# The Final Exam Schedule is Final!

Friday, December 18, 1:30 - 4:30 pm
Frank Kennedy Brown & Gold Gyms
The whole course
30 multiple choice questions
Formula sheet provided

# Seating (this info is on Aurora)

## Brown Gym: A - S

## Gold Gym: T - Z



# Next Week: Experiment 4

Centripetal Force

# WileyPLUS Assignment 4

Chapters 8, 9, 10
Due: Friday, November 27 at 11 pm

# An Opportunity

You can switch to the calculus stream next term and study even more physics...

(but only if you want!)

– PHYS 1070 and beyond –

if you get a B ($B^+$ for honours physics) in PHYS 1020



# Simple Harmonic Motion

- The restoring force has the form: F = –kx
- The motion is: x = A cos(ωt), or x = A sin(ωt)
- The angular frequency is: $\omega = \sqrt{\frac{k}{m}}$

$$\omega = 2\pi f = 2\pi/T \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

- Simple pendulum, motion simple harmonic, with k = mg/L:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

# Chapter 11: Fluids

- Density
- Pressure, variation of pressure with depth in a fluid
- Pascal's Principle
- Archimedes' Principle
- Fluids in motion -
  - equation of continuity
  - Bernoulli's equation
- **Leave out 11.11, viscous flow**



# Density

The density of a gas, liquid or solid is its mass divided by its volume:

$$\text{Density, } \rho = \frac{\text{mass}}{\text{volume}} = \frac{m}{V} \ (\text{kg/m}^3)$$

Specific gravity is the density of a substance relative to water:

$$\text{Specific gravity } = \frac{\text{Density of substance}}{\text{Density of water at } 4^\circ \text{ C}} = \frac{\text{Density of substance}}{1000 \text{ kg/m}^3}$$

$$\text{Mass, } m = \rho V$$

**Table 11.1 Mass Densities[a] of Common Substances**

| Substance | Mass Density $\rho$ (kg/m$^3$) |
|---|---|
| **Solids** | |
| Aluminum | 2700 |
| Brass | 8470 |
| Concrete | 2200 |
| Copper | 8890 |
| Diamond | 3520 |
| Gold | 19 300 |
| Ice | 917 |
| Iron (steel) | 7860 |
| Lead | 11 300 |
| Quartz | 2660 |
| Silver | 10 500 |
| Wood (yellow pine) | 550 |
| **Liquids** | |
| Blood (whole, 37 °C) | 1060 |
| Ethyl alcohol | 806 |
| Mercury | 13 600 |
| Oil (hydraulic) | 800 |
| Water (4 °C) | $1.000 \times 10^3$ |
| **Gases** | |
| Air | 1.29 |
| Carbon dioxide | 1.98 |
| Helium | 0.179 |
| Hydrogen | 0.0899 |
| Nitrogen | 1.25 |
| Oxygen | 1.43 |

[a] Unless otherwise noted, densities are given at 0 °C and 1 atm pressure.



11.6/92: A chunk of concrete of mass 33 kg has a hollow spherical cavity inside. The volume of the chunk is 0.025 m$^3$. What is the radius of the spherical cavity? The density of concrete is 2,200 kg/m$^3$.

If the mass of the chunk is 33 kg, then its volume should be,
V = m/ρ:

V = (33 kg) / (2,200 kg/m$^3$) = 0.015 m$^3$.

Its actual volume is 0.025 m$^3$, so the volume of the spherical cavity is 0.025 – 0.015 = 0.010 m$^3$.

Volume of a sphere: $V = \frac{4}{3}\pi r^3$

$$\text{So, } r = \left[\frac{3V}{4\pi}\right]^{1/3} = \left[\frac{3 \times 0.01}{4\pi}\right]^{1/3} = 0.134 \text{ m}$$

11.10/9: An antifreeze solution is made by mixing ethylene glycol (density = 1116 kg/m$^3$) with water. The specific gravity of the solution is 1.073. Find the percentage of ethylene glycol by volume.

Density of the antifreeze = 1.073 × 1000 = 1073 kg/m$^3$.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m_1 + m_2}{V_1 + V_2} = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

$$\rho_1 = 1116 \text{ kg/m}^3 \text{ (ethylene glycol)}$$
$$\rho_2 = 1000 \text{ kg/m}^3 \text{ (water)}$$

$$\text{Put } \frac{V_1}{V_1 + V_2} = \alpha, \text{ then } \frac{V_2}{V_1 + V_2} = 1 - \alpha$$

$\alpha$ = fraction of ethylene glycol by volume

$$\text{Density of antifreeze } = \rho_1 \alpha + \rho_2 (1 - \alpha) = 1073 \text{ kg/m}^3$$

$$\text{So, } 1116\alpha + 1000(1 - \alpha) = 1073$$

$$\rightarrow \alpha = 0.629, \text{ i.e. } 62.9 \text{ percent ethylene glycol by volume}$$



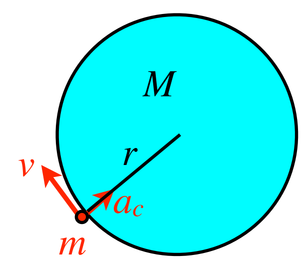
11.9/8: A hypothetical spherical planet consists entirely of iron. What is the period of a satellite that orbits the planet just above the surface?

Table: density of iron, $\rho$ = 7860 kg/m$^3$

Mass of planet = M = $\rho$V

Radius of planet = r

Mass of satellite = m



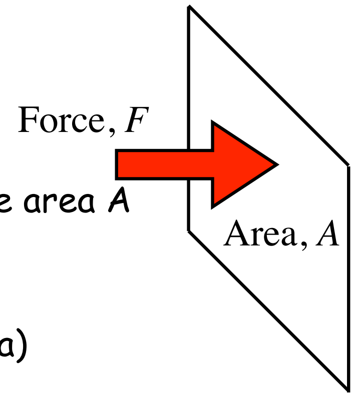

Period = 2$\pi$r/v

What is v ?

Better still, what is r/v ?

# Pressure

Pressure is the force exerted by a fluid on its surroundings. The force is measured per unit area of surface.



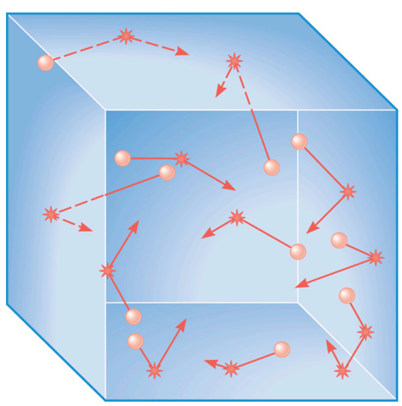

The pressure exerted by the force F on the area A perpendicular to the force is:

$P = F/A$, Units: 1 $N/m^2$ = 1 Pascal (Pa)

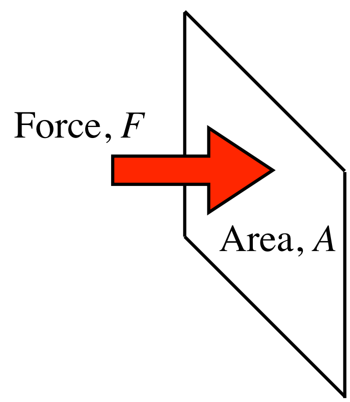
Normal atmospheric pressure is $1.013 \times 10^5$ Pa = 101.3 kPa.

Pressure is exerted equally in all directions.





# Pressure



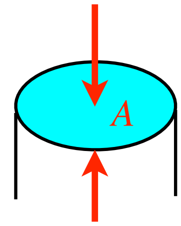

Pressure is due to the impact of molecules with the surface – the molecules of the fluid carry momentum and exert an impulse on the surface when they bounce from it.

The resulting force is equal to the change of momentum per second of the molecules as they bounce from the surface.

The total force on a surface is proportional to its area.

11.15/12: A bottle of soda has a screw cap. The absolute pressure inside the bottle is 180 kPa.

If the cap has an area $4.1\times10^{-4}$ m$^2$, calculate the force exerted on the cap by the screw thread that keeps it in place.




Inside the bottle: $P_1$ = 180 kPa → outward force on cap = $P_1A$

Outside the bottle: $P_2$ = 101.3 kPa → inward force on cap = $P_2A$

The net outward force on the cap is $F = (P_1 - P_2)A$

$F = [(180 - 101.3) \times 1000 \text{ Pa}] \times (4.1\times10^{-4} \text{ m}^2) = 32.3 \text{ N}$

The thread exerts an inward force of 32.3 N



11.11/11: An airtight box has a removable lid of area 0.013 m$^2$ and negligible weight. The air is removed from the box and the box is taken up a mountain where the air pressure outside the box is 85 kPa. What force is needed to remove the lid?

There is zero pressure inside the box and 85 kPa outside, so there is a force pushing the lid onto the box.

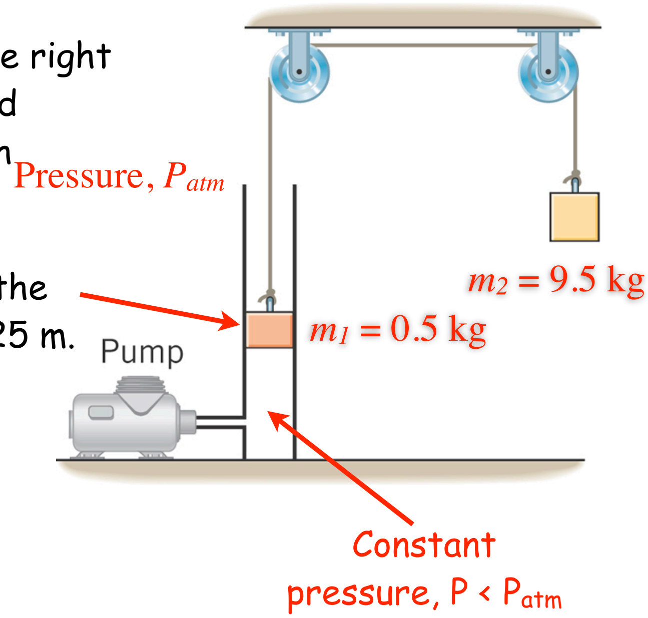
The force is $F = PA = (85{,}000 \text{ Pa})(0.013 \text{ m}^2) = 1105 \text{ N}$

If instead the airtight box contained air at normal atmospheric pressure, 101.3 kPa, there would be a net outward force on the lid, as the pressure inside would be greater than the pressure on the outside.

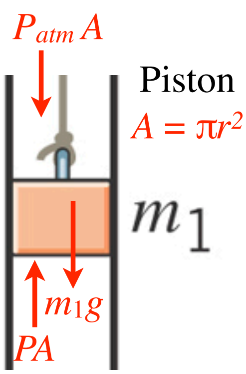
The outward force would be $(P_{in} - P_{out})A = (101{,}300 - 85{,}000)(0.013 \text{ m}^2)$

F = 212 N, outwards.

11.-/18: Given that the block at the right falls 1.25 m from rest in 3.3 s, find the pressure in the cylinder, which is held constant by the pump. Ignore friction.

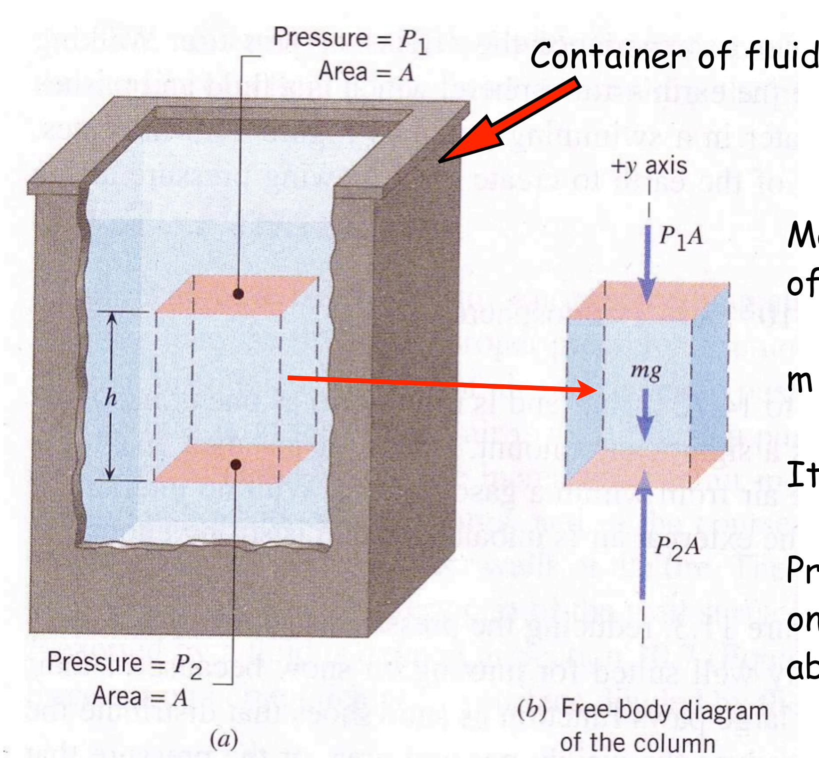



The radius of the piston is r = 0.025 m.






# Variation of Pressure with Depth




(a)

(b) Free-body diagram of the column

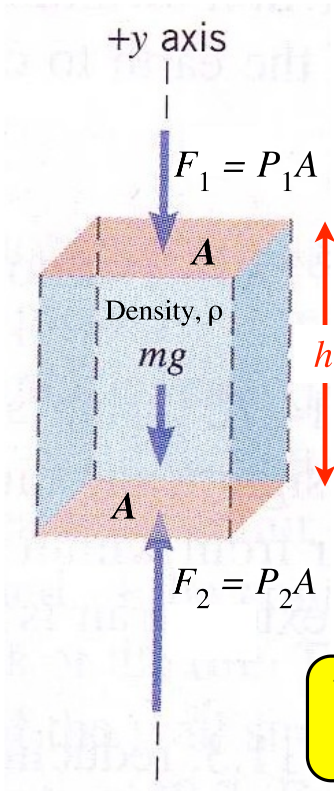
Mass of small column of fluid is:

$m = \rho V = \rho Ah$

It is in equilibrium

Pressure forces act on the column from above and from below

## Variation of Pressure with Depth




For the column of fluid to be in equilibrium:

$$-mg - F_1 + F_2 = 0$$

So, $-mg - P_1A + P_2A = 0$

or, $P_2 = P_1 + \frac{mg}{A}$

The mass of the column of fluid is:

$$m = \rho V = \rho A h$$

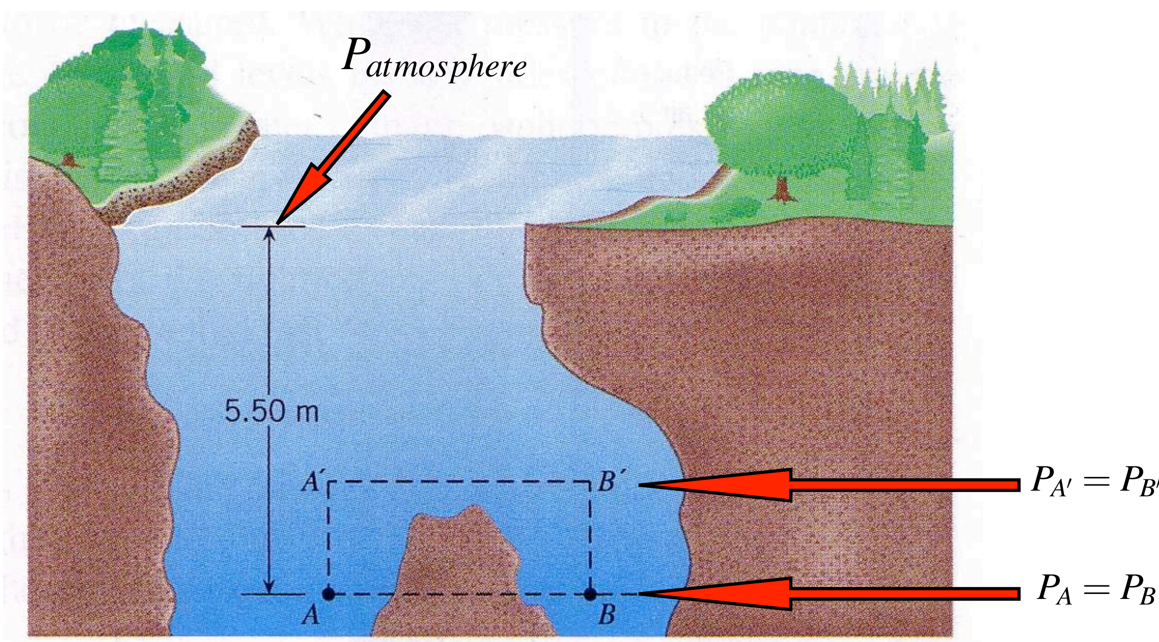
Therefore, $P_2 = P_1 + \rho g h$

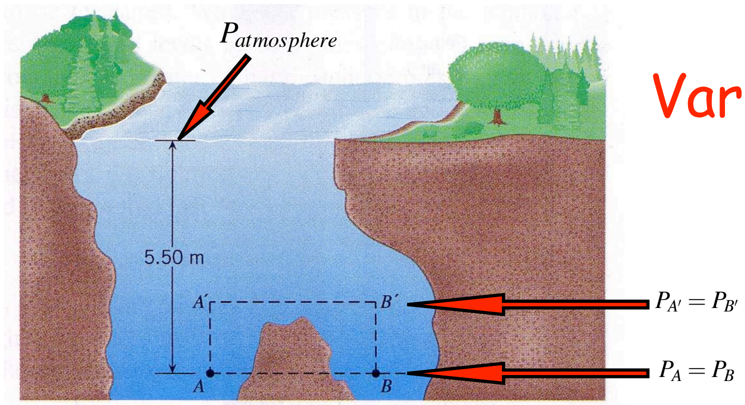
The pressure is the same at all points at the same depth



## Variation of Pressure with Depth

The pressure is the same at all points at the same depth






# Variation of Pressure with Depth

Both A and B are 5.5 m below the surface of the water.

$$P_A = P_B = P_{atmosphere} + \rho g h$$

$$= P_{atmosphere} + (1000\ \text{kg/m}^3)(9.8\ \text{m/s}^2)(5.5\ \text{m})$$

$$= P_{atmosphere} + 53{,}900\ \text{Pa}$$

Standard atmospheric pressure is 101.3 kPa,

so $P_A$ = 1.53 atmospheres (i.e., 1.53 × $P_{atmosphere}$)



# Fluids, the story so far...

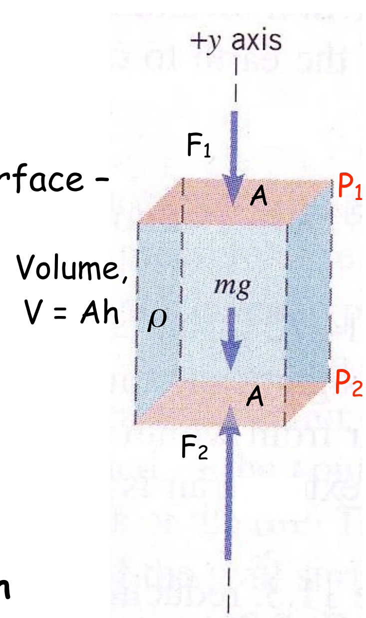
Density = Mass/Volume

Specific gravity $= \dfrac{\text{Density of substance}}{\text{Density of water at } 4°\text{C}}$

Pressure = Force/Area

Pressure – due to impact of molecules with a surface – acts equally in all directions

Increase of pressure with depth:
Mass m of fluid is in equilibrium, so $mg = F_2 - F_1$




As $m = V\rho = Ah\rho$,

$Ah\rho g = A(P_2 - P_1) \rightarrow P_2 = P_1 + \rho g h$

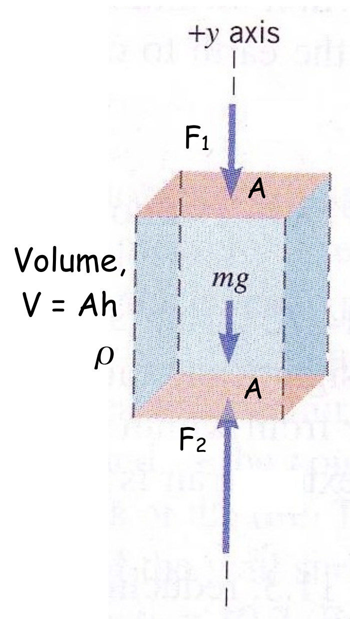
**Pressure depends only on depth**

# Buoyant Force

The buoyant force on an object placed in a fluid, floating or not, is:

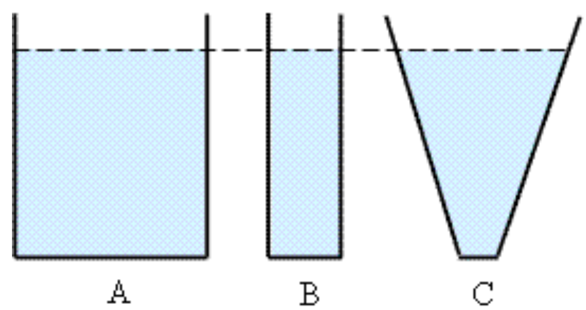
$F_b = F_2 - F_1 = A(P_2 - P_1) = \rho Ahg = \rho Vg$
= weight of fluid displaced by the object.

and on to Archimedes...






## Focus on Concepts, Question 1

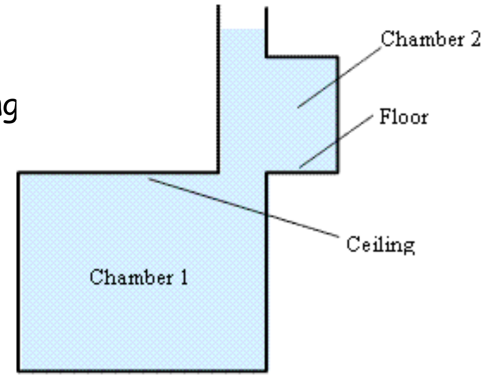



The drawing shows three containers filled to the same height with the same fluid. In which container, if any, is the pressure at the bottom greatest?

A) Container B, because it has the least volume of fluid.
B) Container C, because its bottom has the least surface area.
C) Container A, because its bottom has the greatest surface area.
D) All three containers have the same pressure at the bottom.
E) Container A, because it has the greatest volume of fluid.

## Focus on Concepts, Question 2

Two chambers are filled with a fluid. The ceiling of chamber 1 is at the same level as the floor of chamber 2. As the drawing suggests, the area of the ceiling in chamber 1 is greater than the area of the floor in chamber 2. Which experiences the greater pressure due to the fluid, the ceiling of chamber 1 or the floor of chamber 2?



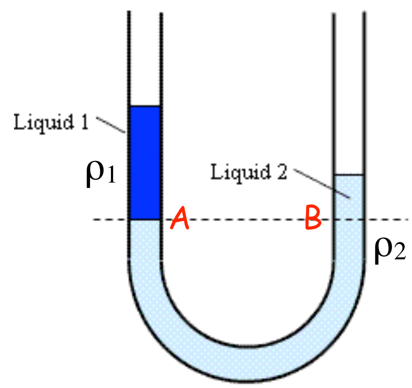
(Side view)

A) The floor experiences the greater pressure, because there is fluid above it and there is no fluid above the ceiling.
B) The floor experiences the greater pressure, because it has the smaller area.
C) The ceiling experiences the greater pressure, because it has the greater area.
D) The ceiling experiences the greater pressure, because there is more fluid in chamber 1 than in chamber 2.
E) Both the ceiling and the floor experience the same pressure.



## Focus on Concepts, Question 4

Two liquids, 1 and 2, are in equilibrium in a U-tube that is open at both ends, as in the drawing. The liquids do not mix, and liquid 1 rests on top of liquid 2. How is the density $\rho_1$ of liquid 1 related to the density $\rho_2$ of liquid 2?




A) $\rho_1$ is less than $\rho_2$.
B) $\rho_1$ is greater than $\rho_2$.
C) There is not enough information to tell which liquid has the greater density.
D) $\rho_1$ is equal to $\rho_2$, since the liquids are in equilibrium.

$$P_2 = P_1 + \rho g h$$