PHYSICS

BOOKS - HC VERMA PHYSICS (ENGLISH)

FLUID MECHANICS

Worked Out Examples

1. A beaker of circular cross-section of radius 4 cm is filled with mercury up to a height of 10 cm. Find the force exerted by the mercury on the bottom of the beaker. The atmospheric pressure $= 10^5 Nm^{-2}$. Density of mercury $= 13600 kgm^{-3}. Take g 10 ms^{-2}$

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2. The density of asir ner earth's surface is $1.3kgm^{-3}$ and the atmospheric pressure is $1.0 \times 10^5 Nm^{-2}$. If the atmosphere had uniform density, same as that observed at the surface of the earth what would be the height of the atmosphere to exert the same pressure?

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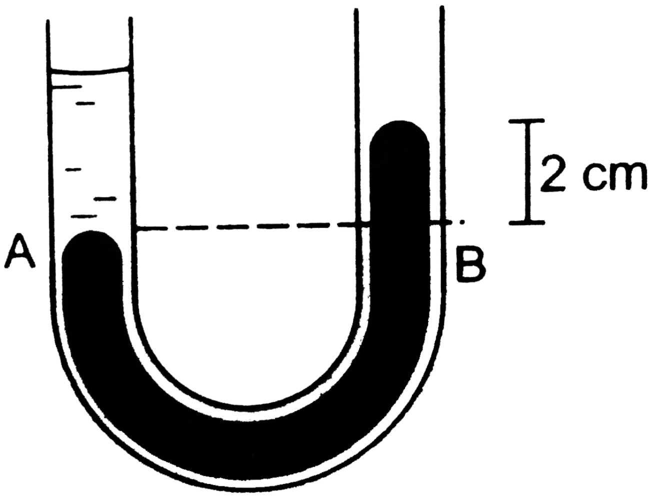
3. The liquids shown in figure in the two arms are mercury (specific gravity =13.6) and water. If the difference of heights of the mercury columns is 2 cm, find the height of the water column.



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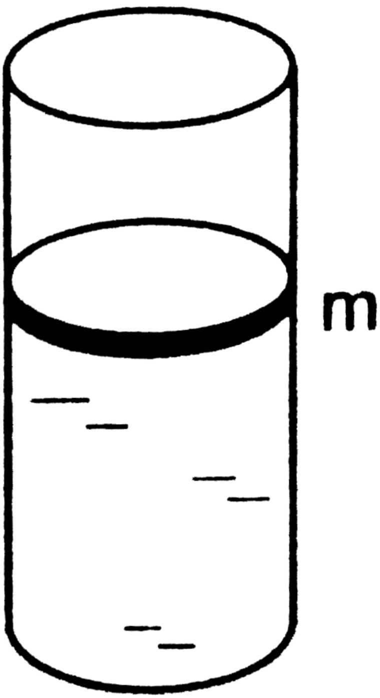
4. A cylidrical vesel containing a liquid is closed by a smooth piston of mass m as shown in the figure. The area of cross section of the piston is A. If the atmospheric pressure is P_0, find the pressure of the liquid just below the piston.



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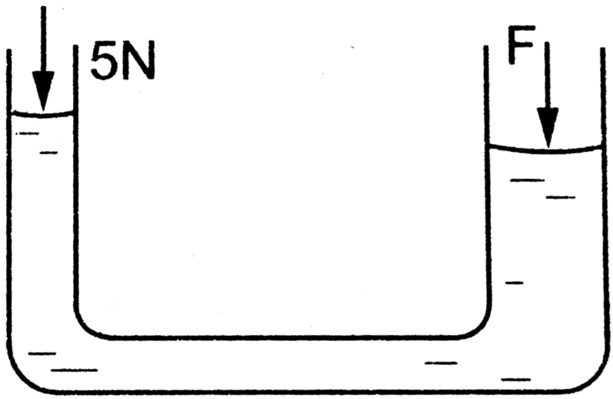
5. The area of cross section of the two arms of a hydraulilc press are 1 cm^2 and 10 cm^2 respectively figure. A force of 5N is applied on the water in the thinner arm. What force should be applied on the water in the thicker arm so that the water may remain in equilibrium?



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6. A copper piece of mass 10 g is suspended by a vertical spring. The spring elongates 1 cm over its natural length to keep the piece in equilibrium. A beaker containing water is now placed below the piece so as to immerse the piece completely in water. Find the elongation of the spring. Density of copper =9000 kgm^-3. $Take g = 10 m s^{-2}$

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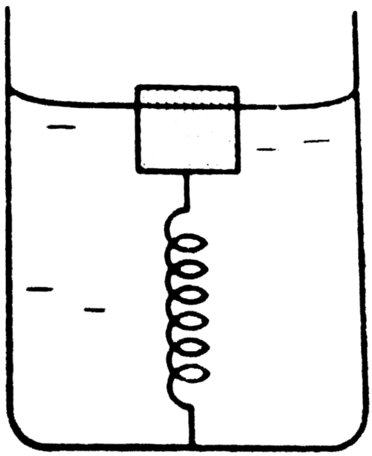
7. A cubical block of wood of edge 3 cm floats in water. The lower surface of the cube just touches the free end of a vertical spring fixed at the bottom of the pot. Find the maximum weight that can be put on the block without wetting it. Density of wood =$800 kg m^{-3}$ and spring constant of the spring $= 50 N m^{-1} Take g = 10 m s^{-2}$.



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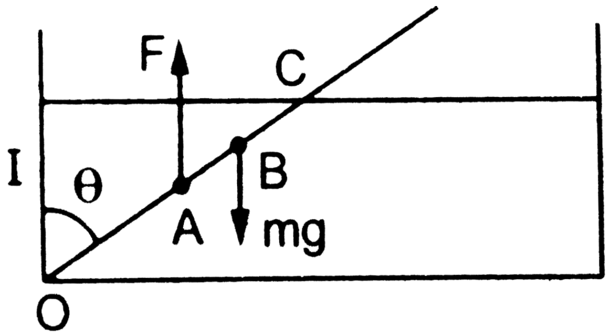
8. The wooden plank of length 1 m and uniform cross section is hinged at one end to the bottom of a tank as shown in figure. The tank is filled with water up to a height of 0.5 m. The specific gravity of the plank is 0.5. Find the angle θ that the plank makes with the vertical in the equilibrium position. (Exclude the case $\theta = 0$)



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9. A cylindrical block of wood of mass M is floating n water with its axis vertica. It is depressed a little and then released. Show that the motion of the block is simple harmonic and find its frequency.

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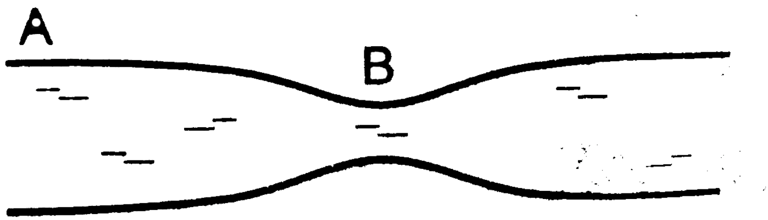
10. Water flows in a horizontal tube as shown in figure. The pressure of water changes by 600 N m^-2 between A and B where the areas of cross section are `30cm^2 and 15cm^2 respectively. Find the rate of flow of water through the tube.



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11. A area of cross section of a large tank is $0.5m^2$. It has an opening near the bottom having area of cross section $1cm^2$. A load of 20 kg is applied on the water at the top. Find the velocity of the water coming out of the opening at the time when the height of water level is 50 cm above the bottom. Take $g = 10ms^{-2}$

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Objective 1

1. A liquid can easily change its shape but a solid can not because

A. the density of a liquid is smaller than that of a solid

B. the forces between the molecules is stronger in solid than in liquids

C. the atoms combine to form bigger molecules in a solid

D. the average sepration between the molecules is larger in solids.

Answer: B

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2. Consider the equations

$$P = \lim_{\triangle s \to 0} \frac{F}{\triangle S} \text{ and } P_1 - P_2 = \rho g z$$

In an elevator acceleratin upward

A. both the equations are valid

B. the first is valid but not the second

C. the second is valid but not the first

D. both are invalid

Answer: B

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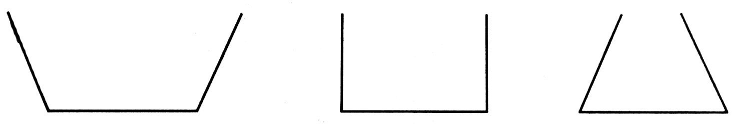
3. The three vessels shown in figure have same base area. Equal volumes of a liquid are poured in three vessels. The force on the base will be



A. maximum in vessel A

B. maximum in vessel B

C. maximum in vessel C

D. equal in al the vessels

Answer: C

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4. Equal mass of three liquids are kept in three identical cylindrical vessels A, B and C. the densities are $\rho_A, \rho_B, \rho_C with \rho_A < \rho_B < \rho_C$. The force on the base will be

A. maximum in vessel A

B. maximum in vessel B

C. maximum in vessel C

D. equal in al the vessels

Answer: D

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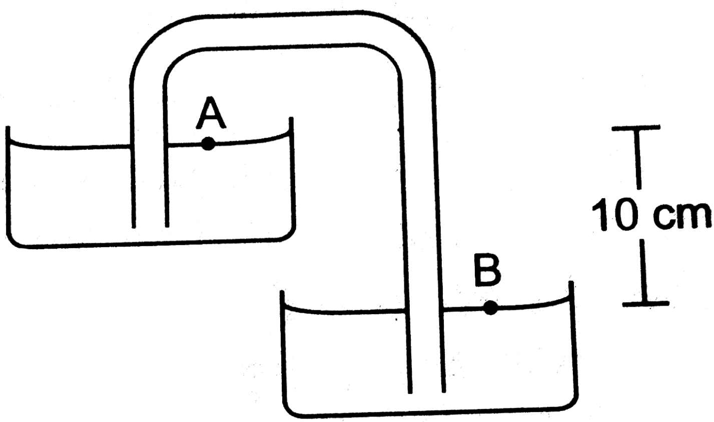
5. Figure shows a siphon. The liquid shown in water. The pressure difference $P_B - P_A$ between the points A and B is



A. $400 Nm^{-2}$

B. $3000 Nm^{-2}$

C. $1000 Nm^{-2}$

D. zero

Answer: D

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6. A beaker containing a liquid is kept inside a big closed jar. If the air inside the jar is continuously pumped out, the pressure in the liquid near the bottom of the liquid will

A. increase

B. decrease

C. reamin constant

D. first decrease and then increse

Answer: B

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7. The pressure in a liquid at two points in the same horizontal plane are equal. Consider an elevator accelerating upward and a car accelerating on a horizontal road. The above statement is correct in

A. the car only

B. the elevator only

C. both of them

D. neither of them

Answer: B

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8. Suppose the pressure at the surface of mercury in as barometer tube is P_1 and the pressure at the surface of mercury in the cup is P_2.

A. $P_1 = 0, P_2 =$ atgmospheric pressure

B. P_1= atmosphereic pressure $P_2 = 0$

C. $P_1 = P_2 =$ atmospheric pressure

D. $P_1 = P_2 = 0$

Answer: A

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9. A barometer kept in an elevator reads 76 cm when it is at rest. If the elevator goes up with increasing speed, the reading will be

A. zero

B. 76cm

C. < 76cm

D. > 76cm

Answer: C

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10. A barometer kept in an elevator accelerating upward reads 76 cm. The air pressure in the elevator is

A. 76cm

B. lt76cm

C. gt76cm

D. zero

Answer: C

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11. To construct a barometer, a tube of length 1m is filled completely with mercury and is inverted in a mercury cup. The barometer reading on a particular day is 76 cm. Suppose a 1m tube is filled with mercury up to 76 cm and then closed by a cork. It is inverted in a mercury cup and the cork is removed. It is inverted in a mercury column in the tube over the surface in the cup will be

A. zero

B. 76 cm

C. > 76 cm

D. < 76 cm

Answer: D

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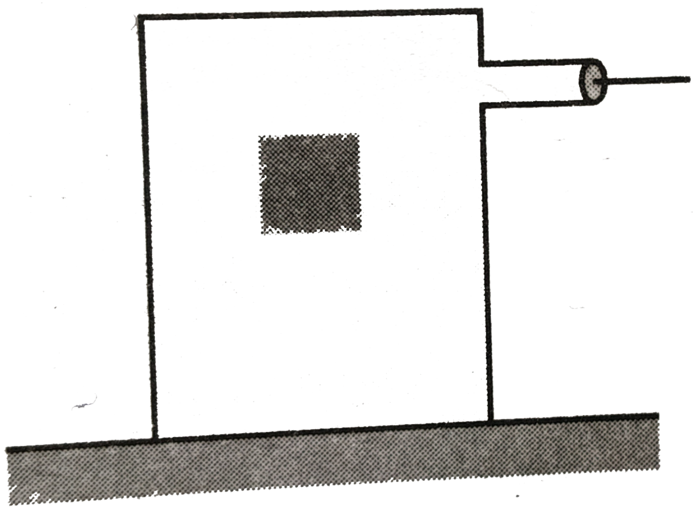
12. A block of wood is floating in water in a closed vessel as shown in the figure. The vessel is connected to an air pump. When more air is pushed into the vessel, the block of wood floats with (neglect compressibility of water)



A. larger path in the water

B. lesser part in the water

C. same part in the water

D. it will sink

Answer: C

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13. A meta cube is plced in an empty vessel. When water is filed in the vessel so that the cubeis completely immersed in the water, the fore on the bottom of the vessel in contact with the cube

A. will increase

B. will decrease

C. will remain the same

D. will become zero

Answer: C

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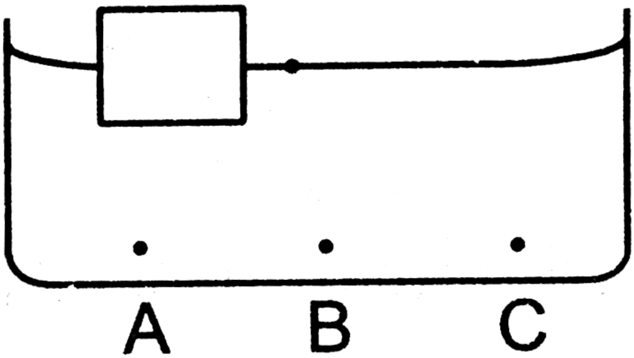
14. A wooden object floats in water kept in as beaker. The object is near a side of the beaker figure. Let P_1, P_2, P_3 be the pressure at the three points A,B and C of the bottom as shown in the figure.



A. $P_1 = P_2 = P_3$

B. $P_1 < P_2 < P_3$

C. $P_1 > P_2 > P_3$

D. $P_2 = P_3 = P_1$

Answer: A

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15. A closed cubical box is completely filled with water and is accelerated horizontally towards right with an acceleration a. The resultant normal force by the water on the top of the box.

A. passes through the centre of top

B. passes through a point to the righ of the centre

C. passes through a point to the left of the centre

D. becomes zero

Answer: C

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16. Consider the situations of the previous proble. Let the water push the left wass by a force F_1 and the right wall byi as force F_2.

A. $F_1 = F_2$

B. $F_1 > F_2$

C. $F_1 < F_2$

D. the information in insufficient to know the relation between F_1 and F_2

Answer: B

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17. Water enters through end A with speed v_1 and leaves through end B with speed v_2 of a cylindrical tube AB. The tube is always completely fielled with water . Im case I, the tube is horizontal and in case II, it is vertical with end A upwards and in case III, it is vertical with end B upwards. We have $v_1 = v_2$ for

A. caseI

B. caseII

C. caseIII

D. each case

Answer: D

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18. Bernoulli's theorem is based on conservation of

A. momentum

B. mass

C. energy

D. angular momentum

Answer: C

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19. Water is flowing through a long horizontal tube. Let P_A and P_B be the pressures at two points A and B of the tube

A. P_A must be equal to P_B

B. P_A must be greater than P_B

C. P_A must be smaller than P_B

D. $P_A = P_B$ only ilf the cross sectional area at A and B are equal

Answer: D

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20. Water and mercury are filled in two cylindrical vessels up to same height. Both vessels have a hole in the wall near the bottom. The velocity of water and mercury coming out of the holes are v_1 and v_2 respectively. Then

A. $v_1 = v_2$

B. $v_1 = 13.6 v_2$

C. $v_1 = \frac{v_2}{13.6}$

D. $v_1 = \sqrt{13.6} v_2$

Answer: A

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21. A large cylindrical tank has a hole of area A at its bottom and water is poured into the tank through a tube of cross-sectional area A ejecting water at the speed v. Which of the following is true?

A. the water level in the tank wil keep on rising.

B. no water an be stored in the tank

C. the water level will rise to a height $\frac{v^2}{2}g$ and then stop

D. the water level will oscillate.

Answer: C

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Objective 2

1. A solid floats in a liquid in a partially dipped position.

A. the solid exerts a force equal to its weight on the liquid

B. the liquid exerts a force of buoyancy on the solid which is equal to the weight of the solid

C. the weight of the displaced liquid equals the weights of the solid

D. the weight of the dipped part of the solid is equal to the weight of the displaced liquid

Answer: A::B::C

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2. An empty balloon weighs W_1. If air equal in weight to W is pumped into the balloon, the weight of the balloon becomes W_2. Suppose that the density of air inside and outside the balloon is the same. Then

A. $W_2 = W_1$

B. $W_2 = W_1 + W$

C. $W_2 < W_1 + W$

D. $W_2 > W_1$

Answer: A::C

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3. A solid is completely immersed in a liquid. The force exerted by the liquid on the solid will

A. increase if it is pushed deeper inside the liquid

B. change if its orientation is changed

C. decrese if it is taken partially out of the liquid

D. be in the vertially upward direction

Answer: C::D

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4. A closed vessel is half filled with water. There is a hole near the top of vessel and air is pumped out from this hole.

A. the water level will rise up in the vessel

B. the pressure at the surface of the water will decrease

C. the force by the water on the bottom of the vessel will decrease

D. the density of the liquid will decrease

Answer: B::C

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5. IN a streamine flow

A. the speed of a particle always remains same

B. the velocity of a particle always remains same

C. the kinetic energies of all the particles arriving at a given point are the same

D. the momenta of all the particles arriving at a given point are the same

Answer: C::D

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6. Water floows through two identical tubes A and B. A volume V_0 of water passes through the tube A and $2V_0$ through B in a given time. Which of the following may be correct?

A. Flow in both the tubes are steady

B. Flow in both the tubes are turbulent

C. Flow is steady in A but turbulent in B

D. Flow is steady in B but turbulent in A.

Answer: A::B::C

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7. Water is flowing through a long horizontal tube. Let P_A and P_B be the pressures at two points A and B of the tube

A. The pressures at A and B are equal for any shape of the tube

B. the pressure are never equal

C. the pressure are equal even if the tube has a uniform cross section

D. the pressures may be equal even if the tube has a nonuniform cross section.

Answer: C::D

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8. There is a small hole near the botton of an open tank filled with liquid. The speed of the water ejected does not depend on

A. area of the hole

B. density of the liquid

C. height of the liquid from the hole

D. acceleration due to gravity

Answer: A::B

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Exercises

1. The surface of water in a water tank on the top of a house is 4 m above the tap level. Find the pressure of water at the tap, when the tap is closed. Is it necessary to specify that the tap is closed? Take $g = 10ms^{-2}$

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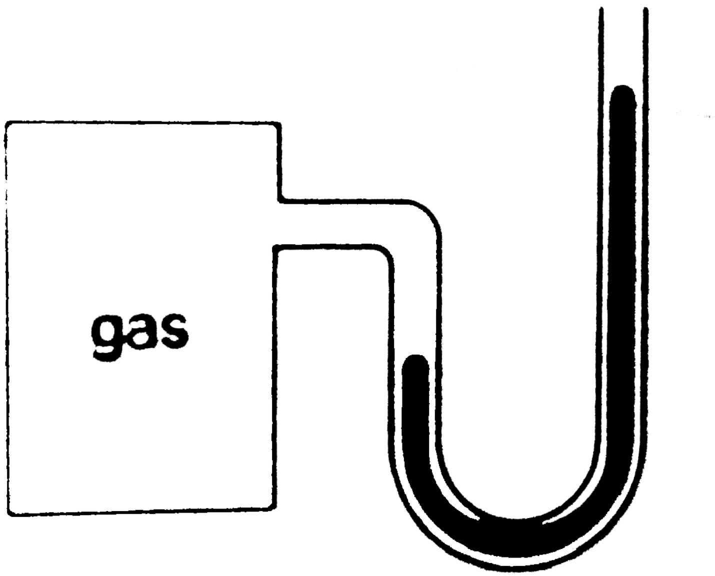
2. The heights of mercury surfaces in the two arms of the manometer shown in figure are 2 cm and 8cm. Atmospheric pressure $= 1.01 \times 10^5 Nm^{-2}$. Find (a). the pressure of the gas in the cylinder and (b). the pressure of mercury at the bottom of the U tube.



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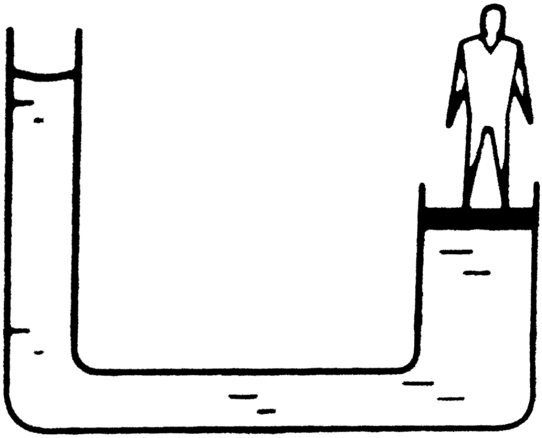
3. The area of cross section of the wider tube shown in figure is $900cm^2$. If the boy standing on the piston weights 45 kg, find the difference in the levels of water in the two tubes.



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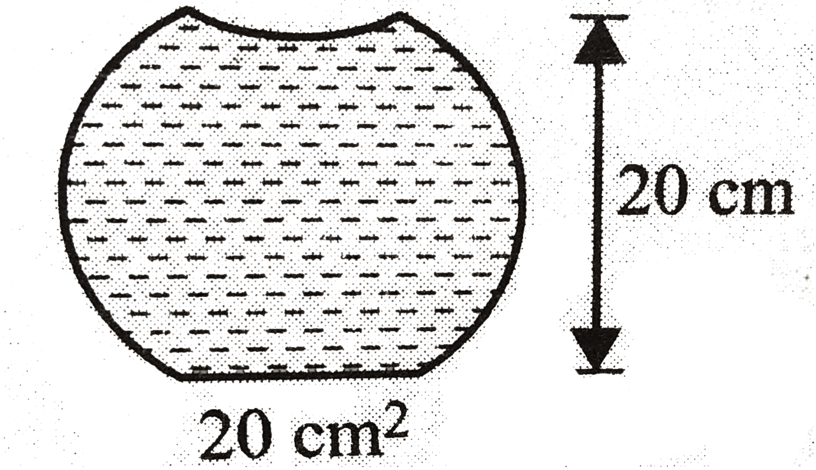
4. A glass full of water has a bottom of area $20cm^2$, top of area $20cm$, height $20cm$ and volume half a litre.



a. Find the force exerted by the water on the bottom.

b. Considering the equilibrium of the v, after. find the resultant force exerted by the side, of the glass on the water. Atmospheric pressure $= 1.0 \times 10^5 N/m^2$. Density of water $= 1000 kg/m^{-3}$ and $g = 10 m/s^2$

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5. Suppose the glass of the previous problem is covered by a jar and air inside the jar is completely pumped out a. What will be the answer to the problem? b.Show that the answers do not change if a glass of different shape is used provided the height, the bottom area and the volume are unchanged.

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6. If water be used to construct a barometer, what would be the height of water column at a standard atmospheric presure (76cm of mercury)?

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7. Find the force exerted by the water on a $2m^2$ plane surface of a large stone placed at the bottom of a sea 500 m deep. Does the force depend on the orientation of the surface? Neglect the size of the stone in comparison to the depth of the sea.

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8. Water is filled in a rectangular tank of size $3m \times 2m \times 1m$. a) Find the total force exerted by the water on the bottom surface of the tank. b) Consider a vertical side of area $2m \times 1m$. Take a horizontal strip of wide δx metre in this side, situated at a depth of x metre from the surface of water.Find the force by the water on this strip. c) Find the torque of the force calculate in part b) about the bottom edge of this side. d) Find the total force by the water on this side. e) Find the total torque by the water on the side about the bottom edge. neglect the atmospheric pressure and take $= 10ms^{-2}$.

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9. An ornament weighting 36g in air, weighs only 34g in water. Assuming that some copper is mixed with gold to prepare the ornament, find the amount of copper in it. Specific gravity of gold is 19.3 and that of copper is 8.9.

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10. Refer to the previous problem. Suppose, the goldsmith argues that he has not mixed copper or any other material with gold, rather some cavities might have been left inside the ornament. Calcuate the weighs given in that problem.

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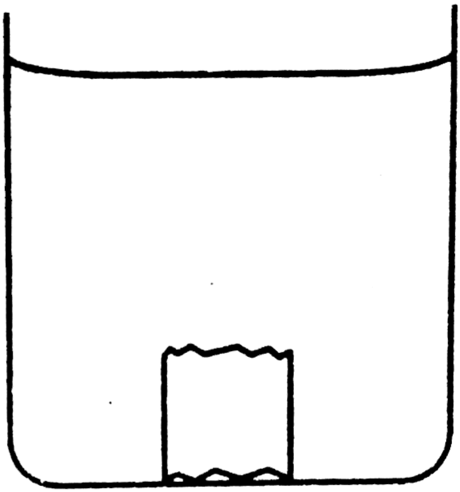
11. A metal piece of mass 160 g lies in equilibrium inside a glass of water as shown in figure. The piece touches the bottom of the glass at a small number of points. If the density of the metal is $8000 kg m^{-3}$, find the normal fore exerted by the bottom of the glass on the metal piece.



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12. A ferry boat has internal volume $1m^3$ and weight 50 kg. a. Neglecting the thickness of the wood, find the fraction of the volume of the boat immersed in water. b. If a leak develops in the bottom and water starts coming in, what fraction of the boat's volume will be filled with water before water starts coming in from the sides?

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13. A cubical block of ice floating in water has to support a metal piece weighing 0.5 kg. What can be the minimum edge of the block so that it does not sink in water? specific gravity of ice=0.9.

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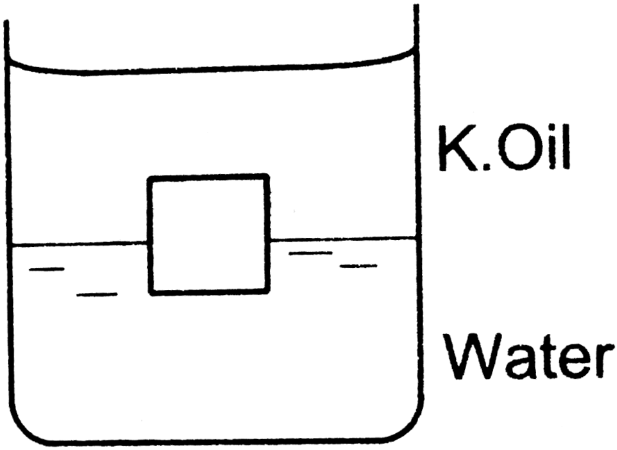
14. A cube of ice floats partly in water and partly in K.oil figure. Find the ratio of the volume of ice immersed in water to that in K.oil. Specific gravity of K.oil is 0.8 and that of ice is 0.9.



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15. A cubical box is to be constructed with iron sheets 1 mm in thickness. What can be the minimum value of the external edge so that the cube does not sink in water? Density of iron $= 8000 kgm^{-3}$ and density of water $= 1000 kgm^{-3}$.

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16. A cubical block of wood weighing 200 g has a lead piece fastened underneath. Find the mass of the lead piece which will just allow the block of float in water. Specific gravity of wood is 0.8 and that of lead is 11.3.

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17. Solve the prievious problem if the lead piece is fastened on the top surface of the block and the block is to float with its upper surface just dipping into water.

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18. A cubical metal block of edge 12 cm floats in mercry with one fifth of the height inside the mercury. Water poured till the surface of the block is just immersed in it. Find the height of the water column to be poured. Specific gravity of mercury =13.6.

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19. A hollow spherical body of inner and outer radii 6 cm, and 8 cm respectively floats half submerged in water. Find the density of the material of the sphere.

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20. A solid sphere of radius 5 cm floats in water. If a maximum load of 0.1 kg can be put on it without wetting the load, find the specific gravity of the material of the sphere.

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21. Find the ratio of the weights, as measured by a spring balance, of a 1 kg block of iron and a 1kg block of wood. Density of iron $= 7800 kgm^{-3}$ density of wood $= 800 kgm^{-3}$ and density of air $= 1.293 kgm^{-3}$.

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22. A cylindrical object of outer diameter 20 cm and mass 2 kg floats in water with its axis vertical. If it is slightly depressed and then released, find the time period of the resulting simple harmonic motion of the object.

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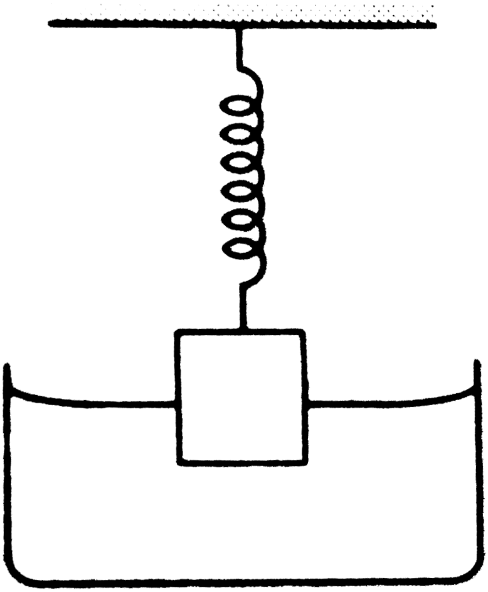
23. A cylindrical object of outer diameter 10 cm, height 20 cm and density 8000 kgm^{-3} is supported by a vertical spring and is half dipped in water as shown in figure. a. Find the elongation of the spring in equilibrium condition. b. If the object is slightly depressed and released, find the time period of resulting oscillations of the object. The spring constant

$= 500 Nm^{-1}$.



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24. A wooden block of mass 0.5 kg and density 800 kgm^{-3} is fastened to the free end of a vertical spring of spring constant 50 Nm^{-1} fixed at the bottom. If the entire system is completely immersed in water, find a. the elongation (or compression) of the spring in equilibrium and b. the time period of vertical oscillations of the block when it is slightly depressed and released.

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25. An ice cube of edge a is placed in an empty cylindrical vessel of radius 2a. Find the edge (in cm) of ice cube when it just leaves the contact with the bottom assuming that ice melts uniformly maintaining its cubical shape. Take a = 12 π cm (Ice is lighter than water)

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26. A U-tube containing a liquid is accelerated horizontally with a constant acceleration a_0. If the separation between the vertical limbs is l find the difference in the heights of the liquid in the two arms.

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27. At Deoprayag (Garhwal, UP) river Alaknanda mixes with the river Bhagirathi and becomes river Ganga. Suppose Alaknanda has a width of 12 m, Bhagirathi has a width of 8m and Ganga has a width of 16m. Assume that the depth of water is same in the three rivers. Let the average speed of water in Alaknanda be $20kmh^{-1}$ and in Bhagirathi be $16kmh^{-1}$. Find the average speed of water in the river Ganga.

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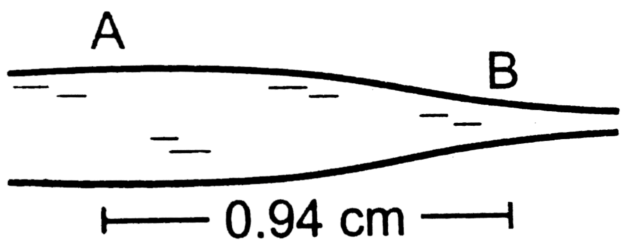
28. Water flows through a horizontal tube of variable cross-section. The area of cross section at A and B are $4mm^2$ and $2mm^2$ respectively. If 1 cc of water enters per seconds through. A find a. The speed of water at A, b. the speed of river at B and c. the pressure difference $P_A - P_B$.



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29. Suppose the tube in the previous problem is kep vertical with A upward but the other conditions remain the same. The separation between the cross sections at A and B is 15/16 cm. Repeat parts a., b, and c of the previous problem. $take g = 10 ms^{-2}$.

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30. Suppose the tube in the previous problem is kept verticla with B upward. Water enters through B at the rate of $1 cm^3 s^{-1}$. Repeat parts a, b, and c. Note that the speed decreases as the water falls down.

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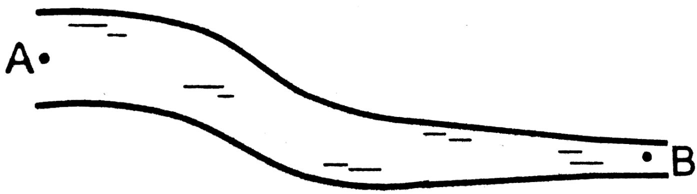
31. Water flows through a tube shown in figure. The areas of cross section at A and B are $1 cm^2$ and $0.5 cm^2$ respectively. The height difference between A and B is 5cm. If the speed of water at A is 10 cms^{-1}. Find a.

the speed at B and b. the difference in pressures at A and B.



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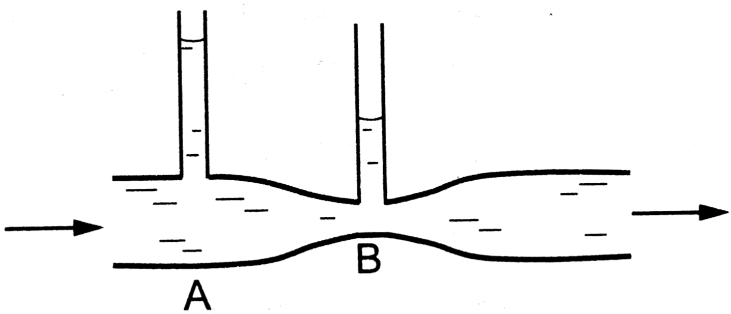
32. Water flows through a horizontal tube as shown in figure. If the difference of heights of water colun in the vertical tubes is 2 cm and the area of cross section at A and B are $4cm^2$ and $2cm^2$ respectively, find the rate of flow of water across any section.



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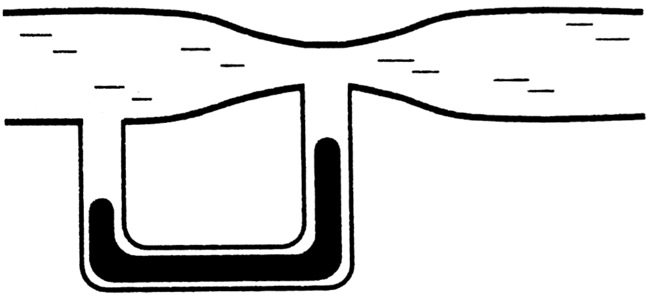
33. Water flows through the tube shown in figure. The areas of cross section of the wide and the narrow portions of the tube are $5cm^2$ and $2cm^2$ respectively. The rate of flow of water through the tube is $500cm^3s^{-1}$. Find the difference of mercury levels in the U-tube.



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34. Water leaks out from an open tank through a hole of area $2mm^2$ in the bottom. Suppose water is filled up to a height of 80 cm and the area of cross section of the tankis $0.4m^2$. The pressure at the open surface and the hole are equal to the atmospheric pressure. Neglect the small velocity of the water near the open surface in the tank. a. Find the initial speed of water coming out of the hole. b. Findteh speed of water coming out when half of water has leaked out. c. Find the volume of water leaked out during a time interval dt after the height remained is h. Thus find the decrease in height dh in term of h and dt.

d. From the result of part c. find the time required for half of the water to leak out.

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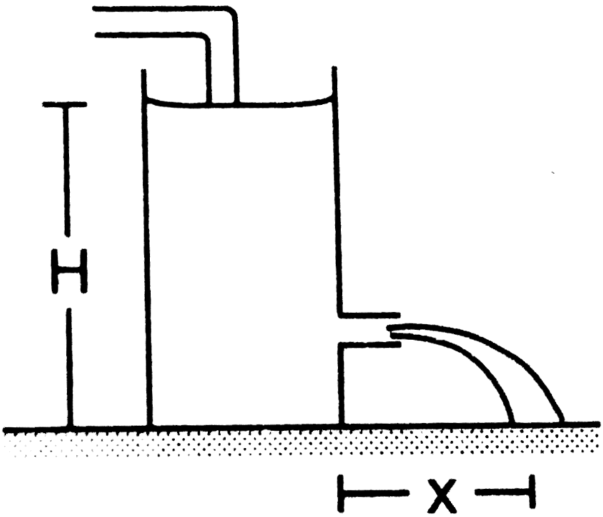
35. Water level is maintained ina cylindrical vessel up to a fixed height H. The vessel is kept on a horizontal plane. At what height above the bottom should a hole be made in the vessel so that the water stream coming out of the hole strikes the horizontal plane at the greatest distance from the vessel.



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Questions For Short Answer

1. Is it always true that the molecules of a dense liquid are heavier than the molecules of a lighter liquid?

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2. If someone presses a pointed needle against your skin, your are hurt. But if someone presses as rod against your skin with the same force you easily tolerate. Explain

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3. In the derivation of $P_1 - P_2 = \rho g z$ it was asumed that the liquid is incompressible. Why will this equation not be stictly valid for a compressible liquid?

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4. Suppose the density of air at Madras is ρ_0 and atmosphere pressure is $P_0. Ifwegoupthedensity$ and $thepressure \perp hdecreae. Supposewewish$ P_0-P=rho_0gz` will we get a pressure more than the actual or less than the actual? Neglect the variation in g. Does your answr change if you also consider the variation in g?

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5. The free surface of a liquid resting in an inertial frame is horizontal. Does the normal to the free surface pass through the centre of the earth? Think separately if the liquid is a. at te equaltor b. at a pole c. somewhere else.

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6. A barometer tube reads 76 cm of mercury. If the tube is gradually inclined keeping the open end immersed in the mercury reservoir, will the length of mercury column be 76 cm, more than 76 cm or less than 76 cm?

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7. A one meter long glas tube is open at both ends. One end of the tube is dipped into a mercury cup, the tube is kept vertical and the air is pumped out of the tube by connecting the upper end ot a suction pump. Can mercury be puled up into the pump by this process?

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8. A satellite revolves round the earth. Air pressure inside the satellite is maintained at 76 cm of mercury. What will be the height of mercury column in a barometer tube 1m long placed inn the satellite?

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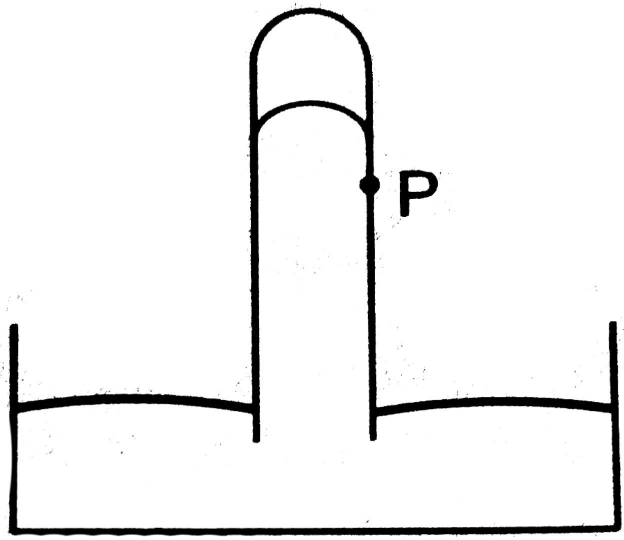
9. Consider the barometer shown in figure. If a small hole is made at a point P in the barometer tube, will the mercury come out from this hole?



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10. Is Archimedes principle valid in an elevator accelerting up? In a car accelerating on a level road?

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11. Why is it easier to swim in sea water than in fresh water?

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12. A glass of water has an ice cube floating in water. The water level just touches the rim of the glass. Will the water overflow when the ice melts?

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13. A ferry boat loaded with rocks has to pass under a bridge. The maximum height of the rock is slightly more than the height of the rocks is slightly more than the height of the bridge so tht the boat just fails to pass under the bridge. Should some of the rocks be removed or some more rocks be added?

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14. Water is slowly coming out from a vertical pipe. As the water descends after coming out its area of cross section reduces. Explain this on the basis of the equation of continuity.

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15. While watering a distant plant, a gardener partially closes the exit hole of the pipe by putting his finger on it. Explain why this results in the water stream going to a larger distance.

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16. A Gipsy car has a canvas top. When the car runs at high speed, the top bulges out. Explain.

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Others

1. Water is filled in a flask up to a height of 20 cm. The bottom of the flask is circular with radius 10 cm. If the atmospheric pressure is 1.01×10^5 Pa, find the force exerted by the water on the bottom. Take $g = 10ms^{-2}$ and density of water =1000 kgm^-3.

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2. A 700 g solid cube having an edge of length 10 cm floats in water. How much volume of the cube is outside the water? Density of water $= 1000kgm^{-3}$

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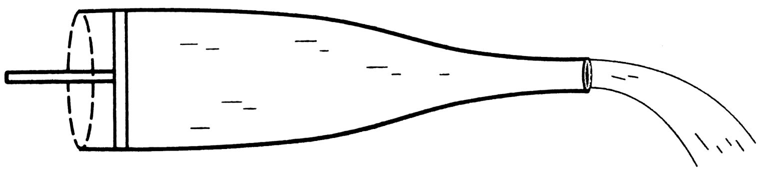
3. Figure shows a liquid being pushed out of a tube by pressing a piston. The area of cross section of the piston is 1.0 cm^2 and that of the tube at the outlet is $20mm^2$. If the piston is pushed at a speed of $2cms^{-1}$. What is the speed of the outgoing liquid?



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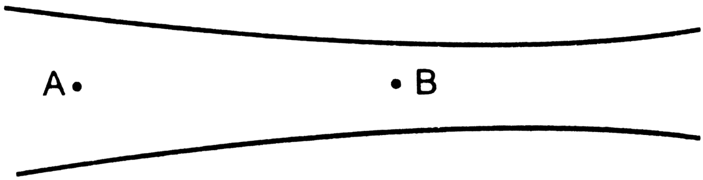
4. Figure shows a liquid of densith $1200kgm^{-3}$ flowing steadily in a tube of varying cross section. The cross section at a point A is $1.0cm^2$ and that at B is $20mm^2$, the points A and B are in the same horizontal plane.The speed of the liquid at A is 10 cms^{-1}. Calculate the difference in pressure at A and B.



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5. A water tank is constructed on the top of a building. With what speed will the water come out of a tap 6.0 m below the water level in the tank? Assume steady flow and that the pressure above the water level is equal to the atmospheric pressure

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