Fluid Mechanics

Question1

The liquid (mercury) meniscus in capillary tube will be convex if the angle of contact is

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Options:

A.

greater than 90°

B.

less than 90°

C.

equal to 90°

D.

equal to 0°

Answer: A

Solution:

Key Concept:

- The **angle of contact** (or contact angle) is the angle between the tangent to the liquid surface at the point of contact and the solid surface **inside the liquid**.
- If the angle of contact $\boldsymbol{\theta < 90^\circ}$, the liquid wets the surface → concave meniscus (e.g., water in glass tube).
- If the angle of contact $\boldsymbol{\theta > 90^\circ}$, the liquid does not wet the surface → convex meniscus (e.g., mercury in glass tube).

- If $\theta = 0°$, perfect wetting → completely concave upward.
- If $\theta = 90°$, theoretically flat at surface.

For **mercury in glass**, the contact angle is around 128°, which is > 90°, hence the meniscus is **convex**.

✅ **Correct Answer:**

Option A: greater than 90°

Question2

A vessel completely filled with water has two holes ' P ' and ' Q ' at depths ' 2 h ' and ' 8 h ' from the top respectively. Hole ' P ' is square of side ' a ' and hole ' Q ' is a circle of radius ' r '. The water flowing out per second from both the holes is same, then side ' a ' of hole ' P ' is

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Options:

A.

$\sqrt{2 \pi r}$

B.

r$\sqrt{2 \pi}$

C.

$2 \sqrt{\pi r}$

D.

$2 \pi x$

Answer: B

Solution:

Speed of efflux, $V=\sqrt{2 g h}$

∴ The ratio of velocities of water is given by

$\frac{V_P}{V_Q} = \sqrt{\frac{2\,h}{8\,h}} = \frac{1}{2}$

∴ $V_Q = 2\,V_P$

As the quantity of water flowing is the same, we get, $A_P V_P = A_Q V_Q$

∴ $V_P \times a^2 = V_Q \times \pi r^2$

∴ $V_P a^2 = 2\,V_Q \times \pi r^2$

∴ $a^2 = 2\pi r^2$

∴ $a = r\sqrt{2\pi}$

Question3

A spherical liquid drop splits in to 729 identical spherical drops. If E is the surface energy of the original drop and U is the total surface energy of resulting drops, then $\frac{E}{U} = \frac{1}{x}$. The value of x is

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Options:

A.

9

B.

7

C.

6

D.

13

Answer: A

Solution:

Step 1: Recall relation between surface energy and surface area

Surface energy:

$E = T \cdot A,$

where T is the surface tension, A the surface area.

Since T is constant for the liquid, energy is proportional to **surface area**.

So:

$\frac{E}{U} = \frac{A_{\text{original}}}{A_{\text{final}}}.$

Step 2: Let original radius be R

- Volume of original drop:

  $V = \frac{4}{3}\pi R^3$

- Surface area of original drop:

  $A_{\text{original}} = 4\pi R^2$

Step 3: Splitting into 729 identical small drops

Total volume is conserved.

If radius of each small drop is r, then:

$729 \cdot \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

$729 r^3 = R^3$

$r = \frac{R}{9}.$

Step 4: Surface area of smaller drops

Surface area of one small drop:

$A_{\text{one}} = 4\pi r^2 = 4\pi \left(\frac{R}{9}\right)^2 = \frac{4\pi R^2}{81}.$

Total surface area of 729 drops:

$A_{\text{final}} = 729 \cdot \frac{4\pi R^2}{81}.$

Since $729/81 = 9$,

$A_{\text{final}} = 9 \cdot 4\pi R^2.$

Step 5: Energy ratio

$\frac{E}{U} = \frac{4\pi R^2}{9 \cdot 4\pi R^2} = \frac{1}{9}.$

So $x = 9$.

✅ **Final Answer:**

$x = 9$

Correct Option: A (9)

Question4

The work done in splitting a water drop of radius R into 64 droplets is (T = surface tension of water)

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Options:

A.

$6\pi T\mathrm{R}^2$

B.

$24\pi\mathrm{TR}^2$

C.

$12\pi\mathrm{TR}^2$

D.

$16\pi\mathrm{TR}^2$

Answer: C

Solution:

Given the radius of drop is R .

Let r be the radius of smaller droplets.

As the total volume remains the same,

$$\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$$
$$\therefore \quad r = \frac{R}{(64)^{\frac{1}{3}}} = \frac{R}{4}$$

Initial surface energy $E_1 = 4\pi R^2 T$

Final surface energy

$E_2 = 64 \times 4\pi \times \left(\frac{R}{4}\right)^2 \times T = 16\pi R^2 T$

$\therefore$ Work done, $W = E_2 - E_1$

$\mathrm{W} = 12\pi \mathrm{TR}^2$

Question5

Under isothermal conditions, two soap bubbles of radii r_1 and r_2 coalesce to form a big drop. The radius of the big drop is

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Options:

A.

$(r_1 + r_2)^{\frac{1}{2}}$

B.

$(r_1 + r_2)^2$

C.

$\left(r_1^2 + r_2^2\right)^{\frac{1}{2}}$

D.

$(r_1 + r_2)^3$

Answer: C

Solution:

Number of moles is conserved, so

$P_1 V_1 + P_2 V_2 = P_3 V$

But, $P = \frac{4T}{r}$ where, r is the radius of the bubble

$$\therefore \quad \frac{4T}{r_1}\left(\frac{4}{3}\pi r_1^3\right)+\frac{4T}{r_2}\left(\frac{4}{3}\pi r_2^3\right)=\frac{4T}{r}\left(\frac{4}{3}\pi r^3\right)$$
$$r_1^2+r_2^2=r^2$$
$$r=\left(r_1^2+r_2^2\right)^{\frac{1}{2}}$$

Question6

When one end of the capillary is dipped in water, the height of water column is ' h '. The upward force of 108 dyne due to surface tension is balanced by the force due to the weight of water column. The inner circumference of the capillary is (surface tension of water $= 7.2 \times 10^{-2}$ N/m)

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Options:

A.

3 cm

B.

2.5 cm

C.

1.8 cm

D.

1.5 cm

Answer: D

Solution:

Step 1: Force due to surface tension

The total upward force by surface tension is given by:

$F = T \times \text{circumference}$

Here $T = 7.2 \times 10^{-2}\,\text{N/m}$.

Convert force into SI:

$108\ \text{dyne} = 108 \times 10^{-5}\ \text{N} = 1.08 \times 10^{-3}\ \text{N}$.

So,

$1.08 \times 10^{-3} = T \times C$,

where C is the circumference.

Step 2: Solve for circumference

$C = \frac{1.08 \times 10^{-3}}{7.2 \times 10^{-2}}$

$C = \frac{1.08}{7.2} \times 10^{-3+2}$

$C = 0.15 \times 10^{-1} = 0.015\ \text{m}$

$C = 1.5\ \text{cm}$.

✅ Final Answer:

The inner circumference of the capillary is:

Option D: 1.5 cm

Question7

A capillary tube when immersed vertically in water, the rise of water column is upto height h_1 on earth's surface. When this arrangement is taken into a mine of depth 'd', below earth's surface, the height of the water column is h_2. If R is the radius of the earth, the ratio $\frac{\mathrm{h}_2}{\mathrm{h}_1}$ is

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Options:

A. $\frac{R+d}{R}$

B. $\frac{\mathrm{R-d}}{\mathrm{R}}$

C. $\frac{R}{R+d}$

D. $\frac{R}{R-d}$

Answer: D

Solution:

If h_1 is the height through which a liquid rises in a capillary tube at depth d below the surface of the earth, $\frac{\mathrm{h}_1}{\mathrm{h}_2} = 1 - \frac{\mathrm{d}}{\mathrm{R}}$

$\therefore$ From the given data,

$\frac{h_2}{h_1} = \frac{R}{(R-d)}$

Question8

125 small water drops of same size fall through air with constant velocity $4 \mathrm{~cm/s}$. They coalesce to form a big drop. The terminal velocity of the big drop is

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Options:

A. $0.5 \mathrm{~m/s}$

B. $1 \mathrm{~m/s}$

C. $1.5 \mathrm{~m/s}$

D. $2.5 \mathrm{~m/s}$

Answer: B

Solution:

Step 1: Recall scaling law for terminal velocity of a sphere

The terminal velocity of a sphere of radius r falling under gravity in a viscous fluid is given (in Stokes law regime) by

$v \propto r^2$

because

$v = \frac{2}{9} \frac{(\rho - \sigma) g r^2}{\eta}$

(for small Reynolds number).

So:

$\frac{v_{\text{big}}}{v_{\text{small}}} = \left(\frac{R}{r}\right)^2$

Step 2: Relating radii when drops coalesce

125 small drops (radius r) coalesce → one big drop (radius R).

Volume of big drop = sum of small drops.

$\frac{4}{3}\pi R^3 = 125 \cdot \frac{4}{3}\pi r^3$

$R^3 = 125r^3$

$R = 5r$

Step 3: Ratio of terminal velocities

$\frac{v_{\text{big}}}{v_{\text{small}}} = \left(\frac{R}{r}\right)^2 = (5)^2 = 25$

So,

$v_{\text{big}} = 25 \times v_{\text{small}}$

Step 4: Substitute numbers

Small drop velocity = $4\,\text{cm/s} = 0.04\,\text{m/s}$.

$v_{\text{big}} = 25 \times 0.04 = 1.0\,\text{m/s}$

✅ **Final Answer:**

Option B: $1\,\text{m/s}$

Question9

Let R_1, R_2 and R_3 be the radii of three mercury drops. A big mercury drop is formed from them under isothermal conditions. The radius of the resultant drop is

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Options:

A. $\left(R_1^3+R_2^3+R_3^3\right)^{\frac{1}{3}}$

B. $\left(R_1^2+R_2^3-R_3^3\right)^{\frac{1}{3}}$

C. $\left(R_1^3+R_2^3+R_3^3\right)$

D. $\left(R_1+R_2+R_3\right)^3$

Answer: A

Solution:

Under isothermal conditions, the total volume of mercury remains the same.

$$\begin{aligned} \therefore \quad & V=V_1+V_2+V_3 \\ & \frac{4}{3} \pi R^3=\frac{4}{3} \pi R_1^3+\frac{4}{3} \pi R_2^3+\frac{4}{3} \pi R_3^3 \\ \therefore \quad & R=\left(R_1^3+R_2^3+R_3^3\right)^{\frac{1}{3}} \end{aligned}$$

Question10

A horizontal pipeline carries water in a streamline flow. At a point along the pipe, where the cross-sectional area is $10 \mathrm{~cm}^2$, the velocity of water is $1 \mathrm{~m} / \mathrm{s}$ and pressure is 2000 Pa . The pressure of water at another point where the cross-sectional area $5 \mathrm{~cm}^2$ is

[Given $\rightarrow$ density of water $=1000 \mathrm{~kg} / \mathrm{m}^3$]

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Options:

A. 1000 Pa

B. 750 Pa

C. 500 Pa

D. 250 Pa

Answer: C

Solution:

A horizontal pipeline with flowing water. At one section:

- Cross-sectional area $A_1 = 10\,\text{cm}^2 = 10 \times 10^{-4}\,\text{m}^2 = 1.0 \times 10^{-3}\,\text{m}^2$
- Velocity $v_1 = 1.0\,\text{m/s}$
- Pressure $P_1 = 2000\,\text{Pa}$

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

At another section: $A_2 = 5\,\text{cm}^2 = 5 \times 10^{-4}\,\text{m}^2$. Pressure P_2?

Step 1: Continuity equation

$A_1 v_1 = A_2 v_2$

$(1.0 \times 10^{-3})(1) = (5 \times 10^{-4})(v_2)$

$v_2 = \frac{1.0 \times 10^{-3}}{5 \times 10^{-4}} = 2.0\,\text{m/s}$

Step 2: Apply Bernoulli's theorem

Since pipe is horizontal (no height change):

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$

So:

$P_2 = P_1 + \frac{1}{2}\rho(v_1^2 - v_2^2)$

$= 2000 + \frac{1}{2}(1000)(1^2 - 2^2)$

$= 2000 + 500(1 - 4)$

$= 2000 - 1500 = 500\,\text{Pa}$

✅ Final Answer:

The pressure at the second point is

Option C: 500 Pa

Question11

The amount of work done in blowing a soap bubble such that its diameter increases from 'd' to ' D ' is ($T =$ surface tension of

solution)

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Options:

A. $\pi\left(D^2-d^2\right)T$

B. $2\pi\left(D^2-d^2\right)T$

C. $4\pi\left(\mathrm{D}^2-\mathrm{d}^2\right)\mathrm{T}$

D. $8\pi\left(D^2-d^2\right)T$

Answer: B

Solution:

Step 1: Concept

The work done to increase the size of bubble goes into increasing **surface energy**.

- Surface energy $E=$ surface area $\times$ surface tension (T).
- For a soap bubble, there are **two surfaces** (inner and outer), hence we need to account for **2 × area**.

So,

$E=2\times(4\pi r^2)\times T=8\pi r^2T$

Step 2: Initial and Final Energies

- Initial radius $r_i=\frac{d}{2}$.
- Final radius $r_f=\frac{D}{2}$.
- Initial energy:

$E_i=8\pi\left(\frac{d}{2}\right)^2T=8\pi\frac{d^2}{4}T=2\pi d^2T$

- Final energy:

$E_f=8\pi\left(\frac{D}{2}\right)^2T=8\pi\frac{D^2}{4}T=2\pi D^2T$

Step 3: Work Done

$W=E_f-E_i=2\pi T(D^2-d^2)$

Final Answer:

$$\boxed{2\pi(D^2 - d^2)T}$$

✅ That corresponds to **Option B**.

Question12

When one end of a capillary tube is dipped in water, the height of water column is ' h '. The upward force of 105 dyne due to surface tension is balanced by the force due to the weight of water column. The inner circumference of the capillary tube is

(Surface tension of water $= 7 \times 10^{-2}$ N/m)

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Options:

A. 1.5 cm

B. 2 cm

C. 2.5 cm

D. 3 cm

Answer: A

Solution:

Step 1: Concept

In capillary rise:

- **Upward force** due to surface tension = Surface tension × inner circumference of tube

$F_{\text{up}} = T \cdot C$

- **Downward force** = Weight of the liquid column

But here it's already given: **Upward force = 105 dynes**.

So,

$F_{\text{up}} = T \cdot C$

Thus,

$C = \frac{F}{T}$

Step 2: Convert units

- Surface tension given: $T = 7 \times 10^{-2}$ N/m.

Convert into dyne/cm:

$1 \text{ N} = 10^5 \text{ dynes}, \quad 1 \text{ m} = 100 \text{ cm}$

So,

$T = 7 \times 10^{-2} \text{ N/m} = \frac{7 \times 10^{-2} \times 10^5 \text{ dynes}}{100 \text{ cm}}$

$T = \frac{7 \times 10^3}{100} \text{ dyne/cm} = 70 \text{ dyne/cm}$

Step 3: Calculate circumference

$C = \frac{F}{T} = \frac{105}{70} = 1.5 \text{ cm}$

✅ **Final Answer:**

The inner circumference of the capillary tube is

Option A: 1.5 cm

Question13

In a capillary tube of area of cross-section 'a' water rises to height ' h '. To what height will water rise in a capillary tube of area of cross-section $4a$?

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Options:

A. 4 h

B. 2 h

C. $\frac{h}{2}$

D. $\frac{h}{4}$

Answer: C

Solution:

If r_1 and r_2 are the radii, then with the given data,

$$a = \pi r_1^2 \text{ and } 4a = \pi r_2^2$$

$$\therefore \quad \frac{r_1^2}{r_2^2} = \frac{a}{4a} = \frac{1}{4}$$

$$\therefore \quad \frac{r_1}{r_2} = \frac{1}{2}$$

$$h \propto \frac{1}{r}$$

$$\therefore \quad \frac{h_2}{h_1} = \frac{r_1}{r_2} = \frac{1}{2}$$

$$\therefore \quad h_2 = \frac{h_1}{2} = \frac{h}{2}$$

Question14

The velocity of small spherical ball of mass ' m ' and density ' d_1 ', when dropped in a container filled with glycerine becomes constant after some time. The viscous force acting on the ball if density of glycerine is ' d_2 ' is

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Options:

A. $mg\left(1-\frac{d_2}{d_1}\right)$

B. $mg\left(1+\frac{d_2}{d_1}\right)$

C. $mg\left(1-\frac{d_1}{d_2}\right)$

D. $mg\left(1+\frac{d_1}{d_2}\right)$

Answer: A

Solution:

As the velocity is constant, the net force acting on the ball is zero. Forces acting on the ball are

$$\begin{aligned} &\text{Weight of the ball } = mg \quad (\text{ downward }) \\ &\text{Upthrust } = \text{weight of glycerine displaced} \\ &\qquad = (\text{ volume of glycerine }) \times (\text{ density of glycerine }) \times g \\ &\qquad = (\text{ volume of ball }) \times (\text{ density of glycerine }) \times g \\ &\qquad = \frac{m}{d_1} \times d_2 \times g = mg\frac{d_2}{d_1} \end{aligned}$$

F = viscous force (upwards)

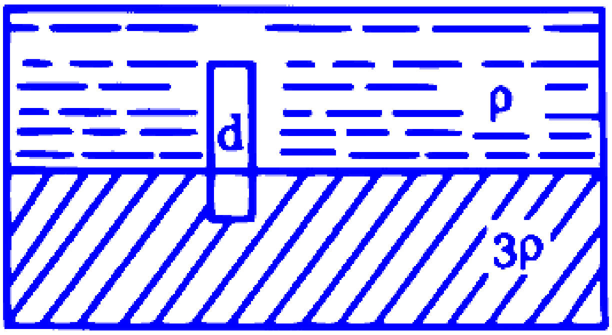
Total upward force = Total downward force

$$\therefore \quad F + mg\frac{d_2}{d_1} = mg$$

$$\therefore \quad F = mg\left(1 - \frac{d_2}{d_1}\right)$$

Question15

A solid cylinder of length l and cross-sectional area $\frac{a}{5}$ is immersed such that it floats with its axis vertical at the liquid-liquid interface with length $l/4$ in the denser liquid as shown in figure. The lower density liquid (ρ) is open to atmosphere having pressure P_0. The density d of solid cylinder is



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Options:

A. $\frac{1}{2}\rho$

B. $\frac{3}{2}\rho$

C. $\frac{3}{4}p$

D. ρ

Answer: B

Solution:

Weight of the cylinder = Upthrust due to liquid 1+ Upthrust due liquid 2

$$
\begin{aligned}
&=\left(\rho_1 g V_1\right)+\left(\rho_2 g V_2\right) \\
&=\left(\rho g L_1 A_1\right)+\left(3 \rho g L_2 A_2\right) \\
&=\rho g \frac{31}{4} A+3 \rho g \frac{1}{4} A=\frac{3}{2} \rho g A l \\
&=\frac{3}{2} \rho
\end{aligned}
$$

Question16

The amount of work done in blowing a soap bubble such that its diameter increases from d_1 to d_2 is ($\mathrm{T}=$ surface tension of soap solution)

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Options:

A. $4 \pi\left(\mathrm{~d}_2^2-\mathrm{d}_1^2\right) \mathrm{T}$

B. $8 \pi\left(\mathrm{~d}_2^2-\mathrm{d}_1^2\right) \mathrm{T}$

C. $\pi\left(d_2^2-d_1^2\right) \mathrm{T}$

D. $2 \pi\left(d_2^2-d_1^2\right) \mathrm{T}$

Answer: D

Solution:

Step 1: Recall the concept

- A soap bubble has **two surfaces** (inner and outer).
- Work is done against surface tension when increasing surface area.
- Work done = Increase in surface energy = $\Delta U = T \times \Delta A$.
- Since there are **two surfaces**,

$\Delta U = 2T \times (\Delta A_{\text{sphere}})$.

Step 2: Surface area of a sphere

For diameter d, radius $r = \frac{d}{2}$.

$A = 4\pi r^2 = 4\pi\left(\frac{d}{2}\right)^2 = \pi d^2$.

Step 3: Increase in total area

$\Delta A = A_2 - A_1 = \pi d_2^2 - \pi d_1^2 = \pi\left(d_2^2 - d_1^2\right)$.

Since there are two surfaces:

$\Delta A_{\text{total}} = 2\pi\left(d_2^2 - d_1^2\right)$.

Step 4: Work done

$W = T \times \Delta A_{\text{total}} = 2\pi\left(d_2^2 - d_1^2\right)T$.

✅ **Final Answer:**

$\boxed{2\pi\left(d_2^2 - d_1^2\right)T}$

That corresponds to **Option D.**

Question17

The energy needed for breaking a liquid drop of radius ' R ' into 216 droplets, each of radius ' r ' is ' x ' times TR^2. The value of ' x ' is [$T =$ surface tension of the liquid].

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Options:

A. 4π

B. 12π

C. 180π

D. 20π

Answer: D

Solution:

Total volume is constant.

$$\therefore \quad \frac{4}{3}\pi R^3 = 216 \times \frac{4}{3}\pi r^3$$
$$\Rightarrow \quad r^3 = \frac{R^3}{216}$$
$$\Rightarrow \quad r = \frac{R}{6}$$

Surface Energy of drop of radius R is

$$E_1 = T\left(4\pi R^2\right)$$

Total Surface energy of 216 drops of radius r is

$$E_2 = 216 \times T\left(4\pi r^2\right)$$
$$E_2 = 216 \times 4\pi T\left(\frac{R}{6}\right)^2$$
$$E_2 = 216 \times 4\pi T \times \frac{R^2}{36}$$
$$E_2 = 24\pi T R^2$$

$\therefore$ Energy needed for breaking the liquid drop is

$$\Delta \mathrm{E} = \mathrm{E}_2 - \mathrm{E}_1 = 24\pi \mathrm{TR}^2 - 4\pi \mathrm{TR}^2 = 20\pi \mathrm{TR}^2$$
$$\therefore \quad x = 20\pi$$

Question18

The excess pressure inside first soap bubble is three times that of a second soap bubble. The ratio of volumes of the first to second bubble

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Options:

A. $1:3$

B. $1:9$

C. $1:27$

D. $27:1$

Answer: C

Solution:

We are dealing with **soap bubbles**, so remember:

$\Delta P = \frac{4T}{r}$

where T is surface tension and r is radius of bubble.

Step 1: Relation of pressures

Let bubble 1 and bubble 2 have radii r_1, r_2.

$\Delta P_1 = \frac{4T}{r_1}, \quad \Delta P_2 = \frac{4T}{r_2}$

Given:

$\Delta P_1 = 3\Delta P_2$

$\frac{4T}{r_1} = 3 \cdot \frac{4T}{r_2}$

$\frac{1}{r_1} = \frac{3}{r_2}$

$r_2 = 3r_1$

Step 2: Volume ratio

$V = \frac{4}{3}\pi r^3$

$\frac{V_1}{V_2} = \frac{r_1^3}{r_2^3} = \frac{r_1^3}{(3r_1)^3} = \frac{1}{27}$

✅ Final Answer:

Ratio of volumes $V_1 : V_2 = 1 : 27$

Correct Option: C ($1:27$ **)**

Question19

A disc of paper of radius ' R ' has a hole of radius ' r '. It is floating on a liquid of surface tension ' T '. The force of surface tension on the disc is

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Options:

A. $2\pi \mathrm{~T}(\mathrm{R}-\mathrm{r})$

B. $2\pi \mathrm{~T}(\mathrm{R}+\mathrm{r})$

C. $3\pi \mathrm{TR}$

D. $4\pi \mathrm{~T}(\mathrm{R}+\mathrm{r})$

Answer: B

Solution:

Force due to surface tension acts along the edge in contact with liquid.

$\therefore$ Force on outer perimeter $= 2\pi \mathrm{~T}(\mathrm{R})$

$\therefore$ Force on inner perimeter $= 2\pi \mathrm{~T}(\mathrm{r})$

$\therefore$ Force on the disk $= 2\pi \mathrm{~T}(\mathrm{R}+\mathrm{r})$

Question20

A wind with speed $50 \mathrm{~m/s}$ blows parallel to the roof of a house. The area of the roof is $300 \mathrm{~m}^2$. Assume that the pressure inside the house is atmospheric pressure. Density of air is $1.2 \mathrm{~kg/m}^3$. The magnitude of the force exerted by the wind on the roof will be

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Options:

A. 1.5×10^5 N

B. 3.0×10^5 N

C. 4.5×10^5 N

D. 9.0×10^5 N

Answer: C

Solution:

Step 1: Concept

This is an application of **Bernoulli's principle**.

Wind flowing above the roof reduces the pressure on the outside relative to the inside (atmospheric pressure). The pressure difference produces a lift-type force on the roof.

Bernoulli:

$P + \frac{1}{2}\rho v^2 = \text{constant}$

Inside, air is still (v ≈ 0), so pressure inside = atmospheric pressure = P_{atm} .

Outside (on top of roof), wind has speed 50, so pressure there is reduced by

$\Delta P = \frac{1}{2}\rho v^2$

Step 2: Compute the pressure difference

$\Delta P = \frac{1}{2}(1.2)(50^2)$

$= 0.6 \times 2500 = 1500 \text{ Pa}$

Step 3: Force on the roof

$F = \Delta P \times A = 1500 \times 300 = 4.5 \times 10^5 \text{ N}$

Final Answer:

The magnitude of the force exerted by the wind is:

Option C: 4.5×10^5 N ✅

Question21

The energy needed for breaking a liquid drop of radius ' R ' into ' n ' droplets each of radius ' r ' is $[\mathrm{T} =$ surface tension of the liquid]

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Options:

A. $4\pi \mathrm{TR}^2\left[\frac{\mathrm{R}}{\mathrm{r}}+1\right]$

B. $4\pi \mathrm{TR}^2\left[\frac{\mathrm{R}}{\mathrm{r}}-1\right]$

C. $4\pi \mathrm{TR}^2\left[\frac{\mathrm{r}}{\mathrm{R}}+1\right]$

D. $4\pi \,\mathrm{Tr}^2\left[\frac{\mathrm{R}}{\mathrm{r}}-1\right]$

Answer: B

Solution:

Step 1: Volume conservation

A single drop of radius R is broken into n drops of radius r.

So volumes must be equal:

$\frac{4}{3}\pi R^3 = n \cdot \frac{4}{3}\pi r^3$

$R^3 = nr^3 \quad \Rightarrow \quad n = \left(\frac{R}{r}\right)^3$

Step 2: Surface energy of a drop

Surface energy = Surface area $\times$ surface tension.

- Initial energy:

$E_i = 4\pi R^2 T$

- Final energy:

$E_f = n \cdot 4\pi r^2 T = 4\pi T\, nr^2$

Step 3: Energy required

$\Delta E = E_f - E_i = 4\pi T(nr^2 - R^2)$

Substituting $n = \frac{R^3}{r^3}$:

$\Delta E = 4\pi T\left(\frac{R^3}{r^3} \cdot r^2 - R^2\right) = 4\pi T\left(\frac{R^3}{r} - R^2\right)$

Factorize:

$\Delta E = 4\pi TR^2\left(\frac{R}{r} - 1\right)$

✅ **Final Answer:**

$$\boxed{4\pi TR^2\left(\frac{R}{r} - 1\right)}$$

Correct Option: B

Question22

The excess pressure inside a soap bubble is 1.5 times the excess pressure inside a second soap bubble. The volume of the second bubble is ' x ' times the volume of the first bubble. The value of ' x ' is

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Options:

A. $\frac{3}{2}$

B. $\frac{9}{4}$

C. $\frac{8}{27}$

D. $\frac{27}{8}$

Answer: D

Solution:

Step 1: Recall the formula for excess pressure inside a soap bubble.

For a soap bubble of radius r:

$\Delta P = \frac{4T}{r}$

where T is the surface tension.

Step 2: Compare the pressures.

Let the first bubble radius = r_1,

the second bubble radius = r_2.

Given:

$\Delta P_1 = 1.5\,\Delta P_2$

So:

$\frac{4T}{r_1} = 1.5 \cdot \frac{4T}{r_2}$

Canceling $4T$:

$\frac{1}{r_1} = \frac{1.5}{r_2}$

$r_2 = 1.5\,r_1$

Step 3: Relating volumes.

Volume of a bubble:

$V = \frac{4}{3}\pi r^3$

So:

$\frac{V_2}{V_1} = \frac{r_2^3}{r_1^3} = (1.5)^3 = \frac{27}{8}$

Thus:

$x = \frac{27}{8}$

Final Answer:

$\boxed{\frac{27}{8}}$ (Option D)

Question23

Water rises in a capillary tube of radius r upto ^{2} height h . The mass of water in a capillary is m. The mass of water that will rise in capillary of radius $\frac{\mathrm{r}}{5}$ will be

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Options:

A. $\frac{\mathrm{m}}{5}$

B. $\frac{\mathrm{m}}{2}$

C. m

D. $\frac{111}{25}$

Answer: A

Solution:

Step 1: Formula for capillary rise

The relation for capillary rise h is

$h = \frac{2T\cos\theta}{\rho g r}$,

where

- T = surface tension,
- θ = angle of contact,
- ρ = liquid density,
- g = gravity,
- r = radius of the tube.

So, height of rise is $\propto \frac{1}{r}$.

Step 2: Volume and mass of liquid in the capillary

The volume of the liquid column is

$V = \pi r^2 h.$

So, the mass inside the capillary is

$m = \rho V = \rho\pi r^2 h.$

Substitute $h = \frac{k}{r}$, where $k = \frac{2T\cos\theta}{\rho g}$:

$m = \rho\pi r^2 \cdot \frac{k}{r} = \rho\pi k r.$

Thus, mass $m \propto r$.

Step 3: Mass when radius changes

If radius is changed from r to $r/5$, then

$m' = \frac{r}{5} \cdot$ (same proportionality const.).

So,

$m' = \frac{m}{5}.$

✅ **Final Answer:**

The mass of water that will rise in the narrower capillary is

$\boxed{\frac{m}{5}}$

Correct option: A.

Question24

A rectangular film of liquid is expanded from $(5 \text{ cm} \times 4 \text{ cm})$ to $(7 \text{ cm} \times 8 \text{ cm})$. If the work done is 3×10^{-4} J, the surface tension of the liquid is (nearly)

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Options:

A. $0.4 \mathrm{~N} / \mathrm{m}$

B. $\quad 0.04 \mathrm{~N} / \mathrm{m}$

C. 0.4 dyne $/ \mathrm{cm}$

D. $4.0 \mathrm{~N} / \mathrm{m}$

Answer: B

Solution:

$W =$ Surface tension $\times$ increase in surface area

But since a film has **two surfaces**,

$W = 2T\Delta A$

Step 2: Initial and final areas

$A_i = 5 \times 4 = 20 \text{ cm}^2$

$A_f = 7 \times 8 = 56 \text{ cm}^2$

So,

$\Delta A = A_f - A_i = 36 \text{ cm}^2$

Convert to m²:

$1 \text{ cm}^2 = 10^{-4} \text{ m}^2$

$\Delta A = 36 \times 10^{-4} = 3.6 \times 10^{-3} \text{ m}^2$

Step 3: Apply formula

$W = 2T\Delta A$

$3 \times 10^{-4} = 2T(3.6 \times 10^{-3})$

$3 \times 10^{-4} = 7.2 \times 10^{-3} T$

$T = \frac{3\times10^{-4}}{7.2\times10^{-3}} \approx 0.0417 \text{ N/m}$

Answer:

$\boxed{0.04 \text{ N/m}}$

Correct option: **B**

Question25

A capillary tube is taken from earth's surface to moon's surface. The rise of liquid column on the moon's surface is (acceleration due to gravity on the earth's surface is six times that of moon's surface)

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Options:

A. zero.

B. six times that on the earth's surface.

C. equal to that on the earth's surface.

D. $\left(\frac{1}{6}\right)^{\text{th}}$ that on the earth's surface.

Answer: B

Solution:

Concept

The formula for capillary rise h is:

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

where

- T: surface tension of the liquid,
- θ: angle of contact,
- ρ: density of liquid,
- g: acceleration due to gravity,
- r: radius of capillary.

So:

$$h \propto \frac{1}{g}.$$

On Earth

Let $h_E = \frac{2T\cos\theta}{\rho g_E r}$.

On Moon

Since $g_E = 6g_M$:

$$h_M = \frac{2T\cos\theta}{\rho g_M r}.$$

$$\frac{h_M}{h_E} = \frac{g_E}{g_M} = \frac{6g_M}{g_M} = 6.$$

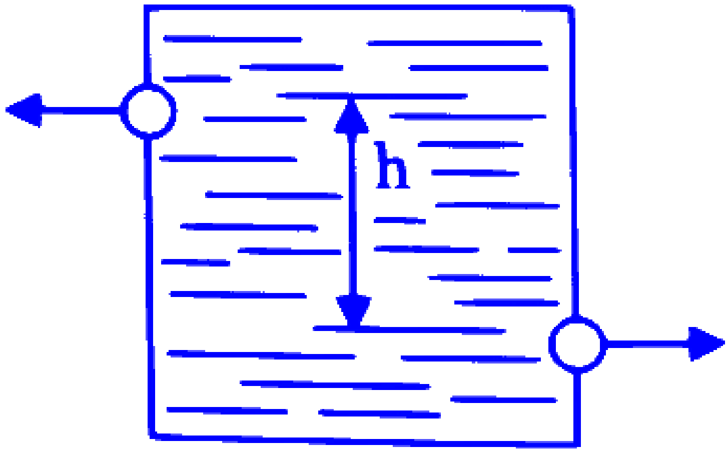
Final Answer

On the Moon, the liquid column will rise **six times higher** than on Earth.

Correct Option: B) six times that on the earth's surface. ✅

Question26

There are two identical small holes on the opposite side of a tank containing full of a liquid. The tank is open at the top. The difference in height between the two holes is ' h '. As the liquid comes out of the two holes, the tank will experience a net horizontal force proportional to



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Options:

A. $h^{3/2}$

B. h^2

C. $\sqrt{h}$

D. h

Answer: D

Solution:

There are two identical small holes on the opposite sides of a tank, hence velocities of liquid flowing out of both the holes are

$v_1 = \sqrt{2 g(h + x)}$ and $v_2 = \sqrt{2gx}$

Now, we know:

Volume of the liquid discharged per second at a hole: $V = Av$.

Thus, mass of the liquid discharged per second:

$M = \rho V = \rho A v$

$\therefore$ Momentum of the liquid discharged per second

$p = \rho A v^2$

Now, Net force on the tank = Change in momentum

$$
\begin{aligned}
F &= A\rho v_1^2 - A\rho v_2^2 = A\rho\left(v_1^2 - v_2^2\right) \\
&= A\rho[2g(h+x) - 2gx] \\
&= 2A\rho gh
\end{aligned}
$$

$\Rightarrow \quad F \propto h$

Question27

In air, a charged soap bubble of radius R breaks into 64 small soap bubbles of equal radius r. The ratio of mechanical force per unit area of big soap bubble to that of a small bubble is

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Options:

A. 1 : 4

B. 4 : 1

C. 2 : 1

D. 1 : 2

Answer: A

Solution:

The question is about a charged soap bubble with radius R that breaks into 64 smaller soap bubbles, each with radius r.

Electrostatic Pressure:

Because the bubble is charged, there is a force called electrostatic pressure, which is given by $\frac{\sigma^2}{2\varepsilon_0}$. When the bubble is stable, the extra pressure inside it matches this electrostatic pressure.

Total Volume is Constant:

When the big bubble breaks into 64 small ones, the total amount of soap (volume) stays the same.

$\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$

This means:$R^3 = 64r^3 \text{so} r = \frac{R}{4}$

Mechanical Pressure in Bubbles:

The extra pressure inside a soap bubble is given by $\frac{4T}{R}$ for the big bubble and $\frac{4T}{r}$ for a small bubble, where T is the surface tension.

So,$P_B = \frac{4T}{R}$for the big bubble, and$P_s = \frac{4T}{r}$for the small bubble.

Ratio of Mechanical Pressures:

Now, to find the ratio of the mechanical pressure of the big bubble to that of a small bubble:
$\frac{P_B}{P_s} = \frac{4T/R}{4T/r} = \frac{r}{R}$

We already found that $r = \frac{R}{4}$, so: $\frac{P_B}{P_s} = \frac{R/4}{R} = \frac{1}{4}$

Question28

Two capillary tubes of same diameter are kept vertically in two liquids whose densities are in the ratio $4 : 3$. If their surface tensions are in the ratio $6 : 5$, the ratio of heights $\left(\frac{h_1}{h_2}\right)$ of liquids in the two capillary tubes is (Their angle of contacts are same)

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Options:

A. $\frac{10}{7}$

B. $\frac{9}{10}$

C. $\frac{10}{9}$

D. $\frac{1}{2}$

Answer: B

Solution:

We are solving:

$\frac{h_1}{h_2} = ?$

Step 1: Formula for capillary rise

The height of liquid rise in a capillary tube is given by

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

where

- T = surface tension
- θ = angle of contact
- ρ = density of liquid
- r = radius of the tube

Since both tubes have the same radius and same angle of contact, and g is constant,

$h \propto \frac{T}{\rho}$

Step 2: Ratio of heights

$\frac{h_1}{h_2} = \frac{\frac{T_1}{\rho_1}}{\frac{T_2}{\rho_2}} = \frac{T_1}{T_2} \cdot \frac{\rho_2}{\rho_1}$

Step 3: Substitute given ratios

- Densities ratio: $\rho_1 : \rho_2 = 4 : 3$
- Surface tensions ratio: $T_1 : T_2 = 6 : 5$

So,

$\frac{h_1}{h_2} = \frac{6}{5} \cdot \frac{3}{4} = \frac{18}{20} = \frac{9}{10}$

✅ **Final Answer:**

$\frac{h_1}{h_2} = \frac{9}{10}$

Correct Option: B

Question29

Water flows through a horizontal pipe of varying cross-section at the rate of $\pi \times 10^{-1}$ m/s. The velocity of water at a point where the radius of the pipe is 10 cm is $(\pi = 3.14)$

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Options:

A. 0.1 m/s

B. 1 m/s

C. 10 m/s

D. 100 m/s

Answer: C

Solution:

We need to carefully interpret the question:

Question restated:

Water flows through a horizontal pipe of varying cross-section at the rate of

$Q = \pi \times 10^{-1}\,\text{m}^3/\text{s}$.

The velocity of water at a point where the **radius** of the pipe is 10 cm ($r = 0.1\,\text{m}$) is asked.

$\pi = 3.14$.

Step 1: Recall continuity equation

$Q = A \cdot v$

where

- Q = volume flow rate = $\pi \times 10^{-1}\,\text{m}^3/\text{s}$,
- $A = \pi r^2$ = cross-sectional area,
- v = velocity.

Step 2: Compute area at given radius

$r = 0.1\,\text{m}, \quad A = \pi(0.1)^2 = \pi \cdot 0.01 = 0.01\pi\,\text{m}^2.$

Step 3: Solve for velocity

$v = \frac{Q}{A} = \frac{0.1\pi}{0.01\pi} = \frac{0.1}{0.01} = 10\,\text{m/s}.$

✅ Final Answer:

$\boxed{10\,\text{m/s}}$ (Option C)

Question30

A liquid drop of volume V is placed on the surface of glass plate. Then another glass plate is placed on it such that liquid forms a thin layer of area A between the surfaces of two plates. To separate the plates a force F has to be applied normal to the surfaces. The surface tension of the liquid is

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Options:

A. $\frac{\mathrm{FV}}{2\ \mathrm{A}}$

B. $\frac{\mathrm{FV}}{2\ \mathrm{A}^2}$

C. $\frac{\mathrm{FV}}{\mathrm{A}^2}$

D. $\frac{F}{VA}$

Answer: B

Solution:

Let the thickness of the liquid layer between the plates be d.

The volume of the liquid is:

$V = A \times d \implies d = \frac{V}{A}$

When you separate the plates, you **create two new surfaces** (one on each plate). The **increase in surface area** is $2A$.

Work done (W) to separate the plates by a small distance dx against a force F:

$W = F \cdot dx$

This work is used to increase the surface energy, which is:

Increase in surface energy $=$ surface tension $\times$ increase in area $= T \times (2A)$

For complete separation, $dx = d$, i.e., plates are moved apart by the thickness of the layer.

Total work done (force $\times$ distance):

$W = F \cdot d$

Equate this to the increase in surface energy:

$F \cdot d = T \cdot 2AT = \frac{F \cdot d}{2A}$

Substitute $d = \frac{V}{A}$:

$T = \frac{F \cdot \frac{V}{A}}{2A} = \frac{FV}{2A^2}$

The **correct answer is:**

$$\boxed{\frac{FV}{2A^2}}$$

Option B is correct.

Question31

An incompressible fluid flows steadily through a cylindrical pipe having radius R at point A and $\left(\frac{\mathrm{R}}{3}\right)$ at point B further along the direction of flow of liquid. If the velocity at point A is ' V ' then that at point B is

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Options:

A. $\frac{\mathrm{V}}{9}$

B. $\frac{\mathrm{V}}{3}$

C. 3 V

D. 9 V

Answer: D

Solution:

According to the law of conservation of mass (continuity equation) for incompressible fluids,

$A_1 v_1 = A_2 v_2$

where

- A_1 is the area at point A,
- v_1 is the velocity at point A,

- A_2 is the area at point B,
- v_2 is the velocity at point B.

Given:

- At point A: radius $= R$, velocity $= V$
- At point B: radius $= \frac{R}{3}$, velocity $= v_2$

Calculate the cross-sectional areas:

- At A: $A_1 = \pi R^2$
- At B: $A_2 = \pi\left(\frac{R}{3}\right)^2 = \pi\frac{R^2}{9}$

Applying the continuity equation:

$\pi R^2 \times V = \pi\frac{R^2}{9} \times v_2$

Dividing both sides by π:

$R^2 V = \frac{R^2}{9} v_2$

Divide both sides by R^2:

$V = \frac{1}{9} v_2$

Now, multiply both sides by 9:

$v_2 = 9V$

So, the velocity at point B is $9V$.

Correct option:

$\boxed{9V}$ (Option D)

Question32

Two raindrops reach the earth with different terminal velocities having the ratio $9 : 4$. The ratio of their volumes is

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Options:

A. $\frac{8}{27}$

B. $\frac{9}{4}$

C. $\frac{3}{2}$

D. $\frac{27}{8}$

Answer: D

Solution:

The terminal velocity is given by,

$$V_T = \frac{2}{9}\frac{(\rho-\sigma)r^2 g}{\eta}$$

$$\therefore \frac{v_{T_1}}{v_{T_2}} = \frac{r_1^2}{r_2^2} \qquad \Rightarrow \frac{r_1^2}{r_2^2} = \frac{9}{4}$$

$$\therefore \frac{r_1}{r_2} = \frac{3}{2}$$

Now, Volume of the drop will be:

$V = \frac{4}{3}\pi r^3$

$\therefore$ Ratio of Volumes:

$\frac{V_1}{V_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{3}{2}\right)^3 = \frac{27}{8} = 27:8$

Question33

The temperature of an air bubble while rising from bottom to surface of a lake remains constant but diameter is doubled. If pressure on the surface is h meter of mercury column and relative density of mercury is ' ρ ' then the depth of the lake is

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Options:

A. 5 hρ

B. 7 hρ

C. $\frac{3h}{\rho}$

D. $\frac{4h}{\rho}$

Answer: B

Solution:

When the diameter doubles, the volume increases by $2^3 = 8$ times

Using Boyle's law

$$P_1 V_1 = P_2 V_2$$
$$V_2 = 8V_1 \Rightarrow P_{\text{bottom}} = 8P_{\text{atm}}$$

Pressure in terms of mercury column

$$\mathrm{P}_{\text{atm}} = \rho_{\mathrm{Hg}} \mathrm{gh}$$

$$\therefore \quad P_{\text{bottom}} = P_{\text{atm}} + \rho_{\text{water}} gd$$
$$8\rho \cdot \rho_{\text{water}} gh = \rho \cdot \rho_{\text{water}} gh + \rho_{\text{water}} gd \quad (\because \rho_{Hg} = \rho \cdot \rho_{\text{water}})$$
$$8\rho h = \rho h + d$$
$$d = 7h\rho$$

Question34

A liquid drop having surface energy E is sprayed into 512 droplets of same size. The final surface energy is

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Options:

A. 12 E

B. 4 E

C. 8 E

D. 6 E

Answer: C

Solution:

Surface area of drop, $A_1 = 4\pi R^2$

Surface area of 512 droplets, $A_2 = 512\left(4\pi r^2\right)$

volume of drop $=$ n$\times$ (volume of droplet)

$\therefore \quad \frac{4}{3}\pi R^3 = 512 \times \frac{4}{3}\pi r^3$
$\therefore \quad R = 8r$

$\therefore \quad A_2 = \frac{512\left(4\pi R^2\right)}{64}$
$\therefore \quad A_2 = 8\left(4\pi R^2\right)$
Surface energy $\propto$ Area
$\therefore \quad \frac{E_2}{E_1} = \frac{A_2}{A_1} = \frac{8\left(4\pi R^2\right)}{4\pi R^2}$
$\therefore \quad E_2 = 8E_1 = 8E \quad \ldots.(\because E_1 = E)$

Question35

Pure water rises through a height h in a capillary tube of internal radius r . Surface tension of water is T . The pressure difference between the water level in the container and the lowest point of the concave meniscus is

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Options:

A. $\frac{\mathrm{r}}{\mathrm{T}}$

B. $\frac{\mathrm{T}}{\mathrm{r}}$

C. $\frac{2T}{r}$

D. $\frac{\mathrm{r}}{2\mathrm{~T}}$

Answer: C

Solution:

When water rises in a capillary tube, the pressure difference across the curved meniscus is due to the surface tension. This is given by the **Laplace's formula**:

$\Delta P = \frac{2T}{r}$

where,

- T = surface tension,
- r = radius of the tube.

Therefore, the correct answer is:

$$\boxed{\frac{2T}{r}}$$

Option C is correct.

Question36

The surface energy of a liquid drop is ' V '. It is sprayed into 1000 equal droplets. The surface energy of all the droplets is

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Options:

A. V

B. 10 V

C. 100 V

D. 1000 V

Answer: B

Solution:

Let R be radius of bigger drop and r be radius of smaller droplet.

As mass of liquid is conserved before and after spreading of drop,

$$\therefore \quad \text{mass of big drop} = n\times \text{ mass of droplet}$$

$$\rho \times \frac{4}{3}\pi R^3 = \rho \times \frac{4}{3}\pi r^3 \times 1000$$

$$\therefore \quad R^3 = 1000 r^3$$

$$\therefore \quad R = 10r$$

Surface energy of bigger drop $= \mathrm{V} = \mathrm{AT}$

$= \left(4 \pi R^2\right) \mathrm{T}$

Total surface energy of small droplets

$$\begin{aligned} V' &= nA'T = 1000 \times 4\pi r^2 \times T \\ &= 1000 \times 4\pi \times \left(\frac{R}{10}\right)^2 \times T = \frac{1000}{100} \times 4\pi R^2 T \end{aligned}$$

$$\therefore \quad V' = 10 \times V$$

Question37

A liquid drop having surface energy E is spread into 729 droplets of same size. The final surface energy of the droplets is

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Options:

A. 6 E

B. 9 E

C. E

D. 3 E

Answer: B

Solution:

Given:

- Initial surface energy of the single drop = E
- The drop is divided into 729 small droplets of **same size**.

Let's proceed step by step.

Step 1: Relation Between Surface Energy and Radius

Surface energy is given by:

$E = S \cdot T$

where S = surface area, T = surface tension (assumed constant).

For a sphere of radius r:

Surface area, $S = 4\pi r^2$

So, initial energy:

$E_{\text{initial}} \quad = 4\pi R^2 T$

where R is the radius of the big drop.

Step 2: Volume Conservation

When 1 big drop is converted into 729 small droplets,

- Volume before = Volume after

Big drop: Volume = $\frac{4}{3}\pi R^3$

Small drop (each): Volume = $\frac{4}{3}\pi r^3$

Total 729 small drops: Volume = $729 \times \frac{4}{3}\pi r^3$

Equate:

$$\frac{4}{3}\pi R^3 = 729 \times \frac{4}{3}\pi r^3$$

$$R^3 = 729 r^3$$

$$R = 9r$$

Step 3: Surface Energy After

Each small drop: Surface area = $4\pi r^2$

Total small drops' area = $729 \times 4\pi r^2 = 4\pi \times 729 r^2$

So, final energy:

$E_{\text{final}} \quad = \text{total area} \times T = 4\pi \times 729 r^2 \times T$

Step 4: Express r in terms of R

Previously found $R = 9r \implies r = \frac{R}{9}$

So,

$$E_{\text{final}} \quad = 4\pi \times 729 \left(\frac{R}{9}\right)^2 T$$

$$= 4\pi \times 729 \times \frac{R^2}{81} \times T$$

$$= 4\pi \times 9 \times R^2 \times T$$

$= 9 \times 4\pi R^2 T$

$= 9E$

Final Answer

Option **B**

$\boxed{9E}$

Question38

A water drop of $0.01\ \text{cm}^3$ is squeezed between two glass plates and spreads in to area of $10\ \text{cm}^2$. If surface tension of water is 70 dyne $/\text{cm}$ then the normal force required to separate glass plates from each other will be

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Options:

A. 12 N

B. 14 N

C. 16 N

D. 28 N

Answer: B

Solution:

Given:

- Volume of water drop, $V = 0.01\ \text{cm}^3$
- Area of spread between the plates, $A = 10\ \text{cm}^2$
- Surface tension of water, $T = 70\ \text{dyne/cm}$

Step 1: Calculate the thickness of the water layer.

Thickness, $d = \dfrac{\text{volume}}{\text{area}} = \dfrac{V}{A}$

So,

$d = \frac{0.01}{10} = 0.001$ cm

Step 2: Normal force required to separate plates

When pulling the plates apart, the force required is given by:

$F = \frac{2TA}{d}$

- The numerator is $2TA$ because when the plates are pulled apart, two surfaces are created (top and bottom).
- The denominator d represents the separation (thickness of the water film).

Step 3: Plug in the values

$F = \frac{2 \times 70 \times 10}{0.001}$

First, compute the numerator:

$2 \times 70 \times 10 = 1400$

So,

$F = \frac{1400}{0.001} = 1,400,000$ dyne

Step 4: Convert dyne to Newton

$1 \text{ N} = 10^5$ dyne

So,

$F = \frac{1{,}400{,}000}{100{,}000} = 14 \text{ N}$

Step 5: Match with the correct option

The correct answer is:

$\boxed{14 \text{ N}}$

Mark: Option B

Question39

' n ' small water drops of same size (radius r) fall through air with constant velocity V. They coalesce to form a big drop of radius R . The terminal velocity of the big drop is

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Options:

A. $\frac{\mathrm{VR}^2}{\mathrm{r}^2}$

B. $\frac{\mathrm{Vr}^2}{\mathrm{R}^2}$

C. $\frac{VR}{r}$

D. $\frac{\mathrm{Vr}}{\mathrm{R}}$

Answer: A

Solution:

Let us solve the problem step by step:

Step 1: Terminal velocity of a water drop

The terminal velocity (V_t) of a sphere of radius r, falling through a fluid with viscosity η, according to Stokes' Law, is:

$$V = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

where

ρ = density of the sphere (water drop)

σ = density of air

g = acceleration due to gravity

Step 2: Relation between radius of small and big drop

When n small drops of radius r combine to form one large drop of radius R, the total volume is conserved:

$$n \cdot \left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3$$

$$nr^3 = R^3$$

$$R = n^{1/3}r$$

Step 3: Terminal velocity of the big drop

Let the terminal velocity of the big drop be V'. By Stokes' Law:

$$V' = \frac{2}{9}\frac{R^2(\rho-\sigma)g}{\eta}$$

Substitute $R = n^{1/3}r$:

$$V' = \frac{2}{9}\frac{(n^{1/3}r)^2(\rho-\sigma)g}{\eta} = \frac{2}{9}\frac{n^{2/3}r^2(\rho-\sigma)g}{\eta}$$

Step 4: Find the ratio of V' and V

Terminal velocity of a single small drop:

$V = \frac{2}{9} \frac{r^2(\rho - \sigma)g}{\eta}$

Therefore,

$\frac{V'}{V} = \frac{n^{2/3} r^2}{r^2} = n^{2/3}$

But we are to answer in terms of V, r, and R only.

Recall $R^3 = nr^3$, so $n = \frac{R^3}{r^3}$

So,

$V' = n^{2/3} V = \left(\frac{R^3}{r^3}\right)^{2/3} V = \left(\frac{R}{r}\right)^2 V$

So,

$V' = V \frac{R^2}{r^2}$

Step 5: Choose the correct option

The answer is:

Option A: $\boxed{\frac{VR^2}{r^2}}$

Question40

A small metal sphere of density ρ is dropped from height h into a jar containing liquid of density $\sigma(\sigma > \rho)$. The maximum depth up to which the sphere sinks is (Neglect damping forces)

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Options:

A. $\frac{\rho}{\rho - \sigma}$

B. $\frac{h\sigma}{(\rho - \sigma)}$

C. $\frac{\sigma}{(\rho - \sigma)}$

D. $\frac{h\rho}{(\rho-\sigma)}$

Answer: D

Solution:

Given:

- Density of sphere = ρ
- Density of liquid = σ (where $\sigma > \rho$)
- Height dropped = h
- We are to neglect damping forces (ignore viscosity and friction)
- We have to find the **maximum depth the sphere sinks** after falling from height h into the liquid.

Let us proceed step by step:

Step 1: Find the velocity of the sphere just before entering the liquid

When the sphere falls from height h under gravity:

- Initial velocity, $u = 0$
- Acceleration, $a = g$
- Distance, $s = h$

Using the equation of motion:

$v^2 = u^2 + 2as$

So,

$v^2 = 0 + 2gh \implies v = \sqrt{2gh}$

Step 2: Forces acting on the sphere inside the liquid

- **Weight of sphere (downward):** $W = mg = V\rho g$
- **Buoyant force (upward):** $B = V\sigma g$

Net force acting on the sphere **upward** inside the liquid:

$F_{\text{net}} = B - W = V\sigma g - V\rho g = Vg(\sigma - \rho)$

(Since $\sigma > \rho$, the net force is upward.)

Step 3: Acceleration of the sphere inside the liquid

By Newton's second law:

$ma = Vg(\sigma - \rho)$

But $m = V\rho$, so:

$V\rho a = Vg(\sigma - \rho)$

$a = \frac{g(\sigma-\rho)}{\rho}$

This acceleration is **upward**.

Step 4: Maximum depth calculation

Inside the liquid, the sphere enters with velocity $v = \sqrt{2gh}$ (downward).

It will go down, but since the net force is upward, it will slow down, stop momentarily, and then start rising.

Let the sphere sink to depth x before coming to rest.

We use the kinematic equation (taking **downward as positive**):

Final velocity, $v_f = 0$ (momentarily stops)

Initial velocity, $v_0 = \sqrt{2gh}$ (downward)

Acceleration, $a = -\dfrac{g(\sigma - \rho)}{\rho}$ (upward, so take as negative compared to downward direction)

Distance travelled in liquid = x

Use:

$v_f^2 = v_0^2 + 2ax$

So,

$0 = (2gh) + 2\left(-\frac{g(\sigma-\rho)}{\rho}\right)x$

Simplify:

$0 = 2gh - 2g\frac{(\sigma-\rho)}{\rho}x$

$2g\frac{(\sigma-\rho)}{\rho}x = 2gh$

$x = \frac{2gh \cdot \frac{\rho}{2g(\sigma-\rho)}}{1}$

$x = \frac{h\rho}{\sigma-\rho}$

Step 5: Final Answer

The **maximum depth** up to which the sphere sinks is:

$$\boxed{\frac{h\rho}{\sigma - \rho}}$$

Correct option: Option D

Question41

Water is flowing steadily in a river. A and B are the two layers of water at heights 40 cm and 90 cm from the bottom. The velocity of the layer A is $12 \mathrm{~cm} / \mathrm{s}$. The velocity of the layer B is

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Options:

A. $15 \mathrm{~cm} / \mathrm{s}$

B. $21 \mathrm{~cm} / \mathrm{s}$

C. $27 \mathrm{~cm} / \mathrm{s}$

D. $36 \mathrm{~cm} / \mathrm{s}$

Answer: C

Solution:

First, according to **Poiseuille's law** for flow between two horizontal layers, the **velocity of liquid increases linearly with the height** from the stationary surface (assuming laminar flow):

Let,

- y = height from the stationary bottom
- v = velocity of water at height y

For flow between layers, velocity at height y is proportional to y:

$v \propto y$

Let v_A and v_B be the velocities at heights y_A and y_B respectively.

Given:

- $y_A=40$ cm, $v_A=12$ cm/s
- $y_B=90$ cm, $v_B=?$

Using the proportionality,

$\frac{v_A}{v_B}=\frac{y_A}{y_B}$

Substitute the values:

$\frac{12}{v_B} = \frac{40}{90}$

Cross-multiply:

$12 \times 90 = v_B \times 40$

$v_B = \frac{12 \times 90}{40}$

$v_B = \frac{1080}{40}$

$v_B = 27 \text{ cm/s}$

Correct Option:

Option C

$27 \mathrm{~cm/s}$

Question42

A liquid rises to a height of 2.4 cm in a glass capillary P. Another glass capillary Q having diameter 80% of capillary P is immersed in the same liquid. The rise of liquid in capillary Q is

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Options:

A. 2.4 cm

B. 3.4 cm

C. 3 cm

D. 2.5 cm

Answer: C

Solution:

Let the rise of liquid in capillary Q be h_Q.

Let:

- Height in capillary $P = h_P = 2.4 \text{ cm}$
- Diameter of capillary $P = d_P$
- Diameter of capillary $Q = d_Q = 0.8 d_P$

Step 1: Formula for capillary rise

The capillary rise h is given by:

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

where

- T = surface tension,
- θ = angle of contact,
- ρ = density of liquid,
- g = acceleration due to gravity,
- r = radius of the capillary.

Step 2: Relation between height and radius

Since $h \propto \frac{1}{r}$, if the radius decreases, the height increases.

Diameter of Q is 80% of P:

- $d_Q = 0.8 d_P$
- $r_Q = 0.8 r_P$

So,

$h_Q = \frac{h_P r_P}{r_Q}$

But since $r_Q = 0.8 r_P$,

$h_Q = \frac{h_P r_P}{0.8 r_P} = \frac{h_P}{0.8}$

Step 3: Substitute the values

Given $h_P = 2.4$ cm,

$h_Q = \frac{2.4}{0.8} = 3$ cm

Final Answer:

Option C

3 cm

Question43

One end of a capillary tube is dipped in water, the rise of water column is ' h '. The upward force of 98 dyne due to surface tension is balanced by the force due to the weight of the water column. The

inner circumference of the capillary is (surface tension of water $= 7 \times 10^{-2} \mathrm{Nm}^{-1}$)

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Options:

A. 1.4 cm

B. 0.7 cm

C. 0.14 cm

D. 0.07 cm

Answer: A

Solution:

1. **Identify Given Quantities and Units:**
   - Upward force due to surface tension (F_T) = 98 dyne
   - Surface tension of water (σ) = $7 \times 10^{-2} \mathrm{Nm}^{-1}$
   - We need to find the inner circumference (L) of the capillary.

2. **Ensure Consistent Units:**

   The force is given in dyne (CGS unit), and surface tension is in Nm^{-1} (SI unit). It's best to convert the surface tension to CGS units (dyne/cm) for consistency.

   - We know that $1\mathrm{N} = 10^5 \mathrm{dyne}$ and $1\mathrm{m} = 100\mathrm{cm}$.
   - So, $\sigma = 7 \times 10^{-2} \mathrm{Nm}^{-1} = 7 \times 10^{-2} \times \frac{10^5 \mathrm{dyne}}{100 \mathrm{cm}}$
   - $\sigma = 7 \times 10^{-2} \times 10^3 \mathrm{dyne/cm}$
   - $\sigma = 7 \times 10^1 \mathrm{dyne/cm}$
   - $\sigma = 70 \mathrm{dyne/cm}$

3. **Recall the Formula for Upward Force due to Surface Tension:**

   The upward force due to surface tension (F_T) acting along the inner circumference (L) of the capillary tube is given by:

   $F_T = \sigma \times L \times \cos \theta$

   where θ is the angle of contact between the water and the glass.

4. **Consider the Angle of Contact:**

For pure water in a clean glass capillary tube, the angle of contact (θ) is approximately 0°.

Therefore, $\cos\theta = \cos(0^{\circ}) = 1$.

5. **Simplify the Formula:**

   Substituting $\cos\theta = 1$ into the force equation:

   $F_T = \sigma \times L$

6. **Solve for the Inner Circumference (L):**

   We need to find L, so rearrange the formula:

   $L = \frac{F_T}{\sigma}$

7. **Substitute Values and Calculate:**

   Now, substitute the given force and the calculated surface tension:

   $L = \frac{98\text{dyne}}{70\text{dyne/cm}}$

   $L = \frac{98}{70}\text{cm}$

   $L = \frac{14\times7}{10\times7}\text{cm}$

   $L = \frac{14}{10}\text{cm}$

   $L = 1.4\text{cm}$

Therefore, the inner circumference of the capillary is 1.4cm.

The final answer is $\boxed{1.4 \text{ cm}}$.

Question44

When a big drop of water is formed from ' n ' small drops of water, the energy loss is ' 3 E ' where ' E ' is the energy of the bigger drop. The radius of the bigger drop is ' R ' and that of smaller drop is ' r ' then the value of ' n ' is

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Options:

A. $\frac{2R^2}{r}$

B. $\frac{4R^2}{r^2}$

C. $\frac{4R}{r}$

D. $\frac{4R}{r^2}$

Answer: B

Solution:

Step 1: Volume Conservation

When n small drops (radius r) combine to form one big drop (radius R):

Volume before = Volume after

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

Cancelling $\frac{4}{3}\pi$ from both sides:

$nr^3 = R^3$

So,

$n = \left(\frac{R}{r}\right)^3 \quad (1)$

Step 2: Surface Energy Calculation

Surface energy $E =$ Surface Tension $(\gamma) \times$ Surface Area

Surface area of a sphere $= 4\pi r^2$

So energy for one small drop:

$E_1 = \gamma \times 4\pi r^2$

Total surface energy for **all** n drops:

$E_i = n \cdot E_1 = n \cdot \gamma \cdot 4\pi r^2$

Energy of big drop:

$E_f = \gamma \cdot 4\pi R^2$

Step 3: Energy Loss

Energy loss $= E_i - E_f$

Given: Energy loss $= 3E_f$

$E_i - E_f = 3E_f$

$E_i = 4E_f$

Step 4: Substitute Values

From above:

$n \cdot \gamma \cdot 4\pi r^2 = 4 \cdot (\gamma \cdot 4\pi R^2)$

We can cancel $\gamma \cdot 4\pi$ from both sides:

$nr^2 = 4R^2$

$n = \frac{4R^2}{r^2}$

Answer:

Option B:

$n = \frac{4R^2}{r^2}$

Question45

On the surface of the liquid in equilibrium, molecules of the liquid possess

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Options:

A. maximum potential energy.

B. minimum potential energy.

C. maximum kinetic energy.

D. minimum kinetic energy.

Answer: A

Solution:

On the surface of a liquid in equilibrium, molecules of the liquid possess **maximum potential energy**.

When considering the surface of a liquid, the molecules at this boundary are subjected to different forces compared to those within the bulk of the liquid. Surface molecules are exposed to both the cohesive forces from within the liquid and are also influenced by the surrounding environment (such as air).

As a result, these surface molecules are less surrounded by other molecules and thus experience an increase in potential energy. This is due to the higher tendency for these molecules to interact with external influences, as opposed to the internal cohesive forces alone. Thus, the surface tension of the liquid can be associated with this concept, where the surface attempts to minimize its potential energy by reducing its area.

Therefore, the correct choice is:

Option A : Maximum potential energy.

Question46

A water drop is divided into 8 equal droplets. The pressure difference between the inner and outer side of the big drop will be

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Options:

A. same as the smaller droplet.

B. half of that for smaller droplet

C. $\left(\frac{1}{4}\right)^{\text{th}}$ of that for smaller droplet.

D. twice that for smaller droplet

Answer: B

Solution:

When a water drop is divided into 8 equal smaller droplets, each of those droplets collectively has the same volume as the original larger drop.

Calculating the Relationship Between Radii:

Since the total volume of the 8 smaller droplets is equal to the volume of the larger drop, we have:

$8 \times \frac{4}{3} \pi r^3 = \frac{4}{3} \pi R^3$

Simplifying this equation, we find:

$8 r^3 = R^3$

Taking the cube root of both sides gives:

$2 r = R \quad \text{or} \quad r = \frac{R}{2}$

Pressure Difference Explanation:

For a liquid drop, the excess pressure across its surface (from inside compared to outside) is given by the formula:

$\Delta P = \frac{2T}{r}$

Where:

T is the surface tension,

r is the radius of the droplet.

For the 8 smaller droplets, the excess pressure is (ΔP_S):

$\Delta P_S = \frac{2T}{r} = \frac{2T}{\left(\frac{R}{2}\right)} = \frac{4T}{R}$

For the larger initial droplet (ΔP_B):

$\Delta P_B = \frac{2T}{R}$

Comparing Excess Pressures:

The ratio of the excess pressure in the larger drop to that in the smaller droplets is:

$\frac{\Delta P_B}{\Delta P_S} = \frac{\frac{2T}{R}}{\frac{4T}{R}} = \frac{1}{2}$

Thus, the excess pressure difference (ΔP_B) for the larger drop is half of that for the smaller droplet (ΔP_S):

$\Delta P_B = \frac{\Delta P_S}{2}$

Question47

A liquid drop having surface energy ' E ' is spread into 512 droplets of same size. The final surface energy of the droplets is

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Options:

A. 2 E

B. 4 E

C. 8 E

D. 12 E

Answer: C

Solution:

To determine the final surface energy of 512 droplets, initially, we consider a single liquid drop with surface energy E.

Surface Area of Initial Drop:

$A_1 = 4\pi R^2$

Surface Area of 512 Droplets:

$A_2 = 512 \times (4\pi r^2)$

Volume Equivalence:

The volume of the initial drop is equal to the combined volume of the 512 smaller droplets.

$\frac{4}{3}\pi R^3 = 512 \times \frac{4}{3}\pi r^3$

Calculating the Radius:

$R = 8r$

Surface Area of 512 Droplets:

Using the relation from the radii:

$A_2 = \frac{512 \times (4\pi R^2)}{64}$

$A_2 = 8 \times (4\pi R^2)$

Surface Energy Relation:

Since surface energy is proportional to surface area:

$\frac{E_2}{E_1} = \frac{A_2}{A_1} = \frac{8 \times (4\pi R^2)}{4\pi R^2}$

$\therefore E_2 = 8 \times E_1 = 8E \quad (\text{as } E_1 = E)$

Thus, the final surface energy of the 512 droplets is $8E$.

Question48

In most liquids, with rise in temperature, surface tension of a liquid

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Options:

A. first decreases and then increases.

B. increases.

C. decreases.

D. remains unchanged.

Answer: C

Solution:

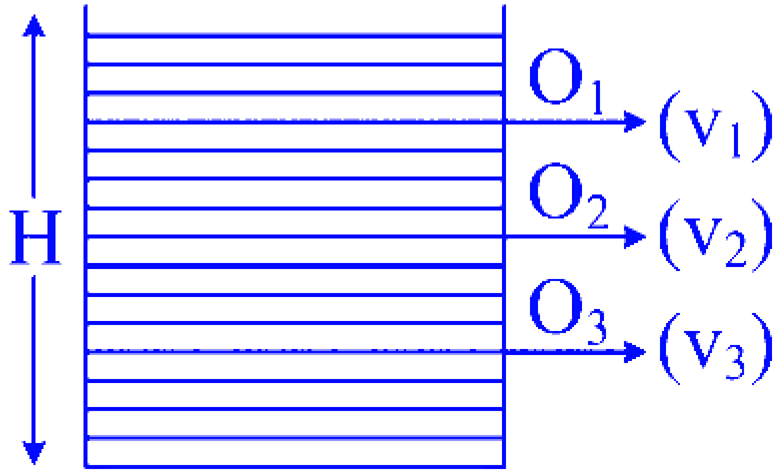
The surface tension of a liquid generally **decreases** with an increase in temperature.

As the temperature rises, the kinetic energy of the molecules also increases. This increased molecular motion results in a reduction in the cohesive forces between the molecules at the surface of the liquid. Consequently, the surface tension, which is a measure of these cohesive forces, decreases.

Option C: decreases.

Question49

A cylinder contains water upto a height ' H '. It has three orifices $\mathrm{O}_1, \mathrm{O}_2, \mathrm{O}_3$ as shown in the figure. Let V_1, V_2, V_3 be the speed of efflux of water from the three orifices. Then



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Options:

A. $V_1=V_2=V_3$

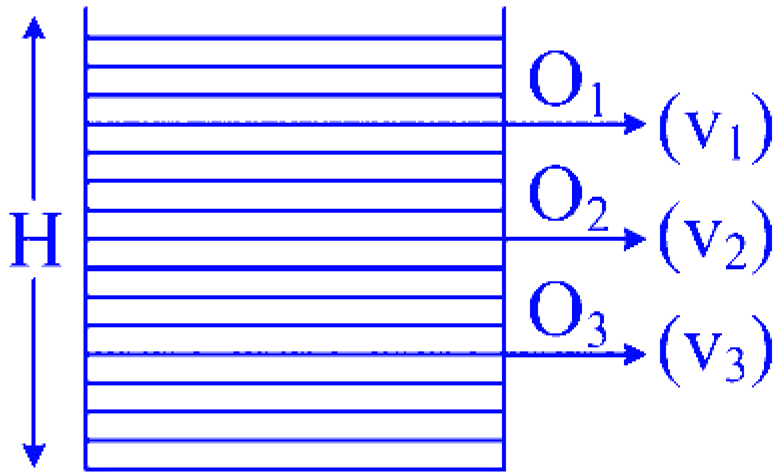
B. $V_1<V_2<V_3$

C. $V_1>V_2>V_3$

D. $V_1 = V_3 > V_2$

Answer: B

Solution:



We know,

$V = \sqrt{2gh}$ ... (where ' h ' is depth from the surface)

$h_1 < h_2 < h_3$ ...(From figure)

$\therefore \quad V_1 < V_2 < V_3$

Question50

When capillary is dipped vertically in water, rise of water in capillary is ' h '. The angle of contact is zero. Now the tube is depressed so that its length above the water surface is $\frac{h}{3}$. The new apparent angle of contact is $(\cos 0^\circ = 1)$

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Options:

A. $\cos^{-1}\left(\frac{1}{2}\right)$

B. $\cos^{-1}\left(\frac{1}{3}\right)$

C. $\cos^{-1}\left(\frac{1}{4}\right)$

D. $\cos^{-1}\left(\frac{1}{6}\right)$

Answer: B

Solution:

Surface tension in terms of capillary rise h is

$$\mathrm{T}=\frac{\mathrm{rh}\rho g}{2\cos\theta} \Rightarrow \frac{\mathrm{rh}'\rho g}{2\cos\theta'}$$

$$\therefore \quad \frac{\cos\theta'}{\cos\theta}=\frac{\mathrm{h}'}{\mathrm{h}}=\frac{1}{3}$$

$$\therefore \quad \cos\theta'=\frac{1}{3}\cos 0^{\circ}=\frac{1}{3}$$

$$\therefore \quad \theta'=\cos^{-1}\left(\frac{1}{3}\right)$$

Question51

The viscous force between two liquid layers is

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Options:

A. radial.

B. normal to the liquid surface.

C. tangential to the liquid surface.

D. neither purely tangential nor purely normal.

Answer: C

Solution:

The viscous force between two liquid layers is **tangential to the liquid surface**.

Viscosity is a measure of a fluid's resistance to flow and deformation. In the context of fluid layers moving past each other, this resistance manifests as a tangential force. When a layer of fluid moves with respect to an adjacent layer, the layer in motion exerts a shear force on the neighboring layer. This force acts parallel (tangential) to the surface separating the layers, offering resistance to the relative motion of those layers. This tangential force is what defines the viscous interactions within the fluid, often described by Newton's law of viscosity.

In mathematical terms, the shear stress τ between fluid layers is given by:

$\tau=\eta \frac{du}{dy}$

where:

τ is the shear stress.

η is the dynamic viscosity of the fluid.

$\frac{du}{dy}$ is the velocity gradient perpendicular to the direction of flow.

This equation shows that the viscous force depends on the rate at which one fluid layer is moving relative to another, emphasizing its tangential nature to the interface of the layers.

Question52

A ball rises to surface at a constant velocity in liquid whose density is 3 times greater than that of the material of the ball. The ratio of force of friction acting on the rising ball to its weight is

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Options:

A. 2 : 1

B. 3 : 1

C. 4 : 1

D. 6 : 1

Answer: A

Solution:

The ball is moving with constant velocity. Therefore, the net force acting on it is zero.

The weight of the ball $=\mathrm{W}=\frac{4}{3} \pi \mathrm{r}^3 \rho_{\mathrm{b}} \mathrm{g}$ ....(acting downwards)

As the ball is rising up, the viscous force F_v will be in the downward direction.

The buoyant force $\mathrm{F}_B=\frac{4}{3} \pi \mathrm{r}^3 \rho_l$ g....(acting upwards)

$\therefore \quad F_v + W = F_B$

$\therefore \quad F_v = F_B - W = \frac{4}{3}\pi r^3 g(\rho_l - \rho_b)$

$F_v = \frac{4}{3}\pi r^3 g \times 2\rho_b \quad \ldots (\because \rho_l = 3\rho_b)$ ...(ii)

$\therefore \quad \frac{F_v}{W} = \frac{\frac{4}{3}\pi r^3 g \times 2\rho_b}{\frac{4}{3}\pi r^3 \rho_b g} = \frac{2}{1}$ ...[From(i) and (ii)]

Question53

When a mercury drop of radius ' R ' splits up into 1000 droplets of radius ' r ', the change in surface energy is ($T =$ surface tension of mercury)

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Options:

A. $8\pi R^2 T$

B. $16\pi R^2 T$

C. $34\pi R^2$ T

D. $36\pi R^2 T$

Answer: D

Solution:

When a larger mercury drop of radius R splits into 1000 smaller droplets, each of radius r, the change in surface energy can be calculated using the concept of surface area and the formula for surface energy. The surface energy (E) of a sphere is given by:

$E =$ Surface Area $\times$ Surface Tension

The surface area (A) of a sphere is given by:

$A = 4\pi R^2$

Initial Surface Energy:

The initial surface area of the larger drop is:

$A_{\text{initial}} = 4\pi R^2$

The initial surface energy is:

$E_{\text{initial}} = 4\pi R^2 \times T$

Final Surface Energy:

Each smaller droplet has a radius r and a surface area:

$A_{\text{small}} = 4\pi r^2$

For 1000 droplets, the total surface area is:

$A_{\text{final}} = 1000 \times 4\pi r^2 = 4000\pi r^2$

The final surface energy is:

$E_{\text{final}} = 4000\pi r^2 \times T$

Change in Surface Energy:

The change in surface energy (ΔE) is the difference between the final and initial energies:

$\Delta E = E_{\text{final}} - E_{\text{initial}} = 4000\pi r^2 T - 4\pi R^2 T$

Volume Conservation:

Because volume is conserved during the splitting, the volume of the larger drop equals the total volume of the smaller droplets:

$\frac{4}{3}\pi R^3 = 1000 \times \frac{4}{3}\pi r^3$

Simplifying gives:

$R^3 = 1000 r^3$

Thus, the radius r of each small droplet is:

$r = \frac{R}{10}$

Substitute for r:

Substitute $r = \frac{R}{10}$ into the expression for ΔE:

$\Delta E = 4000\pi \left(\frac{R}{10}\right)^2 T - 4\pi R^2 T$

Simplifying:

$\Delta E = 4000\pi \frac{R^2}{100} T - 4\pi R^2 T$

$\Delta E = 40\pi R^2 T - 4\pi R^2 T$

$\Delta E = 36\pi R^2 T$

Therefore, the correct answer is **Option D:** $36\pi R^2 T$.

Question54

The angle of contact between glass and water is 0° and water rises in a glass capillary upto 6 cm (Surface tension of water is T). Another liquid of surface tension ' $2 \mathrm{~T}^{\prime}$ ', angle of contact 60° and relative density 2 will rise in the same capillary up to
$\left(\cos 0^{\circ}=1, \cos 60^{\circ}=0.5\right)$

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Options:

A. 1.5 cm

B. 2 cm

C. 3 cm

D. 4.0 cm

Answer: C

Solution:

$\mathrm{h}=\frac{2 \mathrm{~T} \cos \theta}{\mathrm{r} \rho \mathrm{~g}}$

For water:

$$6=\frac{2 T \cos (0)}{r \times 1 \times g}$$

$$\therefore \quad r=\frac{2 T}{6 g}=\frac{T}{3 g}$$

For other liquid:

$h=\frac{4 T \cos 60}{r \times 2 \times g}=\frac{4 \mathrm{~T} \times 0.5}{\frac{T}{3 g} \times 2 \times g}=3 \mathrm{~cm}$

Question55

Two capillary tubes A and B of the same internal diameter are kept vertically in two different liquids whose densities are in the ratio $4: 3$. If the surface tensions of these two liquids are in the ratio $6: 5$,

then the ratio of rise of liquid in capillary A to that in B is (assume their angles of contact are nearly equal)

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Options:

A. 10 : 9

B. 9 : 10

C. 7 : 10

D. 10 : 7

Answer: B

Solution:

$$r_1 = r_2$$
$$\frac{\rho_1}{\rho_2} = \frac{4}{3}; \frac{T_1}{T_2} = \frac{6}{5}; \theta_1 = \theta_2$$
$$\mathrm{h} = \frac{2\,\mathrm{T}\cos\theta}{\mathrm{r}\rho\,\mathrm{g}} \Rightarrow \mathrm{h} \propto \frac{\mathrm{T}}{\rho}$$
$$\frac{h_1}{h_2} = \frac{T_1}{T_2} \times \frac{\rho_2}{\rho_1}$$
$$\therefore \quad \frac{h_1}{h_2} = \frac{6}{5} \times \frac{3}{4} = \frac{9}{10}$$

Question56

Two rain drops of same radius are falling through air each with a steady speed of $5\ \mathrm{cm/s}$. If the drops coalesce, the new steady velocity of big drop will be

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Options:

A. $5 \mathrm{~cm/s}$

B. $5\sqrt{2} \mathrm{~cm/s}$

C. $5 \times 2^{1/3} \mathrm{~cm/s}$

D. $5 \times (4)^{1/3} \mathrm{~cm/s}$

Answer: D

Solution:

Terminal speed $v \propto r^2$

$$\therefore \quad \frac{v_1}{v_2} = \frac{r^2}{R^2} = \frac{r^2}{\left(2^{1/3} r\right)^2}$$

$$\therefore \quad v_2 = v_1 \times \frac{\left(2^{1/3} r\right)^2}{r^2} = 5 \times 2^{2/3} = 5 \times 4^{1/3} \mathrm{~cm~s}^{-1}$$

Question57

A capillary tube stands with its lower end dipped into liquid for which the angle of contact is 90°. The liquid will

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Options:

A. neither rise nor fall.

B. get depressed only.

C. rise only.

D. rise upto the top of the tube.

Answer: A

Solution:

$$h = \frac{2\,T\cos\theta}{\rho g r}$$
$$h = \frac{2\,T\cos 90}{\rho g r}$$
$$h = 0 \quad \ldots(\cos 90^\circ = 0)$$
Hence, the liquid will neither rise nor fall.

Question58

A lead sphere of mass ' m ' falls in viscous liquid with terminal velocity V_0. Another lead sphere of mass ' 8 m ' but of same material will fall through the same liquid with terminal velocity

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Options:

A. V_0

B. $8V_0$

C. $4V_0$

D. $64\ V_0$

Answer: C

Solution:

The formula for terminal velocity for a spherical body

$$V = \frac{2\ g(\rho-\sigma)r^2}{2\eta}$$

If mass is made 8 times, material being same volume also becomes 8 times $\because$ density is same. So, radius of sphere becomes twice.

$\therefore$ The new terminal velocity

$$\frac{V_0}{V_2} = \left(\frac{r_1}{r_2}\right)^2$$
$$\frac{V_0}{V_2} = \left(\frac{1}{2}\right)^2$$
$$V_2 = 4V_0$$

Question59

A big water drop is formed by the combination of ' n ' small water droplets of equal radii. The ratio of the surface energy of ' n ' droplets to the surface energy of the big drop is

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Options:

A. $\sqrt{n} : 1$

B. $\sqrt[3]{n} : 1$

C. $n : 1$

D. $n^2 : 1$

Answer: B

Solution:

Let R be the radius of bigger drop and r be the radius of single small water drop.

Volume of big drop $=$ n (Volume of small drop)

$$\therefore \quad \frac{4}{3}\pi R^3 = n \times \frac{4}{3}\pi r^3$$
$$\Rightarrow R^3 = nr^3$$
$$R = n^{\frac{1}{3}} r$$

Surface energy of n drops $(E_n) = n \times 4\pi r^2 \times T$

Surface energy of big drop $(E) = 4\pi R^2 T$

$$\therefore \quad \frac{E_n}{E} = \frac{nr^2}{R^2} = \frac{nr^2}{\left(n^{\frac{1}{3}}\right)^2} = \frac{nr^2}{n^{\frac{2}{3}} r^2} = n^{\frac{1}{3}} = \sqrt[3]{n} : 1$$

Question60

Water rises in a capillary tube of radius ' r ' up to height ' h '. The mass of water in capillary is ' m '. The mass of water that will rise in capillary of radius $\mathrm{r}/3$ will be

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Options:

A. m

B. $\frac{\mathrm{m}}{3}$

C. $\frac{m}{6}$

D. $\frac{\mathrm{m}}{9}$

Answer: B

Solution:

Rise of water in capillary tube is given by

$\mathrm{h}=\frac{2 \mathrm{~T} \cos \theta}{\mathrm{rpg}}$

For water, $\cos \theta=1$

Also, the radius of capillary tube becomes (r/3).

$\therefore \quad \mathrm{h}^{\prime}=\frac{3 \cdot 2 \mathrm{~T}}{\mathrm{rgg}} \Rightarrow \mathrm{h}^{\prime}=3 \mathrm{~h}$

Now, $m=\pi r^2 \mathrm{~h} \times \rho$

$\therefore \quad \mathrm{m}^{\prime}=\pi(\mathrm{r}/3)^2(3 \mathrm{~h}) \times \rho=\frac{\pi \mathrm{r}^2 \mathrm{~h} \rho}{3}=\frac{\mathrm{m}}{3}$

Question61

The work done in blowing a soap bubble of radius R is W_1 at room temperature. Now the soap solution is heated. From the heated solution another soap bubble of radius 2 R is blown and the work done is W_2. Then

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Options:

A. $\mathrm{W}_2 = 0$

B. $\mathrm{W}_2 = 4\ \mathrm{W}_1$

C. $\mathrm{W}_2 < 4\ \mathrm{W}_1$

D. $\mathrm{W}_2 = \mathrm{W}_1$

Answer: C

Solution:

Expression for Work Done in Forming a Soap Bubble :

When forming a soap bubble, the work done is essentially the energy required to create the new surface area. A soap bubble has two surfaces (an inner and an outer surface). Hence, if the bubble has radius R, then :

The surface area of one spherical surface is $4\pi R^2$.

Since there are two surfaces, the total surface area is $2 \times 4\pi R^2 = 8\pi R^2$.

The energy (or work) required to create this bubble from scratch can be approximated as:

$W = (\text{Surface Tension}) \times (\text{Total Surface Area}) = T \cdot 8\pi R^2$.

Thus, for a bubble of radius R at room temperature with surface tension T_1:

$W_1 = 8\pi R^2 T_1$.

When the Radius is Doubled :

If we were to form a bubble of radius $2R$ at the same (initial) surface tension T_1, then:

$W' = 8\pi(2R)^2 T_1 = 8\pi(4R^2)T_1 = 32\pi R^2 T_1$.

Comparing W' and W_1:

$\frac{W'}{W_1} = \frac{32\pi R^2 T_1}{8\pi R^2 T_1} = 4$.

If the surface tension remained the same, the work required to form a bubble of twice the radius would be $4W_1$.

Effect of Heating on Surface Tension :

The problem states that the solution is heated. Generally, increasing the temperature reduces the surface tension of a liquid. Let the new surface tension at the elevated temperature be T_2, with $T_2 < T_1$.

Thus, when blowing a bubble of radius $2R$ from the heated solution:

$W_2 = 8\pi(2R)^2 T_2 = 32\pi R^2 T_2$.

Since $T_2 < T_1$, we have:

$W_2 = 32\pi R^2 T_2 < 32\pi R^2 T_1$.

But $32\pi R^2 T_1 = 4W_1$. Therefore:

$W_2 < 4W_1$.

Conclusion :

Due to the reduction in surface tension upon heating, the work required to form a bubble of twice the radius is less than four times the original work at room temperature.

Correct Answer :

$\boxed{W_2 < 4W_1}$ (Option C)

Question62

Two soap bubbles having radii ' r_1 ' and ' r_2 ' has inside pressure ' P_1 ' and ' P_2 ' respectively. If P_0 is external pressure then ratio of their volume is

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Options:

A. $\frac{(\mathrm{P}_1-\mathrm{P}_0)}{(\mathrm{P}_2-\mathrm{P}_0)}$

B. $\frac{(\mathrm{P}_2-\mathrm{P}_0)}{(\mathrm{P}_1-\mathrm{P}_0)}$

C. $\frac{(P_2-P_0)^3}{(P_1-P_0)^3}$

D. $\frac{(\mathrm{P}_1-\mathrm{P}_0)^3}{(\mathrm{P}_2-\mathrm{P}_0)^3}$

Answer: C

Solution:

The pressure inside a soap bubble is given by the formula:

$P_{\text{inside}} = P_0 + \frac{4T}{r}$

where:

P_0 is the external pressure,

T is the surface tension,

r is the radius of the soap bubble.

For two soap bubbles with radii r_1 and r_2, and inside pressures P_1 and P_2 respectively, we can write:

$P_1 = P_0 + \frac{4T}{r_1}$

$P_2 = P_0 + \frac{4T}{r_2}$

Rearranging for r_1 and r_2, we have:

$r_1 = \frac{4T}{P_1 - P_0}$

$r_2 = \frac{4T}{P_2 - P_0}$

The volume V of a sphere (soap bubble) is given by:

$V = \frac{4}{3}\pi r^3$

Thus, the volumes of the two soap bubbles are:

$V_1 = \frac{4}{3}\pi r_1^3 = \frac{4}{3}\pi\left(\frac{4T}{P_1 - P_0}\right)^3$

$V_2 = \frac{4}{3}\pi r_2^3 = \frac{4}{3}\pi\left(\frac{4T}{P_2 - P_0}\right)^3$

The ratio of their volumes is:

$\frac{V_1}{V_2} = \frac{\left(\frac{4T}{P_1 - P_0}\right)^3}{\left(\frac{4T}{P_2 - P_0}\right)^3} = \left(\frac{P_2 - P_0}{P_1 - P_0}\right)^3$

Thus, the correct option for the ratio of their volumes is:

Option C

$\frac{(P_2 - P_0)^3}{(P_1 - P_0)^3}$

Question63

Two metal spheres are falling through a liquid of density $2.5 \times 10^3 \text{ kg/m}^3$ with the same uniform speed. The density of material of first sphere and second sphere is $11.5 \times 10^3 \text{ kg/m}^3$ and

$8.5 \times 10^3\ \mathrm{kg/m^3}$ respectively. The ratio of the radius of first sphere to that of second sphere is

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Options:

A. $\frac{2}{3}$

B. $\sqrt{\frac{2}{3}}$

C. $\frac{3}{2}$

D. $\sqrt{\frac{3}{2}}$

Answer: B

Solution:

Terminal velocity is given by

$v=\frac{2 r^2(\rho-\sigma) g}{9 \eta}$

As the velocity is the same,

$\therefore \quad r_A^2\left(\rho_A-\sigma\right)=r_B^2\left(\rho_B-\sigma\right)$

$\therefore \quad \frac{r_A}{r_B}=\sqrt{\frac{\rho_B-\sigma}{\rho_A-\sigma}}$

Substituting the given values, we get

$\frac{r_A}{r_B}=\sqrt{\frac{8.5 \times 10^3-2.5 \times 10^3}{11.5 \times 10^3-2.5 \times 10^3}}=\sqrt{\frac{6}{9}}=\sqrt{\frac{2}{3}}$

Question64

A glass capillary of radius 0.35 mm is inclined at 60° with the vertical in water. The height of the water column in the capillary is (surface tension of water $=7 \times 10^{-2}\ \mathrm{N/m}$, acceleration due to gravity, $g=10\ \mathrm{m/s^2}, \cos 0^{\circ}=1, \cos 60^{\circ}=0.5$)

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Options:

A. 6 cm

B. 8 cm

C. 10 cm

D. 12 cm

Answer: B

Solution:

$$h = \frac{2\ T\cos\theta}{r\rho\ g} = \frac{2\times(7\times10^{-2})\times\cos 0^{\circ}}{(0.35\times10^{-3})\times10^{3}\times10}$$

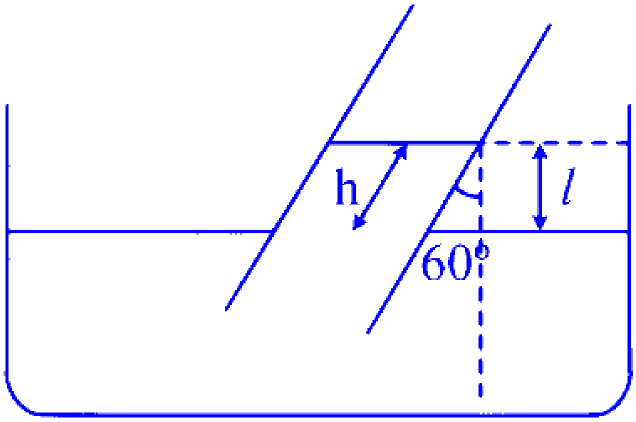
$\ldots(\theta = 0^{\circ},\ \text{for glass-water})$

$h = 0.04\ \text{m}$

$l = \frac{h}{\cos\phi}$

where ϕ is angle of capillary with vertical as shown in figure.

$l = \frac{0.04}{\cos(60)} = 0.08\ \text{m} = 8\ \text{cm}$



Question65

A closed pipe containing a liquid showed a pressure P_1 by gauge. When the valve was opened, pressure was reduced to P_2. The speed

of water flowing out of the pipe is ($\rho =$ density of water)

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Options:

A. $\left[\frac{4(\mathrm{P}_1-\mathrm{P}_2)}{\rho}\right]^{1/2}$

B. $\left[\frac{4(P_2-P_1)}{\rho}\right]^{1/2}$

C. $\left[\frac{2(\mathrm{P}_1-\mathrm{P}_2)}{\rho}\right]^{1/2}$

D. $\left[\frac{2(\mathrm{P}_2-\mathrm{P}_1)}{\rho}\right]^{1/2}$

Answer: C

Solution:

According to Bernoulli's equation,

$$P_1+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho v_2^2$$

$$\therefore \quad v_2^2=\frac{2\left(P_1-P_2\right)}{\rho} \qquad [\because v_1=0]$$

$$v_2=\sqrt{\frac{2\left(P_1-P_2\right)}{\rho}}$$

Question66

A completely filled water tank of height ' h ' has a hole at the bottom. The total pressure of the bottom is 4 H and atmospheric pressure is H . The velocity of water flowing out of the hole is ($\rho =$ density of water)

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Options:

A. $\sqrt{\frac{3H}{\rho}}$

B. $\sqrt{\frac{5H}{\rho}}$

C. $\sqrt{\frac{6H}{\rho}}$

D. $\sqrt{\frac{9H}{\rho}}$

Answer: C

Solution:

To determine the velocity of water flowing out of the hole at the bottom of the tank, we use Torricelli's theorem, which is derived from Bernoulli's principle. According to Torricelli's theorem, the speed v of efflux of a fluid under the force of gravity through a small hole at depth h is given by:

$$v = \sqrt{2gh}$$

Here, g is the acceleration due to gravity and h is the height of the fluid column above the hole.

Given:

The total pressure at the bottom of the tank is $4H$.

The atmospheric pressure is H.

The pressure exerted by the water column is the difference between the total pressure at the bottom and the atmospheric pressure:

$$P_{\text{water}} = 4H - H = 3H$$

Now, equate the pressure due to the water column to ρgh:

$$\rho gh = 3H$$

Solving for gh, we find:

$$gh = \frac{3H}{\rho}$$

Substituting this into Torricelli's theorem gives:

$$v = \sqrt{2gh} = \sqrt{2 \times \frac{3H}{\rho}} = \sqrt{\frac{6H}{\rho}}$$

Thus, the velocity of water flowing out of the hole is:

Option C

$$\sqrt{\frac{6H}{\rho}}$$

Question67

A metal sphere of radius R, density ρ_1 moves with terminal velocity V_1 through a liquid of density σ. Another sphere of same radius but density ρ_2 moves through same liquid. Its terminal velocity is V_2. The ratio $\mathrm{V}_1 : \mathrm{V}_2$ is

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Options:

A. $(\rho_2+\sigma):(\rho_1-\sigma)$

B. $(\rho_1+\sigma):(\rho_2-\sigma)$

C. $(\rho_2-\sigma):(\rho_1-\sigma)$

D. $(\rho_1-\sigma):(\rho_2-\sigma)$

Answer: D

Solution:

Terminal velocity, $\mathrm{v}_1=\frac{2}{9} \frac{(\rho_1-\sigma) \mathrm{R}^2 \mathrm{~g}}{\eta}$

Similarly,

$$\mathrm{v}_2=\frac{2}{9} \frac{(\rho_2-\sigma) \mathrm{R}^2 \mathrm{~g}}{\eta}$$

$$\therefore \quad \frac{\mathrm{v}_1}{\mathrm{v}_2}=\frac{(\rho_1-\sigma)}{(\rho_2-\sigma)}$$

Question68

Three liquids of densities ρ_1, ρ_2 and ρ_3 (with $\rho_1>\rho_2>\rho_3$) having same value of surface tension T , rise to the same height in three identical capillaries. Angle of contact θ_1, θ_2 and θ_3 respectively obey

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Options:

A. $\frac{\pi}{2} > \theta_1 > \theta_2 > \theta_3 > 0$

B. $0 \leqslant \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

C. $\frac{\pi}{2} < \theta_1 < \theta_2 < \theta_3 < \pi$

D. $\pi > \theta_1 > \theta_2 > \frac{\pi}{2}$

Answer: B

Solution:

Rise of a liquid in a capillary tube:

$$h = \frac{2\,T\cos\theta}{rgg}$$
$$\cos\theta = \frac{hr\rho g}{2\,T}$$

$\ldots.(\because \cos 0 = 1$ is the max. value for cosine)

$\therefore$ Here, $\rho_1 > \rho_2 > \rho_3$, so

$\theta_1 < \theta_2 < \theta_3$

The all three angles of contact should be acute.

$0 \leqslant \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

Question69

Let ' n ' is the number of liquid drops, each with surface energy ' E '. These drops join to form single drop. In this process

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Options:

A. some energy will be absorbed

B. energy absorbed is $\left[E\left(n-n^{2/3}\right)\right]$

C. energy released will be $\left[\mathrm{E}\left(\mathrm{n}-\mathrm{n}^{2/3}\right)\right]$

D. energy released will be $\left[\mathrm{E}\left(2^{2/3}-1\right)\right]$

Answer: C

Solution:

When n liquid drops, each with a surface energy E, combine to form a single larger drop, the total surface area of the drops decreases. This process results in the release of energy, as the surface energy is directly related to the surface area.

To find the amount of energy released or absorbed, we can consider the following:

The initial total surface energy for the n drops, each having surface energy E, is nE.

When these droplets combine, they form a single drop whose radius will be larger.

For n spherical drops of radius r, the total volume V is:

$V=n\cdot\frac{4}{3}\pi r^3$

When they merge into a single sphere, the new radius R must satisfy:

$\frac{4}{3}\pi R^3=n\cdot\frac{4}{3}\pi r^3$

So, the radius of the new drop, R, can be determined as:

$R=n^{1/3}\cdot r$

The surface area of one original drop is $4\pi r^2$ and so, for n such drops, the initial total surface area is:

$A_{\text{initial}}=n\cdot 4\pi r^2$

For the newly formed single drop, the surface area becomes:

$A_{\text{final}}=4\pi R^2=4\pi(n^{1/3}\cdot r)^2=4\pi n^{2/3}r^2$

The change in surface area as the drops combine is:

$\Delta A=A_{\text{initial}}-A_{\text{final}}=4\pi r^2(n-n^{2/3})$

Thus, the change in surface energy, which corresponds to the energy released, is given by:

$\Delta E=E(n-n^{2/3})$

Therefore, Option C is correct, where the energy released will be $\left[E\left(n-n^{2/3}\right)\right]$.

Question70

The work done in splitting a water drop of radius R into 64 droplets is ($\mathrm{T}=$ Surface tension of water)

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Options:

A. $6 \pi \mathrm{TR}^2$

B. $12 \pi \mathrm{TR}^2$

C. $8 \pi \mathrm{TR}^2$

D. $24 \pi \mathrm{TR}^2$

Answer: B

Solution:

Given the radius of drop is R.

Let r be the radius of smaller droplets.

As the total volume remains the same,

$$\frac{4}{3} \pi \mathrm{R}^3=64 \times \frac{4}{3} \pi \mathrm{r}^3$$

$$\therefore \quad \mathrm{r}=\frac{\mathrm{R}}{(64)^{\frac{1}{3}}}=\frac{\mathrm{R}}{4}$$

Initial surface energy $E_1=4 \pi R^2 T$

Final surface energy $E_2=64 \times 4 \pi \times\left(\frac{R}{4}\right)^2 \times T$

$=16 \pi R^2 T$

$\therefore \quad$ Work done, $\mathrm{W}=\mathrm{E}_2-\mathrm{E}_1$

$\mathrm{W}=12 \pi \mathrm{TR}^2$

Question71

Two identical drops of water are falling through air with steady velocity ' V '. If the two drops come together to form a single drop. The new velocity of the single drop is

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Options:

A. $(2)^{1/3}$ V

B. (2) $^{3/2}$ V

C. $(2)^{2/3}$ V

D. $(2)^{1/4}$ V

Answer: C

Solution:

Let the radius of the 2 rain droplets be r each. They coalesce to form a drop of radius R.

As volume is conserved, $\mathrm{R}^3=2 \mathrm{r}^3$

$\therefore \quad R=2^{\frac{1}{3}} r$

Terminal velocity $V=\frac{2 r^2(\rho-\sigma) g}{\eta}$

$\therefore \quad \mathrm{V} \propto \mathrm{r}^2$

$\therefore \quad \mathrm{V}^{\prime}=\mathrm{V} \frac{\mathrm{R}^2}{\mathrm{r}^2}=\mathrm{V} \times \frac{2^{\frac{2}{3}} \mathrm{r}^2}{\mathrm{r}^2}=\mathrm{V} \cdot 2^{2/3}$

Question72

When an air bubble rises from the bottom of lake to the surface, its radius is doubled. The atmospheric pressure is equal to that of a column of water of height ' H '. The depth of the lake is

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Options:

A. H

B. 2 H

C. 7 H

D. 8 H

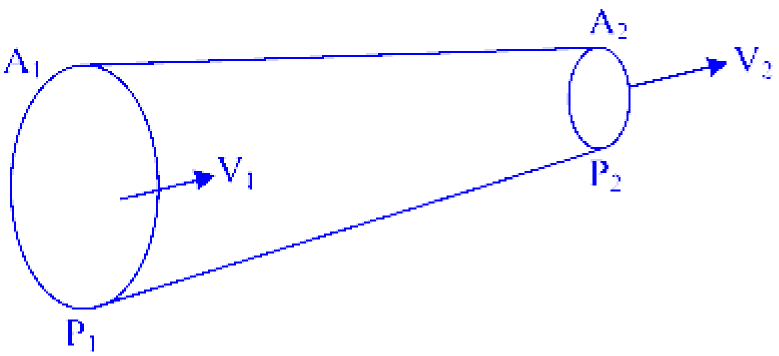
Answer: C

Solution:

$$P_1 V_1 = P_2 V_2$$
$$\Rightarrow (P_0 + hpg) \times \frac{4}{3}\pi r^3 = P_0 \times \frac{4}{3}\pi(2r)^3$$
Where, h = depth of lake
$$\Rightarrow \mathrm{h}\rho\,\mathrm{g} = 7\mathrm{P}_0 \Rightarrow \mathrm{h} = 7 \times \frac{\mathrm{Hpg}}{\rho\,\mathrm{g}} = 7\mathrm{H}$$

Question73

Water is flowing in a conical tube as shown in figure. Velocity of water at area ' A_2 ' is $60\ \mathrm{cm/s}$. The value of ' A_1 ' and ' A_2 ' is $10\ \mathrm{cm}^2$ and $5\ \mathrm{cm}^2$ respectively. The pressure difference at both the cross-section is



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Options:

A. $230 \mathrm{~N} / \mathrm{m}^2$

B. $200 \mathrm{~N} / \mathrm{m}^2$

C. $135 \mathrm{~N} / \mathrm{m}^2$

D. $105 \mathrm{~N} / \mathrm{m}^2$

Answer: C

Solution:

$$\begin{aligned} A_1 \times V_1 & =A_2 \times V_2 \\ 10 \times V_1 & =5 \times 60 \\ V_1 & =30 \mathrm{~cm} / \mathrm{s} \end{aligned}$$

From Bernoulli's equation

$$\begin{aligned} \left(\mathrm{P}_{\mathrm{A}}-\mathrm{P}_{\mathrm{B}}\right) & =\frac{1}{2} \rho\left(\mathrm{V}_2^2-\mathrm{V}_1^2\right) \\ & =\frac{1}{2} \times 10^3\left(60^2-30^2\right) \times 10^{-4} \\ & =\frac{1}{2} \times 10^{-1}(3600-900) \\ & =\frac{1}{2} \times 2700 \\ & =1350 \text { dyne } / \mathrm{cm}^2 \\ & =135 \mathrm{~N} / \mathrm{m}^2 \end{aligned}$$

Question74

A hemispherical portion of radius ' R ' is removed from the bottom of a cylinder of radius ' R '. The volume of the remaining cylinder is ' V ' and its mass is ' M '. It is suspended by a string in a liquid of density ' ρ ', where it stays vertical. The upper surface of the cylinder is at a depth ' h ' below the liquid surface. The force on the bottom of the liquid is

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Options:

A. Mg

B. $\mathrm{Mg}-\mathrm{V} \rho g$

C. $\mathrm{Mg}+\pi \mathrm{R}^2 \mathrm{~h} \rho g$

D. $\mathrm{pg}\left(\mathrm{V}+\pi \mathrm{r}^2 \mathrm{~h}\right)$

Answer: D

Solution:

Net upward zone force on the bottom of the liquid = weight of the liquid displaced by cylinder + thrust force on upper surface of the cylinder due to h column of liquid

$$\begin{aligned} \mathrm{F}_{\text {net }} & =\rho \mathrm{Vg}+\rho \mathrm{gh} \times \pi \mathrm{r}^2 \\ & =\rho g\left(V+\pi \mathrm{r}^2 h\right)\end{aligned}$$

Question75

A water film is formed between two parallel wires of 10 cm length. The distance of 0.5 cm between the wires is increased by 1 mm . The work done in the process is (surface tension of water $=72 \mathrm{~N} / \mathrm{m}$)

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Options:

A. $2.88 \times 10^{-2} \mathrm{~J}$

B. $7.2 \times 10^{-2} \mathrm{~J}$

C. $1.44 \times 10^{-2} \mathrm{~J}$

D. $3.6 \times 10^{-2} \mathrm{~J}$

Answer: C

Solution:

Surface area of film,

$\mathrm{A}_1=l \times \mathrm{d}=10 \times 0.5=5 \mathrm{~cm}^2$

The distance between wires ' d ' is increased by

$1 \text{ mm} = 0.1 \text{ cm}$

Surface area of film becomes,

$A_2 = 10 \times (0.5 + 0.1) = 6 \text{ cm}^2$

Increase in the surface area of the film is,

$\Delta A = A_2 - A_1$
$\Delta A = 6 - 5 = 1 \text{ cm}^2 = 10^{-4} \text{ m}^2$

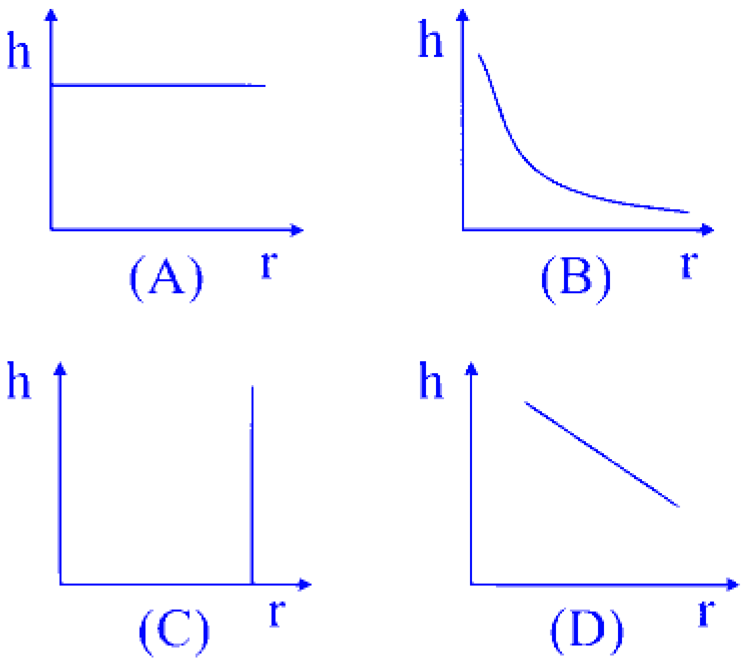
Work done,

$W = 2 T . \Delta A \quad \ldots$ (where T is surface tension)

$W = 2 \times 72 \times 10^{-4} \text{ J}$
$W = 1.44 \times 10^{-2} \text{ J}$

Question76

Identify the correct figure which shows the relation between the height of water column in a capillary tube and the capillary radius.



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Options:

A. (B)

B. (D)

C. (A)

D. (C)

Answer: B

Solution:

Height if liquid in capillary tube is given by,

$h=\frac{2 \mathrm{~T} \cos \theta}{r \rho g}$

$\therefore \quad h \propto \frac{1}{r}$

Question77

Water rises up to height ' X ' in a capillary tube immersed vertically in water. When the whole arrangement is taken to a depth ' d ' in a mine, the water level rises up to height ' Y '. If ' R ' is the radius of earth then the ratio $\frac{Y}{X}$ is

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Options:

A. $\left(1-\frac{d}{R}\right)^{-1}$

B. $\left(1-\frac{d}{R}\right)$

C. $\left(1+\frac{d}{R}\right)^{-1}$

D. $\left(1+\frac{d}{R}\right)$

Answer: A

Solution:

Rise in capillary tube is given as,

$h = \frac{2\ T \cos \theta}{rpg}$

As all the other quantities are kept constant, in mine of depth d,

$h \propto \frac{1}{g}$

At a depth $d, g_d = g\left(\frac{1-d}{R}\right)$

Also, given that, $h = x$ and $h_d = y$

$\therefore \quad \frac{x}{y} = \frac{g_d}{g} = \left(1 - \frac{d}{R}\right) \Rightarrow \frac{y}{x} = \left(1 - \frac{d}{R}\right)^{-1}$

Question78

The surface of water in a water tank of cross section area $750\ \mathrm{cm}^2$ on the top of a house is ' h ' m above the tap level. The speed of water coming out through the tap of cross section area $500\ \mathrm{mm}^2$ is $30\ \mathrm{cm/s}$. At that instant $\frac{\mathrm{dh}}{\mathrm{dt}}$ is $x = 10^{-3}\ \mathrm{m/s}$. The value of ' x ' will be

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Options:

A. 2

B. 3

C. 4

D. 6

Answer: A

Solution:

From equation of continuity, $A_1 v_1 = A_2 v_2$

$\left(750 \times 10^{-4}\right) v_1=\left(500 \times 10^{-6}\right) \times\left(30 \times 10^{-2}\right)$

$v_1=\frac{500 \times 10^{-6} \times 30 \times 10^{-2}}{750 \times 10^{-4}}=2 \times 10^{-3} \mathrm{~m} / \mathrm{s}$

But, $v_1=\frac{dh}{dt}=x \times 10^{-3} \mathrm{~m} / \mathrm{s}$

$\therefore \quad x=2$

Question79

The excess pressure inside a spherical drop of water A is four times that of another drop B. Then the ratio of mass of drop A to that of drop B is

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Options:

A. 1 : 4

B. 1 : 8

C. 1 : 16

D. 1 : 64

Answer: D

Solution:

Excess pressure inside 1^{st} spherical drop(A) is given by, $P_A=\frac{2T}{r_1}$

For 2^{nd} drop(B), $P_B=\frac{2T}{r_2}$

$\therefore \quad \frac{2T}{r_1}=4\left(\frac{2T}{r_2}\right) \ldots(\text{ given, } P_A=4P_B)$

$\therefore \quad \frac{r_1}{r_2}=\frac{1}{4}$

Now, $\frac{m_1}{m_2}=\frac{V_1 \rho_1}{V_2 \rho_2}$

As both are drops of water, $\rho_1=\rho_2$

$\therefore \quad \frac{m_1}{m_2}=\frac{V_1}{V_2}=\frac{\frac{4}{3} \pi \pi_1^3}{\frac{4}{3} \pi \pi_2^3}=\left(\frac{1}{4}\right)^3=\frac{1}{64}$

Question80

A steel ball of radius 6 mm has a terminal speed of $12 \mathrm{cms}^{-1}$ in a viscous liquid. What will be the terminal speed of a steel ball of radius 3 mm in the same liquid?

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Options:

A. 12 cms^{-1}

B. 9 cms^{-1}

C. 6 cms^{-1}

D. 3 cms^{-1}

Answer: D

Solution:

The terminal speed of a sphere moving through a viscous fluid can be described by Stokes' Law, which relates terminal speed to the radius of the sphere. The terminal velocity v_t is given by:

$v_t = \frac{2}{9} \cdot \frac{r^2(\rho-\sigma)g}{\eta}$

where:

r is the radius of the ball,

ρ is the density of the ball,

σ is the density of the fluid,

g is the acceleration due to gravity,

η is the viscosity of the liquid.

The terminal speed is directly proportional to the square of the radius:

$v_t \propto r^2$

For a ball with a radius of 6 mm, the terminal speed is 12 cm/s. Let the terminal speed for a ball of radius 3 mm be v_t'.

Using the proportionality:

$\frac{v_t'}{v_t} = \left(\frac{r'}{r}\right)^2$

Substitute the known values:

$\frac{v_t'}{12} = \left(\frac{3}{6}\right)^2$

This simplifies to:

$\frac{v_t'}{12} = \left(\frac{1}{2}\right)^2$

$\frac{v_t'}{12} = \frac{1}{4}$

Solving for v_t':

$v_t' = 12 \cdot \frac{1}{4}$

$v_t' = 3\,\text{cm/s}$

Therefore, the terminal speed of the steel ball with a radius of 3 mm is **3 cm/s**, which corresponds to option D.

Question81

The pressure inside a soap bubble A is 1.01 atmosphere and that in a soap bubble B is 1.02 atmosphere. The ratio of volume of bubble A to that of B is [Surrounding pressure $= 1$ atmosphere]

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Options:

A. 101 : 102

B. 102 : 101

C. 8 : 1

D. 2 : 1

Answer: C

Solution:

The pressure difference between the inside and outside of a soap bubble is given by the formula:

$\Delta P = \frac{4T}{R}$

where:

ΔP is the pressure difference between the inside and outside of the bubble.

T is the surface tension of the soap film.

R is the radius of the bubble.

For bubble A, the pressure difference ΔP_A is:

$\Delta P_A = (1.01 - 1)\,\text{atm} = 0.01\,\text{atm}$

For bubble B, the pressure difference ΔP_B is:

$\Delta P_B = (1.02 - 1)\,\text{atm} = 0.02\,\text{atm}$

According to the formula, the radius of each bubble is inversely proportional to the pressure difference:

$R_A = \frac{4T}{0.01}$

$R_B = \frac{4T}{0.02}$

To find the ratio of the volumes of the bubbles, we need to use the fact that the volume of a sphere (which is the shape of a bubble) is:

$V = \frac{4}{3}\pi R^3$

Thus, the ratio of the volumes V_A to V_B can be expressed in terms of the radii:

$\frac{V_A}{V_B} = \left(\frac{R_A}{R_B}\right)^3 = \left(\frac{0.02}{0.01}\right)^3 = 2^3 = 8$

Therefore, the ratio of the volume of bubble A to that of bubble B is:

$\boxed{8:1}$

The correct option is **C:** 8 : 1.

Question82

A liquid drop of density ' ρ ' is floating half immersed in a liquid of density ' d '. If ' T ' is the surface tension then the diameter of the liquid drop is ($\mathrm{g}=$ acceleration due to gravity)

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Options:

A. $\left[\frac{6\ \mathrm{T}}{g(2p-d)}\right]^{\frac{1}{2}}$

B. $\left[\frac{8\ \mathrm{T}}{3\ \mathrm{g}(2\rho-\mathrm{d})}\right]^{\frac{1}{2}}$

C. $\left[\frac{12\ \mathrm{T}}{\mathrm{g}(2\rho-\mathrm{d})}\right]^{\frac{1}{2}}$

D. $\left[\frac{3T}{g(2p-d)}\right]^{\frac{1}{2}}$

Answer: C

Solution:

$$\text{Surface Tension } = T \times 2\pi r$$

$$\frac{4}{3}\pi r^3 \rho g = 2\pi r T + \frac{1}{2} \times \frac{4}{3}\pi r^3 d g$$

$$\therefore \quad 2\pi r T = \frac{4}{3}\pi r^3 \rho g - \left(\frac{4}{3}\pi r^3 d g\right) \times \frac{1}{2}$$

$$2\pi T = \frac{4}{3}\pi r^2 g\left(\rho - \frac{d}{2}\right)$$

$$\therefore \quad r^2 = \frac{2\pi T}{\frac{4}{3}\pi g\left(\rho-\frac{d}{2}\right)}$$

$$\therefore \quad r^2 = \frac{3T}{g(2\rho-d)} \Rightarrow r = \sqrt{\frac{3T}{g(2\rho-d)}}$$

$$\text{Diameter } = 2r = \sqrt{\frac{12T}{g(2\rho-d)}}$$

Question83

A gardening pipe having an internal radius ' R ' is connected to a water sprinkler having ' n ' holes each of radius ' r '. The water in the pipe has a speed ' v '. The speed of water leaving the sprinkler is

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Options:

A. $\left(\frac{\mathrm{R}^2}{\mathrm{r}^2}\right)\mathrm{nV}$

B. $\frac{\mathrm{R}^2\mathrm{v}}{\mathrm{nr}^2}$

C. $\left(\frac{nr^2}{R^2}\right)V$

D. $\left(\frac{\mathrm{nR}^2}{\mathrm{r}^2}\right)\mathrm{V}$

Answer: B

Solution:

To determine the speed of water leaving the sprinkler, we can apply the principle of conservation of mass, also known as the continuity equation for incompressible fluids. According to this principle, the volumetric flow rate must be constant throughout the system. The flow rate can be expressed as the product of the cross-sectional area and the speed of the fluid.

Given:

Internal radius of the pipe: R

Speed of water in the pipe: v

Number of holes in the sprinkler: n

Radius of each hole: r

The cross-sectional area of the pipe is:

$A_{\text{pipe}} = \pi R^2$

The flow rate through the pipe is:

$Q_{\text{pipe}} = A_{\text{pipe}} \cdot v = \pi R^2 v$

The total cross-sectional area of the holes in the sprinkler is the sum of the areas of the n holes:

$A_{\text{holes}} = n \cdot \pi r^2$

Let v_s be the speed of water leaving the sprinkler. The flow rate out of the sprinkler is:

$Q_{\text{sprinkler}} = A_{\text{holes}} \cdot v_s = n \cdot \pi r^2 \cdot v_s$

By the continuity equation, the flow rate through the pipe is equal to the flow rate out of the sprinkler:

$\pi R^2 v = n \cdot \pi r^2 \cdot v_s$

Solving for v_s, we have:

$v_s = \frac{R^2 v}{n r^2}$

Therefore, the speed of water leaving the sprinkler is given by option B:

$\frac{\mathrm{R}^2\mathrm{v}}{\mathrm{nr}^2}$

Question84

The pressure inside two soap bubbles, (A) is 1.01 and that of (B) is 1.02 atmosphere respectively. The ratio of their respective radii (A to B) is (outside pressure $= 1$ atm.)

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Options:

A. 2 : 1

B. 4 : 1

C. 6 : 1

D. 8 : 1

Answer: A

Solution:

The pressure inside a soap bubble can be described by the formula:

$P = P_0 + \frac{4T}{r}$

where:

P is the internal pressure of the bubble,

P_0 is the external (atmospheric) pressure,

T is the surface tension of the soap solution,

r is the radius of the bubble.

Given:

For bubble A: $P_A = 1.01$ atm

For bubble B: $P_B = 1.02$ atm

$P_0 = 1$ atm

Using the formula for pressure inside a bubble, we have:

For bubble A:

$1.01 = 1 + \frac{4T}{r_A}$

Simplifying,

$\frac{4T}{r_A} = 0.01$

For bubble B:

$1.02 = 1 + \frac{4T}{r_B}$

Simplifying,

$\frac{4T}{r_B} = 0.02$

Now, divide the equations for bubble A and bubble B:

$\frac{r_B}{r_A} = \frac{0.02}{0.01}$

Therefore,

$\frac{r_B}{r_A} = 2$

The ratio of the radii $r_A : r_B$ is 1 : 2.

Hence, the ratio of their radii (A to B) is:

Option A: 2 : 1

Question85

A metal ball of radius 9×10^{-4} m and density 10^4 kg/m^3 falls freely under gravity through a distance ' h ' and enters a tank of water. Considering that the metal ball has constant velocity, the value of h is [coefficient of viscosity of water $= 8.1 \times 10^{-4}$pa $-$ s, g $= 10$ m/s^2 density of water $= 10^3$ kg/m^3]

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Options:

A. 20 m

B. 18 m

C. 15 m

D. 12 m

Answer: A

Solution:

Velocity of the ball when the ball hits the surface of water

$v = \sqrt{2gh}$ .... (i)

Terminal velocity of the ball,

$v = \frac{2}{9} r^2 g \frac{(P-\sigma)}{\eta}$ .... (ii)

Equating (i) and (ii),

$\sqrt{2gh} = \frac{2}{9} \frac{r^2 g}{\eta} (P - \sigma)$

Solving for h,

$h = \frac{2}{81} r^4 \left(\frac{P-\sigma}{\eta}\right)^2 g$

Substituting the given values in the above equation, we have

$h = \frac{2}{81} \times \left(9 \times 10^{-4}\right)^4 \times \left(\frac{10^4-10^3}{8.1 \times 10^{-4}}\right)^2 g = 20 \text{ m}$

Question86

Liquid drops are falling slowly one by one from vertical glass tube. The relation between the weight of a drop ' w ', the surface tension ' T ' and the radius ' r ' of the bore of the tube is (Angle of contact is zero)

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Options:

A. $W = \pi r^2 T$

B. $W = 2\pi^2 rT$

C. $W = \left(\frac{4}{3}\right)\pi^2 rT$

D. $W = 2\pi rT$

Answer: D

Solution:

When liquid drops are falling from a vertical tube with an angle of contact of zero, the relation between the weight of a drop w, the surface tension T, and the radius r of the tube's bore can be determined using the concept of force balance at the detachment of a drop.

For the drop to detach, the weight of the drop must be balanced by the surface tension force acting around the circumference of the tube. The surface tension force F can be given by:

$F = 2\pi rT$

Here, r is the radius of the tube and T is the surface tension of the liquid. Thus, the weight of the drop w, which is balanced by the surface tension force, is:

$w = 2\pi rT$

Therefore, the correct relationship is given by:

Option D: $\mathrm{W} = 2\pi rT$

Question87

A ball rises to surface at a constant velocity in liquid whose density is 4 times greater than that of the material of the ball. The ratio of the force of friction acting on the rising ball and its weight is

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Options:

A. 3 : 1

B. 4 : 1

C. 1 : 3

D. 1 : 4

Answer: A

Solution:

Frictional force $=$ Viscous Force $= V\left(\rho_1 - \rho_2\right)g$

Weight $= \mathrm{mg} = \mathrm{V} \rho_1 \mathrm{~g}$

Where ρ_1 is the density of ball and ρ_2 is density of liquid.

$$\begin{aligned} & \rho_2 = 4\rho_1 \quad \text{... (given)} \\ \therefore \quad V \quad & V(\rho_1 - 4\rho_1)g = V(-3\rho_1)g \\ & \text{Frictional force } = 3V(\rho_1 g) \\ \therefore \quad & \frac{\text{Frictional force}}{\text{Weight}} = \frac{3}{1} = 3:1 \text{ ratio} \end{aligned}$$

Question88

A drum of radius ' R ' full of liquid of density ' d ' is rotated at angular velocity ' ω ' $\mathrm{rad/s}$. The increase in pressure at the centre of the drum will be

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Options:

A. $\frac{\omega^2 R^2 d}{2}$

B. $\frac{\omega^2 \mathrm{Rd}}{2}$

C. $\frac{\omega \mathrm{Rd}^2}{2}$

D. $\frac{\omega^2 R^2 d^2}{2}$

Answer: A

Solution:

$$\begin{aligned} & P_1 + \frac{1}{2}\rho v^2 + \rho g h = \text{ constant } \quad \text{.... (i)} \\ & \text{and } v = R\omega \\ & \text{At centre } R = 0 \Rightarrow v_1 = 0 \quad \text{.... (ii)} \\ \therefore \quad & \text{From (i),} \end{aligned}$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h = P_2 + \frac{1}{2}\rho v_1^2 + \rho g h$$

$$P_1 + 0 = P_2 + \frac{1}{2}\rho v_1^2 \quad \text{... [From (ii)]}$$

$$\therefore \quad P_1 = P_2 + \frac{1}{2}\rho (R\omega)^2$$

$$\therefore \quad P_1 - P_2 = \frac{\omega^2 R^2 d}{2} \quad \ldots (\because \rho = d)$$

Question89

A streamline flow of a liquid of density ' ρ ' is passing through a horizontal pipe of crosssectional area A_1 and A_2 at two ends. If the pressure of liquid is ' P ' at a point where flow speed is ' v ', then pressure at another point where the flow of speed becomes 3 v is

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Options:

A. P $- \frac{3}{4}\rho v^2$

B. P $- 2\rho \mathrm{v}^2$

C. P $- 3\rho \mathrm{v}^2$

D. P $- 4\rho \mathrm{v}^2$

Answer: D

Solution:

Using Bernoulli's equation,

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho \mathrm{gh}_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2 \quad \text{...(given horizontal pipe)}$$

Substituting the given values,

$$P+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho(3v)^2$$

$$P_2=P+\left(\frac{1}{2}\rho v^2-\frac{9}{2}\rho v^2\right)=P-4\rho v^2$$

Question90

The pressure inside a soap bubble A is 1.01 atmosphere and that in a soap bubble B is 1.02 atmosphere. The ratio of volume of A to that of B is

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Options:

A. 2 : 1

B. 8 : 1

C. 101 : 102

D. 102 : 101

Answer: B

Solution:

Outside pressure $=1$ atm

Pressure inside soap bubble $\mathrm{A}=1.01$ atm

Pressure inside soap bubble $B=1.02$ atm

$\therefore$ Excess pressures will be

$\Delta \mathrm{P}_{\mathrm{A}}=1.01-1=0.01$ atm and
$\Delta \mathrm{P}_{\mathrm{B}}=1.02-1=0.02$ atm

Now, $\Delta \mathrm{P} \propto \frac{1}{\mathrm{r}} \Rightarrow \mathrm{r} \propto \frac{1}{\Delta \mathrm{P}}$

$$\therefore \quad \frac{r_A}{r_B}=\frac{\Delta P_B}{\Delta P_A}=\frac{0.02}{0.01}=\frac{2}{1}$$

Now, $V=\frac{4}{3}\pi r^3$

$\Rightarrow V \propto r^3$

$$\therefore \quad \frac{V_A}{V_B}=\left(\frac{r_A}{r_B}\right)^3=\left(\frac{2}{1}\right)^3=\frac{8}{1}$$

Question91

Glycerine of density $1.25\times10^3\ \mathrm{kg/m^3}$ is flowing in conical shaped horizontal pipe. Crosssectional area of the pipe at its both ends is $10\ \mathrm{cm}^2$ and $5\ \mathrm{cm}^2$ respectively. Pressure difference at both the ends is $3\ \mathrm{N/m^2}$. Rate of flow of liquid in the pipe is

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Options:

A. $4\times10^{-5}\ \mathrm{m^3/s}$

B. $2\times10^{-5}\ \mathrm{m^3/s}$

C. $5\times10^{-5}\ \mathrm{m^3/s}$

D. $6\times10^{-5}\ \mathrm{m^3/s}$

Answer: A

Solution:

Using Bernoulli's equation,

Using Bernoulli's equatuon,

$$P_1+\frac{1}{2}\rho v_1^2+\rho g h_1=P_2+\frac{1}{2}\rho v_2^2+\rho g h_2$$

$$P_1+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho v_2^2$$

$$P_1-P_2=\frac{1}{2}\left(\rho v_2^2-\rho v_1^2\right)$$

$$v_2^2-v_1^2=\frac{2\times3}{1.25\times10^3}=4.8\times10^{-3} \quad \ldots.\text{(i)}$$

From equation of continuity,

$$A_1 v_1 = A_2 V_2$$
$$\frac{v_1}{V_2} = \frac{A_2}{A_1} = \frac{5}{10} = 0.5$$
$$v_1 = 0.5 v_2 \quad .... \text{(ii)}$$

Substituting (ii) into (i),

$$0.75 v_2^2 = 4.8 \times 10^{-3} \Rightarrow v_2 = 0.08 \mathrm{~m/s}$$
$$\begin{aligned} \text{Rate of flow of glycerine } &= A_2 v_2 \\ &= 5 \times 10^{-4} \times 0.08 \\ &= 4 \times 10^{-5} \mathrm{~m}^3/\mathrm{s} \end{aligned}$$

Question92

Two spherical soap bubbles of radii 'a' and 'b' in vacuum coalesce under isothermal conditions. The resulting bubble has a radius equal to

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Options:

A. $a+b$

B. $\frac{a+b}{2}$

C. $\sqrt{a^2+b^2}$

D. $\frac{a+b}{ab}$

Answer: C

Solution:

Number of moles is conserved, so

$$P_1 V_1 + P_2 V_2 = P_3 V$$

But, $P = \frac{4T}{r}$ where, r is the radius of the bubble

$$\therefore \quad \frac{4\,T}{a}\left(\frac{4}{3}\pi a^3\right)+\frac{4\,T}{b}\left(\frac{4}{3}\pi b^3\right)=\frac{4\,T}{c}\left(\frac{4}{3}\pi c^3\right)$$

$$a^2+b^2=c^2$$

$$c=\sqrt{a^2+b^2}$$

Question93

1000 small water drops of equal size combine to form a big drop. The ratio of final surface energy to the total initial surface energy is

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Options:

A. 10 : 1

B. 1 : 10

C. 1000 : 1

D. 1 : 1000

Answer: B

Solution:

To solve this problem, we need to understand the relationship between the surface energy of a drop and its radius.The surface energy E of a drop is proportional to its surface area A. The surface area of a sphere (which is the shape of a water drop) can be calculated using the formula:

$A = 4\pi r^2$

where r is the radius of the sphere. The surface energy is then given by:

$E = \sigma A = \sigma 4\pi r^2$

where σ is the surface tension of the liquid.When 1000 small drops combine to form one large drop, the volume of the large drop is equal to the sum of the volumes of the small drops. The volume of a sphere is given by

$V = \frac{4}{3}\pi r^3$

If the radius of each small drop is r, the total volume of the small drops is $1000 \times \frac{4}{3}\pi r^3$. Let the radius of the large drop be R. Then,

$1000 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$

Canceling common terms and taking the cube root of both sides, we get

$1000^{1/3} \times r = R$

Since $1000 = 10^3$, the cube root of 1000 is 10.

$10 \times r = R$

So the radius of the large drop is ten times the radius of each small drop.

Now we can compare the initial surface energy of all small drops with the final surface energy of the large drop. Let's denote the initial surface energy as E_{initial} and the final surface energy as E_{final}.

$E_{\text{initial}} = 1000 \times \sigma 4\pi r^2 E_{\text{final}} = \sigma 4\pi R^2$

Substituting $R = 10r$ into the final energy equation, we get:

$E_{\text{final}} = \sigma 4\pi(10r)^2 E_{\text{final}} = \sigma 4\pi(100r^2) E_{\text{final}} = 100\sigma 4\pi r^2$

Now, we compare the final energy to the initial energy:

$\frac{E_{\text{final}}}{E_{\text{initial}}} = \frac{100\sigma 4\pi r^2}{1000\sigma 4\pi r^2} \frac{E_{\text{final}}}{E_{\text{initial}}} = \frac{100}{1000} \frac{E_{\text{final}}}{E_{\text{initial}}} = \frac{1}{10}$

Hence, the ratio of the final surface energy to the total initial surface energy is $1 : 10$. Therefore, the correct answer is:

Option B$1 : 10$

Question94

It is easier to spray water to which soap is added because addition of soap to water

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Options:

A. decreases surface tension of water

B. increases surface tension of water.

C. makes surface tension of water zero.

D. increases its density.

Answer: A

Solution:

The correct answer is **A) decreases surface tension of water**

Surface Tension

- Water molecules are attracted to each other due to cohesive forces.
- At the surface of the water, there's an imbalance of force because there are no water molecules above to create attraction.
- This results in a net inward force, causing the surface to behave like a stretched membrane – this is surface tension.

Effect of Soap

- Soap molecules have a hydrophilic (water-loving) head and a hydrophobic (water-hating) tail.
- When soap is added to water, the hydrophobic tails disrupt the cohesive forces between water molecules at the surface.
- This reduces the net inward force, decreasing the surface tension.

Why it's easier to spray

- Spraying creates tiny droplets of water, which increases the surface area significantly.
- High surface tension would require extra energy to overcome the cohesive forces and create those droplets.
- Soap, by reducing surface tension, makes this process easier, requiring less energy for spraying.

The other options are incorrect:

- **B) increases surface tension of water:** This would make it harder to spray.
- **C) makes surface tension of water zero:** While surfactants reduce surface tension significantly, they don't reduce it to zero.
- **D) increases its density:** Density isn't directly related to ease of spraying in this context.

Question95

By adding soluble impurity in a liquid, angle of contact

Options:

A. decreases

B. increases

C. remains unchanged

D. first increases and then decreases

Answer: A

Solution:

The angle of contact, also known as the contact angle, is the angle at which a liquid/vapor interface meets the solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation:

$\cos(\theta) = \frac{\sigma_{SG} - \sigma_{SL}}{\sigma_{LG}}$

where:

- θ is the contact angle
- σ_{SG} is the interfacial tension between the solid and gas
- σ_{SL} is the interfacial tension between the solid and liquid
- σ_{LG} is the interfacial tension between the liquid and gas

When a soluble impurity is added to a liquid, it affects the surface tension of the liquid-gas interface (σ_{LG}). If the solute has a surface-active property, meaning it tends to accumulate at the surface, it typically reduces the surface tension of the liquid.

A lower σ_{LG} (surface tension of the liquid) influences the balance of forces and consequently could decrease the contact angle if the impurity does not significantly affect the solid-liquid and solid-gas interfacial tensions. A decreased contact angle means the liquid spreads out more on the surface, leading to better wetting.

So, when considering the effects of a soluble impurity in a liquid, and assuming the impurity is surface-active and does not significantly affect the solid-liquid and solid-gas interfacial tensions, the correct answer is:

Option A: decreases

This is because the addition of the impurity decreases the surface tension of the liquid, typically resulting in a smaller contact angle and increased wetting.

Question96

The potential energy of a molecule on the surface of a liquid compared to the molecules inside the liquid is

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Options:

A. zero

B. less

C. same

D. large

Answer: D

Solution:

The potential energy of a molecule on the surface of a liquid is higher compared to the molecules inside the liquid. This is because molecules on the surface are not surrounded by as many neighboring molecules as those inside, meaning they experience fewer attractive forces. Hence, the correct answer is :

Option D :large

Question97

Water rises in a capillary tube of radius 'r' upto a height 'h'. The mass of water in a capillary is 'm'. The mass of water that will rise in a capillary tube of radius $\frac{'r'}{3}$ will be

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Options:

A. 3 m

B. $\frac{\mathrm{m}}{3}$

C. m

D. $\frac{2 \mathrm{~m}}{3}$

Answer: B

Solution:

The rise of water in a capillary tube is due to capillary action, which is described by the formula:

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

where:

h is the height of the liquid column,

T is the surface tension of the liquid,

θ is the contact angle,

ρ is the density of the liquid,

g is the acceleration due to gravity, and

r is the radius of the capillary tube.

When water rises in the capillary, the volume of water raised is given by the volume of the cylinder:

$V=\pi r^2 h$

The mass of water in the tube is given by:

$m=\rho V=\rho\left(\pi r^2 h\right)$

Substitute the expression for h into this equation:

$m=\rho\left(\pi r^2 \frac{2 T \cos \theta}{\rho g r}\right)=\frac{2 \pi T \cos \theta r}{g}$

Now, for another capillary tube with radius $\frac{r}{3}$, the corresponding mass $m^{\prime}$ is:

$m^{\prime}=\frac{2 \pi T \cos \theta\left(\frac{r}{3}\right)}{g}=\frac{2 \pi T \cos \theta r}{3 g}$

Thus, the ratio of the new mass $m^{\prime}$ to the original mass m is:

$\frac{m^{\prime}}{m}=\frac{\frac{2 \pi T \cos \theta r}{3 g}}{\frac{2 \pi T \cos \theta r}{g}}=\frac{1}{3}$

Therefore, the mass of water that will rise in the capillary tube of radius $\frac{r}{3}$ is $\frac{m}{3}$.

Option B: $\frac{\mathrm{m}}{3}$

Question98

There is hole of area A at the bottom of a cylindrical vessel. Water is filled to a height h and water flows out in t second. If water is filled to a height $4h$, it will flow out in time (in second)

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Options:

A. t

B. $4t$

C. $2t$

D. $t/4$

Answer: C

Solution:

$\because$ We know that, time required to empy the tank is

$t=\frac{A}{A_0}\sqrt{\frac{2H}{g}}$

and $t \propto \sqrt{H}$

$\therefore \quad \frac{t_2}{t_1}=\sqrt{\frac{H_2}{H_1}}$ .... (i)

and we know that (given data)

$H_1=h$ and $t_1=t$
$H_2=4h$ and $t_2=?$

Put H_1 and H_2 value in Eq. (i), we get

$$\begin{aligned} & \frac{t_2}{t_1}=\sqrt{\frac{4h}{h}}=\sqrt{4}=2 \\ \Rightarrow \quad & \frac{t_2}{t}=2 \Rightarrow t_1=2t \end{aligned}$$

Question99

If work done in blowing a soap bubble of volume V is W, then the work done in blowing the bubble of volume 2 V from same soap solution is

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Options:

A. $W/2$

B. $\sqrt{2}$ W

C. $(2)^{1/3} W$

D. $(4)^{1/3} W$

Answer: D

Solution:

Work done in blowing a soap bubble, $W =$ Surface Tension $\times$ change in area

$\Rightarrow \quad T \times \Delta A$

As, we know that,

$V = \frac{4}{3}\pi r^3$

and $A = 4\pi r^2$

$\Rightarrow \quad A \propto (V)^{\frac{2}{3}}$

or $\quad \Delta A \propto (\Delta V)^{\frac{2}{3}}$

According to the question,

$$\frac{W_1}{W_2} = \frac{\Delta A_1}{\Delta A_2} = \left(\frac{\Delta V_1}{\Delta V_2}\right)^{2/3}$$

$$\Rightarrow \quad W_2 = W_1\left(\frac{2V}{V}\right)^{2/3} = W \cdot (2)^{\frac{2}{3}} = (4)^{\frac{1}{3}} \cdot W$$

Question100

A large number of water droplets each of radius 't' combine to form a large drop of Radius 'R'. If the surface tension of water is 'T' & mechanical equivalent of heat is 'J' then the rise in temperature due to this is

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Options:

A. $\frac{2 \mathrm{~T}}{\mathrm{rJ}}$

B. $\frac{3 \mathrm{~T}}{\mathrm{RJ}}$

C. $\frac{3T}{J}\left(\frac{1}{r}-\frac{1}{R}\right)$

D. $\frac{2 \mathrm{~T}}{\mathrm{J}}\left(\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right)$

Answer: C

Solution:

Radius of each droplet = r

Radius of the drop = R

As volume remains constant,

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

$$\therefore \quad \mathrm{n}=\frac{\mathrm{R}^3}{\mathrm{r}^3}$$

Decrease in surface area $=4 \pi r^2 n-4 \pi R^2 n$

$$\begin{aligned} \Delta \mathrm{A} & =4 \pi\left[\mathrm{nr}^2-\mathrm{R}^2\right] \\ & =4 \pi\left[\frac{\mathrm{R}^3}{\mathrm{r}^3} \mathrm{r}^2-\mathrm{R}^2\right] \\ & =4 \pi \mathrm{R}^3\left[\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right] \end{aligned}$$

Energy released $\mathrm{W}=\mathrm{T} \times \Delta \mathrm{T}$

$=\mathrm{T} \times 4 \pi \mathrm{R}^3\left[\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right]$ ..... (i)

Heat produced $\mathrm{Q}=\frac{\mathrm{W}}{\mathrm{J}}$ ..... (ii)

$Q = m \cdot s \cdot \Delta\theta$

Put (i) and (iii) into (ii)

$$m \cdot S\Delta\theta = \frac{4\pi R^3 T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\frac{4}{3}\pi R\rho_{\text{water}} \quad S_{\text{water}} \quad \Delta\theta = \frac{4\pi R^3 T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

$$\Delta Q = \frac{3T}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$$

Question101

Twenty seven droplets of water each of radius 0.1 mm merge to form a single drop then the energy released is

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Options:

A. 1.6×10^{-3} J

B. 1.6 J

C. 1600 J

D. 1.6×10^{-7} J

Answer: D

Solution:

To determine the energy released when 27 droplets merge into a single droplet, consider the surface energy. The surface energy change happens due to the change in surface area when droplets coalesce.

Calculate the initial total volume of droplets:

The volume of a single droplet of radius $r = 0.1 \text{ mm} = 0.1 \times 10^{-3}$ m is given by:

$$V_{\text{droplet}} = \frac{4}{3}\pi r^3$$

Therefore, the total initial volume of 27 droplets is:

$$V_{\text{total}} = 27 \times \frac{4}{3}\pi(0.1 \times 10^{-3})^3$$

$V_{\text{total}} = \frac{4}{3}\pi(27 \times 10^{-9})\text{m}^3$

Calculate the radius of the final large droplet:

Since volume is conserved, the volume of the large droplet V_{large} is:

$V_{\text{large}} = V_{\text{total}} = \frac{4}{3}\pi R^3$

Equate the volumes:

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi(27 \times 10^{-9})$

Solve for R:

$R^3 = 27 \times 10^{-9}$

$R = 3 \times 10^{-3}\,\text{m}$

Surface area calculations:

Initial surface area of 27 small droplets:

$A_{\text{initial}} = 27 \times 4\pi r^2 = 27 \times 4\pi(0.1 \times 10^{-3})^2$

$A_{\text{initial}} = 27 \times 4\pi(10^{-8})\text{m}^2$

Final surface area of the large droplet:

$A_{\text{final}} = 4\pi R^2 = 4\pi(3 \times 10^{-3})^2$

$A_{\text{final}} = 4\pi(9 \times 10^{-6})\text{m}^2$

Energy released (due to surface area change):

The surface tension (σ) of water is approximately $0.072\,\text{J/m}^2$.

Change in surface energy:

$\Delta E = \sigma(A_{\text{initial}} - A_{\text{final}})$

Plug in the values:

$A_{\text{initial}} = 108\pi \times 10^{-8}\text{m}^2$

$A_{\text{final}} = 36\pi \times 10^{-6}\text{m}^2$

Therefore:

$\Delta E = 0.072(108\pi \times 10^{-8} - 36\pi \times 10^{-6})$

Convert to common units and simplify:

$\Delta E = 0.072 \times 72\pi \times 10^{-8}\,\text{J}$

$\Delta E = 0.072 \times 72 \times 3.1416 \times 10^{-8}\,\text{J}$

$\Delta E = 0.016 \times 10^{-3} \times \pi\,\text{J}$

$\Delta E \approx 1.6 \times 10^{-7}$ J

Thus, the energy released when the droplets merge to form a single drop is approximately

Option D: 1.6×10^{-7} J.

Question102

Venturimeter is used to

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Options:

A.

measure liquid pressure.

B.

measure liquid density.

C.

measure rate of flow of liquids.

D.

measure surface tension.

Answer: C

Solution:

The primary function of a Venturimeter is to measure the rate of flow of liquids. Therefore, the correct option is:

Option C: measure rate of flow of liquids.

Explanation

A Venturimeter is a device that utilizes the principles of fluid dynamics to measure the flow rate of a liquid through a pipe. It works based on the Bernoulli's equation and the principle of continuity.

Components

Inlet Section: This is the section where the liquid enters. It is generally wider.

Throat: The narrowest part of the Venturimeter where the velocity of the fluid increases and pressure decreases.

Outlet Section: The section where the liquid exits, returning to its original diameter.

Working Principle

Bernoulli's Equation: According to Bernoulli's principle, the sum of pressure energy, kinetic energy, and potential energy per unit volume remains constant for a streamline flow.

$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$

Here, P is the pressure, ρ is the density of the liquid, v is the velocity, and h is the height of the fluid column.

Continuity Equation: The principle of conservation of mass as applied to fluid flow can be expressed as:

$A_1 v_1 = A_2 v_2$

where A represents the cross-sectional area and v represents the velocity.

Application

When the fluid passes through the throat, its velocity increases, causing a drop in pressure. By measuring the pressure difference between the inlet and the throat, and knowing the dimensions of the Venturimeter, the flow rate can be calculated using the above equations.

This method is widely used for its accuracy and reliability in various industrial applications, including water supply systems, chemical factories, and oil refineries.

Question103

The fundamental frequency of a sonometer wir carrying a block of mass 'M' and density 'ρ' is 'n' Hz. When the block is completely immerse in a liquid of density 'σ' then the new frequency will be

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Options:

A. n$\left[\frac{\rho-\sigma}{\rho}\right]^{\frac{1}{2}}$

B. $n\left[\frac{\rho-\sigma}{\sigma}\right]^{\frac{1}{2}}$

C. $n\left[\frac{\rho}{\rho-\sigma}\right]^{\frac{1}{2}}$

D. $n\left[\frac{\sigma}{\rho-\sigma}\right]^{\frac{1}{2}}$

Answer: A

Solution:

When a block of mass M is attached to a sonometer wire, the fundamental frequency n is given by:

$$n=\frac{1}{2L}\sqrt{\frac{T}{\mu}}$$

where T is the tension in the wire, L is the length of the vibrating segment of the wire, and μ is the linear mass density of the wire.

The tension T is due to the weight of the block, so initially,

$$T=Mg$$

where g is the acceleration due to gravity.

When the block is completely immersed in a liquid of density σ, the effective weight, and hence the tension, is reduced due to the buoyant force. The new tension T' is given by:

$$T'=Mg-V\sigma g$$

where V is the volume of the block. Given the density ρ and mass M of the block, we have:

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

Thus, the new tension is:

$$T'=Mg-\frac{M}{\rho}\sigma g=Mg\left(1-\frac{\sigma}{\rho}\right)$$

The new frequency n' with the reduced tension is:

$$n'=\frac{1}{2L}\sqrt{\frac{T'}{\mu}}$$

Substituting the expression for T', we get:

$$n'=\frac{1}{2L}\sqrt{\frac{Mg(1-\frac{\sigma}{\rho})}{\mu}}$$

Comparing with the original frequency formula,

$$n'=n\sqrt{1-\frac{\sigma}{\rho}}$$

Therefore, the correct option for the new frequency when the block is immersed is:

Option A

$n\left[\frac{\rho-\sigma}{\rho}\right]^{\frac{1}{2}}$

Question104

Eight small drops of mercury each of radius 'r', coalesce to form a large single drop. The ratio of total surface energy before and after the change is

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Options:

A. 2 : 1

B. 1 : 1

C. 1 : 4

D. 1 : 8

Answer: A

Solution:

When mercury drops coalesce to form a larger drop, the volume is conserved. The total initial volume of the eight small drops is equal to the final volume of the large single drop.

For a single small drop with radius r, its volume is:

$V_{\text{small}} \quad = \frac{4}{3}\pi r^3$

For eight such drops, the total initial volume is:

$V_{\text{initial}} \quad = 8 \times \frac{4}{3}\pi r^3 = \frac{32}{3}\pi r^3$

Let the radius of the large drop be R. Since the volume is conserved:

$V_{\text{large}} \quad = \frac{4}{3}\pi R^3 = \frac{32}{3}\pi r^3$

Equating the volumes:

$\frac{4}{3}\pi R^3 = \frac{32}{3}\pi r^3$

Solving for R gives:

$R^3 = 8r^3 \implies R = 2r$

The total surface energy of the drops depends on the surface area and the surface tension (σ). The formula for surface energy is:

$\text{Surface Energy} = \sigma \times \text{Surface Area}$

The surface area of a single small drop is:

$A_{\text{small}} = 4\pi r^2$

The total initial surface area of the eight small drops is:

$A_{\text{initial}} = 8 \times 4\pi r^2 = 32\pi r^2$

The surface area of the large drop is:

$A_{\text{large}} = 4\pi R^2 = 4\pi(2r)^2 = 16\pi r^2$

Thus, the initial total surface energy of the small drops is:

$E_{\text{initial}} = \sigma \times 32\pi r^2$

The surface energy of the large drop is:

$E_{\text{large}} = \sigma \times 16\pi r^2$

The ratio of the total surface energy before and after the amalgamation is:

$\frac{E_{\text{initial}}}{E_{\text{large}}} = \frac{\sigma \times 32\pi r^2}{\sigma \times 16\pi r^2} = \frac{32}{16} = 2$

Therefore, the ratio is:

Option A: 2 : 1

Question105

A spherical metal ball of radius 'r' falls through viscous liquid with velocity 'V'. Another metal ball of same material but of radius $\left(\frac{r}{3}\right)$ falls through same liquid, then its terminal velocity will be

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Options:

A. $\frac{\mathrm{V}}{3}$

B. $\frac{V}{4}$

C. $\frac{\mathrm{V}}{6}$

D. $\frac{V}{9}$

Answer: D

Solution:

The terminal velocity of a sphere falling through a viscous fluid is governed by Stokes' law, which states that:

$V = \frac{2}{9} \frac{r^2(\rho-\sigma)g}{\eta}$,

where:

V is the terminal velocity,

r is the radius of the sphere,

ρ is the density of the sphere,

σ is the density of the fluid,

g is the acceleration due to gravity,

η is the dynamic viscosity of the fluid.

Given that the original ball has a radius r and terminal velocity V, for the smaller ball with radius $\frac{r}{3}$, the terminal velocity V' can be calculated by substituting the new radius into the equation:

$V' = \frac{2}{9} \frac{\left(\frac{r}{3}\right)^2(\rho-\sigma)g}{\eta}$.

Simplifying, we get:

$V' = \frac{2}{9} \frac{\frac{r^2}{9}(\rho-\sigma)g}{\eta}$.

This can be further reduced to:

$V' = \frac{1}{9}\left(\frac{2}{9} \frac{r^2(\rho-\sigma)g}{\eta}\right)$.

Recognizing that the term in the parentheses is the expression for the original terminal velocity V, we find:

$V' = \frac{1}{9}V$.

Therefore, the terminal velocity of the smaller ball is:

Option D: $\frac{V}{9}$

Question106

Select the WRONG statement from the following. In a streamline flow

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Options:

A. velocity of a fluid at a given point is never constant.

B. velocity is smaller than critical velocity.

C. layers are always parallel.

D. the particles do not move in random direction.

Answer: A

Solution:

In a streamline flow, the WRONG statement is:

Option A: Velocity of a fluid at a given point is never constant.

In streamline or laminar flow, the velocity of the fluid at a given point is typically constant over time. This is characterized by smooth and orderly fluid motion, where layers of fluid flow parallel to each other without mixing.

Question107

Consider a soap film on a rectangular frame of wire of area $3 \times 3 \mathrm{~cm}^2$. If the area of the soap film is increased to $5 \times 5 \mathrm{~cm}^2$, the work done in the process will be (surface tension of soap solution is $2.5 \times 10^{-2} \mathrm{~N} / \mathrm{m}$)

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Options:

A. $9 \times 10^{-6} \mathrm{~J}$

B. 16×10^{-6} J

C. 40×10^{-6} J

D. 80×10^{-6} J

Answer: D

Solution:

$$A_1 = 9 \times 10^{-4} \text{ m}^2, \ A_2 = 25 \times 10^{-4} \text{ m}^2$$
$$T = 2.5 \times 10^{-2} \text{ N/m}$$

Work done,

$$W = 2\,T\Delta A = 2 \times 2.5 \times 10^{-2} \times (25 - 9) \times 10^{-4}$$
$$W = 80 \times 10^{-6} \text{ J}$$

The rectangular frame has two surfaces. Hence, the formula for work done contains the factor of ' 2 '.

Question108

A spherical drop of liquid splits into 1000 identical spherical drops. If 'E_1' is the surface energy of the original drop and 'E_2' is the total surface energy of the resulting drops, then $\frac{E_1}{E_2} = \frac{x}{10}$. Then value of '$x$' is

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Options:

A. 9

B. 7

C. 3

D. 1

Answer: D

Solution:

To solve this problem, consider the following steps:

Let R be the radius of the original spherical drop, and let r be the radius of each of the resulting smaller spherical drops.

Since the volume is conserved during the splitting process, the volume of the original drop must equal the total volume of the smaller drops:

$\frac{4}{3}\pi R^3 = 1000 \cdot \frac{4}{3}\pi r^3$

Simplifying gives:

$R^3 = 1000r^3$

$R = 10r$

The surface energy E is proportional to the surface area. Thus, we calculate the surface energy for the original and smaller drops:

Surface area of the original drop:

$A_1 = 4\pi R^2$

Surface energy of the original drop:

$E_1 = \sigma \cdot 4\pi R^2$

where σ is the surface tension.

For the 1000 smaller droplets:

Surface area of one small drop:

$A_2 = 4\pi r^2$

Total surface area for 1000 drops:

$1000 \cdot 4\pi r^2 = 4000\pi r^2$

Total surface energy for 1000 drops:

$E_2 = \sigma \cdot 4000\pi r^2$

Substitute $R = 10r$ into the expression for E_1 and E_2:

$E_1 = \sigma \cdot 4\pi(10r)^2 = \sigma \cdot 4\pi \cdot 100r^2 = \sigma \cdot 400\pi r^2$

$E_2 = \sigma \cdot 4000\pi r^2$

Compute the ratio $\frac{E_1}{E_2}$:

$\frac{E_1}{E_2} = \frac{\sigma \cdot 400\pi r^2}{\sigma \cdot 4000\pi r^2} = \frac{400}{4000} = \frac{1}{10}$

From $\frac{E_1}{E_2} = \frac{x}{10}$, we find that $x = 1$.

Therefore, the value of x is:

Option D: 1

Question109

The excess pressure inside a first spherical drop of water is three times that of second spherical drop of water. Then the ratio of mass of first spherical drop to that of second spherical drop is

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Options:

A. 1 : 3

B. 1 : 6

C. 1 : 9

D. 1 : 27

Answer: D

Solution:

The excess pressure inside a spherical drop of water is given by the formula:

$P = \frac{2T}{r}$

where P is the excess pressure, T is the surface tension, and r is the radius of the drop.

Given that the excess pressure inside the first spherical drop is three times that of the second spherical drop, we can express this as:

$\frac{2T}{r_1} = 3 \times \frac{2T}{r_2}$

Simplifying, we find:

$\frac{1}{r_1} = 3 \times \frac{1}{r_2}$

This implies:

$r_2 = 3r_1$

The volume V of a spherical drop is given by:

$V = \frac{4}{3}\pi r^3$

Hence, the mass m of a spherical drop (assuming constant density ρ) is:

$m = \rho V = \rho\left(\frac{4}{3}\pi r^3\right)$

For the first drop:

$m_1 = \rho\left(\frac{4}{3}\pi r_1^3\right)$

For the second drop:

$m_2 = \rho\left(\frac{4}{3}\pi r_2^3\right) = \rho\left(\frac{4}{3}\pi(3r_1)^3\right)$

Simplifying m_2:

$m_2 = \rho\left(\frac{4}{3}\pi \cdot 27r_1^3\right) = 27\rho\left(\frac{4}{3}\pi r_1^3\right) = 27m_1$

Thus, the ratio of the mass of the first drop to the second drop is:

$\frac{m_1}{m_2} = \frac{1}{27}$

Therefore, the ratio of the mass of the first spherical drop to that of the second spherical drop is:

Option D

1 : 27

Question110

A liquid drop of radius 'R' is broken into 'n' identical small droplets. The work done is [T = surface tension of the liquid]

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Options:

A. $4\pi \mathrm{R}^2\left(\mathrm{n}^{\frac{2}{3}}-1\right)\mathrm{T}$

B. $4\pi R^2\left(n^{\frac{1}{3}}-1\right)T$

C. $4\pi R^2\left(1-n^{\frac{1}{3}}\right)T$

D. $4\pi \mathrm{R}^2\left(1-\mathrm{n}^{\frac{2}{3}}\right)\mathrm{T}$

Answer: B

Solution:

Volume of n smaller droplets $=$ Volume of bigger drop

$$\mathrm{n}\frac{4}{3}\pi\mathrm{r}^3 = \frac{4}{3}\pi\mathrm{R}^3$$

$$\therefore \quad \mathrm{R} = \mathrm{n}^{\frac{1}{3}} \cdot \mathrm{r}$$

$$\mathrm{r} = \frac{\mathrm{R}}{\mathrm{n}^{\frac{1}{3}}}$$

Work done

$$\begin{aligned} W &= \left[n \cdot 4\pi r^2 - 4\pi R^2\right] T \\ &= 4\pi\left[n \cdot \frac{R^2}{n^{\frac{2}{3}}} - R^2\right] T \\ &= 4\pi R^2\left[n^{\frac{1}{3}} - 1\right] T \end{aligned}$$

Question111

A fluid of density 'ρ' is flowing through a uniform tube of diameter 'd'. The coefficient of viscosity of the fluid is 'η', then critical velocity of the fluid is

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Options:

A. inversely proportional to 'η'

B. directly proportional to 'η'

C. directly proportional to 'd'

D. directly proportional to 'ρ'

Answer: B

Solution:

Let's break down the problem step by step.

In fluid dynamics, the flow in a tube is characterized by the Reynolds number, which is given by:

$\mathrm{Re} = \frac{\rho v d}{\eta}$

where:

ρ is the fluid density,

v is the average velocity,

d is the tube diameter, and

η is the coefficient of viscosity.

The flow transitions to turbulence when the Reynolds number exceeds a critical value (denoted as $\mathrm{Re}_{\text{crit}}$). For laminar flow in a pipe, $\mathrm{Re}_{\text{crit}}$ is around 2000.

To find the critical velocity v_{crit}, we set:

$\mathrm{Re}_{\text{crit}} = \frac{\rho\, v_{\text{crit}}\, d}{\eta}$

Rearranging for v_{crit}, we get:

$v_{\text{crit}} = \frac{\mathrm{Re}_{\text{crit}}\, \eta}{\rho\, d}$

From the expression above, notice the following relationships:

v_{crit} is directly proportional to η (if viscosity increases, so does the critical velocity).

v_{crit} is inversely proportional to ρ (if density increases, the critical velocity decreases).

v_{crit} is inversely proportional to d (if the diameter increases, the critical velocity decreases).

Now, let's look at the options:

Option A: Inversely proportional to η (This is incorrect. The critical velocity is directly proportional to η.)

Option B: Directly proportional to η (This is correct.)

Option C: Directly proportional to d (This is incorrect; it is inversely proportional to d.)

Option D: Directly proportional to ρ (This is incorrect; it is inversely proportional to ρ.)

Thus, the correct answer is:

Option B

Critical velocity is directly proportional to η.

Question112

What should be the diameter of a soap bubble, in order that the excess pressure inside it is $25.6\ \mathrm{Nm}^{-2}$? [surface tension of soap solution $= 3 \cdot 2 \times 10^{-2}\ \mathrm{Nm}^{-2}$]

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Options:

A. 2 cm

B. 1.5 cm

C. 1 cm

D. 0.5 cm

Answer: C

Solution:

The formula for excess pressure inside the bubble is given as $P_0 = \frac{4T}{R}$

Where, T is surface tension and R is the radius of the sphere

Rearranging the formula for R and substituting the values,

$$R = \frac{4T}{P_0}$$
$$R = \frac{4 \times 3.2 \times 10^{-2}}{25.6}$$
$$R = 0.5 \times 10^{-2} \text{ m} = 0.5 \text{ cm}$$

The diameter then becomes, 2R = 1 cm

Question113

Two capillary tubes of the same diameter are kept vertically in two different liquids whose densities are in the ratio $4:3$. The rise of liquid in two capillaries is 'h_1' and 'h_2' respectively. If the surface tensions of liquids are in the ratio $6:5$, the ratio of heights $\left(\frac{h_1}{h_2}\right)$ is

(Assume that their angles of contact are same)

Options:

A. 0.4

B. 0.5

C. 0.8

D. 0.9

Answer: D

Solution:

Given the problem, we have two capillary tubes with the same diameter, each immersed in different liquids.

Density Ratio:

The ratio of the densities of the two liquids is given as:

$\frac{\rho_1}{\rho_2} = \frac{4}{3}$

Surface Tension Ratio:

The ratio of the surface tensions of the two liquids is provided as:

$\frac{T_1}{T_2} = \frac{6}{5}$

Equation for Capillary Rise:

The capillary rise h in a tube is given by the formula:

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

Where:

T is the surface tension,

θ is the angle of contact,

ρ is the density,

g is the acceleration due to gravity, and

r is the radius of the tube.

In this scenario, since the angle of contact θ, the radius r, and g are constant, we simplify the formula to:

$h \propto \frac{T}{\rho}$

Ratio of Heights:

So, the ratio of the heights of the liquid columns in the capillaries $\frac{h_1}{h_2}$ is:

$\frac{h_1}{h_2}=\frac{T_1\rho_2}{T_2\rho_1}$

Substitute the given ratios into the equation:

$\frac{h_1}{h_2}=\frac{6\times3}{5\times4}=\frac{18}{20}=0.9$

Thus, the ratio of heights $\frac{h_1}{h_2}$ is 0.9.

Question114

A spherical liquid drop of radius R is divided into 8 equal droplets. If surface tension is S, then the work done in this process will be

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Options:

A. $2\pi R^2 S$

B. $3\pi\mathrm{R}^2\ \mathrm{S}$

C. $4\pi R^2 S$

D. $2\pi\mathrm{RS}^2$

Answer: C

Solution:

The work done when a spherical liquid drop of radius R is divided into 8 equal droplets can be calculated using the formula:

$W=S\times\Delta A$

where ΔA represents the change in surface area.

Initial Surface Area:

The initial surface area of the large drop is given by:

$A_{\text{initial}}=4\pi R^2$

Final Surface Area:

If the radius of each small drop is r, the final surface area of all 8 small drops combined is:

$A_{\text{final}} = 8 \times 4\pi r^2$

Volume Conservation:

The volume of the large drop is equal to the total volume of the smaller droplets, so:

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3$

Simplifying gives:

$R^3 = 8r^3 \quad \Rightarrow \quad R = 2r$

Calculate Work Done:

Substituting the values into the work done formula:

$W = S \times (A_{\text{final}} - A_{\text{initial}})$

$W = S \times \left(8 \times 4\pi r^2 - 4\pi R^2\right)$

Substitute $r = \frac{R}{2}$ into the equation:

$W = S \times \left(32\pi\left(\frac{R}{2}\right)^2 - 4\pi R^2\right)$

$W = S \times \left(8\pi R^2 - 4\pi R^2\right)$

$W = 4\pi R^2 S$

Thus, the work done in dividing the drop is $4\pi R^2 S$.

Question115

A body of density 'ρ' is dropped from rest at a height 'h' into a lake of density 'σ'$(\sigma > \rho)$. The maximum depth to which the body sinks before returning to float on the surface is (neglect air dissipative forces)

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Options:

A. $\frac{\text{h}\rho}{(\sigma-\rho)}$

B. $\frac{h\rho}{(\sigma+\rho)}$

C. $\frac{\mathrm{h} \rho}{(\rho-\sigma)}$

D. $\frac{2 \mathrm{~h} \rho}{(\sigma-\rho)}$

Answer: A

Solution:

The body (of mass $m=\rho V$) is dropped from a height h above the lake. Just before touching the water, its speed is given by energy conservation:

$\frac{1}{2} v^2=g h \quad \Longrightarrow \quad v=\sqrt{2 g h}.$

When it enters the lake (density σ) it is fully immersed. Two constant forces now act on it:

Its weight: $W=\rho V g$,

The buoyant force: $B=\sigma V g$.

Since $\sigma>\rho$, the buoyant force is greater than the weight, so after entry the net force acts upward. In fact, the net upward force is

$F_{\text {net }}=B-W=(\sigma V g-\rho V g)=(\sigma-\rho) V g.$

As the body sinks into the water, it will decelerate due to this net upward force. Its initial kinetic energy is

$K=\frac{1}{2} m v^2=\frac{1}{2}(\rho V)(2 g h)=\rho V g h.$

Let the additional distance the body sinks below the water surface be d (that is, the maximum extra immersion beyond the water level). As it sinks this extra distance, two contributions affect the energy:

The weight does positive work (adding energy) equal to $\rho V g d$,

The buoyant force does negative work (removing energy) equal to $\sigma V g d$.

Thus, the net work done while moving a distance d is

$W_{\text {net }}=(\rho V g-\sigma V g) d=-(\sigma-\rho) V g d.$

Note that this net work exactly opposes the kinetic energy gained before entering the water. At the point of maximum immersion, the body comes momentarily to rest. Therefore, equate the kinetic energy with the work done against the net force:

$\rho V g h=(\sigma-\rho) V g d.$

Solving for d:

$d=\frac{\rho V g h}{(\sigma-\rho) V g}=\frac{h \rho}{\sigma-\rho}.$

Thus, the maximum depth the body sinks into the lake is

$\boxed{\frac{h \rho}{\sigma-\rho}}.$

Comparing this with the given options, the correct one is Option A.

Question116

'n' number of liquid drops each of radius 'r' coalesce to form a single drop of radius 'R'. The energy released in the process is converted into the kinetic energy of the big drop so formed. The speed of the big drop is

$[\mathrm{T}=$ surface tension of liquid, $\rho=$ density of liquid.]

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Options:

A. $\sqrt{\frac{T}{\rho}\left[\frac{1}{r}-\frac{1}{R}\right]}$

B. $\sqrt{\frac{2 \mathrm{~T}}{\rho}\left[\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right]}$

C. $\sqrt{\frac{4 \mathrm{~T}}{\rho}\left[\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right]}$

D. $\sqrt{\frac{6 \mathrm{~T}}{\rho}\left[\frac{1}{\mathrm{r}}-\frac{1}{\mathrm{R}}\right]}$

Answer: D

Solution:

To determine the speed of a large drop formed by 'n' smaller liquid drops each with radius 'r' coalescing into a drop with radius 'R', where the energy released during the process converts to kinetic energy, follow these steps:

Volume Conservation:

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

Simplifying gives:

$R^3=n r^3$

Surface Energy Released:

The change in surface energy (ΔU) when the smaller droplets merge to form a bigger drop is:

$\Delta U = T \times 4\pi r^2 \times n - T \times 4\pi R^2$

Substituting $n = \frac{R^3}{r^3}$ leads to:

$\Delta U = T \times 4\pi \frac{R^3}{r} - T \times 4\pi R^2$

Kinetic Energy and Surface Energy Conversion:

The surface energy released is converted into kinetic energy (KE) of the big drop:

$\frac{1}{2}mv^2 = T \times 4\pi R^3 \left[\frac{1}{r} - \frac{1}{R}\right]$

Insert Mass of Large Drop:

$\frac{1}{2}\rho \times \frac{4}{3}\pi R^3 \times v^2 = T \times 4\pi R^3 \left[\frac{1}{r} - \frac{1}{R}\right]$

Solving for Speed v:

$v^2 = \frac{6T}{\rho}\left[\frac{1}{r} - \frac{1}{R}\right]$

Thus, the speed v of the larger drop becomes:

$v = \sqrt{\frac{6T}{\rho}\left[\frac{1}{r} - \frac{1}{R}\right]}$

Question117

At critical temperature, the surface tension of liquid is

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Options:

A. zero

B. infinity

C. unity

D. same as that at any other temperature

Answer: A

Solution:

At the critical temperature of a liquid, the surface tension becomes zero. This happens because at the critical temperature, the properties of the liquid and gas phases become indistinguishable, leading to the disappearance of the liquid-gas interface. Surface tension is a property that arises due to the difference in intermolecular forces between the liquid and gas phases. When these phases become indistinguishable at the critical point, there's no longer a distinct interface, and thus no surface tension.

Therefore, the correct answer is :

Option A : zero

Question118

A metal sphere of mass 'm' and density 'σ_1' falls with terminal velocity through a container containing liquid. The density of liquid is 'σ_2'. The viscous force acting on the sphere is

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Options:

A. $mg\left(1+\frac{\sigma_2}{\sigma_1}\right)$

B. $mg\left(1-\frac{\sigma_1}{\sigma_2}\right)$

C. $\mathrm{mg}\left(1-\frac{\sigma_2}{\sigma_1}\right)$

D. $mg\left(1+\frac{\sigma_1}{\sigma_2}\right)$

Answer: C

Solution:

Given: Mass of sphere $= m$, Density of sphere $= \sigma_1$, Density of liquid $= \sigma_2$.

At $= \mathrm{v} = \mathrm{v_t}$,

Weight of sphere $(\mathrm{W}) =$ Viscous Force $(\mathrm{F_V}) +$ Buoyant Force due to the medium $(\mathrm{F_B})$

$$\Rightarrow \mathrm{W} = \mathrm{F_V} + \mathrm{F_B}$$
$$\mathrm{Mg} = \mathrm{F_V} + (\sigma_2\ \mathrm{V})\mathrm{g} \quad \ldots.(\because \mathrm{m} = \mathrm{D.V})$$

$$\therefore \quad F_V = mg - (\sigma_2 \mathrm{V}) g$$
$$= mg\left[1 - \frac{\sigma_2 \mathrm{V}}{\mathrm{m}}\right]$$
$$= mg\left[1 - \frac{\sigma_2 \mathrm{V}}{\sigma_1 \mathrm{V}}\right]$$
$$= mg\left[1 - \frac{\sigma_2}{\sigma_1}\right]$$

Question119

Water flows through a horizontal pipe at a speed 'V'. Internal diameter of the pipe is 'd'. If the water is coming out at a speed 'V_1' then the diameter of the nozzle is

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Options:

A. $\mathrm{d}\sqrt{\frac{\mathrm{V}_1}{\mathrm{V}}}$

B. $\mathrm{d}\sqrt{\frac{\mathrm{V}}{\mathrm{V}_1}}$

C. $\frac{\mathrm{dV}}{\mathrm{V}_1}$

D. $\frac{\mathrm{V}_1}{\mathrm{dV}}$

Answer: B

Solution:

To find the diameter of the nozzle (d_n) from which water is exiting at speed V_1, we can use the equation of continuity, which states that the product of the cross-sectional area and velocity of a fluid remains constant along a streamline:

$A_1 \cdot V = A_2 \cdot V_1$

Here, A_1 is the cross-sectional area of the pipe, V is the speed of water in the pipe, A_2 is the cross-sectional area of the nozzle, and V_1 is the speed of water exiting from the nozzle.

Given that the cross-sectional area A of a circular pipe or nozzle is calculated using the formula:

$A = \frac{\pi d^2}{4}$

where d is the internal diameter of the pipe. Substituting this into the continuity equation gives:

$\frac{\pi d^2}{4} \cdot V = \frac{\pi d_n^2}{4} \cdot V_1$

We can simplify this equation by canceling out $\pi/4$ from both sides:

$d^2 \cdot V = d_n^2 \cdot V_1$

Rearranging to solve for d_n^2:

$d_n^2 = d^2 \cdot \frac{V}{V_1}$

Taking the square root of both sides gives us the diameter of the nozzle:

$d_n = d\sqrt{\frac{V}{V_1}}$

Question120

Three liquids have same surface tension and densities ρ_1, ρ_2, and ρ_3 $(\rho_1 > \rho_2 > \rho_3)$. In three identical capillaries rise of liquid is same. The corresponding angles of contact θ_1, θ_2 and θ_3 are related as

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Options:

A. $\theta_1 > \theta_2 > \theta_3$

B. $\theta_1 > \theta_3 > \theta_2$

C. $\theta_1 < \theta_2 < \theta_3$

D. $\theta_1 = \theta_2 = \theta_3$

Answer: C

Solution:

Rise in capillary tube,

$\mathrm{h} = \frac{2 \mathrm{~T} \cos \theta}{\mathrm{r} \rho \mathrm{g}}$

Given that, h, T, r and g are constant.

$$\therefore \quad \frac{\cos\theta}{\rho} = \text{constant}$$

$$\text{i.e.,} \frac{\cos\theta_1}{\rho_1} = \frac{\cos\theta_2}{\rho_2} = \frac{\cos\theta_3}{\rho_3}$$

as $\rho_1 > \rho_2 > \rho_3$

$\cos\theta_1 > \cos\theta_2 > \cos\theta_3$

$\therefore \quad \theta_1 < \theta_2 < \theta_3$

Question121

The height of liquid column raised in a capillary tube of certain radius when dipped in liquid 'A' vertically is 5 cm. If the tube is dipped in a similar manner in another liquid 'B' of surface tension and density double the values of liquid 'A', the height of liquid column raised in liquid 'B' would be (Assume angle of contact same)

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Options:

A. 0.20 m

B. 0.5 m

C. 0.05 m

D. 0.10 m

Answer: C

Solution:

The height of the liquid column in a capillary tube is given by the formula:

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

Given that the height of the liquid column for liquid A is $h_1 = 5$ cm.

For liquid B, which has double the surface tension and density of liquid A, we have:

$T_2 = 2T_1 \quad \text{and} \quad \rho_2 = 2\rho_1$

The height for liquid B, h_2, is calculated as:

$h_2 = \frac{2T_2 \cos\theta}{r\rho_2 g} = \frac{2(2T_1)\cos\theta}{r(2\rho_1)g} = \frac{4T_1 \cos\theta}{2r\rho_1 g}$

This simplifies to:

$\frac{h_1}{h_2} = \frac{2T_1 \cos\theta}{r\rho_1 g} \times \frac{r \cdot 2\rho_1 g}{4T_1 \cos\theta}$

This results in:

$\frac{5}{h_2} = 1$

Thus, the height of the liquid column for liquid B is:

$h_2 = 5\,\text{cm} = 0.05\,\text{m}$

Question122

A film of soap solution is formed between two straight parallel wires of length 10 cm each separated by 0.5 cm. If their separation is increased by 1 mm while still maintaining their parallelism. How much work will have to be done?

(surface tension of solution $= 65 \times 10^{-2}\text{ N/m}$)

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Options:

A. 7.22×10^{-6} J

B. 13.0×10^{-5} J

C. 2.88×10^{-5} J

D. 5.76×10^{-5} J

Answer: B

Solution:

The increase in surface area of the film is,

$\Delta A = A_2 - A_1$

$A_1 = 2 \times l \times b = 2 \times 10 \times 10^{-2} \times 0.5 \times 10^{-2}$

$A_2 = 2 \times l \times (b + 1) = 2 \times 10 \times 10^{-2} \times (0.5 + 0.1)$
$\times 10^{-2}$

$$\begin{aligned} A_2 - A_1 = & \left[2 \times 10 \times 10^{-2} \times (0.5 + 0.1) \times 10^{-2}\right] \\ & - \left[2 \times 10 \times 10^{-2} \times 0.5 \times 10^{-2}\right] \\ & = 2 \times 10^{-4}\ m^2 \end{aligned}$$

$$\begin{aligned} \therefore \quad \text{Work done} & = \text{Increase in surface energy} \\ & = TdA \\ & = \left(65 \times 10^{-2}\right) \times \left(2 \times 10^{-4}\right) \\ & = 1.3 \times 10^{-4} \\ & = 13 \times 10^{-5}\ J \end{aligned}$$

A factor of 2 appears in the calculation of area of the film because the soap film has two surfaces which are in the contact with the wire.

Question123

A soap bubble of radius 'R' is blown. After heating a solution, a second bubble of radius '2R' is blown. The work required to blow the 2^{nd} bubble in comparison to that required for the 1^{st} bubble is

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Options:

A. exactly double.

B. slightly more than 4 times.

C. slightly less than 4 times.

D. slightly less than double.

Answer: C

Solution:

A soap bubble with a radius 'R' is initially blown. After heating the solution, a second bubble is created with a radius of '2R'. Let's compare the work needed to blow the second bubble to the first one.

For the first bubble (radius R), the work required, W_1, is given by:

$W_1 = 8\pi R^2 T_1$

For the second bubble (radius 2R), the work required, W_2, is:

$W_2 = 8\pi(2R)^2 T_2 = 32\pi R^2 T_2$

The ratio of the work required for the two bubbles is:

$\frac{W_1}{W_2} = \frac{T_1}{4T_2}$

When the surface tension of the solution is the same for both bubbles ($T_1 = T_2$), theoretically $W_2 = 4W_1$.

However, as the process of blowing the bubble involves work being done, it leads to a rise in temperature and subsequently a decrease in surface tension. Therefore, in practice:

$W_2 < 4W_1$

This means the work required for the second bubble is slightly less than four times the work needed for the first bubble.

Question124

A fluid of density 'ρ' and viscosity 'η' is flowing through a pipe of diameter 'd', with a velocity 'v'. Reynold number is

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Options:

A. $\frac{2\ d\rho v}{\eta}$

B. $\frac{d\rho v}{\eta}$

C. $\frac{d\rho v}{\eta^2}$

D. $\frac{2\eta d v}{\rho}$

Answer: B

Solution:

The Reynolds number (R_e) is given by the formula :

$R_e = \frac{\rho v d}{\eta}$

where ρ is the density of the fluid, v is the velocity of the fluid, d is the characteristic linear dimension (diameter of the pipe in this case), and η is the dynamic viscosity of the fluid.

Based on this formula, the correct answer would be Option B : $\frac{d\rho v}{\eta}$.

Question125

Water is flowing through a horizontal pipe in stream line flow. At the narrowest part of the pipe

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Options:

A. velocity is maximum and pressure minimum.

B. pressure is maximum and velocity minimum.

C. both pressure and velocity are minimum.

D. both pressure and velocity are maximum.

Answer: A

Solution:

Using equation of continuity,

$A_1 v_1 = A_2 v_2$

In streamlined flow, as the product of Av is a constant, the velocity at the narrowest part will be maximum.

By using Bernoulli's principle,

$\mathrm{P} + \frac{1}{2} \rho \mathrm{v}^2 + \rho \mathrm{gh} = \text{ Constant}$

We see that $\rho g h$ is constant because the pipe is horizontal.

As velocity increases, for the equation to remain constant, P has to decrease.

$\therefore$ Velocity will be maximum and pressure is minimum.

Question126

The excess of pressure in a first soap bubble is three times that of other soap bubble. Then the ratio of the volume of first bubble to other is

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Options:

A. 1 : 3

B. 27 : 1

C. 1 : 9

D. 1 : 27

Answer: D

Solution:

$$\Delta \mathrm{P} \propto \frac{1}{\mathrm{r}} \Rightarrow \frac{\mathrm{r}_1}{\mathrm{r}_2}=\frac{\Delta \mathrm{P}_2}{\Delta \mathrm{P}_1}=\frac{1}{3}$$

$$\therefore \quad \frac{\mathrm{V}_1}{\mathrm{V}_2}=\left(\frac{\mathrm{r}_1}{\mathrm{r}_2}\right)^3=\frac{1}{27}$$

Question127

The radii of two soap bubbles are r_1 and r_2. In isothermal condition they combine with each other to form a single bubble. The radius of resultant bubble is

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Options:

A. $R = \frac{r_1 + r_2}{2}$

B. $R = r_1 (r_1 r_2 + r_2)$

C. $R = \sqrt{r_1^2 + r_2^2}$

D. $R = r_1 + r_2$

Answer: C

Solution:

Under isothermal condition, T is constant.

This means the surface energy of the bubbles before combining will be equal to the surface energy after combining.

$$\text{i.e. } 4\pi r_1^2 T + 4\pi r_2^2 T = 4\pi R^2 T$$
$$\Rightarrow r_1^2 + r_2^2 = R^2$$
$$\therefore \quad R = \sqrt{r_1^2 + r_2^2}$$

Question128

The work done in blowing a soap bubble of radius R is 'W_1' at room temperature. Now the soap solution is heated. From the heated solution another soap bubble of radius $2R$ is blown and the work done is 'W_2'. Then

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Options:

A. $W_2 = W_1$

B. $W_2 = 4 W_1$

C. $W_2 < 4 W_1$

D. $W_2 = 0$

Answer: C

Solution:

Understanding Surface Tension and Work Done

- **Surface tension (T):** A property of liquids that causes their surface to behave like a stretched membrane, minimizing surface area. It's represented by the symbol T and has units of force per unit length.
- **Work done in forming a bubble:** When you blow a bubble, you increase its surface area. This requires work to be done against the surface tension forces trying to minimize the area.

Relationship Between Work, Surface Area, and Surface Tension

The work done (W) in increasing the surface area of a liquid is:

$W = T\Delta A$

where:

- T is the surface tension
- ΔA is the change in surface area

1. **Bubble 1:**

- Radius = R
- Surface Area = $4\pi R^2$ (Since a soap bubble has two surfaces, inner and outer)
- Work Done = W_1

1. **Bubble 2:**

- Radius = $2R$
- Surface Area = $4\pi(2R)^2 = 16\pi R^2$
- Work Done = W_2

Temperature's Effect:

- Surface tension of liquids generally decreases with an increase in temperature.

Calculations

Since the surface area of bubble 2 is four times that of bubble 1, you might think $W_2 = 4W_1$. However, the surface tension is lower for bubble 2 due to the heated soap solution.

Conclusion

Because the surface tension decreases with temperature:

- Work done (W_2) to form bubble 2 will be less than four times the work (W_1) needed to form bubble 1.

Therefore, the correct answer is C: $W_2 < 4W_1$

Question129

A steel coin of thickness 'd' and density 'ρ' is floating on water of surface tension 'T'. The radius of the coin (R) is [g $=$ acceleration due to gravity]

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Options:

A. $\frac{\mathrm{T}}{\rho \mathrm{gd}}$

B. $\frac{4 \mathrm{~T}}{3 \rho g \mathrm{~d}}$

C. $\frac{3 \mathrm{~T}}{4 \rho \mathrm{gd}}$

D. $\frac{2 \mathrm{~T}}{\rho \mathrm{gd}}$

Answer: D

Solution:

Upward force (F) for the steel coin due to S.T.

$= 2\pi \mathrm{r} \times \mathrm{T} \quad \left[\because \mathrm{T} = \frac{\mathrm{F}}{\mathrm{L}} = \frac{\mathrm{F}}{2\pi \mathrm{r}}\right]$

and it is equal to downward force due to weight $=$ mg

$=$ volume of coin $\times$ density $\times$g

$= \pi \mathrm{r}^2 \mathrm{~d} \times \rho \times \mathrm{g}$ [d $=$ thickness of the coin]

$\therefore 2\pi \mathrm{rT} = \pi \mathrm{r}^2 \mathrm{~d} \rho \mathrm{g}$

$\therefore 2 \mathrm{~T} = \mathrm{rd} \rho \mathrm{g}$

$\therefore \mathrm{r} = \frac{2 \mathrm{~T}}{\rho \mathrm{dg}}$

Question130

The excess pressure inside a soap bubble of radius 2 cm is 50 dyne/cm^2. The surface tension is

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Options:

A. 50 dyne/cm

B. 60 dyne/cm

C. 75 dyne/cm

D. 25 dyne/cm

Answer: D

Solution:

The excess pressure inside a soap bubble is given by the formula:

$\Delta P = \frac{4T}{r}$

where ΔP is the excess pressure, T is the surface tension, and r is the radius of the bubble.

Given:

$\Delta P = 50\,\text{dyne/cm}^2$

$r = 2\,\text{cm}$

Substitute these values into the formula:

$50 = \frac{4T}{2}$

Solving for T:

Simplify the equation:

$50 = 2T$

Solve for T:

$T = \frac{50}{2}$

$T = 25\,\text{dyne/cm}$

Therefore, the surface tension is 25 dyne/cm.

Option D: 25 dyne/cm is the correct answer.

Question131

'n' small drops of same size fall through air with constant velocity $5 \mathrm{~cm/s}$. They coalesce to form a big drop. The terminal velocity of the big drop is

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Options:

A. $7 \mathrm{n}^{2/3} \mathrm{~cm/s}$

B. $5 \mathrm{n}^{2/3} \mathrm{~cm/s}$

C. $3 \mathrm{n}^{2/3} \mathrm{~cm/s}$

D. $9 \mathrm{n}^{2/3} \mathrm{~cm/s}$

Answer: B

Solution:

$$\begin{aligned} & \text{Volume } = \frac{4}{3} \pi r^3 n = \frac{4}{3} \pi R^3 \\ & \therefore R = n^{1/3} r \quad \therefore \frac{R}{r} = n^{\frac{1}{3}} \end{aligned}$$

Terminal velocity $\mathrm{v} \propto \mathrm{r}^2$

$$\begin{aligned} & \frac{v_2}{v_1} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{R}{r}\right)^2 = n^{2/3} \\ & \therefore v_2 = n^{2/3} v_1 = 5 \mathrm{n}^{2/3} \mathrm{~m/s} \end{aligned}$$

Question132

Pressure inside two soap bubbles are 1.01 atm and 1.03 atm. The ratio between their volumes is (Pressure outside the soap bubble is 1 atmosphere)

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Options:

A. 9 : 1

B. 27 : 1

C. 81 : 1

D. 3 : 1

Answer: B

Solution:

Here's how to determine the ratio of volumes of the soap bubbles:

Understanding the Concept

The pressure inside a soap bubble is slightly higher than the pressure outside due to the surface tension of the soap film. The excess pressure inside a soap bubble is inversely proportional to the radius of the bubble. This relationship can be expressed as:

$P_{inside} - P_{outside} = \frac{4T}{r}$

Where:

- P_{inside} is the pressure inside the bubble
- $P_{outside}$ is the pressure outside the bubble
- T is the surface tension of the soap film
- r is the radius of the bubble

Applying the Concept to the Problem

Let's denote the radii of the two bubbles as r_1 and r_2. We are given:

- $P_{inside1} = 1.01\ atm$
- $P_{inside2} = 1.03\ atm$
- $P_{outside} = 1\ atm$

Using the formula, we can write:

- $1.01 - 1 = \frac{4T}{r_1}$
- $1.03 - 1 = \frac{4T}{r_2}$

Dividing the first equation by the second equation, we get:

$\frac{1.01-1}{1.03-1} = \frac{r_2}{r_1}$

Simplifying the equation:

$\frac{0.01}{0.03} = \frac{r_2}{r_1}$

$\frac{1}{3} = \frac{r_2}{r_1}$

Calculating the Volume Ratio

The volume of a sphere is given by:

$V = \frac{4}{3}\pi r^3$

Therefore, the ratio of volumes is:

$\frac{V_2}{V_1} = \frac{\frac{4}{3}\pi r_2^3}{\frac{4}{3}\pi r_1^3} = \left(\frac{r_2}{r_1}\right)^3 = \left(\frac{1}{3}\right)^3 = \frac{1}{27}$

Since we want the ratio of V_1 to V_2, we invert the above result:

$\frac{V_1}{V_2} = \boxed{27:1}$

Therefore, the correct answer is Option B: 27 : 1.

Question133

If the work done in blowing a soap bubble of volume 'V' is 'W', then the work done in blowing a soap bubble of volume '2 V' will be

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Options:

A. 2 W

B. $(4)^{1/3}$ W

C. W

D. $\sqrt{2}$ W

Answer: B

Solution:

If Vis the volume then we have

$$V=\frac{4}{3}\pi r^3$$

$$V\propto r^3 \quad \therefore \frac{V_2}{V_1}=\left(\frac{r_2}{r_1}\right)^3$$

$$\therefore \quad \frac{r_2}{r_1}=\left(\frac{v_2}{v_1}\right)^{1/3}=(2)^{\frac{1}{3}}$$

$$W_1=8\pi\pi_1^2\cdot T \text{ and } W_2=8\pi\pi_2^2 T$$

$$\therefore \quad \frac{W_2}{W_1}=\left(\frac{r_2}{r_1}\right)^2=(2)^{\frac{2}{3}}=(4)^{\frac{1}{3}}$$

$$\therefore \quad W_2=(4)^{1/3}W_1$$

Question134

A glass tube of uniform cross-section is connected to a tap with a rubber tube. The tap is opened slowly. Initially the flow of water in the tube is streamline. The speed of flow of water to convert it into a turbulent flow is [radius of tube $=1\text{ cm}, \eta=1\times10^{-3}\frac{\text{Ns}}{\text{m}^2}, R_n=2500$ and density of water $=10^3\text{ kg/m}^3$]

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Options:

A. 0.15 m/s

B. 0.125 m/s

C. 0.3 m/s

D. 0.2 m/s

Answer: B

Solution:

Reynold number is given by

$$R_n = \frac{v_c \rho d}{\eta}$$

$$\therefore \quad v_c = \frac{R_n \eta}{\rho d}$$

$R_n = 2500, \eta = 10^{-3} \mathrm{Ns/m^2}, R_n = 2500, \rho = 10^3 \mathrm{~kg/m^3}$
$d = 2r = 2 \mathrm{~cm} = 2 \times 10^{-2} \mathrm{~m}$

Substituting these values and calculating we get critical velocity $\mathrm{v_c} = 0.125 \mathrm{~m/s}$

Question135

A thin metal disc of radius 'r' floats on water surface and bends the surface downwards along the perimeter making an angle 'θ' with the vertical edge of the dsic. If the weight of water displaced by the disc is 'W', the weight of the metal disc is [T = surface tension of water]

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Options:

A. $2\pi\mathrm{r}\cos\theta + W$

B. $\mathrm{W} - 2\pi\mathrm{T}\cos\theta$

C. $2\pi\mathrm{rT} + \mathrm{W}$

D. $2\pi\mathrm{T}\cos\theta - \mathrm{W}$

Answer: A

Solution:

The weight of the disc is balanced by the force due to the surface tension and the upthrust of water.

The component of surface tension in vertically upward direction is $T\cos\theta$ and the force acting due to it is $2\pi\mathrm{T}\cos\theta$.

The upthrust is equal to the weight of the water displaced (W).

$\therefore$ Weight of the disc $= 2\pi\mathrm{rT}\cos\theta + \mathrm{W}$

Question136

The work done in blowing a soap bubble of volume 'V' is 'W'. The work required to blow a soap bubble of volume '2 V' is [T = surface tension of soap solution]

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Options:

A. $2^{2/3}$ W

B. 2 W

C. W

D. $2^{1/3}$ W

Answer: A

Solution:

To determine the work required to blow a soap bubble, we need to consider the surface energy involved. The work done in blowing a soap bubble is related to the change in surface area and the surface tension (T) of the soap solution.

For a bubble of volume V, the radius of the bubble can be related by the formula:

$$\mathrm{V}=\frac{4}{3} \pi r^3$$

Here, we know the relationship between volume and radius. Thus, the radius r for volume V can be written as:

$$r=\left(\frac{3 \mathrm{~V}}{4 \pi}\right)^{1 / 3}$$

The surface area of a soap bubble (which has two surfaces) is given by:

$$A=2 \times 4 \pi r^2=8 \pi r^2$$

Substituting the radius r calculated from the volume V, we get:

$$A=8 \pi\left(\frac{3 \mathrm{~V}}{4 \pi}\right)^{2 / 3}$$

The work done in creating this surface area is thus:

$$\mathrm{W}=\mathrm{T} \times \Delta \text {Surface Area}=\mathrm{T} \times 8 \pi\left(\frac{3 \mathrm{~V}}{4 \pi}\right)^{2 / 3}$$

Now, considering the bubble with volume 2 V, the radius will be:

$r' = \left(\frac{3\times2V}{4\pi}\right)^{1/3} = 2^{1/3}\left(\frac{3V}{4\pi}\right)^{1/3}$

The corresponding surface area of the new bubble would be:

$A' = 8\pi\left[2^{1/3}\left(\frac{3V}{4\pi}\right)^{1/3}\right]^2 = 8\pi \times 2^{2/3}\left(\frac{3V}{4\pi}\right)^{2/3}$

Thus, the work required to blow the bubble with volume 2 V is:

$W' = T \times 8\pi \times 2^{2/3}\left(\frac{3V}{4\pi}\right)^{2/3} = 2^{2/3}\ W$

Therefore, the correct answer is Option A:

$2^{2/3}\ W$

Question137

A glass rod of radius 'r_1' is inserted symmetrically into a vertical capillary tube of radius 'r_2' ($r_1 < r_2$) such that their lower ends are at same level. The arrangement is dipped in water. The height to which water will rise into the tube will be ($\rho =$ density of water, T = surface tension in water, g = acceleration due to gravity)

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Options:

A. $\frac{2T}{(r_2-r_1)\rho g}$

B. $\frac{T}{(r_2^2-r_1^2)\rho g}$

C. $\frac{T}{(r_2-r_1)\rho g}$

D. $\frac{2\ T}{(r_2^2-r_1^2)\rho g}$

Answer: A

Solution:

The force due to surface tension at the wall of the capillary is given by f_T = (surface tension) × (length in contact)

$= T \times 2\pi r_2$

The vertical component of this force is

$fV_V = T \times 2\pi r_2 \cos\theta$

where θ is the angle of contact.

Similarly the vertical component of the force at the surface of the rod is

$f_V' = T \times 2\pi\pi_1 \cos\theta$

Total force $F = f_V + f_V{}'$

$F = (r_2 + r_1)2\pi T\cos\theta$

Weight of the liquid in the capillary

$W = \pi\left(r_2^2 - r_1^2\right)h\rho g$

This is balanced by the vertical component of the face due to the surface tension

$\therefore \pi\left(r_2^2 - r_1^2\right)h\rho g = (r_2 + r_1) \times 2\pi T\cos\theta$

Simplifying and solving for h we get,

$h = \frac{2\ T\cos\theta}{(r_2 - r_1)\rho g} = \frac{2\ T}{(r_2 - r_1)\rho g}$

(For pure water, $\theta = 0°, \cos\theta = 1$)

Question138

An ice cube of edge $1\ \mathrm{cm}$ melts in a gravity free container. The approximate surface area of water formed is (water is in the form of spherical drop)

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Options:

A. $(36\pi)^{1/3}\ \mathrm{cm}^2$

B. $(24\pi)^{1/3}\ \mathrm{cm}^2$

C. $(28\pi)^{1/3}\ \mathrm{cm}^2$

D. $(12\pi)^{1/3}\ \mathrm{cm}^2$

Answer: A

Solution:

$x = 1$ cm

$\therefore$ Volume of the cube $v = x^3 = 1\ \mathrm{cm}^3$, volume of drop = volume of cube.

$\frac{4}{3}\pi \mathrm{r}^3 = \mathrm{x}^3 = 1\ \mathrm{cm}^3$

$$\therefore r^3 = \frac{3}{4\pi} \quad \text{or } r = \left(\frac{3}{4\pi}\right)^{\frac{1}{3}}$$

$$\therefore r^2 = \left(\frac{9}{16\pi^2}\right)^{\frac{1}{3}}$$

$$\begin{aligned}\text{Surface area of drop } &= 4\pi \mathrm{r}^2 = 4\pi\left(\frac{9}{16\pi \mathrm{r}^2}\right)^{\frac{1}{3}} \\ &= \left(64\pi^3 \times \frac{9}{16\pi^2}\right)^{\frac{1}{3}} \\ &= (36\pi)^{\frac{1}{3}}\end{aligned}$$

Question139

Water rises upto a height of 4 cm in a capillary tube. The lower end of the capillary tube is at a depth of 8 cm below the water level. The mouth pressure required to blow an air bubble at the lower end of the capillary will be 'X' cm of water, where X is equal to

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Options:

A. 10

B. 8

C. 6

D. 12

Answer: D

Solution:

To determine the mouth pressure required to blow an air bubble at the lower end of the capillary tube, we'll need to consider both the height to which the water rises in the capillary tube due to capillary action and the depth of the lower end of the tube below the water level.

The total pressure needed to blow the bubble at the lower end of the tube will be the sum of the pressure due to the capillary rise and the pressure due to the water column above the lower end of the tube.

Given:

- The height to which water rises in the capillary tube: $h_1 = 4$ cm
- The depth of the lower end of the capillary tube below the water level: $h_2 = 8$ cm

The pressure due to the capillary rise can be calculated using the height of the water rise:

Pressure due to capillary rise: $P_1 = h_1$ cm of water $= 4$ cm of water

The pressure due to the water column above the lower end of the tube is given by the depth below the water level:

Pressure due to water column: $P_2 = h_2$ cm of water $= 8$ cm of water

Therefore, the total pressure required to blow an air bubble at the lower end of the capillary tube is the sum of these two pressures:

$X = P_1 + P_2 = 4$ cm of water $+ 8$ cm of water $= 12$ cm of water

Thus, the required mouth pressure X is equal to 12 cm of water.

The correct answer is:

Option D: 12

Question140

The speed of a ball of radius $2 \mathrm{~cm}$ in a viscous liquid is $20 \mathrm{~cm} / \mathrm{s}$. What will be the speed of a ball of radius $1 \mathrm{~cm}$ in same liquid?

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Options:

A. 10 cm/s

B. 4 cm/s

C. 5 cm/s

D. 8 cm/s

Answer: C

Solution:

Terminal velocity $V \propto r^2$

$$\therefore \frac{V_2}{V_1} = \left(\frac{r_2}{r_1}\right) = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$
$$\therefore V_2 = \frac{V_1}{4} = \frac{20}{4} = 5 \text{ cm/s}$$

Question141

Water rises to a height of 2 cm in a capillary tube. If cross-sectional area of the tube is reduced to $\frac{1}{16}^{\text{th}}$ of initial area then water will rise to a height of

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Options:

A. 4 cm

B. 8 cm

C. 12 cm

D. 16 cm

Answer: B

Solution:

$$h = \frac{2\,T\cos\theta}{r\rho g}$$
$$\therefore h \propto \frac{1}{r}$$
$$\therefore \frac{h_2}{h_1} = \frac{r_1}{r_2}$$
Area $A = \pi r^2 \quad \therefore A \propto r^2$
$$\therefore \frac{A_1}{A_2} = \frac{r_1^2}{r_2^2} \text{ or } \frac{r_1}{r_2} = \sqrt{\frac{A_1}{A_2}} = \sqrt{16}$$
$$\frac{r_1}{r_2} = 4$$
$$\therefore \frac{h_2}{h_1} = 4 \text{ or } \quad h_2 = 4\,h_1 = 4 \times 2 = 8 \text{ cm}$$

Question142

Work done in increasing the size of a soap bubble from radius of 3 cm to 5 cm in millijoule is nearly (surface tension of soap solution $= 0.03\ \mathrm{Nm}^{-1}$)

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Options:

A. 0.4π

B. 0.2π

C. 4π

D. 2π

Answer: A

Solution:

$$W = 8\pi T\left(r_2^2 - r_1^2\right)$$

$$= 8\pi \times 0.03(25 - 9) \times 10^{-4}$$

$$= 0.384\pi \times 10^{-3}\ \mathrm{J}$$

$$= 0.384\pi \mathrm{mJ} \approx 0.4\pi \mathrm{mJ}$$

Question143

A ball rises to the surface of a liquid with constant velocity. The density of the liquid is four times the density of the material of the ball. The viscous force of the liquid on the rising ball is greater than the weight of the ball by a factor of

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Options:

A. 4

B. 3

C. 2

D. 5

Answer: B

Solution:

The ball is moving with constant velocity.Hence the net force acting on it is zero.

The weight of the ball $= \mathrm{W} = \frac{4}{3}\pi \mathrm{r}^3 \rho_{\mathrm{b}} \mathrm{g}$ (in downward direction)

The viscous force F_{v} is in downward direction

The buoyant force $F_B = \frac{4}{3}\pi r^3 \rho_\ell g$ (in upward direction)

$$\therefore F_v + W = F_B$$
$$\therefore F_v = F_B - W$$
$$= \frac{4}{3}\pi r^3 g(\rho_\ell - \rho_b) = \frac{4}{3}\pi r^3 g \times 3\rho_b \quad (\because \rho_l = 4\rho_b)$$
$$\therefore \frac{F_v}{W} = 3$$

Question144

If the terminal speed of a sphere A [density $\rho_A = 7.5 \text{ kg m}^{-3}$] is 0.4 ms^{-1}, in a viscous liquid [density $\rho_L = 1.5 \text{ kg m}^{-3}$], the terminal speed of sphere B [density $\rho_B = 3 \text{ kg m}^{-3}$] of the same size in the same liquid is

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Options:

A. 0.3 ms^{-1}

B. 0.1 ms^{-1}

C. 0.2 ms^{-1}

D. 0.4 ms^{-1}

Answer: B

Solution:

Terminal speed is given by

$$V = \frac{2}{9}\frac{r^2 g(\rho - \rho_L)}{\eta}$$
$$\therefore \frac{V_A}{V_B} = \frac{\rho_A - \rho_L}{\rho_B - \rho_L} = \frac{7.5 - 1.5}{3 - 1.5} = \frac{6}{1.5} = 4$$
$$\therefore V_B = \frac{V_A}{4} = \frac{0.4}{4} = 0.1 \text{ ms}^{-1}$$

Question145

A needle is 7 cm long. Assuming that the needle is not wetted by water, what is the weight of the needle, so that it floats on water?

[$\mathrm{T}=$ surface tension of water $=70 \frac{\text{dyne}}{\text{cm}}$]

[acceleration due to gravity $=980 \text{ cm s}^{-2}$]

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Options:

A. 1 g wt

B. 5 g wt

C. 3 g wt

D. 7 g wt

Answer: A

Solution:

The weight of the needle is balanced by the force due to surface tension

$W = 2TL$

$= 2 \times 70 \times 7$

$= 980$ dyne

$= 1$ g wt

Question146

Water rises in a capillary tube of radius 'r' up to a height 'h'. The mass of water in a capillary is 'm'. The mass of water that will rise in

a capillary tube of radius $\frac{'r'}{3}$ will be

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Options:

A. 3 m

B. $\frac{\mathrm{m}}{3}$

C. m

D. $\frac{2\ \mathrm{m}}{3}$

Answer: B

Solution:

The phenomenon of capillary rise is driven by surface tension, and the height to which the liquid rises in a capillary tube is given by the Jurin's Law. The formula to determine the height of water rise in a capillary tube is:

$\mathrm{h}=\frac{2 \gamma \cos \theta}{\rho g r}$

where:

- γ is the surface tension of water.
- θ is the contact angle.
- ρ is the density of water.
- g is the acceleration due to gravity.
- r is the radius of the capillary tube.

From the above formula, it is evident that the height 'h' is inversely proportional to the radius 'r'.

If the radius of the capillary tube is reduced to $\frac{r}{3}$, the new height 'h'' of water rise will be:

$h'=\frac{2 \gamma \cos \theta}{\rho g\left(\frac{r}{3}\right)}=3 \times \frac{2 \gamma \cos \theta}{\rho g r}=3 h$

The mass of water in a capillary tube of radius 'r' up to height 'h' is:

$\mathrm{m}=\rho \times(\text{Volume of water})=\rho \times\left(\pi r^2 h\right)$

Substituting height h' and radius $\frac{r}{3}$ into the new volume, the new volume V' will be:

$V'=\pi\left(\frac{r}{3}\right)^2 \times 3 h=\pi \frac{r^2}{9} \times 3 h=\pi \frac{r^2 h}{3}$

Thus, the new mass m' will be:

$\mathrm{m}' = \rho \times V' = \rho \times \pi \frac{r^2 h}{3} = \frac{\mathrm{m}}{3}$

Therefore, the mass of water that will rise in a capillary tube of radius $\frac{r}{3}$ is:

Option B: $\frac{\mathrm{m}}{3}$

Question147

A drop of liquid of density 'ρ' is floating half immersed in a liquid of density 'd'. If 'T' is the surface tension, then the diameter of the drop of the liquid is

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Options:

A. $\sqrt{\frac{6\ \mathrm{T}}{\mathrm{g}(2p-\mathrm{d})}}$

B. $\sqrt{\frac{T}{g(2\rho-d)}}$

C. $\sqrt{\frac{2T}{g(2p-d)}}$

D. $\sqrt{\frac{12T}{g(2\rho-d)}}$

Answer: D

Solution:

The drop is in equillibrium under the action of the following forces :

Weight of the liquid $= \mathrm{Mg} = \frac{4}{3}\pi \mathrm{r}^3 \rho g \quad$ (downwards)

Upthrust = weight of the liquid displaced

$\therefore U = \frac{4}{6}\pi r^3 dg$ (upwards)

(Since the drop is half immersed, the volume of the liquid displaced is half the volume of the drop)

Force due to surface tension $\mathrm{F} = 2\pi \mathrm{rT}$ (upwards)

$\therefore \mathrm{Mg}=\mathrm{F}+\mathrm{U}$
$\therefore \mathrm{F}=\mathrm{Mg}-\mathrm{U}$
$\therefore 2 \pi \mathrm{T}=\frac{4}{3} \pi \mathrm{r}^3 \rho g-\frac{4}{6} \pi \mathrm{r}^3 \mathrm{dg}$
$\therefore \mathrm{T}=\frac{2}{3} \mathrm{r}^2 \rho g-\frac{1}{3} \mathrm{r}^2 \mathrm{dg}$
$=\mathrm{r}^2 g\left(\frac{2}{3} \rho-\frac{1}{3} d\right)$
$=r^2 g\left(\frac{2 \rho-d}{3}\right)$
$\therefore \mathrm{r}^2=\frac{3 \mathrm{~T}}{\mathrm{g}(2 \rho-\mathrm{d})}$

If D is the diameter of the drop then $\mathrm{r}^2=\frac{\mathrm{D}^2}{4}$

$\therefore \frac{D^2}{4}=\frac{3 T}{g(2 \rho-d)}$
$\therefore D^2=\frac{12 T}{g(2 \rho-d)}$
$\therefore D=\sqrt{\frac{12 T}{g(2 \rho-d)}}$

Question148

Under isothermal conditions, two soap bubbles of radii 'r_1' and 'r_2' combine to form a single soap bubble of radius 'R'. The surface tension of soap solution is ($P=$ outside pressure)

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Options:

A. $\frac{P\left(R^3+r_1^3+r_2^3\right)}{4\left(r_1^2-r_2^2+R^2\right)}$

B. $\frac{P^2+r_1^2+r_2^2}{4\left(r_1^2+r_2^2+R^2\right)}$

C. $\frac{P\left(R^3-r_1^3-r_2^3\right)}{4\left(r_1^2+r_2^2-R^2\right)}$

D. $\frac{P\left(R^2-r_1^2-r_2^2\right)}{4\left(r_1^3+r_2^3-R^3\right)}$

Answer: C

Solution:

pressure in side the first bubble $= P+\frac{4T}{r_1}$

Pressure inside the second bubble $= P+\frac{4T}{r_2}$

using the formula PV =n R θ $\quad \theta=$ absolute temp.

we have : $\left(P+\frac{4T}{r_1}\right)\cdot\frac{4\pi}{3}r_1^3=n_1R'\theta \quad$ (R' is molar gas constant)

$\left(\mathrm{P}+\frac{4\ \mathrm{T}}{\mathrm{r}_2}\right)\cdot\frac{4\pi}{3}\mathrm{r}_2^3=\mathrm{n}_2\mathrm{R}'\theta$

and $\left(\mathrm{P}+\frac{4\ \mathrm{T}}{\mathrm{R}}\right)\cdot\frac{4\pi}{3}\mathrm{R}^3=(\mathrm{n}_1+\mathrm{n}_2)\mathrm{R}'\theta$

$$\therefore\left(P+\frac{4T}{R}\right)\cdot\frac{4\pi}{3}R^3=\left(\frac{P+4T}{r_1}\right)\cdot\frac{4\pi}{3}r_1^3+\left(P+\frac{4T}{r_2}\right)\cdot\frac{4\pi r^3}{3}$$
$$\therefore\left(p+\frac{4T}{R}\right)R^3=\left(P+\frac{4T}{r_1}\right)r_1^3+\left(p+\frac{4T}{r_2}\right)r_2^3$$

on solving : $T=\frac{p\left(R^3-r_1^3-r_2^3\right)}{4\left(r_1^2+r_2^2-R^2\right)}$

Question149

In a capillary tube having area of cross-section A, water rises to a height 'h'. If cross-sectional area is reduced to $\frac{A}{9}$, the rise of water in the capillary tube is

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Options:

A. 3h

B. 9h

C. h

D. 6h

Answer: A

Solution:

$$A=\pi r^2, \quad \frac{A_2}{A_1}=\frac{1}{9}$$
$$\therefore \frac{r_2^2}{r_1^2}=\frac{1}{3}$$
$$h \propto \frac{1}{r} \quad \therefore \frac{h_2}{h_1}=\frac{r_1}{r_2}=3$$
$$\therefore h_2=3h_1$$

Question150

Water rises upto a height $10\ \mathrm{cm}$ in a capillary tube. It will rise to a height which is much more than $10\ \mathrm{cm}$ in a very long capillary tube if the apparatus is kept.

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Options:

A. on the surface of the moon.

B. at the north pole.

C. in a lift moving up with an acceleration.

D. on the equator.

Answer: A

Solution:

Rise in a capillary tube is given by

$$\mathrm{h}=\frac{2\,\mathrm{T}\cos\theta}{\mathrm{r}\rho \mathrm{g}}$$
$$\therefore \mathrm{h} \propto \frac{1}{\mathrm{g}}$$

Smaller the value of g, greater will be h. Out of the given options, value g will be minimum for option (A).

Question151

A big water drop is divided into 8 equal droplets. ΔP_s and ΔP_B be the excess pressure inside a smaller and bigger drop respectively. The relation between ΔP_s and ΔP_B is

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Options:

A. $\Delta P_B = \Delta P_S$

B. $\Delta P_B = \frac{1}{2}\Delta P_S$

C. $\Delta P_B = \frac{1}{4}\Delta P_S$

D. $\Delta P_B = 2\Delta P_S$

Answer: B

Solution:

Volume of 8 smaller drop = Volume of the bigger drop

$$\therefore 8 \times \frac{4}{3}\pi r^3 = \frac{4\pi}{3}R^3$$
$$\therefore 2r = R \text{ or } r = \frac{R}{2}$$

Excess pressure $\Delta P_s = \frac{T}{2r}, \Delta P_B = \frac{T}{2R}$

$\therefore \frac{\Delta P_B}{\Delta P_S} = \frac{r}{R} = \frac{1}{2}$

Question152

The surface tension of most of the liquid decreases with rise in

Options:

A. viscosity of the liquid

B. diameter of capillary

C. temperature of the liquid

D. density of the liquid

Answer: C

Solution:

✅ Explanation

Surface tension depends on the strength of intermolecular forces at the surface of a liquid.

- When **temperature increases**, molecules gain **more kinetic energy.**
- As a result, **cohesive forces between molecules decrease.**
- Hence, surface tension **decreases.**

So:

$$\text{Surface tension} \downarrow \quad \text{when} \quad \text{Temperature} \uparrow$$

Useful Facts

- For **water**, surface tension decreases **almost linearly** with temperature.
- At the **critical temperature**, surface tension becomes **zero**, because there is no distinction between liquid and gas phases.

📌 Therefore, the correct option is:

✔ Temperature of the liquid

Question153

The velocity of a small ball of mass 'M' and density 'd_1' when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is 'd_2', the viscous force acting on the ball is ($g =$ acceleration due to gravity)

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Options:

A. $\mathrm{Mg}\frac{\mathrm{d}_1}{\mathrm{d}_2}$

B. $\mathrm{Mgd}_1\ \mathrm{d}_2$

C. $\mathrm{Mg}\left(d_1-d_2\right)$

D. $\mathrm{Mg}\left(1-\frac{\mathrm{d}_2}{\mathrm{d}_1}\right)$

Answer: D

Solution:

Since the velocity is constant, the net force acting on the ball is zero. Forces acting areSince the veloll $=$ Mg (downwards)

$$\begin{aligned} \text{Weight of } & = \text{ weight of water displaced} \\ & = (\text{ volume of water }) \times (\text{ density of water }) \times g \\ & = (\text{ volume of ball }) \times (\text{ density of water }) \times g \end{aligned}$$

$=\frac{M}{d_1} \times d_2 \times g=M g \frac{d_2}{d_1}$ (upwards)

$F=$ viscous force (upwards)

$$\begin{aligned} & \therefore F+M g \frac{d_2}{d_1}=M g \\ & \therefore F=M g\left(1-\frac{d_2}{d_1}\right) \end{aligned}$$

Question154

Two small drops of mercury each of radius 'R' coalesce to form a large single drop. The ratio of the total surface energies before and after the change is

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Options:

A. $\sqrt{2} : 1$

B. $2^{2/3} : 1$

C. $2^{1/3} : 1$

D. $2 : 1$

Answer: C

Solution:

Total surface energy before coalesce

$E_1 = 2\left(4\pi R^2\right)T$

But $\frac{4}{3}\pi R^2 \times 2 = \frac{4}{3}\pi R'^3$

Total surface energy after coalesce

$$E_2 = 4\pi R'^2 T = 4\pi 2^{2/3} R^2 T$$
$$\therefore \frac{E_1}{E_2} = \frac{2\left(4\pi R^2\right)T}{4\pi 2^{2/3} R^2 T} = 2^{1-\frac{2}{3}} = 2^{1/3}$$

Question155

What should be the radius of water drop so that excess pressure inside it is 72 Nm^{-2} ? (The surface tension of water 7.2×10^{-2} Nm^{-1})

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Options:

A. 1 mm

B. 2 mm

C. 8 mm

D. 4 mm

Answer: B

Solution:

Excess pressure in a water drop $= \frac{2T}{R}$

$$T = 7.2 \times 10^{-2} \mathrm{Nm}^{-2}$$
$$\therefore 72 = \frac{2 \times 7.2 \times 10^{-2}}{R}$$
$$\therefore R = \frac{2 \times 7.2 \times 10^{-2}}{72} = 2 \times 10^{-3} \mathrm{~m} = 2 \mathrm{~mm}$$

Question156

A body of density V is dropped from (at rest) height 'h' into a lake of density 'δ' $(\delta > \rho)$. The maximum depth to which the body sinks before returning to float on the surface is [Neglect all dissipative forces]

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Options:

A. $\frac{(\delta-\rho)}{2h\rho}$

B. $\frac{2h\rho}{(\delta-\rho)}$

C. $\frac{h\rho}{2(\delta-\rho)}$

D. $\frac{h\rho}{(\delta-\rho)}$

Answer: D

Solution:

The velocity of the body when it reaches the surface of the lake is given by

$v^2 = 2gh$ ...... (1)

When the body is in air the gravitational force acting on it is

$F = mg = V\rho g$ ...... (2)

Where V is the volume of the body.

When the body enters the lake, there will be an upthrust acting on the body. The upthrust is given by

$U = V\delta g$

Since $\delta > \rho$, upthrust will be greater then the gravitational force. The net force acting on the body will be

$F' = V\delta g - V\rho g \quad Vg = (\delta - \rho)$ .... (3)

By eqs. (2) and (3)

$$\frac{F'}{F} = \frac{\delta - \rho}{\rho}$$
$$\frac{a}{g} = \frac{\delta - \rho}{\rho}$$
$$\therefore a = \left(\frac{\delta - \rho}{\rho}\right)g \quad \therefore \frac{g}{a} = \frac{\rho}{\delta - \rho}$$

If a is the accelertion

If a is the acceleration retardation in the liquid then

$v^2 = 2ad$ ...... (4)

BY eqs (1) and (4)

$2ad = 2gh$

$\therefore d = \frac{g}{a}h \quad \therefore d = \frac{\rho}{\delta - \rho}h$

Question157

The surface energy of a liquid drop is 'U'. It splits up into 512 equal droplets. The surface energy becomes

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Options:

A. 8 U

B. 6 U

C. 4 U

D. 2 U

Answer: A

Solution:

$$U' = 4\pi R^2\,T$$
$$U' = 512 \times 4\pi r^2\,T \quad \left(r = \frac{R}{8}\right)$$
$$= 512 \times \frac{4\pi R^2\,T}{64} = 8\left(4\pi R^2\,T\right) = 8U$$

Question158

Air is pushed in a soap bubble to increase its radius from 'R' to '2R'. In this case, the pressure inside the bubble

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Options:

A. does not change

B. decrease

C. becomes zero

D. increases

Answer: B

Solution:

Excess pressure in a soap bubble is given by

$P = \frac{4T}{R}$.

Hence if radius is increased, the pressure will decrease.

Question159

Let 'R_1' and 'R_2' are radii of two mercury drops. A big mercury drop is formed from them under isothermal conditions. The radius of the resultant drop is

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Options:

A. $\sqrt{\mathrm{R}_1^2+\mathrm{R}_2^2}$

B. $\left(\mathrm{R}_1^3+\mathrm{R}_2^3\right)^{\frac{1}{3}}$

C. $\sqrt{\mathrm{R}_1^2-\mathrm{R}_2^2}$

D. $\frac{\mathrm{R}_1+\mathrm{R}_2}{2}$

Answer: B

Solution:

The volume of the bigger drop will be equal to the sum of the volumes of the smaller drops

$$\therefore \quad \frac{4}{3}\pi\mathrm{R}^3=\frac{4}{3}\pi\mathrm{R}_1^3+\frac{4}{3}\pi\mathrm{R}_2^3$$

$$\therefore \quad \mathrm{R}=\left(\mathrm{R}_1^3+\mathrm{R}_2^3\right)^{1/3}$$

Question160

The force required to take away a flat circular plate of radius $2\ \mathrm{cm}$ from the surface of water is $\left[\right.$Surface tension of water $\left.=70\times10^{-3}\mathrm{Nm}^{-1}, \pi=\frac{22}{7}\right]$

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Options:

A. 4.4×10^{-4} N

B. 8.8×10^{-3} N

C. 6.6×10^{-4} N

D. 11×10^{-3} N

Answer: B

Solution:

Force due to surface tension

$F = 2\pi rT$

$= 2 \times \frac{22}{7} \times 2 \times 10^{-3} \times 70 \times 10^{-3}$

$= 8.8 \times 10^{-3}$ N

Question161

Two spherical rain drops reach the surface of the earth with terminal velocities having ratio $16 : 9$. The ratio of their surface area is

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Options:

A. $4 : 3$

B. $64 : 27$

C. $16 : 9$

D. $9 : 16$

Answer: C

Solution:

The terminal velocity of rain drop is

$$v_T = \frac{2(\sigma - \rho)r^2 g}{9\eta}$$

$\Rightarrow \quad v_T \propto r^2 \quad$ .... (i)

Also, surface area of rain drop, $A = 4\pi r^2$

$\Rightarrow \quad A \propto r^2 \quad$ .... (ii)

From Eqs. (i) and (ii), we get

$\frac{A_1}{A_2} = \frac{V_{T_1}}{V_{T_2}} = \frac{16}{9}$ or 16 : 9

Question162

Water rises upto a height h in a capillary tube on the surface of the earth. The value of h will increase, if the experimental setup is kept in [$g =$ acceleration due to gravity]

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Options:

A. a lift going upward with a certain acceleration

B. accelerating train

C. a satellite rotating close to earth

D. a lift going down with acceleration $a < g$

Answer: D

Solution:

The height of liquid column in a capillary tube is

$h = \frac{2T\cos\theta}{\rho r g} \Rightarrow h \propto \frac{1}{g}$

$\therefore$ When the setup is kept in a lift going down with acceleration $a < g$, then the height of water in the tube increases as net downward acceleration becomes $(g - a)$.

Question163

If the surface tension of a soap solution is $3 \times 10^{-2}\ \mathrm{N/m}$ then the work done in forming a soap film of $20\ \mathrm{cm} \times 5\ \mathrm{cm}$ will be

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Options:

A. 6×10^{-2} J

B. 6 J

C. 6×10^{-4} J

D. 6×10^{-3} J

Answer: C

Solution:

Given, surface tension, $T = 3 \times 10^{-2}\ \mathrm{N/m}$ and surface area of soap film, $A = 20\ \mathrm{cm} \times 5\ \mathrm{cm}$

$$= 100\ \mathrm{cm}^2$$
$$= 100 \times 10^{-4}\ \mathrm{m}^2$$

The work done in forming a soap film, $W = 2(TA)$

$$= 2\left(3 \times 10^{-2} \times 100 \times 10^{-4}\right)$$
$$= 6 \times 10^{-4}\ \mathrm{J}$$

Question164

A large open tank containing water has two holes to its wall. A square hole of side a is made at a depth y and a circular hole of radius r is made at a depth $16y$ from the surface of water. If equal amount of water comes out through both the holes per second, then the relation between r and a will be

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Options:

A. $r=\frac{a}{2\sqrt{\pi}}$

B. $r=\frac{a}{2\pi}$

C. $r=\frac{2a}{\pi}$

D. $r=\frac{2\mathrm{a}}{\sqrt{\pi}}$

Answer: A

Solution:

Using principle of continuity,
$A_1v_1=A_2v_2$ ... (i)

where, A_1 is the area of square hole, $A_1=a^2$,

A_2 is the area of circular hole, $A_2=\pi r^2$,

v_1 is the velocity at depth $y, v_1=\sqrt{2gy}$

and v_2 is the velocity at depth 16y, $v_2=\sqrt{2g(16y)}$.

Substituting values in Eq. (i), we get

$$a^2(\sqrt{2gy})=\pi r^2(\sqrt{2g(16y)})$$
$$a^2(\sqrt{2gy})=4\pi r^2(\sqrt{2gy})$$
$$r^2=\frac{a^2}{4\pi}$$

$\therefore \quad r=\frac{a}{2\sqrt{\pi}}$

Question165

The work done in blowing a soap bubble of radius R is W. The work done in blowing a bubble of radius $2R$ of the same soap solution is

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Options:

A. $\frac{W}{4}$

B. $\frac{W}{2}$

C. $4W$

D. $2W$

Answer: C

Solution:

The work done in blowing a soap bubble,

$W = T \times A$

where, T is the surface tension and A is the area of soap bubble.

$W = T \times 4\pi R^2$
$W \propto R^2$

So, $\frac{W_1}{W_2} = \frac{R_1^2}{R_2^2}$

$\Rightarrow \quad W_2 = W_1\left(\frac{2R}{R}\right)^2 = 4W$

Question166

A square frame of each side L is dipped in a soap solution and taken out. The force acting on the film formed is ($T =$ surface tension of soap solution)

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Options:

A. $8TL$

B. $2TL$

C. $R=\left(R_1^3+R_2^3\right)^{1/3}$

D. 12 TL

Answer: A

Solution:

The surface tension is given by

$T=\frac{F}{L}$

For soap film, force on single side of square frame,

$F=2TL$ (film has two surfaces)

Hence, force on four sides of square frame,

$F=4(2TL)=8TL$

Question167

Water rises in a capillary tube of radius r upto a height h. The mass of water in a capillary is m. The mass of water that will rise in a capillary of radius $\frac{r}{4}$ will be

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Options:

A. $4m$

B. $\frac{m}{4}$

C. m

D. $\frac{4}{m}$

Answer: B

Solution:

The height of water column in a capillary tube is given by

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

$\Rightarrow \quad h \propto \frac{1}{r} \quad$ .... (i)

Also, mass of liquid in a column of radius r and height h, is

$m = (\pi r^2 h)\rho$
$m \propto r^2 h \quad$ .... (ii)

From Eqs. (i) and (ii), we get

$$m \propto r^2 \times \frac{1}{r}$$
$$m \propto r$$
$$\Rightarrow \quad \frac{m'}{m} = \frac{\frac{r}{4}}{r} \Rightarrow m' = \frac{m}{4}$$

Question168

A small metal sphere of mass M and density d_1 when dropped in a jar filled with liquid moves with terminal velocity after sometime. The viscous force acting on the sphere is ($d_2 =$ density of liquid and $g =$ gravitational acceleration)

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Options:

A. $Mg\left(\frac{d_1}{d_2}\right)$

B. $Mg\left(1 - \frac{d_2}{d_1}\right)$

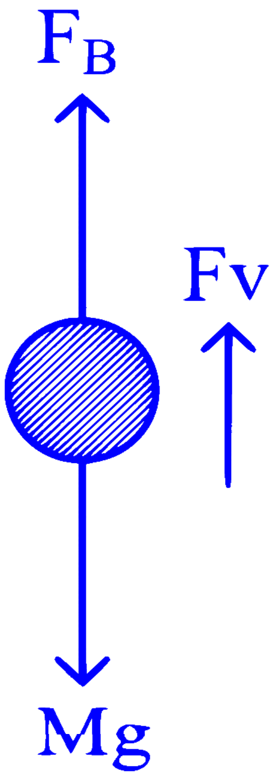
C. $Mg\left(\frac{d_2}{d_1}\right)$

D. $Mg\left(1 - \frac{d_1}{d_2}\right)$

Answer: B

Solution:

The motion of metal sphere is shown as



where, $F_B =$ Buoyant force and $F_V =$ viscous force. At terminal velocity, the net force on the sphere is zero.

$$
\begin{aligned}
& W = F_B + F_V \\
\Rightarrow \quad & Mg = d_2 V g + F_V \\
& \quad = d_2 \frac{M}{d_1} g + F_V \\
\therefore \quad & F_V = Mg\left(1 - \frac{d_2}{d_1}\right)
\end{aligned}
$$

Question169

Two small drops of mercury each of radius r coalesce to form a large single drop. The ratio of the total surface energies before and after the change is

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Options:

A. $\sqrt{2} : 1$

B. $2^{\frac{1}{3}} : 1$

C. $2 : 1$

D. $2^{\frac{2}{3}} : 1$

Answer: B

Solution:

The surface energy of a drop is directly proportional to its surface area. The surface area of a sphere (in this case, a mercury drop) is given by the formula $4\pi r^2$, where r is the radius of the sphere. When two small drops, each of radius r, coalesce, they form a larger drop. The volume of mercury is conserved in this process. Let's perform the calculations step by step:

Step 1: Calculate the volume of one small drop and the total volume of two drops.

The volume of a sphere is given by $\frac{4}{3}\pi r^3$. Thus, the volume of one small drop is $\frac{4}{3}\pi r^3$, and the total volume of the two small drops before coalescence is $2 \times \frac{4}{3}\pi r^3 = \frac{8}{3}\pi r^3$.

Step 2: Calculate the radius of the large drop formed after coalescence.

Let the radius of the large drop be R. The volume of the large drop is $\frac{4}{3}\pi R^3$. Since volume is conserved, we have:

$\frac{4}{3}\pi R^3 = \frac{8}{3}\pi r^3$

Solving for R gives:

$R^3 = 2r^3$

So, $R = 2^{\frac{1}{3}} r$.

Step 3: Calculate the ratio of the total surface energies before and after the change.

The surface energy is proportional to the surface area. The total surface area of the two small drops is

$2 \times 4\pi r^2 = 8\pi r^2$, and the surface area of the large drop is $4\pi R^2$. Substituting $R = 2^{\frac{1}{3}} r$:

$4\pi R^2 = 4\pi (2^{\frac{1}{3}} r)^2 = 4\pi 2^{\frac{2}{3}} r^2$

The ratio of the total surface energies (which is proportional to the ratio of the total surface areas) before and after the change is thus:

$\frac{8\pi r^2}{4\pi 2^{\frac{2}{3}} r^2} = \frac{8}{4 \cdot 2^{\frac{2}{3}}} = \frac{2}{2^{\frac{2}{3}}} = 2^{\frac{3}{3}} : 2^{\frac{2}{3}} = 2 : 2^{\frac{2}{3}} = 2^{\frac{1}{3}} : 1$

Therefore, the correct option is:

Option B $2^{\frac{1}{3}} : 1$.

Question170

A molecule of water on the surface experiences a net

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Options:

A. downward resultant unbalanced adhesive force

B. upward resultant unbalanced cohesive force

C. downward resultant unbalanced cohesive force

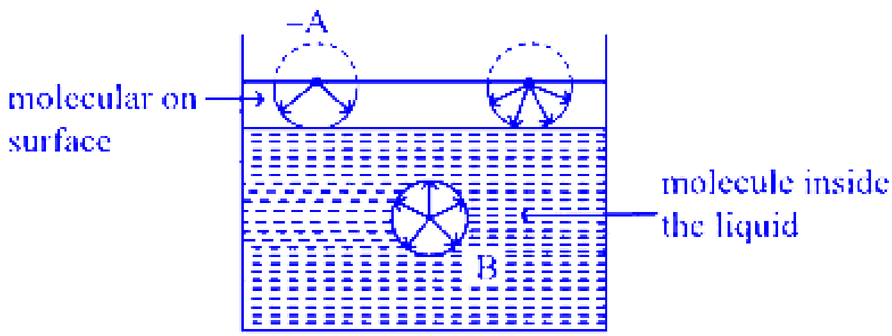
D. upward resultant unbalanced adhesive force

Answer: C

Solution:

A molecule on the surface experiences a net force (Cohesive force) in downward direction due to net number of molecules pulling it in the downward direction (molecule A as shown in figure underneath).

In contrast, a molecule well inside is equally pulled in all directions by molecules around at (molecule B as shown in figure).



Question171

Eight identical drops of water falling through air with uniform velocity of $10 \mathrm{~cm/s}$ combine to form a single drop of big size, then terminal velocity of the big drop will be

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Options:

A. 80 cm/s

B. 10 cm/s

C. 30 cm/s

D. 40 cm/s

Answer: D

Solution:

Given, terminal velocity of each small drop

$v_1 = 10 \mathrm{~cm/s}$

When 8 small drops are combined to form bigger drop, then volume will be same.

If r_1 be radius of small drop and r_2 be radius of bigger drop, then $v_2 = v_1$

$\frac{4}{3}\pi r_2^3 = 8 \times \frac{4}{3}\pi r_1^3 \Rightarrow r_2 = 2r_1$

$\therefore$ Terminal velocity of the drop

$$v = \frac{2}{9}\frac{r^2(\rho - \sigma)}{9\eta}$$

i.e., $v \propto r^2$

$$\therefore \quad \frac{v_1}{v_2} = \frac{r_1^2}{r_2^2} = \frac{r_1^2}{(2r_1)^2} \Rightarrow \frac{v_1}{v_2} = \frac{1}{4}$$

$$v_2 = 4v_1 = 4 \times 10 = 40 \text{ cm/s}$$

Question172

When a large bubble rises from bottom of a water lake to its surface, then its radius doubles. If the atmospheric pressure is equal to the pressure of height H of a certain water column, then the depth of lake will be

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Options:

A. 2H

B. H

C. 7H

D. 4H

Answer: C

Solution:

When a large bubble rises from bottom of water lake to its surface, then its radius becomes double.

i.e., $r_2 = 2r_1$

Since, volume $V \propto r^3$

$$\therefore \quad \frac{V_2}{V_1} = \left(\frac{r_2}{r_1}\right)^3 = \left(\frac{2r_1}{r_1}\right)^3 = 8$$
$$\Rightarrow \quad V_2 = 8V_1 \quad \text{... (i)}$$

From Boyle's law,

$p_1 V_1 = p_2 V_2$

Where, $p_2 =$ atmospheric pressure.

$p_1 V_1 = p_2 8 V_1$ [From Eq. (i)]

$p_2 = \frac{p_1}{8}$ .... (ii)

Where, $p_2 =$ atmospheric pressure and $p_1 =$ pressure at depth d.

$$\therefore \quad p_1 = p_{\text{atmospheric}} + \rho g d$$
$$p_1 = p_2 + \rho g d \quad \text{.... (iii)}$$

From Eqs. (ii) and (iii), we have

$$p_2 = \frac{p_2 + \rho g d}{8}$$
$$7p_2 = \rho g d$$
$$7 \cdot \rho g H = \rho g d$$
$$7H = d \Rightarrow d = 7H$$

Question173

Which one of the following statement is correct?

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Options:

A. Surface energy is potential energy per unit length

B. Surface tension is work done per unit area

C. Surface tension is work done per unit length

D. Surface energy is work done per unit force

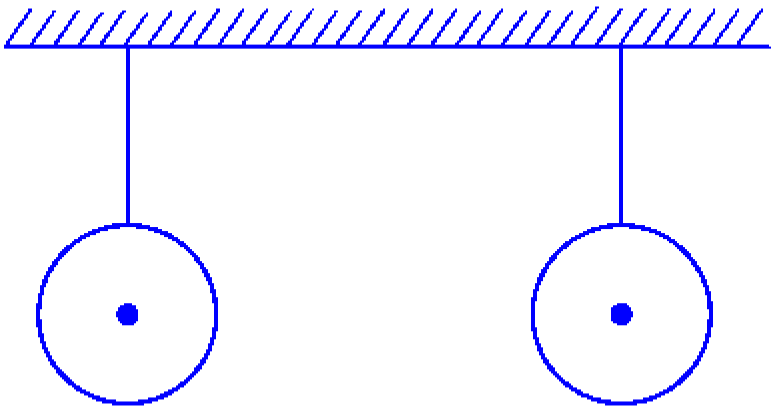
Answer: B

Solution:

Surface tension is the force applied per unit length or work done (or energy) per unit area of a liquid surface. While surface energy is the amount of work done per unit area by the force.

Question174

Two light balls are suspended as shown in figure. When a stream of air passes through the space between them, the distance between the balls will



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Options:

A. remain same

B. increase

C. may increase or decrease, depending on speed of air

D. decrease

Answer: D

Solution:

When a stream of air passes through the space between the balls, the pressure reduce between them as compared to the atmospheric pressure on either side. So, according to Bernoulli's theorem, the pressure energy should be constant and is compensated by movement of balls toward each other. So, the distance between the balls will decrease.

Question175

The excess of pressure, due to surface tension, on a spherical liquid drop of radius ' R ' is proportional to

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Options:

A. R^{-1}

B. R

C. R^{-2}

D. R^2

Answer: A

Solution:

The excess of pressure due to surface tension on a spherical liquid drop is given by

$p=\frac{2T}{R}$ .... (i)

where, $T=$ surface tension

and $R=$ radius of liquid drop.

so, from Eq. (i), we get

$p \propto \frac{1}{R}$ or $p \propto R^{-1}$

Question176

Two small drops of mercury each of radius ' R ' coalesce to form a large single drop. The ratio of the total surface energies before and after the change is

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Options:

A. $2^{2/3}:1$

B. $\sqrt{2}:1$

C. $2^{1/3}:1$

D. $2:1$

Answer: C

Solution:

Given that, the two small drops of mercuryand radius R of each drop coalesce to form a large drop of radius r, so the net volume remains constant i.e,

$$\begin{aligned} \text{initial volume} &= \text{final volume} \\ V_{\text{initial}} &= \mathrm{V}_{\text{final}} \\ 2 \times \frac{4}{3}\pi R^3 = 1 \cdot \frac{4}{3}\pi r^3 &\Rightarrow r = 2^{1/3}R \quad \text{.... (i)} \end{aligned}$$

As, surface tension is constant for both the drops.

So, the surface energy of two small drops,

$E_1 = 2 \times TA_1 = 2 \times 4\pi R^2 \times T$

Surface energy of one big drop,

$E_2 = TA_2 = 4\pi r^2 \times T = 2^{1/3}.4\pi R^2 T$ (using Eq. (i))

Ratio the total surface energy before and after the change is given as,

$$\frac{E_1}{E_2} = \frac{8\pi}{2^{2/3}} \frac{R^2 T}{4\pi R^2 T} = \frac{2^{1-\frac{2}{3}}}{1} = 2^{\frac{1}{3}}:1$$

Hence, the ratio of surface energy of the each drop is $2^{\frac{1}{3}}:1$.

Question177

In air, a charged soap bubble of radius ' R ' breaks into 27 small soap bubbles of equal radius ' r '. Then the ratio of mechanical force acting per unit area of big soap bubble to that of a small soap bubble is

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Options:

A. $\frac{1}{81}$

B. $\frac{3}{1}$

C. $\frac{1}{3}$

D. $\frac{9}{1}$

Answer: C

Solution:

The force per unit area is pressure Pressure inside a soap bubble of radius R. is given by

$P=\frac{4T}{R}$

where, $T=$ surface tension and $R=$ radius of the drop

Pressure inside a soap bubble, $P=\frac{4T}{R}$.

If a bubble is break into 27 small soap bubbles then the volume of single bubble of radius R and the combined volume of 27 bubbles of radius r would be constant.

$27\times$ volume of small bubbles $=$ volume of larger bubble

$$\Rightarrow \quad 27\left(\frac{4}{3}\pi r^3\right)=\frac{4}{3}\pi R^3$$
$$\Rightarrow \quad 27r^3=R^3$$
$$\Rightarrow \quad r=\frac{R}{3} \quad \text{.... (i)}$$

Now, the pressure inside smaller soap bubble,

$P_{\text{small}}=\frac{4T}{r}=\frac{12T}{R}$ (using the relation)

and similarly $P_{\text{large}}=\frac{4t}{R}$

$\therefore$ Ratio of pressure of the smaller and larger soap bubble is given as,

$$\frac{P_{\text{larger}}}{P_{\text{small}}}=\frac{4T}{R}\times\frac{R}{12T}=\frac{1}{3}$$
$$P_{\text{larger}}:P_{\text{small}}=1:3$$

Hence, the ratio of mechanical force acting per unit area of big soap bubble to that of a small bubble is 1 : 3.

Question178

Two capillary tubes of different diameters are dipped in water. The rise of water is

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Options:

A. zero in both the tubes.

B. same in both the tubes.

C. more in the tube of larger diameter.

D. more in the tube of smaller diameter.

Answer: D

Solution:

The rise of water in a capillary tube is expressed as, $h=\frac{2 T \cos \theta}{r d g}$

where, $h=$ height of the capillary rise, $T=$ surface tension, $r=$ radius of the capillary tube, $g=$ gravitational acceleration and $d=$ density of the liquid Here, T, d and, g remain constant.

So, $h \propto \frac{1}{r}$

The rise of water is more in the tube of smaller radius.

Question179

A metal sphere of radius ' R ' and density ' ρ_1 ' is dropped in a liquid of density ' σ ' moves with terminal velocity ' v '. Another metal sphere of same radius and density ' ρ_2 ' is dropped in the same liquid, its terminal velocity will be

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Options:

A. $v\left[\rho_2+\sigma\right)/\left(\rho_1+\sigma\right)]$

B. $v\left[\rho_1+\sigma\right)/\left(\rho_2+\sigma\right)]$

C. $v\left[\rho_2-\sigma\right)/\left(\rho_1-\sigma\right)]$

D. $v\left[\rho_1-\sigma\right)/\left(\rho_2-\sigma\right)]$

Answer: C

Solution:

The terminal velocity of the sphere

$v=\frac{2}{9} R^2 \frac{\left(\rho_1-\sigma\right) g}{\eta}$ .... (i)

Here, $R=$ radius of sphere, $\rho_1=$ density of sphere and $\sigma=$ density of liquid.

Now, if density of metal sphere is changed to ρ_2, then terminal velocity

$v_2=\frac{2}{9} \frac{R^2\left(\rho_2-\sigma\right) g}{\eta}$ ... (ii)

Divide Eqs. (i) and (ii), we get

$\frac{v_2}{v}=\frac{\left(\rho_2-\sigma\right)}{\left(\rho_1-\sigma\right)}$ or $v_2=\frac{v\left(\rho_2-\sigma\right)}{\left(\rho_1-\sigma\right)}$

Hence, the terminal velocity is $\frac{v\left(\rho_2-\sigma\right)}{\rho_1-\sigma}$.
