

Pressure in Fluids

Practice Problems 1.

Question 1.

Calculate pressure exerted by 0.8 m vertical length of alcohol of density 0.80 g cm^{-3} in SI units. [Take $g = 10 \text{ ms}^{-2}$].

Answer:

Vertical length of alcohol column = $h = 0.8 \text{ m}$

Density of alcohol = $\rho = 0.80 \text{ g cm}^{-3}$

$$\rho = \frac{0.80 \times 10^6}{10^3} \text{ kg m}^{-3}$$

$\rho = 0.80 \times 1000 \text{ kg m}^{-3}$.

$\rho = 800 \text{ kg m}^{-3}$

Pressure = $P = ?$

$p = h\rho g$

$P = 0.8 \times 800 \times 10$

$= 6400 \text{ Pa}$

Question 2.

What is the pressure exerted by 75 cm vertical column of mercury of density 13600 kg m^{-3} in SI units.

[Take $g = 9.8 \text{ ms}^{-2}$].

Answer:

Vertical length of mercury column = $h = 75 \text{ cm} = 0.75 \text{ m}$

Density of mercury = $\rho = 13600 \text{ kg m}^{-3}$

Acceleration due to gravity = $g = 9.8 \text{ ms}^{-2}$

Pressure = $P = ?$

$p = h\rho g$

$P = 0.75 \times 13600 \times 9.8$

$P = 99960 \text{ Pa}$

Practice Problems 2.

Question 1.

66640 Pa pressure is exerted by 0.50 m vertical column of a liquid. If $g = 9.8 \text{ N kg}^{-1}$, calculate density of the liquid.

Answer:

Pressure + $P = 66640 \text{ Pa}$.

Vertical length of liquid column = $h = 0.50 \text{ m}$

Acceleration due to gravity - $g = 9.8 \text{ ms}^{-2}$

$$P = \frac{66640}{0.50 \times 9.8}$$

$$\rho = 13600 \text{ kg m}^{-3}$$

Question 2.

What vertical height of water will exert pressure of 333200 Pa ? Density of water is 1000 kg m^{-3} and $g = 9.8 \text{ ms}^{-2}$.

Answer:

Vertical height of water = $h = ?$

Pressure due to water column = $P = 333200 \text{ Pa}$ Acceleration due to gravity = $g = 9.8 \text{ ms}^{-2}$

$$P = h\rho g$$

$$h = P/\rho g$$

$$h = \frac{333200}{1000 \times 9.8}$$

$$h = 34 \text{ m}$$

Question 3.

Pressure at bottom of sea at some particular place is 8968960 Pa . If density of sea water is 1040 kg m^{-3} calculate the depth of sea. Take $g = 9.8 \text{ ms}^{-2}$. Neglect the pressure of the atmosphere.

Answer:

Pressure at the bottom of the sea = $P = 8968960 \text{ Pa}$

$$P = h\rho g$$

$$h = P/\rho g$$

$$h = \frac{8968960}{1040 \times 9.8}$$

$$h = 880 \text{ m}$$

Practice Problems 3.

Question 1.

Atmospheric pressure at sea level is 76 cm of mercury. Calculate the vertical height of air column exerting the above pressure. Assume the density of air 1.29 kgm^{-3} and that of mercury is 13600 kgm^{-3} . Why the height calculated by you is far less than actual height of atmosphere?

Answer:

Height of mercury column = $h_{\text{Hg}} = 76 \text{ cm} = 0.76 \text{ m}$

Vertical height of air column = $h_{\text{air}} = ?$

Density of mercury = $\rho_{\text{Hg}} = 13600 \text{ kgm}^{-3}$

Density of air = $\rho_{\text{air}} = 1.29 \text{ kgm}^{-3}$

According to question:

Pressure due to air column = Pressure due to Hg column

$$\rho_{\text{air}} \times h_{\text{air}} \times g = \rho_{\text{Hg}} \times h_{\text{Hg}} \times g$$

$$h_{\text{air}} = \frac{\rho_{\text{Hg}} \times h_{\text{Hg}}}{\rho_{\text{air}}}$$

$$h_{\text{air}} = \frac{13600 \times 0.76}{1.29} = 8012.4 \text{ m}$$

Question 2.

Calculate the equivalent height of mercury, which will exert as much pressure as 960 m of sea water of density 1040 kgm^{-3} . Density of mercury is 13600 kgm^{-3} .

Answer:

Height of mercury column = $h_{\text{Hg}} = 76 \text{ cm} = 0.76 \text{ m}$

Vertical height of air column = $h_{\text{air}} = ?$

Density of mercury = $\rho_{\text{Hg}} = 13600 \text{ kgm}^{-3}$

Density of air = $\rho_{\text{air}} = 1.29 \text{ kgm}^{-3}$

According to question:

Pressure due to air column = Pressure due to Hg column

$$\rho_{\text{air}} \times h_{\text{air}} \times g = \rho_{\text{Hg}} \times h_{\text{Hg}} \times g$$

$$h_{\text{air}} = \frac{\rho_{\text{Hg}} \times h_{\text{Hg}}}{\rho_{\text{air}}}$$

$$h_{\text{air}} = \frac{13600 \times 0.76}{1.29} = 8012.4 \text{ m}$$

Density of mercury = $\rho_{\text{Hg}} = 13600 \text{ kgm}^{-3}$

Density of sea water = $\rho_{\text{water}} = 1040 \text{ kgm}^{-3}$

Height of sea water column = $h_{\text{water}} = 960 \text{ m}$

Height of mercury column = $h_{\text{Hg}} = ?$

According to question,

Pressure due to mercury column = Pressure due to sea water column

$$\rho_{\text{Hg}} \times h_{\text{Hg}} \times g = \rho_{\text{water}} \times h_{\text{water}}$$

$$h_{\text{Hg}} = \frac{\rho_{\text{water}} \times h_{\text{water}}}{\rho_{\text{Hg}}} = \frac{1040 \times 960}{13600} = 73.41 \text{ m}$$

Practice Problems 4.

Question 1.

The pressure of water on the ground floor, in a water pipe is 150000 Pa, whereas pressure on the fourth floor is 30000 Pa. Calculate height of fourth floor. Take $g = 10 \text{ ms}^{-2}$.

Answer:

Pressure of water at fourth floor = $P_2 = 30000 \text{ Pa}$ Let h be the height of fourth floor

Difference in pressure of water at ground floor and fourth floor

$$= P_1 - P_2 = 150000 - 30000$$

$$= 120000 \text{ Pa}$$

Pressure of water due to height (h) = hpg

$$\Rightarrow P_1 - P_2 = h p$$

$$\Rightarrow P_1 - P_2 = h \rho g$$

$$120000 = h \times 1000 \times 10$$

$$[\rho = 1000 \text{ kgm}^{-3} = \text{Density of water}]$$

$$h = \frac{120000}{10000} = 12 \text{ m}$$

Question 2.

The pressure of water on ground floor is 160000 Pa. Calculate the pressure at the fifth floor, at a height of 15 m.

Answer:

Pressure of water at ground floor = $P_1 = 160000 \text{ Pa}$

Pressure of water at fifth floor = $P_2 = ?$

Height of fifth floor = $h = 15 \text{ m}$

Density of water = $\rho = 1000 \text{ kgm}^{-3}$

Difference in pressure of water at ground and fifth floor

$$= P_1 - P_2$$

Pressure of water due to height (h) = $h\rho g$

$$= P_1 - P_2 = h\rho g$$

$$160000 - P_2 = 15 \times 1000 \times 10$$

$$P_2 = 160000 - 150000$$

$$P_2 = 10000 \text{ Pa}$$

Practice Problems 5.

Question 1.

(a) The area of cross-sections of the pump plunger and press plunger of a hydraulic press are 0.02 m^2 and 8 m^2 respectively. If the hydraulic press overcomes a load of 800 kgf , calculate the force acting on pump plunger.

(b) If the mechanical advantage of the handle of pump plunger is 8, calculate the force applied at the end of the handle of pump plunger.

Answer:

(a) Load on the press plunger = $L = 800 \text{ kgf}$

Let the effort acting on the pump plunger = E

Area of cross-section of pump plunger = $A_1 = 0.02 \text{ m}^2$

Area of cross-section of press plunger = $A_2 = 8 \text{ m}^2$

$$\text{Area of cross-section of pump plunger} = A_1 = 0.02 \text{ m}^2$$

$$\text{Area of cross-section of press plunger} = A_2 = 8 \text{ m}^2$$

$$\text{Now, } \frac{L}{E} = \frac{A_2}{A_1}$$

$$\frac{800}{E} = \frac{8}{0.02} = \frac{800}{2} = 400$$

$$E = \frac{800}{400} = 2 \text{ kgf}$$

$$\Rightarrow \text{Force acting on the pump plunger} = 2 \text{ kgf}$$

(b)

Mechanical advantage = 8

But mechanical advantage = $\frac{L}{E}$

Here, $L = 2 \text{ kgf}$

Force applied at the of handle of pump plunger = $E = ?$

$$\Rightarrow \text{M.A.} = \frac{L}{E}$$

$$8 = \frac{2}{E}$$

$$E = \frac{2}{8} = \frac{1}{4} = 0.25 \text{ kgf.}$$

Question 2.

The radii of the press plunger and pump plunger are in ratio of 50 : 4. If an effort of 20 kgf acts on the pump plunger, calculate the maximum effort which the press plunger can over come.

Answer:

Effort acting on the pump plunger – $E = 20 \text{ kgf}$

Load acting on the press plunger = $L = ?$

So let radius of pump plunger = $50x = R$ and radius of press plunger = $Ax = r$

$$\text{Now, } \frac{L}{E} = \frac{\pi R^2}{\pi r^2}$$

$$\frac{L}{20} = \frac{(50x)^2}{(4x)^2} = \frac{2500}{16} = \frac{625}{4}$$

$$L = \frac{625}{4} \times 20$$

$$L = 625 \times 5 = 3125 \text{ kgf.}$$

QUESTIONS BASED ON ICSE EXAMINATION
(A) Objective Questions

Multiple Choice Questions.
Select the correct option.

1. Unit of thrust in SI system is

- (a) dynes
- (b) joule
- (c) N/m^2
- (d) newton**

2. The unit Nm^2 is the unit of

- (a) force
- (b) pressure**
- (c) thrust
- (d) momentum

3. One Pascal is equal to:

- (a) Nm^2
- (b) Nm^{-2}**
- (c) Nm^2
- (d) Nm^{-1}

4. Thrust acting perpendicularly on the unit surface area is called :

- (a) pressure**
- (b) moment of force
- (c) down thrust
- (d) none of these

5. Pressure applied in liquids is transmitted with undiminished force:

- (a) in downward direction
- (b) upward direction only
- (c) sides of containing vessel
- (d) in all directions**

6. As we move upwards, the atmospheric pressure :

- (a) increases
- (b) decreases**
- (c) remains same
- (d) cannot be said

7. A dam for water reservoir is built thicker at the bottom than at the top because :

- (a) **pressure of water is very large at the bottom due to its large depth**
- (b) water is likely to have more density at the bottom due to its large depth
- (c) quantity of water at the bottom is large
- (d) variation in value of 'g'

8. The pressure exerted by 50 kg ($g = 10 \text{ m/s}^2$) on an area of cross section of 2 m^2 is :

- (a) 50 Pa
- (b) 200 Pa
- (c) **250 Pa**
- (d) 1000 Pa

Ans. (c) 250 Pa

Explanation : $m = 50 \text{ kg}$; $g = 10 \text{ ms}^{-2}$

Area of cross-section = $A = 2\text{m}^2$

$$\text{Pressure} = P = \frac{F}{A} = \frac{mg}{A} = \frac{50 \times 10}{2} = 250 \text{ Pa}$$

9. Pressure at a point inside a liquid does not depend on :

- (a) The depth of the point below the surface of the liquid
- (b) The nature of the liquid
- (c) The acceleration due to gravity at that point
- (d) **The shape of the containing vessel**

10. The atmospheric pressure on earth's surface is approximately

- (a) **10^5 Pa**
- (b) 10^4 Pa
- (c) $9.6 \times 10^4 \text{ N/m}^2$
- (d) 10^{-4} Pa

(B) Subjective Questions

Question 1.

State three factors on which the pressure at a point in a liquid depends.

Answer:

Factors on which the pressure at a point in a liquid depends are:

1. Pressure in a liquid is directly proportional to its height or depth.
2. Pressure in a liquid is directly proportional to its density.
3. Pressure in a liquid is directly proportional to the acceleration due to gravity.

4. Pressure in a liquid is independent of the area of crosssection.

Question 2.

The normal pressure of air is 76 cm of mercury. Calculate the pressure in SI units.
[Density of mercury = 13600 kg/m³ and g = 10 m/s²]

Answer:

Height of mercury column = h = 76 cm

h = 0.76 m

Density of mercury = ρ = 13600 kg/m³

Acceleration due to gravity = g = 10 m/s²

Pressure = P = ?

P = h ρ g

P = 0.76 x 13600 x 10 = 103360 N/m²

Question 3.

At a given place, a barometer records 70 cm of Hg. If the mercury in barometer is replaced by water, what would be resulting reading? (Density of Hg = 13600 kg/m³; Density of water = 1000 kg/m³)

Answer:

Height of mercury column = h = 70 cm = 0.70 m

Density of mercury = ρ = 13600 kg/m³

Acceleration due to gravity = g = 10 m/s²

Pressure = h ρ g

For water:

Height of water column = h' = ?

Pressure due to water column = P'

Density of water = ρ_w = 1000 kg/m³

$$P' = h'\rho_w g$$

But, P' = P

$$h'\rho_w g = h\rho g$$

$$h'\rho_w = h\rho$$

$$h' = \frac{h\rho}{\rho_w} = \frac{0.7 \times 13600}{1000} = 9.52 \text{ m}$$

Question 4.

The base of cylindrical vessel measures 300 cm². Water is poured into it upto a depth of 6 cm. Calculate the pressure of water on the base in vessel.

Answer:

Area of base of cylinder = $A = 300 \text{ cm}^2$

$$A = 300 \times 10 \text{ m}^2$$

$$A = 3 \times 10^2 \text{ m}^2$$

Height (or depth) of water column = $h = 6 \text{ cm}$

$$h = \frac{6}{100} \text{ m}$$

Density of water = $\rho = 1000 \text{ kg/m}^3$

Acceleration due to gravity = $g = 10 \text{ m/s}^2$

Pressure at the base in vessel = $P = h\rho g$

$$P = \frac{6}{100} \times 1000 \times 10$$

$$P = 600 \text{ Pa}$$

Question 5.

The pressure in water pipe on the ground floor of a building is 40000 pascals, whereas on the first floor it's 10000 pascals. Find the height of first floor. (Acceleration due to gravity $g = 10 \text{ ms}^{-2}$)

Ans.

Pressure on the ground floor of a building = $P_1 = 40000 \text{ Pa}$

Pressure on the first floor of a building = $P_2 = 10000 \text{ Pa}$

$\rho = 1000 \text{ kg/m}^3$ = density of water

Acceleration due to gravity = $g = 10 \text{ m/s}^2$

Difference in pressure = $P_1 - P_2 = 40000 - 10000 = 30000 \text{ Pa}$

Let h = height of first floor

Pressure of water due to height (h) = $h\rho g$

$$30000 = h \times 1000 \times 10$$

$$h = \frac{30000}{10000} = 3 \text{ m}$$

Question 6.

(a) Define SI unit of pressure.

(b) The atmospheric pressure at a place is 650 mm of Hg. Calculate this pressure in Pascals (Pa).

Answer:

(a) SI unit of pressure is pascal (Pa) or Nm^{-2}

One Pascal: When a force of one newton acts normally on an area of one square metre (1 m^2) then pressure acting on the surface is called one Pascal.

(b) Height of mercury column = $h = 650 \text{ mm}$

$h = 65 \text{ cm} = 0.65 \text{ m}$

Density of mercury = $\rho = 13600 \text{ kg/m}^3$

Acceleration due to gravity = $g = 10 \text{ ms}^{-2}$

Pressure (P) = 650 mm of Hg = $h\rho g$

$= 0.65 \times 13600 \times 10$

$= 88400 \text{ Pa}$

Question 7.

Pressure in a water pipe on the ground floor of a building is 100,000 Pa. Calculate the pressure in water pipe on first floor at a height of 3 m. [Density of water = 1000 kgm^{-3} ; $g = 10 \text{ ms}^{-2}$]

Answer:

Pressure of water at ground floor = $P_1 = 1,00,000 \text{ Pa}$

Pressure of water at first floor = $P_2 = ?$

Height of first floor = $h = 3 \text{ m}$

Density of water = $\rho = 1000 \text{ kgm}^{-3}$

Acceleration due to gravity = $g = 10 \text{ ms}^{-2}$

Difference in pressure of water at-ground floor and first floor

$= P_1 - P_2$

Pressure of water due to height (h) = $h\rho g$

$\Rightarrow P_1 - P_2 = h\rho g$

$1,00,000 - P_2 = 3 \times 1000 \times 10$

$P_2 = 1,00,000 - 30,000$

$P_2 = 70,000 \text{ Pa}$

$\therefore$ Pressure of water in pipe at first floor of a building is 70,000 Pa.

Question 8.

P is the pressure at some point in a liquid. State whether pressure P is a scalar or vector quantity.

Answer:

Pressure exerted on an enclosed fluid gets transmitted equally and undiminishingly in all directions. So no particular direction is associated with pressure.

That is why Pressure is a scalar quantity.

Question 9.

A beaker contains a liquid of density ' ρ ' upto height ' h ' such that ' P_A ' is atmospheric pressure and ' g ' is acceleration due to gravity. Answer the following questions :

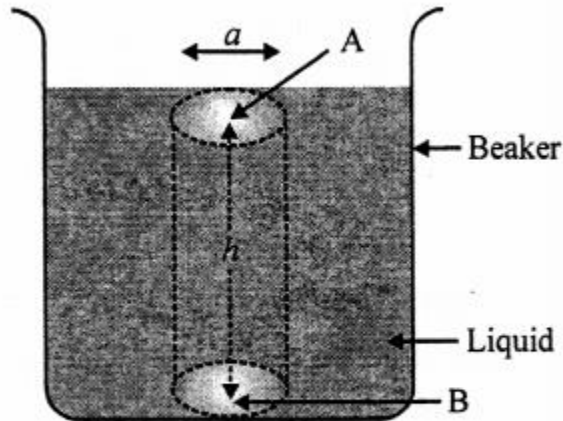
(a) What is the pressure on the free surface of liquid?

(b) What is the pressure on the base of beaker?

(c) What is the lateral pressure at the base on the inner walls of beaker?

Answer:

- (a) Pressure on the free surface of liquid is equal to the atmospheric pressure (P_a).
(b) Consider a liquid contained in a beaker, such that ' ρ ' is the density of liquid. Consider a point B at the base of liquid and the liquid column of area of cross-section ' a ' around it, such that ' h ' is the height of the liquid column as shown in the figure.



$\therefore$ Volume of imaginary column of liquid

$$= \text{area of cross-section} \times \text{length} = ah$$

$\therefore$ Mass of liquid column = Volume $\times$ density

$$= V \times \rho = a.h.\rho$$

$\therefore$ Weight of liquid column = mass $\times g = mg$

$$= a.h.\rho.g.$$

$\therefore$ Thrust exerted by liquid column on the base of the beaker

$$= a.h.\rho.g.$$

$\therefore$ Pressure due to liquid column

$$P = \frac{\text{Force}}{\text{Area}} = \frac{F}{a} = \frac{ah\rho g}{a}$$

$$P = h.\rho.g.$$

So, pressure on the base of beaker = $h\rho g$

$\therefore$ Total pressure at base of beaker = Atmospheric pressure + $h\rho g$

$$= P_a + h\rho g$$

(c) Also lateral pressure at the base on the inner walls of beaker = $P_a + h\rho g$

Question 10.

State the law of transmission of pressure in liquids.

Ans.

Pascal's law : "The pressure applied on the surface of a confined liquid is transmitted equally and undiminished in all directions throughout the liquid."

Question 11.

Calculate the hydrostatic pressure exerted by water at the bottom of a beaker. Take the depth of water as 40 cm, the density of water 1000 kgm^{-3} and $g = 9.8 \text{ ms}^{-2}$.

Ans.

Pressure at the bottom of beaker = $P = ?$

Height (or depth) of water in beaker = $h = 40 \text{ cm}$

$h = 0.4 \text{ m}$

Density of water = ρ

= 1000 kgm^{-3} Acceleration due to gravity = $g = 9.8 \text{ ms}^{-2}$

$P = h\rho g$

$P = 0.4 \times 1000 \times 9.8$

= 3920 Pa

Question 12.

State Pascal's law of transmission of pressure in a liquid.

Answer:

Pascal's law : "The pressure applied on the surface of a confined liquid is transmitted equally and undiminished in all directions throughout the liquid."

Question 13.

State briefly, how and why the atmospheric pressure of a place varies with the altitude. Draw an approximate graph to illustrate this variation.

Answer:

1. We know atmospheric pressure = height of air column $\times$ density of air $\times$ acceleration due to gravity; $P = h\rho g$ So, as we go up i.e. at higher altitudes, height of air column and hence atmospheric pressure decreases.
2. Also with the increase in altitude, density of air decreases and hence atmospheric pressure decreases.

If we take average density of air as 1.29 kgm^{-3} and the density of mercury as 13600 kgm^{-3}

we can find the height

Column which will exert as much pressure as* is exerted by 1 cm or (0.01 m) column of mercury as

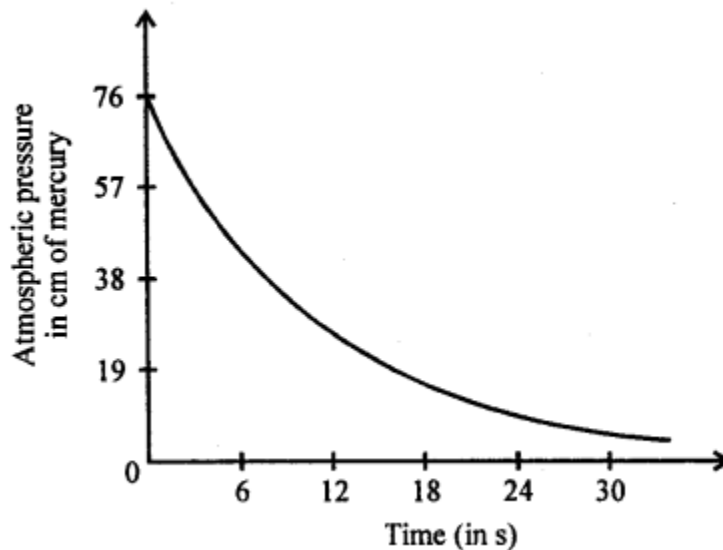
Height of air column $\times$ density of air = height of mercury column $\times$ density of mercury
height of air column $\times 1.29 \text{ kg/m}^3$

= $0.01 \text{ m} \times 13600 \text{ kg/m}^3$

$$\therefore \text{Height of air column} = \frac{136}{1.29} \text{ m} = \mathbf{105 \text{ m (approx)}}.$$

Thus, 105 m of air column, on the average, will exert as much pressure as 1 cm column of mercury. Further, 1 cm of mercury column exerts pressure = 105 m of air column. 76 cm of mercury column exerts pressure = $105 \times 76 \text{ m} = 7980 \text{ m} = \mathbf{8 \text{ km}}$ (approx).

Thus, **8 km of air column will** exert as much pressure as 76 cm of mercury column. However, it does not mean that atmosphere extends to only 8 km. As it is pointed out earlier, the density of atmosphere also changes with height. Thus, a fall of one cm in pressure does not mean that we have covered a vertical height of 105 m. On higher altitudes the vertical height of air is far in excess of 105 m, because of low density of air. A graph showing fall in pressure with height is shown in the figure.



Question 14.

The blood pressure reading of a patient is recorded 160/ 100. Express the lower pressure in SI units.

[Take density of mercury as $13.6 \times 10^3 \text{ kgm}^{-3}$ and the value of 'g' as 10 ms^{-2}]

Answer:

Lower pressure of the patient = 100 mm of Hg column

Height of mercury column = $h = 100 \text{ mm} = 10 \text{ cm} = 0.1 \text{ m}$

Density of mercury = $\rho = 13.6 \times 10^3 \text{ kgm}^{-3}$

Acceleration due to gravity = $g = 10 \text{ ms}^{-2}$

So lower pressure of patient = $P = h\rho g$

$P = 0.1 \times 13.6 \times 10^3 \times 10$

$P = 13600 \text{ Pa}$

Question 15.

State two advantages of aneroid barometer.

Answer:**Advantages of aneroid barometer :**

1. It is compact, portable and hence can be carried anywhere.
2. It does not contain any liquid and there is no chance of spilling over of liquid as in mercury barometer.

Question 16.

Explain, why a gas bubble released at the bottom of a lake grows in size as it rises to the surface of the lake.

Answer:

Bubble released at the bottom of a lake grows in size as it rises to the surface of the lake because the pressure exerted on it by water of the lake DECREASES hence by BOYLE'S LAW $PV = \text{constant}$ the VOLUME of bubble INCREASES and the bubble grows in size.