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Internal Assesment Test – 2

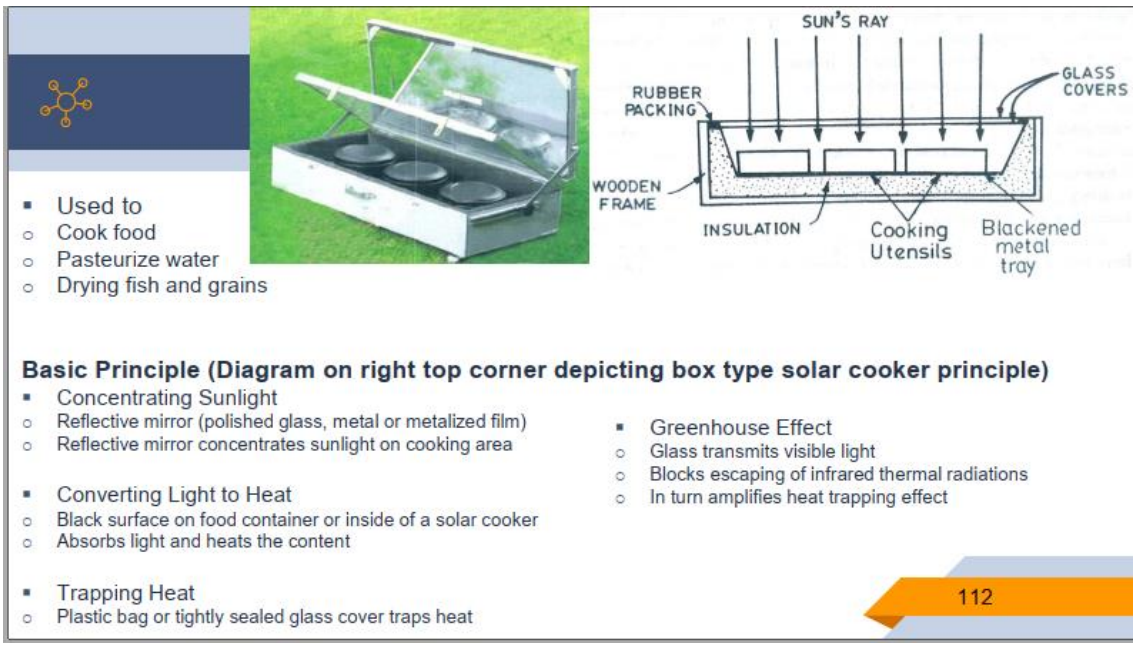
Sub: Solar and Wind Energy (Professional Elective)				Code: 18EE731
Date: 17/12/2021	Duration: 90 mins	Max Marks: 50	Sem: 7	Section: A&B [EEE]

Answer ANY FIVE full questions. Explain your notations explicitly and clearly. Sketch figures wherever necessary. Good luck!

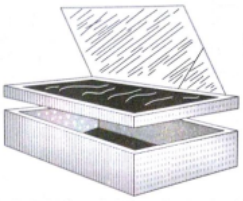
		Marks	OBE	
			CO	RBT
Q1.	With a neat sketch, Explain box type solar cooker.	[10]	CO3	L2
Q2a.	With a neat sketch, explain flat plate type evacuated tube collector.	[6]	CO3	L2
Q2b.	Calculate the number of day light hours (sunshine hours) in Srinagar on January 1 and on July 1. The latitude of Srinagar is 340 05' N.	[4]	CO2	L3
Q3.	List out various types of solar cells. Explain in detail the type of solar cells based on junction structure.	[10]	CO2	L2
Q4.	With the help of block diagrams, explain the different configurations of stand-alone solar PV systems.	[10]	CO2	L3
Q5.	What is the effect of partial and complete shadowing of a cell in a solar PV module?	[10]	CO2	L3
Q6a.	With the help of as neat sketch, explain the working of a solar water pump.	[6]	CO2	L2
Q6b.	Calculate the optimum wavelength of light for photovoltaic generation in a CdS cell. The band gap for CdS is 2.42 eV.	[4]	CO2	L2

Solution

1. With a neat sketch, explain box type of solar cooker.

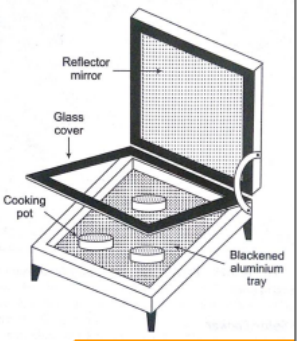


TYPES OF SOLAR COOKERS

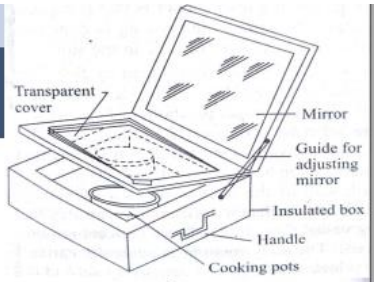


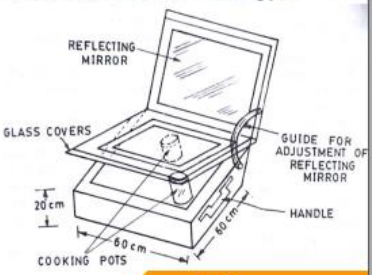
Box Type Solar Cooker

- Well insulated box
- Double glass lid
- Reflector cover on inside
- External dimension of a typical family size (4 dishes) box cooker is 60 x 60 x 20 cm
- Simple in construction and operation
- Box receives direct radiation and reflected radiation from reflector mirror fixed on inner side of box cover hinged to one side of the box
- Angle of reflector is adjusted accordingly
- With addition of reflector temperature rise of 15 to 25 °C is achieved
- Glass cover consisting of two layers of clear window glass sheets serves as box door
- Box cover traps heat due to green house effect
- With single reflector temperature in solar cooker in maintained from 70 to 110 °C
- Maximum air temperature obtained inside the box is 140 °C in winter to 160 °C in summer
- This is enough to cook boiling type food slowly in 1 to 4 hours



- Meat should be allowed to cook for 3 to 4 hours, vegetables form 1 ½ to 2 ½ hours, all types of dals can be cooked in 1 ½ to 2 hours, rice is cooked between 30 min to 2 hours Best time of day to cook is between 11 am to 2 pm
- Cooking is faster in summer than in winter
- Can cook 2 kg of food and can save 3 to 4 LPG cylinder fuel a year
- Electrical back up is provided to use during non sunshine hours
- Cost varies between Rs. 5000/- to Rs. 6290/- depending on type, size, quality, and electrical backup facility
- More affordable, folding type solar cooker made of cardboard is also developed
- In India a typical good quality cooker with a mirror varies between Rs. 1000/- to Rs. 2500/- and can be used for at least 250 days in a year with a pay back period of 3 to 4 years
- Keeps food warm in afternoon and evening
- Most widely used
- It is estimated that more than 600,000 cookers have been sold and the number is growing at a rate of about 20,000 to 30,000 every year





ADVANTAGES

- No attention during cooking
- No fuel required
- Negligible maintenance
- No pollution
- No problem of charring of food and no over flowing
- Vitamins of food are not destroyed and food cooked is nutritive and delicious with natural taste

DISADVANTAGES

- Should cook according to sunshine and menu has to be planned
- More time for cooking
- Food cannot be cooked in cloudy days or night
- Box type cookers with no reflector or with one reflector cannot be used for cooking chapatis and purees as they require high temperatures

2a. With a neat sketch, explain flat plate type evacuated tube collector.

EVACUATED TUBE COLLECTOR (ETC)

CONSTRUCTION

- Consists of parallel rows of double layer transparent glass tubes (borosilicate or lime soda) connected to header pipe
- Glass tubes (Vacuum tubes) are evacuated to provide insulation to heat loss.
- Vacuum pressure ranges between 10^{-3} torr to 10^{-4} torr
- Tube diameter 25 mm to 75 mm and length 1500 mm to 2400 mm
- Each tube has thick glass outer tube and metal (copper) inner tube (thin) attached to a fin
- Inner tube (one or two) is coated with selective coating
- ETC attains 100⁰ C to 130⁰ C
- Expensive

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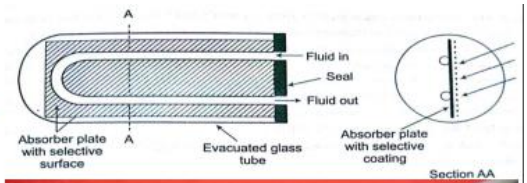
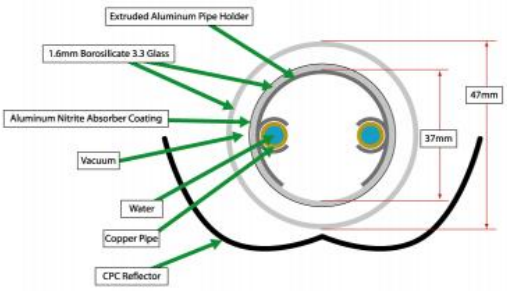
- **Working of Flat Plate Type (Direct Flow type ETC)**
- Consists of two inner tubes forming a U shape
- One acts as inlet for fluid (water) and the other acts as outlet
- Solar radiations are absorbed by the fin and the heat is transferred to the water flowing in inner tubes





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2b. Calculate the number of day light hours (sunshine hours) in Srinagar on January 1 and on July 1. The latitude of Srinagar is 34^0 05' N.

Jan 1 $\quad n = 1$

$$\delta = 23.45^\circ \sin\left[360^\circ \left(\frac{284+n}{365}\right)\right] = -23.01^\circ$$

$$\phi = 34^\circ 05' = 34.083^\circ$$

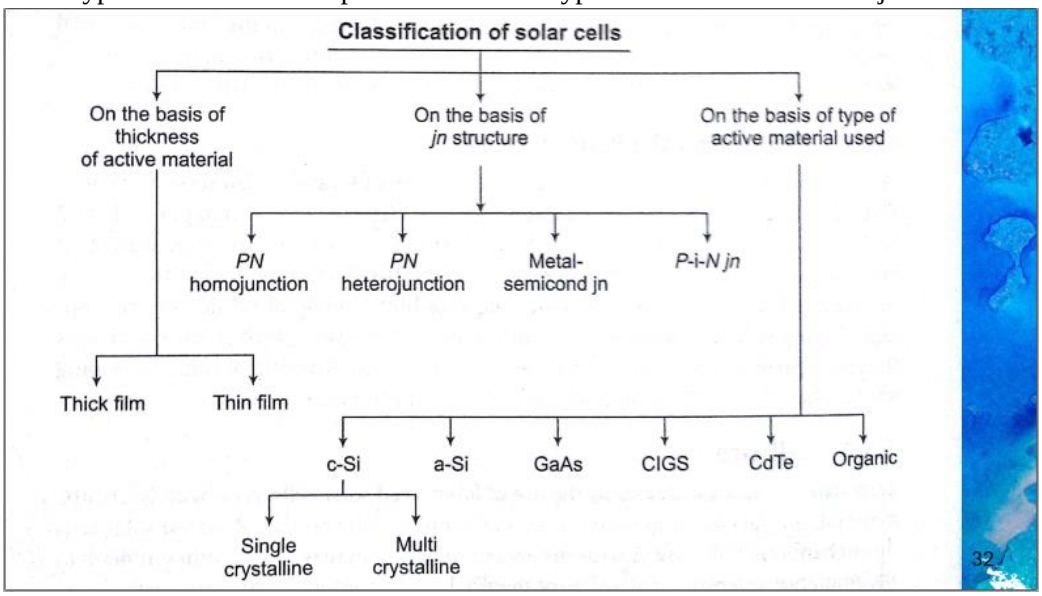
$$t_d = \frac{2}{15}\cos^{-1}\left[-\tan\phi \tan\delta\right] = 9.77\,h = 9h\ 46m\ 25s$$

July 1 $\quad n = 182$

$$\delta = 23.45^\circ \sin\left[360^\circ \left(\frac{284+n}{365}\right)\right] = 23.12^\circ$$

$$t_d = \frac{2}{15}\cos^{-1}\left(-\tan\phi \tan\delta\right) = 14.238\,h = 14h\ 14m\ 20s$$

3. List out various types of solar cells. Explain in detail the type of solar cells based on junction structure.



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-Cu_2S), Cadmium Sulphide-Copper Indium Diselenide (CdS-$CuInSe_2$), Cadmium Sulphide-Cadmium Telluride (CdS-CdTe)

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Table 6.1 Elemental semiconductors used in solar photovoltaic devices

Group of periodic table				
II	III	IV	V	VI
	B	C		
	Al	Si	P	S
Zn	Ga	Ge	As	Se
Cd	In		Sb	Te

Table 6.2 Band gap of typical elemental and complex semiconductors used in solar PV applications

Element or compound	Name	Band gap (eV) at 300 K
C	Carbon (diamond)	5.5
Ge	Germanium	0.67
Si	Silicon	1.12
GaAs	Gallium Arsenide	1.43
CdS	Cadmium sulfide	2.42
CdTe	Cadmium telluride	1.5
$CuInSe_2$	Copper Indium Di-selenide	1
$CuGaSe_2$	Copper Gallium Di-selenide	1.7

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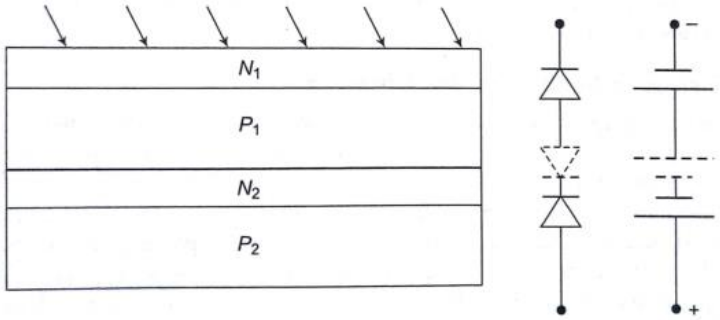
Metal semiconductor (Shottky) junction

- When metal and semiconductor are brought in contact either an ohmic contact (permitting bidirectional current) or an rectifying contact (permitting unidirectional current) is formed
- Rectifying contact if formed is termed as Schottky Junction (SJ)
- SJ has depletion layer and a built in electric field on semiconductor side of the junction
- This field sweeps minority carriers on other side of the junction
- Simple to fabricate
- But has relatively low V_{oc}

P-n multijunction cell

- Stacks junctions of different band gaps
- Top junction has wider band gap followed with junctions having band gaps in decreasing order
- All junctions are in series
- Higher energy photons are absorbed at the top junction followed by absorption of lower energy photons by subsequent junctions

- Drawback is the unwanted reverse biased pn junction(dotted line) in series opposition between two junctions
- This will lead to power dissipation



P-i-n (p-type-intrinsic-n-type) semiconductor junction

- Eliminates unwanted reverse biased junction by introducing
- P^+ N^+ tunnel junction or P-i-N-type junction
- Intrinsic silicon is interposed between p and n layers
- This technology is used in amorphous silicon solar cells

Based on Types of Active Material Used

- Single crystal silicon cell (c-Si)
- Multicrystaline silicon cell (c-Si)
- Amorphous silicon cell(a-Si)
- Gallium Arsenide cell (GaAs)
- Copper indium Deselenide cell (CIGS)
- Cadmium Telluride cell (CdTe)
- Organic PV cell

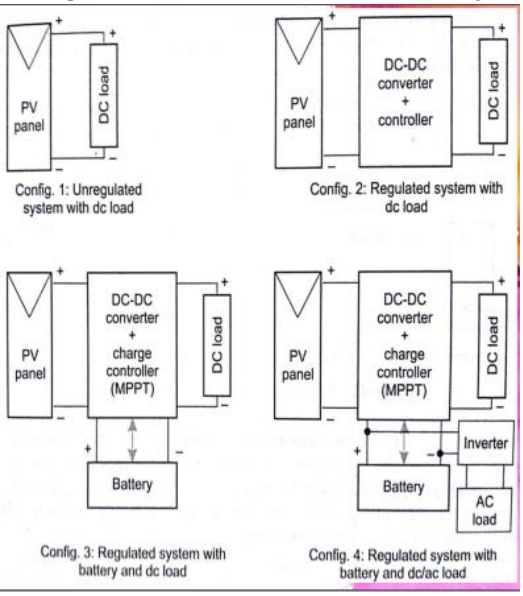
4. With the help of block diagrams, explain the different configurations of stand-alone solar PV systems.

Stand Alone or Off Grid System

- Located at load centers and meets the demand of village or community
- Useful in rural areas which does not have access to grid
- 10 W_p to 100 kW_p capacity systems are used
- Four configurations of stand-alone PV systems

Configuration 1
- simplest
- Uses dc load
- Power is available only during sunshine
- No storage facility
- Used to supply raw load like minor irrigation

Configuration 2
- Supplies regulated power to load
- Inserts dc-dc converter between panel and load
- Converter is controlled by MPPT to extract maximum power



Config. 1: Unregulated system with dc load

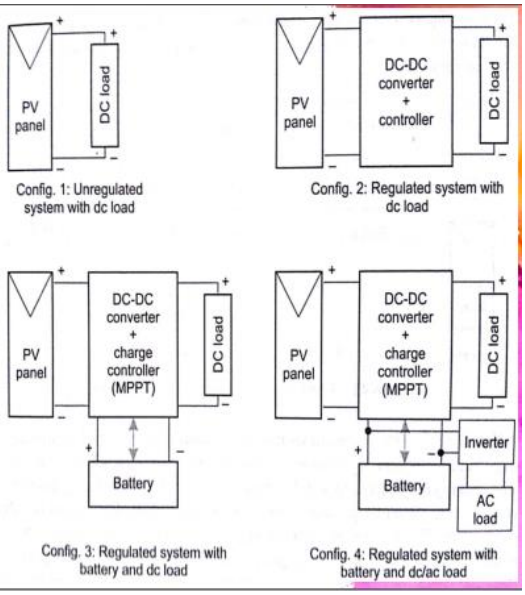
Config. 2: Regulated system with dc load

Config. 3: Regulated system with battery and dc load

Config. 4: Regulated system with battery and dc/ac load

Configuration 3
- Same as configuration 2 with battery included for storage
- For safe charging and discharging charge controller is used
- Battery ensures uninterrupted and smooth supply availability
- Used for loads such as lighting

Configuration 4
- Includes inverter for ac loads
- Used for domestic and commercial applications



Config. 1: Unregulated system with dc load

Config. 2: Regulated system with dc load

Config. 3: Regulated system with battery and dc load

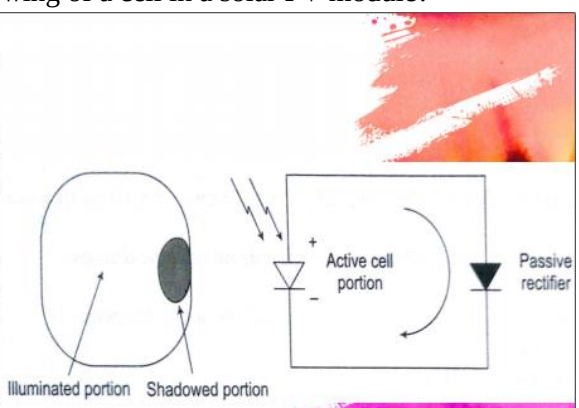
Config. 4: Regulated system with battery and dc/ac load

5. What is the effect of partial and complete shadowing of a cell in a solar PV module?

Effect of Shadowing

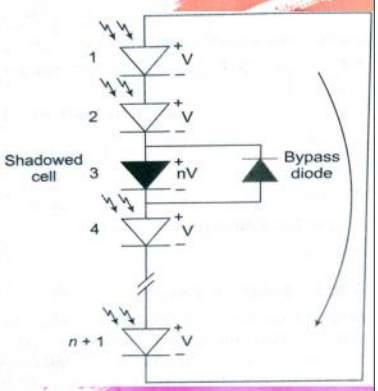
Partial shadowing of a cell in an open circuited series strings of cells

- Partial shadowed portion of the cell will not produce any power but the illuminated portion remains active producing power
- Generated voltage by illuminated (active) portion forward bias the parallel rectifier corresponding to the shadowed portion
- If shadowed area is small, large circulating current through it results in excessive heating of the shadowed portion
- This creates a hotspot and completely damages the module



Complete shadowing of one cell in a short circuited series strings of cells

- Assume n+1 series cells with one complete cell shadowed are short circuited
- Voltages produced by n illuminated cell add up and appear as reverse bias voltage of nV volt across shadowed cell
- No current flows until peak inverse voltage (PIV) of the shadowed cell is more than the reverse bias
- If PIV is less than the total reverse bias voltage, current flows through series string dissipating large power in shadowed cell damaging the module
- Problem is avoided by connecting bypass diode across shadowed cell
- Bypass diode provides alternate path for load current
- During healthy operation bypass diode has no role but would provide some loss because of finite reverse leakage current through it
- As per international practice one bypass diode is provided for every 18 crystalline silicon solar cells in a series string



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6a. With the help of as neat sketch, explain the working of a solar water pump.

Solar Water Pumps

- Pumping water from open well, bore well, stream, pond, canal or river for drinking or irrigation
- Components: PV array mounted on stand and a compatible motor-pump set
- Drives a pump by a motor run by solar electricity
- Pumps 15,000 ltr/day for 200 W_p panel on clear sunny day
- 1,70,000 ltr/day for 2,250 W_p panel on clear sunny day
- Suction height 7m or total head of 10 m
- Types of motors
  - Permanent magnet dc motor (in low capacity pumping system)
  - Bruch-less dc motors
  - Variable voltage and variable frequency ac motors with appropriate electronic control and conversion system

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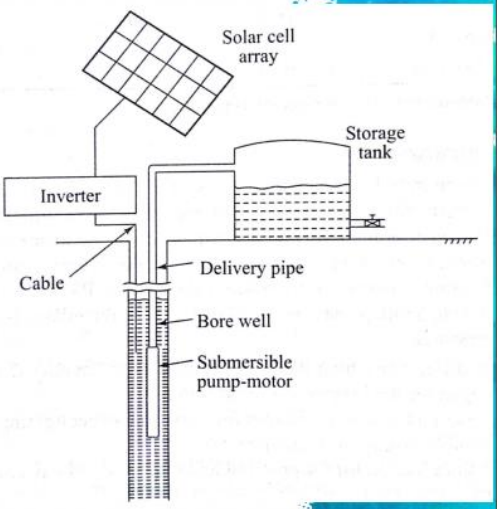
- Can pump water from depths of 20 m to 100 m
- Solar cell array supplies power from a dc-ac inverter to an electric motor coupled to submersible pump
- Pump is installed below the water level of the bore well
- Its discharge is connected through a delivery pipe to a storage tank at ground level
- Water is withdrawn from storage tank for use
- Usually solar water pumping does not require storage batteries as it is operated during day time



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6b. Calculate the optimum wavelength of light for photovoltaic generation in a CdS cell. The band gap for CdS is 2.42 eV.

$E_G = 2.42\ eV$

photon energy $E = \frac{1.24}{\lambda}$ must be greater than or equal to E_G for generation of each pair

i.e., $E = \frac{1.24}{\lambda} \geq E_G$

$\Rightarrow \lambda \leq \frac{1.24}{E_G} \leq \frac{1.24}{2.42} \leq 0.512\ \mu m.$