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SO_2 as Pollutant ⇒
(i) London Smog.

(ii) Acid rain :-

$SO_2 + H_2O \rightarrow H_2SO_4$.
$NO_x + H_2O \rightarrow HNO_3$
↓
falls on ground as acid rain.

Effect of acid rain :-

i) < 4.5
(ii) Attack plant foliage & roots.
acid → nutrients
↓
(iii) damage

$\underset{\text{Limestone}}{CaCO_3} + H_2SO_4(aq) \rightarrow \underset{\text{Gypsum}}{CaSO_4(s)} + H_2O + CO_2(g)$

Particulate matter (PM) :

Small solid particles or drops of liquids or small.
↓↓
aerosols

PM 2.5, PM 10
↓
< 2.5 μm   1 μm = 10^{-4} cm

Diameter of hair = 50-70 μm
dust,
metals

low grade coal → contain high % of sulphur.

Effect :-

1) < 10 pm →.

Organic air pollutants :-

CH_4

1) Natural sources :- Manmade

CH_4, terpene, etc.

$CH_2O \xrightarrow{microorganism} CO_{2(g)} + CH_{4(g)}$

$CH_4 \xrightarrow{sunlight} CO + O_3$

2) manmade organics

1) Ethylene.
2) Propylene
3) PAH, benzene, toluene etc.

Effects :-

Q. A power plant generate 2.76×10^5 mega watt hour of electricity per year by burning 1.66×10^9 tons of low grade coal containing 3.2 % of sulphur and 15.4 % of ash. The ratio of fly ash to bottom : 0.65 & the plants particulate collection efficiency is 85 % Determine the amount of each pollutants emitted per year in pounds/kilowatt hour.

Soln: Particulate Matter $= e_p = a \cdot b \cdot c\left[1-\left(P/100\right)\right] \times 10^{-2}$

$e_{SO_2} = 1.90 (c) \times S \times 10^{-2}$

Nitrooxide $= e_{NO_x} = 15 \times C \times 10^{-3}$.

a = mass % ash contains of coal burns.
b = ratio of flyash to bottom ash
c = coal consumption in tons/y
P = % particulate collection efficiency of the collector.

S = average annual mass % of coal sulphur contain.

$a = 15.4$
$b = 0.65$
$c = 1.66$
$P = 85$
$S = 3.2$
$e_p = 2492$ ton/year
$e_p = 4.98 \times 10^6$ pound/year

$\boxed{1 \text{ ton} = 2000 \text{ pounds}}$

$$e_p = \frac{4.98 \times 10^6 \text{ lb/year}}{2.76 \times 10^5 \text{ MWh/y}}$$

$= 0.018$ lb/kilowatt hours.

foot pound sec

Q. Fly ash particles settle down through air. You are asked to calculate the particle terminal velocity and determine how far it ~~is~~ will fall in 30 sec.

Data:- Fly ash diameter is equal 40 μm
Air temperature & pressure = 238°F & 1 atm
air viscocity = 1.41×10^{-5} pound / ft sec
Molecular mass in air = 29 lb/mole.
specific gravity of Fly ash = 2.31

Solⁿ:- Dimension constant determine the appropriate range of fluid particle diameter law.

$$K = d_p\left(\frac{g(\rho_p-\rho)\rho}{\mu^2}\right)^{1/3} = 0.33$$

d_p = Particle diameter
g = gravititional force
$\rho_p \Rightarrow$ Particle density
$\rho \Rightarrow$ fluid gas density,
$\rho \rightarrow$ density of air,
$\mu \Rightarrow$ viscocity of air.

$K < 3.3 \Rightarrow$ Stokes law $\Rightarrow$
$3.33 < K < 43.6 \Rightarrow$ Intermediate law range $\Rightarrow$
$43.6 < K < 2360 \Rightarrow$ Newton law range.

Stoke $\boxed{v = \frac{g d_p^2 \rho_p}{\mu^2}}$

Newton $\Rightarrow v = 1.74\left(\frac{g d_p \rho_p}{\rho}\right)^{0.5}$

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Greenhouse Effect :-

Avg. Surface temp should be ⇒ -18°C
Actualy avg. surface temp ⇒ 15°C

Sun's spectral output is composed of 9% UV, 41% visible light & 50% IR radiation.

Absorbed by atmosphere + cloud = 18%
Scattered by atm. + cloud = 26%

51% is absorbed by earth surface.
Only 4-5% reflected from this surface.

⇒ Example of green house Effect
CO_2, water vapour, CH_4, NO_x, CFC.

Longwave radiation emitted by earth's surface ⇒ goes back to the space.

much of LW radiation emitted by earth's surface ⇒ trapped inside the atm. by GHG.

⇒ Wein's Law :-

(a) $\lambda_{max} = \frac{2900}{T} \mu m$

(b) $E_{Total} = 5.67 \times 10^{-8} T^4$
σ = Stefan Boltzman const

Unit of $\sigma = Wm^{-2}K^{-4}$.

Q. What is the max. λ & total energy emitted by ...

Soln. $\lambda_{max} = \frac{2900}{6000} = 0.48\ \mu m = 480\ nm$

$$E_{Total} = 5.67 \times 10^{-8} \left(6 \times 10^3\right)^4$$
$$= 7.35 \times 10^7\ W/m^2$$

Air Pollution & Meteorology :-

⇒ Atmospheric stability — Adiabatic lapse rate $\Gamma = -1°C/100\,m$

atmosphere (ambient lapse rate)

actual change in temp. with height.

looping plume

(i) $\frac{dT_{ATM}}{dz} > \Gamma$ ⇒ unstable ⇒ Superadiabatic condn.

atm temp drops at a rate more than 1°C/100m (when ambient lapse rate greater than adiabatic lapse rate)

(ii) $\frac{dT_{ATM}}{dz} = \Gamma$ ⇒ neutral ⇒ Coning plume.

fanning plume

(iii) $\frac{dT_{ATM}}{dz} < \Gamma$ ⇒ Stable ⇒ subadiabatic condn.

temp inversion is special case of sub-adiabatic condn ⇒ fumigation.

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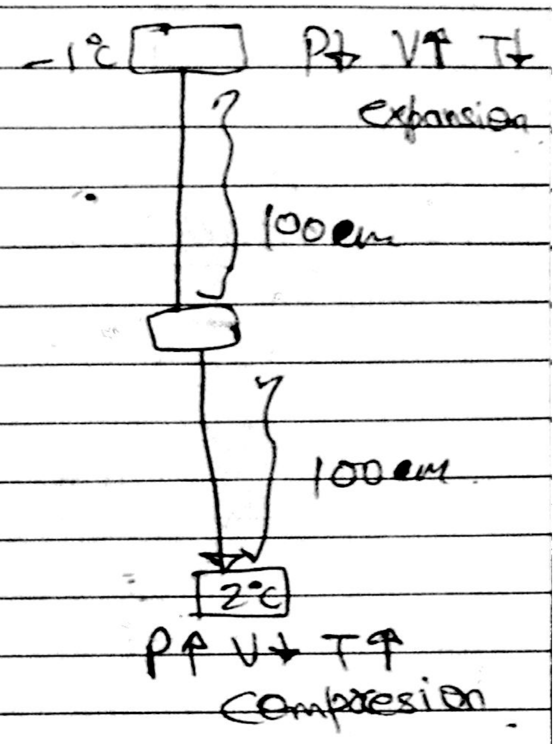
Parcel Method of determining Stability :-

⇒ adiabatic lapse rate.
$\pm 1°c/100m$.

* Small body of air, a few metre wide.
* adiabatically.

$PV = RT$

$P \propto \frac{1}{V}$

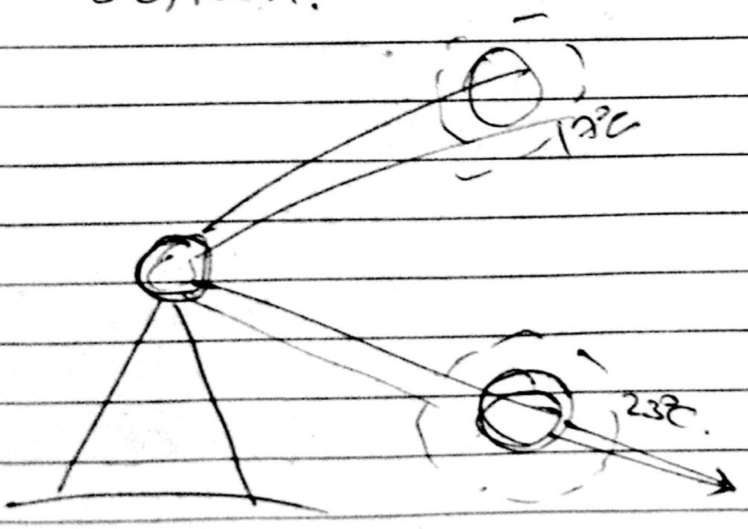


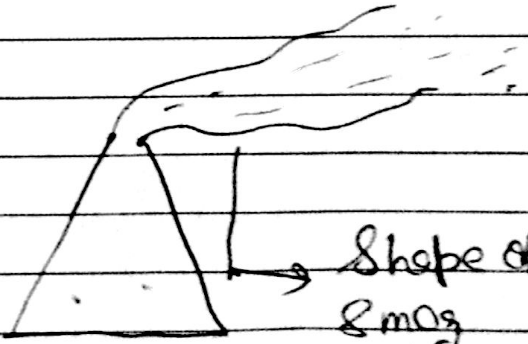
⇒ This is known as adiabatic lapserate.

(I) Unstable cond^n :-

$\frac{dT_{ATM}}{dZ} > \Gamma$ 1°c/100m

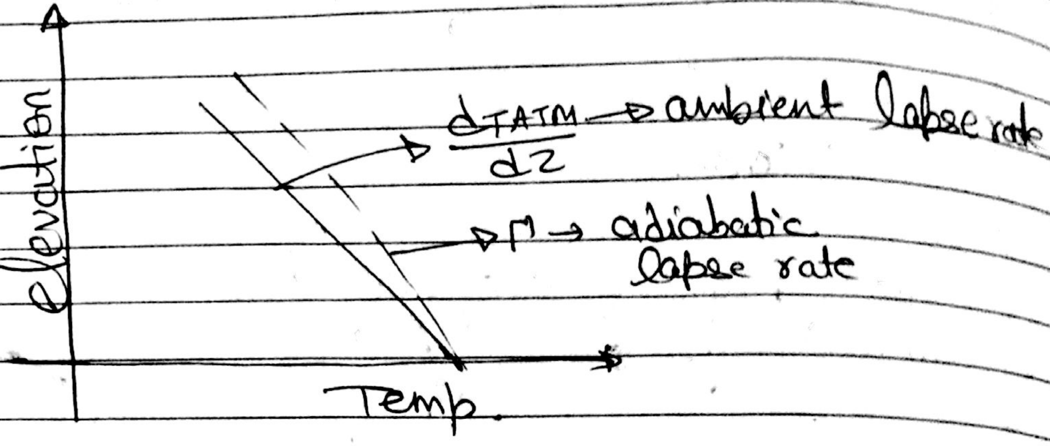
3°c/100m.





Shape of smog under unstable cond^n.

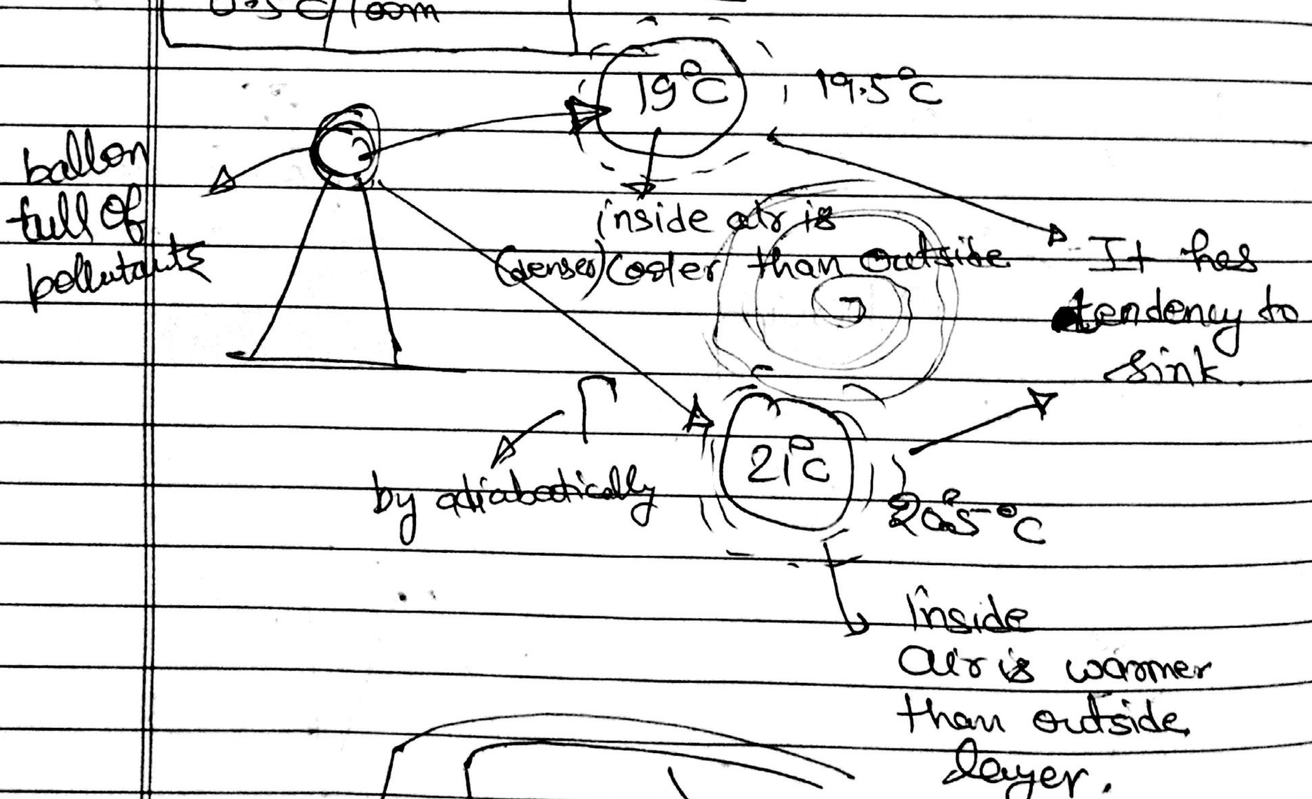
Ex :- Bright sunny day. (afternoon)

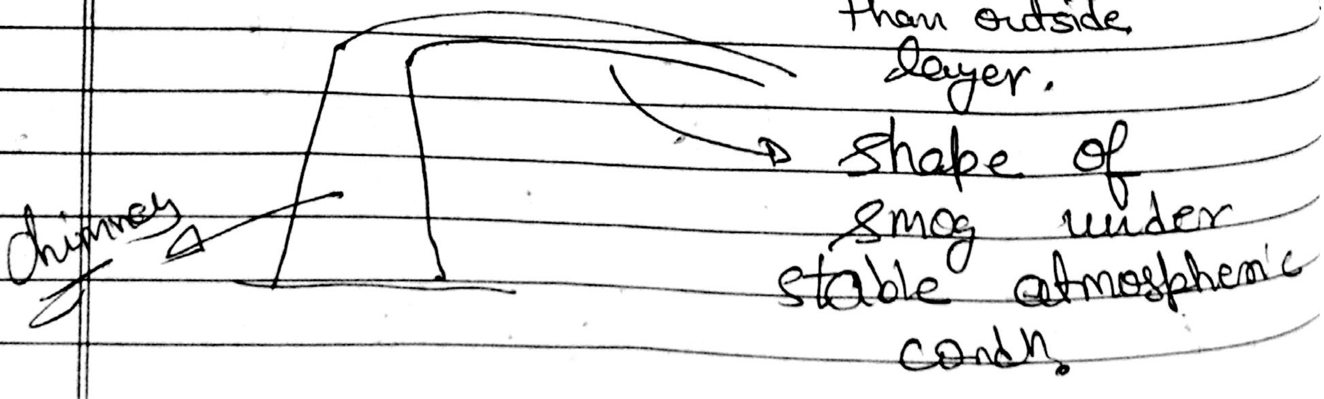


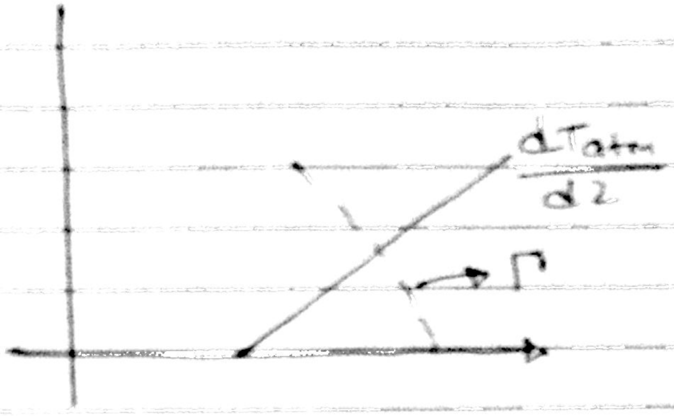
(III) Stable :-

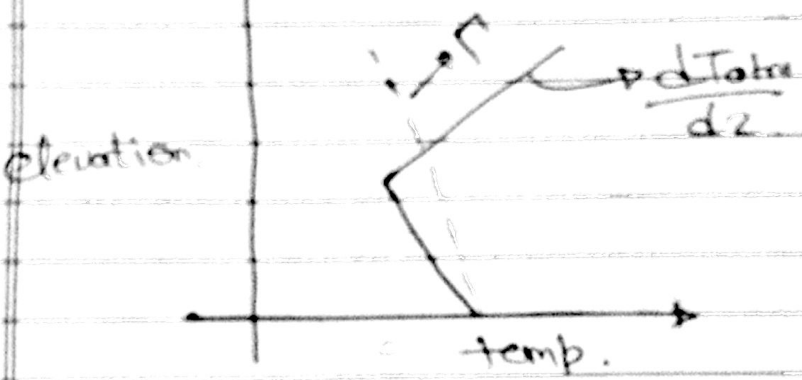
$$\boxed{\frac{dT_{ATM}}{dz} < \Gamma}$$

$0.5^\circ C/100m$ $\quad$ $1^\circ C/100m$









IV. Inversion

Eg:- Late at night after 1-2 am. → Stable cond^n.

↓ Very stable cond^n.

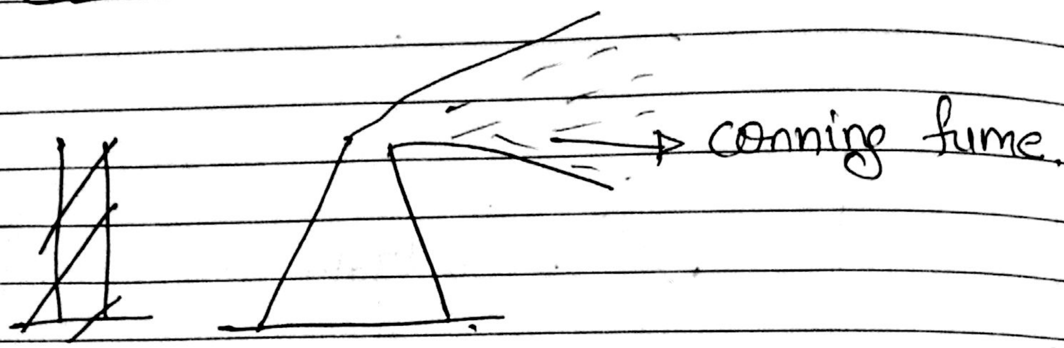
↓

Inversion

Ex:- Early in the morning.

II Neutral Condⁿ :-

$$\frac{dT_{ATM}}{dZ} = \Gamma$$



Elevation(m)	Temp(°C)
2.00	14.35
32400	[redacted] 11.13

3.23
~~32998~~

A : strongly unstable atm
B : moderately unstable.
C : slightly unstable.
D : neutral.
E : Slightly stable.
F : moderately stable.
G : Strongly stable. (Inversion layer).

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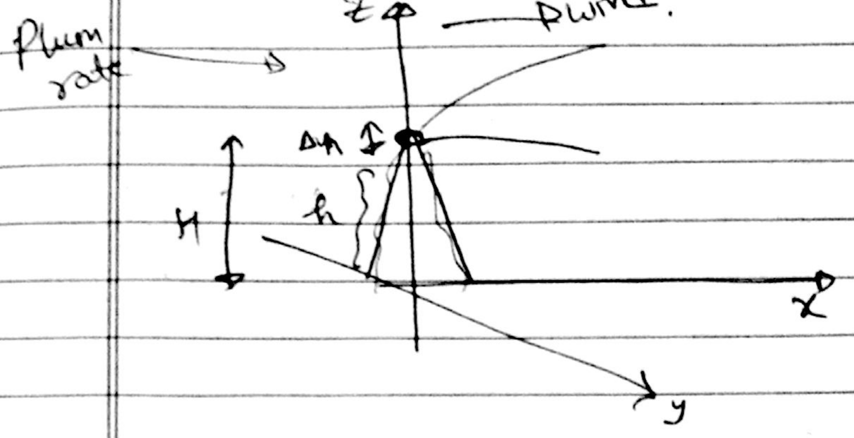
Gaussian Dispersion Method :-



(i) Ground level concⁿ.
(ii) Wind speed
(iii) Brigg's model

⇒ Δh

H = h + Δh

$$C_{(x,0,0)} = \frac{Q}{\pi u \sigma_y \sigma_z}$$

Q = Emission rate of the pollution source. (g/s)

u = av. wind speed,

σ_y = std derivation of plum or dispersion coefficient.
= measure the plum speed in the vertical dirⁿ.

σ_z = measure of the plum speed in cross wind.

Q. An oil pipeline leak results in emission of 100 gm/hour of hydrogen sulphide (H_2S). On a very sunny summer day. Wind speed is 3m/s What will be the concⁿ of H_2S is 1.5 KM directly downwind from the leak.

$\sigma_y = 210m$. $\sigma_z = 160m$

Solⁿ :- $C_{(x,0,0)} = \frac{Q}{\pi u \sigma_y \sigma_z} = 8.77 \times 10^{-8} g/m^3$
$= 0.088 \mu g/m^3$.

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Grd. level conc^n of pollutants in any dir^n (along the plume centreline) ((z = 0, y = 0))

$$C(x,0,0) = \frac{Q}{\pi u \sigma_y \sigma_z} e^{\left(\frac{-H^2}{2\sigma_z^2}\right)}$$

$H = h + \Delta h$
$\downarrow$
plume rise

$$C = \frac{Q}{\pi \bar{u} \sigma_y \sigma_z}$$

Variation of windspeed with elevation :-

$$u = u_0 \left(\frac{h}{h_0}\right)^p$$

u = wind speed at height h
u_0 = " " 10m
p = exponent.

Stability	h
A	1
B	1
C	1
D	1

Q. h = 10 m measures windspeed at 2.5 m/s. Estimate the windspeed at an elevation of 300 m if atm is slightly unstable.

Sol^n:- $u_H = u_0 \left(\frac{H}{h_0}\right) = 2.5 \left(\frac{300}{10}\right)^{0.2}$

$$\boxed{u_H = 4.9 \text{ m/s}}$$

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Plume rise :-

Stable :-

$\bar{u} = \langle u \rangle$

$$\Delta h = 2.6 \left(\frac{F}{\bar{u} S} \right)^{1/3}$$

F_b = initial bioyancy flux of the emitted plume.

$$= g \frac{(T_s - T_A)}{T_s} \cdot V_s \cdot r^2$$

r → radius of chimney.

V_s = exit velocity of plume (m/s)

Stable

$$\boxed{S = \frac{g}{T_A}\left(\frac{dT}{dz}\right)}$$

Unstable

$$\Delta h = \frac{1.6 \times F^{1/3} \times x_f^{2/3}}{\bar{u}}$$

x_f = distance downwind to pt. of plume rise (m)

(a) $F \geq 55 \; m^4/s^3$
then $x_f = 120 F^{0.4}$

(b) $F < 55 \; m^4/s^3$.
$x_f = 50 F^{5/8}$.

Q. A large power plant a 250m stack inside radius 2m $u_s = 15$ m/s at a temp of 140°C, $T_A = 25$°C and winds at the stack height is 5 m/s.

H ⇒ stable, unstable condⁿ.

Solⁿ:- $H = h + \Delta h$

$$F = g r^2 u_s \left(1 - \frac{T_A}{T_s}\right)$$

$$= 9.8 \ldots \ldots = 164 \; m^4/s^3 = F$$

⇒ Stable ⇒ $S = \frac{g}{T_A}\left(\frac{dT}{dz}\right)$

⇓

$$\frac{9.8 \; m/s^2}{298 \; K} \quad = 0.015 \; K/m$$

$$S = 0.004/s^2$$

$$\Delta h = 2.6\left(\frac{F}{u S}\right)^{1/3} = 113 \; m$$

$H = 113 \; m + 250 \; m$

$H = 363 \; m$

⇒ unstable

$$x_f = 120 \, F^{0.4}$$

$$= 923 \; m - x_f$$

$$\Delta h = \frac{1.6 F^{1/3} \cdot x_f^{2/3}}{\bar{u}}$$

$$= 166m$$

$$H = 413m$$

Solid Waste Management (SWM) :-

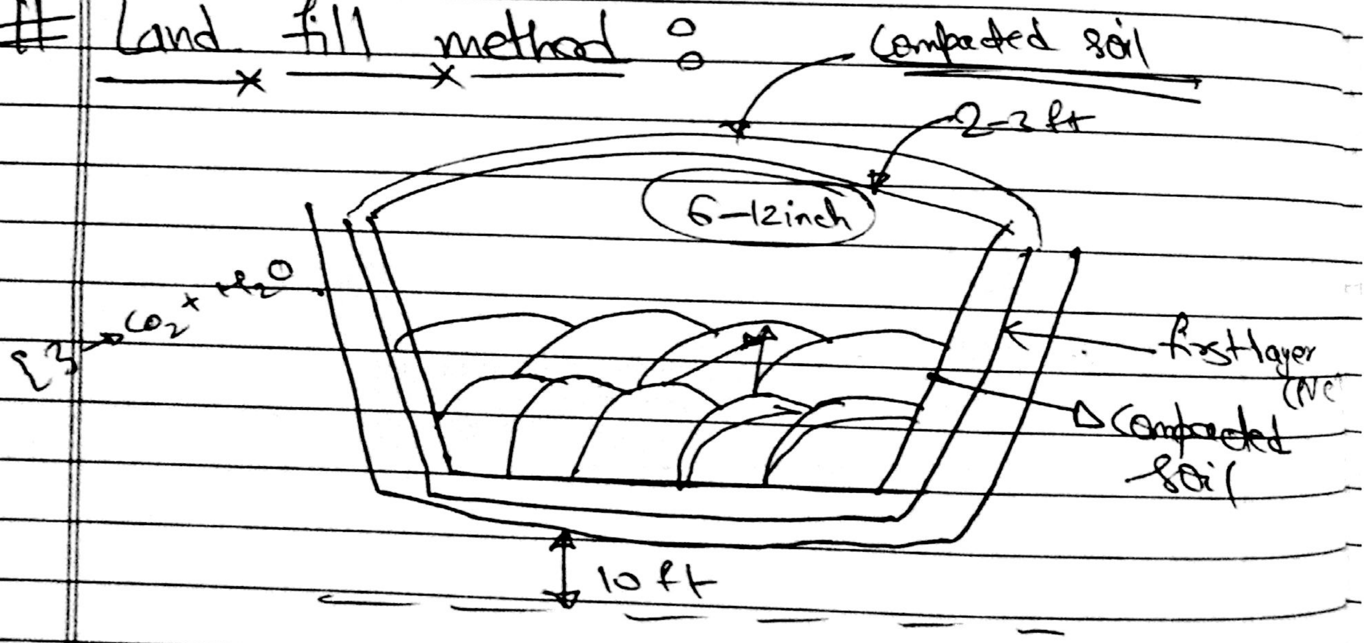
Solid waste :-

1. Open dumping
2. Land fill method
3. Inxcineration
4. Vermitechnology
5. Composting.

Open dumping :-

Dispord

Land fill method :



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Darcy's law

$Q \propto SA$ or $Q = kSA$ — ①

Q = Quality of liq. flowing through area a per unit time.

k = coefficient of hydraulic Conductivity.

i.e $Q = nvA$ — ②

$kSA = nvA$

$$v = \frac{kS}{n}$$

n = soil porosity.
v = velocity at which the liq. travels through the soil.
S = hydraulic gradient.

$$S = \frac{H}{d}$$

H = diff. in elevation b/w water surface at the bottom of the landfill & at the top of groundwater table.

d = distance through which liq. must travel.

Q. If a sanitary landfill were set in a Clay having 50% porosity & $k = 1 \times 10^{-7}$ cm/s.

$H = 1.5$ m $d = 15$ m / Cal. time reqd to travel?

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Sol^n:- $S = \frac{H}{d} = 1.0$

$t = \frac{d}{v} = \frac{1.5 m}{6.3 \times 10^{-2} m/year} = 24$ yr.

$v = \frac{3.15 cm/yr \times 1.0 cm/yr}{0.5}$

$= 630$ cm/yr.

Q. Estimate the req^r landfill for a community with a population of 260000.

Sol^n:- Solid waste generation = 7.6 g/Captia/d.

Compacted sp. wt of solid waste = 830 g/m^3.

Av. depth of compacted solid waste = 6 m

daily waste generation = 17,76,000 g/d.

vol req^r = 2381 m^3/d.

$Area = \frac{V \times 365}{d} = 14,485$ m^2/yr.

Q. Municipal solid waste from truck are placed & will compacted in a landfill in on lift with 6m deep. Estimate (i) water retaining capability of compacted solid.
(ii) time req^r for the leachates to reach to the bottom of the landfill.

(a) Annual rainfall = 450 mm
(b) weight of the water in refuse = 250 kg
(c) Density of compacted solid = 600 kg/m^3.
(d) Weight of compacted refuse = 1000 kg.

(i) Vol^m of water $= \frac{wt}{density} = \frac{250 \text{ kg}}{1000 \text{ kg/m}^3} = 0.25 \text{ m}^3$.

(ii) Vol. of compacted solid $= \frac{1000}{600 \text{ kg/m}^3} = 1.67 \text{ m}^3$.

Water retaining Capacity $= \frac{0.25 \text{ m}^3}{1.667 \text{ m}^3} = 15\%$

If leachate produced at the rate of 450 mm/yr percolating through 6 m of refuse which has 15% water retaining capacity.

3) Composting :-

(I) C : N → green

C : N → 35 : 50

green → kitchen waste

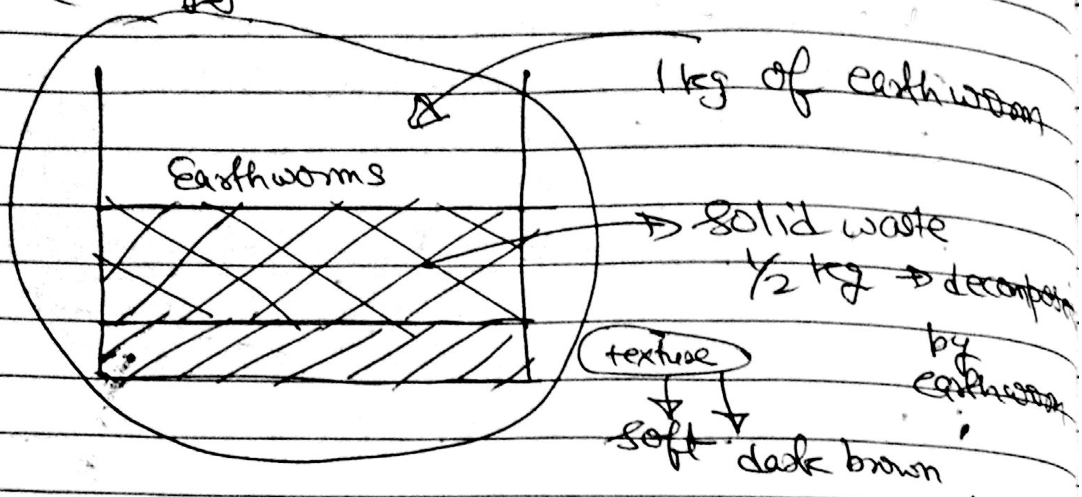
brown material (agricultural waste)

II Moisture → 40-60 %.

III temp → 50-60°C

> 70°C → 3 days.
< 40°C

4) Vermitechnology :-



5) Incineration

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