Pressure

Introduction

Simply pressure can be defined as the perpendicular force per unit area. The property of pressure exists in all states of matter; in solids, liquids and gases.

In solids, the pressure is the force (F) per unit area applied in a direction perpendicular to the surface of an object. It is proportional to force and inversely proportional to area (A).

$$P = F/A \quad \left(\frac{Newten}{m^2} \quad or \quad Pascal \right)$$

For a solid the quantity force per unit area is referred to as stress. In the metric system pressure is measured in dynes per square centimeter (Dy/cm^2) or Newton per square meter (N/m^2) or Pascal (Pa).
If the unit is Dy/cm^2

 in liquids, it is equal to the pressure (P) under a column of this liquid which is depending on density (ρ) of the liquid, acceleration gravity (g) and height (h) of the liquid column. The pressure of liquid can be calculated as following:

From eq. 1, If $V = Ah$, $m = \rho V \rightarrow m = \rho Ah$

$$P = \rho gh \quad \left(\frac{Newten}{m^2} \quad or \quad Pascal \right)$$

Where
ρ density of the liquid
g acceleration gravity of the earth
h height of the column of liquid

In gases, the pressure exerted by a gas on the walls of its container resulted from the bombardment of the walls of the container by the gas molecules.

 There are two pressure readings; gauge and absolute pressure as following:

$$Gauge\ pressure = P = \rho gh$$

$$Absolute\ pressure = P_{abs} = P + P_{atm} = \rho gh + P_{atm}$$

Gauge pressure (ρgh) may be positive or negative according to its value with respect to atmospheric pressure (Patm), then:

- Gauge pressure is positive when ρgh > Patm
- Gauge pressure is negative when ρgh < Patm

Pressure units:

P = ρ g h ρ = density of liquid (g/cm^3)
g=980(cm/sec^2) acceleration of gravity
h= in (cm) the height of liquid

Or the unit is N/m^2
P = ρ g h ρ = (kg/m^3)
g= 9.8 m/ sec^2
h= In (m)

Example -1-
Find the pressure of 10 m of water in Dy/cm^2 and N/m^2?
10 × 100 = 1000 cm 1m=100cm
∴ P = ρ g h =1×980×1000=980000=9.8×10^5 Dy/cm^2
P = ρ g h =1000 × 9.8 ×10 =9.8×10^4 N/m^2
The most common method of indicating pressure in medicine is by the height of a column of mercury (Hg). For example , a peak (systolic)blood pressure reading of 120 mmHg indicates that a column of mercury of this height has a pressure at its base equal to the patients systolic blood pressure .

Example -2-
Calculate the systolic pressure in Dy/cm^2 and N/m^2?
In systolic pressure =120 mmHg=12 cmHg
= 0.12 m Hg
∴ P = ρ_{Hg} g h_{Hg} =13.6×980×12=159936=1.6×10^5 Dy/cm^2

$P = \rho_{Hg}\, g\, h_{Hg} = 13600 \times 9.8 \times 0.12 = 1.6 \times 10^4\ N/m^2$

The Instrument that measures pressure is called a manometer. A common type of manometer is U- shaped tube containing a fluid that is connected to the pressure to be measured Fig (1).
P_0= atmospheric pressure
h= height of liquid
P=the pressure of container.

The most common clinical instrument used in measuring pressure is the sphygmomanometer , which measures blood pressure. Two types of pressure gauges are used in sphygmomanometers.

1- Mercury manometers.

2- Aneroid.

3- Recently another type used (digital).

.

Gauge pressure :is defined as the excess pressure over atmospheric pressure.

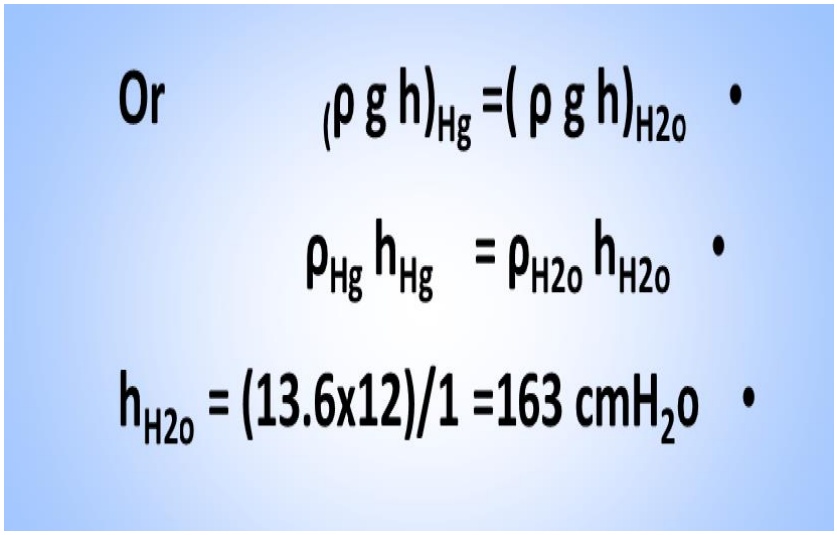
Gauge pressure $=\rho\, g\, h$
$=1000 \times 9.8 \times 10$
$=10^5\ N/m^2 = 1$ atm

Absolute pressure=atmospheric pressure+gauge pressure
$=1+1=2$ atm

Or In N/m^2
$=10^5 + 10^5 = 2 \times 10^5\ N/m^2$

Atmospheric pressure $= \rho_{Hg}\, g\, h_{Hg} = 13600 \times 9.8 \times 0.76$
$=10^5\ N/m^2$

Ex:-what height of water will be produced the same pressure as 120 mmHg.
Solution:
P= ρ g h= 13.6x980x12
=1.6x105dy/cm2
For water P= ρ g h
1.6x105=1x980xh
So h= 163 cm H_2o



Negative pressure:

Any pressure lower than atmospheric pressure. For example , when we breathe in (inspire)the pressure in the lungs must be somewhat lower than atmospheric pressure or the air would not flow in.

Blood pressure

The blood pressure (BP) of a patient is used as a routine clinical measure of health. This pressure is often measured using a device called a sphygmomanometer.

BP is the force originating in the pumping action of the heart, exerted by the blood against the walls of the blood vessels. Typical value of BP in an adult is approximately 120 mmHg (16 kPa) in systolic pressure, and 80 mmHg (11 kPa) in diastolic pressure, abbreviated "120/80 mmHg"..

Systolic pressure (Ps): The maximum pressure exerted on the inner arterial walls during ventricle contraction of the heart.

Diastolic pressure (Pd): The minimum pressure exerted on the inner arterial walls during ventricle relaxation of the heart.

Blood pressure measurements

- *Arterial blood pressure (BP)* -

$$Blood\ pressure\ (BP) = \frac{Systole\ pressure}{Daistole\ pressure} = \frac{120\ mm\ Hg}{80\ mm\ Hg} = \frac{120}{80} \quad (Normal)$$

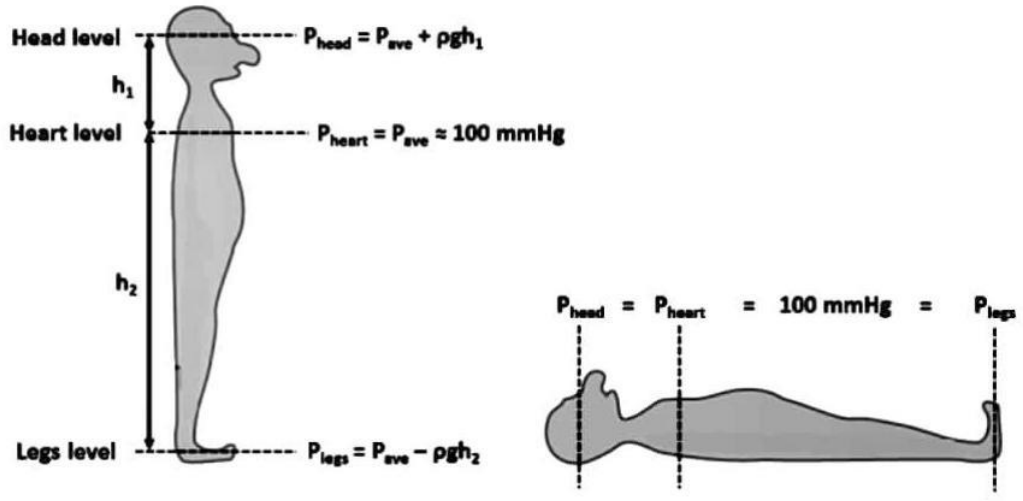
- *Average blood pressure (P_{ave})* - $P_{ave} = \frac{P_s + P_d}{2}$

- *Pulse pressure (P_{pulse})* - $P_{pulse} = P_s - P_d$ (Typical value = 40 mmHg)

- *Mean Arterial Pressure (MAP or P_m)* - which represents the averaged arterial pressure over the cardiac cycle or the pressure that propels the blood to the tissues. ***MAP*** remains almost constant and it is given by:

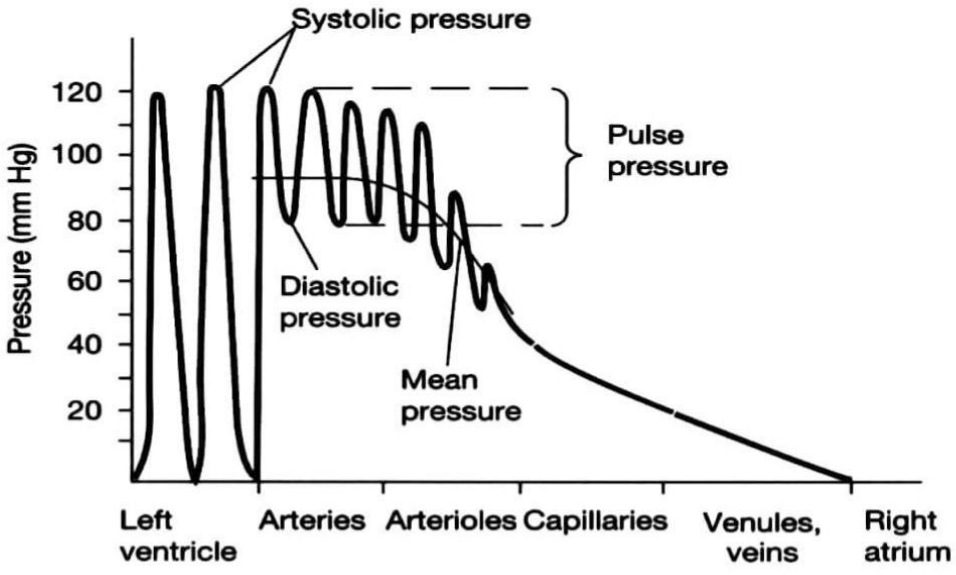
$$P_m = P_d + \frac{1}{3}(P_s - P_d) \qquad \text{(Typical value = 93 mmHg)}$$

The blood pressure at any point in the body is given as shown in the figure below



If the gravity on earth suddenly became three times greater, blood pressure in head is lower and lead to blackout.

The pressure various throughout the circulatory system, it is high at big arteries like aorta and very low when enters the capillaries.

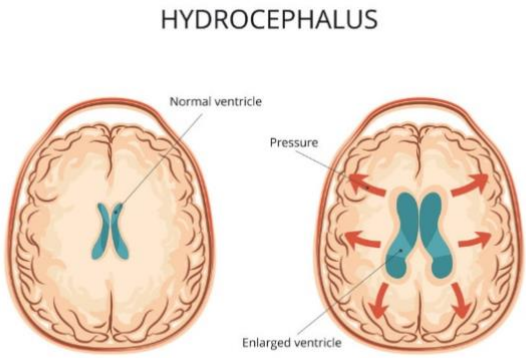


Pressure inside the skull :

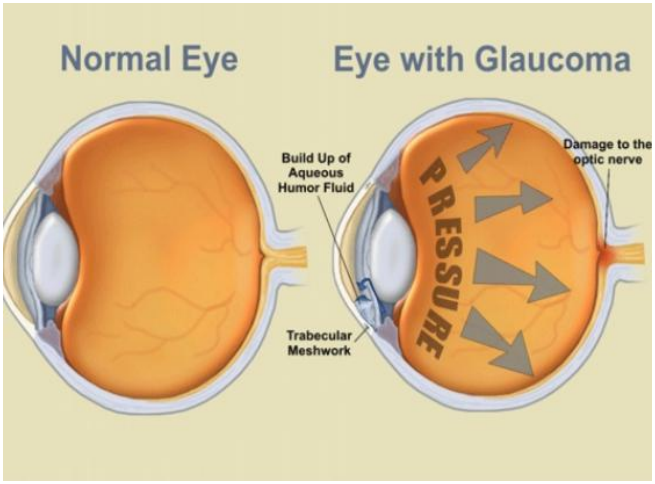
The brain contains approximately 150 cm^3 of cerebrospinal fluid (CSF) in a series of interconnected openings called ventricles.
If at birth this opening is blocked for any reason, the CSF is trapped inside the skull and increased the internal pressure. This serious condition, called hydrocephalus.

Measurement of hydrocephalus

1- Crude method: - In this method the circumference of the skull just above the ears .Normal values of newborn infants are from 32-37 cm, and larger than this may indicate hydrocephalus.
2- qualitative method (transillumination):-
In this method light – scattering properties is used.



Eye pressure: The clear fluids in the eye ball (aqueous and vitreous hu mors) that transmit the light to retina (the light sensitive part of the eye). Are under pressure and maintain the eye ball in fixed size and shape.



If a partial blockage of the drain system occurs, the pressure increase then restrict the blood the blood supply to the retina then affect the vision. This condition, called glaucoma.

Glaucoma : a. Moderate ----------tunnel vision

b . Sever----------blindness

The pressure in normal eyes ranges from (12 –23) mm.Hg

Measuring the eye pressure :

1- By (feel)the physician estimate the pressure inside the eye by (feel) as they pressed on the eye with their fingertips
2- Tonometers .

Pressure in skeleton:

The highest pressures in the body are found in the weight bearing bone (joints).

The pressure in the knee joint may be more

Than 10 atm. P=F/A---------- (1)

the surface area of a bone at the joint is greater than its area either above or below the joint. The larger area at the joint distributes the force thus reducing the pressure according to the equation 1.

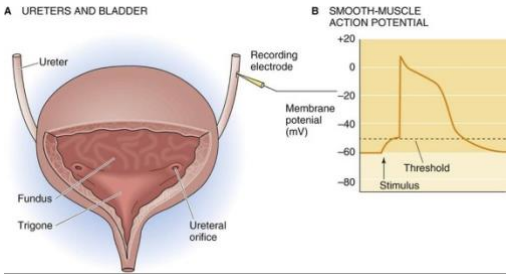
Bone has adapted in another way to reduce pressure the finger bones are flat rather than cylindrical on the gripping side and the force is spread over a large surface this reducing tissues over the bones according to P=F/A .

الضغط

.

Pressure in the urinary bladder :

The internal pressure in the bladder is due to the accumulation of the urine. The figure below shows the typical pressure - volume curve for the bladder, which stretches as the volume increase.



. Volume in the bladder before voiding is (500) ml. at some pressure (~30 cm H_2o) the micturition reflex occurs .

The resulting sizable muscular contraction in the bladder wall produces a momentary pressure of up to 150 cmH_2O.

The pressure in the bladder can be measured:

*By passing a catheter with a pressure sensor into the bladder through the urinary passage (urethra).

*By a needle inserted through the wall of the abdomen directly into the bladder.

This technique gives information about the function of the exit valves that can not be obtained with the catheter technique.

The bladder pressure increases during coughing, straining, sitting up, also during pregnancy the weight of the fetus over the bladder increase the bladder pressure and causes frequent urination.

Normal voiding pressure is fairly low (20-40)cmH_2O but for

Men who suffer from prostate obstruction of the urinary passage it may be over 100cmH_2o.

The bladder pressure increase……

Boyle s law:

For a fixed quantity of gas at a fixed temperature the product of the absolute and volume is constant.(PV=constant)

$P_1 V_1 = P_2 V_2$

That is ,if the absolute pressure is double, the volume is halved.

The middle ear is one of the air cavities that exist within the body. For comfort the pressure in the middle ear should be equal

To the pressure on the outside of the eardrum.

$P_{middle\ ear} = P_{outside\ the\ eardrum}$, this equalization is produced by air flowing through the Eustachian tube , which is usually closed except during swallowing , chewing ,and yawning.

*When diving many people have difficulty obtaining pressure equalization and feel pressure on their ears.

*(120mmHg) across the eardrum, which can occur in about 1.7 m of water, can cause the damage (rupture) to the eardrum.

One method of equalization used by a diver is to raise the pressure in the mouth by holding the nose and trying to blow out.

The pressure in the lung:-

$P_{in\ the\ lung\ at\ any\ depth} > P_{in\ the\ lung\ at\ sea\ level}$

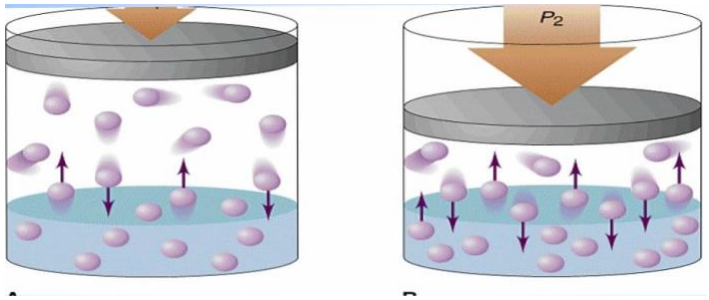
This means that the air in the lung is denser under water and that the partial pressures of all the air components are proportionately higher .

1- The higher partial pressure of O_2 causes more O_2 molecules to be transformed into the blood , and oxygen poisoning results if the partial pressure of O_2 gets high .Partial pressure of O_2 is (0.8 atm) and absolute air pressure is (4 atm) at depth of (30 m).
2- Breathing air at a depth of (30m) is also dangerous because it may result in excess N_2 in the blood and tissues ,there is a possibility of having :
   - Nitrogen narcosis (intoxication effect).
   - The bends or decompression sickness (a scant problem).

*O_2 is attached to red blood cells , while N_2 is dissolved in the blood and tissues .

Henrys law

The amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid.



Hyperbaric Oxygen Therapy (HOT):-

The body normally lives in an atmosphere that is about one fifth O_2 and four – fifth N_2. In some medical situations it is beneficial to increase the proportion of O_2 in order to provide more O_2 to the tissue.

1- Gas gangrene :-
   The bacillus causes gas gangrene then its treated with (HOT) . That is due to bacillus cannot survive in the presence of oxygen (O_2).
2- Carbon Monoxide poisoning :-
   - The red blood cells cannot carry O_2 to the tissues because the carbon monoxide fasters to the hemoglobin at the places normally used by O_2.
   - Normally the amount of O_2 dissolved in the blood is about 2% of that carried on the red blood cells.
   - By using the (HOT) technique , the partial pressure of O_2can be increased by a factor of 15, permitting enough O_2 to be dissolved to fill the body's need .
3- Treatment of cancer :-
   (HOT) with radiation is given to the patient in transparent plastic tank. The theory was that more oxygen would make the poorly oxygenated radiation-resistant cell in the center of the tumor more susceptible to radiation damage .

Q: If the pressure of a man is 8 cm Hg, Does the man have prostate or not?
A/: PHg= PWater

PghHg=ρghwater
The (g) is canceled from both sides
13.6x8=1xhwater
HWater=108.8 cm.so the man has prostate

Note:

▲ If hwater =100…..the man has prostate

▲ If hwater >100…..the man has prostate

▲ If hwater <100…..the man is normal