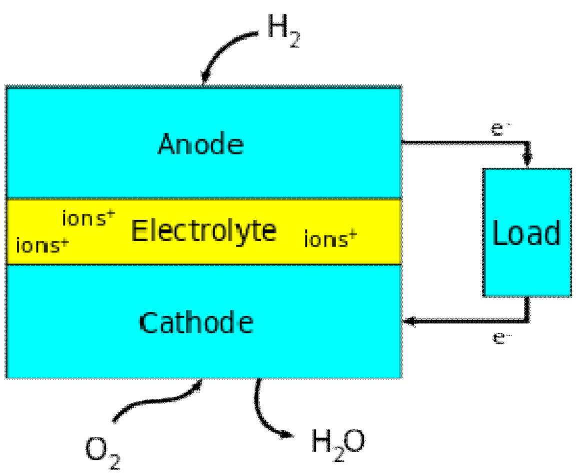
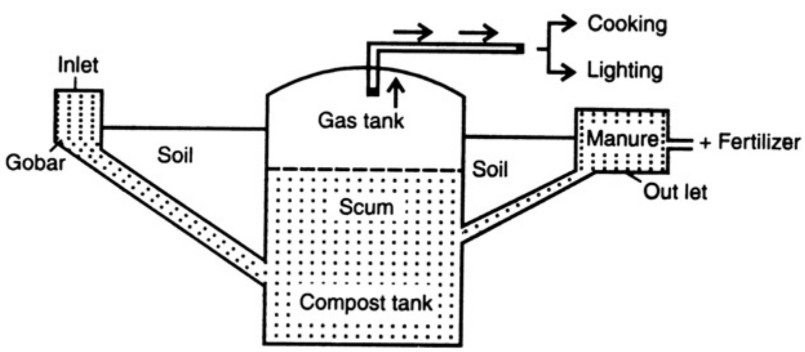
Important Instructions to examiners:

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 thefigure. 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 judgment 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.	Answer	Marks	Total marks
Q 1 A	**Attempt any three**		**12**
a)	**Primary energy** 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** 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. **OR** **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 2	4
b)	**Fuel cell** Construction: Fuel cells come in many varieties; however, they all work in the same general manner. They are made up of three adjacent segments: the anode, the electrolyte, and the cathode. Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel is consumed, water or carbon dioxide is created, and an electric current is	4	4

	created, which can be used to power electrical devices, normally referred to as the load. Working: At the anode a catalyst oxidizes the fuel, usually hydrogen, turning the fuel into a positively charged ion and a negatively charged electron. The electrolyte is a substance specifically designed so ions can pass through it, but the electrons cannot. The freed electrons travel through a wire creating the electric current. The ions travel through the electrolyte to the cathode. Once reaching the cathode, the ions are reunited with the electrons and the two react with a third chemical, usually oxygen, to create water or carbon dioxide.  		
c)	**Objectives of energy managements:** • To maximize profit at minimize cost. • Conserving energy and reducing cost • Cultivating good communication on energy matters • Developing and maintaining effective monitoring, reporting and managements strategies for efficient energy uses.	One mark each for any four	04

	• Finding new and better ways to increase returns from energy investments		
d)	**Biogas** 	4	4
Q1 B	**Attempt any one**		**6**
a)	**Modes of heat transfer** 1. Conduction 2. Convection and 3. Radiation CONDUCTION: Conduction is the mode of heat transfer occurs from one part of a substance to another part of within the substance itself or with another substance which is placed in physical contact. In conduction, there is no noticeable movement oof molecules. You ight be think that then how this heat tranbsfer occurs? The heat transfer occurs here by the two mechanisms happen. 1. By the transfer of free electrons. (Good conductors like metals have a plenty of free electrons to make conductive heat transfer. 2. The atoms and molecules having energy will pass those energy they have with their adjacent atoms or molecules by means of lattice vibrations. CONVECTION:	2	6

	Conductive heat transfer occurs within a fluid itself and it is carried out by transfer of one fraction of the fluid to the remaining portion. Hence unlike conduction, transfer of molecules occurs during convection. Since movement of particles constitutes convection, it is the macro form of heat transfer. Also convection is only [possible in fluids where the particles can moved easily and the rate of convective heat transfer depends on the rate of flow to a great extend. Convection can be of two types: 1. Natural convection: In this type of convection, the movement of particles which constitutes convection occurs by the variation in densities of the fluids. As we already know, as temperature increases, the density decreases and this variation in density will force the fluid to move through the volume. This cause convection to occur. 2. Forced Convection: The difference between natural convection and forced convection is that in forced convection, a work is done to make movement in the fluid. This is done using a pump or blower. RADIATION Radiation is the third mode of heat transfer. This mode of heat transfer didn't require any medium to occur. Every matter having a temperature, pressure above absolute zero will emit energy in the form of electromagnetic waves and called radiation. It is the same way the energy of the Sun reach us. The key features about radiation are it do not require any medium and also laws of reflection is applicable for radiation.	2 2	
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. It is calculated by following formula	1	6

	P = √3 x V x I x PF Given : active power P = 50 kW V = 415 V , I = 80 Amp. Apparent power =[√3 x V x I] / 1000= =[√3 x 415 x 80] / 1000 = 57.504 Power factor = active power / apparent power = 50 / 57.504 = 0.8695	1 4	
Q 2	**Attempt any four**		**16**
a)	**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	1 mark each for any four	4
b)	**Factors to considered for energy security** • Natural hazards	One mark each for	4

	• Political instability • Dependency on import • Range of energy sources used • Cost of energy	any four	
c)	**Heat:** heat is energy that spontaneously passes between a system and its surroundings in some way other than through work or the transfer of matter. **Sensible heat:** It is the amount of heat transferred without change of phase. **Calorific Value**: It is the amount of heat released during combustion of a unit quantity of fuel. **Wet bulb temperature :** It is the temperature recorded by thermometer when bulb is surrounded by wet cloth	1 mark each	4
d)	**Energy conservation opportunities in pumping system** • 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 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	1 mark each for any four	4

	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 conservation cell as a catalyst for energy conservation** All energy intensive industries should have a dedicated energy management cell with a full time 'Energy Manager' who will be responsible for overseeing its operations. The energy management cell should provide necessary structure and formalise the process of energy conservation thereby enhancing its efficacy with full support from top management. Besides energy manager, the cell should also have skilled persons in different disciplines. The cell should interact with manufacturing and other divisions like production, engineering, maintenance, utilities, and even finance. This will help in carrying out its activities like planned internal and external energy audits, conceptualisation and implementation of projects in close coordination with respective departments/divisions, carrying out educational campaigns etc. Thus, the cell will become the focal point for effective energy management in the plant. This dedicated working will also bring to the fore the energy issues in the minds of personnel working in different areas and will influence their decision-making.	4	4
Q 3	**Attempt any four**		**16**
Q3 a)	**Advantages** 1) It is an inexhaustible source of energy.	2	4

	2) Tidal energy is environment friendly energy and doesn't produce greenhouse gases. **Disadvantages** 1) There are very few ideal locations for construction of plant and they too are localized to coastal regions only. 2) Intensity of sea waves is unpredictable and there can be damage to power generation units.	2	
b)	**Energy efficient pumping system to replace throttle valve** 1) Impeller trimming 2) Reducing speed of impeller (Use VSD) 3)Using pump of required size (avoid oversize pump) 4)Use pump in parallel	1 mark each for any four	4
c)	**Energy M &T:** the consumption of energy cannot be effectively controlled without a clear understanding of its use. Continuous monitoring is required to observe the trend of use. Targeting of energy use for the particular equipment can be done after effective monitoring. **Benefits of effective energy M & T system :** Energy consumption trend can be analyzed. Energy saving activities can be implemented through effective M&T. Efficiency of equipment can find out by monitoring. Cost of energy for the production can be controlled.	2 2	4
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	4

	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.		
e)	(see table below)	4	4

Energy conservation	Energy efficiency
Energy conservation refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. For example, driving less is an example of energy conservation.	Energy efficiency is the goal to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. .
Even though energy conservation reduces energy services, it can result in increased environmental quality, national	Improvements in energy efficiency are generally achieved by

	security, personal financial security and higher savings. It is at the top of the sustainable energy hierarchy . It also lowers energy costs by preventing future resource depletion .	adopting a more efficient technology or production process or by application of commonly accepted methods to reduce energy losses.		
	It also reduce energy import	In many countries energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted.		
Q 4 A	**Attempt any three**			**12**
a)	**Energy saving opportunities in cooling tower** • Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake or exhaust		½ mark each for any eight	4

<table>
<tr><td></td><td>

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

Restrict flows through large loads to design values</td><td></td><td></td></tr>
<tr><td>b)</td><td>
<table>
<tr><th>Sr No</th><th>Renewable energy sources</th><th>Non renewable energy sources</th></tr>
<tr><td>1</td><td>These sources can renew again and again.</td><td>These sources are exhaustible after use.</td></tr>
<tr><td>2</td><td>These sources are pollution free.</td><td>These sources are creating pollution.</td></tr>
</table>
</td><td>1 mark for each point</td><td>4</td></tr>
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<table>
<tr><td></td><td><table><tr><td>3</td><td>Capital investment is more but fuel cost zero for power generation</td><td>Capital investment is less but fuel cost is more for power generation</td></tr><tr><td>4</td><td>e.g Solar, Wind, Biomass, Hydro</td><td>e.g Coal, crude oil, Gas</td></tr></table></td><td></td><td></td></tr>
<tr><td>c)</td><td>Three T`s of combustion:</b><br>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.</td><td>4</td><td>4</td></tr>
<tr><td>d)</td><td>Energy generated from tide and ocean:
Tidal:
The technology required to convert tidal energy into electricity is comparable to technology used in traditional hydroelectric power plant. The first requirement is a dam across the tidal bay.
Best sites are those where a bay has a narrow openings, thus reducing the length of dam required.Gates and turbines are installed. When there is a adequate difference in the level of the water on the different sides of the dam ,</td><td>2</td><td>4</td></tr>
</table>

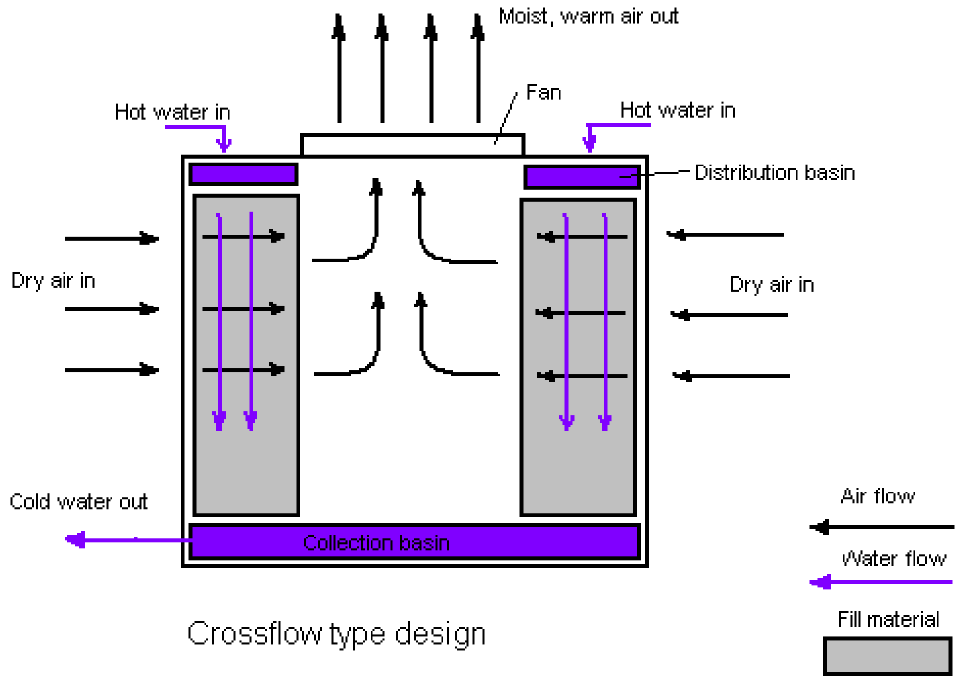
	the gates are opened.This causes water to flow though the turbines , turning the generator to produce electricity. Electricity produced by water flowing both inwards and out of a bay. There are periods of maximum generation every 12 hrs. , with no electricity generation at the 6 hrs. mark in between. 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. **From ocean:** Ocean thermal energy conversion (OTEC): Is a method for generating electricity which uses the temp. difference that exist between deep and shallow water to run heat engine. As with any heat engine, the greatest efficiency and power is produced with the largest temp. difference. This temp difference increases with decreasing latitude. Evaporation prevent the surface temp from exceeding 27 deg. C .also the subsurface water rarely falls below 5 deg. C. The earth`s ocean are continuously heated by sun. this temp difference contains a vast amount of solar energy	2	
Q4 B	**Attempt any one**		**6**
a)	**Specific heat**: The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. **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. Given data $T1= 100^oC$ $T2= 80^oC$ λ = 200 kJ/kg Cp = 4.817 kJ/kg^oC	1 1 4	6

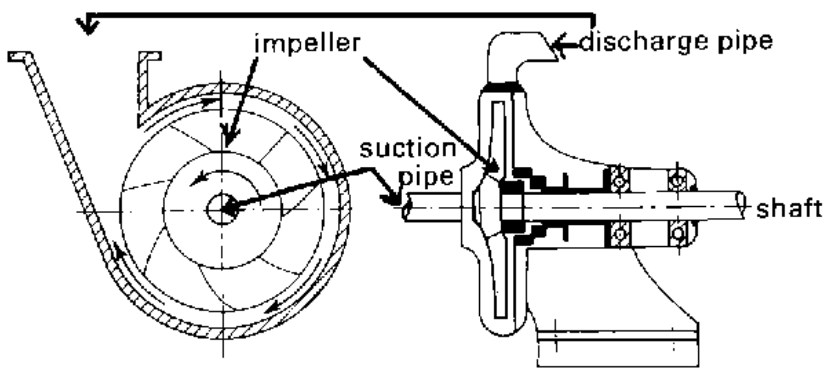
	For 20 kg steam Q = m[λ + (Cp ΔT)]= 20[200+(4.187x20)] = 5674.8 kJ		
b)	**Benchmarking** Benchmarking is the process of comparing one's business processes and performance metrics to industry bests or best practices from other companies. **Gross production related:** kWh/MT clinker or cement produced (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 2	6
Q 5	**Attempt any two**		**16**
a)	**Efficiency of pump** *Hydraulic power (liquid H.P.)* H.P. = Q x (hd – hs) x density of the fluid Suction head (h_s) Discharge head (h_d) *Pump shaft power* Ps = Rated power of motor x efficiency of motor *Pump efficiency*	2	8

	Pump efficiency = H.P / Pump shaft power **Running pump operating parameters at full speed [N]** $Q_1 = 38\ m^3/h$, $H_1 = 65\ m$, $P_1 = 12.5\ kW$ Power consumption at reduced speed (80 % of full speed) $P2 = P1\ x\ (N_2/N_1)^3$ $P2 = 12.5\ X\ (0.80\ N_1/N_1)^3$ [here $N_2 = 0.80\ N_1$] = 12.5 x 0.512 = 6.4 kW Reduction in power = 12.5 - 6.4 = 6.1 kW	6	
b)	**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 / 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.	4	8

	Detailed audit is carried out in three phases: Phase I : pre audit phase Phase II : audit phase Phase III : post audit phase		
	Contents of energy audit report Introduction General requirements Engineering calculation methods Scope of report Energy Audit Report outline Key contacts information Table of contents Executive summary Introduction Energy consumption Baseline period enrgy consumption System, process or equipment description Energy efficiency upgrades Economic analysis Conclusions and recommendations Appendix	2	
	Energy cost Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.	2	

	Energy invoices can be used for the following purposes: • It provide a record of energy purchased in a given year, which gives a base-line for future reference • Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc. • When electricity is purchased on the basis of maximum demand tariff It can suggest where savings are most likely to be made. • In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures		
c)	**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	Any one type of cooling tower-4 marks	8

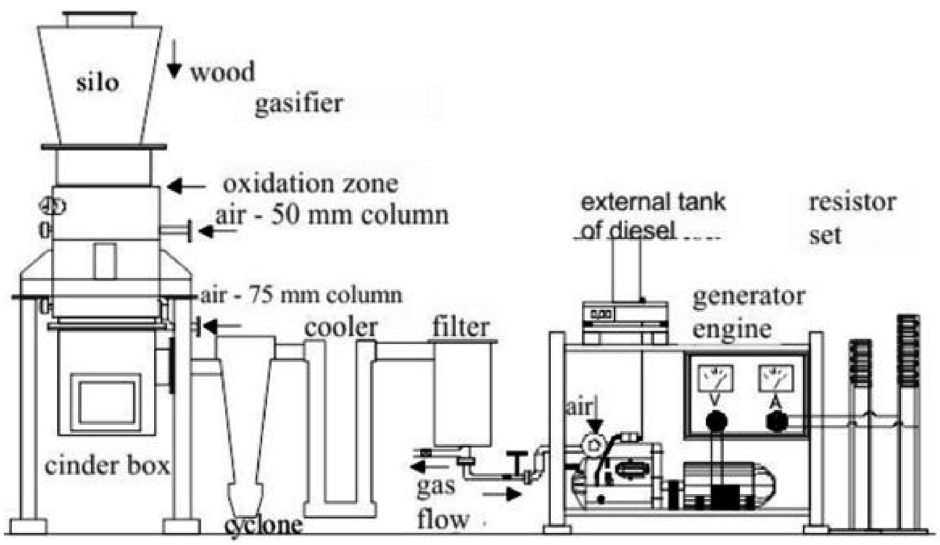
	 Crossflow type design **The factors affecting the cooling of water in a cooling tower:** Wet bulb temperature Dry bulb temperature of air Cooling tower inlet water temperature Cooling tower outlet water temperature Exhaust air temperature Electrical readings of pump and fan motors Water flow rate Air flow rate	4	
Q6	**Attempt any two**		**16**
a)	**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.	4	8

	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	
b)	**Gasification** is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. A gasifier is a reactor that converts biomass into clean gaseous fuel called producer gas (having calorific value of the order of 1000–1200 kilocalories per normalized cubic metre). Biomass gasifier system optimally utilizes wood for power generation. It consists of a downdraft gasifier, a gas-cleaning train, and an engine. The technological innovation provided users with the option of dual-fuel operation. The existing diesel genset could run on both diesel and	4	8

producer gas, instead of running only on diesel. The producer gas is fed into the diesel engine to let the engine operate in a dual-fuel mode, thereby reducing diesel consumption by more than 70%

The resulting gas mixture is called syngas (from synthesis gas or synthetic gas) or producer gas and is itself a fuel.

Syngas produced from gasifier is send to generator as afuel. Generator is used to produce power. The power derived from gasification and combustion of the resultant gas is considered to be a source of renewable energy if the gasified compounds were obtained from biomass.



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c) **Performance assessment of H.E.:**

8

Step A:

2

Monitoring and reading of steady state parameters of the H.E. under evaluation are tabulated as below:

parameters	units	inlet	Outlet
Hot fluid flow	Kg/h		
Cold fluid	Kg/h		

flow			
Hot fluid temp.	Deg. C		
Cold fluid temp.	Deg. C		
Hot fluid P	Bar g		
Cold fluid P	Bar g		

Step B:physical properties of stream can be tabulated as: 2

parameters	unit	Inlet	outlet
Hot fluid density	Kg/h		
Cold fluid density	Kg/h		
Hot fuid viscosity	MPas		
cold fuid viscosity	MPas		
Hot fuid them. coductivity	kW/(mK)		
Cold fuid ther. conductivity	kW/(mK)		
Hot fuid heat capacity	KJ/Kg.K		
Cold fuid heat capacity	KJ/Kg.K		

2

Step c:

Calculate the thermal parameters of H.E. & compare with the design data:

parameters	Unit	Test date	Design data
Heat duty	kW		
Hot fluid side P drop	Bar		
Cold fluid side P drop	Bar		
Temp. Range hot fluid	Deg. C		
Temp. Range cold fluid	Deg. C		
Capacity ratio , R	-		
Effectiveness , S	-		
Corrected LMTD	Deg. C		
H.T.Coeff. , U	$KW/(m^2.K)$		

Step D:

1) heat duty , $Q = Q_s + Ql$

Qs = sensible heat , Ql = latent heat

For sensible heat

Qs = (m x Cp x dT)hf

Qs =(m x Cp x dT)cf

For latent heat

	Ql = (m x latent heat)hf Ql = (m x latent heat)cf 2) Hot fluid side P drop , (dP)hf = Pi –Po 3) Cold fluid side P drop , (dP)cf = Pi –Po 4) Temp. Range hot fluid , dT = Ti - To 5) Temp. Range cold fluid , dt = ti – to 6) Capacity ratio , R = (Ti- To) / (to – ti) 7) Effectiveness , S = (to- ti) / (Ti –ti) 8) LMTD: LMTD for counter current flow LMTD for co-current flow Correction factor for LMTD, $F = \frac{(R + 1)^{1/2} \times \ln [(1 - S R) / (1 - S)]}{(1 - R) \times \ln \{ 2 - S [R + 1 - (R + 1)^{1/2}] / 2 - S [R + 1 + (R + 1)^{1/2} \}}$ 9) Corrected LMTD = F x LMTD 10) Overall heat transfer coeff. , U = Q / (A x Corrected LMTD)	2	