FLUID MECHANICS

SHEET 1

Units and Dimensions and Basic fluid properties

1- Convert from column A to the corresponding units of column B.

A	B
26.7psi	Bar
350 $L.min^{-1}$ (liters per minute)	$m^3.s^{-1}$
1.6 bar	MPa
3.6 atm	psi
1050 mmHg	bar
0.63 Pa.s.	cP
16 cSt	$m^2.s^{-1}$

2. Write down the dimensions of the following variables in terms of the basic dimensions:
   (a) Power defined as work per unit time
   (b) Angular momentum = $m.v.r$
   (c) Surface tension defined as force per unit length
   (d) Specific weight defined as weight per unit volume
   (e) Mass flux, defined as mass flow rate per unit area
   (f) Resistance of soil to water seeping defined by $R = \frac{\Delta p}{\mu . v}$

3. (a) A body weighs 1000 N. Calculate its mass in kg and in lb.
   (b) The specific gravity of ethyl alcohol = 0.87.
   Calculate its density in $kg.m^{-3}$ and in $g.L^{-1}$.
   (c) The atmospheric pressure was 1060 mbar. Deduce its value in atm.
   (d) A steel cube has a 2" side. Estimate its volume in m^3 and calculate its density in $kg.m^{-3}$ if it weighs 2.2 lb.
   (e) The viscosity of an oil = 16cP and its specific gravity = 0.87. calculate its kinematic viscosity in cSt.

4. Evaluate the density of air at 25°C if its molecular weight = 29.

5. The viscosities of glycerol at 20°C and 60°C are 1.48 and 0.102 Pa.s respectively. Determine the activation energy of viscosity.

6. Two rectangular horizontal plates measure 600×200 mm^2. They are set 3 mm apart and the gap between them is filled with an oil of viscosity 120cP. What is the force necessary to drag the upper plate over the fixed lower plate at 0.3 $m.s^{-1}$?

SHEET 2

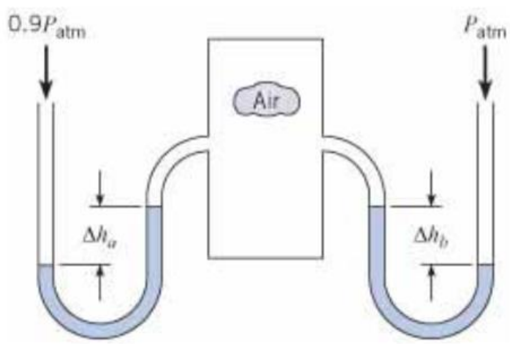
Basic of fluid statics

1. A cylindrical flask is 45 mm in diameter. It is filled with 750 g of alcohol of specific gravity 0.78. calculate in millibar the pressure exerted on the bottom of the flask.

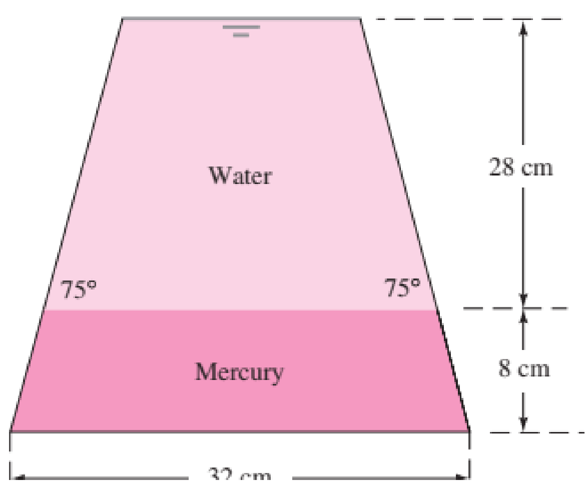
2. A reservoir in the form of a cuboid has a square base of side 0.8 m. it is used to separate oil from water (specific gravity of oil = 0.83). It is filled with 1.06 tons of water on which floats 275 kg oil. What is the maximum pressure exerted on the walls of the reservoir in psi?

3. A U-tube manometer is filled with water and compressed air at 2.5 millibar (gauge) is applied on one of its branches. What will be the difference in the levels of the liquids in the two branches of the U-tube?

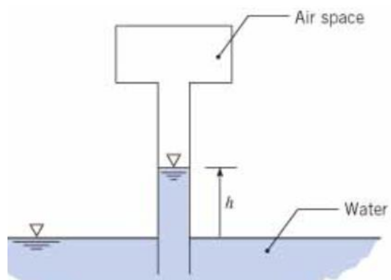
4. In the figure, the left tube is subjected to a pressure of 0.9 atm (gauge), while the right one is under 1 atm (gauge). Calculate the difference in the levels of water in the two branches of the U-tube.



5. In the figure, the absolute pressure at the water – mercury interface = 93 kPa. Calculate the pressure above water and the pressure on the bottom of the tank in kPa.

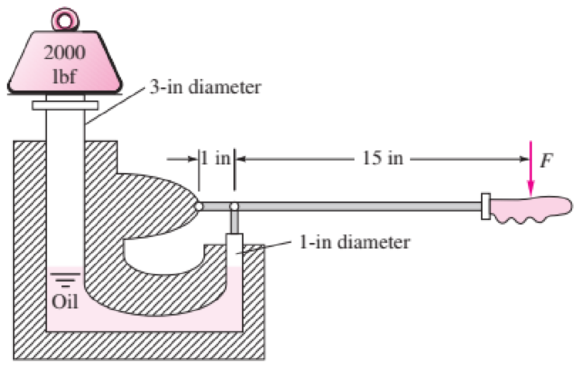


6. In the figure, the space above the tube was kept at a pressure of 50kPa (abs). Why does water rise in the tube? If the pressure was raised to 75 kPa, what would the height of the level of the liquid in the tube be?

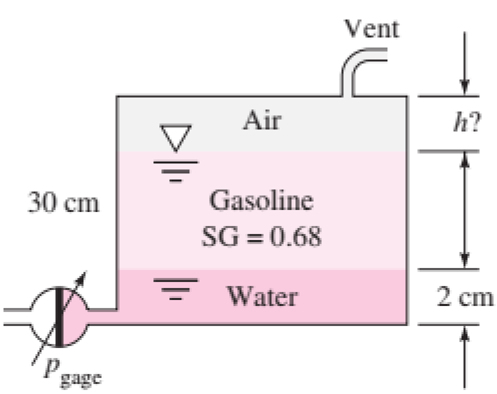


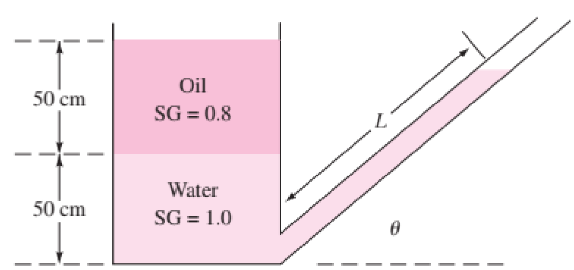
7. 26 kg of ammonia gas is stored at 25°C in a spherical container of 3.5 m in diameter. The molecular weight of the gas is 17. Calculate the pressure exerted on the container in MPa.

8. In the figure, the hydraulic jack is filled with oil. What force in lb_f must be applied on the handle to support a load of 2000 lb_f?



9. The fuel gauge from gasoline in a car tank is proportional to the pressure at the bottom of the tank. The tank is 300 mm deep and accidentally contains 20 mm water besides gasoline. How many mm of air remains at the top of the tank when the gauge reads erroneously "Full"? (Figure to the left).





10. If the length L in figure = 110 cm, evaluate the measure of the angle θ. (Figure to the right).

SHEET 3

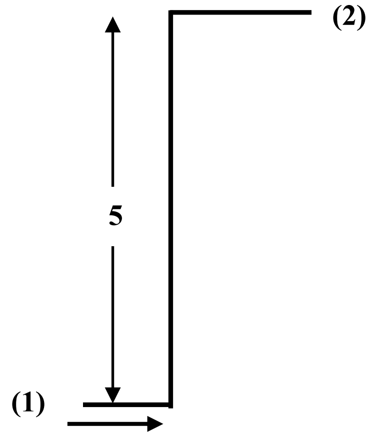
Basic Laws of Fluid of fluid flow

1. Oil with specific gravity = 0.92 flows in a 12” pipe at a rate = 62 ton.h^{-1}. Calculate its velocity through the pipe.

2. Lubricating oil flows in a pipe 1.5” in diameter at a velocity = 1.6 m.s^{-1}. It is then admitted to a smaller pipe of diameter 1”. Calculate the flow rate and the velocity of oil in the second pipe.

3. Water flows in a 8” pipe at a speed of 0.8 m.s^{-1}. It splits into two pipes of diameters 6” and 4”. Calculate the flow rate of water and its velocity in both pipes if the velocity in the second pipe = 1.2 m.s^{-1}.

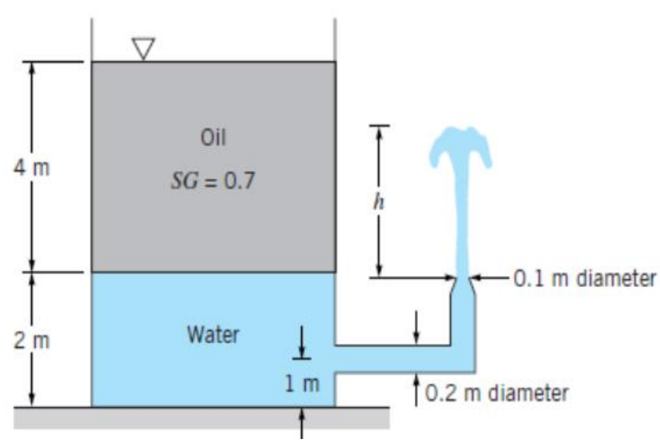
4. The figure shows the flow of water in a 2” pipe at 6 m^3.h^{-1} from a lower level (1) to a higher level (2) where it is discharged to the atmosphere. Calculate the velocity of water in the pipe and the required pressure at level (1) in bar. (Assume no losses).



5. A large tank contains a layer of oil floating on water (See Figure). Determine the maximum height of the water jet.

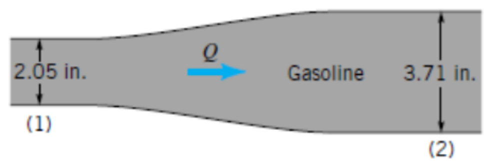
6. In Problem 5, what is the pressure in the horizontal pipe?

7. Oil flows in a horizontal pipe 2” in diameter. A venturi meter containing mercury and throat diameter 1” is installed on the pipe. Its reading indicates 120mm. Calculate the flow rate in m^3.h^{-1}. Take $C_d = 0.98$.

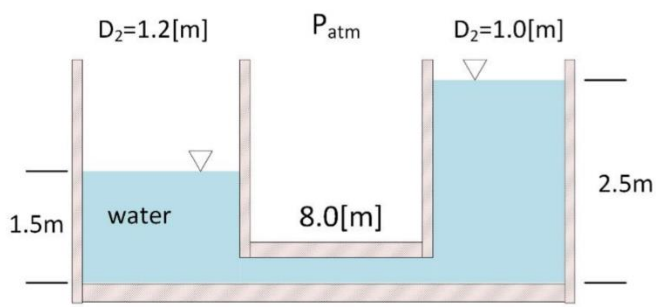


8. A circular orifice of diameter 60 mm is opened at the lowest point of the vertical walls of a cylindrical container of diameter 1.2 m filled with water at level = 2.3 m. Estimate the time it would take to empty the container, assuming the discharge coefficient of the orifice to be 0.65.

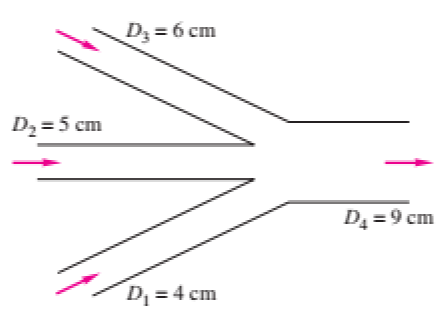
9. For the pipe enlargement shown, the pressures at sections (1) and (2) are 56.3 and 58.2 psi respectively. Determine the flow rate of water in $m^3.h^{-1}$.



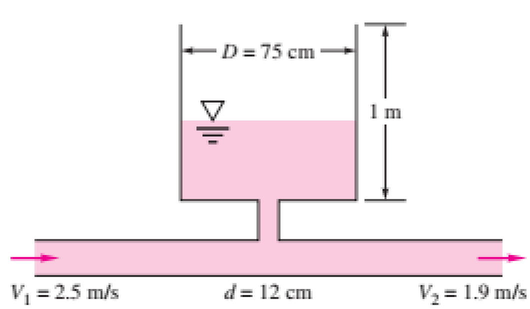
10. In the given figure, the two tanks are connected by a horizontal pipe. Establish a relation between the heights of water in the two tanks. What would be the final equal level of water at the two tanks?



11. In the figure, three pipes deliver water to a main pipe 9cm in diameter. If $v_1 = 5, v_2 = 4\ \text{cm/s}$ and $Q_4 = 120\ m^3.h^{-1}$. Find the value of v_3 and v_4.



12. In the figure below, the original depth of water in the tank was 30 cm. Calculate the time required to fill the tank.



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SHEET 4

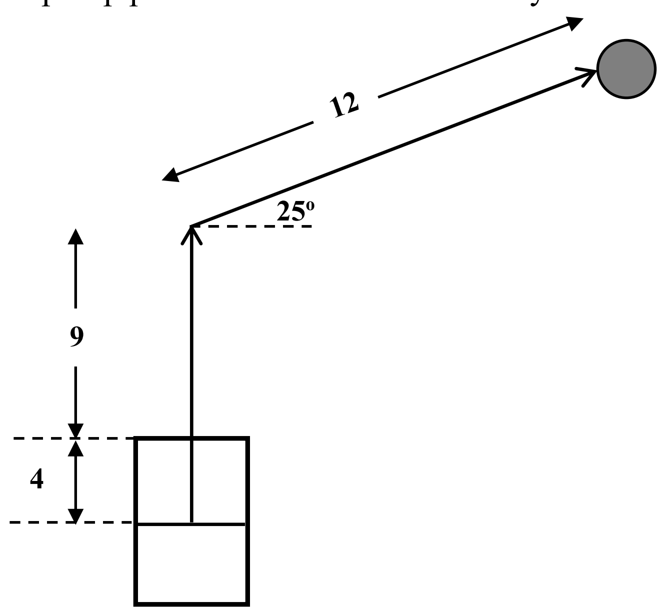
Flow of fluids in ducts

1. Crude oil of specific gravity 0.9 flows in a 12” pipe at the rate of 860 $m^3.h^{-1}$. At the prevailing temperature, its kinematic viscosity = 42 cSt. Determine the Reynold number of the fluid.

2. Water at 1 $m.s^{-1}$ flowing through a large pipe is pumped from a lower level of a building to a level 30 m higher in a 1.5” pipe to be delivered at a velocity of 3.5 $m.s^{-1}$. The head losses amount to 8 m. Can a 3 hp pump of efficiency 65% fulfill that task?

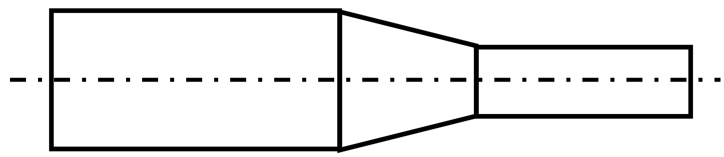
3. Crude oil of specific gravity 0.88 is to be delivered from the surface of a field to a facility along a 5 km horizontal pipe 18” diameter discharging to the atmosphere at a rate = 250 $m^3.h^{-1}$. The friction factor = 0.003 and the other head losses amount to 35 m. What is the maximum pressure required at the entrance of the pipe? Calculate the required pumping power in kW (Assume pump efficiency = 0.75).

4. It is required to pump ground water at a flow rate = 24 $m^3.h^{-1}$ from a well to the atmosphere using the piping system shown in Figure. The vertical pipe and the inclined pipe are 2” in diameter. The total head loss along the water path amounts to 1.2 m. Estimate the required pump power in kW for an efficiency of 0.65.



5. A horizontal pipe 8” in diameter is used for the transportation of sea water (specific gravity = 1.08 and viscosity = 1.6 cP) along a 1 km path involving two fully open globe valves and four 90° flanged elbows. Water flows at the rate of 108 $m^3.h^{-1}$. If the friction factor = 0.02, estimate the total pressure loss in kPa.

6. In the figure, water flows from the large 6” pipe to a 4” pipe at 98 $m^3.h^{-1}$. The conical angle = 20°. Evaluate the pressure drop due to contraction in Pa.



7. A viscous polymer is to be pumped through a 4” horizontal pipe at 14.2 $m^3.h^{-1}$ at 25°C. Under these conditions, the specific gravity = 1.2 and the viscosity 0.23 Pa.s. Estimate the pressure drop caused by the flow of that polymer over 200 m and the theoretical power required in W.

8. Crude oil of specific gravity 0.85 flows in a 12” pipe at an hourly rate of 265 $m^3.h^{-1}$ at 25°C, at which temperature its kinematic viscosity = 6 cSt. If the pipe extends for 2 km, calculate the pressure drop at the end of the pipe in kbar, assuming the presence of 3 fully open globe valves and two 90° flanged elbows. (Consider the roughness of the pipe = 0.01). What pumping power is necessary to sustain that flow? (Assume a pump efficiency of 0.75).

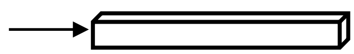
9. A 5mm capillary tube is used to measure viscosity. When the flow rate of a liquid is 0.071 $m^3.h^{-1}$, the measured pressure drop per unit length = 375 $kPa.m^{-1}$. If the flow is laminar, estimate the viscosity of the liquid.

10. Mercury flows through 4 m in a 7 mm diameter smooth glass pipe at 0.692 $m^3.h^{-1}$. Calculate the pressure drop in MPa. (At the prevailing temperature, viscosity = 1.55 cP).

SHEET 5

Flow past immersed bodies

1. Water flows at 3.6 $m.s^{-1}$ in an open channel when it impinges over a sphere of diameter 50 mm placed in its path. Determine the drag force developed.
2. Oil flows in a rectangular duct 1.2 m wide and 20 mm high at 72 $m^3.h^{-1}$. A cylindrical body is placed in its path such that its axis is perpendicular to the direction of flow. The diameter and height of the cylinder = 50 and 120 mm respectively. Determine the drag force developed.
3. In the figure, water flows at 5 $m.s^{-1}$ past the thin plate shown perpendicular to its thinnest cross-section. The breadth of the plate = 10 mm, its height = 15 mm and its length = 250 mm. Evaluate the drag force on the plate.



4. The front face of a car can be assumed to be rectangular with dimensions 2100×1750 mm. It moves at 120 $km.h^{-1}$ against wind blowing at 30 $km.h^{-1}$ at 1.1 bar and 15ºC. Estimate the drag force developed. (Assume the drag coefficient to be constant = 0.7)
5. 680 L of an emulsion of oil and water contains 15% by volume water. It is placed in a cylindrical tank of 1 m diameter. After enough time, oil droplets of average size 0.1mm move upward to the water surface. What is the time required for oil to totally separate from water? (Specific gravity of oil = 0.79, viscosity = 12 cP).

SHEET 6

Flow of non-Newtonian fluids

1. A paint is known to follow Bingham behavior. When subjected to a shear rate of 40 s^{-1}, the developed shear stress = 0.56 kPa. As the shear rate is doubled, the shear stress increases to 0.98 kPa. Evaluate the plastic viscosity and its yield stress in kPa.

2. An engine oil behaves as a shear thinning liquid. When the applied shear rate = 25 s^{-1}, the shear stress = 0.13 kPa and as the shear rate is increased to 150 s^{-1}, the shear stress reaches 0.32 kPa. Determine the value of the flow index.

3. The following data belong to a test carried out in a Brookfield rheometer on a lubricating oil at 25°C:

Shear rate s^{-1}	10	20	50	100	150	200	300	400
Shear stress Pa	481	588	705	836	909	994	1065	1125

   Show that these data conform effectively to a shear thinning behavior and determine the flow index and consistency coefficient.

4. It is desired to pump the oil described in the last example at the rate of 1.3 $m^3.h^{-1}$ in a 3" pipe for 120 m. Determine the necessary theoretical power needed in W.

5. A nanofluid is tested for its rheological behavior. The following data were obtained.

Shear rate s^{-1}	100	200
Shear stress Pa	195	505

   If this fluid follows a shear thickening mechanism, calculate the flow and the consistency indices. Determine the expected shear stress at walls as this liquid flows in a 10 mm tube at 150 $mm.s^{-1}$. Use the equation: $\dot{\gamma}_w = \frac{8v}{D}$.

6. A suspension of silt in water follows a Bingham fluid behavior having the following constitutive law: $\tau = 0.228 + 0.12\dot{\gamma}$ (Pa)
   The suspension contains 15% by volume silt of specific gravity 2.6 and it flows through a 4" pipe at the rate of 16 $m^3.h^{-1}$ for 120 m. Prove that the friction factor ≈ 0.02325, then evaluate the pressure drop across the line in kPa.

7. The following data belong to a test carried out in a Brookfield rheometer on a drilling fluid at 25°C:

Shear rate s^{-1}	20	40	60	100	200	300	500
Viscosity cP	180	115	94	81	66	62	55

   Show that these data conform effectively to a Bingham behavior and determine the plastic viscosity of the fluid.