CMR INSTITUTE OF TECHNOLOGY	USN										

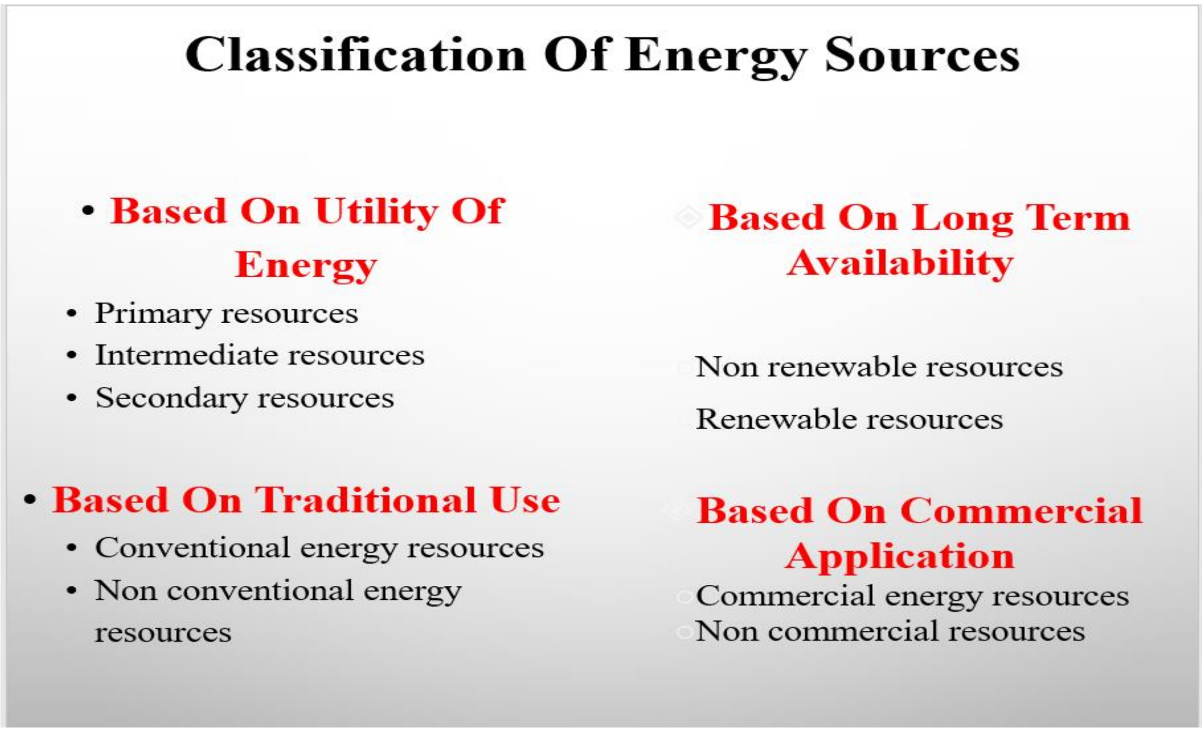
Internal Assesment Test –IV

Sub:	SOLAR AND WIND ENERGY							Code:	18EE731
Date:	07/02/22	Duration:	90 mins	Max Marks:	50	Sem:	7th	Branch:	EEE

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1	Enumerate the criteria based on which energy sources are classified. Briefly explain each classification.	[10]	CO1	L2
2	With schematic representation, explain the mechanism of absorption, scattering, beam and diffuse radiation received on the earth surface.	[10]	CO2	L2
3	For Coimbatore (11.01830 N, 76.97250 E, and Elevation of 411 m above sea level), assuming average sunshine hours per day for the month of March as 9.5h, estimate the value of average daily global radiation on horizontal surface.	[10]	CO3	L3
4	List out various types of solar cells. Explain in detail the type of solar cells based on junction structure.	[10]	CO4	L2
5	Derive an expression for the maximum power output (P_{max}) of a horizontal axis wind turbine.	[10]	CO5	L3

1.



Classification Of Energy Sources

- **Based On Origin**
- Fossil fuel energy
- Nuclear energy
- Hydro energy
- Solar energy
- Wind energy
- Biomass energy
- Geothermal energy
- Tidal energy

Utility Of Energy

- **Primary resources**
  - Natural / raw energy resources
  - Coal, crude oil, sunlight, wind, rivers, uranium etc.
  - Located, extracted, processed and transformed
  - Fairly high EYR
  - Energy yield ratio = $\frac{\text{Energy received from raw energy source}}{\text{energy spent to obtain raw energy source}}$

Utility Of Energy

- **Intermediate resources**
- Obtained from primary energy by one or more steps of transformation
- Electricity, hydrogen

- **Secondary resources**
- Energy supplied to consumer for utilization
- Usable energy
- Electrical energy, thermal energy (steam, hot water), chemical energy (hydrogen, fossil fuels)

2.

DEPLETION OF SOLAR RADIATION

- Due to present of various ***gaseous constituents, suspended dust& other minute solid and liquid particulate matter***, solar radiation is depleted during its passage through atmosphere
- **1. Absorption**
  - Selective absorption of various wavelength occur by different molecules
  - Absorbed radiation increases the energy of absorbing molecules, thus raising their temperature
  - **Nitrogen, molecular oxygen and other atmospheric gases** absorb the x-ray and extreme **ultraviolet radiation**
  - **Ozone** absorb **ultraviolet radiation**
  - **Water vapor and carbon dioxide** absorb almost completely **infrared radiation**
  - **Dust particle and air molecule** absorb part of **solar radiant energy**

- **Scattering**
  - Scattering by dust particle and air molecules involves ***redistribution of incident energy***
  - A part of scattered radiation is lost to space while remaining is ***directed downwards to the earth surface*** from different direction as diffuse radiation
  - **1. In cloudy atmosphere**
  - Major part of incoming solar radiation is reflected back into the atmosphere by clouds
  - Another part is absorbed by clods
  - Rest is transmitted downwards to the earth surface as diffuse radiation
  - **2. Energy reflected back to the space**
  - Reflection from clouds
  - Scattering by the atmospheric gases and dust particle
  - Reflection from earth surface is called earth albedo

- **Surface of earth have 2 components of solar radiation:**
- ***Direct or beam radiation***: unchanged direction
- ***Diffuse radiation***: radiation which changed its direction by scattering and reflection
- Global radiation= beam radiation+ diffuse radiation
- **Beam radiation**
  - Solar radiation propagating in straight line & received at the earth surface without change of direction ie in line with sun
- **Diffuse radiation**
  - Solar radiation scattered by aerosols, dust and molecule is known as diffuse radiation
  - It does not have unique direction
- **Global radiation**
  - Total radiation

- Even on clear days there will some diffuse radiation depending upon the amount of dust particle, ozone and water vapor present in the atmosphere
- On overcast days(when sun is not visible) all the radiation reaching the ground will be diffuse radiation
- ***Intensity of diffuse radiation*** from various direction in the sky is ***not uniform*** : **Anisotropic**
- In many situation the ***intensity*** from all direction tends to be reasonably ***uniform***: **Isotropic**
- Radiation available on earth surface< received outside the earth atmosphere

3.

$\phi = 11.0183^\circ$; $\bar{t}_d = 9.5h$

For the month of March,

Daily extraterrestrial radiation H_o = Average radiation for the whole month $\bar{H}_o$

on March 16

$$\therefore \; n = \overset{J}{31} + \overset{F}{28} + \overset{M}{16} = 75 \text{ days}$$

$$\delta = 23.45^\circ \sin\left(\frac{360^\circ}{365}(284+n)\right) = -2.4177^\circ$$

Also day length on March 16 is

$$t_d = \bar{t}_{dmax} = \frac{2}{15}\cos^{-1}(-\tan\phi\tan\delta)$$

$$= 11.937h$$

Solar Constant $I_{sc} = 1367\ W/m^2 = 1.367\ kW/m^2$

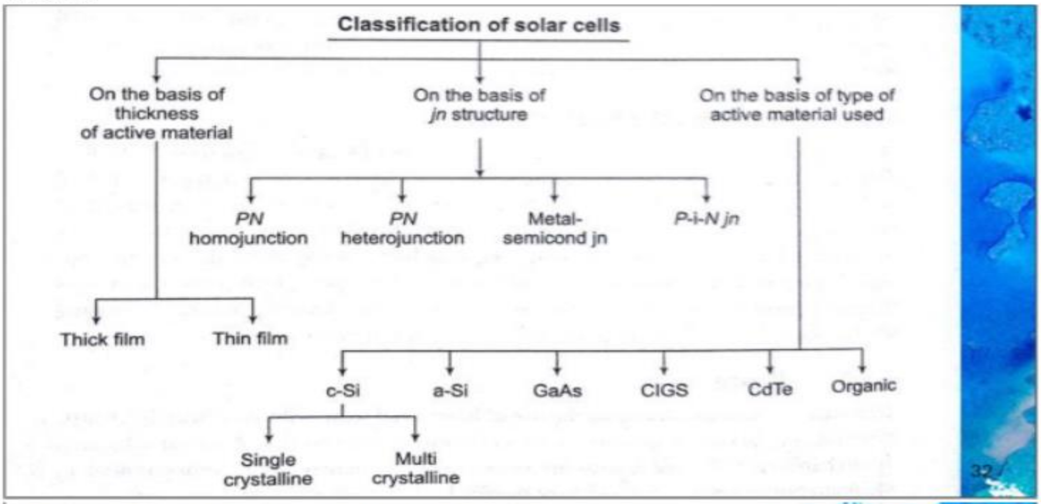
$$\bar{H}_o = H_o = 3600 \times \frac{24}{\pi} \times I_{sc} \times \left[1 + 0.033\cos\left(\frac{360^\circ \times n}{365}\right)\right]\left[\cos\phi \cos\delta \sin\omega_s + \frac{\pi\omega_s}{180^\circ}\sin\phi\sin\delta\right]$$

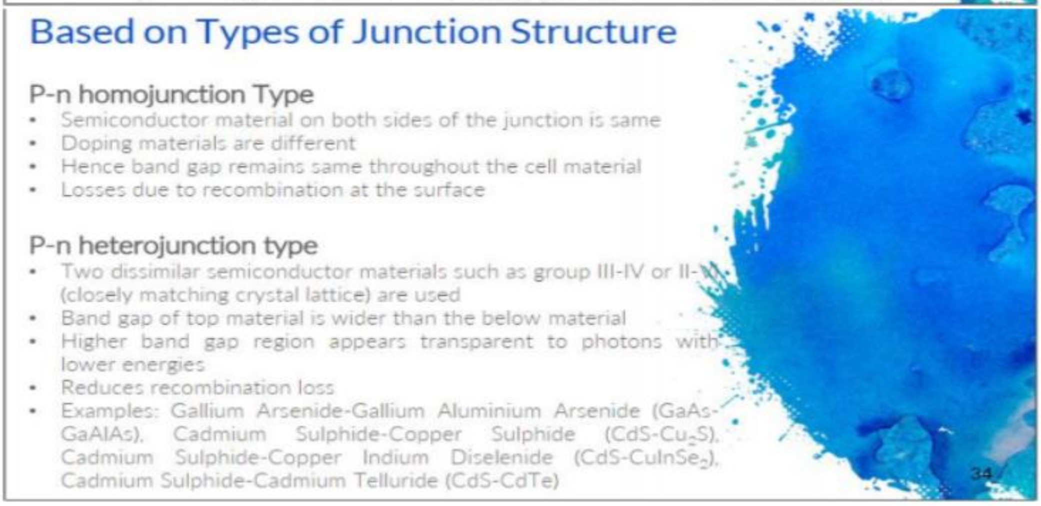
$$\omega_s = \cos^{-1}(-\tan\phi\tan\delta) = 89.528^\circ$$

$$\therefore \; \bar{H}_o = H_o = 36726.05\ kJ/m^2$$ (Note: I_{sc} is taken in kW/m^2)

4.

structure.


Classification of solar cells
On the basis of thickness of active material
On the basis of jn structure
On the basis of type of active material used
PN homojunction
PN heterojunction
Metal-semicond jn
P-i-N jn
Thick film
Thin film
c-Si
a-Si
GaAs
CIGS
CdTe
Organic
Single crystalline
Multi crystalline
32


Based on Types of Junction Structure
P-n homojunction Type
• Semiconductor material on both sides of the junction is same
• Doping materials are different
• Hence band gap remains same throughout the cell material
• Losses due to recombination at the surface
P-n heterojunction type
• Two dissimilar semiconductor materials such as group III-IV or II-VI (closely matching crystal lattice) are used
• Band gap of top material is wider than the below material
• Higher band gap region appears transparent to photons with lower energies
• Reduces recombination loss
• Examples: Gallium Arsenide-Gallium Aluminium Arsenide (GaAs-GaAlAs), Cadmium Sulphide-Copper Sulphide (CdS-Cu2S), Cadmium Sulphide-Copper Indium Diselenide (CdS-CuInSe2), Cadmium Sulphide-Cadmium Telluride (CdS-CdTe)
34

5.

MAXIMUM POWER (P_{MAX})

- HAWT is considered
- Betz model of expanding air stream tube is shown
- Air mass flow rate is the mass of substance which passes per unit time

$$\dot{m} = \frac{dm}{dt}$$

- The air mass flow rate remains same throughout the steam tube

$$\dot{m} = \rho A_1 V_1 = \rho A_2 V_2 = \rho A V$$

Where V_1 or V_i velocity at the upstream (incoming) of the turbine

V_2 or V_e velocity at the downstream (exit) of the turbine

A area of the wind turbine rotor

- Force exerted on the wind by the rotor is

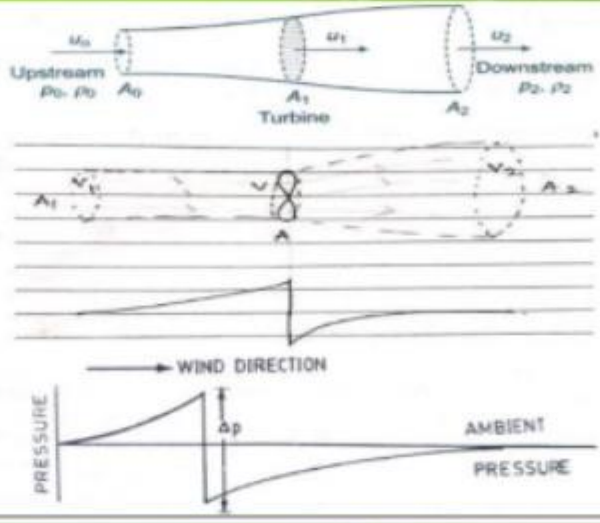
$$F = ma = m\frac{dv}{dt} = \rho AV(V_1 - V_2) \text{ ----- } (1)$$

- Work done to move the rotor to dx distance by the force of the air at uniform speed is

$$dE = F \times dx$$

- The power extracted by the turbine is

$$P = \frac{dE}{dt} = F\frac{dx}{dt} = FV \text{ ----- } (2)$$



- (1) in (2)

$$P = \rho AV^2(V_1 - V_2) \text{ ----- } (3)$$

- Power can be computed using kinetic energy as

$$P = \frac{\Delta E}{\Delta t} = \frac{1}{2}\dot{m}V_1^2 - \frac{1}{2}\dot{m}V_2^2 = \frac{1}{2}\dot{m}(V_1^2 - V_2^2) = \frac{1}{2}\rho AV\,(V_1^2 - V_2^2) \text{ ---- } (4)$$

- Equating (3) and (4)

$$\rho AV^2(V_1 - V_2) = \frac{1}{2}\rho AV\,(V_1^2 - V_2^2)$$

$$\rho AV^2(V_1 - V_2) = \frac{1}{2}\rho AV\,(V_1 + V_2)\,(V_1 - V_2)$$

$$V = \frac{V_1 + V_2}{2} \text{ ---- } (5)$$

- Hence wind velocity of the rotor is taken as the average of upstream and downstream velocities
- (5) in (4)

$$P = \frac{1}{4}\rho A\,(V_1 + V_2)\,(V_1^2 - V_2^2) \text{ ---- } (6)$$

5.

Open with

$P = \ldots (V_1^2 - V_2^2)$ ---- (6)

$$P = \frac{1}{4}\rho A\,(V_1^3 - V_1 V_2^2 + V_2 V_1^2 - V_2^3)$$

- From (6) it is observed that V_2 is +ve in one term and –ve in the other because of which too low or too high value of V_2 will result in reduced power
- Hence there is an optimum exit velocity V_2 which results in maximum power P_{max} obtained by

$$\frac{dP}{dV_2} = 0$$

$$-V_1 2V_2 + V_1^2 - 3V_2^2 = 0$$

$$3V_2^2 + 2V_1V_2 - V_1^2 = 0 \text{ ----- (7)}$$

- Solution for (7) is $V_2 = V_1$ or $V_2 = \frac{1}{3}V_1$
- Only second solution is physically acceptable giving the optimum exit velocity of

$$V_{2\,opt} = \frac{1}{3}V_1 \text{ ------ (8)}$$

SWE (18EE731) - IAT2 Q... IAT 1 SWE (18EE731) - S... IAT 1 SWE (18EE

- (8) in (6)

$$P_{max} \text{ or } P_T = \frac{1}{4}\rho A\,(V_1 + \frac{1}{3}V_1)\,(V_1^2 - \frac{1}{9}V_1^2)$$

$$= \frac{1}{4}\rho A \left(\frac{4V_1}{3}\right)\left(\frac{8V_1^2}{9}\right)$$

$$P_{max} = \frac{8}{27}\rho A V_1^3$$

$$= \frac{16}{27} \times \frac{1}{2}\rho A V_1^3$$