

# **Concept Questions**

## **Archimedes Principle**

**8.01t**

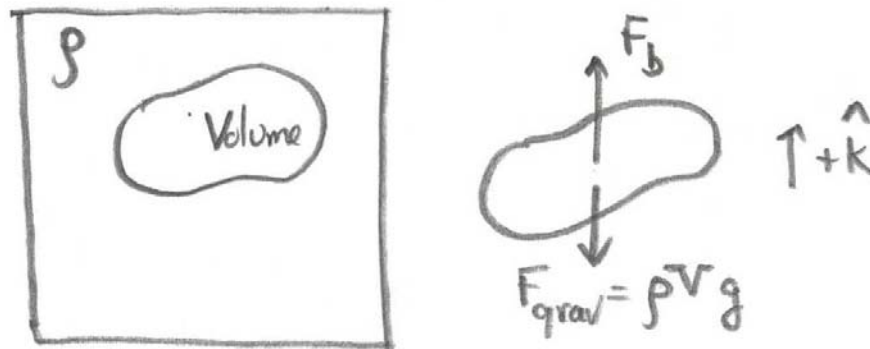
**Nov 24, 2004**

# Pascal's Law

- Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel

# Archimedes' Principle

- The buoyant force in a liquid is equal in magnitude to the gravitational force on the displaced volume of liquid

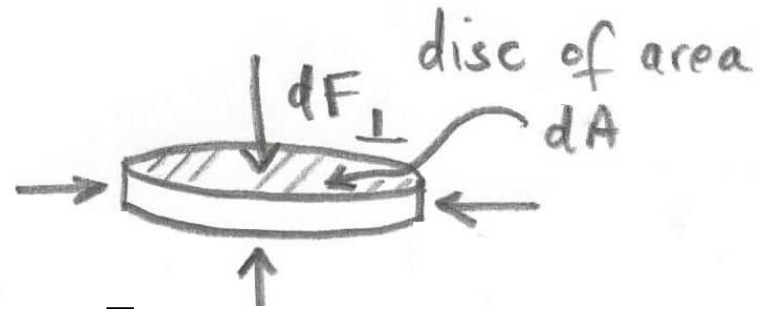


$$F_b = \rho g V$$

# Mass Density and Pressure

- Mass density =  $\rho$  = Mass/volume

- Pressure  $P = \frac{dF_{\perp}}{dA}$



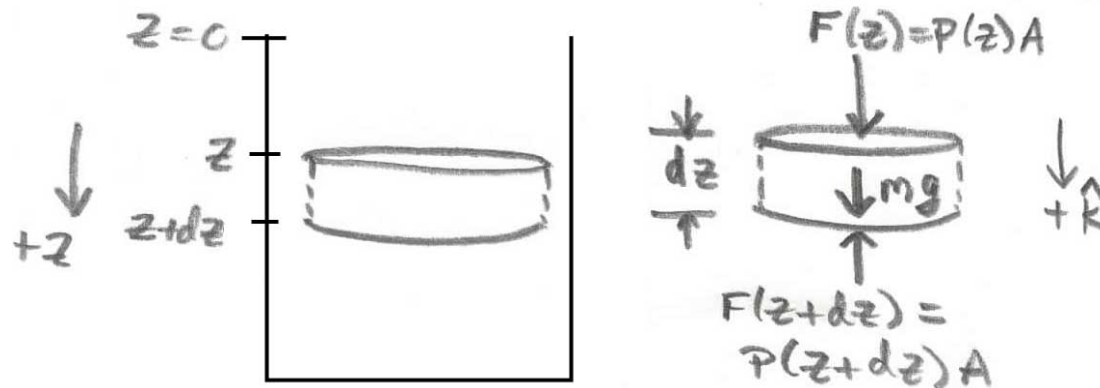
- Units: pascal  $[Pa] = [N \cdot m^{-2}]$

- bar:  $1bar = 10^5 Pa$

- atmosphere  $1atm = 1.013 \times 10^5 Pa$

# Pressure and Depth

- Fluid with one end open to atmosphere pressure  $P_0$ . Consider a slice of the fluid of cross sectional area  $A$  at a depth  $z$  and thickness  $dz$ .



- Newton's Second Law

$$A(P(z) - P(z + \Delta z)) + \rho g A \Delta z = 0$$

# Pressure and Depth

- Fluid Equation

$$\frac{P(z + \Delta z) - P(z)}{\Delta z} = \rho g$$

- Definition of derivative

$$\frac{dP}{dz} = \lim_{\Delta z \rightarrow 0} \frac{P(z + \Delta z) - P(z)}{\Delta z}$$

- Differential equation

$$\frac{dP}{dz} = \rho g$$

- Integration

$$\int_{P_0}^{P(z)} dP = \int_{z=0}^z \rho g dz'$$

- Solution

$$P(z) - P_0 = \rho g z$$

# PRS Question 1

Imagine holding two bricks under water. Brick *A* is just beneath the surface of the water, while brick *B* is at a greater depth. The force needed to hold brick *B* in place is

1. larger
2. the same as
3. smaller

than the force required to hold brick *A* in place.

# PRS Question 2

A 200-ton ship enters the lock of a canal. The fit between the sides of the lock and the ship is tight so that the weight of the water left in the lock after it closes is much less than 200 tons. Can the ship still float if the quantity of water left in the lock is much less than the ship's weight?

1. Yes, as long as the water gets up to the ship's waterline.
2. No, the ship touches bottom because it weighs more than the water in the lock.



# PRS Question 3

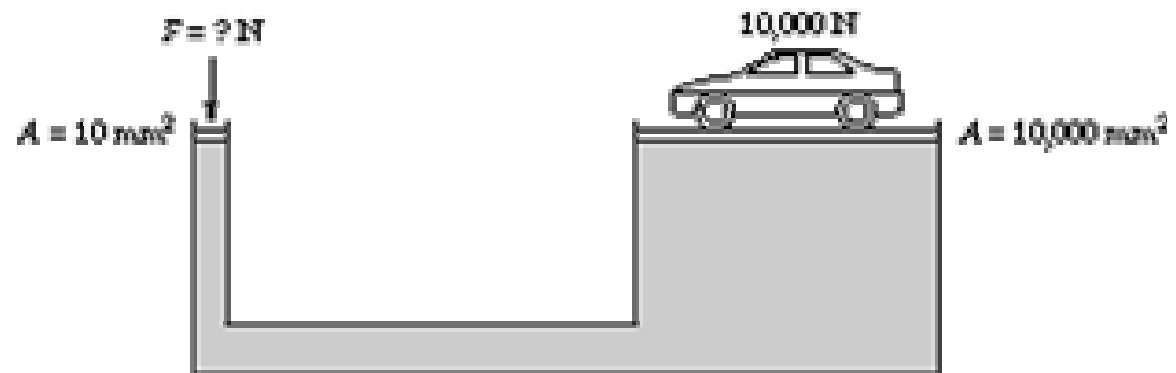
When a hole is made in the side of a container holding water, water flows out and follows a parabolic trajectory. If the container is dropped in free fall, the water flow

1. diminishes.
2. stops altogether.
3. goes out in a straight line.
4. curves upward.

# PRS Question 4

A container is filled with oil and fitted on both ends with pistons. The area of the left piston is  $10 \text{ mm}^2$ ; that of the right piston  $10,000 \text{ mm}^2$ . What force must be exerted on the left piston to keep the  $10,000\text{-N}$  car on the right at the same height?

1.  $10 \text{ N}$
2.  $100 \text{ N}$
3.  $10,000 \text{ N}$
4.  $106 \text{ N}$
5.  $108 \text{ N}$
6. insufficient information



# PRS Question 5

Two cups are filled to the same level with water. One of the two cups has ice cubes floating in it. Which weighs more?

1. The cup without ice cubes.
2. The cup with ice cubes.
3. The two weigh the same.

# PRS Question 6

Two cups are filled to the same level with water. One of the two cups has ice cubes floating in it. When the ice cubes melt, in which cup is the level of the water higher?

1. The cup without ice cubes.
2. The cup with ice cubes.
3. It is the same in both.

# PRS Question 7

Two cups are filled to the same level with water. One of the two cups has plastic balls floating in it. If the density of the plastic balls is less than that of ice, which of the two cups weighs more?

1. The cup without plastic balls.
2. The cup with plastic balls.
3. The two weigh the same.

# PRS Question 8

A piece of lead is fastened on top of a large solid piece of Styrofoam that floats in a container of water.

Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down so that the piece of lead is now suspended underneath it,

1. the arrangement sinks.
2. the water line is below the top surface of the Styrofoam.
3. the water line is still flush with the top surface of the Styrofoam.

# PRS Question 9

A piece of lead is fastened on top of a large solid piece of Styrofoam that floats in a container of water.

Because of the weight of the lead, the water line is flush with the top surface of the Styrofoam. If the piece of Styrofoam is turned upside down, so that the piece of lead is now suspended underneath it, the water level in the container

1. rises.
2. drops.
3. remains the same.

# PRS Question 10

A piece of lead is fastened on top of a large solid piece of Styrofoam, and the combination floats in a container of water. Suppose the lead becomes unfastened and sinks to the bottom of the container. After the lead has sunk, the height of the water in the container will be

1. higher.
2. the same.
3. lower.
4. than it was before the combination separated.



# PRS Question 11

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks. The water level in the lake (with respect to the shore)

1. rises.
2. drops.
3. remains the same.

# PRS Question 12

Consider an object that floats in water but sinks in oil. When the object floats in water, half of it is submerged. If we slowly pour oil on top of the water so it completely covers the object, the object

1. moves up.
2. stays in the same place.
3. moves down.

# PRS Question 13

Consider an object floating in a container of water. If the container is placed in an elevator that accelerates upward,

1. more of the object is below water.
2. less of the object is below water.
3. there is no difference.

# PRS Question 14

Which weighs more?

1. a bathtub filled to the brim with water
2. the same bathtub brim full with water with a battleship floating in it
3. both weigh the same

# Class Problem

A rock of mass  $m$ , suspended by a rope, is completely immersed in a beaker of water that sits on a scale. The beaker of water has mass  $m_b$ . What weight does the scale measure? Is this weight equal to, less than, or greater than the weight of the rock and beaker?

# Class Problem

- One of the moons of Jupiter, Europa, is reported to have its surface covered by an ocean of water which is 100 km deep. The outermost 8 km are frozen as ice. The radius of Europa is approximately  $\frac{1}{4}$  the radius of the earth. Estimate the pressure at the bottom of Europa's ocean. (Note: there is some speculation that the combination of internal heat and water makes the ocean of Europa the best candidate in the solar system outside the earth for organized life to evolve.)