Environmental Sciences

Notes

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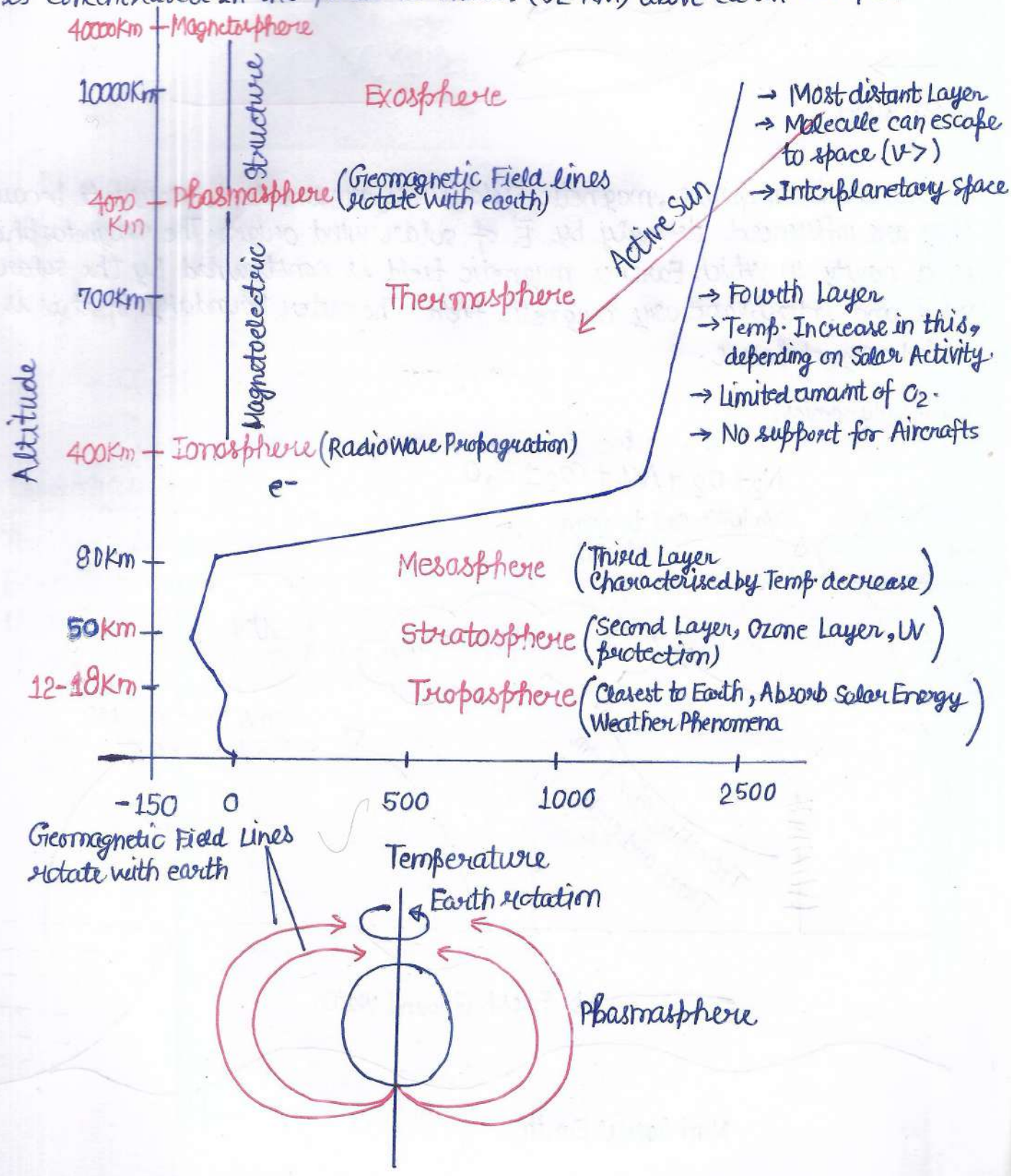
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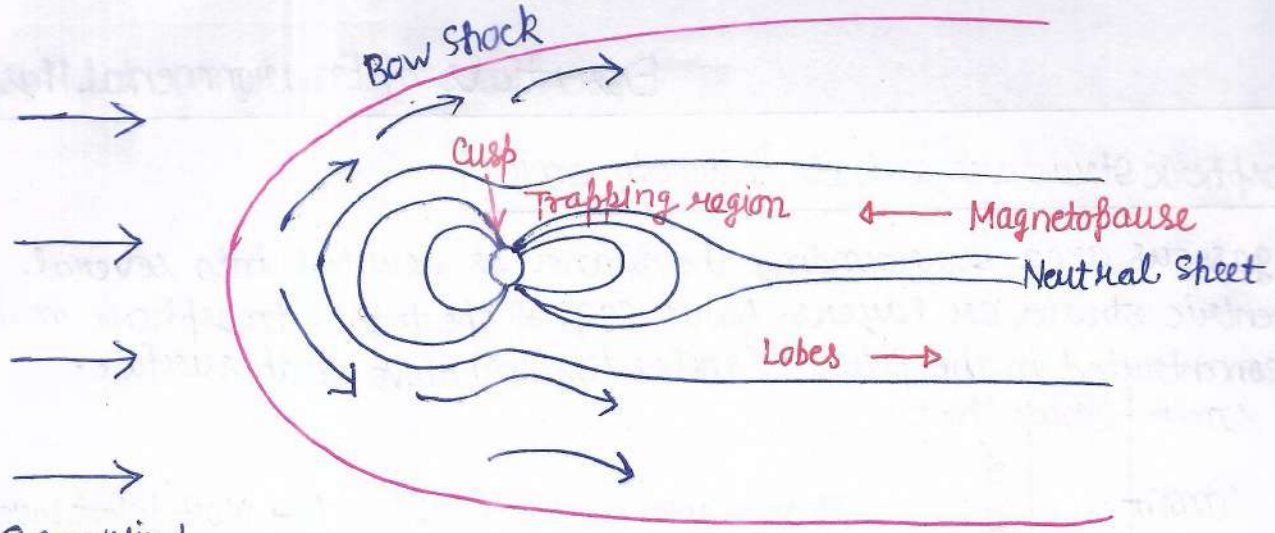
Environmental Physics

- Essentials of Environment
- Solar and Terrestrial
- Environmental Pollution and degradation
- Environmental Change and Remote Sensing
- Global and Regional Climate

• Atmospheric Structure and its thermodynamics :

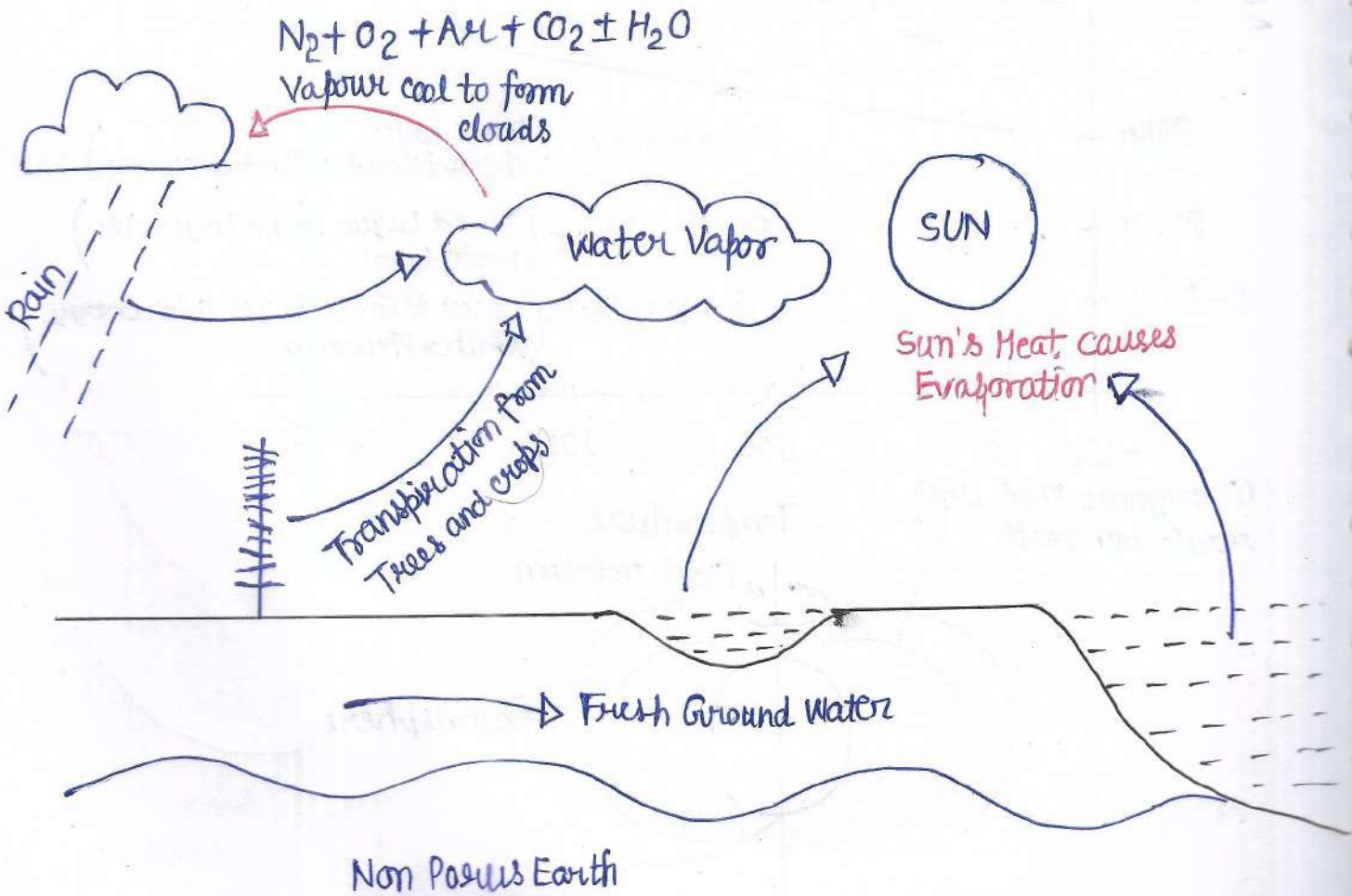
The gaseous area surrounding the planet is devided into several concentric strata or layers. About 99% of the total atmospheric mass is concentrated in the first 20 miles (32 Km) above earth surface.





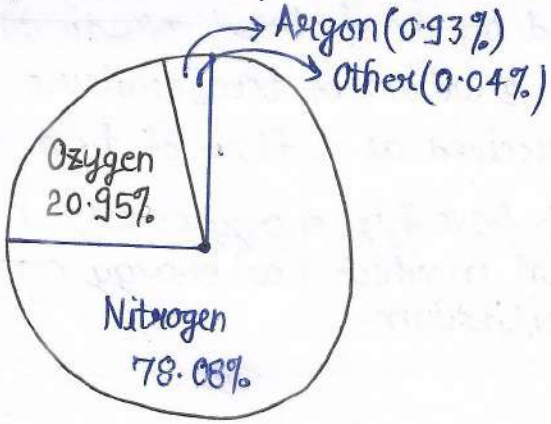
Outside the plasmapause, magnetic field lines are unable to corotate because they are influenced strongly by $\vec{E}$ of solar wind origin. The magnetosphere is a cavity in which Earth's magnetic field is constrained by the solar wind and Interplanetary magnetic field. The outer boundary of this is called magnetopause.

Thermodynamics;



Composition of Air-

The Air in our atmosphere is composed of molecules of different gases.

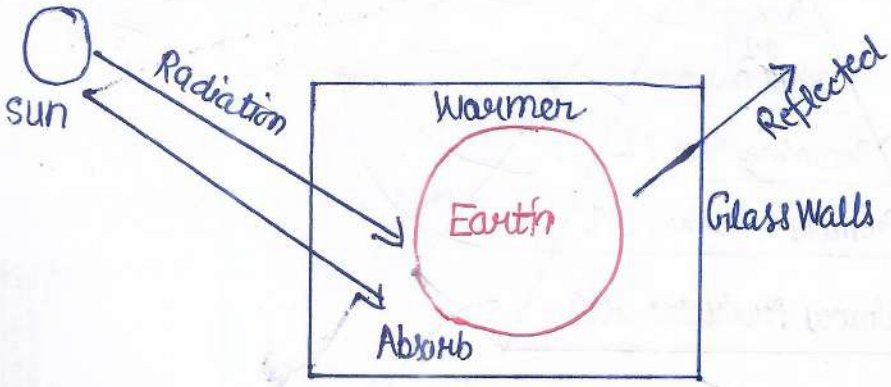


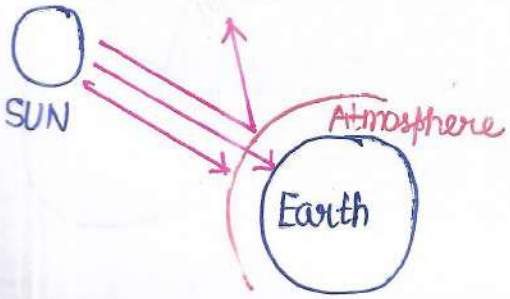
Nitrogen	78.08%
Oxygen	20.95%
Argon	0.93%
Other	0.04%

→ $CO_2 + O_3 + H_2 + Ne + He + CH_4 + Kr + N_2O$

Greenhouse Effect-

The greenhouse Effect is a process that occurs when gases in Earth's atmosphere trap the Sun's Heat. This process makes Earth warmer than it would be without an atmosphere. The greenhouse effect is one of the things that makes Earth a comfortable place to live.

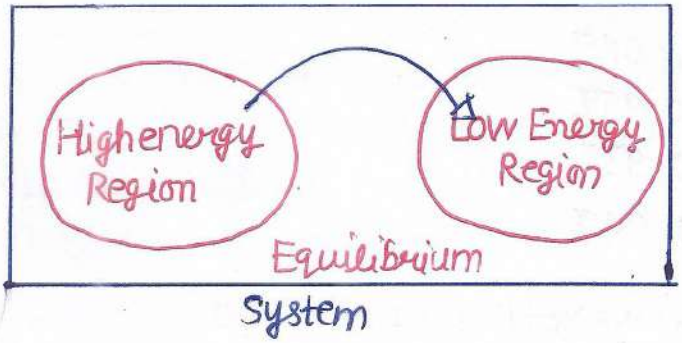




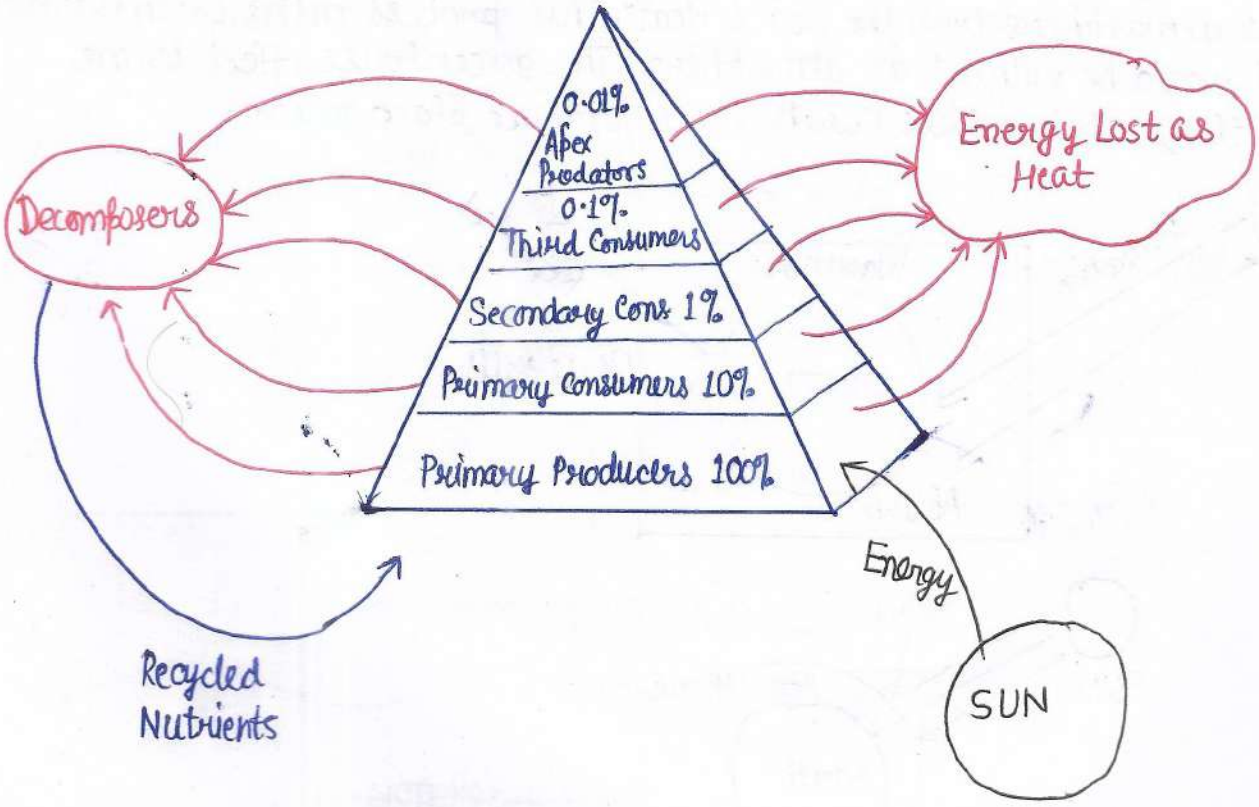
Transport of Matter-

Transport properties of matter express the way a current of a certain quantity is created by an imposed gradient of another conjugate quantity. For e.g. A gradiant of temperature causes an entropy current which is perceived as a flow of heat.

Those molecule which have high energy content in a particular region moves in those region in which heat energy content is less to set up the thermal equilibrium.



- Energy transfer in Nature !



A pyramid of energy represents how much energy, initally from the sun, is retained or stored in the form of new biomass at each trophic level in an ecosystem.

- The Momentum Conservation!

In a system, the total momentum is constant. This fact is known as law of conservation of momentum.

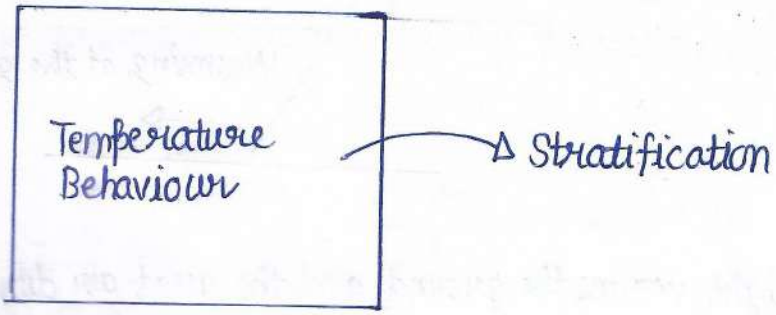
$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$ — Momentum conservation

$$\frac{1}{2} m_1 u_1^2 + \frac{1}{2} m_2 u_2^2 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$ — Energy conservation

- Stratification of Atmosphere!

In general, Air pressure and density decreases with Attitude in the atmosphere. Howevertemperature has a very compicated profile with Attitude, and may remain relatively constant or even increase with Attitude in some regions. Because the general pattern of the atmosphere's temperature/Attitude Profile, or lapse rate, is constant and measurable by means of Instruments balloon surroundings, the temperature behaviour provides a useful metric to distinguish atmospheric layers. In this way, Earth's atmosphere can be devided into 5 main layers, is called Atmospheric Stratification.

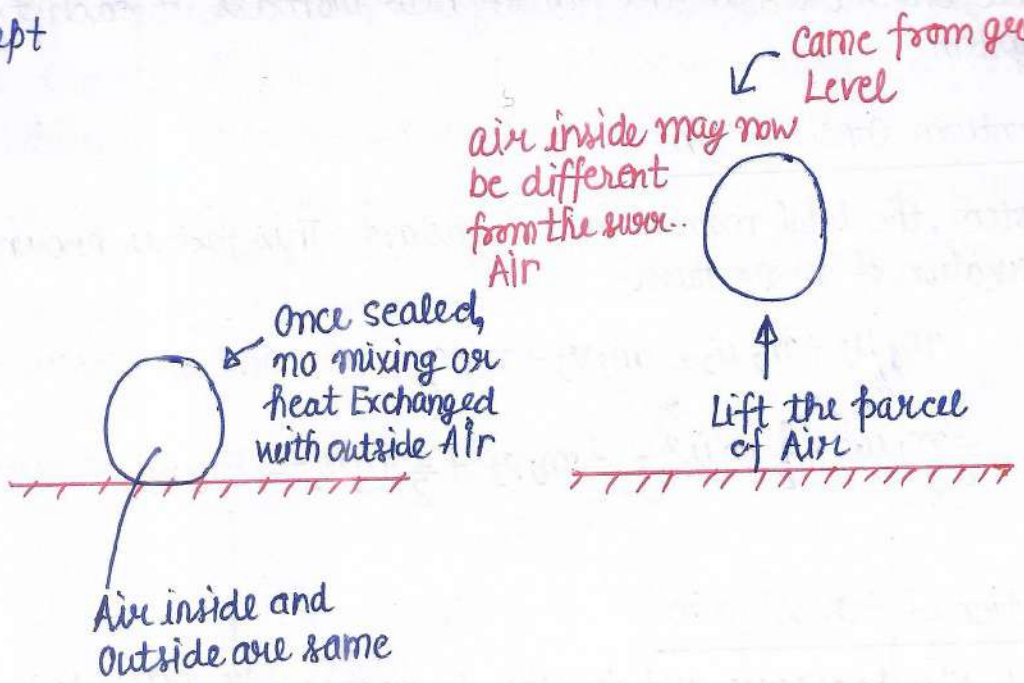
Exosphere! 700 to 10000 Km
Thermosphere! 80 to 700Km
Mesosphere! 50 to 80 Km
Stratosphere! 50 to 12 Km
Troposphere! 0 to 12 Km

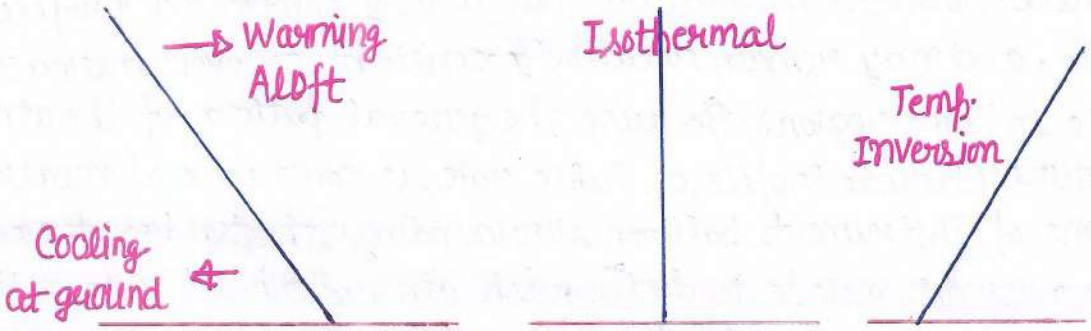


• Stability of Atmosphere :

→ We will learn when the atmosphere is stable and when is unstable.

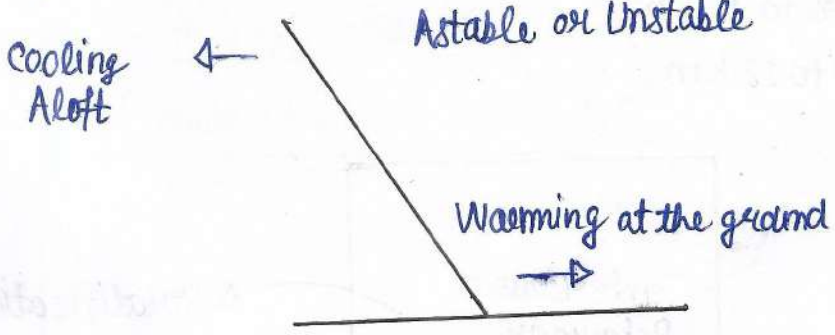
→ Concept





→ Warming the air above the ground and/or cooling the air next to the ground will make the atmosphere more stable.

→ The ground and the air above it cool during the night. The atmosphere is usually most stable early in the morning.



→ Sunlight warms the ground and the next air during day → Unstable.

#Laws of Motion:

Newton's Laws of motion are three physical laws.

1st-

In an inertial frame of Reference, an object either remains at rest or continues to move at a constant velocity, unless acted upon by a force.

2nd-

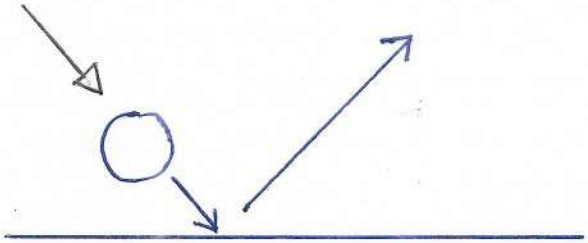
$$\vec{F} = m\vec{a}$$

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt}$$

The rate of change of the momentum of a body is directly proportional to the force applied.

3rd-

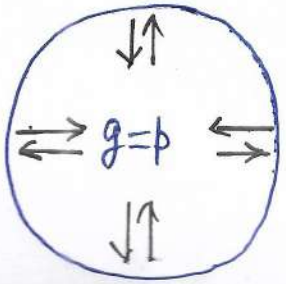
When one body exerts a force on a second body, the second body simultaniously exerts a force on the first body, equal in magnitude and opposite in direction.



Every Action has a equal and opposite reaction.

#Hydrostatic Equilibrium:

In the atmosphere, the pressure of the air decreases with increasing Altitude. This pressure difference causes an upward force called the pressure gradient force. The force of gravity balance this out, keeping the atmosphere bound to Earth and maintaining pressure difference with Altitude.



$$\frac{Gmdm}{r^2} = -4\pi r^2 dp$$

UNIT-2

SOLAR AND TERRESTRIAL

Radiation-

Radiation is the emission or transmission of energy in the form of wave or particle through space or through a material medium.

- Electromagnetic Radiation such as Radiowaves, Microwaves, IR, Visible, UV, X-rays, and γ rays
- Particle Radiation, such as α, β and neutron radiation, cosmic radn.
- Acoustic Radiation such as Ultrasonic, sound and seismic waves.
- Gravitational Radiation.

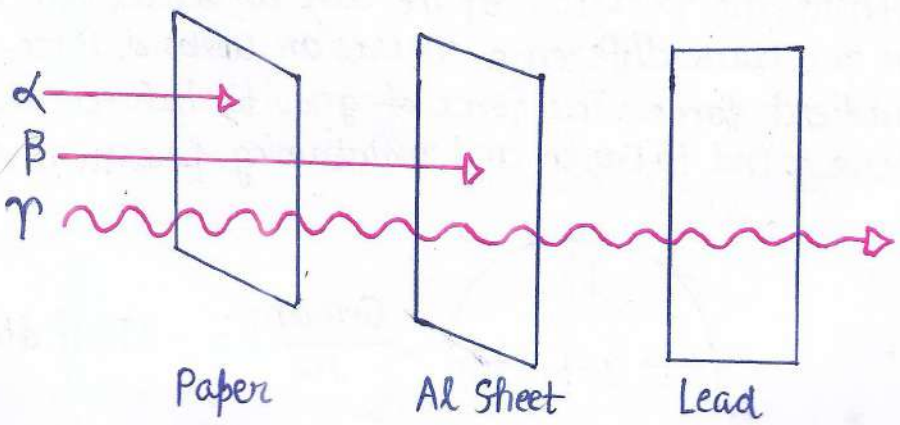
Types

Ionizing Radiation
(Radiation more than 10 eV)

- UV
- X Rays
- γ rays
- α radn
- β
- Nelitron
- Cosmic

Non Ionizing Radiation

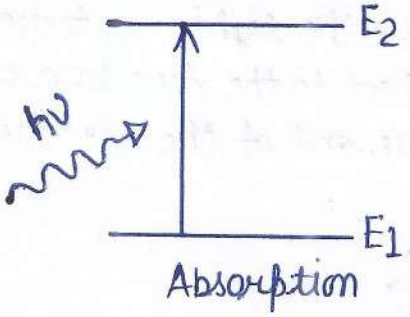
- UV Light
- Visible
- IR
- Microwave
- Radiowave
- Thermal Radn
- Blackbody Radn



Interaction of Light with Matter:

The Interaction of light with matter can take many forms.

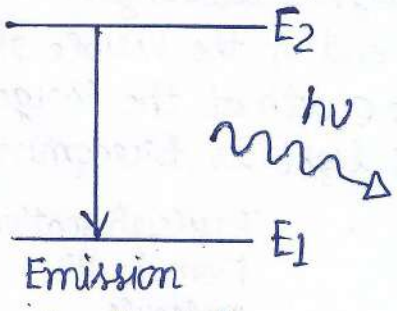
(1) Absorption and Emission of Photons: Photons are annihilated or created.



Absorption

$E_2 - E_1 = h\nu$

must satisfy Bohr relation

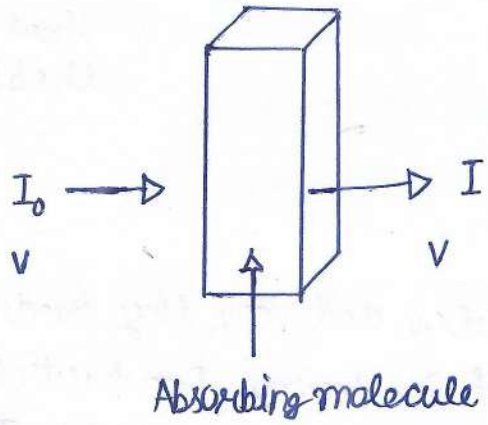


Emission

$E_2 - E_1 = h\nu$

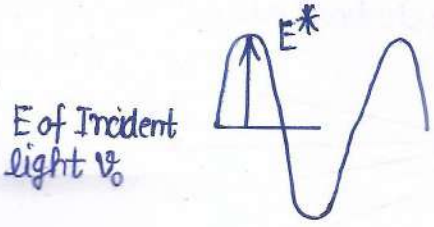
Emission could be induced or spontaneous.

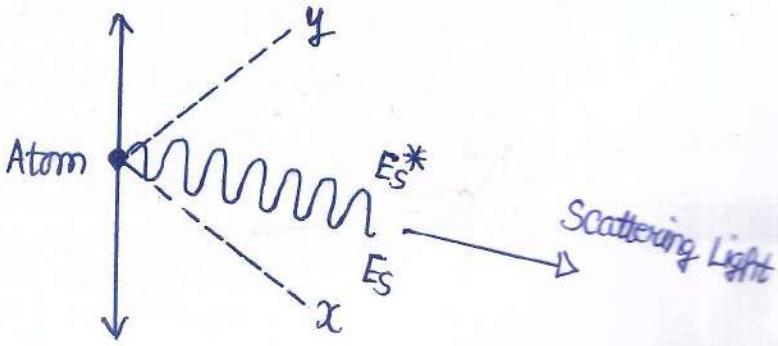
Most absorbing meterials satisfy the Beer Lambert Law.



$$E_S^* = \frac{|e|a \sin\phi}{c^2 r}$$

(2) Light Scattering.

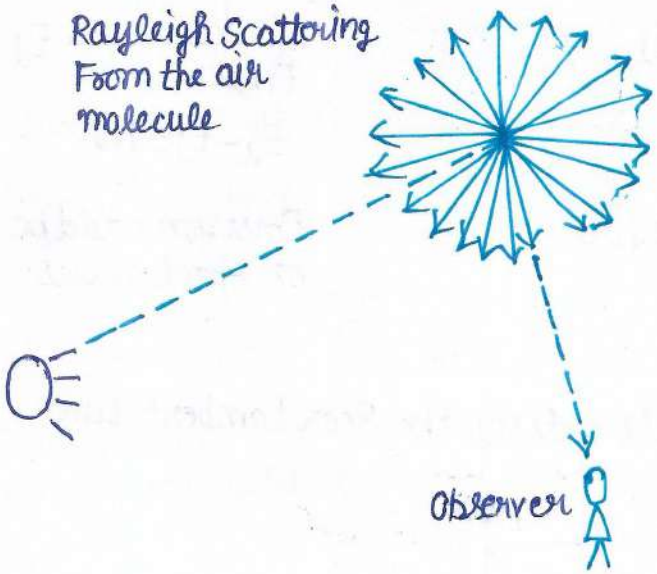




(a) Rayleigh Scattering
(b) Brillioin Scattering
(c) Raman Scattering

#Rayleigh Scattering :

The blue colour of the sky is caused by the scattering of sunlight off the molecule of the atmosphere. This scattering is called Rayleigh Scattering, is more effective at short wavelengths (the blue end of the visible spectrum). Therefore the light scattered down to the earth at the large Angle with respect to the direction of the sun's light is predominantly in the blue end of the spectrum.

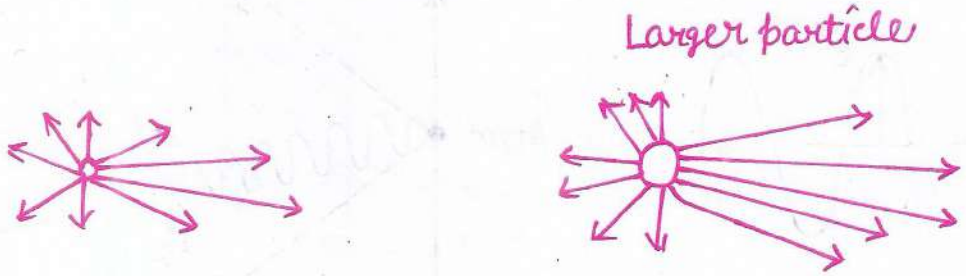


$$I \propto \frac{1}{\lambda^4}$$

The Strong wavelength dependance of Rayleigh Scattering hence the short wavelength, gives us the blue sky.

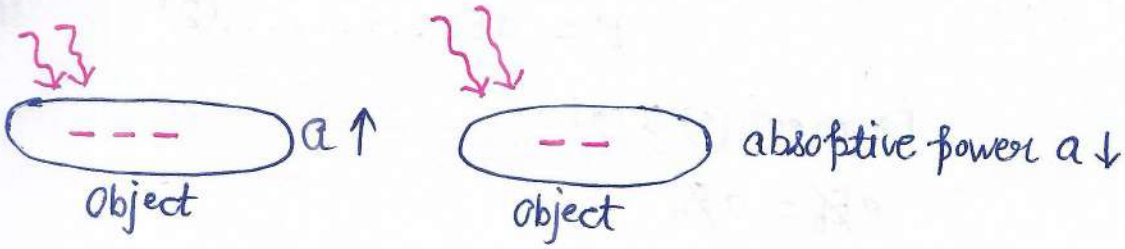
#Mie Scattering :

The scattering from molecules and very tiny particles ($< \frac{1}{10}$ wavelength) is predominantly Rayleigh Scattering. For particles sizes larger than a wavelength, Mie Scattering predominates. This scattering produces a pattern like an anteena lobe, with a sharper and more intense forward lobe for larger particles.

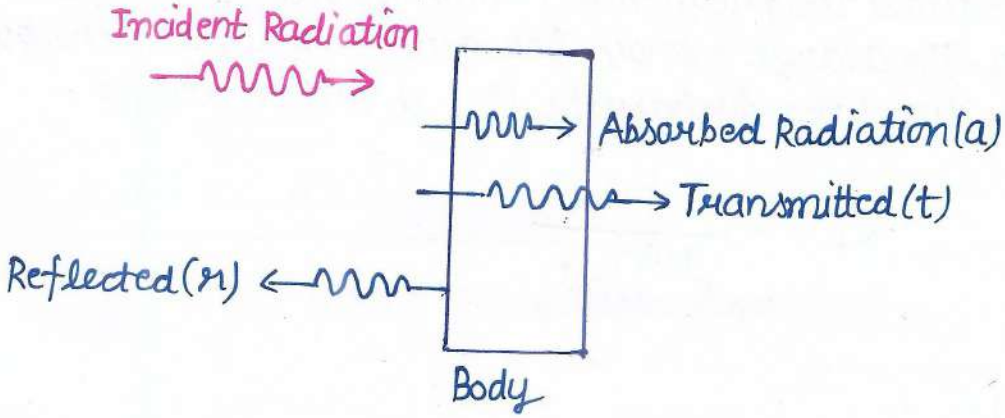


Laws of Radiation:

- Kirchoff's Law-
  - Good absorbers are good emitters



All bodies radiates energy in the form of Photons. Where these photons reach another surface, they may either be absorbed, reflected or transmitted. The behaviour of a surface with incident radiation is described by the following quantities.



Real bodies radiates less effectively than blackbodies. The measurement of this emissitivity (e) defined by

$$e = \frac{E}{E_b}$$

E ← Radiated power from Real bodies

E_b ← from Blackbody Radiation.

$e = 1$ for Blackbodies

$0 < e < 1$ for Real bodies

$$e = \frac{E}{E_b}$$

$$E = eE_b \quad \ldots\ldots\ldots (1)$$

Power absorbed per unit area $= aE_b$

$$E = aE_b \quad \ldots\ldots\ldots (2)$$

From eqn (1) & (2)

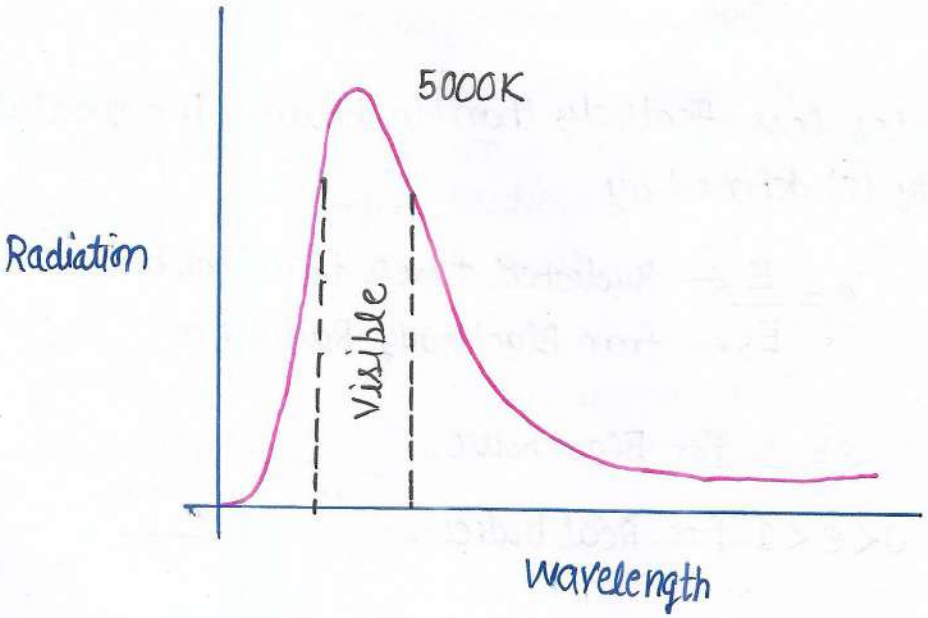
$$eE_b = aE_b$$

$$\boxed{e = a}$$

- **Plank's Law-**

From the assumption that the electromagnetic modes in a cavity were quantized with the quantum energy. Equal to Plank's constant times the frequency, Plank derived a radiation formula. The avarge energy per quantum is the energy of quantum times the probability that it will be occured.

$$\langle E \rangle = \frac{h\nu}{e^{h\nu/KT} - 1}$$



#Wein's Displacement Formula -

When the temperature of the blackbody radiator increases, the overall radiated energy increases and the peak of the radiation curve moves to shorter wavelength. When the maximum is evaluated from Plank's law, the product of the peak wavelength and the temperature is found to be constant.

$$u_\lambda d\lambda = \frac{8\pi hc}{\lambda^5} \cdot \frac{d\lambda}{e^{hc/\lambda KT} - 1}$$

For short wavelength or high frequency $e^{hc/\lambda KT} >> 1$

$$u_\lambda d\lambda = \frac{8\pi hc}{\lambda^5} \frac{d\lambda}{e^{-hc/\lambda KT}}$$

$$u_\lambda d\lambda = (8\pi hc)\, \lambda^{-5} e^{-hc/\lambda KT} d\lambda$$

$8\pi hc \rightarrow A$

$\frac{hc}{K} = B$

$$\boxed{u_\lambda d\lambda = A\lambda^{-5} e^{-B/\lambda T} d\lambda}$$

This relationship is called Wein's displacement Law.

Solar Spectra -

Sunlight is a portion of the electromagnetic radiation given off by the Sun, in particular IR, Visible and UV light. On Earth, sunlight is filtered through Earth Atmosphere, and is obvious as daylight when the sun is above horizon.

The intensity of Sunlight can be measure using a sunshine recorder, pyranometer or pyrheliometer. To calculate the amount of sunlight reaching the ground, both the eccentricity of Earth elliptical orbit and

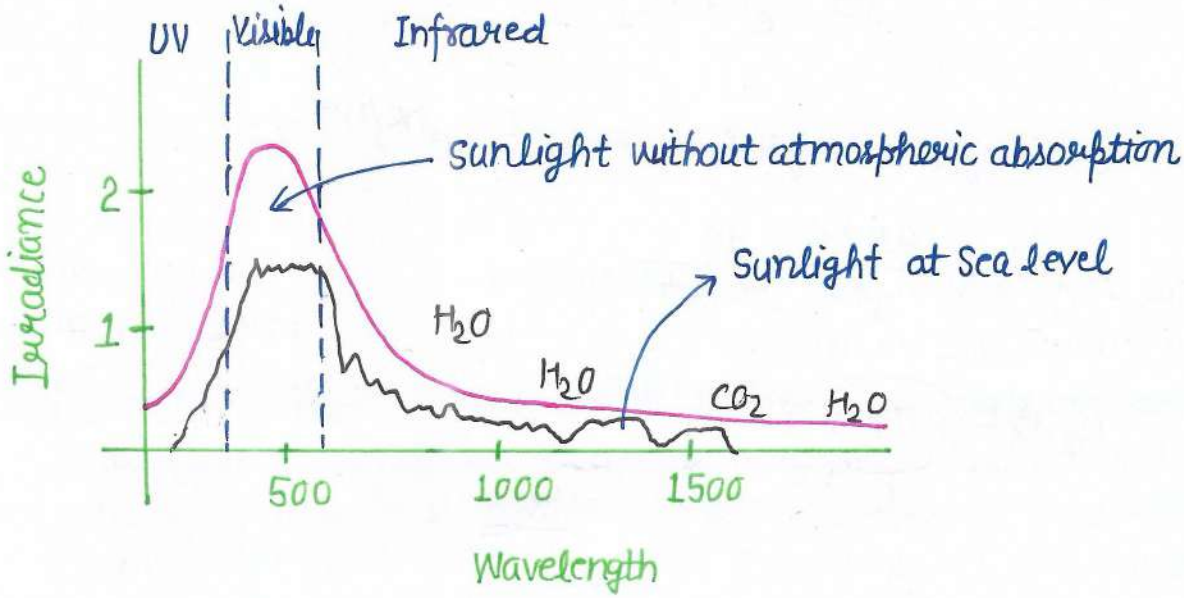
the attenuation by Earth's atmosphere have to be taken into account.

$$E_{ext} = E_{SC}\left(1 + 0.033412 \cos\left[2\pi \frac{dn-3}{365}\right]\right)$$

dn: different for each month.

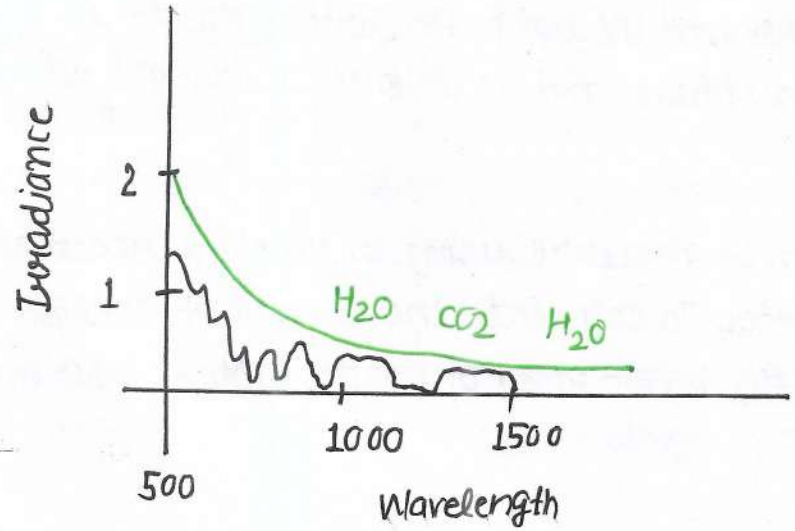
E_{SC}: Solar(E) Illumination Constant

E_{ext}: Extraterrestrial Solar Illumination



Terrestrial Source of Radiation-

Electromagnetic radiation emitted by Earth's surface and atmosphere is called terrestrial or longwave radiation. Since these bodies exhibit radiation temp. in the range 200-300 K, terrestrial radiation lies in the Infrared portion of the EM Spectrum.



#UV Radiation -

Everyone is exposed to UV radiation from the sun and an increasing no. of people are exposed to artificial source used in industry, commerce and recreation. Emissions from the sun including visible light, heat and UV radiation.

The UV region covers the wavelength range 100-400 nm and devided into three bands.

(1) UVA (315-399 nm)
(2) UVB (280-315 nm)
(3) UVC (100-280 nm)

As sunlight passes through the atmosphere, all UVC and approx. 90% UVB radiation is absorbed by ozone, water vapour, O_2 and CO_2. UVA radiation is less affected by the atmosphere. Therefore, the UV radiation reaching the Earth's surface is largly composed of UVA with small UVB component.

Factors that influence the UV Levels :

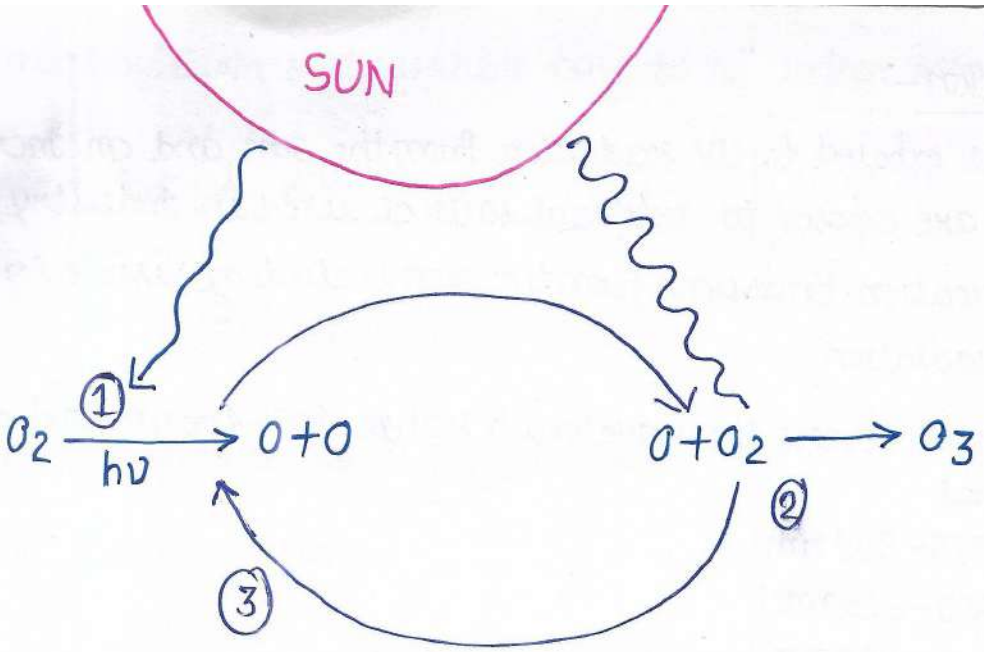
- Sunlight
- Latitude
- Cloud cover
- Altitude
- Ozone
- Ground Reflection

#Ozone Depletion :

The ozone shield or Ozone Layer is a region of Earth Stratosphere that absorbs most of the Sun's UV radiation.

$$O_2 + hU_{UV} \longrightarrow 2O$$
$$O + O_2 \longrightarrow O_3$$

(O_3) → Ozone



Ozone depletion consists of two related events observed since the 1970's, a steady lowering of about four percent in the total amount of ozone in Earth Atmosphere, and a much larger Springtime decrease in Stratospheric ozone around Earth polar regions. The phenomena is referred to as Ozone hole.

Effect of UV deplation;

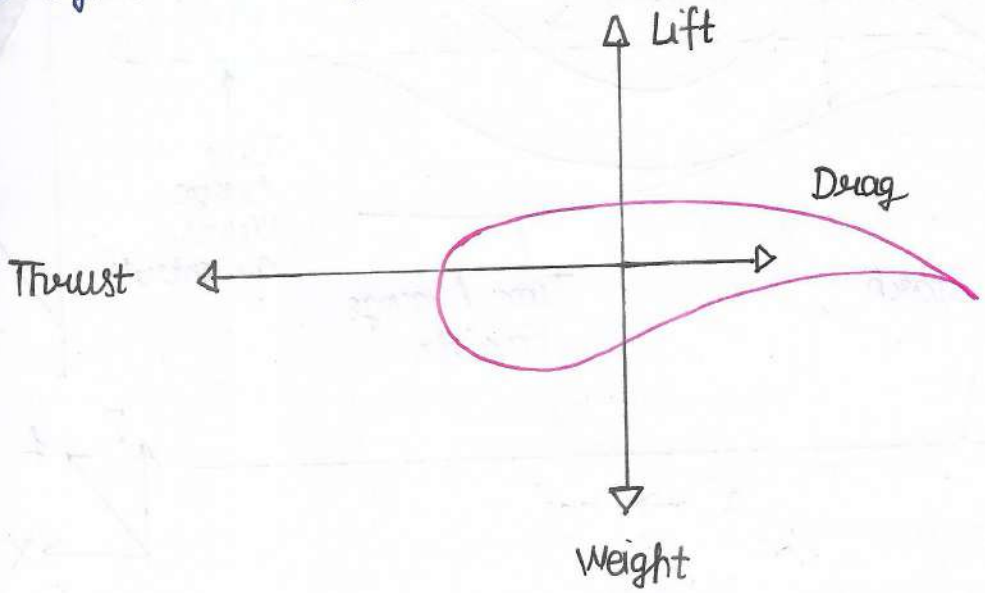
(1) Effect on Human Health
(2) Effect on Plants
(3) Effect on Marine Ecological system.
(4) Effect on Biochemical cycle
(5) Effect on Materials.

IR Absorption -

IR Spectroscopy is a universal, analytical technique for the structure elucidation and quantification of a large variety of Organic, Inorganic and biological samples. The technique is based on the measurement of IR radiation absorbed or emitted by a sample. IR Spectroscopy is used in the broad range of Environmental Applications. It is viable tool in remote measurement of Gases, liquid, and Solids and as fast and reliable method.

Elementary Fluid Dynamics:

Fluid dynamics is a subdiscipline of Fluid Mechanics that describes the flow of fluids: liquids and gases. It has several subdisciplines includ aerodynamics and hydrodynamics.



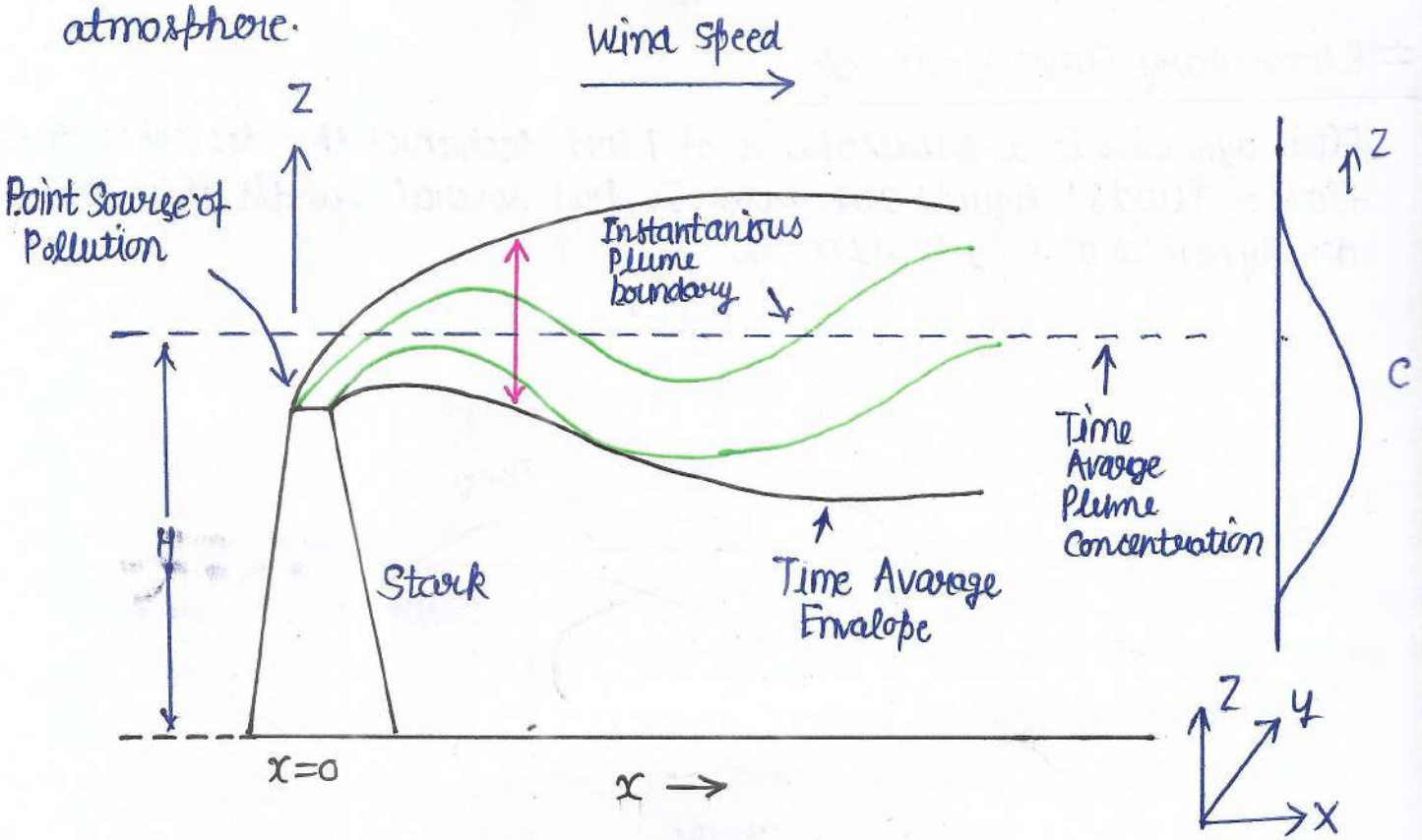
Understanding the motion of air around an object (often called a flow field) enables the calculation of forces and moments acts on the object. In many aerodynamics problem, the forces of interest are the fundamental forces of flight: lift, drag, thrust and weight. Of these, lift and drag are aerodynamics forces i.e. forces due to air flow over the solid body. Calculation of these quantities is often found upon the assumptions that the flow field behaves like a continuum.

A system should be designed also considering the surroundings.

Atmospheric Diffusion-

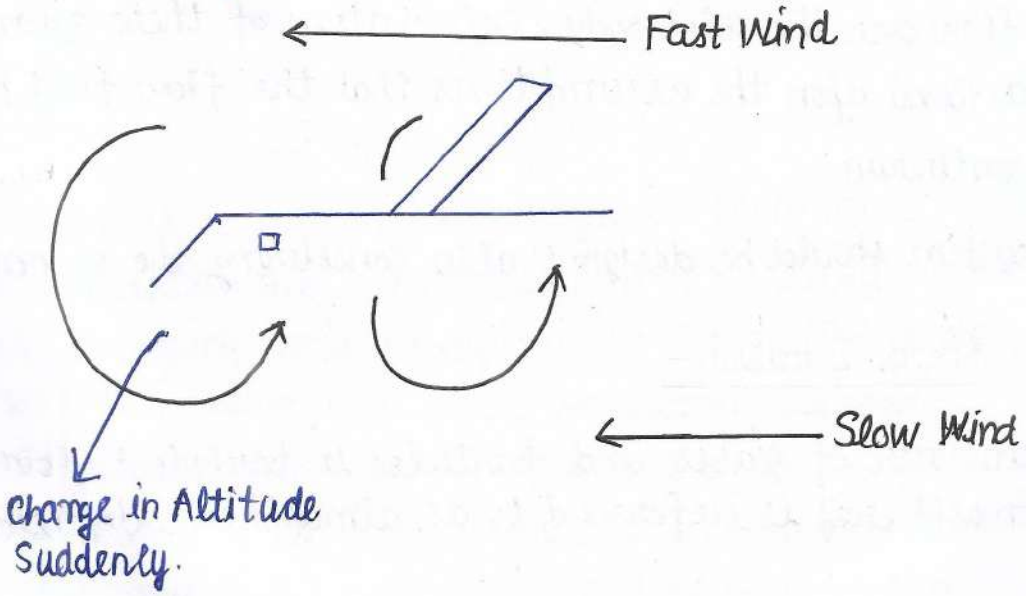
- Behaviour of gases and particles in turbulent Flow (in the atmosphere) is referred to as atmospheric diffusion.

- Goals of diffusion models is to describe mathematically the spatial and temporal distribution of contaminants released into atmosphere.



Turbulence and Turbulent diffusion -

Turbulence is fluid motion characterized by chaotic changes in pressure and Flow velocity. Turbulence is commonly observed in everyday phenomena such as fast flowing rivers, Storm clouds, or smoke from the chimney.



Turbulent diffusion is the transport of mass, heat or momentum within a system due to random and chatic time dependant motions. It occurs when turbulent fluid system reaches critical conditions in response to shear Flow.

Eulerian Approach to turbulent diffusion forces on a infinisitimal volume at a specific space and time in a fixed frame of reference.

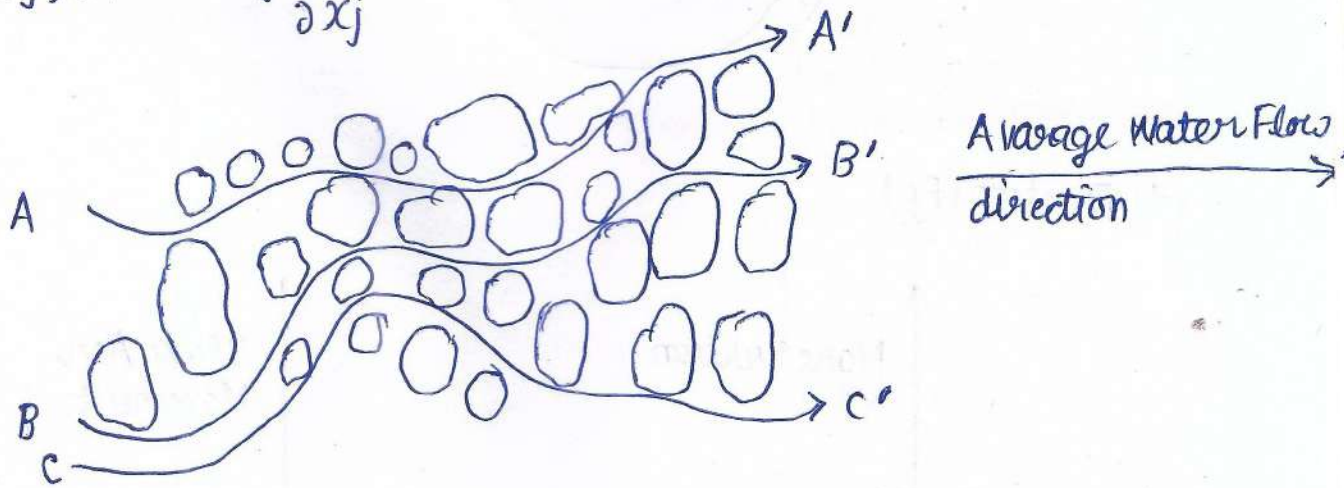
$$\frac{\partial c_i}{\partial t} + \frac{\partial}{\partial x_i}(u_j, c_j) = D_i \frac{\partial^2 c_i}{\partial x_j \partial x_j} + R_i(c_1, \ldots c_N, T) + S_i(x,t)$$

$$i = 1, 2, \ldots, N$$

where c_i = specific concentration of interest
u_j = velocity
t = time
x_j = direction
D_i = diffusion constant
R_j = Rate of c_i generalized reaction
S_i = Rate of c_i generalized by source

Eddy diffusivity

$$\langle u_j', c' \rangle = -K_{ij} \frac{\partial (C)}{\partial x_j}$$



Factor Governing Air–

There are different Factors affecting the movement of the air.

(1) Temperature (T)

Low Pressure ⟶ High Pressure

High Temperature ⟶ Low Temperature

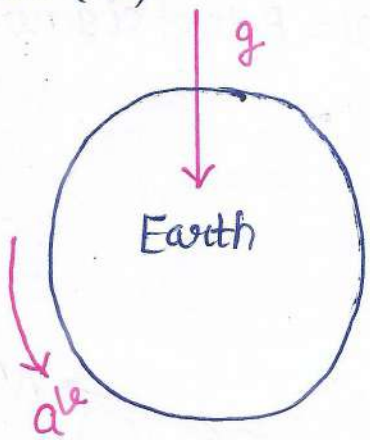
Air Flow

(2) Pressure (P)

Air Pressure decrease ↓

↑ Move Upper to Sea Level

(3) Coriolis Moroment (Cm)



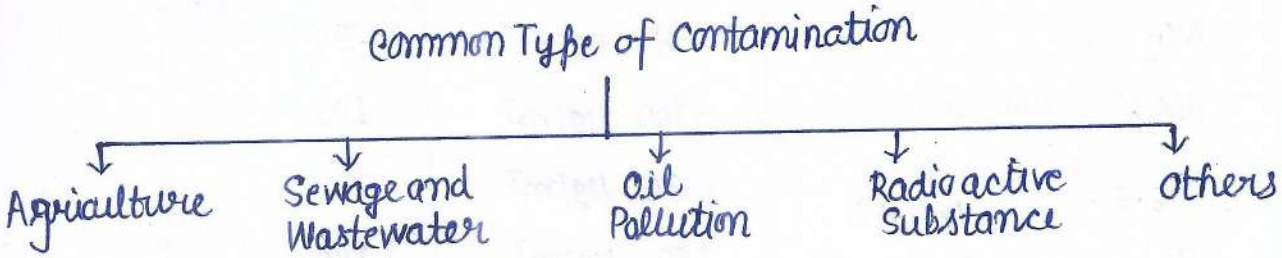
(4) Friction (Ff)

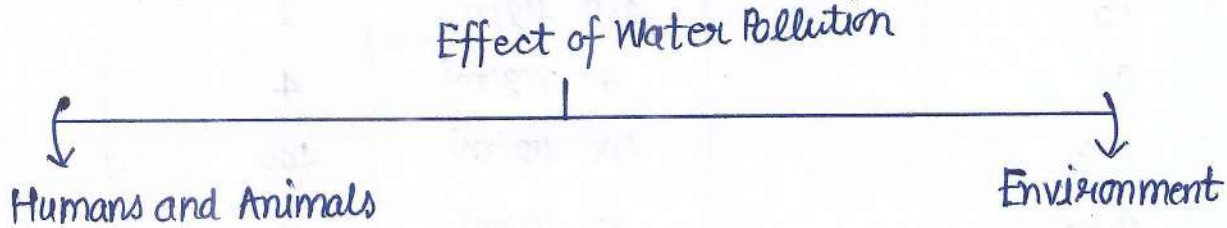
↑ More Friction

↓ Slow Air Movement

Water Pollution-

Water pollution occurs when harmful substances- often chemicals or microorganisms- contaminate a stream, river, lake, ocean, aquifer or other body of water, degrading water quality and rendering its toxic to humans or the environment.

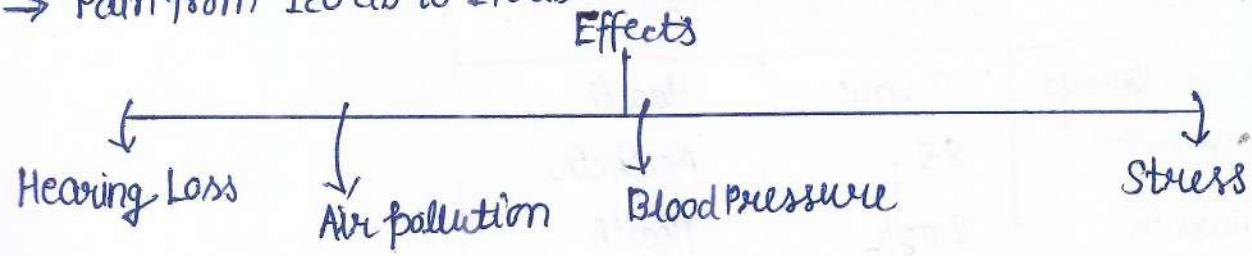




Noise Pollution-

Noise Pollution, unwanted or excessive sound that can have deletrious effect on human health and environmental quality. Noise Pollution is commonly generated inside many industrial facilities and some other workplaces, but it also comes from highway, railway and airoplane traffic and From outdoor contruction activities.

→ Viberations of air molecules
→ Described in terms of Amplitude, frequency and wave
→ Pain from 120 dB to 140 dB to more.



Air Quality Standards-

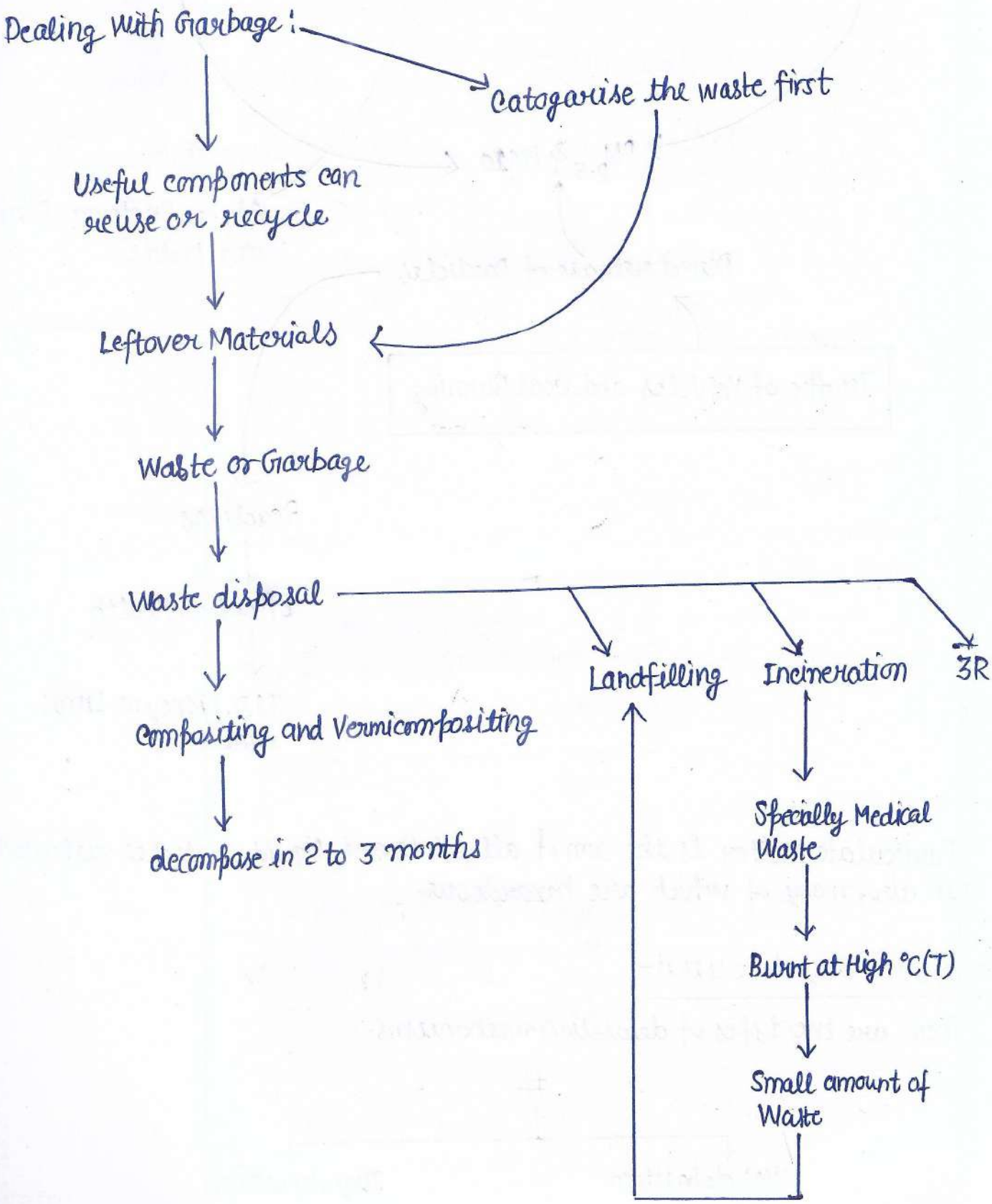
Pollutant	Time Weighted Avarage	Concentration in Ambient Air	
		Industrial and Res.	Ecologically Sens.
SO_2	Annual* 24 Hours*+	50-80 ug/m3	30-80
NO_2		40-80 ug/m3	20-80
PM_{10}		100 ug/m3	100
$PM_{2.5}$		60 ug/m3	60
O_3		180 ug/m3	180
Pb		1.0 ug/m3	1
CO		4 mg/m3	4
NH_3		400 ug/m3	400
C_6H_6		5 ug/m3	5
BaP		1 ng/m3	1
As		6 ng/m3	60
Ni		20 ng/m3	20

Water Quality Standards-

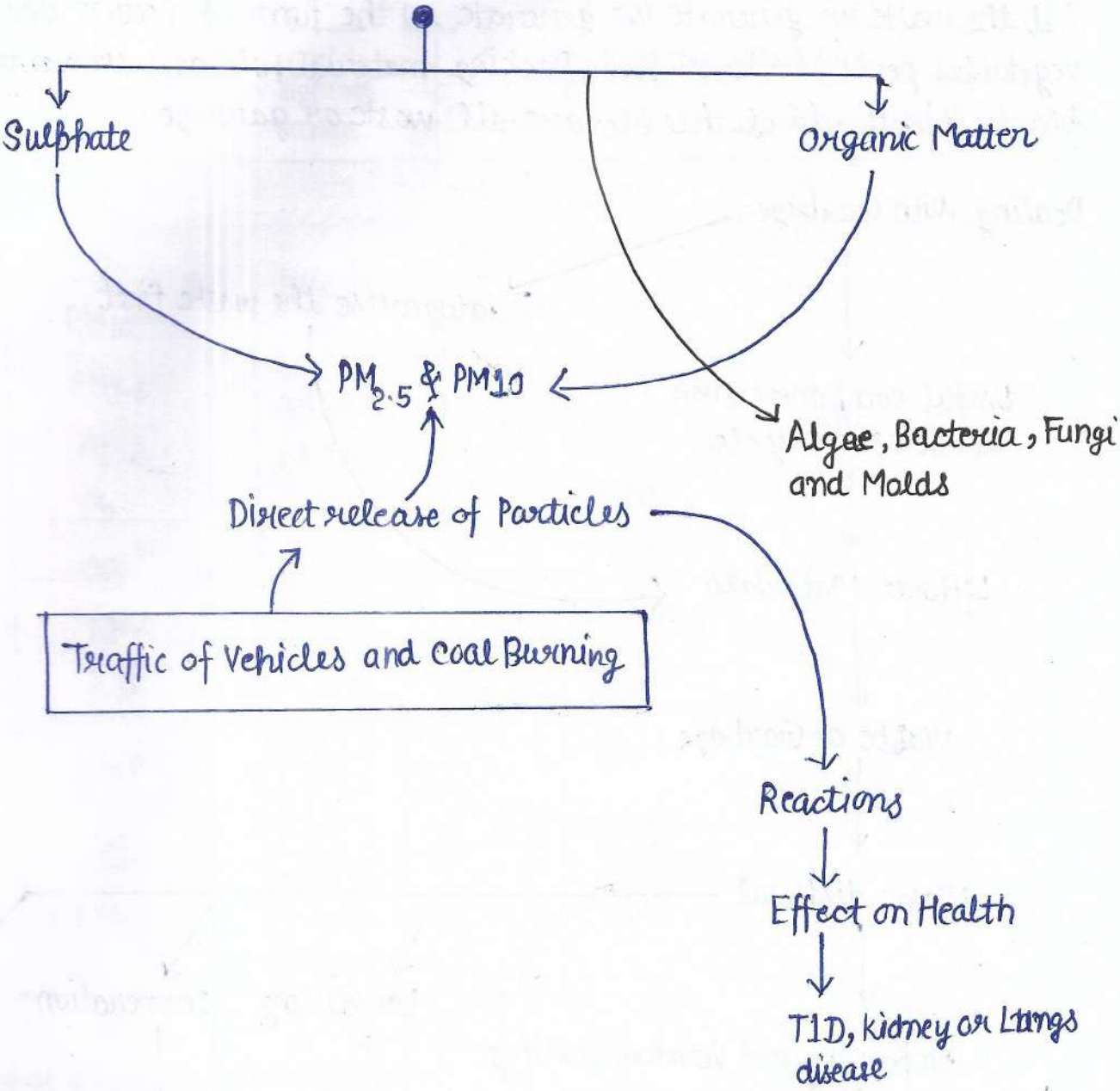
Criteria	Standards	Reasons
Coliform Bacteria	0 C/ml	Health
pH	8.5	Aesthetic
Barium	2 mg/L	Health
Nitrate	10 mg/L	Health
Total dissolved S	500 mg/L	Taste

Waste Disposal -

All the waste we generate we generate in the form of fruits and vegetables peels, leftover food, Packing material, old and unwanted plastic objects, old clothes etc. are all waste or garbage.



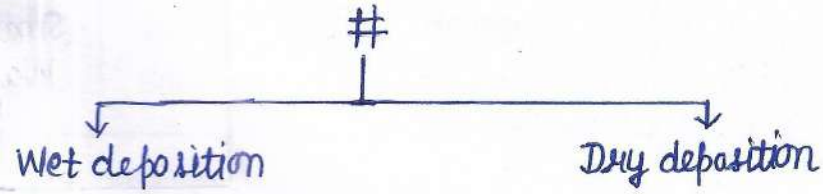
Gaseous and Particulate Matter-



Particulate Matter is the sum of all solids and liquid particles suspended in air, many of which are hazardeous.

Wet and dry deposition-

There are two types of deposition mechanisms.

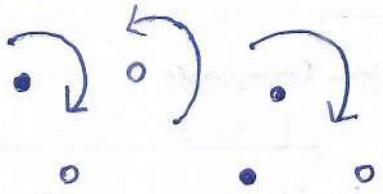


The dry deposition i.e., the uptake at the earth surface (Soil, water, or vegetations) and wet deposition i.e. absorption into droplets following by droplet precipitations or impactation on the earth surface.

Dry Deposition

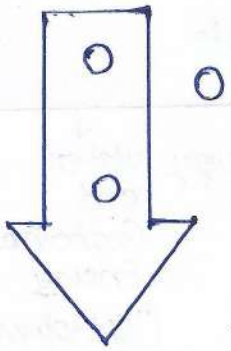
tarbulant diffusion

Gases and small particles

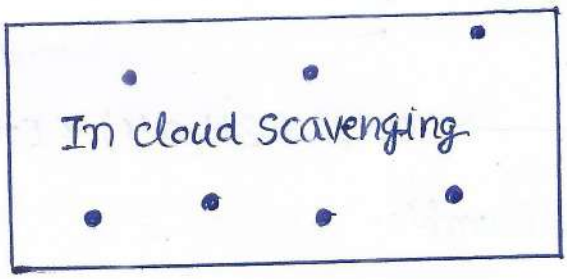


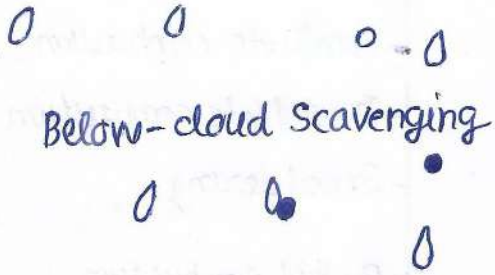
Sedimentation

Large particles



Wet deposition

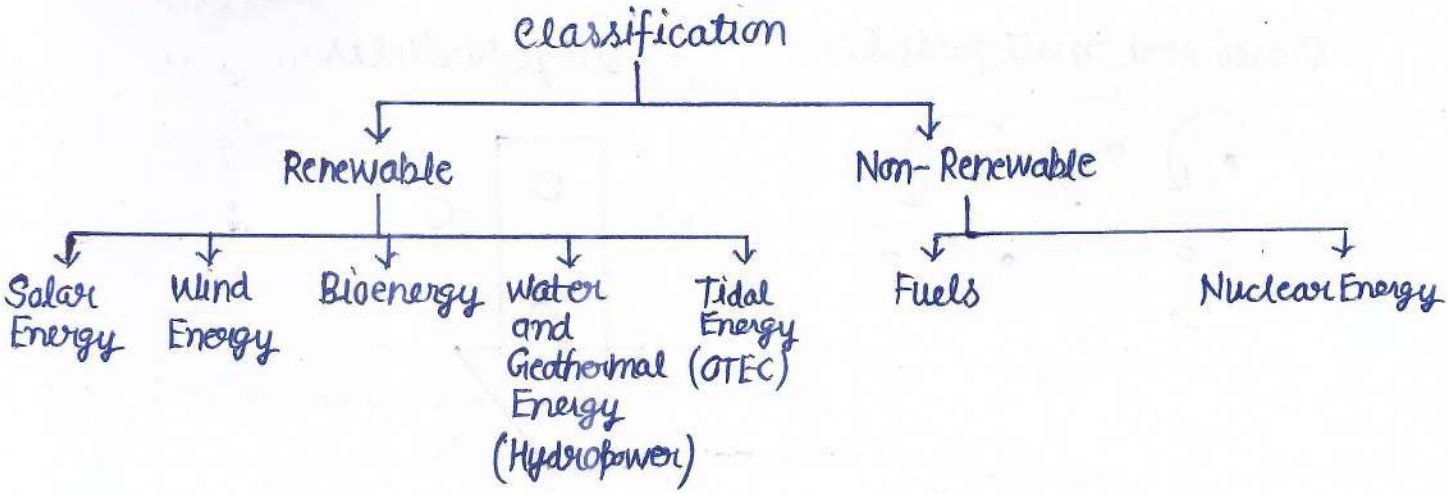




Environmental Change and Remote Sensing

#Energy Source and Combustion Process-

The Energy is the capacity of a physical system to perform work. Energy Exists in several forms such as heat, kinetic or mechanical energy, light, potential energy, electrical or other forms.



The Heat given off when a specific amount (1 mole) of substance (reactant) burns in Oxygen gas.

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l) + Energy$$

This is combustion process Example.

Types

- Complete combustion
- Incomplete combustion
- Smoldering
- Rapid Combustion
- Sponteneous combustion
- Turbulant Combustion
- Micro combution

#Renewable Source of Energy-

Renewable Energy is derived from Natural Processes that are replenished constantly such as Solar, wind, ocean, hydropower, bioenergy, geothermal, biofuels and hydrogen.

Solar Energy-

Sun is primary source of energy. Sunlight is a clean, renewable source of Energy. It is a sustainable resource means it doesn't run out, but can be maintained because the sun shines almost every day. Coal or gas are not sustainable or renewable: once they are gone, there is nothing left. It is called Green Power too.

Advantages:

- Natural source.
- Free.
- Available in Plenty.
- Non-Polluting.
- Doesn't emit any greenhouse gas.
- Ecofriendly.

Disadvantages:

- Depend on Seasons.
- High Investment.
- Doesn't work at night.
- Bulky.

Technologies:

- Electricity generation.
- DC Voltage.
- Solar Photovoltaic cells.

Wind Energy -

Wind is the natural movement of air across the land or sea. The wind when used to turn the blades of a wind mill turns the shaft to which they are attached. This movement of shaft through a pump or generator produces electricity.
Private agencies own 95% of the wind farms in India.

Advantages -

- Ecofriendly.
- Freely Available

Disadvantages -

- High Investment.
- Speed is not uniform.

Bioenergy -

The Plants fix solar energy through the process of Photosynthesis to produce biomass. The biomass passes through various cycles producing different form of energy source.

Uses -

- 1/3 of total energy of our country.

Advantages -

- Available locally.
- Clean fuel compared to Fossil Fuels.

Disadvantages -

- Air pollution.
- Health Hazardeous.
- Unsustainable.
- Ineffecient use.

#Hydropower-

Hydropower or hydroelectricity refers to the conversion of energy from the flowing water into electricity. It is considered a renewable source of energy because the water cycle is constantly renewed by the Sun.

Advantages-

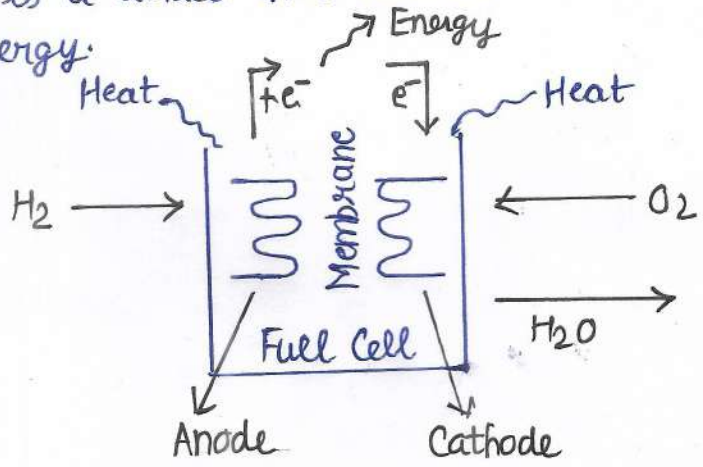
- Reliable.
- Ecofriendly.
- Mature and Proven Technology.
- Non-Polluting.
- Small Capital Investment.
- Minium Transmission Losses.

Other-

- Ocean Energy.
- Wave Energy.
- Current Energy.
- Ocean Thermal Energy Conversion (OTEC).

#Fuel Cells-

A Fuel cell is a device that converts chemical potential energy into electrical energy.



#Nuclear Energy-

Nuclear power is the use of nuclear reactions that release nuclear energy to generate heat.

$$^{6}_{3}Li + ^{2}_{1}H \longrightarrow 2\,^{4}_{2}He + 22.2\ MeV$$