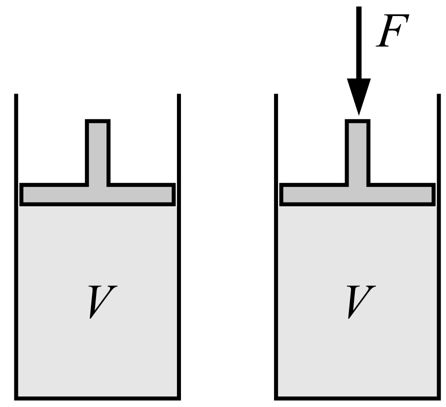
FLUIDS & DENSITY



1. A volume of an unknown fluid is contained in a cylinder below a piston as shown in the figure above. A downwards force is then applied to the piston. If the unknown fluid is a liquid or a gas, which of the following correctly describes how the volume of the fluid changes when the force is applied?

(A)

Liquid volume	Gas volume
Decreases	Does not change

(B)

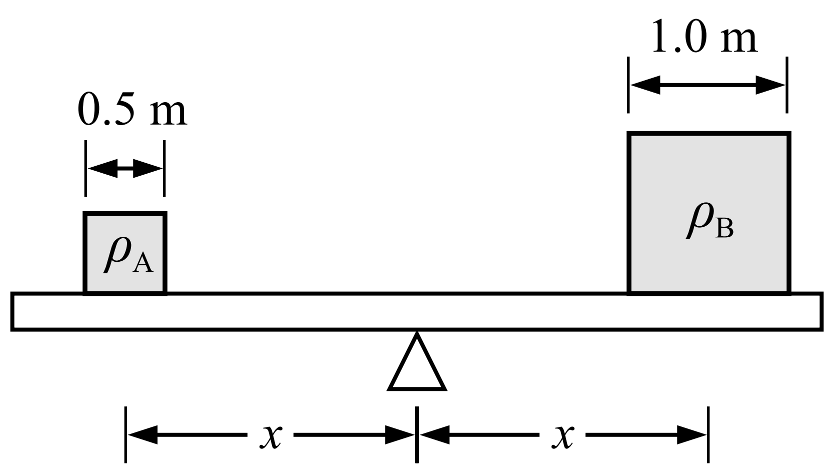
Liquid volume	Gas volume
Does not change	Does not change

(C)

Liquid volume	Gas volume
Decreases	Decreases

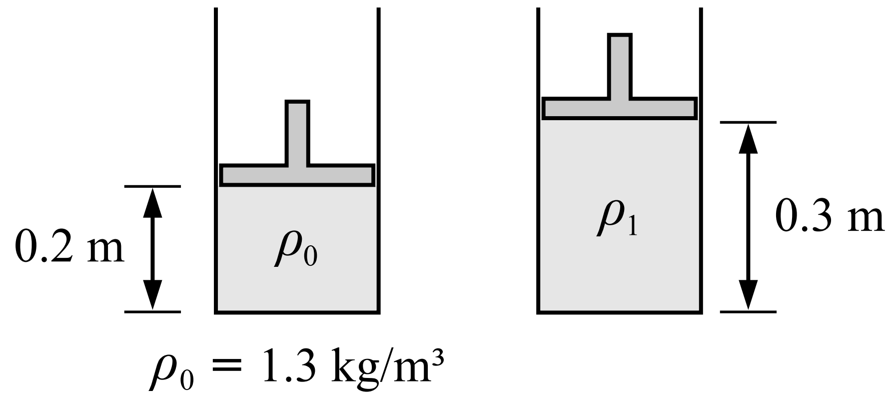
(D)

Liquid volume	Gas volume
Does not change	Decreases



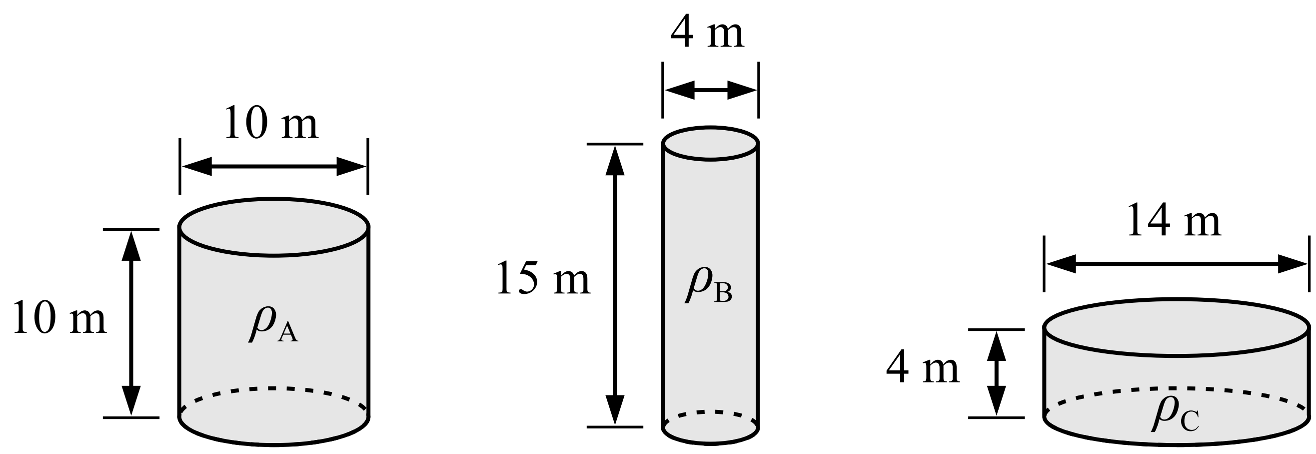
2. Two cubes are balanced on a beam which is at rest as shown in the figure above. The centers of mass of each cube are the same distance from the pivot point of the beam. Cube A has a side length of 0.5 m and cube B has a side length of 1.0 m. What is the ratio of the density of cube A to the density of cube B, ρ_A/ρ_B?

(A) 1/8
(B) 4
(C) 8
(D) 2



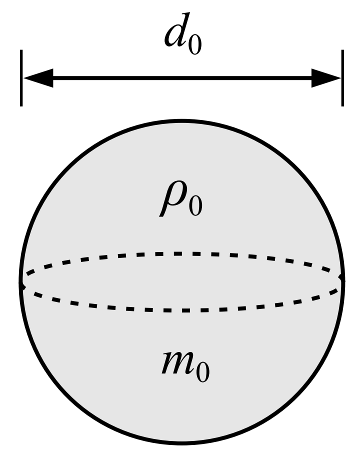
3. A volume of gas is contained in a cylinder below a piston as shown in the figure above. The density of the gas is 1.3 kg/m³. When the piston is raised to the new position shown in the figure, the density of the gas is most nearly

   (A) 0.9 kg/m³
   (B) 2.0 kg/m³
   (C) 1.3 kg/m³
   (D) Cannot be determined



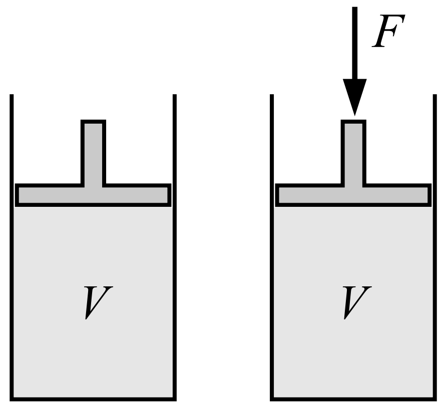
4. The heights and diameters of three cylinders are shown in the figure above. All three cylinders are filled with the same mass of gas. Which of the following correctly relates the densities of the gas in each cylinder?

   (A) $\rho_C < \rho_A < \rho_B$
   (B) $\rho_B < \rho_C < \rho_A$
   (C) $\rho_A < \rho_C < \rho_B$
   (D) $\rho_A = \rho_B = \rho_C$



5. A solid sphere with a diameter of d_0, a mass of m_0 and a density of ρ_0 is shown in the figure above. A second sphere with the same density and twice the diameter would have a mass of

(A) $4\,m_0$
(B) $16\,m_0$
(C) $2\,m_0$
(D) $8\,m_0$



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Liquid volume	Gas volume
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(B)

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(C)

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Decreases	Decreases

(D)

Liquid volume	Gas volume
Does not change	Decreases

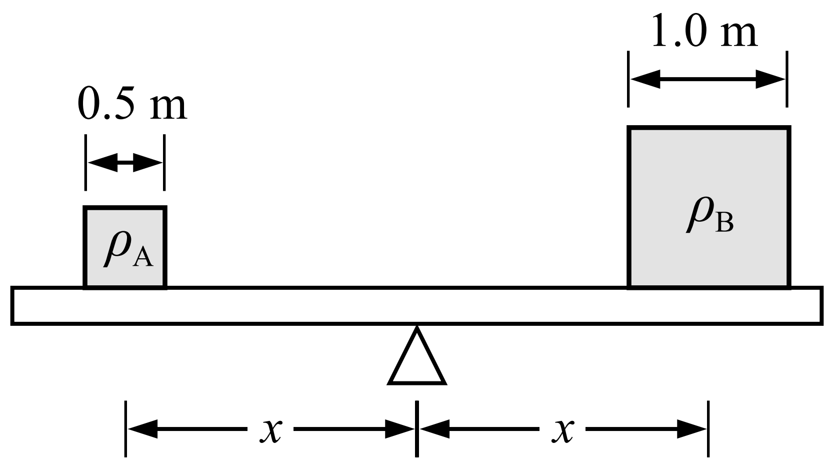
A Incorrect

B Incorrect

C Incorrect

D **Correct**

A liquid is nearly incompressible (and an ideal fluid is defined as completely incompressible) so the volume would not change if the fluid was a liquid. A gas is very compressible so the volume would decrease if the fluid was a gas.



2. Two cubes are balanced on a beam which is at rest as shown in the figure above. The centers of mass of each cube are the same distance from the pivot point of the beam. Cube A has a side length of 0.5 m and cube B has a side length of 1.0 m. What is the ratio of the density of cube A to the density of cube B, ρ_A/ρ_B?

(A) 1/8

(B) 4

(C) 8

(D) 2

A Incorrect
This answer may have been found by incorrectly dividing the volume of cube A by the volume of cube B.

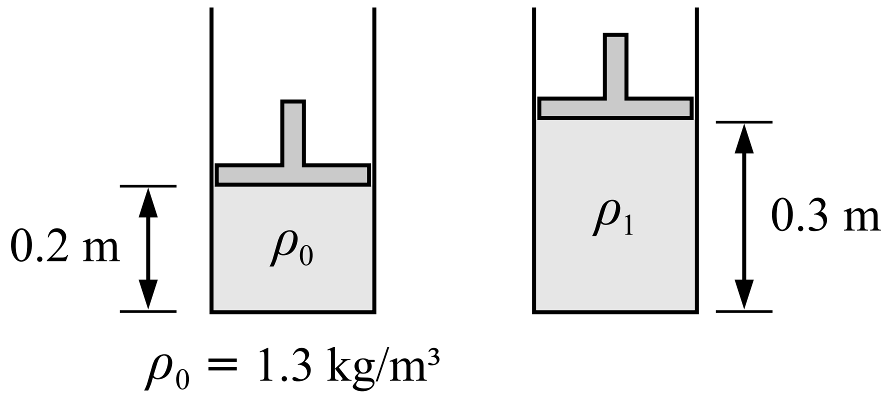
B Incorrect
This answer may have been found by incorrectly calculating the volume as the square of the side length.

C **Correct**
The beam is balanced at rest so the net torque on the beam is zero. The center of mass of each cube is the same distance away from the pivot point so the weight force of each cube must be the same and therefore the mass of each cube must be the same. The density of a cube is its mass divided by its volume.

$$\rho_A = \frac{m_A}{V_A} \qquad m_A = \rho_A V_A \qquad \rho_B = \frac{m_B}{V_B} \qquad m_B = \rho_B V_B$$

$$m_A = m_B \qquad \rho_A V_A = \rho_B V_B \qquad \rho_A (0.5\text{ m})^3 = \rho_B (1.0\text{ m})^3 \qquad \frac{\rho_A}{\rho_B} = \frac{(1.0\text{ m})^3}{(0.5\text{ m})^3} = 8$$

D Incorrect
This answer may have been found by incorrectly assuming the density of the smaller cube is twice the density of the larger cube because it has half of the side length of the larger cube.



3. A volume of gas is contained in a cylinder below a piston as shown in the figure above. The density of the gas is 1.3 kg/m³. When the piston is raised to the new position shown in the figure, the density of the gas is most nearly

(A) 0.9 kg/m³
(B) 2.0 kg/m³
(C) 1.3 kg/m³
(D) Cannot be determined

A Correct

The mass of the gas in the cylinder remains the same but the volume of the gas increases, so the density of the gas decreases. We can relate the densities and volumes of the gas at the two different states by setting the mass in each state as equal. We are not given the shape or dimensions of the cylinder so we can represent the cross sectional area of the cylinder with the variable A which is the same for both states and will cancel out, allowing us to relate the density with the height of the piston.

$\rho_0 = \dfrac{m}{V_0}$ $\quad m = \rho_0 V_0$ $\quad \rho_1 = \dfrac{m}{V_1}$ $\quad m = \rho_1 V_1$

$m = m$ $\quad \rho_0 V_0 = \rho_1 V_1$ $\quad \rho_0 A h_0 = \rho_1 A h_1$ $\quad \rho_0 h_0 = \rho_1 h_1$ $\quad (1.3\ \text{kg/m}^3)(0.2\ \text{m}) = \rho_1(0.3\ \text{m})$ $\quad \rho_1 = 0.9\ \text{kg/m}^3$

B Incorrect

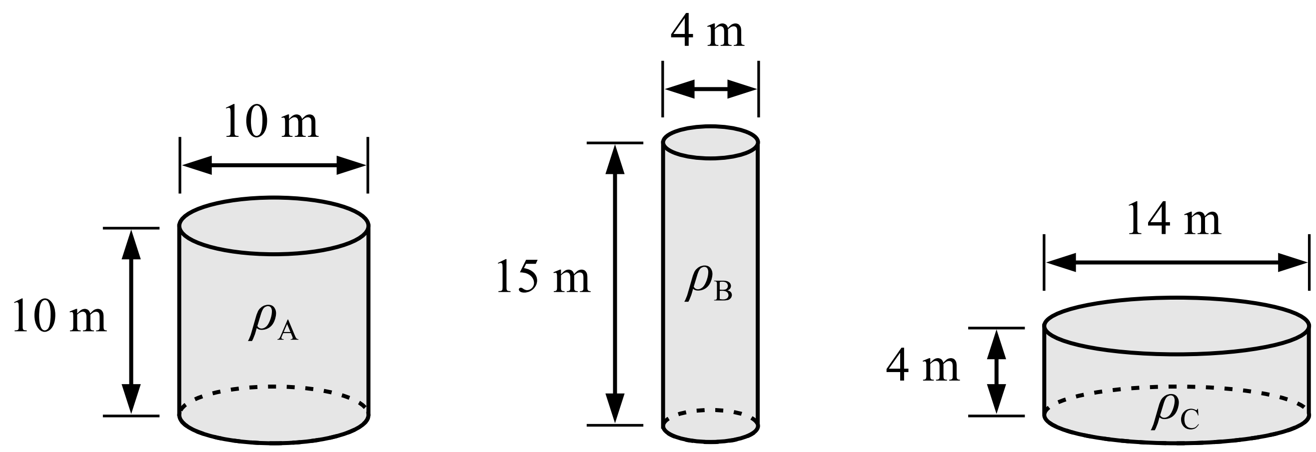
This answer incorrectly relates the densities and volumes as $\rho_0 V_1 = \rho_1 V_0$.

C Incorrect

This answer incorrectly assumes the density of the gas does not change.

D Incorrect

This answer may incorrectly assume that the cross sectional area of the cylinder must be known.



4. The heights and diameters of three cylinders are shown in the figure above. All three cylinders are filled with the same mass of gas. Which of the following correctly relates the densities of the gas in each cylinder?

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(B) $\rho_B < \rho_C < \rho_A$

(C) $\rho_A < \rho_C < \rho_B$

(D) $\rho_A = \rho_B = \rho_C$

A Incorrect
This answer may have been found by incorrectly ranking the volumes of the cylinders based on height only.

B Incorrect
This answer may have been found by incorrectly reversing the order of the density ranking.

C Correct
We can find the density of the gas in each cylinder in terms of the same mass m and compare the densities.

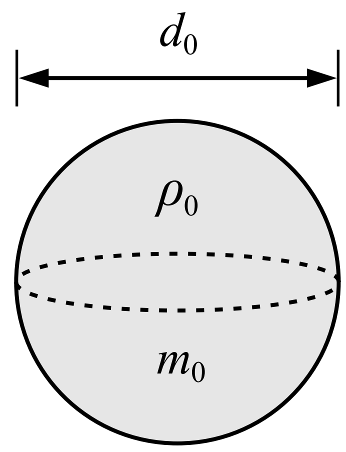
$$\rho_A = \frac{m}{V_A} = \frac{m}{\pi r^2 h} = \frac{m}{\pi(5\text{ m})^2(10\text{ m})} = \frac{m}{785\text{ m}}$$

$$\rho_B = \frac{m}{V_B} = \frac{m}{\pi r^2 h} = \frac{m}{\pi(2\text{ m})^2(15\text{ m})} = \frac{m}{188\text{ m}^3}$$

$$\rho_C = \frac{m}{V_C} = \frac{m}{\pi r^2 h} = \frac{m}{\pi(7\text{ m})^2(4\text{ m})} = \frac{m}{616\text{ m}^3}$$

$\rho_A < \rho_C < \rho_B$

D Incorrect
This answer may have been found by incorrectly assuming the density of the gas in each cylinder is the same.



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(A) $4\,m_0$
(B) $16\,m_0$
(C) $2\,m_0$
(D) $8\,m_0$

A Incorrect

B Incorrect

C Incorrect

D **Correct**
The equation for density and the volume of a sphere are given below. We can simplify the equation to find that the mass of the sphere is directly proportional to its diameter cubed. If the diameter of the sphere is mutliplied by 2 then the mass will be multiplied by 8.

$$\rho = \frac{m}{V} = \frac{m}{(4/3)\pi(d/2)^3} \qquad m = \rho\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \qquad m \propto d^3 \qquad 8\,m_0 \propto (2\,d_0)^3$$