flow

http://www.youtube.com/watch?v=blJwTcD1WoU
Where is the flow speed larger?

A

B

C: speed stays the same
Clicker Question

A B

Where is the pressure larger?

A
B
C: pressure stays the same

Explanation: water accelerates from A to B – the pressure adjust to create the necessary net-force to the right with high pressure at A and low pressure at B