FLUIDS & DENSITY

Fluids and States of Matter

1. When describing the properties and behavior of matter (solids, liquids and gasses) we are mainly focused on the interactions between which particles that make up a substance?
   - A protons
   - B neutrons
   - C electrons
   - D atoms or molecules

2. Which of the following is changing when a substance transitions between a solid, liquid and gas state? (Select all that apply)
   - A The size of the molecules
   - B The kinetic energy of the atoms or molecules
   - C The number of atoms or molecules
   - D The temperature of the substance

3. A substance is at the lowest temperature in which of the following states?
   - A Liquid
   - B Solid
   - C Gas
   - D Any of the above, temperature is not related to the state of matter

4. In which of the following states are the atoms or molecules of a substance the farthest apart?
   - A Gas
   - B Liquid
   - C Solid
   - D Any of the above, the distance between atoms or molecules is not related to the state of matter

5. In which of the following states can the atoms or molecules move around freely without being bonded in an organized structure? (Select all that apply)
   - A Solid
   - B Gas
   - C Liquid
   - D Any of the above

6. A substance is considered to be a fluid in which of the following states? (Select all that apply)
   - A Liquid
   - B Solid
   - C Gas
   - D All of the above

7. Which of the following are properties of a fluid (any fluid, not an ideal fluid)? (Select all that apply)
   - A It has no fixed volume and it expands to completely fill its container
   - B It can flow freely because the atoms or molecules are not rigidly bonded together
   - C It is incompressible and its density does not change
   - D It has no fixed shape and it takes the shape of its container

8. Which of the following are examples of fluids? (Select all that apply)
    A Oil
    B Air
    C Ice
    D Helium

9. Which of the following are properties of an ideal fluid? (Select all that apply)
    A It has no mass
    B It is easily compressible
    C It has no viscosity
    D It is completely incompressible

10. True or false: A gas can never be considered an ideal fluid.

Volume

11. The volume of a substance is…
    A the amount of mass the substance has
    B the amount of space the substance occupies
    C the density of the substance
    D none of the above

12. In which of the following states of matter does a substance's volume change a significant amount when a force or pressure is applied to it? (Select all that apply)
    A Liquid
    B Solid
    C Gas
    D None of the above

13. Which of the following states of matter expand so that they have the same volume as their container? (Select all that apply)
    A Gas
    B Liquid
    C Solid
    D None of the above

14. Which of the following is the SI unit of volume?
    A liters (L)
    B cubic centimeters (cm³)
    C milliliters (mL)
    D cubic meters (m³)

15. Which of the following are valid units of volume? (Select all that apply)
    A cm³
    B mL
    C g
    D mm³

16. A tub is filled with 0.3 m³ of water. What is the volume of the water in units of L?

17. A balloon is filled with 14 L of helium gas. What is the volume of the gas in units of cm³?

18. A syringe is filled with 80 mL of saline. What is the volume of the saline in units of m³?

19. What is the volume of a gallon of milk in units of cm³ if 1 gallon is equal to 3.785 L?

20. The international space station (ISS) contains approximately 900 m³ of air. How many liters of air are in the ISS?

21. A 2.5 m long tube with a diameter of 3 cm is shown in Figure 1 (not drawn to scale). What is the volume of liquid in L that would be required to fill the tube?
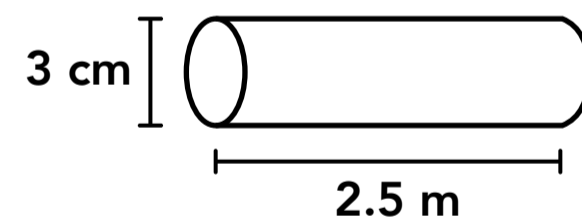
3 cm

2.5 m

Figure 1

22. A block of wood and its dimensions are shown in Figure 2. What is the volume of the block in mL?
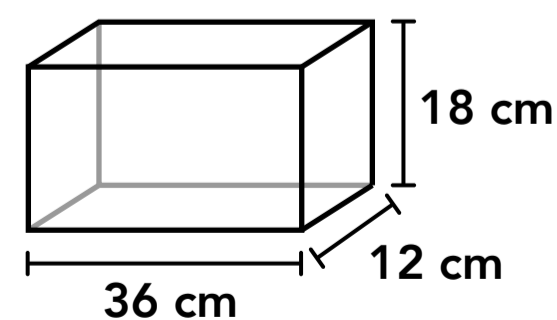
18 cm

12 cm

36 cm

Figure 2

23. A beach ball with a radius of 30 cm is shown in Figure 3. What volume of air in L is needed to inflate the beach ball?
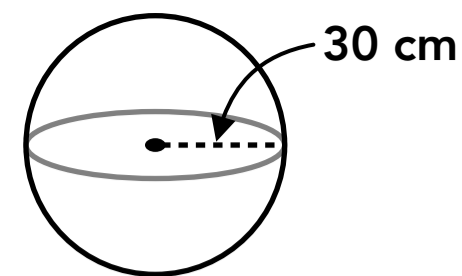

Figure 3

24. 1.4 L of gas is contained in a cylinder with a piston as shown in Figure 4 (not drawn to scale). The radius of the cylinder is 6 cm. The piston is then pushed down 8 cm. What is the new volume of the gas in the cylinder in L?
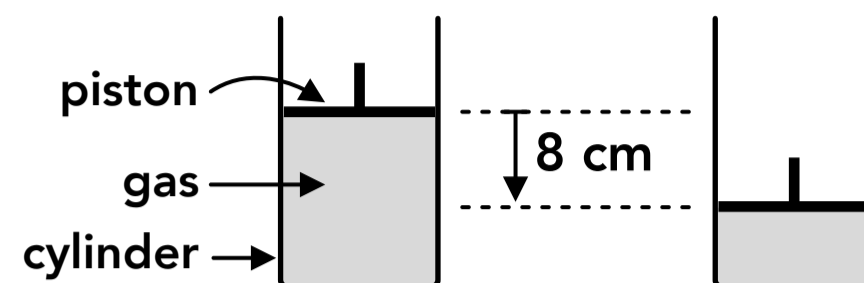

Figure 4

Density

25. The density of a substance is defined as which of the following?
   - A   The mass of the substance per unit of length
   - B   The mass of the substance per unit of volume
   - C   The molecular mass of the substance
   - D   The volume of the substance per unit of mass

26. Which of the following is the SI unit of density?
   - A g/cm^3
   - B kg/L
   - C g/m^3
   - D kg/m^3

27. What is the density of liquid water? (Select all that apply)
   - A $1 \ g/cm^3$
   - B $1,000 \ g/cm^3$
   - C $1 \ g/mL$
   - D $1,000 \ kg/m^3$

28. A solid block with a volume of 60 cm³ is placed in a pool of water. The block will float if it's mass is which of the following? (Select all that apply)
   - A   1 g
   - B   10 g
   - C   100 g
   - D   1,000 g

29. The object shown in Figure 5 has a mass of *m* and dimensions as shown. Which of the following is the density of the object?
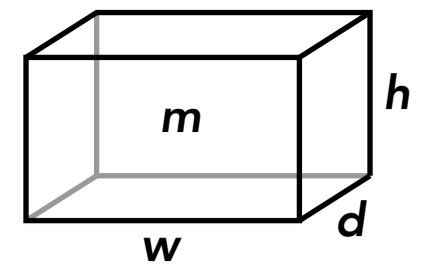
A $\dfrac{m}{wdh}$

B $mwdh$

C $\dfrac{wdh}{m}$

D $\dfrac{mwd}{h}$

Figure 5

30. The object shown in Figure 6 has a density of *ρ* and dimensions as shown. Which of the following is the mass of the object?
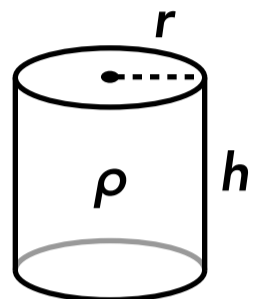
A $\pi r^2 h$

B $\dfrac{\rho}{\pi r^2 h}$

C $\dfrac{\pi r^2 h}{\rho}$

D $\rho \pi r^2 h$

Figure 6

31. The object shown in Figure 7 has a mass of *m*, a density of *ρ* and dimensions as shown. Which of the following is equal to the height of the object *h*?
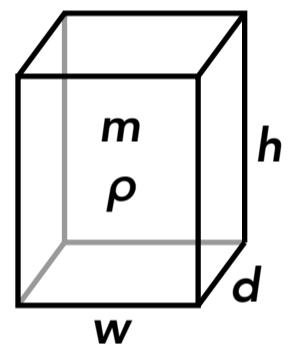
A $\dfrac{\rho wd}{m}$

B ρmwd

C $\dfrac{m}{\rho wd}$

D $\dfrac{\rho m}{wd}$

Figure 7

32. If 0.6 L of olive oil has a mass of 540 g, what is the density of the olive oil in g/cm³ ?

33. A block of foam with a mass of 800 g is floating in water. If the density of the foam block is 30 kg/m³ what is its volume in L?

34. A glass thermometer is made of 35 g of glass and contains 0.2 mL of mercury (at 0°C). If the density of mercury is 13,600 kg/m³ at 0°C, what is the total mass of the thermometer in g?

35. The mass and dimensions of a solid object are shown in Figure 8. What is the density of the object in g/cm³?
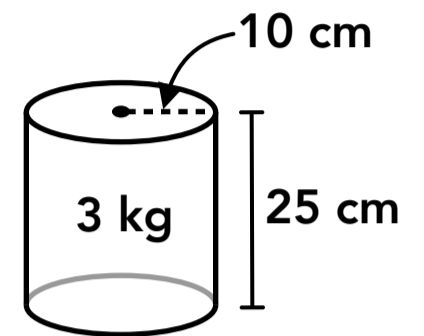

Figure 8

36. The dimensions of a glass fish tank is shown in Figure 9. If the fish tank is completely filled with water, what is the mass of water in the tank in kg?
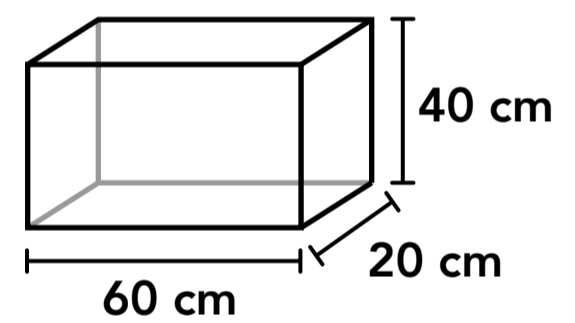

Figure 9

Answers

1. D	11. B	21. 1.8 L	31. C
2. B, D	12. C	22. 7,776 mL	32. 0.9 g/cm³
3. B	13. A	23. 113 L	33. 26.7 L
4. A	14. D	24. 0.5 L	34. 37.7 g
5. B, C	15. A, B, D	25. B	35. 0.38 g/cm³
6. A, C	16. 300 L	26. D	36. 48 kg
7. B, D	17. 14,000 cm³	27. A, C, D	
8. A, B, D	18. 8×10^{-5} m³	28. A, B	
9. C, D	19. 3,785 cm³	29. A	
10. True	20. 900,000 L	30. D	

Answers - Fluids and States of Matter

1. **Answer: D**

   All substances are made up of atoms which themselves are made up of protons, neutrons and electrons. Atoms are often bonded together in groups called molecules. When describing the behavior and properties of matter we are mainly focused on the interactions between the atoms (if the substance is made of atoms that do not form molecules) or the interactions between the molecules (if the atoms in the substance are grouped into molecules).

2. **Answer: B, D**

   When a substance transitions between different states (solid, liquid or gas) the kinetic energy of the atoms or molecules and the temperature of the substance is changing (temperature is related to the average kinetic energy of the atoms or molecules).

3. **Answer: B**

   When a substance is in the solid state it is at a lower temperature than in the liquid or gas state, and the atoms or molecules have the least amount of kinetic energy.

4. **Answer: A**

   When a substance is in the gas state the atoms or molecules are much farther apart than they are in the liquid or solid state.

5. **Answer: B, C**

   When a substance is in the liquid or the gas state the atoms or molecules are free to move around or "flow" and they are not bonded together in a rigid structure like they are in the solid state.

6. **Answer: A, C**

   A fluid is a liquid or a gas, which are the states of matter where the substance can flow and has no fixed shape. A substance in the solid state is not a fluid.

7. **Answer: B, D**

   A fluid (a liquid or gas) is a substance that can flow freely and has no fixed shape so it takes the shape of its container. A gas has no fixed volume and expands to fill its container, but a liquid (which is a fluid) does not. An ideal fluid is incompressible, but a gas (which is a fluid) is compressible.

8. **Answer: A, B, D**

   Any substance in the liquid or gas state is a fluid. Oil is a liquid, air is a gas and helium is a gas. Ice is a solid so it is not a fluid.

9. **Answer: C, D**

   An ideal fluid is defined as a fluid that is completely incompressible (so its volume and density do not change) and has no viscosity (no resistance to flow).

10. **Answer: True**

    One of the properties of an ideal fluid is that it is completely incompressible. A gas is very compressible (its volume and density change when a force is applied to it) so a gas can not be considered an ideal fluid.

Answers - Volume

11. **Answer: B**

    The volume of a substance is the amount of three-dimensional space that it occupies.

12. **Answer: C**

    A gas is easily compressible so its volume will change a significant amount when a force or pressure is applied to it. Solids and liquids are considered to be nearly incompressible so their volumes do not change.

13. **Answer: A**

    A gas expands to completely fill its container so it has the same volume as its container. A liquid can flow to take the shape of its container, but it does not expand to fill the entire volume of its container. A solid's volume does not change.

14. **Answer: D**

    The SI unit for volume is cubic meters (m^3).

15. **Answer: A, B, D**

    Cubic centimeters (cm^3), milliliters (mL) and cubic millimeters (mm^3) are valid units of volume. Grams (g) is a unit of mass.

16. **Answer: 300 L**

    We can convert the volume using the following unit relationship:

    $$\frac{0.3 \text{ m}^3}{} \times \frac{1{,}000 \text{ L}}{1 \text{ m}^3} = 300 \text{ L}$$

17. **Answer: 14,000 cm³**

    We can convert the volume using the following unit relationships:

    $$\frac{14 \text{ L}}{} \times \frac{1 \text{ m}^3}{1{,}000 \text{ L}} \times \frac{(100)^3 \text{ cm}^3}{1 \text{ m}^3} = 14{,}000 \text{ cm}^3$$

18. **Answer: 8×10^{-5} m³**

    We can convert the volume using the following unit relationships:

    $$\frac{80 \text{ mL}}{} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} \times \frac{1 \text{ m}^3}{1{,}000 \text{ L}} = 8 \times 10^{-5} \text{ m}^3$$

19. **Answer: 3,785 cm³**

    We can convert the volume using the following unit relationships:

    $$\frac{1 \text{ gallon}}{} \times \frac{3.785 \text{ L}}{1 \text{ gallon}} \times \frac{1 \text{ m}^3}{1{,}000 \text{ L}} \times \frac{(100)^3 \text{ cm}^3}{\text{m}^3} = 3.875 \text{ cm}^3$$

20. **Answer: 900,000 L**

We can convert the volume using the following unit relationship:

$$\frac{900 \text{ m}^3}{} \times \frac{1{,}000 \text{ L}}{1 \text{ m}^3} = 900{,}000 \text{ L}$$

21. **Answer: 1.8 L**

The tube is a cylinder and the equation for the volume of a cylinder is given below. The radius of the cylinder is 1.5 cm or 0.015 m (half of the diameter).

$$V = \pi r^2 h = \pi(0.015 \text{ m})^2(2.5 \text{ m}) = 0.0018 \text{ m}^3$$

Then we can convert the volume from m³ to L:

$$\frac{0.0018 \text{ m}^3}{} \times \frac{1{,}000 \text{ L}}{1 \text{ m}^3} = 1.8 \text{ L}$$

22. **Answer: 7,776 mL**

The block is a rectangular prism and the equation for the volume of a rectangular prism is given below.

$$V = wdh = (36 \text{ cm})(12 \text{ cm})(18 \text{ cm}) = 7{,}776 \text{ cm}^3$$

Then we can convert the volume from cm³ to mL:

$$\frac{7{,}776 \text{ cm}^3}{} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} = 7{,}776 \text{ mL}$$

23. **Answer: 113 L**

The equation for the volume of a sphere is given below and we can use meters for the radius:

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(0.30 \text{ m})^3 = 0.113 \text{ m}^3$$

Then we can convert the volume from m³ to L:

$$\frac{0.113 \text{ m}^3}{} \times \frac{1{,}000 \text{ L}}{1 \text{ m}^3} = 113 \text{ L}$$

24. **Answer: 0.5 L**

The gas fills the volume between the cylinder and the piston. First we can convert the original volume of gas from L to cm³:

$$\frac{1.4 \text{ L}}{} \times \frac{1{,}000 \text{ cm}^3}{1 \text{ L}} = 1{,}400 \text{ cm}^3$$

Then we can find the original height of the piston using the original volume and the radius of the cylinder:

$$V = \pi r^2 h \qquad (1{,}400 \text{ cm}^3) = \pi(6 \text{ cm})^2 h \qquad h_1 = 12.38 \text{ cm}$$

The piston moves down 8 cm so the new height of the piston is:

$$h_2 = 12.38 \text{ cm} - 8 \text{ cm} = 4.38 \text{ cm}$$

Then we can find the new volume of the gas with the piston at the lower height:

$$V = \pi r^2 h = \pi(6 \text{ cm})^2(4.38 \text{ cm}) = 495 \text{ cm}^3$$

Then we can convert the new volume from cm³ to L:

$$\frac{495 \text{ cm}^3}{} \times \frac{1 \text{ L}}{1{,}000 \text{ cm}^3} = 0.5 \text{ L}$$

25. **Answer: B**

Density is defined as the mass of a substance per unit of volume:

$$\rho = \frac{m}{V}$$

26. **Answer: D**

The SI unit of density is kilograms per cubic meter (kg/m³) which is derived from the SI units in the equation for density.

27. **Answer: A, C, D**

The density of liquid water (at 4°C) is 1,000 kg/m³ which is equivalent to 1 g/cm³ or 1 g/mL.

28. **Answer: A, B**

An object will float if its density is less than the density of the fluid that it's in. The density of water is 1 g/cm³ so the block will float if its density is less than 1 g/cm³.

1 g: $\rho = \dfrac{m}{V} = \dfrac{(1\ g)}{(60\ cm^3)} = 0.017$ g/cm³ **(the block will float)**

10 g: $\rho = \dfrac{m}{V} = \dfrac{(10\ g)}{(60\ cm^3)} = 0.17$ g/cm³ **(the block will float)**

100 g: $\rho = \dfrac{m}{V} = \dfrac{(100\ g)}{(60\ cm^3)} = 1.7$ g/cm³ **(the block will sink)**

1,000 g: $\rho = \dfrac{m}{V} = \dfrac{(1{,}000\ g)}{(60\ cm^3)} = 17$ g/cm³ **(the block will sink)**

29. **Answer: A**

The density of the object is its mass divided by its volume:

$$\rho = \frac{m}{V} = \frac{m}{wdh}$$

30. **Answer: D**

The density of the object is its mass divided by its volume:

$$\rho = \frac{m}{V} = \frac{m}{\pi r^2 h} \qquad m = \rho \pi r^2 h$$

31. **Answer: C**

The density of the object is its mass divided by its volume:

$$\rho = \frac{m}{V} = \frac{m}{wdh} \qquad h = \frac{m}{\rho wd}$$

32. **Answer: 0.9 g/cm³**

First we can calculate the density of the olive oil in g/L:

$$\rho = \frac{m}{V} = \frac{(540 \text{ g})}{(0.6 \text{ L})} = 900 \text{ g/L}$$

Then we can convert the density to g/cm³:

$$\frac{900 \text{ g}}{\text{L}} \times \frac{1 \text{ L}}{1,000 \text{ cm}^3} = 0.9 \text{ g/cm}^3$$

33. **Answer: 26.7 L**

First we can find the volume of the block in m³, using a mass of 0.8 kg (800 g):

$$\rho = \frac{m}{V} \qquad (30 \text{ kg/m}^3) = \frac{(0.8 \text{ kg})}{V} \qquad V = 0.0267 \text{ m}^3$$

Then we can convert the volume from m³ to L:

$$\frac{0.0267 \text{ m}^3}{} \times \frac{1,000 \text{ L}}{1 \text{ m}^3} = 26.7 \text{ L}$$

34. **Answer: 37.7 g**

First we can convert the density of mercury from kg/m³ to g/mL:

$$\frac{13,600 \text{ kg}}{\text{m}^3} \times \frac{1,000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ m}^3}{(100)^3 \text{ mL}} = 13.6 \text{ g/mL}$$

Then we can find the mass of the mercury using the density and volume:

$$\rho = \frac{m}{V} \qquad (13.6 \text{ g/mL}) = \frac{m}{(0.2 \text{ mL})} \qquad m = 2.7 \text{ g}$$

Then we can add the mass of the mercury and glass to find the total mass of the thermometer:

$$m_{\text{total}} = 2.7 \text{ g} + 35 \text{ g} = 37.7 \text{ g}$$

35. **Answer: 0.38 g/cm³**

The object is a cylinder and the equation for the volume of a cylinder is given below.

$$V = \pi r^2 h = \pi(10 \text{ cm})^2(25 \text{ cm}) = 7,854 \text{ cm}^3$$

Then we can find the density using the volume and a mass of 3,000 g (3 kg):

$$\rho = \frac{m}{V} = \frac{(3,000 \text{ g})}{(7,854 \text{ cm}^3)} = 0.38 \text{ g/cm}^3$$

36. **Answer: 48 kg**

The tank is a rectangular prism and the equation for the volume of a rectangular prism is given below.

$$V = wdh = (60 \text{ cm})(20 \text{ cm})(40 \text{ cm}) = 48,000 \text{ cm}^3$$

Then we can convert the volume from cm³ to m³:

$$\frac{48,000 \text{ cm}^3}{} \times \frac{1 \text{ m}^3}{(100)^3 \text{ cm}^3} = 0.048 \text{ m}^3$$

Then we can find the mass of the water using the volume and the density of water:

$$\rho = \frac{m}{V} \qquad (1000 \text{ kg/m}^3) = \frac{m}{(0.048 \text{ m}^3)} \qquad m = 48 \text{ kg}$$