## 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.

<table>
<tr><th>Q No.</th><th>Answer</th><th>marks</th><th>Total marks</th></tr>
<tr><td>Q1 a)<br>(i)</td><td>Energy conservation act 2001<br>The Act empowers the Central Government and, in some instances, State Governments to:<ul><li>specify energy consumption standards for notified equipment and appliances; direct mandatory display of label on notified equipment and appliances;</li><li>prohibit manufacture, sale, purchase and import of notified equipment and appliances not conforming to energy consumption standards;</li><li>notify energy intensive industries, other establishments, and commercial buildings as designated consumers;</li><li>establish and prescribe energy consumption norms and standards for designated consumers;</li><li>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;</li></ul>direct designated consumers to -<ul><li>designate or appoint certified energy manager in charge of activities for efficient use of energy and its conservation;</li><li>get an energy audit conducted by an accredited energy auditor in the specified manner and interval of time;</li><li>furnish information with regard to energy consumed and action taken on the recommendation of the accredited energy auditor to the designed agency;</li><li>comply with energy consumption norms and standards;</li></ul></td><td>One mark each for any four</td><td>4</td></tr>
</table>

| | | | |
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| | • prepare and implement schemes for efficient use of energy and its conservation if the prescribed energy consumption norms and standards are not fulfilled;<br>• get energy audit of the building conducted by an accredited energy auditor in this specified manner and intervals of time; | | |
| (ii) | **Benchmarking**<br>Benchmarking is the process of comparing one's business processes and performance metrics to industry bests or best practices from other companies.<br>**Gross production related:**<br>kWh/MT clinker or cement produced (cement plant)<br>kWh/kg yarn produced (textile unit)<br>kWh/MT , kcal/kg, paper produced (paper plant)<br>kcal/kWh power produced (heat rate of power plant)<br>million cal/MT urea or ammonia (fertilizer plant)<br>kWh/MT of liquid metal output (in a foundry)<br>**utility related :**<br>kW/ ton of refrigeration (on air conditioning plant)<br>% thermal efficiency of a boiler plant<br>% cooling tower effectiveness in a cooling tower<br>kWh/$Nm^3$ of compressed air generated<br>kWh/liter in a diesel power generation plant | 1<br><br><br>1.5<br><br><br><br><br><br><br><br>1.5 | 4 |
| (iii) | **Calorific value**: Is the amount of heat released during the combustion of a specified amount of fuel.<br>**Specific heat:** The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. | 2<br><br>2 | 4 |
| (iv) | **Types of boilers** | One mark | 4 |

| | | | |
|---|---|---|---|
| | • Water tube boiler<br>• Fire tube boiler<br>• Packaged boilers<br>• Stoker fired boiler<br>• Pulverized fuel boiler<br>• FCB boiler | each for any four | |
| b (i) | **Types of fuels**<br>Solid fuels: Coal, Uranium, Wood<br>Liquid fuel : Petroleum products (petrol, diesel, aviation fuel),biodiesel, ethanol<br>Gaseous fuel : LPG, CNG, Biogas, Hydrogen<br>**Storage of fuels**<br>Solid fuels are stored by making piles.<br>Liquid fuels are stored in cylindrical tanks, either above or below the ground<br>Gases flues are stored in cylindrical tanks called as capsules and spherical tanks. | 3<br><br><br><br><br><br>3 | 6 |
| (ii) | **Power factor**<br>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.<br>Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA).<br>**Given data**<br>V = 440 V<br>I = 2.4 A<br>P = 1850 W | 2<br><br><br><br>4 | 6 |

| | | | |
|---|---|---|---|
| | $P = \sqrt{3} \times V \times I \times PF$<br>$PF = P/(\sqrt{3} \times V \times I) = 1850/(\sqrt{3} \times 440 \times 2.4) = 1.2146$ (answer is more than 1 which is not possible, but full marks should be given to correct answer) | | |
| 2 a) | Energy audit is used in the industry because it gives<br>1) true accounting of energy use<br>2) Range of fuels used<br>3) Wastage or loss of fuel in process<br>4) Can minimize resource use<br>5) Can find out energy use to compare with benchmarking | One mark each for any four | 4 |
| b) | **Global Energy Scenario: World's Primary Energy source**<br>In 2005, total worldwide energy consumption was 500 EJ (= $5 \times 10^{20}$ J) with 86.5% derived from the combustion of fossil fuels. This is equivalent to 15 TW (= $1.5 \times 10^{13}$ W) of power. Most of the world energy resources are from the sun's rays hitting earth - some of that energy has been preserved as fossil energy, some is directly or indirectly usable e.g. via wind, hydro or wave power.<br>**Oil**<br>The global proven oil reserve was estimated to be 1147 billion barrels by the end of 2003. Saudi Arabia had the largest share of the reserve with almost 23%. (One barrel of oil is approximately 160 litres)<br>**Coal**<br>The proven global coal reserve was estimated to be 9,84,453 million tonnes by end of 2003. The USA had the largest share of the global reserve (25.4%) followed by Russia (15.9%), China (11.6%). India was 4$^{th}$ in the list with 8.6%.<br>**Gas** | 4 | 4 |

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| | The global proven gas reserve was estimated to be 176 trillion cubic meters by the end of 2003. The Russian Federation had the largest share of the reserve with almost 27%. | | |
| c) | (see table below) | 4 | 4 |
| d) | **ENCON recommendations**<br>• Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speed drives<br>• Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.<br>• Moderation of chilled water temperature for process chilling needs<br>• Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption<br>• Adoption of task lighting in place of less effective area lighting<br>• Eliminate steam leakages by trap improvements<br>• Maximise condensate recovery | One mark for each for any four | 4 |

Table for c):

| Sr No | Non conventional energy sources | Conventional energy sources |
|---|---|---|
| 1 | These sources can renew again and again. | These sources are exhaustible after use. |
| 2 | These sources are pollution free. | These sources are creating pollution. |
| 3 | Capital investment is more but fuel cost zero for power generation | Capital investment is less but fuel cost is more for power generation |
| 4 | e.g Solar, Wind, Biomass, Hydro | e.g Coal, crude oil, Gas |

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| | • Adopt combustion controls for maximizing combustion efficiency<br>• Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist. | | |
| e) | LMTD : The LMTD is a logarithmic average of the temperature difference between the hot and cold streams at each end of the exchanger. The larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties.<br><br>Parallel flow<br>$= (T_{hin}-T_{cin}) - (T_{hout}-T_{cout}) / [\ln(T_{hin}-T_{cin}) - (T_{hout}-T_{cout})]$<br><br>Conunter flow<br>$= (T_{hin}-T_{cout}) - (T_{hout}-T_{cin}) / [\ln(T_{hin}-T_{cout}) - (T_{hout}-T_{cin})]$ | 2<br><br><br><br><br>1<br><br>1 | 4 |
| Q3 a) | **Biomass**<br>Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-based materials. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.<br><br>**Types of biomass**: Wood remains the largest biomass energy source examples include forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips and even municipal solid waste.<br>In the second sense, biomass includes plant or animal matter that can be | 1<br><br><br><br><br><br>3 | 4 |

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| | converted into fibers or other industrial chemicals, including biofuels.<br>Industrial biomass can be grown from numerous types of plants, including miscanthus, switchgrass, hemp, corn, poplar, willow, sorghum, sugar cane,bamboo, and a variety of tree species, ranging from eucalyptus to oil palm (palm oil). | | |
| b) | **Fuel cell**<br>Construction:<br>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 created, which can be used to power electrical devices, normally referred to as the load.<br>Working:<br>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. | 4 | 4 |

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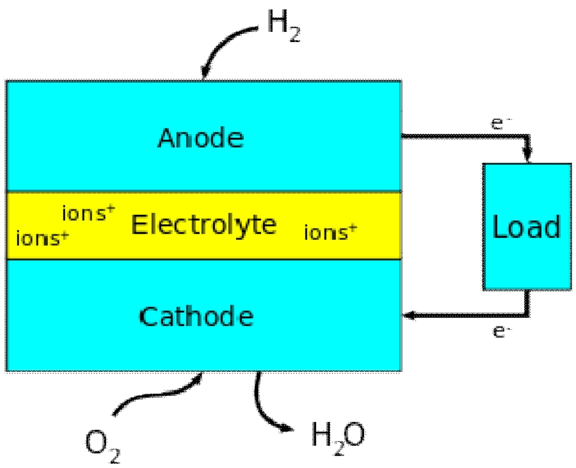
| | <br> | | |
| c) | **Performance assessment of pump:**<br>1) flow measurement by any one method<br>2) determination of total head:<br>Suction head ($h_s$)<br>Discharge head ($h_d$)<br>3) determination of hydraulic power (liquid H.P.)<br>Ph = Q x (hd – hs) x density of the fluid<br>4) measurement of motor input power<br>5) pump shaft power<br>Ps = Pm x efficiency of motor<br>6) pump efficiency<br>Pump efficiency = H.P / pump shaft power | 4 | 4 |
| d) | Types of heat exchange:<br>**By consruction:**<br>Shell & tube HE<br>Plate HE | 3 | 4 |

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| | Regenerative HE<br>Adiabatic wheel HE<br>Fluid HE<br>Scraped surface HE<br>Kettle or reboiler type HE<br>U-tube HE<br>Double pipe HE<br>Finned tube HE<br>Griphide block HE.<br><br>**By flow:**<br>Co-current or parallel flow H.E.<br>Counter current flow H.E.<br>Cross flow H.E. | 1 | |
| e) | **Power available in wind**<br>The kinetic energy (**KE**) of an object (or collection of objects) with total mass **M** and velocity **V** is given by the expression:<br>$KE = 1/2\ M\ V^2$<br>Now, for purposes of finding the kinetic energy of moving air molecules (i.e.:wind), let's say one has a large air parcel with the shape of a huge hockey puck: that is, it has the geometry of a collection of air molecules passing though the plane of a wind turbine's blades (which sweep out a cross-sectional area **A**), with thickness (**D**) passing through the plane over a given time. The volume (**Vol**) of this parcel is determined by the parcel's area multiplied by its thickness:<br>$Vol = A\ D$ | 4 | 4 |

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| | Let ρ (the greek letter 'rho') represent the density of the air in this parcel. Note that density is mass per volume and is expressed as:<br>$$\rho = M / Vol$$<br>and a little algebra gives: $M = \rho\ Vol$<br>Now let's consider how the velocity (**V**) of our air parcel can be expressed. If a time **T** is required for this parcel (of thickness **D**) to move through the plane of the wind turbine blades, then the parcel's velocity can be expressed as<br>$$V = D / T,$$<br>and a little algebra gives<br>$$D = V\ T$$<br>Let's make some substitutions in expression no. 1 **(KE = 1 / 2 M $V^2$)**<br>Substitute for **M** (= **ρ Vol** ) to obtain:<br>$$KE = 1/2\ (\rho\ Vol)\ V^2$$<br>And **Vol** can be replaced by **A D** to give:<br>$$KE = 1/2\ (\rho\ A\ D)\ V^2$$<br>And **D** can be replaced by **V * T** to give**:**<br>$$KE = 1/2\ (\rho\ A\ V\ T)\ V^2$$<br>Leaving us with:<br>$$KE = 1/2\ \rho\ V^3\ A\ T$$<br>Now, power is just energy divided by time, so the power available from our air parcel can be expressed as :<br>$$P = KE / T$$<br>$$= (1/2\ \rho\ V^3\ A\ T) / T$$<br>$$P = 1/2\ \rho\ V^3\ A$$ | | |

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| Q4a)(i) | **Energy conservation**<br>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. | 2 | 4 |
| | **Importance**<br>a) To reduce imports of energy and reduce the drain on foreign exchange.<br>b) To improve exports of manufactured goods (either lower process or increased availability helping sales) or of energy, or both.<br>c) To reduce environmental pollution per unit of industrial output - as carbon dioxide, smoke, sulphurdioxide, dust, grit or as coal mine discard for example.<br>d) Thus reducing the costs that pollution incurs either directly as damage, or as needing, special measures to combat it once pollutants are produced.<br>e) Generally to relieve shortage and improve development. | 2 | |
| ( ii) | **Benefits of energy audit:**<br>1. Energy audits will evaluate your facility "as a whole", their goal is not to evaluate single measures but to consider a wide range of available alternatives (Electrical, Mechanical, Envelope and Water).<br>2. The audit will not only inform you of opportunities but provide you with | One mark each for any four | 4 |

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| | financial analysis. This will enable prioritization based on financial benefit and return on investment.<br>3. Provide you with solid, easy to understand technical information regarding the proposed energy conservation measures.<br>4. A good quality audit will analyze your historical energy use and find potential issues using statistical methods.<br>5. Provide you with emissions analysis to help you understand the benefits of your decisions from an environmental standpoint.<br>6. Understand where energy is used and which areas are worth focusing on the most (energy hogs).<br>7. Provide you with benchmark information to help you understand your energy use performance compared to others in your field and area.<br>8. The cost-benefit analysis of the audit report would help decision makers prioritize opportunities and evaluate them as investments. These indicators would include, rate of return, net present value, cash flow analysis and payback. Furthermore, your auditor should be able to help you understand the effects of borrowing costs on the above indicators. | | |
| (iii) | Energy saving in boiler<br>• Reducing excess air<br>• Installing economizer<br>• Reducing scale and deposits<br>• Reducing blow down<br>• Recovering waste heat from blow down<br>• Stopping dynamic operation<br>• Reducing boiler pressure<br>• Operating at peak efficiency | One mark each for any four | 4 |

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| | • Preheating combustion air<br>• Switching from steam to air atomization<br>• Switching to lower cost fuel | | |
| (iv) | **Performance assessment of H.E.:**<br>Step A:<br>Monitoring and reading of steady state parameters of the H.E. under evaluation are tabulated as below: | 4 | 4 |

| parameters | units | inlet | Outlet |
|---|---|---|---|
| Hot fluid flow | Kg/h | | |
| Cold fluid flow | Kg/h | | |
| 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:

| parameters | unit | Inlet | outlet |
|---|---|---|---|
| Hot fluid density | Kg/h | | |
| Cold fluid density | Kg/h | | |
| Hot fuid viscosity | MPas | | |
| cold fuid | MPas | | |

| | | | |
|---|---|---|---|
| viscosity | | | |
| 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 | | |

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,

$$F = \frac{(R + 1)^{1/2} \text{ X } \ln [ (1 - S R) / (1 - S) ]}{(1 - R) \times \ln \{ 2 - S [R + 1 - ( R + 1 )^{1/2}] / \; 2 - S [R + 1 + (R + 1)^{1/2} \}}$$

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| | 9) Corrected LMTD = F x LMTD<br>10) Overall heat transfer coeff. , U = Q / ( A x Corrected LMTD) | | |
| b) (i) | **Specific heat**: The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius.<br><br>**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.<br><br>Given data<br>T1= 100$^o$C<br>T2= 40$^o$C<br>$\lambda$ = 540 kca/kg<br>Cp = 1 kcal/kg<br>**For 1 kg steam**<br>Q = m[$\lambda$ + (Cp $\Delta$T)]= 1[540+(1x60)] = 600 Kcal<br>Q= 600 x 4.184 = 2510.4 KJ<br>(students answer may change as per quantity of mass taken) | 1<br><br>1<br><br>2<br><br>1 | 6 |
| (ii) | **Biogas**<br>**Construction**<br>It consits of inlet tank, digester and outlet tank. Sluury is prepeared in inlet tank. Mass is digeated in digester. Gas is collected at the top dome. Digested mass comes our from outlet tank. Gas is taken out by outlet pipe from top.<br>**Working**<br>• The feed material is mixed with water in the influent collecting tank The fermentation slurry flows through the inlet into the digester. | 1<br><br>3 | 6 |

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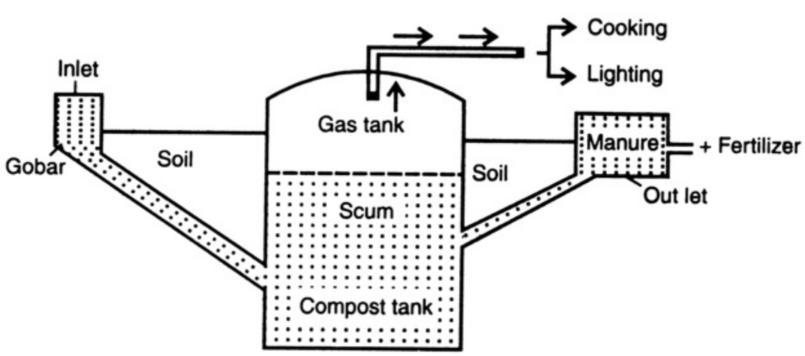
| | • The bacteria from the fermentation slurry are intended to produce biogas in the digester.<br>• The process of anaerobic digestion occurs in a sequence of stages involving distinct types of bacteria.<br>• Hydrolytic and fermentative bacteria first break down the carbohydrates, proteins and fats present in biomass feedstock into fatty acids, alcohol, carbon dioxide, hydrogen, ammonia and sulfides.<br>• This stage is called "hydrolysis" (or "liquefaction").<br>• Next, acetogenic (acid-forming) bacteria further digest the products of hydrolysis into acetic acid, hydrogen and carbon dioxide.<br>• Methanogenic (methane-forming) bacteria then convert these products into biogas.<br>• The combustion of digester gas can supply useful energy in the form of hot air, hot water or steam.<br><br> | 2 | |
| Q 5 a) | **Simple payback period**: Payback period is the time in which the initial cash outflow of an investment is expected to be recovered from the cash inflows generated by the investment. It is one of the simplest investment appraisal techniques.<br>***Formula of payback period:*** | 2 | 8 |

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| | $$\text{Payback period} = \frac{\text{Investment required for a project}}{\text{Net annual cash inflow}}$$ Importance: According to this method, the project that promises a quick recovery of initial investment is considered desirable. If the payback period of a project computed by the above formula is shorter than or equal to the management's maximum desired payback period, the project is accepted otherwise it is rejected. For example, if a company wants to recoup the cost of a machine within 5 years of purchase, the maximum desired payback period of the company would be 5 years. The purchase of machine would be desirable if it promises a payback period of 5 years or less. | 3 | |
| | **Given data:** Investment : 45,000/- Annual saving : 27000/- Annual maintenance: 12000/- Simple payback period = Total investment/ (annual saving – annual maintenance) = 45000/(27000-12000) = 3 years | 3 | |
| b) | **NPSH** The value which the pressure in the pump suction exceeds the liquid vapour pressure, is expressed as a head of liquid and referred to as Net positive Suction Head. | 3 | 8 |
| | A throttling device is often used as a mechanical method to reduce the flow rate in a pumping system. Applying a throttling device to the system changes the pump curve, as shown in Figure. This reduces the flow of the system, but the pump curve is not altered and continues to operate at full speed. This | 5 | |

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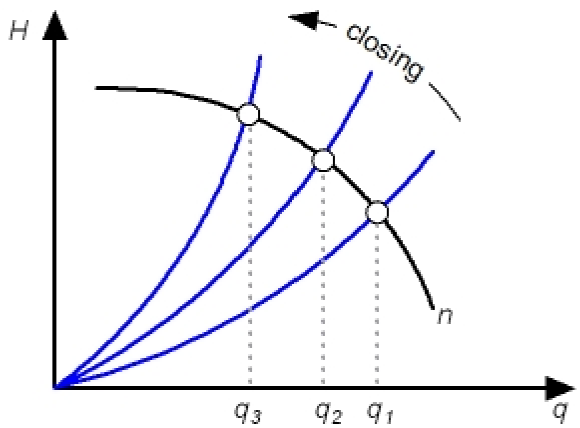
| | creates mechanical stresses-excessive pressure and temperature-on the pump system, which can cause premature seal or bearing failures. More importantly, this also consumes a tremendous amount of energy. Hence throttling should be avoided.<br><br> | | |
| c) | **PAT scheme**<br>The Perform Achieve Trade (PAT) is an innovative, market-based trading scheme announced by the Indian Government in 2008 under its National Mission on Enhanced Energy Efficiency (NMEEE) in National Action Plan on Climate Change (NAPCC).<br>It aims to improve energy efficiency in industries by trading in energy efficiency certificates in energy-intensive sectors .<br>The 2010 amendment to the Energy Conservation Act (ECA) provides a legal mandate to PAT. Participation in the scheme is mandatory for Designated Consumers under the ECA. It is being administered by the BEE that sets mandatory, specific targets for energy consumption for larger, energy-intensive facilities.<br>The PAT Scheme is being implemented in three phases- the first phase runs | 4 | 8 |

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| | from 2012-2015 covering 478 facilities from eight energy-intensive sectors, namely aluminum, cement, chor-alkali, fertilizer, iron and steel, pulp and paper, textiles and thermal power plants. This accounts for roughly 60% of India’s total primary energy consumption. It targets energy consumption reductions of 6.6 million tons of oil equivalent in the 478 covered facilities.<br>The scheme imposes mandatory specific energy consumption targets on the covered facilities with less energy efficient facilities having a greater reduction target than the more energy efficient ones.<br>The PAT scheme establishes plant-specific targets rather than a sectoral target, with the average reduction target being 4.8% that is to be achieved by the end of the first phase (2015).<br>The approach is as follows :<br>• Specification of specific energy consumption (SEC) norm for each designated consumer in the baseline year and in the target year ;<br>• Verification of the SEC of each designated consumer in the baseline year and in the target year by an accredited verification agency;<br>• Issuance of Energy Savings Certificates (ESCerts) to those designated consumers who exceed their target SEC reduction;<br>• Trading of ESCerts with designated consumers who are unable to meet their target SEC reduction after three years;<br>• 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.<br>• The scheme is being designed and implemented by the Bureau of Energy Efficiency (BEE), under the Ministry of Power of India. A newly established company Energy Efficiency Services Ltd (EESL) | 4 | |

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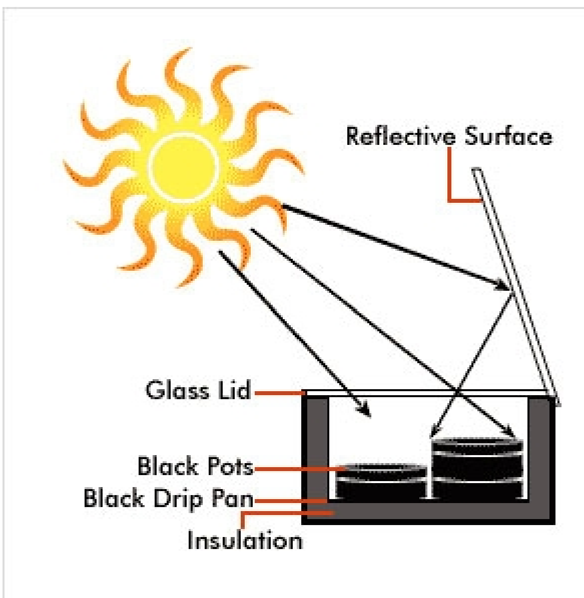
| | will administer the trading .<br>Details of the subsequent phases of the PAT scheme are slim but early signs hint at a broadening of the scheme to include other energy-intensive sectors like petroleum refineries, petrochemicals, chemicals etc. The government is also considering the tightening of targets. | | |
| Q6 a) | **Box type solar cooker**<br>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.<br>**1. Outer Box :** The outer box of a solar cooker is generally made of G.I. or aluminum sheet or fibre reinforced plastic.<br>**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.<br>**3. Double Glass Lid:** A double glass lid covers the inner box or tray. This cover is 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.<br>**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.<br>**5. Mirror:** Mirror is used in a solar cooker to increase the radiation input | 4 | 8 |

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.




**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.

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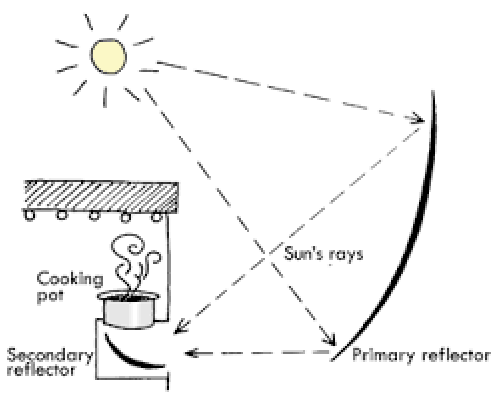
| | • The mirror reflector is set in such a way to reflect the solar radiation falling on it to the cooker box. Up to four black painted vessels are placed inside the box.<br>• The cooker takes 1½ to 2 hours to cook items such as rice, lentils and vegetables.<br>• The cooker may also be used to prepare 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.<br>• It, however cannot be used for frying or chapatti making.<br>**Parabolic Solar Cooker**<br><br><br>The major components of the cooker are as below:<br>• **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. | 4 | |

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| | | • **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.<br>• 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.<br>• The solar cooker has an aperture diameter of 1.4 meter and a focal length of 0.28 meter.<br>• 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.<br>• It has a delivery power of about 0.6 KW that can boil 2 to 3 liters of water in half an hour.<br>• The temperature achieved at the bottom of the vessel could range from 350 to $400^0$C which is sufficient for roasting, frying and boiling.<br>• 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.<br>• 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. | | |

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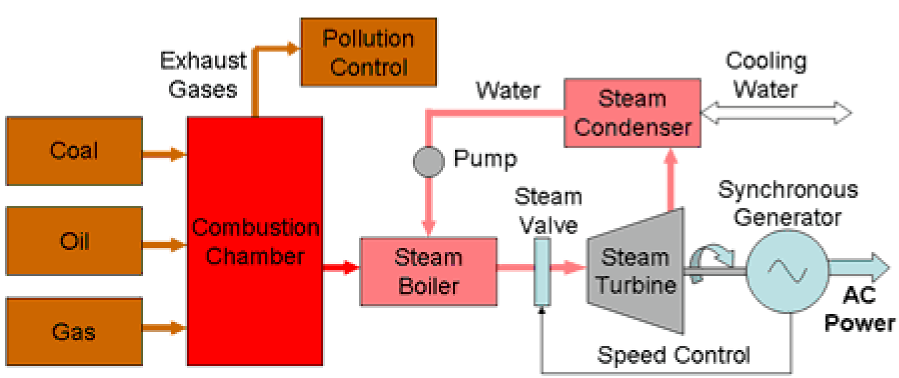
| | • The cooker can save up to 10 LPG cylinders a year on full use in small establishments.<br>• The metallic structure reflecting sheets may, however, have to be replaced once in 5 years. | | |
| b) | **Solid bio fuels**<br>a) Wood – Cooking, water heating<br>b) Charcoal – Cooking<br>c) Briquettes – Industrial boilers<br>d) Agro waste – Small industries | 2 | 8 |
| | **Liquid bio fuels**<br>a) Ethanol – used for mixing in petrol<br>b) Biodiesel- In diesel engines<br>c) Wood pyrolysis product- Industrial use | 3 | |
| | **Gases bio fuel**<br>a) Marsh gas – As a fuel<br>b) Biogas – As a fuel<br>c) Wood gas(syngas) – as a fuel<br>d) Hydrogen- as a fuel | 3 | |
| c) | **Electricity generation form thermal power plant**<br> | 4 | 8 |

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| | 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. | 4 | |