Orifice and Efflux Velocity

Course on Fluid Mechanics and Solids

Kailash Sharma • Lesson 6 • Nov 9, 2024

Fluid Dynamics (Hydrodynamics) →

⇒ Subdiscipline of fluid mechanics that deals with study of flowing fluid.

Ideal Fluid Flow → (i) Incompressible fluid flow
→ during flow density of fluid remain constant.

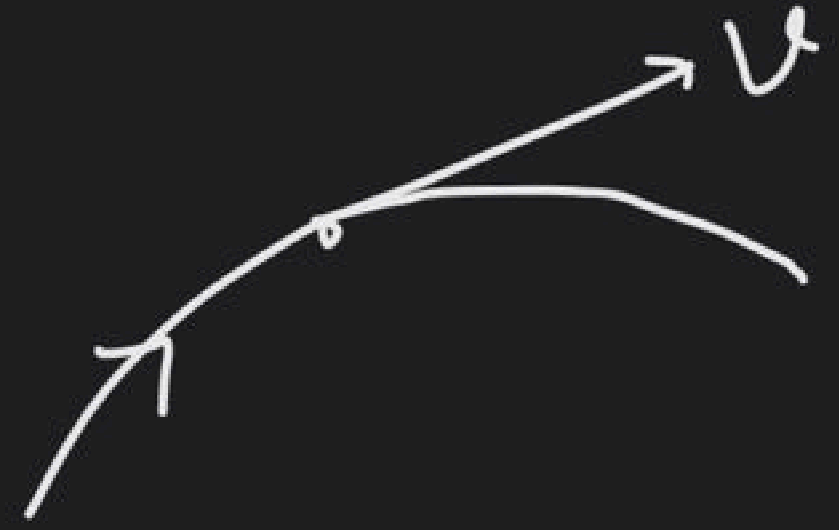
(ii) Non viscous fluid flow

(iii) Irrotational fluid flow

Streamline or laminar fluid flow → If at a particular point velocity of fluid particles does not change with time in magnitude and direction then such flow is called streamline fluid flow.

Stream lines → Family of curves that are instanteneous tangent to the velocity vector are called stream lines.

⇒ Two stream lines do not cross each other.

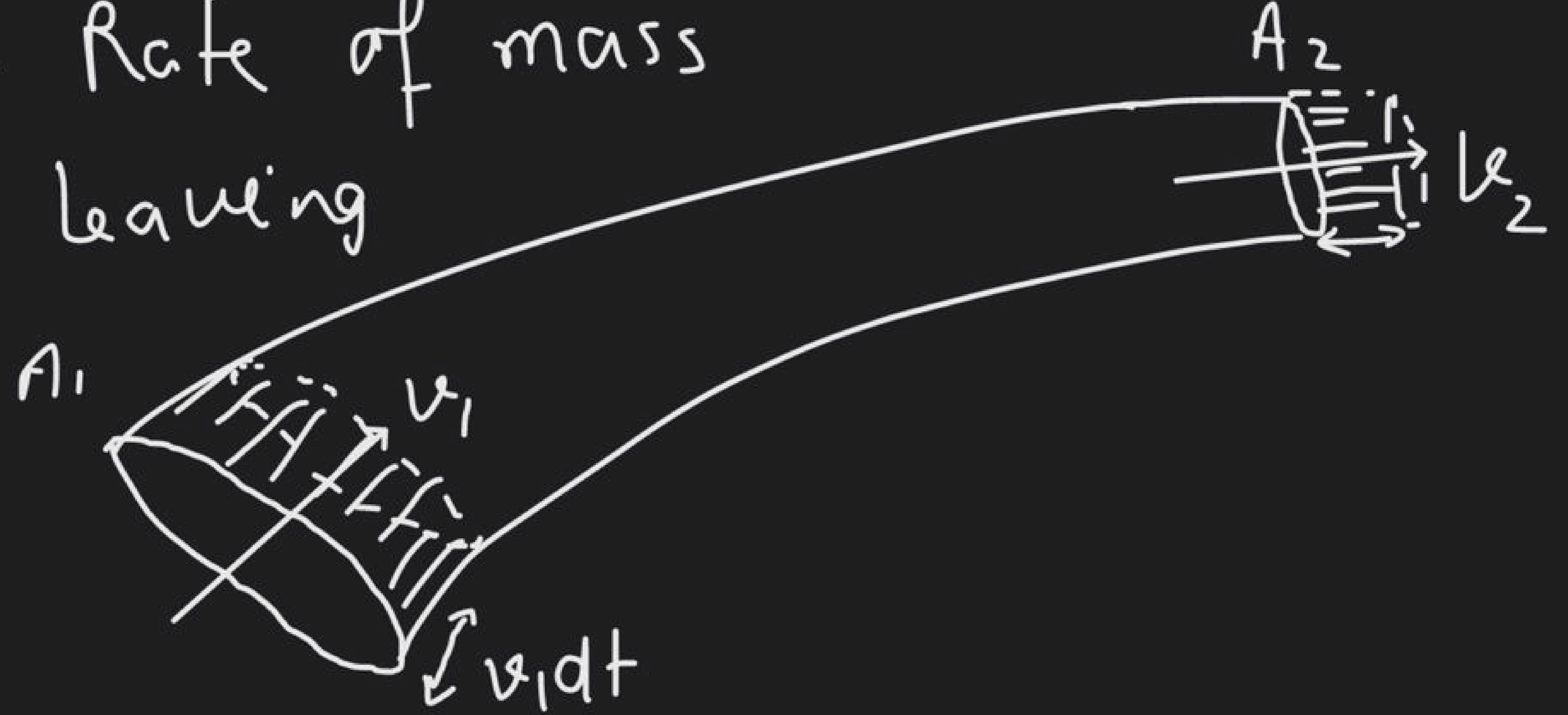


Continuity Equation →

⇒ Based on mass conservation principle.

⇒ For ideal fluid flow (streamline fluid flow)

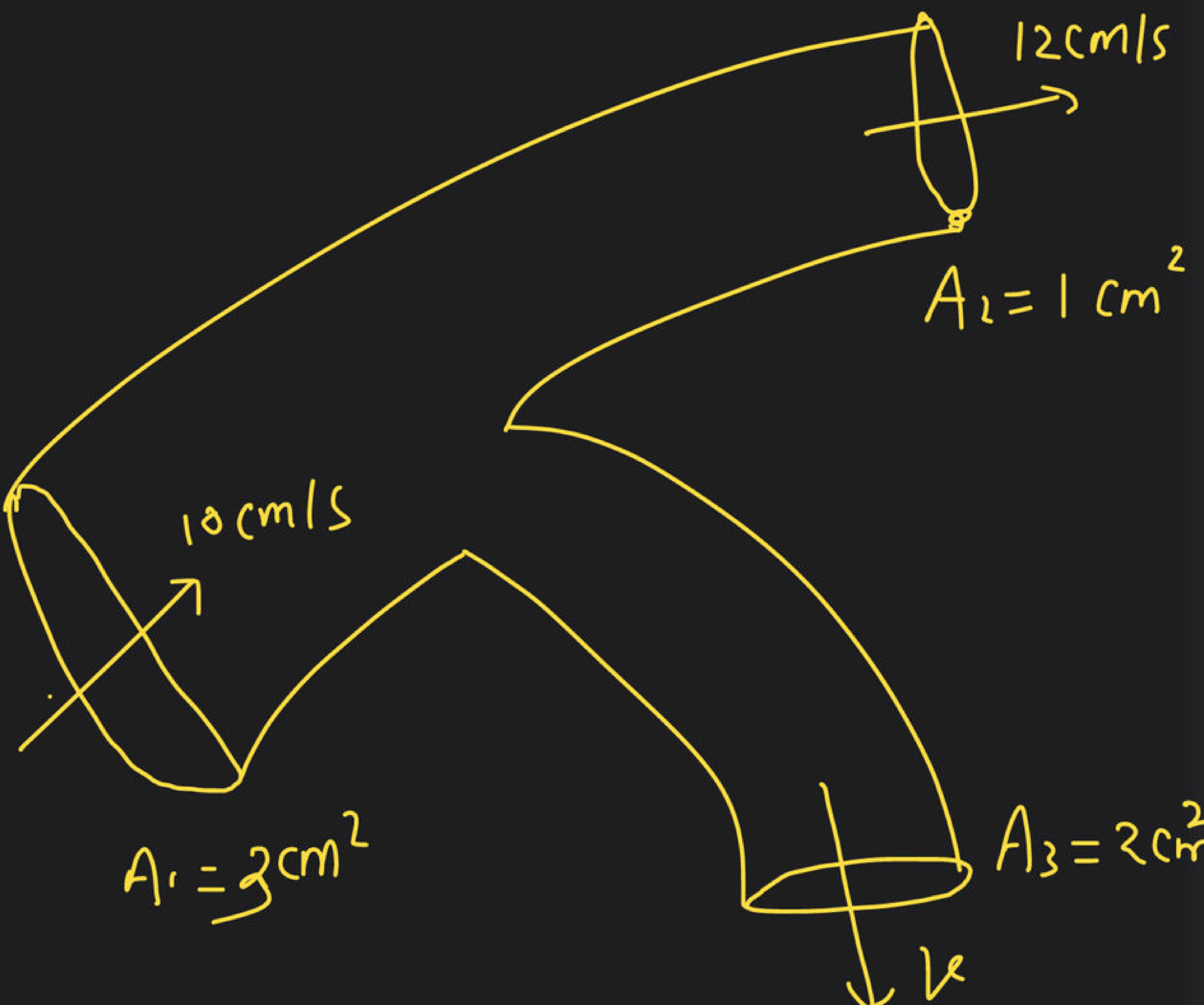
⇒ Rate of mass entering = Rate of mass leaving



$$\rho(v_1 dt)A_1 = \rho(v_2 dt)A_2$$

$$\boxed{A_1 v_1 = A_2 v_2}$$

Ques → find v for ideal fluid flow ?



Sol^n →

$$A_1 v_1 = A_2 v_2 + A_3 v_3$$

$$10 \times 3 = 12 \times 1 + 2v$$

$$\boxed{v = 9\ cm/sec}$$

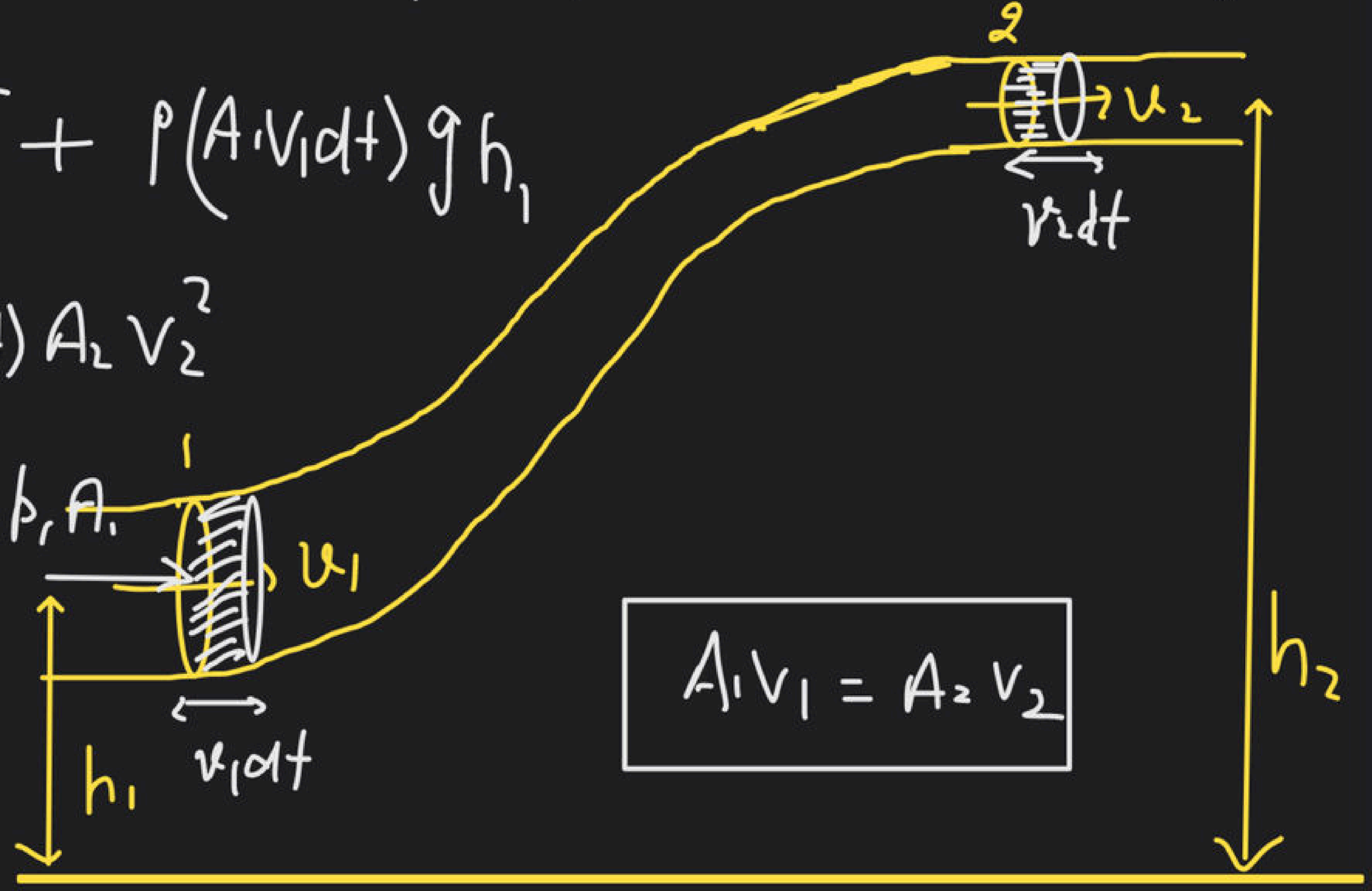
Bernoulli's Equation →

Based on energy conservation principle for stream line flow

$$p_1(A_1v_1)dt + \frac{1}{2}\rho(A_1v_1dt)v_1^2 + \rho(A_1v_1dt)gh_1$$

$$= p_2(v_2dt)A_2 + \frac{1}{2}\rho(v_2dt)A_2v_2^2$$

$$+ \rho A_2 v_2 dt\, gh_2$$



$$p_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2}\rho v_2^2$$

$$+ \rho gh_2$$

For any cross section $\boxed{p + \frac{1}{2}\rho v^2 + \rho gh = \text{Constant}}$

$$p + \frac{1}{2}\rho v^2 + \rho g h = \text{const}$$

pressure energy per unit vol

KE per unit volume

Potential energy per unit volume.

Que→ In a flowing fluid (water) at cross section 1 $A_1 = 10\,cm^2$

$h_1 = 2\,m$ $\quad v_1 = 10\,m/s$ $\quad$ At section 2 $\quad A_2 = 5\,cm^2$

$h_2 = 4\,m$ then find pressure difference $p_1 - p_2$ for both the cross sections ?

$$A_1 v_1 = A_2 v_2$$

$$10 \times 10 = 5\, v_2$$

$$v_2 = 20\,m/sec$$

Solⁿ→

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$p_1 - p_2 = \frac{1}{2} \times 10^3 \left(20^2 - 10^2\right) + 10^3 \times 10\,(4-2)$$

$$\boxed{p_1 - p_2 = 150 \times 10^3 + 2000 = 170\,kPa = 1.7\,atm}$$

Pressure Velocity Trade off in Horizontal Fluid Flow →

$$\boxed{A_1 V_1 = A_2 V_2}$$

$$\Rightarrow p_1 + \frac{1}{2}\rho v_1^2 + \rho g h$$

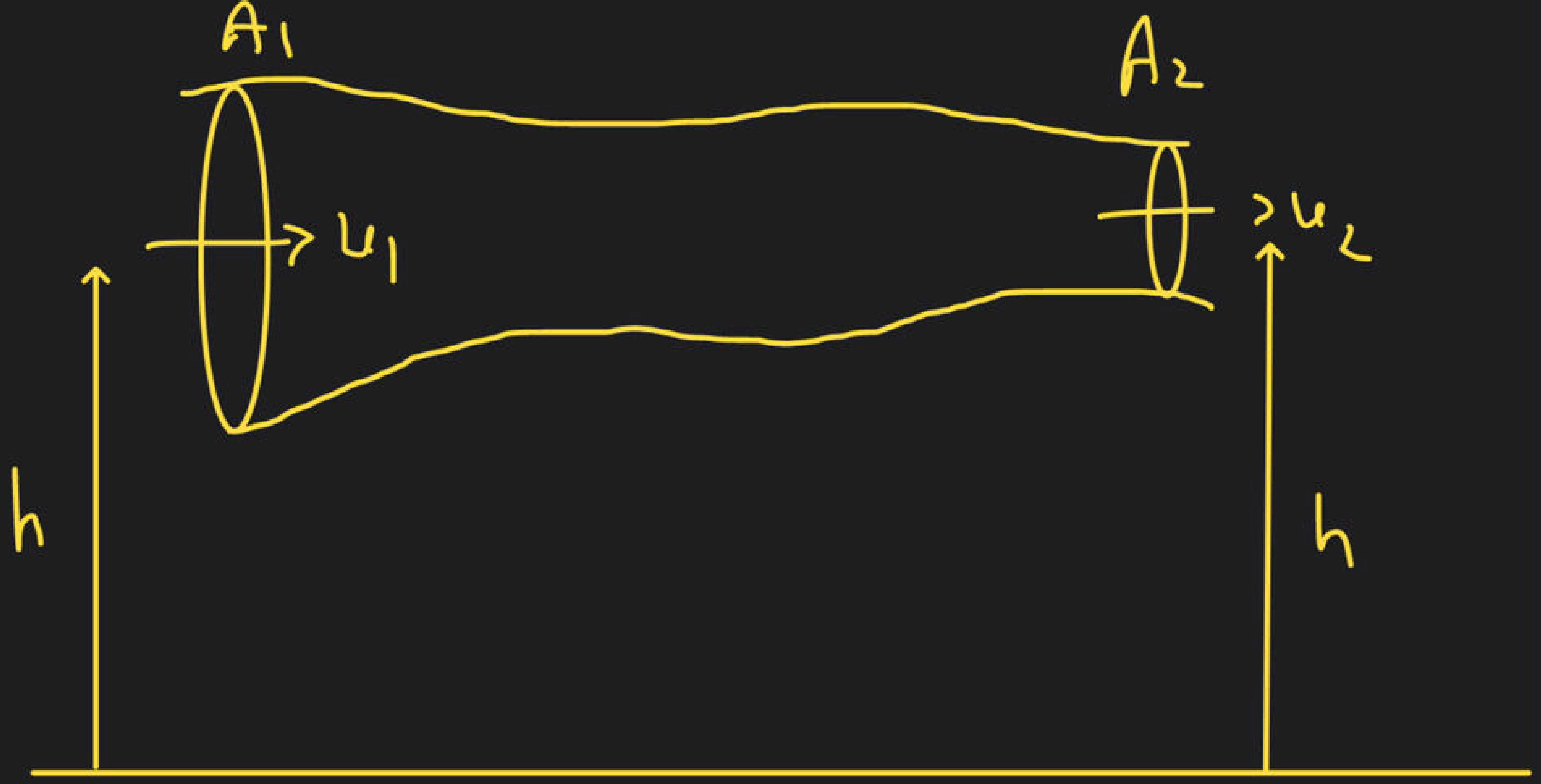
$$= p_2 + \frac{1}{2}\rho v_2^2 + \rho g h$$

$$\boxed{p + \frac{1}{2}\rho v^2 = \text{Constant}}$$

$$\boxed{A_1 > A_2}$$

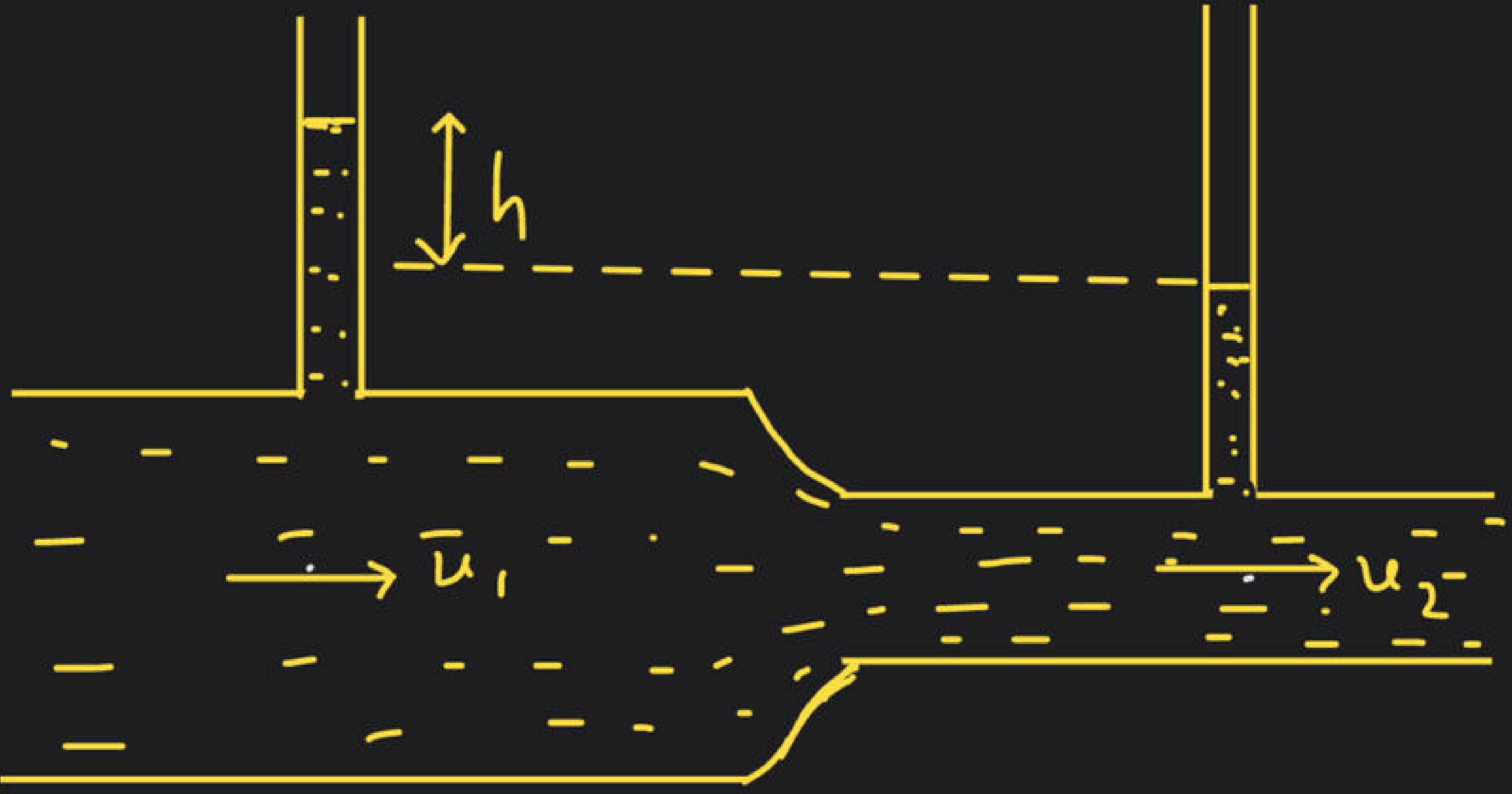
$$\boxed{v_1 < v_2}$$

$$\boxed{p_1 > p_2}$$



Concept of Venturimeter → Device used to measure rate of flow.

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$



$$p_1 - p_2 = \rho g h$$

$$\rho g h = \frac{1}{2}\rho (v_2^2 - v_1^2)$$

$$A_1 v_1 = A_2 v_2 \rightarrow \text{Volume rate of flow.}$$

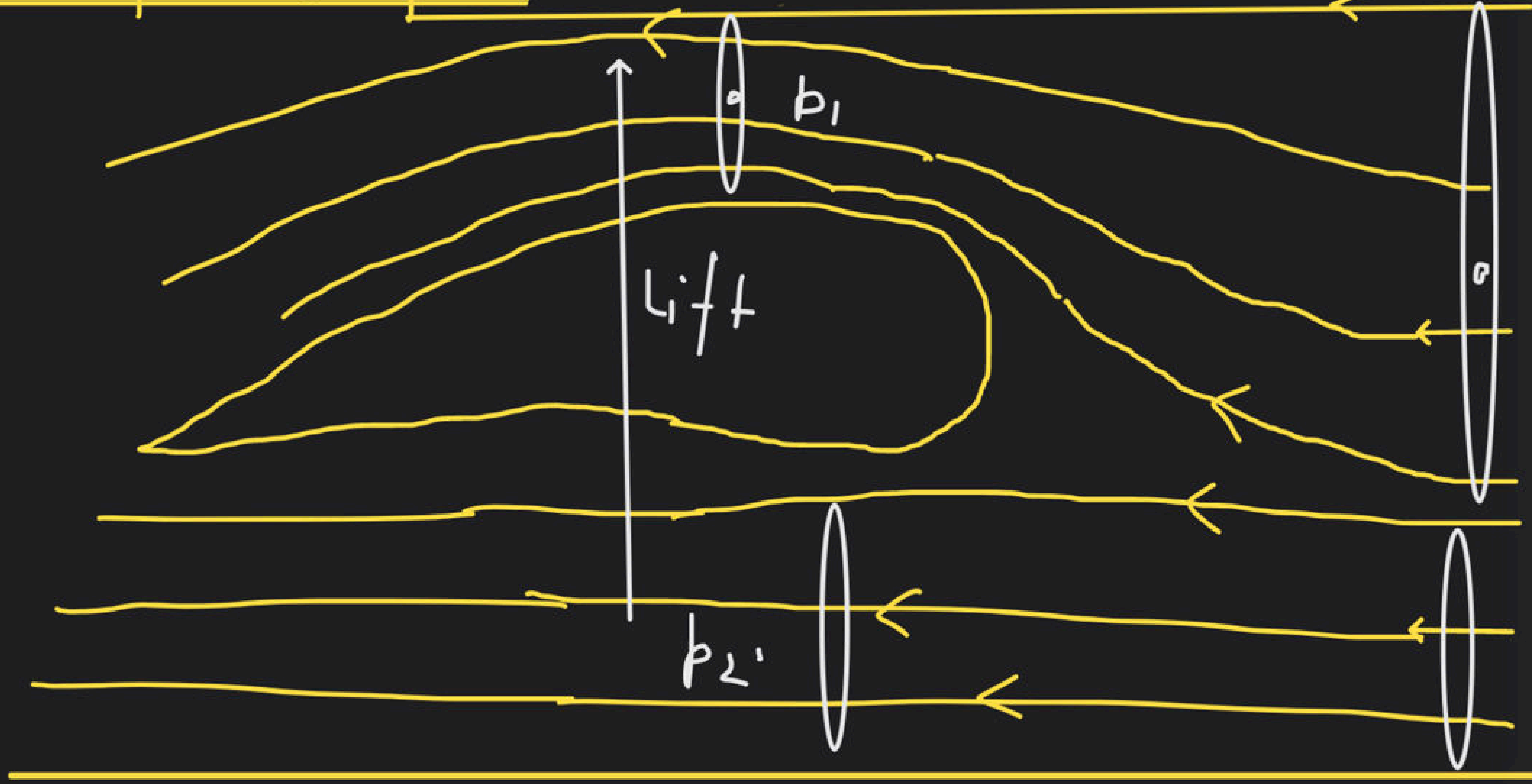
$$\frac{A_1^2 v_1^2}{A_2^2} - v_1^2 = 2gh$$

$$v_1 = \frac{\sqrt{2gh}}{\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}}$$

Volume rate of flow

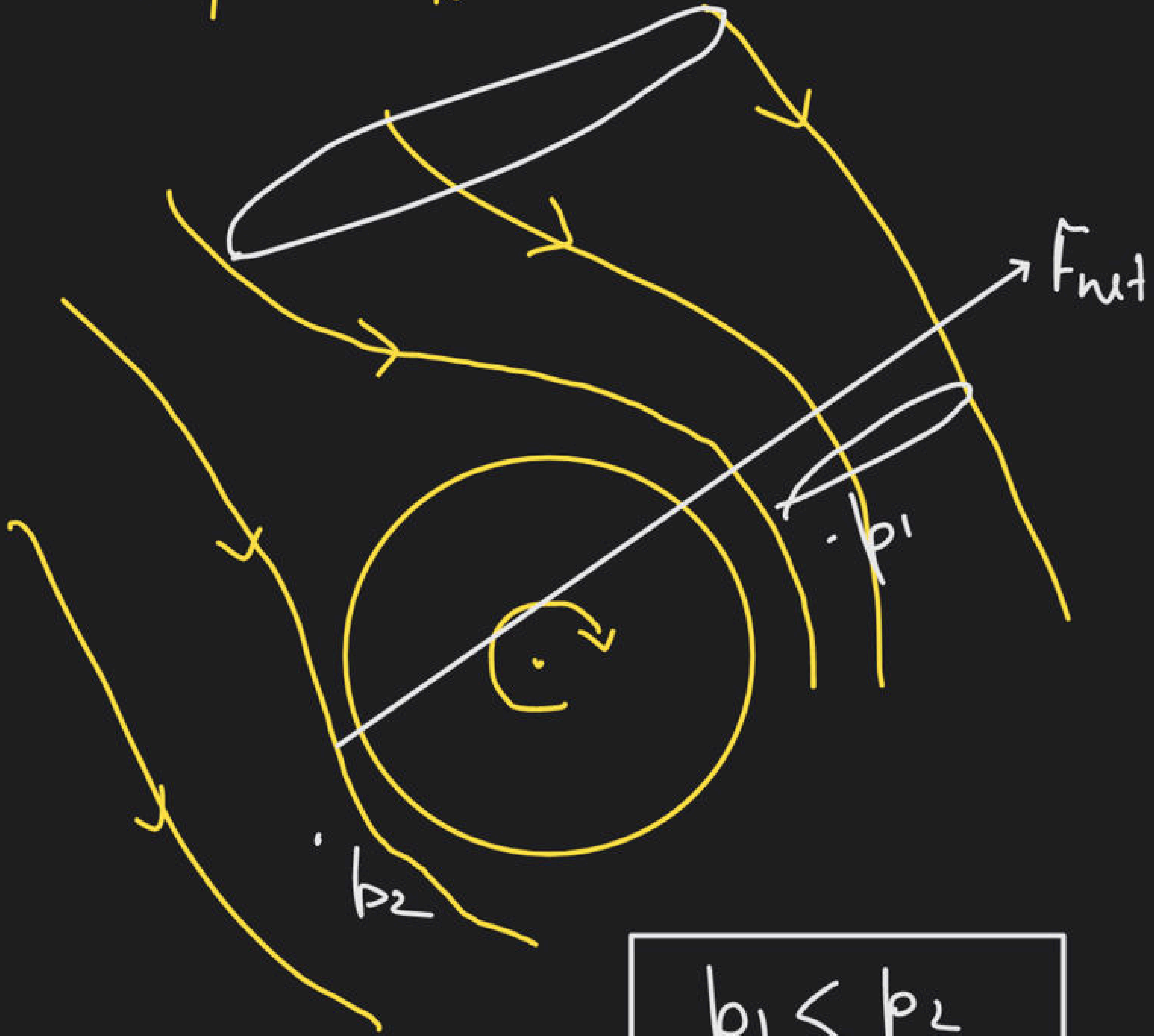
$$\boxed{Q = \frac{A_1 \sqrt{2gh}}{\sqrt{\left(\frac{A_1}{A_2}\right)^2 - 1}}}\ m^3/sec$$

Concept of Airfoil →

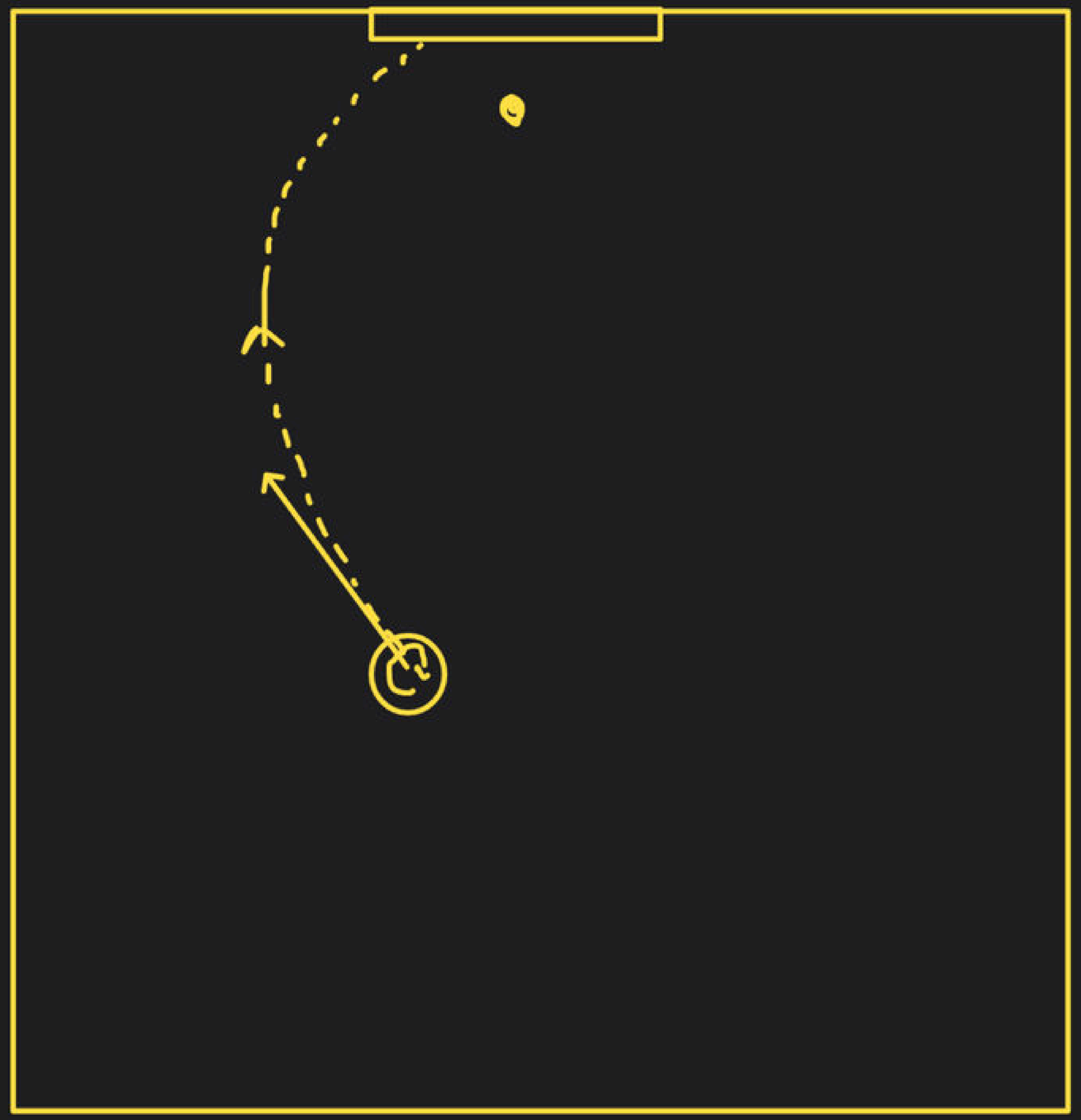


$$\boxed{p_1 < p_2}$$

Magnus Effect



$$\boxed{p_1 < p_2}$$



Velocity of Efflux Through an orifice →

$$\Rightarrow A v_s = a v$$

$$A >> a \qquad v_s << v$$

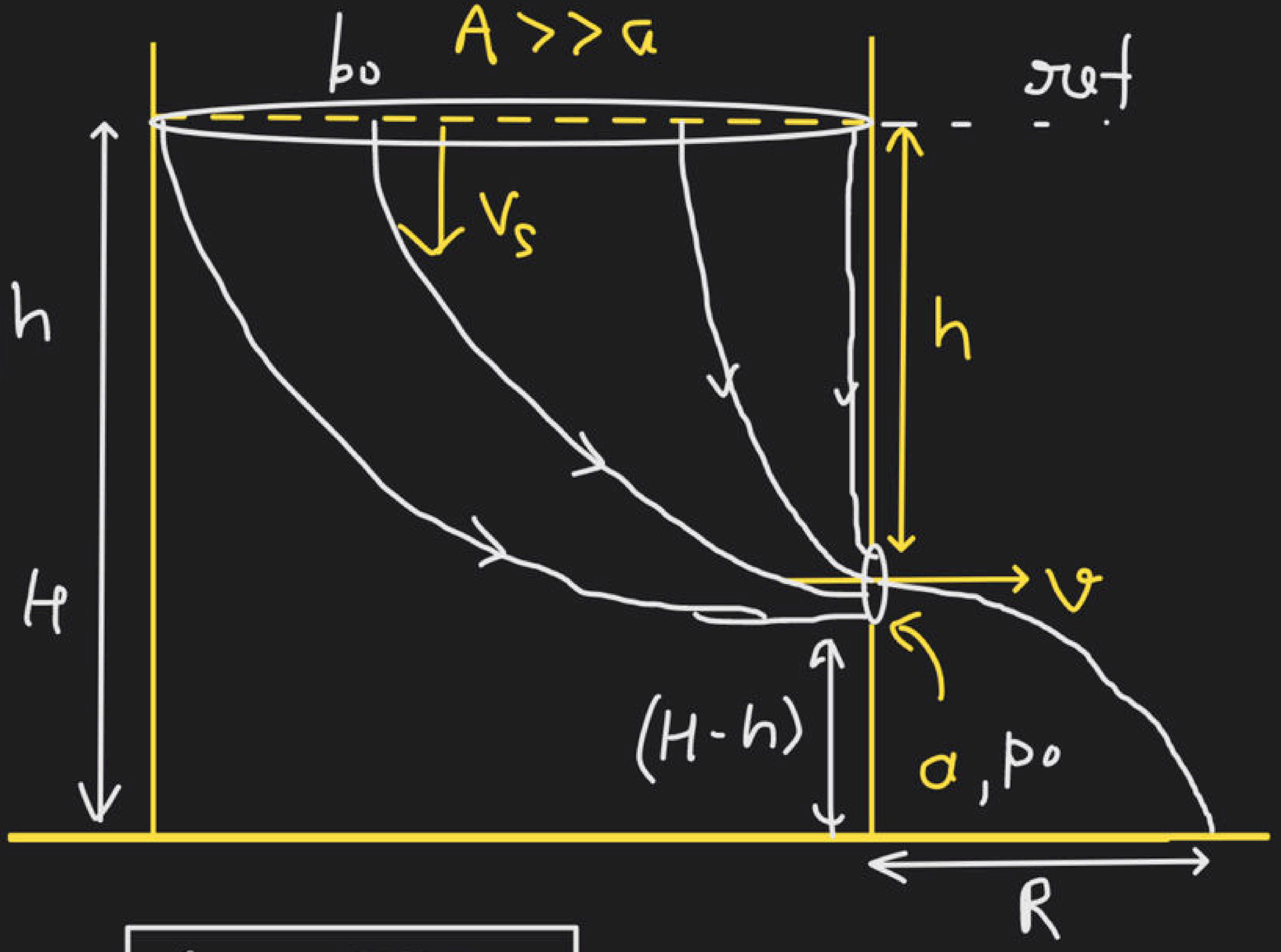
$$\Rightarrow p_0 + \frac{1}{2}\rho v_s^2 + 0 = p_0 + \frac{1}{2}\rho v^2 - \rho g h$$

$$v^2 - v_s^2 = 2gh$$

$$v^2 - \frac{a^2 v^2}{A^2} = 2gh$$

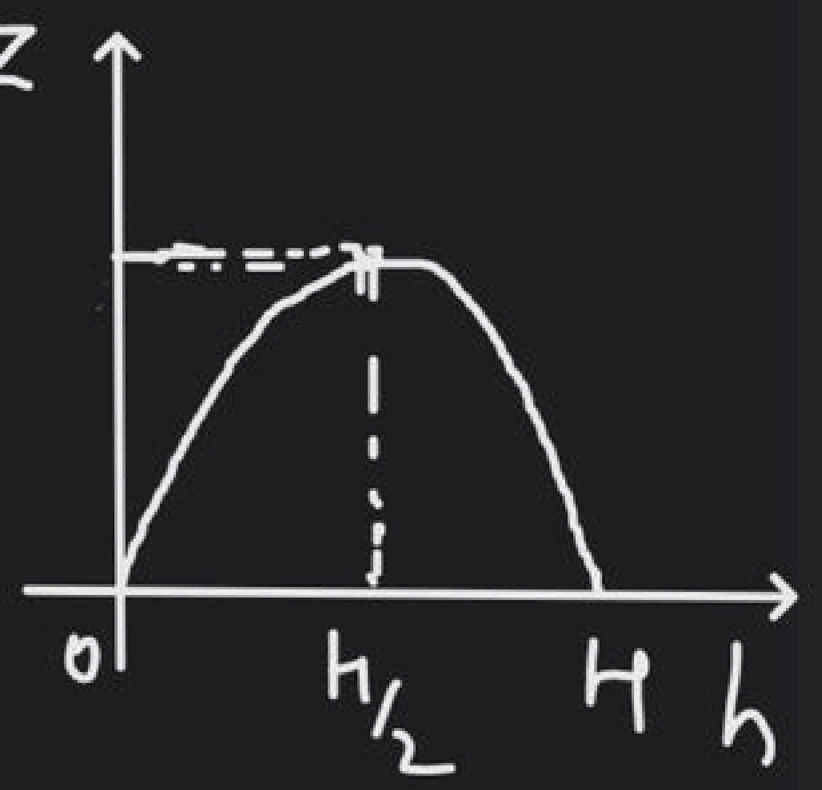
$$v = \sqrt{\frac{2gh}{(1 - a^2/A^2)}}$$

$$A >> a$$



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

time to strike the ground $= \sqrt{\dfrac{2(H-h)}{g}}$



$$\boxed{R = vT = \sqrt{2gh}\sqrt{\frac{2(H-h)}{g}} = 2\sqrt{h(H-h)}}$$

$\Rightarrow$ R will be max when $z = h(H-h)$ will be max

$$\frac{dz}{dh} = H - 2h = 0$$

$$\boxed{h = H/2}$$

$$\boxed{R_{max} = H}$$

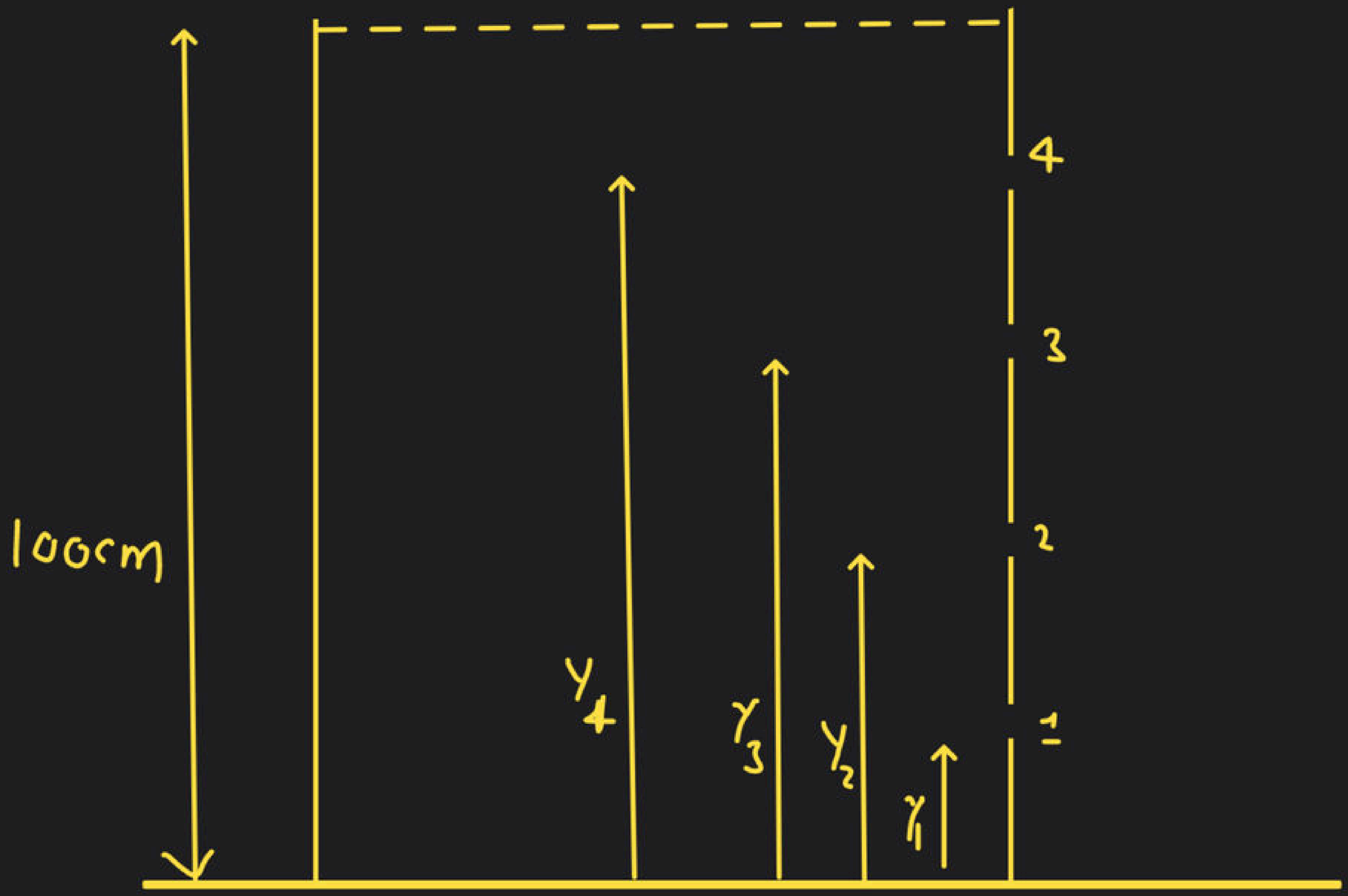
Que 1 -> Compare R_1, R_2, R_3 and R_4 if

$y_1 = 26\ cm$

$y_2 = 44\ cm$

$y_3 = 54\ cm$

$y_4 = 76\ cm$



Sol^n -> $\boxed{R_3 > R_2 > R_1 > R_4}$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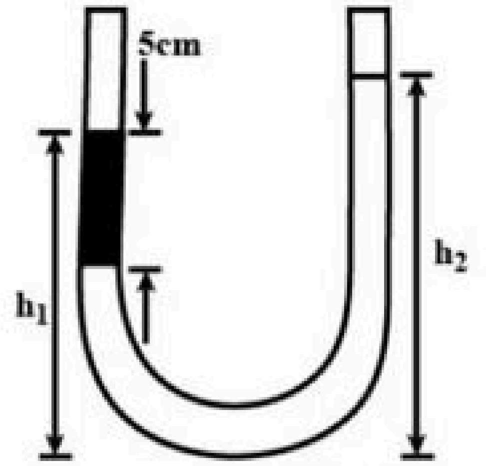
EXERCISE-I
Part-I
(Single Correct type Questions)
Section-A
(Pressure Variation in fluids)

1. The pressure at the bottom of a tank of water is 3P where P is the atmospheric pressure. If the water is drawn out till the level of water is lowered by one fifth, the pressure at the bottom of the tank will now be

(A) 2P (B) (13/5) P (C) (8/5) P (D) (4/5) P

2. An open-ended U-tube of uniform cross-sectional areal contain water (density 1.0 gram/cm³) standing initially 20 cm from the bottom in each arm. An immiscible liquid of density 4.0 grams/cm³ is added to one arm until a layer 5 cm high forms, as shown in the figure above. What is the ratio h_2/h_1 of the heights of the liquid in the two arms ?



(A) 3/1 (B) 5/2 (C) 2/1 (D) 3/2

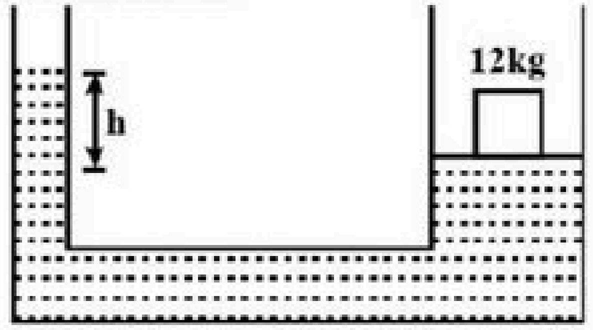
3. A U-tube having horizontal arm of length 20 cm, has uniform cross-sectional area = 1 cm². It is filled with water of volume 60 cc. What volume of a liquid of density 4g/cc should be poured from one side into the U-tube so that no water is left in the horizontal arm of the tube ?

(A) 60 cc (B) 45 cc (C) 50 cc (D) 35 cc

4. A bucket contains water filled upto a height = 15 cm. The bucket is tied to a rope which is passed over a friction less light pulley and the other end of the rope is tied to a weight of mass which is half of that of the (bucket + water). The water pressure above atmosphere pressure at the bottom is

(A) 0.5 kPa (B) 1 kPa (C) 5 kPa (D) None of these

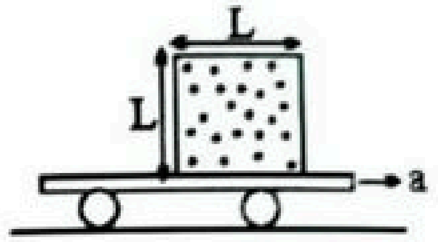
5. The area of cross-section of the wider tube shown in figure is 800 cm^2. If a mass of 12 kg is placed on the massless piston, the difference in heights h in the level of water in the two tubes is:



(A) 10 cm (B) 6 cm (C) 15 cm (D) 2 cm

Section-B
(Pressure variation in accelerated fluids)

6. A cubical sealed vessel with edge L is placed on a cart, which is moving horizontally with an acceleration 'a' as shown in figure. The cube is filled with a ideal fluid having density ρ. The gauge pressure at the centre of the cubical vessel is

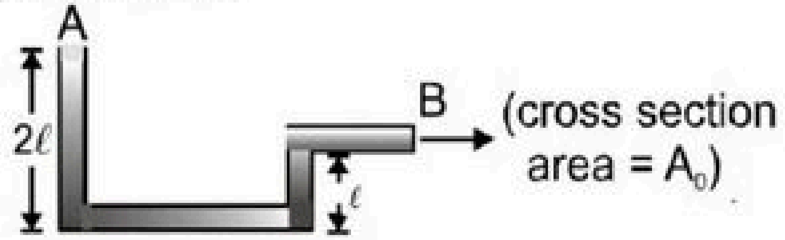


(A) $\frac{L}{2}\rho g$ (B) $\frac{L}{2}\rho(g+a)$ (C) $\frac{L}{2}\rho a$ (D) $\frac{L}{2}\rho(g-a)$

7. An open cubical tank was initially fully filled with water. When the tank was accelerated on a horizontal plane along one of its side it was found that one third of volume of water spilled out. The acceleration was

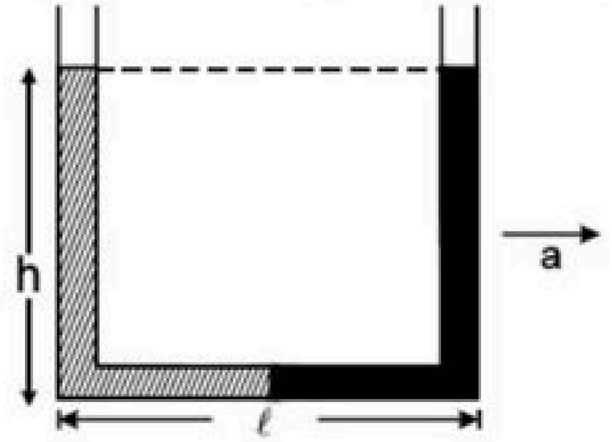
(A) g/3 (B) 2g/3 (C) 3g/2 (D) None of these

8. A tube in vertical plane is shown in figure. It is filled with a liquid of density ρ and its end B is closed. Then the force exerted by the fluid on the tube at end B will be: [Neglect atmospheric pressure and assume the radius of the tube to be negligible in comparison to λ]



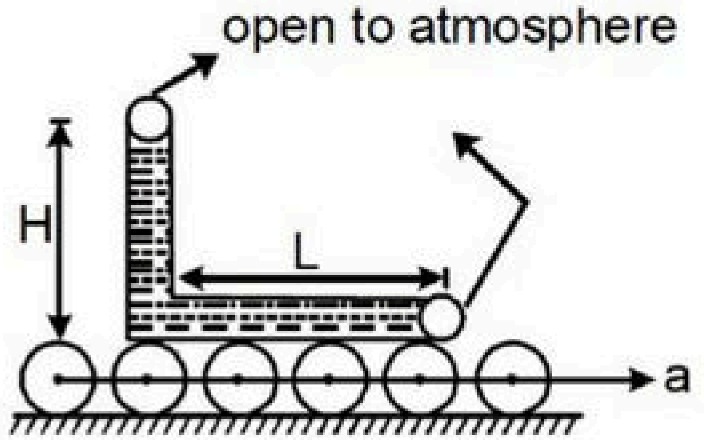
(A) 0 (B) $\rho g \lambda A_0$ (C) $2\rho g \lambda A_0$ (D) $\frac{\rho g \ell A_0}{2}$

9. A U-tube of base length "λ" filled with same volume of two liquids of densities ρ and 2ρ is moving with an acceleration "a" on the horizontal plane as shown in the figure. If the height difference between the two surfaces (open to atmosphere) becomes zero, then the height h is given by:



(A) $\frac{a}{2g}\ell$ (B) $\frac{3a}{2g}\ell$ (C) $\frac{a}{g}\ell$ (D) $\frac{2a}{3g}\ell$

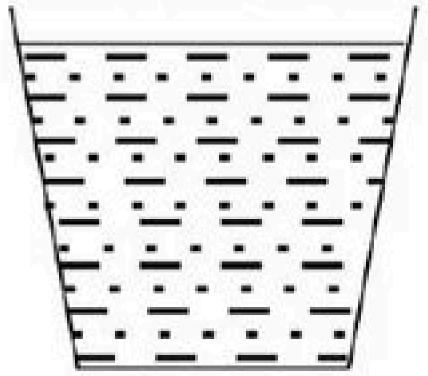
10. A narrow tube completely filled with a liquid is lying on a series of cylinders as shown in figure. Assuming no sliding between any surfaces, the value of acceleration of the cylinders for which liquid will not come out of the tube from anywhere is given by



(A) $\frac{gH}{2L}$ (B) $\frac{gH}{L}$ (C) $\frac{2gH}{L}$ (D) $\frac{gH}{\sqrt{2}L}$

Section-C
(Force on walls of container by fluid)

11. A liquid of mass 1 kg is filled in a flask as shown in figure. The force exerted by the flask on the liquid is ($g = 10\ m/s^2$) [Neglect atmospheric pressure]:

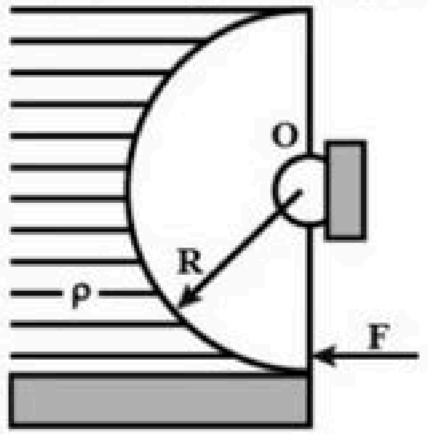


(A) 10 N (B) greater than 10N (C) less than 10N (D) zero

12. Some liquid is filled in a cylindrical vessel of radius R. Let F_1 be the force applied by the liquid on the bottom of the cylinder. Now the same liquid is poured into a vessel of uniform square cross-section of side R. Let F_2 be the force applied by the liquid on the bottom of this new vessel. (Neglect atmosphere pressure) Then:

(A) $F_1 = \pi F_2$ (B) $F_1 = \frac{F_2}{\pi}$ (C) $F_1 = \sqrt{\pi} F_2$ (D) $F_1 = F_2$

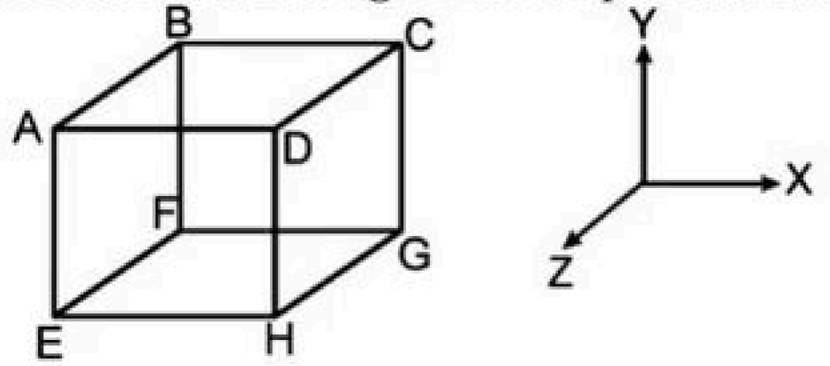
13. A light semi-cylindrical gate of radius R is pivoted at its mid-point O, of the diameter as shown in the figure holding liquid of density ρ. The force F required to prevent the rotation of the gate is equal to



(A) $2\pi R^3 \rho g$ (B) $2\rho g R^3 l$

(C) $\frac{2R^2 l \rho g}{3}$ (D) None of these

14. The cubical container ABCDEFGH which is completely filled with an ideal (non-viscous and incompressible) fluid, moves in a gravity free space with a acceleration of $a = a_0(\hat{i} - \hat{j} + \hat{k})$ where a_0 is a positive constant. Then the only point in the container shown in the figure where pressure is maximum, is

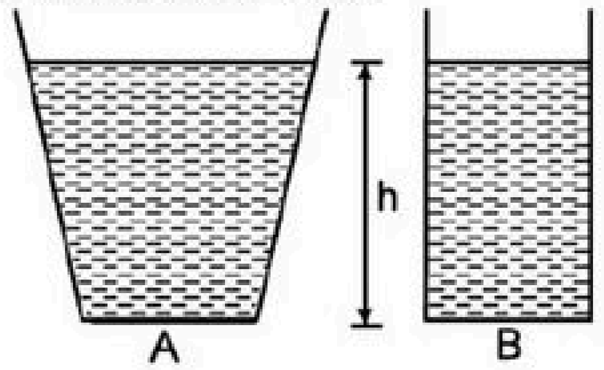


(A) B (B) C (C) E (D) F

15. In previous question pressure will be minimum at point –

(A) A (B) B (C) H (D) F

16. Two vessels A and B of different shapes have the same base area and are filled with water up to the same height h (see figure). The force exerted by water on the base is F_A for vessel A and F_B for vessel B. The respective weights of the water filled in vessels are W_A and W_B. Then



(A) $F_A > F_B$; $W_A > W_B$
(B) $F_A = F_B$; $W_A > W_B$
(C) $F_A = F_B$; $W_A < W_B$
(D) $F_A > F_B$; $W_A = W_B$

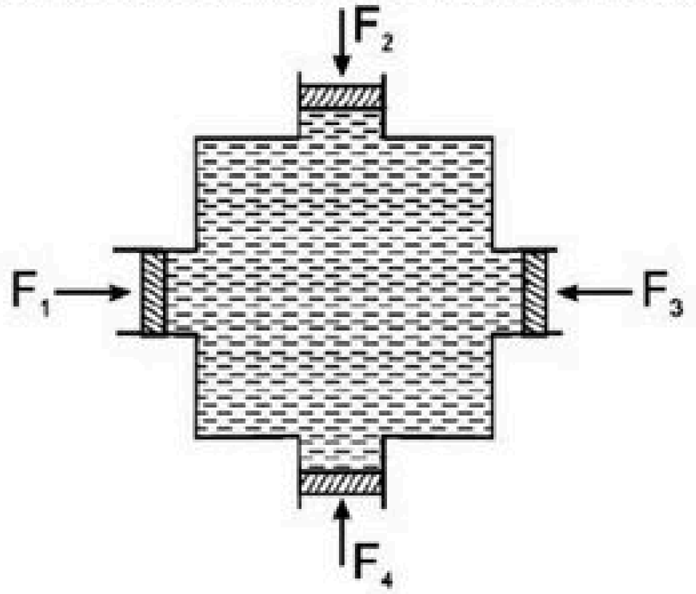
17. A container of large surface area is filled with liquid of density ρ. A cubical block of side edge a and mass M is floating in it with four-fifth of its volume submerged. If a coin of mass m is placed gently on the top surface of the block is just submerged. M is

(A) 4m/5 (B) m/5 (C) 4m (D) 5m

18. A boy carries a fish in one hand and a bucket (not full) of water in the other hand. If the places the fish in the bucket, the weight now carried by him (assume that water does not spill):

(A) is less than before
(B) is more than before
(C) is the same as before
(D) depends upon his speed

19. In the figure shown water is filled in a symmetrical container. Four pistons of equal area A are used at the four opening to keep the water in equilibrium. Now an additional force F is applied at each piston. The increase in the pressure at the centre of the container due to this addition is



(A) $\frac{F}{A}$ (B) $\frac{2F}{A}$ (C) $\frac{4F}{A}$ (D) 0

Section-D
(Achemdes Principle (Buoyancy force))

20. A cork of density 0.5 g cm^{-3} floats on calm swimming pool. The fraction of the cork's volume which is under water is

(A) 0% (B) 25% (C) 10% (D) 50%

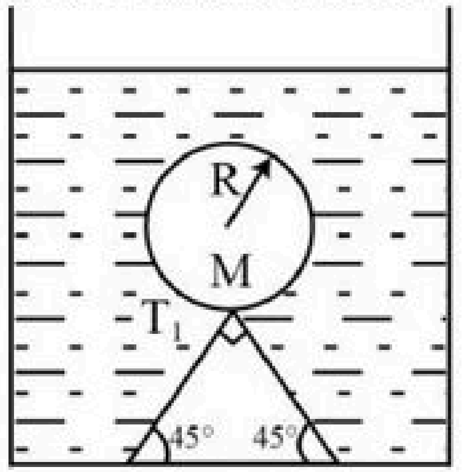
21. A small ball of relative density 0.8 falls into water from a height of 2m. The depth to which the ball with sink is (neglect viscous forces):

(A) 8m (B) 2m (C) 6m (D) 4m

22. A small wooden ball of density ρ is immersed in water of density σ to depth h and then released. The height H above the surface of water up to which the ball will jump out of water is

(A) $\frac{\sigma h}{\rho}$ (B) $\left(\frac{\sigma}{\rho}-1\right)h$ (C) h (D) zero

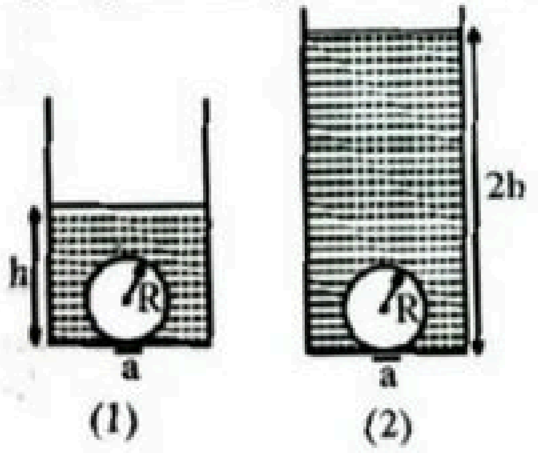
23. A hollow sphere of mass M and radius R is immersed in a tank of water (density ρ_w). The sphere would float if it were set free. The sphere is tied to the bottom of the tank by two wires which makes angle 45° with the horizontal as shown in the figure. The tension T_1 in the wire is:



(A) $\dfrac{\frac{4}{3}\pi R^3\rho_w g - Mg}{\sqrt{2}}$ (B) $\frac{2}{3}\pi R^3\rho_w g - Mg$

(C) $\dfrac{\frac{4}{3}\pi R^3\rho_w g - Mg}{2}$ (D) $\frac{4}{3}\pi R^3\rho_w g + Mg$

24. Two identical cylinders have a hole of radius a (a << R) at its bottom. A ball of radius R is kept on the hole and water is filled in the cylinder such that there is no water leakage from bottom. In case-1 water is filled upto height h and in second case it is filled upto height 2h. If F_1 is net force by liquid on sphere in case-1 and F_2 is net force by liquid on sphere in case-2 then.

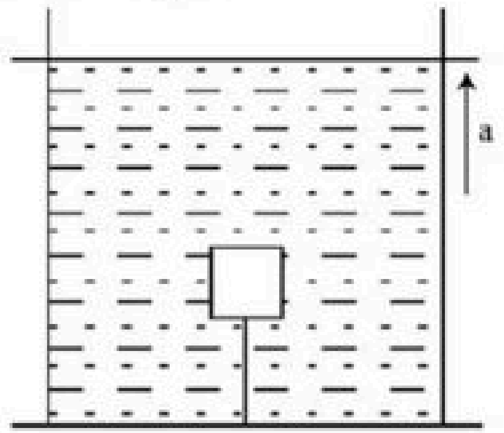


(A) $F_1 = F_2$ (B) $F_1 > F_2$ (C) $F_2 > F_1$ (D) $F_1 = F_2 \neq 0$

25. A sphere of radius R and made of material of relative density σ has a concentric cavity of radius r. It is just floats when placed in a tank full of water. The value of the ratio R/r will be

(A) $\left(\frac{\sigma}{\sigma-1}\right)^{1/3}$ (B) $\left(\frac{\sigma-1}{\sigma}\right)^{1/3}$ (C) $\left(\frac{\sigma+1}{\sigma}\right)^{1/3}$ (D) $\left(\frac{\sigma-1}{\sigma+1}\right)^{1/3}$

26. A body having volume V and density ρ is attached to the bottom of a container as shown. Density of the liquid is d (>ρ). Container has a constant upward acceleration a. Tension in the string is

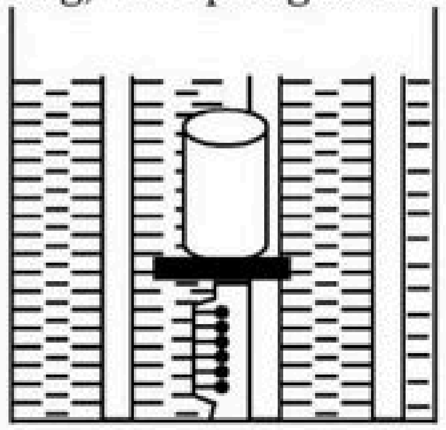


(A) V[Dg – ρ(g + a)] (B) V[(g + a) (d – ρ)] (C) V (d – ρ)g (D) None of these

27. The frequency of a sonometer wire is f, but when the weights producing the tensions are completely immersed in water the frequency becomes f/2 and on immersing the weights in a certain liquid the frequency becomes f/3. The specific gravity of the liquid is :

(A) $\frac{4}{3}$ (B) $\frac{16}{9}$ (C) $\frac{15}{12}$ (D) $\frac{32}{27}$

28. A cylindrical block of area of cross-section A and of material of density ρ is placed in a liquid of density one-third of density of block. The block compress a spring and compression in the spring is one-third of the length of the block. If acceleration due to gravity is g, the spring constant of the spring is:



(A) ρAg (B) 2ρAg (C) 2ρAg/3 (D) ρAg/3

29. A beaker containing water is placed on the platform of a spring balance. The balance reads 1.5 kg. a stone of mass 0.5 kg and density 500 kg/m^3 is completely immersed in water without touching the walls of beaker. What will be the balance reading now ?

(A) 2 kg (B) 2.5 kg (C) 1 kg (D) 3 kg

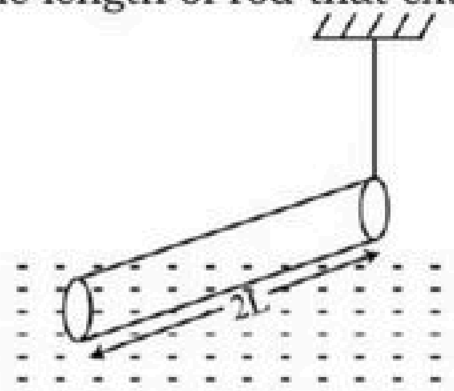
30. Two cylinders of same cross-section and length L but made of two material of densities d_1 and d_2 are cemented together to form a cylinder of length 2L. The combination floats in a liquid of density d with a length L/2 above the surface of the liquid. If $d_1 > d_2$ then:

(A) $d_1 > \frac{3}{4}d$ (B) $\frac{d}{2} > d_1$ (C) $\frac{d}{4} > d_1$ (D) $d < d_1$

31. Two bodies having volumes V and 2V are suspended from the two arms of a common balance and they are found to balance each other. If larger body is immersed in oil (density $d_1 = 0.9$ gm/cm^3) and the smaller body is immersed in an unknown liquid, then the balance remain in equilibrium. The density of unknown liquids is given by:

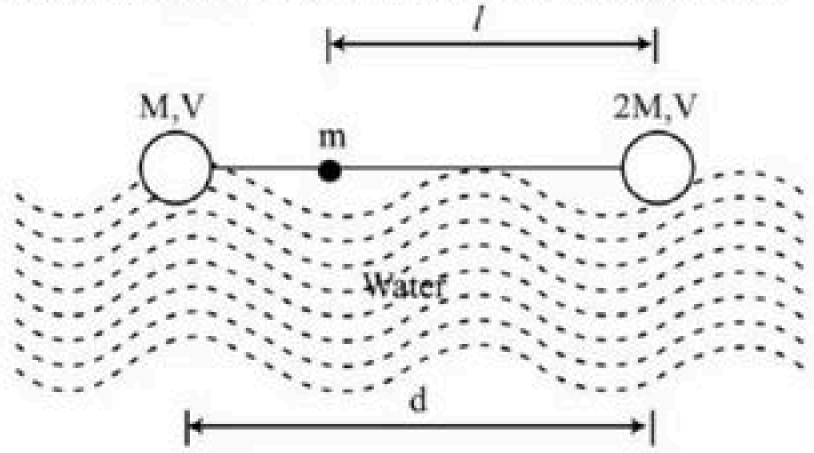
(A) 2.4 gm/cm^3 (B) 1.8 gm/cm^3 (C) 0.45 gm/cm^3 (D) 2.7 gm/cm^3

32. A slender homogeneous rod of length 2L floats partly immersed in water, being supported by a string fastened to one of its ends, as shown. The specific gravity of the rod is 0.75. The length of rod that extends out of water is:



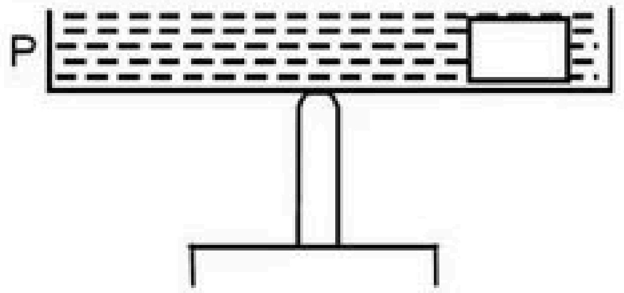
(A) L (B) $\frac{1}{2}L$ (C) $\frac{1}{4}L$ (D) 3L

33. A dumbbell is placed in water of density ρ. It is observed that by attaching a mass m to the rod, the dumbbell floats with the rod horizontal on the surface of water and each sphere exactly half submerged as shown in the figure. The volume of the mass m is negligible. The value of length l is



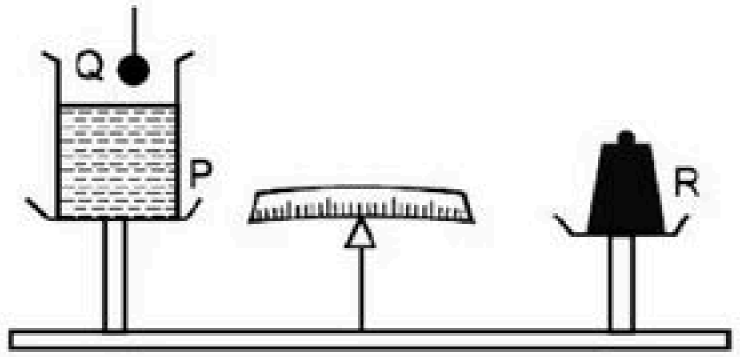
(A) $\frac{d(V\rho-3M)}{2(V\rho-2M)}$ (B) $\frac{d(V\rho-2M)}{2(V\rho-3M)}$ (C) $\frac{d(V\rho+2M)}{2(V\rho-3M)}$ (D) $\frac{d(V\rho-2M)}{2(V\rho+3M)}$

34. An open pan P filled with water (density ρ_w) is placed on a vertical rod, maintaining equilibrium. A block of density ρ is placed on one side of the pan as shown in the figure. Water depth is more than height of the block.



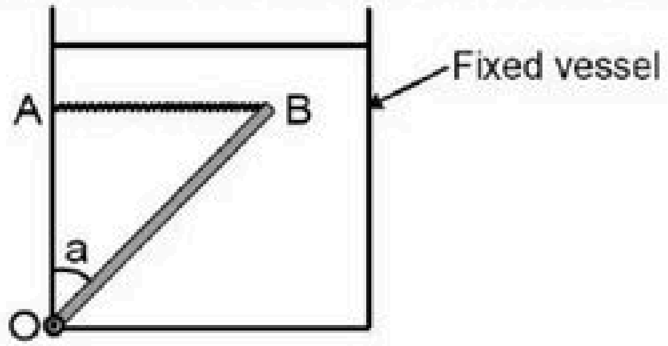
(A) Equilibrium will be maintained only if $\rho < \rho_w$
(B) Equilibrium will be maintained only if $\rho \le \rho_w$
(C) Equilibrium will be maintained for all relations between ρ and ρ_w
(D) It is not possible to maintained the equilibrium

35. Figure shows a weighing-bridge, with a beaker P with water on one pan and a balancing weight R on the other. A solid ball Q is hanging with a thread outside water. It has volume 40 cm^3 and weighs 80 g. If this solid is lowered to sink fully in water, but not touching the beaker anywhere, the balancing weight R' will be



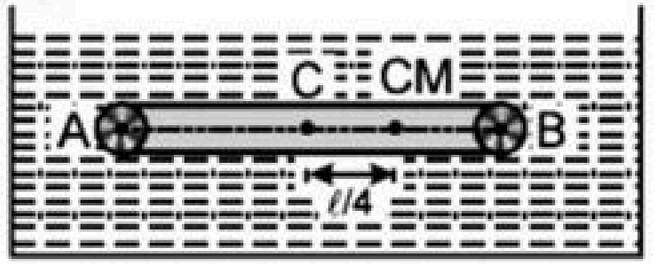
(A) same as R
(B) 40 g less than R
(C) 40 g more than R
(D) 80 g more than R

36. A uniform rod OB of length 1m, cross-sectional area 0.012 m^2 and relative density 2.0 is free to rotate about O in vertical plane. The rod is held with a horizontal string AB which can withstand a maximum tension of 45 N. The rod and string system is kept in water as shown in figure. The maximum value of angle α which the rod can make with vertical without breaking the string is



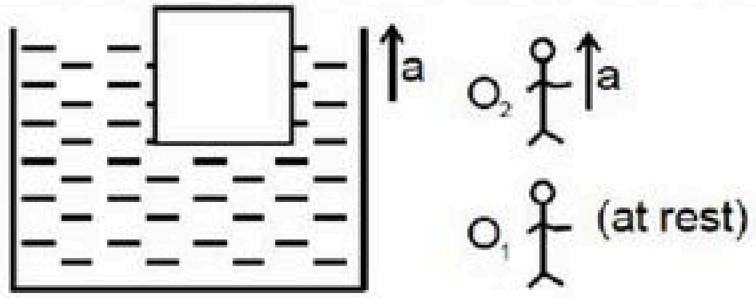
(A) 45°
(B) 37°
(C) 53°
(D) 60°

37. A non uniform cylinder of mass m, length λ and radius r is having its centre of mass at a distance $\lambda/4$ from the centre and lying on the axis of the cylinder as shown in the figure. The cylinder is kept in a liquid of uniform density ρ. The moment of inertia of the rod about the centre of mass is I. The angular acceleration of point A relative to point B just after the rod is released from the position shown in figure is



(A) $\frac{\pi\rho g\ell^2 r^2}{I}$ (B) $\frac{\pi\rho g\ell^2 r^2}{4I}$ (C) $\frac{\pi\rho g\ell^2 r^2}{2I}$ (D) $\frac{3\pi\rho g\ell^2 r^2}{4I}$

38. A block is partially immersed in a liquid and the vessel is accelerating upwards with an acceleration "a". The block is observed by two observers O_1 and O_2, one at rest and the other accelerating with an acceleration "a" upward as shown in the figure. The total buoyant force on the block is:



(A) same for O_1 and O_2
(B) greater for O_1 than O_2
(C) greater for O_2 than O_1
(D) data is not sufficient

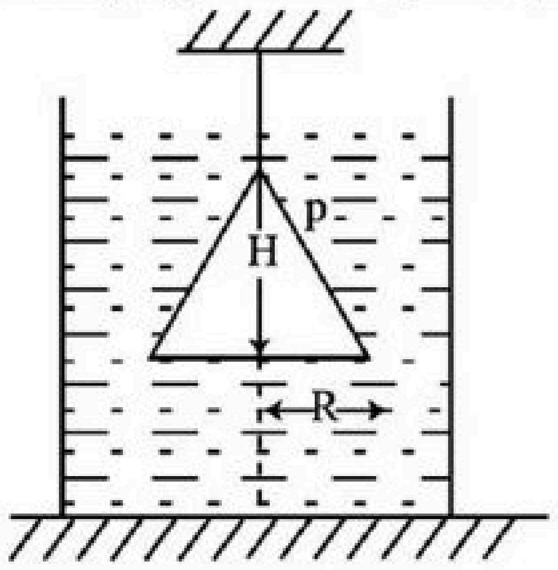
39. Two cubes of size 1.0 m sides, one of relative density 0.60 and another of relative density = 1.15 are connected by weightless wire and placed in a large tank of water. Under equilibrium the lighter cube will projected above the water surface to a height of

(A) 50 cm (B) 25 cm (C) 10 cm (D) zero

40. A cuboidal piece of wood has dimensions a, b and c. Its relative density is d. It is floating in a large body of water such that side a is vertical. It is pushed down a bit and released. The time period of SHM executed by it is:

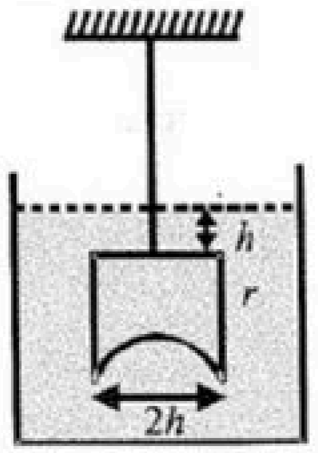
(A) $2\pi\sqrt{\frac{abc}{g}}$ (B) $2\pi\sqrt{\frac{g}{da}}$ (C) $2\pi\sqrt{\frac{bc}{dg}}$ (D) $2\pi\sqrt{\frac{da}{g}}$

41. A cone of radius R and height H, is hanging inside a liquid of density ρ by means of a string as shown in the figure. The force due to the liquid acting on the slant surface of the cone is (Neglect atmosphere pressure)



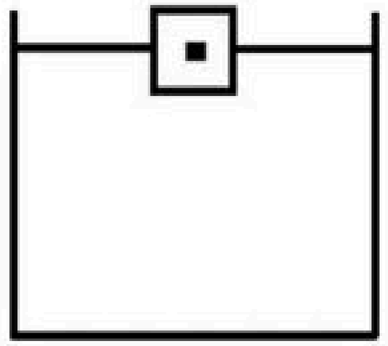
(A) $\rho\pi gHR^2$ (B) $\pi\rho HR^2$ (C) $\frac{4}{3}\pi\rho gHR^2$ (D) $\frac{2}{3}\pi\rho gHR^2$

42. 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 mass 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 cylinder by the liquid is



(A) Mg
(B) Mg – Vρg
(C) Mg + $\rho R^2 h\rho R$
(D) $\rho g(V + \pi R^2 h)$

43. There is a metal cube inside a block of ice which is floating on the surface of water. The ice melts completely and metal falls in the water. Water level in the container

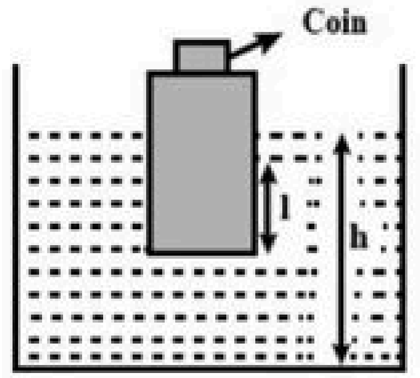


(A) Rises (B) Falls
(C) Remains same (D) Nothing can be concluded

44. An ice cube of size a = 20 cm is floating in a lake filled with water. The relative density of ice is 0.9. The change in gravitational potential energy when ice melts completely will be

(A) Zero (B) increase by 0.72 J
(C) decrease by 0.72 J (D) increase by 7.2 J

45. A wooden block, with a coin placed on its top floats in water as shown in figure. The distance l and h are shown here. After some time the coin falls into the water. Then



(A) l decreases and h increases (B) l increases and h decreases
(C) both l and h increase (D) both l and h decrease

Section-E
(Continuity and Bernoulli's Equation)

46. Fountains usually seen in gardens are generated by a wide pipe with an enclosure at one end having many small holes. Consider one such fountain which is produced by a pipe of internal diameter 2cm in which water flows at a rate 3 ms^{-1}. The enclosure has 100 holes each of diameter 0.05 cm. the velocity of water coming out of the holes is (in ms^{-1}):

(A) 0.48 (B) 96 (C) 24 (D) 48

47. Two water pipes P and Q having diameters 2×10^{-2} and 4×10^{-2} m, respectively, are joined in series with the main supply line of water. The velocity of water flowing in pipe P is

(A) 4 times that of Q
(B) 2 times that of Q
(C) 1/2 times of that of Q
(D) 1/4 times that of Q

48. In the case of fluid, Bernoulli's theorem expresses the application of the principle of conservation of:

(A) linear momentum
(B) energy
(C) mass
(D) angular momentum

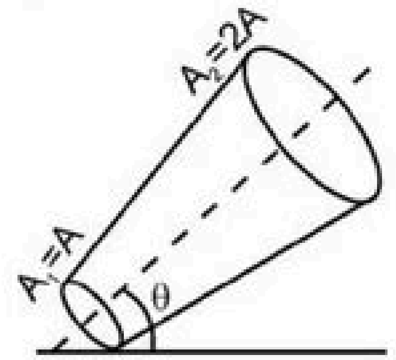
49. Which of the following is not an assumption for an ideal fluid flow for which Bernoulli's principle is valid

(A) Steady flow
(B) Incompressible
(C) Viscous
(D) Irrotational

50. Water is flowing steadily through a horizontal tube of non uniform cross-section. If the pressure of water is 4×10^4 N/m^2 at a point where cross-section is 0.02m^2 and velocity of flow is 2m/s, what is pressure at a point where cross-section reduces to 0.01 m^2.

(A) 1.4×10^4 N/m^2
(B) 3.4×10^4 N/m^2
(C) 2.4×10^{-4} N/m^2
(D) None of these

51. A portion of a tube is shown in the figure. Fluid is flowing from cross-section area A_1 to A_2. The two cross-sections are at distance 'λ' from each other. The velocity of the fluid at section A_2 is $\sqrt{\frac{g\ell}{2}}$. If the pressures at A_1 & A_2 are same, then the angle made by the tube with the horizontal will be:



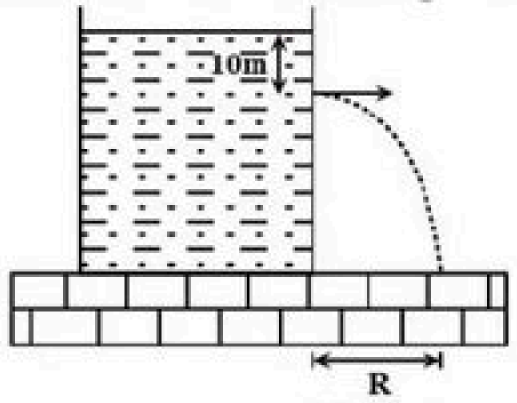
(A) 37°
(B) $\sin^{-1}\frac{3}{4}$
(C) 53°
(D) $\cos^{-1}\frac{3}{4}$

Section-F
(Velocity of Eflux)

52. A water barrel stands on a table of height h. If a small hole is punched in the side of the barrel at its base, it is found that the resultant stream of water strikes the ground at a horizontal distance R from the barrel. The depth of water in the barrel is

(A) $\frac{R}{2}$ (B) $\frac{R^2}{4h}$ (C) $\frac{R^2}{h}$ (D) $\frac{h}{2}$

53. A large tank is filled with water (density = 10^3 kg/m^3). A small hole is made at a depth 10 m below water surface. The range of water issuing out of the hole is Ron ground. What extra pressure must be applied on the water surface so that the range becomes 2R (take 1atm = 10^5 Pa and g = 10m/s^2):

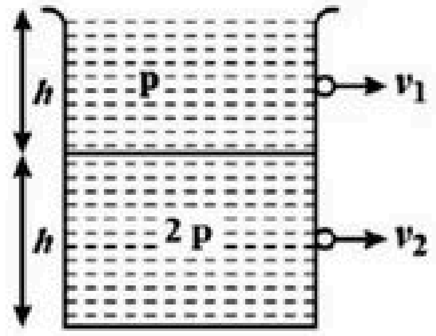


(A) 9 atm (B) 4atm (C) 5 atm (D) 3 atm

54. A cylindrical vessel of cross-sectional area 1000 cm^2, is fitted with a frictionless piston of mass 10kg, and filled with water completely. A small hole of cross-sectional area 10 mm^2 is opened at a point 50 cm deep from the lower surface of the piston. The velocity of efflux from the hole will be

(A) 10.5 m/s (B) 3.4 m/s (C) 0.8 m/s (D) 0.2 m/s

55. Equal volumes of two immiscible liquids of densities ρ and 2ρ are filled in a vessel a shown in figure. Two small holes are punched at depth h/2 and 3h/2 from the surface of lighter liquid. If v_1 and v_2 are the velocities of a flux at these two holes, then v_1/v_2 is:



(A) $\frac{1}{2\sqrt{2}}$ (B) $\frac{1}{2}$ (C) $\frac{1}{4}$ (D) $\frac{1}{\sqrt{2}}$

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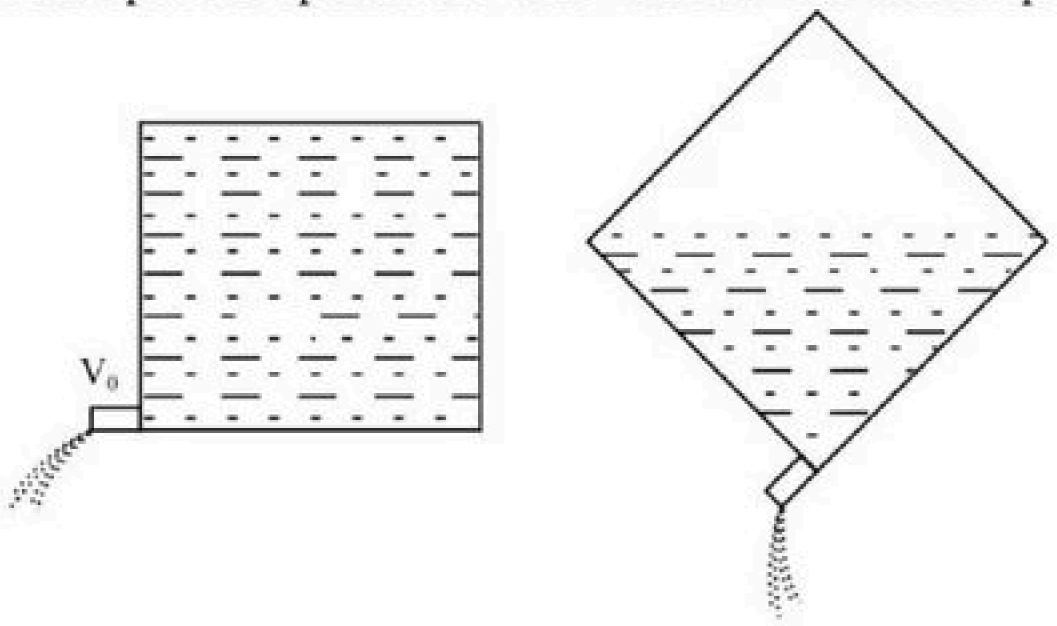
56. A large tank is filled with water to a height H. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to H/η, $(\eta > 1)$ and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is:

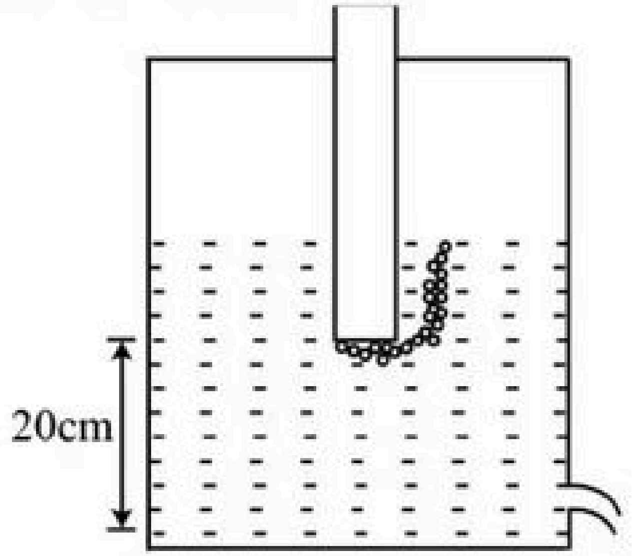
(A) 2 (B) 3 (C) 4 (D) $2\sqrt{2}$

57. A cubical box of wine has a small spout located in one of the bottom corners. When the box is full and placed on a level surface, opening the spout results in a flow of wine with an initial speed of v_0(see figure). When the box is half empty, someone tilts it at 45° so that the spout is at the lowest point (see figure). When the spout is opened the wine will flow out with a speed of



(A) v_0 (B) $v_0/2$ (C) $v_0/\sqrt{2}$ (D) $v_0/\sqrt[4]{2}$

58. A tube is attached as shown in closed vessel containing water. The velocity of water coming out from a small hole is:



(A) $\sqrt{2}$ m/s
(B) 2m/s
(C) depends on pressure of air inside vessel
(D) None of these

upt que 58

59. There is a small hole in the bottom of a fixed container containing a liquid upto height 'h'. The top of the liquid as well as the hole at the bottom are exposed to atmosphere. As the liquid comes out o the hole. (Area of the hole is 'a' and that of the top surface is 'A') :

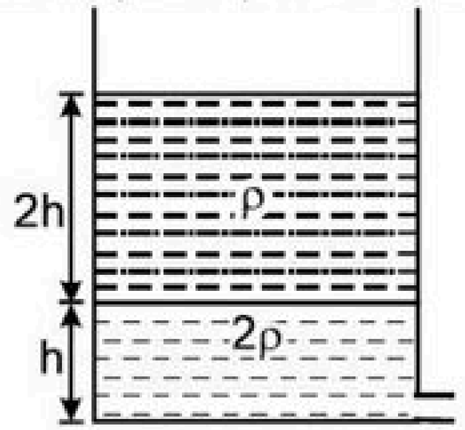
(A) the top surface of the liquid accelerates with acceleration = g

(B) the top surface of the liquid accelerates with acceleration = $g\frac{a^2}{A^2}$

(C) the top surface of the liquid retards with retardation = $g\frac{a}{A}$

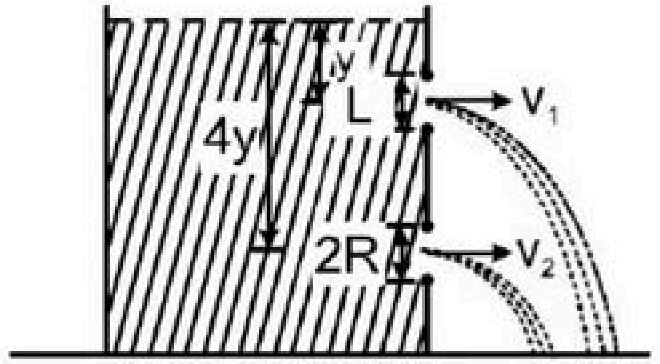
(D) the top surface of the liquid retards with retardation = $\frac{ga^2}{A^2}$

60. The velocity of the liquid coming out of a small hole of a large vessel containing two different liquids of densities 2ρ and ρ as shown in figure is



(A) $\sqrt{6gh}$ (B) $2\sqrt{gh}$ (C) $2\sqrt{2gh}$ (D) $\sqrt{gh}$

61. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth 4y from the top. When the tank is completely filled with water, the quantities of water flowing out per second from both holes are the same. Then radius R, is equal to :



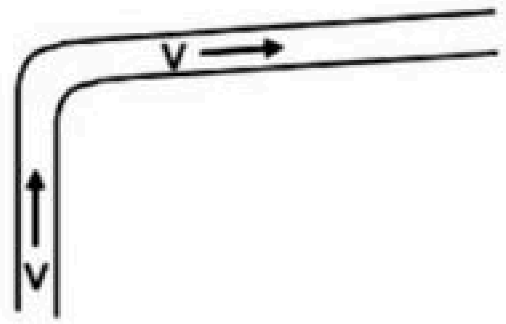
(A) $\frac{L}{\sqrt{2\pi}}$ (B) $2\pi L$ (C) L (D) $\frac{L}{2\pi}$

Section-F
(Miscellaneous)

62. A jet of water with cross section of 6 cm^2 strikes a wall at angle of 60° to the normal and rebounds elastically from the wall without losing energy. If the velocity of the water in the jet is 12 m/s, the force acting on the wall is

(A) 0.864 Nt (B) 86.4 Nt (C) 72 Nt (D) 7.2 Nt

63. A fire hydrant delivers water of density ρ at a volume rate L. The water travels vertically upward through the hydrant and then does 90° turn to emerge horizontally at speed V. The pipe and nozzle have uniform cross-section throughout. The force exerted by the water on the corner of the hydrant is



(A) ρVL (B) zero (C) $2\rho VL$ (D) $\sqrt{2}\rho VL$

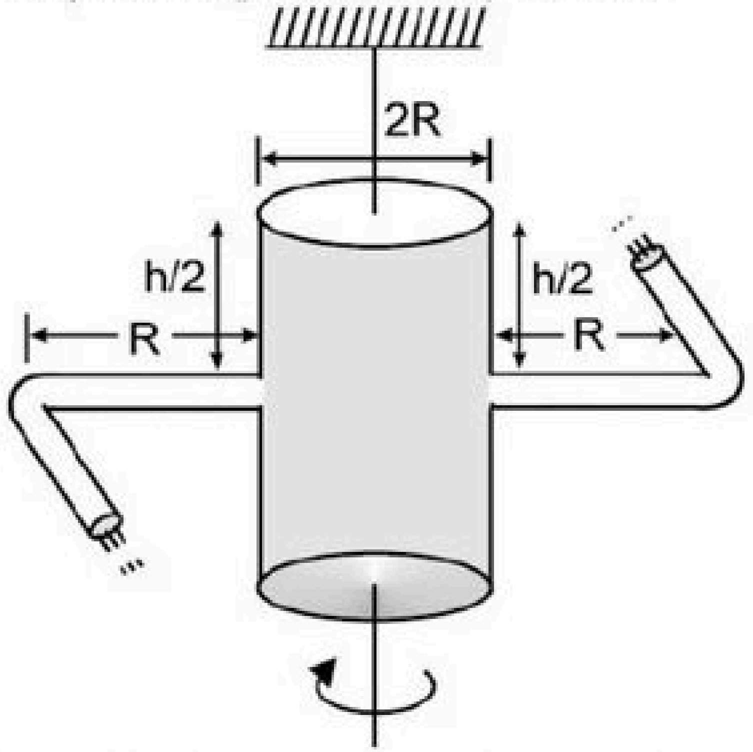
64. A vertical tank, open at the top, is filled with a liquid and rests on a smooth horizontal surface. A small hole is opened at the centre of one side of the tank. The area of cross-section of the tank is N times the area of the hole, where N is a large number. Neglect mass of the tank itself. The initial acceleration of the tank is

(A) $\frac{g}{2N}$ (B) $\frac{g}{\sqrt{2}N}$ (C) $\frac{g}{N}$ (D) $\frac{g}{2\sqrt{N}}$

65. A cylindrical vessel filled with water upto height of H stands on a horizontal plane. The side wall of the vessel has a plugged circular hole touching the bottom. The coefficient of friction between the bottom of vessel and plane is μ and total mass of water plus vessel is M. What should be minimum diameter of hole so that the vessel begins to move on the floor if plug is removed (here density of water is ρ)

(A) $\sqrt{\frac{2\mu M}{\pi\rho H}}$ (B) $\sqrt{\frac{\mu M}{2\pi\rho H}}$ (C) $\sqrt{\frac{\mu M}{\rho H}}$ (D) None of these

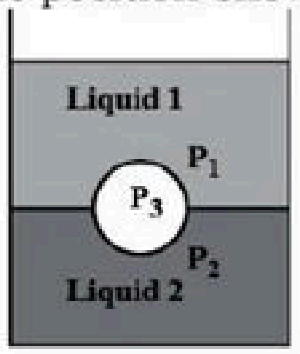
66. A cylindrical container of radius 'R' and height 'h' is completely filled with a liquid. Two horizontal L shaped pipes of small cross-section area 'a' are connected to the cylinder as shown in the figure. Now the two pipes are opened and fluid starts coming out of the pipes horizontally in opposite directions. Then the torque due to ejected liquid on the system is:



(A) 4 aghρR (B) 8 aghρR (C) 2 aghρR (D) aghρR

Part-II
Previous Year's JEE Main Questions (2008-2020)

1. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 respectively. A solid ball, made of a material of density ρ_3, is dropped in the jar. It comes to equilibrium in the position shown in the figure.

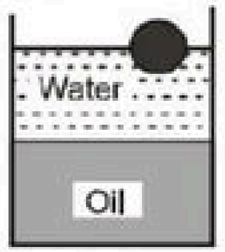


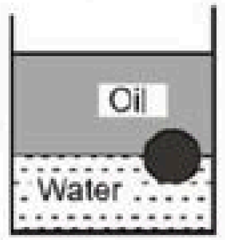
Which of the following is true for ρ_1, ρ_2 and ρ_3 ?

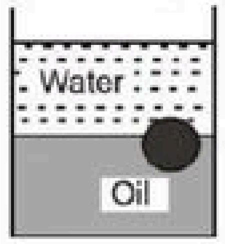
(A) $\rho_1 > \rho_2 > \rho_3$ (B) $\rho_1 < \rho_2 < \rho_3$ (C) $\rho_1 < \rho_3 < \rho_2$ (D) $\rho_3 < \rho_1 < \rho_2$

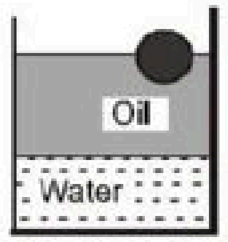
[AIEEE-2008]

2. A ball is made of a material of density ρ where $\rho_{oil} < \rho < \rho_{water}$ with ρ_{oil} and ρ_{water} representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position?

(A) 

(B) 

(C) 

(D) 

[AIEEE-2010]

3. Water is flowing continuously from a tap having an internal diameter 8×10^{-3} m. The water velocity as it leaves the tap is 0.4 ms^{-1}. The diameter of the water stream at a distance 2×10^{-1} m below the tap is close to:

(A) 5.0×10^{-3} m (B) 7.5×10^{-3} m (C) 9.6×10^{-3} m (D) 3.6×10^{-3} m

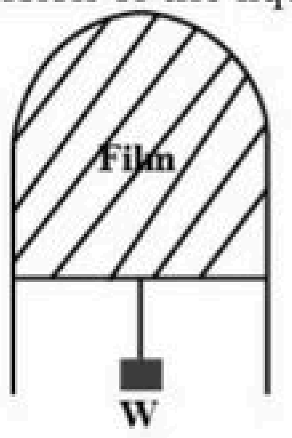
[AIEEE – 2011]

4. A wooden cube (density of wood 'd') of side 'λ' floats in a liquid of density 'ρ' with its upper and lower surfaces horizontal. If the cube is pushed slightly down and released, it performs simple harmonic motion of period 'T'. Then, 'T' is equal to:

(A) $2\pi\sqrt{\frac{\ell d}{\rho g}}$ (B) $2\pi\sqrt{\frac{\ell \rho}{d g}}$ (C) $2\pi\sqrt{\frac{\ell d}{(\rho - d)g}}$ (D) $2\pi\sqrt{\frac{\ell \rho}{(\rho - d)g}}$

[AIEEE – 2011]

5. A thin liquid film formed between a U-shaped wire and a light slider supports a weight of 1.5×10^{-2} N (see figure). The length of the slider is 30 cm and its weight negligible. The surface tension of the liquid film is



(A) 0.1 Nm^{-1} (B) 0.05 Nm^{-1} (C) 0.025 Nm^{-1} (D) 0.0125 Nm^{-1}

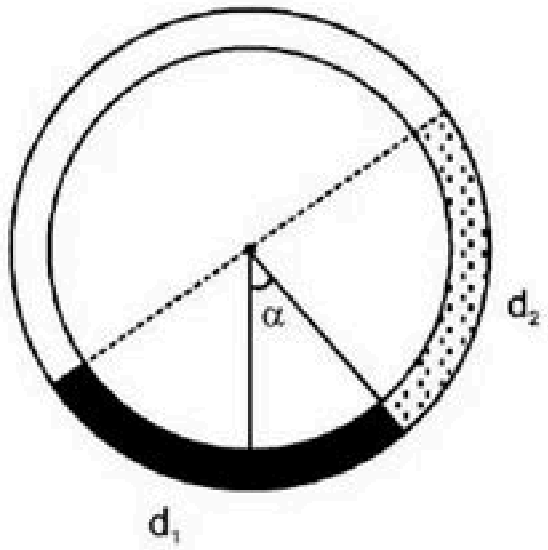
[JEE Main-2012]

6. A uniform cylinder of length L and mass M having cross-sectional area A is suspended, with its length vertical, from a fixed point by a massless spring such that it is half submerged in a liquid of density σ at equilibrium position. The extension x_0 of the spring when it is in equilibrium is:

(A) $\frac{Mg}{k}$ (B) $\frac{Mg}{k}\left(1-\frac{LA\sigma}{M}\right)$ (C) $\frac{Mg}{k}\left(1-\frac{LA\sigma}{2M}\right)$ (D) $\frac{Mg}{k}\left(1+\frac{LA\sigma}{M}\right)$

[JEE Main-2013]

7. There is a circular tube in a vertical plane. Two liquids which do not mix and of densities d_1 and d_2 are filled in the tube. Each liquid subtends 90° angle at centre. Radius joining their interface makes an angle α with vertical. Ratio $\frac{d_1}{d_2}$ is:



(A) $\frac{1+\sin\alpha}{1-\sin\alpha}$ (B) $\frac{1+\cos\alpha}{1-\cos\alpha}$ (C) $\frac{1+\tan\alpha}{1-\tan\alpha}$ (D) $\frac{1+\sin\alpha}{1-\cos\alpha}$

[JEE Main-2014]

8. If it takes 5 minutes to fill a 15 litre bucket from a water tap of diameter $\frac{2}{\sqrt{\pi}}$ cm then the Reynolds number for the flow is (density of water = 10^3 kg/m^3 and viscosity of water = 10^{-3} Pa.s) close to

(A) 5500 (B) 11,000 (C) 550 (D) 1100

[JEE Main-2015]

9. A uniformly tapering conical wire is made from a material of Young's modulus Y and has a normal, unextended length L. The radii, at the upper and lower ends of this conical wire, have value R and 3R, respectively. The upper end of the wire is fixed to a rigid support and a mass M is suspended from its lower end. The equilibrium extended length, of this wire, would equal

(A) $L\left(1+\frac{2}{9}\frac{Mg}{\pi YR^2}\right)$ (B) $L\left(1+\frac{1}{9}\frac{Mg}{\pi YR^2}\right)$

(C) $L\left(1+\frac{1}{3}\frac{Mg}{\pi YR^2}\right)$ (D) $L\left(1+\frac{2}{3}\frac{Mg}{\pi YR^2}\right)$

[JEE Main-2016]

10. Two tubes of radii r_1 and r_2, and lengths l_1 and l_2, respectively, are connected in series and a liquid flows through each of them in stream line conditions. P_1 and P_2 are pressure differences across the two tubes. If P_2 is $4P_1$ and l_2 is $l_1/4$, then the radius r_2 will be equal to :

(A) $2r_1$ (B) $r_1/2$ (C) $4r_1$ (D) r_1

[JEE Main-2017]

11. A solid sphere of radius r made of a soft material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area a floats on the surface of the liquid, covering entire cross section of cylindrical container. When a mass m is placed on the surface of the piston to compress the liquid, the fractional decrement in the radius of the sphere, $\left(\frac{dr}{r}\right)$, is:

(A) $\frac{Ka}{mg}$ (B) $\frac{Ka}{3mg}$ (C) $\frac{mg}{3Ka}$ (D) $\frac{mg}{Ka}$

[JEE Main-2018]

12. The top of a water tank is open to air and its water level is maintained. It is giving out 0.74 m^3 water per minute through a circular opening of 2 cm radius in its wall. The depth of the centre of the opening from the level of water in the tank is close to:

(A) 9.6 m (B) 4.8 m (C) 2.9 m (D) 6.0 m

[JEE Main-2019]

13. Water flows into a large tank with flat bottom at the rate of 10^{-4} $m^3 s^{-1}$. Water is also leaking out of a hole of area 1 cm^2 at its bottom. If the height of the water in the tank remains steady, then this height is:

(A) 4 cm (B) 2.9 cm (C) 1.7 cm (D) 5.1 cm

[JEE Main-2019]

14. A liquid of density ρ is coming out of a hose pipe of radius a with horizontal speed v and hits a mesh. 50% of the liquid passes through the mesh unaffected. 25% looses all of its momentum and 25% comes back with the same speed. The resultant pressure on the mesh will be:

(A) $1/4\ \rho v^2$ (B) $3/4\ \rho v^2$ (C) $1/2\ \rho v^2$ (D) ρv^2

[JEE Main-2019]

15. A load of mass M kg is suspended from a steel wire of length 2 m and radius 1.0 mm in Searle's apparatus experiment. The increase in length produced in the wire is 4.0 mm. Now the load is fully immersed in a liquid of relative density 2. The relative density of the material of load is 8. The new value of increase in length of the steel wire is:

(A) 3.0 mm (B) 4.0 mm (C) 5.0 mm (D) zero

[JEE Main-2019]

16. A long cylindrical vessel is half filled with a liquid. When the vessel is rotated about its own vertical axis, the liquid rises up near the wall. If the radius of vessel is 5 cm and its rotational speed is 2 rotations per second, then the difference in the heights between the centre and the sides, in cm, will be:

(A) 2.0 (B) 0.1 (C) 0.4 (D) 1.2

[JEE Main-2019]

17. Water from a pipe is coming at a rate of 100 liters per minute. If the radius of the pipe is 5 cm, the Reynolds number for the flow is of the order of: (density of water =1000 kg/m^3, coefficient of viscosity of water = 1 mPa.s)

(A) 10^4 (B) 10^3 (C) 10^2 (D) 10^6

[JEE Main-2019]

18. A simple pendulum oscillating in air has period T. The bob of the pendulum is completely immersed in a non-viscous liquid. The density of the liquid is 1/16th of the material of the bob. If the bob is inside liquid all the time, its period of oscillation in this liquid is:

(A) $2T\sqrt{\frac{1}{10}}$ (B) $2T\sqrt{\frac{1}{14}}$ (C) $4T\sqrt{\frac{1}{14}}$ (D) $4T\sqrt{\frac{1}{15}}$

[JEE Main-2019]

19. A wooden block floating in a bucket of water has 4/5 of its volume submerged. When certain amount of an oil is poured into the bucket, it is found that the block is just under the oil surface with half of its volume under water and half in oil. The density of oil relative to that of water is:

(A) 0.6 (B) 0.7 (C) 0.8 (D) 0.5

[JEE Main-2019]

20. A submarine experience a pressure of 5.05×10^6 Pa at a depth of d_1 in a sea. When it goes further to a depth of d_2. It experiences a pressure of 8.08×10^6 Pa. Then $d_2 - d_1$ is approximately (density of water = 10^3 kg/m^{3}and acceleration due to gravity = $10ms^{-2}$).

(A) 500m (B) 300m (C) 600m (D) 400m

[JEE Main-2019]

21. Water from a tap emerges vertically downwards with an initial speed of 1.0 ms^{-1}. The cross-sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water and that the flow is streamlined. The cross-sectional area of the stream, 0.15m below the tap would be (Take = g = $10ms^{-2}$)

(A) 1×10^{-5} m^2 (B) 2×10^{-5} m^2 (C) 5×10^{-5} m^2 (D) 5×10^{-4} m^2

[JEE Main-2019]

22. A cubic block of side 0.5m floats on water with 30% of its volume under water. What is the maximum weight that can be put on the block without fully submerging it under water? (Take, density of water = 10^3 kg/m^3)

(A) 87.5kg (B) 65.4kg (C) 30.1kg (D) 46.3kg

[JEE Main-2019]

23. An ideal fluid flows (laminar flow) through a pipe of non-uniform diameter. The maximum and minimum diameters of the pipes are 6.4 cm and 4.8 cm, respectively. The ratio of the minimum and the maximum velocities of fluid in this pipe is:

(A) $\frac{9}{16}$ (B) $\frac{\sqrt{3}}{2}$ (C) $\frac{81}{256}$ (D) $\frac{3}{4}$

[JEE Main-2020]

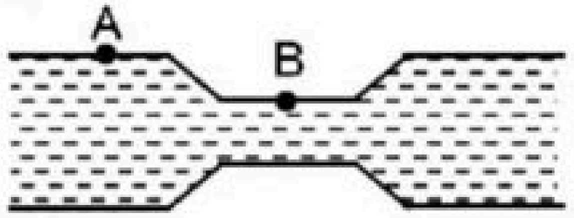
24. Consider a solid sphere of radius R and mass density $\rho(r) = \rho_0\left(1-\frac{r^2}{R^2}\right) 0 < r \le R$.

The minimum density of a liquid in which it will float is:

(A) $\frac{\rho_0}{3}$ (B) $\frac{2\rho_0}{3}$ (C) $\frac{\rho_0}{5}$ (D) $\frac{2\rho_0}{5}$

[JEE Main-2020]

25. Water flows in a horizontal tube (see figure). The pressure of water changes by 700 Nm^{-2} between A and B where the area of cross section is 40 cm^2 and 20 cm^2, respectively. Find the rate of flow of water through the tube. (density of water = 1000 kgm^{-3})



(A) 2720 cm^3 /s (B) 2420 cm^3 /s (C) 3020 cm^3 /s (D) 1810 cm^3 /s

[JEE Main-2020]

EXERCISE-II
Part-I
(Multiple Correct type Questions)
Section-A

1. An air bubble in a water tank rises from the bottom to the top. Which of the following statements are true ?

(A) Bubble rises upwards because pressure at the bottom is less than that at the top.
(B) Bubble rises upwards because pressure at the bottom is greater than that at the top.
(C) As the bubble rises, its size increases.
(D) As the bubble rises, its size decreases.

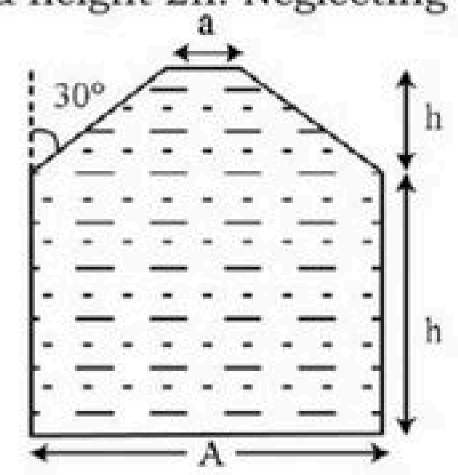
2. A beaker is filled in with water is accelerated a m/s^2 in +x direction. The surface of water shall make on angle

(A) $\tan^{-1}$ (a/g) backwards (B) $\tan^{-1}$ (a/g) forwards
(C) $\cot^{-1}$ (g/a) backwards (D) $\cot^{-1}$ (g/a) forwards

3. Pressure gradient in a static fluid is represented by (z–direction is vertically upwards, and x-axis is along horizontal, d is density of fluid) :

(A) $\frac{\partial p}{\partial z} = -dg$ (B) $\frac{\partial p}{\partial x} = dg$ (C) $\frac{\partial p}{\partial x} = 0$ (D) $\frac{\partial p}{\partial z} = 0$

4. The vessels shown in the figure has two sections. The lower part is a rectangular vessel with area of cross-section A and height h. The upper part is a conical vessel of height h with base area 'A' and top area 'a' and the walls of the vessel are inclined at an angle 30° with the vertical. A liquid of density ρ fills both the sections upto a height 2h. Neglecting atmospheric pressure.



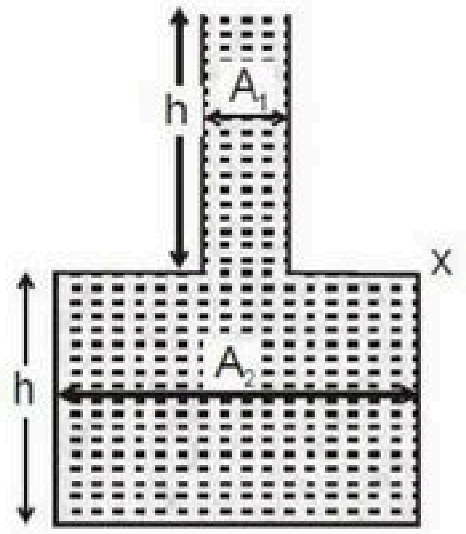
(A) The force F exerted by the liquid on the base of the vessel is $2h\rho g\frac{(A+a)}{2}$

(B) The pressure P at the base of the vessel is $2h\rho g\frac{A}{a}$

(C) The weight of the liquid W is greater than the force F exerted by the liquid on the base

(D) The walls of the vessel exert a downward force (F–W) on the liquid

5. The vessel shown in Figure has two sections of area of cross-section A_1 and A_2. A liquid of density ρ fills both the sections, up to height h in each. Neglecting atmospheric pressure,



(A) the pressure at the base of the vessel is $2h\rho g$
(B) the weight of the liquid in vessel is equal to $2h\rho g A_2$
(C) the force exerted by the liquid on the base of vessel is $2h\rho g A_2$
(D) the walls of the vessel at the level X exert a force $h\rho g(A_2 - A_1)$ downwards on the liquid.

6. A cubical block of wood of edge 10cm and mass 0.92 kg floats on a tank of water with oil of rel. density 0.6 to a depth of 4cm above water. When the block attains equilibrium with four of its sides edges vertical

(A) 1cm of it will be above the free surface of oil.
(B) 5cm of it will be under water
(C) 2cm of it will be above the common surface of oil and water
(D) 8cm of it will be under water.

7. A cubical block of wood of edge 10cm and mass 0.92kg floats on a tank of water with oil of rel. density 0.6. Thickness of oil is 4cm above water. When the block attains equilibrium with four of its sides edges vertical:

(A) 1 cm of it will be above the free surface of oil.
(B) 5 cm of it will be under water.
(C) 2 cm of it will be above the common surface of oil and water.
(D) 8 cm of it will be under water.

8. Following are some statements about buoyant force, select incorrect statement/statements (Liquid is of uniform density)

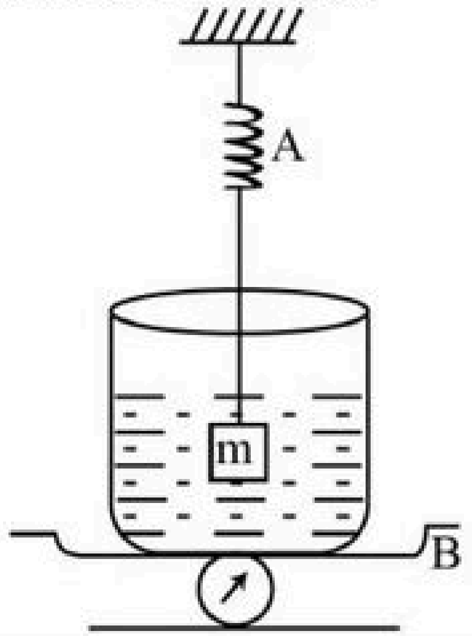
(A) Buoyant force depends upon orientation of the concerned body inside the liquid.

(B) Buoyant force depends upon the density of the body immersed.

(C) Buoyant force depends on the fact whether the system is on moon or on the earth.

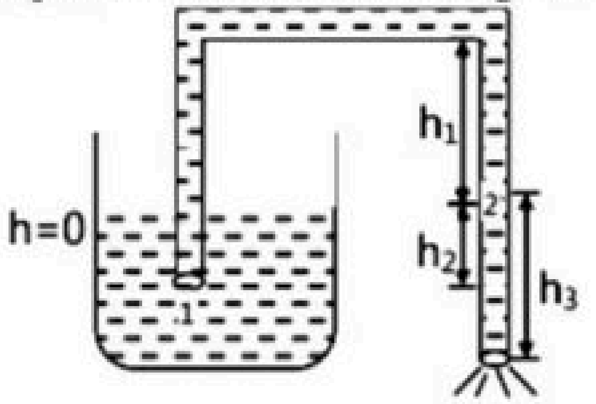
(D) Buoyant force depends upon the depth at which the body (fully immersed in the liquid) is placed inside the liquid.

9. The spring balance A read 2 kg with a block m suspended from it. A balance B reads 5 kg when a beaker with liquid is put on the pan of the balance. The two balances are now so arranged that the hanging mass is inside the liquid in the beaker as shown in the figure in this situation:



(A) the balance A will read more than 2kg
(B) the balance B will read more than 5 kg
(C) the balance A will read less than 2 kg and B will read more than 5 kg.
(D) the balance A and B will read 2 kg and 5 kg respectively

10. Figure shown a siphon. Choose the wrong statement:



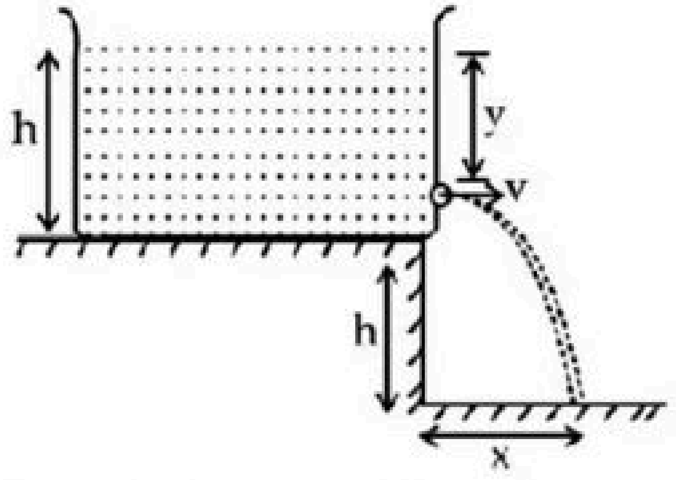
(A) Siphon works when $h_3 > 0$
(B) Pressure at point 2 is $P_2 = P_0 - \rho g h_3$
(C) Pressure at point 3 is P_0
(D) None of these

(P_0 = atmospheric pressure)

11. A wooden block with a coin placed on its top, floats in water as shown in figure. The distance λ and h are shown here. After some time the coin falls into the water. Then:

(A) λ decreases and h increase
(B) λ increases and h decreases
(C) both λ and h increases
(D) both λ and h decrease

12. A tank is filled upto a height h with a liquid and is placed on a platform of height h from the ground. To get maximum range x_m a small hole is punched at a distance of y from the free surface of the liquid. Then



(A) $x_m = 2h$
(B) $x_m = 1.5\ h$
(C) $y = h$
(D) $y = 0.75\ h$

13. A block of density 2000 kg/m^3 and mass 10 kg is suspended by a spring stiffness 100 N/m. The other end of the spring is attached to a fixed support.

The block is completely submerged in a liquid of density 1000 kg/m^3 If the block is in equilibrium position then,

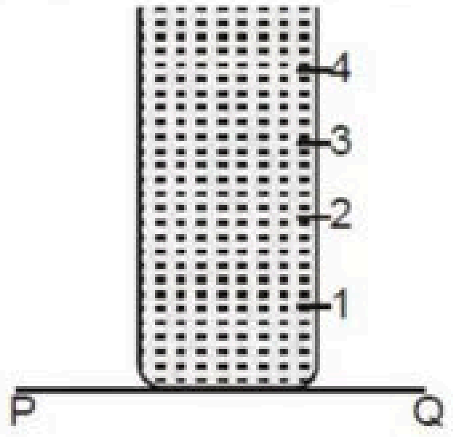
(A) the elongation of the spring is 1 cm.

(B) the magnitude of buoyant force acting on the block is 50 N.

(C) the spring potential energy is 12.5 J.

(D) magnitude of spring force on the block is greater than the weight of the block.

14. A cylindrical vessel of 90 cm height is kept filled upto the brim as shown in the figure. It has four holes 1, 2, 3, 4 which are respectively at heights of 20cm, 30 cm, 40 cm and 50 cm from the horizontal floor PQ. The water falling at the maximum horizontal distance from the vessel comes from



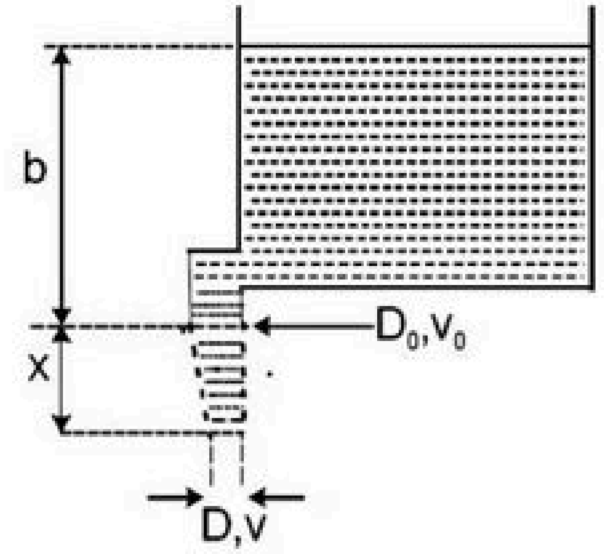
(A) hole number 4
(B) hole number 3
(C) hole number 2
(D) hole number 1

Section-B

(Comprehension type Questions)

Paragraph for Qus 1 to 5

The tap has internal diameter D_0 and is connected to a large tank of water. The surface of the water is at a height b above the end of the tap. By considering the dynamics of a thin "cylinder" of water in the stream answer the following: (Ignore any resistance to the flow and any effects of surface tension, given ρ_w = density of water)



1. Equation for the flow rate, i.e. the mass of water flowing through a given point in the stream per unit time, as function of the water speed v will be

(A) $v\rho_w\pi D^2/4$
(B) $v\rho_w(\pi D^2/4 - \pi D_0^2/4)$
(C) $v\rho_w\pi D^2/2$
(D) $v\rho_w\pi D_0^2/4$

2. Which of the following equation expresses the fact that the flow rate at the tap is the same as at the stream point with diameter D and velocity v (i.e. D in terms of D_0 , v_0 and v will be) :

(A) $D = \frac{D_0 v_0}{v}$
(B) $D = \frac{D_0 v_0^2}{v^2}$
(C) $D = \frac{D_0 v}{v_0}$
(D) $D = D_0\sqrt{\frac{v_0}{v}}$

3. The equation for the water speed v as a function of the distance x below the tap will be :

(A) $v = \sqrt{2gb}$
(B) $v = [2g(b + x)]^{1/2}$
(C) $v = \sqrt{2gx}$
(D) $v = [2g(b - x)]^{1/2}$

4. Equation for the stream diameter D in terms of x and D_0 will be:

(A) $D = D_0\left(\frac{b}{b+x}\right)^{1/4}$ (B) $D = D_0\left(\frac{b}{b+x}\right)^{1/2}$

(C) $D = D_0\left(\frac{b}{b+x}\right)$ (D) $D = D_0\left(\frac{b}{b+x}\right)^{2}$

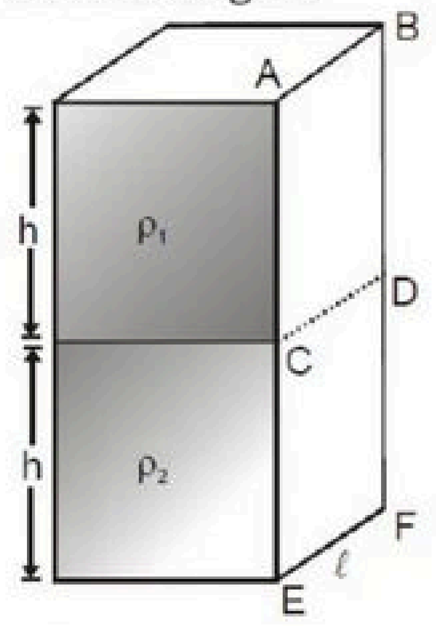
5. A student observes after setting up this experiment that for a tap with D_0 = 1 cm at x = 0.3 m the stream diameter D = 0.9 cm. The heights b of the water above the tap in this case will be :

(A) 5.7 cm (B) 57 cm (C) 27 cm (D) 2.7 c

Section-C

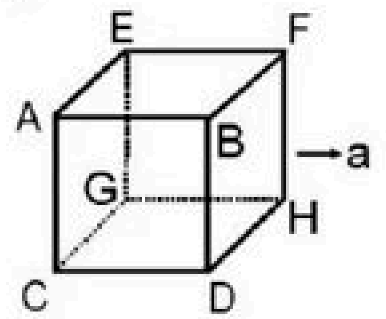
[MATRIX TYPE]

1. A cuboid is filled with liquid of density ρ_2 upto height h & with liquid of density ρ_1, also upto height h as shown in the figure



	Column-I		Column-II
(A)	Force on face ABCD due to liquid of density ρ_1	(P)	zero
(B)	Force on face ABCD due to liquid of density ρ_2	(Q)	$\frac{\rho_1 g h^2 \ell}{2}$
(C)	Force on face CDEF transferred due to liquid of density ρ_1	(R)	$\rho_1 g h^2 \lambda$
(D)	Force on face CDEF due to liquid of density ρ_2 only	(S)	$\frac{\rho_2 g h^2 \ell}{2}$

2. A cubical box is completely filled with mass m of a liquid and is given horizontal acceleration a as shown in the figure. Match the force due to fluid pressure on the faces of the cube with their appropriate values (assume zero pressure as minimum pressure)

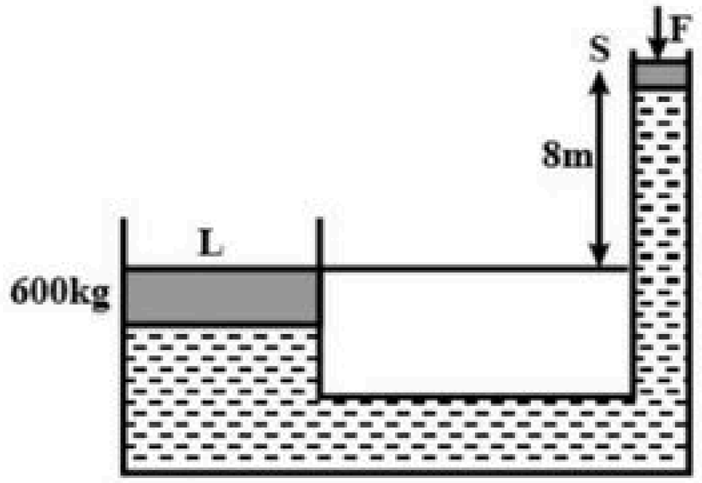


	Column-I		Column-II
(A)	force on face ABFE	(P)	$\frac{ma}{2}$
(B)	force on face BFHD	(Q)	$\frac{mg}{2}$
(C)	force on face ACGE	(R)	$\frac{ma}{2}+\frac{mg}{2}$
(D)	force on face CGHD	(S)	$\frac{ma}{2}+mg$
			$\frac{mg}{2}+ma$

PART-II

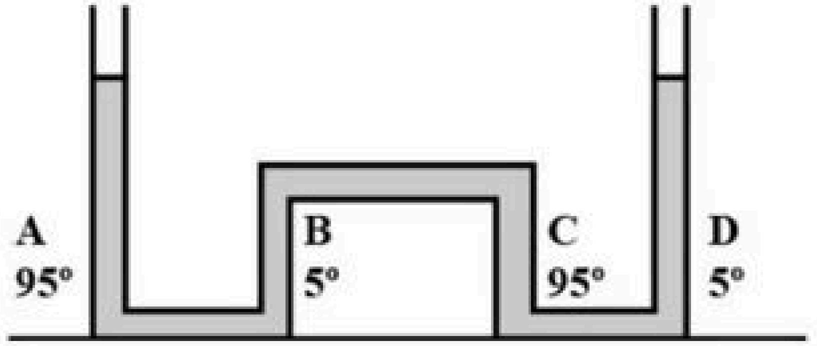
(Subjective type Questions)

1. For the system shown in the figure, the cylinder on the left at L has a mass of 600 kg and a cross sectional area of 800 cm^2. The piston on the right, at S, has a cross sectional area 25cm^2 and negligible weight. If the apparatus is filled with oil. (ρ = 75 gm/cm^3) Find the force F required to hold the system in equilibrium.



2. A U-tube with a liquid of volumetric coefficient of 10^{-5}/°C lies in a vertical plane. The height of liquid column in the left vertical limb is 100 cm. The liquid in the left vertical limb is maintained at a temperature = 0°C while the liquid in the right limb is maintained at a temperature = 100°C. Find the difference in levels in the two limbs.

3. The apparatus shown in the figure consists of four glass columns connected by horizontal sections. The height of two central columns B & C are 46 cm each. The two outer columns A & D are open to the atmosphere. A & C are maintained at a temperature of 95°C while the columns B & D are maintained at 5°C. The height of the liquid in A & D measured from the base line are 52.8 cm & 51 cm respectively. Determine the coefficient of thermal expansion of the liquid.

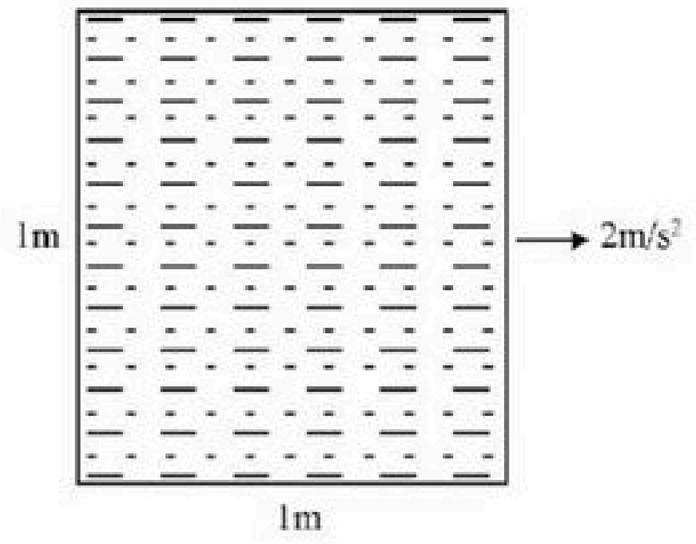


4. (a) A spherical tank of 1.2 m radius is half filled with oil of relative density 0.8. If the tank is given a horizontal acceleration of $10 m/s^2$. Calculate the inclination of the oil surface to horizontal and maximum pressure on the tank.

(b) The volume of an air bubble is doubled as it rises from the bottom of a lake to its surface. It the atmosphere pressure is H m of mercury and the density of mercury is n times that of lake water. Find the depth of the lake.

5. A vertical uniform U tube open at both ends contains mercury. Water is poured in one limb until the level of mercury is depressed 2cm in that limb. What is the length of water column when this happens?

6. An open cubical tank completely filled with water is kept on a horizontal surface. Its acceleration is then slowly increased to $2 m/s^2$ as shown in the fig. The side of the tank is 1m. Find the mass of water would spill out of the tank.

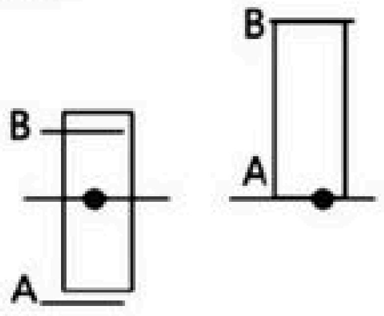


7. In air an object weighs 15N, when immersed completely in water the same object weighs 12N. When immersed in another liquid completely, it weighs 13N. Find
(a) the specific gravity of the object and
(b) the specific gravity of the other liquid.

8. A solid ball of density half that of water falls freely under gravity from a height of 19.6 m and then enter water. Upto what depth will the ball go? How much time will it take to come again to the water surface ? Neglect air resistance and velocity effects in water.

9. In a sonometer wire the tension is maintained by suspending a 50.7 kg mass from the free end of the wire. The suspended mass has a volume of $0.0075 m^3$. The fundamental frequency of the wire is 260 Hz. Find the new fundamental frequency if the suspended mass is completely submerged in water.

10. A cylindrical rod of length l = 2m and density $\frac{\rho}{2}$ floats vertically in a liquid of density ρ as shown in figure (a).



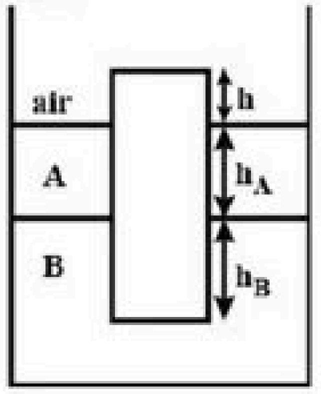
(a) (b)

(a) Show that it performs SHM when pulled slightly up & released & find its time period. Neglect change in liquid level.

(b) Find the time taken by the rod to completely immerse when released from position shown in fig. (b). Assume that it remains vertical throughout its motion. (take $g = \pi^2 m/s^2$)

11. A wooden stick of length l and radius R and density ρ has a small metal piece of mass m (of negligible volume) attached to its one end. Find the minimum value for the mass m (in terms of given parameters) that would make the stick floats vertically in equilibrium in a liquid of density $\sigma(>\rho)$.

12. A uniform solid cylinder of density 0.8 gm/cm^2 floats in equilibrium in a combination of two non mixing liquids A and B with its axis vertical. The densities of the liquids A and B are 0.7 gm/cm^3 and 1.2 gm/cm^3, respectively. The height of liquid A is h_A =1.2cm.The length of the part of the cylinder immersed in liquid B is h_B = 0.8cm.

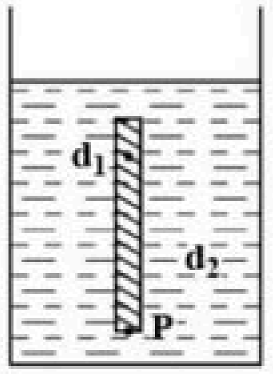


(a) Find the total force exerted by liquid A on the cylinder.

(b) Find h, the length of the part of the cylinder in air.

(c) The cylinder is depressed in such a way that its top surface is just below the upper surface of liquid A and is then released. Find the acceleration of the cylinder immediately after it is released.

13. A thin rod of length L and area of cross section S is pivoted at its lowest point P inside a stationary, homogeneous and non viscous liquid (Figure). The rod is free to rotate in a vertical plane about a horizontal axis passing through P. The density d_1 of the material of the rod is smaller than the entity d_2 of the liquid. The rod is displaced by a small angle θ from its equilibrium position and then released. Show that the motion of the rod is simple harmonic and determine its angular frequency in terms of the given parameters.



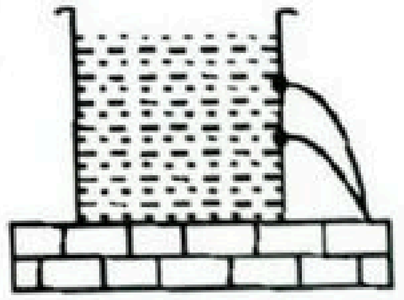
14. Place a glass beaker, partially filled with water, in a sink. The beaker has a mass 390 gm and an interior volume of 500 cm^3. You now start to fill the sink with water and you find, by experiment, that if the beaker is less than half full, it will float; but if it is more than half full. It remains on the bottom of the sink as the water rises to its rim. What is the density of the material of which the beaker is made ?

15. A test tube of thin walls has some lead shots in it at its bottom and the system floats vertically in water, sinking by a length l_0 = 10cm. A liquid of density less than that of water, is poured into the tube till the levels inside and outside the tube are even. If the tube now sinks to a length l = 40 cm, the specific gravity of the liquid is________.

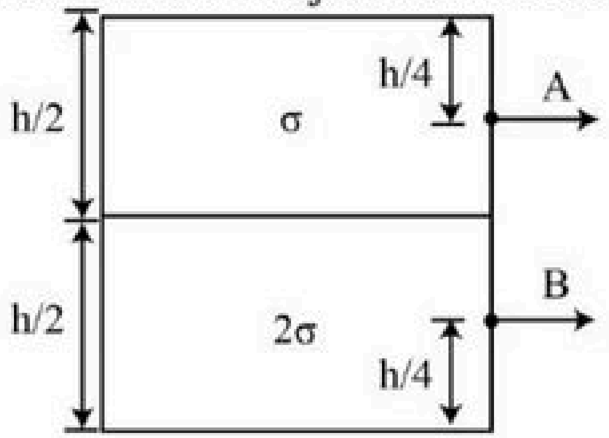
16. Water is pumped from a depth of 10m and delivered through a pipe of cross section 10^{-2} m^2 upto a height of 10m. If it is needed to deliver a volume 0.2 m^3 per second, find the power required.
[Use g = 10 m/s^2]

17. A laminar stream is flowing vertically down from a tap of cross-section areal 1 cm^2. At a distance 10cm below the tap, the cross-section area of the stream has reduced to 1/2 cm^2. Find the volumetric flow rate of water from the tap.

18. In a cylindrical vessel containing liquid of density ρ, there are two holes in the side walls at heights of h_1 and h_2 respectively such that the range of efflux at the bottom of the vessel is same. Find the height of a hole, for which the range of efflux would be maximum.



19. A large tank is filled with two liquids of specific gravities 2σ and σ. Two holes are made on the wall of the tank as shown. Find the ratio of the distances from O of the points on the ground where the jets from holes A and B strike.



20. A cylindrical vessels open at the top is 20cm high and 10cm in diameter. A circular hole whose cross-sectional area $1 cm^2$ is cut at the centre of the bottom of the vessel. Water flows from a tube above it into the vessel at the rate $100\ cm^3 s^{-1}$. Find the height of water in the vessel under steady state.

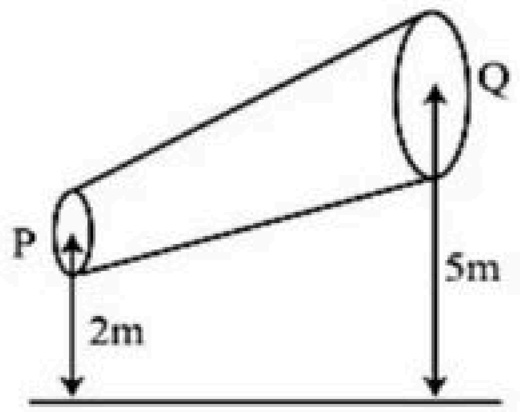
21. A large open top container of negligible mass and uniform cross-sectional area A has a small hole of cross-sectional area A/100 in its side wall near the bottom. The container is kept on a smooth horizontal floor and contains a liquid of density ρ and mass m_0. Assuming that the liquid starts flowing out horizontally through the hole at t = 0, calculate

(i) the acceleration of the container and

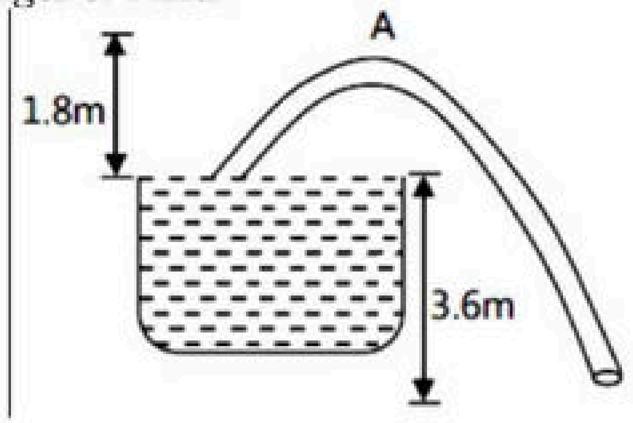
(ii) its velocity when 75% of the liquid has drained out.

22. Calculate the rate of flow of glycerine of density $1.25 \times 10^3\ kg/m^3$ through the conical section of a pipe if the radii of its ends are 0.1m and 0.4m the pressure drop across its length is $10\ N/m^2$.

23. A non viscous liquid of constant density 1000 kg/m^3 flows in a streamline motion along a tube of variable cross section. The tube is kept inclined in the vertical plane as shown in the figure. The area of cross section of the tube at two points P and Q at heights of 2m and 5m are respectively 4×10^{-3} m^2 and 8×10^{-3} m^3. The velocity of the liquid at point P is 1m/s. Find the work done per unit volume by the pressure and the gravity forces as the fluid flows from point P to Q.



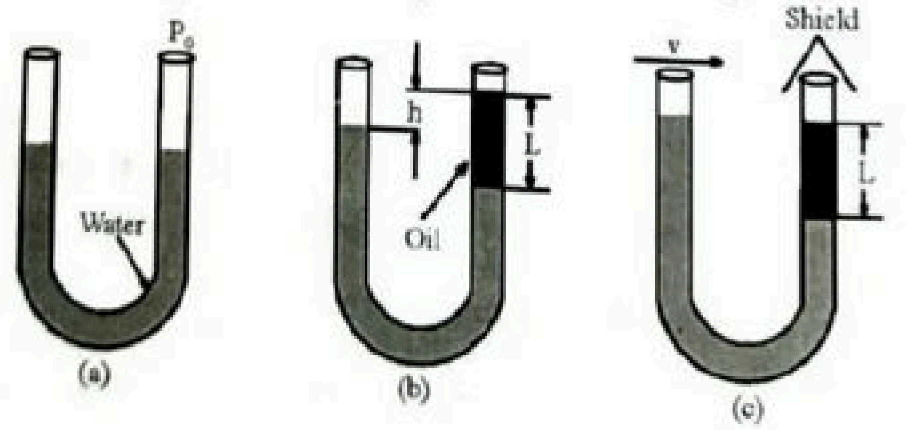
24. A siphon has a uniform circular base of diameter $\frac{8}{\sqrt{\pi}}$ cm with its crest A 1.8 m above water level as in figure. Find



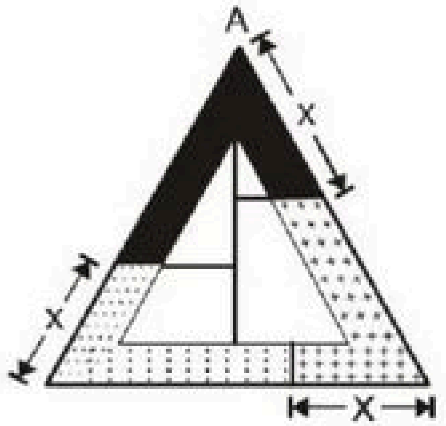
(a) velocity of flow
(b) discharge rate of the flow in m^3/sec.
(c) absolute pressure at the crest level A. [Use $P_0 = 10^5$ N/m^2 & $g = 10$m/s^2]

25. A jet of water having velocity = 10 m/s and stream cross-section = 2cm^2 hits a flat plate perpendicularly, with the water splashing out parallel to plate. Find the force that the plate experiences.

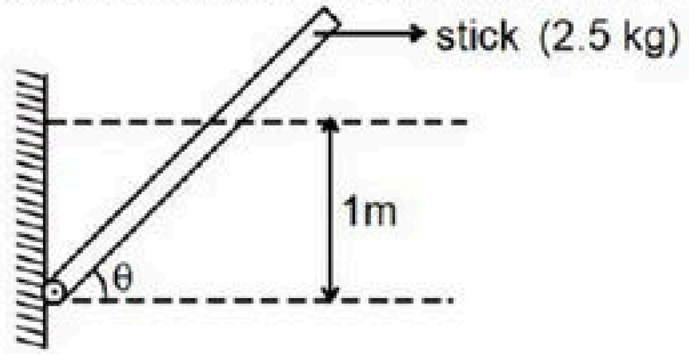
26. A U-tube open at both ends is partially filled with water (figure (a)). Oil having a density of 750 kg/m³ is then poured into the right arm and forms a column L = 10 cm in height (figure-(b)). The right arm is shielded from any air motion while air is blown across the top of the left arm until the surfaces of the two liquids are at the same height (figure (c)). Determine the speed of the air (in m/s) being blown across the left arm. (Take the density of air as 1.25 kg/m³.)



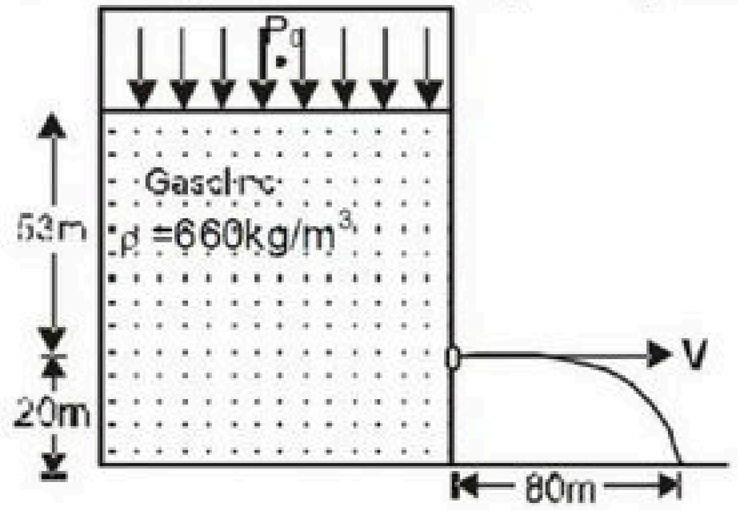
27. A closed tube in the form of an equilateral triangle of side λ = 3m contains equal volumes of three liquids which do not mix and is placed vertically with its lowest side horizontal. Find 'x' (in meter) in the figure if the densities of the liquids are in A.P.



28. A stick of square cross-section (5 cm × 5 cm) and length '4m' weighs 2.5 kg is in equilibrium as shown in the figure below. Determine its angle of inclination (in degree) in equilibrium when the water surface is 1 m above the hinge.



29. A tank containing gasoline is sealed and the gasoline is under pressure P_0 as shown in the figure. The stored gasoline has a density of 660 kg m^{-3}. A sniper fires a rifle bullet into the gasoline tank, making a small hole 53 m below the surface of gasoline. The total height of gasoline is 73 m from the base. The jet of gasoline shooting out of the hole strikes the ground at a distance of 80 m from the tank initially. If the pressure above the gasoline surface is $(1.39)\ \alpha \times 10^5\ N/m^2$ than α is- (The local atmospheric pressure is $10^5\ Nm^{-2}$)



30. A large open top container of negligible mass and uniform cross–sectional area A has a small hole of cross–sectional area $\frac{A}{100}$ in its side wall near the bottom. The container is kept on a smooth horizontal floor and contains a liquid of density ρ and mass m_0. Assuming that the liquid starts flowing out horizontally through the hole at $t = 0$, The acceleration of the container is $\frac{x}{10} m/s^2$ than x is –

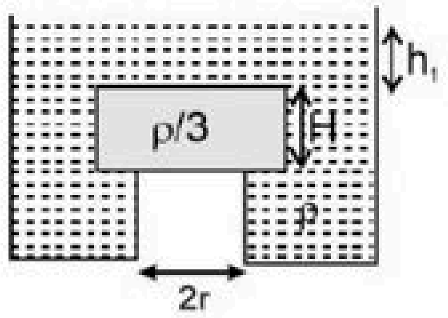
EXERCISE-III

JEE ADVANCED Previous Year's Questions

Comprehension for Qus 1 to 3

A wooden cylinder of diameter 4r, height H and density $\rho/3$ is kept on a hole of diameter 2r of a tank, filled with liquid of density ρ as shown in the figure.

1. If level of the liquid starts decreasing slowly when the level of liquid is at a height h_1 above the cylinder the block starts moving up. At what value of h_1, will the block rise:

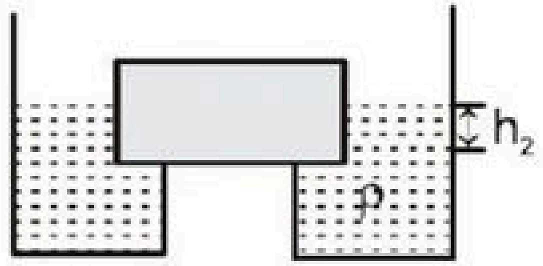


(A) $\frac{4H}{9}$ (B) $\frac{5H}{9}$

(C) $\frac{5H}{3}$ (D) Remains same

[IIT-JEE 2006]

2. The block in the above question is maintained at the position by external means and the level of liquid is lowered. The height h_2 when this external force reduces to zero is



(A) $\frac{4H}{9}$ (B) $\frac{5H}{9}$ (C) Remains same (D) $\frac{2H}{3}$

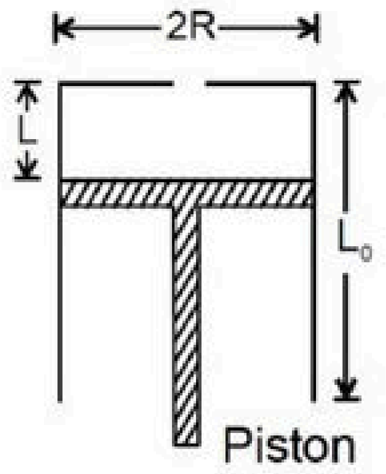
[IIT-JEE 2006]

3. If height h_2 of water level is further decreased then,
(A) cylinder will not move up and remains at its original position.
(B) for $h_2 = H/3$, cylinder again starts moving up
(C) for $h_2 = H/4$, cylinder again starts moving up
(D) for $h_2 = H/5$ cylinder again starts moving up

[IIT-JEE 2006]

Comprehension for Qus 4 to 6

A fixed thermally conducting cylinder has a radius R and height L_0. The cylinder is open at its bottom and has a small hole at its top. A piston of mass M is held at a distance L from the top surface, as shown in the figure. The atmospheric pressure is P_0.



4. The piston is now pulled out slowly and held at a distance 2L from the top. The pressure in the cylinder between its top and the piston will then be

(A) P_0 (B) $\frac{P_0}{2}$ (C) $\frac{P_0}{2}+\frac{Mg}{\pi R^2}$ (D) $\frac{P_0}{2}-\frac{Mg}{\pi R^2}$

[IIT-JEE 2007]

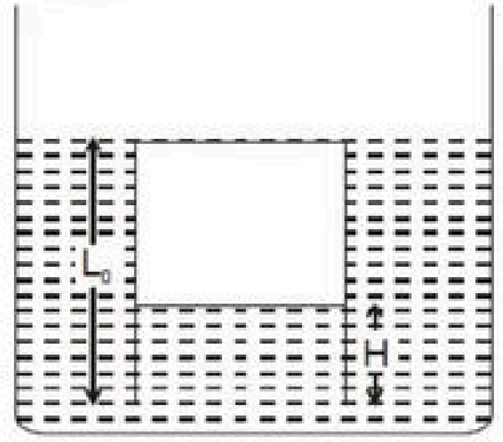
5. While the piston is at a distance 2L from the top, the hole at the top is sealed. The piston is then released, to a position where it can stay in equilibrium. In this condition, the distance of the piston from the top is

(A) $\left(\frac{2P_0\pi R^2}{\pi R^2 P_0+Mg}\right)(2L)$ (B) $\left(\frac{P_0\pi R^2-Mg}{\pi R^2 P_0}\right)(2L)$

(C) $\left(\frac{P_0\pi R^2+Mg}{\pi R^2 P_0}\right)(2L)$ (D) $\left(\frac{P_0\pi R^2}{\pi R^2 P_0-Mg}\right)(2L)$

[IIT-JEE 2007]

6. The piston is taken completely out of the cylinder. The hole at the top is sealed. A water tank is brought below the cylinder and put in a position so that the water surface in the tank is at the same level as the top of the cylinder as shown in the figure. The density of the water is ρ. In equilibrium, the height H of the water column in the cylinder satisfies



(A) $\rho g (L_0 - H)^2 + P_0 (L_0 - H) + L_0 P_0 = 0$
(B) $\rho g (L_0 - H)^2 - P_0 (L_0 - H) - L_0 P_0 = 0$
(C) $\rho g (L_0 - H)^2 + P_0 (L_0 - H) - L_0 P_0 = 0$
(D) $\rho g (L_0 - H)^2 - P_0 (L_0 - H) + L_0 P_0 = 0$

[IIT-JEE 2007]

7. **STATEMENT -1 :**
The stream of water flowing at high speed from a garden hose pipe tends to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.

STATEMENT -2: In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant.

(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 is a correct explanation for STATEMENT-1

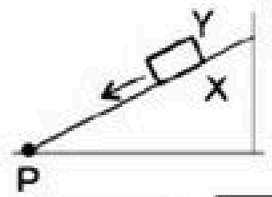
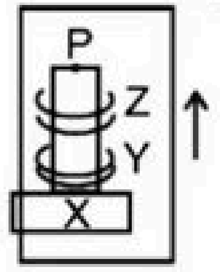
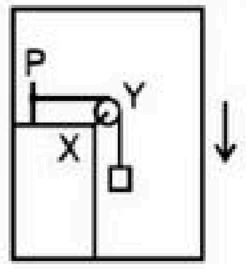
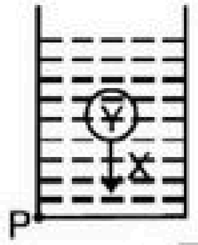
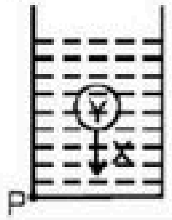
(B) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT -2 is NOT a correct explanation for STATEMENT-1

(C) STATEMENT-1 is True, STATEMENT-2 is False

(D) STATEMENT-1 is False, STATEMENT-2 is True.

[IIT-JEE 2008]

8. **Column II** shows five systems in which two objects are labeled as X and Y. Also in each case a point P is shown. **Column I** gives some statements about X and and/or Y. Match these statements to the appropriate system(s) from **Column II.**

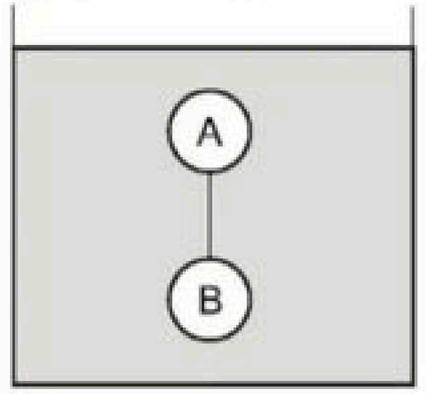
	Column-I			Column-II
(A)	The force exerted by X and Y has a magnitude Mg.	(p)		Block Y of mass M left on a fixed inclined plane X, slides on it with a constant velocity.
(B)	The gravitational potential energy of X is continuously increasing	(q)		Two ring magnets Y and Z, each of mass M, are kept in frictionless vertical plastic increasing, stand so that they repel each other. Y rests on the base X and Z hangs in air in equilibrium. P is the topmost point of the stand on the common axis of the two rings. The whole system is in a lift that is going up with a constant velocity.
(C)	Mechanical energy of the system X+ Y is continuously decreasing.	(r)		A pulley Y of mass m_0 is fixed to a table through a clamp X. A block of mass M hangs from a string that goes over the pulley and is fixed at point P of the table. The whole system is kept in a lift that is going down with a constant velocity.
(D)	The torque of the weight of Y about point P is zero	(s)		A sphere Y of mass M is put in a non viscous liquid X kept in a container at rest. The sphere is released and it moves down in the liquid.
		(t)		A sphere Y of mass M is falling with its terminal velocity in a viscous liquid X kept in container.

[IIT-JEE 2009]

9. A cylindrical vessel of height 500 mm has an orifice (small hole) at its bottom. The orifice is initially closed and water is filled in it up to height H. Now the top is completely sealed with a cap and the orifice at the bottom is opened. Some water comes out from the orifice and the water level in the vessel becomes steady with height of water column being 200 mm. Find the fall in height (**in mm**) of water level due to opening of the orifice. [Take atmospheric pressure = 1.0×10^5 N/m^2, density of water = 1000 kg/m^3 and g = 10 m/s^2. Neglect any effect of surface tension]

[IIT-JEE 2009]

10. Two solid spheres A and B of equal volumes but of different densities d_A and d_B are connected by a string. They are fully immersed in a fluid of density d_F. They get arranged into an equilibrium state as shown in the figure with a tension in the string. The arrangement is possible only if



(A) $d_A < d_F$
(B) $d_B > d_F$
(C) $d_A > d_F$
(D) $d_A + d_B = 2d_F$

[IIT-JEE 2011]

11. A solid sphere of radius R and density ρ is attached to one end of a mass-less spring of force constant k. The other end of the spring is connected to another solid sphere of radius R and density 3ρ. The complete arrangement is placed in a liquid of density 2ρ and is allowed to reach equilibrium. The correct statement(s) is (are)

(A) the net elongation of the spring is $\frac{4\pi R^3 \rho g}{3k}$

(B) the net elongation of the spring is $\frac{8\pi R^3 \rho g}{3k}$

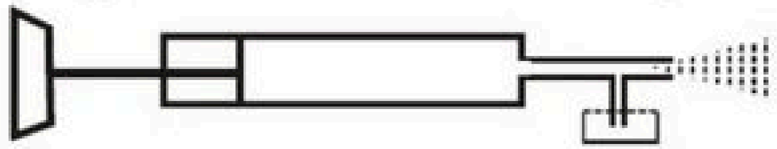
(C) the light sphere is partially submerged.

(D) the light sphere is completely submerged.

[JEE (Advanced)-2013]

Paragraph for Question 12 to 13

A spray gun is shown in the figure where a piston pushes air out of a nozzle. A thin tube of uniform cross section is connected to the nozzle. The other end of the tube is in a small liquid container. As the piston pushes air through the nozzle, the liquid from the container rises into the nozzle and is sprayed out. For the spray gun shown, the radii of the piston and the nozzle are 20 mm and 1mm respectively. The upper end of the container is open to the atmosphere.



12. If the piston is pushed at a speed of 5 mms^{-1} , the air comes out of the nozzle with a speed of

(A) 0.1ms^{-1} (B) 1ms^{-1} (C) 2ms^{-1} (D) 8ms^{-1}

[JEE (Advanced)-2014]

13. If the density of air is ρ_a and that of the liquid ρ_λ, then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to

(A) $\sqrt{\frac{\rho_a}{\rho_\ell}}$ (B) $\sqrt{\rho_a\rho_\ell}$ (C) $\sqrt{\frac{\rho_\ell}{\rho_a}}$ (D) ρ_λ

[JEE (Advanced)-2014]

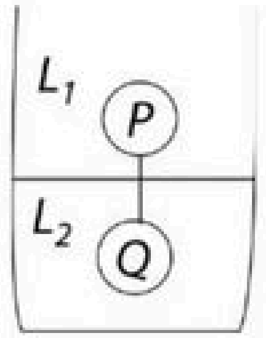
14. A person in a lift is holding a water jar, which has a small hole at the lower end of its side. When the lift is at rest, the water jet coming out of the hole hits the floor of the lift at a distance d = 1.2 m from the person. In the following, state of the lift's motion is given in List-I and the distance where the water jet hits the floor of the lift is given in List-II. Match the statements from List-I with those in List-II and select the correct answer using the code given below the lists.

List -I	List -II
P. Lift is accelerating vertically up.	**1.** d = 1.2 m
Q. Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.	**2.** d > 1.2m
R. List is moving vertically up with constant Speed	**3.** d < 1.2 m
S. Lift is falling freely.	**4.** No water leaks out of the jar

(A) P-2, Q-3, R-2, S-4 (B) P-2, Q-3, R-1, S-4
(C) P-1, Q-1, R-1, S-4 (D) P-2, Q-3, R-1, S-1

[JEE (Advanced)-2014]

15. Two spheres P and Q of equal radii have densities ρ_1 and ρ_2, respectively. The spheres are connected by a massless string and placed in liquids L_1 and L_2 of densities σ_1 and σ_2 and viscosities η_1 and η_2, respectively. They float in equilibrium with the sphere P in L_1 and sphere Q in L_2 and the string being taut (see fig). If sphere P along in L_2 has terminal velocity $\vec{V}_P$ and Q along in L_1 has terminal velocity $\vec{V}_Q$, then



(A) $\dfrac{|\vec{V}_P|}{|\vec{V}_Q|}=\dfrac{\eta_1}{\eta_2}$ (B) $\dfrac{|\vec{V}_P|}{|\vec{V}_Q|}=\dfrac{\eta_2}{\eta_1}$ (C) $\vec{V}_P\cdot\vec{V}_Q>0$ (D) $\vec{V}_P\cdot\vec{V}_Q<0$

[JEE (Advanced)-2015]

16. Consider a thin square plate floating on a viscous liquid in a large tank. The height h of the liquid in the tank is much less than the width of the tank. The floating plate is pulled horizontally with a constant velocity u_0. Which of the following statements is (are) true?

(A) The resistive force of liquid on the plate is inversely proportional to h

(B) The resistive force of liquid on the plate is independent of the area of the plate

(C) The tangential (shear) stress on the floor of the tank increases with u_0.

(D) The tangential (shear) stress on the plate varies linearly with the viscosity η of the liquid.

[JEE (Advanced)-2018]

17. A uniform capillary tube of inner radius r is dipped vertically into a beaker filled with water. The water rises to a height h in the capillary tube above the water surface in the beaker. The surface tension of water is σ. The angle of contact between water and the wall of the capillary tube is θ. Ignore the mass of water in the meniscus. Which of the following statements is (are) true?

(A) For a given material of the capillary tube, h decreases with increase in r

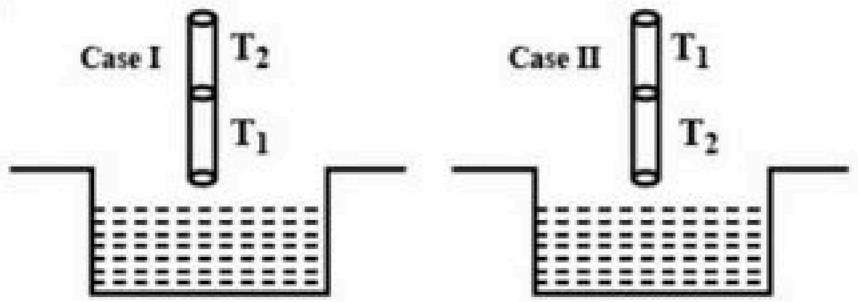
(B) For a given material of the capillary tube, h is independent of σ

(C) If this experiment is performed in a lift going up with a constant acceleration, then h decreases

(D) h is proportional to contact angle θ

[JEE (Advanced)-2018]

18. A cylindrical capillary tube of 0.2 mm radius is made by joining two capillaries T_1 and T_2 of different materials having water contact angles of 0° and 60° respectively. The capillary tube is dipped vertically in water in two different configurations, case I and II as shown in figure. Which of the following option(s) is (are) correct?
[Surface tension of water = 0.075N/m, density of water = 1000 kg/m³, take g = 10 m/s²]



(A) For case I, if the joint is kept at 8 cm above the water surface, the height of water column in the tube will be 7.5 cm. (Neglect the weight of the water in the meniscus)

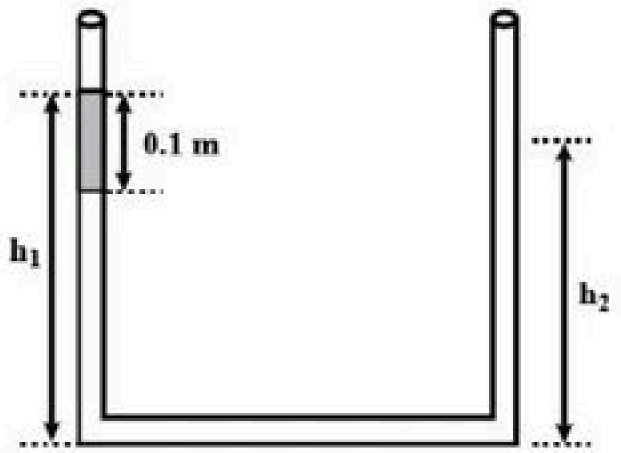
(B) For case I, capillary joint is 5cm above the water surface, the height of water column raised in the tube will be more than 8.75 cm. (Neglect the weight of the water in the meniscus)

(C) The correction in the height of water column raised in the tube, due to weight of water contained in the meniscus, will be different for both cases.

(D) For case II, the capillary joint is 5 cm above the water surface, the height of water column raised in the tube will be 3.75 cm. (Neglect the weight of the water in the meniscus)

[JEE (Advanced)-2019]

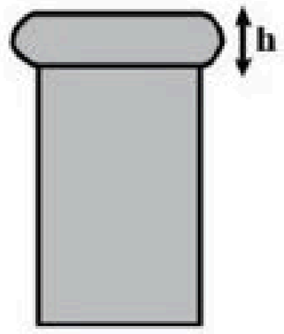
19. An open-ended U-tube of uniform cross-sectional area contains water (density 10^3kg m^{-3}). Initially the water level stands at 0.29 m from the bottom in each arm. Kerosene oil (a water-immiscible liquid) of density 800 kg m^{-3} is added to the left arm until its length is 0.1 m, as shown in the schematic figure below. The ratio (h_1/h_2) of the heights of the liquid in the two arms is



(A) 15/16 (B) 35/33 (C) 7/6 (D) 5/4

[JEE (Advanced)-2020]

20. When water is filled carefully in a glass, one can fill it to a height h above the rim of the glass due to the surface tension of water. To calculate h just before water starts flowing, model the shape of the water above the rim as a disc of thickness h having semicircular edges, as shown schematically in the figure. When the pressure of water at the bottom of this disc exceeds what can be withstood due to the surface tension, the water surface breaks near the rim and water starts flowing from there. If the density of water, its surface tension and the acceleration due to gravity are 10^3kg m^{-3}, 0.07 Nm^{-1} and 10 ms^{-2}, respectively, the value of h (in mm) is ________.



[JEE (Advanced)-2020]

21. A train with cross-sectional area S_t is moving with speed v_t inside a long tunnel of cross-sectional area S_0 ($S_0 = 4S_t$). Assume that almost all the air (density ρ) in front of the train flows back between its sides and the walls of the tunnel. Also, the air flow with respect to the train is steady and laminar. Take the ambient pressure and that inside the train to be p_0. If the pressure in the region between the sides of the train and the tunnel walls is p, then $p_0 - p = \frac{7}{2N}\rho v_t^2$. The value of N is ________.

[JEE (Advanced)-2020]

22. A hot air balloon is carrying some passengers, and a few sandbags of mass 1 kg each so that its total mass is 480 kg. Its effective volume giving the balloon its buoyancy is V. The balloon is floating at an equilibrium height of 100 m. When N number of sandbags are thrown out, the balloon rises to a new equilibrium height close to 150 m with its volume V remaining unchanged. If the variation of the density of air with height h from the ground is $\rho(h) = \rho_0 e^{-\frac{h}{h_0}}$, where ρ_0 = 1.25 kg m^{-3} and h_0 = 6000 m, the value of N is ________.

[JEE (Advanced)-2020]

ANSWER KEY

EXERCISE-I

Part-I
Section-A to G

1. B	**2.** C	**3.** D	**4.** B	**5.** C	**6.** B	**7.** B	**8.** B	**9.** B	**10.** A
11. A	**12.** D	**13.** D	**14.** A	**15.** C	**16.** B	**17.** C	**18.** C	**19.** A	**20.** D
21. A	**22.** B	**23.** A	**24.** B	**25.** A	**26.** B	**27.** D	**28.** B	**29.** B	**30.** A
31. B	**32.** A	**33.** B	**34.** B	**35.** C	**36.** B	**37.** B	**38.** A	**39.** B	**40.** D
41. D	**42.** D	**43.** B	**44.** C	**45.** B	**46.** D	**47.** A	**48.** B	**49.** C	**50.** B
51. B	**52.** B	**53.** D	**54.** B	**55.** D	**56.** C	**57.** D	**58.** B	**59.** D	**60.** B
61. A	**62.** B	**63.** D	**64.** C	**65.** B	**66.** A				

Part-II
Previous Year's Question (2008-2020)

1. C	**2.** B	**3.** D	**4.** A	**5.** C	**6.** C	**7.** C	**8.** A	**9.** C	**10.** B
11. C	**12.** B	**13.** D	**14.** B	**15.** A	**16.** A	**17.** A	**18.** D	**19.** A	**20.** B
21. C	**22.** A	**23.** A	**24.** D	**25.** A					

EXERCISE-II

PART-I

Section-A

1. BC	**2.** AC	**3.** AC	**4.** D	**5.** ACD	**6.** CD	**7.** CD
8. ABD	**9.** BC	**10.** D	**11.** D	**12.** AC	**13.** BC	**14.** AB

Section-B

1. A	**2.** D	**3.** B	**4.** A	**5.** B

Section-C

1. A–Q; B -P; C-R; D-S	**2.** A-P; B-Q; C-T; D-S

PART-II

1. 37.5 N **2.** 0.1 cm **3.** 2×10^{-4} C **4.** (a) $9600\sqrt{2}$ (b) nH

5. 54.4 cm **6.** 100 kg **7.** (a) 5, (b) 2/3 **8.** 19.6 m, 4 sec

9. 240 Hz **10.** (a) 2sec, (b) 1sec

11. $m_{min} = \pi r^2 l\,(\sqrt{\rho\sigma} - \rho)$; if tilted then it's axis should become vertical. C.M. should be lower than centre of buoyancy.

12. (a) 0 (b) h = 0.25 cm, (c) a = g/6 (upward)

13. $w = \sqrt{\frac{3g}{2L}\left(\frac{d_2 - d_1}{d_1}\right)}$ **14.** 2.79 gm/cc

15. 0.75 **16.** 80 kW **17.** 4.9 litre/min **18.** $\frac{h_2 + h_1}{2}$

19. $\sqrt{3} : \sqrt{2}$ **20.** 5 cm **21.** (i) 0.2 m/s^2 (ii) $\sqrt{2g\frac{m_0}{A\rho}}$

22. 6.43×10^{-4} m^3/s **23.** +29625 J/m^3, –30000 J/m^3

24. (a) $6\sqrt{2}\,m/s$ (b) $9.6\sqrt{2} \times 10^{-3} M^3/sec$ (c) 4.6 × 104 N/m^2

25. 20 N **26.** 20 m/s **27.** $x = \frac{\ell}{3} = \frac{3}{3} = 1$

28. θ = 30° **29.** α = 2 **30.** x = 2

EXERCISE-III

JEE ADVANCED Previous Year's Questions

1. C	**2.** A	**3.** A	**4.** A	**5.** D	**6.** C	**7.** A
8. (A)–(p),(t); (B)–(q), (s), (t); (C)– (p), (r), (t); (D)–(q)				**9.** 6	**10.** ABD	**11.** AD
12. C	**13.** A	**14.** C	**15.** AD	**16.** ACD	**17.** AC	**18.** ACD
19. B	**20.** 3.65 to 3.85		**21.** 9	**22.** 4		