3.1 Introduction:
Through out the world, the energy consumption has been growing with advance civilization. Today, energy consumption is directly related to the standard of living of the people of nation and degree of industrialization of the country. The existing energy sources of fossil fuels may not be adequate to meet the ever increasing energy demands. These energy resources are also depleting in nature and may be exhausted in a short time. Thus a necessary exists to look for other forms of energy sources i.e., non-conventional energy sources such as geothermal, ocean tides, wind, solar, etc. Among all these energy sources, solar energy is the most promising alternative energy source which will meet considerable part of energy demand. The solar energy has its own advantages such as its availability at free of cost, inexhaustible, free from pollution, available almost all parts of the world, and is available in abundance. Solar water heaters, space heaters, solar cookers, solar photo-voltaic cells, solar refrigerators and solar thermal power plants are used for various purposes and in all these devices, solar energy is used either for the purpose of water heating, space heating, or cooling or for conversion into other forms of energy. The energy comes from the sun, keeps the temperature of the earth higher, causes current in the atmosphere and ocean. The differential heating of the earth's surface by the sun produces the wind and energy of the wind may be used to run wind mills which in turn drives a generator to produce electricity. Solar energy is a renewable resource and cannot be depleted. It has the greatest potential of all renewable energy sources. The sun constantly delivers 1.36 kW (1360 joules/see) of energy per square meter to the earth. It is one of the promising alternative energy sources and its nature and magnitude available on earth's surface varies depending on the location and weather conditions.

The applications of solar energy are:

i. Space heating or cooling for residential building.
ii. Solar water heating
iii. Solar cookers
iv. Solar distillation on a small scale
v. Drying of agricultural and animal products by suitable solar driers.
vi. Food refrigeration
vii. Electric power generation
viii. Solar ponds
ix. Direct conversion of solar energy into electricity by using photo-voltaic cells
x. Bio-conversion and wind energy, which are indirect source of solar energy
Solar radiation outside the earth's atmosphere

The sun is considered a large sphere of diameter \(1.39 \times 10^6\) km, consisting of very hot gases. The earth's diameter is \(1.27 \times 10^4\) km and the averagedistance between the earth and sun is \(1.496 \times 10^8\) km. The earth receives beam radiation from the sun, almost parallel, because of very large distance between the sun and the earth. Even though the sun's brightness varies from center to its edge, we assume that the brightness is uniform all over the solar disc. It is to be noted that the radiation coming from the sun is almost equal to that of radiation coming from a black surface which is at 5762 K. The energy flux radiated from the sun outside the earth's atmosphere is considered to be constant and this yields the definition of solar constant. Solar constant is the rate at which solar energy reaches at the top of the atmosphere and is denoted by \(I_{sc}\). This is the amount of energy received from the sun in unit time on a unit area perpendicular to the sun's direction and at the mean distance of the earth from the sun. The distance between the earth and the sun varies as the earth revolves around the sun in an elliptical orbit with a small eccentricity and sun at one of the foci. This changes the solar radiation and hence the energy flux reaching the earth's atmosphere.

Thus the solar constant value obtained is the average one and a standard value of 1353 W/m² was adopted in 1971. Later, the solar constant value was revised to 1367 W/m² through measurements. The variation in the extra-terrestrial flux outside the earth's atmosphere due to change in distance between earth and the sun produces a sinusoidal variation in the intensity of solar radiation that reaches the earth. The value of this extra-terrestrial flux on any day of the year can be obtained by using the equation.

The figure 6.1 shows the spectral distribution of extra-terrestrial solar radiation. It is seen from the figure that the spectral beam radiation first increases shortly with wave length and reaches a maximum value of 2074 W/m² at 0.48 Ilm wave length and then decreases. It is to be noted that, up to a wave length of 4 Ilm, 99 percent of sun's radiation is obtained.

3.2 Solar radiation at the Earth's surface
The solar energy received at the earth's surface depends on the time of day, the time of year, local latitude, and amount of cloud cover, amount of atmospheric pollution, etc. The solar radiation received at the earth's surface is attenuated and composed of beam and diffuse radiation, scattered component, and the reflected short wavelength radiation from the surrounding terrestrial surfaces after subjecting to the mechanisms of absorption and scattering during its travel through the earth's atmosphere. The ozone, water vapor, and to some extent other gases (like CO2, N2O, CO, O2, and CH4) and particulate matter, absorb all the ultraviolet solar radiation and energy in the infrared range. This absorption of solar radiation by the atmosphere increases its presence of all gaseous molecules and particulate matter or dust particles in the atmosphere, scatters the solar radiation, i.e., changes its direction. The scattered radiation is redistributed in all the directions, a portion of which goes back into space and remains reaching the earth's surface as diffuse radiation. Thus, the radiation finally reaches the earth's surface consists partly of beam radiation and it is obvious that the solar radiation received at the earth's surface is maximum when the atmosphere is not covered or partly covered with cloud. However, the mechanisms of absorption and scattering are similar under the conditions of cloudless sky or atmosphere with clouds. Solar radiation which is not scattered or absorbed and reaches the earth's surface directly from the sun without changing its direction is called "Beam or Direct radiation". The solar radiation received at the earth's surface after scattering absorption and reflection by the atmosphere is called "Diffuse radiation". It is the radiation at the earth's surface from all parts of the sky's hemisphere and its direction has been changed by scattering, absorption, and reflection. Therefore, the total radiation received at the earth's surface is the sum of beam and diffuse radiation and is known as total or global radiation. Reflected radiation

The intensity of diffuse radiation is not isotropic in nature, but it changes with respect to the latitude, time of the year, time of the day, content in the atmosphere and many other factors.

A term called air mass (AM) is often used to indicate the distance travelled by beam radiation through the atmosphere to reach a location on the surface of the earth. The air mass (AM) is the term represents the ratio of atmospheric mass through which beam radiation passes to the mass of the atmosphere, if the position of the sun is directly overhead (i.e., at its zenith).

3.3 Solar Radiation Measurement

It is necessary to measure solar radiation because of the use of solar heating and cooling devices, and the results of the measurements are used to predict the performance of the devices. The instrument used for measurement of solar radiation includes measurement of direct solar radiation and diffuse solar radiation.
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totalsolar radiation. The instruments used for measurement of solar radiation includes measurement of direct solar radiation and diffuse solar radiation or totalsolar radiation. The instruments which are commonly used for measuring the solar radiation are

1. **Pyrheliometer**: An instrument which measures beam radiation intensity as a function of incident angle, and

2. **Pyranometer**: An instrument used to measure total solar radiation.

### 3.4 Pyrheliometers

This instrument is used to measure beam radiation and operates on the photovoltaic effect. The instrument consists of a tube whose axis is aligned with the direction of sun's rays by using two-axis tracking mechanism and alignment indicator. The tube contains a sensor disc at its base. The arrangement is made such that the diffuse radiation is blocked from the sensor surface and hence the device measures only Beam radiation. The use of shading ring also gives measurement of direct solar radiation, the value of which is obtained by subtracting the shaded (diffuse) reading from the unshaded (global) reading.

The pyrheliometers which are commonly used are

- i) Angstrom compensation pyrheliometer
- ii) Abbot silver disk pyrheliometer and
- iii) Epple pyrheliometer

### Questions

1. Explain briefly the application of Solar pond
2. Draw the sketch and label the parts (i) Horizontal wind mill (ii) Vertical wind mill
4. Classify solar radiation measuring instruments. Explain any one instrument with Sketch
5. With the help of a neat sketch describe the photovoltaic cell
6. With a neat sketch explain the flat plate solar collector.
7. List the problem associated with solar power