Exercise-1

✍ **Marked Questions can be used as Revision Questions.**

PART - I : SUBJECTIVE QUESTIONS

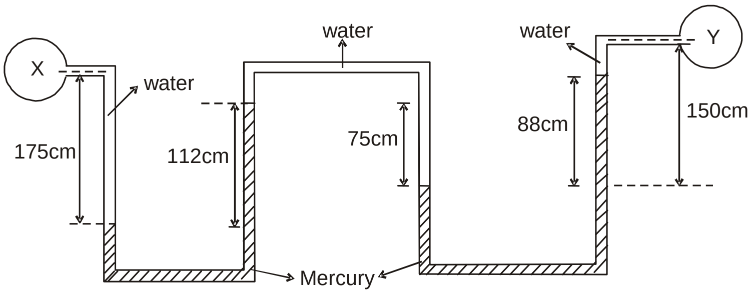
Section (A) : Measurement and calculation of pressure

A-1. We can cut an apple easily with a sharp knife as compared to a blunt knife. Explain why?

A-2. Why mercury is used in barometers instead of water ?

A-3. Pressure 3 m below the free surface of a liquid is $15 KN/m^2$ in excess of atmosphere pressure. Determine its density and specific gravity. [$g = 10\ m/sec^2$]

A-4.✍ Two U-tube manometers are connected to a same tube as shown in figure. Determine difference of pressure between X and Y. Take specific gravity of mercury as 13.6. ($g = 10\ m/s^2$, $\rho_{Hg} = 13600\ kg/m^3$)



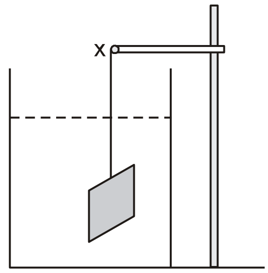
A-5. A rectangular vessel is filled with water and oil in equal proportion (by volume), the oil being twice lighter than water. Show that the force on each side wall of the vessel will be reduced by one fifth if the vessel is filled only with oil. (Assume atmospheric pressure is negligible)

Section (B) : Archemedies principle and force of buoyancy

B-1. A cube of wood supporting a 200 gm mass just floats in water. When the mass is removed the cube rises by 2 cm at equilibrium. Find side of the cube.

B-2.✍ A small solid ball of density half that of water falls freely under gravity from a height of 19.6 m and then enters into water. Upto what depth will the ball go ? How much time will it take to come again to the water surface? Neglect air resistance, viscosity effects of water and energy loss due to collision at water surface. ($g = 9.8\ m/s^2$)

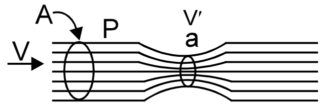
B-3. A metallic square plate is suspended from a point x as shown in figure. The plate is made to dip in water such that level of water is well above that of the plate. The point 'x' is then slowely raised at constant velocity. Sketch the variation of tension T in string with the displacement 's' of point x.



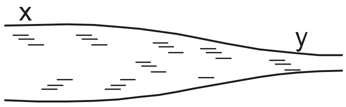
Section (C) : Continuity equation & Bernoulli theorem and their application

C-1. Calculate the rate of flow of glycerin of density $1.25 \times 10^3\ kg/m^3$ through the conical section of a pipe placed horizontally, if the radii of its ends are 0.1m and 0.04 m and the pressure drop across its length is $10\ N/m^2$.

C-2. Consider the Venturi tube of Figure. Let area A equal 5a. Suppose the pressure at A is 2.0 atm. Compute the values of velocity v at 'A' and velocity v′ at 'a' that would make the pressure p′ at 'a' equal to zero. Compute the corresponding volume flow rate if the diameter at A is 5.0 cm. (The phenomenon at a when p′ falls to nearly zero is known as cavitation. The water vaporizes into small bubbles.) (P_{atm} = 10^5 N/m^2, ρ = 1000 kg/m^3).



C-3. Water flows through a horizontal tube of variable cross-section (figure). The area of cross-section at x and y are 40 mm^2 and 20 mm^2 respectively. If 10 cc of water enters per second through x, find (i) the speed of water at x, (ii) the speed of water at y and (iii) the pressure difference $P_x - P_y$.



C-4. Suppose the tube in the previous problem is kept vertical with x upward but the other conditions remain the same. The separation between the cross-section at x and y is 15/16 cm. Repeat parts (i), (ii) and (iii) of the previous problem. Take g = 10 m/s^2.

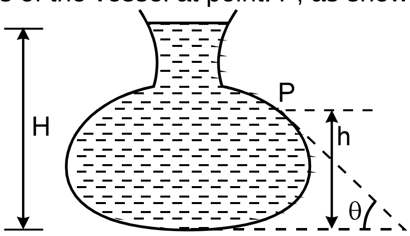
C-5. Suppose the tube in the previous problem is kept vertical with y upward. Water enters through y at the rate of 10 cm^3/s. Repeat part (iii). Note that the speed decreases as the water falls down.

C-6. Let air be at rest at the front edge of wing of an aeroplane and air passing over the surface of the wing at a fast speed v. If density of air is ρ, then find out the highest value for v in stream line flow when atmospheric pressure is p_{atm}.

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Measurement and calculation of pressure

A-1. Figure here shows the vertical cross-section of a vessel filled with a liquid of density ρ. The normal thrust per unit area on the walls of the vessel at point. P, as shown, will be



(A) h ρ g (B) H ρ g (C) (H – h) ρ g (D) (H – h) ρ g cosθ

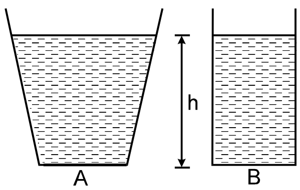
A-2. A tank with length 10 m, breadth 8 m and depth 6m is filled with water to the top. If g = 10 m s^{-2} and density of water is 1000 kg m^{-3}, then the thrust on the bottom is (neglect atmospheric pressure)

(A) 6 × 1000 × 10 × 80 N (B) 3 × 1000 × 10 × 48 N
(C) 3 × 1000 × 10 × 60 N (D) 3 × 1000 × 10 × 80 N

A-3. In a hydraulic lift, used at a service station the radius of the large and small piston are in the ratio of 20 : 1. What weight placed on the small piston will be sufficient to lift a car of mass 1500 kg ?

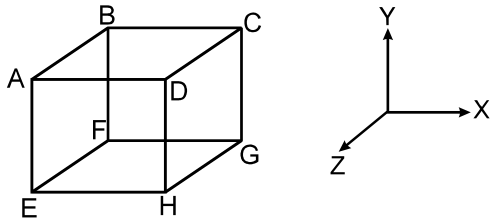
(A) 3.75 kg (B) 37.5 kg (C) 7.5 kg (D) 75 kg.

A-4. 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) $F_A > F_B$; $W_A = W_B$

A-5.(i) The cubical container ABCDEFGH which is completely filled with an ideal (nonviscous 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

(ii) In previous question pressure will be minimum at point –

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

Section (B) : Archemedies principle and force of buoyancy

B-1. The density of ice is x gm/cc and that of water is y gm/cc. What is the change in volume in cc, when m gm of ice melts?

(A) M (y – x) (B) (y – x)/m (C) mxy (x – y) (D) m (1/y – 1/x)

B-2. The reading of a spring balance when a block is suspended from it in air is 60 newton. This reading is changed to 40 newton when the block is fully submerged in water. The specific gravity of the block must be therefore :

(A) 3 (B) 2 (C) 6 (D) 3/2

B-3. A block of volume V and of density σ_b is placed in liquid of density $\sigma_l(\sigma_l > \sigma_b)$, then block is moved upward upto a height h and it is still in liquid. The increase in gravitational potential energy of the block is :

(A) $\sigma_b Vgh$ (B) $(\sigma_b + \sigma_l)Vgh$ (C) $(\sigma_b - \sigma_l)Vgh$ (D) none of these

B-4. A block of steel of size 5 cm × 5 cm × 5 cm is weighed in water. If the relative density of steel is 7. Its apparent weight is :

(A) 6 × 5 × 5 × 5 gf (B) 4 × 4 × 4 × 7 gf (C) 5 × 5 × 5 × 7 gf (D) 4 × 4 × 4 × 6 gf

B-5. A metallic sphere floats in an immiscible mixture of water ($\rho_w = 10^3$ kg/m^3) and a liquid ($\rho_L = 13.5 \times 10^3$) with (1/5)th portion by volume in the liquid and remaining in water. The density of the metal is :

(A) 4.5×10^3 kg/m^3 (B) 4.0×10^3 kg/m^3 (C) 3.5×10^3 kg/m^3 (D) 1.9×10^3 kg/m^3

B-6. Two bodies are in equilibrium when suspended in water from the arms of a balance. The mass of one body is 36 g and its density is 9 g/cc. If the mass of the other is 48 g, its density in g/cc is :

(A) 4/3 (B) 3/2 (C) 3 (D) 5

B-7. In order that a floating object be in a stable equilibrium, its centre of buoyancy should be

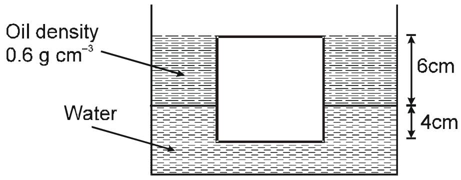
(A) vertically above its centre of gravity

(B) vertically below its centre of gravity

(C) horizontally in line with its centre of gravity

(D) may be anywhere

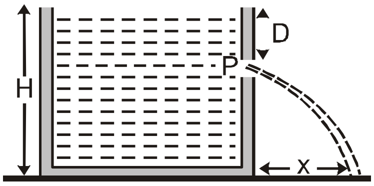
B-8. A cubical block of wood 10 cm on a side, floats at the interface of oil and water as shown in figure. The density of oil is 0.6 g cm^{-3} and density of water is 1 g cm^{-3}. The mass of the block is



(A) 706 g (B) 607 g (C) 760 g (D) 670 g

Section (C) : Continuity equation and Bernoulli theorem & their application

C-1. A tank is filled with water up to height H. Water is allowed to come out of a hole P in one of the walls at a depth D below the surface of water as shown in the figure. Express the horizontal distance x in terms of H and D :

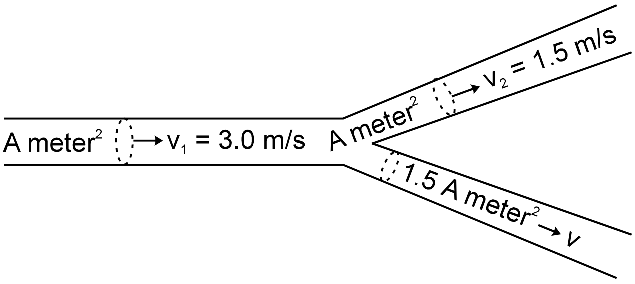


(A) $x = \sqrt{D(H-D)}$ (B) $x = \sqrt{\frac{D(H-D)}{2}}$ (C) $x = 2\sqrt{D(H-D)}$ (D) $x = 4\sqrt{D(H-D)}$

C-2. A fixed cylindrical vessel is filled with water up to height H. A hole is bored in the wall at a depth h from the free surface of water. For maximum horizontal range h is equal to :

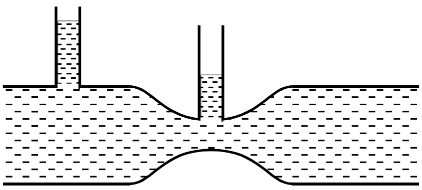
(A) H (B) 3H/4 (C) H/2 (D) H/4

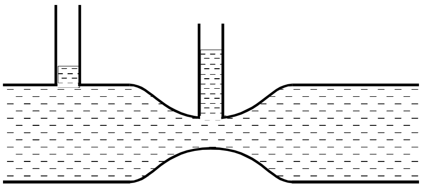
C-3. An incompressible liquid flows through a horizontal tube as shown in the figure. Then the velocity ' v ' of the fluid is :

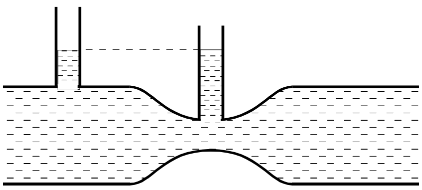


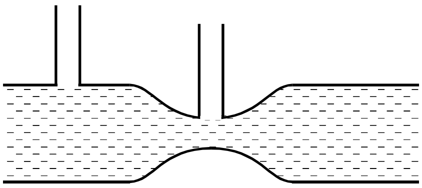
(A) 3.0 m/s (B) 1.5 m/s (C) 1.0 m/s (D) 2.25 m/s

C-4. For a fluid which is flowing steadily in a horizontal tube as shown in the figure, the level in the vertical tubes is best represented by

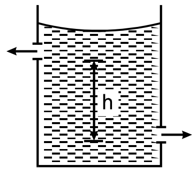
(A)


(B)


(C)


(D)


C-5. There are two identical small holes on the opposite sides of a tank containing a liquid. The tank is open at the top. The difference in height of the two holes is h as shown in the figure. As the liquid comes out of the two holes, the tank will experience a net horizontal force proportional to:



(A) $h^{1/2}$ (B) h (C) $h^{3/2}$ (D) h^2

C-6. A cylindrical tank of height 0.4 m is open at the top and has a diameter 0.16 m. Water is filled in it up to a height of 0.16 m. How long it will take to empty the tank through a hole of radius 5×10^{-3} m at its bottom ?

(A) 46.26 sec. (B) 4.6 sec. (C) 462.6 sec. (D) 0.46 sec.

C-7. A large cylindrical vessel contains water to a height of 10m. It is found that the thrust acting on the curved surface is equal to that at the bottom. If atmospheric pressure can support a water column of 10m, the radius of the vessel is **[Olympiad 2014 (stage-1)]**

(A) 10 m (B) 15m (C) 5m (D) 25m

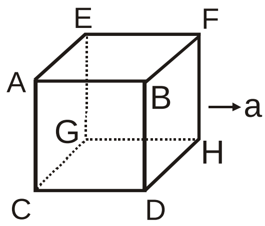
C-8. A jet of water of cross-sectional area A hits a plate normally with velocity v. the plate is moving in the direction of the jet with velocity V. therefore, the force exerted on the plate is proportional to

[Olympiad 2015 (stage-1)]

(A) v (B) v^2 (C) (v – V) (D) $(v – V)^2$

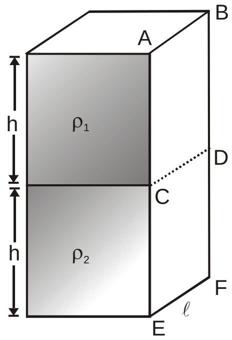
PART - III : MATCH THE COLUMN

1. 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
	(t) $\frac{mg}{2}$ + ma

2. 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



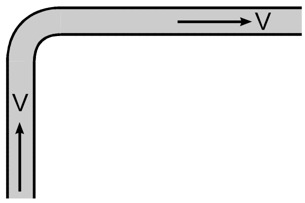
Column I	Column II
(A) Force on face ABCD due to liquid of density ρ_1	(p) zero
(B) Force on face ABCD due to liquid of density ρ_2	(q) $\frac{\rho_1 g h^2 \ell}{2}$
(C) Force on face CDEF transferrred due to liquid of density ρ_1	(r) $\rho_1 g h^2 \ell$
(D) Force on face CDEF due to liquid of density ρ_2 only	(s) $\frac{\rho_2 g h^2 \ell}{2}$

Exercise-2

✍ Marked Questions can be used as Revision Questions.

PART - I : ONLY ONE OPTION CORRECT TYPE

1.✍ A fire hydrant (as shown in the figure) 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

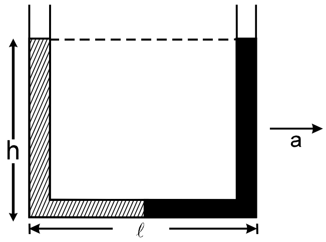


(A) ρVL (B) zero (C) $2\rho VL$ (D) $\sqrt{2}\rho VL$

2.✍ 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 ℓ]

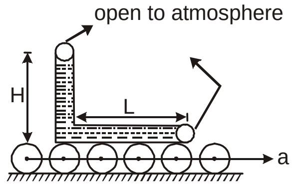
(A) 0 (B) $\rho g \ell A_0$ (C) $2\rho g \ell A_0$ (D) $\frac{\rho g \ell A_0}{2}$

3.✍ A U-tube of base length "ℓ" 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:



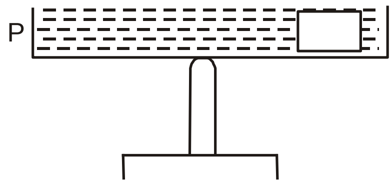
(A) $\frac{a}{2g}\ell$ (B) $\frac{3a}{2g}\ell$ (C) $\frac{a}{g}\ell$ (D) $\frac{2a}{3g}\ell$

4. 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) $\frac{gH}{\sqrt{2}L}$

5. 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.



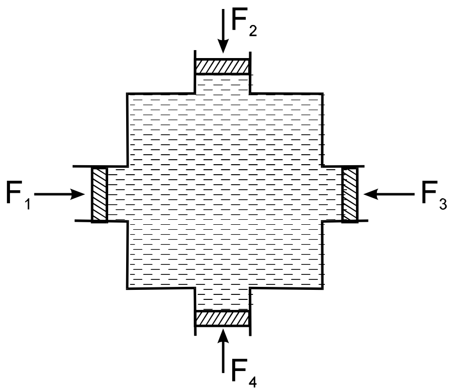
(A) Equilibrium will be maintained only if $\rho < \rho_w$.

(B) Equilibrium will be maintained only if $\rho \leq \rho_w$.

(C) Equilibrium will be maintained for all relations between ρ and ρ_w.

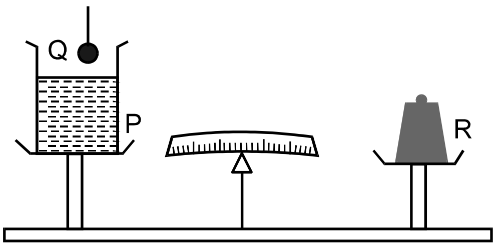
(D) It is not possible to maintained the equilibrium

6. 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



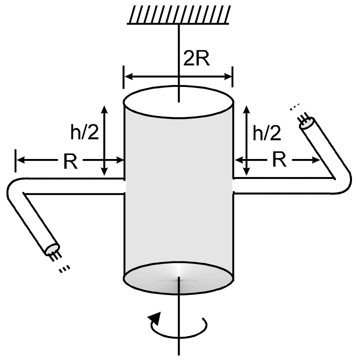
(A) $\frac{F}{A}$ (B) $\frac{2F}{A}$ (C) $\frac{4F}{A}$ (D) 0

7. 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

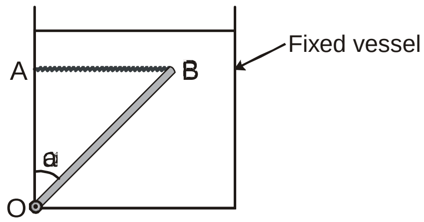
8. A cylindrical container of radius ' R ' and height ' h ' is completely filled with a liquid. Two horizontal L shaped pipes of small cross-section area ' a ' are connected to the cylinder as shown in the figure. Now the two pipes are opened and fluid starts coming out of the pipes horizontally in opposite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



(A) $4agh\rho R$ (B) $8agh\rho R$

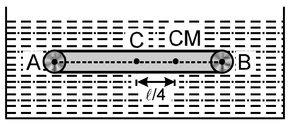
(C) $2agh\rho R$ (D) $agh\rho R$

9. 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) 45º (B) 37º (C) 53º (D) 60º

10. A non uniform cylinder of mass m, length ℓ and radius r is having its centre of mass at a distance $\ell/4$ 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) $\frac{3\pi\rho g\ell^2 r^2}{4I}$

11. A block of iron is kept at the bottom of a bucket full of water at 2°C. The water exerts buoyant force on the block. If the temperature of water is increased by 1°C the temperature of iron block also increases by 1°C. The buoyant force on the block by water

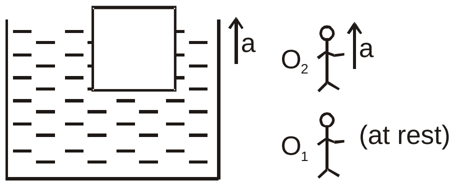
(A) will increase (B) will decrease (C) will not change

(D) may decrease or increase depending on the values of their coefficient of expansion

12. A liquid is kept in a cylindrical vessel which is rotated about its axis. The liquid rises at the sides. If the radius of the vessel is 0.05 m and the speed of rotation is 2 rev/s. The difference in the height of the liquid at the centre of the vessel and its sides will be ($\pi^2 = 10$) :

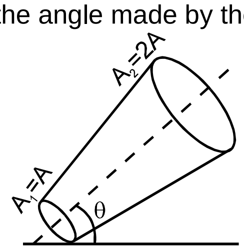
(A) 3 cm (B) 2 cm (C) 3/2 cm (D) 2/3 cm

13. 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

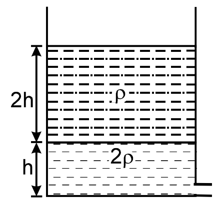
14. A portion of a tube is shown in the figure. Fluid is flowing from cross-section area A_1 to A_2. The two cross-sections are at distance ' ℓ ' from each other. The velocity of the fluid at section A_2 is $\sqrt{\frac{g\ell}{2}}$. If the pressures at A_1 & A_2 are same, then the angle made by the tube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



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

15. 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 of 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 $= \frac{ga^2}{A^2}$

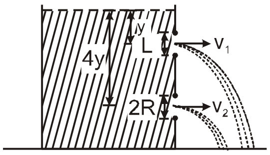
16. The velocity of the liquid coming out of a small hole of a large vessel containing two different liquids of densities 2ρ and ρ as shown in figure is



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

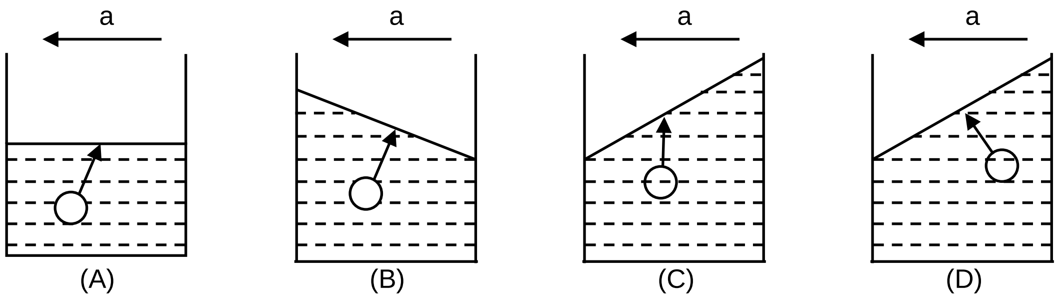
17. Two water pipes P and Q having diameters 2×10^{-2} m and 4×10^{-2} m, respectively, are joined in series with the main supply line of water. The velocity of water flowing in pipe P is
(A) 4 times that of Q
(B) 2 times that of Q
(C) 1/2 times that of Q
(D) 1/4 times that of Q

18. 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 : **[JEE - 2000, 2/105]**



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

19. A cup of water is placed in a car moving at a constant acceleration a to the left. Inside the water is a small air bubble. The figure that correctly shows the shape of the water surface and the direction of motion of the air bubble is. **[Olympiad (State-1) 2016]**



(A) A (B) B (C) C (D) D

20._ Two identical solid block A and B are made of two different materials. Block A floats in a liquid with half of its volume submerged. When block B is pasted over A, the combination is found to just float in the liquid. The ratio of the densities of the liquid, material of A and material of B is given by

[Olympiad (Stage-1) 2017]

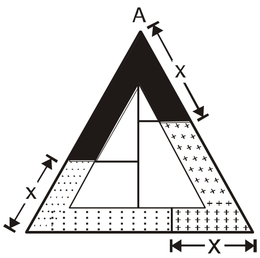
(A) 1 : 2 : 3 (B) 2 : 1 : 4 (C) 2 : 1 : 3 (D) 1 : 3 : 2

21._ A hollow sphere of inner radius 9 cm and outer radius 10 cm floats half submerged in a liquid of specific gravity 0.8. The density of the material of the spere is **[Olympiad (Stage-1) 2017]**

(A) 0.84g cm^{-3} (B) 1. 48g cm^{-3} (C) 1. 84g cm^{-3} (D) 1.24g cm^{-3}

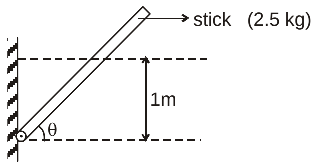
PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

1. A closed tube in the form of an equilateral triangle of side ℓ = 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.

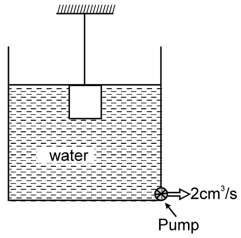


2. An open tank 10 m long and 2m deep is filled upto height 1.5 m of oil of specific gravity 0.80. The tank is accelerated uniformly from rest to a speed of 10 m/sec. The shortest time (in seconds) in which this speed may be attained without spilling any oil (in sec). [g = 10m/s^2]

3. 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.

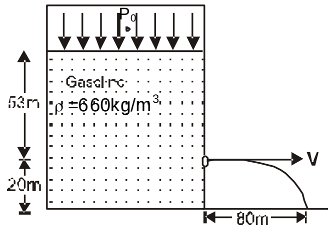


4. Figure shows a cubical block of side 10 cm and relative density 1.5 suspended by a wire of cross sectional area 10^{-6} m^2. The breaking stress of the wire is 7×10^6 N/m^2. The block is placed in a beaker of base area 200 cm^2 and initially i.e. at t = 0, the top surface of water & the block coincide. There is a pump at the bottom corner which ejects 2 cm^3 of water per sec constantly. If the time at which the wire will break is $(20)\alpha$ (in second) then find 'α' .



5.✍ A cylindrical vessel filled with water upto a height of 2m stands on horizontal plane. The side wall of the vessel has a plugged circular hole touching the bottom. If the minimum diameter of the hole so that the vessel begins to move on the floor if the plug is removed is $\frac{x}{10\sqrt{\pi}}$ meter then x will be (if the coefficient of friction between the bottom of the vessel and the plane is 0.4 and total mass of water plus vessel is 100 kg.)

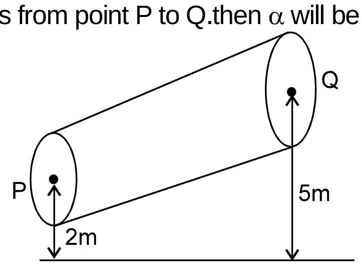
6.✍ A tank containing gasoline is sealed and the gasoline is under pressure P_0 as shown in the figure. The stored gasoline has a density of 660 kg m^{-3}. A sniper fires a rifle bullet into the gasoline tank, making a small hole 53 m below the surface of gasoline. The total height of gasoline is 73 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})



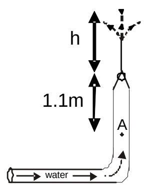
7. A large open top container of negligible mass and uniform cross–sectional area A has a small hole of cross–sectional area $\frac{A}{100}$ in its side wall near the bottom. The container is kept on a smooth horizontal floor and contains a liquid of density ρ and mass m_0. Assuming that the liquid starts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

[JEE - 1997 Cancel, 5/100]

8. 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 2 meters and 5 meters are respectively 4×10^{-3} m^2 and 8×10^{-3} m^2. The velocity of the liquid at point P is 1 m/s. If the work done per unit volume by the pressure is $(1161)\alpha$ joule/m^3 as the liquid flows from point P to Q.then α will be (g = 9.8 m/s^2) **[JEE - 1997, 5/100]**



9. Water shoots out of a pipe and nozzle as shown in the figure. The cross–sectional area for the tube at point A is four times that of the nozzle. The pressure of water at point A is 41×10^3 Nm^{-2} (guage). If the height 'h' above the nozzle to which water jet will shoot is x/10 meter than x is. (Neglect all the losses occurred in the above process) [g = 10 m/s^2]



PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

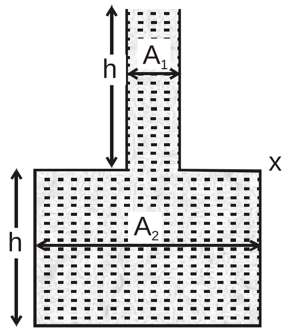
1.✍ An air bubble in a water tank rises from the bottom to the top. Which of the following statements are true ?

(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. 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) $\frac{\partial p}{\partial z} = 0$

3. 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 atomospheric pressure,

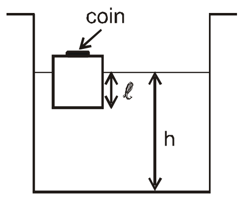


(A) the pressure at the base of the vesel is 2 h ρ g
(B) the weight of the liquid in vessel is equal to 2 h ρ gA_2
(C) the force exerted by the liquid on the base of vessel is 2 h ρ g A_2
(D) the walls of the vessel at the level X exert a force h ρ g ($A_2 - A_1$) downwards on the liquid.

4. 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.

5. 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.

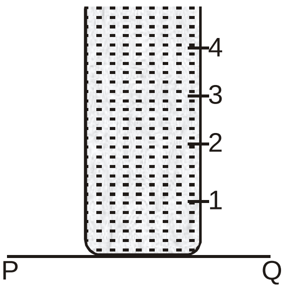
6. A wooden block with a coin placed on its top, floats in water as shown in figure. The distance ℓ and h are shown here. After some time the coin falls into the water. Then : **[JEE-2002 (Screening), 3/105]**



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

7. 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.

8. 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



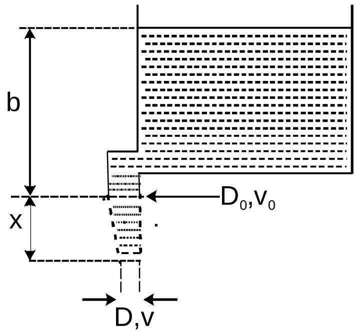
(A) hole number 4 (B) hole number 3 (C) hole number 2 (D) hole number 1.

PART - IV : COMPREHENSION

Comprehension-1

The figure shows the commonly observed decrease in diameter of a water stream as it falls from a tap. 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 cm

Comprehension-2

One way of measuring a person's body fat content is by "weighing" them under water. This works because fat tends to float on water as it is less dense than water. On the other hand muscle and bone tend to sink as they are more dense. Knowing your "weight" under water as well as your real weight out of water, the percentage of your body's volume that is made up of fat can easily be estimated. This is only an estimate since it assumes that your body is made up of only two substances, fat (low density) and everything else (high density). The "weight" is measured by spring balance both inside and outside the water. Quotes are placed around weight to indicate that the measurement read on the scale is not your true weight, i.e. the force applied to your body by gravity, but a measurement of the net downward force on the scale.

6.✍ Ram and Shyam are having the same weight when measured outside the water. When measured under water, it is found that weight of Ram is more than that of Shyam, then we can say that
(A) Ram is having more fat content than Shyam.
(B) Shyam is having more fat content that Ram.
(C) Ram and Shyam both are having the same fat content.
(D) None of these.

7.✍ Ram is being weighed by the spring balance in two different situations. First when he was fully immersed in water and the second time when he was partially immersed in water, then
(A) Reading will be more in the first case. (B) Reading will be more in the second case.
(C) Reading would be same in both the cases. (D) Reading will depend upon experimental setup.

8.✍ Salt water is denser than fresh water. If Ram is immersed fully first in salt water and then in fresh water and weighed, then
(A) Reading would be less in salt water.
(B) Reading would be more in salt water.
(C) Reading would be the same in both the cases.
(D) reading could be less or more.

9.✍ A person of mass 165 Kg having one fourth of his volume consisting of fat (relative density 0.4) and rest of the volume consisting of everything else (average relative density $\frac{4}{3}$) is weighed under water by the spring balance. The reading shown by the spring balance is -
(A) 15 N (B) 65 N (C) 150 N (D) 165 N

10.✍ In the above question if the spring is cut, the acceleration of the person just after cutting the spring is
(A) zero (B) 1 m/s^2 (C) 9.8 m/s^2 (D) 0.91 m/s^2

Exercise-3

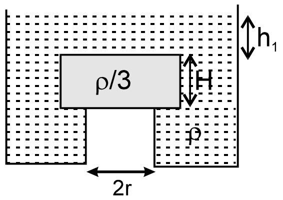
✍ **Marked Questions can be used as Revision Questions.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

Comprehension-1

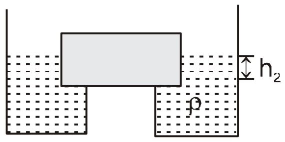
A wooden cylinder of diameter 4r, height H and density $\rho/3$ is kept on a hole of diameter 2r of a tank, filled with liquid of density ρ as shown in the figure.

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 : **[IIT-JEE 2006, 5/184]**



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

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 **[IIT-JEE 2006, 5/184]**

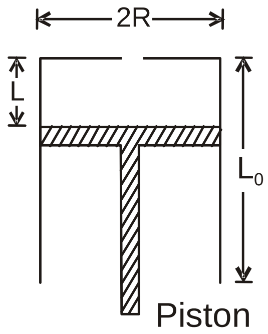


(A) $\frac{4H}{9}$ (B) $\frac{5H}{9}$ (C) Remains same (D) $\frac{2H}{3}$

3. If height h_2 of water level is further decreased then, **[IIT-JEE 2006, 5/184]**
(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

Comprehension-2

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. **[IIT-JEE 2007, 4 × 3/184]**



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

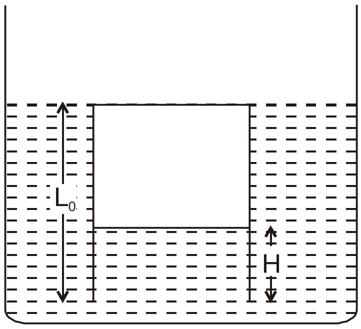
(A) P_0 (B) $\frac{P_0}{2}$ (C) $\frac{P_0}{2} + \frac{Mg}{\pi R^2}$ (D) $\frac{P_0}{2} - \frac{Mg}{\pi R^2}$

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

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) $\rho g (L_0 - H)^2 + P_0 (L_0 - H) + L_0P_0 = 0$ (B) $\rho g (L_0 - H)^2 - P_0 (L_0 - H) - L_0P_0 = 0$

(C) $\rho g (L_0 - H)^2 + P_0 (L_0 - H) - L_0P_0 = 0$ (D) $\rho g (L_0 - H)^2 - P_0 (L_0 - H) + L_0P_0 = 0$

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.

and

STATEMENT -2 : In any steady flow of an incompressible fluid, the volume flow rate of the fluid remains constant. **[IIT-JEE 2008, 3/162]**

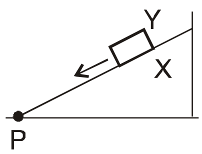
(A) STATEMENT-1 is True, STATEMENT-2 is True; STATEMENT-2 is a correct explanation for STATEMENT-1

(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.

8. **Column II** shows five systems in which two objects are labelled 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.** **[IIT-JEE 2009, 8/160]**

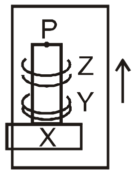
Column I	**Column I**
(A) The force exerted by X on Y has a magnitude Mg.	(p)  Block Y of mass M left on a fixed inclined plane X, slides on it with a constant velocity.

(B) The gravitational potential energy of X is continuously increasing,

(C) Mechanical energy of the system X + Y is continuously decreasing.

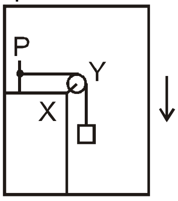
(D) The torque of the weight of Y about point P is zero.

(q)



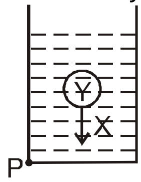
Two ring magnets Y and Z, each of mass M, are kept in frictionless vertical plastic stand so that they repel each other. Y rests on the base X and Z hangs in air in equilibrium. P is the topmost point of the stand on the common axis of the two rings. The whole system is in a lift that is going up with a constant velocity.

(r)



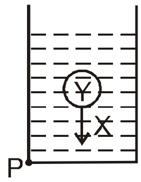
A pulley Y of mass m_0 is fixed to a table through a clamp X. A block of mass M hangs from a string that goes over the pulley and is fixed at point P of the table. The whole system is kept in a lift that is going down with a constant velocity.

(s)



A sphere Y of mass M is put in a nonviscous liquid X kept in a container at rest. The sphere is released and it moves down in the liquid.

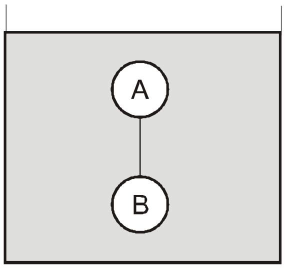
(t)



A sphere Y of mass M is falling with its terminal velocity in a viscous liquid X kept in a container.

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, 4/160, –1]**

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 **[IIT-JEE 2011, 4/160]**



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

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) **[JEE (Advanced)-2013, 3/60, –1]**

(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.

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 5mms^{-1}, the air comes out of the nozzle with a speed of

[JEE (Advanced) 2014, 3/60, –1]

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

13. If the density of air is ρ_a and that of the liquid ρ_ℓ, then for a given piston speed the rate (volume per unit time) at which the liquid is sprayed will be proportional to **[JEE (Advanced) 2014, 3/60, –1]**

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

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. **[JEE (Advanced)-2014, 3/60, –1]**

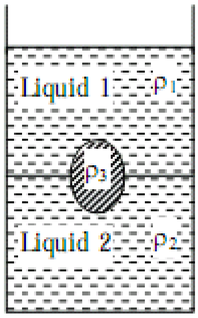
List -I	List-II
P. Lift is accelerating vertically up.	**1.** d = 1.2 m
Q. Lift is accelerating vertically down with an acceleration less than the gravitational acceleration.	**2.** d > 1.2m
R. List is moving vertically up with constant Speed	**3.** d < 1.2 m
S. Lift is falling freely.	**4.** No water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

Code :

(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

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

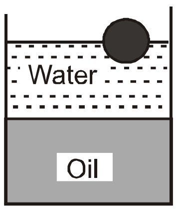
1. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2, respectively. A solid ball, made of a material of density ρ_3, is dropped in the jar. It comes to equilibrium in the position shown in the figure. **[AIEEE 2008, 4/300]**

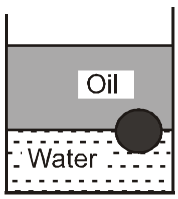


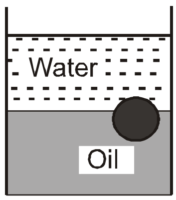
Which of the following is true for ρ_1, ρ_2 and ρ_3 ?

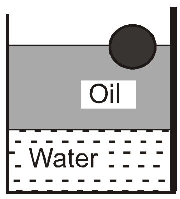
(1) $\rho_1 > \rho_3 > \rho_2$ (2) $\rho_1 < \rho_2 < \rho_3$ (3) $\rho_1 < \rho_3 < \rho_2$ (4) $\rho_3 < \rho_1 < \rho_2$

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? **[AIEEE 2010, 4/144]]**

(1) 

(2) 

(3) 

(4) 

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 : **[AIEEE - 2011, 4/120, –1]**

(1) 5.0×10^{-3} m (2) 7.5×10^{-3} m (3) 9.6×10^{-3} m (4) 3.6×10^{-3} m

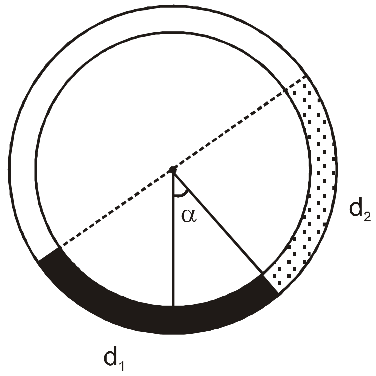
4. A wooden cube (density of wood 'd') of side 'ℓ' floats in a liquid of density 'ρ' with its upper and lower surfaces horizontal. If the cube is pushed slightly down and released, it performs simple harmonic motion of period 'T'. Then, 'T' is equal to : **[AIEEE 2011, 11 May; 4/120, –1]**

(1) $2\pi\sqrt{\frac{\ell d}{\rho g}}$ (2) $2\pi\sqrt{\frac{\ell \rho}{dg}}$ (3) $2\pi\sqrt{\frac{\ell d}{(\rho - d)g}}$ (4) $2\pi\sqrt{\frac{\ell \rho}{(\rho - d)g}}$

5. 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 :**[JEE (Main) 2013, 4/120,–1]**

(1) $\frac{Mg}{k}$ (2) $\frac{Mg}{k}\left(1 - \frac{LA\sigma}{M}\right)$ (3) $\frac{Mg}{k}\left(1 - \frac{LA\sigma}{2M}\right)$ (4) $\frac{Mg}{k}\left(1 + \frac{LA\sigma}{M}\right)$

6. 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 subtands 90° angle at centre. Radius joining their interface makes an angle α with vertical. Ratio $\frac{d_1}{d_2}$ is : **[JEE(Main) 2014, 4/120, –1]**



(1) $\frac{1+\sin\alpha}{1-\sin\alpha}$ (2) $\frac{1+\cos\alpha}{1-\cos\alpha}$ (3) $\frac{1+\tan\alpha}{1-\tan\alpha}$ (4) $\frac{1+\sin\alpha}{1-\cos\alpha}$

Answers

EXERCISE-1

PART - I

Section (A) :

A-1. Sharp kinife applies more pressure as compare to blunt knife because of lesser area of contact.

A-2. It has high specific gravity.

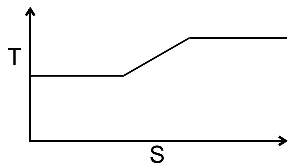
A-3. 500 kg/m^3, 0.5

A-4. If $g = 10 m/s^2$, 253200 N/m^2

Section (B) :

B-1. 10 cm **B-2.** 19.6 m, 4 sec

B-3.



Section (C) :

C-1. $6.43 \times 10^{-4}\ m^3/s$

C-2. $v = \frac{10}{\sqrt{6}}$ m/s = 4.1 m/s; $v' = \frac{50}{\sqrt{6}}$ m/s = 21 m/s ;

$Av = 8.1 \times 10^{-3}\ m^3$ /sec

C-3 (i) 25 cm/s, (ii) 50 cm/s (iii) 93.75 N/m^2

C-4. (i) 25 cm/s, (ii) 50 cm/s (iii) zero

C-5. 187.5 N/m^2

C-6. $v_{max} = \left(\frac{2p_{atm}}{\rho}\right)^{1/2}$

PART - II

Section (A) :

A-1.	(C)	**A-2.**	(A)	**A-3.**	(A)
A-4.	(B)	**A-5.**	(i) (A), (ii) (C)		

Section (B) :

B-1.	(D)	**B-2.**	(A)	**B-3.**	(A)
B-4.	(A)	**B-5.**	(C)	**B-6.**	(C)
B-7.	(A)	**B-8**	(C)		

Section (C)

C-1.	(C)	**C-2.**	(C)	**C-3.**	(C)
C-4.	(A)	**C-5.**	(B)	**C-6.**	(A)
C-7.	(B)	**C-8.**	(D)		

PART - III

1. $A \to p$; $B \to q$; $C \to t$; $D \to s$

2. $A \to q$; $B \to p$; $C \to r$; $D \to s$

EXERCISE-2

PART - I

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

PART - II

1.	1	**2.**	10	**3.**	30
4.	5	**5.**	2	**6.**	2
7.	2	**8.**	25	**9.**	32

PART - III

1.	(BC)	**2**	(AC)	**3.**	(ACD)
4.	(CD)	**5.**	(ABD)	**6.**	(D)
7.	(BC)	**8.**	(AB)		

PART - IV

1.	(A)	**2.**	(D)	**3.**	(B)
4.	(A)	**5.**	(B)	**6.**	(B)
7.	(B)	**8.**	(A)	**9.**	(C)
10.	(D)				

EXERCISE-3

PART - I

1.	(C)	**2.**	(A)	**3.**	(A)
4.	(A)	**5.**	(D)	**6.**	(C)
7.	(A)				

8. (A) $\to$ (p), (t) ; (B) $\to$ (q), (s), (t); (C) $\to$ (p), (r), (t); (D) $\to$ (q)

9.	6	**10.**	(ABD)	**11.**	(AD)
12.	(C)	**13.**	(A)	**14.**	(C)

PART - II

1.	(3)	**2.**	(2)	**3.**	(4)
4.	(1)	**5.**	(3)	**6.**	(3)