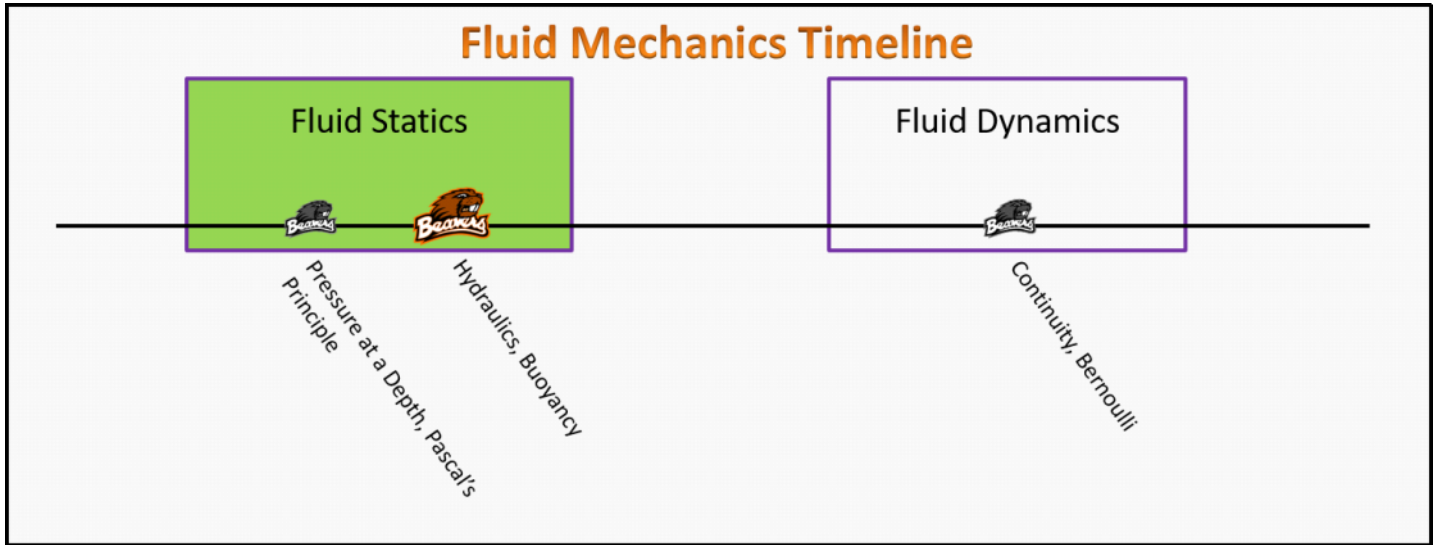


# Fluid Statics

## Familiarize Stage (FS.L2.1)

### Lecture 2

#### Hydraulics, Buoyancy



**FS.L2.1-01**

**Description:** Nature of buoyancy

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** What is the major cause of the buoyancy force?

- (1) The gravitational force reverses directions in a fluid
- (2) Obi Wan Kenobi
- (3) The pressure on the bottom of an object is greater than on the top
- (4) The normal force of the fluid on the object

**FS.L2.1-02**

**Description:** Infographic quiz buoyancy - label matching

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** Match each term in the equation with the correct description from the following list. (1) Density of fluid, (2) Gravity, (3) Volume of displaced fluid, (4) Buoyant force

The diagram shows the equation  $|F^B| = \rho_f V_d g$ . Arrows point from labels (a) through (d) to specific parts of the equation: (a) points to  $|F^B|$ , (b) points to  $\rho_f$ , (c) points to  $V_d$ , and (d) points to  $g$ .

**FS.L2.1-03**

**Description:** Buoyancy force

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** The buoyancy force is equal to \_\_\_\_\_.

- (1) the mass of the displaced fluid
- (2) the weight of the displaced fluid
- (3) the volume of the displaced fluid
- (4) the pressure of the displaced fluid

**FS.L2.1-04**

**Description:** Buoyancy analysis methods

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** Which of the following are relevant in a static system where buoyancy is present.

- (1) Free-body diagram physical representation
- (2) Change in position physical representation
- (3) Kinematics analysis in the mathematical representation
- (4) Newton's 2nd Law force analysis in the mathematical representation
- (5) Conservation of energy analysis

**FS.L2.1-05**

**Description:** Buoyancy force on a fully submerged object

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** Consider a cell phone fully submerged in water. What happens to the buoyancy force on

the phone as it is pushed further down into the water?

- |  |
|--|
| (1) Increases  |
| (2) Decreases  |
| (3) Stays the same                                       |
| (4) Depends on whether or not it is an Android or iPhone |

**FS.L2.1-06**

**Description:** Buoyancy force on a partially submerged object

**Learning Objectives:** [x,xx,...] Put the learning objective numbers here

**Problem Statement:** Consider an object that is partially submerged in water. The mass of the displaced water is 1 kg.

(a) What is the buoyancy force acting on the object?

- |            |
|------------|
| (1) 1 kg   |
| (2) 9.8 kg |
| (3) 1 N    |
| (4) 9.8 N  |

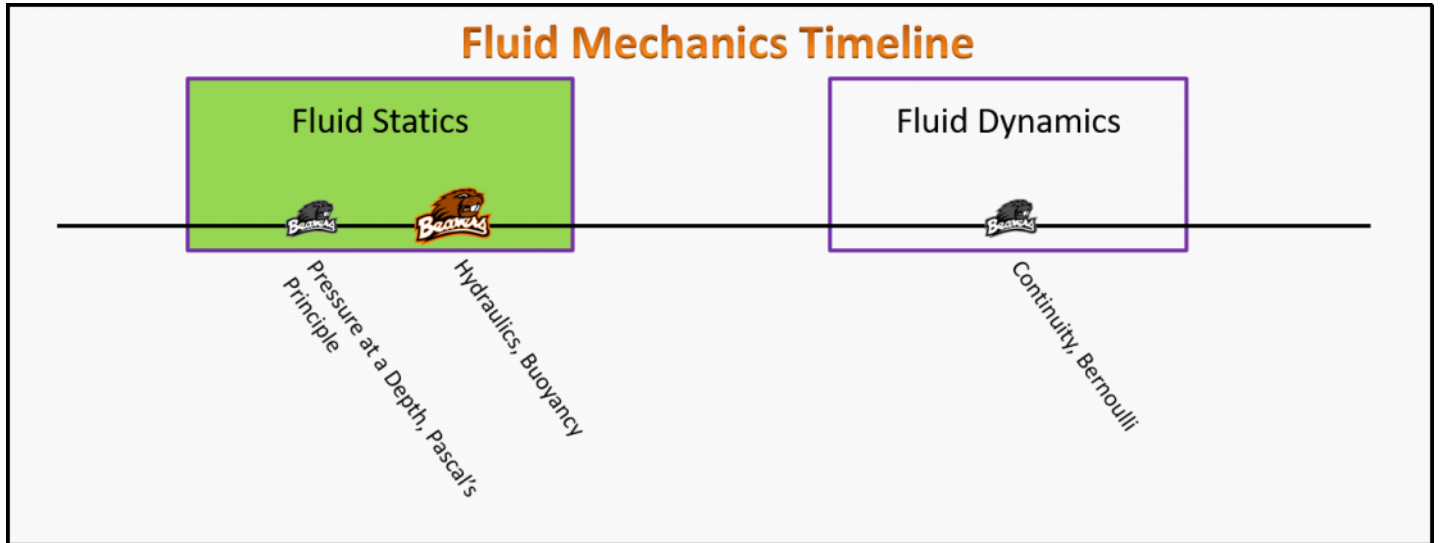
(b) What is the volume of water displaced?

- |                           |
|---------------------------|
| (1) 1.0 m <sup>3</sup>    |
| (2) 0.1 m <sup>3</sup>    |
| (3) 0.01 m <sup>3</sup>   |
| (4) 0.001 m <sup>3</sup>  |
| (5) 0.0001 m <sup>3</sup> |

# Fluid Statics

## Foundation Stage (FS.L2.2)

### Lecture 2 Hydraulics, Buoyancy



#### Textbook Chapters (\* Calculus version)

- **BoxSand** :: KC videos ( [Buoyancy](#) )
- **Knight** (College Physics : A strategic approach 3<sup>rd</sup>) :: 13.4
- **\*Knight** (Physics for Scientists and Engineers 4<sup>th</sup>) :: 14.4
- **Giancoli** (Physics Principles with Applications 7<sup>th</sup>) :: 10-7

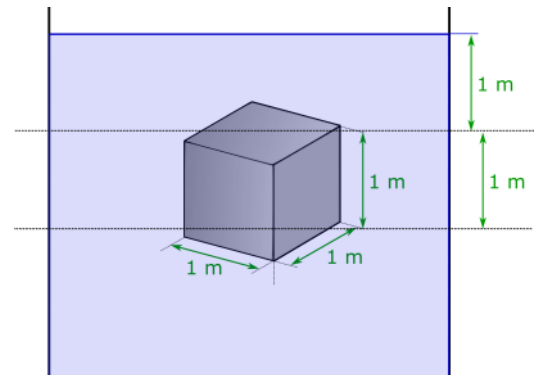
#### Warm up

##### FS.L2.2-01:

**Problem Statement:** A box of 1 m x 1 m x 1 m ( L x W x H ) is submerged 1 meter underwater as shown in the image below. The container of water the box is in is near the surface of the earth, so the pressure right outside the water is atmospheric pressure.

(a) Calculate the pressure at the top surface of the box.

(b) Calculate the pressure at the bottom surface of the box.



(c) Calculate the force from the pressure at the top of the box. (d) Calculate the force from the pressure at the bottom of the box.

(e) What is the sum of the two forces due to the pressures at the top and bottom of the box. Be careful with signs.

(f) Use the definition of buoyant force  $|\vec{F}^B| = \rho_f V_{fd} g$  to calculate the value of the buoyant force and compare it to your answer from part (e). What can you conclude about the buoyant force definition?

**Hints:**  $\rho_f$  is the density of the fluid which is water in this problem,  $V_{fd}$  is the volume of the fluid that the object displaces which is just the volume of the object in the problem because the entire block is submerged, finally  $g$  is the acceleration of an object in free-fall.

### Selected Learning Objectives

1. Coming soon to a lecture template near you.

### Key Terms

- Archimedes Principle
- Buoyant force

### Key Equations

$ \vec{F}^B  = \rho_f V_{fd} g$	
---------------------------------	--

### Key Concepts

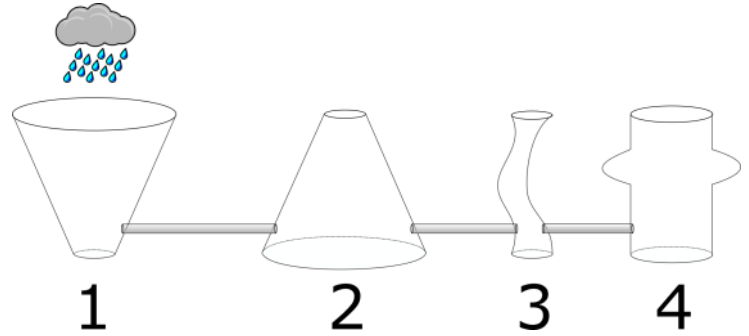
- Coming soon to a lecture template near you.

### Questions

**FS.L2.2-02:**

**Problem Statement:** Consider the odd shaped container shown below.

(a) You pour water into the left most tube only. Rank the heights of the fluid in each tube at equilibrium.



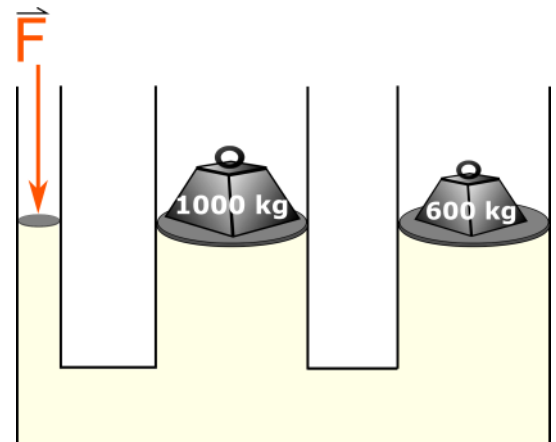
(b) Rank the pressure at the bottom of each tube.

**FS.L2.2-03:**

**Problem Statement:** Consider two different masses are initially placed on top of equal area low friction pistons as shown in the figure below. The container has a third piston where a force  $F$  is applied such that it doesn't move.

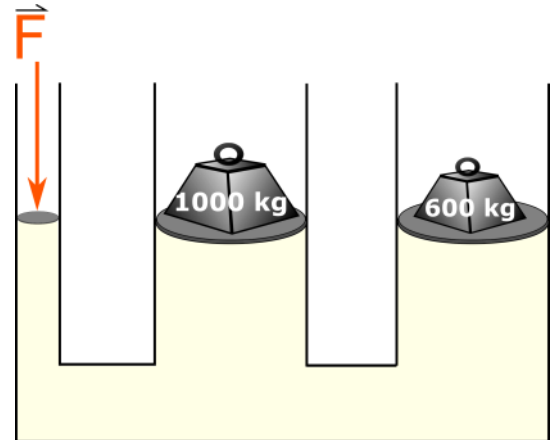
(a) What happens to the other two pistons?

- (1) The 1000 kg and 600 kg masses move upwards.
- (2) The 1000 kg mass moves upwards while the 600 kg mass moves downwards.
- (3) The 1000 kg and 600 kg masses move downwards.
- (4) The 1000 kg mass moves downwards while the 600 kg mass remains still.
- (5) The 1000 kg mass moves downwards while the 600 kg mass moves upwards.
- (6) Both the 1000 kg and 600 kg mass remain at rest.



(b) Which of the following actions could cause the 1000 kg mass to move upwards and the 600 kg mass to move downwards.

- (1) Make the area under the 600 kg mass smaller.
- (2) Make the area under the 1000 kg mass smaller.
- (3) Make the area under the 600 kg mass larger.
- (4) Make the area under the 1000 kg mass larger.
- (5) No actions can cause the 1000 kg mass to move upwards and the 600 kg mass downwards.

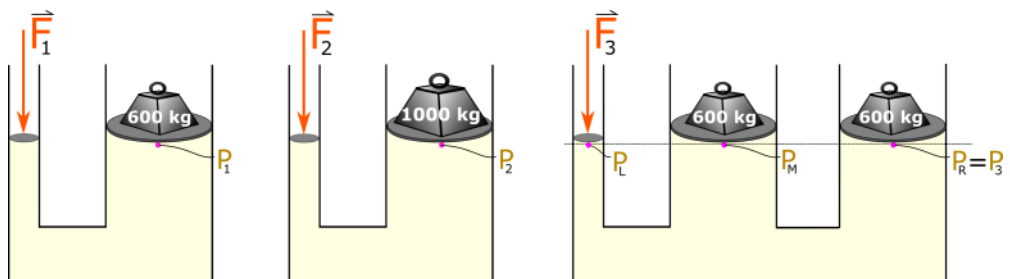


**FS.L2.2-04:**

**Problem Statement:** We eventually wish to rank the forces required to balance the masses on frictionless pistons. The areas of all the pistons holding the masses are the same. The areas of the pistons where the forces are applied are also the same.

(a) Consider system 3, which of the following statements are true?

- (1)  $P_L = P_M = P_R$
- (2)  $P_L > P_M > P_R$
- (3)  $P_L < P_M < P_R$
- (4)  $P_L > P_M = P_R$
- (5)  $P_L < P_M = P_R$



(b) Which of the following is true comparing  $P_1$  and  $P_3$ ?

- (1)  $P_1 = P_3$
- (2)  $P_1 > P_3$
- (3)  $P_1 < P_3$
- (4) Unable to determine because they are separate containers.

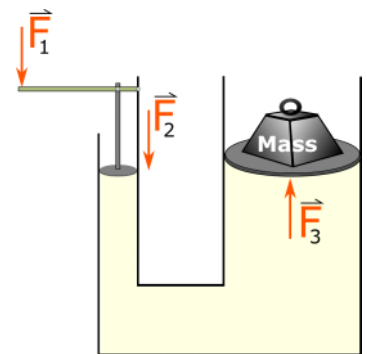
(c) Rank the magnitude forces required to balance the masses at the same height as shown.

**FS.L2.2-05:**

**Problem Statement:** Consider the image below which is a very basic hydraulic lift with a lever that pushes down on a small frictionless piston, which in turn applies pressure on the oil which then lifts the object. Many hydraulic car jacks work in a similar way.

(a) What ratio of radii ( $r_3/r_2$ ) would give you a hydraulic mechanical advantage of 3?

- (1)  $1/9$
- (2)  $1/3$
- (3)  $1/\text{sqrt}(3)$
- (4)  $\text{sqrt}(3)$
- (5) 3
- (6) 9

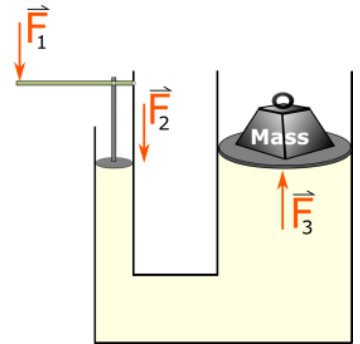


(b) If the area of the larger piston is  $9.42 \text{ m}^2$ , what should be the radius of the smaller piston so that the hydraulic mechanical advantage is 3?



(c) As the picture is drawn, what is the mechanical advantage of the total system?

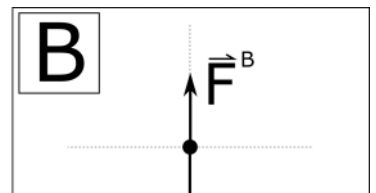
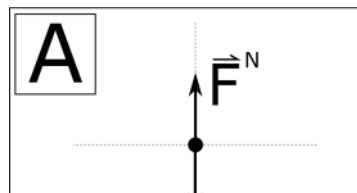
- (1) Greater than 3
- (2) Less than 3
- (3) Equal to 3

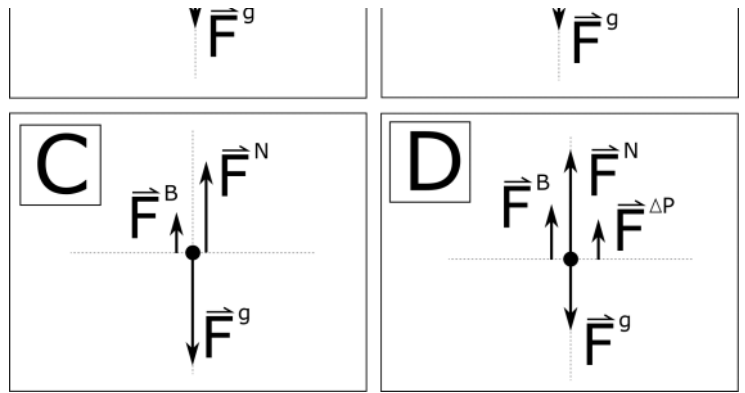


**Act II: Buoyancy**

**FS.L2.2-06:**

**Problem Statement:** Consider a person standing on the level ground near the surface of the earth. Which one of the FBD correctly describe the forces acting on the person?

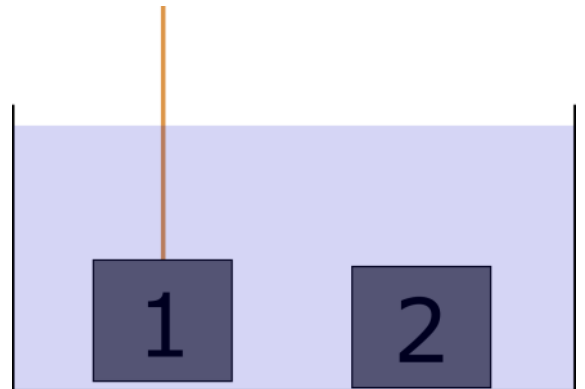




**FS.L2.2-07:**

**Problem Statement:** Consider two identical blocks in a beaker of water. Block 1 is suspended such that it is just barely above the surface of the bottom. Block 2 is resting on the bottom. Which block experiences a larger buoyant force?

- (1) Block 1
- (2) Block 2
- (3) Equal buoyant forces
- (4) Unable to determine without the density of water.



**FS.L2.2-08:**

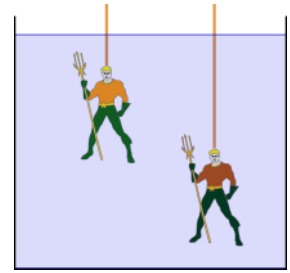
**Problem Statement:** Two equal-sized action figures that have different masses are held by strings so that they are submerged in water at different depths.

(a) The pressure exerted on the bottom of the 3 kg mass by the water is \_\_\_\_\_ the pressure on the bottom surface of the 1 kg mass.

- (1) greater than
- (2) less than



(3) equal to

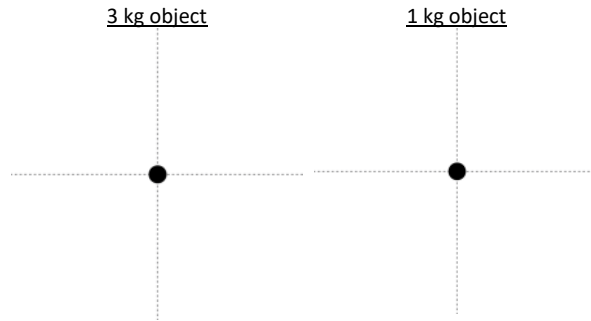


(b) The buoyant force exerted by the water on the 3 kg mass is \_\_\_\_\_ the buoyant force on the 1 kg mass.

- (1) greater than
- (2) less than
- (3) equal to

(c) The tension in the string holding the 3 kg mass is \_\_\_\_\_ the tension in the string holding the 1 kg mass.

- (1) greater than
- (2) less than
- (3) equal to



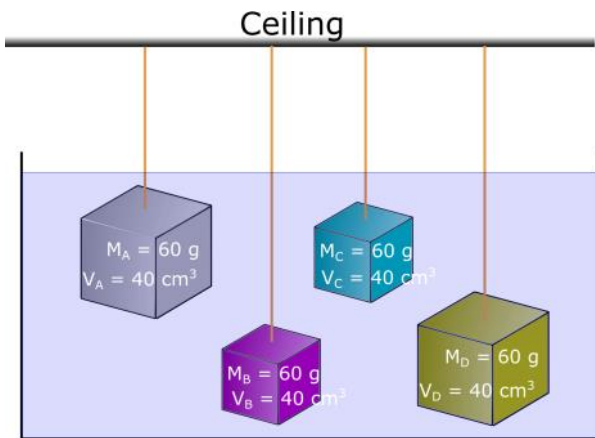
**FS.L2.2-09:**

**Problem Statement:** In each case, a block hanging from a string is suspended in a liquid. All of the blocks are the same size, but they have different masses (labeled  $M_b$ ) because they are made of different materials. All of the containers have the same volume of liquid, but the masses of these liquids vary (labeled  $M_L$ ) since the liquids are different. The volume of the blocks is one-sixth the volume of the liquids. Rank the buoyant forces on the blocks.

A	B	C	D
$M_b = 40 \text{ g}$ $M_L = 200 \text{ g}$	$M_b = 50 \text{ g}$ $M_L = 200 \text{ g}$	$M_b = 30 \text{ g}$ $M_L = 150 \text{ g}$	$M_b = 40 \text{ g}$ $M_L = 120 \text{ g}$


**FS.L2.2-10:**

**Problem Statement:** Four blocks are suspended from strings in water. Blocks **A** and **C** are at the same depth, as are **B** and **D**. Rank the tensions in the strings.



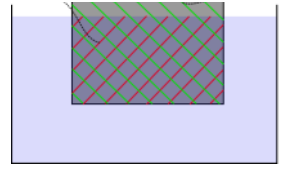
**FS.L2.2-11:**

**Problem Statement:** Consider a distant planet where the acceleration of a freely falling object ( $g$ ) is greater than that on earth.

(a) Would you float more or less easily in water on this planet compared to earth? Hint: how easily we float  $V_B$    $V_T$

can be quantified by looking at the ratio of your volume below the water to your total volume.

- (1) More easily
- (2) Less easily
- (3) Float the same.



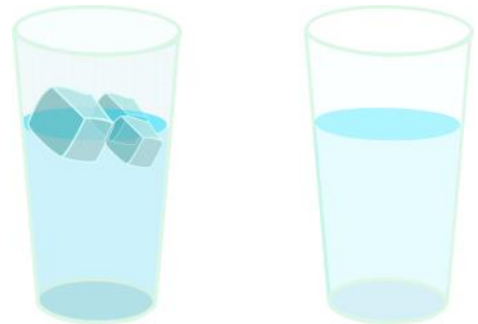
**(b)** If the density of the fluid is less than an object, which of the following statements are true?

- (1)  $V_b/V_T = 1$  ; and it sinks
- (2)  $V_b/V_T = 1$  ; and it floats
- (3)  $V_b/V_T > 1$  ; and it sinks
- (4)  $V_b/V_T > 1$  ; and it floats
- (5)  $V_b/V_T < 1$  ; and it sinks
- (6)  $V_b/V_T < 1$  ; and it floats

**FS.L2.2-12:**

**Problem Statement:** 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?

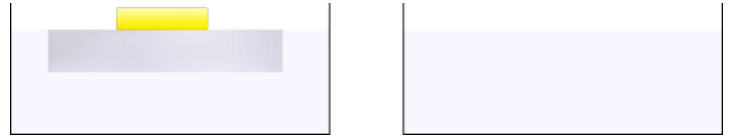
- (1) The cup without ice.
- (2) The cup with ice.
- (3) It is the same in both.



**FS.L2.2-13:**

**Problem Statement:** A piece of gold is fastened on top of a large solid piece of Styrofoam that floats in a container of water. Because the weight of the gold, the waterline is flush with the top surface of the Styrofoam.

(a) Which of the following statements are true if the system is turned upside down so that the lead is now suspended underneath the Styrofoam?



- (1) The system sinks.
- (2) The waterline is below the top surface of the Styrofoam.
- (3) The waterline is still flush with the top surface of the Styrofoam.

(b) The water level in the container

- (1) rises.
- (2) drops.
- (3) remains the same.

**FS.L2.2-14:**

**Problem Statement:** Two mobsters drop a suspiciously large brick of concrete out of a boat in a large lake. Does the level of the water in the lake, relative to the shore, increase, decrease, or stay the same?

- (1) Increase.
- (2) Decrease.
- (3) Stays the same.
- (4) Depends on who's asking, are you asking?

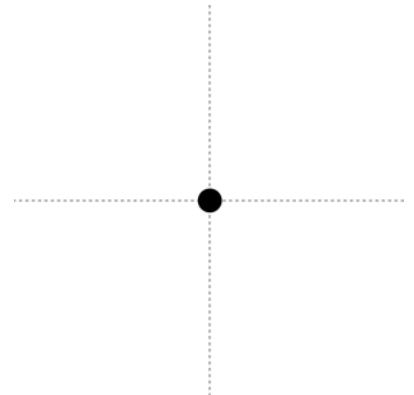
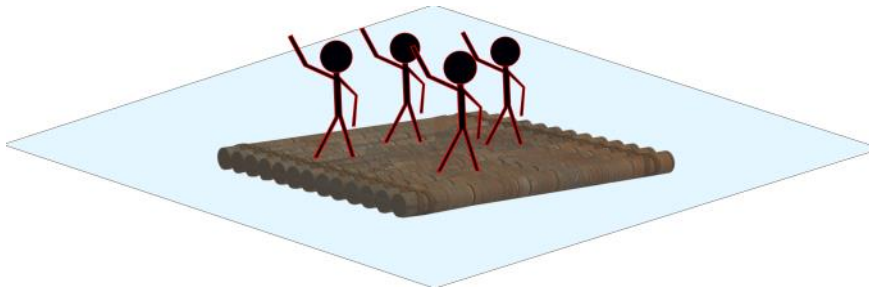
Extreme case solution

General solution

**FS.L2.2-15:**

**Problem Statement:** We eventually wish to determine the smallest number ( $N$ ) of whole logs ( $\rho_{\text{log}} = 725 \text{ kg/m}^3$ , radius = 0.08 m, length = 3.0 m) that can be used to build a raft that will carry four people, each of whom has a mass of 80 kg.

(a) Draw a FBD for the raft or the raft + people system. You choose the system, there is no right or wrong system.



(b) Which of the following equations can be used to determine the mass of the raft?

- (1)  $\rho_{\text{log}} \cdot 2 \cdot \pi \cdot r \cdot L$
- (2)  $\rho_{\text{log}} \cdot N \cdot \pi \cdot r^2 \cdot L$
- (3)  $\rho_{\text{log}} / N \cdot \pi \cdot r \cdot L$
- (4)  $\rho_{\text{log}} / N \cdot \pi \cdot r^2 \cdot L$

(c) Which of the following equations represents the volume of the displaced water if the raft has a minimum number of logs?

- (1)  $V_{\text{log}}$
- (2)  $V_{\text{raft}}$
- (3)  $1/2 V_{\text{log}}$
- (4)  $1/2 V_{\text{raft}}$

(d) What is the smallest number ( $N$ ) of whole logs ( $\rho_{\text{log}} = 725 \text{ kg/m}^3$ , radius = 0.08 m, length = 3.0 m) that can be used to build a raft that will carry four people, each of whom has a mass of 80 kg?

---

## Conceptual questions for discussion

1. Coming soon.
- 

## Hints

**FS.L2.2-01:** No hints.

**FS.L2.2-02:** No hints.

**FS.L2.2-03:** No hints.

**FS.L2.2-04:** No hints.

**FS.L2.2-05:** No hints.

**FS.L2.2-06:** No hints.

**FS.L2.2-07:** No hints.

**FS.L2.2-08:** No hints.

**FS.L2.2-09:** No hints.

**FS.L2.2-10:** No hints.

**FS.L2.2-11:** No hints.

**FS.L2.2-12:** No hints.

**FS.L2.2-13:** No hints.

**FS.L2.2-14:** No hints.

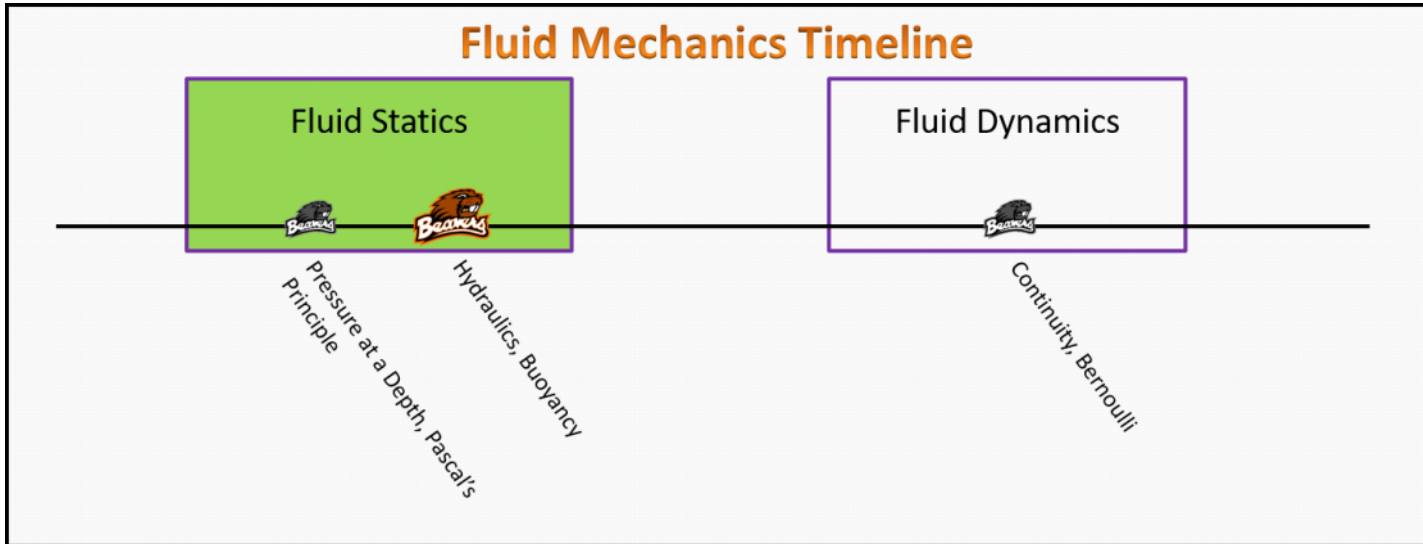
**FS.L2.2-15:** Not hints.

# Fluid Statics

## Practice Stage (FS.L2.3)

### Lecture 2



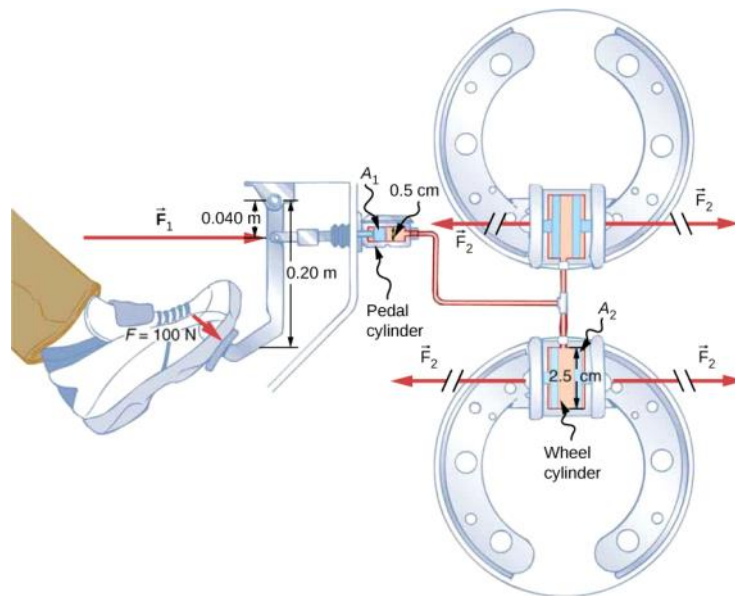


**FS.L2.3-01**

**Description:** Mechanical advantage and a car's hydraulic brakes

**Learning Objectives:** [x]

**Problem Statement:** Hydraulic brakes use Pascal's principle. The driver exerts a force of 100 N on the brake pedal. This force is increased by the simple lever and again by the hydraulic system. Each of the identical slave cylinders receives the same pressure and, therefore, creates the same force output  $F_2$ . The circular cross-sectional areas of the master and slave cylinders are represented by  $A_1$  and  $A_2$ , respectively. How much pressure is transmitted in the hydraulic system? Express your answer in pascals and in atmospheres.



- (1)  $6.37 \times 10^6$  Pa; or 62.9 atm
- (2)  $5.09 \times 10^6$  Pa; or 50.2 atm
- (3)  $2.55 \times 10^7$  Pa; or 251 atm
- (4)  $1.02 \times 10^6$  Pa; or 10.1 atm

**FS.L2.3-02**

**Description:** Buoyancy and mass

**Learning Objectives:** [x]

**Problem Statement:** A boat is 4.0 meters long and 2.0 meters wide. Its water line is 1.0 meter from the bottom of the boat; it is submerged to this water line. What is the mass of the boat?

- (1) 8000 kg
- (2) 600 kg
- (3) 130 kg
- (4) 800 kg
- (5) 200 kg

**FS.L2.3-03**

**Description:** Fish and buoyancy

**Learning Objectives:** [x]

**Problem Statement:** Some fish have a density slightly less than that of water and must exert a force (swim) to stay submerged. What force must an 85.0-kg grouper exert to stay submerged in salt water if its body density is  $1015\text{kg/m}^3$ ?

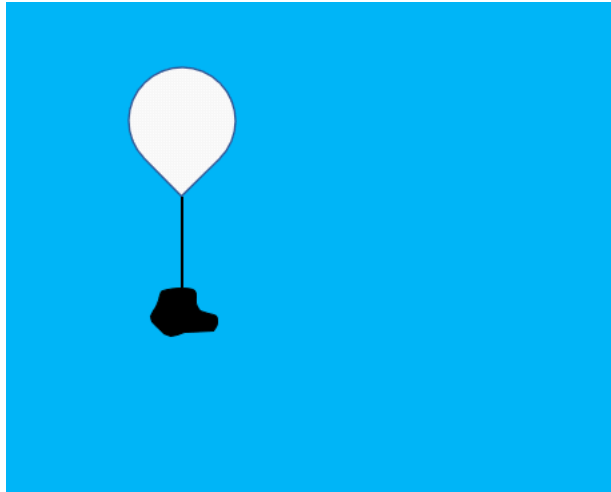
- (1) 8.21 N
- (2) 841 N
- (3) 832 N
- (4) 0.84 N

**FS.L2.3-04**

**Description:** Consider the buoyant force on a sinking balloon

**Learning Objectives:** [mmm]

**Problem Statement:** Consider the buoyant force on a balloon attached to a rock, as it sinks in a lake.



(a) What happens to the volume of the balloon as it sinks deeper?

- |                               |
|-------------------------------|
| (1) The volume increases      |
| (2) The volume decreases      |
| (3) The volume stays the same |

(b) What happens to the buoyant force on the balloon?

- |                                      |
|--------------------------------------|
| (1) The buoyant force increases      |
| (2) The buoyant force decreases      |
| (3) The buoyant force stays the same |