Extraterrestrial and Terrestrial Solar Radiation

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A perfect match between infinite source and sink

Solar Radiation

- The total quality of solar energy incident upon the earth is immense
- The energy is very diffuse
- Because of the earths rotation
- It also suffers from atmospheric interference from clouds, particulate matter, gases

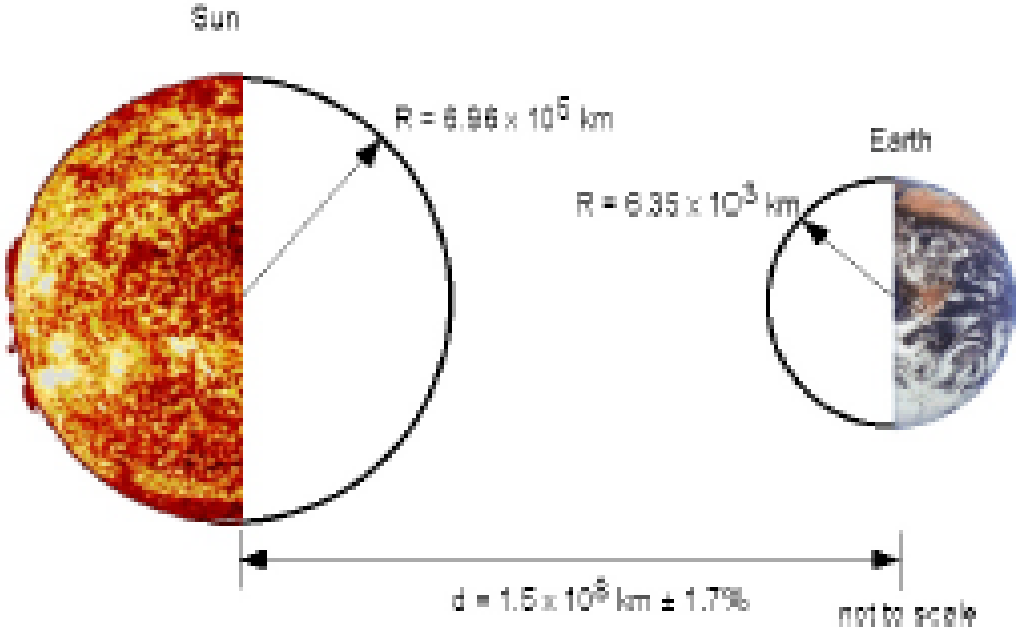
Extraterrestrial Solar Radiation

The energy incident on the earth out side of its atmosphere is called extraterrestrial radiation

Sun is a large sphere of very hot gases , the heat being generated by various kinds of fusion reactions.

The diameter of sun is $1.39*10^6$ km and that of earth is $1.27*10^4$ km . It subtends an angle of 32’ at the earths surface

The earth is closest to the sun on December 21 at a distance of about $1.45*10^8$ km and farthest on June 22 at $1.54*10^8$ km, The average distance is $1.49*10^8$ km


Sun
R = 6.96 x 10^5 km
Earth
R = 6.35 x 10^3 km
d = 1.5 x 10^8 km ± 1.7%
not to scale

Measurements indicate that the energy flux received from the sun outside the earths atmosphere is essentially constant

Solar Constant(I_{sc})

Is the rate at which energy is received from the sun on a unit area perpendicular to the rays of the sun , at the mean distance of the earth from the sun

Based on 1970 measurements :1353 W/m2
Subsequent measurements : 1367 W/m2

Earth revolves around the sun in an elliptical orbit , having very small eccentricity and with the sun at one of the foci

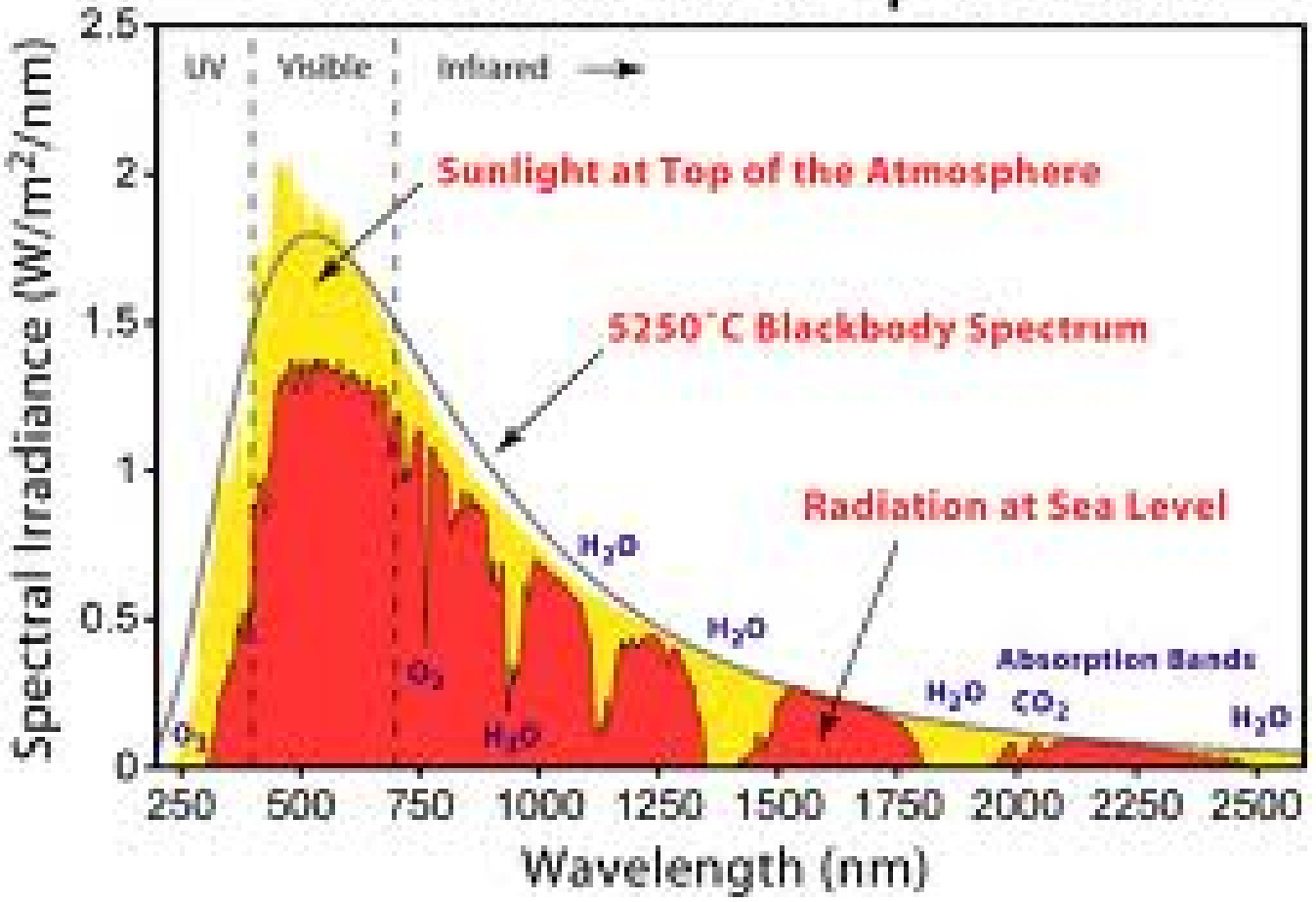
The distance between the earth and the sun varies a little through the year.

Because of this the extra terrestrial flux also varies

This value on any day can be calculated from this equation

$$I'_{SC} = \textbf{(1+0.033 cos (360*n/365))}$$

Solar Radiation Spectrum

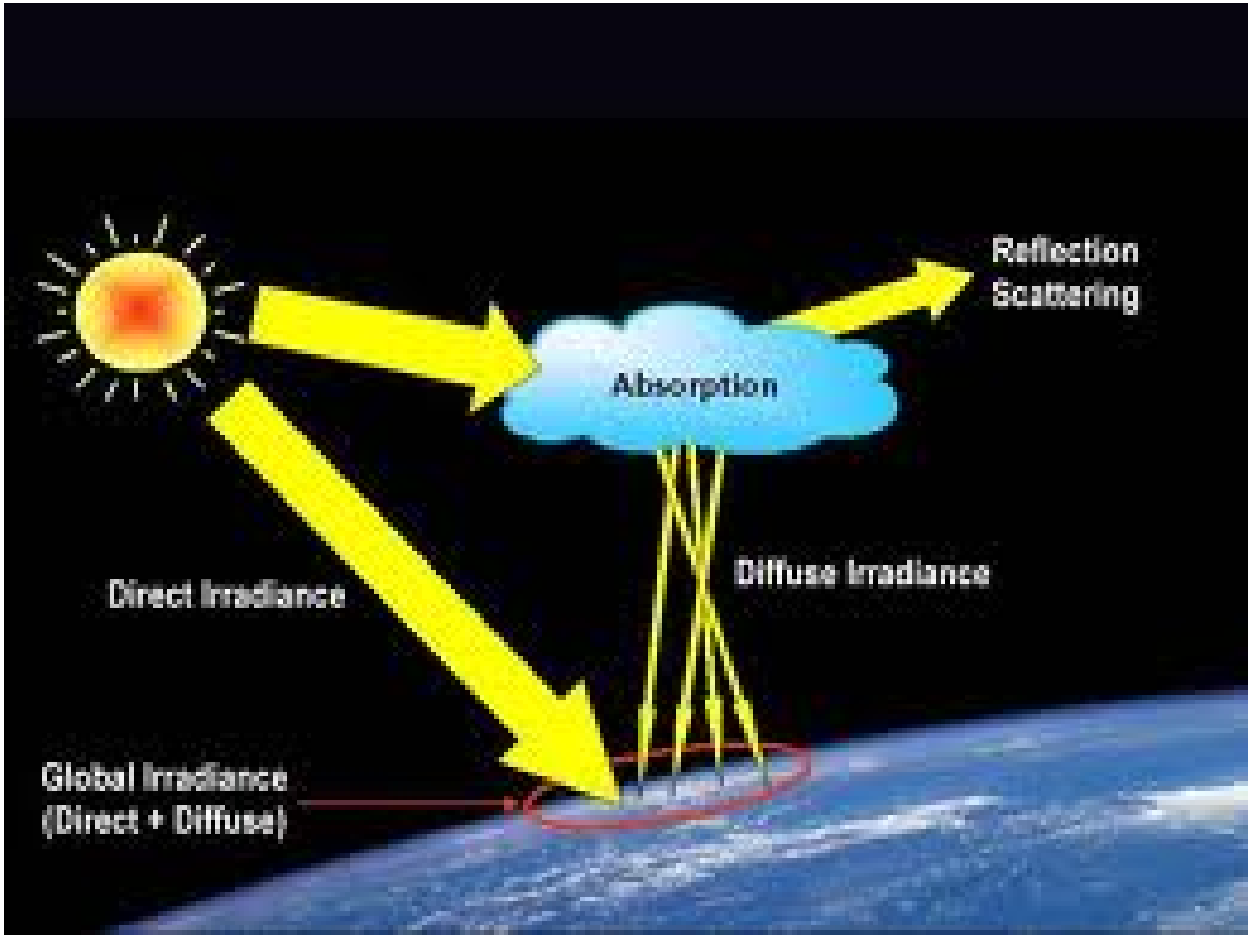


Terrestrial Solar radiation

The energy falling on the earths surface is called terrestrial radiation

The rate of terrestrial energy falling on unit surface area in (W/m2) is variably referred to as radiation, irradiation, irradiance, insolation or energy flux.

It is received at the earths surface in an attenuated form because of scattering and absorption


Reflection
Scattering
Absorption
Diffuse Irradiance
Direct Irradiance
Global Irradiance
(Direct + Diffuse)

Important Terms

Beam Radiation(Ib): Solar radiation received on earths surface without change in direction

Diffuse radiation(Id): The radiation received at the earths surface from all parts of the sky's hemisphere (after being subjected to scattering in the atmosphere) is called diffuse radiation

Total radiation: Ib+Id

Sun at Zenith: Position of sun directly overhead

Air mass(AM)

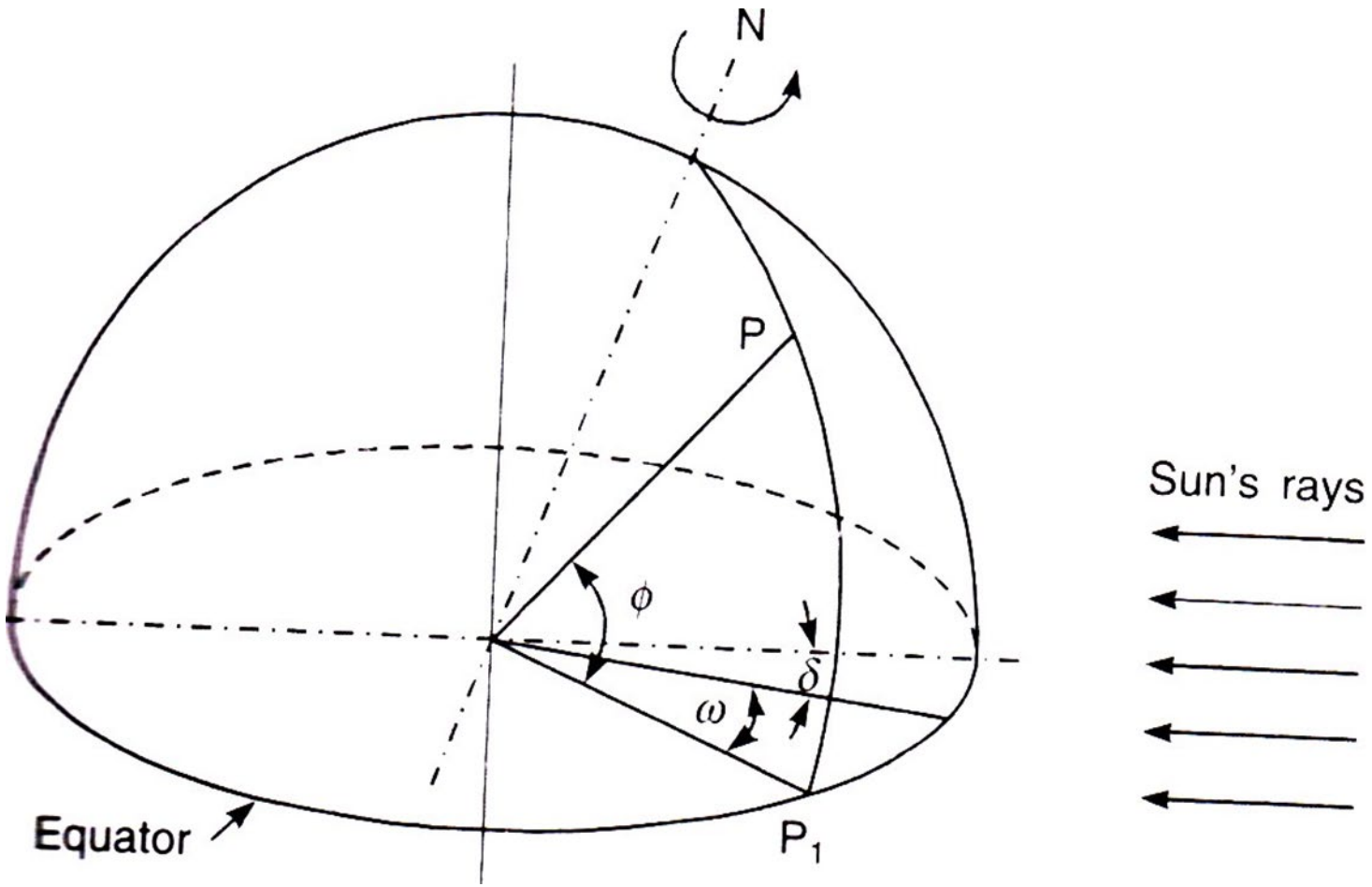
m_a= air mass= ratio of optical thickness of the atmosphere through which beam radiation passes to the surface to its optical thickness if the sun were at the zenith

If m_a=0 extraterrestrial , m_a=1 indicates the sea level on the earth when sun is at the zenith, m_a=2 when the sun is at the zenith angle θz equal to 60^o.

The air mass is related to zenith angles from θz =0 to 70^o at the sea level by

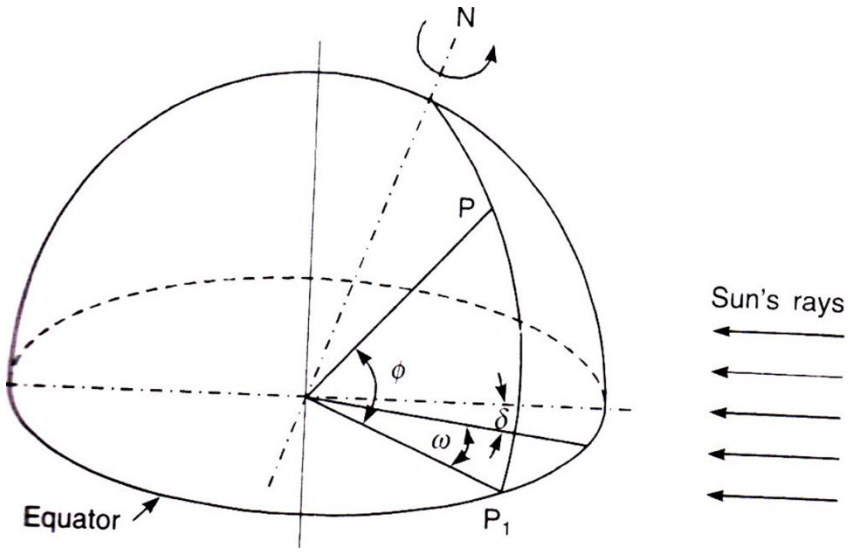
$m_a = (\cos \theta z)^{-1}$

Solar radiation geometry



Latitude (ϕ) :The latitude ϕ of a place is the angle subtended by the radial line joining the place to the center of the earth with the projection of the line on the equatorial plane

Declination (δ): Is the angle subtended by a line joining the centers of the earth and the sun with its projection on the earths equatorial plane



What are Solar Radiation Measurements?

Energy from the Sun at the Earth's Surface

- Different parts of the sky
- Change with time (minutes, hours)
- Change with time (seasons, years, decades)
- Change with location

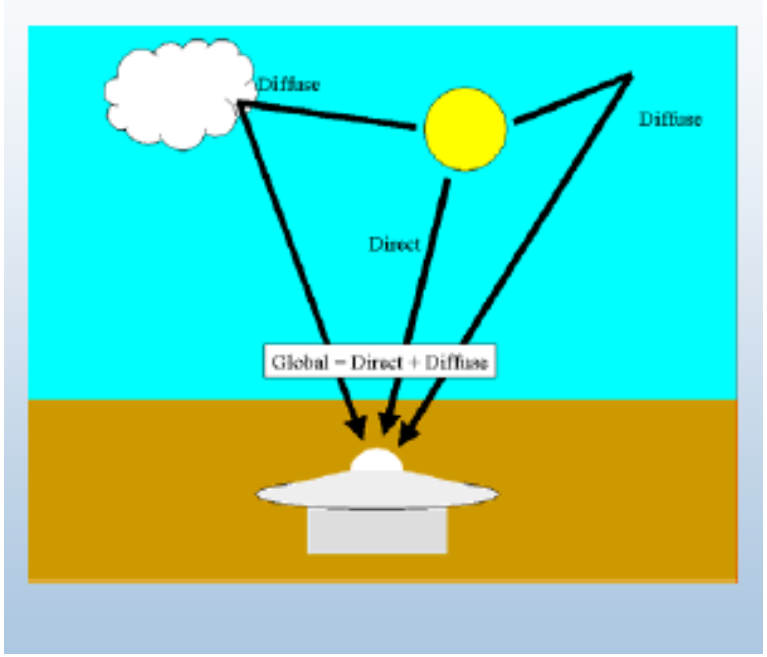
What are Solar Radiation Measurements?

Light from the sky dome

- Direct from the sun
- Everywhere but not from the sun
- Entire sky

We call it

- Direct (beam)
- Diffuse (sky)
- Global (total)



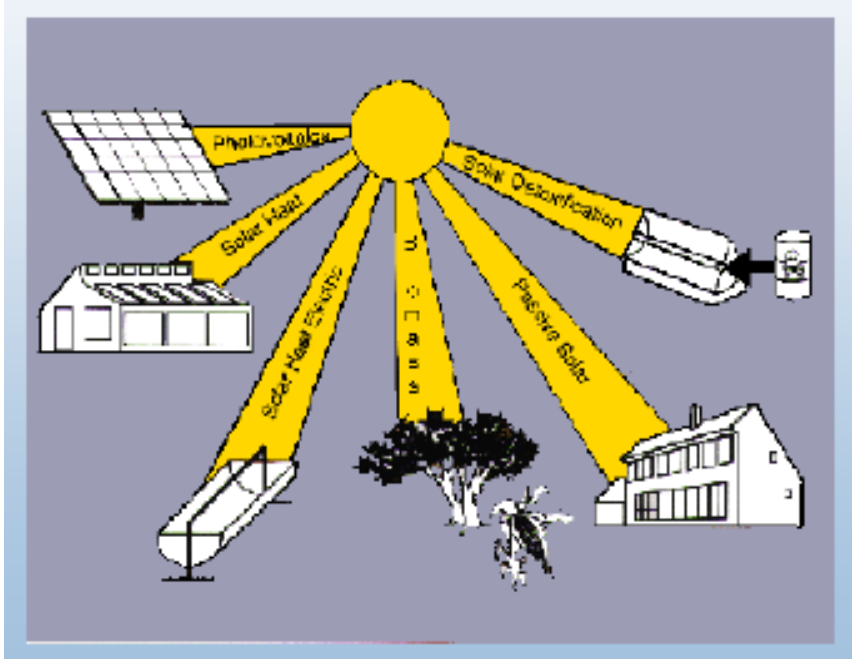
Why Do We Need Solar Radiation Data?

- Agriculture Photosynthesis
- Astronomy Solar Output Variation
- Atmospheric Science Numerical Weather Prediction
- Climate Change Energy Balance
- Health UV effects on skin
- Hydrology Evaporation
- Materials Degradation
- Oceanography Energy Balance
- Renewable Energy Sustainability

Renewable Energy

The amount of solar energy reaching the earth's land areas in 1 hour is enough to supply the U.S. energy needs for 1 year

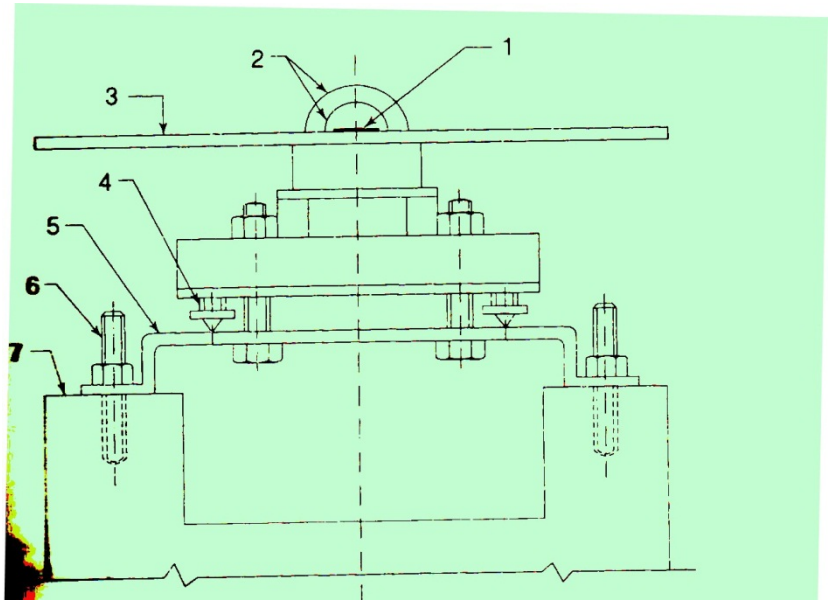
- Photovoltaics
- Solar Heat-thermal
- Solar Heat-electric
- Solar Fuel-biomass
- Passive Solar Lighting
- Building HVAC
- Solar Detoxification



Instruments for Measuring Solar Radiation and Sunshine

Pyranometer

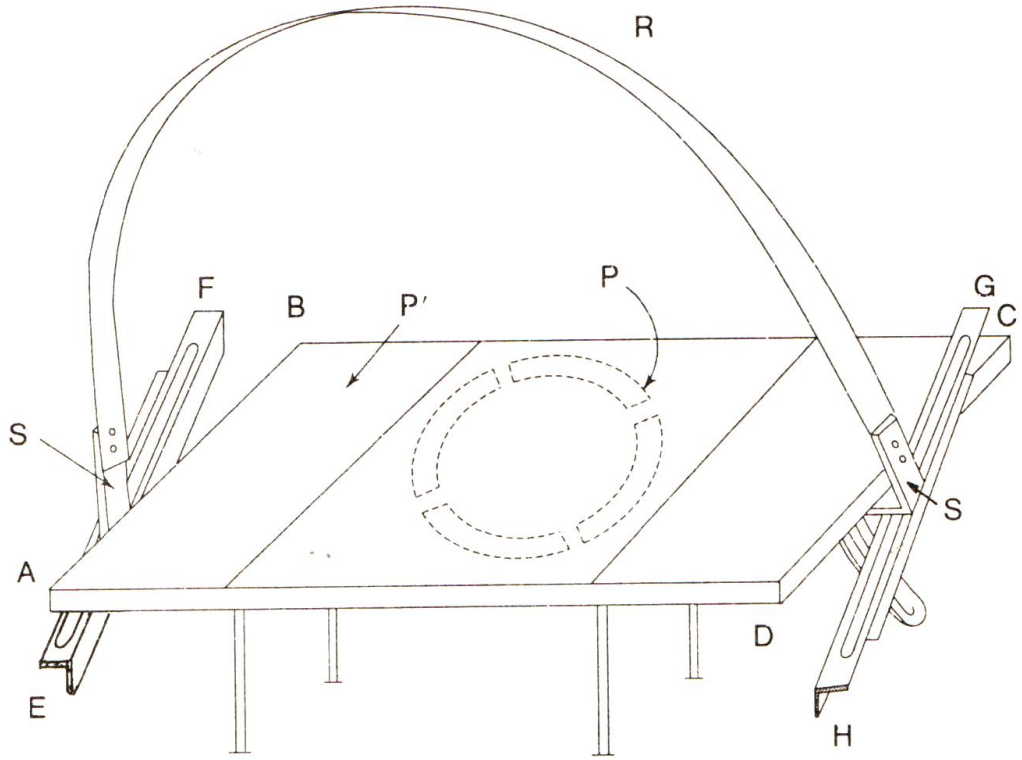
- Used to measure either global or diffuse radiation
- It consists of a black surface which heats up when exposed to solar radiataion
- Its temperature increases until the rate of heat gain equal to heat loss by conduction, convection and reradiation
- The hot junctions of a thermopile are attached to the black surface, while the cold junctions are located in such a way that they do not receive radiation
- As result emf is generated
- This is measure of global radiation



1. Black Surface 2. Glass Domes 3. Guard Plate
4. Leveling Screws 5. Mounting plate
6. Grouted bolts 7. Platform

Pyrometer for Diffuse Radiation Measurement

- This is done by mounting it at the center of the shading ring
- The shading ring is fixed in such a way that its plane is parallel to the plane of the path of the suns daily movement across the sky
- This shades the thermopile element and the two glass domes from direct sunshine
- It measures only the diffuse radiation received from the sky



Shading ring arrangement for the measurement for diffuse radiation

ABCD is a horizontal rectangular frame of 35cmX80 cm
The sides AB and CD of the frame are pivoted to arms EF and GH , 70cm with slots

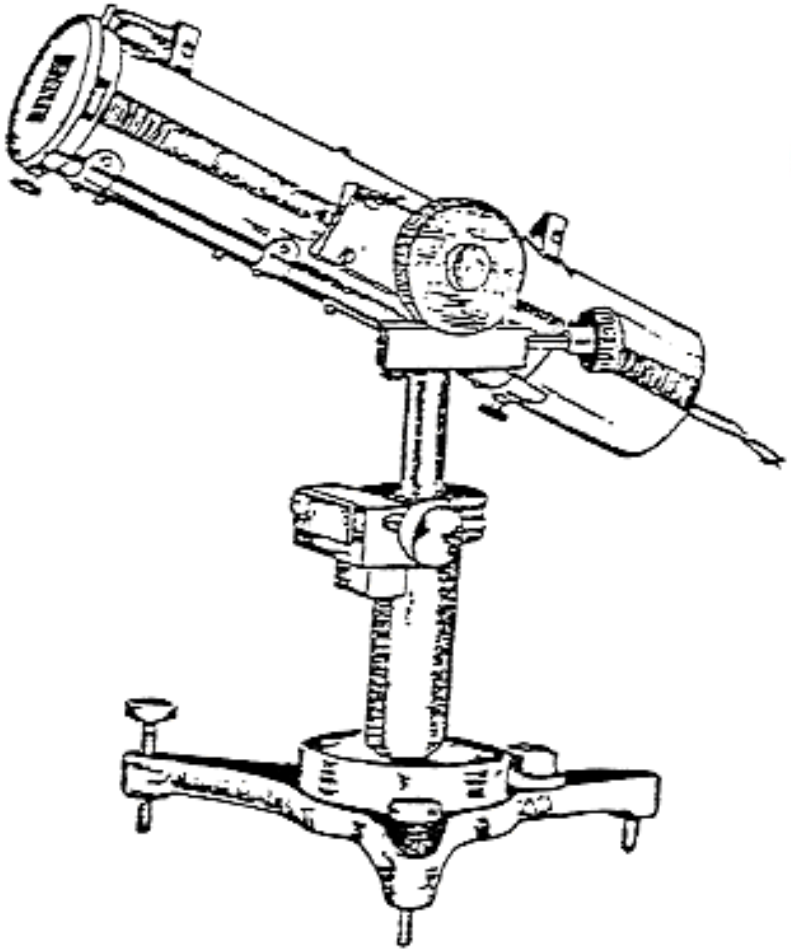
SS is a slider
R semicircular shading ring
The movement of the ring up and down the arms allow for changes in sun's declination

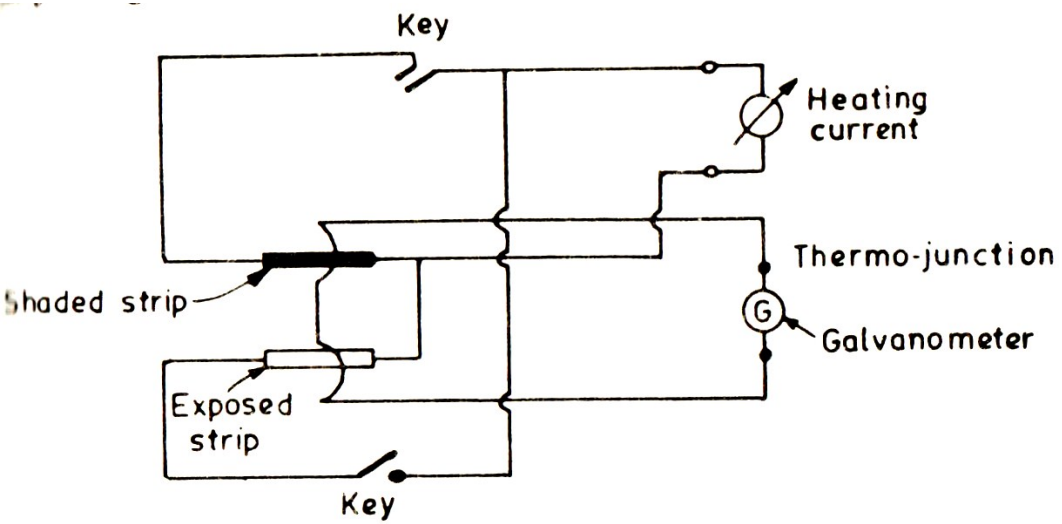
The shading ring is 50 mm broad and bent to 450mm
The inner surface painted dull black and rest dull matt white.

Pyrheliometer

- This measures beam radiation
- Black absorber plate located at the base
- The tube is aligned with the direction of the sun rays with help of two axis tracking mechanism
- Black plate receives only beam radiation and small amount of diffuse radiation

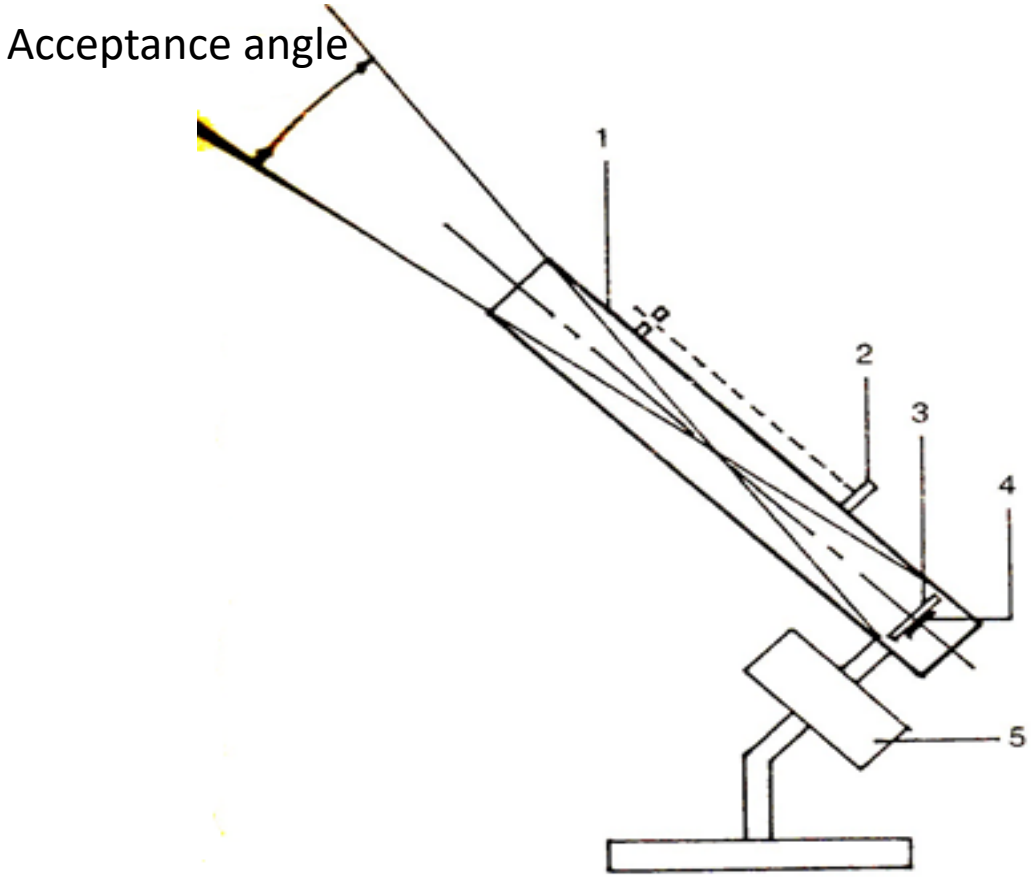
Angstrom electrical compensation pyrheliometer





If S is the intensity of direct solar irradiance
and i is the current, then
$S = Ki^2$,
where K is a constant intrinsic to the instrument and is determined from the size and electric resistance of
the sensor strips and the absorption coefficient of their surfaces.
$K=R/W\alpha$
R- resistance per unit length of the absorbing strip
W- mean width of strip
α- coefficient of absorptivity

Thermo electric type



1. Tube blackened on inside surface 2. Alignment indicator 3. Black absorber plate 4. Thermopile junctions 5. Two axis tracking mechanisam

Sunshine recorder:

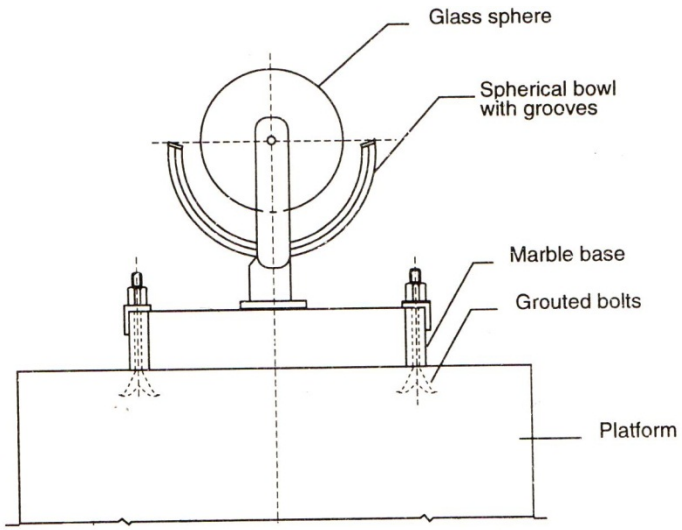
The suns rays are focused by a glass sphere to a point on a card strip

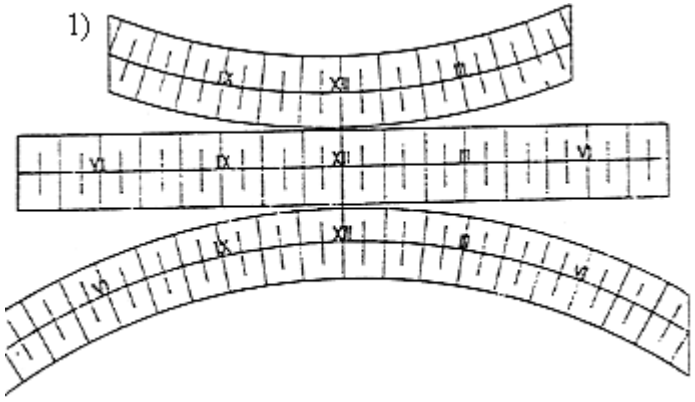
Whenever there is bright sunshine the image formed is intense enough to burn a spot on the card strip

As the sun moves across the sky, the image moves along the strip

Thus the burnt trace whose length is proportional to the duration of sunshine is obtained on the strip

Sunshine recorder:





1)For winter
2) For spring and autumn
3) For summer