i-clicker:

A glass of water is resting on a scale that reads its weight. What will happen to the reading when you dip a finger into the water?

a) Increase
b) Decrease
c) Stay the same
d) Not enough information
e) I just don’t understand how to answer this
Explanation: Think about the change in the forces acting on the water+beaker when the finger is submerged.

Force due to air on top surface decreases by $P_0 A$.

Force due to bottom surface of finger is $(P_0 + \rho g d) A$.

Net added force is $\rho g d A$ downwards; scale reading increases.
Hands on demos
Ask me about prelecture materials
Suggest good office hour times
Get out your clickers!

1st HW due Monday January at 11:59PM
Recitations start this week with a quiz from chapter 14

Fluids-Part 2
Last time: learned that pressure changes with height in a liquid
\[ P_2 = P_1 - \rho \ g \ (y_2 - y_1) \]
no change in height -> no change in pressure
Simple rule: \[ P = P_0 + \rho \ g \ d \ (P_0 \text{ is the pressure at the surface}) \]
Last time: learned that pressure changes with height in a liquid
\[ P_2 = P_1 - \rho \, g \, (y_2 - y_1) \]
no change in height -> no change in pressure
CRAZY SHAPED CONTAINER: simple rule: \( P = P_0 + \rho \, g \, d \)
Last time: learned that pressure changes with height in a liquid
\[ P_2 = P_1 - \rho g (y_2 - y_1) \]
no change in height \( \rightarrow \) no change in pressure
Simple rule: \( P = P_0 + \rho g d \)
Last time: learned that pressure changes with height in a liquid

\[ P_2 = P_1 - \rho g (y_2 - y_1) \]

no change in height -> no change in pressure

CRAZY SHAPED CONTAINER: Simple rule: \( P = P_0 + \rho g d \)

Same pressure even if there is not a horizontal path in the liquid that connects them
CONTAINER WITH TWO SEPARATE OPENINGS
pour liquid in to reach marked level on left side
What will be the level on the right side?
Right level is lower
Same height, same pressure
Check?
Right level is higher
Same height, same pressure
Check?
Level of surface is the same in both openings!
Pascal’s vase demo
Simple rule: $P = P_0 + \rho g d$ ($P_0$ is the pressure at the surface)
If I change the pressure at the surface $P_0 \rightarrow P_0' = P_0 + \Delta P$
Then the pressure everywhere in the liquid changes by $\Delta P$

**PASCAL’S PRINCIPLE**

True for “incompressible fluids”
(r does not change with P)

$F$ on piston of area $A \rightarrow \Delta P = F/A$
If I increase the pressure by $\Delta P$ at the right surface, pressure increases by $\Delta P$ at the left surface. Force on left surface has to increase to maintain equilibrium.
F=P A
Apply an additional force of F = 10,000 N to right surface
Increase the pressure at the right surface by \( \Delta P = F/A_{\text{right}} \)

the pressure at the left surface increases by \( \Delta P = F/A_{\text{right}} \)
To keep equilibrium, increase force on the left surface
A container is filled with oil and fitted on both ends with pistons. The area of the left piston is 10 mm$^2$; that of the right piston 10,000 mm$^2$. What extra force must be exerted on the left piston to support the 10,000-N car on the right at the same height?

a. 10 N
b. 100 N
c. 10,000 N
d. $10^6$ N
e. I just don’t understand how to do this
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a. 10 N  
b. 100 N  
c. 10,000 N  
d. $10^6$ N  
e. I just don’t understand how to do this
\[ F_{\text{left}} = \Delta P A_{\text{left}} \]
Smaller area on left means smaller force on left

**Hydraulic lever = simple machine**
One can support a heavy car with a smaller force
Open U-tube  U-tube with two different pressures

\[ P = P_0 + \rho gh \]
TWO DIFFERENT LIQUIDS

\[ P_2 = P_1 - \rho \ g \ (y_2 - y_1) \text{ \textit{within the liquid}} \]

Compute pressure from using depth from top interface

Simple rule: \[ P = P_0 + \rho \ g \ d \]
U-tube with two different immiscible liquids

\[ P_0 + \rho_1 g h_1 = P_0 + \rho_2 g h_2 \]

\[ \rho_1 h_1 = \rho_2 h_2 \]

Larger \( \rho \) means smaller \( h \)
Iclicker: 2 different IMMISCIBLE liquids

In one of the 4 situations below, the liquids CANNOT be in equilibrium. Which one is it?

A             B             C             D
Iclicker: 2 different IMMISCIBLE liquids

In one of the 4 situations below, the liquids CANNOT be in equilibrium. Which one is it?

A           B           C           D
A submerged or partially submerged object displaces liquid

volume of liquid displaced = volume of object under the surface

weight of liquid displaced = $\rho_{\text{liquid}} \times \text{volume of liquid displaced}$
In the prelecture material, we learned that the force exerted by the liquid on a partially submerged object is $\rho g d A$ upwards.

For fully submerged object, force is $\rho g L A$ upwards.
In the prelecture material, we learned that the force exerted by the liquid on a partially submerged object is
\[ \rho g \, d \, A \, \text{upwards} = \rho g \, V_{\text{dis}} = \rho \, V_{\text{dis}} \, g = m_{\text{dis}} \, g \]

For fully submerged object, force is \( \rho \, g \, L \, A \, \text{upwards} = \rho \, g \, V_{\text{dis}} \)

In both cases, magnitude of force = weight of the water displaced

This force exerted by the liquid is called the BUOYANT FORCE
DEMO – beaker of water, aluminum cylinder and cup with the same volume as the cylinder
Object in water: equilibrium

Floating vs sinking

Floating = partially submerged
f = fraction of object under water (less than or equal to 1)

Downwards force \( m\ g \)
Upwards force \( f\ V\ \rho_{\text{liq}}\ g \)

NET FORCE IS ZERO – EQUATION

\( f\ V\ \rho_{\text{liq}} = m \) (mass of liquid displaced = mass of the object)

\( f = m/(\rho_{\text{liq}}\ V) = (\rho_{\text{obj}}\ V)/(\rho_{\text{liq}}\ V) = \rho_{\text{obj}}/\rho_{\text{liq}} \)

(fraction submerged of floating object = \( \rho_{\text{obj}}/\rho_{\text{liq}} \))

For an object to float, density must be less than the density of the liquid

OTHERWISE SINKS TO THE BOTTOM
Float or sink?
Rocks / blocks of wood
Bowling balls
Cans of coke
Cartesian diver
Example: What fraction of an ice cube’s volume is below the water surface? $\rho_{\text{ice}} = 0.92 \rho_{\text{water}}$
Example: What fraction of an ice cube’s volume is below the water surface? \( \rho_{\text{ice}} = 0.92 \rho_{\text{water}} \)

Answer: \( V_B = 0.92 V_{\text{ice}} \)
Consider three identical open-top containers filled to the brim with water. Toy ducks float in two of them. Rank the containers and contents according to their weight, greatest first.

(A) 3,2,1
(B) 1,2,3
(C) All equal
(D) I need more information about the ducks
(E) I just don’t understand how to do this
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If the object is accelerating then net force is not zero

Example:
submerged object sinking or rising to the surface

Free body diagram  \[ mg \text{ down,} \]
\[ \text{buoyant force up} \]

\[ F = ma \]
Example: A stone of density 3 times that of water is thrown into a pond. With what acceleration does it sink?
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Downward force \( \rho_{\text{stone}} V g = 3 \rho_{\text{water}} V g \)
Upward force \( \rho_{\text{water}} V g \)

Downward net force = 2 \( \rho_{\text{water}} g \)
\[ a = \frac{(2 \rho_{\text{water}} g)}{m_{\text{stone}}} = \frac{(2 \rho_{\text{water}} g)}{(3 \rho_{\text{water}})} = \frac{2}{3} g \]