**Basics of Mechanical Engineering-3**


**Prof. J. Ramkumar**

**Prof. Amandeep Singh Oberoi**

**Department of Mechanical Engineering**

**Indian Institute of Technology, Kanpur**

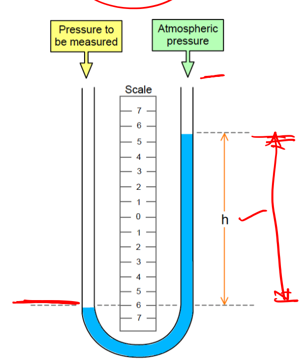

**Week 10**

**Lecture 41: Tutorial 9**

Welcome back to the course Basics of Mechanical Engineering 3. I am here in the first tutorial session of Fluid Mechanics. This tutorial session is mainly focused on the introduction to fluid mechanics, where I will talk about the pressure differences in a manometer. I'll talk about surface tension and some properties of fluids. For example, surface tension is one of the properties. Density, capillarity—those parts I will discuss in this tutorial. I am Dr. Amandeep Singh Oberoi from the Indian Institute of Technology, Kanpur. Manometer—to recall the concept, I've just jotted down some text here.

## Manometer

- A U-tube mercury manometer is a classical and widely used device for measuring the pressure of fluids, relying on the principle of hydrostatic equilibrium.
- It consists of a transparent U-shaped tube that is partially filled with mercury, a dense and stable liquid.
- One end of the tube is connected to the fluid system whose pressure is to be measured, while the other end is open to the atmosphere or another reference pressure.
- The pressure difference between the fluid and the reference causes mercury to move, creating a difference in mercury column heights on the two arms of the U-tube.

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A U-tube mercury manometer is a classic and widely used device for measuring the pressure of fluids, relying on the principle of hydrostatic equilibrium. It consists of a transparent U-shaped tube that is partially filled with mercury, a dense and stable liquid that is a property of mercury. One end of the tube is connected to the fluid system whose pressure is to be measured, while the other end is open to the atmosphere or another reference pressure.

So, there is a reference pressure. Based on the reference pressure, we have one end of the tube where the pressure is to be measured. The pressure difference between the fluid and the reference causes mercury to move, creating a difference in mercury column heights on the two arms of the U-tube. This part is already covered. Here, for example, the pressure of the fluid is to be measured. This atmospheric pressure, which is open on the scale, creates a difference known as the pressure head difference. This lets us know the pressure of the fluid system here.

## Manometer

To calculate the pressure in the simple U tube mercury manometer we use the formula:

$$h + h_1S_1 = h_2S_2$$

Where,

- $h$ = Pressure in terms of height of water column (m)
- $h_1$ = Height of water column on the left limb (m)
- $h_2$ = Height difference of mercury column (right limb is higher) (m)
- $S_1$ = Specific gravity of water ($S_1$ = 1)
- $S_2$ = Specific gravity of mercury ($S_2$ = 13.6)

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To calculate the pressure in the simple U-tube mercury manometer, we use this relation: h + h1S1 = h2S2. So, h is the pressure in terms of the height of the water column. h1 is the height of the water column on the left limb. h2 is the height difference of the mercury column on the right limb, which is higher. You can see it mentioned here. This is h. S1 and S2 are the specific gravities of water and mercury.

For water, the specific gravity value S1 is 1. For mercury, this value is 13.6. Now, I will draw a simple illustration to show you how all these parameters we have mentioned here are present in an operator setup and how we measure the pressure difference.

## Manometer

***Problem statement:*** *A simple U tube mercury manometer is used to measure the pressure of water in a pipe line. The mercury level in the open tube is 70 mm higher than that on the left tube. The height of water in the left tube is 50 mm. Calculate the pressure in the pipe in:*

*a) 'm' of water*

*b) kN/m²* $P = 8.848\ kN/m^2$

***Solution:***

$h_1 = 50mm = 0.05m$

$h_2 = 70mm = 0.07m$

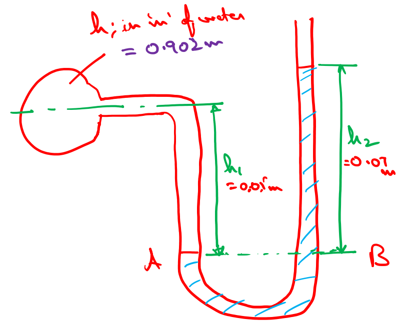
$h = ?$

a) $h + h_1 S_1 = h_2 S_2$

$h = h_2 S_2 - h_1 S_1$

$h = (0.07 \times 13.6) - (0.05 \times 1)$

$h = 0.902$ 'm' of water






## Manometer

$P = w \times h$ ($w$ = specific weight of water)

$= 9.81 \times 0.902$

$= 8.848\ kN/m^2$



A simple U tube mercury manometer is used to measure the pressure of water in a pipe line. The mercury level in the open tube is 70 mm higher than that on the left tube. The height of water in the left tube is 50 mm. Calculate the pressure in the pipe in:

a) 'm' of water

b) $kN/m^2$

h1 = 50 mm = 0.05 m

h2 = 70 mm = 0.07 m

h = ?

Solution:

a) h + h1S1 = h2S2

h = h2S2 – h1S1

h = (0.07 x 13.6) – (0.05 x 1)

h = 0.902 'm' of water

P = w x h     (w = specific weight of water)

= 9.81 x 0.902

= 8.846 $kN/m^2$

## Manometer

**U-tube differential manometer:**

- A U-tube differential manometer is a device used to measure the pressure difference between two points in a fluid system.
- It consists of a U-shaped tube partially filled with a manometric liquid (like mercury), with both ends connected to the points of interest, allowing direct visual comparison of fluid columns.

For the U-tube manometer, let me recall the theory part here. A U-tube manometer is a differential manometer. So, a U-tube differential manometer is a device used to measure the pressure difference between two points in a fluid system. It consists of a U-tube partially filled with a manometric liquid like mercury. Both ends are connected to the points of interest, allowing direct visual comparison of the fluid columns. So, what happens here?

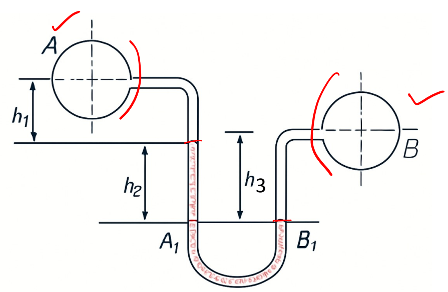
## Manometer

To calculate the pressure in the differential U tube manometer we use the formula:

$$h_a - h_b = h_3 S_3 - h_1 S_1 - h_2 S_2$$

Where

- $h_a$ = Pressure head at point A (m of water)
- $h_b$ = Pressure head at point B (m of water)
- $h_1$ = Height of liquid 1 column (m)
- $h_2$ = Height of mercury column (m)
- $h_3$ = Height of liquid 3 column (m)
- $S_1$ = Specific gravity of fluid in Pipe A
- $S_2$ = Specific gravity of mercury (13.6)
- $S_3$ = Specific gravity of fluid in Pipe B

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You can see this diagram here. Now, here both ends are connected to the points of interest. Those are the things which are to be measured. For instance, we need to measure the pressure difference for both a and b. So, here the differential U tube manometer is there. Difference between a and b, it will tell $h_a - h_b = h_3 S_3 - h_1 S_1 - h_2 S_2$. So, where is h3 here? It is the distance between the lower and the upper level of mercury in this tube, that is h3. And h1 is for the point a, h2 is for point b, and these differences are from the upper and the lower heights, respectively. So h1 is height of liquid 1 column in meter. h2 is height of mercury column. h3 is the height of liquid 3 column. So, here S1 and S3 are the specific gravity of the fluid in pipe A and B, and S2 is the specific gravity of mercury.

# Manometer

***Problem statement:*** *An U-tube differential manometer is used to find out the pressure difference between two pipe lines A and B. The pipe A carries carbon tetrachloride of specific gravity 1.594. The pipe B contains oil of specific gravity 0.8. The pipe A lies 2.5 m above pipe B. The centre of the pipe B is at the level of mercury in the other limb. The difference in levels of mercury is 342 mm. Calculate the pressure difference between A and B.*

***Solution:***

$h_1 = 2.5 m$

$h_2 = 342 mm = 0.342 m$

$h_2 = h_3 = 0.342 m$

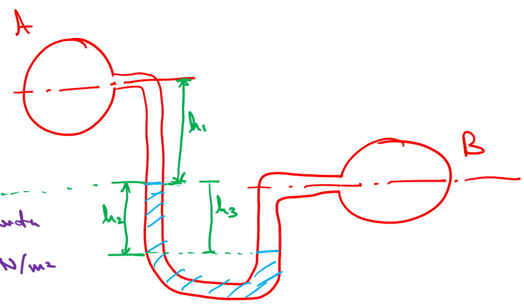
$S_1 = 1.594$

$S_2 = 13.6$

$S_3 = 0.8$

$\Delta h = -8.3626 m$ of water

$\Delta P = -82.0371 kN/m^2$






# Manometer

$h_a + h_1 S_1 + h_2 S_2 = h_b + h_3 S_3$

$h_a - h_b = h_3 S_3 - h_1 S_1 - h_2 S_2$

$= (0.342 \times 0.8) - (2.5 \times 1.594) - (0.342 \times 13.6)$

$= -8.3626$ 'm' of water $= \Delta h$

$\Delta P = P_a - P_b$

$= \rho g \Delta h$

$= 1000 \times 9.81 \times (-8.3626)$

$= -82037 N/m^2$

$= -82.037 kN/m^2$



Now, let me state the problem. An U-tube differential manometer is used to find out the pressure difference between two pipe lines A and B. The pipe A carries carbon tetrachloride of specific gravity 1.594. The pipe B contains oil of specific gravity 0.8. The pipe A lies 2.5 m above pipe B. The centre of the pipe B is at the level of mercury in the other limb. The difference in levels of mercury is 342 mm. Calculate the pressure difference between A and B.

Given:

$h1 = 2.5$ m

$h2 = 342$ mm $= 0.342$ m $= h3$

$S1 = 1.594$

$S2 = 13.6$

$S3 = 0.8$

$ha + h1S1 + h2S2 = hb + h3S3$

$ha – hb = h3S3 – h1S1 – h2S2$

$= (0.342 \times 0.8) – (2.5 \times 1.594) – (0.342 – 13.6)$

$= - 8.3626$ ‘m’ of water $= \Delta h$

$\Delta P = Pa – Pb$

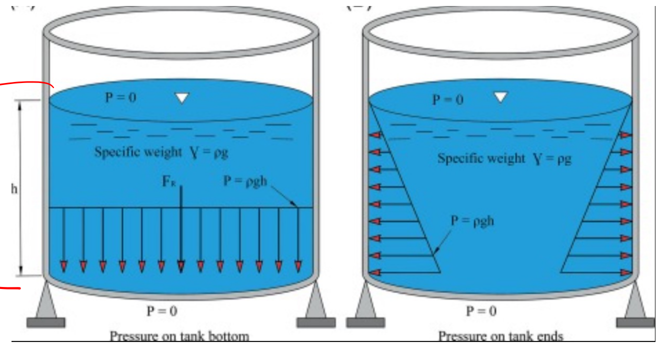
$= pg\Delta h$

$= 1000 \times 9.81 \times (-8.3626)$

$= - 82.037$ $N/m^2$

# Hydrostatic Forces

- Hydrostatic force is the resultant force exerted by a fluid at rest on a submerged surface due to the pressure created by the weight of the fluid above.
- It acts perpendicular (normal) to the surface and increases with depth because fluid pressure increases with the height of the fluid column above the surface.

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Next is hydrostatic forces. When we talk about the properties of fluids, when we talk about fluid mechanics, hydrostatic forces are very important. What is hydrostatic force? It is the resultant force exerted by a fluid at rest on a submerged surface due to the pressure created by the weight of the fluid above. That is the hydrostatic force because of the weight of the whole fluid.

So, depending upon the weight of the fluid, the overall volume of the fluid is proportional to the weight. This height is a major factor—the level of the fluid height determines the pressure exerted. So, it is proportional to the height here. It acts perpendicular, that is normal to the surface, and increases with depth because fluid pressure increases with the height of the fluid column above the surface. So, it is very important to understand hydrostatic forces.

# Hydrostatic Forces

Total Hydrostatic Force ( Total Pressure ):

$$F = \rho g A\bar{h}$$

Position of Center of Pressure:

$$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$$

$h^* = h_{cp}$

Where,

- F = Total hydrostatic force or total pressure (N or kN)
- $\rho$ = Density of water (1,000 kg/m$^3$)
- $\bar{h}$ = Depth of center of gravity of the plate below free surface (in m)
- $h^*$ = Depth of center of pressure below free surface (in m)
- $I_G$ = Second moment of area (moment of inertia) of the plate about horizontal axis through centroid

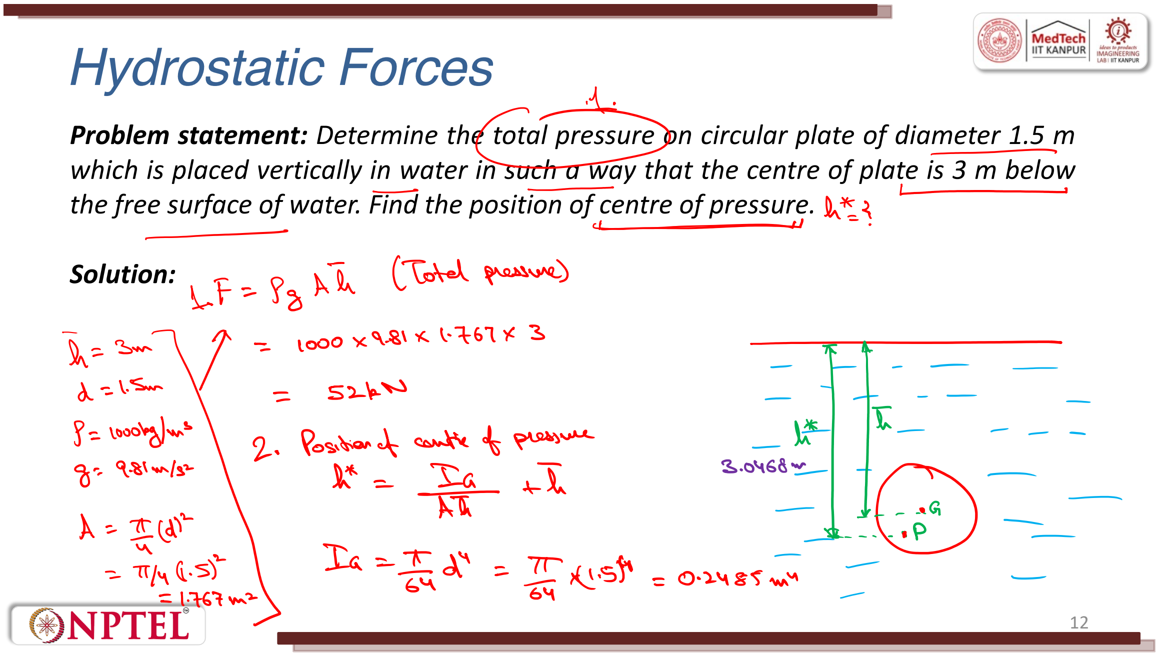




What is the total hydrostatic force? It is a function of ρgh, a relation I have also provided here: F = ρgAh̄, where ρ is the density of water. When discussing hydrostatic forces and referring to water, ρ represents the density of water or the density of the fluid of interest. Then, g—since we are discussing hydrostatic forces acting against gravity—g also comes into play, right? Then, A is the area upon which the fluid acts. h̄ is the depth of the center of gravity of the plate below the free surface. Here, h* (h-star) is the point of center of pressure, also known as Hcp, where 'cp' stands for center of pressure.

$$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$$

Here, IG is the second moment of area, which is the moment of inertia of the plate about the horizontal axis through the centroid. Now, this moment of inertia divided by the area multiplied by h̄, plus h̄ (the depth of the center of gravity of the plate below the free surface), gives h*. This is generally calculated as the depth of the center of pressure. I will draw a simple diagram to help you understand better. Before that, let me read the statement here—I will draw the diagram afterward.




It states: Determine the total pressure on circular plate of diameter 1.5 m which is placed vertically in water in such a way that the centre of plate is 3 m below the free surface of water. Find the position of centre of pressure.

Given:

$\bar{h}$ = 3 m

d = 1.5 m

p = 1000 kg/m$^3$

g = 9.81 m/s$^2$

A = π/4 (d)$^2$

= π/4 (1.5)$^2$

= 1.767 m$^2$

1. F = pgAh (Total pressure)

= 1000 x 9.81 x 1.767 x 3

= 52 kN

2. Position of centre of pressure

$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

IG = π/64 $d^4$ = π/64 x $(1.5)^4$ = 0.2485 $m^4$

$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

$= \frac{0.2485}{1.767 \times 3} + 3$

h* = 3.0468 m

## Properties of Fluid

**Density (ρ)**

- Definition: The mass of a fluid per unit volume.
- Formula: $\rho = \frac{\text{mass}}{\text{Volume}}$
- Units: $kg/m^3$

**Specific Weight (w or γ)**

- Definition: The weight of a fluid per unit volume. It shows how heavy the fluid is in a given space.
- Formula: $w = \rho \times g$
- Units: $N/m^3$

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Now, I will move on to the properties of fluids. Properties of fluids—many properties are discussed in the lecture series. I will only take some numerical examples on some of the properties. For instance, I will just recall the properties and take some examples on capillarity, maybe on specific gravity—that part I will cover.

To recall, what is density? That is p. Density is, anyway, mass per unit volume. That is the mass of the fluid per unit volume. Its units are kilograms per meter cubed. Then we have specific weight, which is w or γ. By definition, it is the weight of the fluid per unit volume. It shows how heavy the fluid is in a given space. That is, w= ρ × g, which is given in $N/m^3$.

# Properties of Fluid

**Specific Gravity (SG)**

- Definition: The ratio of the density of a fluid to the density of water (for liquids) or density of air (for gases). It is dimensionless.
- Formula: SG= $\frac{\rho_{fluid}}{\rho_{water}}$

**Weight (W)**

- Definition: The force exerted by gravity on a given mass of fluid.
- Formula: W= m × g
- Units: Newton (N)



Then comes specific gravity (SG). Definition: the ratio of the density of the fluid to the density of water. That is for liquids or the density of air for gases. When we talk about fluids, both liquids and gases could come into play. So, this is the density of fluid per unit density of water. This is what specific gravity is. The weight of the fluid is the force exerted by gravity on a given mass of fluid. That is W= m × g. It is in Newtons.

# Properties of Fluid

***Problem statement:*** *Calculate the density, specific weight and the weight of one litre of petrol with specific gravity 0.7.*

***Solution:***

Volume = 1 l = 1000 $cm^3$

$= \frac{1}{1000}\ m^3$

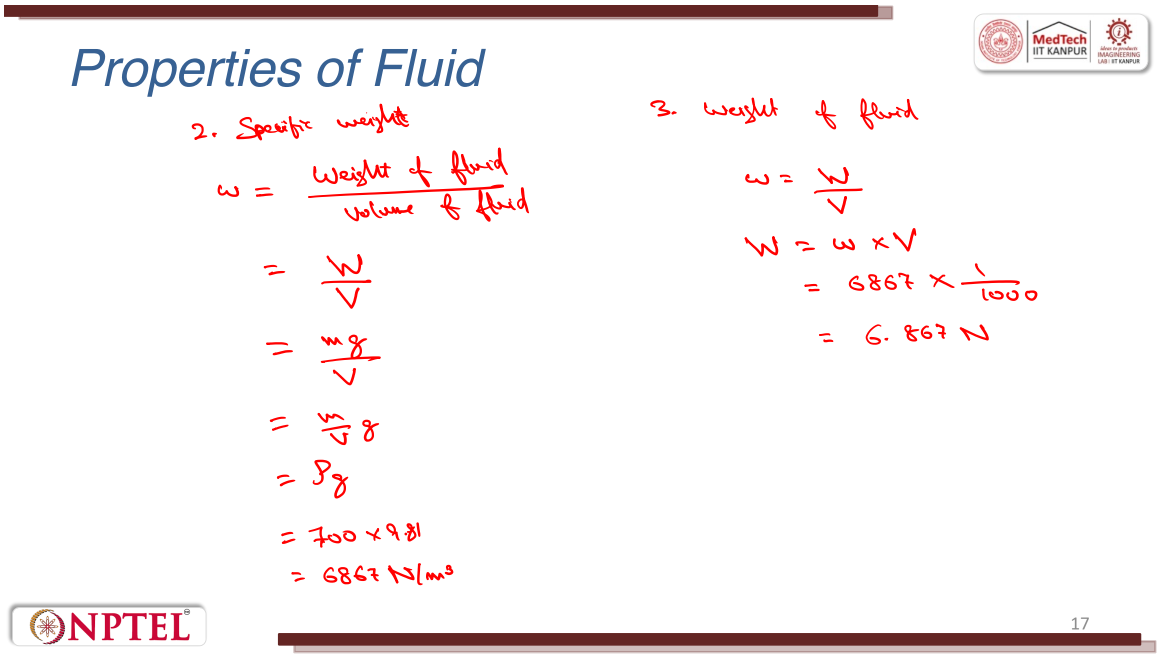
SG = 0.7

$SG = \frac{\rho_{petrol}}{\rho_{water}}$

1. $\rho_{petrol} = 0.7 \times \rho_{water}$

$= 0.7 \times 1000$

$= 700\ kg/m^3$




Let me see a very simple problem statement here. Calculate the density, specific weight and the weight of one litre of petrol with specific gravity 0.7.

Volume = 1l = 1000 $cm^3$ = 1/1000 $m^3$

SG = 0.7

SG = $\frac{\rho_{petrol}}{\rho_{water}}$

1. $\rho_{petrol} = 0.7 \times \rho_{water}$

   = 0.7 x 1000

   = 700 kg/$m^3$

2. Specific weight

   ω

That is rho of the fluid, or here in this case, petrol per unit rho of water. We are given this. This means rho of petrol, the density of petrol, is equal to 0.75 into the density of water. To put the value of the density of water, this is 0.7 into 1000. The density turns out to be 700 kilograms per meter cube. This is the first part. The second part they asked about is specific weight.

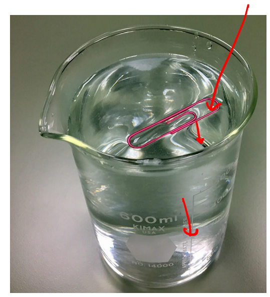
For specific weight, I can use this relation. Specific weight is w over gamma, which is rho into g, right? This specific weight is rho into g. How did we come to rho into g? That also I can derive here. For example, w is the weight of fluid per unit volume of fluid, right? This is equal to w per unit V. What is this w?

w is m into g. That also you can see here. w is m into g here. And mg by V gives me m by v into g. m by v is what? rho g. So, I will put the values of rho and g. rho is 700. That is for the fluid we are talking about. That is petrol into g is 9.81. This is equal to 6867 newtons per meter cubed. Now, the third part asks about the weight of the fluid. The weight of the fluid—I can put this relation here as well. The weight of the fluid is mass times gravity (m × g), or I can use this relation directly here. Specific weight is equal to the weight of the fluid per unit volume, meaning the weight of the fluid equals specific weight multiplied by volume.

The specific weight has already been calculated. The specific weight is 6867, and the volume we have here is 1 liter, which is 1/1000 of a meter cubed. I will write this as 1/1000. This comes out to 6.867 newtons. These were very simple calculations. Now, I will discuss surface tension.

## Surface Tension

- Surface tension is the property of a liquid's surface that makes it behave like a stretched elastic film or membrane. This happens because molecules at the surface are pulled inward by cohesive forces from the liquid below, minimizing the surface area.
- Surface tension causes the surface of a liquid to resist external force, allowing objects heavier than the liquid (like a small insect or a razor blade) to float without sinking.
- It is measured as the force exerted along a line of unit length on the liquid surface, and its SI unit is newtons per meter (N/m).



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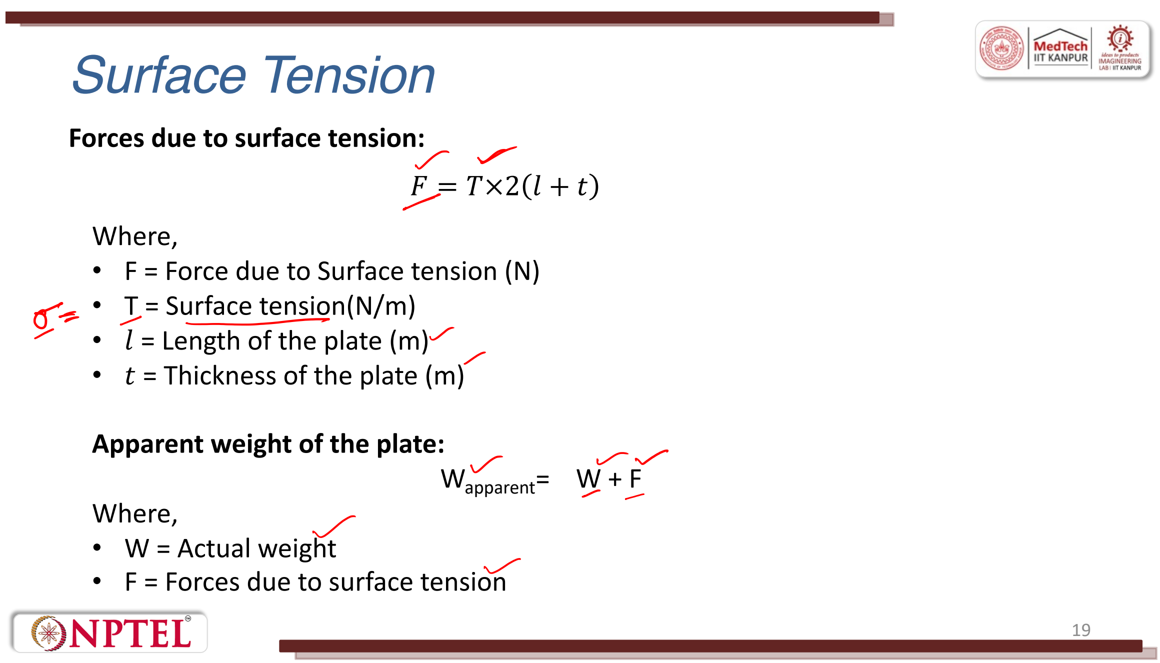
Surface tension is very important when storing fluids. We discussed hydrostatic forces below the surface, which depend on the fluid's weight, the height of the fluid from the base, or from the center of the body or pressure. What is the force or load that is hydrostatic? At the surface, there is surface tension. Surface tension concept could be recalled here. Surface tension is the property of liquid's surface that makes it behave like a stretched elastic film or membrane. This happens because molecules at the surface are pulled inward by cohesive forces from the liquid below minimizing the total surface area. You can see there is a clip kept here because of the surface tension. If you make the clip to completely dip into the liquid or this water, it will go and sink there, because surface tension it does not sink.

Surface tension causes the surface of liquid to resist external forces allowing objects heavier than liquid like a small insect or a razor blade to float without sinking just because of surface tension only lot of the objects float on the liquid bodies. It is measured as the force exerted along a line of unit length on the liquid surface and SI units is force per unit length that is Newton per meter.




To put the relations here, surface tension F is equal to T times 2 into l plus t where t is surface tension here. It is given here. F is force due to surface tension. And L and T are the length and thickness of the plate on which the surface tension is exerted. These are all given in meters here. Apparent weight of the plate. So, apparent weight is W apparent, which is W plus F: actual weight plus forces due to surface tension. This is the apparent weight.

## Surface Tension

***Problem statement:*** *A square glass plate of length 10 cm and thickness 0.4 cm weighs 40 g in air. It is held vertically such that its lower edges rest on water surface. What is the apparent weight of glass plate now? (Surface Tension of water is 0.073 N/m).*

***Solution:***

$l = 10\text{cm} = 0.1\text{m}$ $\quad m = 40\text{g} = 0.04\text{kg}$

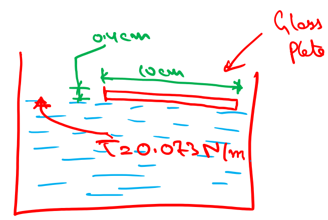
$t = 0.4\text{cm} = 0.004\text{m}$ $\quad T = 0.073\text{ N/m}$

Weight of plate: $W = mg$

$= 40 \times 9.81$

$= 0.04 \times 9.81 \text{ N}$

$= 0.3924 \text{ N}$






Let me see a problem statement here. A square glass plate of length 10 cm and thickness 0.4 cm weighs 40 g in air. It is held vertically such that its lower edge rests on the water surface. What is the apparent weight of the glass plate now? The surface tension of water is 0.073 Newton per meter. It says the glass plate has these dimensions: 10 centimeters in length and 0.4 centimeters in thickness. Let me put these values: l is equal to 10 centimeters, which is equal to 0.1 meter, and thickness is equal to 0.4 centimeters, which is equal to 0.004 meters or 4 millimeters. The weight of the plate W is equal to mg. What they are saying is there is a liquid contained in a container. In this container, we have a plate kept here with a thickness of 0.4 and a length of 10 centimeters.

This is, they say, a glass plate. So, this is a glass plate where they have given the length as 10 centimeters and the thickness here as 0.4 centimeters. Now, the weight is equal to m multiplied by g. This is the weight of the plate. Because we have been given the value of m, that it weighs 40 grams in air. It is 40 grams multiplied by g, that is 9.81. This weight turns out to be, if I need to calculate this in newtons, this 40 is, I will say m is equal to 40 grams, which is equal to 0.04 kg, because I am going to talk about SI units. So this 40 grams into 9.81, or I will better put it as 0.04 into 9.81, this is in newtons. This is 0.3924 newtons of weight. Now, they are asking about apparent weight. For the apparent weight, we have seen that apparent weight is the weight in air plus the weight or forces due to surface tension. So, apparent weight is the regular weight in air plus the weight due to surface tension. That is, it is higher than the regular weight.

## Surface Tension

Forces due to surface tension

$$F = T \times 2(l + t)$$

$$F = 0.073 \times 2(0.1 + 0.04)$$

$$F = 0.015\,N$$

$$W_{apparent} = W + F$$

$$= 0.3924 + 0.015$$

$$= 0.4074\,N$$

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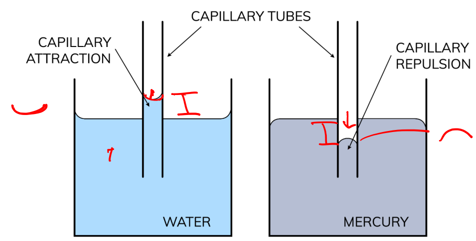
Now, forces due to surface tension. F is equal to T multiplied by 2 times l plus t. Putting the values, we can say F is equal to, the value is given here. The surface tension of water is, that is T is 0.073 newtons per meter. That is here T is equal to 0.073 newtons per meter.

This T is at the surface. This is 0.073 times 2 into length plus thickness. Length is 0.4 meters and thickness is 0.04 meters. This gives me the value of F as 0.015 newtons. Now, apparent weight, that is, weight due to surface tension, is weight in air plus force that is due to surface tension. This is equal to w, calculated here as 0.3924, plus F. F is 0.015. This turns out to be 0.4074 newtons. This is surface tension. I am taking one numerical example for each concept. For example, for surface tension, I have taken one numerical. You can take simple or similar numericals to practice on your own. And then you can come to the forum. That is, you can ask questions if you have any problems or face any challenges there. We will try our best to solve your problems here.

## Capillarity

- Capillarity is the natural ability of a liquid to flow into narrow spaces or thin tubes without external forces, often against gravity. This is due to the combination of surface tension and the adhesive forces between the liquid and the surface of the tube.
- It occurs because the adhesive forces between the liquid molecules and the solid surface can be stronger than the cohesive forces within the liquid, causing the liquid to rise or fall inside the narrow space.
- Capillarity is responsible for phenomena such as water rising in thin tubes, absorption of water by paper towels, movement of water in plants from roots to leaves, and the functioning of wicks in lamps.

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Now, the next concept is capillarity. Capillarity is the natural ability of a liquid to flow in narrow spaces or thin tubes without external forces, often against gravity. This is due to a combination of surface tension and adhesive forces between the liquid and the surface of the tube. Whether we talk about water being absorbed by plants, ink coming to the tip of a pen, or water being absorbed by a towel. This is all due to capillarity. So, capillarity as a property is the ability of a liquid to flow into narrow spaces or thin tubes. It occurs because adhesive forces between the liquid molecules and the solid surface can be stronger than cohesive forces within the liquid, causing the liquid to rise or fall inside the narrow space.

For instance, here the forces are lesser; here the force becomes high, so it rises here. This is capillary attraction. Also, there could be capillary repulsion because mercury has a higher specific gravity. There is capillary repulsion here as well. Capillarity is responsible for phenomena such as water rising in thin tubes, absorption of water by paper towels, movement of water in plants from roots to leaves, and functioning of wicks in lamps.

So, this is known as the meniscus, this curve here. This is the lower meniscus. And this, in the case of mercury, is the upper meniscus. This is present in capillarity.

# Capillarity

Capillary Effect in a Tube

$$h = \frac{4\sigma \cos\theta}{\rho g d}$$

Where,

- $h$ = Capillary rise
- σ = Surface tension of the liquid
- $\theta$ = Angle of contact between liquid and tube wall, in degrees (°)
- ρ = Density of the liquid, in kilogram per cubic meter ($kg/m^3$)

T= Temp.

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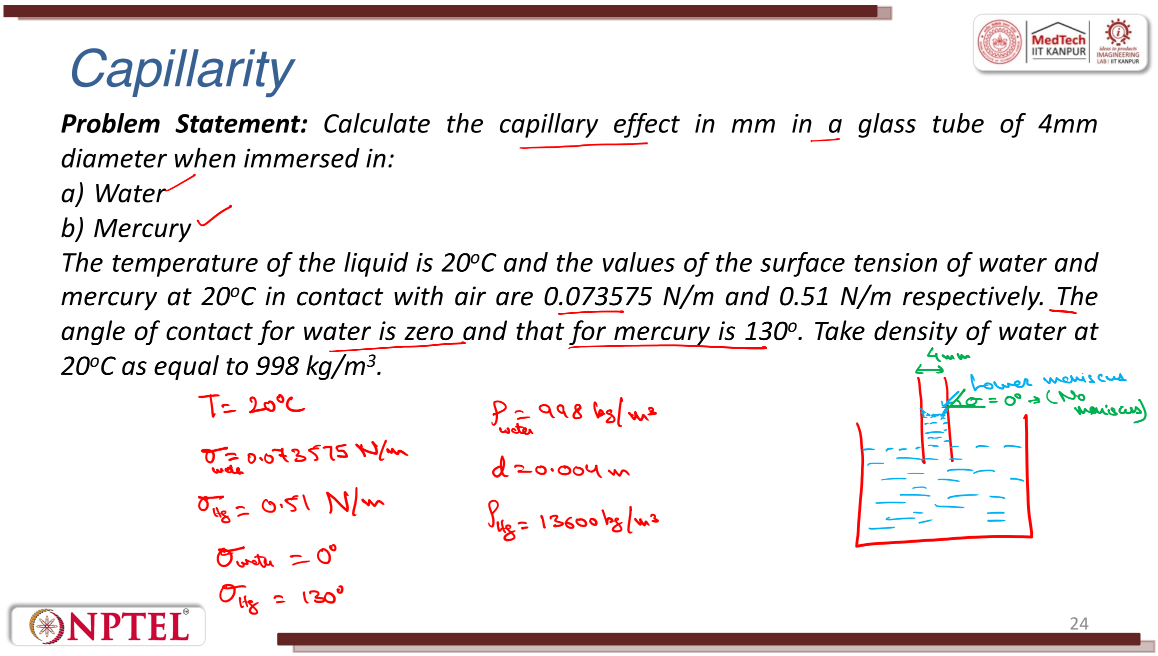
Now, when we talk about some relations or formulas in capillarity, the capillarity effect in a tube is given by h = 4σ cosθ / ρ g d. Here, h is again the height, that is, the rise of the liquid due to capillary action, that is, capillary rise, that is, h is present.

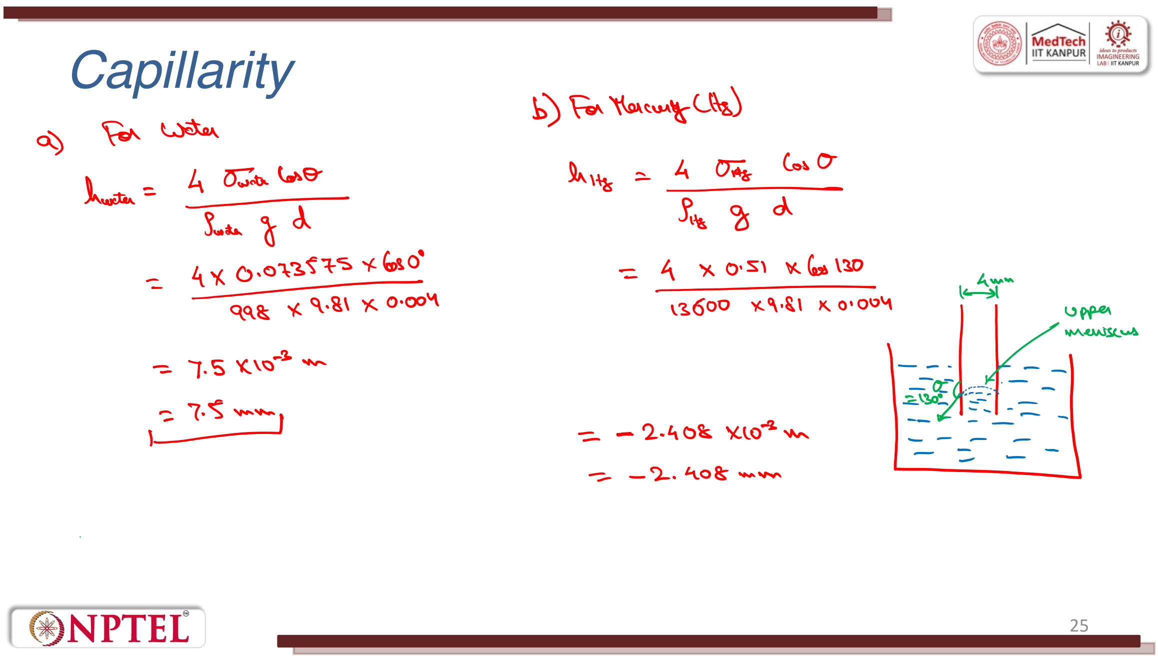
Here, σ is the surface tension of the liquid. θ is the angle of contact between the tube wall, that is, in degrees. ρ is the density of the liquid in kilograms per cubic meter. And this σ is the same as what was given as T in the previous relation. This is surface tension T. So, do not confuse this with the T here. So, we need to understand that I have just put or given another notation here, that is sigma, which represents surface tension. It is sometimes denoted as sigma and sometimes as T. In this relation, I have used sigma because in the numerical example I will discuss, T will represent the temperature of the liquid. That is why I have used the notation sigma here, representing the surface tension of the liquid. The angle is the angle of contact between the liquid and the tube wall, measured in degrees. rho is the density.




Now, let me look at this problem statement. Calculate the capillary effect in millimeters in a glass tube with a 4-millimeter diameter when immersed in water and when immersed in mercury. So, I will draw it here. First, I will draw it for water. To recall, for water, it will rise higher. For mercury, it will be lower, and the meniscus will also be different. For water, if I draw it, and there is a tube immersed here. I would have to draw it this way. This is water here. For the water, there would be a rise in the level here. It says the temperature of the liquid is 20 degrees Celsius. The temperature T is 20 degrees Celsius.

The value of surface tension of water and mercury at 20 degrees centigrade in contact with air is 0.73575 Newton per meter. This is for water. That is, sigma for water is 0.07. It should be 0.05. 0.073575 Newton per meter. This is sigma for water. And we have sigma for mercury output, sigma for Hg. That is given as 0.51 Newton per meter. The angle of contact for water is 0. Here, the angle of contact for water is 0, and for mercury, it is 130. That is, theta for water is 0 degrees, and theta for mercury is given as 130 degrees.

Take the density of water at 20 degrees as 998 kilograms per meter cube. Rho is given as 998 kg per meter cube. So here, we will have a meniscus like this. That is, water will have a lower meniscus. We put it as a lower meniscus. Now, let me calculate what I have been asked. That is, the capillary effect in millimeters in a glass tube, and the diameter of the glass tube is 4 millimeters. The diameter is also given as 4 millimeters. That is, D is 0.004 meters. Let me try to put the values there for water.




That is part A. For water, I will put h for water equal to 4 sigma for water multiplied by cos theta divided by rho for water multiplied by g multiplied by the diameter of the tube. Here, the diameter of the tube is said to be 4 millimeters. This is 4 millimeters only, and there is an angle theta here of this meniscus.

This angle theta is 0 degrees in water. There is no angle here. So, let me put the value. This is equal to 4 multiplied by the surface tension of water. The surface tension of water is 0.07. It should be 0.073575. 0.073575 multiplied by cos theta, that is, cos 0 degrees. Cos 0 is 1, multiplied by rho of water, which is given as 998 kilograms per meter cubed at 20 degrees, multiplied by g, that is 9.81, multiplied by the diameter in meters of the capillary, which is 0.004. This gives the value as 7.5 multiplied by 10 raised to the power of minus 3 meters, or I can put that in millimeters as well. This is equal to 7.5 millimeters. So, this is the capillary rise in water for the given specifications and parameters. Now, for mercury, that is Hg, the figure would be something like this. They say the angle is also there, and there would be a capillary downfall here. For instance, if I have mercury here, a tube of 4 mm immersed here, it would be something like this.

There is a mercury field here. I have taken a darker color here. So, when capillary action happens in mercury, it falls down here, and there is an upper meniscus here. So, here it is something like this. So, here they have also given that there is an angle of 130 degrees. That is, this theta is 130 degrees. This is the upper meniscus. Though in water, we have a lower meniscus, but here there is no meniscus because the angle is 0. This means no meniscus is there. This is again a 4 mm thickness of the tube.

Now, putting again those values here. We have the rho for water given here as 998. I will also put rho for mercury, in kilograms per meter cube, it is 13600 kilograms per meter cube, and the same relation could be put here: h for mercury, this is equal to 4 times the surface tension for mercury. And cos of the angle, that is for mercury, is given. Rho for mercury into g into the diameter of the capillary tube. Putting all these values, this is similar to the previous relation; you can just calculate it. I'm leaving it for you.

We'll put all the values and try to find the value. You will find this in negative form. You will find this value as 2.408 into 10 raised to the power minus 3 meters, and this is a negative value because it is lowering down. This can also be written as minus 2.408 millimeters. You can calculate this by yourself. With this, I am concluding the introduction to the fluid mechanics tutorial. I will discuss fluid mechanics, more properties, and other aspects of fluid mechanics in the next two videos.

Thank you.