WINTER– 17 EXAMINATION
Model Answer

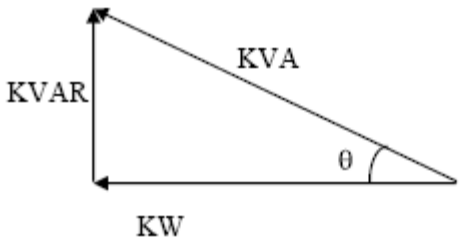
Subject Name: Energy Management **Subject Code:** 17559

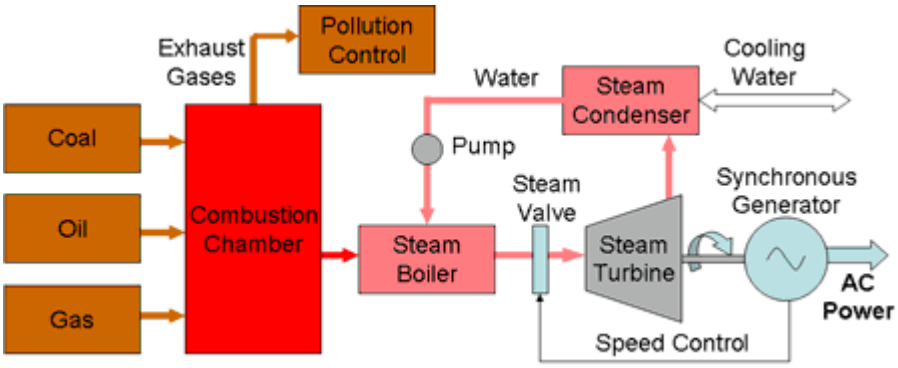
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
1	A	**Attempt any three of the following**	12
	i)	**Energy conservation** Energy Conservation is the deliberate practice or an attempt to save electricity, fuel oil or gas or any other combustible material, to be able to put to additional use for additional productivity without spending any additional resources or money. Energy is a scarce commodity; Energy in any form is a scarce commodity and an expensive resource. During the last four decades the induction of energy efficient technologies has lead to dramatic reduction in energy usage in chemical process industries. Due to compulsions from global competition to be highly cost competitive and the awareness thereof, companies are on a drive to reduce costs. Energy consumption in Chemical Process Industries (CPI) is dependent on the products manufactured and process employed. Energy cost in caustic chlorine plant is around 60% of the manufacturing cost. **Importance** a) To reduce imports of energy and reduce the drain on foreign exchange.	2

		b) To improve exports of manufactured goods (either lower process or increased availability helping sales) or of energy, or both. c) To reduce environmental pollution per unit of industrial output - as carbon dioxide, smoke, sulphurdioxide, dust, grit or as coal mine discard for example. d) Thus reducing the costs that pollution incurs either directly as damage, or as needing, special measures to combat it once pollutants are produced. e) Generally to relieve shortage and improve development.	2
	ii)	**A lux meter** is a device for measuring brightness, specifically, the intensity with which the brightness appears to the human eye. This is different than measurements of the actual light energy produced by or reflected from an object or light source. The lux is a unit of measurement of brightness, or more accurately. While accessing light requirement at various places in buildings, industries light requirement should be maintained as per standard norms. If excess lighting is done, energy will be wasted. If lux meter is used , accurate requirement can fulfilled by using enquired lighting fixtures.	4
	iii)	**Power factor** The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number between 0 and 1. Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA). $\text{Power Factor } (\text{Cos}\Phi) = \frac{Active\ Power\ (kW)}{Apparent\ Power\ (kVA)}$ $= \frac{kW}{\sqrt{(kW)^2 + (kVAr)^2}}$	2 2

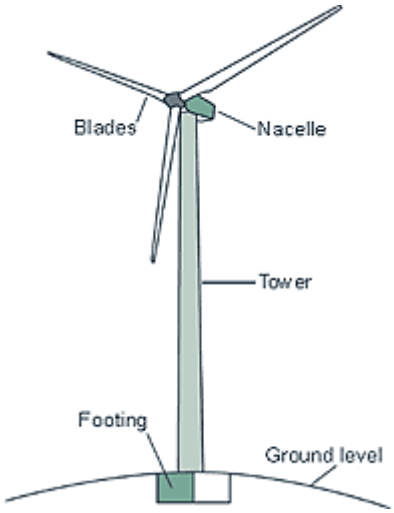
		The Power Triangle  $P.F. = \frac{KW}{KVA} = \cos\theta$	
	iv)	**Energy saving opportunities in boiler:** • Reducing excess air • Installing economizer • Reducing scale and deposits • Reducing blow down • Recovering waste heat from blow down • Stopping dynamic operation • Reducing boiler pressure • Operating at peak efficiency • Preheating combustion air • Switching from steam to air atomization • Switching to lower cost fuel	1 mark each for any four
	B	**Attempt any one of the following**	**6**
	i)	**Electricity generation form thermal power plant** The function of the coal fired thermal power plant is to convert the energy available in the coal to electricity. The working of a coal power plant is explained in brief: Firstly, water is taken into the boiler from a water source. The boiler is heated with the help of coal. The increase in temperature helps in the transformation of water into steam. The steam generated	3

		in the boiler is sent through a steam turbine. The turbine has blades that rotate when high velocity steam flows across them. This rotation of turbine blades is used to generate electricity. A generator is connected to the steam turbine. When the turbine turns, electricity is generated and given as output by the generator, which is then supplied to the consumers through high-voltage power lines.  	3
	ii)	**Three T`s of combustion**  Combustion efficiency can be explained in terms of 3 T`s Time, temperature and turbulence. Simply stated, thermal oxidation is the effective employment of the process which provide through mixing of an organic substance with sufficient oxygen at a high enough temp. for a sufficient time to cause the organic to oxidize to the desire degree of completion . To achieve successful thermal oxidation , the thermal oxidizer must include : a) Turbulence – through mixing b) Temperature- oxidizing temperature (1200 – 1650 F) c) Time- combustion chamber residence time(0.5 – 2 secs.) The level of turbulence , the reaction temperature and the amount of time is depends on the fuel characteristics.	6

2		Attempt any four of the following	16
	a	**Structure of energy audit report** 1. Executive Summary 2. Audit objectives, scope and methodology 3. Plant Overview 4. Production Process Description 5. Energy and Utility System Description 6. Detailed Process Flow Diagram and Energy & Material Balance 7. Energy Use Analysis in Utility and Process Systems (any of the following that are applicable) 8. Energy Use and Energy Cost Analysis in the Plant 9. Energy-Efficiency Options and Recommendations 10. Conclusion and a brief action plan for the implementation of energy-efficiency options Acknowledgements Appendixes List of energy audit worksheets List of vendors for energy-efficient technologies and other technical details	4
	b	**Salient features of Energy conservation act 2001** The Act empowers the Central Government and, in some instances, State Governments to: • specify energy consumption standards for notified equipment and appliances; direct mandatory display of label on notified equipment and appliances; • prohibit manufacture, sale, purchase and import of notified equipment and appliances	1 mark each for any four features

		not conforming to energy consumption standards; • notify energy intensive industries, other establishments, and commercial buildings as designated consumers; • establish and prescribe energy consumption norms and standards for designated consumers; • prescribe energy conservation building codes for efficient use of energy and its conservation in new commercial buildings having a connected load of 500 kW or a contract demand of 600 kVA and above; **direct designated consumers to -** • designate or appoint certified energy manager in charge of activities for efficient use of energy and its conservation; • get an energy audit conducted by an accredited energy auditor in the specified manner and interval of time; • furnish information with regard to energy consumed and action taken on the recommendation of the accredited energy auditor to the designed agency; • comply with energy consumption norms and standards; • prepare and implement schemes for efficient use of energy and its conservation if the prescribed energy consumption norms and standards are not fulfilled; • get energy audit of the building conducted by an accredited energy auditor in this specified manner and intervals of time.	
	c	**The need of energy audit in industry:** In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel	4

		are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists. The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a "bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.	
	d	**Components of wind mill** **1) Rotor:** Blades are attached to rotor and it connected by shaft to generator. **2) Blades:** Wind lift and drag force will act on blades which are connected to rotor. **3) Shaft:** It is used to transmit mechanical power produced by blades to generator. **4) Generator:** It is device used to produce electricity using mechanical energy. **5) Tower:** It is assembly on which wind turbine is placed at certain height. **Working** • Tower produces turbulence behind it, the turbine is usually pointed upwind of the tower.	2

		• The wind passes over both surfaces of the airfoil shaped blade but passes more rapidly over the longer (upper) side of the airfoil, thus creating a lower-pressure area above the airfoil. • The pressure differential between top and bottom surfaces results in aerodynamic lift. • The lift force causes rotation about the hub. • In addition to the lift force, a drag force perpendicular to the lift force impedes rotor rotation. • When blades are rotating they give this mechanical energy to the generator shaft through gear box, which produces electricity.  	2
	e	**Types of Heat exchanger by construction** • Shell and tube • Double pipe • Finned tube	2

		• Plate type **Type of heat exchangers by flow** • Co current • Counter current • Cross flow	2
3		**Attempt any four of the following**	**16**
	a	**Construction and working of cooling tower** The principle of operation of cooling towers is very similar to that of the evaporative type of condensers, in which the warm water gets cooled by means of evaporation. Water evaporates as a result of the hot water droplet coming in contact with the air (which is being pumped out by means of a fan). This evaporating water also absorbs the latent heat from the water surrounding it. By losing latent heat, the water is cooled. According to the method adopted to circulate the air, cooling towers may be classified as: 1. Natural draft cooling towers 2. Mechanical draft cooling towers. **Natural Draft Cooling Tower** As the name indicates, the air is circulated inside the cooling tower by natural convection. The natural draft cooling towers are further classified as: 1. Natural draft cooling towers spray type, and 2. Natural draft cooling towers splash deck type. ***Spray Type*** The entire system is housed inside a box-shaped structure which also accommodates spray headers, spray nozzles, and louvers. The louvers (usually made of steel) are placed on the sides to enhance natural circulation of air inside the cooling tower. To prevent the carryover of water droplets to the atmosphere, the louvers are slanted towards the inside. Warm water from the condenser is fed to the spray header by means of a pump. The spray header is	4

located on top as shown in the sketch. The spray nozzles spray the warm water inside the tower. Air from the atmosphere comes in contact with the warm water, thereby causing some water droplets to evaporate. The evaporating water also absorbs some amount of latent heat from the surrounding water, which causes the remaining water to cool. The passing air also absorbs some amount of sensible heat from the warm water. A make-up line, which may be controlled by a simple float, may be used to make up the loss of water due to evaporation. The size of the spray plays a vital role. If the spray is too fine, a greater amount of water will be taken away by the air. On the other hand, if the size of the spray is too large, the area of contact of water with the air will be reduced.

Splash Deck Type

This type of cooling tower is very similar to that of the spray type. Instead of a spray header, a water box is used. The water box has small holes at the bottom. It also contains decking inside the tower. The hot water from the condenser enters into the water box and splashes via holes in the water box on the decking. The main objective of the decking is to increase the surface area of contact of air with the warm water. This type of cooling tower is 20-30% more effective than the spray type.

Mechanical Draft Cooling Towers

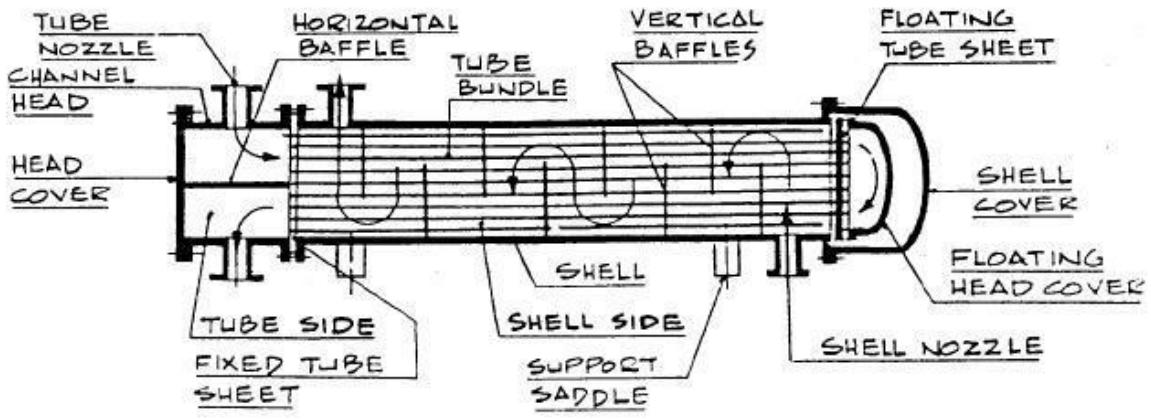
The mechanical draft cooling towers are very much similar to that of the natural draft cooling towers. As the name indicates, air is circulated inside the tower mechanically instead of natural circulation. Propeller fans or centrifugal fans may be used.

Forced Draft Cooling Towers

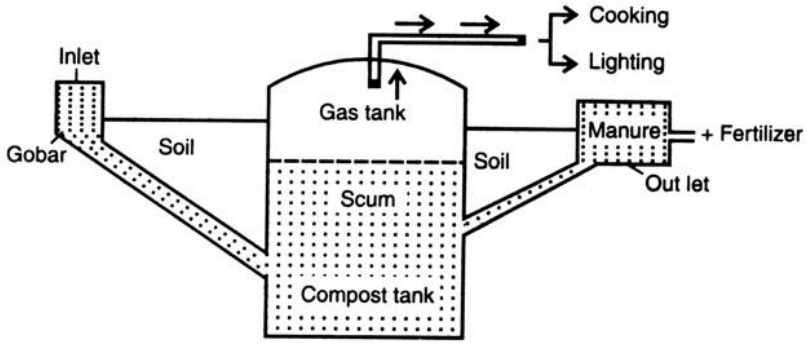
In this system, fan is located near the bottom and on the side. This fan forces the air from bottom to top. An eliminator is used to prevent loss of water droplets along with the forced air.

Induced Draft Cooling Towers

In this system, a centrally located fan at the top, takes suction from the tower and discharges it to the atmosphere. The only between the induced draft cooling tower and forced draft cooling tower is that the fan is located at the top in the induced draft cooling tower.

	b	**Boiler efficiency calculation by Direct method** This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula: Boiler Efficiency (η) = (Heat output/Heat input)x 100 Boiler Efficiency (η) =$[Qx(h_g-h_f)/q \text{ X GCV}] \text{ x } 100$ Parameters to be monitored for the calculation of boiler efficiency by direct method are: 1. Quantity of steam generated per hour (Q) in kg/hr. 2. Quantity of fuel used per hour (q) in kg/hr. 5. Calorific value of the fuel (GCV) in kcal/kg of fuel 6. h_g – Enthalpy of saturated steam in kcal/kg of steam 7. h_f – Enthalpy of feed water in kcal/kg of water	4
	c	**Shell and tube heat exchanger**  	4

	d	**Performance assessment of pump:** 1) flow measurement by any one method (Ultrasonic flow meter can be used) 2) Determination of total head :(Use pressure gauge) Suction head (h_s) Discharge head (h_d) 3) Determination of hydraulic power (liquid H.P.) Ph = Q x (hd – hs) x density of the fluid 4) measurement of motor input power (Power analyzer) 5) pump shaft power Ps = Pm x efficiency of motor 6) pump efficiency Pump efficiency = H.P / pump shaft power	4
	e	**Biogas** **Working** • The feed material is mixed with water in the influent collecting tank The fermentation slurry flows through the inlet into the digester. • The bacteria from the fermentation slurry are intended to produce biogas in the digester. • The process of anaerobic digestion occurs in a sequence of stages involving distinct types of bacteria. • Hydrolytic and fermentative bacteria first break down the carbohydrates, proteins and fats present in biomass feedstock into fatty acids, alcohol, carbon dioxide,	**2**

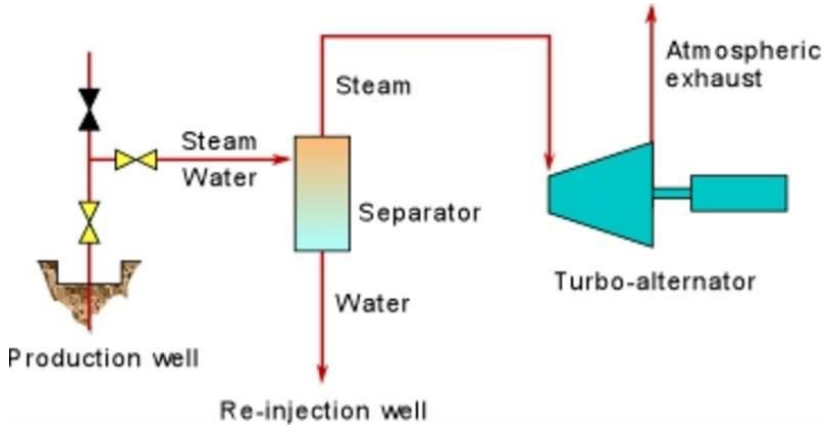
		hydrogen, ammonia and sulfides. • This stage is called "hydrolysis" (or "liquefaction"). • Next, acetogenic (acid-forming) bacteria further digest the products of hydrolysis into acetic acid, hydrogen and carbon dioxide. • Methanogenic (methane-forming) bacteria then convert these products into biogas. • The combustion of digester gas can supply useful energy in the form of hot air, hot water or steam.  	2
4	A	**Attempt any three of the following**	12
	i)	**Energy Scenario in India** • Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. • Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environmentally friendly. • India ranks sixth in the world in total energy consumption and needs to accelerate the development of the sector to meet its growth aspirations. • The country, though rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and bio-energy has very small hydrocarbon reserves (0.4% of the world's reserve). • India, like many other developing countries, is a net importer of energy, more than 25 percent of primary energy needs being met through imports mainly in the form of	4

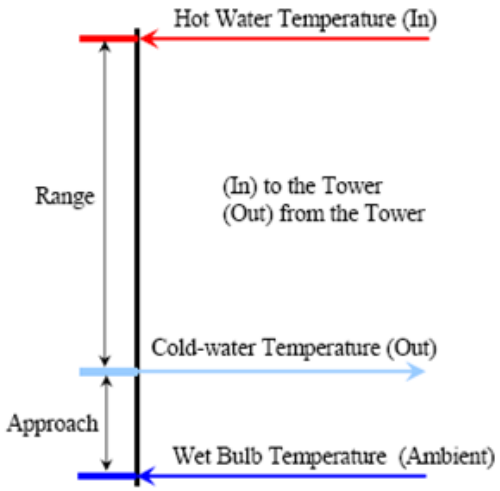
		crude oil and natural gas. • The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources and is also largely responsible for energy supply shortages. The sub-optimal consumption of commercial energy adversely affects the productive sectors, which in turn hampers economic growth. • If we look at the pattern of energy production, coal and oil account for 54 percent and 34 percent respectively with natural gas, hydro and nuclear contributing to the balance. In the power generation front, nearly 62 percent of power generation is from coal fired thermal power plants and 70 percent of the coal produced every year in India has been used for thermal generation.	
	ii)	**Energy Benchmarking Parameters** **Gross production related:** kWh/MT clinker or cement produced (cement plant) kWh/kg yarn produced (textile unit) kWh/MT , kcal/kg, paper produced (paper plant) kcal/kWh power produced (heat rate of power plant) million cal/MT urea or ammonia (fertilizer plant) kWh/MT of liquid metal output (in a foundry) **Utility related :** kW/ ton of refrigeration (on air conditioning plant) % thermal efficiency of a boiler plant % cooling tower effectiveness in a cooling tower kWh/Nm^3 of compressed air generated	1/2 mark each for any 8 parameters

		kWh/liter in a diesel power generation plant	
	iii)	**Advantages of direct method:** • Plant people can evaluate quickly the efficiency of boilers • Requires few parameters for computation • Needs few instruments for monitoring **Disadvantages of direct method:** • Does not give clues to the operator as to why efficiency of system is lower • Does not calculate various losses accountable for various efficiency levels	2 2
	iv)	**Effect of speed variation:** A centrifugal pump is a dynamic device with the head generated from a rotating impeller. There is therefore a relationship between impeller peripheral velocity and generated head. Peripheral velocity is directly related to shaft rotational speed, for a fixed impeller diameter and so varying the rotational speed has a direct effect on the performance of the pump. All the parameters will be change if the speed is varied and it is important to have an appreciation of how these parameters vary in order to safely control a pump at different speeds. The equation relating rotodynamic pump performance parameters of flow , head and power absorbed , to speed are k/as the affinity laws: $Q \propto N$ $H \propto N^2$ $P \propto N^3$ Q = FLOW RATE H = HEAD P = POWER ABSORBED N = ROTATING SPEED	2

		As can be seen from the above laws, doubling the speed of the centrifugal pump will increase the power consumption by 8 times. Conversely a small reduction in speed will result in drastic reduction in power consumption. This form the basis for energy conservation in centrifugal pumps with varying flow requirements. The most commonly used method to reduce the pump speed is variable speed drive(VSD) VSD allow pump speed adjustments overa continuous range , avoiding the need to jump from speed to speed as multiple-speed pumps. VSD control pump speed. **Impeller trimming:** Changing the impeller diameter gives the proportional change in the impeller`s peripheral velocity.simillar to the affinity laws, the following equation is apply to the impeller diameter D: $Q \propto D$ $H \propto D^2$ $P \propto D^3$ Changing the impeller diameter is an energy efficient way to control the pump flow rate This option cannot be used where varying flow pattern exist. The impeller should not be trimmed more than 25 % of the original impeller size. Changing the impeller itself is a better option than trimming the impeller.	2
	B	**Attempt anyone of the following**	**6**
	i)a	**Energy generated from tide and wave** *Tidal* The technology required to convert tidal energy into electricity is comparable to technology	3

		used in traditional hydroelectric power plant. The first requirement is a dam across the tidal bay. Best sites are those where a bay has narrow openings, thus reducing the length of dam required. Gates and turbines are installed. When there is an adequate difference in the level of the water on the different sides of the dam, the gates are opened. This causes water to flow though the turbines, turning the generator to produce electricity. Electricity produced by water flowing both inwards and out of a bay. There are periods of maximum generation every 12 hrs. , with no electricity generation at the 6 hrs. mark in between. The turbines may also used pumps to pump extra water into the basin behind the dam at times when demand on electricity is low. This water can later be released when the demand on the system is very high. *Wave* Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves. Wave power is the transport of energy by wind waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a wave energy converter (WEC).	
	i)b	**Geothermal energy** Geothermal power plants use steam produced from reservoirs of hot water found a few miles or more below the Earth's surface to produce electricity. The steam rotates a turbine that activates a generator, which produces electricity. There are three types of geothermal power plants: dry steam, flash steam, and binary cycle. Water is introduced into heat source which produces steam. Steam I will act as primary heat	3

		source to produce steam again.. If primary steam is used in the turbine, it will be damaged in short time. Hence clean steam is used. Alternator connected to turbine will produce electricity.  	
4-B	ii)	**Performance assessment of cooling tower** The performance of cooling towers is evaluated to assess present levels of approach and range against their design values, identify areas of energy wastage and to suggest improvements. During the performance evaluation, portable monitoring instruments are used to measure the following parameters: • Wet bulb temperature of air • Dry bulb temperature of air • Cooling tower inlet water temperature • Cooling tower outlet water temperature • Exhaust air temperature • Electrical readings of pump and fan motors • Water flow rate Air flow rate These measured parameters and then used to determine the cooling tower performance in several ways. These are	6



a**) Range**. This is the difference between the cooling tower water inlet and outlet temperature. A high CT Range means that the cooling tower has been able to reduce the water temperature effectively, and is thus performing well.

The formula is:

CT Range (°C) = [CW inlet temp (°C) – CW outlet temp (°C)]

b) **Approach**. This is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. The lower the approach the better the cooling tower performance. Although, both range and approach should be monitored, the `Approach' is a better indicator of cooling tower performance.

CT Approach (°C) = [CW outlet temp (°C) – Wet bulb temp (°C)]

c) **Effectiveness.** This is the ratio between the range and the ideal range (in percentage), i.e. difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach). The higher this ratio, the higher the cooling tower effectiveness.

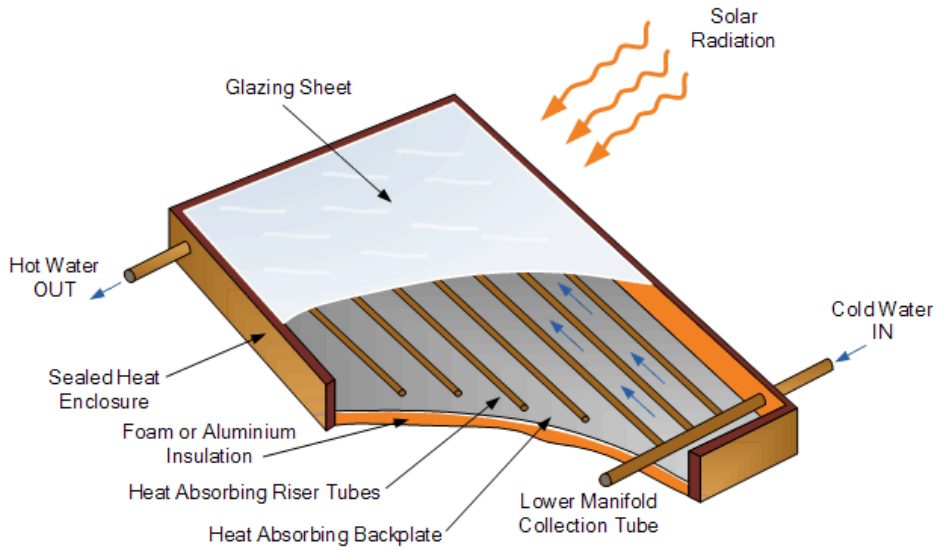
CT Effectiveness (%) = 100 x (CW temp – CW out temp) / (CW in temp – WB temp)

d) **Cooling capacity**. This is the heat rejected in kCal/hr or TR, given as product of mass

		flow rate of water, specific heat and temperature difference.	
5		**Attempt any two of the following**	**16**
	a	**Preliminary energy audit** The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency. Typically, only major problem areas will be covered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. A list of energy conservation measures (ECMs, or energy conservation opportunities, ECOs) requiring further consideration is also provided. This level of detail, while not sufficient for reaching a final decision on implementing proposed measure, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit. **Detailed Energy Audit** Detailed energy audit includes a complete description of the facility, including an equipment inventory, an energy balance, detailed energy savings and costs associated with each low-cost and not-cost measure, financial analysis of each recommended measure, identification and rough estimates of capital project costs and savings. Energy savings and economic feasibility are determined as accurately as possible. The reports contain more detailed descriptions of the measures. The portable instruments, trend logs and data loggers are used in detailed energy audits for assessing the current performance accurately .The scope of an energy audit includes an examination of the following areas: Energy generation/conversions equipments like boilers, furnaces, Heaters ,pumps, fans,	3 5

		compressors, transformers etc. Energy distribution network of electricity, water, steam, condensate, compressed air etc. Energy utilization efficiency of all equipment and buildings. Efficient planning, operation, maintenance and housekeeping Management aspects of design and operating data collection, field measurements, data analysis, and training	
	b	**NPSH** The net positive suction head available (NPSHA) is the difference between the pressure at the suction of the pump and the saturation pressure for the liquid being pumped. **Energy saving opportunities in cooling tower(any 8)** • Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust • Optimize cooling tower fan blade angle on a seasonal and/or load basis • Correct excessive and/or uneven fan blade tip clearance and poor fan balance • In old counter-flow cooling towers, replace old spray type nozzles with new square spray nozzles that do not clog • Replace splash bars with self-extinguishing PVC cellular film fill • Install nozzles that spray in a more uniform water pattern • Clean plugged cooling tower distribution nozzles regularly • Balance flow to cooling tower hot water basins • Cover hot water basins to minimize algae growth that contributes to fouling • Optimize the blow down flow rate, taking into account the cycles of concentration (COC) • limit • Replace slat type drift eliminators with low-pressure drop, self-extinguishing PVC cellular units	2 6

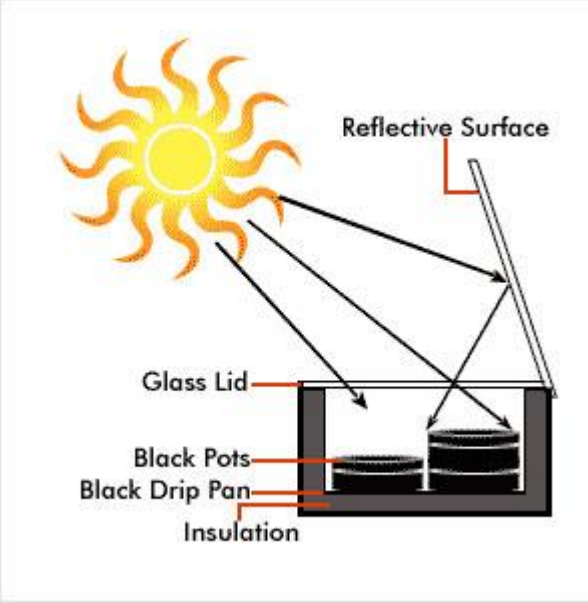
		• Restrict flows through large loads to design values	
	c	**Features of Perform Achieve Trade (PAT)** • Specification of specific energy consumption (SEC) norm for each designated consumer in the baseline year and in the target year • Verification of the SEC of each designated consumer in the baseline year and in the target year by an accredited verification agency • Issuance of Energy Savings Certificates (ESCerts) to those designated consumers who exceed their target SEC reduction • Trading of ESCerts with designated consumers who are unable to meet their target SEC reduction after three years • Checking of compliance, and reconciliation of ESCerts at the end of the 3-year period. In case of non-compliance, a financial penalty is due.	2 mark for each for any four
6		**Attempt any two of the following**	**16**
	a	**Flat plate solar collector:** **Construction** A solar flat plate collector typically consists of a large heat absorbing plate, usually a large sheet of copper or aluminium as they are both good conductors of heat, which is painted and chemically etched black to absorb as much solar radiation as possible for maximum efficiency. This blackened heat absorbing surface has several parallel copper pipes or tubes called risers, running length ways across the plate which contains the heat transfer fluid, typically water. These copper pipes are bonded, soldered or brazed directly to the absorber plate to ensure maximum surface contact and heat transfer. The pipes and absorber plate are enclosed in an insulated metal or wooden box with a sheet of glazing material, either glass or plastic on the front to protect the enclosed absorber plate and create an insulating air space. **Working**	2

		Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal—typically copper or aluminum—because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminum. In locations with average available solar energy, flat plate collectors are sized approximately one-half- to one-square foot per gallon of one-day's hot water use.  	2 4
	b	***Marks should be given for any one(box type or parabolic)type*** **Box type solar cooker** The important parts of a hot box solar cooker include the outer box, inner cooking box or tray, the double glass lid, thermal insulator, mirror and cooking containers. **1. Outer Box :** The outer box of a solar cooker is generally made of G.I. or aluminum sheet or fibre reinforced plastic. **2. Inner Cooking Box (Tray) :** This is made from aluminum sheet. The inner cooking box is slightly smaller than the outer box. It is coated with black paint so as to easily absorb solar radiation and transfer the heat to the cooking pots. **3. Double Glass Lid:** A double glass lid covers the inner box or tray. This cover is	3

slightly larger than the inner box. The two glass sheets are fixed in an aluminum frame with a spacing of 2 centimeters between the two glasses. This space contains air which insulates and prevents heat escaping from inside. A rubber strip is affixed on the edges of the frame to prevent any heat leakage.

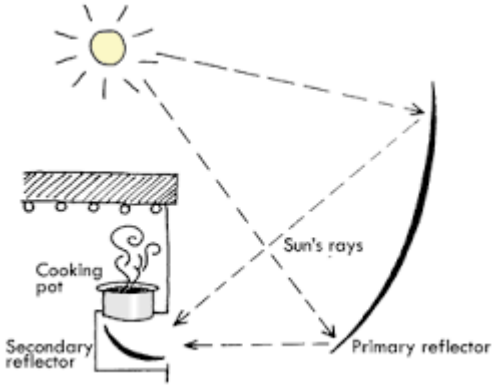
4. **Thermal Insulator:** The space between the outer box and inner tray including bottom of the tray is packed with insulating material such as glass wool pads to reduce heat losses from the cooker. This insulating material should be free from volatile materials.
5. **Mirror:** Mirror is used in a solar cooker to increase the radiation input on the absorbing space and is fixed on the inner side of the main cover of the box. Sunlight falling on the mirror gets reflected from it and enters into the tray through the double glass lid. This radiation is in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the inside temperature of the cooker.
6. **Containers:** The cooking containers (with cover) are generally made of aluminum or stainless steel. These pots are also painted black on the outer surface so that they also absorb solar radiation directly.

2



Working

- The incoming solar radiation falls onto the double glass lid and passes through

		it to strike the blackened cooking pots and the cooking tray. • The heat is absorbed by the blackened surface and gets transferred to the food inside the pots to facilitate cooking. • The mirror reflector is set in such a way to reflect the solar radiation falling on it to the cooker box. Up to four black painted vessels are placed inside the box. • The cooker takes 1½ to 2 hours to cook items such as rice, lentils and vegetables. • The cooker may also be used to prepare simple cakes, roast cashew nuts, dry grapes, etc. It is an ideal device for domestic cooking during most of the year, except for the monsoon season and cloudy days. • It, however cannot be used for frying or chapatti making.	3
		OR **Parabolic Solar Cooker**  	2
		The major components of the cooker are as below: • **Reflecting bowl:** It is a parabolic dish made of reflecting sheets supported on suitable rings for holding them in a fixed position. The sheets will be joined together in such a way that they automatically form the parabolic shape. The structure and frame of the bowl will be so strong that the reflectors do not get deformed while turning in various directions.	3

		• **Reflecting stand:** It is made of mild steel with powder coating for battery durability. The stand is designed in such a way that the reflector can rotate 3500 around the horizontal axis passing through the focus and the centre of gravity. It should also be able to rotate around the vertical axis so as to adjust the cooker in the direction of the sun. • The concentrating type parabolic dish solar cooker will be useful for individuals in rural as well as urban areas and also for small establishments like dhabas, tea shops etc. • The solar cooker has an aperture diameter of 1.4 meter and a focal length of 0.28 meter. • The reflecting material used for its fabrication is anodized aluminum sheet that has a reflectivity of over 75 %. The tracking of the cooker is manual and so has to be adjusted in 15 to 20 minutes during the cooking time. • It has a delivery power of about 0.6 KW that can boil 2 to 3 liters of water in half an hour. • The temperature achieved at the bottom of the vessel could range from 350 to 400^0C which is sufficient for roasting, frying and boiling. • A cooker with about 40% thermal efficiency can meet the needs of around 15 people and can be used from one hour after sunrise until one hour before sunset on clear days. • It can be easily dismantled and assembled. and therefore can be transported anywhere in the country. It can also be placed at a convenient level for its users. • The cooker can save up to 10 LPG cylinders a year on full use in small establishments. • The metallic structure reflecting sheets may, however, have to be replaced once in 5 years.	3
	c	**Specific heat**: The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius.	2

		Latent heat: Amount of heat that changes the state of a material (from solid to liquid or liquid to gas) without raising its temperature any further.	2
		Given Data :	
		active power P = 1.85 kW =1850 W	
		V = 440 V ,	1
		I = 2.4 Amp.	
		P = √3 x V x I x Power Factor	2
		Power factor = P/(√3 x V x I) = 1850/(√3 x 440 x2.4)	1
		=1.01	