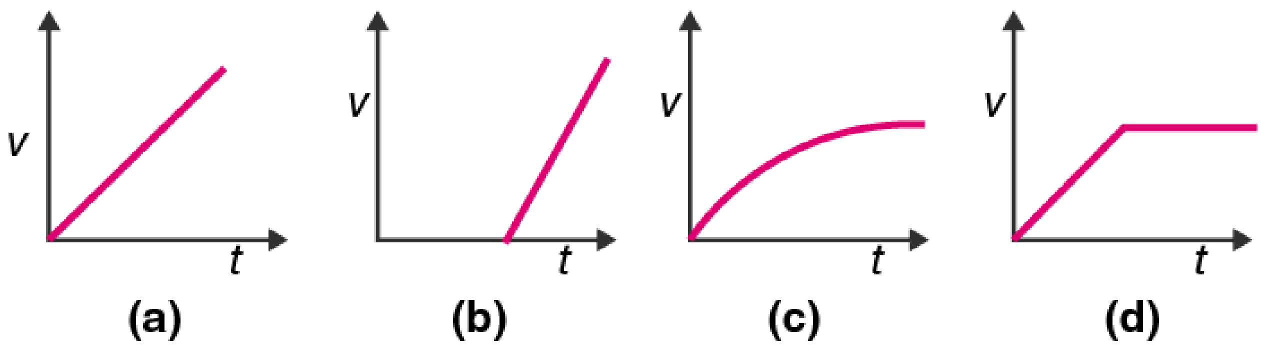
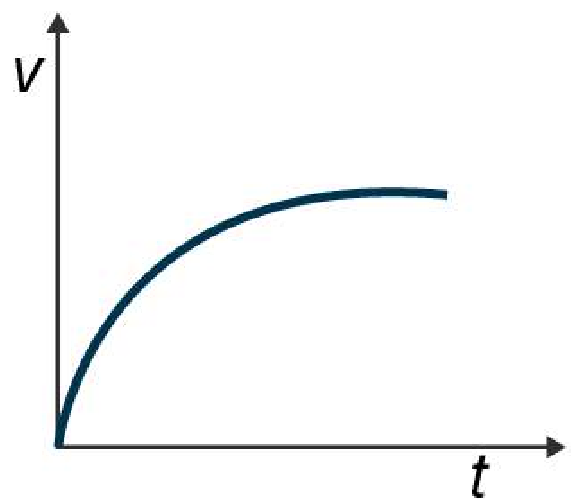
Multiple Choice Questions I

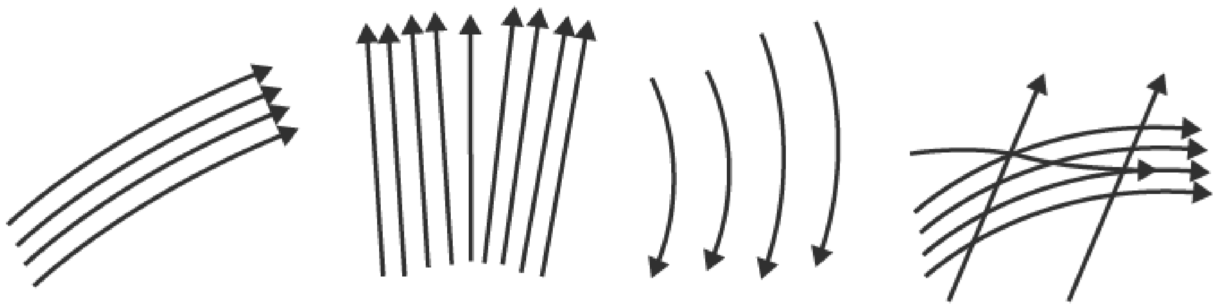
10.1. A tall cylinder is filled with viscous oil. A round pebble is dropped from the top with zero initial velocity. From the plot shown in figure, indicate the one that represents the velocity (v) of the pebble as a function of time (t).



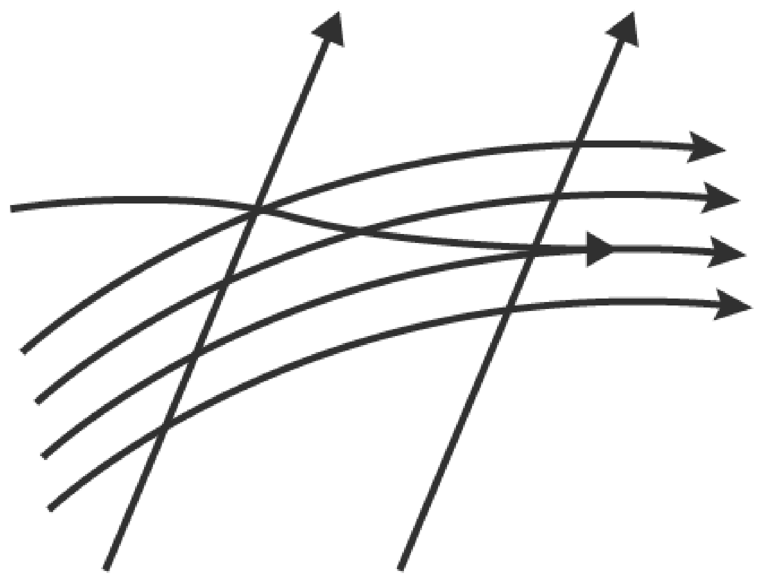
Answer:
The correct answer is c)



10.2. Which of the following diagrams does not represent a streamline flow?



Answer:
The correct answer is d)



10.3. Along a streamline
a) the velocity of a fluid particle remains constant
b) the velocity of all fluid particles crossing a given position is constant
c) the velocity of all fluid particles at a given instant is constant
d) the speed of a fluid particle remains constant
Answer:
The correct answer is b) the velocity of all particles crossing a given position is constant

10.4. An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is
a) 9:4
b) 3:2
c) √3: √2
d) √2: √3
Answer:
The correct answer a) 9:4

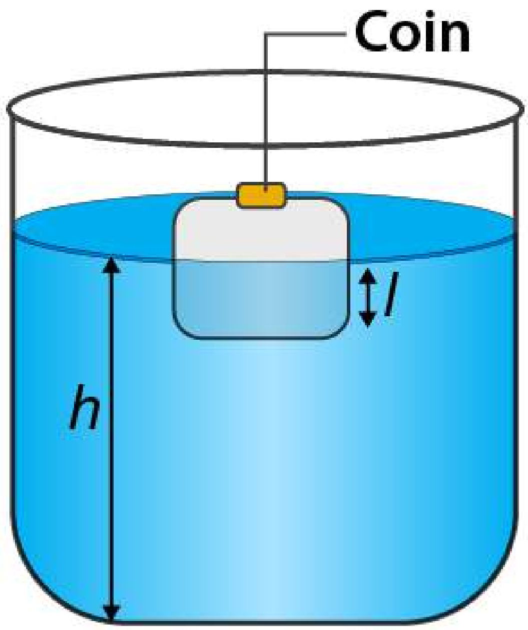
10.5. The angle of contact at the interface of water-glass is 0o, ethylalcohol-glass is 0o, mercury-glass is 140o, and methyliodide-glass is 30o. A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is
a) water
b) ethylalcohol
c) mercury
d) methyliodide
Answer:
The correct answer c) mercury

Multiple Choice Questions II

10.6. For a surface molecule
a) the net force on it is zero
b) there is a net downward force
c) the potential energy is less than that of a molecule inside
d) the potential energy is more than that of a molecule inside
Answer:
The correct answer is
b) there is a net downward force
d) the potential energy is more than that of a molecule inside

10.7. Pressure is a scalar quantity because
a) it is the ratio of force to area and both force and area are vectors
b) it is the ratio of the magnitude of the force to area
c) it is the ratio of component of the force normal to the area
d) it does not depend on the size of the area chosen
Answer:
The correct answer is
b) it is the ratio of the magnitude of the force to area
c) it is the ratio of component of the force normal to the area

10.8. A wooden block with a coin placed on its top, floats in water as shown in figure:



The distance l and h are shown in the figure. After some time the coin falls into the water. Then
a) l decreases
b) h decreases
c) l increases
d) h increases
Answer:
The correct answer is
a) l decreases
b) h decreases

10.9. With increase in temperature, the viscosity of
a) gases decreases
b) liquids increases
c) gases increases
d) liquids decreases
Answer:
The correct answer is
c) gases increases
d) liquids decreases

10.10. Streamline flow is more likely for liquids with
a) high density
b) high viscosity
c) low density
d) low viscosity
Answer:

The correct answer is
b) high viscosity
c) low density

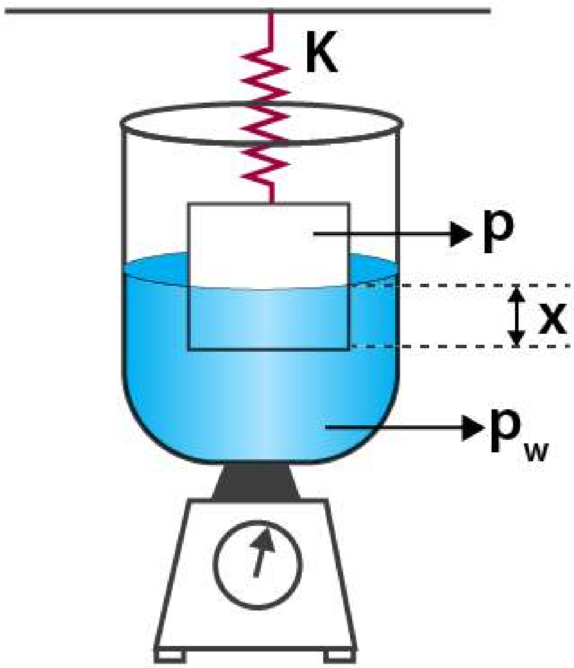
Very Short Answers

10.11. Is viscosity a vector?
Answer:
Viscosity is not a vector quantity. It is a scalar quantity and it is a property of liquid with no direction.

10.12. Is surface tension a vector?
Answer:
Surface tension is a scalar quantity as it has a specific direction.

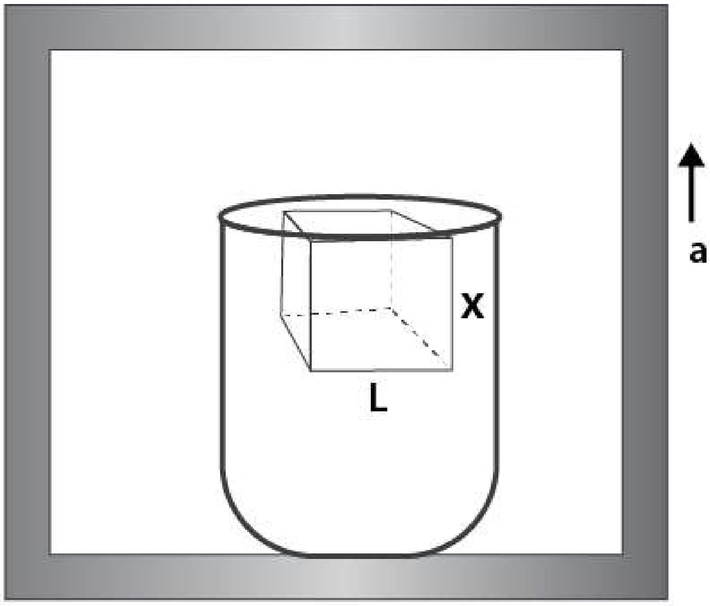
10.13. Iceberg floats in water with part of it submerged. What is the fraction of the volume of iceberg submerged if the density of ice is $\rho_i = 0.917$ g/cm^3?
Answer:
Density of ice, $\rho_{ice} = 0.917$ g/cm^3
Density of water, $\rho_{water} = 1$ g/cm^3
V_i is the volume of the iceberg
V_w is the volume of the water displaced by the iceberg
Weight of iceberg, $W = \rho_i V_i g$
Upthrust, $F_B = \rho_w V_w g$
At equilibrium, weight of iceberg = $V_w/V_i = 0.917$

10.14. A vessel filled with water is kept on a weighing pan and the scale adjusted to zero. A block of mass M and density ρ is suspended by a massless spring of spring constant k. This block is submerged inside into the water in the vessel. What is the reading of the scale?
Answer:



The upthrust of the block = weight of water displaced = $V\rho_w g$
Let x be the compression in the spring
When the block is in equilibrium,
$Mg - (kx + V\rho_w g) = 0$
The force acting on the pan is the force applied by the water and it is the reading of the pan which is given as:
$M_{vessel} + m_{water} + V\rho_w g$
Therefore, the new reading is $V\rho_w g$.

10.15. A cubical block of density ρ is floating on the surface of water. Out of its height L, fraction x is submerged in water. The vessel is in an elevator accelerating upwards with acceleration a. What is the fraction immersed?
Answer:



Density of block = ρ
Height of block = L
Mass of the block, m = Vρ = $L^3\rho$
Weight of the block = mg = $L^3\rho g$
Let the height of the cube submerged be x

Case I
When the volume of part of cube submerged in water = xL^2
Weight of water displaced is given as:

$$xL^2 \times \rho_w g$$

Therefore, the weight of block = weight of water displaced by the block

$$\frac{l}{L} = \frac{\rho}{\rho_w} = x$$

Case II
When the vessel is placed on an elevator which is accelerating upwards with a as acceleration is given as = (g + a)
The weight of the block = m(g + a) = L^3 ρ(g + a)
Therefore, the effective weight = m (g + a)
The new fraction of block submerged in water = x_1

$$x_1 = \frac{m}{L^3 \rho_w} = \frac{L^3 \rho}{L^3 \rho_w} = \frac{\rho}{\rho_w} = x$$

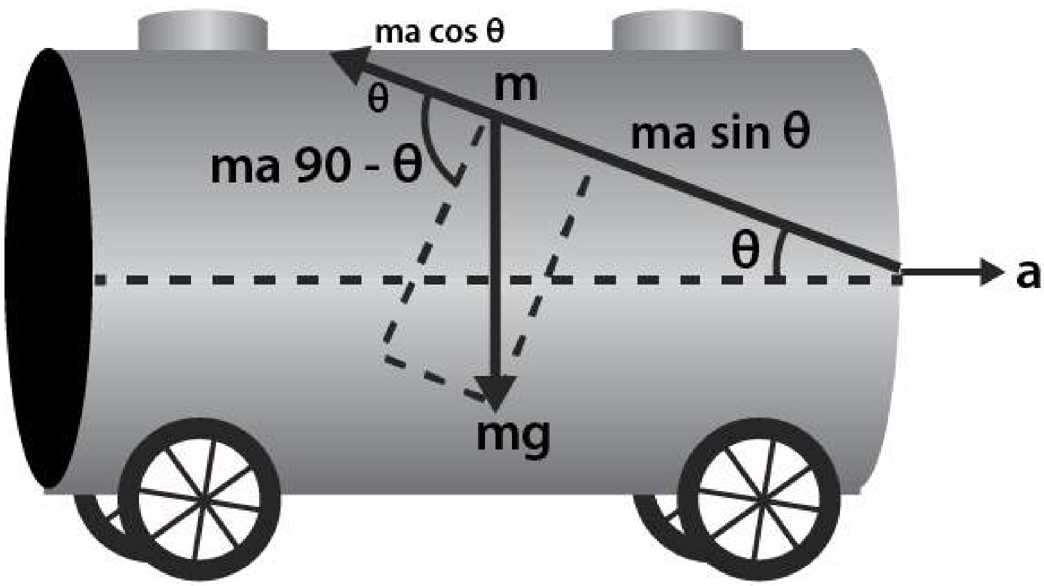
Short Answer

10.16. The sap in tress, which consists mainly of water in summer, rises in a system of capillaries of radius r = 2.5 × 10^{-5} m. The surface tension of sap is T = 7.28 × 10^{-2} N/m and the angle of contact is 0^o. Does surface tension alone account for the supply of water to the top of all tress?
Answer:
Radius, r = 2.5 × 10^{-5} m
Surface tension, T = 7.28 × 10^{-2} N/m
Angle of contact, θ = 0o
Density, ρ = 103 kg/m3
The maximum height h is given as:

$$h = \frac{2Scos\theta}{r\rho g}$$

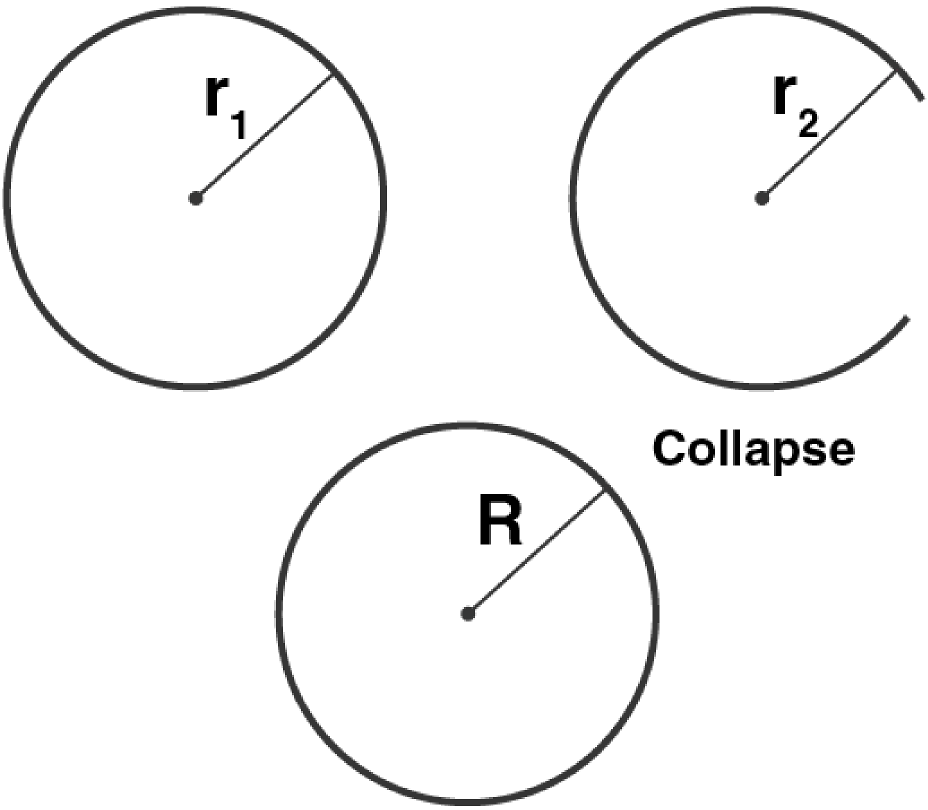
Substituting the values we get, h = 0.6 m

10.17. The free surface of oil in a tanker, at rest, is horizontal. If the tanker starts accelerating the free surface will be titled by an angle θ. If the acceleration is a m/s^2, what will be the slope of the free surface?
Answer:



Let the mass of an elementary particle of oil be m
The balancing forces are inclined along the direction of the surface
Pseudo force = ma
Weight of small part of oil = mg
Net force = 0
Therefore, ma cos θ = mg sin θ
$\theta = \tan^{-1}(a/g)$

10.18. Two mercury droplets of radii 0.1 cm and 0.2 cm collapse into one single drop. What amount of energy is released? The surface tension of mercury $T = 435.5 \times 10^{-3}$ N/m.
Answer:



For volume to remain conserved, the two drops should form a bigger drop
Radius of smaller drop, r_1 = 0.1 cm = 10^{-3} m
Radius of bigger drop, r_2 = 0.2 cm = 2×10^{-3} m
Surface tension = 435.5×10^{-3} N/m
Let V_1 and V_2 be the volume of the drops of mercury and when they collapse their volume is V
$V = V_1 + V_2$

$$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r_1^3 + \frac{4}{3}\pi r_2^3$$

R = 0.21 cm = 2.1×10^{-3} m
Decrease in surface area is given as:

$$\Delta A = 4\pi R[2] - (4\pi r_1^2 + 4\pi r_2^2) = 4\pi[R^2 - (r_1^2 + r_2^2)]$$

Energy released is E = (T)(ΔA) = -32.23×10^{-7}

10.19. If a drop of liquid breaks into smaller droplets, it results in lowering of temperature of the droplets. Let a drop of radius R, break into N small droplets each of radius r. Estimate the drop in temperature.
Answer:
Volume of the liquid of drop of radius R = (N)(volume of liquid droplet of radius r)

$$\frac{4}{3}\pi R^3 = N \times \frac{4}{3}\pi r^3$$

$$N = \frac{R^3}{r^3}$$

Energy released is:

$$\Delta U = T \times \Delta A = T[4\pi R^2 - N(4\pi r^2)] = 4\pi T(R^2 - Nr^2)$$

When the energy is released, the temperature reduces.

$$\Delta T = \frac{\Delta U}{mc} = \frac{4\pi T(R^2 - Nr^2)}{\frac{4}{3}R^3\rho c}$$

Where c is the specific heat of liquid.
Solving the above equation, it can be said that ΔT will be negative and therefore, the temperature of the droplet falls.

10.20. The surface tension and vapour pressure of water at 20ºC is 7.28×10^{-2} N/m and 2.33×10^3 Pa, respectively. What is the radius of the smallest spherical water droplet which can form without evaporating at 20ºC?
Answer:
Surface tension of water, T = 7.28×10^{-2} N/m
Vapour pressure, P = 2.33×10^3 Pa
Radius of drop = r
2T/r is the excess pressure which is greater than the vapour pressure.
Vapour pressure = excess pressure in drop
Using the above relation, we can calculate r = 6.25×10^{-5} m

Long Answers

10.21. a) Pressure decreases as one ascends the atmosphere. If the density of air is ρ, what is the change in pressure dp over a differential height dh?
b) Considering the pressure p to be proportional to the density, find the pressure p at a height h if the pressure on the surface of the earth is ρ_o.
c) If $p_o = 1.03 \times 10^5$ N/m^2, $\rho_o = 1.29$ kg/m^3 and g is 9.8 m/s^2 at what height will the pressure drop to (1/10)

the value at the surface of the earth?
d) This model of the atmosphere works for relatively small distances. Identify the underlying assumption that limits the model.
Answer:
a) As we move above, the pressure decreases because the thickness of the gas above us decreases. Let A be the cross-section of the horizontal layer of the air and height be dh.
Then P is the pressure on the top layer and p + dp is the pressure at the bottom.
Since the layer of the air is in equilibrium, the net upward force is balanced
That is net upward force = net downward force
Which is given as:
dp = -ρgdh
The negative sign indicates the decrease in pressure with height.

b) Let ρo be the density of air on the surface of the earth such that pressure is proportional to the density.

$$\rho \propto p$$

$$\frac{pressure\ at\ some\ height(p)}{pressure\ at\ the\ surface\ of\ earth(p_0)} = \frac{\rho}{\rho_0}$$

Solving the above, we get pressure as:

$$p = p_0 e^{\left(-\frac{\rho_0 g h}{p_0}\right)}$$

c) We know that $p = p_0 e^{\left(-\frac{\rho_0 g h}{p_0}\right)}$
By substituting the values, we can calculate h = 18.43 km

d) For the relation $p \propto \rho$ to be valid, the temperature in the air should be uniform which is known as isothermal situation and this possible only near the surface of the earth and not at greater heights.

10.22. Surface tension is exhibited by liquids due to force of attraction between molecules of the liquid. The surface tension decreases with increase in temperature and vanishes at boiling point. Give that the latent heat of vaporisation for water Lv = 540 k cal/kg, the mechanical equivalent of heat J = 4.2 J/cal, density of water ρ_w = 103 kg/l, Avogadro's number NA = 6.0 1026 k/mole, and the molecular weight of water MA = 18 kg for 1 k mole.
a) Estimate the energy required for one molecule of water to evaporate.

b) Show that the inter-molecular distance for water is $d = [\frac{M_A}{N_A} \times \frac{1}{\rho_w}]^{\frac{1}{3}}$ **and find its value.**
c) 1 g of water in the vapour state at 1 atm occupies 1601 cm^3. Estimate the intermolecular distance at boiling point, in the vapour state.
d) During vaporisation a molecule overcomes a force F, assumed constant to go from an inter-molecular distance d to d'. Estimate the value of F.
e) Calculate F/d which is a measure of the surface tension.
Answer:
a) According to the given problem,
Latent heat of vaporisation for water is = 2268×10^3 J
Energy required to evaporate 1 k mol water = 4.0824×10^7 J
Energy required for evaporation of 1 molecule is, U = 6.8×10^{-20} J

b) Let the distance between the water molecules be d
Then the volume around one molecule is:

$$\frac{volume\ of\ 1\ kmol}{number\ of\ molecules/kmol} = \frac{M_A}{N_A\rho_w}$$

Therefore, the volume around one molecule = d^3
Which is given as:

$$d^3 = \frac{M_A}{N_A\rho_w}$$

d = 3.1×10^{-10}m

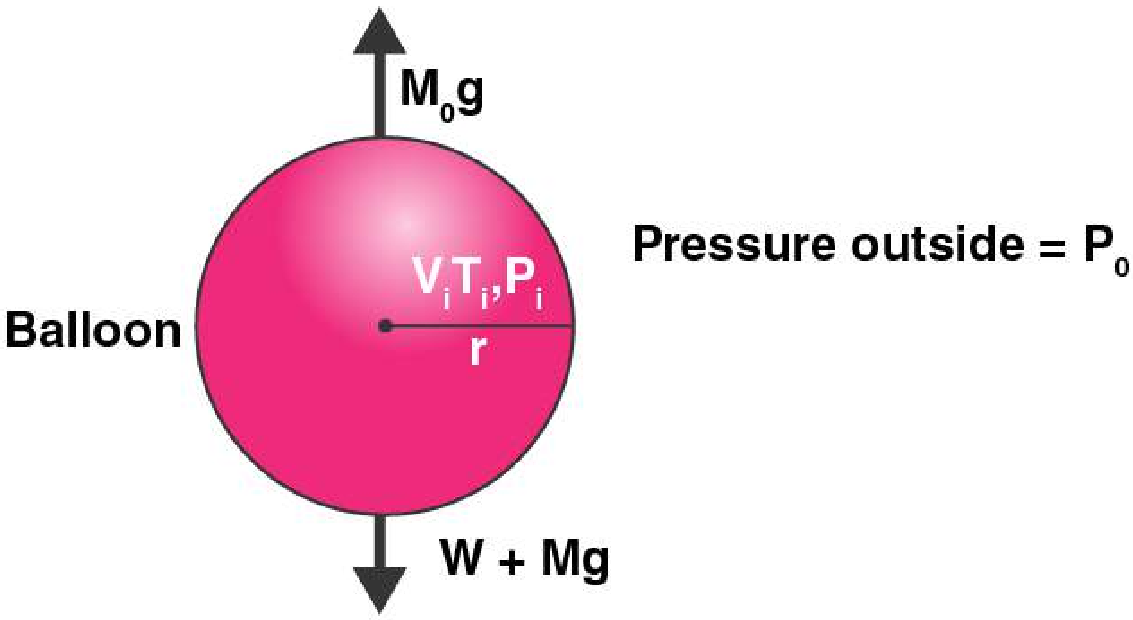
c) Volume occupied by 1 kmol of water molecules = 28818×10^{-3} m^3
Volume occupied by 1 molecule of water = 48030×10^{-30} m^3
Let d' be the intermolecular distance, then
(d')3 = 48030×10^{-30} m^3
d' = 36.3×10^{-10} m

d) Work done to change the distance from d to d' U = F(d'-d)
F = 2.05×10^{-11} N

e) Surface tension = F/d = 6.6×10^{-2} N/m

10.23. A hot air balloon is a sphere of radius 8 m. The sir inside is at a temperature of 60^{o}C. How large a mass can the balloon lift when the outside temperature is 20^{o}C?
Answer:
Let p_i be the pressure inside the balloon.
Then p_o be the pressure outside the balloon.

The excess pressure is given as: $p_i - p_o = 2T/r$
Where,
T is the surface tension
r is the radius of balloon



Let us consider the air to behave like an ideal gas.
Let the number of moles of air inside the balloon be n_i
Then,
$P_iV = n_iRT_i$
$n_i = P_iV/RT_i$
Mass of air inside the balloon,
$M_i = M_AV/R(P_i/T_i)$
Where,
M_i is the mass of air inside
M_A is the molar mass of the air
$n_o = p_oV/RT_o = M_o/M_A$
Where, M_o is the mass of air outside
W is the load that is raised
$W + M_ig = M_og$
$W = M_og - M_ig = M_AV/R\ [(P_o/T_o)\text{-}(P_i/T_i)]g$
Pressure inside the balloon due to membrane tension (T) = 2T/r = 1.25 N/m^2
$T_o = 20 + 273 = 293K$
$T_i = 60 + 273 = 333K$
R = 8 m
$V = 2.144 \times 10^3\ m^3$
$P_o = P_i = 1.013 \times 10^5\ N/m^2$

In atmosphere, 21% O2 and 79% N2 is present
M_a = 21% of O2 + 79% of N2 = 28.84×10^{-3} kg/mol

Therefore, the weight of the balloon raised is 301 kg.