DEPARTMENT OF EDUCATION

GRADE 12

PHYSICS

MODULE 1

FLUIDS

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GRADE 12

PHYSICS

MODULE 1

FLUIDS

IN THIS MODULE, YOU WILL LEARN ABOUT:

12.1.1: FLUID STATIC

12.1.2: FLUID DYNAMICS

Acknowledgement

We acknowledge the contribution of all Lower and Upper Secondary teachers who in one way or another helped to develop this Course.

Our profound gratitude goes to the former Principal of FODE, Mr. Demas Tongogo for leading FODE towards this great achievement.

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DIANA TEIT AKIS
Principal-FODE

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SECRETARY'S MESSAGE

Achieving a better future by individual students, their families, communities or the nation as a whole, depends on the kind of curriculum and the way it is delivered.

This course is part of the new Flexible, Open and Distance Education curriculum. The learning outcomes are student-centred and allows for them to be demonstrated and assessed.

It maintains the rationale, goals, aims and principles of the National Curriculum and identifies the knowledge, skills, attitudes and values that students should achieve.

This is a provision by Flexible, Open and Distance Education as an alternative pathway of formal education.

The Course promotes Papua New Guinea values and beliefs which are found in our constitution, Government policies and reports. It is developed in line with the National Education Plan (2005 – 2014) and addresses an increase in the number of school leavers affected by lack of access into secondary and higher educational institutions.

Flexible, Open and Distance Education is guided by the Department of Education's Mission which is fivefold;

- To develop and encourage an education system which satisfies the requirements of Papua New Guinea and its people
- To establish, preserve, and improve standards of education throughout Papua New Guinea
- To make the benefits of such education available as widely as possible to all of the people
- To make education accessible to the physically, mentally and socially handicapped as well as to those who are educationally disadvantaged

The College is enhanced to provide alternative and comparable path ways for students and adults to complete their education, through one system, two path ways and same learning outcomes.

It is our vision that Papua New Guineans harness all appropriate and affordable technologies to pursue this program.

I commend all those teachers, curriculum writers, university lecturers and many others who have contributed so much in developing this course.

UKE KOMBRA, PhD
Secretary for Education

MODULE 12.1: FLUIDS

Introduction

Fluid is a substance that offers no permanent resistance to deforming forces. Fluids are characterized by their tendency to 'flow', a concept that describes how fluids behave and how they interact with their surrounding environment. In fluids, the molecules are free to move from one point in the fluid to another. Therefore we can say that molecules have a certain degree of translational freedom. Fluids classifications are liquids and gases.

In gases, the molecules are sufficiently far apart to move almost independently of one another, and gases tend to expand to fill any volume available to them. In liquids, the molecules are more or less in contact, and the short-range attractive forces between them make them bind; the molecules are moving too fast to settle down into the ordered arrangements that are characteristic of solids, but not so fast that they can fly apart. Thus, samples of liquid can exist as drops or as sprays with free surfaces, or they can sit in beakers controlled only by gravity, in a way that samples of gas cannot. Such samples may evaporate in time, as molecules one by one pick up enough speed to escape across the free surface and are not replaced. The lifetime of liquid drops and sprays, however, is normally long enough for evaporation to be ignored.

There is another section that study the liquid flow- called hydrodynamics. It deals primarily with the flow of water in pipes or open channels. In gas flow, there are many similarities to the flow of liquid, but it also has some important differences. First, gas is compressible, whereas liquids are considered to be incompressible. Gas flow is not affected by gravity.

The study of fluids has two parts, statics and dynamics. Fluid statics concentrates on fluids at rest. It requires the concepts of Newton's First and Third Law. Newton's First Law states that "an object will continue in a state of rest or uniform motion in a straight line unless an external force acts upon it". Newton's Third law states that "For every action there is an equal and opposite reaction". Fluid dynamics focuses on properties related to the motion of fluids based on Newton's laws and the principle of conservation of energy.

In this module, Newton's first law can be observed in the second subheading on Pascal's Law and hydraulic jack while the third law can be observed in the third subheading on Archimedes Principle and Surface tension.

Therefore, learning outcomes in the module cover the following major topics: Density and Pressure in States of Matter, Pascal's Law and Hydraulic jack, Archimedes Principle and Surface tension. The last topic is fluid dynamics and discusses the Continuity and Bernoulli's equations

Learning outcomes

After going through this module, you are expected to:

- explain density (in solids and liquids) and specific gravity and specify their units.
- explain pressure in solids and liquids.
- states the equation of pressure in solids and liquids and its units.
- explain Pascal's law and the application of this law to the operation principle of hydraulic lift or jack.
- explain buoyancy and Archimedes principle.
- explain surface tension in liquids and capillarity.
- solve examples and problems on density , specific gravity, pressure in solids and liquids, buoyancy and Archimedes principle.
- illustrate surface tension in liquids.
- distinguish cohesion and adhesion.
- discuss and explain capillary.
- describe flow rate and its applications, equation of continuity.
- apply Bernoulli's equation to solve problems on the concepts.

Time Frame

Suggested allotment time: **10 weeks**

This module should be completed within 10 weeks.

If you set an average of 3 hours per day, you should be able to complete the module comfortably by the end of the assigned week.

Try to do all the learning activities and compare your answers with the ones provided at the end of the module. If you do not get a particular question right in the first attempt, you should not get discouraged but instead, go back and attempt it again. If you still do not get it right after several attempts then you should seek help from your friend or even your tutor.

DO NOT LEAVE ANY QUESTION UNANSWERED.

12.1.1 Fluid Static

Fluid static deals with fluids at rest. It includes the study of the conditions under which fluids are at rest in stable equilibrium.

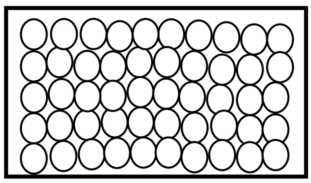
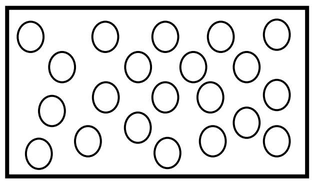
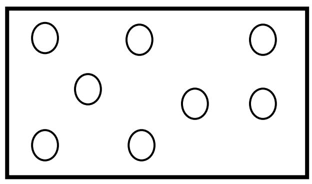
The fluid can either be gaseous or liquid. When a fluid is a liquid, it is called **hydrostatics**. It offers explanations for many phenomena of everyday life. Some examples are why atmospheric pressure changes with altitude, why wood and oil float on water, and why the surface of the water is always flat and horizontal whatever the shape of its container.

When the fluid is a gas that is not in motion with respect to the considered coordinate system, it is called **aerostatics**. It studies density allocation, especially in air.

Fluid statics has, is no relative motion between adjacent fluid layers that may deform it, since no shear (tangential) stresses found in the fluid. However, the only stress we deal with in fluid statics is normal stress, which is pressure, and the variation of pressure is due to the weight of the fluid.

Density and Pressure In States Of Matter

Matter comes in three states that are distinguished by the strength of the bonds that holds the molecules of the matter together. The three states of matter are:

States of matter and its property	Arrangement of particles
Solids • the forces between molecules are so strong that the solid has a definite shape and size. • particles are compact.	
Liquids • these have relatively weak bonds between molecules which allow deforming without effort. • have a fixed volume, but their shape is determined by the size of the container holding it.	
Gases • these have virtually no bonds existing between their molecules, so they can spread into available space. • the volume of the gas is determined by the size of the container holding it.	

Density in solid and liquids and specific gravity

The density of a material tells us how much of the material (that is its mass) is packed into a unit volume.

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \quad r \quad \rho = \frac{m}{V}$$

If the mass is measured in kg (kilograms) and the volume in m^3 (cubic meters), then density is measured in kg/m^3. Density values can also be quoted in g/cm^3. It is simpler to calculate densities in g/cm^3. Conversion to kg/m^3 is easy; $1g/cm^3 = 1000kg/m^3$.

For example, measurements on different volumes of water show that:

$1m^3$ of water has a mass of 1000kg

$2m^3$ of water has a mass of 2000kg

$3m^3$ of water has a mass of 3000kg

Using any of these sets of figures in the above equation, the density of water is found to be $1000kg/m^3$.

Densities of solids and liquids vary slightly with temperature. In most cases, the substances get a little bigger when they are heated and the increase in volume causes a reduction in density. The densities of gases can vary enormously depending on how compressed they are.

Density explains why some things are light and some are heavy. Whether an object will float or sink in a fluid depends on density. The table below shows the densities of common substances:

Substances			Density (kg/m^3)	Density (g/cm^3)
Solid	**Liquid**	**Gas**		
Gold			19 000	19.0
	Mercury		14 000	13.6
Lead			11 000	11.4
Steel			8000	8
Aluminium			2700	2.7
	Water		1000	1.00
Ice			920	0.92
	Petrol		800	0.80
		Air	1.3	0.0013

Table 1 Densities of common substances

The density of the material can be found by calculation, once the mass and volume have been measured.

The mass of a small solid or liquid can be found using a top pan balance. In the case of the liquid, you must remember to allow for the mass of its container as seen in illustration (b) on the next page.

The volume of the liquid can be found using measuring cylinder. In many case, it is possible to calculate the volume of a solid from its dimensions. If the shape is too awkward, the solid can be lowered into a partly filled measuring cylinder as shown in the figure below. The rise in level on the volume scale gives the volume of the solid.

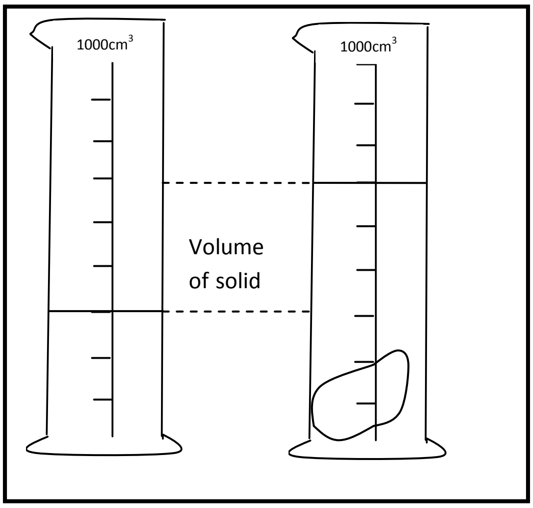


Figure 1 Measuring of small solid

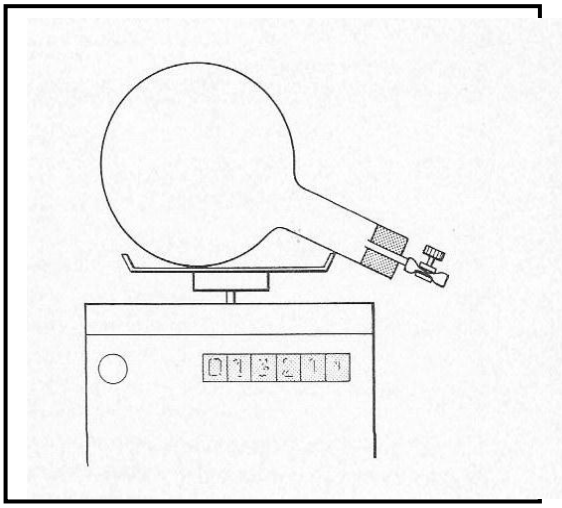


Figure 2 Measuring liquids

Example

An engineer needs to know the mass of a steel girder which is 20m long, 0.1m wide and 0.1m high. (Density of steel = 8000kg/m^3)

Calculate the volume first: Volume of girder = length x width x height
= 20m x 0.1m x 0.1m
= 0.2m^3

Formula: Density = $\frac{\text{mass}}{\text{volume}}$

Then put in the numbers: 8000 = $\frac{\text{mass}}{0.2}$

Mass = 8000 x 0.2
= 1600kg

Specific gravity / Relative density

The **specific gravity** (abbreviated as sg) of a substance tells you how many times heavier the substance is than water. It is defined as the ratio of the density of the substance to the density of water ($\rho_{water} = 1 \times 10^3 kgm^{-3}$). Note that specific gravity has no units, but it is always the same number as the density measured in gcm^{-3}.

$$\text{Specific gravity (sg)} = \frac{\text{Density of substance}}{\text{Density of water}}$$

For example, take the density of lead as $11300kgm^{-3}$ and the density of water as $1000kgm^{-3}$.

The specific gravity of lead = $\frac{11,300}{1000}$ = **11.3**

The specific gravity of a few substances is given in the table below. An object with specific gravity less than 1 will float and an object with a specific gravity greater than 1 will sink. Similarly, an object will float in water if its density is less than the density of water and sink if its density is greater than that of water.

Substance	**Density**		**Specific gravity**
	(kgm^{-3})	**(gcm^{-3})**	
Methylated spirit	$800kgm^{-3}$	$0.80gcm^{-3}$	0.80
Water	$1000kgm^{-3}$	$1.0gcm^{-3}$	1.0
Aluminium	$2700kgm^{-3}$	$2.7gcm^{-3}$	2.7
Lead	$11\,400kgm^{-3}$	$11.4gcm^{-3}$	11.4

Table 2 Density and specific gravity comparison

Pressure in solids

When a fluid is in a container, it exerts a perpendicular or uniform inward force on any surface exposed to it mainly due to the weight of the fluid sitting on top of it or surrounding it. It applies to solids as well. The size of this force divided by the area over which it acts is called **pressure**. Pressure is calculated by dividing the force or thrust acting at right angles to a surface by the area over which it acts.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad \text{in symbol} \quad P = \frac{F}{A}$$

If the force is measured in Newton (N) and area in m^2, pressure is measured in Nm^{-2} or Pascal (Pa) where:

$$1Nm^{-2} = 1Pa$$

Why is it that you can push a drawing pin into a piece of wood but you cannot push your finger into the wood even if you exert a larger force? What is the difference between a sharp knife and a blunt knife? The difference in each case is a difference of area. The point of the drawing pin and the edge of the sharp knife has a small area. Force acting over a small area gives a large pressure.

Example 1

What pressure is exerted on the ground by an elephant weighing 40 000N stands on one foot of area 1000cm^2 (= 1/ 10m^2).

Formula first: Pressure = Force/ Area

Then put in numbers: = 40 000 /1/10m^2

= 40 000 x 10Nm^{-2}

= 400 000Nm^{-2}

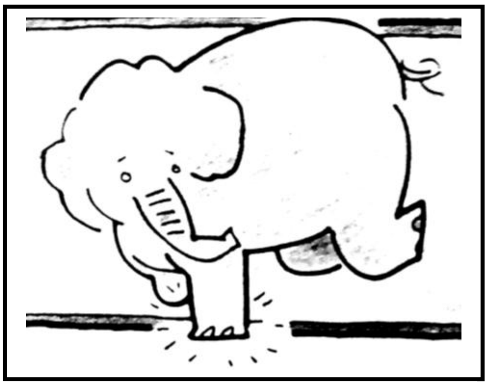


Figure 3 Elephants foot exerting pressure to ground

Example 2

Find the pressure exerted by a girl weighing 400N standing on one's stiletto heel of area 1 cm^2 (= 1 / 10 000m^2)?

Formula first: Pressure = Force/ Area

Then put in the numbers: = $\frac{400N}{1/10\,000m^2}$

= 400 x 10 000Nm^{-2}

= 4 000 000Nm^{-2} (ten times bigger)

Figure 4 Stiletto heel exerting pressure to the ground

So the elephant's foot exerts less pressure because it is heavier but the girl's heel exerts a larger pressure because of its smaller area. Her heel would sink farther into the ground.

Example 3

If atmospheric pressure is 100 000Nm^{-2}, what force is exerted on a wall of area 10m^2? Solve the problem simply by rearranging the pressure equation given above.

Force = pressure x area

= 100 000Nm^{-2} x 10m^2

= 1 000 000N

(Cancel out m^2, what is left is N which is the unit of force).

The force on exerted on the wall is 1 000 000N.

Pressure in liquids

Gravitational force tries to pull downwards in its container. This causes pressure on the container, and pressure on any object put into the liquid. The pressure in a liquid has several important features, some of which are illustrated below.

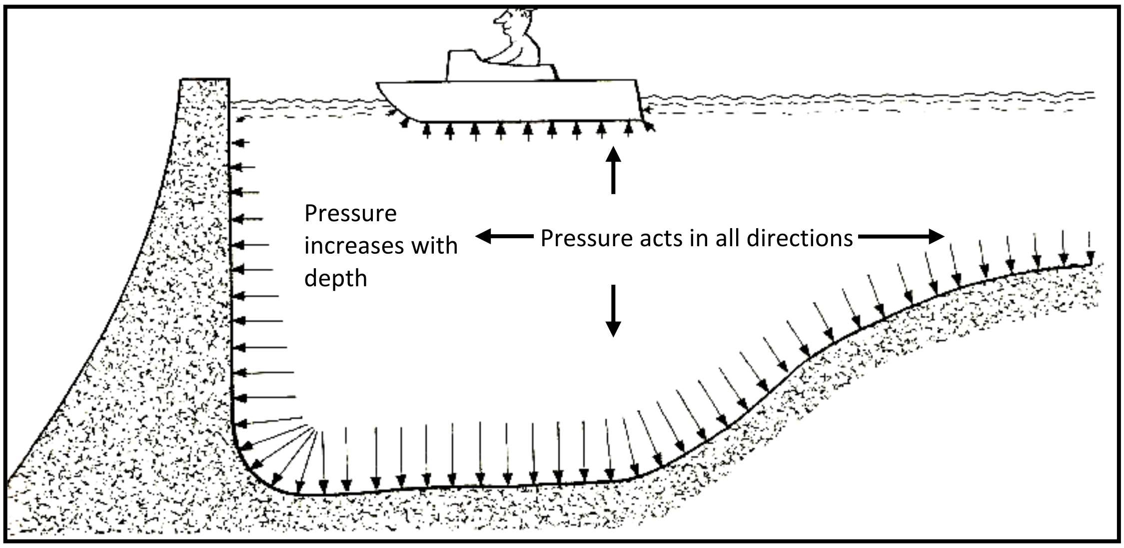


Figure 5 Pressure transmitted throughout the liquid but acts in all directions

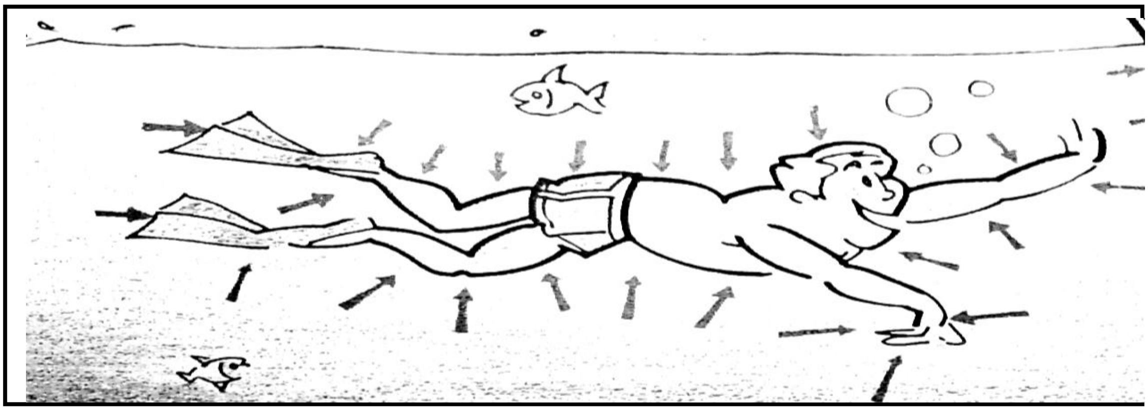


Figure 6 Pressure acts in all direction. A liquid under pressure pushes every surface in contact with it no matter which way the surface is facing

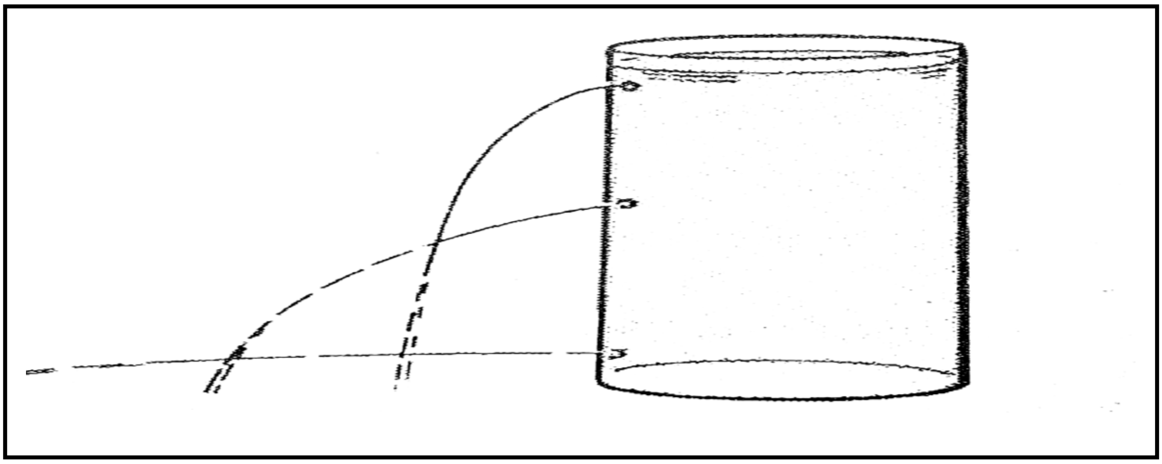


Figure 7 Pressure increases with depth. The deeper into the liquid you go, the greater the weight of liquid above and the higher the pressure.

Figure 8 Pressure depends on the density of the liquid. If water in a lake were replaced by a less dense liquid, the pressure at all points would be less.

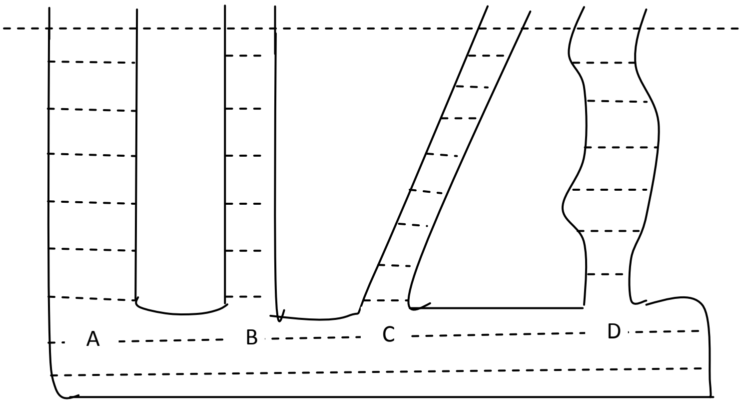


Figure 9 Pressure doesn't depend on the shape of the container. In the strange looking container above, the liquid stays at the same level in all four sections. Pressure at points A, B, C and D are all the same despite the different container shapes and widths.

Calculating pressure in a liquid

The pressure at any point in a liquid can be calculated provided you know the depth beneath the surface and the density of the liquid.

The container in figure below has a base area **A**. It is filled to a depth **h** with a liquid of density **ρ**. To calculate the pressure acting on the base, you first need to know the weight of liquid pressing down on the base.

Volume of liquid = base area x depth = Ah

Mass of liquid = density x volume = ρAh

Weight of liquid = mass x gravity = ρgAh

therefore, force on base = ρgAh

This force is acting on an area A:

Pressure = force/ area = ρgAh/A = ρgh

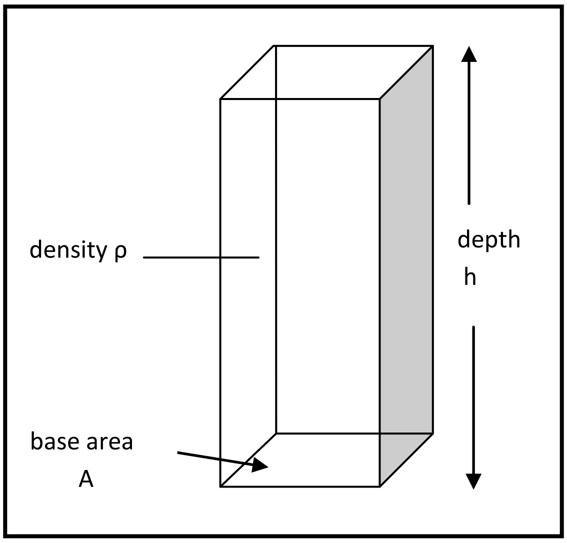


Figure 10 Pressure under a free surface

As well as depth, the pressure also depends on the:

- density of the fluid
- pull of gravity, g = 10N/kg

The pressure at a point h vertically beneath the surface of a liquid of density P = ρgh

Pressure = density x g x depth
(Nm^{-2}) = (kgm^{-3}) x (N/kg) x (m)

Example

Determine the pressure at a point 5.0m below the surface of fresh water of density 1000kgm^{-3}. Assume g = 10ms^{-2}.

Answer

Using the formula P=ρgh = 1000 x 10 x 5 = 50 000Pa

Now check what you have just learnt by trying out the learning activity on the next page!

Learning Activity 1

40 minutes

Answer all questions given and write the answer on the spaces provided. All working out must be shown.

1. Define the following terms:

   (i) Density

   ____
   ____

   (ii) Pressure

   ____
   ____

   (iii) Specific gravity

   ____
   ____

---

2. What is the density of an object of mass equal to 100 grams and a volume of 20 cubic centimeters?

---

3. What is the mass of an object of volume equal to 3 cubic metres and a density of 6000 kilograms per cubic metre?

---

4. A stone of mass 30 grams is placed in a measuring cylinder containing some water. The reading of the water level increases from $50cm^3$ to $60cm^3$.

   What is the density of the stone?

5. An empty density bottle has a mass of 25g. Its mass is 50g when full of water and 45g when full of another liquid.

   (a) What is the specific gravity of the liquid?

   (b) What is its density in kgm^{-3}?

---

6. A box weighs 100N, and its base has an area of $2m^2$.

   What pressure does it exert on the ground?

---

7. If atmospheric pressure is 100 000Nm^{-2}, what force is exerted on a wall of area $10m^2$?

---

8. Explain the following.

   a) Stiletto heels are more likely to mark floors.
   ____
   ____

   b) Eskimos wear snowshoes.
   ____
   ____

   c) It is useful for camels to have large flat feet.
   ____
   ____

Thank you for completing learning activity 1. Check and your work. Answers are at the end of the module.

Pascal's Law and Hydraulic Jack

Have you ever noticed that when an inflated balloon is pressed at one point, there is an increased pressure at every other point of the balloon? Measurement shows that the increase is the same at every point and equals to the applied pressure. This important observation led the French scientist Blaise Pascal (1623-62) to say that:
"Any pressure applied to fluid in an enclosed vessel is transmitted equally or undiminished to every point of the fluid." This law is known as **Pascal's principle**.

Thus, in the figure below,

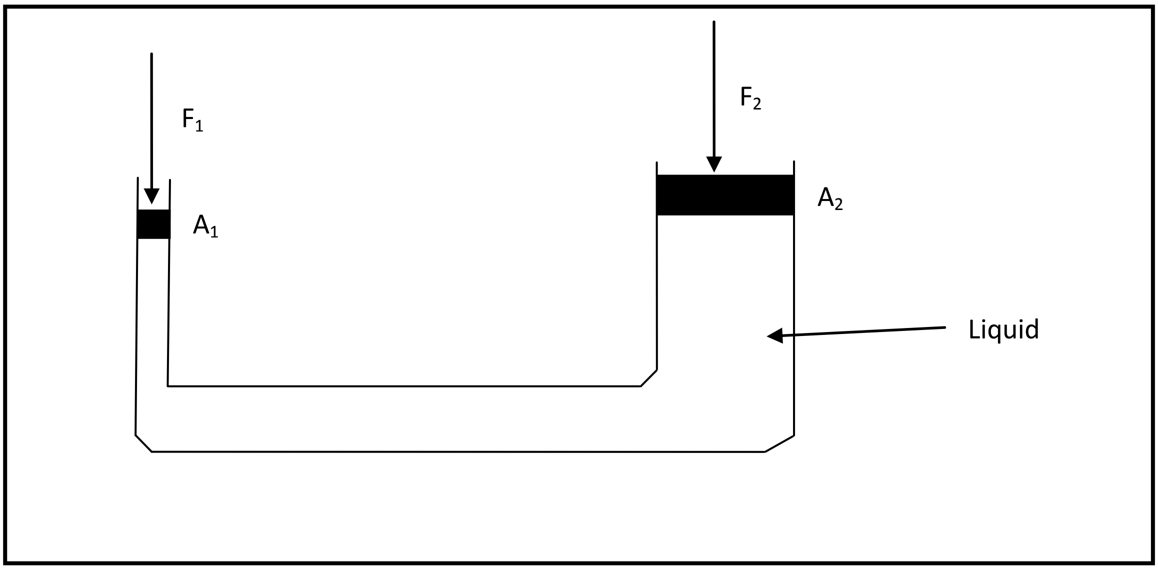


Figure 11 Pascal's principle

A pressure of $P_1 = F_1/A_1$ applied downward to the surface on the left of the container gets transmitted as an equal pressure upward of $P_2=P_1$ on the surface on the other side of the container. The force on the other side is given as:

$$F_2 = P_2A_2 = F_1 = (P_1/A_1)$$

If A_1 is less than A_2, the transmitted force F_2, is greater than the applied force.

From figure 11 above let say, $A_1 = 0.001m^2$ and A_2 is $0.1m^2$ with the same pressure of 10,000Pa.

Calculate the force applied by deriving F from the equation P= F/A then force would be $F_1 = P_1A_1$.

Next, substitute the given values of A_1 and $P_1$to give F_1= 10,000Pa x $0.001m^2$ = 10N.
Do the same for $F_2 = P_2A_2$ by substituting P_2 and A_2 to get F_2= 10,000 x 0.1= 1000N.

From the calculation above, you can say that output force is greater if A_1 is less than A_2. This is the principle behind hydraulic machines.

Hydraulic machines work by using liquids under pressure rather than levers or wheels. They make use of two properties of liquids.

1. Liquids are virtually incompressible; they cannot be squashed.
2. The pressure on a trapped liquid is transmitted to all parts of the liquid.

A hydraulic jack shown in the diagram below is an application of Pascal's principle. When a force, pushes down on the smaller surface, the liquid is forced into the large surface, pushing the liquid up. The force exerts a pressure on the liquid. This pressure is transmitted through the liquid and acts on the larger area, producing a greater upward force. Since a liquid is incompressible, the volume of liquid forced down the small cylinder is equal to that forced up the larger cylinder.

Pressure in small cylinder = pressure in large cylinder.

Pascal's principle states that, any pressure applied to fluid in an enclosed vessel is transmitted equally or undiminished to every point of the fluid

The Hydraulic jack and pumps

Hydraulic jacks are used to lift a heavy load. An example is changing a car tyre. Hydraulic pumps are used to raise cars in a motor workshop.

This device consists of two pistons "connected" by a liquid which is enclosed by metallic walls. The pistons have different cross-sectional areas as shown in figure 12.

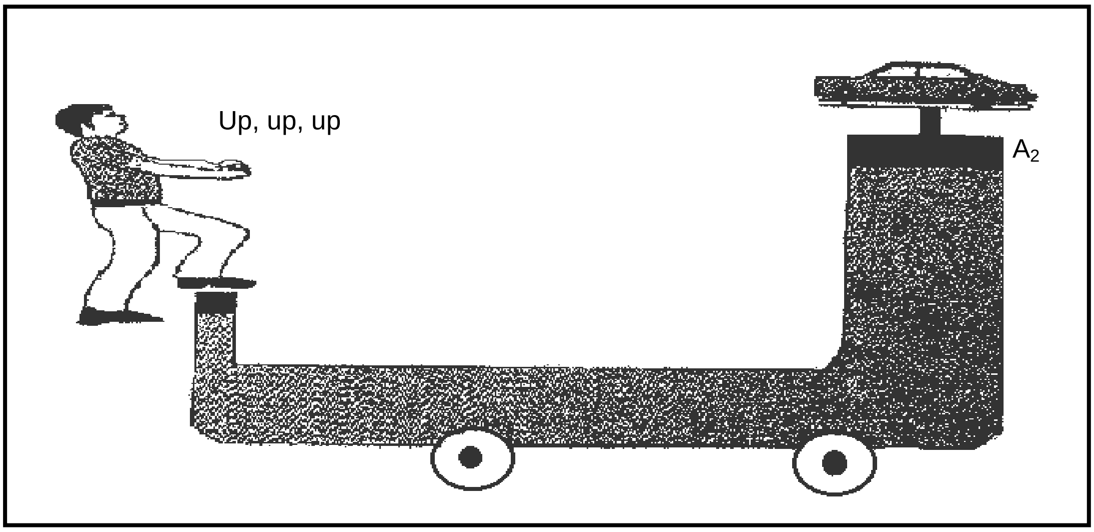


Figure 12 Hydraulic lift

Hydraulic brakes

Hydraulic brakes are used in cars, lorries and motorcycles. In a hydraulic brake system, a liquid, known as brake fluid is used to transmit pressure from the brake pedal to all the wheels of the vehicle. When the brake is pressed, the piston of the control cylinder applies a pressure on the brake fluid and this pressure is transmitted, via system of pipes, to each cylinder at the wheels. See diagram below.

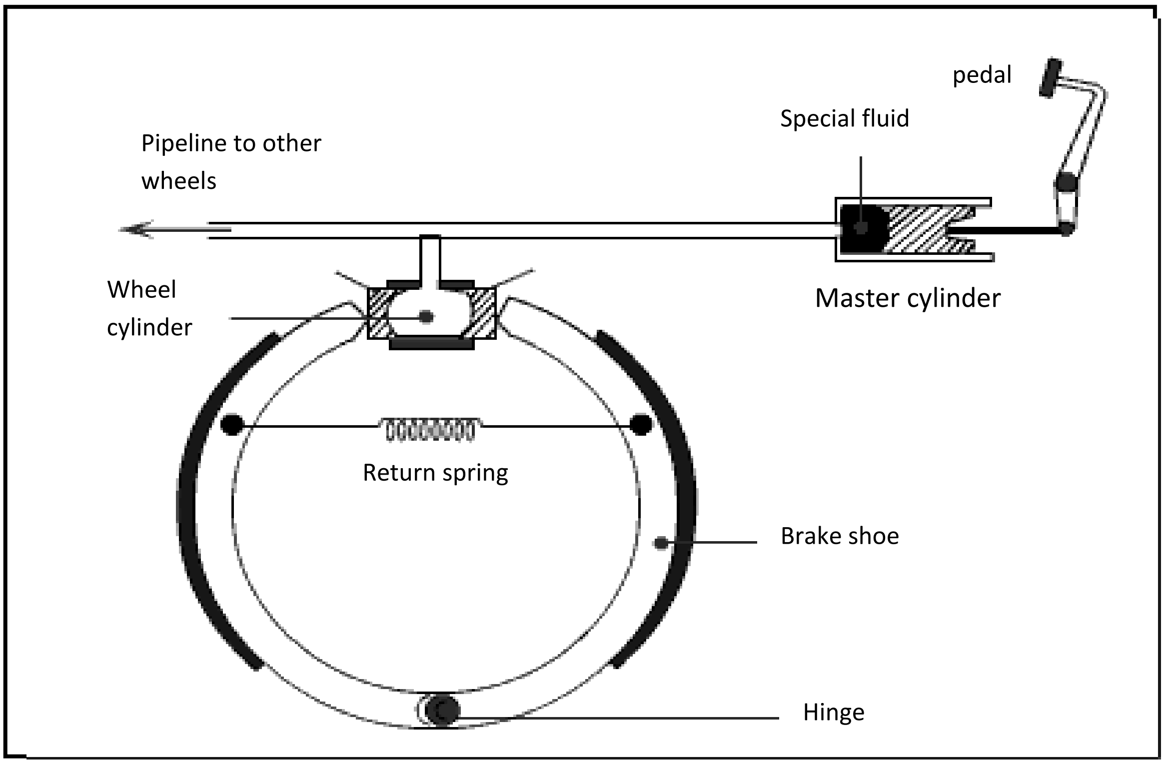


Figure 13 A Hydraulic brakes

Hydraulic lift and hydraulic hoist are the other example that uses the same principles.

Now check what you have just learnt by trying out the learning activity below!

Learning Activity 2

30 minutes

Read and answer the following questions on the spaces provided.

1. What is Pascal's Principle?

____
____
____

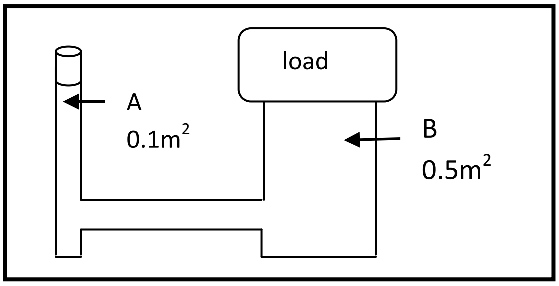
2. The area of the piston in a hydraulic hoist is $0.1m^2$. Calculate the pressure the compressed oil must have to lift a car on the hoist, if the weight of the car and the moveable part of the hoist is 20 000N.

---

3. For a hydraulic hoist, the area of the small piston is $0.001m^2$ while the area of the large piston is $0.1m^2$. What weight can be lifted by the large piston when a force of 70N is applied to the small piston?

---

4. The figure below shows a simple hydraulic jack. The load is just being lifted using an effort of 20N.



Simple hydraulic jack

Find the pressure at:

(i) A?

(ii) B?

---

5. A force of 500N in a hydraulic brake is applied to a piston of area $5cm^2$.

(a) What is the transmitted pressure throughout the liquid?

(b) If the piston has an area of $20cm^2$, what is the force exerted on it?

Thank you for completing learning activity 2. Now check your work. Answers are at the end of the module.

Archimedes Principle

The Greek scientist, Archimedes (287 to 211 B.C.) discovered the relationship between the principle of buoyancy or upthrust. It states that 'when an object is immersed partially or completely in a fluid, it is buoyed up by a force equal to the weight of the fluid displaced by the object'. It explains why an object is lighter when immersed in fluids.

When an object is immersed in a fluid, the fluid applies an upward force, a buoyant force (F_b) or upthrust on the object. The object rises if its weight is less than the buoyant force.

An object immersed in a fluid displaces a volume of the fluid that is equal to the volume of the object. The weight of the fluid displaced is equal to, W=mg.

From density, mass is equal to, m= ρv. Hence, W = ρVg, Where ρ = density in kg/m^3, V = volume in m^3 and g = pull of gravity in N/kg.

The principle of buoyancy or upthrust states that 'when an object is immersed partially or completely in a fluid, it is buoyed up by a force equal to the weight of the fluid displaced by the object.

Archimedes Principle applies to objects with different densities. If the density of the object is:

- greater than that of the fluid, the object will sink.
- equal to that of the fluid, the object will neither sink nor float.
- less than that of the fluid, the object will float.

A special case is the principle of floatation which states that:

A floating object displaces its weight

Consider the illustration below which shows a cylinder of cross sectional area A, immersed upright in a liquid of density ρ.

Downward thrust at top = $P_1A = \rho g h_1 A$
Upward thrust at the base= $P_2A = \rho g h_2 A$
Resultant thrust = $P_2A - P_1A$
= $\rho g h_2 - \rho g h_1 A$
= $(h_2 - h_1)\rho g A$
= $h \rho g A$

But Ah = volume of cylinder; Hence
ρAh = mass of fluid displaced, and
ρAhg = weight of liquid displaced; hence Archimedes principle.

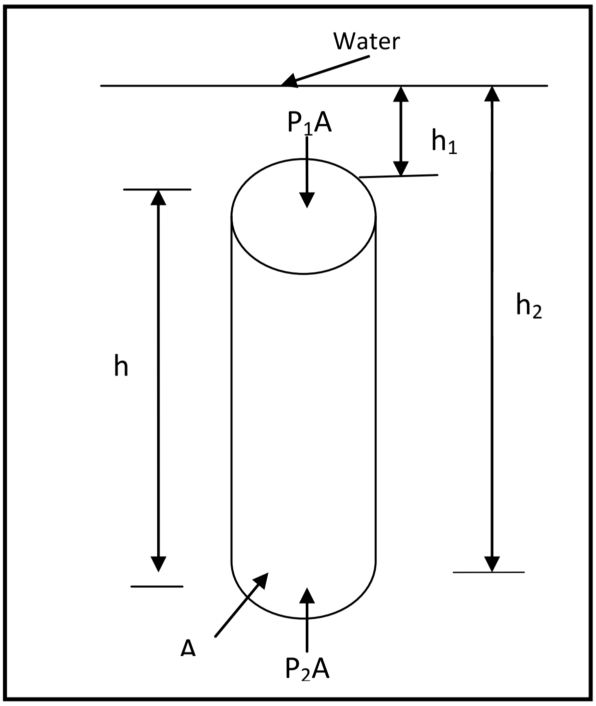


Figure 14 Cylinder of cross sectional area immersed upright in a liquid

All liquids exert an upthrust because the pressures inside the liquid increases as you go deeper (see figure 15). It means that the pressure on the bottom of an object is greater than at the top making a resultant force upwards.

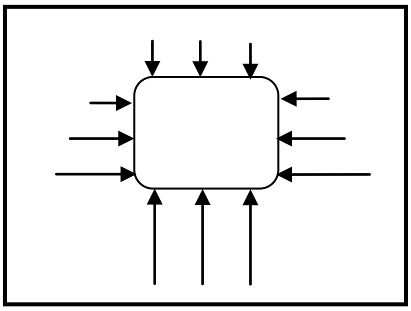


Figure 15 Pressure increases with depth

In tackling problems, note the following points:

1. Archimedes principle applies when an object is immersed in a fluid, whether the object is floating or not. The law of floatation applies only to floating object.

2. Archimedes principle and law of floatation are both concern with the weights of object and fluids. When solving problems however, you are often dealing with volumes. There is a link between the weight of a substance and its volume, as shown below.
   The density equation in the form
   Mass = volume x density
   but: weight = mass x gravity

It follows therefore that:

Weight = volume x density x gravity

Measurement of density using Archimedes principle

Archimedes' principle describes the relationship between the buoyant force and the volume of the displaced fluid.

We can write this principle in equation form as:

$$F_b = \rho_f V_f g$$

Where F_b is the buoyant force
ρ_f is the density of the displaced fluid
V_f is the volume of the displaced fluid
G is the acceleration due to gravity (9.8ms^{-2} or 10ms^{-2})

It is very important to remember that the density and volume in this equation refer to the displaced fluid and not the object submerged in it.

Buoyant force depends on density. The more dense a fluid, the more easily an object will float in it.

For a body floating in water:

Weight of the body = weight of the water displaced

$$mg = m_{water}g$$

Example 1

An object weighs 20N in the air. When placed in a can full of water it weighs only 15N.

What is the size of the upthrust of the object?

Upthrust = weight of an object in air – weight of an object in water

= 20N – 15N = 5N

What weight of water is displaced from the can?

According to Archimedes Principle,

Upthrust on the object = to the weight of the fluid displaced.
Upthrust on an object is 5N, therefore the weight of the water displaced = 5N

Example 2

A ship weighing 46 328t is lowered into water.

What weight of water would it displace?

Weight of the object = weight of the water displaced

Therefore the amount of water displaced is = 46 328t

Example 3

A ball of mass 2kg having a diameter of 50cm falls in the swimming pool. Calculate its buoyant force and volume of water displaced.

Solution

Given:

mass of water, m= 2kg

diameter of ball, d = 50 ÷100 = 0.5 m

r = 0.25m (r is the radius which is half of the diameter)

Step 1: Calculating Volume of a sphere.

volume of sphere, $V = 4/3\pi r^3$ (this is the formula to calculate for volume of any spherical object)

$V = 4/3\pi 0.25^3$ (substitution from the formula)

$V = 0.0208m^3$

Step 2: Calculate for the density.

Density = mass/volume

$= 2kg/0.208m^3$

$= 96kgm^{-3}$

Step 3: Calculate the Buoyant force by using the formula on calculating force.

Force = mg $(g=9.8ms^{-2})$

$F = 2kg \times 9.8m^{-2}$

F = 19.6N

Step 4: Calculate for Volume of the fluid by deriving based on Archimedes' formula.

$F_b= \rho_f V_f g$

$V_f = F/\rho_f g$

$V_f= 19.6/ 96 \times 9.8$

$V_f= 0.0208m^3$

Hence the volume of the ball = volume of displaced fluid.

Hydrometers

A hydrometer is a small float with a scale on it; used for measuring the relative densities of liquids. A hydrometer floats due to buoyancy. The portion of a volume of the rod immersed depends on the density of the liquid.

Note that the weight of the rod in each liquid is the same, it follows that

Upthrust = ρAhg (upward) Weight = mg (downwards)

Upthrust = Weight

ρAhg = mg

Example

If a hydrometer was a rod that had a length of 0.250m, with a cross- sectional area of 2.00 x 10^4 m^2, and a mass of 4.50 x 10^{-2}kg.

(a) How far from the bottom end of the rod should a mark of 1000 be placed to indicate the relative density of the water (density of 1000kg m^{-3})?

Solution

Since the problem is asking for height then we could derived from the equation

Upthrust = ρAhg = mg

$h = m/\rho A$

$h = 4.50 \times 10^{-2} / 1000 \times 2.00 \times 10^{-4}$

h **= 0.225m**

(b) If the hydrometer sinks to a depth of 0.229m when placed into an alcohol solution. What is the density of the alcohol solution?

Solution

In alcohol solution

$\rho = m/Ah$

$\rho = 4.50 \times 10^{-2} / 2.00 \times 10^{-4}(0.229)$

ρ = 983Pa

Now check what you have just learnt by trying out the learning activity on the next page!

Learning Activity 3

30 minutes

Read and analyse each question/s and write all your answer on the spaces provided.

1. When a person floats in a swimming pool, he or she experiences an upthrust. What causes this effect?

   ____
   ____
   ____

---

2. A hot air balloon has a volume of $200m^3$. It has a total weight of 2200N and keeps to the ground by a vertical rope. Given the density of air is $1.2kgm^{-3}$ find the upthrust acting on the balloon.

---

3. A basketball float in a bathtub of water. The ball has a mass of 0.5kg and a diameter of 22cm.

   What is the:

   (a) upthrust or buoyant force?

   (b) volume of water displaced by the ball?

---

4. A block of wood of volume $50cm^3$ and density $0.60gcm^{-3}$ floats in water.

   What is the mass of the:

   a) block?

b) water displaced?

---

5. What is:

a) Archimedes Principle?
____
____
____
____

b) the law of floatation?
____
____
____
____

Thank you for completing learning activity 3. Now check your work. Answers are at the end of the module.

Surface Tension and Capillarity

Have you ever wondered how a water strider is able to stride on water? How a razor blade or needle is able to rest on water surface without sinking? Or how a bubble and droplet are able to maintain their spherical shape? All these are possible due to a property of water called **surface tension**.

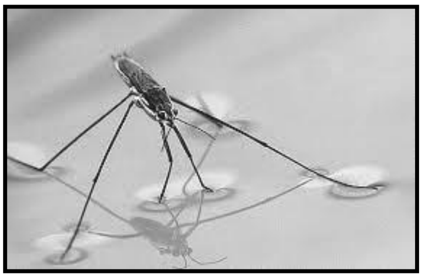


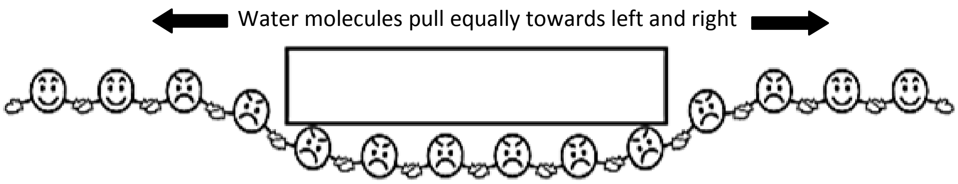
Figure 16 Insect on the water

Surface tension is the tendency of the surface of a liquid to behave like a stretched elastic skin. It is a liquid's ability to stick to itself at the surface.

What causes surface tension?
It occurs because of attractive forces between liquid molecules. The attractive force that causes surface tension to occur is called **cohesion**. Cohesion refers to forces between molecules of the same substance. Thus, surface tension is the reason a water strider is able to stride along water surface because cohesion makes it possible for water molecules to be attracted to each other at the surface. As a result water molecules pull together to stop themselves from breaking up and thus making the water surface to stretch like an elastic

skin. Therefore, a water strider is able to stride along the water surface without sinking and a razor is also able to rest on water.

(a) Water molecules on the surface pull together to form a stretched elastic skin



(b) Light objects like razor represented by this rectangular block cannot break the stretched elastic skin because water molecules are holding tight each other (cohesion). This is called surface tension

Figure 17 Surface tension

Consequently surface tension can also be referred to as a force because it is the tension between water molecules. Thus, surface tension can also be defined mathematically as:
"The force per unit length that acts across any line on a surface tending to pull the surface open".

$$\frac{F}{L} = \gamma$$

F = Force (N) L = Length (m) γ= coefficient of surface tension (Nm^{-1})

Liquid	Surface tension (Nm^{-1})
Benzene at 20	0.029
Blood at 37	0.058
Glycerine at 20	0.063
Mercury at 20	0.47
Water at 20	0.073
Water at 100	0.059
Ethanol at 20	0.023

Table 3 Surface tension of common liquids

Guidelines for calculations:
When you do calculations, the following are some guidelines for you to follow:

- objects with **one** surface in contact with water surface, you will use the equation

$$\gamma = \frac{F}{L}$$

- objects with **two** surfaces in contact with water surface, you will use the equation

$$\gamma = \frac{F}{2L}$$

- all calculations will be restricted to circular loops, circular plate and needle or razor
- if circular objects are used for calculations, length (L) is the circumference(2r)

objects with one surfaces	**objects with two surfaces**
Razor (all flat objects)	needle (all cylindrical objects)
circular plate	circular loops (rings)

Example 1

A horizontal circular loop of wire has a diameter of 5cm and is lowered in a sample of crude oil. The additional force required to pull the loop out of the oil is 0.04N; calculate the surface tension of the sample of crude oil. (use π = 3.14)

Solution with a circular loop there are two surfaces $\gamma = \frac{F}{2L}$

F = 0.04N γ =?

length = circumference = 2πr = 5cm ÷ 2 (convert to metres)

$$\gamma = \frac{F}{2L}$$

$$\gamma = \frac{0.04}{2 \times 2 \times 3.14 \times 0.025}$$

$\gamma = 0.127 Nm^{-1}$

Example 2

Calculate the force required to pull a flat circular plate of radius 15cm away from the surface of a liquid which has a surface tension of $0.053Nm^{-1}$. (use π = 3.14)

Solution with a circular plate there is only one surface $\gamma = \frac{F}{L}$

$\gamma = 0.053Nm^{-1}$ F = ?

length = circumference = 2πr = 15cm (convert to metres)

F = L x γ

F = 2πr x 0.053

F = 2 x 3.14 x 0.15 x 0.053

F = **0.05N**

Example 3

A needle has a length of 3.2cm. When placed gently on the surface of the water (0.073N/m) in a glass, this needle will float if it is not too heavy. What is the weight of the heaviest needle that can be used in this demonstration?

Solution with a needle it has two surfaces $\gamma = \frac{F}{2L}$

$\gamma = 0.073Nm^{-1}$ F = ?

length = 3.2cm (convert to metres)

$F = 2L \times \gamma$

$F = 2 \times 0.032 \times 0.073$

$F =$ **$0.0045N$**

Effects of surface tension

There are many effects of surface tension of which some have been mentioned earlier where light weight objects or insects are able to rest or walk on water. It also provides enough tension for the formation of bubbles with water and pulls the bubbles into spherical shapes. Surface tension is responsible for the shape of liquid droplets which tend to be pulled into spherical shape by cohesive forces of the surface layer. One of the vital effects of surface tension is called **capillary action**.

Capillary action

When you drink a vita juice, the liquid travels up the straw by capillary action. **Capillary action** is the rise or fall of a liquid in a small passage such as a tube of small cross-sectional area, like the spaces between the fibres of a towel or the openings in a porous material. The two forces responsible for the movement of water molecules up the tube are **cohesion** and **adhesion**. **Adhesion** refers to forces between molecules of different substances.

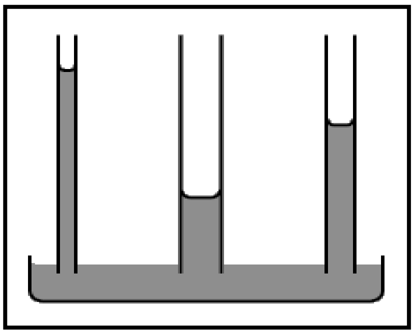


Figure 18 Capillary tubes

Consider the three glass tubes in the diagram on the right. Inside the tube, adhesive forces draw the water up the sides of the glass tubes to form a meniscus. Cohesive force then tries to minimize the surface area by drawing water up the tube against gravity. This rise in the water level in the tube is due to the **adhesive** and **cohesive** forces.

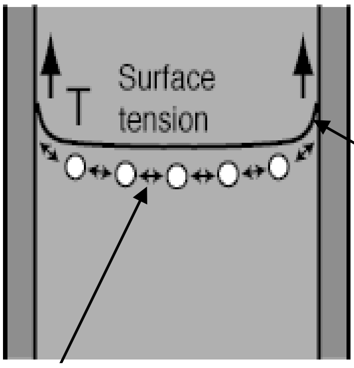


Figure 19 Comparison between adhesion and cohesion

In the diagram above, we can see that water molecules are attracted to the side of the glass molecules. Since the adhesive force is greater than cohesive, water level rises. While water rises, cohesive forces maintain the surface tension on the water surface. Thus, water rises up the tube as we know it as capillary action.

A material becomes **wet** because the adhesive forces are greater than the cohesive forces. This is the principle used for diapers, towels, sponges and other liquid absorbent technologies. Before concrete is laid on the foundation of a house or building a sheet of polythene is laid in the concrete base to stop water from moving from the ground up into the concrete which is porous. Whether a liquid rises or falls in a tube depends on the relative strength of the adhesive and cohesive forces.

Capillary action calculation

The actual amount of rise (or fall) depends on the surface tension (γ) (since it is this which keeps the surface of the liquid from breaking apart) as well as on the contact angle **ϕ** and the radius ***r*** of the tube.

The height (**h**) to which the liquid can be lifted is given by $h = \frac{2\gamma\cos\phi}{\rho g r}$

h - height (**m**)

γ - surface tension (**Nm^{-1}**)

ρ - density of liquid (**kgm^{-3}**)

g - 10 (**Nkg^{-1})**

Example 1

When a capillary tube stands upright in a beaker of water $\gamma = 0.073Nm^{-1}$), the water rises **h** cm in the tube. If the radius of the tube is 2mm, calculate **h** assume $\phi = 30^o$ and density of water $\rho = 1000kgm^{-3}$. (Use $g = 10Nkg^{-1}$)

Solution

$$h = \frac{2\gamma \cos \phi}{\rho g r}$$

$$h = \frac{2 \times 0.073 \times \cos 0°}{1000 \times 10 \times 0.002}$$

$$h = 0.0073m \qquad (0.73cm)$$

Example 2

At a certain temperature, water has a surface tension of 0.4N/m. In a 3mm diameter vertical tube if the liquid rises 6 mm above the liquid outside the tube, calculate the contact angle. (Use $g = 10Nkg^{-1}$, $\rho = 1000kgm^{-3}$)

Solution

$$h = \frac{2\gamma \cos\phi}{\rho g r}$$

$$\cos \phi = \frac{\rho g h r}{2\gamma}$$

$$\cos \phi = \frac{1000 \times 10 \times 0.0015 \times 0.006}{2 \times 0.4}$$

$$\cos \phi = 0.1125$$ (take the inverse of cosine)

Bubbles and liquid drops

Because of surface tension, a liquid will tend to form droplets which are spherical in size. Surface Tension acts to minimize the surface area of the liquid.

Pressure difference in a bubble

The pressure in a bubble is normally greater than the pressure on the outside. This difference in pressure depends on the surface tension γ of the fluid and the radius R of the bubble. This relationship is given by the equation;

$$P_i - P_o = \frac{4\gamma}{R}$$

This equation comes about by the assumption that there are two surfaces (one inside and the other outside) to a bubble. An interesting fact is that the pressure inside a smaller bubble is greater than the pressure in a larger bubble.

Pressure difference in a spherical droplet

The pressure difference in a liquid droplet is about half that of a bubble.

$$P_i - P_o = \frac{2\gamma}{R}$$

A bubble has two surfaces; whereas a droplet only has one surface.

Example 1

A student uses a circular loop of wire and a pan of soapy water, to produce a soap bubble whose radius is 1.0mm. The surface tension of the soapy water is $\gamma = 2.5 \times 10^{-2} Nm^{-1}$ Determine the pressure difference between the inside and outside of the bubble.

Solution

$$P_i - P_o = 4\gamma/R$$

$$P_i - P_o = \frac{4 \times 2.5\ 10^{-2}}{0.001}$$

$$P_i - Po = 100\ Pa$$

Example 2

The same soapy water used in example 1 is used to produce a spherical droplet whose radius is one-half that of the bubble, or 0.50mm. Find the pressure difference between the inside and outside of the droplet.

Solution

$$P_i - P_o = 2\gamma/R$$

$$P_i - P_o = \frac{2 \times 2.5 \times 10^{-2}}{0.0005}$$

$$P_i - P_o = 100Pa$$

Example 3

A needle has a length of 3.2cm. When placed gently on the surface of the water (γ= 0.073N/m) in a glass, the needle will float if it is not too heavy.

What is the weight of the heaviest needle that can be used?

Reasoning

As the end view in the diagram below shows, three forces act on the needle, its weight W and the two forces F_1 and F_2 due to the surface tension of the water. The forces F_1 and F_2 result from the surface tension acting along the length of the needle on either side.

According to equation $\gamma = F / L$, they have the same magnitude $F_1 = F_2 = \gamma L$ where γ= 0.073N/m is the surface tension of the water and L is the length of the needle. F_1 and F_2 is each tangent to the indented water surface that is formed when the needle presses on the surface, with the result that each acts at an angle θ with respect to the vertical. The needle floats in equilibrium. Therefore, the net force acting on the needle is zero

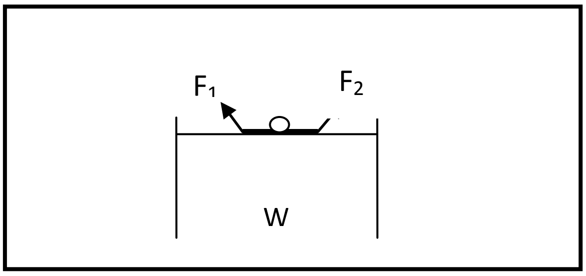
$$\Sigma F = 0$$

$$F_1 + \quad F_2$$

$$W = (\gamma L) \cos \theta + (\gamma L) \cos \theta$$

$$W = 2(\gamma L) \cos \theta$$

$$W = 2(0.073N/m)\ (0.032m) \cos 0$$



Three forces act on the needle

W = 4.7×10^{-3}N

Now check what you have just learnt by trying out the learning activity below.

Learning Activity 4

30 minutes

Read and understand each question below and write ALL your answer in the space provided after each number. Show all your working out if necessary.

1. Define the following terms:

   (i) Capillary action

   ____
   ____
   ____

   (ii) Surface tension

   ____
   ____
   ____

   (iii) Adhesion

   ____
   ____
   ____

   (iv) Cohesion

   ____
   ____
   ____

---

2. A student using a pan of soapy water and a circular loop of wire produces a soap bubble whose radius is 1.5mm. The surface tension of the soapy water is $\gamma = 3.0 \times 10^{-2}$ N/m.

   Find the bubble's pressure difference between the inside and outside.

3. Suppose a horizontal circular loop of wire has a diameter of 5cm and is lowered into sample of crude oil and suppose the additional force that is required to pull the loop out of the oil is 0.04N.

   Calculate the surface tension of the sample of crude oil.

---

4. A razor blade has a length of 4.2cm. When placed gently on the surface of the water (γ= 0.083 N/m) in a glass, the needle will float if it is not too heavy.

   What is the weight of the heaviest razor blade that can be used?

Thank you for completing learning activity 4. Now check your work. Answers are at the end of the module.

12.1.2 Fluid Dynamics

Fluid dynamics deals with fluids in motion.

It has a broad range of applications which include calculation of forces and moments on aircraft or determining the mass flow rate of petroleum through pipelines and so on.

Fluid dynamics offers a systematic structure that underlies these practical applications derived from flow measurement to solving practical problems.

Problems typically involve calculating various properties of the fluid such as flow velocity, pressure and density and temperature as a function of space and time.

The study of fluid dynamics can be complicated due to turbulence, frictional forces between molecules and layers of the fluid and other influences.

Thus, we can make certain simple assumptions to help us understand fluid in motion. An ideal fluid is a fluid that cannot be compressed. These main assumptions are the following:

i. Zero viscosity
No internal friction between layers of fluid.

ii. Non- compressibility
The density of the fluid remains the same throughout the fluid.

iii. Streamline or laminar flow
The fluid particles follow smooth, predictable flow lines.

iv. Steady state condition
Fluid velocity and pressure at each point in the fluid do not change with time.

Definition of types of flow

1. **Steady flow**
Fluid particles that pass any given point in a steady flow follow the same path at the same speed.

2. **Turbulent flow**
Turbulent flow is a disorderly flow in which the fluid velocity of the fluid particles changes with time.

3. **Laminar flow**
Laminar flow is a kind of steady flow in which the velocities of all particles on a given streamline are the same. However, the particles of different streamlines may move at different speeds.

4. Irrotational flow

The flow in which the element of the moving fluid suffers no net rotation from one instant to the next with respect to the given frame of reference. It is the flow in which fluid particles do not rotate about their own axes and retain their own orientations.

Continuity and Bernoulli's Equations

Continuity and Bernoulli's equations express the conservation of mass in the flow of fluids under steady conditions.

Flow rate and equation of continuity

Volume flow rate is a volume of fluid passing through a pipe, at a point, per unit time in a non-uniform cross section of a pipe or hose. Mathematically, defined as:

$$\text{Flowrate} = \frac{\Delta V}{\Delta t} = A\frac{\Delta x}{\Delta t} = Av$$

where A is the cross-sectional area of the pipe at that point and $v = \Delta x/\Delta t$ is the fluid velocity. The unit of flow rate is m^3s^{-1}.

Example

A tank of capacity $500m^3$ is being filled in half an hour. Calculate its flow rate.

Solution

Given

$V = 500m^3$

T = 30 minutes = 30 x 60 = 180s

Flow rate is given by

$Q = V/t$

$= 500/180$

$= 2.778m^3s^{-1}$

Mass flow rate is defined as the rate of fluid mass through a unit area. It directly depends on the density, velocity of a fluid and area of cross section. In other words, it is the movement of mass per unit time. It is denoted by m and the unit is kgs^{-1}. The formula for mass flow rate is given as:

$$m = \rho VA$$

Where ρ is the density of fluid

V is the velocity of the fluid

A is the area of cross section

Example 1
Calculate the mass flow rate of a given fluid whose density is $785kgm^{-3}$. Velocity and area of cross section are $10ms^{-1}$ and $15cm^2$ respectively.

Solution

Given parameters are
$\rho = 785kgm^{-3}$
$V = 10ms^{-1}$
$A = 15cm^2 = 0.15m^2$

The formula for mass flow rate is
$m = \rho VA$
$m = 785 \times 10 \times 0.15$
$m = 1177.5kgs^{-1}$

Example 2
Density and velocity of a fluid is given as $920kgm^{-3}$ and $5ms^{-1}$, this fluid is flowing through an area of $25cm^2$. Calculate the mass of flow rate.

Solution

Given parameters are
$\rho = 920kgm^{-3}$
$V = 5ms^{-1}$
$A = 25cm2 = 0.25m^2$

The formula for mass flow rate is
$m = \rho VA$
$m = 920 \times 5 \times 0.25$
$m = 1150kgs^{-1}$

The **continuity equation** states that if the fluid is incompressible, the flow rate must be the same everywhere along the cross-section of the pipe.

According to the conservation of fluid particles which states that 'All material that enters a pipe will leave the pipe'. (See Figure 20 below) This statement is based on Newton's mechanics, and the idea that mass could not be created or destroyed. Mathematically, this is defined as:

$$Av = \text{constant}$$

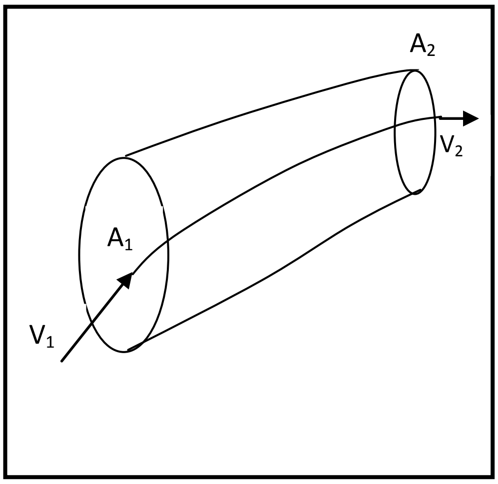


Figure 20 The flow of fluid through a pipe

Derivation of the Equation of Continuity
Consider a fluid under steady flow, then;

Mass of the fluid entering X= Mass of fluid leaving Y
If ρ is the density of the fluid and V is the volume

then

$$\rho_1 V_1 = \rho_2 V_2$$

where

$$V_1 = A_1 \times V_1 \times \Delta t$$

Where $v_1\Delta t = \Delta d$ is the distance moved within a time interval Δt.

Likewise at Y the volume of the fluid leaving Y is

$$V_2 = A_2 \times V_2 \times \Delta t$$

Cancelling out Δt leads to the equation of continuity that is

$$\rho_1 A_1 v_1 = \rho_2 A_2 v_2 \quad \text{(equation 1)}$$

For an incompressible fluid, equation (1) above density is constant therefore equation above reduces to

$$A_1 v_1 = A_2 v_2 \quad \text{(equation 2)}$$

The product Av is the flow rate whose SI units are in m^3/s. Therefore, ρAv expresses the conservation of mass in the steady flow of fluid.

Example

Air flows into a house through the open window. The airspeed is a gentle $30cms^{-1}$. It is a sliding window of dimension 1200mm x 400mm. Inside the room, the far door is open by just 10cm. The door is a standard height of 2050mm. What is the speed of the air as it flows through the door?

Window area $= A_1$

$= 1.2m \times 0.4m$ (convert 1200mm and 400mm to m)

$\mathbf{= 0.48m^2}$

Fluid speed through the window $= v_1$

$\mathbf{= 0.30ms^{-1}}$

Door area $= A_2$

$= 0.10m \times 2.05m$

$\mathbf{= 0.205m^2}$

The rate of air flow is a constant.

Flow rate in through the window = flow rate out through the door

$$A_1 v_1 = A_2 v_2$$

$0.30ms^{-1} \times 0.48m^2 = 0.205m^2 \times v_2$

$\mathbf{v_2 = 0.70ms^{-1}}$

Bernoulli's Equation

Bernoulli equation is an equation of fluid motion valid for an ideal fluid under steady flow. An ideal fluid is incompressible and non-viscous.

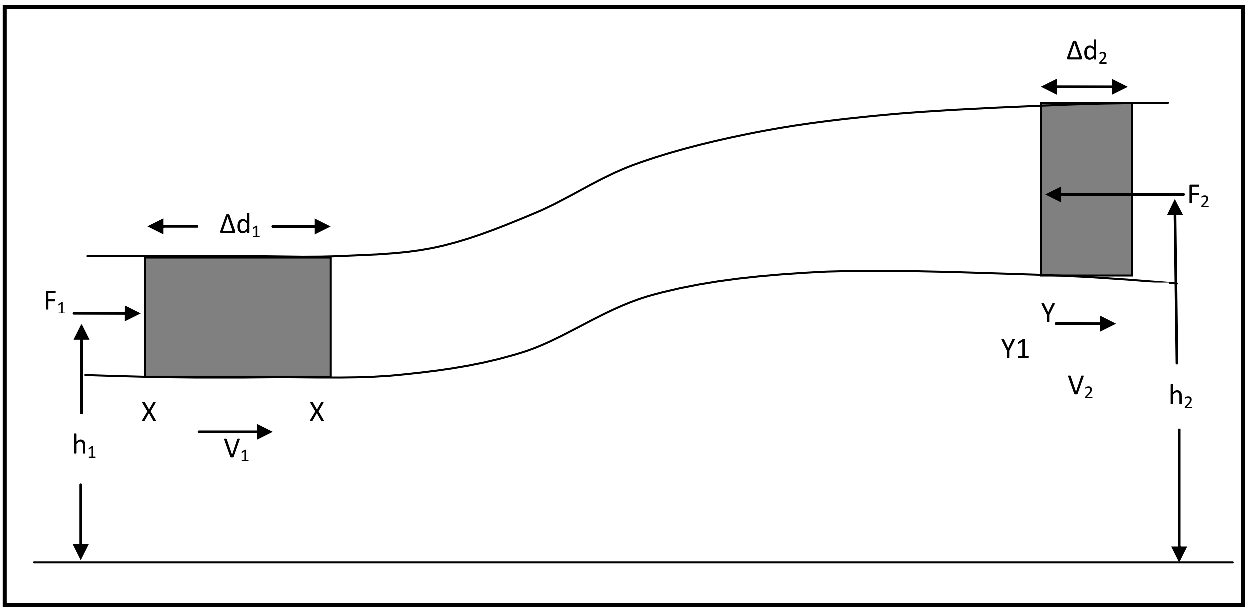


Figure 21 Illustration of Bernoulli principle

In words, Bernoulli's equation states that
"The pressure plus kinetic energy per unit volume plus potential energy per unit volume is constant at all points on a streamline".

Force F_1 does work on the shaded fluid to move it from X to Y. The fluid therefore, gains kinetic and potential energy, applying the work -energy principle to the fluid.

From conservation of energy, the work done in moving a volume of fluid through a portion of pipe must go into kinetic energy and potential energy of the fluid. The conservation of energy in this situation is kinetic energy and potential energy, which is the mechanical energy of the fluid, must be conserved.

$$E_1 = E_2$$

$$W_1 + PE_1 + KE_1 = W_2 + PE_2 + KE_2$$

$$W_1 = F_1 d_1 = P_1 A_1 \Delta d_1$$

On the right, the work done by the pressure = $W_2 = -F_2 d_2 = -P_2 A_2 \Delta d_2$

The minus sign signifies the force is in opposite direction to the motion. By the Continuity Equation, the amount of fluid entering the pipe on the left must equal to the amount leaving on the right. This is expressed in equation, (see next page)

$$A_1v_1 = A_2v_2$$

The volume (V) of the fluid can undergo both a change in kinetic energy and potential energy as it is pushed through the pipe.

$$\Delta KE = ½ \rho Vv_2^2 – ½ \rho Vv_1^2$$

$$\Delta PE = \rho Vgh_2 – \rho Vgh_1$$

Now we equate the work done ($W = W_1 + W_2$) to the change in mechanical energy ($\Delta KE + \Delta PE$) lead us to Bernoulli's equation.

$$P_1 + ½ \rho v_1^2 + \rho gh_1 = P_2 + ½ \rho v_2^2 + \rho gh_2$$

The equation above, P_1, v_1 and h_1 are the pressure. Fluid velocity and height of the fluid on the left side of the equation and P_2, v_2, and h_2 are the same parameters on the other side. If there is no height difference, Bernoulli's equation relates the pressure at two points along the flow to the fluid velocities and reduces to:

$$P_1 – P_2 = ½ \rho (v_2^2 – v_1^2)$$

Therefore, a pressure in the fluid decreases whenever the fluid velocity increases. Example application are a lift produced by an airplane wing, the curving of a spinning baseball and the fact that the shower curtain gets sucked in when you first turn on the shower.

Applications of Bernoulli's principle

The dynamic lift

The dynamic lift is one of the forces acting on an aeroplane.

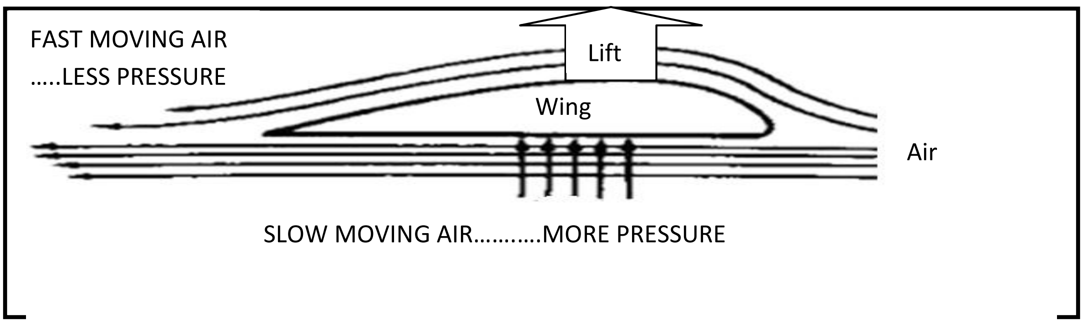


Figure 22 Dynamic lift on an aeroplane

In an aeroplane wing, the top of the wing is somewhat curved, while the bottom of the wing is totally flat. While in the sky, air travels across both the top and the bottom simultaneously. Because both the top and the bottom part of the plane are design differently, this allows for the air on the bottom to move slower which creates more pressure on the bottom, and allows for the air on the top to move faster, which creates less pressure. This is what creates the lift, drag and thrust. Thrust is the force that enables the aeroplane to move forward while drag is air resistance that opposes the thrust force.

Baseball

One example in baseball is in the case of the curve ball. The entire pitch work because of Bernoulli's principle. Since the stitches of the ball actually form a curve, it is necessary for the pitcher to grip seams of the baseball. The reason as to why it is necessary is that by gripping the baseball this way, the pitcher can make the ball spin. This allows for friction to cause a thin layer of air. It allows more air pressure on the top of the ball and less air pressure on the bottom of the ball. Therefore, according to Bernoulli's principle there should be less speed on top of the ball than there is on the bottom of the ball. What transpire is that the bottom part of the ball accelerates downward faster than the top part, and this phenomenon allows for the ball to curve downward, which cause the batter to miscalculate the ball's position.

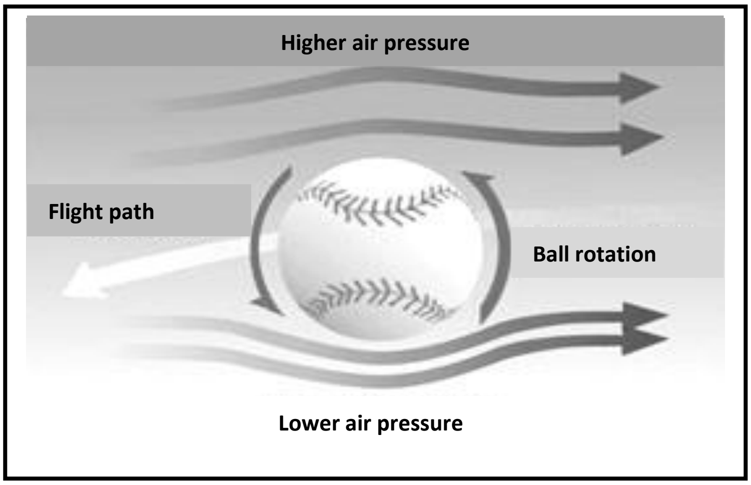


Figure 23 Air movement in baseball

Now check what you have just learnt by trying out the learning activity on the next page.

Learning Activity 5

40 minutes

Read and analyse each question and write your answers on the space provided.

1. A wind blows at the speed of 30m/s across a 175m^2 flat roof of a house.

   (a) What is the pressure difference between the inside of the house and the outside of the house just above the roof?
   (Assume that the air pressure inside the house is atmospheric pressure)

   (b) What is the force on the roof due to the pressure difference?

---

2. Water enters a house from a ground pipe with an inside diameter of 2.0cm at an absolute pressure of 4.0 x 10^{5}Pa. A pipe that is 1.0cm in diameter leads to the second floor bathroom 5.0m above the ground floor. The flow speed at the ground pipe is 1.5ms^{-1}.

   Find the:

   (a) flow speed.

   (b) pressure.

---

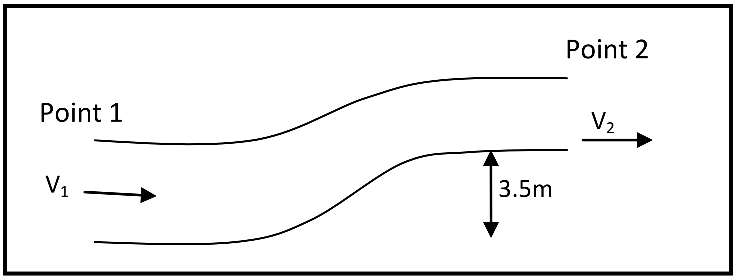
3. A needle inserted into a vein during blood transfusion has a gauge pressure of 1525Pa.

   The density of blood is 1.06 x 10^{3}kgm^{-3}.

   What is the height that a blood container is placed so that blood may just enter the vein?

4. Water flows through a pipe as shown below at a velocity of $0.20ms^{-1}$. The diameter at point 1 is 0.5m. At point 2, which is 3.5m higher than point 1, the diameter is 0.30m.

If the end point 2 is open to the air, determine the pressure at point 2.



Water flowing through a pipe

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5. A hosepipe of diameter 4cm is used to fill a 40 litre container. It takes 2 minutes to fill the container.

a) Calculate the speed at which the water enters the hose.

b) The open end of the hose is squeezed to a diameter 2.5cm. What is the speed at which water comes out of the hose?

Thank you for completing learning activity 5. Now check your work. Answers are at the end of the module.

NOW REVISE WELL USING THE MAIN POINTS ON THE NEXT PAGE.

Summary

You will now revise this module before doing **ASSESSMENT 1**.
Here are the main points to help you revise. Refer to the module topics if you need more information.

- A fluid is a substance that offers no permanent resistance to deforming forces. Gases and liquids are fluids because they have the ability to flow.
  Gases
  - freely moving particles
  - compressible
  - Pressure due to the particle collisions with walls

  Liquids
  - loosely bound particles
  - incompressible
  - pressure due to the weight of the liquid
- The density of a material is defined as its mass per unit volume with unit measured of grams per cubic centimeters or kilograms per cubic meter,

  Density = mass/ volume.

  The specific gravity of a substance tells you how many times more dense the substance is than water. It is defined as the ratio of the density of the substance to the density of water ($\rho_{water} = 1 \times 10^3 \ kgm^{-3}$).
- Pressure is defined as force per unit area. The force being at right angles to the area

  P= F/A.

  Pressure is measured in Pascals where one Pascal equals one Newton per square meter.
- Pressure of a fluid increases with depth. The pressure at a depth (h) in a liquid is given by ρgh where ρ is the density of the liquid and g is the acceleration due to gravity.
  Pascal's Principle: if an external pressure is applied to a confined fluid, this pressure is transmitted equally to every other point in the fluid and the walls of the container.

  P = F/A

  Hydraulic jack, Hydraulic lift, hydraulic brakes, hydraulic hoist are examples that uses Pascal's principles.
- Archimedes Principle states that an object submerged wholly or partially in a fluid is buoyed up by a force equal to the weight of fluid it displaces. This principle is used in a method to determine specific gravity, and explains why objects whose density is less than that of a liquid will float in that liquid.
- Law of floatation: A floating object displaces its own weight of fluid in which it floats. A material floats in a fluid if its density is the same as or less than that of the fluid.
- Fluid flow rate is the mass or volume of fluid that passes a given point per unit time. The equation of continuity states that for an incompressible fluid flowing in an enclosed tube, the product of the velocity of flow and the cross-sectional area of the tube remains constant:

  Flow rate = $A_1v_1 = A_2x_2$

- Primary, two types of fluid flow exist – laminar and turbulent. Laminar flow occurs when the fluid particles move along a uniform, smooth path called a streamline and typically occurs in a small pipe or other low flow media. Turbulent flows occurs when fluid particles irregularly and cause a change in velocity and typically occurs in large pipes or other high flow media.
- Bernoulli's principle states that pressure and velocity are inversely related, or that the presence in a fluid decreases when the fluid's velocity increases as seen in the equation.

$$P_1 + ½ \rho v_1^2 + \rho g h_1 = P_2 + ½ \rho v_2^2 + \rho g h_2$$

Bernoulli's equation remains equal at different points in a horizontal pipe. In a pipe that is not consistent in height, Bernoulli's equation still remains equal, but takes into account height differences at different points in a pipe as noted by h in equation above.

We hope you have enjoyed studying this module. We encourage you to revise well and complete Assessment 1.

NOW YOU MUST COMPLETE ASSESSMENT 1 AND RETURN IT TO THE PROVINCIAL CENTRE CO-ORDINATOR.

✓ Answers to Learning Activities 1 - 5

Learning Activity 1

1. (i) Density of a material tells us how much of the material (that is its mass) is packed into a unit volume.

   (ii) Pressure is the size of the force divided by area over which it acts.

   (iii) Specific gravity is the ratio of the density of the substance to the density of water.

2. D = m/V

   D = 100g / 20cm^3

   D = 5gcm^{-3} (5000kgm^{-3}) (any of the two is accepted)

3. D = m/V m = DV

   m = 6000kg/m^3 x 3m^3 = 18000kg

4. m = 30g

   V = 60 -50 = 10cm^3

   D = m/V

   D = 30g / 10cm^3 = 3gcm^{-3}

5. a) 50 – 25 = 25 (water)

   45 – 25 = 20 (substance)

   Spec. Gravity = Density of substance/ Density of water

   Spec. Gravity = 20 /25 = 0.8

   b) 0.8 X 1000 = 800kg/m^3

6. P =F / A

   P =100N/ 2m^2 = 50N/m^2

7. P = F/A F = PA

   F = 1 00 000 X 10 = 1 000 000N

8. a) Because the surface area of the stiletto is small so it exert greater pressure on the floor hence the mark.

b) To avoid sinking into the ice, snowshoes have a larger surface area so exerting lesser pressure on the ice.

c) So it would not exert greater pressure on the sand preventing the animals from sinking

---

Learning Activity 2

1. Pascal's Principle states that any pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid.

2. P = F / A

   P = 20 000N/ 0.1m^2

   P = 200 000N/m^2 or 200 000Pa

3. P = F/A

   $$\frac{f}{a} = \frac{F}{A}$$

   $$\frac{70}{0.001} = \frac{F}{0.1}$$

   70 (0.1) = 0.001 F

   $$\frac{7}{0.001} = \frac{0.001F}{0.001}$$

   F = 7000 N

4. (i) Pressure A = F/A
   = 20/0.1
   = 200Pa

   (ii) Pressure B = F/A
   = 20/0.5
   = 200Pa

5. (a) 100Ncm^{-2} (1 000 000Nm^{-2})

   (b) 2000N

Learning Activity 3

1. Upward pressure of the water
2. Upthrust = weight of air displaced

   Mass of air = density of air x volume of air

   = 1.2 x 200 = 240kg

   Weight of displaced air = mg

   = 240 x 10 = 2400N

   Upthrust = 2400N

3. a) F_b =mg

   F_b –mg = 0

   F_b= 0.5 X 10 = 5N

   b) By Archimedes principle, the buoyant force is equal to the weight of fluid displaced.

   $F_b = \rho Vg$

   $V = F_b/\rho g = 5/\ 1000\ (10) = 0.05m^3$

4. a) $\rho = m/V$ derived $m = \rho V = 0.60g/cm^3(50cm^3) = 30g$

   b) Mass of the object = mass of the water displaced

   Mass of object is 30g therefore mass of the water displaced is also 30g

5. a) The principle of buoyancy or upthrust states that 'when an object is immersed partially or completely in a fluid, it is buoyed up by a force equal to the weight of the fluid displaced by the object.

   b) Law of floatation states that "A floating object displaces its own weight"

Learning Activity 4

1. (i) Capillary action is the rise or fall of a liquid in a small passage such as a tube of small cross-sectional area, like the spaces between the fibres of a towel or the openings in a porous material.

   (ii) Surface Tension is the tendency of the surface of a liquid to behave like a stretched elastic skin. It is a liquid's ability to stick to itself at the surface.

(iii) Adhesion - refers to forces between molecules of different substances.

(iv) Cohesion - refers to forces between molecules of the same substance.

2. (a) The pressure difference $P_1 - P_2$ between the inside and outside of the soap bubble is given by equation

P_1-P_2 = 2ϒ/r = 2 (3.0 x 10^{-2} N/m) / 1.5 x 10^{-3}m = 40Nm^{-2}

3. γ = F/L

= 0.04 / 0.05m (5cm = 0.05m)

= 0.8Nm^{-1}

4. W = 2(ϒL) cos θ

= 2 (0.083N/m) (0.042m) (convert 4.2cm to m)

W = 6.97x 10^{-3}N

Learning Activity 5

1. Convert mm to m

1m = 1000mm

Window area = A_1

= 1.2m x 0.4m

= 0.48m^2

Fluid speed through the window = V_1 = 0.30ms^{-1}

Door Area = A_2

= 0.10m x 2.05m

= 0.205m^2

The rate of air flow is a constant
Flow rate in through the window = flow rate out through the door

$A_1v_1 = A_2v_2$

0.30ms^{-1} x 0.48m^2 = 0.205m^2 x v

v_2 = 0.70ms^{-1}

The flow rate through the door at a speed of 0.70ms^{-1} or 70cms^{-1}

2. a) Flow speed at the second floor $A_1v_1 = A_2v_2$, $v_2 = A_1v_1/A_2 = \pi\ (0.01)^2\ (1.5)\ /\ \pi\ (0.005)^2 = 6.0$m/s

b) Pressure at the second floor $P_1 + ½\ \rho v_1^2 + \rho gh_1 = P_2 + ½\ \rho v_2^2 + \rho gh_2$

$P_1 + \rho v_1^2 + \rho gh_1 – ½\ \rho v_2^2 – \rho gh_2 = P_2$

$P_2 = P_1 + ½\ \rho\ (v_1^2 – v_2^2) + \rho g\ (h_1\text{-}h_2)$ = 400 000 + ½ (1000) (1.52-6.02) + (1000)(10)(0-5)

P_2 = 400 000 + ½ (1000) (1.52-6.02) + (1000) (10) (0-5) = 400 000 – 16 875- 49 050 =334 075.

P_2 = 334 075 Pa

3. $P_2\text{-}P_1 = \rho gh$ derived h

h $= P_2 – P_1 / \rho g$

$= 1500 / 1.06 \times 10^3 \times 10$

= 0.1415m

4. Given:

v_1 =0.20m/s

Point 1	**Point 2**
Diameter = 0.5m	Diameter = 0.30m
Density of the water = 1000kgm^{-3}	h= 3.5m

Using the formula

$P_1 + ½\ \rho v_1^2 + \rho gh_1 = P_2 + ½\ \rho v_2^2 + \rho gh_2$

Since v_2 is unknown. Calculate v_2 by deriving from the formula

$A_1v_1 = A_2v_2$ Area = πr^2

$v_2 = A_1v_1 / A_2$ r is half of the diameter

Substitute

$v_2 = \pi\ (0.25)^2\ (0.20) / \pi\ (0.15)^2$

= 0.0125 / 0.0225

v_2 = 0.56ms^{-1}

$P_1\text{-}P_2 = ½\ \rho v_2^2 + \rho gh_2 \text{-}\ ½\ \rho v_1^2 – \rho gh_1 = ½\ \rho(v_2^2\text{-}v_1^2) – \rho g\ (h_1\text{-}h_2)$

$P_1\text{-}P_2 = ½\ (1000)\ ((0.56)^2 – (0.20)^2) – 1000\ (10)\ (0.0\ \text{-}3.5)$

= ½ (1000) (0.2736) – (1000) (10) (-3.5)

= ½(273.6) – (-3500

P_2 = 35 136.8Pa

5. Given:

Diameter = 4cm = 0.04m

Volume of the container = 40L

t = 2 minutes = 120s

(a) Since the problem asked for velocity we derived velocity from the equation

Flow rate = Av

v = Flow rate / A $A = \pi r^2$ $\pi = 3.14$ (constant)

Substitute

$v = (40L/120\ s)\ (1 \times 10^{-3}\ m^3/L) / 3.14(0.02)^2$

$v = 0.265 ms^{-1}$

(b) Convert 2.5cm to meter that is 2.5 /100 = 0.025m

v = Flow rate / A

$= (40L/120)\ (1 \times 10^{-3}\ m^3/L) / 3.14\ (0.0125)^2$

$= 0.679 ms^{-1}$

If you have queries regarding the answers, then please visit your nearest FODE provincial centre and ask a distance tutor to assist you.

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FODE PROVINCIAL CENTRES CONTACTS

PC NO.	FODE PROVINCIAL CENTRE	ADDRESS	PHONE/FAX	CUG PHONES	CONTACT PERSON		CUG PHONE
1	DARU	P. O. Box 68, Daru	6459033	72228146	The Coordinator	Senior Clerk	72229047
2	KEREMA	P. O. Box 86, Kerema	6481303	72228124	The Coordinator	Senior Clerk	72229049
3	CENTRAL	C/- FODE HQ	3419228	72228110	The Coordinator	Senior Clerk	72229050
4	ALOTAU	P. O. Box 822, Alotau	6411343 / 6419195	72228130	The Coordinator	Senior Clerk	72229051
5	POPONDETTA	P. O. Box 71, Popondetta	6297160 / 6297678	72228138	The Coordinator	Senior Clerk	72229052
6	MENDI	P. O. Box 237, Mendi	5491264 / 72895095	72228142	The Coordinator	Senior Clerk	72229053
7	GOROKA	P. O. Box 990, Goroka	5322085 / 5322321	72228116	The Coordinator	Senior Clerk	72229054
8	KUNDIAWA	P. O. Box 95, Kundiawa	5351612	72228144	The Coordinator	Senior Clerk	72229056
9	MT HAGEN	P. O. Box 418, Mt. Hagen	5421194 / 5423332	72228148	The Coordinator	Senior Clerk	72229057
10	VANIMO	P. O. Box 38, Vanimo	4571175 / 4571438	72228140	The Coordinator	Senior Clerk	72229060
11	WEWAK	P. O. Box 583, Wewak	4562231/ 4561114	72228122	The Coordinator	Senior Clerk	72229062
12	MADANG	P. O. Box 2071, Madang	4222418	72228126	The Coordinator	Senior Clerk	72229063
13	LAE	P. O. Box 4969, Lae	4725508 / 4721162	72228132	The Coordinator	Senior Clerk	72229064
14	KIMBE	P. O. Box 328, Kimbe	9835110	72228150	The Coordinator	Senior Clerk	72229065
15	RABAUL	P. O. Box 83, Kokopo	9400314	72228118	The Coordinator	Senior Clerk	72229067
16	KAVIENG	P. O. Box 284, Kavieng	9842183	72228136	The Coordinator	Senior Clerk	72229069
17	BUKA	P. O. Box 154, Buka	9739838	72228108	The Coordinator	Senior Clerk	72229073
18	MANUS	P. O. Box 41, Lorengau	9709251	72228128	The Coordinator	Senior Clerk	72229080
19	NCD	C/- FODE HQ	3230299 Ext 26	72228134	The Coordinator	Senior Clerk	72229081
20	WABAG	P. O. Box 259, Wabag	5471114	72228120	The Coordinator	Senior Clerk	72229082
21	HELA	P. O. Box 63, Tari	73197115	72228141	The Coordinator	Senior Clerk	72229083
22	JIWAKA	c/- FODE Hagen		72228143	The Coordinator	Senior Clerk	72229085

FODE SUBJECTS AND COURSE PROGRAMMES

GRADE LEVELS	SUBJECTS/COURSES
Grades 7 and 8	1. English
	2. Mathematics
	3. Personal Development
	4. Social Science
	5. Science
	6. Making a Living
Grades 9 and 10	1. English
	2. Mathematics
	3. Personal Development
	4. Science
	5. Social Science
	6. Business Studies
	7. Design and Technology- Computing
Grades 11 and 12	1. English – Applied English/Language& Literature
	2. Mathematics - Mathematics A / Mathematics B
	3. Science – Biology/Chemistry/Physics
	4. Social Science – History/Geography/Economics
	5. Personal Development
	6. Business Studies
	7. Information & Communication Technology

REMEMBER:

- For Grades 7 and 8, you are required to do all six (6) subjects.
- For Grades 9 and 10, you must complete five (5) subjects and one (1) optional to be certified. Business Studies and Design & Technology – Computing are optional.
- For Grades 11 and 12, you are required to complete seven (7) out of thirteen (13) subjects to be certified.

Your Provincial Coordinator or Supervisor will give you more information regarding each subject and course.

GRADES 11 & 12 COURSE PROGRAMMES

No	Science	Humanities	Business
1	Applied English	Language & Literature	Language & Literature/Applied English
2	Mathematics A/B	Mathematics A/B	Mathematics A/B
3	Personal Development	Personal Development	Personal Development
4	Biology	Biology/Physics/Chemistry	Biology/Physics/Chemistry
5	Chemistry/ Physics	Geography	Economics/Geography/History
6	Geography/History/Economics	History / Economics	Business Studies
7	ICT	ICT	ICT

Notes: You must seek advice from your Provincial Coordinator regarding the recommended courses in each stream. Options should be discussed carefully before choosing the stream when enrolling into Grade 11. FODE will certify for the successful completion of seven subjects in Grade 12.

CERTIFICATE IN MATRICULATION STUDIES		
No	**Compulsory Courses**	**Optional Courses**
1	English 1	**Science Stream:** Biology, Chemistry, Physics
2	English 2	**Social Science Stream:** Geography, Intro to Economics and Asia and the Modern World
3	Mathematics 1	
4	Mathematics 2	
5	History of Science & Technology	

REMEMBER:
You must successfully complete 8 courses: 5 compulsory and 3 optional.