	CMR INSTITUTE OF TECHNOLOGY	
	Renewable Energy Sources -17EE563	Date: 09/09/2019
	Internal Assesment Test-1 . Solution Manual	Semester: V Dept. EEE/ECE/ISE

Answer any five FULL Questions. Sketch neat figures wherever necessary.

1. (a) Define Energy Scarcity?
   - The energy crisis is the concern that the world's demands on the limited natural resources that are used to power industrial society are diminishing as the demand rises.
   - The gap between the (Scarce) limited energy resources, and unlimited or limitless energy consumption.
   - This situation requires people to make decisions about how to allocate resources efficiently, in order to satisfy basic needs and as many additional wants as possible.

   (b) Mention the causes of Energy scarcity
   1. Increasing Population
   2. Increase Energy Usage or Consumption
   3. Uneven Distribution of Energy Resources
   4. Lacks of Technical Knowhow
   5. Poor Infrastructure at power generating stations
   6. Unexplored Renewable Energy Options
   7. Delay in Commissioning of Power Plants
   8. Wastage of Energy
   9. Poor Distribution System
   10. Major Accidents and Natural Calamities
   11. Wars and Attacks
   12. Miscellaneous Factors-strikes, military coup, political events, severe hot summers or cold winters.

   (c) Explain the solutions for the energy crisis problem?
   1. Minimizing population growth exploitation
   2. Harnessing the large utilization of known and unknown energy reservoirs.
   3. development of energy conversion techniques from one form to other
   4. Move Towards Renewable Resources
   5. Buy Energy Efficient products
   6. Lighting Controls
   7. Easier Grid Access
   8. Energy Simulation
   9. Perform Energy Audit
   10. Common Stand on Climate Change

2. (a) Briefly explain the factors affecting the energy resouce development.
   1. Energy or Fuel Substitution or Scale of Shift
      - Substitute for fossil fuels at requisite scale is not available.
   2. Energy Density
      - The amount of energy contained in a unit of material object (energy resource) is termed as energy density.
      - Air-dry crop residue (mostly straw and agricultural waste) contain only 12–15 MJ/kg.

- The energy density of good quality coal is twice as high (i.e., 25–30 MJ/ kg) as that of crude oil (i.e., 42–45 MJ/kg).
- In order to obtain an equivalent output, replacement of a unit of fossil fuels with approximately 2 kg of phytomass will be needed to substitute solid biofuel.
- The ratio would be about 1.5 times when substituting plant-derived ethanol for petrol.
- These realities would be reflected in the reserve capacity, cost, and operation of the required infrastructure.

3. Power Density
   - Power density refers to the rate of energy production per unit of earth's area.
   - Expressed in watts per square meters (w/m^2).
   - Owing to lengthy period of formation (from biomass to coal and then from coal to hydrocarbons), fossil fuel deposits are an extraordinarily concentrated source of high quality energy.
   - They are commonly produced with power densities of 10^2 or 10^3 w/m^2.
   - small land areas are required to supply enormous energy flows.
   - Biomass Energy production has densities below 1 w/m^2, while density of electricity produced by water and wind is below 10 w/m^2.
   - Photovoltaic electricity generation can deliver larger than 20 w/m^2.
   - The cost and performance are the constraints of mass utilization.
4. Intermittency
   - Growing demand for fuels, energy, and electricity fluctuates daily and seasonally in modern civilization.
   - Further, the base load, which is defined as the minimum energy required meeting the demand of the day, has been increasing.
   - Easily storable high-energy density fossil fuels and thermal electricity generating stations that are capable of operating with high load factors meet these needs.
   - On the other hand, wind and direct solar radiation are intermittent and far from practicable. They can never deliver such high load factors.
   - Photovoltaic electric generation is still so negligible to offer any meaningful averages.
   - The annual load factors of wind generation in countries with relatively large capacities are 20%-25%.
   - Unfortunately, we still lack the means for storing wind or solar-generated electricity on a large scale.
5. Geographical Energy Distribution
   - There are uneven distributions of fossil fuels and the non-fossil fuels (solar, wind, etc.).
   - Cloudiness in the equatorial zone reduces direct solar radiation.
   - Whole stretches of continent has insufficient wind.
   - There are very few sites with the best potential for geothermal, tidal, or ocean energy conversions.
6. Inadequate documentation and evaluation of past experience
   - a paucity of validated field performance data and a lack of clear priorities for future work.
7. Weak or non-existent institutions and policies to finance and commercialize renewable energy systems. With regard to
   - Energy planning, separate and completely uncoordinated organisations are often responsible for petroleum, electricity, coal, forestry, fuel-wood, renewable resources and conservation.
8. Technical and economic uncertainties in many renewable energy systems
   - High economic and financial costs for some systems in comparison with conventional supply options and energy efficiency measures.

9. Skeptical attitudes towards renewable energy systems on the part of the energy planners.
10. Lack of qualified personnel to design, manufacture, market, operate and maintain of such systems
11. Inadequate donor coordination in renewable energy assistance activities

(b) Explain classification of energy resources. Mention their merits and demerits.
Energy resources can be classified in the following ways.

- Based on usability of energy
  - **Primary Resources**
    * These are available in nature in raw form are called primary energy resources, e.g. fossil fuels (coal, oil and gas), uranium, hydro energy, etc.
    * These are also known as raw energy resources.
    * Generally, this form of energy cannot be used directly.
    * These are located, explored, extracted, processed and are converted to a form as required by the consumer.
  - **Intermediate Resources**
    * This is obtained from primary energy by one or more steps of transformation and is used as a vehicle of energy.
  - **Secondary Resources**
    * The form of energy, which is finally supplied to consumer for utilization, is known as secondary or usable energy, e.g. electrical energy, thermal energy (in the form of steam or hot water), chemical energy (in the form of Hydrogen or fossil fuels), etc.
    * Some forms of energies may be categorized both in intermediate as well as secondary resources, e.g. electricity and hydrogen.
- Based on Traditional Use
  - **Conventional Energy resources**, which have been traditionally used for many decades, and were in common use around oil crisis of 1973, are called conventional energy resources, e.g. fossil fuels, nuclear and hydro resources.
  - **Non-conventional Energy resources**, which are considered for large-scale use after the oil crisis of 1973, are called non-conventional energy sources, e.g., solar, wind, biomass, etc.
- Based on long-term availability
  - **Non-renewable Resources**, which are finite and do not get replenished after their consumption, are called non-renewable, e.g. fossil fuels, uranium etc.
  - **Renewable Resources**, which are renewed by nature again and again and their supply is not affected by the rate of their consumption are called renewable e.g. solar, wind, biomass, ocean (thermal, tidal and wave), geothermal, hydro, etc.
- Based on commercial application
  - **Commercial energy resource** The secondary usable energy forms such as electricity, petrol, diesel, gas, etc. are essential for commercial activities and are categorized as commercial energy resource. The economy of a country depends on its ability to convert natural raw energy into commercial energy.
  - **Non-commercial energy** The energy derived from nature and used directly without passing through commercial outlet is called non-commercial resource, e.g. wood, animal dung cake, crop residue, etc.
- Based on origin
  The different types of energy based on their origin are as follows:
  - Fossil fuels energy
  - Nuclear energy
  - Hydro energy

  - Solar energy
  - Wind energy
  - Biomass energy
  - Geothermal energy
  - Tidal energy
  - Ocean thermal energy
  - Ocean wave energy

Conventional Energy Sources Advantages and disadvantages are as follows

- Advantages
  - low initial cost.
  - Security By storing certain quantity, the energy availability can be ensured for a certain period.
  - It is very convenient to use.
- Disadvantages
  - Fossil fuels generate pollutants CO, CO_2, NO_x, SO_x, particulate matter and heat.
  - The pollutants degrade the environment, pose health hazards and cause various other problems.
  - Coal is also a valuable petrochemical and used as source of raw material for chemical, pharmaceuticals and paints, etc. industries.
  - Nuclear power plants produces dangerous levels of radioactivity. It harms environment and health.
  - Hydro electric power plants causes deforestation, ecological disturbances, causes dislocation of people.

Non-conventional Energy Sources Advantages and disadvantages are as follows

- Advantages
  - Non-conventional sources are available in nature, free of cost.
  - They cause no or very little pollution. Thus, by and large, they are environment friendly.
  - They are inexhaustible.
  - They have low gestation period.
- Disadvantages
  - Though available freely in nature, the cost of harnessing energy from non-conventional sources is high, as in general, these are available in dilute forms of energy.
  - Uncertainty of availability: the energy flow depends on various natural phenomena beyond human control.
  - Difficulty in transporting this form of energy.

3. (a) Briefly explain the Renewable energy scenario in India?
   - India is one of the countries with the largest production of energy from renewable sources.
   - In the electricity sector, renewable energy account for 34.6% of the total installed power capacity.
   - Large hydro installed capacity was 45.399 GW as of 30 June 2019, contributing to 13% of the total power capacity.
   - The remaining renewable energy sources accounted for 22% of the total installed power capacity (80467 GW) as of 30 June 2019.
   - Wind power capacity was 36,625 MW as of 31 March 2019, making India the fourth-largest wind power producer in the world.

- The country has a strong manufacturing base in wind power with 20 manufactures of 53 different wind turbine models of international quality up to 3 MW in size with exports to Europe, the United States and other countries.
- Wind or Solar PV paired with four-hour battery storage systems is already cost competitive, without subsidy, as a source of dispatchable generation compared with new coal and new gas plants in India.
- The government target of installing 20 GW of solar power by 2022 was achieved four years ahead of schedule in January 2018, through both solar parks as well as roof-top solar panels.
- India has set a new target of achieving 100 GW of solar power by 2022.
- Four of the top seven largest solar parks worldwide are in India including the second largest solar park in the world at Kurnool, Andhra Pradesh, with a capacity of 1000 MW.
- The world's largest solar power plant, Bhadla Solar Park is being constructed in Rajasthan with a capacity of 2255 MW and is expected to be completed by the end of 2018.
- Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). India was the first country in the world to set up a ministry of non-conventional energy resources, in the early 1980s.
- Solar Energy Corporation of India is responsible for the development of solar energy industry in India.
- Hydroelectricity is administered separately by the Ministry of Power and not included in MNRE targets.
- In the 2027 forecasts, India aims to have a renewable energy installed capacity of 275 GW,
- In addition to 72 GW of hydro-energy, 15 GW of nuclear energy and nearly 100 GW from "other zero emission" sources

(b) Explain the following phenomenon effect on the solar energy reaching to earth surface

(a) **Scattering**

- When energy waves (such as light, sound, and various electromagnetic waves) are caused to depart from a straight path due to imperfections in the medium, it is called scattering.
- Scattering is the redirection of electromagnetic energy by suspended particles in the atmosphere. The type and amount of scattering that occurs depends on the size of the particles and the wavelength of the energy. (b) **Reflection**
  - Reflection is the change in direction of a wave-front at an interface between two different media so that the wave-front returns into the medium from which it originated.
  - Reflection is the process by which a surface of discontinuity turns back a portion of the incident radiation into the medium through which the radiation approached

(c) **Absorption**

- Absorption is the process by which incident radiant energy is retained by a substance.
- A portion of the incoming solar radiation is absorbed by gases in the Earth's atmosphere.
- These gases absorb electromagnetic energy at certain wavelengths, therefore in certain portions of the electromagnetic spectrum very little energy is absorbed while in other portions like the Ultraviolet, nearly all incoming energy is absorbed.

(d) **Direct solar radiation**

- The amount of solar radiation that has not been absorbed or scattered and reaches the ground directly from the sun.

(e) **Solar Constant**

- The solar radiation received on a unit area exposed perpendicularly to the rays of the sun at an average distance between the sun and the earth.
- The solar constant varies between 1353 - 1395 W/m^2.

4. (a) Define Tilt angle

- The earth's axial tilt is the angle between the earth's axis and a line perpendicular to the earth's orbit.
- The earth's axial tilt changes gradually over thousands of years, but it's current value is about $\varepsilon = 23.45^o$.

(b) Briefly explain the Declination angle and Hour angle with neat sketch

Declination Angle

- The declination angle of the sun is the angle between the rays of the sun and the plane of the earth's equator.
- If a line is drawn between the centre of the earth and the sun, then the angle between this line and earth's equatorial plane is called the declination angle(δ).
- The earth's axial tilt is the angle between the earth's axis and a line perpendicular to the earth's orbit.
- The earth's axial tilt changes gradually over thousands of years, but it's current value is about $\varepsilon = 23.45^o$.
- Because this axis tilt is nearly constant, the solar declination angle (δ) varies with the seasons, and its period is one year.
- At the solstices, the angle between the rays of the sun and the plane of the earth's equator reaches its maximum value of 23.45^o.
- Therefore, $\delta = +23.45^o$ at the northern summer solstice and $\delta = -23.45^o$ at the southern summer solstice.
- At the moment of each equinox, the centre of the sun appears to pass through the celestial equator, and the declination angle ($\delta = 0^o$).
- The plane that includes the earth's equator is called equatorial plane.
- When the northern part of the earth's rotational axis is inclined towards the sun, the earth's equatorial plane is inclined 23.45 ^{o} to the earth-sun line.
- At this time (about June 21), it is observed that the noon time sun is al its highest point in the sky and the declination angle ($\delta = +23.45^o$).
- This condition is known as the summer solstice. and it marks the beginning of summer in the Northern Hemisphere.
- As the earth continues its yearly orbit about the sun, a point is reached about 3 months later where a line from the earth to the sun lies on the equatorial plane.
- At this point, an observer on the equator would observe that the sun was directly overhead at noon time. This condition is called an equinox.
- At the time of equinox, the time during which the sun is visible (daytime) is exactly 12 h and the time when it is not visible (night time) is 12 h.
- There are two such conditions during a year the autumnal equinox on about September 23, which marks the start of the fall
- The vernal equinox on about March 22. which marks the beginning of spring.

$$\delta = 23.45 \times sin(360^o \times \frac{284 + n}{365}) \tag{1}$$

Hour Angle

- The hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains the sun.
- To describe the earth's rotation about its polar axis, the concept of the hour angle (ω) is used.
- The hour angle is zero at solar noon (when the sun reaches its highest point in the sky).

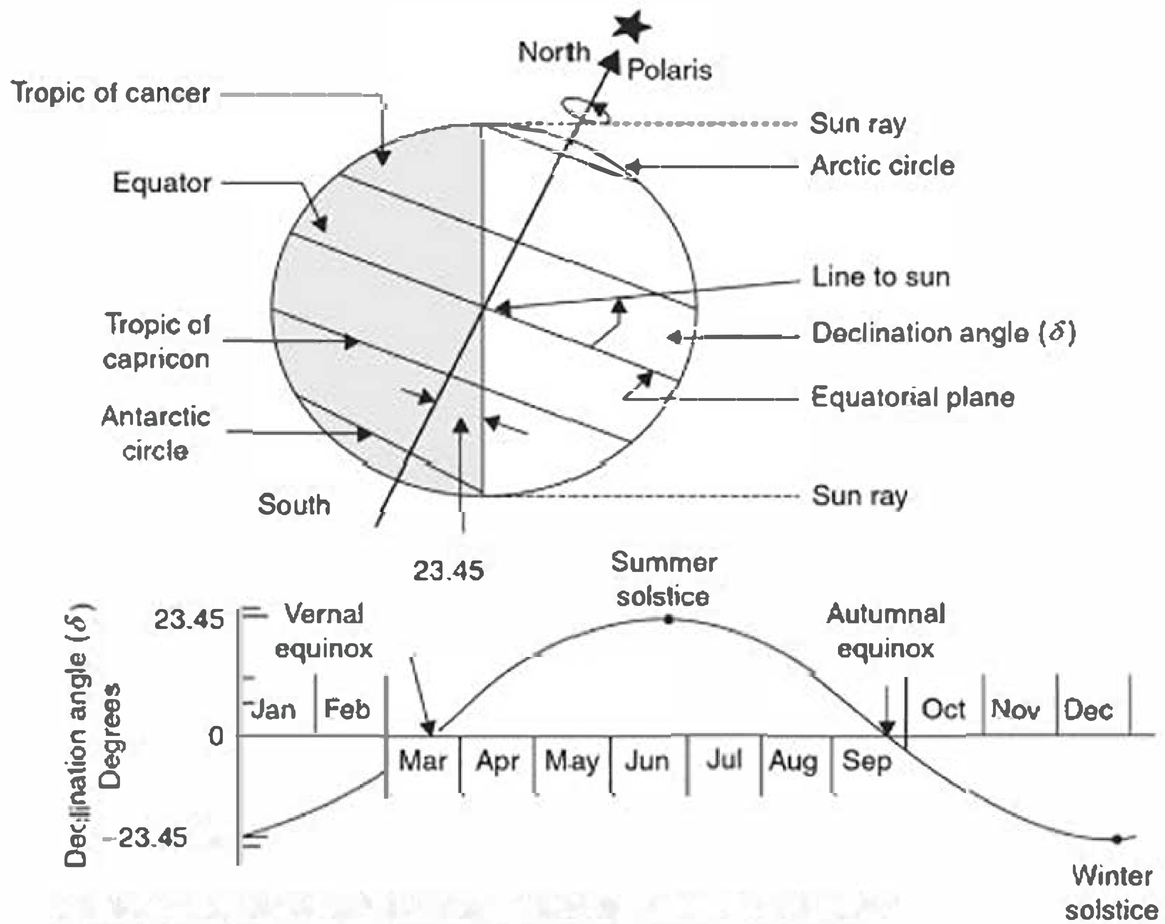

Figure 1: Declination angle

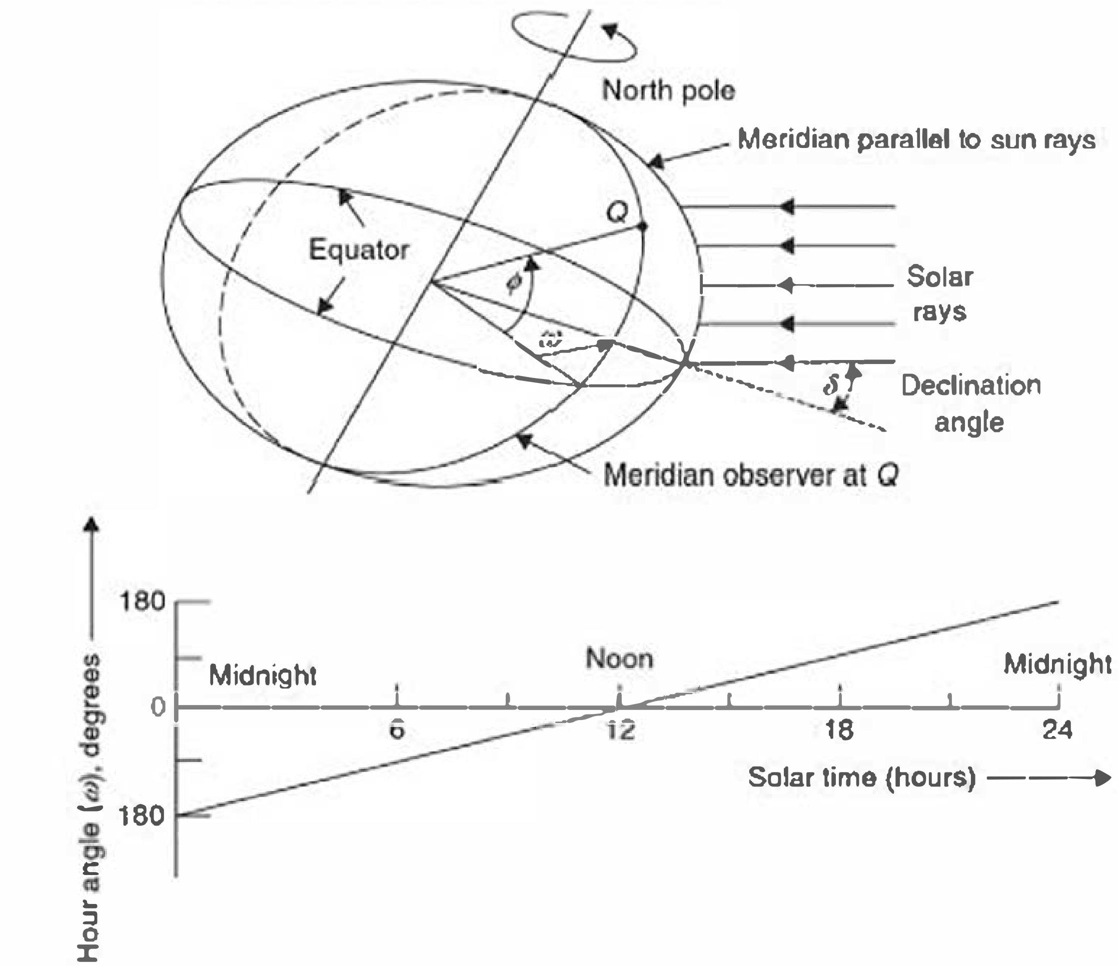

Figure 2: Hour angle

- The hour angle increases by 15^o every hour. An expression to calculate the hour angle from solar time is,

$$\omega = 15 \times (t_s - 12) \tag{2}$$

  Where t_s is the solar time in hours.

- Hour angle (ω) can be calculated simply as follows: Since the earth makes one revolution on its axis in 24 h, then 15 minutes will be equal to $\frac{15}{60} = \frac{1}{4}$ min

$$\omega = \frac{1}{4} \times t_m \tag{3}$$

- Where, t_m is the time in minutes after local solar noon. ω will be + ve if solar time is after solar noon. However, ω will be -ve if solar time is before solar noon.

(c) Calculate the Declination angle and Hour angle on September 09 2019 at 9:55 AM at New Delhi?

- Declination angle $\delta = 23.45 \times sin(\frac{360}{365}(n + 284))$
  n=252
  $\delta = 4.612^o$
  Hour angle ($\omega = \frac{1}{4} \times t_m$)
  t_m = 125 min.
  Therefore, Hour angle ($\omega = -31.25^o$)

5. (a) Explain the significance of energy consumption as a measure of prosperity.
   - Prosperity is the state of flourishing, thriving, good fortune or successful social status.
   - Prosperity often encompasses wealth but also includes happiness and health.
   - Energy is an economic good
     - Capable of improving the living standards of billions of people
     - In developing countries who lack access to service or whose consumption levels are far below those of people in industrialised countries.
     - Energy supplies will need to be expanded to meet emerging demands if living standards are to be improved and developing countries are to achieve prosperity.
   - The total amount of primary energy consumed from all sources in the year specified.
   - Primary energy includes losses from transportation, friction, heat loss and other inefficiencies.
   - Consumption = indigenous production + (imports and stock changes)-(exports and international marine bunkers)
   - Energy Consumption per capita is the total amount of energy consumed per person, in each country in the year specified.
   - This variable includes energy from all energy sources.
   - Energy Consumption per GDP indicates the amount of energy consumed per unit of income generated by the country's economy.
   - No country has been able to raise per capita incomes from low levels without increasing its use of commercial energy.

   (b) Explain the zenith angle and azimuth angle with a neat sketch.

Zenith angle

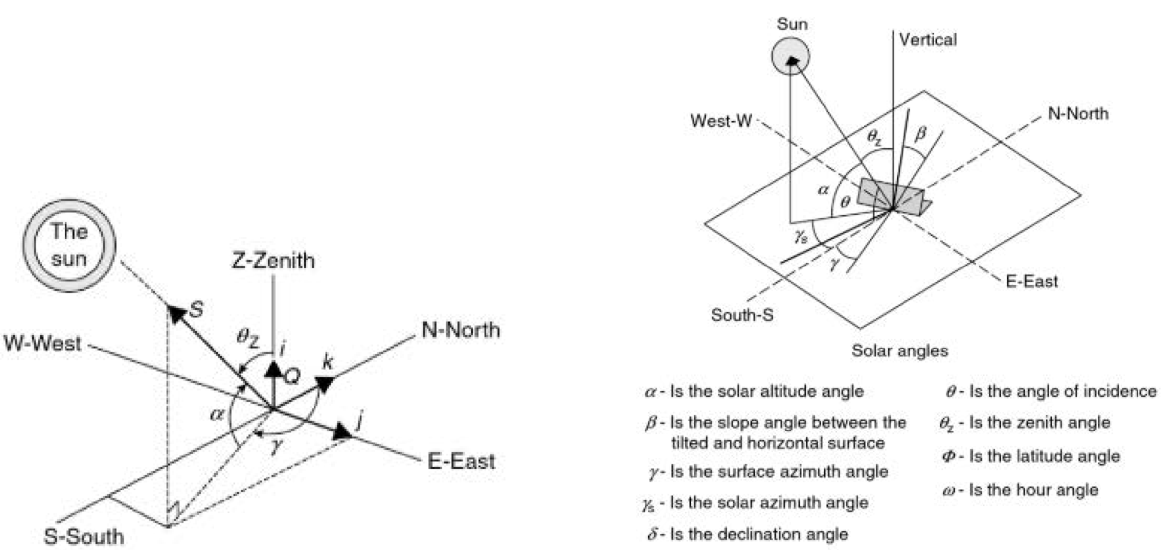

Figure 3: Solar Angles

- The zenith angle is the angle between the sun and the vertical.
- Solar Zenith angle (θ_z) : It is simply the complement of the solar altitude angle
-
- Solar Elevation (Altitude) angle (α): It is defined as the angle between the central ray from the sun and a horizontal plane containing the observer.

Azimuth Angle

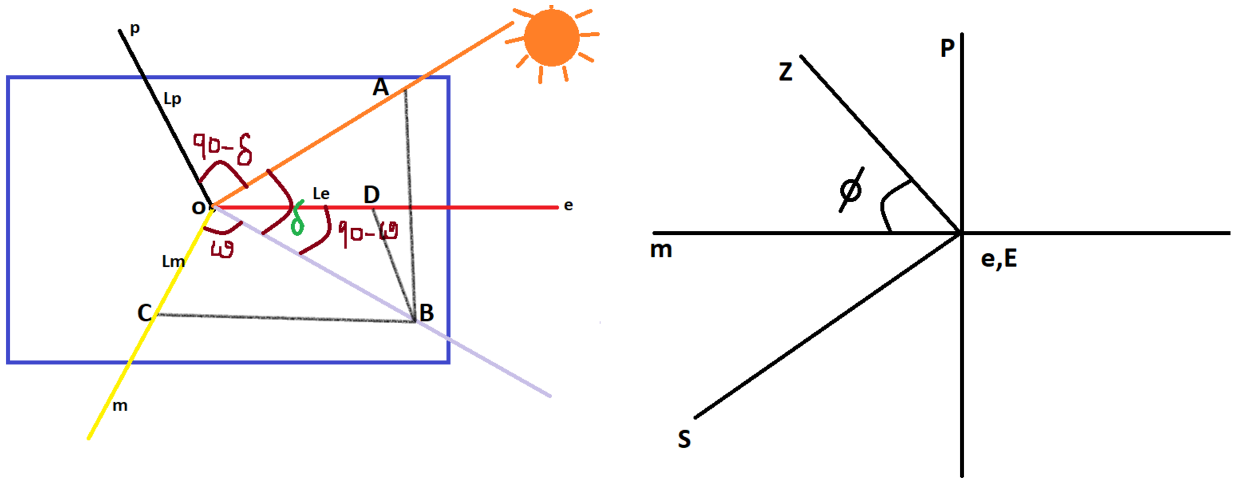

Figure 4: Earth-Sun Coordinate System

- Solar Azimuthal angle (γ_s) It is the angle made in horizontal plane between the line due south and the projection of line of site of the sun on the horizontal plane.
- Surface Azimuthal angle (γ) It is the angle made in the horizontal plan between the line due south and the projection and of the normal to the surface on the horizontal plane.

6. (a) Explain solar time with relevant formula

Solar Time

- The solar time can be obtained from the standard time observed on a clock by applying two corrections.
- The first correction arises because of the difference in longitude between a location and the meridian on which the standard time is based.
- The correction has a magnitude of 4 minutes for every degree difference in longitude.
- The second correction called the equation of time, correction is due to the fact that earth's orbit and rate of rotation are subject to small perturbations.
- LST = Standard time $\pm 4 \times [L_{STM} - Longitude\, of\, location(L_{LOL})] + EOT$

- This is the difference between the local apparent solar time and the local mean solar time.
- The actual equation of time (EQT), which is mathematically defined as apparent solar time minus mean solar time, varies slightly from year to year due to variations in the earth's eccentricity and obliquity and in the time of the solstices and equinoxes.
- However, for a century, either side of the year 2000, it may be approximated (to an accuracy of better than 1'%) by the formula:

$$EOT = 9.87 \times sin(2B) - 7.53 \times cos(B) - 1.5 \times sin(B), (minutes) \tag{4}$$

- where $B = 360\frac{n-81}{365}$

(b) Derive the formula to find zenith angle from earth and local solar centric system.

Equatorial plane

$$\begin{aligned} L &= L_m + L_e + L_p \qquad (5) \\ L_m &= Lcos(\delta)cos(\omega) \\ L_e &= Lcos(\delta)sin(\omega) \\ L_p &= Lsin(\delta) \end{aligned}$$

Horizon plane –Normal to the Zenith

$$L = L_S + L_E + L_Z \quad (6)$$
$$L_S = Lsin(\theta_z)cos(\gamma_s)$$
$$L_E = Lsin(\theta_z)sin(\gamma_s)$$
$$L_Z = Lcos(\theta_z)$$

Angle made by beam radiation with normal,

$$L_Z = L_m cos(\phi) + L_p sin(\phi) \quad (7)$$
$$cos(\theta_z) = cos(\delta)cos(\omega)cos(\phi) + sin(\delta)sin(\phi)$$

7. Calculate Declination angle, Hour angle, Zenith angle, altitude angle (Solar Elevation angle), solar time, daylight and sunrise and sunset hours of the sun at CMR Institute of Technology (12.9675^o N, 77.7141^o E) at 3:00 pm on September 10,2019.

   - n=253
   - $\delta = 4.215^o$
   - Hour angle $\omega = \frac{180}{4} = 45$
   - $\phi = 12.9675$
   - $cos(\theta_z) = cos(\delta)cos(\omega)cos(\phi) + sin(\delta)sin(\phi)$
   - $\theta_z = 45.275$
   - $\alpha = \frac{\pi}{2} - \theta_z = 44.725$
   - B= 169.6438^o
   - EOT= 3.647 min.
   - Solar Time = 2:44:51 PM
   - The daylight = sunrise time + sunset time = 2 $T_H = 2 \times \frac{1}{15}\cos^{-1}(-tan(\phi) \times tan(\delta)) = \frac{2}{15}90.97 = 12.13Hrs.$
   - Sunrise time $= 12:00 - T_H = 5:56AM$
   - Sunset time $= 12:00 + T_H = 6:04PM$

8. (a) Write Solar Thermal Energy Applications
   1. Heating and cooling of residential building
   2. Solar water heating
   3. Solar drying of agricultural and animal products
   4. Solar distillation on a small community scale
   5. Salt Production by evaporation of seawater or inland brines.
   6. Solar Cooker
   7. Solar Engines for water pumping
   8. Food refrigeration
   9. Bio conversion and wind energy, which are indirect source of solar energy
   10. Solar furnaces
   11. Solar electric power generation by-
       - Solar ponds
       - Stream generators heated by rotating reflectors, or by tower concept.
       - Reflectors with lenses and pipes for fluid circulation
   12. Solar photovoltaic cells

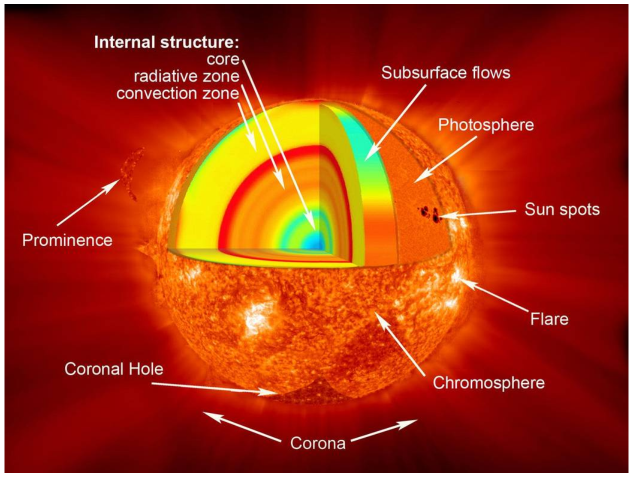

Figure 5: Layers of the sun

(b) Explain the layers of the sun with a neat sketch

- Six layers of the sun
- The Three Layers of The Sun
  - The core
  - The Radiative layer
  - The Convective layer
- The Three Atmospheric Layers
  - The Photosphere
  - The Chromosphere
  - The Corona

Core

- The core starts from the center and extends outward to encompass 25 percent of the sun's radius.
- Its temperature is greater than 15 million degrees Kelvin. At the core, gravity pulls all of the mass inward and creates an intense pressure.
- The pressure is high enough to force atoms of hydrogen to come together in nuclear fusion reactions

The Radiative Layer

- The radiative zone extends outward from the core, accounting for 45 percent of the sun's radius.
- In this zone, the energy from the core is carried outward by photons, or light units.
- As one photon is made, it travels about 1 millionth of a meter (1 micron) before being absorbed by a gas molecule.
- Upon absorption, the gas molecule is heated and diffuses another photon of the same wavelength.

The Convective Layer

- The convective zone, which is the final 30 percent of the sun's radius.
- In the convective zone, the energy is transferred much faster than it is in the radiative zone this is because it is transferred through the process of convection.
- Hotter gas coming from the radiative zone expands and rises through the convective zone.

- It can do this because the convective zone is cooler than the radiative zone and therefore less dense.

The Photosphere

- The photosphere is the innermost region of the sun's atmosphere and is the region that we can see.
- "The surface of the sun" typically refers to the photosphere.
- It is 300-400 kilo-meters wide and has an average temperature of 5,800 degrees Kelvin.
- It appears granulated or bubbly, much like the surface of a simmering pot of water.
- As we pass up through the photosphere, the temperature drops and the gases, because they are cooler, do not emit as much light energy.

The Chromosphere

- The chromosphere extends above the photosphere to about 1,200 miles (2,000 kilo-meters).
- The temperature rises across the chromosphere from 4,500 degrees Kelvin to about 10,000 degrees Kelvin.
- The chromosphere is thought to be heated by convection within the underlying photosphere.

The corona

- The corona is the final layer of the sun and extends several million miles or kilo-meters outward from the other spheres.
- It can be seen best during a solar eclipse and in X-ray images of the sun.
- Although no one is sure why the corona is so hot, it is thought to be caused by the sun's magnetism.
- The corona has bright areas (hot) and dark areas called coronal holes.
- Coronal holes are relatively cool and are thought to be areas where particles of the solar wind escape.