LECTURE NOTE

ON

HYDRAULICS & IRRIGATION ENGINEERING
(TH.2)

4^{TH} SEMESTER IN CIVIL ENGG.

PREPARED BY

Er. SWAGATIKA SAMAL

(LECTURER)

DEPARTMENT OF CIVIL ENGG.

G.I.E.T (POLYTECHNIC),JAGATPUR,CUTTACK,ODISHA

1.2 pressure and its measurement :-

Intensity of pressure:-

It is defined as the force exerted on a unit area. Let F be the total force that is uniformly distributed over an area A.

Mathematically $p = (F/A)$

In M.K.S system units = kgf/m^2 and kgf/cm^2

In S.I system units - N/m^2 or N/mm^2

problem:-

Find out intencity of pressure for a foundation having length (10×2)m size bearing a total pressure of 500 k.N

Sol^n

$F = 500\ k.N$

$A = (10\times2)\ mt = 20\ mt^2$

Intensity of pressure $= p = \frac{F}{A}$

$= \frac{500}{20} = 25\ k.N/m^2$

$= 25\times10^{-3}\ m^2$

ABSOLUTE PRESSURE:- It is defined as the pressure which is measured with referense to absolute vaccume pressure. It is dennoted as Pab

GAUGE PRESSURE:- It is defined as the pressure which is measured with the help of a pressure measuring, in which the atomospheric pressure is taken as datum. It is dinnoted as Patm

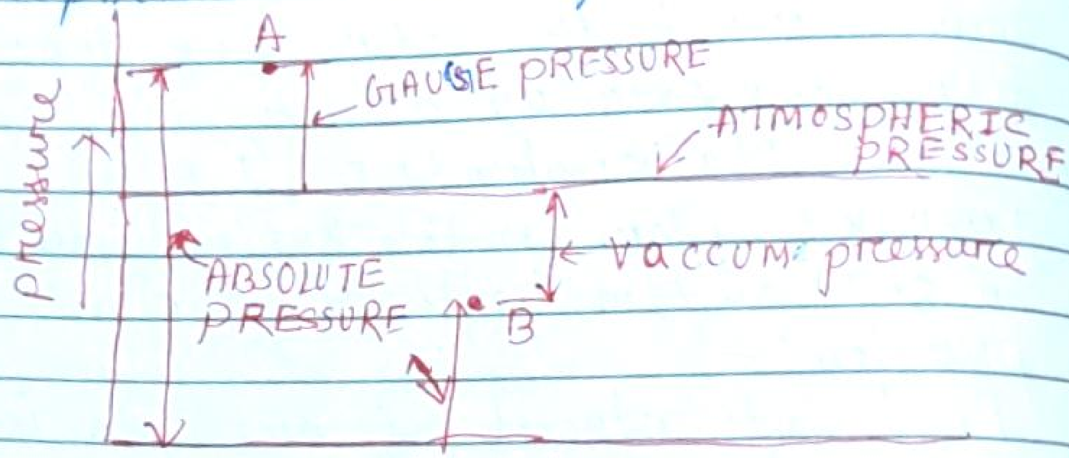
VACUUM PRESSURE:- It is defined as the pressure below the atmospheric pressure. It is dinnoted as Pgauge

The relationship between the absolute pressure gauge pressure and vacuum pressure

(i) Absolute pressure = Atmospheric pressure + Gauge pressure

$P_{ab} = P_{atm} + P_{gauge}$

(ii) Vaccum pressure
= Atmospheric - Absolute pressure



Pressure Head:-
Pressure head is defined as it is the ratio of pressure to weight density.
~~It is dinnoted as (K)~~

pressure head $= \frac{P}{V} = \frac{W/A}{V} = \frac{N/mm^2}{N/mm^3}$

$H = mm$

Pressure Gauge:-
It is a device used to measure pressure.
Various type of pressure measuring instrument
1) mano meter.
2) Mechanical Gauges.

Manometer:- Manometers are defined as the devices used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of the fluid. They are classified as:-
(a) simple manometers (b) Differential manometer

Mechanical Gauges:-
Mechanical gauges are defined as the devices used for measuring the pressure by balancing the fluid column by the spring or dead weight

The commonly used mechanical gauges are:—
(a) Diaphragram pressure gauge
(b) Bourdon tube pressure gauge
(c) Dead weight pressure gauge
(d) Bellows pressure gauge

Simple Manometer

- piezometer
- U-tube manometer
- Single column manometer

Differential Manometer

- U-tube Differential manometer
- Inverted U-tube differential manometer.

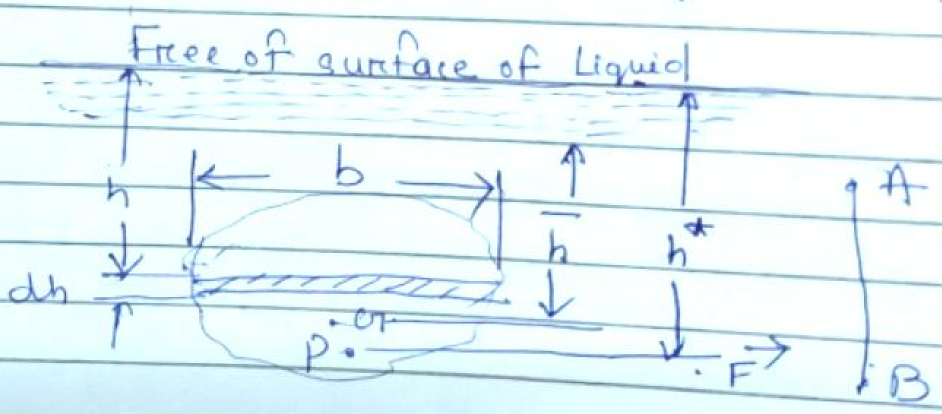
1.3 Pressure exerted on an immersed surface

Total pressure:– Total pressure is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surfaces.

Center of pressure:– It is defined as the point of application of the total pressure on the surface. There are four cases of submerged surfaces on which the total pressure and centre of pressure is calculated.

1. Vertical plane surface
2. Horizontal plane surface
3. Inclined plane surface
4. Curved surface.

Vertical plane surface submerged in liquid:–



Consider a plane vertical surface.

Let A = Total area of the surface

$\bar{h}$ = Distance of C.G of the area from free surface

G = Centre of gravity

P = Centre of pressure

h^* = Distance of centre of pressure from free surface.

(a) Total pressure (F)

It is determined by deviding the entire surface of small parallel strips.

Consider a strip thickness dh and width b at depth of h.

pressure intensity on the strip $p = \rho g h$

Area of strip $= dA = b \times dh$

Total pressure $dF = P \times Area$

$= \rho g h \times b \times dh$

Totall pressure on whole surface.

$F = \int dF = \int \rho g h \times b \times dh$

$= \rho g \int b \times h \times dh$

But $\int b \times h \times dh = \int h \times dA$

= Moment of surface Area

= Area x Distance of C.G

$= A \times \bar{h}$

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

For water $\rho = 1000 kg/m^3$ & $g = 9.81 m/s^2$

(b) Centre of pressure :—

It is calculated by using principle of Moment which states that the the moment of ressultant force about an axis is equal to the sum of moment of the components.

$P = F \times h^*$

Moment of force $dF = dF \times h$ ($\because dF = \rho g h \times b \times dh$)

$= \rho g h \times b \times dh \times h$

Sum of moments $= \int \rho g h \times b \times dh \times h = \rho g \int b \times h \times dh$

$= \rho g \int b h^2 dh = \rho g \int h^2 dA$

But $\int h^2 dA = \int b h^2 dh$

$=$ Moment of inertia $= I_0$

Sum of moments $= \rho g I_0$

$$F \times h^* = \rho g I_0$$

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

But $\rho g A \bar{h} \times h^* = \rho g I_0$

$$h^* = \frac{\rho g I_0}{\rho g A \bar{h}} = \frac{I_0}{A \bar{h}}$$

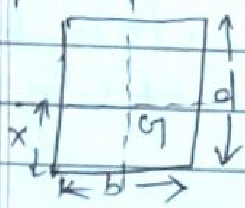
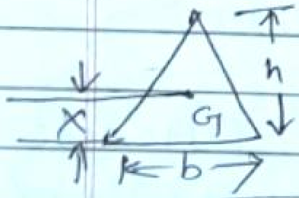
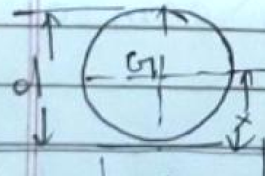
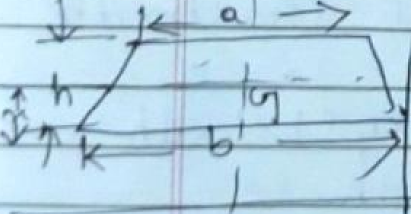
By the theorem of parall axis, we have

$$I_0 = I_G + A \times \bar{h}^2$$

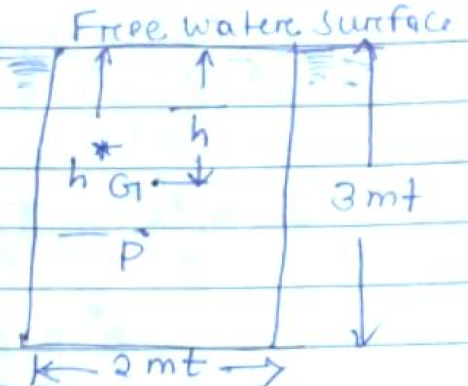
I_G = Moment of interteal about an axis.

Putting the value of I_0 = (Moment of intertia about base)

$$= h^* = \frac{I_G + A\bar{h}^2}{A\bar{h}} = \frac{I_G}{A\bar{h}} + \bar{h}$$

plane surface	C.G from the base	Area	I_G	I_0
	$x = d/2$	bd	$\frac{bd^3}{12}$	$\frac{bd^3}{3}$
	$x = h/3$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$
	$x = d/2$	$\frac{\pi d^2}{4}$	$\frac{\pi d^4}{64}$	—
	$x = \left(\frac{2a+b}{a+b}\right)\frac{h}{3}$	$\left(\frac{a+b}{2}\right) \times h$	$\left(\frac{a^2+4ab+b^2}{36(a+b)}\right) \times h^3$	—

Q) A rectangular plane surface is 2m wide & 3m deep. It lies in vertical plane in water. Determine the total pressure & position of centre of pressure on the plane surface when its upper edge is horizontal and (a) coincides with water surface (b) 2.5m below the free water surface:-



Sol^n $b = 2mt$

$d = 3mt$

(a) $F = \rho g A \times \bar{h}$

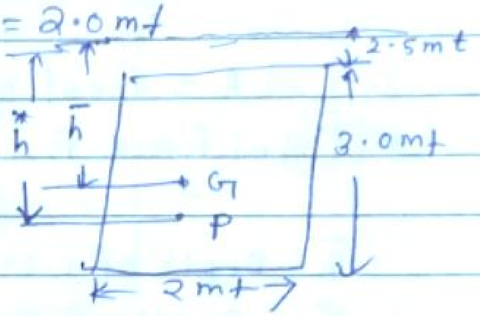
$\rho = 1000 \, kg/m^3$, $g = 9.81 \, m/s^2$

$A = 3 \times 2 = 6 mt^2$, $\bar{h} = \frac{1}{2}(3) = 1.5 mt$

$F = 1000 \times 9.81 \times 6 \times 1.5 = 88290 N$.

$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$, $I_G = \frac{bd^3}{12} = \frac{2 \times 3^3}{12} = 4.5 \, m^4$

$h^* = \frac{4.5}{6 \times 1.5} + 1.5 = 0.5 + 1.5 = 2.0 mt$



(b) $F = \rho \times g \times A\bar{h}$

$\bar{h}$ = Distance of C.G

$= 2.5 + \frac{3}{2} = 4.0 mt$

$F = 1000 \times 9.81 \times 6 \times 4.0$

$= 235440 N$ Ans

$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$, $I_G = 4.5$, $A = 6.0$, $\bar{h} = 4.0$

$h^* = \frac{4.5}{6.0 \times 4.0} + 4.0$

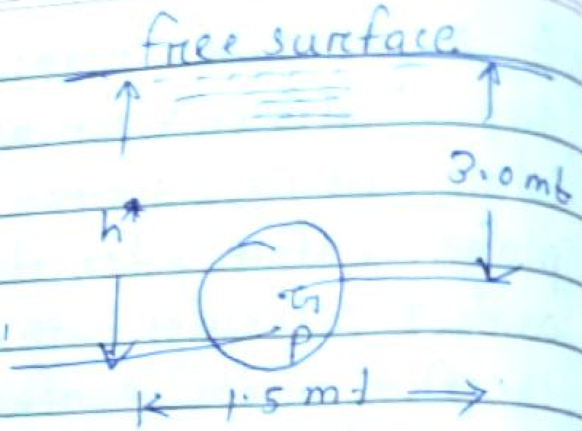
$= 0.1875 + 4.0 = 4.1875 mt.$

Q) Determine the total pressure on a circular plate of diameter 1.5 mt which is placed vertically in water in such a way that the centre of the plate is 3mt below the free surface of water. Find centre of pressure.

Sol^n $d = 1.5$ mt

$A = \frac{\pi}{4} \times (1.5)^2 = 1.767\ m^2$

$\bar{h} = 3.0$ mt



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

$= 1000 \times 9.81 \times 1.767 \times 3.0$ N

$= 52002.81$ N

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

$I_G = \frac{\pi d^4}{64} = \frac{\pi \times 1.5^4}{64} = 0.2485\ m^4$

$h^* = \frac{0.2485}{1.767 \times 3.0} + 3.0 = 0.0468 + 3.0$

$= 3.0468$ mt.

Horizontal plane surface submerged in liquid:-

Let A = Total area of surface

Total force $F = p \times \text{Area}$

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

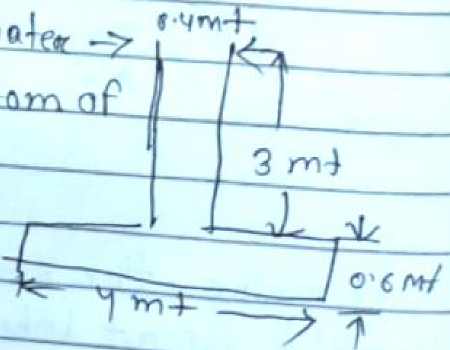
$\bar{h}$ = Depth of C.G = h

h^* = Depth of centre of pressure = h

Q) fig 1. shows a tank full of water → find (i) Total pressure on the bottom of tank

(ii) Weight of water in tank

(iii)



Sol^n Depth of water on bottom of tank $= h_1 = 3 + 0.6 = 3.6$ mt

width of tank = 2 mt, Length of tank = 4 mt

Area $= A = 4 \times 2 = 8\ m^2$

$F = \rho g A \bar{h} = 1000 \times 9.81 \times 8 \times 3.6 = 282528$ N

Weight of water tank $= \rho g \times$ volume of tank

$= 1000 \times 9.81 \times \{3 \times 0.4 \times 2 + 4 \times .6 \times 2\} = 70632$ N.

CHAPTER - 2

KINEMATICS OF FLUID FLOW

2.1 Basic Equation of fluid flow and their application :—

Rate of discharge :— It is defined as the quantity of a fluid flowing per second through a section of a pipe or a channel

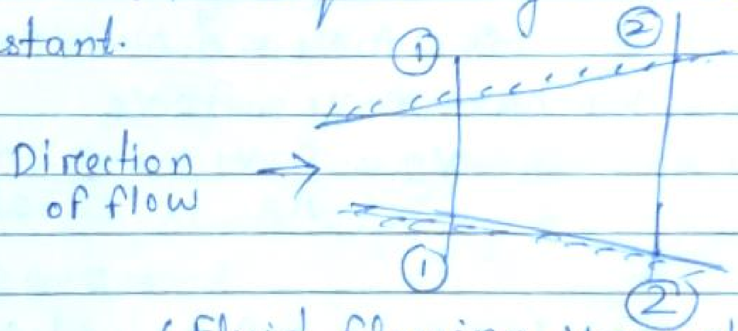
If A = cross-sectional area of pipe
V = Average velocity of fluid across the section

$$Q = A \times V$$

Continuity eq^n for liquid flow :—

→ It is based on the principle of conservation of mass

→ Thus for a fluid flowing through the pipe at all the cross-section, the quantity of fluid per second is constant.



(Fluid flowing through the pipe)

Let v_1 = Average velocity at cross-section 1-1
ρ_1 = Density of section 1-1
A_1 = Area of pipe at section 1-1
and V_2, ρ_2, A_2 are corresponding value at section 2-2

Then rate of flow at section-1-1 = $\rho_1 A_1 V_1$
" " " " " " 2-2 = $\rho_2 A_2 V_2$

According to law of conservation of mass.
Rate of flow section 1-1 = Rate of flow at section 2-2

DEFINITION →

The science of studying the different forms of water available above the earth surface ore below the earth surface is known as hydrology.

It includes the following points.

(1) The measurement of precipitation (i.e rain fall).

(2) The study of water losses due to transpiration, evaporation, absorption and infiltration.

(3) Estimation of run-off and peak flow.

(4) The procedure of river gauging.

(5) Preparation of hydrograph to predict maximum flood discharge.

(6) The procedure of river training works.

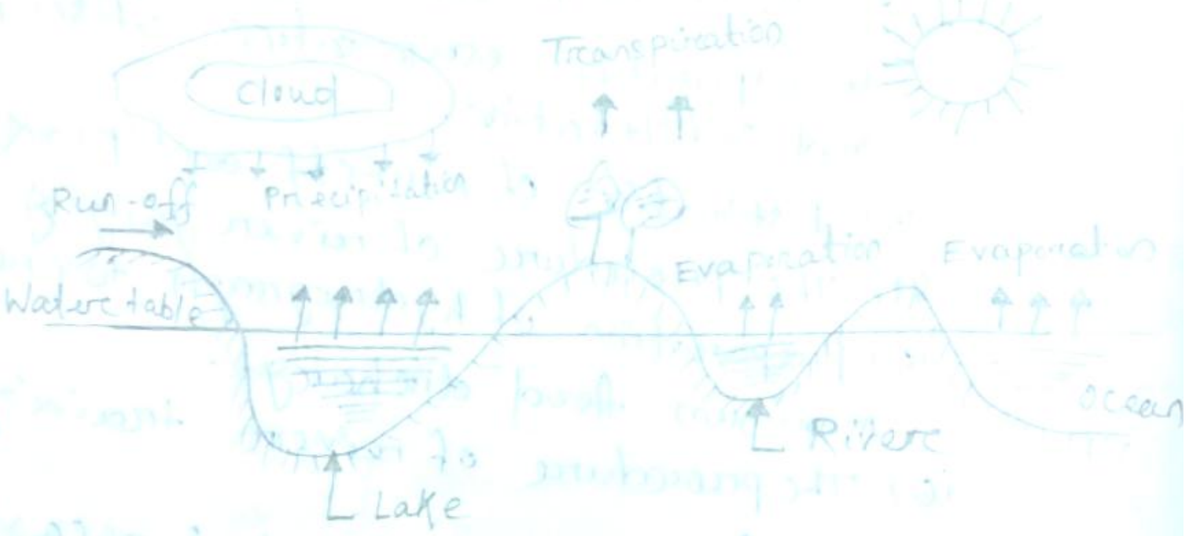
(7) The procedure of flood forecasting and flood control works.

(8) Availability of underground water.

HYDROLOGIC CYCLE →

The water of the universe always changes from one state to other under the effect of the sun. The water from the surface sources like lakes, rivers, ocean, etc. converts to vapour by evaporation due to solar heat. The vapour goes on accumulating continuously in the atmosphere. This vapour is again condensed due to the sudden fall of temperature and pressure. This clouds are formed. These clouds again causes the precipitation (i.e. rainfall).

some of the vapoure is converted to ice at the peak of the mountains. The ice again melts is summer and flows as rivers to meet the sea or ocean. There processes of evaporation, precipitation and melting of ice goes continuously like an endless chain and thus a balance is maintained in the atmosphere. This phenomenon is known as hydrologic cycle.



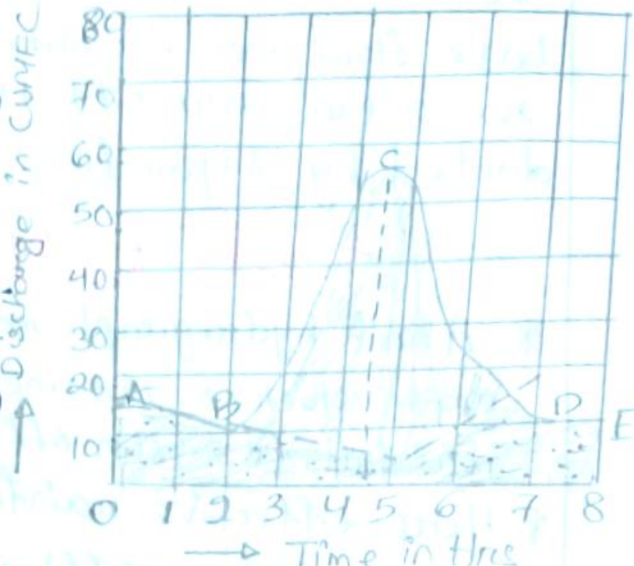
(Hydrologic Cycle)

HYETOGRAPH→

The graphical representation of rainfall and run-off is known as hyetograph. The graph is prepared with intensity of rainfall (in cm/hr) as ordinate and time (in hrs) as abscissa. The infiltration capacity curve is drawn on this graph to show the amount of infiltration loss (shown by dotted portion). The upper portion indicates the effective rainfall (shown by hatched lines). The centroid of the effective rainfall is ascertained on the graph for the determination of total run-off at any specified period.

HYDROGRAPH →

The hydreograph is a graphical representation of the dischange of a rivere (in cumec) against the time (in hrs or days). The dischange is plotted as ordinate (y-axis) and the time is plotted as abscissa (x-axis)



(Hydreograph)

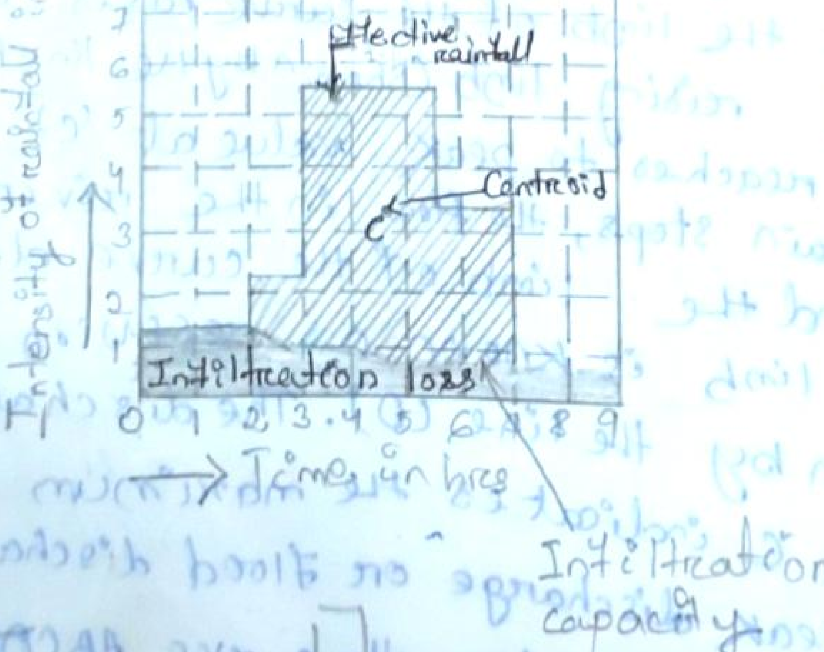
During the dry-season, there is only base flow (i.e ground water flow) but no surface run off. This may be shown by a line which is approximately straight.

* In rainy season, at the beginning of the rainfall there is only base flow (shown by the line AB).
* After some period when the initial losses (like interception, evaporation and infiltration) are fulfilled, the surface runoff starts and hence the discharge of the rivere goes on increasing.
* Hence the limb of the curve rises which is called rising limb (shown by the line BC). This line reaches to peak value at 'C'. Again when the rain stops, the flow in the rivere decreases and the limb of the curve declines.
* This limb is known as recession limb) (as shown by the line CD). The discharge at the point C indicates the maximum dicharge (i.e peak discharge or flood discharge). The total area undere the curve ABCDE indicates

the total run off. But this run off includes the base flow and the direct runoff. So, to get the actual run off the base flow is to be deducted by separating is from total area.

UNIT HYDROGRAPH

* A unit hydrograph may be defined as a hydrograph which is obtained from one cm of effective rainfall (i.e. run-off) for unit duration.
* Here, effective rainfall means the rainfall excess (i.e run-off) which directly flows to river or stream.
* The unit duration is the period during which the effective rainfall is assumed to be uniformly distributed.
* The unit duration may be considered, as hre, 2hre, 3hre, 4hre...., etc. As for example if a hydrograph is prepared for an effective rainfall of one cm lasting for 2 hrs, then it is known as 2hre, unit hydrograph, for the duration of 3 hrs it is known as 3 hrs hydrograph and so on.



[Hyetograph]