SUMMER–19 EXAMINATION
Model Answer

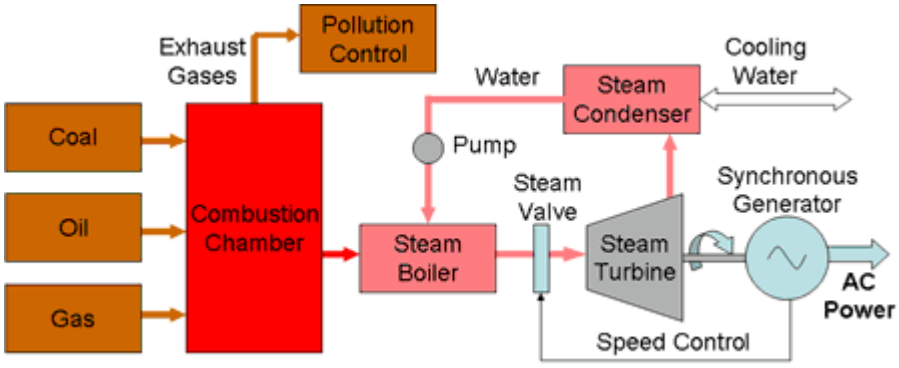
Subject Name: Energy Management **Subject Code:** 17559

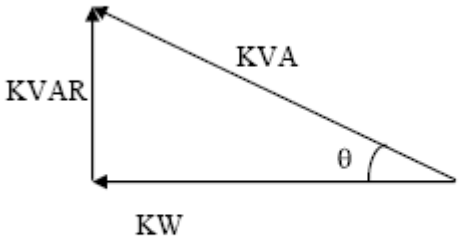
Important Instructions to examiners:

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
	a)	**Types of energy Source** **Primary energy source** is an energy form found in nature that has not been subjected to any conversion or transformation process. The primary energy sources are derived from: the sun, the earth's heat, the wind, water (rivers, lakes, tides, and oceans), fossil fuels - coal, oil, and natural gas, biomass, and radioactive minerals. **Secondary energy source** Secondary energy refers to the more convenient forms of energy which are transformed from other, primary, energy sources through energy conversion processes. Examples are electricity, which is transformed from primary sources such as coal, raw oil, fuel oil, natural gas, wind, sun, streaming water, nuclear power, gasoline etc. **Conventional Energy sources:** These sources are exhaustible after use. e.g Coal, crude oil, Gas **Non-Conventional energy sources:** These sources can renew again and again. e.g Solar, Wind, Biomass, Hydro	2 marks each for any two types with example

	b)	**Geothermal energy** Geothermal energy refers to the production of energy using the internal heat of the Earth's crust. This heat comes from the radioactive decay of minerals and continual heat loss from the earth's original formation **Renewable source** Geothermal energy is renewable because the Earth has retained a huge amount of the heat energy that was generated during formation of the planet. In addition, heat is continuously produced by decay of radioactive elements within the Earth. The amount of heat within the Earth, and the amount that is lost though natural processes (e.g. volcanic activity, conduction/radiation to the atmosphere), are much, much more than the amount of heat lost through geothermal energy production. At any one geothermal field, however, the temperature of the geothermal reservoir or the fluid levels/fluid pressure in the reservoir may decrease over time as fluids are produced and energy is extracted.	2 2
	c)	**The need of energy audit** 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 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	4

		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.	4
	B	**Attempt any ONE of the Following**	**6**
	a)	**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 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 3

	b)	**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. *The Power Triangle*  $P.F. = \frac{KW}{KVA} = \cos\theta$ Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA). $\text{Power Factor } (\cos\Phi) = \frac{Active\ Power\ (kW)}{Apparent\ Power\ (kVA)}$ $= \frac{kW}{\sqrt{(kW)^2 + (kVAr)^2}}$ **Given Data** Rated power 75 kW = 75000 W Opearting power 55 kW =55000 W Voltage 415 V Current 80 A P = √3 x V x I x Power Factor Power factor = P/(√3 x V x I) = 55000/(√3 x 415 x80) Power factor = 0.9564	3 3
2		**Attempt any FOUR of the Following**	**16**

	a)	**Energy Benchmarking** Benchmarking is the practice of comparing the measured performance of a device, process, facility, or organization to itself, its peers, or established norms, with the goal of informing and motivating performance improvement. When applied to building energy use, benchmarking serves as a mechanism to measure energy performance of a single building over time, relative to other similar buildings, or to modeled simulations of a reference building built to a specific standard (such as an energy code). Benchmarking is useful for state and local government property owners and facility operators, managers, and designers. It facilitates energy accounting, comparing a facility's energy use to similar facilities to assess opportunities for improvement, and quantifying/verifying energy savings. Benchmarking is the process of comparing one's business processes and performance metrics to industry bests or best practices from other companies. **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 kWh/liter in a diesel power generation plant	2 2
	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	1 mark each for any four

		mandatory display of label on notified equipment and appliances; • prohibit manufacture, sale, purchase and import of notified equipment and appliances 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)	**Modes of Heat Transfer** **Conduction** It is the mode of heat transfer particularly in solids and also for liquid at rest. In this mode of heat transfer, the heat transfers from one atom to its neighbouring atom through molecular vibrations. At the molecular level, First heat energy of a higher energy level molecule converts to vibrating kinetic energy and this kinetic energy is transferred to neighbouring atoms and so on. again process repeats until the temperature difference between two	4

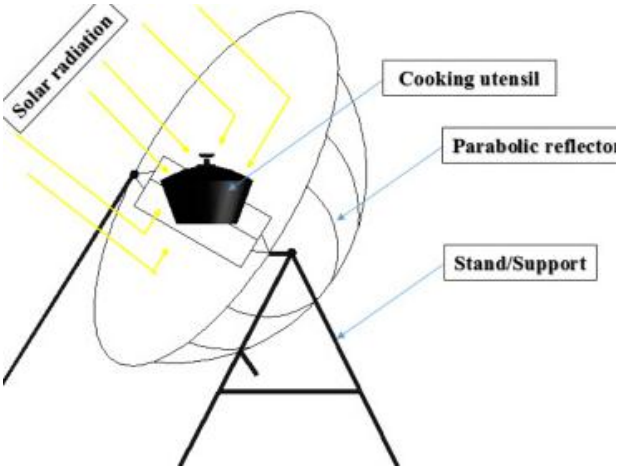
		neighbouring atoms is zero. Heat spontaneously flows from a hotter to a colder body. For example, heat is conducted from the hotplate of an electric stove to the bottom of a saucepan in contact with it. Heat energy of fuel given to tubes of boiler. **Convection** This mode of heat transfer particularly occurs in fluids in motion. That is in both liquids and gases that are in motion. This mode of heat transfer occurs due to the transfer of energy through the bulk mass. Whenever there is a temperature difference in a fluid, density difference occurs and motion of fluid starts as lower density fluid attempts to reach the top of the fluid. During this motion mass and energy transfer occurs thus heat transfer takes place. e.g. Boiling liquid in column, breeze in air, water heating in boiler **Radiation** Radiation is a mode of heat transfer which takes place through vacuum and hence, does not need a physical medium. Radiation takes place either through vacuum or through a transparent medium. In radiative mode, heat transfer takes place through photons present in the electromagnetic waves. The random movement of atoms and molecules in heated substances results in emission of electromagnetic waves which carry the heat to be transferred. The radiative heat transfer is governed by Stephen- Boltzman law. A body radiates heat at all temperatures above the absolute zero, irrespective of the ambient temperature. e.g. Heat from sun, from fire, bulb, from insulation of boiler	
	d)	**Energy conservation opportunities in pumping system (any eight)** • Ensure adequate NPSH at site of installation • Ensure availability of basic instruments at pumps like pressure gauges, flow meters. • Operate pumps near best efficiency point. • Modify pumping system and pumps losses to minimize throttling. • Adapt to wide load variation with variable speed drives or sequenced control of multiple units. • Stop running multiple pumps - add an auto-start for an on-line spare or add a booster	½ mark each for any eight

		pump in the problem area. • Use booster pumps for small loads requiring higher pressures. • Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers. • Repair seals and packing to minimize water loss by dripping. • Balance the system to minimize flows and reduce pump power requirements. • Avoid pumping head with a free-fall return (gravity); Use siphon effect to advantage: • Conduct water balance to minimise water consumption • Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.	
	e)	**Energy security** The basic aim of energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth. India will continue to experience an energy supply shortfall throughout the forecast period. Increasing dependence on oil imports means reliance on imports from the Middle East, a region susceptible to disturbances and consequent disruptions of oil supplies. Some of the strategies that can be used to meet future challenges to their energy security are • Building stockpiles • Diversification of energy supply sources • Increased capacity of fuel switching • Demand restraint • Development of renewable energy sources • Energy efficiency • Sustainable development	2 2
3		**Attempt any FOUR of the Following**	**16**
	a)	**Biomass**	2

		Biomass is organic material that comes from plants and animals, and it is a renewable source of energy. Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. **Biomass as a renewable energy** Biomass is considered a renewable energy source because its inherent energy comes from the sun and because it can regrow in a relatively short time. Trees take in carbon dioxide from the atmosphere and convert it into biomass and when they die, it is released back into the atmosphere. Whether trees are burned or whether they decompose naturally, they release the same amount of carbon dioxide into the atmosphere. The idea is that if trees harvested as biomass are replanted as fast as the wood is burned, new trees take up the carbon produced by the combustion, the carbon cycle theoretically remains in balance, and no extra carbon is added to the atmospheric balance sheet—so biomass is arguably considered "carbon neutral." Since nothing offsets the CO2 that fossil fuel burning produces, replacing fossil fuels with biomass theoretically results in reduced carbon emissions.	2
	b)	**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
	c)	**Types of energy audit:** i) preliminary audit ii) detailed audit **i) preliminary energy audit** indentify the quantity and the cost of energy forms and in the plant. Energy consumption in various equipment/sections , process level. Relates energy inputs to production and highlights the wastage of energy in equipment /	1 1

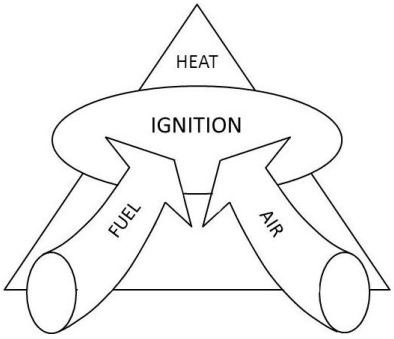
		process areas. Recommendation for low cost energy conservation measures. Identify of major areas/ equipments require indepth study / analysis **ii)detailed energy audit** a comprehensive audit provides a detailed project implementation plan for a facility , since it evaluate all major energy using systems. This type of audit offers the most accurate estimate of energy savings and cost.it considers the interactive effects of all projects, accounts for the energy use of all major equipments , and include detailed energy cost saving calculation and project cost. Detailed audit is carried out in three phases: Phase I : pre audit phase Phase II : audit phase Phase III : post audit phase	2
	d)	**Capacity Factor of Wind Energy** Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible, i.e. running full time at rated power. Wind turbines generate electricity at an annual average rate of 25%–35% of their capacity. That means, for example, a 2-MW turbine may produce an annual total energy of 2 MW × 365 days × 24 hours × 0.25 = 4,380 MWh, or at an average rate of 2 MW × 0.25 = 0.5 MW. The turbine, or any group of turbines, generates at or above its average rate (i.e., its capacity factor), however, only 40% of the time. When wind turbines do generate power, they do so at highly variable rates depending primarily on the wind speed.	4
	e)	**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	2

		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. 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
4	**A**	**Attempt any THREE of the Following**	**12**
	a)	**Energy saving opportunities in cooling tower (any eight)** • 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)	½ mark each for any 8

		• limit • Replace slat type drift eliminators with low-pressure drop, self-extinguishing PVC cellular units Restrict flows through large loads to design values	
	b)	**Parabolic Solar Cooker**  **Construction** • **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. • **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	2

		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. **Working** Parabolic solar cookers use a parabolic-shaped reflector to direct sunlight to a small area in order to generate heat for cooking. They are able to reach high temperatures, 350 °C or higher, which allows them to be used for grilling and frying. These temperatures are significantly higher than what can be reached by a solar box cookers or solar panel cookers. The amount of food being cooked and the way in which the heat is used is generally dictated by the size of parabolic dish. Smaller dishes, which are generally around one meter in diameter, are intended to heat a traditional size pot or pan much like how you would cook on a traditional cooktop. The larger dishes, which can be as wide as five meters in diameter, are generally not used to heat a pot or pan directly, but instead are used to create steam by directing sunlight onto pipes carrying water. The steam is directed to cooking surfaces in a kitchen and is regulated by valves in order to offer control to the chef.	2
	c)	**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	4

fuel characteristics.



d) **Difference between conventional and non-conventional energy sources** — 1 mark each for any four differences

Conventional energy	Non-conventional energy
Conventional sources of energy are not abundant, present in limited quantity, e.g. coal, petroleum, natural gas.	Non-conventional sources of energy are abundant in nature, e.g. solar energy, wind energy, tidal energy, bio-gas from biomass etc.
Conventional source have been in use for a long time.	Non-Conventional source are development phase over the past few years.
Conventional source aren't refill continuously. They are formed over a million years.	Non-conventional source are continuously fill by natural processes.
Conventional source are called non-renewable fuel sources of energy.	Non-conventional source are called renewable source of energy.
Conventional source are mostly used industrial and commercial purposes.	Non-conventional source are mostly used for household purposes.

B **Attempt any ONE of the Following** — **6**

a) **Specific heat**

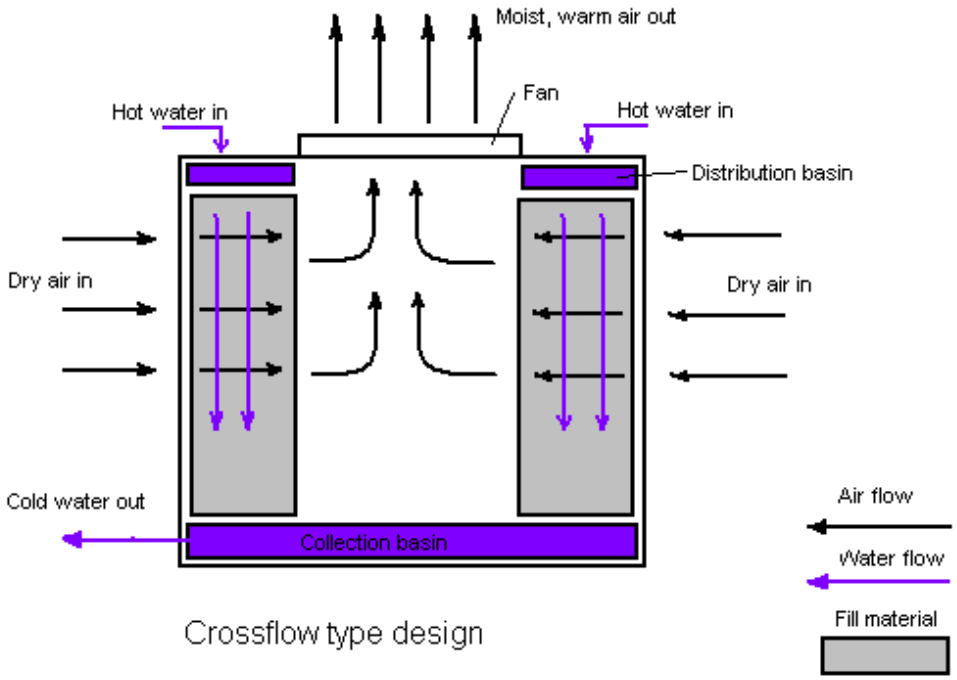
The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. — 1

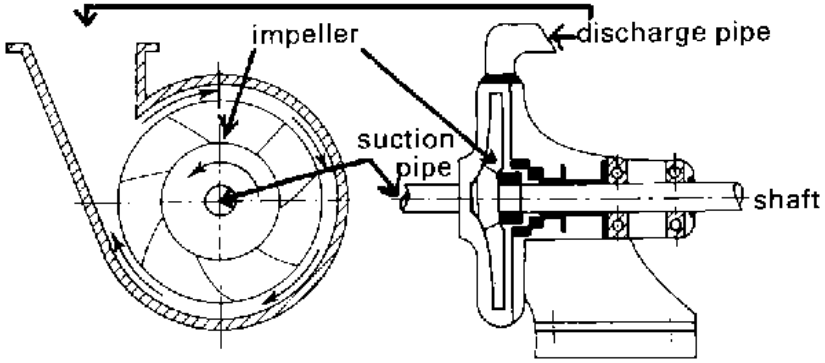
Latent heat

The heat required to convert a solid into a liquid or vapour, or a liquid into a vapour, without — 1

		change of temperature.(Phase change) **Given Data** Steam temp = 100^oC Cooled upto = 30^oC Latent heat = 540 Kcal/kg Sp heat =1 Kcal/kgK Let m = 1 kg Q =(m X Cp X dT) + (m x latent heat) = 1 x 1 x (373- 303) + (1 x 540) = 70 + 540 = 610 Kcal = 610 x 4.187 = 2554.07 kJ	4
	b)	**Instruments used for energy audit:** • Electrical measuring instruments- to measure current, voltage, power, PF • Combustion analyzer- For flue gas analysis • Thermometer (contact thermometer)- For temperature measurement • Infrared thermometer- For temperature measurement • Flow meter – Doppler effect, ultra sonic – for flow measurement • Leak detector- To find change in pressure • Lux meter – to measure intensity of light **Combustion analyzer:** Combustion analyzers are multifunction instruments designed to calculate the efficiency of all types of boilers, heaters and furnaces by measuring a range of parameters such as stack temperature, flue pressure and levels of gases. This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_X and SO_X. **Electrical Measuring Instruments:** These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-	2 2 marks each for any two

		held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals. **Contact thermometer:** These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument. **Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc. **Water flow meter:** This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter **Leak Detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities. **Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.	
5		**Attempt any TWO of the Following**	
	a)	**Cross flow type of cooling tower** Cross flow is a design in which the air flow is directed perpendicular to the water flow as shown in figure. Air flow enters one or more vertical faces of the cooling tower to meet the fill material. Water flows perpendicular to air through the fill by gravity. The air continuous through the fill and thus past the water flow into an open plenum area. A distribution or hot water basin consisting of a deep pan with holes or nozzles in the bottom is utilized in a cross flow tower. Gravity distributes the water through the nozzles uniformly across the fill material	4

		 Crossflow type design	4
	b)	**ENCON recommendations** • Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speed drives • Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency. • Moderation of chilled water temperature for process chilling needs • Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption • Adoption of task lighting in place of less effective area lighting • Eliminate steam leakages by trap improvements • Maximise condensate recovery • Adopt combustion controls for maximizing combustion efficiency • Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist.	1 mark each for any eight

	c)	**Different parts of centrifugal pump** Seal : Centrifugal pump can be provided with packing rings or mechanical seal which helps prevent the leakage of the pumped liquid into the atmosphere. Shaft :The main function of the shaft in a centrifugal pump is to transmit the input power from the driver into the impeller. Casing: The casing contains the liquid and acts as a pressure containment vessel that directs the flow of liquid in and out of the centrifugal pump. Impeller :Centrifugal pumps use impeller as the primary source for their pumping action. Its function is to increase the pressure of the liquid. Bearing :The function of the bearing is to support the weight of the shaft (rotor) assembly, to carry the hydraulic loads acting on the shaft, and to keep the pump shaft aligned to the shaft of the driver. Suction and discharge nozzles**:** These are inlet and outlet for pump. 	4 4
6		**Attempt any TWO of the Following**	**16**
	a)	**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	4

		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 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.	4
	b)	**Solar Water Heater** **Construction** A typical domestic solar water heater consists of a hot water storage tank and one or more	4

		flat plate collectors. Inlet and outlet pipes are connected to water tank which is insulated to avoid heat loss. Material of construction of tube is copper in side collector. Glass cover is provided on the collector. Water is place on the metal structure at the top and flat plate collectors are the bottom facing the sun. **Working** The collectors are glazed on the sun facing side to allow solar radiation to come in. A black absorbing surface (absorber) inside the flat plate collectors absorbs solar radiation and transfers the energy to water flowing through it. A black surface heats up when left in the sun, by absorption of solar radiation; The good absorption property of black surfaces is used to improve solar energy absorption in a solar heater Heated water is collected in the tank which is insulated to prevent heat loss. Circulation of water from the tank through the collectors and back to the tank continues automatically due to density difference between hot and cold water (thermosyphon effect).	4
	c)	**Performance assessment of boiler** Performance of the boiler, like efficiency and evaporation ratio reduces with time, due to poor combustion, heat transfer fouling and poor operation and maintenance. Deterioration of fuel quality and water quality also leads to poor performance of boiler. Efficiency testing helps us to find out how far the boiler efficiency drifts away from the best efficiency. Measurements Required for Direct Method Testing Heat input Both heat input and heat output must be measured. The measurement of heat input requires knowledge of the calorific value of the fuel and its flow rate in terms of mass or volume, according to the nature of the fuel. For gaseous fuel: A gas meter of the approved type can be used and the measured volume should be corrected for temperature and pressure. A sample of gas can be collected for calorific value determination, but it is usually acceptable to use the calorific value declared	8

		by the gas suppliers. For liquid fuel: Heavy fuel oil is very viscous, and this property varies sharply with temperature. The meter, which is usually installed on the combustion appliance, should be regarded as a rough indicator only and, for test purposes, a meter calibrated for the particular oil is to be used and over a realistic range of temperature should be installed. Even better is the use of an accurately calibrated day tank. For solid fuel: The accurate measurement of the flow of coal or other solid fuel is very difficult. The measurement must be based on mass, which means that bulky apparatus must be set up on the boiler-house floor. Samples must be taken and bagged throughout the test, the bags sealed and sent to a laboratory for analysis and calorific value determination. In some more recent boiler houses, the problem has been alleviated by mounting the hoppers over the boilers on calibrated load cells, but these are yet uncommon. Heat output There are several methods, which can be used for measuring heat output. With steam boilers, an installed steam meter can be used to measure flow rate, but this must be corrected for temperature and pressure. It is now more viable with modern flow meters of the variable-orifice or vortex-shedding types.	