CHAPTER 3: FORCES AND PRESSURE

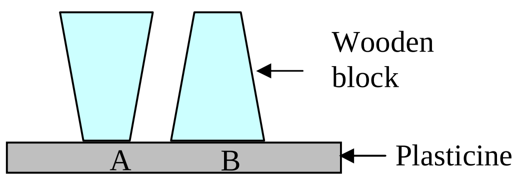
3.1 UNDERSTANDING PRESSURE

1. The pressure acting on a surface is defined as ***force*** per unit ***area*** on the surface.

2. Pressure, P = $\dfrac{F}{A}$

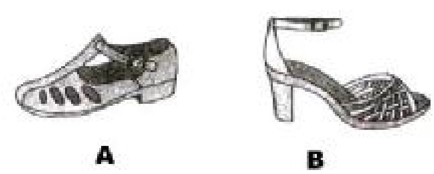
3. Unit for pressure is ***Nm^{-2}*** or ***Pascal (Pa).***

4. *Example 1* : A wooden block is placed at different position on the surface of a piece of plasticine. At what position the pressure is higher?



Answer: ***A***

5. *Example 2* : Which shoe will exert a greater pressure to the ground?



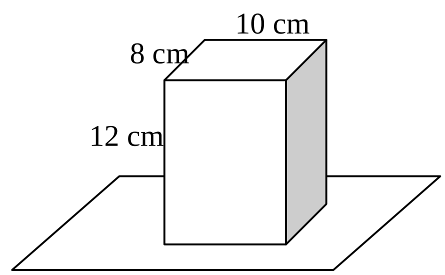
Answer: ***B***

6. *Example 3* : The diagram below shows a wooden block of dimensions 8 cm × 10 cm × 12 cm. Its weight is 120 N. On which side should the wooden block be placed to produce a **maximum** pressure exerted on the table. What is value of this pressure ?

$$P = \frac{\text{Weight (F)}}{\text{Minimum Area (A)}}$$

$$= \frac{120}{0.08 \times 0.1}$$

$$= 15000 \ Nm^{-2}$$



Application of Pressure

1. Tools like knives, chisels, axes and saws have sharp cutting edges. The surface area of contact is ***small***. When a force is applied on the tool, the small area of contact will produce a ***high*** pressure to cut the material.
2. The flat base of each metal pole of a tent has a ***big*** surface area to ***decrease*** the pressure exerted on the ground. The poles will not sink into the ground because of the flat bases.


Exercise 3.1

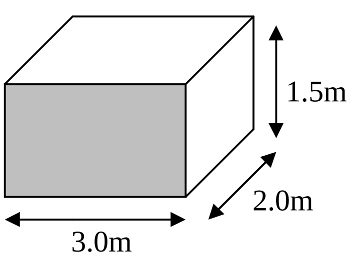
1. A table of mass 50 kg has four legs is placed on a floor. Each leg has a cross sectional area of 25 cm^2. Find the **pressure** exerting on the floor ($g = 10ms^{-2}$) :

$$\textit{Pressure, } P = \frac{F}{A} = \frac{mg}{A}$$

$$= \frac{50 \times 10}{4 \times 25 \times 10^{-4}}$$

$$= 50\ kPa$$

2. The diagram below shows a concrete block of dimension 1.5m x 2.0m x 3.0m. Its weight is 60N. Calculate (a) **maximum** pressure, (b) **minimum** pressure:



a)

$$P\max = \frac{W}{\textit{Minimum area}}$$

$$= \frac{60}{2 \times 1.5}$$

$$= 20\ Pa$$

b)

$$P\max = \frac{W}{\textit{Maximum area}}$$

$$= \frac{60}{3 \times 2}$$

$$= 10\ Pa$$

3.2 UNDERSTANDING PRESSURE IN LIQUIDS

Density

1. Density (r) is defined as ..*mass*.. per unit ..*volume*.. The SI unit for density is ...*kg m*$^{-3}$...

   $$\text{Density } (\rho) = \frac{mass}{volume} \qquad \boxed{\rho = \frac{m}{V}}$$

2. Change of unit example:

   $$\mathbf{800\ kg\ m^{-3}} = \frac{800\ kg}{m^3} = \frac{(800)(10^3)}{(10^2)^3} = \frac{(800)(1000)}{1000000} = \frac{800}{1000} = \mathbf{0.8\ g\ cm^{-3}}$$

3. *Example 1*: Calculate the density of a stone of mass 250 g if its volume is 100 cm^3.

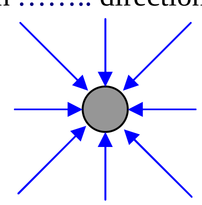
   $$\rho = \frac{m}{V} = \frac{250\ g}{100\ cm^3} = 2.5\ \text{g cm}^{-3} = \ldots 2\,500\ \text{kg m}^{-3}\ldots$$

4. *Example 2*: Abu with mass 60 kg, when he is totally immersed in a tank of water, the water level raise by 55 liter. ($1\,liter = 1000 cm^3$)

   $$\textbf{Density, } \rho = \frac{m}{V} = \frac{60{,}000\ g}{55{,}000\ cm^3} = \ldots 1.091 \ldots\ \text{g cm}^{-3} = \ldots 1\,091 \ldots\ \text{kg m}^{-3}$$

The Pressure in Liquids

1. Pressure in liquids acts in ..*all*... directions.



2. The pressure in a liquid is the product of depth, density and gravitational acceleration.

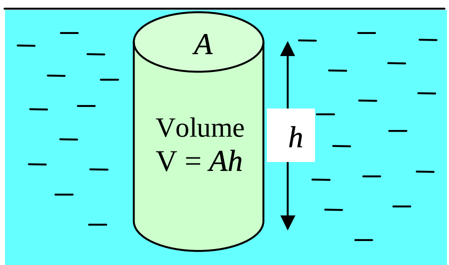
   P = $\boxed{\rho}$ x $\boxed{g}$ x $\boxed{h}$

3. The above formula can be derived from the following steps:

   Mass of a cylinder of water, $m = \rho V$ = ..***ρ A h***..........

   Weight of the cylinder of water, W = ..***m g***.. = ***ρ A h g***

   A cylinder of water



   The pressure of water at the base of the cylinder of water is,

   Water pressure, $P = \frac{F}{A} = \frac{W}{A} = \frac{m\ g}{A} = \frac{r\ \ A\ h\ g}{A} = r\ \ g\ h$

4. ***Example 1*** : A balloon is situated at 10 m below sea level, what is the total pressure experienced by the balloon ? [The density of sea water is 1100 kg m^{-3}]

   Total Pressure,

   P = Atmospheric pressure + Liquid pressure
   = 100,000 N m^{-2} + $\rho g h$
   = 100,000 + ..***(1100)(10)(10)***
   = 100,000 + ..***110,000***........
   = ..***210,000***.... N m^{-2}
   = ..***210,000***.... Pa

Atmospheric pressure at sea level :
P_{atm} = ***1.0 x10⁵*** Pa

5. ***Example 2*** : Water with density of 1 g cm^{-3} and oil are filled into a U-tube. What is the density of the oil ?

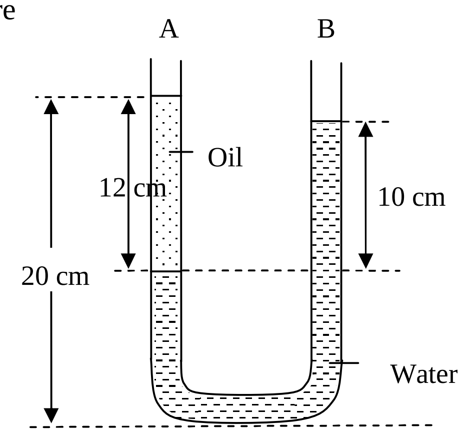
   Pressure at A = Pressure at B

   $P_{atm} + h_1 r_1 g = P_{atm} + h_2 r_2 g$

   $h_1 r_1 g = h_2 r_2 g$

   $h_1\ r_1 = h_2\ r_2$

   $r_1 = \frac{h_2\ r_2}{h_1}$ = (10)(1) ÷ (12) = ..***0.83 g cm⁻³***..



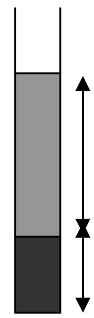
Exercise 3.2

1. Given that the density of mercury is 13600kgm^{-3}. Calculate the pressure of mercury at a point 25cm from the mercury surface (g=10ms^{-2})

   Solution:

   $P = \rho gh$
   $= (13600)(10)(0.25)$
   $= 34\ kPa$

2. The figure shows a glass tube filled with 50cm height of liquid M and 30cm height of liquid N. The densities of liquid M and N are 1000kgm^{-3}and 2500kgm^{-3} respectively. By giving g=10ms^{-2}, what is the pressure of
   a) liquid M at point x
   b) liquid M and N at point y



   Solution:

   a) $P = \rho gh$
   $= (1000)(10)(0.5)$
   $= 5\ kPa\ \ /\ 5000\ Nm^{-2}$

   b) $P = (\rho gh)_M + (\rho gh)_N$
   $= (1000)(10)(0.5) + (2500)(10)(0.3)$
   $= 5\ kPa + 7.5\ kPa$
   $= 12.5\ kPa$

3.3 UNDERSTANDING GAS PRESSURE AND ATMOSPHERIC PRESSURE

Gas Pressure

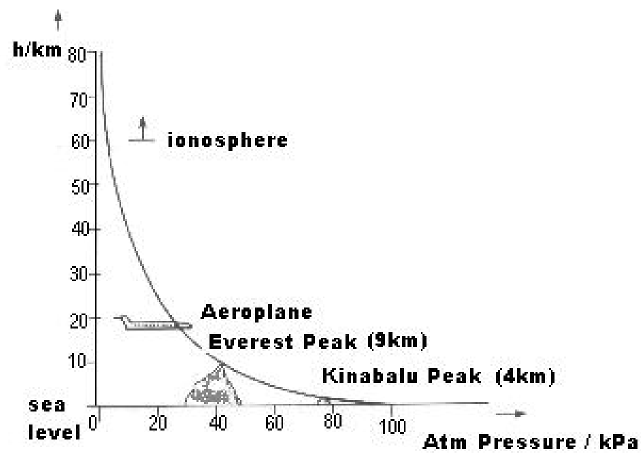
1. The gas pressure in a container is caused by the ***collision*** of gas molecules with the ***wall*** of the container.
2. Gas pressure can be measured by using two types of instrument known as :
   (a) ***Bourdon*** gauge (consists of a semi-circular or C-shaped copper tube that tends to straighten if more and more gas is pumped (compressed) into it).
   (b) ***Manometer*** (consists of a U-tube about 1 m in height. About 50% of the volume of the U-tube is filled with liquid such as mercury or water).

Atmospheric Pressure

1. The ..*atmospheric pressure*.. is caused by the downward force exerted by the air, s the weight of the atmosphere on the Earth's surface.
2. 1 atmosphere = ..*760*.. mm Hg = ..*10.3*.. m water = ..*1.0 x 10⁵*....Pa

Altitude and the Magnitude of Atmospheric Pressure

The greater ..*altitude*... from the sea level, the smaller will the atmospheric pressure.



Instruments for Measuring Atmospheric Pressure

1. Barometer is an instrument to measure atmospheric pressure. There are 2 types of barometer:
   (a) ..*Aneroid barometer*.. (is made of a partially vacuum sealed metal box).
   (b) ..*Fortin barometer*.. (is made of a long glass tube about 1 meter in length fully filled with mercury and then inverted (turned upside down) into a bowl of mercury).

2. *Example 1*: The atmospheric pressure is 760 mm Hg. What is the value of the atmospheric

   pressure in Pascal? [Density of mercury, ρ (Hg) = 13 600 kg m^{-3}]

   h = 760 mm = 76 cm = 0.76 m

   Atmospheric pressure, P_{atm} = $h \rho g$ = (0.76)(13600)(9.8)

   = ...*101293*..... Pa

Exercise 3.3

1. Figure 3.3 shows apparatus set up which is used to measure atmospheric pressure.

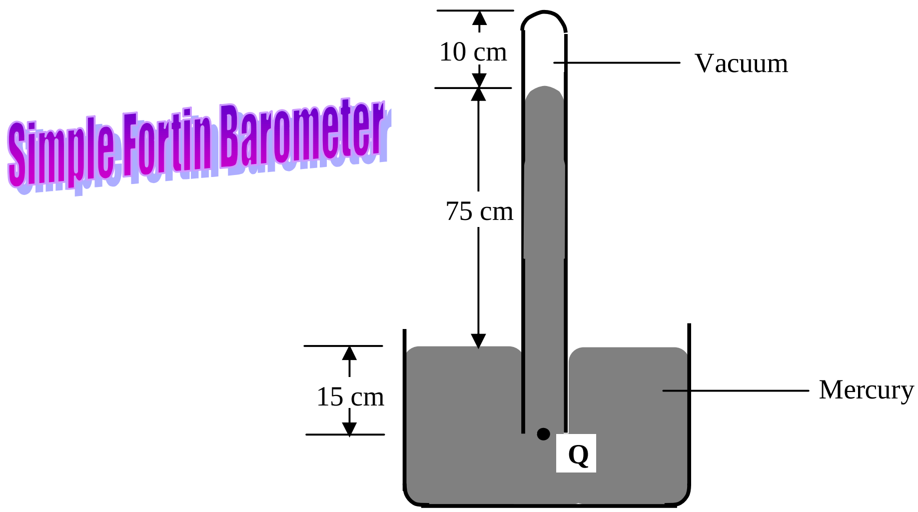


Figure 3.3

(a) Calculate the pressure at point Q in Pa unit.

[Mercury density = 1.36×10^4 kg m^{-3}]

Solution:

Pressure at point Q = ***(75 + 15)cm Hg***

= ***90 cm Hg***

= ***$(1.36 \times 10^4)(10)(0.9)$***

= ***122.4 kPa***

2.

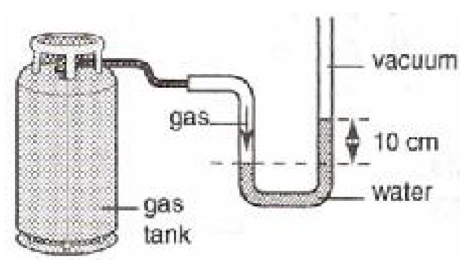


Figure shows a manometer connected to a gas tank whose valve is then turned on. What is the pressure of the gas, in unit N m^{-2}, in the tank?

[Density of water = 1 000 kg m^{-3}]

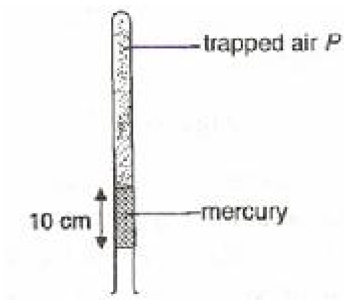
Solution:

Pgas **=** $(h\rho g)_{water} + P_{atm}$

= (1000)(10)(0.1) + 100000 Nm-2

= 101 000 N m^{-2}

3. If the atmospheric pressure is 76 cm Hg, what is the pressure of the trapped air P ?



Solution:

Pair + Pmercury = Patm

Pair + 10cmHg = 76cmHg

Pair = (76 – 10) cmHg

= 66 cmHg

3.4 APPLYING PASCAL'S PRINCIPLE

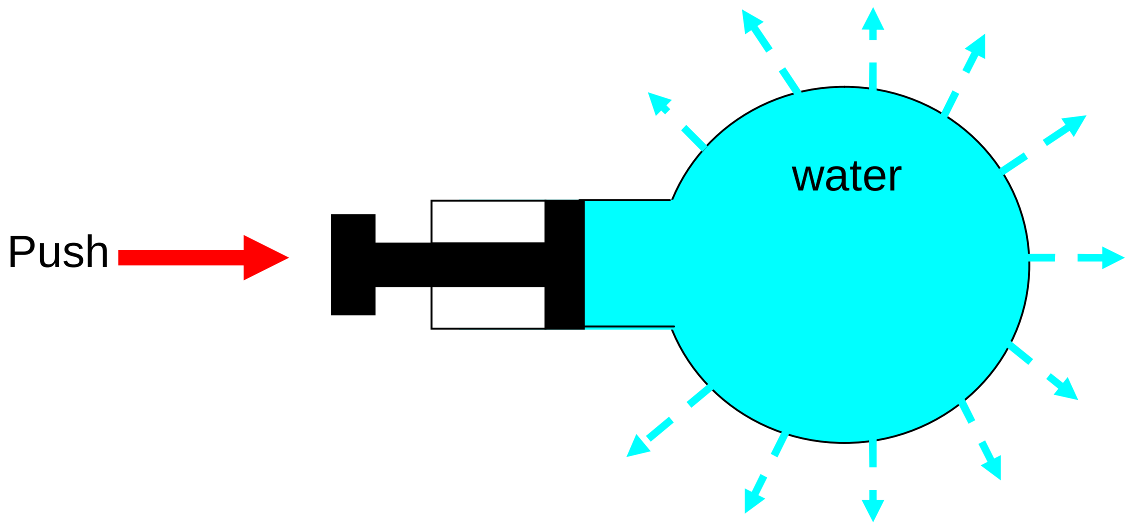
Fill in the blanks with appropriate word.

1. ..***Pascal's*** Principle state that pressure exerted on an ***enclosed***. liquid is transmitted ..***equally / with same magnitude*** to every part of the liquid.

Exercise 3.4

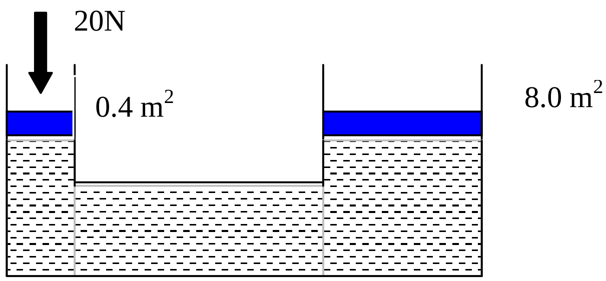
Pascal's Principle

1. By applying the Pascal's Principle, draw the direction of water when the piston is pushed.



Hydraulic Systems

1. The figure below shows a hydraulic jack. The cross-sectional area of the smaller piston and the larger piston is $0.4m^2$ and $8m^2$ respectively. If the smaller piston is pushed with a force of 20N, what will be the force experience by the larger piston?

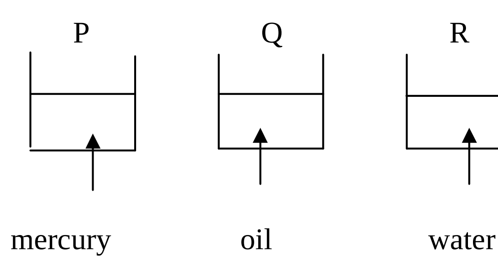


Solution:

Let $F_1 = 20N$, $A_1 = 0.4m^2$, $A_2 = 8m^2$, $F_2 = ?$

$\frac{F_1}{A_1} = \frac{F_2}{A}$, $\frac{20}{0.4} = \frac{F_2}{8}$, $F_2 = \frac{(20 \times 8)}{0.4} = 400N$

2. The diagram shows 3 beakers containing different liquid at same level. Arrange the diagrams according to descending order of pressure exerted at the bottom of the beaker.



Answer: ***P, Q, R***

Applications of Pascal's Principle

1.

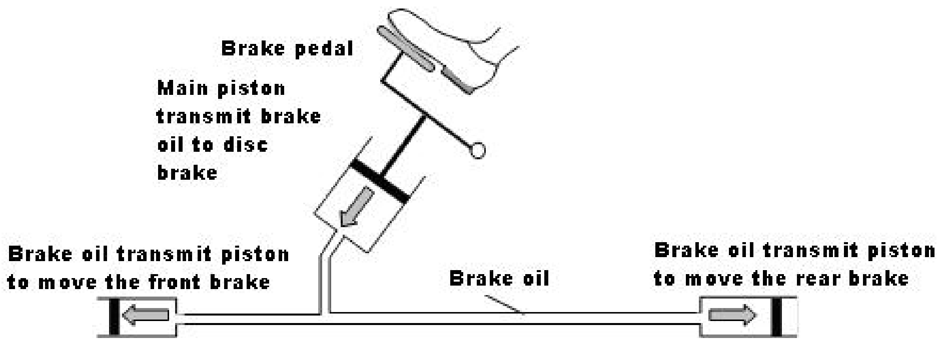


FIGURE 1

Figure 1 shows a person brake his car by pressing the brake pedal. The brake pedal is linked to the main piston. The main pedal transmit the brake oil through a serial of tube to operate the front and rear brake.

a) (i) Name the physics principle that relates with the above situation.

Pascal's Principle

(ii) Brake will not well function if there is some air bubbles in the brake oil. Explain why?

The resultant pressure will be used to compress the air bubbles.

Therefore, pressure distribution will be not effective.

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3.5 APPLYING ARCHIMEDES' PRINCIPLE

Fill in the blanks with appropriate word.

1. Archimedes' Principle states that when an object is *wholly* or *partially* immersed in a fluid, it experiences a *buoyant force* equal to the weight of the fluid displaced.
2. For a free floating object, the buoyant force is equal to the *weight* of the object.

Exercise 3.5

Archimedes' Principle

1. An object of density, $40 gcm^{-3}$ and mass 500g is immersed in a liquid of density 2 gcm^{-3}. Calculate

   a) the volume of liquid displaced b) the mass of the liquid displaced

   c) the buoyant force experienced by the object ($g=10 ms^{-2}$)

   Solution:

   a) $V = m / \rho$

   $= 500 / 40$

   $= 12.5 \ cm^3$

   b) Let the liquid mass as m' and density ρ'

   $m' = \rho' V$

   $= (2)(12.5)$

   $= 25g = 0.025 \ kg$

   c) Buoyant force = ***Weight of liquid displaced***

   $= m'g$

   $= (0.025)(10)$

   $= 0.25N$

3.6 UNDERSTANDING BERNOULLI'S PRINCIPLE

1. Bernoulli's Principle states that for uniform flow of a fluid, region of high velocity corresponds to ..***low***.. pressure whereas region of .***low***... velocity corresponds to high pressure.

Bernoulli's Principle

1.

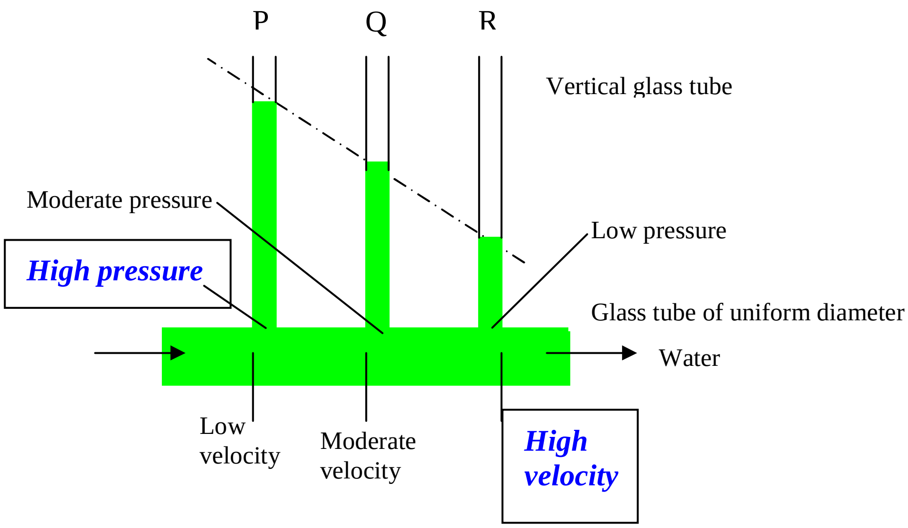
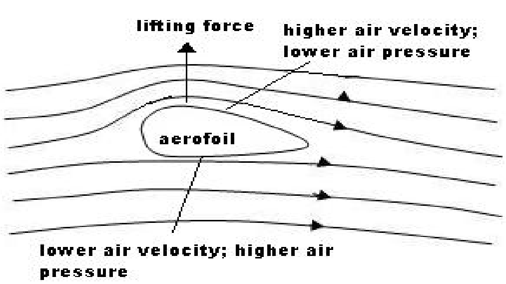


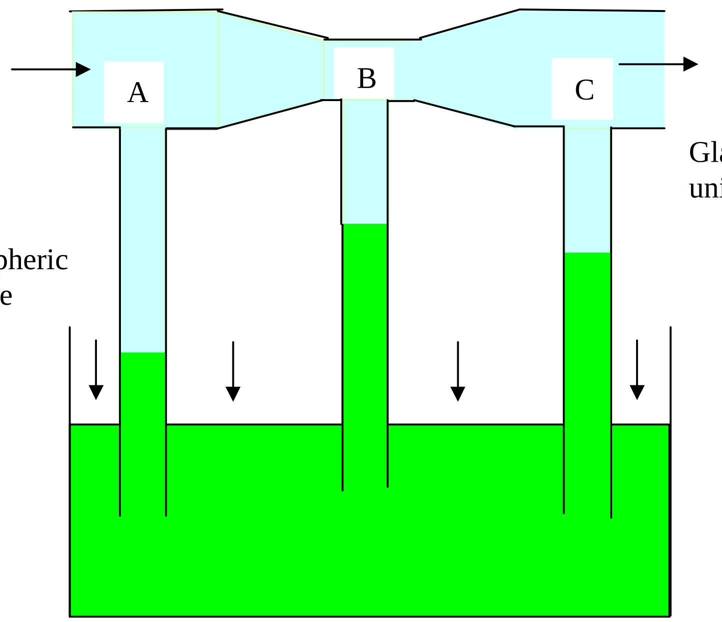
Figure above shows that water flows through a horizontal tube from left to right. The velocity of water ..***increases***.. gradually from left side of the tube to the right side of the tube. The water pressure is ...***higher***.. on the left side of the tube than the right side of the tube. This can be seen from the gradual decrease in water column of the vertical tubes P, Q and R. The relationship between velocity and pressure is in accordance to Bernoulli's Principle.

2. Figure below shows an ..***aerofoil***.. The upper region of the aerofoil has higher air velocity than the lower region of the aerofoil. By Bernoulli's principle, the lower region has ***higher***...... pressure than the upper region of the aerofoil. This causes a ***lifting force***.. on the aerofoil.



Exercise 3.6

1.

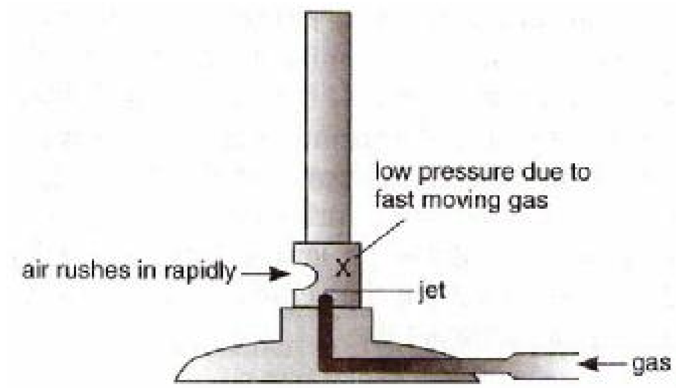


Air flows through a horizontal tube as shown in the figure causing water columns to rise in three vertical glass tubes. Compare and tabulate the value of air velocity and pressure in the three positions A, B and C of the horizontal tubes.

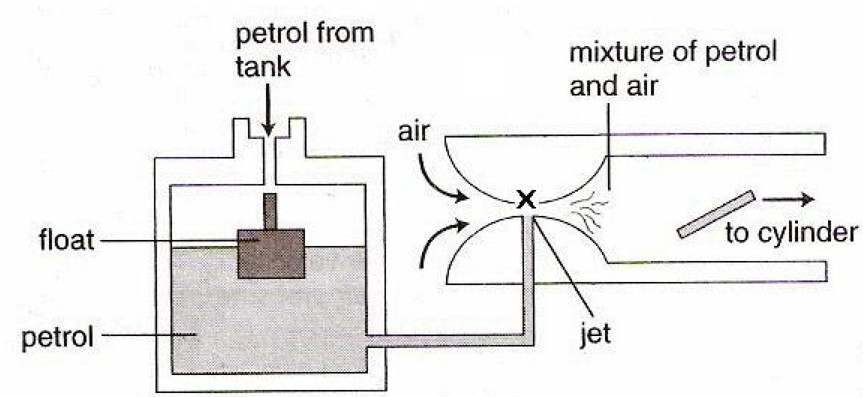
Answer:

	A	**B**	**C**
Velocity	***Low***	High	***Moderate***
Pressure	***High***	***Low***	Moderate

2. Figure below shows a Bunsen burner and a carburetor. Mark with X for low pressure area.



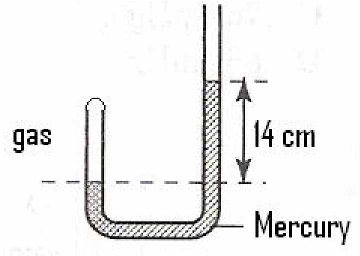
Bunsen burner



Carburetor

Reinforcement Test

1. A cylinder has a mass of 12kg and a cross-sectional area of 200cm^2. What is the pressure acting at its base?
   - (A.) 6 kPa
   - B. 9 kPa
   - C. 12 kPa
   - D. 15 kPa
   - E. 18 kPa
2. Wind blows normally on a wall at a pressure of 200kPa. If the wall has an area of 5m^2, what is the force acting on the wall?
   - A. 40kN
   - B. 800kN
   - (C.) 1000kN
   - D. 1200kN
   - E. 1600kN
3. Which of the following factor does not influence the pressure of a liquid?
   - A. Depth
   - B. Acceleration due to gravity
   - C. Density
   - (D.) Volume
4. Mercury has density of 13600kgm^{-3}. If the pressure of mercury is 650kPa, what is the depth from its surface?
   - A. 4.0m
   - (B.) 4.8m
   - C. 5.8m
   - D. 6.4m
   - E. 8.0m
5. What is the pressure of the gas trapped inside the J-tube, in Pa unit?



   - (A.) 1.19 x 10^5 Pa
   - B. 1.90 x 10^5 Pa
   - C. 2.19 x 10^5 Pa
   - D. 2.90 x 10^5 Pa
   - E. 3.14 x 10^5 Pa
6. Which instruments is meant for measuring atmospheric pressure?
   - A. Carburetor
   - B. Siphon
   - (C.) Fortin's Barometer
   - D. Hydrometer
7. Figure 7 shows a hydraulic jack. Piston A and piston B have cross-sectional areas 5cm^2 and 100cm^2 respectively. If mass of 3kg is placed on piston A, what is the maximum weight that can be lifted by piston B?

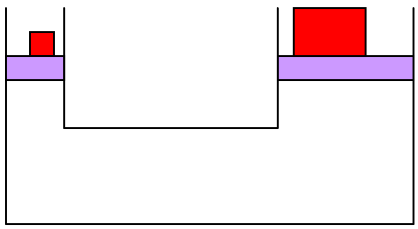


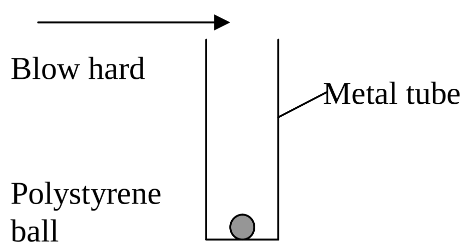
Figure 7

A. 300N D. 900N
B. 600N E. 1000N
C. 800N

8. Which of the following device is based on the Pascal's Principle of pressure transmission?
   A. Hydrometer
   B. Car's hydraulic brake
   C. Bunsen burner
   D. Fire extinguisher

9. A ship of mass 80000kg floats on the sea surface. If the density of the sea water is $1250 kgm^{-3}$, what is the volume of the displaced sea water?
   A. $6.4\ m^3$ D. $800\ m^3$
   B. $64\ m^3$ E. $900\ m^3$
   C. $640\ m^3$

10. Figure 10 shows metal tube is blowed hardly at the opening. It is observed that the polystyrene ball is lifted to the opening of metal tube.



This phenomenon occurs because
   A. The air velocity at the upper section of the metal tube is less than the air velocity at its lower section.
   B. The air pressure at the upper section of the metal tube is less than the air pressure at its lower section.
   C. The air density at the upper section of the metal tube is more than the air density at its lower section.
   D. The air temperature at the upper section of the metal tube is more than the air temperature at its lower section

Part B: Structured Question

1.

FIGURE 1

Figure 1 shows a Perodua Myvi with a mass of 900 kg.

Air pressure for each tyre is 2×10^5 Pa.

(a) What is the meaning of pressure ?

Pressure is force per unit area

(b) Calculate the area in contact with the ground for each tyre.

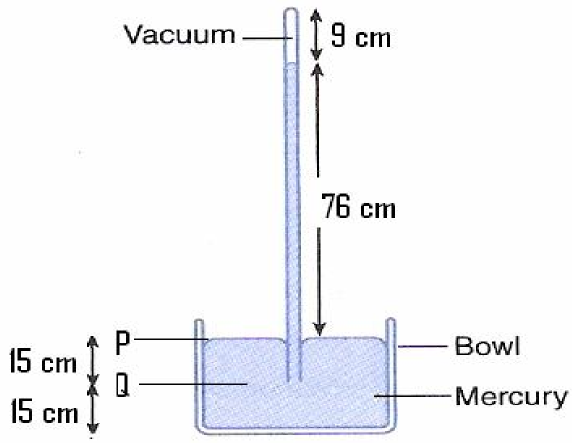
$$Area = \frac{(900 \times 10) / 4}{2 \times 10^5} = 0.01125 \ m^2$$

(c) Zamani drives his car to his school with a distance of 10km and find his car tyre become harder than usual. Explain why this is happen?

Increasing temperature / Increasing kinetic energy

Increasing pressure/ Increasing rate of molecule collision

2. Diagram shows a set up of apparatus for measuring atmospheric pressure.



(a) What is the name for the instrument?

Simple Barometer………………………………………………………

(b) Determine the atmospheric pressure as measured by the instrument ,

(i) in the cm Hg unit

………***76 cm Hg***……………………..

(ii) in the Pa unit

………***101 300 Pa***……………………..

(c) State the change of length of the <u>mercury column</u> above the mercury surface

(i) The tube is raised by 10cm ...…***Unchanged***……………………………………….

(ii) The surrounding temperature increases ..***Increase***………………………………..

(iii) The instrument is brought to the peak of a mountain .***Decrease***……………………..

(iv) Water vapor is brought to the vacuum region ***Decrease***……………………………

Part C: Essay Question

1.

(a) A fisherman finds that his boat is at different levels in the sea and in the river, although the boat carries the same load. The ***density*** of sea water is 1 025 kg m^{-3} and of river water is 1 000 kg m^{-3}.

Figure 1 and 2 illustrate the situation of the boat in the sea and in the river.

In the sea

FIGURE 1

In the river

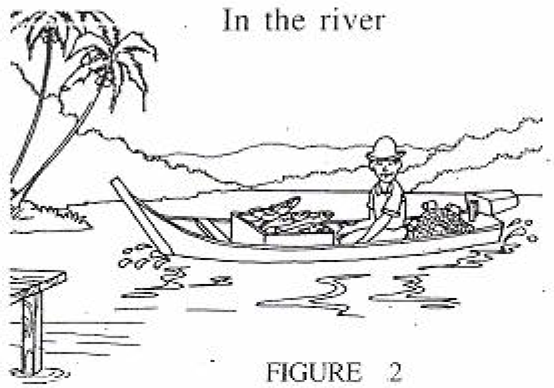


FIGURE 2

(i) What is meant by *density*?

Density is mass per unit volume……………………………………………………..

(ii) Using Figure 1 and 2, compare the levels of the boat and the volumes of water displaced by the boat.

The level of the boat according to the water surface for Figure 1 is higher than in Figure 2. The volume of water displaced by the boat in Figure 1 is less than in Figure 2.

Relating the mass of the boat with its load, the volume of water displaced and the density of the water, deduce a relevant physics concept.

Buoyant force = density of water x gravity x volume of water displaced

= mass of the boat with its load x gravity

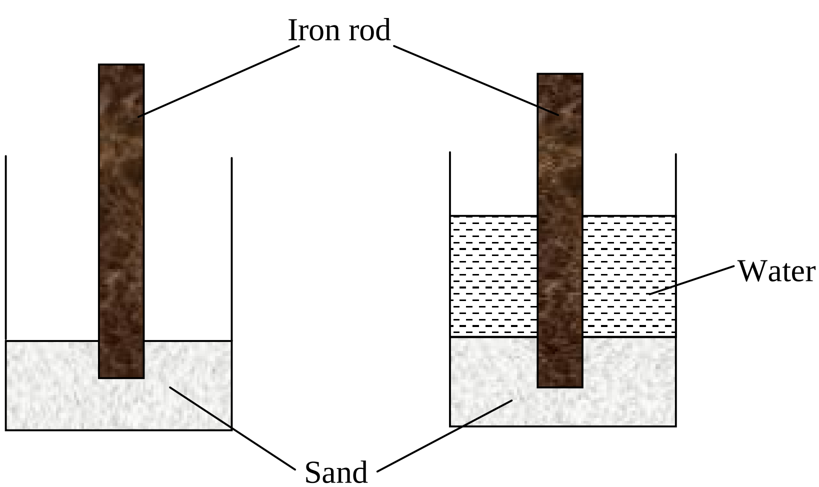
(iii) Name the physics principle that explains the above situation.

Archimedes' Principle……………………………………………………………..

(b) A submarine can sail on the sea surface and under the sea.
Explain how a submarine on the surface submerges.

The magnitude of the buoyant force acting on a submarine will determine whether the submarine will float on sea surface, stay stationary or submerges into the sea. The buoyant force depends on the weight of sea water displaced. A submarine has a ballast tank. As sea water enters the ballast tank, its weight increases. If its weight is more than the buoyant force, the submarine will submerges.

2. Figure below shows an iron penetrates a layer of sand placed in a beaker. When water is poured into the beaker, the iron rod makes another penetration into the sand layer as shown in figure below.



Based on the observation,

a) state one suitable inference that can be made

b) state one appropriate hypothesis for an investigation

c) with the use of apparatus such as spring balance, load, thread, eureka can and other apparatus, describe an experiment framework to test your hypothesis. In your description, state clearly the following:

i) aim of the experiment

ii) variable in your experiment

iii) list of apparatus and materials

iv) arrangement of the apparatus in a sketch

v) the procedure of the experiment

vi) the way you list the data

vii) the way you would analyse the data.

Answer

2. ***a) The iron rod in water makes shallower penetration into the sand layer.***

b) The iron rod in water experiences a buoyant force.

c) (i) To find the relationship between weight of water displaced and the buoyant force.

(ii) Variables:

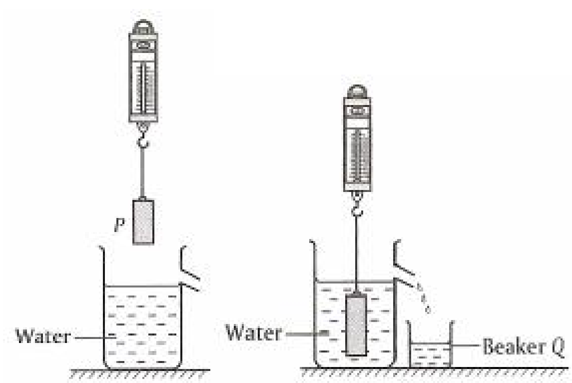
Manipulated: Buoyant force of object in water

Responding: Weight of water displaced

Fixed: Type of liquid used in eureka can

(iii) Spring balance, load, eureka can, beaker, water, thread and triple beam balance.

(iv) Arrangement of apparatus



(v) 1. Weight of empty beaker is recorded as Q1

2. A load P is suspended by a spring balance in air.

3. The read of the spring balance W1 is recorded.

4. The load is immersed completely in water in eureka can.

5. The apparent weight W2 is taken.

6. The water displaced is collected in a beaker as shown in the figure above.

7. Weight of beaker with the displaced water Q2 is recorded.

(vi) 1. Weight of load in air = W1

2. Weight of load in water = W2

3. Weight of empty beaker = Q1

4. Weight of beaker with displaced water = Q2

(vii) 1. Buoyant force = W1 – W2

2. Weight of water displaced = Q2 – Q1

3. It is found that W1 – W2 = Q2 – Q1, in other words, the weight of water displaced is equal to the buoyant force