

Name : _____

Appl. No.: _____

Seat No. : _____

**25th NATIONAL EXAMINATION FOR CERTIFICATION OF
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2025**

PAPER - 1 : GENERAL ASPECTS OF ENERGY MANAGEMENT & ENERGY AUDIT

Date : 27-09-2025 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

General instructions :

- o Ensure that this question paper contains **10** printed pages.
- o Verify that the paper consists of **64** questions.
- o The question paper is divided into three sections (Section I, Section II and Section III).
- o All questions in all three sections are compulsory.
- o All parts of a question must be answered together in one place.

Section – I : OBJECTIVE TYPE

Marks: 50 x 1 = 50

- (i) Answer all **50** questions
- (ii) Each question carries **One** mark
- (iii) Shade the appropriate oval in "**SECTION – I**" of the Main Answer Booklet using a **blue or black ballpoint pen**.

1.	Select the correct statement about the Critical Path Method (CPM): a) CPM is a deterministic model that does not take into account variation in completion time b) CPM is a probabilistic model that takes into account variation in completion time c) CPM is a probabilistic model that does not take into account variation in completion time d) CPM is a deterministic model that takes into account variation in completion time
2.	Acceptable delay time (slack time/float) is equal to: a) Time between Earliest Finish and Latest Finish b) Time between Earliest Start and Latest Start c) Both a) and b) d) None of the above
3.	The objectives of Standards & Labeling (S&L) programme aim to: a) Set sulphur standards for coal-fired power plants b) Provide informed choice about energy saving c) Enforce penalties on renewable obligation non-compliance d) Fix tariff slabs for power-intensive industries
4.	Is the activity critical, given ES = 8 days and LS = 10 days? a) Yes b) No c) More details required d) Next activity details required

SEAL

5.	The relation between gauge pressure (pg), system pressure (ps), and atmospheric pressure (pa) is: a) $pg = ps + pa$ c) $ps = pg - pa$ b) $pg = ps - pa$ d) $pa = ps + pg$
6.	Availability Based Tariff (ABT) was introduced in India to: a) Encourage solar roof-top for industries b) Reduce dependence on oil imports c) Subsidise rural electrification d) Improve grid discipline and frequency control
7.	In a 'Guaranteed Savings' ESCO project, the ESCO company would not be involved in: a) Project design b) Project finance c) Project implementation d) Verifying energy savings
8.	The Reserves-to-Production (R/P) ratio of coal in India is high compared to oil and gas. This implies: a) Coal reserves can provide secure supply for decades b) India has surplus oil reserves to meet its demand c) Natural gas is India's most secure long-term option d) India's coal imports will vanish completely
9.	The use of Purchasing Power Parities (PPPs) in energy intensity calculations ensures that: a) GDP comparisons reflect only exchange rate fluctuations b) GDP of all countries is valued at a uniform price level, showing only differences in real economic volume c) GDP is measured exclusively in domestic currency terms d) GDP comparisons ignore differences in goods and services consumed
10.	Which statement best describes the relationship between energy conservation and energy efficiency?: a) Energy conservation and energy efficiency are identical and interchangeable terms b) Energy efficiency refers to reducing energy intensity per unit of output, while energy conservation refers to reducing overall consumption. c) Energy efficiency requires lowering comfort levels, while energy conservation does not d) Energy conservation excludes energy efficiency measures from its scope
11.	"Designated Consumers" under EC Act are classified mainly because: a) They are exempted from energy audits b) They focus only on renewable generation c) They represent small artisan industries d) They are users of energy in an energy intensive industry

12.	Sankey diagrams help energy managers by: a) Prioritizing improvements based on visualized energy losses b) Reducing the need for energy audits c) Replacing thermodynamic calculations d) Eliminating the use of performance indicators
13.	Which instrument measures power factor directly? a) Ammeter b) Wattmeter c) Lux meter d) Power analyzer
14.	What is the mission of the Bureau of Energy Efficiency (BEE) under the Energy Conservation Act 2001? a) To regulate electricity tariffs at the national level b) To promote renewable energy by providing capital subsidies c) To develop policies and strategies that reduce the energy intensity of the Indian economy d) To license only energy auditors and energy managers
15.	What is the main purpose of the Energy Conservation Building Code (ECBC)? a) To set minimum energy efficiency standards for commercial buildings b) To fix electricity tariffs for buildings c) To mandate use of only renewable energy in construction d) To regulate real estate prices
16.	"Daylight harvesting" in lighting systems means: a) Collecting solar energy for night lighting b) Using flat plate collectors for heating c) Adjusting artificial lighting based on natural daylight d) Storing energy in battery banks
17.	In a cumulative sum chart, a horizontal graph indicates: a) Nothing can be said b) Energy consumption is reduced c) Specific energy consumption is increasing d) Actual and calculated energy consumption are the same
18.	Which of the following is non-commercial energy? a) Lignite b) LPG c) Solar energy for water heating d) Hydro power

19.	Power rating of an electrical heater consuming 12,000 J/min is: a) 12 W b) 100 W ☒ c) 200 W d) 12,000 W
20.	Moles of water in 54 grams: a) 3 b) 4 c) 5 d) 6
21.	The main purpose of Performance Measurement and Verification (PMV) is to: a) Establish new project costs b) ☒ Ensure that guaranteed savings have been achieved c) Increase the baseline consumption d) Eliminate the need for utility bills
22.	ROI for an investment of ₹ 1,00,000 with an annual return of ₹ 20,000 per year is ____ a) 1% b) 10% ☒ c) 20% d) 200%
23.	Biomass gasifier using 1 kg wood (4,000 kCal/kg) producing 2 m ³ gas (1,000 kCal/m ³). What would be the efficiency? a) 25% ☒ b) 50% c) 75% d) 100%
24.	Mean molecular weight of air (77% N ₂ , 23% O ₂ by weight) is ____ grams. a) 26.8 b) 27.8 ☒ c) 28.8 d) 29.8
25.	Energy saving through DSM is treated as equivalent to: ☒ a) A reduction in electricity tariff b) New additions on the supply side in MWs c) Import of cheaper electricity d) Government subsidies
26.	What is the main aim of the Accelerated Power Development and Reform Programme (APDRP)? a) To eliminate subsidies for agricultural consumers b) To privatize all power plants in India c) To promote only renewable energy in the power sector ☒ d) To cut AT&C losses by audits and system improvements
27.	Resistance of 250 V incandescent lamp drawing 0.5 A is _____. a) 5,000 Ω ☒ b) 500 Ω c) 50 Ω d) 5 Ω
28.	A process receives 1000 kg/hr of raw material. The hourly outputs are 700 kg of product, 200 kg of waste, and 50 kg stored. What is the unaccounted loss? a) 100 kg/hr b) 150 kg/hr c) 200 kg/hr ☒ d) 50 kg/hr
29.	A boiler receives 100 MJ of fuel energy. The steam output is 70 MJ, the flue gas loss is 20 MJ and the radiation plus unaccounted loss is 10 MJ. What is the boiler efficiency? a) 65% b) 60% ☒ c) 70% d) 75%

30.	1 tonne of oil equivalent:	a) 41,868 MJ	b) 1,000 kCal	c) 1,000 kWh	d) 1,000 BTU
31.	Maximum specific heat among the following:	a) Water	b) Lead	c) Mercury	d) Iron
32.	Ozone depletion is mainly due to:	a) Oxygen	b) Methane	c) Chlorofluorocarbons	d) Carbon dioxide
33.	The first step in an energy action plan is:	a) Recognition of achievements	b) Designing monitoring reports	c) Selecting new technologies	d) Top management commitment
34.	Heat required for cooling 2000 kg of water for ΔT of 10°C _____	a) 2,000 kCal	b) 20,000 kCal	c) 200 kCal	d) 2×10^5 kCal
35.	Calculate the quantity of water evaporated when 100 kg of feed containing 6% solids is concentrated to 30% solids.	a) 600 kg	b) 180 kg	c) 80 kg	d) 800 kg
36.	In force field analysis, which approach is usually more effective for achieving a goal?	a) Strengthening forces that are already positive	b) Minimising negative forces that act as barriers	c) Ignoring external factors and focusing only on internal ones	d) Changing the organisational goal
37.	Which of the following is NOT a conventional financing option?	a) Debt financing	b) Performance contracting	c) Retained earnings	d) Stock buyback
38.	Two projects: X (IRR=40%, NPV= ₹50,000/-) and Y (IRR=30%, NPV= ₹1,20,000/-) having same life, no finance limit. Choose the best project.	a) X	b) Y	c) Cannot decide	d) Question invalid
39.	Term for asset value decrease over time:	a) Discounting	b) Inflation	c) Depreciation	d) Compounding
40.	In Total Productive Maintenance (TPM), which of the following is not one of the six big losses that lower equipment efficiency?	a) Breakdowns	b) Idling and minor stoppages	c) Reduced speed	d) Excessive overtime hours

PIP

41.	Fixed energy consumption can be determined from: a) Bar chart b) Vertical line chart c) Pie chart d) XY coordinate system
42.	Carbon capture from point sources and storage is called: a) Carbon sequestration b) Carbon sink c) Carbon fixation d) Carbon adsorption
43.	Why is an energy baseline established in Monitoring and Targeting (M&T)? a) To record only monthly electricity bills b) To fix a reference point for measuring energy performance improvements c) To eliminate the need for energy performance indicators d) To avoid sharing information with managers and stakeholders
44.	Life-cycle costing is better than simple purchase cost because it: a) Includes operation, maintenance and energy costs over life b) Ignores maintenance costs c) Forces single-supplier bidding d) Cuts down procurement cycle time
45.	Producer gas consists of: a) CO, H ₂ , CH ₄ b) CO, CH ₄ c) CO, H ₂ d) Only CH ₄
46.	Work Breakdown Structure (WBS) is mainly used for: a) Combining small tasks into one large project b) Dividing complex projects into simpler, manageable tasks c) Preparing cost estimation only d) Eliminating tasks from the project
47.	What is a major limitation of the Gantt chart in project management? a) It does not show the duration of activities b) It does not clearly show logical dependencies between activities c) It cannot be used for construction projects d) It requires advanced statistical methods for preparation
48.	In a project network diagram, why is a dummy activity used? a) To represent an activity with very small duration b) To show logical dependency between activities with the same start and end nodes c) To reduce the total project duration d) To allocate additional resources to critical activities

49.	Solar radiation consists of: a) X-rays, Gamma rays, and Microwaves b) Ultra-violet, Visible, and Infra-red radiation c) Visible, Infra-red, and Radio waves d) Ultra-violet, X-rays, and Cosmic rays
50.	Which of the following are basic objectives of sustainable development? a) Economic security and prosperity b) Social development and advancement c) Environmental sustainability d) All of the above

..... End of Section I

Section - II : SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

- (i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S-1	The facility has a connected load of 500 kW and currently has a contract demand of 500 kVA. The monthly maximum demand recorded is consistently around 350 kW at 0.85 power factor. The utility imposes a penalty of ₹ 350 per excess kVA/month, if recorded demand exceeds contract demand. The demand charge is ₹ 300 per kVA/month. a) Determine current demand in kVA. 1 Mark b) The minimum billing demand is 80% of contract demand. Calculate excess demand charges paid above minimum billing demand per month. 2 Marks c) Calculate minimum power factor required to avoid payment of excess demand charges over minimum billing demand. 2 Marks
S-2	A food processing unit uses the following per day: - LPG consumption: 200 kg/day (Calorific Value = 11,000 kCal/kg, rate ₹ 90/kg) - DG backup: 100 kWh/day is used when the grid fails, using diesel at ₹ 95/litre with a specific fuel consumption of 260 ml/kWh. (Calorific value = 10,000 kCal/litre) - Electrical energy: 1,200 kWh/day at ₹ 7.5/kWh Each 1 Mark a) Convert the LPG energy to kWh equivalent. b) Calculate the thermal energy input (in kCal) required by the DG set to produce 100 kWh. c) Calculate the daily energy cost from all 3 sources. d) Calculate the percentage contribution of each energy source to the total energy input (in kWh equivalent). e) Determine the cost share of each energy source in the total energy cost and identify the most economic source among grid power, LPG and DG power.
S-3	An energy audit conducted in a rubber processing unit identifies the following: - A centrifugal pump (motor rating 30 kW) runs continuously for 16 hours/day, 300 days/year. - Measured motor loading = 65%, Motor efficiency = 88%, with no flow control. - A VFD retrofit is proposed, which is expected to reduce energy consumption by 10% due to optimized flow control.

	- Power cost = ₹ 7.0/kWh. - VFD installation cost = ₹ 1,50,000/-. a) Calculate the current annual energy consumption of the motor. 2 Marks b) Estimate the expected annual energy savings from the VFD. 1 Mark c) Calculate the annual cost savings in ₹. 1 Mark d) Determine the simple payback period for the investment. 1 Mark
S-4	A food dryer processes 1,000 kg/hr of wet material with an initial moisture content of 55% (wet basis) and dries it to a final moisture content of 10% (wet basis). - Steam flow: 2,500 kg/hr at 3.5 bar (enthalpy = 660 kCal/kg) - Latent heat of water vaporization = 540 kCal/kg - Specific heat of dry material = 0.45 kCal/kg°C - Drying temperature rise = 60°C - Ignore heat loss and assume 100% steam used for moisture removal and solid heating. Each 1 Mark a) Calculate the mass of bone-dry solid in the feed. b) Calculate the mass of water removed per hour. c) Estimate the energy required to evaporate the moisture. d) Estimate the energy required to heat the dry solids. e) Calculate the total energy input from steam.
S-5	A medium-sized factory installs an energy efficient air compressor system costing ₹ 6,00,000/-. An audit estimates that it will save ₹ 1,80,000/- per year in energy bills for the next 3 years. Annual maintenance is expected to cost ₹ 10,000/- from the second year onward. Assume: Discount rate (cost of capital) is 10% and Salvage value at the end of third year is ₹ 50,000/-. a) Calculate the net annual cash flow from second year onwards. 2 Marks b) Compute the Net Present Value (NPV) of the investment. 2 Marks c) Based on NPV, assess whether the project is economically acceptable. 1 Mark
S-6	A continuous centrifuge separates 36,000 kg of whole milk containing 4% fat in 6-hour period into skim milk with 0.40% fat and cream with 40 % fat. Find out the flow rates of whole milk, cream and skim milk using mass balance.
S-7	a) Define energy intensity. Explain what low and high energy intensity indicate about a country's economy. 3 Marks b) Country A consumes 2000 toe of energy and has a GDP of US\$ 100 million. Country B consumes 2500 toe of energy and has a GDP of US\$ 140 million. Calculate the Energy Intensity of both countries in toe per US\$ million GDP and indicate which country is more efficient in its use of energy. 2 Marks
S-8	What are the benefits of the Critical Path Method (CPM)? Also explain how the Program Evaluation and Review Technique (PERT) differs from CPM.

..... End of Section II

Section - III : LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

- (i) Answer all **Six** questions
- (ii) Each question carries **Ten** marks

PIP	L-1	In a chemical company, variable consumption was measured 2.2 times of the production and the non-production consumption (fixed energy consumption) was observed 10,000 kWh/month. A company has implemented several energy saving initiatives during the previous financial year.
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- a) Calculate energy saving by preparing a CUSUM chart. The actual production and energy consumption observed during the current financial year for the first two quarters is as follows: **8 Marks**

Month	Production (kg)	Actual Energy Consumption (kWh)
April	75000	170000
May	78000	172000
June	85000	185000
July	72000	155000
Aug	71000	153000
Sept	76000	163000

- b) Also mention four names of different financing options for industry. **2 Marks**

- L-2 An industry is exploring two project development options as part of its pursuing energy efficiency strategy. Using the NPV concept, find out the better option. Consider 10% as the discount rate and 5-year as the project life.

Description	Project A	Project B
Capital cost	80,000	100,000
Year	Net Annual Savings (₹)	Net Annual Savings (₹)
1	+ 25,000	+ 35,000
2	+ 25,000	+ 35,000
3	+ 25,000	+ 35,000
4	+ 25,000	+ 35,000
5	+ 25,000	+ 35,000

- L-3 In a chemical company, Natural Gas (NG) is being used to heat 15 kl/hr of water by 15°C. The company is planning to switch this heating process to steam, which is available from neighboring industries.

- a) Work out the feasibility of this option, considering annual operating hours of 6000 hrs. The effective heat of NG is 8500 kCal/m³, the NG rate is ₹ 55/m³, and the density of NG is 0.717 kg/m³. The latent heat of steam is 540 kCal/kg, and the steam rate is ₹ 2.2/kg. **6 Marks**

- b) Also, calculate the tonnes of CO₂ emission for both the options, if 0.2 kg of CO₂ is emitted per kg of steam consumed and the percentage of carbon in NG is 74%. **4 Marks**

- L-4 (a) Construct a CPM diagram for the activities below: **4 Marks**

Activity	Precedence	Duration in weeks
A	Start	3
B	A	4
C	B	1
D	C	3
E	Start	2
F	B	1
Finish	D, E, F	--

- (b) Compute the earliest start, earliest finish, latest start & latest finish of all activities. **3 Marks**

- (c) Identify the critical path and its duration. **3 Marks**

L-5	A foundry operates an induction furnace with a capacity of 5 t/hr, having a specific electrical energy consumption of 620 kWh/t of liquid metal produced. The overall casting yield of the foundry is 60%. After melting and casting, the products are heat treated in an oil-fired furnace which consumes 75 kg of fuel oil per tonne of castings. The gross calorific value of fuel oil is 10,000 kCal/kg. Additional information provided includes auxiliary connected electrical load of 50 kW, transformer efficiency of 98%, oil density of 0.88 kg/liter and average oil price of ₹ 80 per kg. Average castings produced is 45 tonnes per day and the plant is in continuous operation. Using the above data, a) Calculate the total energy consumption per tonne of finished product, expressed as oil equivalent (kg of oil per tonne of finished casting). 7 Marks b) The foundry is receiving additional order to produce 30 tonnes of casting per day. Assess whether the plant can handle additional demand. 3 Marks
L-6	Answer the following questions: Each 2 Marks a) Briefly explain the working principle of a solar PV system. b) If a 1 kW PV system in Chennai operates at an average of 5 peak sun hours/day with 15% efficiency, calculate the daily energy output. c) List the factors that affect the performance of a wind turbine. d) A wind turbine with rotor area 200 m² is installed in an area with average wind speed of 8 m/s. If air density is 1.2 kg/m³, calculate the wind power available in the air stream. e) Briefly explain how biomass is used for electricity generation.

..... End of Section III

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**25th NATIONAL EXAMINATION FOR CERTIFICATION OF
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PAPER - 2 : ENERGY EFFICIENCY IN THERMAL UTILITIES

Date : 27-09-2025 Timings : 14:00-17:00 HRS Duration : 3 HRS Max. Marks : 150

General instructions :

- o Ensure that this question paper contains **11** printed pages.*
- o Verify that the paper consists of **64** questions.*
- o The question paper is divided into three sections (Section I, Section II and Section III).*
- o All questions in all three sections are compulsory.*
- o All parts of a question must be answered together in one place.*

Section - I : OBJECTIVE TYPE

Marks: 50 x 1 = 50

- (i) Answer all **50** questions
- (ii) Each question carries **One** mark
- (iii) Shade the appropriate oval in "**SECTION - I**" of the Main Answer Booklet using a **blue or black ballpoint pen**.

1.	The main advantages of a cogeneration system include: a) Higher overall efficiency b) Simultaneous production of power and heat c) Reduced fuel consumption d) All of the above
2.	The relationship between heat rate and plant efficiency is such that: a) Higher heat rate means higher efficiency b) Lower heat rate means higher efficiency c) Heat rate and efficiency are unrelated d) Both increase together
3.	A metallic radiation recuperator is primarily used to: a) Recover heat from flue gases to preheat combustion air b) Convert radiant heat into electricity c) Cool furnace walls to prevent overheating d) Measure furnace temperature using radiation
4.	Select the correct statement about the benefits of waste heat recovery: a) It increases fuel consumption b) It reduces overall plant efficiency c) It saves energy and reduces operating costs d) It always requires high-grade heat sources

SEAL

5.	Terminal Temperature Difference (TTD) in a steam to water heat exchanger is: a) Inlet temperature difference b) Outlet temperature difference c) Difference of Steam Saturation temperature and outlet water temperature d) Average temperature difference
6.	Select the correct statement about flash steam: a) It is produced by cooling steam below saturation temperature b) It is produced by cooling steam above saturation temperature c) It forms when hot condensate is released to a lower pressure d) It forms when hot condensate is released to a higher pressure
7.	The specific gravity of a fuel is the ratio of: a) Weight of fuel to its volume b) Density of fuel to the density of water c) Volume of fuel to volume of water d) Mass of fuel to its calorific value
8.	Select the correct statement about volatile matter in coal: a) It reduces flame stability in combustion b) It consists of gases released when coal is heated c) It is the same as fixed carbon d) It increases the ash content of coal
9.	The Net Calorific Value (NCV) of a fuel is obtained by: a) Subtracting the heat of vaporization of water from the Gross Calorific Value b) Adding the heat of vaporization of water to the Gross Calorific Value c) Measuring only the sensible heat of combustion products d) Ignoring latent heat losses in the fuel
10.	Which of the following agro fuels typically has the highest moisture content? a) Saw dust b) Paddy husk c) De-oiled bran d) Coconut shells
11.	Select the correct statement about excess air in combustion: a) Excess air always increases boiler efficiency b) Excess air is needed to ensure complete combustion of fuel c) Excess air reduces flue gas losses d) Excess air is less than the theoretical air
12.	In a pulverised fuel boiler, the fuel is burned in : a) Lump form b) Fluidised bed form c) Fine powder form d) None of the above

P2G

13.	Select the correct statement about a supercritical boiler:
	☒ a) It generates steam at pressures above the critical point ☐ b) It always requires a steam drum for separation of steam and water ☐ c) It operates only with natural circulation ☐ d) It produces steam with high moisture content
14.	A thermic fluid heater is primarily used to:
	☒ a) Generate steam at high pressure ☐ b) Heat a mineral oil ☐ c) Produce hot water ☐ d) Produce hot air
15.	A cupola furnace is primarily used for:
	☐ a) Producing cast iron ☒ b) Producing steel ingots ☐ c) Heating non-ferrous metals ☐ d) Producing coke
16.	Select the correct statement about flue gas losses in a reheating furnace:
	☐ a) Flue gas losses decrease with higher flue gas temperature ☒ b) Flue gas losses increase with excess air and higher exhaust temperature ☐ c) Flue gas losses are unaffected by excess air ☐ d) All of the above
17.	The principle of cogeneration is based on:
	☐ a) Using separate systems to produce heat and power ☒ b) Sequential use of energy to produce both electricity and useful heat from the same fuel ☐ c) Converting all heat into electricity ☐ d) Using waste heat only for cooling
18.	Trigeneration refers to the simultaneous production of:
	☒ a) Power, heat and cold ☐ b) Power, heat and steam ☒ c) Power, steam and compressed air ☐ d) Heat, cold and compressed air
19.	The flash point of an oil is the:
	☐ a) Temperature at which the oil ignites spontaneously ☒ b) Lowest temperature at which the oil vapour momentarily ignites on application of a flame ☐ c) Temperature at which the oil starts boiling ☐ d) Temperature at which the oil burns continuously

P2G

20.	Which type of fuel requires lowest amount of excess air for combustion? a) Furnace oil b) LDO ☒ c) Propane ☒ d) Rice Husk
21.	Which among the following does not release any energy during combustion? a) Carbon b) Sulphur ☒ c) Nitrogen d) Hydrogen
22.	Which is the best suited pump for pumping viscous liquid fuel? a) Centrifugal pump ☒ b) Gear pump c) Vertical turbine pump d) None of the above
23.	In a water tube boiler, what is the primary function of the boiler drum? a) To superheat the steam leaving the economizer ☒ b) To separate steam from water and provide storage for steam and water mixture c) To maintain draft inside the furnace by balancing air and flue gas pressure d) To preheat the feedwater before entering the boiler tubes
24.	Deaeration in boilers is primarily carried out to remove: a) Dissolved solids ☒ b) Dissolved gases c) Suspended particles d) Boiler scale
25.	Which of the following best describes the critical point of steam? a) The point where steam condenses to water at standard atmospheric pressure ☒ b) The highest temperature and pressure at which liquid water and steam can co-exist in equilibrium c) The temperature at which steam becomes superheated d) The point where latent heat of vaporization is maximum
26.	Which of the following is preferable for a heating process? a) Wet steam b) Flash steam c) High pressure steam ☒ d) Dry saturated steam
27.	A float steam trap is an example of which type of steam trap? a) Thermodynamic ☒ b) Mechanical c) Thermostatic d) Hydraulic
28.	Which of the following is commonly used as a low-temperature insulating material? a) Calcium silicate ☒ b) Polyurethane c) Magnesia d) Asbestos

29.	The economic thickness of insulation is the thickness at which: a) Heat loss is zero b) Cost of insulation is minimum c) Combined cost (heat loss cost and insulation cost) is minimum d) Heat transfer rate is maximum
30.	Which of the following is a key advantage of Fluidized Bed Combustion (FBC) over conventional combustion systems? a) Lower power requirement for fans b) Reduced emissions of SO_2 and NO_x c) Higher excess air requirement d) Lower combustion efficiency
31.	In a fluidized bed combustion system, the fuel is burned in a bed of: a) Moving metal plates b) Sand, ash or other granular material suspended by air flow c) Rotating drums d) Water-cooled tubes only
32.	In a combined cycle power plant, the waste heat from the gas turbine is used to: a) Preheat the incoming air to the gas turbine b) Generate steam for a steam turbine c) Cool the exhaust gases directly to the atmosphere d) Operate a diesel generator
33.	The effectiveness of a heat exchanger is defined as the ratio of: a) Actual heat transfer to the maximum possible heat transfer b) Heat loss to the surroundings to the total heat input c) Outlet temperature difference to inlet temperature difference d) Actual heat transfer to the total mass flow rate
34.	In pinch analysis, the "pinch point" represents: a) The location in the heat exchanger where fouling is maximum b) The point of minimum temperature difference between hot and cold streams c) The point where heat transfer rate is maximum d) The location where the heat exchanger pressure drop is minimum
35.	The presence of high sulphur in fuels mainly contributes to: a) Reduction in NO_x emissions b) Corrosion and air pollution c) Decrease in net calorific value d) Prevention of slag formation

36.	Why is viscosity of liquid fuels important in combustion systems? a) It determines the fuel's sulphur content b) It affects atomization and burner performance c) It indicates the ash fusion temperature d) It measures the fuel's calorific value
37.	In boilers, natural draft is produced by: a) A steam ejector b) The height and temperature difference in the chimney c) Compressed air d) Vacuum pump
38.	As per Indian Boiler Regulations (IBR), a pipe is defined as a steam pipe if it carries steam at a pressure exceeding a) 1.5 kg/cm ² (gauge) b) 1.5 kg/cm ² (Absolute) c) 2.5 kg/cm ² (gauge) d) 2.5 kg/cm ² (Absolute)
39.	Which of the following is an example of internal water treatment in boilers? a) Deaeration b) Coagulation and filtration c) Sodium Phosphate dosing d) Clarification
40.	In boiler water treatment, Reverse Osmosis (RO) is primarily used to: a) Remove only suspended solids from water b) Remove dissolved salts and impurities c) Increase the alkalinity of feedwater d) Convert hard water into soft water
41.	Which of the following is not a benefit of condensate recovery in a steam system? a) Energy savings b) Reduced water consumption c) Lower water treatment costs d) All of the above
42.	When steam passes through a Pressure Reducing Valve (PRV), its enthalpy: a) Increases b) Decreases c) Remains the same d) Becomes zero
43.	A thermocompressor in a steam system is primarily used to: a) Convert wet steam into dry saturated steam b) Recompress low-pressure steam with high-pressure steam to obtain medium-pressure steam c) Increase the steam generation rate of the boiler d) Reduce steam temperature at constant pressure

44.	Higher excess air in an oil-fired furnace leads to: a) Higher efficiency c) Zero stack losses b) Lower flue gas heat loss ✓d) None of the above
45.	The main benefit of using preheated air for combustion is: a) Reduced furnace temperature c) Increased excess air requirement ✓b) Increased fuel savings d) Higher flue gas temperature
46.	Choose the correct statement about insulating materials: a) Insulating materials have high thermal conductivity ✓b) Insulating materials reduce heat loss c) Insulating materials increase heat transfer rate d) All of the above
47.	Choose the incorrect statement about refractories: a) Refractories are used to withstand high temperatures in furnaces b) Refractories should have low thermal conductivity for insulation purposes ✓c) Refractories should have low melting points for easy shaping d) Refractories must be resistant to thermal shock
48.	Which of the following defines the Gross Calorific Value (GCV) of a fuel? ✓a) Heat liberated after complete combustion including latent heat of water vapor b) Heat available after combustion excluding latent heat of water vapor c) Heat required to raise 1 kg of fuel by 1°C d) Ratio of heat released to air-fuel ratio
49.	Which of the following statements about a fluidized bed boiler is correct? ✓a) It can efficiently burn low-grade fuels with high ash content b) It requires very high combustion temperatures (above 1600°C) c) It operates without any bed material d) It cannot be used for biomass fuels
50.	An extraction condensing turbine is designed to: a) Exhaust all steam to the process at high pressure ✓b) Extract some steam for process use and balance steam for power generation c) Operate only as a back pressure turbine d) Exhaust steam directly to atmosphere

Section - II : SHORT DESCRIPTIVE QUESTIONS**Marks: 8 x 5 = 40**

- (i) Answer all **Eight** questions
 (ii) Each question carries **Five** marks

S-1	A batch furnace uses LPG and draws combustion air at 30°C from the ambient condition. An energy auditor proposes fitting a recuperator to use hot flue gas at 950°C to preheat this air to 400°C. Given Data: <table border="1" data-bbox="438 477 1273 703"> <thead> <tr> <th>Parameter</th><th>Value</th></tr> </thead> <tbody> <tr> <td>Gross Calorific Value (GCV)</td><td>11,500 kCal/kg</td></tr> <tr> <td>Baseline fuel consumption</td><td>50 kg/h</td></tr> <tr> <td>Excess air</td><td>20 %</td></tr> <tr> <td>Stoichiometric air requirement</td><td>15.5 kg air / kg LPG</td></tr> <tr> <td>Specific heat of air & flue gas</td><td>0.24 kCal/kg°C</td></tr> </tbody> </table> Calculate the following: a) Find the % fuel savings from preheating the air to 400°C. 2 Marks b) Find the new LPG consumption after retrofit. 2 Marks c) Calculate the flue-gas exit temperature from the recuperator using an energy balance. 1 Mark	Parameter	Value	Gross Calorific Value (GCV)	11,500 kCal/kg	Baseline fuel consumption	50 kg/h	Excess air	20 %	Stoichiometric air requirement	15.5 kg air / kg LPG	Specific heat of air & flue gas	0.24 kCal/kg°C
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S-2	Match the Following: <table border="0"> <tbody> <tr> <td>a) Topping Cycle</td><td>i) Produces power first, then recovers heat for process use</td></tr> <tr> <td>b) Bottoming Cycle</td><td>ii) Produces power, heat and cooling from the same energy source</td></tr> <tr> <td>c) Heat-to-Power Ratio</td><td>iii) Produces heat first, then uses waste heat to generate power</td></tr> <tr> <td>d) Combined Cycle Plant</td><td>iv) Useful thermal energy to electrical energy output</td></tr> <tr> <td>e) Trigeneration</td><td>v) Uses gas turbine and steam turbine in series</td></tr> </tbody> </table>	a) Topping Cycle	i) Produces power first, then recovers heat for process use	b) Bottoming Cycle	ii) Produces power, heat and cooling from the same energy source	c) Heat-to-Power Ratio	iii) Produces heat first, then uses waste heat to generate power	d) Combined Cycle Plant	iv) Useful thermal energy to electrical energy output	e) Trigeneration	v) Uses gas turbine and steam turbine in series		
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e) Trigeneration	v) Uses gas turbine and steam turbine in series												
S-3	Fill in the Blanks: a) A furnace oil consumption of 250 liters/day, with density 0.96 kg/l and GCV 10,200 kCal/kg, provides a total heat input of _____ kCal/day. b) If the NCV of a fuel is 9,500 kCal/kg and the mass of fuel burned is 500 kg, the total heat energy released is _____ MWh c) For complete combustion of 1 kg of carbon, the theoretical air requirement is _____ kg. d) Calculate % of nitrogen in dry flue gas if 1 kg of hydrogen is completely burned in presence of 34.8 kg of air. e) A coal sample with a GCV of 4,500 kCal/kg and moisture content of 10% has an approximate NCV of _____ kCal/kg, assuming latent heat of vaporization of water = 587 kCal/kg.												
S-4	A 10 TPH forced-draft boiler is tested at a load of 8 TPH. Fuel flow is 0.53 TPH and the fuel GCV is 10,000 kCal/kg. Feedwater temperature is 70°C. The boiler delivers saturated steam at 10 bar(g) at 180°C. Take the specific enthalpy of saturated steam as 664 kCal/kg. a) Calculate the direct efficiency assuming dry saturated steam. 3 Marks b) The indirect method efficiency is 87%, which does not match with the direct method. The auditor claims this difference is due to the wetness of steam. Establish the auditor's claim by calculating the dryness fraction. 2 Marks												

S-5	A boiler has an air preheater whose design and actual conditions are given below:		
	Parameters	Design (°C)	Actual (°C)
	Flue gas Inlet temperature to APH	330	330
	Flue gas outlet temperature from APH	180	210
	Air inlet temperature to APH	40	40
	Air outlet temperature from APH	190	190
Assume the following: specific heat of flue gas and air are equal, there is no heat loss to the surroundings and as per design the mass of flue gas is approximately to the mass of air. Analyze and discuss the deviations between actual operating condition and design condition in air mass flow, flue-gas mass flow and APH heat transfer.			
S-6	If the insulation thickness on a steam pipe is increased from 50 mm to 100 mm, calculate the percentage reduction in heat loss. The surface temperature of the insulation is 70°C for 50 mm thickness and 60°C for 100 mm thickness. Ambient temperature is 35°C.		
S-7	In a food processing industry, steam at 15 kg/cm ² was used to heat 10 TPH of milk from 40°C to 80°C. An energy auditor suggests installing a PRV to reduce steam pressure from 15 kg/cm ² to 3 kg/cm ² . Specific heat of milk is 1.0 kCal/kg/°C.		
	Steam Parameters	Present Condition (Steam Pressure 15 kg/cm ²)	Proposed Condition (Steam Pressure 3 kg/cm ²)
	Sensible heat	200.6 kCal/kg	133.287 kCal/kg
	Latent Heat	465.72 kCal/kg	517.17 kCal/kg
	Dryness Fraction	0.9	To be determined
	a) Determine the outlet moisture percentage when steam passes through the PRV. 3 Marks		
	b) Calculate the steam savings per hour due to this measure. 2 Marks		
S-8	In an oil to water counterflow heat exchanger, hot oil enters at 150°C and leaves at 90°C. Cold water enters at 30°C and leaves at an unknown temperature T _{co} . The Log Mean Temperature Difference (LMTD) for the exchanger is 60°C. Calculate the exit temperature of the water.		

..... End of Section - II

Section - III : LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

- (i) Answer all **Six** questions
(ii) Each question carries **Ten** marks

P2G L-1	A hot liquid waste stream with a flow rate of 4.0 kg/s, an inlet temperature of 80°C, and a specific heat capacity of 4200 J/kg K is utilized in a heat exchanger to recover heat for preheating boiler make-up water. The make-up water enters at 35°C with a flow rate of 3.0 kg/s and the same specific heat capacity of 4200 J/kg K and it is required to leave at 55°C. The heat exchanger has an overall heat transfer coefficient of 850 W/m ² K and heat losses to the surroundings are assumed negligible. Based on these conditions, determine:		
	a) The rate of heat transfer		2 Marks
	b) The exit temperature of the waste stream		6 Marks
	c) The required area of the heat exchanger.		2 Marks

L-2	a) An oil-fired boiler is generating 80 TPH of steam at 88% efficiency, operating 300 days in a year. Management has installed a water treatment plant at an investment of ₹ 1.5 crore to reduce the TDS in boiler feed water from 600 ppm to 200 ppm. The maximum permissible limit of TDS in the boiler is 3000 ppm, and the make-up water is 12%. The temperature of blowdown water is 180°C, and the boiler feed water temperature is 50°C. The calorific value of fuel oil is 10,500 kCal/kg, and the cost of fuel is ₹ 40,000/- per tonne. Calculate the payback period for the investment in the water treatment plant. 6 Marks b) Read the following statements carefully. For each statement, mark "True" if it is correct and "False" if it is incorrect. 4 Marks i) Saturated steam and dry steam mean the same thing in practical usage. ii) Installing a steam trap upside down has no effect on its operation because condensate is removed due to pressure difference only. iii) If a boiler operates with 8% blowdown at full load, reducing it to 4% will proportionally increase steam generation without additional fuel consumption. iv) A Pressure Reducing Valve (PRV) saves energy by converting high-pressure steam to low-pressure steam with lower enthalpy.
L-3	Fill in the Blanks: Each 1 Mark a) In a _____, heat exchange takes place between the flue gases and the incoming air through metallic or ceramic walls. b) The _____ stores heat in brickwork during one part of the cycle and releases it to the incoming cold air during the other part of the cycle. c) A _____ is a rotating porous disk that transfers heat between two separate air streams. d) In a _____, heat transfer occurs through evaporation and condensation of a working fluid inside a sealed container. e) _____ in a boiler recovers waste heat from flue gases to preheat the boiler feedwater. f) A _____ uses a series of thin corrugated plates to separate and transfer heat between two fluids. g) In high-temperature applications where metallic recuperators are unsuitable, _____ tube recuperators can be used to handle gas inlet temperatures up to around 1550°C. h) The equipment with a direct contact heat exchange principle in a high-pressure boiler system is _____. i) A _____ upgrades low-temperature waste heat to a higher temperature using mechanical work. j) Steam generation from gas turbine waste heat is typically carried out through a _____.
L-4	A small-scale industry with an old 2-pass gas fired boiler, operating at 65% efficiency is considering replacing it with a new 3-pass boiler that has an efficiency of 80%. The industry has an average steam load of 8 TPH at 10 kg/cm² with steam enthalpy of 665 kCal/kg and the new boiler is also equipped with an economizer to preheat the feedwater from 35°C to 75°C. The flue gas exit temperature of the old boiler is 160°C and the new boiler's flue gas exit temperature will be 85°C. The total operating hours for the year are 6,000 hrs. The GCV of natural gas is 9,500 kCal/m³. Given the above conditions, calculate the following: a) The annual fuel savings by replacing the old boiler with the new 3-pass boiler. 6 Marks b) Fuel saving due to preheating the feed water. 2 Marks c) Evaluate the % improvement in boiler evaporation ratio if natural gas density is 0.68 kg/m³ 2 Marks

L-5	A chemical plant is considering the following two schemes: Scheme 1: A boiler supplies steam for a condensing turbine as well as for the process heat requirement. The condensing turbine produces 1 MW of electric power with an overall efficiency of 33%. The process requires 3 MW of heat and the boiler efficiency is 80%. Scheme 2: A boiler supplies steam for a back-pressure turbine, which produces 1 MW of electric power with an overall efficiency of 90%. The process heat requirement of 3 MW is met by the back-pressure steam and the boiler efficiency is 75%. Calculate the following: a) Determine the heat input to the boiler (in MW) and energy utilization factor for both the schemes. 6 Marks b) The percentage fuel savings achieved by the energy-efficient scheme compared to the other. 4 Marks																																										
L-6	The operating parameters of the re-heating furnace in a hot rolling mill, both before after improved conditions, are presented below: <table border="1" data-bbox="279 705 1372 1512"> <thead> <tr> <th>Parameter</th><th>Value</th></tr> </thead> <tbody> <tr> <td>Fuel consumption</td><td>2300 litres/hour ✓</td></tr> <tr> <td>Furnace oil density</td><td>0.92 ✓</td></tr> <tr> <td>Furnace oil is pre-heated</td><td>30°C to 105°C</td></tr> <tr> <td>GCV of furnace oil</td><td>10200 kCal/kg ✓</td></tr> <tr> <td>Cost of fuel per ton</td><td>₹ 49,000/-</td></tr> <tr> <td>Exit flue gas temperature after recuperator</td><td>400°C</td></tr> <tr> <td>Specific heat of flue gas</td><td>0.24 kCal/kg°C</td></tr> <tr> <td>Specific heat of steel</td><td>0.12 kCal/kg°C</td></tr> <tr> <td>Billet temperature</td><td>1250°C</td></tr> <tr> <td>Present combustion air preheat temperature</td><td>290°C</td></tr> <tr> <td>Average production</td><td>650 tonnes/day</td></tr> <tr> <td>Average operating hours per day</td><td>12 hours</td></tr> <tr> <td>Annual operation days</td><td>300</td></tr> <tr> <td>Ambient temperature</td><td>30°C</td></tr> <tr> <td>Oxygen in flue gas</td><td>11 % ✓</td></tr> <tr> <td>Theoretical air requirement</td><td>14 kg/kg fuel ✓</td></tr> <tr> <td colspan="2">Improved Condition:</td></tr> <tr> <td>Oxygen in flue gas</td><td>5 %</td></tr> <tr> <td>Combustion air preheat temperature</td><td>390°C</td></tr> <tr> <td>Flue gas temperature after improving recuperator performance</td><td>340°C</td></tr> </tbody> </table> Calculate the following: a) Present Specific Energy Consumption (SEC) in litres/ton 1 Mark b) Fuel savings achieved after improvements in recuperator in per tonne of metal 6 Marks c) New Specific Energy Consumption (SEC) in litres/ton 1 Mark d) Annual savings in Rs. Lakhs 2 Marks	Parameter	Value	Fuel consumption	2300 litres/hour ✓	Furnace oil density	0.92 ✓	Furnace oil is pre-heated	30°C to 105°C	GCV of furnace oil	10200 kCal/kg ✓	Cost of fuel per ton	₹ 49,000/-	Exit flue gas temperature after recuperator	400°C	Specific heat of flue gas	0.24 kCal/kg°C	Specific heat of steel	0.12 kCal/kg°C	Billet temperature	1250°C	Present combustion air preheat temperature	290°C	Average production	650 tonnes/day	Average operating hours per day	12 hours	Annual operation days	300	Ambient temperature	30°C	Oxygen in flue gas	11 % ✓	Theoretical air requirement	14 kg/kg fuel ✓	Improved Condition:		Oxygen in flue gas	5 %	Combustion air preheat temperature	390°C	Flue gas temperature after improving recuperator performance	340°C
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..... End of Section III

Seat No. : _____

Date : 28-09-2025 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

- o Ensure that this question paper contains **11** printed pages.
- o Verify that the paper consists of **64** questions.
- o The question paper is divided into three sections (Section I, Section II and Section III).
- o All questions in all three sections are compulsory.
- o All parts of a question must be answered together in one place.

Marks: 50 x 1 = 50

- (i) Answer all **50** questions
- (ii) Each question carries **One** mark
- (iii) Shade the appropriate oval in “**SECTION – I**” of the **Main Answer Booklet** using a **blue or black ballpoint pen**.

1.	Which lamp is most suitable for color-critical applications?	a) Halogen lamps	b) LED lamps
		c) CFLs	d) Metal halide lamps
2.	Iron losses in an electric motor can be reduced by using	a) More copper and large conductors	b) Use of thinner gauge, low-loss core steel
		c) Use of low loss fan design	d) Optimised design and strict quality control
3.	A cooling tower has an evaporation loss of 12 m ³ /hr and COC of 2.5. What will be the blowdown loss in m ³ /hr?	a) 5.2	b) 8.0
		c) 9.6	d) 10.2
4.	Energy savings by motor replacement can be worked out by:	a) KW output ($\eta_{old} - \eta_{new}$)	b) KW output ($\eta_{new} - \eta_{old}$)
		c) KW output ($1/\eta_{old} - 1/\eta_{new}$)	d) KW output ($1/\eta_{new} - 1/\eta_{old}$)
5.	Stray losses in a motor are mainly caused by:	a) Leakage flux induced by load currents	b) Hysteresis and eddy currents
		c) Frictional losses	d) Copper winding losses

6.	In a vapor compression refrigeration system, enthalpy changes occur across:
	a) Compressor b) Condenser c) Evaporator d) All of the above
7.	The purpose of inter-cooling in a multistage compressor is to:
	a) Increase final pressure b) Reduce compression work c) Separate oil vapour d) Remove all moisture
8.	When air is cooled by evaporation in an air washer:
	a) Humidity ratio decreases b) Dry bulb temperature decreases c) Dry bulb temperature increases d) Enthalpy decreases
9.	Amorphous core transformers primarily reduce:
	a) Load loss b) No-load loss c) Stray loss d) None of the above
10.	If a pump delivery valve is throttled to 30% of rated flow, best energy efficiency measure is:
	a) Replacing the motor b) Installing a larger impeller c) Increasing pump speed d) None of the above
11.	Calculate the FAD in CFM for an air compressor with a cylinder displacement of 150 CFM and volumetric efficiency of 90%:
	a) 165 b) 135 c) 150 d) None of the above
12.	If pump speed is reduced to $2/3^{\text{rd}}$ of its original speed, power consumption will:
	a) Decrease by half b) Decrease to one-fourth c) Decrease to approx. 30% of original d) Remains same
13.	At higher altitudes, for same FAD, air compressors:
	a) Consume less power b) Consume more power c) Show no difference d) Work without lubrication
14.	In a 4-stroke diesel engine, fuel is injected during:
	a) Induction stroke b) Compression stroke c) Ignition and Power stroke d) Exhaust stroke
15.	Voltage unbalance in motors:
	a) Reduces motor temperature b) Increases motor slip c) Causes excessive heating and reduces life d) Improves torque
16.	Soft starters are used to:
	a) Increase motor speed b) Reduce inrush current c) Convert AC to DC d) Improve efficiency

17.	An air compressor is driven by an IE3 premium efficiency motor. Compared to an IE2 motor of the same rating, which of the following statements is most accurate? a) The IE3 motor will always consume less power under all load conditions. b) The IE3 motor achieves higher efficiency mainly by reducing copper and iron losses. c) The IE3 motor has lower inrush current during starting compared to IE2. d) The IE3 motor achieves efficiency by increasing slip.
18.	Scale in condenser tubes: a) Increases energy use b) Reduces heat transfer c) Can lead to higher operating pressure d) All of the above
19.	Larger diameter ducts in fans: a) Increase system resistance b) Reduce system resistance c) No effect d) Increase static pressure
20.	Which of the following is a common symptom indicating that a pump is oversized? a) High discharge pressure b) Throttle valve-controlled systems c) Low suction pressure d) High motor power consumption
21.	Reducing the diameter of an impeller in a centrifugal pump will: a) Increase head b) Decrease head c) No effect on head d) Increase flow
22.	The main function of fill media in a cooling tower is to: a) Reduce drift losses b) Increase water-air contact c) Reduce fan noise d) Filter suspended solids
23.	Energy-saving opportunities in cooling towers include: a) Optimizing fan blade angle seasonally b) Maintaining correct water chemistry c) Cleaning fill media regularly d) All of the above
24.	The L/G ratio in a cooling tower is: a) Ratio of liquid water mass flow to gas (air) mass flow b) Ratio of drift loss to make-up water c) Ratio of cooling load to fan power d) Ratio of TDS in blowdown to TDS in make-up water
25.	Increasing chilled water leaving temperature in a centrifugal chiller: a) Increases efficiency b) Decreases efficiency c) No effect d) Limited information

26.	Luminaires are used to:
	a) Store electrical energy b) Distribute and control light from lamps c) Produce light directly d) Increase lamp wattage
27.	The Envelope Performance Factor (EPF) in ECBC is used to:
	a) Compare energy efficiency of proposed and baseline building designs b) Determine cooling tower sizing c) Calculate lighting power density d) Measure indoor air quality
28.	In a cooling tower, if any three of the four parameters: heat load, range, approach, and wet-bulb temperature, are kept constant, the required tower size will vary
	a) Directly with the heat load b) Inversely with the range c) Inversely with the approach d) All of the above
29.	A system resistance curve of a fan changes with:
	a) Inlet guide vanes b) Discharge dampers c) Speed change with VFD d) Any of the above
30.	A centrifugal pump has BEP efficiency of 65%. At shut-off head, efficiency is:
	a) 0% b) 65% c) 50% d) 30%
31.	A pump with 200 mm impeller delivers 120 m ³ /h. To deliver 100 m ³ /h by trimming, impeller size will be approximately:
	a) 240 mm b) 167 mm c) 60 mm d) 276 mm
32.	If tail-end power factor is improved from 0.80 to 0.95, distribution loss reduction is:
	a) 13.33% b) 21% c) 29% d) 16%
33.	In a vapour compression system, refrigerant changes from vapour to liquid in the:
	a) Compressor b) Evaporator c) Condenser d) Expansion valve
34.	Unity power factor means:
	a) No reactive power is drawn from the supply b) Current leads voltage c) Current lags voltage d) Reactive power is maximum
35.	Examples of lighting controls include:
	a) Dimmer switches b) Timers c) Photo-sensors d) All of the above
36.	A 4-pole, 50 Hz induction motor runs at 1470 rpm. Slip is:
	a) 0.02 b) 0.20 c) 0.25 d) 0.30

37.	Which type of compressed air dryer consumes the least power for capacities higher than 250 CFM? a) Refrigeration type c) Heat of compression type	b) Blower reactivated type d) Heatless purge type
38.	A DG set operates at 1250 kVA, 0.8 PF, with specific fuel consumption of 0.23 l/kWh. Quantity of fuel used is _____. a) 175 l/h b) 230 l/h	c) 250 l/h d) 300 l/h
39.	In a UPS, DC to AC conversion is carried out by: a) Converter b) Charger	c) Battery d) Inverter
40.	If a plant receives 96 Million Units (MU) with a T&D efficiency of 80%, generation required is: a) 101.2 MU b) 76.9 MU	c) 120 MU d) 68.1 MU
41.	Synchronous speed of a motor is inversely proportional to: a) Number of poles b) Frequency	c) Voltage d) Temperature
42.	If 27,216 kCal of heat is removed per hour, tonnage of refrigeration is: a) 10 TR b) 5 TR	c) 11 TR d) None of the above
43.	The most influential component for cooling tower performance is: a) Fill media b) Drift eliminator	c) Casing d) Fan motor
44.	An equipment room measures 12 m × 8 m × 3.5 m. Ventilation required for 15 ACH is: a) 5060 m ³ /h b) 5020 m ³ /h	c) 5040 m ³ /h d) 5080 m ³ /h
45.	Luminous efficacy is: a) Ratio of lumens to watts b) Measured in candela c) Same as luminance d) Measures reflection of light	
46.	If dew point temperature equals air temperature, percentage relative humidity is: a) 0% b) 45%	c) 50% d) 100%
47.	In a DG set, the component causing maximum energy loss is: a) Coolant loss b) Alternator loss	c) Radiation loss d) Flue gas loss
48.	The Energy Conservation Act applies to buildings with connected load: a) All HT connections b) Commercial buildings having ≥ 100 kW c) Residential buildings only d) Residential apartment having ≥ 100 kW	

49.	A 750 kVA transformer has 1200 W no-load loss and 7200 W full-load copper loss. At 60% load, total loss is: a) 4320 W b) 5520 W c) 7632 W d) 3792 W
50.	In vapour compression and vapour absorption systems, the common refrigerant is: a) Lithium bromide b) R-134a c) Ammonia d) None of the above

----- End of Section - I -----

Section - II : SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

- (i) Answer all **Eight** questions
(ii) Each question carries **Five** marks

S-1	A steel manufacturing facility is powered by a 3-phase, 6.6 kV, 50 Hz supply and operates the following electrical loads: An electric arc furnace consumes 1.2 MW at a lagging power factor of 0.65, a bank of induction motors for rolling operations consumes 800 kW at a 0.80 lagging power factor, and the lighting and instrumentation systems consume 100 kW at unity power factor. Due to utility regulations, the overall plant power factor must be improved to 0.95 lagging. A capacitor bank will be installed for compensation. As an energy auditor evaluate the following: a) Total active power consumption. 1 Mark b) Total initial apparent power drawn by the facility. 1 Mark c) The operating power factor. 1 Mark d) Determine the total reactive power required to achieve the desired power factor. 2 Marks																								
S-2	Determine the difference in heat rejected in kCal/TR to the cooling tower for two different types of air conditioning system operating at same capacity. <table><tr><th>Parameter</th><th>Centrifugal chiller</th><th>VAM</th></tr><tr><td>Chilled water flow (m³/h)</td><td>-</td><td>180</td></tr><tr><td>Condenser water flow (m³/h)</td><td>-</td><td>340</td></tr><tr><td>Chiller inlet temp (°C)</td><td>13.0</td><td>14.6</td></tr><tr><td>Condenser water inlet temp (°C)</td><td>-</td><td>33.5</td></tr><tr><td>Chiller outlet temp (°C)</td><td>7.7</td><td>9.0</td></tr><tr><td>Condenser water outlet temp (°C)</td><td>-</td><td>39.1</td></tr><tr><td>Specific power consumption (kW/TR)</td><td>0.6</td><td>-</td></tr></table>	Parameter	Centrifugal chiller	VAM	Chilled water flow (m ³ /h)	-	180	Condenser water flow (m ³ /h)	-	340	Chiller inlet temp (°C)	13.0	14.6	Condenser water inlet temp (°C)	-	33.5	Chiller outlet temp (°C)	7.7	9.0	Condenser water outlet temp (°C)	-	39.1	Specific power consumption (kW/TR)	0.6	-
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Condenser water outlet temp (°C)	-	39.1																							
Specific power consumption (kW/TR)	0.6	-																							
S-3	An energy audit in an industrial unit revealed a fan directly coupled with motor was operating at 37 Hz through VFD for 500 hours/month and supplying air through a 150 mm diameter duct. The fan is designed to deliver an air flow of 1300 m³/h with a rated input power of 3 kW at 50 Hz. Calculate the air velocity and annual energy savings ignoring the motor losses.																								

S-4	A pump is used to fill a rectangular overhead tank measuring 5 m × 3.5 m with a height of 10 m. The inlet pipe to the tank is positioned at a height of 25 m above ground level. The following additional data is available: The pump draws water from an underground sump situated 4 meters below the pump level and delivers it to a tank whose overflow line is positioned 8 meters above the tank bottom. The motor driving the pump draws 7.5 kW of power. The operating efficiencies of the motor and the pump are 90% and 70% respectively. Calculate the time taken by the pump to fill the tank up to the overflow level.																
S-5	A commercial training hall with dimensions 18 m × 12 m is being planned. Calculate the number of 18 W LED lamps, each providing 1800 lumens, required to achieve an illuminance level of 300 Lux. The lamps will be installed at a height of 3 meters from the working plane. The utilisation factor (UF) of the system is 0.70, and the light loss factor (LLF) is 0.80.																
S-6	A private power distribution company has implemented new digital metering and billing systems to improve efficiency in a residential zone. After six months of operation, the following data was recorded: <table border="1"> <thead> <tr> <th>Parameter</th><th>Value</th></tr> </thead> <tbody> <tr> <td>Input energy to the system</td><td>75 MU</td></tr> <tr> <td>Metered billed energy</td><td>56 MU</td></tr> <tr> <td>Unmetered average billing</td><td>4 MU</td></tr> <tr> <td>Amount billed</td><td>₹ 680 million</td></tr> <tr> <td>Total amount received</td><td>₹ 600 million</td></tr> <tr> <td>Arrears collected</td><td>₹ 90 million</td></tr> <tr> <td>Purchased energy cost</td><td>₹ 8.50 per kWh</td></tr> </tbody> </table> i) Estimate the Aggregate Technical and Commercial loss (AT&C) in percentage and the revenue realized per kWh. 4 Marks ii) Calculate the revenue loss per kWh to the company due to AT&C loss. 1 Mark	Parameter	Value	Input energy to the system	75 MU	Metered billed energy	56 MU	Unmetered average billing	4 MU	Amount billed	₹ 680 million	Total amount received	₹ 600 million	Arrears collected	₹ 90 million	Purchased energy cost	₹ 8.50 per kWh
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S-7	List five energy saving measures in compressed air system.																
S-8	Match the Following: <table> <tbody> <tr> <td>a) Solar Heat Gain Coefficient (SHGC)</td> <td>i. Coefficient of Performance (COP)</td> </tr> <tr> <td>b) U-value</td> <td>ii. Solar Reflectance</td> </tr> <tr> <td>c) HVAC System Efficiency</td> <td>iii. Fenestration Heat Gain</td> </tr> <tr> <td>d) Cool Roof</td> <td>iv. Building Insulation</td> </tr> <tr> <td>e) Thermal Bridging</td> <td>v. Conductive path for unwanted heat transfer</td> </tr> </tbody> </table>	a) Solar Heat Gain Coefficient (SHGC)	i. Coefficient of Performance (COP)	b) U-value	ii. Solar Reflectance	c) HVAC System Efficiency	iii. Fenestration Heat Gain	d) Cool Roof	iv. Building Insulation	e) Thermal Bridging	v. Conductive path for unwanted heat transfer						
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----- End of Section - II -----

Section - III : LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

- (i) Answer all **Six** questions
 (ii) Each question carries **Ten** marks

L-1

A distribution company (DISCOM) plans to implement a comprehensive Demand Side Management (DSM) initiative to reduce its peak load and overall energy procurement cost. The program targets two consumer categories, residential consumers and industrial consumers.

For residential consumers, DISCOM has taken LED replacement as a DSM intervention, whereas for industrial consumers load shifting strategy has been adopted through peak and off-peak electricity pricing.

The DISCOM supplies electricity to 10,000 households, each using 4 CFL bulbs (30 W each). These bulbs are used for 5 hours per day during evening peak hours. The DISCOM replaces each CFL bulb with a 9W LED bulb. Procurement cost of each LED bulb is ₹ 100/-, however the DISCOM provides the LED bulbs in place of CFL to consumers at a subsidized rate of ₹ 70/- per bulb. Administrative cost per household for the program is ₹ 10/-.

DISCOM also serves 50 industrial consumers, each with a shiftable evening load of 100 kW, used from 6 PM to 10 PM. DISCOM incentivizes these consumers to shift their load from 10 PM to 2 AM by offering an incentive of ₹ 2 per kWh shifted. Eighty percent of industrial consumers agree to take advantage of the tariff incentive scheme.

Power purchase cost for DISCOM:

- o Evening Peak (5 PM - 10 PM): ₹ 7/kWh
- o Late Night (10 PM - 6 AM): ₹ 3/kWh

Calculate the following:

a) For the residential consumers:

- i) Calculate the total daily energy savings in kWh/day from the LED replacement program. **2 Marks**
- ii) Determine the daily cost savings for the DISCOM from the LED program. **1 Mark**
- iii) Calculate the total one-time cost to the DISCOM for the LED program, including subsidies and administrative costs. **2 Marks**
- iv) Estimate the simple payback period in days for the LED program. **1 Mark**

b) For the industrial consumers:

- i) Calculate the total energy shifted in kWh/day. **1 Mark**
- ii) Compute the net daily savings for DISCOM, considering power cost reduction and incentive payout. **1 Mark**

c) Estimate the carbon emission avoidance due to above two DSM activity, if emission factor of grid electricity is 0.716 tCO₂/MWh. **2 Marks**

L-2

a) A clear water pump with rated flow of 125 m³/hr, head 55 m, rated speed of 1460 rpm and 79% efficiency is being used for supplying clarified water to a residential colony's water treatment facility. The daily water requirement is 3000 m³. The pump is directly coupled and driven by a three phase 50 hp, 415 V, 64 A, 0.9 pf, 1460 rpm induction motor with 90.5% full load efficiency.

During an internal energy audit, it was found that the motor is designed to operate with only 65% loading at pump rated conditions, therefore compromising on motor efficiency. The plant management has considered replacing the standard motor with a 30 kW IE3 motor. The following are operating parameters before and after motor replacement:

Parameters	Before motor replacement	After motor replacement
Flow (m ³ /hr)	130	?
Head (m)	52	51

Supply Voltage (V)	415	415
Current (Amp)	42	39
Power Factor	0.9	0.92
Motor Efficiency (%)	0.88	0.932

As an external auditor, you observed that, although the plant has reduced the size of the induction motor to improve loading and enhance motor efficiency, the slip of the new IE3 motor has decreased by 20 rpm. This raises concerns about the actual energy savings achieved. Validate the savings claimed, calculate the following:

- i) % Loading of motor after replacement. **1 Mark**
 - ii) Flow after replacing the standard motor with 30 kW IE 3 motor. **1 Mark**
 - iii) Operating Pump Efficiency before and after motor replacement. **2 Marks**
 - iv) Daily energy saving during operation due to motor replacement. **1 Mark**
- b) Read the following statements carefully. For each statement, mark "True" if it is correct and "False" if it is incorrect. **Each 1 Mark**
- i) Totally Enclosed Fan Cooled (TEFC) motors are less efficient than Screen Protected Drip Proof (SPDP) motors.
 - ii) Stray loss in induction motors is inversely proportional to load current.
 - iii) As per BIS standard, the motor output should not be affected with voltage variation up to $\pm 6\%$.
 - iv) Motor life doubles for each 10°C reduction in operating temperature.
 - v) Starting torque of energy efficient motors is higher than standard motors.

L-3

A commercial office building accommodates two government departments. The total employees working in both the departments is 250 out of which on an average 70% of employees are present at any time. Being a government office, the building is operational 6 days a week with 10 working hrs a day. The building receives electricity supply from local electricity distribution company through a 33 kV feeder, and it is distributed after stepping down to 415 V. The building does not have separate parking, lawn, internal roads etc. The building information sheet is as below:

Sl No.	Parameter	Annual Data (April 2024 - March 2025)
1	Contract Demand	130 kW
2	The installed capacity of the Diesel Generating (DG) set(s)	160 kVA
3	a) Annual Electricity Consumption, purchased from Utilities	1,05,753 kWh
	b) Annual Electricity Consumption, through DG Set(s)	2,136 kWh
4	a) Annual Cost of Electricity, purchased from Utilities	₹ 10,43,557/-
	b) Annual Cost of Electricity generated through DG Set(s)	₹ 54,405/-
5	Area of the Building	Built Up Area 3,591.96 sq.m Conditioned Area 2,155.18 sq.m
6	Installed capacity of Chiller of Air Conditioning System	137.5 TR
7	Installed lighting load	8.11 kW
8	Office Appliances	11.0 kW
9	Other Loads	12.5 kW
10	HSD Consumption in DG (GCV 10,800 kCal/kg and density of 0.85)	585 Litres

	Calculate the following: a) The total electricity consumed by the building and average electricity unit cost. 2 Marks b) EPI of the building considering the reported data for past one year. Also recommend the appropriate rating under BEE star rating program for buildings if the bandwidth of the EPI range between 150-50 kWh/sq. m/year. 3 Marks c) Calculate the design diversity factor of the building, if the design EER of the chiller is 3.5 and recorded maximum demand is 75% of the contract demand. 2 Marks d) Estimate the overall operating efficiency of the DG set 2 Marks e) Calculate the lighting power density 1 Mark												
L-4	A 5-star business hotel operates a centralized HVAC system operating round the clock with the following configuration. Only one chiller operates at a time, while the other is on standby. Two centrifugal chillers, each rated at 250 TR, with EER varying with load as below: <table border="1"><thead><tr><th>Load (%)</th><th>EER</th><th>Operating Days/Year</th></tr></thead><tbody><tr><td>85%</td><td>5.2</td><td>180</td></tr><tr><td>60%</td><td>4.6</td><td>120</td></tr><tr><td>40%</td><td>3.9</td><td>65</td></tr></tbody></table> No change in EER observed above 85% load, assume chiller motor efficiency of 90% at all loading conditions and the energy consumption by the auxiliary systems is as below: During chiller operation, two pumps run in parallel at an 80% load factor, consuming a total of 19.7 kW. In addition, two cooling tower fans operate continuously with a power consumption of 5.89 kW. Both the pumps and fans function 24 hours a day, with overall efficiencies of 75% and 70% respectively. The applicable electricity tariff is ₹ 6.5 per kWh. Evaluate the following: a) The total annual energy consumption in MWh and cost of the HVAC system, considering part-load EERs and auxiliary loads. 4 Marks b) Heat removal by condenser in TR at different loads. 3 Marks c) The hotel is planning to use the chiller partially as a heat pump by mounting a plate heat exchanger in series between the compressor and condenser (de-superheater for partial heat recovery) for producing hot water. The heat recovery can be only 20% of the condenser heat discharge. If the hot water requirement is 2000 liters/hr with 10°C temperature rise, evaluate whether the hot water requirement can be met at 40% loading conditions. 3 Marks	Load (%)	EER	Operating Days/Year	85%	5.2	180	60%	4.6	120	40%	3.9	65
Load (%)	EER	Operating Days/Year											
85%	5.2	180											
60%	4.6	120											
40%	3.9	65											
L-5	a) In a large-scale steel manufacturing facility, a cooling tower is used to reject heat from continuous casting operations. The circulating water flow rate is 2000 m³/hr. The cooling tower is currently operating at a Cycles of Concentration (COC) of 3. The evaporation loss is estimated at 1.0% of the circulating flow, and the drift loss is 0.1% of the circulating flow. The facility is planning to improve the COC from 3 to 6 through advanced water treatment. Evaluate the following: 4 Marks i) Calculate the make-up water requirement at the current COC of 3. ii) Calculate the revised make-up water requirement if the COC is increased to 6. iii) Estimate the total water savings per day. iv) Discuss one limitation or risk associated with increasing the COC.												

	b) Read the following statements carefully. For each statement, mark "True" if it is correct and "False" if it is incorrect. 6 Marks i) Cooling towers primarily reject heat through evaporative cooling. ii) The approach temperature in a cooling tower is the difference between the hot water temperature and the ambient dry bulb temperature. iii) Blowdown in a cooling tower is required to prevent the build-up of dissolved solids. iv) Drift losses in a cooling tower refer to water carried away with the exhaust air. v) Cooling tower effectiveness improves with higher approach temperatures. vi) Cycles of concentration in a cooling tower relate to how many times the water is re-used before discharge.
L-6	a) A manufacturing plant operates a 180 kVA diesel generator set rated at 0.8 lagging PF. The prime mover is a diesel engine rated 240 BHP. The alternator has total losses (including exciter power) of 5.44 kW. Assume no derating for site conditions. The generator is required to supply a mixed industrial load at its full kVA rating. The plant manager wishes to improve system efficiency by operating at a higher power factor. The diesel engine operates at a brake thermal efficiency of 32% when loaded near its rated capacity. The calorific value of the diesel fuel is 10,500 kCal/kg, and the specific gravity of the fuel is 0.85. Calculate the following: i) Maximum power factor that can be maintained at full kVA load without exceeding the engine capacity. 3 Marks ii) Corresponding diesel fuel consumption (litres per hour) at this maximum power factor. 2 Marks b) Read the following statements carefully. For each statement, mark "True" if it is correct and "False" if it is incorrect 5 Marks i) Improving power factor of the load on a DG set reduces the apparent power drawn and increases the system's overall fuel efficiency. ii) Alternator losses are independent of the load power factor. iii) Turbocharger in a diesel engine helps to reduce engine noise. iv) A diesel generator set must always be operated at unity power factor for maximum efficiency. v) DG sets are designed to handle unbalanced load between phases to 25% of their capacity.

----- End of Section - III -----

Name : _____

Appl. No.: _____

Seat No. : _____

**25th NATIONAL EXAMINATION FOR CERTIFICATION OF
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2025**

PAPER - 4 : ENERGY PERFORMANCE ASSESSMENT FOR EQUIPMENT AND UTILITY SYSTEMS

Date : 28-09-2025 Timings : 14:00-16:00 HRS Duration : 2 HRS Max. Marks : 100

General instructions :

- o Ensure that this Question Paper contains **6** printed pages.
- o Verify that the paper consists of **16** questions
- o The Question Paper is divided into three sections: Section I, Section II and Section III.
- o All questions in all three sections are compulsory
- o All parts of a question must be answered together in one place.
- o Time Management Guidance: Section I - 10 minutes, Section II - 10 minutes, Section III - 100 minutes.

Section - I : BRIEF QUESTIONS**Marks: 10 x 1 = 10**

- (i) Read the following statements carefully. For each statement, write "True" if it is correct and "False" if it is incorrect in the Main Answer Booklet.
- (ii) Answer all ten questions. Each question carries **One** mark.
- (iii) Suggested Time: 10 minutes.

1.	The lower the TTD (Terminal Temperature Difference) and DCA (Drain Cooler Approach) for feedwater heaters, the higher will be the cycle efficiency.
2.	If wet steam is generated, the high evaporation ratio indicates high efficiency of boiler.
3.	The only reason for installing condensate recovery systems is to reduce makeup water.
4.	The heat rate of a thermal power plant can be improved by decreasing the condenser cooling water temperature.
5.	In a cement rotary kiln, the highest heat loss occurs through clinker discharge.
6.	Evaporation ratio is based on actual performance data (steam output and fuel input) and does not depend on whether efficiency is expressed on GCV or NCV basis.
7.	Isentropic efficiency of a back-pressure turbine increases if the extraction steam temperature is higher than the back-pressure steam temperature.
8.	Profitability Index (PI) will be greater than 1 for projects with positive NPV, but its value varies with cash flow patterns and is not always higher for all positive NPV projects.
9.	In an integrated iron & steel plant, all the rolling mills consume more energy compared to energy consumed for iron making.
10.	In indirect method of boiler efficiency calculations, blowdown losses are also considered.

SEAL

..... End of Section - I

Section - II : SHORT NUMERICAL QUESTIONS**Marks: 2 x 5 = 10**

- (i) Answer both questions. Each question carries **Five** marks.
 (ii) Suggested Time: 10 minutes.

L-1

During the assessment year 2024-25, one of the thermal power plants reported a gross heat rate of 2300 kCal/kWh and an auxiliary power consumption of 8%, while the baseline net heat rate was 2600 kCal/kWh.

If the baseline generation is 5000 MU and considering that 1 kg of oil equivalent corresponds to 10,000 kCal and one e-Certificate corresponds to one ton of oil equivalent (TOE), calculate the reduction in net heat rate compared to the baseline and determine the expected number of e-Certificates.

L-2

In a petrochemical industry, both the Low-Pressure (LP) boiler and the High-Pressure (HP) boiler operate with the same evaporation ratio of 14, using the same fuel oil. The operating details are provided below:

Particulars	LP Boiler	HP Boiler
Pressure	10 kg/cm ² a	32 kg/cm ² a
Temperature	Saturated steam	400°C
Enthalpy of steam	665 kCal/kg	732 kCal/kg
Temperature of feed water	80°C	105°C
Evaporation Ratio	14	14

If the efficiency of the LP boiler is 80%, calculate the efficiency of the HP boiler.

..... End of Section - II

Section - III : LONG NUMERICAL QUESTIONS**Marks: 4 x 20 = 80**

- (i) Answer all **Four** questions. Each question carries twenty marks.
 (ii) For Question N-4, answer any one of the four alternatives (A) or (B) or (C) or (D).
 (iii) Suggested Time: 100 minutes.

N-1	A boiler is fired with 200 kg/hr hydrogen-enriched hydrocarbon fuel at atmospheric pressure and a temperature of 20°C. The flue gas, leaving the boiler at atmospheric pressure and 300°C, has the following dry composition by weight: • CO₂ = 12% • O₂ = 3% • N₂ = 85% Based on this information, determine: a) The main constituents of the fuel (carbon and hydrogen). 12 Marks b) The percentage composition of each constituent in the fuel. 4 Marks c) The total mass flow rate in kg/hr of the dry flue gas. 4 Marks
N-2	i) A small Topping Cycle Gas Turbine cogeneration plant has the following operating parameters given in the table below. Estimate the power generation in kW and the steam supplied from the HRSG in TPH. The Energy Auditor has suggested that the HRSG exit flue gas temperature can be maintained at 95°C by recovering more heat. If the HRSG exit flue gas temperature is maintained at 95°C, estimate the additional steam generation and also the EUF with improved steam generation. 12 Marks

Parameter	Value
Natural Gas Fuel Firing Rate	1500 Sm ³ /hr
Lower Heating Value (LHV)	9600 kCal/Sm ³
Exhaust Gas Flow Rate	16.35 kg/s
Exhaust Gas Temperature	525°C
Mean Specific Heat of Gas (Cp)	0.265 kcal/kg.°C
Specific Power Generation	3.044 kWh/Sm ³
HRSG Inlet Temperature	520 °C
HRSG Exit Temperature	135 °C
Steam Pressure	10 kg/cm ²
Saturated Steam Temperature	179°C
Steam Enthalpy	663 kCal/kg
Feedwater Temperature	105°C
HRSG Efficiency	79%

ii) A coal-fired boiler operates with the following parameters.

8 Marks

Parameter	Value
Hours of Operation	24 hours
Feed Water Temperature	145°C
Steam Enthalpy	805 kCal/Kg
GCV of Coal	4200 kCal/kg
Evaporation Ratio	5.7
Steam Flow Rate	265 TPH

Calculate the Boiler Efficiency and Coal Consumption per hour. If the boiler efficiency is improved by 2% relative to the existing efficiency, then estimate the coal savings per day.

- N-3** A pharmaceutical manufacturing plant operates a central chilled water system that serves both cleanroom AHUs and a process cooling water loop for tablet coating machines. The process cooling water passes through a counterflow heat exchanger, entering at 20°C and leaving at 14°C with a flow rate of 166 m³/h. On the other side, the chilled water enters at 7°C and leaves at 12°C, with a flow rate of 200 m³/h. The heat exchanger has an overall heat transfer coefficient of 2.8 kW/m²°C.
- The chilled and condenser cooling water loops are each served by centrifugal pumps with operating efficiencies of 78% and 80 %, respectively and a head of 18 m. The cooling tower is fitted with an induced-draft axial fan delivering 28 m³/s of air at 42.83 mmWC total pressure, with a fan efficiency of 62%. All pumps and the fan are driven by directly coupled three-phase induction motors with an efficiency of 92%.
- The plant's HVAC system, with an ISEER of 4.5, operates for 300 days annually, running 18 hours per day to handle an average cooling load of 850 kW.
- Find out the following:
- Estimate the required heat exchanger surface area. **6 Marks**
 - Determine the combined electrical load in kW of both pumps and the cooling tower fan, if condenser cooling water flow is 600 m³/h. **6 Marks**
 - Determine the Specific Energy Consumption (SEC) of the chiller in kWh/TR and calculate the overall SEC. **4 Marks**
 - Calculate the annual energy consumption in kWh and the annual operating cost in ₹ Lakhs if electricity is charged at ₹ 7.5 per kWh. **4 Marks**

Answer any ONE of the following among four questions given below:

N-4
(A)

The following data was collected from a 500 MW turbine unit during an energy audit. The power plant operates with a main steam (MS) flow of 1561 TPH at a pressure of 166 kg/cm² and temperature of 529°C. The hot reheat (HRH) flow is 1413 TPH, with steam conditions of 42.4 kg/cm² and 540°C, while the cold reheat (CRH) section records a pressure of 44.3 kg/cm² and temperature of 341°C. The feed water enters at 246°C, whereas the MS, CRH and HRH enthalpies are 806.47 kCal/kg, 730.71 kCal/kg and 844.28 kCal/kg respectively. These optimized steam cycle parameters enable the generator to deliver a substantial power output of 501.7 MW with a boiler efficiency of 88%. The turbine cycle heater operating parameters are as below:

Heater Reference	Steam				Feed Water in		Feed Water out		Design Values	
	Temp (°C)	Pressure (kg/cm ²)	Saturation Temp (°C)	Drain Temp (°C)	Temp (°C)	Pressure (kg/cm ²)	Temp (°C)	Pressure (kg/cm ²)	TTD	DCA
LP Heater 1	92.5	-0.23	93.07	64.2	47.2	13.7	63.6	12.6	2.88	4.8
LP Heater 2	140	0.49	111.23	70.4	-	-	105	11.5	2.95	4.95
LP Heater 3	209	1.97	132.9	110	-	-	130	10.4	2.95	4.95
HP Heater 5	416	17.4	207.33	171	170	202	210	199	0	5
HP Heater 6	335	43	254.94	212	-	-	255	197	0.1	5

Neglect temperature loss in the feedwater line between heaters and calculate the following:

- Turbine Heat Rate and the Unit Heat Rate. **8 Marks**
- Determine the loss or gain in the Turbine Heat Rate due to deviations of the TTD (Terminal Temperature Difference) and DCA (Drain Cooler Approach) of the LP/HP Heater systems from their design values. Consider the following criteria.
 - For every 0.56°C increase or decrease in TTD from the design value, the Heat Rate will increase or decrease by 0.014%.
 - For every 0.56°C increase or decrease in DCA from the design value, the Heat Rate will increase or decrease by 0.005%. **12 Marks**

Or

N-4
(B)

A DRI-route steel plant operates a DRI unit and a Steel Melting Shop (SMS). The plant also has a coal-based captive power plant (CPP). Any shortfall in electrical energy is met by imported grid power. On average, the plant imports 1,20,000 kWh/day and the operational parameters are given below:

Description	Parameter	Value
DRI Unit	Rated capacity	500 TPD
	Capacity utilization	70%
	Specific coal consumption	1.25 t coal / t sponge iron
	Specific power consumption	95 kWh / t sponge iron
	Coal GCV	5000 kCal/kg
SMS	Yield	87%
	Specific power consumption	830 kWh / t liquid steel
CPP	Gross efficiency	27%
	Auxiliary power consumption	8% of gross generation
	Coal GCV	5000 kCal/kg
Grid	Grid electricity heat rate	2700 kCal/ kWh

Calculate the following:

- The daily production of sponge iron and liquid steel in TPD. **2 Marks**
- DRI coal consumption in TPD and its thermal input in Million kCal/day. **2 Marks**

	c) Total daily electrical energy demand of DRI and SMS in kWh/day. 3 Marks d) The CPP gross generation in kWh/day, CPP heat rate in kCal/kWh, CPP thermal input in Million kCal/day and the CPP coal consumption in TPD. 6 Marks e) The overall specific energy consumption (SEC) in Million kcal per tonne of liquid steel. 4 Marks f) Compare your SEC with a benchmark of 6.5 Million kCal/t of liquid steel and comment briefly on performance. 3 Marks																																								
	Or																																								
N-4 (C)	A composite textile mill uses stenters for drying and heat-setting applications, currently the stenter system is running on a coal-fired boiler and there is a proposal to modify the system to a biomass-fired Thermic Fluid Heater. The relevant data is given below: <table border="1" data-bbox="414 672 1268 1668"> <thead> <tr> <th>Parameter</th><th>Value</th></tr> </thead> <tbody> <tr><td>Cloth inlet temperature</td><td>32°C</td></tr> <tr><td>Cloth outlet temperature</td><td>78°C</td></tr> <tr><td>Cloth inlet moisture</td><td>65%</td></tr> <tr><td>Cloth outlet moisture</td><td>6%</td></tr> <tr><td>Stenter output</td><td>1250 kg/hr</td></tr> <tr><td>Stenter Efficiency</td><td>48%</td></tr> <tr><td>Latent heat of inlet steam to stenter at 10 bar</td><td>477 kCal/kg</td></tr> <tr><td>Sensible heat of inlet steam to stenter at 10 bar</td><td>184 kCal/kg</td></tr> <tr><td>Dryness fraction of inlet steam</td><td>0.95</td></tr> <tr><td>Condensate temperature</td><td>87°C</td></tr> <tr><td>Boiler efficiency (coal-fired)</td><td>72%</td></tr> <tr><td>Distribution line losses (boiler)</td><td>5%</td></tr> <tr><td>Cost of coal</td><td>₹ 7000/ton</td></tr> <tr><td>GCV of coal</td><td>4200 kCal/kg</td></tr> <tr><td>Operating hours per annum</td><td>7200</td></tr> <tr><td>Thermic Fluid Heater efficiency</td><td>70%</td></tr> <tr><td>Distribution line losses (Thermic Fluid Heater)</td><td>7%</td></tr> <tr><td>Biomass cost</td><td>₹ 4000/ton</td></tr> <tr><td>GCV of biomass</td><td>3800 kCal/kg</td></tr> </tbody> </table> Calculate the following: a) Steam and coal required for the current coal-fired boiler. 8 Marks b) If the system is converted to a biomass-fired thermic fluid heater, calculate the biomass required and its associated cost per hour. 8 Marks c) Estimate the difference in annual fuel cost savings. 4 Marks	Parameter	Value	Cloth inlet temperature	32°C	Cloth outlet temperature	78°C	Cloth inlet moisture	65%	Cloth outlet moisture	6%	Stenter output	1250 kg/hr	Stenter Efficiency	48%	Latent heat of inlet steam to stenter at 10 bar	477 kCal/kg	Sensible heat of inlet steam to stenter at 10 bar	184 kCal/kg	Dryness fraction of inlet steam	0.95	Condensate temperature	87°C	Boiler efficiency (coal-fired)	72%	Distribution line losses (boiler)	5%	Cost of coal	₹ 7000/ton	GCV of coal	4200 kCal/kg	Operating hours per annum	7200	Thermic Fluid Heater efficiency	70%	Distribution line losses (Thermic Fluid Heater)	7%	Biomass cost	₹ 4000/ton	GCV of biomass	3800 kCal/kg
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Dryness fraction of inlet steam	0.95																																								
Condensate temperature	87°C																																								
Boiler efficiency (coal-fired)	72%																																								
Distribution line losses (boiler)	5%																																								
Cost of coal	₹ 7000/ton																																								
GCV of coal	4200 kCal/kg																																								
Operating hours per annum	7200																																								
Thermic Fluid Heater efficiency	70%																																								
Distribution line losses (Thermic Fluid Heater)	7%																																								
Biomass cost	₹ 4000/ton																																								
GCV of biomass	3800 kCal/kg																																								
	Or																																								

**N-4
(D)**

A 10,000 TPD cement plant purchases power from the grid, operates an 18 MW Captive Power Plant (CPP) and also has a Waste Heat Recovery (WHR) system with a 9 MW turbine. Electricity is used for cement production and also supplied to the colony and other utilities. The plant also exports excess energy to the grid. The annual energy and production data are given below:

Parameter	Value
Annual operating hours	8,300 hrs
Energy imported	60,210,000 kWh
Energy exported	3,150,000 kWh
Energy supplied to colony & others	3,500,000 kWh
CPP gross average generation	18 MW
CPP heat rate	3100 kCal/kWh
WHR turbine average generation	9 MW
WHR turbine heat rate	3600 kCal/kWh
Indian coal consumption	96,000 MT (GCV 4500 kCal/kg)
Pet coke consumption	80,000 MT (GCV 7500 kCal/kg)
Imported coal consumption	198,000 MT (GCV 7200 kCal/kg)
Biomass consumption	10,000 MT (GCV 2850 kCal/kg)
Clinker produced	2,700,000 MT
Clinker-to-cement ratio	1.375

Calculate the following:

- Specific Electrical Energy Consumption (SEEC) in kWh/ton of cement. **8 Marks**
- Estimate the Specific Thermal Energy Consumption (STEC) in kCal/kg clinker. **7 Marks**
- If the CPP is operated using only Indian coal and Imported coal, calculate the coal blending ratio by weight required to achieve a blended coal GCV of 6000 kCal/kg. **5 Marks**

..... End of Section - III