Chap No. 6 Fluid Dynamics

1. Fluid Types:
   (1) Hydrostatic
   (2) Fluid dynamics
       (a) Hydrodynamics.
       (b) Aerodynamics
2. A substance which flows is called fluid.
3. The study of fluid at rest is called hydrostatic.
4. The study of proporeties of Fluids and effect of Moving fluids is called fluid dynamics.
5. The study of liquids in motion is called hydrodynamics.
6. The study of gases in motion is called aerodynamics.
7. Viscosity determines the rate of flow of liquids.
8. The law of conservation of mass gives us equation of continuity.
9. The law of conservation of energy is the basis of Bernoulli's equation.

Viscous drag and Strokes Law

10. Substance that flow easily have small co-efficient of viscosity.
11. Substance which do not flow easily have large co-efficient of viscosity.
12. The SI unit of co-efficient of viscosity is Nsm^{-2} or Kg/ms. ***so important***
13. An object moving through a fluid experiences a retarding force called the drag force.
14. The drag force increasea as the speed of the object increases.
15. The resistance offered by fluids to the motin of objects or bodies is called viscous drag.

The viscous drag depends upon the

16. Size
17. Shape
18. orientation of the object
19. relative speed of the object with respect to fluid
20. viscosity of the fluid

Strokes Law

21. $F_d \alpha \eta r v$
22. $F_d = 6\pi \eta r v$
23. $F_d \alpha v$ when speed is slow of the object. ***so important***
24. $F_d \alpha v^2$ when speed is high. ***so important***

Unit of η

$F = 6\pi \eta r v$
$\eta = F/ 6\pi r v$
$\eta = N/mm/s = Ns/m^2$
or
$\eta = F/ 6\pi r v = ma/rv = mv/trv = m/tr$ =kg/ms

MCQs FOR ETEA

25. If the velocity is double and body is moving with slow speed then drag force becomes
    A)same b) double
    C) triple d)quadruples
    Ans: b

Solution: $F_d = 6\pi\ \eta\ r\ v$

$\rightarrow$ $F_d\ \alpha\ v$ making v double force also doubles.

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26. If object velocity becomes double and already it is moving with high speed, then drag force will be

A)same b) double

C) triple d)quadruples

Ans;d

Solution: $\rightarrow$ $F_d\ \alpha\ v^2$ when speed is high.

Making the v doubles $F_d\ \alpha\ (2v)^2$

$\rightarrow F_d\ \alpha\ 4\ v^2$

Thus force will increase four times.

Terminal velocity

27. Wheen the drag force becomes equal to the weight of the object then the body will fall at steady state,we call it terminal velocity.
28. At terminal velocity

$F_d = W \rightarrow 6\pi\ \eta\ r\ v = mg \rightarrow v = mg/6\pi\ \eta\ r$ ***so important***

29. Terminal velocity if directedly proportional to the mass of the object. ***so important***
30. Larger rain drop have larger mass so it has larger terminal velocity so it hurts more than light rain drops.
31. $m = \rho\ V$ and $V = 4/3\ \pi r^3$ so $m = \rho\ 4/3\ \pi r^3$ ***so important***
32. $v = mg/6\pi\ \eta\ r$
33. $\eta = [\rho \frac{4}{3} \pi r^3\ ][g/6\pi\ \eta\ r] = \frac{4}{18} \rho g r^2$
34. $\eta = 2\rho g r^2/ 9\eta$
35. $v_t = 2\rho g r^2/ 9\eta$ ***so important***
36. the terminal velocity is directly proportional ot the square of the radius. $v\ \alpha\ r^2$
37. The paratrooper attains the terminal velocity of the 200 k/h.

MCQs FOR ETEA

38. the realtion of terminal velocity and radius of the objects

$\rightarrow v\ \alpha\ r^2$

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39. the ratio of the terminal velocity of drop A to B if B have double radius of A.

a)1:1 b)1:4

c)4:1 d)1:2

ans: b

Solution: $v_{t\ A}/\ v_{t\ B} = 2\rho g r_A{}^2/ 9\eta\ /\ 2\rho g r_B{}^2/ 9\eta$

$v_{t\ A}/\ v_{t\ B} = r_A{}^2/r_B{}^2$

$v_{t\ A}/\ v_{t\ B} = r_A{}^2/(\ 2r_A)^2$

$v_{t\ A}/\ v_{t\ B} = r_A{}^2/\ 4r_A{}^2$

$v_{t\ A}/\ v_{t\ B} = 1/4 = 1:4$

Fluids Flow

40. if every particles that passes a particular ponts moves along exactly the same smooth path followed by previous particle passing that point, this is called streamline.
41. Different streamlines cannot cross each other under this steady flow condition, and the streamlines cannot cross each other under this steady dlow conditionds.
42. The irregular flow is called turbulent flow.

Ideal fluid characteristics

43. Fluid is non-viscous (no friction)
44. Incompressible (constant density)
45. Laminar flow

Proof

- $V = s \times A$
- $V/\Delta t = sA/\Delta t$
- $V/\Delta t = Av$

Equation of continuity

46. Mass flow into the volume must be equal to mass flow rate out.

Different forms of equations

47. The area of fluid is inversely proportional to the speed of fluid.
48. The product of area and velocity remains constant,

Proof

- $\rho = \Delta m/\Delta V$
- $\Delta m = \rho\Delta V$
- $\frac{\Delta m}{\Delta t} = \rho\frac{\Delta V}{\Delta t}$

49. If area is increase the speed will be decreases.
50. If area is increase the speed will be decreases.
51. $A \propto 1/v$
52. $A_1 v_1 = A_2 v_2$
53. $\frac{A1}{A2} = \frac{v2}{v1}$

Proof

- $\Delta m = \Delta m$
- $\rho/\Delta V = \rho/\Delta V$
- $\rho/sA = \rho/sA$
- $\rho/v\Delta tA = \rho/v\Delta tA$
- $A_1 v_1 = A_2 v_2 = K$

CASE-1

54. If radius is given instead of area

→ $\pi r_1^2 v_1 = \pi r_2^2 v_2$
→ $r_1^2 v_1 = r_2^2 v_2$

CASE-2

55. If diameter is given instead of area

$\pi r_1^2 v_1 = \pi r_2^2 v_2$
→ $r_1^2 v_1 = r_2^2 v_2$
→ $(d_1/2)^2 v_1 = (d_2/2)^2 v_2$
→ $\frac{d_1^2}{4} v_1 = \frac{d_2^2}{4} v_2$
→ $d_1^2 v_1 = d_2^2 v_2$

CASE-3

56. $Av = \frac{\Delta V}{\Delta t}$ :: Rate of flow

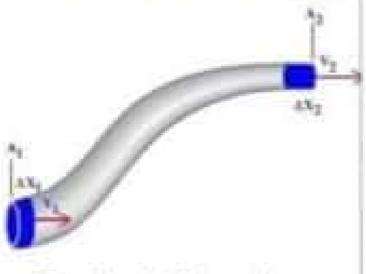
CASE-4

57. $\frac{\Delta m}{\Delta t} = \rho\frac{\Delta V}{\Delta t}$

Flow Rate

$m_1 = \rho V_1$
$m_1 = \rho A_1 \Delta x_1$
$m_1 = \rho A_1 v_1 t$

$m_1 = m_2$
$\rho A_1 v_1 t = \rho A_2 v_2 t$

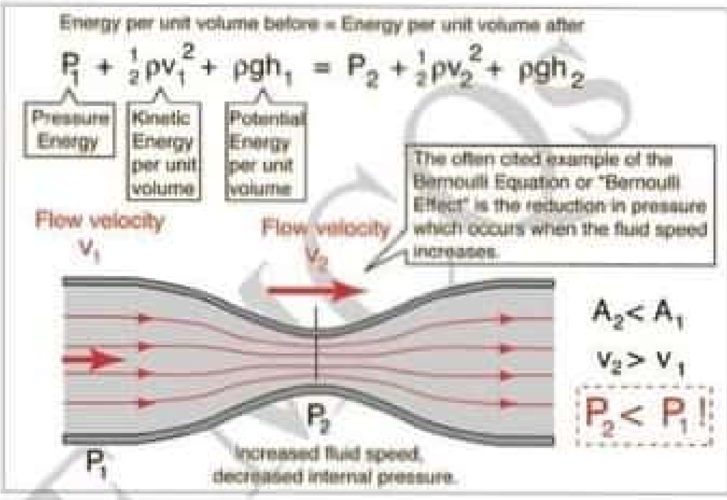


Continuity Equation
$A_1 v_1 = A_2 v_2$
Av is the volume flow rate

58. Deeep water flows slowly in comparision to shallow water but the volume flow rates in both cases are same.

Bernoulli's Equation

59. In 1738, a swiss physicst Daniel Bernoulli derived an expression that relates the pressure of a fluid to its speed and elevation.
60. Speed is inverly proportional to the pressure.
61. Bernoulli's equation is applicable for incompressible, non-viscous and flows in non-turbulent, steady state manner.
62. The realationship between the pressure, flow speed and height for flow of an ideal fluid is called Bernoulli's fluid.
63. $P + 1/2\ \rho v^2 + \rho gh = constant$
    so important
64. If height is zero then
    $P + 1/2\ \rho v^2 = constant$
    so important



Usese

65. Plumbing system
66. Hydroelectric generation stations
67. Flight of an aeroplane

Application of Bernoulli's Equation

1. **Jets and nozzles**

68. The smaller is the cross sectional area, the greater is the increase in speed and so greater in the pressure drop.

2. **Torricelli's theorem (speed of flux)**

69. $v = \sqrt{2gh}$ ***so important***
70. $V = s \times t \rightarrow V = v\,t\,t \rightarrow V = vt^2$
71. The volume of tank is directly proportional to the speed of outlet and v is directly preoportional to the underroot of h.

MCQs FOR ETEA

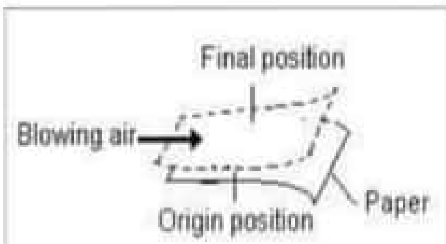
72. The ratio of velocity of height 20 meter tank to that of 10 m tank

a)1:1 b)1:4
c)4:1 d)2:1
ans: b

Solution: $\rightarrow \frac{v_{20}}{v_{10}} = \frac{\sqrt{2gh}}{\sqrt{2gh}}$

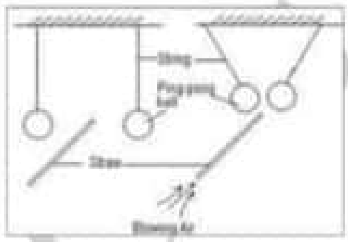
$\rightarrow \frac{v_{20}}{v_{10}} = \frac{20}{10}$

$\rightarrow \frac{v_{20}}{v_{10}} = 2:1$



73. If air si blown over paper page at rest what will happen to page.
   a) move upward
   b) remains the same
   c) move to right
   d) move to left
   ans: a
   Solution:→ if air is blown, the air speed increase over the page ad pressure decrease so page will move upward.

74. When the air is blown harder through the straw .The two ping-pong balls will move closely to each other.The air moved at a very high velocity between the balls. According to Bernoulli's Principle , the pressure of the moving air decreases as the speed of the air increases . The higher atmospheric pressure caused the ping-pong balls closer to each other.



75. When two speed ships move faster and closely to each other, an accident may be occurred. It is because the water moved at a very high velocity between the boats. According to Bernoulli's Principle , the pressure of the moving air decreases as the speed of the air increases . The higher water pressure on either sides of the boats caused its closer to each other .

76. A person who stands near a railway feels like falling into it when suddenly a train moves with a high speed passes him. It is because the velocity of the air in front of him increases. According to Bernoulli's Principle , the pressure of the moving air decreases as the speed of the air increases. The higher atmospheric pressure behind pushes him forward.

77. **If You climbed a mountain carrying a mercury barometer, would the level of the mercury column in the glass tube of the barometer increase or decrease as you climb the mountain? Explain.**
   Ans. The level of mercury in the column depends upon the atmospheric pressure i.e. greater the atmospheric pressure, high will be the level of mercury in the column and vice versa. Now we know that the atmospheric pressure decreases at the top of mountains, so the level of mercury in glass tube of the barometer will fall down i.e. decreases.

78. **Walnuts can be broken in the hand by squeezing together but not one why?**
   Ans. Instead of one walnut, if we squeeze two walnuts together in hands, the contact area decreases significantly due to which the stress or pressure increases sufficiently. As a result the walnuts can be broken easily.

79. **Why is the cutting edge of the knife made very thin?**
   Ans. We know that the pressure is given by
   $P = F/A$
   Equation 1 shows that pressure is inversely proportional to the area. That is greater the area, smaller will be the pressure and vice versa. Now the cutting edge of the knife is made very thin for getting smaller area and maximum pressure. By doing so we can cut various objects with knife very easily.

80. **Why water tanks are constructed at the highest level in our houses?**

Ans. Water has the ability to maintain its level the pressure of water pipe system increases with height. Thus for the easy flow of water in a pipe system, the water tanks are constructed at the highest level in our houses.

81. **Why a small needle sinks in water but huge ships travel easily in water without sinking?**
Ans. The specific gravity of a needle is greater than that of water. The weight of needle is greater than the weight of water displaced by it so the needle sinks in water. Incase of huge ships the weight of water displaced is greater than weight of the ship so according to Archimedes principle, the ship does not sink and float on water.

82. **Explain how and why camels have adapted to allow them to walk more easily in desert conditions?**

Ans. Since camels have feet with comparatively large surface area, therefore they exert little pressure. As a result of less pressure they can walk in desert easily.

59. You would have probably experienced your ears popping while driving in the mountains. Why ear's pop?

Ans: In plane area, the pressure of air inside the ears and outside remains the same, so we feel comfortable.

Now if we drive a car in mountains, the atmospheric pressure decreases. At this stage the pressure of air inside the air is higher than outside pressure. So the ear drum is stressed out wards due to higher inner pressure of the ear. This high pressure air pushes out through a tabe into our throat with bubble popping sound. So the reason of our ears pop while driving in mountains is due to the escape of high pressure air from the inner ear region.

60. **If you filled an airtight ballon at the top of a mountain, would the ballon expand or contract as you descend the mountain?**

Ans: At the top of mountain, the air pressure is lower as compared to plane area. So law pressure air will be filled in a balloon at the top of mountains.

Now when moves from mountain towards plane areas, the air pressure increases. Thus the outside air pressure becomes higher than air pressure inside the balloon. The high atmospheric pressure stress the wall of the balloon inwards, due to which the balloon contract and its volume decreases.

61. **A rowboat is floating in a swimming pool when the anchor is drooped over the side. When the anchor is drooped, will the water level in the swimming pool increase, decrease, or remain the same? Explain.**

Ans: When the anchor is in the boat, the water is displaced more due to combine weight and specific shape of the boat. When the anchor is dropped into the water, it sinks and displace water whose volume is equal to the volume of the anchor. The water displaced by volume. So when the anchor is droped into the water, the level of water in the pool decreases.

62. Which material is name elastic? Steel or rubber and why?

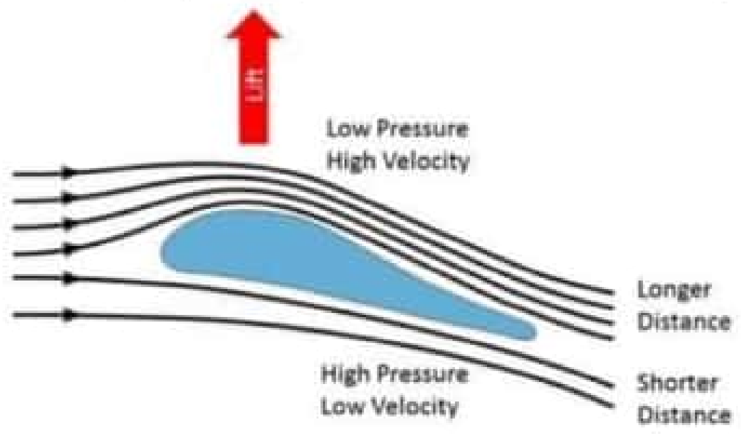
Ans: Steel is more elastic the rubber, because fir a given stress, the strain produced in steel is much smaller than that produced in rubber.

The steel comes back to its original shape faster than rubber after the removal of deforming force.

63. **Aerofoil: Lift of an aeroplane wings**

The lift on an aero plane is explained on the basis of relationship between pressure and velocity. The wing of the aero plane is designed to deflect the air so that the streamlines are closer together above the wing than below it. Thus, air is travelling faster on the upper side of the wing than on the lower. As the result, the pressure will be lower at the top of the wing, and the wing will be forced upward.

Aerodynamic Lift – Explained by Bernoulli's Conservation of Energy Law



Also known as the "Longer Path" or "Equal Transit" Theory

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3. **Flow merters the venture meter**

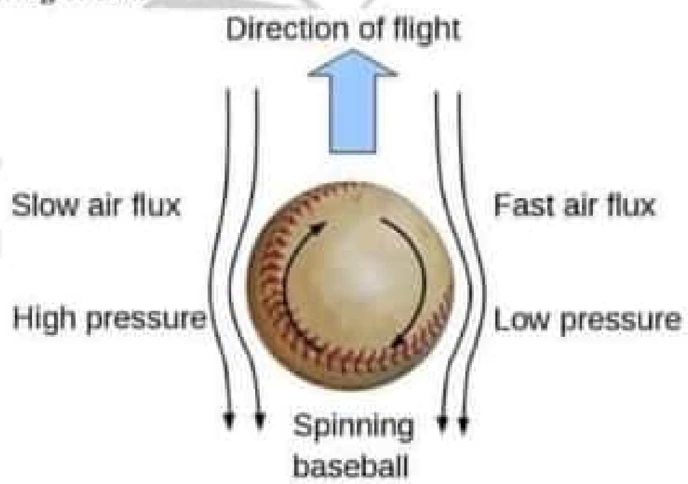
83. $v_1 = \sqrt{\frac{2gh}{(\frac{A_1^2}{A_2^2} - 1)}}$ ***so important***

4.

1. The pressure act from downward to upward direction and airplane goes upward.

5. **Bloood flow meter**

2. **Swing of Ball**



pascal, law or pascals principle?

Pascal Law: This law states that all the liquids exerts same pressure in all directions.

Explanation: Consider a liquid is enclosed in a container having four openings A,B,C, and D

As shown in the figure. These openings are fitted with movable pistons. Now if an external pressure is applied on piston at opening A in downward direction due to which pressure is exerted on the liquid which transmitted in all directions. As a result the pistons at opening B, C, and D will move outwards. This shows that liquids exerts same pressure in all directions.

application of Pascal Law?

Hydraulic Lift Or Hydraulic Jack: It is a device which works on pascals, principle and is used for lifting heavy loads very easily.

Construction: It consist of two cylinders "A" and "B" of different sizes as shown in the figure. Both cylinders are fitted with each other by means of a tube and they are fitted with some incompressible fluid. The other ends of the cylinder are fitted with movable pistons.

Working: When a external pressure is applied on the piston of cylinder "A" in downward direction, then its pressure is transmitted through the fluid towards the piston of cylinder B. As a result the piston of cylinder B moves upwards. In this way the load on the platform of piston can be fitted easily.

Let F_1 be force applied on the piston of cylinder A and A_1 be the area of cross section of the piston, then the pressure exerted on the piston in downwards directions is given by

$P_1 = F_1 / A_1$ ________(1)

Similarly, the pressure exerted on pistons of cylinder "B" in upwards directions is given by

$P_2 = F_2 / A_2$ ________(2)

Now according to pascal law, the pressure at one side will be equal to the pressure at the other side. So we have.

$P_1 = P_2 \rightarrow F_1 / A_1 = F_2 / A_2$

$F_2 = A_2 / A_1$ ________(3)

From eq 3 we can calculate the force exerted on the piston of cylinder "B" in upward direction.

ETEA PAST MCQs

Viscous Drag, Strokes Law & Terminal Velocity

1. A metal sphere of radius r is dropped into a tank of water. As it sink at speed v, it experience a drag force F given by F=krv, where k is a constant: What are the SI base units of k? 2017-Med
A. kgm^2s^{-1} B. kgm^2s^{-2}
C. $kgm^{-1}s^{-1}$ D. $kgms^{-2}$
C — $F=krv \rightarrow k=F/rv = ma/rv = kgm^{-1}s^{-1}$

2. Eight drops of water each radius 2mm are falling through air at a terminal velocity of 8cm/s. If they coalesce to form a single drop the terminal velocity of the combined drop will be: 2017-Med
A. 8 cm/s B. 16 cm/s
C. 24 cm/s D. 32 cm/s
D — $V_t' = n^{2/3} V_t$, Here n=no. of drops. Thus $V_t' = 8^{2/3} V_t = 4 \times 8 = 32$ cm/s

3. Rain drops falling from sky reach the ground with: 2009-54 Med
(a) Constant acceleration
(b) Constant terminal velocity
(c) Acceleration greater than g
(d) Variable acceleration
B — Constant terminal velocity because drag force become equal to weight of the poilet after some time

4. When the drag force on the object becomes equal to its real weight then the; 2011-59 Eng:
(a) Object will become stationary
(b) Object will fall freely
(c) Object will fall with terminal velocity
(d) Object will fall with critical velocity
C — When the drag force on the object becomes equal to its real weight then the Object will fall with terminal velocity

5. The acceleration of falling body in fluid depends upon: Med-2009
(a) Velocity (b) Viscosity of fluid
(c) Density of the body (d) All of the above
D — Acceleration dpeeds on v and v depends upon density,radius and viscosisty.

Eqation of Continuity & Its Applications

6. The speed of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ of the liquid. The speed is given by the equation $v = k\left(\frac{\Delta P}{\rho}\right)^{\Delta n}$,where k is a constant that has no units. What is the value of n? 2018-Med
a) 1/2 b) 1
c) 3/2 d) 2
A

7. A fluid is undergoing incompressible flow which represents that: 2016- Eng
(a) Pressure at a given point cannot change with time
(b) Velocity at given point cannot change with time
(c) The density cannot change with time or location
C — Incompressible means that bliquid will not compress and density will remains constant

(d) The velocity must be the same everywhere

8.	Water flows through a constriction in horizontal pipe as it enters constriction, water's: med-2015 A) Speed increases and pressure remains constant B) Speed increases and pressure increase C) Speed increases and pressure decreases D) Speed decreases and pressure Increases	C	It is simply Bernoulli,s Application. Sped is iversly proportional to the pressure
9.	A larger water tank open at the top has small hole in the bottom when the water level is 30m above the bottom of the tank the speed of the water leaking from the hole is: med-2015 A) 2.5m/s B) 24 m/s C) 4 44 m/s D) Cannot be calculated unless the area of the hole is given	B	It can be solved by Torricelli Theorem; As speed is given by ;$V = \sqrt{2gh}$ = $\sqrt{2 \times 10 \times 30}$=24.49
10.	The equation of continuity for fluid flow can be derived from the conservation of: eng-2015 A) Volume B) Mass C) Energy D) Pressure	B	From the ceonservation of mass, equation of continuity can be derived m = m $\rightarrow \rho V = \rho V \rightarrow \rho Ax = \rho Ax \rightarrow \rho Avt = \rho Avt \rightarrow Av = Av$
11.	Bernoulli's equation can be derived from the conservation of: med -2015 A) Energy B) Mass C) Volume D) Pressure	A	Work = K.E + P/E, it is the first ste in derivation of bernouli equation, so Bernoulli's equation can be derived from the conservation of: energy.
12. Bernoulli,s Equation & Its Applications			
13.	One end of cylindirical pipe has a radius of 1.5cm, water stream (density = 1.0×10^3 kg/m^3) steadily out at 7.0m/s, the volume rate is: Med-2015 A) 4.9×10^{-3} m^3/s B) 4.9 m^3/s C) 7.0 m^3/s D) 49 m^3/s	A	Volume rate V/t =A v=(πr^2) velocity = 3.14 x $(0.015)^2$x7= 4.9×10^{-3} m^3/s
14.	An Incompressible liquid flow along the pipe with area of cross section Aland A_1 with A_2 with velocities V_1 andV_2 respectively. The ratio of the speeds V_1 / V_2 is: med-2015 A) A_1 / A_2 B) A_2 / A_1 C) $\sqrt{\frac{A_1}{A_2}}$ D) $\sqrt{\frac{A_2}{A_1}}$	B	It is aquation of continuity; As; $A_1 V_1 = A_2 V_2$ and $V_1 / V_2 = A_2 / A_1$
15.	A two meter high tank is full of water. A hole is made in the middle of the tank. The speed of efflux is; 2011- Med (a) 4.9 ms^1 (b) 9.8 ms^{-1} (c) 4.42ms^{-1} (d) 3.75 ms	C	At middle of the tank, height of water is 1m so Efflux velocity = V = $\sqrt{2gh}$ = $\sqrt{2 \times 9.8 \times 1}$ = $\sqrt{19.36}$ =

4.4 m/s

16.	Water flows from a 6.0cm diameter pipe into 8.0cm diameter pipe. The speed in the 6.0cm pipe is 5.0m/s. the speed in the 8cm pipe is: 2016- Med **(a) 2.8m/s** (b) 3.7m/s (c) 6.6m/s (d) 8.8m/s	A	D_1=6 cm and D_2=8 cm or R1= 3 cm and R2= 4 cm and v1= 5m/s so by A1V1=A2V2 or $r_1^2v_1 = r_2^2v_2 \rightarrow 3^2 \times 5 = 4^2 \times v_2 \rightarrow v_2$ = 45/16 =**2.8m/s**
17.	One end of a cylindrical pipe has a radius of 1.5cm. Water (density = 1.0×10^3 kg/m^{3}j which mass is leaving the pipe is: 2016-172 Eng (a) 2.5kg/s **(b) 4.9kg/s** (c) 48 kg/s (d) 7.0×10^3 kg/s	B	