Chapter 1

An introduction to Energy Sources

1.1 Introduction:

We need energy in house, industry, transport, communication, agriculture, research, etc. Every human activity is concerned with consumption of energy, hence energy has become fourth basic requirement of modern society. It is the major dominating factor in the development and progress of mankind. It is known that overall progress of country and standard of living of a given country is directly related to. per capita energy consumption of that country. The per capita energy consumption of U.S.A. is about 8000 kWh per year and per capita energy consumption in India is only 150 kWh per year. To increase standard of living for increasing population, a country must develop their own energy sources. Every country uses different energy sources to meet with their energy needs. In this chapter, need and importance of energy, different renewable energy Sources, solar energy as an alternative, and application of solar energy (by direct and indirect methods) are discussed.

1.1.1 Need and importance:

Man has needed energy since he came on earth millions years ago. Primitive man used energy in the form of food. Later he discovered fire and his energy needs were increased. He used fire for cooking and keeping himself warm. With increasing demand for energy, man began to use wind for driving wind mills and sailing ships. He also began to use force of falling water to turn water wheels. The sun was supplying all energy needs and man was using only renewable sources of energy.

After industrial development, man began to use coal for steam engines and factories. A little after, fossil fuels, oil and natural gas began to be used extensively. Nuclear energy began to be used after Second World War. In past few years, it was observed that fossil fuel (coal, oil and natural gas) resources are fast depleting. Fossil fuel era are coming to an end. This is true particularly for oil and gases. Man has been using commercial energy (coal, oil and gas) for better quality of life. The use of these energy sources created many problems. One of the serious problem is harmful effects on environment. The combustion of fossil fuels has created problem of air pollution, as large amount of harmful gases are released in atmosphere. The release of waste from nuclear power plant causes pollution in rivers and lakes. The nuclear waste destructed life of many plants and animals in the

rivers and lakes. The nuclear energy sources are very expensive. There is long problem of disposal of radioactive waste. Due to reasons stated above a man is in search of alternative sources of energy.

In short the reasons for energy crisis are as follows:

(i) There is increase in the world population.

(ii) There is increase in the individual demands.

(iii) Fuels are not usually located at the places where they are needed.

(iv) Increased uses of oil and gas produce undesirable effects such as pollution.

Also fossil fuel reservoirs are limited.

(v) There is lack of technical knowledge of alternate energy extraction.

Our needs of energy are increasing day by day in accordance with increasing population. The conventional energy sources (or non-renewable sources such as fossil fuel) are depleting. Nuclear energy may be the alternative but it has following limitations.

(i) High capital cost.

(ii) Limited availability of raw material.

(iii) Problems of radioactive wastes.

Considering above facts, alternative energy sources will be the renewable energy sources. Renewable energy sources include solar, wind, tidal, and biomass / biogas.

These sources will find wide applications in future.

1.1.2 Conventional and non-conventional sources of energy:

Energy sources are classified as follows:

(A) Conventional sources or Non-renewable energy sources: The resources once used

re lost forever and cannot be regenerated are called non-renewable sources.

These include 1

(ii) Nuclear power

(i) Fossil fuel: Coal, coke, natural gas, petroleum and its derivative.

(B) Non-conventional or Renewable energy sources: The resources that have inherent capacity to reappear or replenish themselves by quick recycling, reproduction and replacement within a reasonable time are renewable sources.

These include:

(1) Solar energy (2) Wind energy (3) Tidal energy (4) Geothermal energy (5) Wave energy

(6) Energy from biomass (7) Hydroelectric power (water power)

1. Solar Energy:

Solar energy can be a major source of energy. Sun is giving 1000 times more power

than we need.

Advantages of solar energy are as follows:

(i) It is very large inexhaustible source of energy.

(ii) It is non-polluting source.

(iii) It is free and available everywhere.

(iv) It is suitable at places where transmission of electricity is not feasible.

Limitations of solar energy are as follows;

(i) It is dilute in nature requiring huge collecting apparatus.

(ii) It is not available during night and cloudy days.

(iii) Storage of solar energy is not economical.

More details about solar energy are discussed in the section 4.3.

2. Wind Energy:

Movement of air under pressure difference is known as wind.

Wind is caused because of two factors:

(i) absorption of solar energy on the earth surface and in the atmosphere,

(ii) the rotation of the earth about its axis and its motion around the sun Due to these reasons, alternate cooling and heating cycle occurs. The pressure difference is created and the air is caused to move. Thus, wind energy is indirect manifestation of solar energy. Wind mill is a machine that converts wind energy into mechanical energy, which can be used for driving pumps, machine and generation of electricity.

Advantages of using Wind energy are as follows:

(i) It's potential as a source of power is good.

(ii) It is renewable and non-polluting source of energy.

Disadvantages of using wind energy are as follows:

(i) The wind source is dilute and fluctuating in nature.

(ii) It needs storage devices.

(iii) The systems are noisy in operation and has overall weight.

3. Tidal Energy:

Tides are generated by the gravitational attraction between the earth and the moon. They arise twice a day. In a tidal power station, water at high tide is trapped in an artificial basin and then allowed to escape at low tide. The escaping water is used to drive turbines. These turbines drive electrical generators and electricity is produced.

Tidal power is small resource and can be the best supply for localised needs of few regions. In India, three regions for exploiting tidal energy has been identified. These are gulfs of Cambay and Kutch in Gujarat and the Hooghly Estuary in West Bengal.

4. Geothermal Energy:

Geothermal energy is the energy coming out of the molten interior of earth towards the surface. On an average, the temperature of the earth is increased by 30°C per kilometre as one moves inwards.

Earth's crust is non-homogeneous. There are number of local spots just below earth's surface. At these spots, temperature is higher than average value expected. When ground water comes into contact with the hot rock, either dry steam or wet steam of water are formed. A well drilled at these locations causes dry or wet steam to come out at the surface. This steam can be utilized either for generating electricity or space heating.

In India, geothermal resources are known to exist along the west coast, in Ladakh and in part of Himachal Pradesh. This source of energy has vast potential and is long lasting.

Limitations of geothermal energy are as follows:

(i) It causes surface pollution and degradation of soil.

(ii) It causes thermal pollution.

(iii) At certain location, H_2S and other radioactive gases are emitted.

5. Energy from Biomass:

The term 'biomass' means an organic matter which includes all plant life trees, bush, grass and algae. Plant matter created. by photosynthesis process is called as biomass. Photosynthesis is naturally occurring process which derives its energy requirement from solar radiation. The reaction of this process is represented as

$$H_2O+CO_2 \longrightarrow CH_2O + 0_2$$

In this process, water and carbon dioxide are converted into an organic matter i.e. CH_2O.

Biomass may be obtained from forests, woods, agricultural lands, arid lands, and even waste lands. There are different methods of obtaining energy from biomass; These are broadly classified as (i) direct method and`(ii) indirect method. The direct way is to burn biomass. The most commonly used fuel is wood. Indirect method includes thermochemical conversion and biological conversion.

6. Wave Energy:

Wave energy arises because of the interaction of the winds with surface of oceans. It is one of the indirect method of utilizing solar energy. The power available varies with the Amplitude and frequency of wave.

Power can be estimated from the formula:

P = 0.55 H2 tp

Where, P is the power in kW per meter length of wave front

H is the wave height in meter

tp is the time period in seconds.

It is estimated that 10 kW power is available in ocean wave for every meter of wave front. Wave energy is difficult to collect because of, wide fluctuations in amplitude and frequency of wave at any location.

In India, a power station based on wave energy is operating at Thiruvananthapuram. The system is designed to 'deliver average power of 75 kW for eight months from April to November and 25 kW for remaining four months.

7. Water Power:

When water is allowed to fall under the force of gravity, hydroelectric power is generated. It is almost used for electrical power generation. It provides about 20 % of the world‘s production of electricity. It is observed that there is annual increase in installed capacity and electricity generated from hydroelectric PowerStation, Hydroelectric power is one of the indirect ways of utilization of solar energy. It is the only renewable, non-depleting source from -the present commercial sources of energy.

Advantages of Renewable energy sources:

1. Renewable energy sources are inexhaustible while non-renewable sources are depleting.
2. Renewable sources are non-polluting.
3. They are indigenous resources freely available in large quantities in all nations.
4. They are locally available and hence avoid transportation.
5. Several of them are financially and economically competitive for certain applications.
6. They generate local employment.
7. It‘s use can save foreign exchange.

Limitations:

1. Large space is required to collect energy.

2. Storage of energy is not economical.

3. Return on capital investment is quite low. i.e. capital output ratio is low.

4. Cost of energy produced is not yet competitive as compared to conventional methods.

5. Several sources are intermittent and relatively dilute in nature as compared to

non-renewable sources.

1.1.3 SOLAR ENERGY:

If the present rate of consumption of energy and population of world continues, the world will be more crowded and more polluted. During use of coal, gas. and fuel, dangerous glasslike carbon monoxide and carbon dioxide are given out. ‘The presence of these gases cause tremendous pollution.

Due to tremendous increase in consumption, 80 % of petrol will be consumed by year 2020. Similarly, production of coal will reach its peak value in year 2030 and by year 2060 -the entire stock of coal will be exhausted. Natural gas would last for approximately the same period as petrol. The continuous consumption of these conventional sources has made necessary to search for new sources of energy.

The wind energy can be an alternative, but it has limitation that desired velocity does not occur continuously. Similarly, in case of tidal wave, wave having constant and desired amount of energy are difficult to collect. Nuclear energy has long term problems of radioactive waste and possibility of release of radioactive radiations in the atmosphere will be harmful. Geothermal energy sources are rare. When they arrive on the surface, they cause surface pollution, degradation of soil and thermal pollution. Therefore, best alternative source of energy is solar energy.

Solar energy is a very large and inexhaustible source of energy. The power available on earth from sun is 1.8×10^{11} MW. This power is many times larger than present consumption rate on earth from all commercial energy sources. Thus, solar energy is the only source which could supply all present and future needs of world. This makes it most promising unconventional energy source.

Solar energy also has two other factors in favour. Firstly, it is clean and non-polluting source of energy. Secondly, it is free and available in all parts of world, where people live. There are many problems associated with use of solar energy. Firstly, it is dilute source of energy. Even in hottest region on earth, solar radiation flux rarely exceeds 1 k-W/m^2 and total radiation over a day is 7 kW/m^2. These are low values from point of technological utilization. Also, large collecting areas are required in many applications. This increases cost of solar instrument.

Secondly, solar energy availability varies widely with time. Variation is due to day-night cycle and also seasonally due to rotation of earth. Variation also occurs at the specific location because of local weather conditions. In such situation, energy collected when sum is shining must be stored for non-availability of sun. Need of storage increases the cost of system also.

Thus, real challenge in utilizing solar energy as alternative source is to make it economically cheaper / Even with the demerits mentioned above, solar energy can still be regarded as best alternative for the conventional energy sources.

1.2 Structure and characteristics of sun:

A schematic representation of the structure of the sun is shown in Fig. 1.2.1. It is estimated that 90% of the energy is generated in the region of 0 to 0.23 R (where R is the radius of the sun), which contains 40% of the mass of the sun. At a distance of 0.7 R from the centre, the temperature drops to about 130,000 K and the density to 70 kg/m^3; here convection processes begin to become important. The zone from 0.7 to 1.0 R is known as the convective zone. Within this zone the temperature drops to about 5000 K and the density to about 10^{-5} kg/m^3.

The sun's surface appears to be composed of granules (irregular convection cells), with the dimension of cells varying from 1000 to 3000 km, and the lifetime of a few minutes. Other features of the solar surface are - small dark areas called pores, which are of the same order of magnitude as the convective cells, and larger dark areas called sunspots, which vary in size. The outer layer of the convective zone is called the photosphere. The edge of the photosphere is sharply defined, even though it is of low density (about 10^{-4} that of air at sea level). It is essentially opaque, as the gases of which it is composed of are strongly ionized and able to absorb and emit a continuous spectrum of radiation. The photosphere is the source of the most of the solar radiation.

At the outer side of the photosphere is a more or less transparent solar atmosphere, which can be observed during total solar eclipse or by the instruments that obscure the solar disk. Above the photosphere is a layer of cooler gases, several hundred kilometres deep, called the reversing layer. Outer of that is a layer referred to as the chromosphere, with a depth of about 10,000 km. This is a gaseous layer with temperatures somewhat higher than that of the photosphere and with lower density. Still farther out is the corona of very low density and of very high (10^6 K) temperature.

This simplified picture of the sun, its physical structure, and its temperature and density gradients, as shown in Fig. 1.2.1, will serve as a basis for appreciating that the sun does not, in fact, function as a black body radiator at a fixed temperature. Rather, the emitted solar radiation is the composite result of several layers that emit and absorb radiation of various wavelengths.

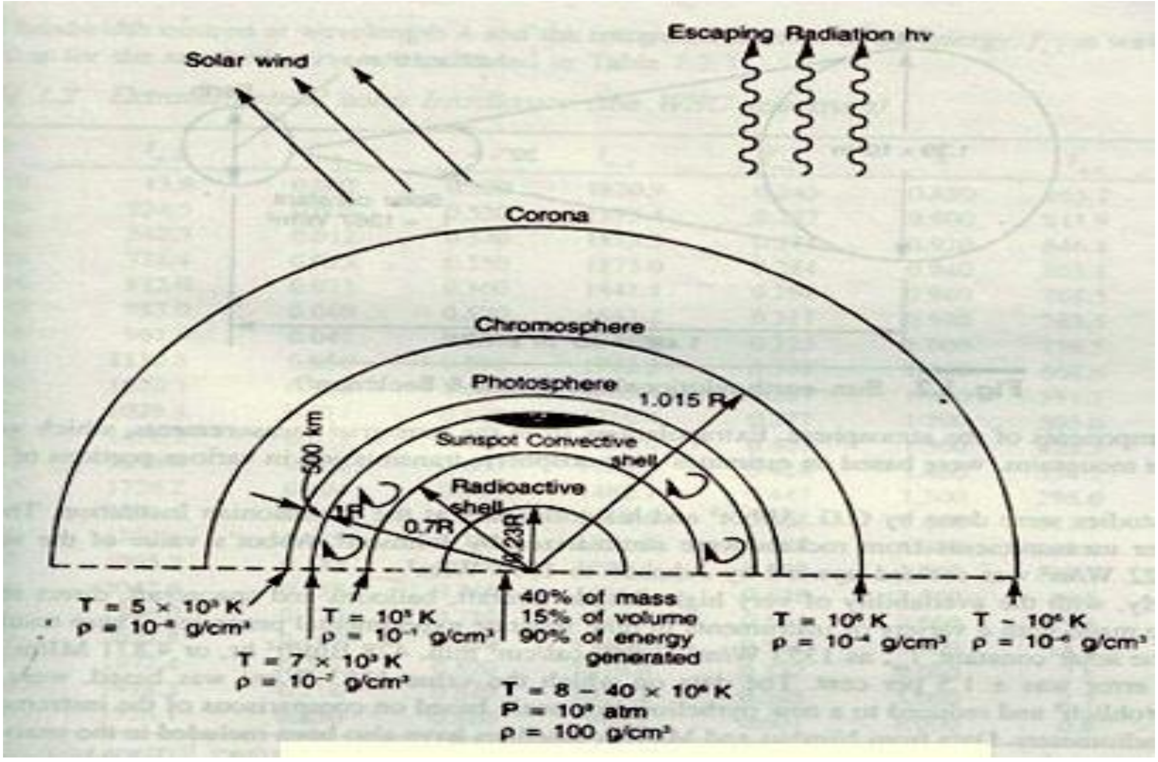


Fig. 1.2.1 The structure of the sun (not to scale)

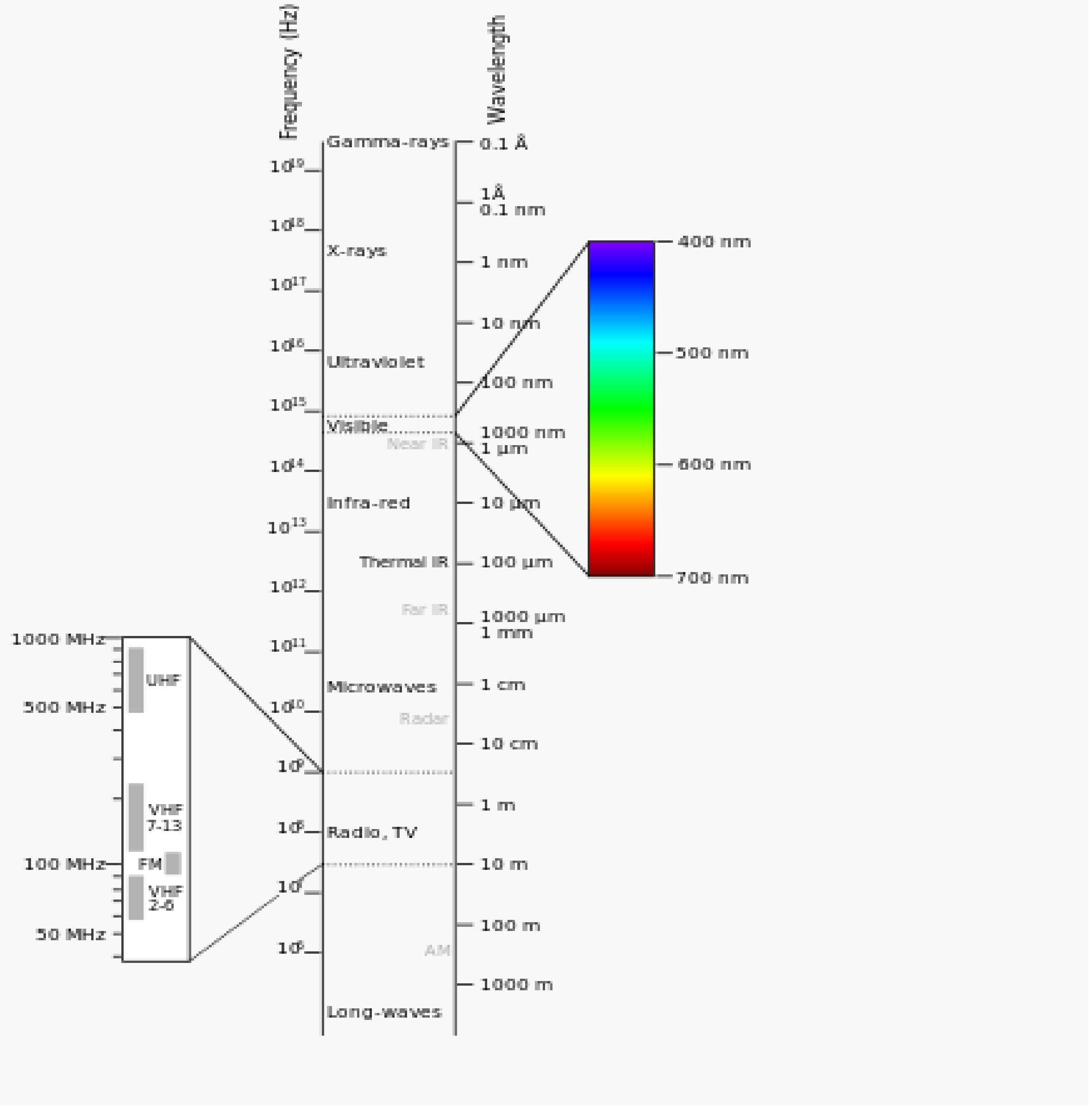
The characteristics of the sun's energy available outside the earth's atmosphere are first considered. The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Its diameter is 1.39x 10^6 km, while that of the earth is 1.27 x 10^4 km. The mean distance between the two is 1.496 X 10^8 km. Although the sun is large, it subtends an angle of only 32 minutes at the earth's surface. This is because it is also at a very large distance. Thus, the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its centre to its edge. However, for engineering calculations, it is customary to assume that the brightness all over the solar disc is uniform.

1.3 Solar constant:

The solar constant is the amount of incoming solar electromagnetic radiation per unit area, measured on the outer surface of Earth's atmosphere on a plane perpendicular to the rays. The solar constant includes all types of solar radiation, not just the visible light. It is estimated to be roughly 1,366 watts per square meter (W/m^2) according to satellite measurements, though this fluctuates by about 6.9 % during a year (from 1,412 W/m^2 in early January to 1,321 W/m^2 in early July) due to Earth's varying distance from the Sun. For the entire planet (Earth has a cross section of 127,400,000 km^2), the power is (1366 W/m^2 x 1.274×10^{14} m^2) 1.740×10^{17} W, plus or minus 3.5 %. The solar constant does not remain constant over long periods of time. The average value cited, 1,366 W/m², is equivalent to 1.96 calories per minute per square centimetre, or 1.96 langleys (Ly) per minute.

1.4 Electromagnetic energy spectrum:

The **electromagnetic spectrum** is the range of all possible frequencies of electromagnetic radiation. The "electromagnetic spectrum" *of an object* has a different meaning, and is instead the characteristic distribution of electromagnetic radiation emitted or absorbed by that particular object. The electromagnetic spectrum extends from below the low frequencies used for modern radio communication to gamma radiation at the short-wavelength (high-frequency) end, thereby covering wavelengths from thousands of kilometers down to a fraction of the size of an atom. The block diagram of electromagnetic spectrum is shown in figure.1.4



.Regions of the spectrum

The types of electromagnetic radiation are broadly classified into the following classes: Gamma radiation

1. X-ray radiation
2. Ultraviolet radiation
3. Visible radiation
4. Infrared radiation
5. Terahertz radiation
6. Microwave radiation
7. Radio waves

This classification goes in the increasing order of wavelength, which is characteristic of the type of radiation. While, in general, the classification scheme is accurate, in reality there is often some overlap between neighbouring types of electromagnetic energy.

Radio frequency:

Radio waves generally are utilized by antennas of appropriate size (according to the principle of resonance), with wavelengths ranging from hundreds of meters to about one millimeter. They are used for transmission of data, via modulation. Television, mobile phones, wireless networking, and amateur radio all use radio waves. The use of the radio spectrum is regulated by many governments through frequency allocation. Radio waves can be made to carry information by varying a combination of the amplitude, frequency, and phase of the wave within a frequency band.

Microwaves:

The super-high frequency (SHF) and extremely high frequency (EHF) of microwaves are on the short side of radio waves. Microwaves are waves that are typically short enough (measured in millimeters) to employ tubular metal waveguides of reasonable diameter. Microwave energy is produced with klystron and magnetron tubes, and with solid state diodes such as Gunn and IMPATT devices. Microwaves are absorbed by molecules that have a dipole moment in liquids. In a microwave oven, this effect is used to heat food. Low-intensity microwave radiation is used in Wi-Fi, although this is at intensity levels unable to cause thermal heating.

Volumetric heating, as used by microwave ovens, transfers energy through the material electromagnetically, not as a thermal heat flux. The benefit of this is a more uniform heating and reduced heating time; microwaves can heat material in less than 1% of the time of conventional heating methods.

Terahertz radiation:

Terahertz radiation is a region of the spectrum between far infrared and microwaves. Until recently, the range was rarely studied and few sources existed for microwave energy at the high end of the band (sub-millimeter waves or so-called terahertz waves), but applications such as imaging and communications are now appearing.

Infrared radiation:

The infrared part of the electromagnetic spectrum covers the range from roughly 300 GHz to 400 THz (1 mm - 750 nm). It can be divided into three parts:

- **Far-infrared**, from 300 GHz to 30 THz (1 mm - 10 μm). The lower part of this range may also be called microwaves.
- **Mid-infrared**, from 30 to 120 THz (10 - 2.5 μm). Hot objects (black-body radiators) can radiate strongly in this range, and human skin at normal body temperature radiates strongly at the lower end of this region. This radiation is absorbed by molecular vibrations, where the different atoms in a molecule vibrate around their equilibrium positions. This range is sometimes called the *fingerprint region*, since the mid-infrared absorption spectrum of a compound is very specific for that compound.
- **Near-infrared**, from 120 to 400 THz (2,500 - 750 nm). Physical processes that are relevant for this range are similar to those for visible light. The highest frequencies in this region can be detected directly by some types of photographic film, and by many types of solid state image sensors for infrared photography and videography.

Visible radiation (light):

Above infrared in frequency comes visible light. The Sun emits its peak power in the visible region, although integrating the entire emission power spectrum through all wavelengths shows that the Sun emits slightly more infrared than visible light.[18] By definition, visible light is the part of the EM spectrum to which the human eye is the most sensitive. Visible light (and near-infrared light) is typically absorbed and emitted by electrons in molecules and atoms that move from one energy level to another. This action allows the chemical mechanisms that underly human vision and plant photosynthesis. The light which excites the human visual is a very small portion of the electromagnetic spectrum. A rainbow shows the optical (visible) part of the electromagnetic spectrum; infrared (if it could be seen) would be located just beyond the red side of the rainbow with ultraviolet appearing just beyond the violet end.

Electromagnetic radiation with a wavelength between 380 nm and 760 nm (400–790 terahertz) is detected by the human eye and perceived as visible light. Other wavelengths, especially near infrared (longer than 760 nm) and ultraviolet (shorter than 380 nm) are also sometimes referred to as light, especially when the visibility to humans is not relevant. White light is a combination of lights of different wavelengths in the visible spectrum.

Ultraviolet radiation:

Next in frequency comes ultraviolet (UV). The wavelength of UV rays is shorter than the violet end of the visible spectrum but longer than the X-ray.

UV in the very shortest range (next to X-rays) is capable even of ionizing atoms (see photoelectric effect), greatly changing their physical behaviour.

At the middle range of UV, UV rays cannot ionize but can break chemical bonds, making molecules to be unusually reactive. Sunburn, for example, is caused by the disruptive effects of middle range UV radiation on skin cells, which is the main cause of skin cancer. UV rays in the middle range can irreparably damage the complex DNA molecules in the cells producing thymine dimers making it a very potent mutagen.

X-rays:

After UV come X-rays, which, like the upper ranges of UV are also ionizing. However, due to their higher energies, X-rays can also interact with matter by means of the Compton effect. Hard X-rays have shorter wavelengths than soft X-rays. As they can pass through most substances with some absorption, X-rays can be used to 'see through' objects with thicknesses less than equivalent to a few meters of water. One notable use in this category is diagnostic X-ray images in medicine (a process known as radiography). X-rays are useful as probes in high-energy physics.

Gamma rays:

After hard X-rays come gamma rays, which were discovered by Paul Villard in 1900. These are the most energetic photons, having no defined lower limit to their wavelength.

Gamma rays are also used for the irradiation of food and seed for sterilization, and in medicine they are occasionally used in radiation cancer therapy. More commonly, gamma rays are used for diagnostic imaging in nuclear medicine, with an example being PET scans. The wavelength of gamma rays can be measured with high accuracy by means of Compton scattering. Gamma rays are first and mostly blocked by Earth's magnetosphere then by the atmosphere.

1.5 SOLAR RADIATION OUTSIDE THE EARTH'S ATMOSPHERE:

The characteristics of the sun's energy available outside the earth's atmosphere are first considered. The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Its diameter is $1.39x\ 10^6$ km, while that of the earth is 1.27×10^4 km. The mean distance between the two is $1.496 \text{ X } 10^8$ km. Although the sun is large, it subtends an angle of only 32 minutes at the earth's surface. This is because it is also at a very large distance. Thus, the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its centre to its edge. However, for engineering calculations, it is customary to assume that the brightness all over the solar disc is uniform.

Measurements indicate that the energy flux received from the sun outside the earth's atmosphere is essentially constant. The solar constant ISC 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. The value of the solar constant has been the subject of many experimental investigations. Based on measurements made up to 1970, a standard value of was adopted in 1971.* However, based on subsequent measurements, a revised values of 1367 W/m^2 has been recommended. The difference between the two values is only l per cent.

The earth revolves around the sun in an elliptical orbit having a very small eccentricity, and with the sun at one of the foci. Consequently, the distance between the earth and the sun varies a little through the year. Because of this variation, the extra-terrestrial flux also varies. The value on any day can be calculated from the equation

$$I'_{sc} = I_{sc}[1+0.033\cos(360n/365)]$$

Where n is the day of the year.

It is also useful to know the spectral distribution of extra-terrestrial solar radiation. Measurements corresponding to both the values of the solar constant are given in Table 1.4. It will be seen that the measurements are in close agreement with each other. For both cases, the spectral value first increases sharply with wavelength, passes through a maximum at a wavelength of 0.48 μm and then decreases asymptotically to zero. 99 per cent of the sun's radiation is obtained up to a wavelength of 4 μm. The percentage of radiation obtained up to a certain wavelength is also given in Table 1.4. This value is useful for calculating the solar flux emitted in any specified range of wavelengths. For easy reference and visualization, the spectral distribution data corresponding to the solar constant value of 1353 W/m^2 plotted in Fig. 1.4.

The radiation coming. From the sun is essentially equivalent to blackbody radiation. Using the Stefan-Boltzmann law, the equivalent back body temperature can be shown to be 5762 K for a solar constant of 1353 W/m^2 and 5779 K for a solar constant of 1367 W/m^2

1.6 SOLAR RADIATION AT THE EARTH'S SURFACE:

The sun is a large sphere of hot gases, where the heat created is due to various fusion reactions which convert hydrogen atom to helium atom. This energy is radiated by sun in all directions and very small fraction of it reaches the earth. The spectrum of electromagnetic radiation is as shown in Table 1.6 (1 1.1 = 10^6 m). The diameter of sun is 1.39 x10^6 km. The mean distance between the earth and sun is 1.496 X 10^8 km. Energy flux received from the sun outside the earth's atmosphere is constant. The amount of energy received per second per unit area on the top of the atmosphere is called solar constant. The value of solar constant is 1.367 kW/m^2.

Table 1.6

Wavelength range	$\lambda < 10^{-8}\mu$	$10^{-8} < \lambda$ $10^{-4}\mu$	$10^{-4} <$ λ $10^{-2}\mu$	$2x10^{-2} < \lambda <$ 0.38μ	$0.38\mu <$ $\lambda < 0.78\mu$	$0.78\mu <$ $\lambda < 10^{2}\mu$	$10^{2}\mu <$ $\lambda < 10^{10}\mu$
Name	Cosmic rays	Gamma rays	X-rays	Ultraviolet rays	Visible rays	Infra-red rays	Radio rays

Earth revolves round the sun in elliptical orbit the sun at one of the foci. This results small variation in the distance between the earth and sun. Because of' this variation, extra-terrestrial flux also varies The spectral distributions of extra-terrestrial solar radiation are given in Figure 1.6

visible light (o.3 µm - 0.76 µm)

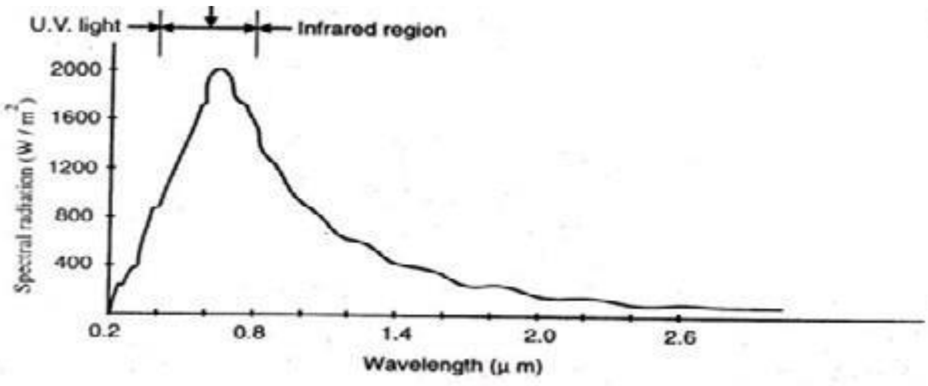


Figure 1.6.1 spectral distributions of extra-terrestrial solar radiation

The radiation first increases sharply with wavelength. It is maximum at 0.48 µm and then decreases asymptotically to zero. About 99 percent solar radiation is obtained up to wavelength 4 um. The curve shows that intensity of solar flux is maximum in region of visible radiation (0.38 µm - 0.78 µm). Above curve is useful to calculate the solar flux emitted in any specified range of wavelength. Solar radiation is absorbed and scattered as it passes through the atmosphere. Absorption is due to presence of ozone, water vapours and a lesser extent to other gases (like CO2, N02, CO, O2 etc.). Ozone absorbs only in ultraviolet band. It absorbs the short radiations below 0.29 um. Water vapour 'absorbs mainly in infrared bands. The scattering is due to all gaseous molecules and matter in the atmosphere. The scattered radiations are reflected back to space and some reach the earths surface as diffuse radiation. The radiation finally received at the earth's surface consist partly of beam radiation land partly of diffuse radiation. Thus, solar radiation received at earth's surface is in an attenuated form. (Fig. Figure 1.6.2).

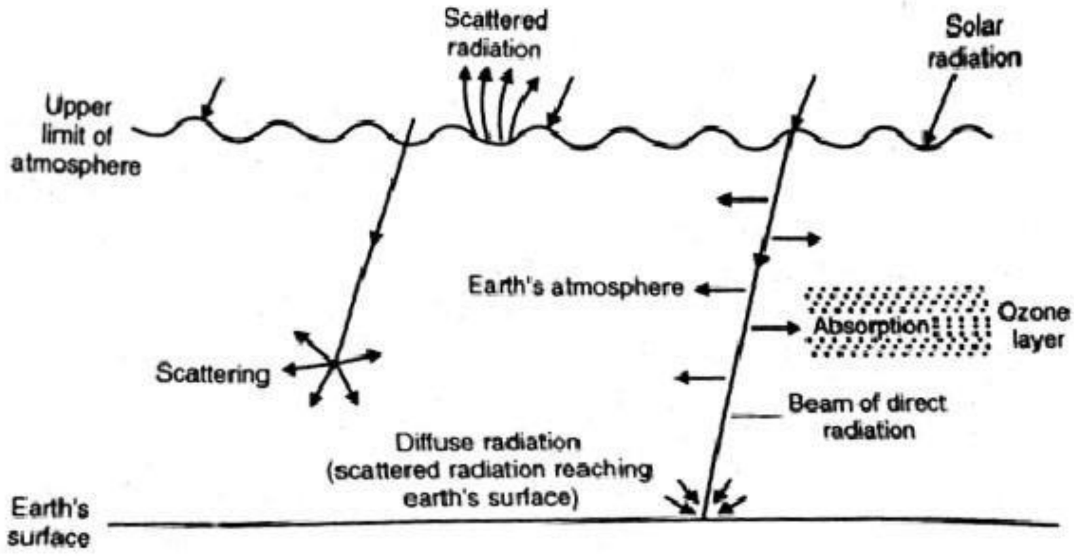


Figure 1.4.2 Schematic representation of (i) Absorption and scattering, (ii) Beam and diffuse radiation

The solar radiation received at the earth's surface without change of direction is called beam or direct radiation. The radiation received at the earth's surface from all parts of sky hemisphere is called as diffuse radiation. The sum of the beam and diffused radiation is called total or global radiation. As the intensity of diffused radiation coming from various direction in the sky is not uniform, it is anisotropic in nature. In many situations, intensify from all beam' tends to be uniform, and is said to be isotropic in nature. The term air mass (AM) is defined as ratio of the mass of atmosphere through which beam radiation passes to the mass it would pass through if sun is directed overhead (i.e. at its zenith). The zenith angle is the angle made by sun's ray with the normal to a horizontal surface. These terms are needed to calculate transmittance of radiation.

Solve Problems:

1. The radius of sun surface is 6.960×10^{8} m and the mean earth-sun distance is 1.5×10^{11} m. Find angular divergence. (Hint : $\delta = d/R$)

$$\delta = d/R$$

$$= 1.5 \times 10^{11} / 6.960 \times 10^{8}$$

$$= 215^{o}$$

2. A monoenergetic radiation beam having a wavelength of one micrometer. Calculate the energy of a single Photon.(Given: h= 6.6256×10^{-34} j.s and C= 3×10^{8} m/s)

Solution: Planck constant = 6.63×10^{-34} Js, 1 eV = 1.6×10^{-19} J, C= 3×10^{8} m/s

λ= 1 micrometer = 1×10^{-6} m, Eg = ?

$$E = h/\upsilon = hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^{8}) / (1 \times 10^{-6} \times 1.6 \times 10^{-19})$$

$$= 12.43125 \times 10^{-1}$$

$$= 1.243 \text{ eV}$$

3. Calculate the Sun’s declination δ by Cooper equation at 7.30 AM on August 1.

Solution: δ(degree)= 23.45 Sin [360/365x (284+n)]

= 23.45 Sin [360/365x (284+1)]

= 23.45 Sin [281.09]

δ(degree) = -23.01^{o}

4. Calculate the Sun’s declination δ by Cooper equation at 7.30 AM on July 15.

Solution: δ(degree)= 23.45 Sin [360/365x (284+n)]

= 23.45 Sin [360/365x (284+15)]

= 23.45 Sin [294.90]

δ(degree) = -21.27^{o}

QUESTIONS AND EXAMPLES

1. What are renewable energy sources ?
2. Discuss in detail renewable energy sources.
3. Explain the use of solar energy as an alternative source of energy.
4. What are different modes and utilization of solar energy?
5. Write a short note on :
   (a) Solar radiation.
6. What are Advantages and disadvantages of Renewable energy sources?

7. Define the term "Air Mass" .
8. Explain the term solar radiation at the earth surface.
9. A monoenergetic radiation beam having a wavelength of one micrometer. Calculate the energy of a single Photon.(Given: h= 6.6256×10^{-34} j.s and C= 3×10^{8} m/s)
10. Define Solar Constant.
11. What are non conventional sources of energy?
12. Explain the term : solar radiation at the earth's surface.
13. Draw a neat diagram of structure of the sun. Explain the electromagnetic energy spectrum.
14. Ina a solar spectrum, the brightest line has a wavelength of 4785A^o. If Wein's constant is 2.9 x 10^{-3} m-k.
15. What are conventional energy sources?
16. Draw schematic diagram of direct, diffuse and total solar radiation.
17. Write a note on solar pond.
18. State the advantages of renewable energy sources. Explain use of hydrogen as potential source of energy.
19. Discuss environmental degradation due to use of conventional energy.
20. What is tidal energy?
21. Write note on tidal energy.
22. What is energy conservation? Explain the principles of energy conservation.
23. What do you mean by renewable energy sources?
24. What is meant by Zenith?
25. Draw and explain the spectral distribution curve of solar radiation at the earth's surface.
26. Write note on energy from sea waves.
27. The radius of sun surface is 6.960x108 m and the mean earth-sun distance is 1.5x1011 m. Find angular divergence. (Hint : δ=d/R)
28. In a solar spectrum, the brightest line has wavelength of 4785 A^o. If Weins constant is 2.9 x 10^{-3} m^o k. Find the surface temperature of sun.