PAPER-3 COLOR C0DE : PINK

24th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS - SEPTEMBER, 2024
PAPER - 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

SECTION –I : OBJECTIVE QUESTIONS Marks 50x1=50

1. What is the primary function of substations in the electrical power supply system?
   a) To generate electricity
   b) To communicate over long distances
   c) To facilitate voltage transformation
   d) None of the above

2. How does the transmission voltage level affect the efficiency of long-distance power transmission?
   a) Higher voltage levels reduce transmission losses
   b) Higher voltage levels increase transmission losses
   c) Voltage levels do not affect transmission losses
   d) None of the above

3. What is the primary purpose of using high voltage direct current (HVDC) transmission over long distances?
   a) To increase the frequency of electricity
   b) To step down the voltage for distribution
   c) To minimize transmission losses over long distances
   d) All of the above

4. What is the impact of voltage imbalance among the three phases in an electrical system?

   a) Improved motor efficiency
   b) Increased motor losses and reduced equipment life
   c) Reduced power consumption
   d) Enhanced power factor

5. How does adding capacitors to an electrical distribution system improve power factor?

   a) By providing the reactive power
   b) By increasing the active power consumption
   c) By lowering the system voltage
   d) By increasing the frequency of the system

6. A transformer has a primary voltage of 220V and a secondary voltage of 110V. If the primary current is 5A, what is the secondary current assuming no losses?

   a) 2.5A b) 5A **c) 10A** d) 20A

7. A factory consumes 500,000 kWh of electricity per month with a power factor of 0.8. How much is the reactive power (kVAR)?

   a) 400,000 kVAR
   b) 375,000 kVAR
   c) 800,000 kVAR
   d) 500,000 Kvar

8. Which of the following best describes an induction motor's operation?

   a) It uses direct current to create mechanical energy.
   b) It generates a rotating magnetic flux that induces current in the rotor.
   c) It operates synchronously with the AC supply frequency.
   d) It requires external excitation to operate.

9. How does operating a motor in star mode affect its performance?

   a) It reduces the voltage and derates the motor capacity.
   b) It increases motor speed.
   c) It improves the power factor at high loads.
   d) It eliminates the need for external capacitors.

10. In a VFD-controlled motor, what happens when the supply frequency is reduced while maintaining the same voltage?

    a) The motor speed increases.
    b) The motor efficiency improves.
    c) The motor draws higher current and may overheat.
    d) The motor torque decreases.

11. Which of the following describes the function of a soft starter in a motor system?

    a) It increases the motor's full-load speed.
    b) It converts AC power to DC power.
    c) It reduces the inrush current during motor start-up.
    d) It improves the motor's efficiency at low speeds.

12. A motor operates at 75% load with an efficiency of 88%. If the motor's rated power is 20 kW, what is the actual output power?

    a) 15 kW b) 13.2 kW c) 17.6 kW d) 14.4 kW

13. What is the main purpose of an after-cooler in a compressed air system?
    a) To remove moisture from the air by cooling it
    b) To increase the pressure of the compressed air
    c) To filter out dust and particles
    d) To lubricate the compressed air

14. How does a desiccant air dryer remove moisture from compressed air?

    a) By cooling the air
    b) By using adsorbents like silica gel or activated carbon
    c) By increasing the pressure
    d) By reducing the air flow rate

15. Which of the following is an efficient method to control the capacity of a centrifugal compressor?

    a) Automatic on/off control
    b) Variable inlet guide vanes
    c) Load and unload control
    d) Multi-step control

16. What is the effect of increasing the intake air temperature on the efficiency of an air compressor?

    a) Increases efficiency by reducing power consumption
    b) Decreases efficiency by increasing power consumption
    c) No significant effect on efficiency
    d) Increases the volumetric capacity of the compressor

17. What is the main benefit of using a variable speed drive (VSD) with a screw compressor?

    a) Increases the maximum pressure capacity b) Reduces the size of the compressor
    c) Eliminates unloaded running condition d) Simplifies maintenance

18. Which of the following describes the primary function of an air receiver in a compressed air system?

    a) To increase the air pressure **b) To act as a reservoir and dampen pulsations**

    c) To filter out impurities d) To cool the compressed air

19. What is the primary function of the evaporator in a refrigeration cycle?

    a) To compress the refrigerant **b) To absorb heat from the environment**

    c) To condense the refrigerant d) To regulate the flow of refrigerant

20. In which component of an ideal refrigeration system, the refrigeration temperature will increase?

    a) Compressor b) Condenser c) Evaporator d) Expansion valve

21. Which refrigerant is commonly used in vapor absorption refrigeration systems?

    a) R-22 b) R-134a **c) H_2O** d) LiBr

22. What is the effect of increasing the chilled water leaving temperature on the efficiency of a centrifugal chiller?

    a) It increases the efficiency of the chiller b) It decreases the efficiency of the chiller

    c) It has no effect on efficiency d) It increases the refrigerant flow rate

23. An HVAC system operates with a COP (Coefficient of Performance) of 4. If the system provides 100 kW of cooling, what is the power input to chiller?

    a) 0.04 kW **b) 25 kW** c) 400 kW d) None of the above

24. What is the effect of decreasing the RPM of a fan by 10% on its power requirement?

    a) Decreases the power requirement by 27% b) Decreases the power requirement by 19%

    c) Increases the power requirement by 10% d) No significant effect

25. How does an increase in system resistance affect the operation of a centrifugal fan?

    a) Increases the airflow **b) Reduces the airflow**

    c) Reduces the static pressure d) No effect on fan performance

26. What is the primary purpose of trimming the impeller in a centrifugal pump?

    a) To increase the pump speed **b) To adjust the pump capacity to match system requirements**
    c) To reduce the pump speed d) To increase the NPSH required

27. How does increasing the diameter of the suction pipe affect the NPSHA in a pumping system?
    a) Reduces NPSHA **b) Increases NPSHA** c) Decreases NPSHR d) Increases NPSHR

28. A pump has a flow rate of 200 cubic meters per hour and operates against a head of 30 meters. If the pump efficiency is 70%, what is the input power required?

    a) 60.5 kW **b) 23.36 kW** c) 95.2 kW d) 100 kW

29. What is the effect of cavitation in pump?
    a) Increases efficiency
    b) Reduces noise and vibration
    c) Causes erosion of impeller surfaces
    d) Increases NPSH required

30. What is the relationship between pump speed and flow rate in a centrifugal pump according to the Affinity Laws?
    a) Flow rate is proportional to the pump speed
    b) Flow rate is proportional to the square of the pump speed
    c) Flow rate is proportional to the cube of the pump speed
    d) Flow rate is independent of pump speed

31. What is the impact of using larger diameter pipes on the system resistance in a pumping system?

    a) Reduces system resistance by lowering friction head losses
    b) Increases system resistance

c) Increases power
d) Increases static head

32. A cooling tower reduces the temperature of water from 40°C to 30°C. If the mass flow rate of water is 5 kg/s, what is the heat removed by the cooling tower?
a) 500 kW **b) 209 kW** c) 2 kW d) 5 kW

33. The approach temperature of a cooling tower is 5°C, and the range is 10°C. If the inlet water temperature is 40°C, what is the outlet water temperature?

a) 25°C
b) 30°C
c) 35°C
d) 45°C

34. How can the performance of a cooling tower be improved?
a) Proper water treatment
b) Regular maintenance
c) Optimizing air and water flow
d) All of the above

35. What is the primary function of a luminaire in a lighting system?
a) To generate light
b) To store electrical energy
c) To distribute light emitted from lamps
d) To control the voltage supply

36. Which type of lamp has the highest luminous efficacy among the following?
a) Low pressure sodium vapour lamp
b) Halogen lamp
c) LED lamp
d) Compact fluorescent lamp (CFL)

37. How does the use of high-efficiency luminaries contribute to energy conservation?
a) By decreasing the power consumption
b) By increasing the luminous efficacy
c) By improving light distribution characteristics
d) All of the above

38. How does altitude affect the performance of a DG set?
a) Increases power output
b) Reduces fuel consumption
c) Reduces power output
d) No change in fuel consumption

39. What is the Solar Heat Gain Coefficient (SHGC) used for in building energy analysis?
a) To measure light transmittance

b) To measure the heat gain through fenestration due to solar radiation
c) To measure air leakage through windows
d) To measure the thermal emittance of roofing materials

40. What is the primary function of an economizer in an HVAC system?
a) To increase indoor air pollution
b) To reduce the cost of heating equipment
c) To use outdoor air for cooling when conditions are favorable, saving energy
d) To increase the use of mechanical cooling systems

41. Energy Performance Index is the ratio of total building annual energy consumption to ------
a) Carpet area
b**) Built up area**
c) roof area
d)Windows and Walls area

42. In a D G set, the generator is generating 1000kVA at 0.7PF. If the specific fuel consumption of this D G set is 0.25 lits per kWh, then how much fuel in litres will be consumed while delivering generated power for one hour?
a)230
b) 250
c)175
d) 225

43. The power measured in an Induced Draft (I D) fan operating at 49 Hz is 52 kW. A Variable Frequency Drive (VFD) is installed and the fan was operated at 34 Hz, The estimated Power saving will be_________
a)35.7 kW
b)17.3 kW
c)34.6 kW
d)36 kW

44. A fan is drawing 16 kW at 800 RPM. If its speed is reduced to 600 RPM, the power drawn by the fan will be____________
a) 6.75 kW
b) 9 kW
c) 12 kW
d) None of the above

45. Harmonics generation is more in_____________
a) **Inverter Drive**
b) LED lamp
c) Transformer
d) Resistance heater

46. A 500 cfm reciprocating compressor has a loading and unloading period of 5 seconds and 20 seconds respectively during a compressor leakage test. The air leakage in the compressor air system will be ________

a)125 cfm
b**)100 cfm**
c) 200 cfm
d) none of the above

47. What is the efficiency of motor with the following nameplate details 22 kW, 415V, 42 A, 0,8 p.f, 1475 rpm?

    a)94.5% **b) 91%** c) 89.9% d) None of the above

48. A hotel building has 14 floors, each of 1000m^2 area, If the Lighting Power Density is 10.8 per m^2 the interior lighting power allowance for the hotel building is_________

    a)110800 W b) 129600 W **c)151200 W** d) 186600 W

49. A pump with 230mm diameter impeller is delivering a flow of 150 m^3/hr. If the flow is to be reduced to 110m^3 /hr by trimming the impeller, what should be the approximate size of the impeller?

    a)207mm b)175 mm **c) 169 mm** d)195 mm

50. What is the main advantage of using a rotary screw air compressor over a reciprocating compressor?

    a) Lower initial cost **b) Continuous, pulsation-free air delivery**
    c) Higher maximum pressure d) None of the above

SECTION –II : SHORT DESCRIPTIVE QUESTIONS Marks 8x5 = 40

(i) Answer all EIGHT questions
(ii) Each question carries FIVE marks

1	A 3 phase Induction motor has the following details: Name plate details: 55 kW,415 V,95 A,0.9 p.f, 50 Hz Running load details: 410 V,75 A,0.80 p.f, 48 Hz Calculate the following: a) loading percentage, b) Rated efficiency, **Ans:** Actual power drawn by the motor = 1.732 x 410 x 75 x 0.80 /1000 = 42.6 kW Rated input power = 1.732 x 415 x 95 x 0.90 /1000 = 61.5 kW Percentage loading of motor = 42.6 / 61.5 = 69.3 % Rated efficiency of motor = (55 / 61.5) x 100 = 89.4%

2 **Match the following:** Each 1 mark

Column A	Column B
1. Envelope Performance Factor (EPF)	a. Lighting System Efficiency
2. Luminous Efficacy	b. Heat Storage in Building Materials
3. Economizer	c. ECBC Compliance
4. Thermal Mass	d. Building Energy Performance Modeling
5. Energy Simulation Software	e. Outdoor Air for Free Cooling

Solution:

Column A	Column B
1. Envelope Performance Factor (EPF)	c. ECBC Compliance
2. Luminous Efficacy	a. Lighting System Efficiency
3. Economizer	e. Outdoor Air for Free Cooling
4. Thermal Mass	b. Heat Storage in Building Materials
5. Energy Simulation Software	d. Building Energy Performance Modeling

3 A cooling water pump has a positive suction head of 5 meters. The discharge pressure is 3.0 kg/cm², and the water flow rate is 150 m³/hr. Determine the pump efficiency given that the actual power input of the connected motor is 18.0 kW and the motor operates with an efficiency of 85%.

Solution:

Flow Rate: 150 m³/hr
Total Head: 30-5 = 25m
Power input to pump = 18*0.85 = 15.3 kW
Hydraulic Power = (150/3600)*25*9.81 = 10.2 kW
Pump Efficiency = 10.2/15.3 = 66.7%

4 A steel industry has 100 MW of captive power plant with 2 nos. of identical extraction condensing steam turbine. Power demand is 80 MW. The turbine specific condensing load is 3.20 kg/kWh and heat rejection in condenser is 560 kCal/kg.

Cold cooling water temperature: 32.0 ^{0}C
Hot cooling water temperature 39.2 ^{0}C

Calculate the following:

a) The Cooling Water circulation flow (m^3/hr) through both condensers, If only one cooling tower supplies water to condenser of both the steam turbines.
b) Make-up water flow rate (kg/hr) to basin, assuming blowdown loss is 1.0 % of circulation flow.

Solution:

Condenser heat load = (3.2*80000*560/1000000) = 143.36 MkCal/hr
Circulated cooling water flow = (143.36*1000000/7.2/1000) = 19911 m^3/hr

Evaporation losses = 0.00085*1.8*19911*7.2= 219.3 m^3/hr
Blowdown loss = 19911*0.01 = 199 m^3/hr
Water makeup to cooling tower = 219.3+199 = 418.4 m^3/hr = 418400 kg/hr

5. A process engineer develops a scheme to put 500 TR absorption-based refrigeration system to bring down process fluid temperature from 34 ^{0}C to 26 ^{0}C and this will result in higher production by 10%. 5 TPH excess steam is available in the plant and this new scheme utilizes this excess steam. COP of refrigeration system is 0.65 and available latent of steam for refrigeration system is 540 kcal/kg.

A)Estimate excess steam utilization for absorption- based refrigeration system in TPH. ……………………………..3 Marks

b) Estimate required Cooling water (m^3/hr), if available approach in condenser is 10 ^{0}C. ……………………………..2 Marks

Solution:

Energy required for refrigeration system
500*3024/0.65 = 2326153.8 kcal/hr

Steam needed for refrigeration system = 4.3 TPH
2326153.8/540

Steam utilization for VAM = 4.3 TPH

Required condenser duty = 3838153.8 kcal/hr
2326153.8+(500*3024)

Required Cooling water = 383.8 m^3/hr
3838153.8/10

6	A process plant continuously operates a furnace oil operated DG set of capacity 3.0 MW to avoid any process safety incident in case of tripping of critical equipment on power failure. Total critical load on DG set is 2.5 MW and exhaust flue gas at 430 deg.C is vented as original design intent was to operate DG set intermittently only during power failure. Since it is being operated continuously, the process team developed a scheme to generate saturated steam at 5 bar(g) using the waste heat boiler. Other operating parameters are given below: Specific heat of flue gas — 0.24 kcal/kg-Deg.C Final stack temperature to avoid Sulphur dewing — 210.0 Deg.C Flue gas flow — 17.5 TPH Sat. temp. of steam at 5 barg — 159.0 Deg.C Latent heat at 5 barg — 498.0 kcal/kg Feed water temperature — 130.0 Deg.C Calculate the quantity of steam generated from waste heat boiler in TPH. Solution: Heat available for steam generation= 17500*0.24*(430-210) = 924000 Kcal/hr Steam Generation= 924000/(498+(159-130)) = 1753.3 kg/hr = 1.75 TPH
7	List five energy efficiency measures in Compressed air system. Solution: Book 3, Refer Page 101
8	Analyse the following data collected for a water pump. If the operating head is 16m explain what will happen to other parameters. (table below) Solution : 1. If the operating head is 16m instead of 20 m, the operating flow will be higher than the rated flow. 2. Since the operating point has deviated from the BEP, the operating efficiency will be less than design efficiency. 3. Since, the flow has increased and pump efficiency decreased than rated, the operating power demand will be more than the rated power.

Design Parameters	Values
Flow (Q)	40 lps
Head (H)	20 m
Power(P)	15 kW
Efficiency	51%

SECTION –III : LONG DESCRIPTIVE QUESTIONS Marks 6 x 10 = 60

L1 A 20 MW co-generation plant operates at a daily load factor of 85% and 8% auxiliary power consumption. The power is generated at 11 kV. Out of the total energy generated, 45% is exported to the grid through a 15 MVA transformer with 99% efficiency. Additionally, 35% of the generated energy is supplied to mill motors at 600 Volts through an 8 MVA step-down transformer with 98.5% efficiency. The remaining energy is used for other LT loads and auxiliaries at 415 Volts through a 4 MVA transformer with 98.2% efficiency. Calculate the following:

1. Daily energy generation in MWh.
2. Daily energy exported in MWh to the grid at 33 kV.
3. Daily mill motors consumption in MWh at 600 V.
4. Daily LT loads and auxiliary consumption in MWh at 415 V.
5. Daily transformer losses in kWh and % transformer losses.

Solution

1. Daily Energy Generation Calculation

Gross energy generated=Plant capacity×Load factor×Hours per day Gross energy generat ed

=20 MW×0.85×24 hours Gross energy generated=408 MWh per day

Net energy available after auxiliary consumption:

Net energy available=Gross energy generated×(1−Auxiliary power consumption)

=408 MWh×0.92 = 375.36 MWh

2. Energy Exported to the Grid

Energy available for exported =Net energy available×45% =375.36 MWh×0.45 =168.912 MWh

Energy exported to the grid after transformation loss=168.912 MWh×0.99 =167.223 MWh

3. Daily Mill Motors Consumption

Energy available for mill motors =Net energy available×35% =375.36 MWh×0.35 =131.376 MWh

Energy supplied to mill motors after transformation loss = 131.376 MWh×0.985 =129.278 MWh

4. Daily LT Loads and Auxiliary Consumption

Energy available to LT loads and auxiliaries = =375.36 MWh×0.20 =75.072 MWh

Energy supplied to LT loads and auxiliaries after transformation loss = 75.072×0.982 =73.78 MWh

	5. Calculate Daily Transformer Losses in kWh and % Transformer Losses **Total Transformer Losses:** Grid Transformer Losses+Mill Motors Transformer Losses+LT Transformer Losses Total l osses= =(168.912-167.223)+(131.376-129.278)+(75.072-73.78) 1,689 kWh+2,098 kWh+1,292 kWh Total losses=5,079 kWh **Percentage of Transformer Losses from Net Generation:** 5079/408000 = 1.24%
L2.	As part of a management initiative to advance green energy in a new process plant, a process engineer is assessing the economic viability of a 650 TR chiller. She is considering proposals for both LiBr-based vapor absorption chillers and vapor compression refrigeration systems. While power is sourced from renewable energy, the steam required is partially generated from excess process heat and additionally from firing furnace oil. COP of advance Vapor Absorption Chiller : 1.3 COP of Vapor Compression Chiller : 4.50 Net steam price including excess steam and from boiler : 1500.00 INR/MT Net Power cost from green source : 7.20 INR/kWh Price of Cooling water : 3.00 INR/M3 Cooling water range : 8^0C Specific steam heat available for chiller : 490.0 kcal/kg Evaluate both the offers and find out the offer which is economical in terms of operating cost. **Solution:** Vapor Absorption chiller Chilling capacity 650.0 TR Required heat duty 1965600 kcal/hr Heat equivalent input to VAM = 1965600/1.3 = 1512000 Required Steam flow = 1512000/490 = 3084 kG/hr Condenser heat duty = (650*3024) + (3084* 490) = 3476760 kcal/hr Required Cooling Water = 434.6 M3/hr Operating cost of Vapor Absorption Chiller =(3084*1.5)+(434.6*3) = 5930 INR/hr Vapor Compression chiller Chilling capacity 650.0 TR Required heat duty 1965600 kcal/hr Required Power consumption 508 kW Condenser heat duty = (650*3024)+(508*860)=2402480kcal/hr Required Cooling Water =300 M3/hr

	Operating cost of Vapor Absorption Chiller = (508*7.2)+(300*3) = 4558 INR/hr Hence, operating vapor compression chiller is economical.

L3 a) Match the following: (4 Marks)

1	Prescriptive Approach	1. Exterior façade
2	Whole Building Performance Approach	2. Trade-Off option
3	Building envelope	3. light admitting potential
4	Effective Aperture	4. Uses simulation to show compliance for the entire building

b. Fill in the following blank statements:

1. The Effective Aperture (EA) or light admitting potential of a glazing system is determined by multiplying the Visible Light Transmittance (VLT) of the glazing by the **______________** of the building.
2. Thermal emittance is the relative ability of a material to **___________**the absorbed heat.
3. If a window has a SHGC of 0.25 and the total incident solar radiation is 600 W/m², the solar heat gain through the window is **__________**
4. The emissivity of a material is the ratio of energy radiated by a particular material to energy radiated by a **___________** at the same temperature.
5. As per ECBC the unit of Energy Performance Index (EPI) **___________**
6. Fenestration surface having a slope of less than **60** degrees from the horizontal plane is termed **___________________**

Solution:

a)

1. Prescriptive Approach – b
2. Whole Building Performance Approach – d
3. Building envelope – a
4. Effective Aperture – c

b)

1. The Effective Aperture (EA) or light admitting potential of a glazing system is determined by multiplying the Visible Light Transmittance (VLT) of the glazing by the **Window-Wall Ratio (WWR)** of the building.
2. Thermal emittance is the relative ability of a material to **radiate** the absorbed heat.
3. If a window has a SHGC of 0.25 and the total incident solar radiation is 600 W/m², the solar heat gain through the window is **150 W/m².**
4. The emissivity of a material is the ratio of energy radiated by a particular material to energy radiated by a **black body** at the same temperature.
5. As per ECBC the unit of Energy Performance Index (EPI) **kWh/Sq.mt/year**
6. Fenestration surface having a slope of less than **60** degrees from the horizontal plane

is termed **<u>Skylight</u>**. (6 Marks)

L4

1. The lumen (lm) is the photometric equivalent of the Watt, weighted to match the eye response of the "standard observer," with blue light receiving the greatest weight - **False.**
2. The CRI of a lamp is 100 if it renders the color of the chips identical to the reference light source, indicating perfect color rendering. - **True.**
3. A commercial building with a high window-to-wall ratio (WWR) and low SHGC glazing will experience higher cooling loads, as more solar heat will be transmitted through the windows - **False.**
4. Rotary screw compressors are preferable for fluctuating air demand- **False**.
5. Operating compressors at lower delivery pressures always results in higher energy efficiency- **True**.
6. Heat of compression dryers have higher operating costs compared to heatless purge dryers- **False**
7. Using variable speed drives in compressors can eliminate unloaded running conditions and save energy-**True**
8. Motor efficiency generally increases as the motor's rated capacity increases. **True**
9. The power factor of an induction motor improves as the load on the motor decreases. **False**
10. A decrease in supply voltage by 10% will decrease the torque of the motor by approximately 19% - **False**

L5

A 2-stage reciprocating compressor is supplying nitrogen from low pressure header to high pressure vessel. This high-pressure nitrogen is only used during any process upset. Compressor is cut-off, once vessel pressure reaches 45 barg, and started, when vessel pressure comes down to 35 barg. During energy audit, it was observed that compressor is started at gap of every 36 hrs when there is no intended consumption. Other data is given below:

Vol. of high pressure N2 vessel	11.5	m^3
Vessel temperature	35.0	Deg.C
Initial gas density	50.3	kg/m3
End gas density	39.4	kg/m3
Compressor load kW drawn	30.0	kW
Compressor capacity at constant suction pressure	250.0	kg/hr

i. Estimate the leak rate (kg/hr).

ii. Estimate the energy saving potential (kWh/Annum), if all leaks are attended. Consider operating time of 8760 hrs/annum.

Solution:

Initial Vessel Pressure	45.0	barg
End vessel pressure	35.0	barg
Initial gas density	50.3	kg/m3
End gas density	39.4	kg/m3

	Change in gas quantity in 36 hrs 125.7 kg N2 leakage rate 3.5 kg/hr Time needed for compressor run 0.51 hrs or 30.6 min % time of compressor running 1.40 % Running time of compressor per annum 122.3 hrs Power consumption per annum due to air leakage 3670.0 kWh/Annum Energy Saving Potential 3670.00 kWh/Annum
L6	a) During performance guarantee test of an induced draft cooling tower, it was found that design approach of cooling tower is not achieved. As one of the probable causes, the team decided to check the efficiency of cooling tower fan. If design static efficiency is 70%, estimate the operating static efficiency using following parameters: Pitot tube coefficient 0.9 Velocity pressure 49.0 mmWC Air Density at operating condition 1.129 kg/m3 Duct diameter 2.1 m Differential pressure across fan 130.0 mmWC Motor shaft Power 190.0 kW Motor Efficiency 95.0 % Gear Box Efficiency 96.0 % b) A centrifugal fan drawing 54 kW and operating at 1440 rpm is delivering air at 30,000 m^3 /hr. The head developed by the fan is 400 mm WC. If the speed is decreased by 200 rpm, calculate the following: 1. Air flow in m^3 / hr 2. Static pressure in mm WC 3. Power drawn in kW **Solution**: a) Air Velocity = 26.3 m/sec Duct Area = 3.5 m^2 Vol. flowrate = 92.0 m^3/sec Air kW transferred = 92*130/102 = 117.25 kW Power input to fan = 190*0.95*0.96 = 182.4 kW Static Efficiency = 117.25 / 182.4 x100 = 64.28% b) 1. Airflow in m^3 / hr = (1240/1440) x 30000 = 25833 m^3 /hr 2. Static pressure in mm WC = $(1240/1440)^2$ x 400 = 296.6 mm WC 3. Power drawn in kW = $(1240/1440)^3$ x54= 34.48 kW

Appl. No: ________________ **Paper 3 Code: Pink**

Name : ________________
(To be written by the candidate)

23rd NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – MARCH, 2023

PAPER – 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Date : 26.03.2023 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

General instructions :

- *Please check that this question paper contains **10** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **One** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with HB pencil only, as per instructions

1.	If the compressor of 200 cfm, loads in 10 seconds and unloads in 20 seconds, the air leakage would be ____________. **A) 67 cfm** B) 100 cfm C) 10 cfm D) 133 cfm
2.	The compressor capacity of a reciprocating compressor is directly proportional to ______________. **A) Speed** B) Pressure C) Volume D) All
3.	Find the correct equation, if M = makeup water (from the mains water supply), E = losses due to evaporation, B = losses due to blow-down and D = drift losses of a cooling tower: **A) M = E + B + D** B) M = E + B - D C) M = E - B + D D) M = E - B – D
4.	If temperature of air increases, the amount of water vapor needed to become saturated _________. **A) Increases** B) Decreases C) not change D) Can't say
5.	The hot water temperature entering the cooling tower is 38 ^oC. Range is twice the approach, the effectiveness of the cooling tower is ___________. A) 33.3% B) 50% C**) 66.7%** D) Insufficient data

6.	Cycles of Concentration (C.O.C) of a cooling tower will depend on ___________. A) TDS in circulating water B) TDS in make-up water **C) both a & b** D) none of the above
7.	Lower power factor of a DG set demands ___________. A) lower excitation currents B) no change in excitation currents **C) higher excitation currents** D) none of the above
8.	The unit of Energy Performance Index (EPI) for rating the building is _________. **A) kWh/sq mtr/yr** B) kWh/sq mtr/hr C) Wh/sq mtr/hr D) sq mtr/Wh/yr
9.	Which of the following statements regarding ECBC are correct? A) ECBC defines the norms of energy requirements per cubic metre of area B) ECBC does not encourage retrofit of Energy conservation measures C) ECBC prescribes energy efficiency standards for design and construction of commercial and industrial buildings **D) One of the key objectives of ECBC is to minimize life cycle costs (construction and operating energy costs)**
10.	A hotel building has four floors each of 1000 m^2 area. If the Lighting Power Density (LPD) is 10.8 W/m^2, the interior lighting power allowance for the hotel building is ____________. A) 10800 W B) 21600 W C**) 43200 W** D) none of the above
11.	A super thermal power station of 2500 MW installed capacity generated 14,000 million units in a year. It's annual Plant Load Factor (PLF) is __________. A) 60% B) 79% C**) 64%** D) none of the above
12.	AT & C losses means ____________. A) aggregate transmission and current losses **B) aggregate technical and commercial losses** C) average technical and commercial losses D) available transmission and commercial losses
13.	The nearest kVAr compensation required for improving the power factor of a 1000 kW load from 0.95 leading power factor to unity power factor is ____________. A) 328 kVAr B) 750 kVAr C) 1000 kVAr D**) none of the above**
14.	Harmonics are generated by __________. A) HT motors B) transformers C) LT motors D**) variable frequency drives**
15.	The no-load loss and copper loss of a 500 kVA transformer is 900 Watts and 6400 Watts respectively. What is the total loss at 50% of transformer loading? A) 4100 Watts B) 6850 Watts C**) 2500 Watts** D) 3650 Watts
16.	Parallel operation of two identical fans in a ducted system. A) will double the flow B) will double the fan static pressure C) will increase flow by more than two times **D) will not double the flow**

17.	Humidification involves ____________. A) reducing wet bulb temperature and specific humidity B) reducing dry bulb temperature and specific humidity C) increasing wet bulb temperature and decreasing specific humidity **D) reducing dry bulb temperature and increasing specific humidity**
18.	Coefficient of Performance (COP) for a refrigeration compressor is given by A) power input to compressor (kW) / cooling effect (kW) **B) cooling effect (kW) / Power input to compressor (kW)** C) Q x CP x (Ti – To) / 3024 D) none of the above
19.	In a water Lithium bromide refrigeration system, the concentration of the lithium bromide increased, in the ___________. A) Evaporator B) Condenser C**) Generator** D) Absorber.
20.	Integrated Part Load Value (IPLV) in a vapor compression refrigeration refers to average of ________ at partial loads. A) TR/kW B) cooling effect C**) kW/TR** D) kW
21.	__________ is a measure of effect of light on the perceived colour of objects. A) lux B) lumens **C) CRI** D) lamp circuit efficacy
22.	Lux is defined as __________. A) ratio of luminous flux emitted by a lamp to the power consumed by the lamp B) lux per square meter C) lumen per square feet **D) none of the above**
23.	Which of the following is not used as a sensor for lighting occupancy linked control? A) Infrared B) acoustic C) ultrasonic D**) pressure**
24.	In an Energy Efficient Motor, the efficiency is increased by increasing __________. **A) stator winding cross sectional area** B) fan losses C) conductor resistance of rotor D) stator winding resistance
25.	By locating the capacitor near the motor terminal ______________. A) motor power factor increases B) motor energy consumption decreases C) system power factor decreases D) **none of the above**
26.	A pump is handling water at 25 deg C and delivering 200 m^3/hr. If the water temperature is 50 deg C then the flow will ___________. A) Increase by 50% B) decrease by 50% C) double D**) None of the above**
27.	If distribution line has losses of 100kW and voltage is raised from 33KV to 66KV, then line losses will be _______________. A) 50KW B) 100KW C) 200KW D) **25KW**
28.	A 2000KVA Transformer has full load losses of 20KW. If transformer is running at 50% loading, then what will be the load losses? A) 10KW B) **5 K W** C) 20KW D) None of the above
29.	Slip% of Induction Motor is calculated as (Ns= Synchronous Speed, Nr= Full Load Rated Speed)

	A) <u>(Ns-Nr)x100/Ns</u> B) (Ns-Nr)x100/Nr C) (Nr-Ns)x100/Ns D) (Nr-Ns)x100/Nr
30.	Which of the following compressed air dryer consumes less power for the same output? A) Refrigeration Dryer **B) Heat of Compression Dryer** C) Heatless Purge type Dryer D) Blower Reactivated Type Dryer
31.	For centrifugal fans, relation between Pressure (P) and speed (N) is given by ___________. A) P1/P2 = N1/N2 **B) P1/P2 = $N1^2/N2^2$** C) P1/P2 = $N1^3/N2^3$ D) None of the above
32.	Pump Shaft Power is _____________. A) Hydraulic Power/ Motor Efficiency **B) Hydraulic Power/ Pump Efficiency** C) Hydraulic Power* Pump Efficiency D) None of the above
33.	The heat load of the cooling tower depends on____________. A) **Range** B) Approach C) Cooling tower fan speed D) Wet Bulb Temperature
34.	A Cooling Tower is operating with the following parameters: Wet Bulb Temp. = 27 ^{0}C, Cooling Water in Temperature = 45^{0}C, Cooling Water out Temperature = 35^{0}C What is the cooling tower effectiveness? A) 50% B) 44.44% **C) 55.55%** D) None of the above
35.	What will be the Power Factor of the system having Active Power as 812 KW and Reactive Power as 418 KVAR. **A) 0.89** B) 0.51 C) Leading 0.94 D) 1
36.	Synchronous speed of motor is directly proportional to __________. A) No. of Poles B) **Frequency** C) Terminal Voltage D) All of the above
37.	Which of the following is not a positive displacement compressor - A) Reciprocating B) Screw C) Roots Blower D) **Centrifugal**
38.	Adsorption drying of air is achieved using _______________. **A) Activated alumina** B) Carbon Molecular Sieves C) Zirconium Molecular Sieves D) None of the above
39.	If air leak quantity is 5 m^3/min, what will be power loss per hour in compressor which is having specific power consumption of 0.09 kWh/m^3 **A) 27 Units/hr** B) 0.45 Units/hr C) 72 Units/hr D) None of the above

40.	Dry Bulb and Wet bulb temperature will be same at ___________. A) 0% Relative Humidity B) 50% Relative Humidity **C) 100% Relative Humidity** D) None of the above
41.	What will be ventilation rate of 15mx10mx5m room having ACH of 10 ___________. A) 750 m^3/hr B) **7500 m^3/hr** C) 75000 m^3/hr D) None of the above
42.	100 kCal/min heat transfer rate is equivalent to ______________. **A) 1.98 TR** B) 0.98 TR C) 19.8 TR D) None of the above
43.	Which of the following equipment is having least compression ratio? A) Compressor B) Blower C) **Axial Fan** D) Radial Fan
44.	Flow control of fans can be achieved by___________. A) Changing pulley dimensions B) Damper Control C) VFD D) **All of the above**
45.	Which of the following is used to capture water droplets in the air stream leaving the cooling tower? A) Splash fill B) Film fill **C) Drift eliminator** **D)** Any of the above
46.	If evaporation loss of Cooling tower is 10 M^3/Hr, what will be make up water flow at a COC of 5? A) 2.5 m^3/hr B) **12.5 m^3/hr** C) 15 m^3/hr D) None of the above
47.	Calculate the Volumetric Flow (m^3/sec) in a pipe with a diameter 200 mm and Velocity 1.5 m/sec? A) 0.19 m^3/sec B) 0.015 m^3/sec C) **0.047 m^3/sec** D) 0.012 m^3/sec
48.	A pump discharge has to be reduced from 120 m^3/hr to 100 m^3/hr by trimming the impeller. What should be the percentage reduction in impeller size? A) 33.3% B) 50% **C) 16.7%** D) 83.3%
49.	If the Collection Efficiency is 90% and Billing Efficiency is 95% then AT&C losses are ______________. A) 85.5% **B) 14.5%** C) 15% D) None of the above
50.	If two pumps are operated in parallel then Shut-off head a. **Does not change** b. Halved c. Doubled d. Less than double

-------- 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 textile industry had installed a 2 MVA transformer. The initial demand of the plant was 1500 kVA with power factor of 0.75. Industry has installed 450 kVA capacitor at the motor end. Calculate the following: 1. Reduction in apparent power (kVA) 2. Improved power factor and 3. Revised % loading of transformer after installing the capacitor
Ans	Real / True Power, kW = 1500 x 0.75 = 1125 kW Old Reactive Power, kVAr = Sqrt of $[(1500)^2 – (1125)^2]$ = 992 kVAr After installation of 450 kVA capacitor, Revised reactive power, kVAr = 992 – 450 = 542 kVAr Revised apparent power, kVA = Sqrt of $[(1125)^2 + (542)^2]$ = 1248 kVA Reduction in apparent power, kVA = 1500 – 1248 = 252 kVA Improved power factor = 1125 / 1248 = 0.90. Revised % loading of transformer = 1248 / 2000 = 62.4%
S-2	Find out the Effective Aperture (EA) of following two glazing and comment about compliance with ECBC. Case # 1 Window to Wall Ratio (WWR): 0.2 Visible Light Transmittance (VLT): Transparent Case # 2 Window to Wall Ratio (WWR): 0.45 Visible Light Transmittance (VLT): 0.2
Ans	Case # 1 EA = VLT x WWR EA = 1.0 x 0.2 = 0.2 As EA > 0.1, Glazing complies with ECBC Case # 2 EA = 0.2 x 0.45 = 0.09. As EA < 0.1, Glazing does not comply with ECBC
S-3	A three-phase induction motor has the following details: - Name plate details : 55 kW, 415V, 95A, 0.90 PF, 50 Hz Running load details : 410V, 75A, 0.80 PF, 48 Hz

	Calculate the loading percentage and rated efficiency of the motor.
Ans	Actual power drawn by the motor = 1.732*410*75*0.80/1000 = 42.6 kW Rated input power = 1.732*415*95*0.90/1000 = 61.5 kW Percentage loading of motor = 42.6/61.5 = 69.3% Rated efficiency of motor = 55/61.5 = 89.4%
S-4	In an engineering industry, compressed air delivered is 500 CFM (FAD) and the compressor discharge pressure is 6 kg/cm^2 (gauge). Calculate the size of the header by considering velocity of compressed air 6 m/s. Assume Temperature remains constant.
Ans	Quantity of Compressed Air = 500CFM = 14.17 m^3/min. Working Pressure = 6 kg/cm^2 (g) = 7.013 kg/cm^2 (a) Atmospheric pressure = 1.013 kg/cm^2 (a) Apply gas law assuming temperature remains constant P1*V1 = P2*V2 P1*V1/P2 = 14.17 m^3/min * 1.013 kg/cm^2/7.013 kg/cm^2 V2 = 2.05 m^3/min. = 0.03417 m^3/ sec. Quantity of Air Flow = Area of Pipeline * Velocity of Air Flow 0.03417 = 22/7*D2/4 * 6 Diameter of pipeline = 0.085 mtr = 3.35 Inch
S-5	A multi storied office has centralized air conditioning system by using the chilled water. The chilled water inlet and outlet temperatures are 13^{o}C and 9 ^{o}C respectively. The chilled water pump discharge pressure is 4.2 kg/cm^{2}g and the suction is 10 meters above the pump centerline. The power drawn by the chilled water pump's motor is 75 kW and an efficiency of 92 %. The chilled water pump efficiency at the operating point from pump characteristic curve is 65 %. Find out the operating refrigeration load in TR.
Ans	Total head of the Chilled Water Pump = (4.2*10) - 10 = 32 Meter Shaft Power of the Pump = 75*0.92 = 69 kW Flow rate = ((69 x 1000) X 0.65} / 32 x 1000 x 9.81 = 0.14287 m^3/s = 514.33m^3/hr Refrigeration load = 514330*4/3024 = 680 TR
S-6	Discuss in brief about working principal Membrane Dryer for Compressed Air.
Ans:	Refer guide book 3, Page no 96
S-7	In a DG set, the generator is rated for 1000 kVA, 415V, 1390 A, 0.8 pf, 1500 rpm. The full load specific energy consumption of this DG set as measured by the energy auditor is 3.7 kWh per liter of fuel and air drawn by the DG set is 25 kg/kg of fuel. The energy auditor recommended for a waste heat recovery system.

	The exhaust gas temperature difference across the waste heat recovery boiler is 215 ^{0}C. The flue gas temperature after waste heat recovery system is maintained at 180^{0}C to avoid corrosion. Calculate the steam generation in kg/hr from waste heat recovery boiler if the heat gain by feed water is 580 kCal/kg, specific gravity of fired fuel oil of 0.86 and specific heat of flue gas is 0.23 kCal/kg ^{0}C.
Ans	

1	Rated kVA of Diesel Generator	1000
2	Rated kW @ 0.8 pf	800
3	Specific fuel consumption (kwh/lts)	3.7
4	Specific gravity of fuel oil	0.86
5	Oil consumption at full load in kg/hr ((Sl. No.2*4)/3)	185.95
6	Air supplied per kg of fuel (kg)	25
7	Mass of flue gas (Sl. No. 6+1 kg) Kg/Kg of fuel	26
8	Mass of flue gas kg per hour (Sl. No. 7*5)	4834.60
9	Delta T across waste heat recovery system	215
10	Heat available for recovery in WHRB (Kcal/ kg) (Sl. No. 8 *9 *0.23)	239070.7
12	Heat Gain by feed water in WHRB (Kcal/Hr)	580
13	Quantity of Steam Generated (Kg/Hr) (Sl. 10/12)	412

S-8	Fill in the blanks for the followings: a) ECBC is applicable to commercial buildings having contract demand of ______ kVA. b) In a centrifugal fan if speed is reduced by 30% static pressure will reduce by____%. c) If the speed of a reciprocating pump is reduced by 30 %, the power consumption will reduce by________%. d) The unit of specific humidity of air is ___________. e) The synchronous speed (rpm) of a 2 pole induction motor at 49 Hz supply frequency is________.
Ans	a) 120 KVA b) 51% c) 30% d) grams moisture/kg of dry air e) 2940 rpm

-------- 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) State: Increases or Decreases (1 Mark each) 1. If air dry bulb temperature is increased then Relative Humidity will 2. In a pumping system, if the suction side liquid level is increased then NPSHa will 3. If the air temperature increases at the inter-cooler outlet, then air compressor power consumption will 4. A blower is retrofitted with a VFD and operated at full speed. The power consumption will 5. As the design speed of the motors decreases the capacitor KVAr requirement will
Ans	1. Decreases 2. Increases 3. Increases 4. Increases 5. Increases
L-1	B) Match the following (1 Mark each) 1. Pitot Tube — A. Cooling Tower 2. Refrigerant Drier — B. Lighting Control 3. Condenser — C. Gas velocity in ducts 4. Spray Nozzles — D. Compressed Air System 5. Occupancy Sensor — E. Refrigeration System
Ans	1. Pitot Tube — C. Gas Velocity in ducts 2. Refrigerant Drier — D. Compressed Air System 3. Condenser — E. Refrigeration System 4. Spray Nozzles — A. Cooling Tower 5. Occupancy Sensor — B. Lighting Control
L-2	During the energy audit of central chiller plant, following parameters were noted. • Chilled water flow (Inlet to evaporator of chiller): 250 m^3/hr • Chilled water inlet temperature: 12 ^oC • Chilled water outlet temperature: 7 ^oC • Motor Input Power: 350 kW • Motor Efficiency: 90% • Condenser water inlet temperature (going to chiller or outlet of cooling tower): 31 ^oC • Condenser water outlet temperature (leaving from to chiller or inlet to cooling tower): 36 ^oC • Wet Bulb temperature of ambient air (going to Cooling tower): 28 ^oC • Make up water TDS (for Cooling tower): 180 ppm • Permissible limit of TDS for cooling water: 720 ppm • Condenser cooling capacity is 25% higher than the evaporator cooling capacity. Calculate the following:

	• kW/TR of chiller compressor 3 m • COP of the chiller 1 m • Effectiveness of cooling tower 1 m • Evaporation loss, m^3/hr 3 m • Blow down quantity, m^3/hr 1 m • Make-up water requirement, m^3/hr ignoring no drift loss. 1 m
Ans:	Chiller machine capacity, TR = [250 x 1000 x 1 x (12 – 7)] / 3024 = 413.4 TR kW/TR of chiller compressor = (350 x 90%) / 413.4 = 0.762 COP = (413.4*3024) / (350*0.9*860) = 4.6 Effectiveness = (36 - 31) / (36 - 28) = 62.5% Cycle of Concentration, COC = 720 / 180 = 4 Condenser capacity, TR = 1.25 x 413.4 = 516.75 TR Condenser water flow or cooling tower circulation flow = 516.75*3024 / [1000 x 1 x (36 – 31)] = 312.5 m^3/hr Evaporation loss, m^3/hr = 0.00085 x 1.8 x 312.5x (36 – 31) = 2.3 m^3/hr Blow down quantity, m^3/hr = 2.3 / (4 – 1) = 0.797 m^3/hr Make up water, m^3/hr = 2.3 + 0.797 = 3.097 m^3/hr
L-3	A 30 MW coal fired thermal power plant uses conventional wet ash disposal system for ash evacuation. During an energy audit at ash slurry disposal pump house it was observed that only one ash slurry disposal series is continually operated out of installed three numbers of series. The other data collected and measured in the pump house are as follows: Name of operating series - Series B Number of pumps per series - Two Rated parameters of each pump- Flow 815 m^3/hr, Head 33 mWc, Slurry Flow rate measured at second series pump discharge- 752 m^3/hr Suction Head to 1st pump- +2.6 meter Final Slurry discharge pressure- 5.2 kg/cm^2 (g) Differential Pressure across 1st slurry pump- 2.44 kg/cm^2 Differential Pressure across 2nd slurry pump- 2.5 kg/cm^2 Ash water ratio (by weight) of the slurry- 1:15 Ash slurry density- 1032 kg/m^3 Electric power input to motor of 1st slurry pump- 141 kW Electric power input to motor of 2nd slurry pump- 139 kW Motor rating of each pump- 200 kW Full Load Motor Efficiency- 93%

	Belt Transmission Efficiency: 92% Evaluate the following: i) Individual pump efficiencies if the operating motor efficiency is 92% for all pumps ii) Specific energy consumption of each pump (kWh/m^3) iii) Specific energy consumption of the series (kWh/m^3) iv) As water conservation measure the energy auditor recommended to maintain ash water ratio of slurry at 1:7 and slurry density of 1067 kg/m^3, calculate the incremental power consumption of each pump and series if all other parameters are unchanged.
Ans	Individual pump Efficiencies and Specific Power Consumption are as follows:

Sl. No	Pump Ref:	1st Pump	2nd Pump
1	Flow Rate (M^3/hr) – Q	752	752
2	Diff. Head (m) – H	24.4	25
3	Slurry Density (kg/m^3) -p	1032	1032
4	Liquid kW (LKW =Q/3600XHXpX9.81/1000)	51.60	52.87
5	Power Drawn by motor kW- Pin	141	139
6	Motor eff. % - Em	92.0%	92.0%
7	Coupling eff. % - Ec	92.0%	92.0%
8	Pump eff. % (Ep=LKW/(PinXEmXEc)X100)	43.0%	44.9%
9	Specific Energy Consumption (kWh/M^3) (Pin/Q)	0.188	0.185
10	Specific Energy Consumption of series (kWh/M^3)	0.372	

In case of changing the ash water ration the following will be additional power consumption.

Sl. No	Pump Ref:	1st Pump	2nd Pump
1	Flow Rate (M^3/hr) – Q	752	752
2	Diff. Head – H	24.4	25
3	Slurry Density – p	1067	1067
4	Liquid kW (LKW= Q/3600XHXpX9.81/1000)	53.35	54.66
5	Motor eff. % - Em	92.0%	92.0%
6	Coupling eff. % - Ec	92.0%	92.0%
7	Pump eff. % - Ep	43.0%	44.9%
8	Power Drawn by motor kW – Pin New =LKW/(EmXEcXEp)	146.58	143.83
9	Earlier Power Drawn by motor kW – Pin	141.0	139.0
10	Inc. Power Cons. in kW = Pin New- Pin	5.58	4.83
11	Inc. Power Consumption in kW of series	10.41	

L-4	An engineering industry operating three shifts per day has replaced their old reciprocating compressors with 1000 CFM screw compressors. During the energy audit, the following data's were collected:

	Run hours counter reading		Power,kW
	Start of the month	End of the month	
Load Hours	7956	8401	166 (Loading kW)
Un-Load Hour	4918	5121	58.1 (un-loading kW)

Calculate the following:

1. Capacity utilization (%) of the compressor
2. Monthly energy consumption for the present loading of the compressor
3. Plant management is considering to install a 750 CFM compressor for energy savings. Estimate the energy saving for same operating load, if loading power is 125 kW and unloading power is 43.75 kW.
4. To meet the present air requirement, if VFD to be installed in the 1000 CFM compressor, what should be the percentage reduction in speed.

Ans

	Start of the month	End of the month	Running Hours
Load Hours	7956	8401	445
Un-Load Hour	4918	5121	203
		Total Running hrs	648

1. Capacity Utilization = Air delivery during the month / full load capacity
   = 445 x 60 x 1000 CFM / 648 x 60 x 1000
   = 0.69 or 69 %
2. Monthly energy consumption for the present loading of the compressor

   = (445 x 166)+ (203x58.1)

   = 85664.3 kWh
3. Monthly air requirement = 445 x 60 x 1000 = 26700000 C.ft

   750 CFM compressor capacity utilization = 26700000 C.ft / 750 x 60 x 648 = 0.92

   Therefore loading time = 648 x 0.92 = 596.2 hrs

   Unloading time = 648- 596.2 = 51.8

   Monthly energy consumption = (596.2 x 125) + (51.8 x 43.75) = 76791.25 kWh

   Energy savings per month = (85664.3 - 76791.25) = 8873.05 kWh
4. Percentage reduction in speed:

	N1/N2 = T2/T1 N2 = T1/T2 x N1 = 445 / 648 x N1 = 0.69 N1 Therefore the percentage reduction is = 1-0.69 = 0.31 or 31%
L-5	A) A trivector-meter installed in a steel plant is monitoring the maximum demand with a demand interval of 15 min. The observed maximum demand during one demand interval is given below: <table><tr><td>Trivector-meter observation period in Minutes</td><td>Demand Recorded (kVA)</td></tr><tr><td>3</td><td>9634</td></tr><tr><td>4</td><td>10257</td></tr><tr><td>3</td><td>8436</td></tr><tr><td>5</td><td>9847</td></tr></table>Calculate the following: a. Recorded maximum demand during the cycle. b. Calculate the demand reduction and capacitor kVAr required for improving power factor to 0.99 from average observed power factor of 0.92.
Ans	<table><tr><td>Maximum Demand Registered</td><td>9631.533</td><td>kVA</td></tr><tr><td>Observed PF</td><td>0.92</td><td>Pf</td></tr><tr><td>Demand in kW</td><td>8861</td><td>kW</td></tr><tr><td>Improved PF</td><td>0.99</td><td>Pf</td></tr><tr><td>New demand with improved PF</td><td>8951</td><td>kVA</td></tr><tr><td>Reduction in demand</td><td>681</td><td>kVA</td></tr><tr><td>Capacitor required</td><td>2508</td><td>kVAr</td></tr></table>
L-5	B) A spinning unit proposed to replace 50 no’s of 22kW IE2 motors with IE3 motors under National Motor Replacement Programme. The present operating details of the motors are as follows: Average Loading of the motor: 74% IE2 Motor Efficiency:90% IE3 Motor Efficiency:93% Annual Operating Hours: 7000 Hrs Energy Cost: Rs.10 / kWh CO_2 Emission from electricity: 0.85 Kg/kWh Calculate annual energy savings and emission reduction in Tons of CO_2.
Ans	<table><tr><td>Motor rating</td><td>22</td><td>kW</td></tr><tr><td>Percentage Loading</td><td>74%</td><td>%</td></tr><tr><td>Present load</td><td>16.28</td><td>kW</td></tr><tr><td>IE2 motor efficiency</td><td>90%</td><td>%</td></tr></table>

	Input power for the present load	18.08	kW
	IE3 Motor efficiency	93%	%
	Input power for the present load	17.50	kW
	Savings in power	0.58	kW
	Operating hours	7000	Hr
	No. of Motors considered for replacement	50	Nos.
	Annual energy savings	4084.59	kWh
	Annual cost savings (Rs.10/kWh)	40845.88	Rs.
	Annual cost savings for 50 Motors (Rs.)	20.4	Rs. Lakhs
	Average CO2 reduction	0.85	kg of CO2/kWh
	Estimated CO2 reduction for 50 motors	173.595	Tons

L-6 A)

In a ventilation duct of 0.6 m x 0.6 m size, the average velocity of air measured by vane anemometer is 30 m/s. The static pressure at inlet of the fan is -25 mm WC and at the outlet is 35 mm WC. A 3 phase induction motor coupled with fan through belt drive draws 19 A at 410 V at a power factor of 0.8. Find out the efficiency of the fan. Assume motor efficiency 90% and belt transmission efficiency of 98% (density correction can be neglected).

Ans

Volume flow rate of the fan, Q = Velocity x Area

= 30 x 0.6 x 0.6

= 10.8 m^3/s

Power input to the fan shaft

= Motor input power x motor efficiency x transmission efficiency

= $(\sqrt{3} \times 0.410 \times 19 \times 0.8 \times 90\% \times 98\%)$

= 9.52 kW

$$\text{Fan efficiency} = \frac{\text{Volume in } m^3/s \times \text{total pressure in mm WC}}{102 \times \text{Power input to the shaft in (kW)}}$$

$$= \frac{10.8 \times [35 - (-25)] \times 100}{102 \times 9.52}$$

$$= 66.7\%$$

L-6 B) Explain how Computational Fluid Dynamics (CFD) can be used for enhancing the Energy Efficiency. **4 Marks**

Ans Refer guide book 3, Page no 165-166

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

Paper 3 Pink

22nd NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – JULY, 2022

PAPER – 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Date : 31.07.2022 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

1.	The advantage of multi-staging compression over single stage compression is a) Lower power consumption per unit of air delivered b) High volumetric efficiency c) Decreased discharge temperature **d) All of above**
2.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by **a) discharge pressure/suction pressure** b) suction pressure/discharge pressure c) discharge pressure/ (suction pressure + discharge pressure) d) suction pressure/ (suction pressure + discharge pressure)
3.	A device that distributes filters or transforms the light emitted from one or more lamps is a) Control gear **b) Luminaire** c) Lamp d) Starter
4.	For the same quantity of power handled by a distribution line, lower the voltage a) lower the current drawn and lower the distribution loss b) lower the voltage drop and lower the distribution loss c) **higher the current drawn and higher the distribution loss** d) higher the voltage drop and lower the distribution loss
5.	The power drawn by a centrifugal fan is **a) inversely proportional to fan efficiency** b) directly proportional to fan efficiency c) inversely proportional to static pressure d) inversely proportional to flow rate
6.	In a transformer on load, if the secondary voltage is one-fourth the primary voltage, then the secondary current will be **a) four times the primary current** b) sixteen times the primary current c) one-fourth the primary current d) two times the primary current
7.	In BEE Star labelled distribution transformers, which of following losses are defined? **a) total loss at 50% and 100% loading** b) total loss at 75 % loading c) total loss at 75% and 100% loading d) total loss at 100% loading
8.	Friction losses in a pumping system is a) inversely proportional to flow b) inversely proportional to cube of flow **c) proportional to square of flow** d) inversely proportional square of flow
9.	If V_1 is actual supply voltage and V_2 is the rated voltage of a capacitor, the reactive kVAr produced would be in the ratio of a) V_2^2/V_1^2 **b) V_1^2 / V_2^2** c) $1 - V_2^2/V_1^2$ d) $1 + V_2^2/V_1^2$

10.	The blow down loss in a cooling tower depends on a) TDS in circulating water b) TDS in make-up water c) evaporation loss **d) all the above**
11.	Energy Star Label Rating scheme for Fluorescent lamp is based on: **a) Lumens per Watt at 100, 2000 and 3500 hours of use** b) End of Lamp Life in terms of burring hours c) Lumen depreciation at 2000 hours d) Color Rendering Index
12.	Identify the wrong statement from the following regarding Vapor Compression Refrigeration system a) condenser rejects heat to atmosphere b) evaporator removes heat from process or space c) compressor sends superheated vapor to condenser **d) high pressure sub-cooled liquid refrigerant returns back to evaporator**
13.	The efficiency of a pump does not depend on a) suction head b) discharge head **c) motor efficiency** d) density of liquid
14.	Which of the following is a positive displacement compressor? a) Screw compressor b) Reciprocating compressor c) Centrifugal compressor **d) Both a & b**
15.	The most energy intensive dryer among the following a) refrigeration b) desiccant (heat of compression) **c) desiccant (heatless purge)** d) desiccant (blower reactivated)
16.	The ratings of the PF correction capacitors at motor terminals for a 37 kW induction motor at 3000 rpm synchronous speed will be ____________ in comparison to the same sized induction motor at 1500 rpm synchronous speed a) more **b) less** c) same d) dependent on the connected load
17.	In a vapor compression refrigeration system, the component across which the enthalpy remains constant a) compressor b) condenser **c) expansion valve** d) evaporator
18.	A pump discharge has to be reduced from 120 m^3/hr to 100 m^3/hr by trimming the impeller. What should be the percentage reduction in impeller size? a) 83.3% **b) 16.7%** c) 50.0% d) 33.3%
19.	In an engine room 15 m long, 10 m wide and 4 m high, ventilation requirement for 20 air changes/hr is___________m^3/hr a) 30 b) 3000 **c) 12000** d) none of the above
20.	Which of the following type of lamps is most suitable for color critical applications ? **a) halogen lamps** b) LED lamps c) CFLs d) Low pressure sodium vapour lamp
21.	Which of the following is not true regarding system characteristic curve in a pumping system with large dynamic head ? a) System curve represents a relationship between discharge and head loss in a system of pipes **b) System curve is dependent on the pump speed** c) The basic shape of a system curve is parabolic d) System curve will start at zero flow and zero head if there is no static lift

22.	The inexpensive way to improve energy efficiency of a motor which operates consistently at below 40% of rated capacity is by _____. a) **Operating in Star mode** b) Replacing with correct sized motor c) Operating in delta mode d) Operating in VFD mode
23.	Installing larger diameter pipe in pumping system results in reduction in-------- a) static head b) **frictional head** c) both a and b d) neither a nor b
24.	If the delivery valve of the pump is throttled such that it delivers 30% of the rated flow, one of the best options for improved energy efficiency would be a) Trimming of the impeller b) Replacing the motor c) **Replacing with a smaller pump** d) operating with VFD
25.	A cooling tower is said to be performing well when: a) **approach is closer to zero** b) range is closer to zero c) approach is larger than design d) range is larger than design
26.	Capacitors with automatic power factor controller when installed in a plant: a) reduces active power drawn from grid b) reduces the voltage of the plant **c) reduces the reactive power drawn from grid** d) increases the load current of the plant
27.	For an air compressor with displacement of 100 CFM and system leakage of 10%, free air delivery is ______. a) 111.11 CFM b) 90 CFM **c) 100 CFM** d) None of the above
28.	If 30,000 kcal of heat is removed from a room every hour then the refrigeration tonnage will be nearly equal to a) 30 TR b) 15 TR **c) 10 TR** d) 100 TR
29.	A 500 cfm reciprocating compressor has a loading and unloading period of 5 seconds and 20 seconds respectively during a compressed air leakage test. The air leakage in the compressed air system would be a) 125 cfm **b) 100 cfm** c) 200 cfm d) none of the above
30.	The Solar Heat Gain Coefficient (SHGC) of window of a building is 0.30. This means that a) The window reflects back to exterior a minimum of 30 % of the sun's heat b) **The window allows 30 % of the sun's heat to pass through into the building interior** c) 70 % of the sun's heat is incident on the window d) The window allows 70 % of the sun's heat to pass through into interior of the buildings
31.	The illuminance is 20 lm/m² from a lamp at 1 meter distance. The illuminance at half the distance will be a) 401 lm/m² b) 10 lm/m² c) 20 lm/m² **d) 80 lm/m²**
32.	Use of soft starters for induction motors results in a) **Lower mechanical stress** b) Lower power factor c) Higher maximum demand d) All the above
33.	Energy performance index is calculated based on a) **total building annual energy consumption /built up area** b) total building annual energy consumption /carpet area c) total building annual energy consumption for HVAC and lighting /carpet area d) none of the above

34.	A 4 pole 50 Hz induction motor is running at 1470 rpm. What is the slip value? a) 20% b) **2%** c) 4% d) 40%
35.	Which of the following power plants has the highest efficiency? a) Open cycle Gas Turbine b) Diesel Engine c) **Combined cycle gas turbine** d) Conventional coal plants
36.	___________is used as refrigerant both in vapour compression and vapour absorption systems a) Lithium Bromide b) Water c) HFC 134A d) **Ammonia**
37.	Which of the following parameters is not required for evaluating volumetric efficiency of reciprocating air compressor? a) **Power input** b) FAD c) Cylinder Stroke d) Cylinder bore
38.	The gross efficiency of a coal based power generating unit with a gross heat rate of 2600 kcal / kWh is _______ a) 41.4% b) 38.7% **c) 33.1%** d) 30.8%
39.	The COP of a vapour compression refrigeration system is 3.3. If the motor draws power of 10 kW at an operating efficiency of 90%, the tonnage of refrigeration system is about: a) 0.8 **b) 8.5** c) 7.2 d) 9.6
40.	Increasing the suction pipe diameter in a pumping system will a) Decrease NPSHA **b) Increase NPSHA** c) Decrease NPSHR d) Increase NPSHR
41.	For a Cooling Tower, if evaporation loss is 15 m^3 / hour and Cycles of Concentration is 2.5, the blowdown is equal to a) 6 m^3 / hour **b) 10 m^3 / hour** c) 22.5 m^3 / hour d) 37.5 m^3 / hour
42.	In T-5 Fluorescent Lamp, "5" is indicative of: a) 5 watt power rating b) 5% Energy Saving with respect to T8 c) 5^{th} generation lamp d) **Tube diameter**
43.	Which of the following is not likely to create harmonics in an electrical system? a) soft starters b) variable frequency drives c) uninterrupted power supply source (UPS) d) **electric heater**
44.	The performance of rewinding of an induction motor can be assessed by which of the following factors? a) load current b) stator resistance c) no load current d) **both b and c**

45.	In a DG set, a 3-phase alternator is supplying on an average 100 A at 420 V and 0.9 pf to a load. If the specific fuel consumption of this DG set is 0.30 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour? a) 11.34 litre **b) 19.64 litre** c) 21.82 litre d) 1964.088 litre
46.	The total loss for a transformer loading at 60% with no load and full load losses of 3 kW and 25 kW respectively, is a) 3 kW **b) 12 kW** c) 18 kW d) 25 kW
47.	A process fluid at 40 m^3/hr, with a density of 0.95, is flowing in a heat exchanger and is to be cooled from 35 ^oC to 29 ^oC. The fluid specific heat is 0.78 kCal/kg. If the chilled water range across the heat exchanger is 4 ^oC, the chilled water flow rate is **a) 44.46 m^3/hr** b) 40.41 m^3/hr c) 35.37 m^3/hr d) none of the above
48.	In which of the following fans the air does not change flow direction from suction to discharge? a) tube axial fan b) vane axial fan c) propeller fan **d) all the above**
49.	What is window to wall ratio________ **a) Vertical fenestration area / gross exterior wall area** b) Vertical fenestration area / Net exterior wall area c) gross exterior wall area/ Vertical fenestration area d) Net exterior wall area/ Vertical fenestration area
50.	The maximum thermal efficiency of a diesel engine power plant is in the range of _____ **a) 43-45 %** b) 53-55% c) 63-65 % d) 73-75%

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

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

S-1	The input parameter measured for a 15 kW, 3 phase, 415 V induction motor is 25 A and 12 kW at 410 V. Calculate the following a) Apparent Power drawn by the motor at the operating load (1 Mark) b) Reactive Power drawn by the motor at the operating load (3 Marks) c) Operating power factor (1 Mark)
Ans	Apparent power = 1.732 x 0.410 x 25 = 17.75 KVA Reactive power = sqrt (apparent power^2 - active power^2) Active power = 12 kW Reactive power = sqrt (17.75^2 - 12^2) = sqrt (171.06) = 13.07 kVAr Operating power factor = Active power/Apparent power

= 12/17.75
= 0.676

S-2 The total system resistance of a water supply piping system is 30 meters and the static head is 10 meters at designed water flow. Calculate the system resistance offered at 75%, 50% and 25% of water flow.

Ans Total System Resistance of piping system: 30m
Static Head :10 m **(Static head will remain same irrespective of the flow)**
So, Dynamic Head at designed water flow: (30-10) =20m

No.	Flow %	Static Head (m)	Dynamic Head (m) = 20 x $(\%flow)^2$	Total System Resistance (m)
1	75%	10	11.25	21.25
2	50%	10	5.0	15.0
3	25%	10	1.25	11.25

S-3 An energy audit study of a central chiller system in a commercial building was conducted and measured parameters are given below.

Chilled water inlet temperature :12 ^{0}C
Chilled water Outlet temperature :7 ^{0}C
Chilled water pump discharge pressure : 3.6 kg/cm^{2}g
Pump suction is 5 meters above the pump center line
Power drawn by the chilled water pump motor:70 kW
Efficiency of pump motor : 93 %
Pump efficiency: 60 %

Find out the operating load of the Chiller system in TR.

Ans Total head 36 –5 = 31 m
Pump shaft power 70 x 0.93 = 65.1 kW
Flow rate = (65.1 x 1000) X 0.6 / 31 x 1000 x 9.81 = 0.128 m^3/s or 460.8 m^3/hr
Refrigeration load (460800 x 5) / 3024 = 761.9 TR

S-4 a) A plant has installed a refrigerant dryer for supplying dry air for their process applications and dryer coil is maintained at 5 ^{0}C & 100% RH. The average air flow through the dryer is 100 kg/min. The air properties are given below — 3 Marks

Parameter	Enthalpy (kJ/kg of dry air)	Absolute Humidity (grams/kg of dry air)
Inlet air 35 ^{0}C & 50% RH	81	18
Dryer coil 5 ^{0}C & 100% RH	19	5.5

Calculate the following:
i) Moisture removed per hour.
ii) Cooling capacity of coil in TR.

b) List down any three energy saving measures in compressed air systems. — 2 Marks

Ans a)
i) Moisture removed = 100 x (18 - 5.5)
= 1250 grams/min = 1.25 kg/min = 75 kg/hr
ii) TR = 100 x (81 - 19)
= 6200 kJ/min = 6200/(4.186) = 1481.13 kcals/min
= 1481.13*60/3024
= 29.39 TR

b) Energy saving measures for compressed air system

Refer guidebook-3, page no 80-99

S-5 A DISCOM has taken initiatives to reduce Aggregate Technical & Commercial (AT & C) losses in their network. The energy supplied, received and revenue details are given below:

Input energy	: 50 MU
Billed Energy (Metered)	: 39 MU
Billed Energy (Un-metered)	: 2 MU
Amount Billed	: Rs. 470 Million
Arrears collected	: Rs. 30 Million
Gross Amount collected	: Rs. 390 Million

a) Estimate the AT & C losses (in %) **3 Marks**

b) List any four strategies to reduce the commercial losses. **2 Marks**

Ans

a) Billing efficiency % = (Total Units billed, MU/ Total Input, MU) x 100

= [(39 + 2) / 50] x 100 = 82%

Collection efficiency, % = (Gross amount collected-Arrears, Rs. / Amount billed,Rs.) x 100

= [(390 - 30) / 470)] x 100 = 76.6%

AT & C Loss = [1 - (Billing efficiency x Collection Efficiency)] x 100

= [1 - (0.82 x 0.766)] x 100 = 37.19%

b)

Strategies to reduce commercial losses.

Refer guidebook-3, page no 27

S-6 The size of an air-conditioned office is 12 m X 7 m. Desired illuminance level is 200 Lux. An architect has suggested to install 24 no's of 20 W LED lights at a height of 3 m from ground level. The working plane is 0.75 m above the floor. The other details of 20W LED lamps are:

- Output of LED Lamp : 2000 lumens
- Utilization factor : 0.65
- Light Loss Factor (LLF) : 0.75

Calculate Room Index & number of LED lights required to get the desired illuminance. As an energy manager do you agree with the architect decision-why?

Ans:

Mounting Height, $H_m = 3 – 0.75 = 2.25$ m

Room Index (RI) = [L x W] / [H_m x (L + W)]
= [12 x 7] / [2.25 x (12 + 7)] = 1.97

$$\text{Number of LED lights} = \frac{E \times A}{F \times UF \times LLF}$$

$$= \frac{200 \times (12 \times 7)}{2000 \times 0.65 \times 0.75}$$

= 17.23

So total number of 20 W LED lights required is 18 nos

No, I don't agree with architect decision as number of LED light required is only 18 against suggested of 24 nos which is an energy inefficient design.

S-7 A centrifugal fan drawing 54 kW and operating at 1440 RPM is delivering air at 30000 m^3/hr. The head developed by the fan is 400mmWC, If the speed is decreased by 200 rpm, calculate the following

a) Air Flow in m^3/hr (1 mark)

b) Static Pressure in mmWC (2 marks)

	c) Power drawn in kW (2 marks)
Ans	1. Air flow in m^3/hr = (1240/1440) *30000 = 25833.33 m^3/hr 2. Static Pressure in mmWC =$(1240/1440)^2$ *400 = 296.61 mmWC 3. Power drawn in kW =$(1240/1440)^3$ *54 =34.48 kW
S-8	State True or False. (1 Mark each)
Ans	1. An industrial electrical system is operating at unity power factor. Addition of further capacitors will reduce the maximum demand (kVA). **- False** 2. In a step-down transformer for a given load the current in the primary will be more than the current in the secondary. **- False** 3. For the same no of poles and kW rating, the RPM of an energy efficient motor is higher than that of a standard motor. **– True** 4. The advantage of evaporative cooling is that it is possible to obtain water temperatures below the wet bulb economically. **– False** 5. A fluid coupling changes the speed of the driven equipment without changing the speed of the motor. **– True**

-------- End of Section - II --------

Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

L-1	Write short notes on the following: (each 2 Marks) a) Energy Performance Index (EPI) b) List any two Energy Efficiency measures in Building air conditioning system c) Building Envelop from an energy efficiency point of view. d) Difference between building area method and space function method for deriving Lighting Power density (LPD) e) Solar Heat Gain Coefficient (SHGC)
Ans	a) Refer Guide Book No 3, Chapter 10, Page No 287 b) Refer Guide Book No 3, Chapter 10, Page No 288 c) Refer Guide Book No 3, Chapter 10, Page No 270 d) Refer Guide Book No 3, Chapter 10, Page No 281 e) Refer Guide Book No 3, Chapter 10, Page No 272
L-2	In a steel industry, cooling water of 7500 m^3/hr and 4200 m^3/hr from two different sections with temperatures of 38 ^0C and 55 ^0C respectively, are fed to cooling tower after proper mixing. If the measured heat rejection by the cooling tower is 38,000 TR, calculate the effectiveness and evaporation loss of the cooling tower at 28 ^0C WBT.
Ans:	Mixed Hot Water Temp, ^0C = [(Flow1 x Temp1) + (Flow2 x Temp2)] / (Total Flow) = [(7500 x 38) + (4200 x 55)] / 11700 = 44.1 ^0C Range of Cooling Tower, ^0C = Heat Rejection / (Flow x Density x Sp. Heat) = (38000 x 3024) / (11700 x 1000 x 1) = 9.82 ^0C Cold Water Temp, ^0C = Mix Hot Water Temp – Range = 44.1 – 9.82 = 34.28 ^0C Approach, ^0C = Cold Water Temp – WBT of Air = 34.28 – 28 = 6.28 ^0C Effectiveness = Range / (Range + Approach) = 9.82 / (9.82 + 6.28) = 60.99% or 61% Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x Range = 0.00085 x 1.8 x 11700 x 9.82 = 175.8 m^3/hr

L-3	**Fill in the blanks for the following**

1. The main input energy used for refrigeration in vapor absorption refrigeration plants is____
2. One ton of refrigeration is equivalent to ______kW
3. Stray losses in an induction motor generally are proportional to the square of the ________current
4. The unit of AAhEPI is ______
5. If the pump impeller diameter is reduced by 10% then head reduces by ______%
6. A 4 pole,50Hz motor operating with slip of 3% will have a shaft speed of ______RPM
7. Effective Aperture Glazing (EA) = VLT x ______
8. In an amorphous core distribution transformer, no-load loss is ______ than a conventional transformer
9. As the condensing temperature increases, kW/TR of refrigeration system will ______
10. The extent of drying compressed air is expressed by the term ______

Ans

1. Thermal energy (or steam or waste heat or gas or any energy related to thermal energy)
2. 3.51
3. Load current
4. Wh/sqm/hr
5. 19%
6. 1455
7. Window to wall ratio
8. Less
9. Increase
10. Atmospheric Dew point /Dew Point

L-4

The data for centrifugal chiller and vapour absorption chiller are given below

Parameter	Centrifugal chiller	VAM
Chilled water flow (m^3/h)	189	180
Condenser water flow (m^3/h)	238	340
Chiller inlet temp (°C)	13.0	14.6
Condenser water inlet temp (°C)	27.1	33.5
Chiller outlet temp (°C)	7.7	9.0
Condenser water outlet temp (°C)	35.7	39.1
Power drawn by compressor (kW)	190	-
Steam consumption (kg/h)	-	1570
Chilled water pump (kW)	28	28
Condenser water pump (kW)	22	33
Cooling tower fan (kW)	6.0	15
Cost of Steam (Rs/kg)	-	2.0
Cost of electricity (Rs/kWh)	9.0	9.0

a) Evaluate the tonnes of refrigeration (TR) of both the systems? (4 Marks)
b) Operating Energy cost per hour for both the systems? (6 Marks)

Ans

a) Refrigeration load (TR) = Chilled water flow (m^3/hr.) x Spec. heat x Diff. in temp. / 3024

Centrifugal chiller TR = 189 x 1000x 1 x (13-7.7) / 3024 = 331.25 TR

VAM TR = 180 x 1000x 1 x (14.6-9.0) / 3024 = 333.33 TR

b) Auxiliary power consumption : Chilled water pump + condenser water pump + cooling tower fan

Auxiliary power (kW) : 28 + 22 + 6.0 = 56 kW

VAM auxiliary power (kW) : 28 + 33 + 15 = 76 kW

Energy cost of centrifugal chiller =(56+190)*9= Rs 2214/hr

Energy cost of VAM system = (76*9)+(1570*2)

= Rs 3824 /hr

L-5 A review of electricity bills of a process plant was conducted as a part of energy audit. The plant has a contract demand of 3000 kVA with the power supply company. The average maximum demand of the plant is 2000 kVA/month at a power factor of 0.95. The maximum demand is billed at the rate of Rs.350/kVA/month. The minimum billable maximum demand is 80% of the contract demand.

An incentive of 0.5 % reduction in energy charges component of electricity bill are provided for every 0.01 increase in power factor over and above 0.95. The average energy charge component of the electricity bill per month for the plant is Rs.80 lakhs.

Calculate the following

a) If the plant decides to improve the power factor to unity, determine the power factor capacitor kVAr required and the annual monetary benefits. **6 Marks**

b) What will be the simple payback period if the cost of power factor capacitors is Rs.1200/kVAr. **4 Marks**

S

kW drawn	2000 x 0.95 = 1900 kW
KVAr required to improve power factor from 0.95 to 1	= kW (tan θ_1 – tan θ_2)
	= kW (tan ($\cos^{-1}\varphi_1$) – tan ($\cos^{-1}\varphi_2$)
	= 1900 (tan ($\cos^{-1}$0.95) – tan ($\cos^{-1}$1)
	= 1900(0.329 - 0)
Power Factor Capacitor KVAr required	= 625 kVAr
Cost of P.F. capacitors @Rs.1200/kVAr	= 625 KVAr x 1200 Rs. / kVAr
	= Rs.7,50,000/-
Maximum Demand at unity power factor	= 1900/1 = 1900 kVA
80% of contract demand (3000 kVA)	= 3000x 0.8 =2400kVA
Reduction in Maximum Demand charges	(NIL) Though demand is reduced to 1900 KVA as per minimum billing requirement plant has to pay for 2400 KVA.
Percentage reduction in energy charge from 0.95 to 1 @ 0.5 % for every 0.01 increase	= ((1-0.95)/0.01) x (0.5%) = 5 x 0.5% = 2.5 %
Monthly energy cost component of the bill	= Rs.80,00,000
Reduction in energy cost component	= 80,00,000 x (2.5/100)
	= Rs.2,00,000/month
Annual reduction in energy cost component owing to P.F. improvement	= Rs.2,00,000 x 12 = 24,00,000/- per year
Annual Savings in electricity bill	= Rs.0+ 24,00,000= Rs. 24,00,000/-
Investment	= Rs.7,50,000/-

Payback period	= (Investment / Annual Savings) X 12 = (Rs.7,50,000/ 24,00,000) X 12
	= 3.75 months

L-6

a) During the performance evaluation of a DG set, the following parameters were noted

Capacity of DG set	750	kVA
Test duration	36	minutes
Units generated	250	kWh
Average Power factor	0.92	pf
Length of diesel tank	100	cm
Width of diesel tank	100	cm
Height of the diesel tank	90	cm
Initial tank dip level (from top)	63	cm
Final tank dip level (from top)	53	cm

Calculate the following:

1. Diesel consumption (Litres) **(1 Mark)**
2. Average load (kW) **(1 Mark)**
3. Percentage Loading (%) **(2 Marks)**
4. Specific power generation (kWh/Litre) **(1 Mark)**

b) A medium sized engineering industry has installed two 480 CFM screw compressors, A & B. Compressor-A is operating at full load and Compressor-B is running in load - unload condition. The load power of both the compressor is 74 kW and the unload power of the Compressor-B is 26 kW. Both the compressors are operated during working day.

The percentage loading of the Compressor-B during working day is 70 %. After arresting the leakage in the system the loading of the compressor was found to be 35 %. Estimate the energy savings per day. **5 Marks**

a)

1. Diesel Consumption = (1x1x 0.1)x 1000 =100 Liters
2. Average load (kW) = (250/36)x60 =416.67 kW
3. Percentage Loading (%) = (416.6/.92)/750 =60.4 %
4. Specific power generation (kWh/Litre) = (250/100) =2.5 kWh/Litre

b)

Existing Case:

Energy consumed per hour by Compressor -A= 74 kWh

	Energy consumed per hour by Compressor -B= 0.70 x 74 + 0.30 X 26 = 59.6 kwh Total energy consumed (Compressor A& B) = 74 + 59.6 = 133.6 kWh/hr Energy consumed per day= 133.6 X 24 hrs = 3206.4 kWh/day **Leakage Calculation** Energy consumed per hour by Compressor -B= 0.70 x 74 + 0.30 X 26 = 59.6 kwh Energy consumed per hour by Compressor -B= 0.35 x 74 + 0.65 X 26 = 42.8 kWh Difference in power consumption = 59.6 - 42.8 = 16.8 kWh/hr Savings by arresting leakage per day= 16.8 X 24 = 403.2 kWh/day

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

PAPER-3 CODE: PINK

21st NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS
PAPER – 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Date : 28.03.2021 Timings : 09:30-12:30 HRS Duration : 3 HRS Max. Marks : 150

General instructions :

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I: OBJECTIVE TYPE **Marks :50 x 1 = 50**

1.	Which of following is not used for speed control ? a) fluid coupling b) eddy current **c) soft starter** d) variable frequency drive	C
2.	Which of the following compressed air dryer requires the use of activated alumina ? a) membrane dryer **b) heat of compression dryer** c) refrigerant dryers d) all of the above	B
3.	During a leak test of a compressed air system, the compressor's average load time was 1.5 minute, average unload time was 10.5 minutes and flow rate was 35 m^3/min. The leakage quantity is **a) 4.375** b) 5.125 c) 7.625 d) 6.250	A
4.	Which of the following is not an adsorption type of air drier for compressed air system? a) blower reactivated type b) heat less purge type c) heat of compression type **d) refrigerant type**	D
5.	At which of the following dew points of the compressed air, the moisture content would be maximum? a) -10°C **b) -5°C** c) -40°C d) -20°C	B
6.	Which of the following uses concept of evaporative cooling? **a) cooling tower** b) domestic refrigerator c) window air conditioner d) deep freezer	A
7.	Specific Ratio is maximum for a) backward curved fan b) forward curved fan c) blowers **d) Compressors**	D
8.	Which of the following can be used to regulate the flow of fans? a) pulley change b) damper control c) inlet guide vane regulation **d) all of the above**	D

9.	What will be the blowdown loss of a cooling tower if evaporation loss is 15.32 m^3/hr and COC is 2.7 ? **a) 9.01 m^3/hr** b) 5.67 m^3/hr c) 41.3 m^3/hr d) 0.17 m^3/hr	A
10.	ECBC code is applicable to commercial buildings having connected load of______________. **a) 100 kW** **b) 500 kW** **c) 250 kW** **d) 1000 kW**	A,B, C,D
11.	Which of the following pump is not a positive displacement pump a) piston pump b) rotary vane c) diaphragm pump **d) centrifugal pump**	D
12.	The power factor of an electrical system having an active power of 100 kW and reactive power of 80 kVAr will be ____________________ a) 0.81 b) 0.88 **c) 0.78** d) cannot be determined	C
13.	A 22 kW motor rated for 415 V, 42 A and 0.8 power factor will have an efficiency of_____. **a) 91 %** b) 92 % c) 89.9 % d) none of the above	A
14.	If the power consumed by an air conditioner compressor is 1.7 kW per ton of refrigeration, then its energy efficiency ratio (Watt/Watt) is _____ a) 1.7 **b) 2.06** c) 0.59 d) none of the above	B
15.	Which of the following devices do not produce any harmonics? a) UPS **b) incandescent bulb** c) arc furnace d) electronic ballast	B
16.	A DG set is consuming 70 litres per hour diesel oil. If the specific fuel consumption is 0.33 litres/kWh, what is the kVA loading at 0.8 power factor? a) 212 kVA **b) 265 kVA** c) 170 kVA d) none of the above	B
17.	Flow control by damper operation in fan system will a) increase energy consumption **b) reduce energy consumption** c) reduce system resistance d) none of the above	B
18.	Which one of the following has the maximum CRI? **a) Incandescent lamp** b) LED lamp c) CFL lamp d) HPSV lamp	A
19.	In a pumping system, if the temperature of the liquid handled decreases, then _________ **a) NPSHa increases** b) NPSHa decreases c) NPSHa remains constant d) NPSHa and NPSHr are independent of temperature	A
20.	If the COP of a vapour compression system is 3.5 and the motor draws a power of 10.7 kW at 80% motor efficiency, the cooling effect of vapour compression system will be_________. **a) 30 kW** b) 42 kW c) 27 kW d) 2.99 kW	A

21.	One of the thermal power plants operating with 2 numbers of 500 MW units has reported the operating heat rate of 11250 kJ/kWh. The Plant Load Factor (PLF) of the power plant is 73 %. The operating efficiency of the power plant will be a) 38 % b) 35 % c) 30 % **d) 32 %**	**D**
22.	Aggregate Technical & Commercial losses in distribution system covers____________ a) only I^2R losses of all transformers b) only transmission & distribution loss c) only transmission losses **d) energy and monetary loss**	**D**
23.	The two-part tariff structure for HT category consumers are **a) one part for capacity drawn and second part for actual energy drawn** b) one part for actual power factor and second part for actual energy drawn c) one part for capacity drawn and second part for actual reactive energy drawn d) one part for actual apparent energy drawn and second part for actual reactive energy drawn	**A**
24.	The illuminance is 10 lm/m^2 from a lamp at 1 meter distance. What will be the illuminance (in lm/m^2) at 2-meter distance from lamp? a) 2.75 **b) 2.5** c) 40 d) 20	**B**
25.	A spark ignition engine is used for firing which type of fuels___________ a) gasoline b) land fill gas c) natural gas **d) all of the above**	**D**
26.	In a water Lithium bromide refrigeration system, the concentration of the lithium bromide gets diluted in_______. a) evaporator b) condenser c) generator **d) absorber**	**D**
27.	Increasing the cycles of concentration of circulating water in a cooling tower will _________. a) increase blow down quantity **b) decrease blow down quantity** c) increase drift losses d) decrease fan power consumption	**B**
28.	Which of the following is not true for energy efficient motors? **a) starting torque is higher than standard motors** b) starting torque is lower than standard motors c) slip is lower than standard motors d) speed is higher than standard motors	**A**
29.	The performance of rewinding of an induction motor can be assessed by which of the following factors? a) no load current b) stator resistance per phase c) load current **d) both no load current and stator resistance per phase**	**D**
30.	The theoretical synchronous speed of 4 pole motor operating at 50 Hz will be **a) 1500 rpm** b) 3000 rpm c) 200 rpm d) none of the above	**A**

31.	If water is flowing through a cooling tower at 120 m^3/h with 5 ^0C range, the load on cooling tower at ambient wet bulb temperature of 33 ^0C is **a) 198.4 TR** b) 357 TR c) 158 TR d) none of the above	**A**
32.	When the evaporation of water from a wet substance at atmospheric condition is zero, it indicates _________. a) RH is 0% **b) RH is 100%** c) wet bulb temperature is greater than dry bulb temperature d) none of the above	**B**
33.	A hotel building has four floors each of 1000m^2 area. If the interior lighting power allowance for the hotel building is 43,000 W. The Lighting Power Density (LPD) is: **a) 10.75** b) 0.09 c) 43 d) data insufficient	**A**
34.	As per Energy Conservation Building Code, compute the Effective Aperture (EA) given that Window Wall Ratio (WWR) is 0.40 and Visible Light Transmittance (VLT) is 0.25 **a) 0.1** b) 1.6 c) 0.65 d) 0.625	**A**
35.	The Solar Heat Gain Co-efficient (SHGC) of a window of a building is 0.30. This means that a) The window allows 70% of the sun's heat to pass through into interior of the building **b) The window allows 30% of the sun's heat to pass through into the building interior** c) 70% of the sun's heat is incident on the window d) The window reflects back to exterior a minimum of 30 % of the sun's heat	**B**
36.	The purpose of after-cooler in a multistage compressor is to__________. **a) remove the moisture in the air** b) reduce the work of compression c) separate moisture and oil vapour d) none of the above	**A**
37.	The outer tube connection of the Pitot tube is used to measure_______in the fan system **a) static pressure** b) total pressure c) velocity pressure d) none of the above	**A**
38.	Which of the following contributes to increased technical losses? a) lower sized conductors b) low power factor c) lengthy distribution lines **d) all of the above**	**D**
39.	Which one has the maximum effect on cooling tower performance? **a) fill media** b) drift c) louvers d) casing	**A**
40.	Single stage Li-Br water absorption refrigeration systems have a COP in the range of a) 0.40 - 0.5 **b) 0.65 - 0.70** c) 0.75 - 0.8 d) 0.2 - 0.3	**B**
41.	Shaft power of the motor driving a pump is 20 kW. The motor efficiency is 0.9 and pump efficiency is 0.55 at that operating load. The power transmitted to the water is a) 12.2 kW b) 9.9 kW **c) 11 kW** d) 12.7 kW	**C**

42.	The unit of AAhEPI is given by a) $kWh/m^2/yr$ b) m^2 x kWh/hr **c) <u>$(Wh/m^2)/hr$</u>** d) $m^2/Wh/yr$	**C**
43.	A pump with 200 mm impeller is delivering a flow of 120 m^3/hr. If the flow is to be reduced to 100 m^3/hr by trimming the impeller, what should be the approximate impeller size? a) 60 mm b) 240 mm **<u>c) 167 mm</u>** d) 145 mm	**C**
44.	Hermetic system is used in **<u>a) domestic refrigerator</u>** b) centrifugal chillers c) screw chillers d) large reciprocating chillers	**A**
45.	Which of the following compressors do not use loading / un-loading method for capacity control? a) screw compresssor **<u>b) centrifugal compresssor</u>** c) reciprocating compresssor d) all of the above	**B**
46.	The input of a 900 kW rated motor operating with 90% efficiency is ___________. a) 900 kW **<u>b) 1000 kW</u>** c) 810 kW d) none of the above	**B**
47.	Power factor is highest in case of a) sodium vapour lamps b) LED lamps c) tube Lights **<u>d) incandescent lamps</u>**	**D**
48.	A package air conditioner of 5 TR capacity delivers a cooling effect of 4 TR. If the Energy Efficiency Ratio (W/W) is 2.90, the power in kW drawn by the compressor would be: **<u>a) 4.84</u>** b) 1.38 c) 1.724 d) none of the above	**A**
49.	A fan is drawing 16 kW at 800 RPM. If the speed is reduced to 600 RPM then the power drawn by the fan would be a) 12 kW b) 9 kW **<u>c) 6.75 kW</u>** d) none of the above	**C**
50.	COP of an air-conditioner will be least with____________. **<u>a) lower evaporator temperature and higher condenser temperature</u>** b) higher evaporator temperature and lower condenser temperature c) higher evaporator temperature and higher condenser temperature d) lower evaporator temperature and lower condenser temperature	**A**

--------------------- **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	Fill in the blanks: **1 Mark each** a) Heat rate of a thermal power plant is expressed in________ b) The _________ loss is independent of load in a transformer. c) _________ is used to reduce the dew point in a compressed air system d) The difference between the total and static pressure in an air duct is_______ e) The speed of an energy efficient motor will be more than the standard motor of same capacity because_______ decreases.
S-1 Sol	a) kCal/kWh or kJ/kWh b) Core loss or iron loss or no-load loss c) Air dryer d) Velocity Pressure or Dynamic Pressure e) Slip
S-2	List five Energy Efficiency measures in buildings **5 Marks**
S-2 Sol	Refer Guidebook 3 (Pg 288-290)
S-3	a) Name six parameters along with units that a psychrometric chart provides to an air conditioning engineer. **3 Marks** b) Explain briefly about Thermal Emittance **2 Marks**
S-3 Sol	a) Following air parameters are being provided by psychometric chart. 1. Dry bulb temperature (°C) 2. Relative humidity (%) 3. Wet bulb temperature (°C) 4. Specific volume (m3/kg of dry air) 5. Enthalpy (kcal/kg of dry air) 6. Specific humidity or Humidity factor (grams/kg of dry air) b) Refer Guidebook-3, page no.- 272
S-4	A process plant has installed 5 MW DG set for base load operation, which is operating at 70% loading. Furnace oil is used as a fuel in the DG set. The DG set generates 8.6 kg of exhaust gas per kWh generation. The plant management has decided to install a heat recovery boiler to generate steam at 3 kg/cm^2(g) from the exhaust gas to reduce the exit flue gas temperature from 450^{o}C to 200^{o}C. The specific heat of flue gas is 0.26 kcal/kg^{o}C. The steam generated from waste heat boiler will be used in double effect Li - Br Vapor Absorption Chiller, with a COP of 1.12. How much TR will be generated through VAM? **5 Marks**

S-4 **Sol**	Loading of DG Set = 70% x 5 MW = 3.5 MW = 3500 kW Quantity of heat available from exhaust gas = 3500 kW x 8.6 kg gas generated/kWh x 0.26 kcal/kg°C x (450 °C - 200°C) =19,56,500 kcal/hr Potential TR generation through double effect VAM COP = (TR/ Heat input) TR= (COP X Heat input) / 3024 = (1.12*1956500) / 3024 = 724.6 TR
S-5	What are the advantages of using vapour absorption refrigeration system over vapour compression system? Under what condition it would be economical? **5 Marks**
S-5 **Sol**	**Refer Guidebook 3 (Pg 112-116)**
S-6	A process plant is situated 100 m above the ground level on the top of the hill. The plant requires 100 kL of water per hour. The management decides to install a pump at the ground level, with suction 3 meter below the ground level. The friction head is 12 meter. Evaluate the rating of the motor required considering 10% extra margin with respect to actual input pump power. The design pump efficiency is 65%. Also calculate the motor input power if the motor efficiency is 93%. **5 Marks**
S-6 **Sol**	Ans.- Q= 100/3600 =1/36 m3/s = 0.0277 m3/s ρ = 1000 kg/m3 Static Head = 100- (- 3) = 103 m Total Head = Static Head + Friction Head = 103 + 12 = 115 Hydraulic power required = Q*p*(hd-hs)*g/1000 = (0.0277* 1000 *115*9.81)/1000 = 31.25 KW Pump efficiency = 65% Pump input power (shaft power) required= 31.25/0.65= 48.07 KW Motor rating (shaft power) = 48.07kW Motor rating (shaft power) with 10% margin above pump input power = 48.07+ (0.1*48.07) =52.87 KW Motor input power = design rated power / motor efficiency = 48.07/0.93 = 51.69 kW
S-7	A small foundry has installed a reciprocating air compressor of 14.25 m^3/min. The plant could not meet the compressed air requirement and hence conducted a capacity test to determine the derating in the compressor capacity. Calculate the actual FAD

	delivered after considering the necessary temperature correction in m^3/min and also the percentage derating. **5 Marks** **The operating parameters are given below:** Volume of air receiver including pipe and cooler = 9 m^3 Atmospheric temperature (T1) = 35°C Receiver temperature (T2) = 44°C Initial Pressure = 0.5 kg/cm^2(g) Final Pressure = 7.0 kg/cm^2(g) Atmospheric pressure = 1.026 kg/cm^2 (a) Time taken to build up the pressure = 5 minutes
S-7 **Sol**	**Ans:-** **FAD delivered in m^3/min :** FAD = ((P2-P1)/ Pa)* (Receiver & holding Volume in m^3/Time in min)*(Temp Corr Factor) P1 = 7.0 kg/ cm^2(g) P2 = 0.5 kg/ cm^2 (g) Pa = 1.026 kg/ cm^2(a) Receiver & holding Volume in m^3 = 9 m^3 Time in min = 5 minutes = [(7.0-0.5) x 9/ (1.026x5)] = 11.40 m^3/min FAD after temperature correction Temperature correction factor = (273+T1) /(273+T2) T1 is suction Temperature and T2 is receiver temperature. = (273+T1) /(273+T2) = (273+35) /(273+44) = 0.972 FAD after temperature correction is = 11.40 m^3/min*0.972 = 11.08 m^3/min Capacity shortfall = 14.25-11.08

	= 3.17 m^3/min, % Capacity de-rating = (3.17/14.25) x100 =22.24%
S-8	A V-belt driven centrifugal fan is supplying air to a chemical process. Calculate the fan static efficiency for the following operating parameters. **5 Marks**

Ambient temperature	40°C
Density of air at 40°C	1.127 kg/m^3
Diameter of the discharge air duct	1 meter
Velocity pressure measured by Pitot tube in discharge duct	47 mm WC
Pitot tube coefficient	0.9
Static pressure at fan inlet	-22 mm WC
Static pressure at fan outlet	188 mm WC
Power drawn by the motor	72 kW
Belt transmission efficiency	95%
Motor efficiency at the operating load	90%

S-8 Sol

To Calculate fan static efficiency:

Air velocity = Cp x (2 x 9.81 x △ p / γ)^ 0.5

= 0.9 x (2 x 9.81 x 47 / 1.127) ^ 0.5

= 25.7 m/s

Area of the discharge duct = [3.14 x 1 x 1]/4 = 0.785 m^2

Volume = 25.7 x 0.785 = 20.17 m^3/s

Power input to the fan shaft = 72 x 0.95 x 0.9 = 61.6 kW

Fan static efficiency $= \dfrac{\text{Volume in m}^3\text{/ sec X total static pressure in mm WC}}{\text{102 x Power input to the shaft in (kW)}}$

$= \dfrac{20.17 \times [188 - (-22)]}{102 \times 61.6}$

= 67.4%

--------------------- **End of Section - II** ---------------------

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

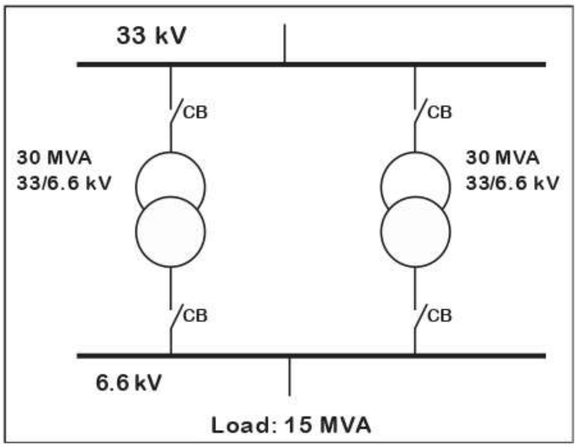
(i) Answer all **Six** questions

(ii) Each question carries **Ten** marks

L-1	a) List five losses in electrical motors and discuss about the measures taken by the motor manufacturers to reduce the losses in energy efficient motor. **5 Marks** b) List five energy conservation opportunities in pumping system. **5 Marks**
L-1 Sol	a. Refer Guidebook-3, Page 51 b. Refer Guidebook-3, Page 193
L-2	a) List any three energy efficient lighting controls. Describe briefly about daylight linked control **5 Marks** b) Explain briefly about various water losses in cooling towers and how they can be minimized? **5 Marks**
L-2 Sol	a. Refer Guidebook-3, Page 243-244 b. Refer Guidebook-3, Page 205
L-3	Rated capacity of bottom ash disposal pump flow rate is 485 m^3/hr and discharge pressure is 13.5 kg/cm^2 at rated speed of 2950 rpm. It has been observed that 450 m^3/hr water is sufficient to dispose the ash. The suction pressure of the pump is 0.5 kg/cm^2. The management has decided to trim the impeller to satisfy the reduced flow requirement. **Calculate:** a) % reduction of impeller diameter. **5 Marks** b) The annual energy savings after modification, if the pump is operating for 6 hours/day and 330 days in a year. **5 Marks**
L-3 Sol	**a) % Reduction of Impeller Diameter** Flow rate ∞ impeller diameter Dnew/Dold = 450/485 Dnew = (450/485)*Dold = 0.928 * Dold % impeller diameter reduction = ((Dold- Dnew) / Dold)*100 = ((Dold- 0.928 * Dold)/ Dold)*100 = (1- 0.928)*100 = (0.072)*100 = 7.2 % **b) Annual energy saved after modification**: Hydraulic power required at rated condition = (Q* p * (hd-hs) * g) / 1000 = (485/3600)*(1000)*((135-5))*9.81/1000) = 171.81 kW New discharge Head: Old Flow=485 m^3/hr New Flow=450 m^3/hr

	Old discharge Head =13.5 x 10 = 135m New discharge Head=? (D2/D1)^2=(H2/H1) D2 =100-7.2 = 92.8% of D1 = 0.928 D1 H2=(D2/D1)^2*H1 = (0.928D1/D1)^2*135 = 116.25 Hydraulic power required at modified condition = (Q* p * (hd-hs) * g) / 1000 = (450/3600)*(1000)*((116.25-5)*9.81/1000 = 136.42 kW Power savings due to impeller size reduction by 7.2% = (171.81 -136.42) = 35.39 kW Annual energy savings = (35.39)*(6*330) = 69,894 kWh/year **OR** Power (P) α D^3 Flow (Q) α D So, Power α Q^3 Power new = $(Q2/Q1)^3$ x 171.81 = $(450/485)^3$ x 171.81 = (0.799) x 171.81 = 137.3 kW Power saving per year = (171.81 – 137.3) x 6 x 330 = 68,329.8 kWh/year
L-4	In a Thermal Power Station, the steam input to a turbine operating on a fully condensing mode is 100 Tonnes/hr. The heat rejection requirement of the steam turbine condenser is 555 kcals/kg of steam condensed. The head developed by the cooling water pump is 2.5 kg/cm^2. During 4500 hours of normal operation per year, the cooling water temperatures at the inlet and outlet of turbine condenser are measured to be 27^{o}C and 35^{o}C and during the winter period operation of 3000 hours per year the cooling water temperatures at the inlet and outlet of turbine condenser are measured to be 15^{o}C and 25^{o}C. **Find out:** i. The circulating cooling water flow for normal operation as well as for winter operation. **5 Marks** ii. Calculate the annual energy reduction during winter operation if the combined efficiency of the pump and motor is 70%. **5 Marks**

L-4 Sol	**1. Cooling water requirement for normal operation at 27^0 C and 35^0 C (4500 Hours):** The quantity of heat rejected in the turbine condenser = Quantity of steam condensed in kg x heat rejection in kCal /kg **= 100,000 x 555 = 55.5 million kCals /hr** Heat gained by circulating cooling water = Heat rejected in the condenser Therefore, Cooling water flow = 55.5 $x10^6$ / (35-27) x specific heat (1)x1000 =**<u>6937.5 m^3 /hr</u>** Head developed by the pump = 2.5 kg/cm^2 Hydraulic power required = (6937.5/3600)*25*9.81 = 472.62 kW Combined efficiency of cooling water motor and pump = 70% Input power required = (472.62/0.7) = 675.16 kW **2. Cooling water requirement for winter operation at 15^0 C and 25^0 C (3000 Hours):** The quantity of heat rejected in the turbine condenser = Quantity of steam condensed in kg x heat rejection in kCal /kg **= 100,000 x 555 = 55.5 million kCals /Hr** Heat gained by circulating cooling water = Heat rejected in the condenser Therefore, Cooling water flow = 55.5 $x10^6$ / (25-15) x specific heat (1)x1000= **<u>5550 m^3/hr</u>** Head developed by the pump = 2.5 kg/cm^2 Hydraulic power required = (5550/3600)*25*9.81 = 378.09 kW Combined efficiency of cooling water motor and pump = 70% Input power required = (378.09/0.7) = 540.13 kW Energy reduction during winter operation = (675.16 - 540.13) x 3000 = 405090 kWh

L-5	a) A cold rolling mill has a maximum demand of 7 MVA at a power factor of 0.95. The plant management converts the existing electrical resistance annealing furnace having steady load of 1250 kW to gas heating as a cost reduction measure. The existing capacitor banks (kVAr) continued to be in the electrical network. What will be the effect on maximum demand and power factor due to this conversion? **5 Marks** b) A cement plant has a constant load of 15 MVA. It has installed two transformers of 30 MVA each. The no load loss and full load copper loss of each 30 MVA transformer is 25 kW and 75 kW respectively. From the energy efficiency point of view the industry management wants to take a decision on whether to operate a single transformer or two transformers equally sharing the load. What is your recommendation? **5 Marks** 
L-5 Sol	**a)** Registered maximum demand = 7 MVA = 7000 kVA Electrical load (real power) = 7000 X 0.95 = 6650 kW kVAr = $\sqrt{(kVA^2 - kW^2)}$ kVAr = $\sqrt{}$sqrt $((7000)^2 - (6650)^2)$ kVAr = 2186 kVAr in the plant will remain same. Reduction in real power due to conversion is 1250 kW. Revised real Power = 6650 – 1250 = 5400 kW Revised kVA = $\sqrt{kW^2 + kVAR^2}$ = $\sqrt{(5400)^2 + (2186)^2}$ Revised kVA = 5825 Reduction in Electrical Demand = 7000 – 5825 = 1175 kVA

	Revised Power factor = 5400 / 5825 = 0.927 Reduction in Power Factor = 0.95 - 0.927 = 0.023 **B)** **Option 1: One transformer in operation** % load = 15/30 = 50% Total Loss = $P_{NOLOAD} + P_{COPPER\ LOSS} \times (\%load)^2$ = $25 + 75 \times (0.5)^2$ = 43.75 kW **Option II: Both transformers in operation** % load = 7.5/30 = 25% Total Loss = $[(P_{NOLOAD} + P_{COPPER\ LOSS} \times (\%load)^2]\times 2$ = $[25 + 75 \times (0.25)^2] \times 2$ = 59.37 kW It is economical to operate one transformer because the losses are less and there is a saving of 59.37 – 43.75 = 15.62 kW.
L-6	a) Calculate the filter area of Air Handling Unit (AHU) for Refrigeration Load of 50 TR. The air enthalpy at inlet of AHU is 85 kJ/kg and at outlet is of 60 kJ/kg. Air velocity at filter is 1.81 m/sec and air density is 1.26 kg/m³. **5 Marks** b) A no load test was conducted in a delta connected 37 kW induction motor. Name plate data : 3 Phase, 415 V, 50 Hz, 55 Amp Measured data at no load: Voltage, V = 415 Volts; Current, I = 18 Amps; Frequency, F = 50 Hz; Stator phase resistance at 30°C = 0.23 Ohms/phase No load power = 955 Watts **Calculate:** i. The iron loss plus friction loss plus windage loss **2 Marks** ii. Stator copper loss at name plate ratings (full load), considering stator temperature as 120 °C **2 Marks** iii. No load power factor of the motor **1 Mark**

L-6 Sol	**Ans:** **Answer (a):** TR of AHU = (Enthalpy difference x density x area x velocity x3600)/ (4.187 x 3024) Filter Area = TR *(4.187*3024)/(Enthalpy difference*density*Velocity*3600) = (50) *(4.187*3024)/(25*1.26*1.81*3600) **= 3.08 m^2** Where, TR = 50 TR Enthalpy difference = (85 – 60) = 25 kJ/kg Air density at filter inlet = 1.26 kg/m^3 Air velocity at filter inlet =1.81 m/s **Answer (b):** Let iron loss plus friction loss plus windage loss be P_i + fw Stator copper loss, P_{st}, 30°C = 3x $(18/\sqrt{3})^2$x0.23 = 74.51 Watt P_i + fw = P_{nl} - P_{st} = 955 – 74.51 = 880.49 W Stator resistance at 120 °C = 0.23 x [(120+235) / (30+235)] = 0.308 Ohms Stator copper loss at name plate ratings = 3 x $(55/\sqrt{3})^2$ x 0.308 = 931.65 Watt No load power factor = 955 / (1.7321 x 415 x 18) = 0.0738

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

20th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2019

PAPER – 3: ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

i) Answer all **50** questions
ii) Each question carries **one** mark
iii) Please hatch the appropriate oval in the OMR answer sheet with HB pencil only, as per instructions

1.	In a pumping system, if the temperature of the liquid handled increases, then____________________. a) NPSHa increases b) **NPSHa decreases** c) NPSHa remains constant d) NPSHa and NPSHr are independent of temperature
2.	Which of the following component has maximum effect on cooling tower performance? a) **Fill media** b) drift c) louvers d) casing
3.	In a vapour compression refrigeration system, the quantum of energy transferred at condenser is more than the energy transferred at ___________. a) Compressor b) Expansion Valve c) Evaporator **d) All of the above**
4.	Demand side Management helps ____________ a) to reduce the energy losses b) to reduce system peak demand c) to promote energy efficiency among users. d) **All of the above**
5.	Which one of the following is true to estimate the range of cooling tower? a) Range = Cooling water inlet temperature – Wet bulb temperature b) Range = Cooling water outlet temperature – Wet bulb temperature c) Range = Wet Bulb Temperature – Cooling Water Inlet Temperature d) **None of the above**
6.	Modest flow variation between 80% to 100%, in a centrifugal fan is achieved more efficiently with ____________________. a) Inlet damper b) Outlet damper c) **Inlet guide vanes** d) Impeller Change
7.	____________is used as refrigerant both in vapour compression and vapour absorption systems a) Lithium Bromide b) Water c) HFC 134A d) **Ammonia**

8.	In electrical distribution system, commercial loss covers discrepancies due to _______________. a) Meter Reading b) Metering c) Collection Efficiency **d) All of the above**
9.	Which of the following parameters is not required for evaluating volumetric efficiency of reciprocating air compressor? **a) Power input** b) FAD c) Cylinder Stroke d) Cylinder bore
10.	____________ is not used for speed control. a) Variable Frequency drive **b) Soft starter** c) Hydraulic coupling d) Eddy current drives
11.	When compared to standard motors, energy efficient motors will have ___________. a) Higher slip b) Higher starting torque **c) Lower No load current** **d)** All the above
12.	For a given air requirement, providing higher volume air receiver will _______________. a) Increase energy consumption b) Reduce energy consumption c) Reduce Unload Power d) **Reduce Pressure fluctuations**
13.	Harmonics generation will be more in ________________ **a. Inverter drives** b. LED Lamps c. Transformers d. Resistance heaters
14.	Thermal Power Plant efficiency is low due to ___________________. a) Higher steam Pressure b) Higher superheat temperature c) Low GCV coal d) **Higher Heat loss in condenser**
15.	Among the following, ____________ has highest design efficiency. a) High tension motors **b) Power transformers** c) Alternators d) Electric melting furnaces
16.	The difference between wet bulb temperature and cooling water inlet temperature in a cooling tower is called ______________. a)Approach b) Range c) Effectiveness **d) None of the above**
17.	Technical loss in a distribution system can be reduced by ________________. a) Maintaining low HT/LT ratio b) Accurate meter reading **c) High voltage supply to consumers** d) Improving Collection Efficiency
18.	Pressure drop can be reduced in a compressed air distribution line by providing _____________.

	a) After Coolers b) Small diameter distribution pipes c) High pressure air flow d) **Large Diameter Distribution pipes.**
19.	Power consumption is very high for ___________ type of compressed air dryers. a) Refrigeration type b) Blower reactivated type c) Heat of compression type d) **Heatless purge type**
20.	A DC excitation is used to vary the speed of _____________. a) **Eddy Current Coupling** b) fluid coupling c) variable frequency drive d) None of the above
21.	The isothermal power of 500 CFM air compressor is 72 kW and the efficiency is 76 %. The actual power drawn by the compressor will be ________ a) 56 kW **b) 94.7 kW** c) 89 kW d) 72 kW
22.	Power factor improvement of a 75-kW compressor motor will ___________ a) Reduce input power to the motor b) Increase input power to the motor c) Reduce the compressor motor shaft power d) **None of the above**
23.	A 500-kVA transformer is designed for No load loss of 750 watts and load loss of 5700 Watts. The calculated total transformer loss is 1662 watts. What will be the percentage loading of the transformer? a) 54.8 % b) 29 % **c) 40 %** d) 25.7 %
24.	Rating of PF correction capacitors for Induction Motors terminal should be a) 100 % kVAr of the induction motor b) 20 % of Motor Rating c) 25 % of Motor rating d) **90 % of the no-load kVAr induction motor**
25.	LLF in lighting calculation refers to a) Light Load factor b) Light lumen factor c) Light Lux factor d) **Light loss factor**
26.	A medium voltage end consumer receives 83 million units with a transmission and distribution cascade efficiency of 82%. The million units generated will be ____________. a) **101.2** b) 68.1 c) 83 d) None of the above
27.	A 1000 kW Gas engine is designed for 38 % efficiency. The operating load of the engine is 825 kW. If the GCV of gas is 8700 kcal/m^3, the hourly gas consumption will be ____________m^3/hr a) **214.6** b) 260.13 c)188.89 d) 272.74

28.	In an electrical power system, transmission efficiency increases as _______________. **a) both voltage and power factor increases** b) both voltage and power factor decrease c) voltage increases but power factor decreases d) Voltage decreases but power factor increases.
29.	Which of the following is expressed in terms of percentage? a) Absolute humidity **b) Relative humidity** c) Specific Gravity d) All of the above
30.	Which among the following is one of the parameters used to classify fans, blowers & Compressors? a) Volume flow rate b) Mass flow rate **c) Specific ratio** d) None of the above
31.	What is the function of drift eliminators in cooling towers? a) maximize water and air contact **b) capture water droplets escaping with air stream** c) enables entry of air to the cooling tower d) eliminates uneven distribution of water into the cooling tower
32.	Which of the following statements is not true regarding centrifugal pumps? a) Flow is zero at shut off head b) Maximum efficiency will be at design rated flow of the pump c) Head decreases with increase in flow **d) Power increases with throttling**
33.	Which of the following is not true with respect to Color Rendering Index (CRI)? a) The CRI is expressed in a relative scale ranging from 0 -100. b) CRI indicates, how perceived colors match with actual colors. **c) LED lamps are having comparatively higher CRI than Incandescent Lamps.** d) The higher the color rendering index, the less color shift or distortion occurs
34.	Flow control with ___________in a fan system will not change the fan characteristic curve. a) Inlet guide vane b) speed change with variable frequency drive c) speed change with hydraulic coupling **d) discharge damper**
35.	The primary purpose of inter-cooling in a multistage compressor is to _____________. a) remove the moisture in the air **b) reduce the work of compression** c) separate moisture and oil vapour

	d) none of the above
36.	Illuminance of a surface is expressed in _____________ a) radians b) **lux** c) lumens d) LPD
37.	A pump discharge has to be reduced from 120 m^3/hr to 110 m^3/hr by trimming the impeller. What should be the percentage reduction in impeller size? a)10.52 % b) **8.34%** c) 9.7 1% d)17.1%
38.	Which of the following power plants has the highest efficiency? a) Open cycle Gas Turbine b) Diesel Engine c) **Combined cycle gas turbine** d) Conventional coal plants
39.	COP of a single effect absorption refrigeration system is likely to be in the range of____________ a) **0.6 to 0.7** b) 1to 1.2 c) 1.5 to 2 d) 3.0 to 4.0
40.	If 30240 kcal of heat is removed from a room every hour then the refrigeration tonnage will be nearly equal to____________. a) 30.24TR b) 3.024TR c) 1TR d) **10 TR**
41.	HVDS (High Voltage Distribution System) is preferred to___________________ **a) Reduce technical loss in distribution system** b) Reduce commercial loss in distribution system c) Reduce capital investment d) Reduce energy bill for the end consumer
42.	When evaporator temperature is reduced, ________ a) refrigeration capacity increases **b) refrigeration capacity decreases** c) specific power consumption remains same d) condenser load increases
43.	A 4 pole 50 Hz induction motor is running at 1470 rpm. What is the slip value? a) 0.2 b) **0.02** c) 0.04 d) 0.4
44.	The basic function of an air dryer in an air compressor is to a) Prevent dust from entering the compressor b) Remove moisture before the intercooler c) Remove moisture in compressor suction **d) Remove moisture in air supplied to the plants**
45.	Power factor is highest in the case of_________________ a) Sodium vapour lamps b) Induction lamps c) LED Lamps d) **Incandescent lamps**

46.	If the COP of a vapour compression system is 3.5 and the motor draws a power of 10.8 kW at 90% motor efficiency, the cooling effect of vapour compression system will be__________. a) **34 kW** b) 42 kW c) 2.8 kW d) 3.4 kW
47.	The blow down requirement in m^3/hr of a cooling tower with evaporation rate of 16 m^3/hr and CoC of 3 is _____________. a) 4 b) 5.3 c) **8** d) 48
48.	The percentage reduction in distribution losses when tail end power factor is raised from 0.8 to 0.95 is___________ a) **29.4%** b)15.5% c)16.6% d)24.7%
49.	Energy performance index (EPI) kWh/m^2 /yr is the ratio of total building annual energy consumption to ___________ **a) Built up area** b) Carpet area c) Roof Area d) Window and Wall Area
50.	Which of the following is not a climate zone as per ECBC classification? a) hot-dry b) warm-humid **c) Cold-humid** d) cold

…………. 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	One of the Machining centres has installed 2 No's of 270 cfm compressors for pneumatic operation and also for cleaning operation of components after machining. The compressors are operated at 7 kg/cm^2(g) and are on-load for 80 % of the time. The load Power and the un-load Power of each 270 cfm compressor is, 40 kW and 15 kW respectively. The energy audit estimated that cleaning air requirement is 60% of the air generated. Calculate the daily energy consumption for cleaning air alone, assuming continuous operation of the compressor.
	Ans : Compressor capacity = 270 cfm % Loading = 80 % Air Delivered by 2 compressors = (270 X 0.80 x 2) = 432 cfm Loading Power drawn by the compressors = (40 + 40) = 80 kW Un-Loading power drawn by the compressors = (15 + 15) = 30 kW Average kW drawn by the compressors = [(80 x (0.8 x24))+ (30x (0.2 x 24))]/(24) = 70 kW SEC of compressor = (70/432) = 0.162 kW/cfm Cleaning air consumption at 7 Kg/cm^2 = (60 % of generation) = (0.60 x 432) = 259 cfm Energy requirement for Cleaning air per day = (259 x 0.162 x 24) = **1007 kWh/day** **(or) Alternate Solution** = (Load Power x load time) + (Unload Power x Unload time) = (40 x 0.8) + (15 x 0.2) = 32+3 = 35 KW Average KW drawn by the compressors = 35 x 2 = 70 KW Energy requirement for Cleaning air per day = (70 kW x 0.6) x 24 **=1008 kWh/day**
S-2	In a pharmaceutical industry a centrifugal pump is pumping 80 m^3/hr of water into a pressurized

container. The container pressure is 3 kg/cm^2(g). The discharge head of the pump is 5 kg/cm^2(g) and water level is 5 meters below the pump central line. If the power drawn by the motor is 22 kW, find out the pump efficiency. Assume motor efficiency as 90% and the water density as 1000 kg/m^3.

S-2-Sol

Ans:

Sl. No.	Parameter	Process	Value
1	Water Flow Rate (m^3/hr)	given	80
2	Discharge Head (meters)	given	50
3	Suction Head (meter)	given	-5
4	Power input to Motor (kW)	given	22
5	Motor Efficiency	given	90%
6	Power Input to Pump (kW)	Sl. 4* Sl. 5	=22 x 0.9 = 19.8
7	Liquid kW	(Sl. 1/3600)*((Sl. 2*10) - Sl. 3)*9.81	= (80/3600) x (50 - (-5) x 9.81=11.98
8	Pump Efficiency	Sl. 7 / Sl. 6	60.56%

S3

A refrigeration system designed with 10 TR AHU is operating at 8.25 TR. The measured air parameters are given below:

Inlet enthalpy = 10.26 kcal/kg
Outlet enthalpy = 7.26 kcal/kg.
Specific volume of air = 0.83 m^3/kg

Calculate the volume of air in m^3/hr handled by AHU.

Ans :

Cooling delivered (TR = (Difference in enthalpy) x (Volume of air / sp. volume x 3024)
= (Hi – Ho) x V / (v x 3024)

Volume of air handled by AHU = (TR x v x 3024 / (Hi – Ho))
= ((8.25 x 0.83 x 3024) / (10.26-7.26))
= **6903 m^3/hr**

S4

A fan is designed for 1300 m^3/hr, 50 Hz and drawing 3 kW. If the fan is operated with VFD at 37 Hz for 6000 hours, calculate the velocity of air, when air is supplied through 150 mm diameter duct and the annual energy savings.

Ans :

Power Drawn at 50 HZ = 3 kW
Operating frequency = 37 Hz
Flow at 37 Hz = 1300 x (37 / 50)
= 962 m^3/hr

Diameter of the duct = 150 mm
Area of the duct = 0.0177 m^2

	Velocity of the air in the duct Power consumption with 37 Hz **Annual Energy Savings for 6000 hours operation**	= [(962 / 3600)] / [(0.0177)] = 15.09 m/s = $(37/50)^3$ x 3 = 1.22 kW = 6000 x (3 -1.22) = **10,680 kWh**
S5	A foundry unit draws power to the tune of 2500 kW. The demand observed during furnace operation is given below: 5 minutes : 2940 kVA 7 minutes : 2550 kVA 3 minutes : 2777 kVA If the billing meter is monitoring demand every 15 minutes, calculate the maximum demand registered and also the average PF, during the demand interval.	
	Ans : Maximum demand registered PF 5 minutes: 2940 KVA 7 minutes 2550 KVA 3 minutes 2777 kVA. Average PF	 = [2940 * (5/15) + 2550 * (7/15) + 2777 * (3/15)] = [980 + 1190 + 555.4] = 2725.4 kVA = (2500 / 2940) = 0.85 = (2500 / 2550) = 0.98 = (2500 / 2777) = 0.90 = [0.85 *(5/15) + 0.98* (7/15) + 0.9 * (3/15)] = 0.92
S6	A process plant has installed 4-cell cooling tower, with 45 kW CT fans for each cell and operating at 40 kW at 1450 rpm. As a part of the energy conservation program, the existing fan motors are replaced with two speed motors which would operate at 1450 rpm and 740 rpm. The cooling towers are operated at high speed mode for 5300 hours and at low speed mode for 1800 hours, in a year. Estimate the annual energy savings when compared to operation of fans continuously at a fixed speed of 1450 rpm.	
	Ans : Present energy consumption of all 4 fans Energy consumption for fans at 1450 rpm for 5300 hours Energy consumption for fans at 740 rpm for 1800 hours Annual savings	 = (4 x 40 x (5300 + 1800)) = 11,36,000 kWh = (4 x 40 x 5300) = 8,48,000 kWh = [$(740/1450)^3$x 40 x 4 x 1800] = 38281 kWh = [11,36,000 - (8,48,000+38,281)] = 2,49,719 kWh
S7	***Write short notes on any two of the following:*** 1. Integrated Part Load Value (IPLV) for chillers 2. Evaporative Cooling	(Each 2.5 Marks)

	3. Heat Pump
	Ans : 1. Integrated Part Load Value (IPLV) for chillers (Page No. 126) 2. Evaporative Cooling (Page No. 136) 3. Heat Pump (Page No. 133)
S8	**Write short notes on any two of the following:** (Each 2.5 Marks) 1. Solar Heat Gain Coefficient (SHGC) 2. Visible Light Transmittance (VLT) 3. Cool Roof
	Ans : 1. Solar Heat Gain Coefficient (SHGC), (Page No. 272) 2. Visible Light Transmittance (VLT), (Page No. 272) 3. Cool Roof, (Page No. 271)

……………… 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

L1

A. For each one of the following, mention whether they belong to "Prescriptive Method" or "Whole Building Performance Method".

(5 Marks)

1. Compliance by meeting or exceeding specific levels for each individual element of building
2. Allows Trade-off option for building envelope
3. Allows use of energy simulation software
4. Computer model of the proposed design (energy consumption) is compared with Standard Design
5. Compliance if energy use in proposed design is less than energy use in standard design

B. Match the Following: (5 Marks)

1.	Building envelope	a)	Day lighting of building
2.	Passive solar design strategy	b)	Exfiltration and Infiltration of air
3.	Visual Light Transmittance	c)	Roof, walls, windows, skylights, doors and other openings
4.	Weather stripping	d)	Property of high solar reflectance and emittance
5.	Cool roof	e)	Cross ventilation

Ans :

A.

1. Prescriptive Method
2. Prescriptive Method
3. Whole Building Performance Method
4. Whole Building Performance Method
5. Whole Building Performance Method

B.

1	Building envelope	C	Roof, walls, windows, skylights, doors and other openings
2	Passive solar design strategy	E	Cross-ventilation
3	Visual Light Transmittance	A	Day lighting of building
4	Weather stripping	B	Exfiltration and Infiltration of air
5	Cool roof	D	Property of high solar reflectance and emittance

L2

An energy audit was conducted in a large machine shop and the audit report suggested replacing 30 machine motors with energy efficient motors. The loading details of old and new motors are given below:

Motor Rating in kW	Operating Load %	Old Motor Efficiency%	New Motor efficiency%	No of motors
7.5	75	86	89	12
11.5	85	88	91	7
15	70	89	92	11

Assuming motor loading in both cases remains same, calculate the annual energy savings, for 4000 hours operation per year.

Ans :

Motor Rating in KW	Operating Load %	Actual Old Motor Load In kW	Actual New Motor Load In kw	Old Motor efficiency	New Motor efficiency	No of motors
7.5	75	7.5/0.86=8.72 =8.72x 0.75=6.54	7.5/0.89=8.43 =8.43x 0.75= 6.32	86	89	12
11.5	85	11.5/0.88=13.07 =13.07 x 0.85= 11.11	11.5/0.91=12.64 =12.64 x 0.85= 10.74	88	91	7
15	70	15/0.89=16.85 =16.85x 0.7= 11.79	15/0.92=16.30 =16.30 x 0.7 11.41	89	92	11

Annual Savings for 7.5 KW Motors, 12 numbers, operating 4000 hours = [4,000 (6.54-6.32) x 12] **= 10,560 kWh**

Annual Savings for 11 KW Motors, 7 numbers, operating 4000 hours = [4000 (11.11 -10.74) x 7] **= 10,360 kWh**

Annual Savings for 15 KW Motors, 11 numbers operating 4000 hours = [4,000 (11.79-11.41) x11] **= 16,720 kWh**

Total annual savings for 30 high efficiency motors **= 37,640 kWh**

L3 A 10 MW co-generation plant is operating at a daily load factor of 85 %. Power is generated at 11 KV.

- 35 % of the power generated, is exported to grid, through a 7.5 MVA Transformer with 99 % efficiency.
- 32 % power generated, is supplied to mill motors, at 600 Volts, through a 5 MVA step down transformer, with 98 % efficiency.
- The balance power generated is supplied to other LT Loads and auxiliaries, at 415 Volts, through a 2 MVA transformer, with 98 % efficiency.

	Calculate the following: 1) Daily energy exported to grid at 33 KV. 2) Daily mill motors consumption at 600 V. 3) Daily LT loads and auxiliary consumption at 415 V. 4) Daily transformers losses in kWh and % transformers losses **(Each 2.5 Marks)**
	Ans : **1.** Daily generation = (10,000 x 0.85 x 24) = 2,04,000 kWh Daily energy generation for export purpose = (2,04,000 x 0.35) = 71,400 KWh 7.5 MVA transformer loss = [71,400 - (71,400 x 0.99)] = (71,400 – 70,686) = 714 kWh Net energy export to the Grid at 33 KV level = (71,400 kWh - 714 kWh) =70,686 KWh **2.** Daily energy generation for mill motor consumption = (2,04,000 x 0.32) = 65,280 kWh 5 MVA Transformer loss = [65,280 - (65,280 x 0.98)] = (65,280 - 63,974.4) = 1,306 kWh Net mill Consumption = 63,974 KWh **3.** Daily generation for LT loads & Auxiliary consumption = (2,04,000 x 0.33) = 67,320 kWh 2MVA Transformer loss = [67320 - (67320 x 0.98)] = 67,320 - 65,974 = 1,346 kWh Net LT loads & Auxiliary Consumption = 65,974 kWh **4.** Transformers losses = (714 +1306 +1346) = 3,366 kWh day % transformers losses = (3,366 / 2,04,000) x 100 = 1.65 % (Or) To meet the plant LT loads and co-gen auxiliary load, the transformer capacity should be more than 2 MVA.

L4	A small machine shop has installed 220 cfm screw compressor to meet air requirement for various operation. The operating details are given below:

Shift reference (8 hrs/ Shift)	Load time in sec	Un-Load time in sec
I	60	10
II	45	25
III	25	45

Load Power = 37 KW
Un-load power = 11 KW

Calculate the following:

1. Energy loss per day (4 Marks)
2. Shift wise average air requirement in cfm (2 Marks)
3. The plant has proposed to install a VFD for the compressor. Calculate the energy savings after installing the VFD operated compressor, if the VFD loss is 3 % of load power. (4 Marks)

Ans :

I^{st} shift consumption = ((60 / 70) x 37) + (10 / 70) x 11) x 8)

= (31.71+1.57) x 8

= 266.24 kWh

II^{nd} shift consumption = ((0.64 x 37 + 0.36 x 11) x 8)

= (23.68 + 3.96) x 8

= 221.12 kWh

III^{rd} shift consumption = ((0.36 x 37 + 0.64 x 11) x 8)

= (13.32 +7.04) x 8)

= 162.88 kWh

Daily Total Energy consumption = (266.24 + 221.12 + 162.88)

= 650.24 kWh

Daily Energy loss due to unloading = (1.57 +3.96 +7.04) x 8

= 100.56 kWh

Daily load cycle Energy consumption = (650.24 – 100.56)

= 549.68 kWh

Daily energy consumption with VFD = (549.68 / 0.97)

= 566.68 kWh

	Daily Energy loss due to VFD = (566.68 – 549.68) **= 17 kWh** Daily Net Energy savings with VFD compressor = (100.56 – 17) **= 83.56 kWh** Ist shift air requirement = (0.86 x 220) **= 189.2 cfm** IInd shift air requirement = (0.64 x 220) **= 140.8 cfm** IIIrd shift air requirement = (0.36 x 220) **= 79.2 cfm**
L5	(a) What is L/G ratio and how it is useful in operation of a cooling tower ? (3 Marks) (b) What are the functions of fill media in a cooling tower? (3 Marks) (c) Calculate the L/G ratio for the cooling tower given the following: (4 Marks) Water Flow = 4540 m^3/hour Approach = 4.45 ^oC Air entering enthalpy at 26.67 ^oC = 24.17 kcal/kg Air leaving enthalpy at 37.8 ^oC = 39.67 Kcal/kg Hot water temperature = 47.77 ^oC Cold water temperature = 31.11^oC
	Ans : **a)** Page 205 **(b)** Page 209 **c)** L / G = $(h_2 - h_1) / (T_1 - T_2)$ L (47.77 - 31.11) = G (39.67 - 24.17) L / G Ratio = (39.67 - 24.17)/ (47.77 - 31.11) = 0.93

L6 a) In an energy audit of a fan, it was observed that the fan was delivering 24,000 Nm^3/hr of air. Suction static pressure was recorded as -15 mm WC and discharge static pressure as 35 mmWC.

The power measurement of the motor using power analyzer was recorded as 7 kW. The motor operating efficiency taken from motor performance curve was 90%. What is the static efficiency of the fan?

b) Match the Following

1. Heat Pump	–	NPSHR
2. Compressor	–	Static Head
3. Pumping Pressure	–	Static Pressure
4. Fan	–	Compressor
5. Pump	–	Free air delivery test

Soln :

a)

Q = 24.000 Nm^3 / hr. = 6.67 m^3/sec

Static pressure rise = 35 – (-15)

= 50 mmWC

η_s =?

Power input to motor = 7 kW

Power input to fan shaft = 7 x 0.90 = 6.3 kW

$$\text{Fan static } \eta = \frac{\text{Volume in } m^3/sec \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}}$$

= (6.67 x 50) / (102 x 6.3)

= 0.519 (or) = 51.9 %

b) Match the Following

1.	Heat Pump	–	NPSHR (5)
2.	Compressor	–	Static Head (3)
3.	Pumping Pressure	–	Static Pressure (4)
4.	Fan	–	Compressor (1)
5.	Pump	–	Free air delivery test (2)

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

19th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – SEPTEMBER, 2018

PAPER – 3 : ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **One** mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with **HB pencil only,** as per instructions

1. Which of the following incandescent bulbs will have the least resistance ?
   a) 220 V, 60 W b) 220 V, 100 W
   c) 115 V, 60 W d) **115 V, 100 W**

2. In a rolling mill, the loading on the transformer was 1200 kVA with the power factor of 0.86. The plant improved the power factor to 0.98 by adding capacitors. What is the reduction in kVA ?
   a) 144 b) **147**
   c) 171 d) 163.3

3. A 22 kW, 415 V, 45 A, 0.8 pf, 1475 rpm, 4 pole 3 phase induction motor operating at 420 V, 40 A and 0.8 pf. What will be the motor efficiency?
   a) **85.0 %** b) 94.5 %
   c) 89.9 % d) None of the above

4. The purpose of inter-cooling in a multistage compressor is to
   a) Increase the pressure of air b) **Reduce the work of compression**
   c) Separate moisture and oil vapour d) None of the above

5. One ton of refrigeration is not equal to__________.
   a) 3024 kCal/hr b) 3.51 kW
   c) 12000 Btu/hr d) **860 kCal/hr**

6. If two identical pumps operate in series, their shut-off head is
   a) Not affected b) More than double
   c) **Doubled** d) Less than double

7. Which of the following is not a part of vapour compression refrigeration cycle ?
   a) Compressor b) Evaporator
   c) Condenser d) **Generator**

8. If the power consumed by an air conditioner compressor is 1.7 kW per ton of refrigeration, then its energy efficiency ratio (Watt/Watt) is _____
   a) 1.7 b) **2.1**
   c) 0.59 d) None of the above

9. The adsorption material used in an adsorption air dryer is

a) Calcium chloride
b) Magnesium chloride
c) **Activated alumina**
d) Potassium chloride

10. The cooling tower size is _____________ to the entering Wet Bulb Temprature (WBT), when the heat load, range and approach are constant.

a) Directly proportional
b) **Inversely proportional**
c) Constant
d) None of above

11. The T5, T8 and T12 fluorescent tube light are categorized based on

a) **Diameter of the tube**
b) Length of the tube
c) Both diameter and length of the tube
d) Power consumption

12. If the wet bulb temperature of air is 38 ^{0}C, then it's relative humidity is __________%.

a) 38 %
b) 90 %
c) 100 %
d) **Insufficient data**

13. The hydraulic power in a pumping system depends on

a) Pump efficiency
b) Motor efficiency
c) Both motor and pump efficiency
d) **None of the above**

14. Small diameter by-pass lines are installed in pumps sometimes to ________________.

a) Save energy
b) Control pump delivery head
c) **Prevent pump running at zero flow**
d) Reduce pump power consumption

15. It is acceptable to run pumps in parallel provided their_________ are similar

a) Suction heads
b) Discharge heads
c) **Closed valve heads**
d) Total head at full flow

16. L / G ratio in a cooling tower is the ratio of _________________.

a) Length and girth
b) Length and Temperature gradient
c) **Water flow rate and air mass flow rate**
d) Air mass flow rate and water flow rate

17. Fiberglass Reinforced Plastic (FRP) fans consume less energy than aluminum fans because

a) They are lighter
b) **They have better efficiencies**
c) They encounter less system resistance
d) They deliver less air flow

18. Ratio of luminous flux (lumen) emitted by a lamp to the power consumed (watt) by the lamp is called

a) Luminous intensity
b) **Luminous efficacy**
c) Reflectance
d) Luminance

19. Illuminance of a surface is expressed in

a) Radians
b) **Lux**
c) Lumens
d) LPD

20. Use of soft starters for induction motors results in

a) **Lower mechanical stress**
b) Lower power factor
c) Higher maximum demand
d) All the above

21. The Energy Performance Index (EPI) of a building as per Energy Conservation Building Code (ECBC) and as defined in the Energy Conservation Act, 2001 is:

a) **kWh per square meter per year**
b) kWh per square meter
c) kW per square meter
d) kWh per year

22. Energy Conservation Act covers buildings having a connected load of

a) **100 kW and above**
b) 100 kVA and above
c) 500 kW and above
d) All buildings with HT connection

23. In a solar PV system the conversion from DC to AC is carried out by

a) Converter
b) Charger
c) Battery
d) **Inverter**

24. The inlet air temperature to a two stage reciprocating air compressor is 35 ^{0}C. At which of the following 2nd stage inlet temperature's the compressor will consume least power ?

a) 75 ^{0}C
b) 65 ^{0}C
c) 60 ^{0}C
d) **50 ^{0}C**

25. A fan is drawing 16 kW at 800 RPM. If the speed is reduced to 600 RPM then the power drawn by the fan would be

a) 12 kW
b) 9 kW
c) **6.75 kW**
d) None of the above

26. In which of the following fans air enters and leaves the fan with no change in direction ?

a) Forward curved
b) Backward curved
c) Radial
d) **Propeller**

27. Increasing the Cycles of Concentration (C.O.C) of circulating water in a cooling tower, the blow down quantity will

a) Increase
b) **Decrease**
c) Not change
d) None of the above

28. __________ can be achieved using infrared, acoustic, ultrasonic or microwave sensors for energy efficient lighting control.

a) Time-based control
b) Daylight-linked control
c) **Occupancy-linked control**
d) Localized switching

29. The 5th and 7th harmonic in a 50 Hz power supply system will have:

a) Voltage and current distortions with 55 Hz & 57 Hz
b) Voltage and current distortions with 500 Hz & 700 Hz
c) **Voltage and current distortions with 250 Hz & 350 Hz**

d) No voltage and current distortion at all

30. A 7.5 kW, 415 V, 15 A, 970 RPM, 3 phase rated induction motor with full load efficiency of 86 % draws 7.5 A and 3.23 kW of input power. The percentage loading of the motor is about

a) **37 %**
b) 43 %
c) 50 %
d) None of the above

31. A two pole induction motor operating at 50 Hz, with 1 % slip will run at an actual speed of

a) 3000 RPM
b) 3030 RPM
c) **2970 RPM**
d) None of the above

32. The value, by which the pressure in the pump suction exceeds the liquid vapour pressure, is expressed as

a) **Net positive suction head available**
b) Static head
c) Dynamic head
d) Suction head

33. Which of the following ambient conditions will evaporate minimum amount of water in a cooling tower ?

a) 35 ^{0}C DBT and 30 ^{0}C WBT
b) 38 ^{0}C DBT and 31 ^{0}C WBT
c) **38 ^{0}C DBT and 37 ^{0}C WBT**
d) 35 ^{0}C DBT and 29 ^{0}C WBT

34. A fan is operating at 970 RPM developing a flow of 3000 Nm^3/hour at a static pressure of 650 mmWC. If the speed is reduced to 700 RPM, the static pressure (mmWC) developed will be

a) 244.3
b) 650
c) 469
d) **None of the above**

35. Select the incorrect statement:

a) Transformers operating near saturation level create harmonics
b) **Devices that draw sinusoidal currents when a sinusoidal voltage is applied create harmonics**
c) Harmonics are multiples of the supply frequency
d) Harmonics occur as spikes at intervals which are multiples of the supply frequency

36. The illuminance is 10 lm/m^2 from a lamp at 1 meter distance. The illuminance at half the distance will be

a) **40 lm/m^2**
b) 10 lm/m^2
c) 5 lm/m^2
d) None of the above

37. In an engine room 15 m long, 10 m wide and 4 m high, ventilation requirement in m^3/hr for 20 air changes/hr is

a) 6000
b) 9000
c) **12000**
d) None of the above

38. A package air conditioner of 5 TR capacity delivers a cooling effect of 4 TR. If Energy Efficiency Ratio (W/W) is 2.90, the power in kW drawn by compressor would be:

a) **4.84**
b) 1.38
c) 1.724
d) None of the above

39. A 5 kVAr, 415 V rated power factor capacitor was found to be having 5.5 kVAr operating capacity. The operating supply voltage at the same supply frequency would be approximately.

a) 400 V
b) 415 V
c) **435 V**
d) None of the above

40. The Solar Heat Gain Coefficient (SHGC) of window of a building is 0.30. This means that

a) The window allows 70 % of the sun's heat to pass through into interior of the buildings
b) **The window allows 30 % of the sun's heat to pass through into the building interior**
c) 70 % of the sun's heat is incident on the window
d) The window reflects back to exterior a minimum of 30 % of the sun's heat

41. The most energy intensive heat transfer loop of a vapour compression refrigeration system is:

a) Indoor air loop
b) Chilled water loop
c) Refrigerant loop
d) **Condenser water loop**

42. One of the thermal power plants operating with 2 nos. of 500 MW units has reported the operating heat rate of 11250 kJ/kW. The Plant Load Factor (PLF) of the power plant is 73 %. The operating efficiency of the power plant will be

a) 38 %
b) 35 %
c) 30 %
d) **32 %**

43. Aggregate Technical & Commercial loss in distribution system covers

a) I^2R losses of all transformers
b) Transmission & distribution loss
c) Only transmission losses
d) **Energy and monetary loss**

44. The power measured in a boiler ID fan is 52 kW operating at 49 Hz. As an energy conservation measure the Variable Frequency Drive (VFD) was installed and the fan was operated at 34 Hz. The estimated power savings will be

a) 36 kW
b) 17.2 kW
c) **34.7 kW**
d) 35 .7 kW

45. The isothermal power of a 500 CFM air compressor is 72 kW and the efficiency is 78 %. The actual power drawn by the compressor will be

a) 56 kW
b) **92 kW**
c) 72 kW
d) None of the above

46. A heat pump used in a heat recovery application extracts 66220 kcal/hr and the power consumed by the heat pump is 23 kW. The estimated heat supplied by the heat pump is

a) 2916 kcal/hr
b) 47300 kcal/hr
c) 86860 kcal/hr
d) **86000 kcal/hr**

47.	A coal fired boiler primary air fan is maintaining a velocity pressure of 70 mmWC and the air temperature is 38^0C. The density of the air is 1.135 kg/m^3 and the pitot tube constant is 0.85. The velocity of air in m/sec will be a) 25.6 b) **<u>29.56</u>** c) 28.67 d) None of the above
48.	A two stage air compressor drawing 75 kW has heat rejection of 862 kCal/kWh. The required capacity of the cooling tower when the operating temperature difference of 5 ^0C will be ________TR. a) **<u>21.55</u>** b) 107.5 c) 22.93 d) 57.4
49.	The star rating scheme of Fluorescent Tube light as per BEE Standards & Labelling Scheme is based on a) Lumen Output b) Lux per Watt c) Lux per Watt per m^2 d) **<u>Lumen per Watt at different operating hours</u>**
50.	A pump with 230 mm diameter impeller is delivering a flow of 150 m^3/hr. If the flow is to be reduced to 110 m^3/hr by trimming the impeller, what should be the approximate impeller size? a) 195 mm b) 175 mm c) **<u>169 mm</u>** d) 207 mm

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

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

(i) Section II contains **<u>Eight</u>** questions (S1- S8)
(ii) Each question carries **<u>Five</u>** marks

S-1	The operating data of an induced draft-cooling tower is as follows: Observed range : 8 ^0C. Cooling water flow rate : 12,500 m^3/hr Drift loss : 0.1 % of circulation rate Wet Bulb Temperature : 27 ^0C Ambient Dry Bulb Temperature : 35 ^0C Effectiveness : 67 % Cycle of Concentration : 3 Estimate the evaporation loss; make up water requirement and TR load of cooling tower.
Ans	Evaporation loss = 0.00085 X 1.8 X 12500 X 8 = 153 m^3/hr Blow Down =153 /(3-1)= 76.5 m^3/hr Make up =153 + 76.5 + (12500*0.001)= 242 m^3/hr Heat load =12500*1000*8/3024=33069 TR

S-2	A plant is operating a chilled water system always at full load. The chilled water inlet and outlet temperatures are 12 ^{0}C and 7 ^{0}C respectively. The chilled water pump discharge pressure is 3.6 kg/cm^{2}g and the suction is 5 meters above the pump centerline. The power drawn by the chilled water pump's motor is 70 kW and an efficiency of 90 %. The chilled water pump efficiency at the operating point from pump characteristic curve is 60 %. Find out the operating refrigeration load in TR.
Ans	Total head: 36 – 5 = 31 m Pump shaft power: 70 x 0.9 63 kW Flow rate: (63 x 1000) X 0.6 / 31 x 1000 x 9.81 0.124297 m^3/s 447.5 m^3/hr Refrigeration load: (447500 x 5) / 3024 740 TR
S-3	In an air washer of a textile humidification system with an airflow of 3000 m^3/h at 25 ^{0}C and 10 % relative humidity is humidified to 60 % relative humidity by adding water through spray nozzles. The specific humidity of air at inlet and outlet are 0.002 kg/kg of dry air and 0.0062 kg/kg of dry air respectively. The density of air at 25 ^{0}C is 1.184 kg/m^3. Calculate the amount of water required in kg/hr.
Ans	The amount of water required: $mw = v\,\rho\,(\omega out - \omega in)$ $= 3000 \text{ X } 1.184 \text{ X } (0.0062 - 0.002)$ $= 14.9$ kg/h
S-4	In a Thermal Power Station, the steam input to a turbine operating on a fully condensing mode is 100 TPH. The heat rejection requirement of the steam turbine condenser is 555 kcal/kg of steam condensed. The temperature of cooling water at the inlet and outlet of the turbine condenser is 27 ^{0}C and 37 ^{0}C respectively. Find out the circulating cooling water flow.
Ans	The quantum of heat rejected in the turbine condenser = Quantum of steam condensed (kg) x heat rejection (kcal/kg) = 100,000 x 555 = 55.5 Million kcal/h. Heat gained by circulating cooling water = Heat rejected in the condenser Circulating cooling water flow = 100,000 x 555 / (37-27) x specific heat (1) = 5550 m^3/hr
S-5	List any five benefits of power factor improvement in an industrial power distribution system
Ans	Refer Guide Book No 3, Chapter 1, Page No 11
S-6	During the performance evaluation of a DG set, the following parameters were noted

Capacity of DG set	1500	kVA
Test duration	36	minutes
Units generated	442	kWh

Average Power factor	0.92	pf
Length of diesel tank	90	cm
Width of diesel tank	90	cm
Height of the diesel tank	90	cm
Initial tank dip level (from top)	63	cm
Final tank dip level (from top)	79	cm

Calculate the following:

1.	Diesel consumption (Litres)	(1 Mark)
2.	Average load (kW)	(1 Mark)
3.	Percentage Loading (%)	(2 Marks)
4.	Specific power generation (kWh/Litre)	(1 Mark)

Ans

1. Diesel Consumption	=	0.9x0.9x0.16	=129.6 Liters
2. Average load (kW)	=	(442/36)x60	=736.7 kW
3. Percentage Loading (%)	=	(736.7/.92)/1500	=53%
4. Specific power generation (kWh/Litre)		(442/129.6)	=3.41 kWh/Litre

S-7 How does a motor lose its efficiency upon rewinding?(2.5 Marks)

What two parameters will indicate the efficacy of the rewinding? (2.5 Marks)

Ans Refer Guide Book No 3, Chapter 2, Page No 61

S-8 A medium sized engineering industry has installed two 480 CFM screw compressors, A & B. Compressor-A is operating at full load and Compressor-B is running in load - unload condition. The load power of both the compressor is 74 kW and the unload power of the Compressor-B is 26 kW. Both the compressors are operated during working day.

The percentage loading of the Compressor-B during working day is 64 %. After arresting the leakage in the system the loading of the compressor was found to be 35 %. Estimate the energy savings per day.

Ans

Existing Case:

Energy consumed per hour by Compressor -A= 74 kW

Energy consumed per hour by Compressor -B= 0.64 x 74 + 0.36 X 26 = 56.72 kW

Total energy consumed (Compressor A& B) = 74 + 56.72 = 130.72 kW/hr

Energy consumed per day= 130.72 X 24 hrs = 3137.3 kWh/day

Leakage Calculation:

Energy consumed per hour by Compressor -B= 0.64 x 74 + 0.36 X 26 = 56.72 kW

Energy consumed per hour by Compressor -B= 0.35 x 74 + 0.65 X 26 = 42.8 kW

Difference in power consumption = 56.72 - 42.8 = 13.92 kW/hr

Savings by arresting leakage per day= 13.92 X 24 = 334 kWh/day

-------- End of Section - II --------

Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Section III contains **Six** questions (L1- L6)

(ii) Each question carries **Ten** marks

L-1	A food processing plant has a contract demand of 2500 kVA with the power supply company. The average maximum demand of the plant is 2000 kVA at a power factor of 0.95. The maximum demand is billed at the rate of Rs.300/kVA. The minimum billable maximum demand is 75 % of the contract demand. An incentive of 0.5 % reduction in energy charges component of electricity bill are provided for every 0.01 increase in power factor over and above 0.95. The average energy charge component of the electricity bill per month for the company is Rs.10 lakhs. The plant decides to improve the power factor to unity. Determine the power factor capacitor kVAr required, annual reduction in maximum demand charges and energy charge component. What will be the simple payback period if the cost of power factor capacitors is Rs.800/kVAr ?

Ans

kW drawn	2000 x 0.95 = 1900 kW
Kvar required to improve power factor from 0.95 to 1	kW (tan θ1 – tan θ2)
	kW (tan (cos-θ1) – tan (cos-θ2)
	1900 (tan (cos-0.95) – tan (cos-1)
	1900 (0.329 - 0)
	625 kVAr
Cost of capacitors @Rs.800/kVAr	Rs.5,00,000
Maximum demand at unity power factor	1900/1 = 1900 kVA
75 % of contract demand	1875 kVA
Reduction in Demand charges	100 kVA x Rs.300
	Rs.30000 x 12
	Rs.3,60,000
Percentage reduction in energy charge from 0.95 to 1 @ 0.5 % for every 0.01 increase	2.5 %
Monthly energy cost component of the bill	Rs.10,00,000
Reduction in energy cost component	10,00,000 x (2.5/100)
	Rs.25,000/month
Annual reduction	Rs.25,000 x 12
	Rs.3,00,000
Savings in electricty bill	Rs.6,60,000
Investment	Rs.5,00,000
Payback period	5,00,000/6,60,000
	0.76 years or 9 months

L-2

Write short notes on the following with respect to the compressed air system :

(each carries 2.5 Marks)

a) Refrigeration drier
b) Heat of compression drier
c) Role of air receiver
d) Dew point

a) Refer Guide Book No 3, Chapter 3, Page No 94
b) Refer Guide Book No 3, Chapter 3, Page No 95
c) Refer Guide Book No 3, Chapter 3, Page No 97
d) **Refer Guide Book No 3, Chapter 3, Page No 93**

L-3

In a boiler, the forced draught fan develops a total static pressure of 300 mmWC. Determine the shaft power (in kW) required to drive the fan if 10,000 kg of coal is burnt per hour with 13 kg of air per kg of coal burnt. The boiler house temperature is 20 ^{0}C and static efficiency of the fan is 80 %.

The operating air density may be calculated from the following:

	R = 847.84 mmWC m^3/kg mole K and Molecular weight of air, M = 28.92 kg/kg mole.
	Total Pressure = 300 mm of WC Mass of air handled, m = 10000 × 13/ 3600 = 36.11 kg/s Atmospheric pressure, P = 1 kg/ cm^2 = 10 mtr of WC = 10,000 mm of WC. Temperature T = 20 + 273 = 293 K Gas Constant for air, R = 847.84 mm WC m3/kg mole K Molecular weight of air, M = 28.92 kg/kg mole Density, kg/m^3 = (P x M) / (R X T) = (10000 x 28.92) / (847.84 x 293) = 1.164 kg/m^3 Volume in m^3/s = mass (kg/s) / density (kg/m3) = 36.11 / 1.164 = 31.02 m^3/s Power to fan shaft, kW = [Volume (m^3/s) x Total pressure (mm of WC)] / [102 x fan efficiency] = [31.02 x 300] / [102 x 0.8] = 114 kW
L-4	A 7.5 TR package air conditioner is provided for a UPS room for removing the heat generated from the UPS of rated capacity 40 kVA. The following parameters were noticed while performing the assessment of the total system.

UPS Parameters:

Rating		Input Power (kW)	Output Power (kW)
40 kVA	On Load (16 hrs)	11.94	8.61
	No Load (8 hrs)	1.16	0.00

Air conditioner parameters:

Installed capacity of Air conditioner	7.5	TR
Outdoor unit (condenser) air velocity	6.1	m/s
Radius of the fan opening at the point of velocity measurement in outdoor unit	0.30	M
Air Density	1.174	kg/m^3
Ambient temperature	305	^{0}K
Temperature of hot air (condenser outlet)	313.5	^{0}K
Specific heat of air	1.009	kJ/kg K

Power drawn by the compressor	5.40	kW
Efficiency of the compressor motor	90	%

Calculate

a) Present delivery capacity of air conditioner (TR) (3 Marks)

b) Power drawn per TR of refrigeration (3 Marks)

c) Calculate the annual energy savings for 7200 hrs, if the UPS is relocated to a non-air-conditioned ventilated area. Assume energy cost Rs.8/kWh. (4 Marks)

Ans

Capacity Installed	7.5	TR
Outdoor unit air velocity	6.1	m/s
Radius of the opening	0.30	m
Area of cross section (3.14 x 0.3^2)	0.283	m^2
Total Air flow (0.283 x 6.1)	1.72	m^3/s
Density of the air	1.174	kg/m^3
Mass of air, m (1.72x1.174)	2.02	kg/s
Ambient temperature, T1	305	°K
Air temperature, T2	313.5	°K
Difference in Temperature (T2-T1), (dT)	8.5	°K
Specific Heat at Constant pressure, cp	1.009	kJ/kgK
Heat Transfer (mxCpx(T2-T1))	17.32	kJ/s
Heat transfer per hour	62352	kJ/hr
	14917	kcal/Hr
Heat input from the compressor (5.4x0.9x860)	4180	kcal/Hr
Evaporator heat load (14949-4180)	10737	kcal/Hr
1 Tonne of refrigeration	3024	kCal/Hr
Effective TR	**3.55**	**TR**
Power drawn by the compressor	5.40	kW
power taken per TR of refrigeration	**1.52**	**kW/ TR**

Heat Load generated by UPS in Conditioned Space							
Rating/ Location	Input Power (kW)	Output Power (kW)	Heat Load				
			(kW)	kCal/Sec	kCal/Hr	TR/hr	Total TR/day

40 kVA	On Load (16hrs)	11.94	8.61	3.33	0.80	2880	0.95	15.2
	No Load (8hrs)	1.16	0	1.16	0.28	1008	0.33	2.64
Total								17.84

The savings that can be achieved by providing clean, cool and dust free environment for UPS operation is given below.

AC Load generated by UPS/ day	= 17.84 TR
Power taken by AC to generate 17.82 TR at 1.52 kW/ TR	= 27.12 kW
Annual energy savings at 300 days of operation	= 8136 **kWh**
Cost of power	= Rs.8/ kWh
Annual Cost Savings	= **Rs.65,088/-**

L-5

One of the textile processing plants has installed two numbers of 6 MW gas turbines and also Heat Recovery Steam Generator (HRSG) to generate steam from the hot gases. The steam generated from HRSG is utilized for process steam requirement and also for 500 TR Vapour Absorption Machine (VAM). The VAM consumes 4.4 kg steam per TR and is operated at full load.

Due to increase in gas price the plant has stopped gas turbine operations and avails power supply from the grid. To meet the steam requirement the plant has installed two numbers of 10 TPH Agro Waste Boilers and steam is supplied to the process plant as well as to VAM machine. The average cost of steam is Rs.1200/- per ton from agro waste boiler. The plant operates for 7000 hours in a year.

The management is planning to replace the VAM chillers by electrical centrifugal chiller which will operate at 0.7 kW/TR.

Compare the annual operating costs of electrical chiller and VAM. The cost of grid power is Rs 6.12/kWh. Consider all the other auxiliary power remains same in both the cases.

Do you agree with the management decision of operating VAM machine for chilling requirements?

Ans

Capacity of VAM Machine	= 500 TR
Steam required/TR	= 4.4 Kg/TR
Total Steam requirement	= 500 X 4.4 = 2200 Kg/hr = 2.2 TPH
Cost of steam from Agro Boiler	= 2.2 X 1200 = Rs 2640 / hr
Power consumed by electric chiller	= 0.7 X 500 = 350 kW
Cost of electricity	= Rs 6.12/kWh
Operating cost of electric chiller	= 350 x 6.12 = Rs 2142
Savings by Electric chiller	= 2640- 2142 = Rs.498/ hr
Annual operating savings	= 7000 X 498 = Rs 34,86,000/-

Disagree with the management decision.

L-6	A distribution company has taken initiatives to reduce Aggregate Technical & Commercial (AT & C) loss in their network. The energy supplied, received and revenue details are given below : Input energy = 60 MU Metered Billed Energy = 43 MU Average Billing = 3 MU Amount Billed = Rs. 540 Million Arrears collected = Rs. 80 Million Amount received = Rs. 470 Million a) Estimate the following : (each carries 2.5 Marks) i) AT & C loss in % and revenue realized in Rs. /kWh ii) Revenue loss per kwh and monthly loss, if the purchased energy cost is Rs. 8.10/kWh b) List five measures to reduce commercial loss in the network (5 Marks)
Ans	a) Billing efficiency = (43+3) /60 X 100 = 76.7 % Collection efficiency = ((470-80)/540) X 100 = 72.2 % AT&C Loss = 1- (Billing efficiency x Collection Efficiency) x 100 = 1- (0.767 x 0.722) X100 = **44.62 %** Revenue realised / kwh = (470-80)/60 = Rs 6.5/kWh Revenue loss / kwh = Rs 8.10- 6.5 = Rs. 1.6/kWh Monthly Revenue loss = 60 X 1.6 = **Rs 96 Million or (Rs.9,60,00,000/-)** b) Few measures to reduce commercial losses in distribution system include: **Refer Guide Book No 3, Chapter 1, Page No 27**

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

Regn No: ____________________

Name : ____________________

(To be written by the candidate)

18th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2017

PAPER – 3: ENERGY EFFICIENCY IN ELECTRICAL UTILITIES

Date: 24.09.2017 Timings: 09:30-12:30 HRS Duration: 3 HRS Max. Marks: 150

General instructions:

- *Please check that this question paper contains **11** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

i) Answer all **50** questions
ii) Each question carries **one** mark
iii) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	An Industrial Consumer has a load pattern of 2000 kW, 0.8 lag for 12 hrs and 1000 kW unity power factor for 12 hrs. The load factor is: a) 0.5 **b) 0.75** c) 0.6 d) 0.2
2.	Which of the following is not likely to create harmonics in an electrical system? a) soft starters b) variable frequency drives c) uninterrupted power supply source (UPS) **d) induction motors**
3.	Which of the following is an example of variable torque equipment ? **a) centrifugal pump** b) reciprocating compressor c) screw compressor d) roots blower
4.	A 10 HP/7.5 kW, 415 V, 14.5 A, 1460 RPM, 3 phase rated induction motor, after decoupling from the driven equipment, was found to be drawing 3 A at no load. The current drawn by the

	motor at no load is high because of a) faulty ammeter reading b) very high supply frequency c) loose motor terminal connections **d) poor power factor as the load is almost reactive**
5.	A 500 cfm reciprocating compressor has a loading and unloading period of 5 seconds and 20 seconds respectively during a compressed air leakage test. The air leakage in the compressed air system would be a) 125 cfm **b) 100 cfm** c) 200 cfm d) none of the above
6.	The percentage reduction in distribution losses when tail end power factor is raised from 0.8 to 0.95 is _________. **a) 29%** b) 15.8% c) 71% d) none of the above
7.	The correction factor for actual free air discharge in a compressor capacity test will be ------------, when the compressed air discharge temperature is 15 ^{0}C higher than ambient air of 40 ^{0}C. a) 0.727 b) 0.920 **c) 0.954** d) none of the above
8.	If we increase the temperature of air without changing specific humidity, dew point temperature of air will a) increase b) decrease **c) remain constant** d) can't say
9.	Which of the following happens to air when it is cooled through evaporation process in an air washer? a) Humidity ratio of the air decreases. **b) Dry Bulb Temp of air decreases.** c) Dry Bulb Temp of air increases. d) Enthalpy of outlet is air is less than enthalpy of inlet air.
10.	In a vapor compression refrigeration system, the component where the refrigerant changes its phase from vapor to liquid is a) compressor **b) condenser** c) expansion valve d) evaporator
11.	In a vapor compression refrigeration system, the component across which the enthalpy remains constant a) compressor b) condenser **c) expansion valve** d) evaporator

12.	If 30,000 kcal of heat is removed from a room every hour then the refrigeration tonnage will be nearly equal to a) 30 TR b) 15 TR **c) 10 TR** d) 100 TR
13.	In a no load test of a 3-phase induction motor, the measured power by the wattmeter consists of: a) core loss b) copper loss c) core loss, windage & friction loss **d) stator copper loss, iron loss, windage & friction loss**
14.	In an engine room 15 m long, 10 m wide and 4 m high, ventilation requirement in m^3/hr for 20 air changes/hr is: a) 30 b) 3000 **c) 12000** d) none of the above
15.	Which among the following is one of the parameters used to classify fans, blowers & compressors ? a) air flow b) speed RPM **c) specific ratio** d) none of the above
16.	The inner tube of a L-type Pitot tube facing the flow ~~is~~ measures _________ in the fan system a) static pressure b) velocity pressure **c) total pressure** d) all of the above
17.	A pump discharge has to be reduced from 120 m^3/hr to 100 m^3/hr by trimming the impeller. What should be the percentage reduction in impeller size? a) 83.3% **b) 16.7%** c) 50.0% d) 33.3%
18.	Increasing the suction pipe diameter in a pumping system will a) reduce NPSHa **b) increase NPSHa** c) decrease NPSHr d) increase NPSHr
19.	If the speed of a reciprocating pump is reduced by 50 %, the head a) is reduced by 25% b) is reduced by 50% c) is reduced by 75% **d) remains same**
20.	If temperature of air increases, the amount of water vapor required for complete saturation will **a) Increase** b) Decrease c) not change d) Can't say
21.	Which of the following is false ?. Air receivers ______

	a) reduce frequent on/off operation of compressors. b) knock out some oil and moisture **c) increase compressor efficiency** d) act as reservoir to- take care of sudden demands
22.	Which among the following inlet air conditions would result in the best cooling tower performance? a) air with lowest wet bulb temperature and high relative humidity **b) air with lowest wet bulb temperature and low relative humidity** c) air with same dry bulb and wet bulb temperature d) air with high dry bulb temperature and high moisture.
23.	As the 'approach' increases while other parameters remain constant, the effectiveness of a cooling tower: a) increases b) remains unchanged **c) decreases** d) none of the above
24.	What is the reduction in distribution loss if the current flowing through the distribution line is reduced by 10%? a)10% b) 81% **c) 19%** d) None of the above
25.	Which among the following types of fans is predominantly used in cooling towers ? a) centrifugal fan **b) axial fan** c) radial fan d) all the above
26.	Which of the following type of lamps is most suitable for color critical applications ? **a) halogen lamps** b) LED lamps c) CFLs d) metal halide lamps
27.	Which of the following factors does not affect waste heat recovery in a DG Set ? a) DG Set loading in kW **b) DG Set reactive power loading** c) operation period of DG Set d) back pressure of flue gas path

28.	The blow down requirement in m^3/hr of a cooling tower for site Cycle of Concentration of 2.5 and approach of 4^oC is: a) 10 b) 0.63 c) 1.6 **d) Data not sufficient to calculate**
29.	Which of the following is not a climate zone as per ECBC classification? a) Hot - dry b) Warm - humid c) Cold **d) Cold humid**
30.	COP of a single effect absorption refrigeration system is likely to be in the range of **a) 0.6 to 0.7** b) 1 to 1.2 c) 1.5 to 2 d) 3.0 to 4.0
31.	Which of the following statements is not true regarding centrifugal pumps? a) Flow is zero at shut off head b) Maximum efficiency will be at design rated flow of the pump c) Head decreases with increase in flow d) **Power increases with throttling**
32.	Which of the following is not true regarding system characteristic curve in a pumping system with large dynamic head ? a) System curve represents a relationship between discharge and head loss in a system of pipes **b) System curve is dependent on the pump characteristic curve** c) The basic shape of system curve is parabolic d) System curve will start at zero flow and zero head if there is no static lift
33.	In a DG set, the generator is generating 1000 kVA, at 0.7 PF. If the specific fuel consumption of this DG set is 0.25 lts/ kWh at that load, then how much fuel is consumed while delivering generated power for one hour. a) 230 litre b) 250 litre **c) 175 litre** d) none of the above
34.	The T2,T5,T8 and T12 fluorescent tube light are categorized based on **a) diameter of the tube** b) length of the tube c) both diameter and length of the tube

	d) power consumption
35.	For an air compressor with displacement of 100 CFM and system leakage of 10%, free air delivery is _______. a) 111.11 CFM b) 90 CFM **c) 100 CFM** d) None of the above
36.	The source of maximum harmonics among the following, in a plant power system is a) 100 CFL lamps of 11 W to 25 W b) 500 kW, 3 Phase, 415 V, 50 Hz resistance furnace c) 5 kVA UPS for computer system **d) variable frequency drive for 225 kW motive load**
37.	The lamp based on high frequency electromagnetic field from outside, exciting the mercury gas sealed in the bulb, to produce UV radiation and light is **a) Induction lamp** b) Fluorescent lamp c) Mercury vapour lamp d) Metal halide lamp
38.	The combined power factor of a set of incandescent bulbs totaling 20 kW and two motors, each of 20 kW with power factor of 0.80 is **a) 0.88** b) 0.90 c) 0.80 d) none of the above
39.	State which of the following statements is true? a) for a given fan operating at a constant temperature, the power input to fan increases by 4 times when the fan speed becomes double **b) for a given fan operating at a constant temperature, the power input to fan increases by 8 times when the fan speed becomes double** c) for a given fan operating at a constant flow rate, the power input increases as the air temperature increases d) for a given fan operating at a constant static pressure rise, the flow rate reduces as the air temperature increases
40.	One tonne of refrigeration has the ability to remove ______ kcal of heat in a 24-hour period. a) 50 kcal b) 3024 kcal **c) 72576 kcal** d) 12000 kcal

41.	In pumping systems where static head is a high proportion of the total, the appropriate solution is a) install two or more pumps to operate in parallel **b) install two or more pumps to operate in series** c) install two or more pumps to operate independently d) install variable frequency drive for the pump
42.	The daily average power factor is 0.95 and the energy consumption is 2200 kWh. The average kVARh drawn is _______ a) 1900 b) 2315 c) **722.5** d) None of the above
43.	HVDS (High Voltage Distribution System) is preferred to a) **reduce technical loss in distribution system** b) improve voltage regulation c) comply with regulatory mandate d) reduce energy bill for the end consumer
44.	When evaporator temperature is increased a) refrigeration capacity decreases **b) refrigeration capacity increases** c) specific power consumption remains same d) power consumption increases
45.	Improving power factor at motor terminals in a factory will a) increase active power **b) release distribution transformer capacity** c) reduce contract demand d) increase motor efficiency
46.	If the COP of a vapour compression system is 3.5 and the motor draws a power of 10.8 kW at 90% motor efficiency, the cooling effect of vapour compression system will be **a) 34 kW** b) 37.8 kW c) 0.36 kW d) none of the above
47.	A parameter that indicates adequacy of lighting for a particular application is a) installed load efficacy b) installed power density **c) lux**

	d) lumens
48.	Which of the following is not an example of lighting controls? a) dimmers b) timers c) photosensors **d) daylight harvesting**
49.	Which of the following flow controls in a fan system will change the system resistance curve: a) Inlet guide vane b) speed change with variable frequency drive c) speed change with hydraulic coupling **d) discharge damper**
50.	When the dew point temperature is equal to the air temperature then the relative humidity is a) 0% b) 50% **c) 100%** d) Unpredictable

…………. 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	Determine the discharge pipe inner diameter size (in mm) for compressed air system, having following parameters. • Compressed Air Flow at NTP (FAD) = 1000 Nm^3/hr • Discharge Air Pressure = 7 bar(g) • Discharge Air Temperature = 35^o C • Air Velocity = 6 m/s. • Atmospheric Pressure = 1.013 bar
Ans	**Actual Condition vs NTP Condition** ▪ $P_2 \times V_2 / T_2$ = $P_1 \times V_1 / T_1$ ▪ $(1.013 + 7) \times V_2 / (273 + 35)$ = $1.013 \times 1000 / 273$ ▪ **V1, actual flow rate** = **142.6 m^3/hr** = **0.0396 m^3/s** **(3 Marks)** ▪ **Flow rate (m^3/s)** = **Area, in mtr^2 x Velocity (m/s)** ▪ **Area, in mtr^2** = **Flow rate (m^3/s) / Velocity (m/s)** = **0.0396 / 6 = 0.0066 m^2** ▪ $A = \pi (d_i^2/4)$ = **0.0066 m^2** ▪ **Pipe, in mm = d_i** = **0.092 m = 92 mm** **(2 Marks)** = ***say 100 mm***
S-2	List five energy saving measures in a centralized chilled water based air conditioning system.
Ans.	• Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains. • Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains. • Minimize the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers etc. • Optimal thermo-static setting of temperature of air conditioned spaces. • Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying load. *Note : Any other relevant point also to be considered*

	………5 marks *(Each point carries one mark)*
S-3	A stream of moist air with a mass flow rate of 10.1 kg/s and with a specific humidity of 0.01 kg per kg dry air, mixes with a second stream of superheated water vapor, flowing at 0.1 kg/s. If we assume proper and uniform mixing without condensation, then what will be humidity ratio of the final stream, in kg per kg dry air?
Ans	**Humidity ratio of final stream,** $$H = \frac{M_1H_1 + M_2H_2}{\text{Dry air}} = \frac{(0.01 \times 10.1) + (0.1 \times 1)}{(10.1 \times (1 - 0.01))} = 0.02 \text{ kg per kg of dry air}$$ **Dry air (*can also be calculated as*) = [10.1 kg/s – (moisture i.e. 10.1 x 0.01)]** ………………..5 marks **Or** Mass of **moist air = 10.1 kg/s.** Specific humidity is = 0.01 kg/**kg dry air** Amount of dry air in moist air can be found out as follows: Let X be the amount of dry air, then by mass balance X + X * (Specific humidity) = 10.1 kg/s X + X * (0.01) = 10.1 kg/s On solving, we get X=10 kg/s Now, Moisture in moist air is 0.1 kg/s Superheated steam = 0.1 kg/s Humidity ratio of final steam = $$H = \frac{M_1H_1 + M_2H_2}{\text{Dry air}} = \frac{(0.01 \times 10) + (0.1 \times 1)}{(10)} = 0.02 \text{ kg per kg of dry air}$$ ………………..5 marks
S-4	A pump is filling water in to a rectangular overhead tank of 5 m x 4 m with a height of 8 m. The inlet pipe to the tank is located at height of 20 m above ground. The following additional data is collected : • Pump suction : 3 m below pump level • Overhead tank overflow line : 7.5 m from the bottom of the tank • Power drawn by motor : 5.5 kW • Motor efficiency η : 92% • Time taken by the pump to fill the overhead tank upto overflow level : 180 minutes Assess the pump efficiency.
Ans	Volume of the tank = 5 x 4 x 7.5 = 150 m^3 Flow = 150/3 = 50 m^3/hr ………………..1.5 marks

	Hydraulic power = Q (m^3/s) x total head (m) x 1000 x 9.81 /1000 = (50/3600) x (20 –(-3)) x 1000 x 9.81/1000 Hydraulic power = 3.13 kW ………………..2.5 marks Power input to pump = 5.5 x 0.92 = 5.06 kW Pump efficiency = 3.13/5.06 = 61.9% ………………..1 mark
S-5	The operating boiler load and associated Induced-draft fan power consumption of a boiler is given below.

Boiler loading	Damper position	Operating hours a day	Fan motor power (with damper operation) (kW)
80%	Position # 1	4	31
70%	Position # 2	12	29
60%	Position # 3	8	26

The fan consumes 35 kW at 100% boiler loading with damper in full open condition.

Estimate the daily energy savings that can be achieved if the damper is replaced by a VFD for induced draft fan to meet the desired requirements.

Assume that the air requirement is proportional to boiler loading.

Ans	Savings can be estimated as follows:

Fan Flow (same as boiler loading) (%)	**Operating hours a day** (hrs / day)	**Fan motor power with damper** (kW)	**Fan motor with VFD** (kW)	**Power savings** (kW)	**Energy savings** (kWh)
A	**B**	**C**	**D = A^3 x 35**	**E = C-D**	**F = B x E**
80	4	31	17.9	13.1	52.32
70	12	29	12	17	203.94
60	8	26	7.6	18.4	147.52
Total Daily Savings					**403.78**

……………….5 marks

S-6 Fill in the blanks for the following

a) Voltage levels can be varied without isolating the connected load to the transformer using _______________

b) Use of _________starter is appropriate in case of high number of motor starts and stops per hour.

c) Operating a highly under loaded motor in star mode reduces voltage by a factor of _________.

d) _____________is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water.

e) In SI units _____________ is the measure of light output of a lamp.

Ans

a) On load tap changer (OLTC)
b) Soft starter
c) √3 (i.e.square root of three)
d) Cycles of Concentration (COC)
e) Lumens

……………….5 marks

(each one carries one mark)

S-7 A 75 kW, 415 V, 140 Amp, 4 pole, 50 Hz, 3-phase squirrel cage induction motor has a full load efficiency of 87.6%. The measured operating motor terminal voltages in a 3-phase supply are 415 V, 418 V & 420 V. The current drawn in 3-phase supply are

	137 Amp, 132 Amp & 137 Amp. Estimate the additional temperature rise of motor, due to unbalanced voltage supply.
	i) **Additional temperature rise:** Phase / V / Deviation from mean voltage R / 415 / -2.67 Y / 418 / 0.33 B / 420 / 2.33 Mean / 417.67 / 0 Voltage unbalance = Maximum deviation from mean/mean voltage = 2.67*100/417.67 = 0.639% --------------------3 Marks Additional temperature rise = 2 X (%voltage unbalance)^2 = 2 X (0.639)^2 = 0.8166% ----------------2 Marks
S-8	Briefly explain any three different methods of flow control for fans
Ans	**Pulley Change:** When a fan flow change is required on a permanent basis, and the existing fan can handle the change in capacity, the volume change can be achieved with a speed change. The simplest way to change the speed permanently is with a pulley change. For this, the fan must be driven by a motor through a v-belt system. **Damper Control:** Dampers provide a means of changing air volume by adding or removing system resistance. This resistance forces the fan to move up or down along its characteristic curve, generating more or less air without changing fan speed. **Inlet Guide Vane:** Guide vanes are curved sections that lay against the inlet of the fan. Guide vanes pre-swirl the air entering the fan housing. This changes the angle at which the air is presented to the fan blades, which, in turn, changes the characteristics of the fan curve. Guide vanes are energy efficient for modest flow reductions – from 100 percent flow to about 80 percent. Below 80 percent flow, energy efficiency drops sharply. **Variable Speed Drive:** Variable speed operation involves reducing the speed of the fan to meet reduced flow

	requirements. Fan performance can be predicted at different speeds using the fan laws. Since power input to the fan changes as the cube of the flow, this will usually be the most efficient form of capacity control. ………………...5 marks **(Any of the above three to be considered)**

…………….. End of Section - II …………….

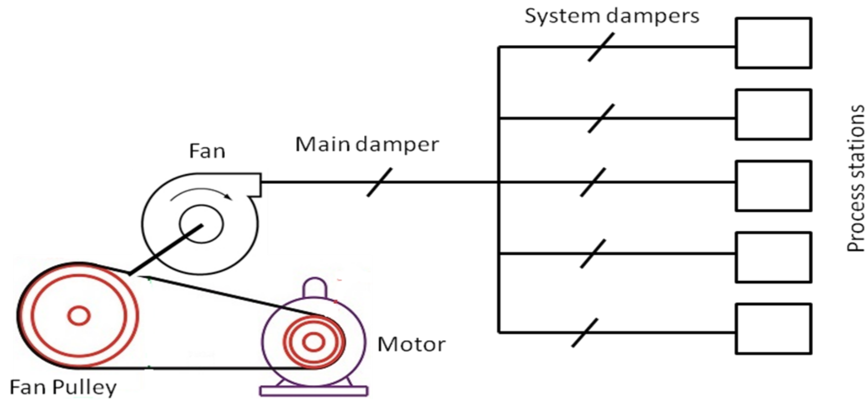
Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

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

L-1	It is required to choose a transformer to cater to a load which varies over a 24 hour period in the following manner : 500 kVA for 6 hours, 1000 kVA for 6 hours and 1500 kVA for 12 hours. Quotations have been received for two transformers, each rated at 1,500 kVA. Transformer-1 has an iron loss of 2.7 kW and a full load copper loss of 18.1 kW , while Transformer-2 has an iron loss of 3.2 kW and a full-load copper loss of 19.8 kW. (i) Calculate the annual cost of losses for each transformer at 365 days of operation if electrical energy cost is Rs. 6 per kWh. (ii) If the transformer-1 is to be purchased at an additional cost of Rs.25,000 over transformer-2, how would you justify it to the finance department ?
Ans	(i) Cost of Losses: **Transformer 1** Energy loss per day due to iron loss = 24 x 2.7 = 64.8 kWh Energy loss per day due to copper loss = $[\left(\frac{500}{1,500}\right)^2$ x 18.1 x 6] + $[\left(\frac{1,000}{1,500}\right)^2$ x 18.1 x 6] + $[\left(\frac{1,500}{1,500}\right)^2$ x 18.1 x 12] = (12.1) + (48.3) + (217.2) = 277.6 kWh Total energy loss per annum = (64.8 +277.6) x 365 = 1,24,976 kWh Annual cost of energy losses = Rs 6 x 124976 kWh = Rs. 7,49,856……….. (3 Marks) **Transformer 2** Energy loss per day due to iron loss = 24 x 3.2 = 76.8 kWh Energy loss per day due to copper loss = [$\left(\frac{500}{1,500}\right)^2$ x 19.8 x 6] + [$\left(\frac{1,000}{1,500}\right)^2$ x 19.8 x 6] + $[\left(\frac{1,500}{1,500}\right)^2$ x 19.8 x 12] = (13.2) + (52.3) + (237.6) = 303 kWh Total energy loss per annum = (76.8 + 303) x 365 = 1,38,663 kWh Annual cost of energy losses = Rs.6 x 1,38,663 = Rs. 8,31,978… (3 Marks) (ii) The capital cost of transformer - 1 is Rs.25,000 more than that of transformer - 2 Annual saving in energy cost due to losses = (Rs 8,31,978 - Rs 7,49,856) = Rs 82,122 Pay Back of additional investment = (25000 / 82,122) = around 4 months = 0.3 Yrs 4 Marks

L-2	a) In an air-handling unit (AHU), the filter area is 1.5 m^2 while air velocity is 2.2 m/s. The inlet air has an enthalpy of 67 kJ/kg. At the outlet of AHU, air has an enthalpy of 56 kJ/kg. The density of air of 1.3 kg/m^3. Estimate the TR of the air-handling unit? b) List out any five energy conservation measures for energy use in buildings
Ans	**a) TR of AHU = (Enthalpy difference x density x area x velocity x 3600) / (4.187 x 3024)** **= (67-56) x 1.3 x 1.5 x 2.2 x 3600 / (4.187x 3024)** **= 13.41 TR**………………..2.5 marks **b)** **1. *Weather-stripping of Windows and Doors* : Minimize exfiltration of cool air and infiltration of warm air through leaky windows and doors by incorporating effective means of weather stripping** **2. *Stripping*. Self-closing doors should also be provided where heavy traffic of people is anticipated.** **3. *Temperature and Humidity Setting*: Ensure human comfort by setting the temperature to between 23oC and 25oC and the relative humidity between 55% to 65%.** **4. *Chilled Water Leaving Temperature*: Ensure higher chiller energy efficiency by maintaining the chilled water leaving temperature at or above 7o C. As a rule of thumb, the efficiency of a centrifugal chiller increases by about 2¼ % for every 1o C rise in the chilled water leaving temperature.** **5. *Chilled Water Pipes and Air Ducts*: Ensure that the insulation of the chilled water pipes and ducting system is maintained in good condition. This helps to prevent heat gain from the surroundings.** **6. *Chiller Condenser Tubes*: Ensure that mechanical cleaning of the tubes is carried out at least once every six months. Fouling in the condenser tubes in the form of slime and scales reduces the heat transfer of the condenser tubes and thereby reducing the energy efficiency of the chiller.** **7. *Cooling Towers*: Ensure that the cooling towers are clean to allow for maximum heat transfer so that the temperature of the water returning to the condenser is less than or equal to the ambient temperature.** **8. *Air Handling Unit Fan Speed*: Install devices such as frequency converters to vary the fan speed. This will reduce the energy consumption of the fan motor by as much as 15%.** 9. ***Air Filter Condition*: Maintain the filter in a clean condition. This will improve the heat transfer between air and chilled water and correspondingly reduce the energy consumption.**

	Note: Any other relevant point may also be considered ………………..7.5 marks (each point carries 1.5 marks and maximum five points has to be considered)
L-3	Fill in the blanks for the following: 1. The dry bulb temperature is 30^0C and the wet bulb temperature is 30^0C. The relative humidity is __________%. 2. Cavitations may occur in a pump when the local static pressure in a fluid reaches a level below the _________ pressure of the liquid at the actual temperature. 3. As the "Approach" decreases, the other parameters remaining constant, the effectiveness of cooling tower will __________. 4. The ratio of luminous flux emitted by a lamp to the power consumed by the lamp is called_________________. 5. A centrifugal pump raises water to a height of 12 meter If the same pump handles brine with specific gravity of 1.2, the height to which the brine will be raised is __________m. 6. Harmonics in electricity supply are multiples of the ____________ frequency. 7. A motor which can conveniently be operated at lagging as well as leading power factors is the __________ motor. 8. As per Energy Conservation Building Code, the Effective Aperture (EA) is ________, given that Window Wall Ratio (WWR) is 0.40 and Visible Light Transmittance (VLT) is 0.25. 9. In an amorphous core distribution transformer, ______ loss is less than a conventional transformer 10. In case of centrifugal pumps, impeller diameter changes are generally limited to reducing the diameter to about _______% of maximum size.
Ans	**1. RH = 100%** **2. Vapor** **3. Increases** **4. Luminous efficacy** **5. 12 meter or the same** **6. Fundamental or 50 Hz** **7. Synchronous** **8. 0.10** **9. No load (other correct answers could be : fixed, iron, total)** **10. 75% (or 80%)** ………………..10 marks **(Each one question carries one mark)**
L-4	A belt-driven centrifugal fan supplies air to a series of process stations as shown in the figure below :



While doing an air balance check on the system, the damper on the main duct and all system dampers had to be partially closed to reduce air flow to the design values.

Energy auditor has recommended that fan power can be saved by fully opening the main damper and reducing the fan speed by changing the fan pulley diameter.

The following initial conditions were measured on the main air supply system:

- Air Volume Flow Rate : 68,400 m^3/hr
- Fan Differential Static Pressure : 112 mmWC
- Pressure differential across main damper : 17 mmWC

The following initial conditions were measured on the air supply fan and motor:

- Motor input power : 26.8 kW
- Supply Fan Speed : 600 rpm
- Motor Speed : 1,460 rpm
- Fan pulley Diameter : 560 mm
- Motor pulley Diameter : 230 mm

Calculate -:
(a) The annual energy savings considering 6000 hours of operation per year.
(b) The new fan pulley diameter.

Ans

- Fan Flow = (68400 / 3600) = 19 m^3 / sec
- The input fan motor power in case-1 (W_1) = 26.8 kW
- Theoretical air power with damper in original partially-closed position (W_{Th1}) = (m^3/s) x (mmWC) / 102

  = (19 x 112) / (102) = 20.86 kW

……………….2 marks

- Theoretical air power with damper in new fully-open position would be position (W_{Th2}) = (m^3/s) x (mmWC) / 102

	$= (19 \times 95) / 102$ $= 17.7$ kW ………………..2 marks - Reduction in differential static pressure across the fan with the main damper fully open = (112-17) = 95 mmWC The input fan motor power in case-2 (W_2) is estimated by proportionality using theoretical fan powers of the fan in the two cases i.e.$(W_1 / W_2) = (W_{Th1} / W_{Th2})$ Fan motor input in case-2 (W_2) $= W_1 \times (W_{Th1} / W_{Th2})$ $= 26.8 \times (17.7/20.86) = 22.7$ kW ………………..2 marks **Annual Energy saving :** Annual Energy saving = Power Reduction x Op. Hours = (26.8 kW - 22.7 kW) x 6000 hrs = 24600 kWh ………………..2 marks **Fan pulley diameter change for reduced speed :** The governing equation for reduced fan speed (N_2) to supply equal air flow with reduced static pressure differential : $(N_1/N_2) = (p_1/p_2)^{0.5}$ Therefore N_2 $= N_1 \times (p_2/p_1)^{0.5}$ $= 600 \times (95/112)^{0.5} = 553$ RPM The governing equation for fan pulley diameter change is : $N_1D_1 = N_2D_2$ (where : N is the speed in rpm and D is the pulley diameter) Therefore D_2 $= (N_1/N_2) \times D_1$ $= (600 / 553) \times 560 = 608$ mm ………………..2 marks
L-5	a) A 3-Phase, 50 kW rated Induction motor drawing 44 kW in a manufacturing industry has a power factor of 0.75 lagging. What size of capacitor in kVAr in each phase is required to improve the operating power factor to 0.96? What is the reduction in current and kVA due to capacitor installation at operating

	voltage of 415 V ? b) List five energy losses in an induction motor
Ans	a) Motor input = P = 44kW Original P.F = $\cos\theta_1$ = 0.75 Final P.F = $\cos\theta_2$ = 0.96 θ_1 = $\cos^{-1}(0.75)$ = 41°.41; Tan θ_1 = Tan (41°.41) = 0.88 θ_2 = $\cos^{-1}(0.96)$ = 16°.26; Tan θ_2 = Tan (16°.26) = 0.29 ***Required Capacitor kVAR to improve P.F from 0.75 to 0.96*** Required Capacitor kVAR = P (Tan θ_1 – Tan θ_2) = 44 kW (0.88 – 0.29) = **25.96 kVAR** ………………..2.5 marks Rating of Capacitors connected in each Phase 25.96/3 = **8.65 kVAR** Current drawn at 0.75 PF = 44 / √3 x 0.415 x 0.75 = 81.6 A Current drawn at 0.96 PF = 44 / √3 x 0.415 x 0.96 = 63.76 A **Reduction in current drawn** = 81.6 – 63.76 = 17.84 A Initial kVA at 0.75 PF = 44 / 0.75 = 58.67 kVA kVA at 0.96 PF = 44 / 0.96 = 45.83 kVA **Reduction in kVA** = 58.67 – 45.83 = 12.84 kVA ………………..2.5 marks b) 1. Iron 2. Stator I^2R 3. Rotor I^2R 4.Friction and windage 5. Stray load ………………..5 marks
L-6	Write short notes on i) Ice Bank System in refrigeration ii) Vapour Absorption Refrigeration System iii) Harmonics in electrical system and its impacts

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<tr>
<td>Ans</td>
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(i) (Page 136 book 3)
Ice Bank Systems:

Ice Bank System is a proven technology that has been utilized for decades Thermal energy storage takes advantage of low cost, off-peak electricity, produced more efficiently throughout the night, to create and store cooling energy for use when electricity tariffs are higher, typically during the day.
The essential element for either full- or partial- storage configurations are thermal-energy storage tanks.

How Ice Bank Works?
During off-peak night time hours, the chiller charges the ICEBANK tanks for use during the next day's cooling.
The lowest possible average load is obtained by extending the chiller hours of operation.
………………..3.33 marks

(ii) (Page 30 book 3)
Vapour Absorption Refrigeration System

The absorption chiller is a machine, which produces chilled water by using heat such as steam, hot water, gas, oil etc.
Chilled water is produced by the principle that liquid (refrigerant), which evaporates at low temperature, absorbs heat from surrounding when it evaporates.
Pure water is used as refrigerant and lithium bromide solution is used as absorbent
Heat for the vapour absorption refrigeration system can be provided by waste heat extracted from process, diesel generator sets etc. Absorption systems require electricity to run pumps only.
Depending on the temperature required and the power cost, it may even by economical to generate heat / steam to operate the absorption system.

Features of VAR systems

Li-Br-water absorption refrigeration systems have a Coefficient of Performance (COP) in the range of 0.65 - 0.70 and can provide chilled water at 6.7 ^{o}C with a cooling water temperature of 30 ^{o}C.
Systems capable of providing chilled water at 3 ^{o}C are also available. Ammonia based systems operate at above atmospheric pressures and are capable of low temperature operation (below 0^{o}C).
Absorption machines of capacities in the range of 10-1500 tons are available.
Although the initial cost of absorption system is higher than compression system, operational cost is much lower-if waste heat is used

………………..3.33 marks
(iii) (Page 114 book 3)
Harmonics in electrical system and its impacts

Harmonics are multiples of the fundamental frequency of an electrical power system.
If, for example, the fundamental frequency is 50 Hz, then the 5th harmonic is five times that frequency, or 250 Hz.
Likewise, the 7th harmonic is seven times the fundamental or 350 Hz, and so on

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	for higher order harmonics **Some of the Harmonic problems are** 1. Blinking of Incandescent Lights 2. Capacitor Failure 3. Conductor Failure 4. Flickering of Fluorescent Lights 5. Motor Failures (overheating) 6. Transformer Failures ………………..3.33 marks

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

REGULAR **Paper 3 – Set A**

Regn No: ____________________

Name : ____________________
(To be written by the candidate)

17th NATIONAL CERTIFICATION EXAMINATION
FOR
ENERGY MANAGERS & ENERGY AUDITORS – September, 2016

PAPER – 3: Energy Efficiency in Electrical Utilities
Date: 25.09.2016 Timings: 0930-1230 HRS Duration: 3 HRS

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I: OBJECTIVE TYPE

1.	Which of the following is the most comfortable conditions for an office room? DBT = Dry bulb temperature, and RH = Relative humidity a) 20°C DBT and 80% RH b) 26°C DBT and 100% RH c) 15°C DBT and 30% RH **d) 25°C DBT and 55% RH**
2.	Energy Star Label Rating scheme for Fluorescent lamp is based on: **a) Lumens per Watt at 100, 2000 and 3500 hours of use** b) End of Lamp Life in terms of burring hours c) Lumen depreciation at 2000 hours d) Color Rendering Index
3.	The effect of increasing the air gap in an induction motor will increase: a) power factor b) speed c) capacity d) **magnetizing current**
4.	The formation of frost on cooling coils in a refrigerator: a) improves C.O.P. of the system b) increases heat transfer c) reduces power consumption

	d) increases power consumption
5.	In a refrigeration system, the expansion device is connected between the a. Compressor and condenser b. Condenser and receiver c. Condenser and evaporator d. Evaporator and compressor
6.	Which of the following is wrong with respect to Color Rendering Index (CRI)? a) The CRI is expressed in a relative scale ranging from 0 - 100 b) CRI indicates how perceived colors match actual colors **c) CRI of Sodium Vapour lamp is much higher than that of a normal Incandescent Lamp** d) The higher the color rendering index, the less color shift or distortion occurs
7.	Which of the following is wrong with reference to heat rate of a coal fired thermal power plant ? a) Heat rate indicates the overall energy efficiency of a power plant b) When calculating plant heat rate, the energy input to the system is GCV of the fuel c) Lower the heat rate the better **d) 860 kCal per kWh is practically achievable**
8.	Installing larger diameter pipe in pumping system results in reduction in: a) Static head **b) Dynamic head** c) Both (a) and (b) d) None of the above
9.	In electrical power system, transmission efficiency increases as **a) both voltage and power factor increase** b) both voltage and power factor decrease c) voltage increases but power factor decreases d) voltage decreases but power factor increases.
10.	Which of the following is wrong statement with reference to LED lamps? a) LED lamps are as energy efficient as CFL bulbs or better. b) LED lampas are more durable than CFLs c) LED lamps has no hazardous material like mercury **d) LED lamps are not suitable for Street Lighting purpose**
11.	In no load test of a poly-phase induction motor, the measured power by the wattmeter consists of: a) core loss b) copper loss c) core loss, windage & friction loss **d) stator copper loss, iron loss, windage & friction loss**

12.	A 10 MVA generator has power factor 0.86 lagging. The reactive power produced will be a) 10 MVAr b) 8 MVAr **c) 5 MVAr** d) 1.34 MVAr.
13.	The no-load loss and copper loss of a 500 kVA transformer is 900 watts and 6400 watts respectively. What is the total loss at 50% of transformer loading? a) 4100 watts b) 6850 watts **c) 2500 watts** d) 3650 watts
14.	Kg of moisture / kg of dry air is defined as **a) Absolute humidity** b) Relative humidity c) Variable humidity d) Dew Point
15.	The basic function of an air dryer in a compressor is to a) Prevent dust from entering the compressor b) Remove moisture before the intercooler c) Remove moisture in compressor suction **d) Remove moisture at the downstream of the after-cooler**
16.	The term “cooling range” in a cooling tower refers to the difference in the temperature of a) dry bulb and wet bulb b) hot water entering the tower and the wet bulb temperature of the surrounding air. c) cold water leaving the tower and the wet bulb temperature of the surrounding air. d) **hot water entering the tower and the cooled water leaving the tower**.
17.	The distinction between fans and blowers is based on a) impeller diameter **b) specific ratio** c) speed d) volume delivered
18.	A better indicator for cooling tower performance is a) Heat load in tower b) Range c) RH of air leaving cooling tower **d) Approach**
19.	As per the building area method given in Energy Conservation Building Code (ECBC) compute the lighting power allowance; given that : the allowed LPD is 12 watt per square meter and enclosed office area is 500 square meter

	a) 6 kW b) 4.16 kW c) 6 W d) 4.16 W
20.	The power factor of a synchronous motor **a) Improves with increase in excitation and may even become leading at high excitations** b) Decreases with increase in excitation c) Is independent of its excitation
21.	A 4 pole 50 Hz induction motor is running at 1470 rpm. What is the slip value? a) 0.2 **b) 0.02** c) 0.04 d) 0.4
22.	As per Energy Conservation Building Code compute the Effective Aperture (EA); given that Window Wall Ratio (WWR) is 0.40 and Visible Light Transmittance(VLT) is 0.25 **a) 0.10** b) 0.65 c) 0.33 d) 0.15
23.	Increasing the impeller diameter in a pump **a. Increases the flow** b. decreases the head c. decreases the power d. all of the above
24.	The percentage reduction in distribution loses when tail end power factor is raised from 0.8 to 0.95 is: a**) 29%** b) 15.8% c) 71% d) 84%
25.	In a Three Phase Transformer, the secondary side line current is 139.1A, and secondary voltage is 415V. The rating of the transformer would be ___________. a. 50 kVA b. 150 kVA **c. 100 kVA** d. 63 kVA
26.	Power factor is highest in case of a. Sodium vapour lamps b. Mercury vapour lamps

	c. Tube Lights d. **Incandescent lamps**
27.	Shunt capacitors connection is normally adopted for: a. Distribution Voltage improvement. b. Power factor improvement. c. **Both a and b**. d. None of these
28.	A company installed a new 100 kVAr, 415Volt capacitor but the power analyzer indicates that it is operating at 93 kVAr. The reason could be a. Operation is at low load b. Higher Voltage at terminals c. **Lower voltage at terminals** d. None of the above
29.	The kVA reduction by improving the power factor of a plant operating at 400 kW load from 0.85 to 0.95 is a) 40 b) **49** c) 72 d) None of the above
30.	For a supply end Voltage of 10.6 kV and receiving end Voltage of 9.8 kV, the percentage regulation works out to: a) 0.80 **b) 8.16** c) 7.55 d) None of these.
31.	Which of the following can be attributed to Commercial Loss in Electrical Distribution System? a) Lengthy Low Voltage Lines b) Low Load side power factor **c) Faulty consumer service meters** d) Undersized conductors
32.	An Induction motor rated 15 kW and 90 % efficiency, at full load will: a) Draw 15 kW b) Draw 13.5 kW c) Deliver 16.66 kW **d) Deliver 15 kW**
33.	A 50 hp motor with a full load efficiency of 90 percent was found to be operating at 25 kW input. The percent Motor Load is a) 75% b) 67% **c) 60%** d) 25%
34.	A DG set has a 300 HP engine drive and is connected to a 300 kVA alternator with 95% efficiency. When a plant load of 290 amps at 415 Volts and 0.76 power factor is connected, the engine loading works out to a) 52% **b) 74.51%** c) 55.4 % d) None of the above
35.	Which of the following devices do not produce any harmonics? a. Electric Motors **b. Filament Lamp** c. Switch Mode power supply of laptops

	d. Electromagnetic ballasts
36.	At which of the following discharge pressures, the same reciprocating air compressor will consume maximum power a) 3 bar b) 5 kgf/cm^2 **c) 90 psi** d) 500 kPa
37.	In a DG set, the generator is consuming 70 litre per hour diesel oil. If the specific fuel consumption of this DG set is 0.33litres/ kWh at that load, what is the kVA loading of the set at 0.8 PF? a) 212 kVA **b) 262.5 kVA** c) 170 kVA d) None of these.
38.	If EER of One Ton Split AC unit is 3.51, what is its power rating? a) **1.0 kW** b) 1.5 kW c) 0.8 kW d) 2.0 kW
39.	As per the Inverse Square Law of illumination what will be the illuminance at half the distance? a) 50% **b) 4 times** c) double d)No change
40.	Find the air density at 35^{o}C temperature at one atmospheric pressure. It is given that at one atmospheric pressure the air density at 20 ^{o}C is 1.2041 kg/m^3 **a) 1.1455** b) 1.2657 c) 1.2024 d) none of the above
41.	A spark ignition engine is used for firing which type of fuels: a) high speed diesel b) light diesel oil **c) natural gas** d) furnace oil
42.	The blow down requirement in m^3/hr of a cooling tower with evaporation rate of 16 m^3/hr and CoC of 3 is a) 4 b) 2 **c) 8** d) 16
43.	Which Loss in a Distribution Transformer is predominant if the transformer is loaded to75% of its rated capacity? a) core loss b) **copper loss** c) hysteresis loss d) magnetic field loss

44.	Which of the following power plants has the highest efficiency a. **Combined cycle gas turbine** b. Diesel Engine c. Conventional coal plants d. Open cycle Gas Turbine
45.	*The voltage unbalance in three phase supply is 1.5 %. If the motor is operating at 100 ^oC, the additional temperature rise in ^oC due to voltage unbalance is* **a. 4.5** b. 9 c. 0 d none of the above
46.	Which of the following cannot be controlled by automatic power factor controllers a) **KW** b) voltage c) Power factor d) KiloVAr
47.	The parameter used in Star labeling of air conditioner is a. COP **b. EER** c. KW/TR d. EPI
48.	The refrigeration load in TR when 30 m^3/hr of water is cooled from a 14 ^{o} C to 6.5 ^{o} C is about **a) 74.4** b) 64.5 c) 261.6 d) none of the above
49.	In a lithium bromide absorption refrigeration system a. lithium bromide is used as a refrigerant and water as an absorbent **b. water is used as a refrigerant and lithium bromide as an absorbent** c. ammonia is used as a refrigerant and lithium bromide as an absorbent d. none of these
50.	A good DG set waste heat recovery device manufacturer will take precautions to prevent which of the following problem while DG set is in operation a) voltage unbalance on generator **b) Excessive back pressure on engine** c) excessive steam generation d) turbulence in exhaust gases

…………. End of Section – I …………..

Section – II: SHORT DESCRIPTIVE QUESTIONS

S-1	a. The rated compressor capacity is 15 m^3/min. Evaluate if there is any capacity de-rating using the air-receiver tank filling method conducted at shop floor. The relevant data is given below. Volume of Air receiver including pipe and cooler = 9 m^3 Initial Pressure = 0.5 kg/cm^2 Final Pressure = 7.0 kg/ cm^2 Atmosphere pressure = 1.026 kg/ cm^2 Time taken to build up the pressure = 5 minutes b. What is the deficiency in this calculation and how can it be corrected ?.
Ans	a. Compressor output from tank filling method = [(7.0-0.5) x9/ (1.026x5)] = 11.40 m^3/min Capacity shortfall = 15-11.40 = 3.60 m^3/min, i.e., (3.60/15)x100 = 24% capacity de-rating b. The above calculation assumes the compression is isothermal. It can be corrected by introducing the temperature correction factor: $(273+T_2)/(273+T_1)$ where T_1 is suction Temperature and T_2 is receiver temperature.
S-2	State three advantages of improvement of Power Factor at Load side. Power Factor at the load side is 0.75 and average minimum load is 100 kW. What is the kVAr rating of capacitor to improve the Power Factor at the load side to 0.95?
Ans.	Advantages of Power Factor improvement. • Reduced kVA (Maximum demand) charges in utility bill • Reduced distribution losses (KWH) within the plant network due to reduced current • Better voltage at motor terminals and improved performance of motors • Reduction in size of transformers • Avoidance of PF penalty and availing of PF incentives. • Better operating efficiency of motors/ drives ***(any three of the above or relevant answers)*** Capacitor required to improve Pf from 0.75 to 0.95 for an Average Load of 100 kW $= 100\{\tan(\cos^{-1} 0.75) - \tan(\cos^{-1} 0.95)\} = 100(0.882-0.329) = 55.3$ kVAr, say 55 kVAr ***Or*** $kVAr_{Old} = \sqrt{(kVA_{old}^2 - kW^2)} = \sqrt{(100/0.75)^2 - 100^2} = 87.67$ kVAr $kVAr_{new} = \sqrt{(kVA_{new}^2 - kW^2)} = \sqrt{(100/0.95)^2 - 100^2} = 32.86$ kVAr Additional kVAr required = 87.67-32.86 = 54.76 kVAr, say 55 kVAr

S-3	One unit of electricity in end-use application is equivalent to about two units of electricity generated. Substantiate your answer with the computation of cascade efficiency from generating plant ex-bus to end-use application. Assume: Efficiency of Generator yard substation as 98%; transmission and Distribution Loss = 20%; Efficiency of End-use application= 65%
Ans	Cascade efficiency from ex-bus generator to end-use = Efficiency of Generator yard substation x Efficiency of transmission and Distribution x Efficiency of End-use application Which is approximately = 0.98x(1-0.20)x0.65 = 0.5096. Therefore one unit at end use application = [1/0.5096] = 1.96 Units, Say 2 Units at ex-generator bus
S-4	Match the following Terms in ECBC <table><tr><td>1</td><td>Lighting Power Density (LPD)</td><td>A</td><td>Rate of Heat Flow in Watt per square meter per degree Centigrade</td></tr><tr><td>2</td><td>Energy Performance Index (EPI) of a building</td><td>B</td><td>Light admitting potential of a Glazing System</td></tr><tr><td>3</td><td>Effective Aperture(EA)</td><td>C</td><td>Watts per square meter</td></tr><tr><td>4</td><td>Visible Light Transmittance (VLT)</td><td>D</td><td>kWh per square meter per year</td></tr><tr><td>5</td><td>U-Factor</td><td>E</td><td>Ratio of Light Passing through glazing to the light passing through perfectly transmissive glazing</td></tr></table>
Ans	**1,C; 2,D; 3,E; 4,B; 5,A**
S-5	List five energy saving measures in a commercial building.
Ans	• Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by providing partitions. • Reduction in solar heat gain through building envelope by providing efficient glazing. • Use of energy efficient lighting systems • Using occupancy/ motion/ sound sensors for lighting system • Use of energy efficient pumping systems • Use of energy efficient air conditioning systems • Providing efficient barriers for avoiding hot air leakage into cold spaces. • Optimizing evaporator temperature to 22^{0}C • Avoiding use of heating appliance in cool spaces.

S-6	Explain how a Variable Frequency Drive saves power in a three phase electric motor driven pumping system? What will be the reduction in power drawn by a motor by reducing the speed by half?
Ans	The VFD converts a basic fixed-frequency, fixed voltage sine-wave power (line power) to a variable frequency, variable-voltage output used to control speed of induction motors. By controlling speed of a pump rather than controlling flow through use of throttling valves, energy savings can be substantial. By affinity law, if the speed of the pumping is reduced by 1/2, the power drawn by the motor will be reduced by a factor of eight $(1/2)^3$ = 1/8.Using a fixed speed motor would require some type of mechanical throttling device, such as a vane or damper; but the fact remains that the motor would running full load and almost full speed (full power), dropping the pressure across the flow control device.
S-7	A performance analysis of a DG set was carried out. The following are the data obtained. • Period of trial – 2 hrs • Energy generated -1500 kWh • Level difference in diesel day tank – 51.6 cm • Diameter of day tank – 1m • Calorific value of fuel -10500 kcals/kg The air drawn by the DG set is 30 kg/kg of fuel. The energy auditor recommended for a waste heat recovery system. Also the auditor indicated waste heat recovery potential is 2.6×10^5 kcal/hr if the flue gas temperature after waste heat recovery system is maintained at 180^0C. a) Calculate the average efficiency of DG set and its specific fuel consumption b) Calculate present flue gas exit temperature if specific gravity of fired fuel oil of 0.86 and specific heat of flue gas is 0.25 kcal/kg ^{0}C.
Ans	(see table below)

1	Fuel consumption (litres) during 2 hrs of trail period {(area x height diff) of day tank} ={3.14x(1^2)/4 x0.516x1000)lit	405	
2	Specific gravity of fuel oil (given)	0.86	
3	Oil consumption in (kg/hr) (405x 0.86 / 2)	174.18 kg/hr or 202.5 lit/hr	
4	Specific fuel consumption (kWh/lit) (**Ans a**)	3.7 kWh/lit or 4.3	

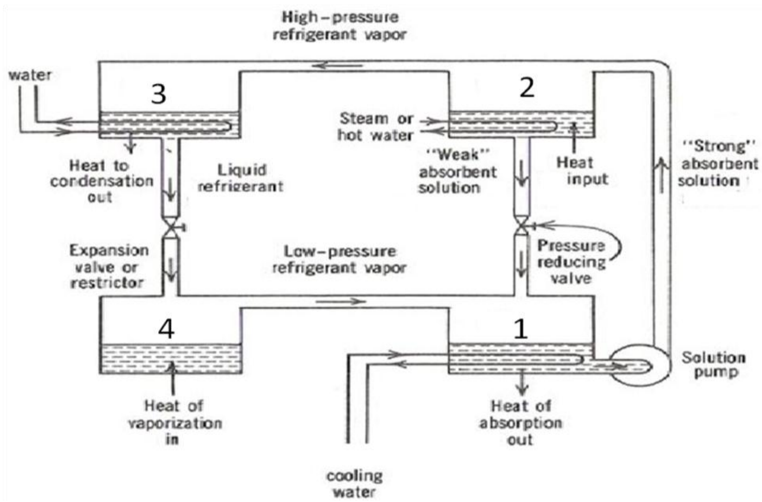
	(continued table below)

		kWh/kg	
5	Air supplied per kg of fuel (kg) (given)	30	
6	Mass of flue gas (Sl.No.5)+1kg	31	
7	Mass of flue gas kg per hour (Sl.No 6 x Sl.No 3)	5399.5	
8	Waste heat recovery potential (kCal/hr) (given)	260000	
9	Delta T across waste heat recovery system (Heat kCal/hr)/(mass of flue gas/hr*specific heat)	192.61	
10	Exit flue gas temp. after waste heat recovery system (given)	180	
11	Present Flue gas temp. or temp. before waste heat recovery system (180^0C+Delta T) (**Ans b**)	372.6	
12	Efficiency of DG set {750x860/(174.18x10500)} (**Ans a)**	=35.3	

S-8	A 415 V, 15kW, 3-ph, 50Hz Induction motor operates at full load, with 88% efficiency and 0.85 power factor lagging: a) Find the current drawn by the motor b) If this motor is replaced by 92.5% energy efficient motor with 0.92 power factor, what will be the power savings in terms of k W and kVA?
Ans	a). kW_{in} (Input power) = 15 / 0.88 = 17.05 kW Line current = 17.050 / (√3 x 0.415 x 0.85) = 27.91 Amp kVA_{in} = 17.05/0.85=20.06 kVA OR (√3 x 415X27.91) b) For the same output of 15 kW Input power with 92.5 % efficiency will be = 15/0.925 = 16.216 kW and Input kVA at 0.92 power factor will be = 16.216 /0.92= 17.62 or 18 kVA Therefore, saving will be 17.05 -16.216 = 0.834 kW 20.06-17.62= 2.44 kVA

……………… End of Section - II ……………..

Section – III: LONG DESCRIPTIVE QUESTIONS

<table>
<tr><td>L-1</td><td>Identify the type of refrigeration system depicted in the following figure and also the components represented by 1,2,3 &4 . Explain briefly the function of each of these components.

</td></tr>
<tr><td>Ans</td><td>Vapor Absorbtion Refrigeration system

1. Absorber : Concentrated LiBr absorbs the refrigerant vapor (water) and becomes dilute.

2. Generator : Heats the dilute LiBr refrigerant, regenerates refrigerant (water vapor) and also concentrates LiBr.

3. Condensor: Condenses the regenerated refrigerant (water vapor)

4. Evaporator : Liquid refrigerant (water) in atomised form picksup the heat from the cooling chilled water coil and becomes water vapor.</td></tr>
<tr><td>L-2</td><td>A 1680 m^3/hr reciprocating compressor is operated by a 160 kW rated motor with an efficiency of 90% and is drawing 159 kW. The actual requirement of the compressed air is increased by 100 m^3/hr due to an additional equipment. Plant is considering to increase the speed of the compressor to meet this marginal requirement by modifying the compressor pulley size. The existing speed and pulley sizes are given below.
o Motor rpm : 1400
o Motor pulley diameter : 300mm
o Compressor rpm : 700 rpm
o Compressor Pulley diameter : 600 mm
Find out the new pulley diameter and also the additional power consumption after increasing the speed?
Based on the calculation check whether the motor has the capacity to handle the additional load.</td></tr>
</table>

Ans	Initial flow rate = 1680 m^3/hr Modified flow rate = (1680 + 100) = 1780 m^3/hr Initial rpm = 700 rpm Modified rpm = (1780 /1680) x 700 = 742 rpm Modified, compressor - pulley size = using the expression $N_1D_1 = N_2D_2$ $D_2 = N_1D_1/N_2$ = (700x600)/742 = 566 mm Modified motor power consumption = (742 / 700) x 159 kW = 168.54 kW Capability of the motor = 160 kW / 0.9 = 178 kW Hence the motor have the margin to absorb the additional load of 100 m^3/hr
L-3	a) A Residential colony having a fixed load of 250 KVA is situated 1 km away from a 3 phase, 11 kV / 415 V transformer from which the power is to be fed. The management is evaluating the choice of LT (1 run x 3.5 core x 300sqmm) Vs HT (1 run x 3 core x 70sqmm) distribution for a 1 km stretch. Given the following data, as a n energy auditor what would you suggest and estimate the payback period on marginal investment (difference in the two investments) b) Support your recommendation with calculations. c) Data • Total Resistance of LT cable (conductor cross section 300sqmm)is 0.13 ohms / km and the cost is Rs 700/m • Total Resistance of HT cable(conductor cross section 70sqmm) is 0.570 ohms / km and the cost is Rs 1300/ m • Unit price is Rs 7 / kWh • Cost of relocating the transformer (in case of HT cabling) = Rs 1 lakh Add voltage regulations loss (single run x root 3)
Ans	Resistance of LT cable is 0.13 ohms / km and the cost is Rs 700/m Resistance of HT cable is 0.570 ohms / km and the cost is Rs 1300/ m Current drawn in LT system = 250/(0.415*1.732) = 347.8 A Current drawn in HT system = 250 /(1.732*11) = 13.1 A Power loss in LT system =($(347.8)^2$x 0.13 x 1x3ph)/1000 = 47.17 kW Power loss in HT system = ($(13.1)^2$x 0.57 x 1x3ph)/1000 = 0.29 kW Energy saving on account of conversion from LT to HT line = 47.17 – 0.29 = 46.87 kW

	Annual energy savings = 46.87 x 8760 = 4,10,639 kWh Annual cost savings = 4,10,639 x 7 = Rs 28,74,470/- Investment required for laying HT cable supply = Rs 1300 x 1000 = 13,00,000/- Investment required for relocating transformer = Rs.1,00,000 Total Investment required for laying HT cable supply and relocating transformer = (13,00,000+1,00,000) = Rs.14,00,000 Investment required for laying LT cable supply = Rs 700 x 1000 = Rs. 7,00,000/- Pay back for the marginal investment = (14,00,000 – 7,00,000)/ 28,74,470 = 0.24 yrs = 3 months
L-4	An air supply system with belt driven centrifugal fan and necessary damper adjustment has a flow rate of 12 m^3/s. One branch of the system, having a flow of 1.5 m^3/s, require static pressure of 89 mmWC. Although, the remainder of the system could operate at 66 mmWC, the fan is operated at 89 mmWC to provide for pressure required by the branch. The system operates for 6000 hours /year Energy auditor proposes to reduce the fan speed to reduce the static pressure to 66 mmWC and provide a booster fan in the duct to deliver 89 mmWC static pressure to the branch. The speed reduction is proposed to be achieved by changing the fan pulley diameter. The motor and fan efficiencies remain same after pulley change. Booster fan has an efficiency of 75% and drive motor of 85% efficiency. Measured motor input power to main supply fan = 16.2 kW Fan data: Initial fan speed = 1200 rpm Initial motor pulley diameter = 209 mm Initial fan pulley diameter = 305 mm hours operation = 6000 Calculate annual energy savings & cost savings
Ans	Solution: Revised fan speed = 1200 x (66/89) ^0.5 = 1031 rpm New fan pulley diameter = 305 x 1200/1031 = 355 mm Initial ideal fan power (Air kW) = 12 x 89/102 = 10.5 kW Revised ideal fan power (Air kW) = 12 x 66/102 = 7.8 kW

	Initial motor input power = 16.2 kW Since motor and fan efficiencies remain same after pulley change (10.5/16.2) = (7.8/Revised motor input power) Revised motor input power = 16.2 x 7.8/10.5 = 12 kW Annual energy savings = (16.2-12) x 6000 = 25,200 kWh Annual cost savings = 25200 x Rs.7/kWh = Rs.1,76,400/- Booster fan flow rate = 1.5 m^3/s Static pressure = (89-66)= 23mmWC Ideal fan power (Air kW) = 1.5 x 23/102 = 0.34 kW Fan shaft power = 0.34/0.75 = 0.45 kW Drive motor capacity = 0.45 / 0.85 = 0.53 kW Annual energy consumption of booster fan = 0.53 x 6000 = 3180 kWh Annual cost savings = 3180 x 7 = Rs.22,260/- Net savings = 1,76,400 – 22,260 = Rs. 1,54,140/-
L-5	A centrifugal water pump operates at 60 m^3/hr and at 1470 RPM. The pump operating efficiency is 65% and motor efficiency is 89%. The discharge pressure gauge shows 3.4 kg/cm2. The suction is 3 m below the pump centerline. An energy auditor recommends to replace the existing motor with a four pole motor of 91% efficiency and a slip of 1% . Determine the new flow rate and the power drawn by the motor. In both the cases the throttle valve is fully open and system head is purely frictional. Comment on the measure.
Ans	**Existing** Flow = 60 m^3/hr Head developed by the pump = 34 – (-3) = 37 m Power drawn by the pump = (60/3600) x 37 x 1000 x 9.81/(1000 x 0.65) = 9.3 kW **Proposed** Speed of the pump with new motor = 1500- [(1/100)x1500] =1485 RPM Flow rate of new pump with increase in RPM Q1 /Q2 = N1/N2 Q2 = Q1 x(N2/N1) = 60 x (1485/1470) = 60.61m^3/h Power drawn by the pump with new motor = 9.3 x $(1485/1470)^3$ = 9.59 kW Power drawn by the existing motor =9.3/0.89 = 10.46 kW Power drawn by the new motor = 9.59/0.91 = 10.54 kW Comment Comment-1: Power consumption is more , so not recommended

	(or) Comment-2: Power consumption is more however flow is also more.
L-6	**State true or false (1 marks each)** 1. The efficiency of gas turbine power plant is lower than that of a combined cycle power plant.(**T**) 2. The performance of air compressor at high altitudes will be lower as compared to that at sea level(**T**). 3. Efficiency of transformer will be minimum when copper loss is equal to iron losses. (**F**) 4. In cooling towers, the water droplets entrapped in the air stream is captured by drift eliminators.(**T**) 5. To get the static pressure, the inner and outer tubes of pitot tube are connected to manometer.(**F**) 6. The throttling of pump discharge will change the pump characteristic curve (**F**). 7. The simplest way to reduce the discharge from a reciprocating air compressor is to throttle it. (**F**) 8. Cycle of Concentration (COC) is the ratio of dissolved solids in circulating water to the dissolved solids in makeup water(**T**) 9. Use of VFD will save power but also create harmonics.(**T**) 10. The synchronous speed of a 4 pole motor will be 3000 rpm (**F**)

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

16th NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS – September, 2015

PAPER – 3: Energy Efficiency in Electrical Utilities			
Date: 20.09.2015	**Timings: 0930-1230 HRS**	**Duration: 3 HRS**	**Max. Marks: 150**

General instructions:

- *Please check that this question paper contains **8** printed pages*
- *Please check that this question paper contains **64** questions*
- *The question paper is divided into three sections*
- *All questions in all three sections are compulsory*
- *All parts of a question should be answered at one place*

Section – I: OBJECTIVE TYPE Marks: 50 x 1 = 50

i) Answer all **50** questions
ii) Each question carries **one** mark
iii) Please hatch the appropriate oval in the OMR answer sheet with Black Pen or HB pencil

1.	Which of the following is not a part of vapour compression refrigeration cycle: a) compressor b) evaporator c) condenser d) <u>absorber</u>
2.	Which of the following can be attributed to commercial loss in electrical distribution system a) lengthy low voltage lines b) low load side power factor <u>c) faulty consumer service meters</u> d) undersize conductors
3.	Which loss in a distribution transformer is dominating; if the transformer is loaded at 68% of its rated capacity a) core loss b) <u>copper loss</u> c) hysteresis loss d) magnetic field loss
4.	When evaporator temperature is reduced a) refrigeration capacity increases b) <u>refrigeration capacity decreases</u> c) specific power consumption remains same d) compressor will stop
5.	What is the function of drift eliminators in cooling towers a) maximize water and air contact b) c<u>apture water droplets escaping with air stream</u> c) enables entry of air to the cooling tower d) eliminates uneven distribution of water into the cooling tower
6.	Trivector meter measures three vectors representing a) active, reactive and maximum demand b) active, power factor and apparent power c) active, harmonics and maximum demand d) <u>active, reactive and apparent power</u>

7.	Time of the Day metering (TOD) is a way to a) reduce the peak demand of the distribution company b) increase the revenue of the distribution company c) increase the peak demand d) increase the maximum demand in a industry
8.	The unit of specific humidity of air is: a) grams moisture/kg of dry air b) moisture percentage in air c) grams moisture/kg of air d) percentage
9.	The purpose of inter-cooling in a multistage compressor is to a) remove the moisture in the air b) reduce the work of compression c) separate moisture and oil vapour d) none of the above
10.	The percentage reduction in distribution loses when tail end power factor raised from 0.85 to 0.95 is a) 10.1% b) 19.9% c)71% d)84%
11.	The nomenclature T2,T5,T8 and T12 for fluorescent lamps are categorized based on a) diameter of the tube b) length of the tube c) both diameter and length of the tube d) power consumption
12.	The inexpensive way to improving energy efficiency of a motor which operates consistently at below 40% of rated capacity is by _____. a) operating in star mode b) replacing with correct sized motor c) operating in delta mode d) none
13.	The indicator of cooling tower performance is best assessed by a) wet bulb temperature b) dry bulb temperature c) range d) approach
14.	The illuminance of a lamp at one meter distance is 10 Lm/m^2. What will be the corresponding value at 0.7 meter distance a)14.28 b) 20.41 c) 10 d) none of these
15.	The fan system resistance is predominately due to a) more bends used in the duct b) more equipments in the system c) volume of air handled d) density of air
16.	The cooling tower size is _____________ with the entering WBT when heat load, range and approach are constant. a) directly proportional b) inversely proportional c) constant d) none of above
17.	The components of two part tariff structure for HT & EHT category consumers are a) one part for capacity(or demand) drawn and second part for actual energy drawn b) one part for actual Power Factor and second part for actual energy drawn c) one part for capacity(or demand) drawn and second part for actual reactive energy drawn d) one part for actual apparent energy drawn and second part for actual reactive energy drawn
18.	The adsorption material used in an adsorption air dryer for compressed air is

	a) calcium chloride b) magnesium chloride c) activated alumina d) potassium chloride
19.	The actual measured load of 1000 k VA transformer is 400 k VA. Find out the total transformer loss corresponding to this load if no load loss is 1500 Watts and full load Copper Loss is 12,000 Watts a) 1920 watts b) 1500 watts c) 3420 watt d) 13500 watts
20.	The percentage imbalance when line-line voltages are 415 V, 418 V and 408 V is a) 1.047% b) 0.32% c) 1.44% d) none of the above
21.	Star – delta starter of an induction motor a) reduces voltage by inserting resistance in rotor circuit b) reduces voltage by inserting resistance in stator circuit c) reduces voltage through a transformer d) reduces the supply voltage due to change in connection configuration
22.	Slip power recovery system is applicable in case of a) squirrel cage induction motor. b) wound rotor motor c) synchronous motor d) DC shunt motor
23.	Rotating magnetic field is produced in a___________ a) single- phase induction motor b) three- phase induction motor c) DC series motor d) all of the above
24.	Power factor is highest in case of a) sodium vapour lamps b) mercury vapour lamps c) fluorescent lamps d) incandescent lamps
25.	Power factor Improvement will result in a) reduction in active power b) reduction in active current c) reduction in reactive power d) all the above
26.	Motor efficiency will be improved by a) reducing the slip b) increasing the slip c) reducing the diameter of the motor d) decreasing the length of the motor
27.	Lower power factor of a DG set demands a) lower excitation currents b) no change in excitation currents c) higher excitation currents c) none of the above
28.	L / G ratio in cooling tower is the ratio of a) length and girth b) length and gradient of temperature c) water mass flow rate and air mass flow rate d) water volume flow rate and air volume flow rate
29.	Installing larger diameter pipe in pumping system results in a) increase in static head b) decrease in static head c) increase in frictional head d) decrease in frictional head
30.	Installation of Variable frequency drives (VFD) allows the motor to be operated with a) constant current b) lower start-up current c) higher voltage d)none of the

	above
31.	In a no load test of a poly-phase induction motor, the measured power by the wattmeter consists of: a) core loss b) copper loss c) core loss, windage & friction loss d) stator copper loss, iron loss, windage & friction loss
32.	In a large compressed air system, about 70% to 80% of moisture in the compressed air is removed at the a) air dryer b) after cooler c) air receiver d) inter cooler
33.	Illuminance of a surface is expressed in a) radians b) lux c) lumens d) LPD
34.	If two identical pumps operate in series, then the combined shutoff head is a) it does not affect head b) more than double c) doubled d) less than
35.	If the speed of a reciprocating pump is reduced by 50 %, the head a) is reduced by 50% b) is reduced by 12.5% c) remains same d) none of the above
36.	If the observed temperature in air receiver is higher than ambient air temperature the correction factor for free air delivery will be: a) less than one b) greater than one c) equal to one d)equal to zero
37.	If the COP of a vapour compression system is 3.5 and the motor draws power of 10.8 kW at 90% motor efficiency, the cooling effect of vapour compression system will be: a) 34 kW b) 37.8 kW c) 0.36 kW d) none of the above
38.	If EER of One Ton Split AC is 3.5, what is its power rating? a) 1.0 k W b) 1.5 kW c) 0.8 kW d) None of the above
39.	Humidification involves a) reducing wet bulb temperature and specific humidity b) reducing dry bulb temperature and specific humidity c) increasing wet bulb temperature and decreasing specific humidity d) reducing dry bulb temperature and increasing specific humidity
40.	Higher COP can be achieved with_____. a) lower evaporator temperature and higher condenser temperature b) higher evaporator temperature and Lower condenser temperature c) higher evaporator temperature and higher condenser temperature d) lower evaporator temperature and Lower condenser temperature
41.	Friction losses in a pumping system is a) inversely proportional to flow b) inversely proportional to cube of flow c) proportional to square of flow d) inversely proportional square of flow
42.	Flow control by damper operation in fan system will

	a) increase energy consumption b) reduce energy consumption c) reduce system resistance d) none of the above
43.	Find the Total Harmonic Distortion (THD) for current for the following current readings. Current at 50 Hz fundamental frequency = 250 A, Third harmonic current = 50 A, fifth harmonic current = 35 A a) 58 % b) 48 % c) 24% d) 34 %
44.	Calculate the density of air at 11400 mmWC absolute pressure and 65^0C. (Molecular weight of air: 28.92 kg/kg mole and Gas constant:847.84 mmWC m^3/kg mole K) a) 1.2 kg/m^3 b) 1.5 kg/m^3 c) 1.15 kg/m^3 d) none of the above
45.	A spark ignition engine is used for firing which type of fuels: a) high speed diesel b) light diesel oil c) natural gas d) furnace oil
46.	A hotel building has four floors each of 1000 m^2 area. If the interior lighting power allowance for the hotel building is 43000W, the Lighting Power Density (LPD) is: a) 10.75 b) 0.09 c) 43 d) data insufficient
47.	A DG set consumes 70 litres per hour of diesel oil. If the specific fuel consumption of this DG set is 0.33 litres/ kWh at that load, then what is the kVA loading of the set at 0.8 PF? a) 212 kVA b) 265 kVA c) 170 kVA d) none of the above
48.	A company installed a 130 kVAr, 600 Volt capacitor but the power meter indicates that it is only operating at 119 kVAr. The reason out of the following could be a) operating at low load b) high voltage c) low voltage d) low current
49.	A 50 hp motor with a full load efficiency rating of 90 percent was metered and found to be operating at 25 kW. The percent motor load is a) 75% b) 50% c) 60% d) 25%
50.	A 22 kW, 415 kV, 45A, 0.8 PF, 1475 RPM, 4 pole 3 phase induction motor operating at 420 V, 40 A and 0.8 PF. What will be the rated efficiency a) 85.0% b) 94.5% c) 89.9% d) 88.2%

…………. 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	List five energy saving measures for air conditioning system.

	• Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains. • Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains. Minimize the air conditioning loads by measures such as • roof cooling, • roof painting, • efficient lighting, • pre-cooling of fresh air by air- to-air heat exchangers • Variable volume air system • Optimal thermo-static setting of temperature of air conditioned spaces • Sun film application Minimize the process heat loads by measures involving TR reduction and refrigeration temperature level reduction • Flow optimization • Heat transfer area increase to accept higher temperature coolant • Avoid wastages by heat gains • Avoid wastages by loss of chilled water • Avoid wastages by ideal flows. • Frequent cleaning and descaling of all heat exchangers At refrigeration and AC plant area • Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying load. • Ensure regular maintenance of all AC plant components as per manufacturers guide lines. • Ensure adequate quantity of chilled water flows, cooling water flows • Avoid by pass flow by closing valves of ideal equipment • Adopt VAR system where economics permit as non CFC solutions • Make efforts to continuously optimize condenser and evaporator parameters for minimizing specific energy consumption and maximizing capacity ….. (5 marks for relevant points as above)
S-2	The total system resistance of a piping loop is 50 meters and the static head is 15 meters at designed water flow. Calculate the system resistance offered at 75%, 50% and 25% of water flow

	Solution: Total System Resistance of piping loop: 50m Static Head :15 m So, Dynamic Head at designed water flow: 35m ….. (2 mark)

Sl.No.	Flow%	Dynamic Head (m) = 35 x $(\%flow)^2$	Static Head (m)	Total Resistance (m)
1	75.0%	19.68	15	34.68
2	50.0%	8.75	15	23.75
3	25.0%	2.19	15	17.19

…. (3 marks-(each 1 mark))

S-3	In a DG set, the generator is rated at 1000 kVA, 415V, 1390 A, 0.8 PF, 1500 RPM. The full load specific energy consumption of this DG set as measured by the energy auditor is 4.0 kWh per liter of fuel and air drawn by the DG set is 14 kg/kg of fuel. The energy auditor has recommended a waste heat recovery (WHR) system. Also the auditor indicated that the waste heat recovery potential is 2.6×10^5 kCal/hr at the existing engine exhaust gas temperature of 583°C. Estimate the exhaust temperature to chimney after installation of proposed WHR system. The specific gravity of fuel oil is 0.86 and specific heat of flue gas is 0.25 kCal/kg ^{0}C.

Solution:

1	Rated kVA of Diesel Generator (given)	1000	
2	Rated kW @ 0.8 pf	800	0.5 mark
3	Specific fuel consumption (kWh/lts) (given)	4	
4	Specific gravity of fuel oil (given)	0.86	
5	Oil consumption at full load in kg/hr ((2*4)/3)	172	1 mark
6	Air supplied per kg of fuel (kg) (given)	14	
7	Mass of flue gas (14+1)	15	
8	Mass of flue gas kg per hour (7*5)	2580	1 mark
9	Waste heat recovery potential kCal/hr (given)	2,60,000	
10	Delta T across waste heat recovery system (Heat kCal/hr)/(mass of flue gas kg/hr*specific heat, kcal/kg^{0}C) = (260000/2580x0.25)	403	1.5 mark
11	Present Flue gas temp. or temp. before waste heat recovery system (given)	583	
12	Exit flue gas temp. after waste heat recovery system (583 – delta T)	180	1 mark

S-4 The input power to a fan is 30kW for a 2500 Nm^3/hr fluid flow. The fan pulley diameter is 300mm. If the flow to be reduced by 15% by changing the fan pulley, what should be the diameter of fan pulley and power input to fan.

Solution

1	Input power to fan kW	30	
2	Fluid flow Nm^3/hr	2500	
3	Diameter of Fan pulley (mm)	300	
4	Governing Equation is $N_1D_1=N_2D_2$	Eqn-1	1 mark
5	$N_2 = 0.85N_1$	given	
6	From Eqn-1 $D_2=(D_1)*(N_1/N_2)$; = $(300)*(N_1/0.85N_1)$	352mm	2 marks
7	$(KW_1/KW_2) = (N_1^3/N_2^3)$; Hence, $KW_2=(N_2/N_1)^3*(KW_1)$ $=(0.85 N_1/N_1)^3*(30)$	18.42KW	2 marks
So Power requirement for fan will be 18.4 kW.			
Fan pulley to be changed to 352 mm diameter.			

S-5 Define Lux and Luminous efficacy

	Ans Lux (lx) is the illuminance produced by a luminous flux of one lumen, uniformly distributed over a surface area of one square meter. It is also defined as the International System unit of illumination, equal to one lumen per square meter. ….. (2.5 marks) Luminous efficacy is defined as the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. Efficacy is energy efficiency of conversion from electricity to light form. ….. (2.5 marks)
S-6	During an energy audit of a power plant cooling tower, the following observations were made. • Power plant generation = 785 MW • Circulation rate =107000 m^3 /hr • Cooling tower range = 10.5^{o}C • Power plant design COC value = 3.8^{0}C As an auditor find out a) The total water consumption per hour, b) Specific water consumption in m^3/MW generation. The plant is pursuing an up-gradation treatment plan to increase COC to 7.0. c) What would be the potential water savings in m^3/hr and m^3/MW generation?
	Ans

S.No.	Item Ref.	Calculation		value	units	
1	Evaporation loss	0.00085*Circulation rate in m^3/hr * (CT range in deg C)*1.8	0.00085 * 107000 * (10.5)*1.8	1719	m^3/hr	0.5 mark
2	Blow-down loss	Evaporation loss/(COC-1)	1719/ (3.8-1)	614	m^3/hr	0.5 mark
3	Total as run hourly consumption	S.No 1 + S.No 2	(1719+614)	2333	m^3/hr	0.5 mark
4	Specific water consumption	S.No. 3/785	(2333/785)	2.97	m^3/MW	0.5 mark
5	Blow down at improved COC of 7.0	Evaporation loss/(COC-1)	1719/(7-1)	286.5	m^3/hr	0.5 mark
6	Total water consumption at improved COC	S.No 1 + S.No 5	(1719+286.5)	2005.5	m^3/hr	0.5 mark
7	Specific water consumption at	S.No 6/785	(2005.5/785)	2.56	m^3/MW	0.5 mark

	improved COC					
8	Total water saving per hour	S.No 3 - S.No 6	(2333-2005.5)	327.5	m^3/hr	0.5 mark
9	Water saving/MW generation	S.No 8/785	(327.5/785)	0.417	m^3/MW	1 mark

S-7 Explain with equation for COP_{Carnot} that:

(a) higher COP_{Carnot} is achieved with higher evaporator temperature and lower condenser temperature.

(b) COP_{Carnot} does not take into account the type of compressor

(c) How is the COP normally used in the industry given?

Ans:

a) The theoretical Coefficient of Performance (Carnot), COP_{Carnot} - a standard measure of refrigeration efficiency of an ideal refrigeration system- depends on two key system temperatures, namely, evaporator temperature Te and condenser temperature Tc with

COP being given as: $COP_{Carnot} = Te / (Tc - Te)$.

….. (2 marks)

b) This expression also indicates that higher COP_{Carnot} is achieved with higher evaporator temperature and lower condenser temperature. But COP_{Carnot} is only a ratio of temperatures, and hence does not take into account the type of compressor.

….. (2 marks)

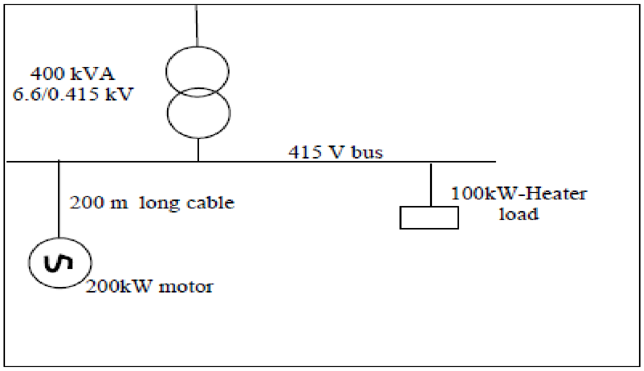
c) Hence the COP normally used in the industry is given by

COP = [Cooling effect (kW)/Power input to compressor (kW)]

where the cooling effect is the difference in enthalpy across the evaporator and expressed as kW

….(1 mark)

S-8 The following single line diagram depicts the location of a 100 kW heater load and a 200 kW motor (which is 200 metres away from the 415V, LT bus). The main incoming line power factor of the system is 0.85 lag. Calculate the rating of capacitors to improve PF of main incoming line to 0.9 lag.



Ans:

Total Inductive load requiring PF compensation = 200kW (since the other 100 kW is a resistive load)

….. (1 mark)

Operating PF cos ø1= 0.85 lag.

Desired PF cos ø2= 0.90 lag

kVAr required = $kW((\tan(\cos^{-1}ø_1)-\tan(\cos^{-1}ø_2))$

….. (1 mark)

$= 200(\tan(\cos^{-1}0.85)-\tan(\cos^{-1}0.90))$

$= 200(\tan(31.78)-\tan(25.84))$

$= 200(0.619-0.484)$

$= 200(0.135)$

= 27 kVAr

….(3 marks)

……………… 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 Compare the performance of centrifugal chiller with vapour absorption chiller using the data given below:

Sl. No.	Parameter	Centrifugal Chiller	VAM
1	Chilled water flow (m^3/h)	192	183
2	Condenser water flow (m^3/h)	245	360
3	Chiller inlet water temperature (^0C)	13	14.5
4	Condenser water inlet temperature (^0C)	28	32
5	Chiller outlet water temperature (^0C)	7.8	9.2
6	Condenser water outlet temperature (^0C)	36.2	40.7
7	Chilled water pump consumption (kW)	32	31
8	Condenser water pump consumption (kW)	38	52
9	Cooling tower fan consumption (kW)	9	22

If the compressor of centrifugal chiller consumes 205 kW, the steam consumption for VAM is 1620 kg/Hr. Calculate the following:

i) Refrigeration load delivered (TR) for both systems?
ii) Condenser Heat load (TR) for both systems?
iii) Compare auxiliary power consumption for both systems, give reason?
iv) If electricity cost is Rs.4.0/kWh and steam cost is Rs.0.45/kg compare the operating cost for both systems.

Solution:

a) Compression Chiller vs. VAM

Sl. No.	Parameter	Centrifugal Chiller	VAM	
1	Refrigeration load delivered (TR) = Mass of Chilled water flow x Specific heat x Delta T of Chilled water = Sl. No.1 m^3/hr * 1000kg/m^3 *1 kcal/kg ^0C * (Sl. No. 3. – Sl. No. 5) / 3024	330.16	320.73	2 marks
2	Condenser heat load delivered (TR) = Mass of condenser water flow x Specific heat * Delta T of condenser water = Sl. No.2 m^3/hr * 1000kg/m^3 *1 kcal/kg ^0C * (Sl. No. 6 – Sl. No. 4) / 3024	664.35	1035.71	2 marks
3	Auxiliary Power Consumption (kW) = (Sl. No. 7 + Sl. No. 8 + Sl. No. 9)	79	105	

	The auxiliary power consumption in case of VAM system is higher because heat rejection in VAM condenser is comparatively higher than centrifugal chiller with approximate similar cooling load.			2 marks
4	Total Energy Consumption:	284 kW (Auxiliary Power of 79kW and Chiller consumption of 205 kW)	Auxiliary Power of 105 kW and Steam consumption of 1620 kg/hr	2 marks
5	Operating Energy Cost per Hour of Operation	Rs. 1136/- (284 * 4 = Rs. 1136/-)	Rs 1149/- (105 * 4 = Rs. 420/- plus 1620 * 0.45 = Rs. 729/-)	2 marks

L-2

a) Calculate the ventilation rate for an engine room of 20m length, 10.5m width and 15m height; if the recommended Air Changes per Hour (ACH) is 20.

b) Air at 25,200 m^3/hr and at 1.2 kg/m^3 density is flowing into an air handling unit of an inspection room. The enthalpy difference between the inlet and outlet air is 2.38 kcal/kg. If the motor draws 22 kW with an efficiency of 90%, find out the kW/TR of the refrigeration system. (1 cal = 4.183)

Solution:

a) Ventilation Rate:

Room Length (m)	20
Room Height (m)	15
Room Width (m)	10.5
Air Changes per Hr (ACH)	20
Ventilation rate (m^3/Hr) = Length (m) * Height (m) * Width (m) * ACH	63000

….. (5 marks)

b)

Refrigeration tonnes

$Q \times \rho \times (h_2-h_1)$

25200 x 1.2 x (2.38) kcal/kg

71,971 kcal/hr

…..(2 marks)

TR

71,971 /3024

23.8 TR

			…..(1 mark)
	Power input to the compressor	22 x 0.9= 19.8 kW	…..(1 mark)
	kW/TR	19.8/23.8 = 0.83	…..(1 mark)

L-3

In a diary plant 3 numbers of cooling water pumps, identical in characteristics are installed in parallel to supply cooling. During normal operation two of the pumps are operational while one pump is on standby. All pump combinations develop a discharge pressure of 3.4 kg/cm^2 (a). The installed water flow meter at the common header during an energy audit reads the following:

Operating Pump No.	Flow Rate (m^3/hr)
Pump No 1 & 2	545
Pump No 2 & 3	535
Pump No 3 & 1	550

The power drawn by motors of cooling water pump 1, 2 & 3 are 33 kW, 31.5 kW & 32.5 kW respectively. While the operating motor efficiency for pump no. 1 & 2 is 92% the motor efficiency for pump no. 3 is 91.5%. If the water level in suction of all pumps is 3 meter below pump central line. Calculate the following:

i) Individual pump efficiencies
ii) Specific energy consumption (kWh/m^3)
iii) Which is the best operating pump combination

Solution:

Let flow of pump 1,2 & 3 be X, Y and Z respectively.

From given:

X + Y = 545 ---------(1)
Y + Z = 535 ---------(2)
X + Z = 550 ---------(3)

Subtracting eqn (2) from eqn (1):

X – Z = 10 --------(4)

Adding eqn (3) and eqn (4):

2X = 560
X= 280

Putting X value in eqn (1) and (2):

Y = 265 and Z = 270

Therefore, individual pump flow rates are: 280 m^3/hr, 265 m^3/hr and 270 m^3/hr respectively.

…. (3 marks)

Pump Ref:	1	2	3	
A) Flow Rate (M^3/hr) *(calculated)*	280	265	270	
B) Discharge Head (m) =3.4 kg/cm^2 (a) = 2.4 kg/cm^2 (g) =24 m *(given)*	24	24	24	
C) Suction Head (m) (g) *(given)*	-3	-3	-3	
D) Total Head (Discharge Head - Suction Head)* *(B-C)*	27	27	27	1 mark
E) Liquid kW [flow (m^3/s)*total head (m)*density (1000 kg./m^3) * 9.81 (m/s^2)/1000]	20.60	20.22	19.87	2 marks
F) Power Drawn by motor kW *(given)*	33	31.5	32.5	
G) Motor eff. % *(given)*	92.0%	92.0%	91.5%	
H) Pump input power kW (FxG)	30.36	28.98	29.74	1 mark
I) Pump eff. % (E/H)	67.9%	69.8%	66.8%	1 mark
J) Specific Energy Consumption (kWh/M^3) (F/A)	0.118	0.119	0.120	1 mark

Pump No. 1 & 2 are the best performing operating combination. …… (1 mark)

Note:
*The total head has been calculated subtracting Discharge Gauge pressure from suction gauge pressure. The candidates can also calculate total head as difference of absolute pressures as follows:

Discharge Head= 3.4 kg/cm^2 (a)
Suction Head = 1- 0.3 kg/cm^2 = 0.7 kg/cm^2
Total Head Developed = 3.4 – 0.7 = 2.7 kg/cm^2 = 27 m

L-4

a) In a chemical industry, cooling water of 9000 m^3/hr and 6000 m^3/hr from two independent heat exchangers with temperature of 41^0C and 52^0C respectively are fed to one cooling tower after proper mixing at top basin. If measured heat rejection by the cooling tower is 45,000TR, calculate effectiveness and evaporation loss of the cooling tower at 31^0C WBT.

b) In an air conditioning duct 0.5 m x 0.5 m, the average velocity of air measured by vane anemometer is 28 m/s. The static pressure at suction of the fan is -20 mmWC and at the discharge is 30 mmWC. A three phase induction motor draws 10.8 A at 415 V with a power factor of 0.9. Find out efficiency of the fan if motor efficiency = 88% (neglect density correction)

Solution:

a)

Sl. No.	Particulars	Stream 1	Stream 2	
1	Flow Rate (m^3/hr) (given)	9000	6000	
2	Temp. ^{0}C (given)	41	52	
3	Mix. Flow Rate (m^3/Hr) (Sl.1 +2)	15000		
4	Mix. Hot Water Temp. ^{0}C [(Flow1 * Temp. 1) + (Flow 2 *Temp. 2)]/ (Flow1 + Flow 2)	45.4		1 mark
5	Heat Rejection (TR) (given)	45000		
6	Range of Cooling Tower ^{0}C: (Heat Rejection TR * 3024) / (Flow M^3/hr * 1000)	9.072		1 mark
7	WBT ^{0}C (given)	31		
8	Cold Water Temp. ^{0}C (Mix. Hot Water Temp. – Range)	36.328		0.5 mark
9	Approach ^{0}C (Cold Water Temp. – WBT)	5.328		0.5 mark
10	Effectiveness (Range/ (Range + Approach))	63		1 mark
11	Evaporation Loss (m^3/hr) = 0.00085*1.8*Mix. Flow m^3/hr*Range	208.2		1 mark

b)

1	Area of the Duct: (0.5*0.5) m^2	0.25	
2	Avg. velocity (m/s) (given)	28	
3	Air Flow (m^3/s) (Sl. 1* Sl. 2)	7	1 mark
4	Suction static Pr. (mmWC) (given)	-20	
5	Discharge Static Pr. (mmWC) (given)	30	
6	Power drawn by the motor (kW): (1.732 * 415*10.8*0.9/1000)	6.99	1 mark
7	Air Power kW: = Flow (m^3/s)* (Dis. Pr – Suc. Pr.) mmWC /102	3.43	1 mark
8	Power to fan Shaft kW (Motor Drawn power * Motor eff. Of 88%)	6.15	1 mark
9	Fan Static Eff. (%) = Air Power*100%/Shaft Input	55.76	1 mark

L-5 One of the process industries has installed 18 MW cogeneration plant. The Cogeneration plant maximum condenser load is 7 MW and the extraction steam of 57 TPH is used for process and also for vapour absorption machine. The condenser heat load is 550 Kcal/kg of steam and the steam rate is 5 kg/KW for condenser power. The heat load of VAM in 127 Kcal/min/TR and the capacity of VAM is 1100 TR. Estimate cooling tower heat load in Kcal/hr. If the tower is designed for 6^{o}C range, calculate the water flow in cooling tower. The design approach temperature of the CT is 5^{o}C.

	Ans. Condenser load = 7 MW Steam rate for condenser = 5 kg/KW Total steam required for condenser power = 7000 X 5 = 35000 Kg/hr. …. (2 marks) Condenser heat load = 35000 x 550 = 19250000 Kcal/hr. …. (2 marks) Heat load of VAM = 1100 x 127 x 60 = 8382000 Kcal/hr. …. (2 marks) Total heat load = 19250000 + 8382000 = 27632000 Kcal/hr. …. (2 marks) Range of tower = 6 deg C Cooling water Flow required=27632000/6=4605333 lts or 4605 m^3. …. (2 marks)
L-6	a) List five disadvantages of low Power Factor ? b) An industry is losing money as penalty on account maintaining a poor power factor of 0.88.The power utility has specified a minimum power factor of 0.9 to avoid penalty. The penalty on energy cost is 1% for every 0.01 power factor less than the minimum prescribed. Also an incentive on energy cost is available @ 1.5% for every 0.01 improvement above 0.95. If the monthly energy bill of the industry is Rs 6 lakhs, calculate the annual cost saving potential if power factor is improved to unity from the current level.
	Answer : (Any five -1 mark each) a) Disadvantages of low power factor are 1.) Large Line Losses (Copper Losses) 2.) Large kVA rating and Size of Electrical Equipments 3.) Greater Conductor Size and Cost 4.) Poor Voltage Regulation and Large Voltage Drop 5.) Low Efficiency 6.) Penalty from Electric Power Supply Company on Low Power factor b) Minimum PF to be maintained to avoid penalty = 0.9 Present penalty = 1.00 % (on energy bill) for every 0.01 P.F. For 0.02 PF = 1.00 x 2 = 2.0% (1 mark) Incentives = 1.5 x 5 = 7.5% (1 mark) Energy saving potential = 9.5% Cost reduction potential per month = 6 lakh x 9.5% = Rs.57000 (2 mark) Annual cost Reduction = 57000x12 = Rs.684000 (1 mark)

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

15^{th} NATIONAL CERTIFICATION EXAMINATION FOR ENERGY MANAGERS & ENERGY AUDITORS– August, 2014

PAPER – 3:	**Energy Efficiency in Electrical Utilities**		
Date: 24.04.2014	Timings: 0930-1230 HRS	Duration: 3 HRS	Max. Marks: 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all 50 questions
(ii) Each question carries one mark

1.	Which loss is considered the most unreliable or complicated to measure in electric motor efficiency testing? a) stator Cu loss b) rotor Cu loss c) stator Iron loss d) <u>stray loss</u>
2.	A pure resistive load in an alternating current (AC) circuit draws a) lagging reactive power b) <u>active power</u> c) leading reactive power d) none of the above
3.	Select the incorrect statement: The advantage of PF improvement by capacitor addition in an electric network is a) active power component of the network is not affected b) <u>reactive power component of the network is not affected</u> c) I^2R power losses are affected in the system d) voltage level at the load end is affected
4.	"Heat Rate" of a thermal power station is the heat input in kilo Calories or kilo Joules, for generating a) one kW of electrical output b) one kVAh of electrical output <u>c) one kWh of electrical output</u> d) one kVA of electrical output
5.	Improving power factor at motor terminals in a plant will a) increase active power drawn by motor b) <u>reduce system distribution losses</u> c) reduce contract demand with utility d) increase motor design power factor
6.	For a 6 pole induction motor operating at 49.5 Hz, the percentage slip at a shaft speed of 950 RPM will be a) <u>4.0 %</u> b) 5.0 % c) 0.04 % d) none of the above
7.	A plant had installed three phase shunt capacitors to improve power factor at Motor Control Circuit (MCC). Busbar three phase Voltages at the main electrical panel of a plant were balanced but at the Motor Control Circuit (MCC),receiving three phase power from busbars, the line voltages were found to be unbalanced. The main reason for this unbalanced voltage at MCC among the following could be a) PF capacitors were operating at higher supply frequency b) <u>PF improvement in all phase was not uniform due to blown fuse in one phase of the 3</u>

	<u>phase PF capacitors</u> c) PF capacitors were operating at higher voltage then their rated values d) PF capacitors were operating at lower voltage then their rated values
8.	A 50 kVAr, 415 V rated power factor capacitor was found to be having terminal supply voltage of 430 V. The capacity of the power factor capacitor at the operating supply voltage would be approximately a) <u>53.67 kVAr</u> b) 50 kVAr c) 46.57 kVAr d) none of the above
9.	A 75 kW rated squirrel cage induction motor installed with static PF correction capacitors across the motor terminals got damaged along with capacitors once supply was switched off due to power failure. The possible reason for the motor burn out among the following could be a) motor was oversized b) motor was undersized <u>c) charging current of the capacitors was more than the magnetizing current of the motor</u> d) charging current of the capacitor was only 85% of the motor magnetizing current
10.	An induction motor rated for 75 kW and 94 % efficiency, operating at full load, will a) deliver 70.5 kW b) <u>deliver 75 kW</u> c) draw 75 kW d) deliver 79.78 kW
11.	Higher chiller COP can be achieved with a) higher evaporator temperature and higher condensing temperature b) <u>higher evaporator temperature and lower condensing temperature</u> c) lower evaporator temperature and higher condensing temperature d) lower evaporator temperature and lower condensing temperature
12.	Increase in the delivery pressure of a compressor by 1 bar would reduce the power consumption by a) 1 to 5 % b) 6 to 10 % c) 11 to 15 % d) <u>none of the above</u>
13.	The FAD of a reciprocating compressor is directly proportional to a) pressure b) volume <u>c) speed</u> d) all of the above
14.	Which of the following is not true of air receivers in a compressed air system? a) smoothens pulsating air output b) <u>increases the compressed air pressure</u> c) stores large volumes of compressed air d) facilitates draining of moisture
15.	Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is a) 1.0 bar b) 0.7 bar c) 0.5 bar d) <u>0.3 bar</u>
16.	All other conditions remaining the same in a refrigeration system, at which of the following condenser temperatures, the power consumption will be the least: a) <u>32.6 ^{o}C</u> b) 35.9 ^{o}C c) 40.8 ^{o}C d) 43.4 ^{o}C
17.	The pressure of refrigerant in vapour compression system changes in

	a) compressor b)expansion valve c) both (a) & (b) d) evaporator
18.	A 1.5 ton air conditioner installed in a room and working continuously for one hour will remove heat of a) 3024 kcals b) 4536 kcals c) 3000 kcals d) 6048 kcals
19.	If the power consumed by a 1.5 TR refrigeration compressor is 2.5 kW , what is the energy efficiency ratio? a) 2.1 b) 1.5 c) 0.6 d) 1.66
20.	In the performance assessment of a refrigeration system, which performance ratio (energy efficiency) does not follow the trend "a higher ratio means a more efficient refrigeration system"? a) Coefficient of performance(COP) b) Energy Efficiency Ratio (EER) c) kW per ton d) none of the above
21.	2 ton of refrigeration (TR) is equivalent to about a) 100.8 kcal/min b) 7032 W c) 428.7 BTU/min d) all of the above
22.	A fan with 25 cm pulley diameter is driven by a 2940 rpm motor through a V-belt system. If the motor pulley is reduced from 20 cm to 15 cm keeping the motor rpm and fan pulley diameter the same, the fan speed will reduce by a) 1176 rpm b) 1764 rpm c) 588 rpm d) none of the above
23.	In series operation of identical centrifugal fans, ideally a) flow doubles b) static pressure doubles c) static pressure goes up by four times d) flow goes up by four times
24.	The hydraulic power of a motor pump set is 8 kW. If the power drawn by the motor is 16 kW at 90% efficiency, the pump efficiency will be a) 55.5% b) 50% c) 45% d) none of the above
25.	The energy saving with variable speed drives in a pumping system will be maximum for systems with a) pure static head b) pure friction head c) high static head and low friction head d) high static head with high friction head
26.	A process fluid at 50 m^3/hr, with a density of 0.96, is flowing in a heat exchanger and is to be cooled from 36^{o}C to 29^{o}C. The fluid specific heat is 0.78 kcal/kg. If the chilled water range across the heat exchanger is 5^{o}C,the chilled water flow rate is a) 67.2 m^3/hr b) 52.42 m^3/hr c) 50 m^3/hr d) none of the above
27.	The inner tube of an L-type pitot tube is used to measure …… in the air duct a) total pressure b) static pressure b) velocity pressure d) dynamic pressure
28.	The intersection point of the centrifugal pump characteristic curve and the design system curve is the a) pump efficiency point b) best efficiency point c) system efficiency point d) none of the above
29.	In case of increased suction lift from open wells, the pump delivered flow rate

	a) increases b) <u>decreases</u> c) remains same d) none of the above
30.	In pumping systems where static head is a high proportion of the total, the appropriate solution is a) install two or more pumps to operate in parallel <u>b) install two or more pumps to operate in series</u> c) install two or more pumps to operate in independent operation d) none of the above
31.	A Plant wants to replace the existing 100 TR water cooled vapour compression refrigeration system with a waste heat driven vapour absorption chiller. The capacity of the existing cooling tower a) needs no change <u>b) is to be doubled</u> c) is to be raised to 1.2 times d) none of the above
32.	Shaft power of the motor driving a pump is 30 kW. The motor efficiency is 0.92 and pump efficiency is 0.5. The power drawn by the motor will be a) 65.2 kW b) 15 kW c) 30 kW d) <u>32.6 kW</u>
33.	If water is flowing through a cooling tower at 120 m^3/h with 5^oC range, the load on cooling tower at an ambient wet bulb ambient temperature of 33 ^oC is a) <u>198.4 TR</u> b) 357 TR c) 158 TR d) none of the above
34.	In a plant, the loading on a transformer was 1000 kVA with the power factor of 0.88. The plant improved the power factor to 0.99 by adding capacitors on the load side. The release in transformer loading(kVA) will be a) <u>111</u> b) 889 c) 999 d) none of the above
35.	The wet bulb temperature normally chosen for designing of cooling tower is a) average maximum wet bulb for rainy months b) <u>average maximum wet bulb for summer months</u> c) average minimum wet bulb for summer months d) average maximum wet bulb for winter months
36.	Which one from the following types of cooling towers consumes least power for the same operating conditions? a) <u>counter flow film fill cooling tower</u> b) cross-flow splash fill cooling tow c) counter flow splash fill cooling tower d) none of the above
37.	Lux is defined as a) ratio of luminous flux emitted by a lamp to the power consumed by the lamp b) <u>one lumen per square meter</u> c) one lumen per square feet d) none of the above
38.	Which among the following is the most energy efficient lamp for the same wattage rating? a) HPMV b) GLS c) CFL d) <u>Metal halide</u>
39.	_____ is a measure of effect of light on the perceived colour of objects

	a) lux b) lumens <u>c) CRI</u> d) lamp circuit efficacy
40.	Which of the following is the best definition of illuminance? <u>a) luminous flux incident on an object per unit area</u> b) flux density emitted from an object without regard for direction c) time rate of flow of light energy d) flux density emitted from an object in a given direction
41.	Two most important electrical parameters, which are to be monitored, among the following for safe operation of Diesel Generator set are: a) voltage and ampere b) <u>kW and kVA</u> c) power factor and ampere d) kVA and ampere
42.	In a DG set, the generator capacity is 1000 kVA with a rated power factor 0.8. It is consuming 150 litre per hour diesel oil. If the specific fuel consumption of this DG set is 0.25 litres/ kWh at that load, then what is the kVA loading of the set at 0.88 PF? a) <u>682 kVA</u> b) 800 kVA c) 750 kVA d) none of the above
43.	The maximum unbalanced load between phases should not exceed _______ % of the capacity of the DG set c) <u>10</u> b) 5 c) 1 d) none of the above
44.	The capacity of largest motor that can be started in the given DG set is…… of kVA rating of DG set a) 25% b) <u>50%</u> c)75% d)100%
45.	The jacket cooling water in a diesel engine flows at 12.9 m^3/hr with a range of 10^oC and accounts for 30% of the engine input energy. What will be the hourly Diesel consumption in kg with a calorific value of 10,000 kcal/kg a) <u>43</u> b) 12.9 c) 17.3 d) none of the above
46.	Select the incorrect statement: a) harmonics occur as spikes at intervals which are multiples of the supply frequency b) <u>harmonics are not multiples of the fundamental frequency</u> c) induction motors are not the major sources of harmonics d) transformers operating near saturation level create harmonics
47.	If the speed of centrifugal fan is reduced to 80% of its rated speed then the power drawn will _______% of its rated power: a) 80% <u>b) 51.2 %</u> c) 40 % d) 64 %
48.	The order of movement of thermal energy in HVAC system is: a) Indoor air - Condenser water - Chilled water - Cooling tower - Refrigerant b) Chilled water - Indoor air - Refrigerant-Cooling tower - Condenser water c) <u>Indoor air - Chilled water - Refrigerant-Condenser water- Cooling</u> tower d) Indoor air - Chilled water – Refrigerant - Cooling tower - Condenser water
49.	Which one of the following device will help to eliminate the hunting problems normally associated with capacitor switching?

	a) Maximum Demand Controller b) Intelligent Power Factor Controller (IPFC) c) Soft Starter d) Eddy Current Drives
50.	The occupancy sensors in a lighting installation are best suited for a) conference halls b) large production shops/hangars c) entrances of offices/buildings d) street lighting

……. End of Section – I …….

Section – II: SHORT DESCRIPTIVE QUESTIONS Marks: 10 x 5 = 50

(i) Answer all Ten questions
(ii) Each question carries Five marks

S-1 A 37 kW, 3 phase, 415 V induction motor draws 56 A and 33 kW power at 410 V . What is the Apparent and Reactive Power drawn by the motor at the operating load?

Ans:

Apparent power = 1.7321 x 0.410 x 56 = 39.769 kVA
Reactive power = squrt (apparent power ^{2}- active power^2)
Active power = 33 kW
Therefore reactive power = sqrt (1581.57-1089)
= 22.19 kVAr

S-2 Compute AT & C (Aggregate Technical and Commercial) Losses for the following data:

S. No.	Description		Annual Data
1	Input Energy = (Import-Export), MU	Ei	20
2a	Energy Billed (Metered), MU	E1	16
2b	Energy Billed (Un-Metered), MU	E2	1
2c	Total Energy Billed (E1 + E2)	Eb	17
3	Amount Billed (Rs. lakhs)	Ab	800
4a	Gross Amount Collected (Rs. lakhs)	AG	820
4b	Arrears Collected (Rs. lakhs)	Ar	40

Ans:

Estimation of AT & C Losses			
S. No.	**Description**		**Annual Data**
1	Input Energy = (Import-Export), MU	Ei	20
2a	Energy Billed (Metered), MU	E1	16
2b	Energy Billed (Un-Metered), MU	E2	1
2c	Total Energy Billed (E1 + E2)	Eb	17
3	Amount Billed (Rs. lakhs)	Ab	800
4a	Gross Amount Collected (Rs. lakhs)	AG	820
4b	Arrears Collected (Rs. lakhs)	Ar	40
4c	Amount Collected without Arrears (Rs. lakhs)	Ac=AG-Ar	780
5	Billing Efficiency (BE)	= Eb/Ei *100%	85%

6	Collection Efficiency(CE)	=Ac/Ab *100%	97.5%
7	AT& C Loss	{1- (BE *CE) *100%	17.12%

S-3 Define Range, approach and effectiveness in cooling tower operation

Ans:

i) "Range" is the difference between the cooling tower water inlet and outlet temperature.

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

iii) Cooling tower effectiveness (in percentage) is the ratio of range, to the ideal range, i.e., difference between cooling water inlet temperature and ambient wet bulb temperature, or in other words it is = Range / (Range + Approach).

S-4 As Energy Manager, what are all the factors you look into for energy saving in operating DG Sets.?

Ans:

1.Ensuring steady load conditions on the DG set & providing cold and dust free intake air

2.Improving air filtration

3.Ensuring fuel oil storage, handling and operation as per manufacturer's guidelines/oil company's data

4. Consideration of fuel oil additives

5.Calibration fuel injection pumps periodically

6.Ensuring compliance with maintenance check lists

7.Ensuring balanced electrical loading

8.In case of a base load operations, consideration of waste heat recovery system

S-5 An energy audit of a fan was carried out. It was observed that the fan was delivering 18,500 Nm^3/hr of air with static pressure rise of 52 mm WC. The power measurement of the 3-phase induction motor coupled with the fan recorded 3.1 kW/ phase on an average. The motor operating efficiency was assessed as 88% from the motor performance curves. What would be the fan static efficiency?.

Ans:

Q = 18,500 Nm^3 / hr.= 5.1388 m^3/sec
SP = 52 mmWC
η_{St} = ?

Power input to motor= 3.1x3=9.3 kW

Power input to fan shaft=9.3 x0.88=8.184 kW

$$\text{Fan static } \eta = \frac{\text{Volume in } m^3/\text{sec} \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}}$$

$$= \frac{5.1388 \times 52}{102 \times 8.184}$$

$$= 0.32$$

$$= 32\%$$

S-6 An induced draft-cooling tower is designed for a range of 7° C. An energy manager finds the operating range as 4 °C. In your opinion what could be the reasons for this type of situation.

Ans:

1. There may be excess cooling water flow rate
2. There may be reduced heat load from the process
3. Some of the cooling tower cells fan is switched off
4. Approach may be poor because of high humid condition
5. Nozzles may be blocked

S-7 State any three major differences between vapor compression refrigeration (VCR) and Vapour Absorption Refrigeration (VAR) system ?

- VCR uses electric power for the compressor as main input while VAR uses a source of heat

- VCR uses compounds of hydrogen, fluorine and carbon as refrigerants while VAR uses water
- VCR works under pressure while VAR works under vacuum
- VCR has a high COP while VAR has a low COP
- VAR requires cooling tower capacity double that of VCR
- *Any other relevant point………*

S-8 A 180 kVA, 0.80 PF rated DG set has diesel engine rating of 210 BHP. What is the maximum power factor which can be maintained at full load on the alternator without overloading the DG set? (Assume alternator losses and exciter power requirement as 5.66 kW and there is no derating of DG set)

Ans:

Engine rated Power = 210 x 0.746 = 156.66 kW

Rated power available for alternator = 156.66 – 5.66 = 151 kW

Maximum power factor possible = 151 /180 = 0.84

……. End of Section - II …….

Section – III: LONG DESCRIPTIVE QUESTIONS Marks: 5 x 10 = 50

(i) Answer all Five questions
(ii) Each question carries Ten marks

L-1 During an energy audit following data were obtained on a 3 phase induction motor:

Rated values: 37 kW,415V, 66 A,0.88 pf
Operating values: 410 V, 49A, 0.76 pf

Note: Motor efficiency in this particular case does not change between 50 –100 % loading.

The plant operates for 7000 hours per year with the electricity cost of Rs. 6.00 per unit.

It is proposed to replace the existing motor by a 30 kW energy efficient motor with 92% efficiency.

a) Determine the rated efficiency and the loading of the existing motor.
b) Calculate the loading with energy efficient motor.
c) If replacing the existing motor with energy efficient motor which costs Rs.75,000, determine the pay back period for the investment required for the energy efficient motor over the existing motor. Consider the salvage value of the existing motor as Rs.10,000/.

Rated input power	**1.732 × 0.415 × 66× 0.88**
	41.746 kW
Rated efficiency of the motor	**37/ 41.746**
	88.63%
Actual input power drawn	**1.732 × 0.410 × 49 × 0.76**
	26.44 kW
Loading of the motor	**26.44/41.746 = 0.633 or 63.3%**
Shaft power or motor output	**37x0.633= 23.44 kW**
Energy efficient motor rating	**30 kW**
Actual output required	**23.44 kW**
% loading of the motor	**23.44/30**
	78 %
Annual energy savings	**23.44(1/0.8863 – 1/0.92) x 7000 x Rs.6**
	Rs.40,740/-
Payback period	**(75,000-10,000)/40740**
	1.59 years

L-2 (a) A 3 phase, 415 V, 75 kW induction motor is drawing 48 kW at a 0.7 PF.

Calculate the capacitor rating requirements at motor terminals for improving PF to 0.95. Also, calculate the reduction in current drawn and kVA reduction, from the point of installation back to the generating side due to the improved PF at operating voltage of 415 V.

(b) A process plant consumes of 2,00,000 kWh per month at 0.9 Power Factor (PF). What is the percentage reduction in distribution losses per month if PF is improved up to 0.96 at load end?

a) kVAr Rating = kW [Tan ϕ1 – tan ϕ2]

Cos ϕ1 = 0.70, ϕ1 = Cos (inv) 0.70 = 45.57, Tan ϕ1 = 1

Cos ϕ2 = 0.95, ϕ2 = Cos (inv) 0.95 = 18.2 , Tan ϕ2 = 0.329

kVAr Rating = 48 kW (1 – 0.329)

= 32.2 kVAr

Current drawn at 0.7 PF = 48 / √3 x 0.415 x 0.7

= 95.4 A

Current drawn at 0.95 PF = 48 / √3 x 0.415 x 0.95

= 70.3 A

Reduction in current drawn = 95.4 – 70.3

= 25.1 A

Initial kVA at 0.7 PF = 48 / 0.7

= 68.57 kVA

kVA at 0.95 PF = 48 / 0.95

= 50.52 kVA

Reduction in kVA = 68.57 – 50.52

= 18.05 kVA

(OR)

Reduction in kVA = $(\sqrt{3}\ VI)_{old} - (\sqrt{3}\ VI)_{new}$
= (√3 x 0.415 x 95.4) – (√3 x 0.415 x 70.3)
= 68.57 – 50.52
= 18.05 kVA

(OR)

Reduction in kVA = 1.7321 x 0.415 x reduction in current

= 1.7321 x 0.415 x 25.1

= 18.04 kVA

b) % Reduction in distribution losses = $\left[1 - (PF_1 / PF_2)^2\right]$

$= [1- (0.9/0.96)^2]$

$= 0.121$

$= 12.1\ \%$

L-3 The measured values of a 20 TR package air conditioning plant are given below:

Average air velocity across suction side filter: 2.5 m/s

Cross Sectional area of suction: 1.2 m^2

Inlet air = Dry Bulb:20^oC, Wet Bulb: 14 ^oC, Enthalpy: 9.37 kcal/kg

Outlet air= Dry Bulb: 12.7 ^oC, Wet Bulb: 11.3 ^oC; Enthalpy: 7.45 kcal/kg

Specific volume of air: 0.85 m^3/kg

Power drawn: by compressor: 10.69 kW

by Pump: 4.86 kW
by Cooling tower fan: 0.87 kW

Calculate:

i. Air Flow rate in m^3/hr
ii. Cooling effect delivered in kW
iii. Specific power consumption of compressor in kW/TR
iv. Overall kW/TR
v. Energy Efficiency Ratio in kW/kW

Ans:

i. Air flow rate = 2.5*1.2 = 3 m^3/sec = 10800 m^3/hr
ii. Cooling Effect delivered = [(9.37-7.45)*10800]/(0.85*3024) = 8.07 TR = 28.32 kW
iii. Compressor kW/TR = 10.69/8.07 = 1.32
iv. Overall kW/TR = (10.69+4.86+0.87)/8.07 = 2.04
v. Energy Efficiency Ratio(EER) in kW/kW = 28.32/10.69 = 2.65

L-4 List five energy conservation measures each for any two of the following

a) Energy use in buildings
b) Compressed air system
c) Pumps and pumping systems
d) Lighting systems

Ans:

a) Energy use in buildings

- *Weather-stripping of Windows and Doors* : Minimise exfiltration of cool air and infiltration of warm air through leaky windows and doors by incorporating effective means of weather stripping. Self-closing doors should also be provided where heavy traffic of people is anticipated.

- *Temperature and Humidity Setting*: Ensure human comfort by setting the temperature to between 23^{o}C and 25^{o}C and the relative humidity between 55% to 65%.

- *Chilled Water Leaving Temperature*: Ensure higher chiller energy efficiency by maintaining the chilled water leaving temperature at or above 7^{o} C. As a rule of thumb, the efficiency of a centrifugal chiller increases by about 2¼ % for every 1^{o} C rise in the chilled water leaving temperature.

- *Chilled Water Pipes and Air Ducts*: Ensure that the insulation of the chilled water pipes and ducting system is maintained in good condition. This helps to prevent heat gain from the surroundings.

- *Chiller Condenser Tubes* : Ensure that mechanical cleaning of the tubes is carried out at least once every six months. Fouling in the condenser tubes in the form of slime and scales reduces the heat transfer of the condenser tubes and thereby reducing the energy efficiency of the chiller.

- *Cooling Towers* : Ensure that the cooling towers are clean to allow for maximum heat transfer so that the temperature of the water returning to the condenser is less than or equal to the ambient temperature.

- *Air Handling Unit Fan Speed* : Install devices such as frequency converters to vary the fan speed. This will reduce the energy consumption of the fan motor by as much as 15%.

- *Air Filter Condition* : Maintain the filter in a clean condition. This will improve the heat transfer between air and chilled water and correspondingly reduce the energy consumption.

b) Compressed Air Systems

- Ensure air intake to compressor is not warm and humid by locating compressors in well-ventilated area or by drawing cold air from outside. Every 4^{0}C rise in air inlet temperature will increase power consumption by 1 percent.
- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter.
- Compressed air piping layout should be made preferably as a *ring main* to provide desired pressures for all users
- Compressed air leakage of 40- 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity of leakage.
- Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not in use.
- Present energy prices justify liberal designs of pipeline sizes to reduce pressure drops.
- If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed air systems.
- Reduce compressor delivery pressure, wherever possible, to save energy.

- Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminate the `unloaded' running condition altogether.
- Keep the minimum possible range between load and unload pressure settings.
- Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should be optimized.
- A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthy pipelines.
- Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air and energy
- Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy.

c) Pumps & Pumping Systems

- Ensure adequate NPSH at site of installation
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequenced control of multiple units.
- Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping.
- Balance the system to minimize flows and reduce pump power requirements.
- Avoid pumping head with a free-fall return (gravity); use siphon effect to advantage.
- Conduct water balance to minimise water consumption
- In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation.
- Replace old pumps by energy efficient pumps
- Reduce system resistance by pressure drop assessment and pipe size optimisation

d) Lighting System

- Switch off Lights When Not In Use
- Provision of Separate Switches for Peripheral Lighting : A flexible lighting system, which made use of natural lighting for the peripherals of the room.

- Install High Efficiency Lighting System : Use lamps with high luminous efficacy. For example, replacing incandescent bulbs with compact fluorescent lamps can reduce electricity consumption by 75% without any reduction in illumination levels.
- Fluorescent Tube Ballasts : The ballast losses of conventional ballast and electronic ballast are 12W and 2W respectively. Hence, consider the use of electronic ballast for substantial energy savings in the lighting system.
- Lamp Fixtures or Luminaires : Optical lamp luminaries made of aluminum, silver or multiple dielectric coatings have better light distribution characteristics. Use them to reduce electricity consumption by as much as 50% without compromising on illumination levels.
- Cleaning of Lights and Fixtures : Clean the lights and fixtures regularly. For best results, dust at least four times a year.
- Use Light Colors for Walls, Floors and Ceilings : The higher surface reflectance values of light colors will help to make the most of any existing lighting system.
- Lighting controls like timer controls, day light controls, voltage controllers, occupancy sensors, switching controls, PLC controls can be adopted.

L-5 Fill in the blanks for the following:

1. One ton of refrigeration (TR) is equal to 3.516 kW.
2. A four pole 15kW induction motor operating at 50 Hz, with 1% slip will have rotor input power of 15.15 kW
3. A Pitot tube is used to measure total pressure and static pressure to determine velocity pressure of the fluid
4. In case of centrifugal pumps, impeller diameter changes are generally limited to reducing the diameter to about 75 % of maximum size.
5. The value, by which the pressure in the pump suction exceeds the liquid vapour pressure, is expressed as Net Positive Suction Head Available (NPSHA).
6. The parameter used by ASME to define fans, blowers and compressors is Specific ratio.
7. It is possible to run pumps in parallel provided their closed valve heads are similar.
8. If the evaporation loss is 16 cubic meters per cell and Cycles of Concentration is 3, the blow down requirement per cell of a cooling tower is 8 cubic meters per cell
9. A centrifugal pump raises water to a height of 12 metre . If the same pump handles brine with specific gravity of 1.2, the height the brine will be raised to is 12 metres or the same height
10. Installing the capacitor near motor terminals will increase the design power factor of the motor - True / False (False)

L 6 : a) The suction head of a pump is 3 m below the pump centerline. The discharge pressure is 2.8 kg/cm^2. The flow rate of water is 120 m^3 /hr. Find out the pump efficiency if the actual power input of the connected motor is 15.0 kW with an operating efficiency of 0.90.

b) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7 kg/cm^2g. 20% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm^2g, whereas balance 80% of the instrument air was used for other application requiring 2 kg/cm^2g. What would you like to advice in this situation?

Ans:

a)

Discharge Head	:	2.8 kg/cm^2 equals 28 metre head.
Suction Head	:	- 3 metre.
Total Head	:	28 – (-3) = 31 metre.

Hydraulic power P_h = Q (m^3/s) xTotal head, h_d - h_s (m) x ρ (kg/m^3) x g (m/s^2) / 1000

Hydraulic Power	:	((120/3600) x 1000 x 9.81 x 31) / 1000 = 10.137 kW
Pump Efficiency	:	(10.137 x 100) /(15x0.9) = <u>75%</u>

b)

It is advisable to

1) Provide a separate small air compressor operating at 7 kg/cm^2 g near the control valves and reduce the existing distribution system pressure from 7 kg/cm^2g to 2 kg/cm^2g for pneumatic instrument

2) Since there will be reduced leakage loss due to reduced system pressure, the compressor unloading may begin due to reduced demand. Reduce appropriately the motor pulley size in order to match the capacity

……. End of Section - III …….

14th NATIONAL CERTIFICATION EXAMINATION 2013
FOR
ENERGY MANAGERS & ENERGY AUDITORS

PAPER – 3:	**Energy Efficiency in Electrical Utilities**
Date: 25.08.2013 Timings: 0930 – 1230 HRS	Duration: 3 HRS Max. Marks: 150

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries one mark
(iii) Please hatch the appropriate oval in the OMR answer sheet with HB Pencil, as per instructions

1.	The gross efficiency of a coal based power generating unit with a gross heat rate of 2490 kcal/kWh is a) 40% **b) 34.5 %** c) 33.3% d) 45.2%
2.	The efficiencies of a power plant and transmission systems are 40%, and 97% respectively. The percentage loss of the distribution system of the same network is 23% . The cascade efficiency of generation ,transmission and distribution system is given by a)8,92 % **b) 29.87**% c) 40 % d) 23%
3.	The rating of power factor correction capacitors at induction motor terminals should be **a) 90% of no load magnetizing kVAr of induction motor** b)100 % of no load magnetizing kVAr of induction motor c) 80% of no load magnetizing kVAr of induction motor d) none of the above
4.	Select the correct statement: Power factor a) is the ratio of active and reactive power b) is the ratio of reactive and apparent power c) **is the ratio of active and apparent power** d) of a pure inductive and capacitive load is unity
5.	The Energy Performance Index (EPI) of a building as per Energy Conservation Building Code (ECBC) and as defined in the Energy Conservation Act,2001 is: **a) kWh per square meter per year** b) kWh per square meter c) kW per square meter d) kWh per year

6.	If the maximum demand is 3500 kVA at 0.88 p.f., the maximum demand will reduce by______ kVA if PF is improved to 0.98 : a) 3143 b) **357** c) 3897 d) maximum demand will not reduce
7.	The performance of rewinding of an induction motor can be assessed by which of the following factors? a) no load current b) stator resistance per phase c) load current d) both no load current and stator resistance per phase
8.	For a synchronous speed of 1500 rpm, at a given mains frequency of 50 Hz, the induction motor will have _________number of poles. a) 8 b) 6 **c) 4** d) 2
9.	A 7.5 kW, 415 V, 14.5 A, 1460 RPM rated 3 phase induction motor with full load efficiency of 90%, draws 9.1 A and 4.6 kW of input power. The percentage loading of the motor is about a) **55.2 %** b) 61.3 % c) 67.5 % d) none of the above
10.	The power input to a rotor of three phase induction motor is 42.3 kW. If the induction motor is operating at a slip of 1.30 % the total mechanical power developed will be : a) 42.3 kW b) **41.75** kW c) 5.48 kW d) 47.79 kW
11.	If the apparent power drawn over a recording cycle of 30 minutes is 5000 kVA for 0.5 minutes, 3400 kVA for 20 minutes and 1800 for 9.5 minutes, the MD recorder will compute MD as a) 5000 kVA b) 3400 kVA c) **2920 kVA** d) 1800 kVA
12.	The rating of the p.f correction capacitors at motor terminals for a 37 kW, 2 poles induction motor will be______ in comparison to the same sized induction motor of 6 poles a) more b) **less** c) same d) sometime less or more
13.	Which parameters need to be measured to assess the percentage loading of a motor by slip method neglecting voltage correction? a) motor speed b) synchronous speed c) **operating motor speed and frequency** d) operating current
14.	Isothermal power of a compressor depends on a) absolute intake pressure b) pressure ratio c) free air delivered **d) all of the above**

15.	Reduction in the delivery pressure of an air compressor working at 7 bar, by 1 bar would reduce the power consumption by a) 2 – 3 % b) 4 - 5 % **c) <u>6 - 10 %</u>** d) none of the above
16.	**Which of the following is correct for air compressors?** a) for every 5.5ºC drop in the inlet air temperature, the increase in energy consumption is by 2% **b) <u>for every 4ºC rise in the inlet air temperature, the increase in energy consumption is by 1</u>%** c) for every 4ºC rise in the inlet air temperature, the decrease in energy consumption is by 1% d) the energy consumption remains same irrespective of inlet air temperature
17.	The Free Air Delivery of a reciprocating air compressor is directly proportional to a) **<u>speed</u>** b) pressure c) volume d) all of the above
18.	Which of these desiccant compressed air dryers uses dry compressed air for regenerating the desiccant? a) blower reactivated type **<u>b) heatless purge type</u>** c) heat of compression type d) all of the above
19.	The unit of specific humidity in a psychrometric chart is a) **<u>grams moisture/kg of dry air</u>** b) moisture percentage in air c) grams moisture/kg of air d) all of the above
20.	The COP of a vapour compression refrigeration system is 3.1 If the motor draws power of 9.3 kW at an operating efficiency of 88%, the tonnage of refrigeration system is about **a)** 8.2 b) 9.3 c) **<u>7.2</u>** d) none of the above
21.	Chilled water enters an evaporator at 10^0C and leaves at 6^0C. The flow rate of chilled water was measured as 200 m^3/hr. The tons of refrigeration capacity is **<u>a) 265</u>** b) 200 c) 661 d) 2.65
22.	In an air conditioning system analysis which one temperature is sufficient to determine the enthalpy of air? a) dry bulb temperature b) **<u>wet bulb temperature</u>** c) ambient temperature d) none of the above
23.	The head generated by a centrifugal pump is: **<u>a) independent of the density of the liquid being pumped</u>** b) directly proportional to the density of the liquid being pumped c) inversely proportional to the density of the liquid being pumped d) proportional to the square of the density of the liquid being pumped

24.	The driving force for refrigeration in a vapour absorption refrigeration system is a) mechanical energy b) electrical energy c) **thermal energy** d) chemical energy
25.	Which of the following happens to air when it is cooled through evaporation process? a) humidity ratio of the air decreases b) **dry bulb temperature of air decreases** c) dry bulb temperature of air increases d) enthalpy of outlet air is less than enthalpy of inlet air
26.	The relation between COP and kW/TR for a refrigeration system is given by a) **kW/TR = 3.516/COP** b) kW/TR = COP /3.516 c) kW/TR = 860/COP d) none of the above
27.	In which of the following fans the air does not change flow direction from suction to discharge? a) tube axial fan b) vane axial fan c) propeller fan d) **all of the above**
28.	The parameter used by ASME to classify fans, blowers and compressors is_______ a) volume ratio **b) specific ratio** c) blade ratio d) impeller ratio
29.	The pressure to be considered for calculating the power required for centrifugal fans is___ a) vapour pressure b) dynamic pressure c) **total static pressure** d) velocity pressure
30.	The inclined manometer connected to a pitot tube is used for measuring which pressure in a gas stream? a) **velocity** b) static c) total d) all of the above
31.	If the power drawn by the motor driving a pump is 20 kW at a 91% efficiency, and the hydraulic power of a motor pump set is 12.5 kW, the pump efficiency will be__ a) **68.7%** b) 62.5% c) 56.8% d) none of the above
32.	Which of the following is not true for impeller trimming? a) **pressure ✪ diameter** b) head ✪ $diameter^2$ c) power ✪ $diameter^3$ d) flow ✪ diameter
33.	If the speed of the pump is doubled, power goes up by a) 2 times b) 6 times **c) 8 times** d) 4 times
34.	The preferred method of flow control for reducing pump flow permanently in a pumping system is------- a) throttling b) speed control c) **impeller trimming** d) none of the above

35.	A water pump is delivering 20 m^3/hr at ambient conditions. The impeller diameter is trimmed by 10%. This will reduce the pump discharge by a) 18 m^3/hr **b) <u>2 m^3/hr</u>** c) 0.2 m^3/hr d) none of the above
36.	Increasing the suction pipe diameter in a pumping system will a) reduce NPSHA <u>b) **increase NPSHA**</u> c) decrease NPSHR d) increase NPSHR
37.	The range of a cooling tower with inlet and outlet temperature as 41° C and 32° C respectively and wet bulb temperature as 29° is <u>a) **9°C**</u> b) 3°C c) 29°C d) 12°C
38.	Find the correct equation, if M = makeup water (from the mains water supply), E = losses due to evaporation, B = losses due to blow-down and D = drift losses of a cooling tower: **<u>a) M = E + B + D</u>** b) M = E + B - D c) M = E - B + D d) M = E - B - D
39.	If the wet bulb temperature of air is 38°C, then its relative humidity in % is a) 38 % b) 90% c) 100% <u>d) **insufficient data**</u>
40.	For a cooling tower if blowdown is 10 m^3 /hour and Cycles of Concentration (CoC) is 2.5 the evaporation loss is equal to: a) 25 m^3/hour **<u>b) 15 m^3/ hour</u>** c) 0.25 m^3/hour d) 6.67 m^3/hour
41.	If the metered kWh is 95, kVAh is 100 and kVARh is 31, the power factor will be: **<u>a) 0.95</u>** b) 0.61 c) 0.69 d) unity
42.	In T-5 Fluorescent Lamp, “5” is indicative of: a) **<u>Tube diameter</u>** b) 5 watt loss c) 5% Energy Saving with respect to T8 d) 5th generation lamp
43.	Identify the statement that is not applicable to heat pumps a) transfers heat by refrigerant through a cycle of evaporation and condensation b) an air conditioner can work as a heat pump **<u>c) no external energy is required</u>** d) a vapour absorption refrigeration system can also work as a heat pump
44.	A refrigeration system using which of the following compressors is likely to be most efficient? a) reciprocating b) screw c) **<u>scroll</u>** d) all the above
45.	Which of the following is not true for a fluorescent lamp with electronic ballast **<u>a) presence of stroboscopic effect</u>** b) energy savings c) increased light output d) no starter required

46.	Which of the following with respect to turbocharger in a Diesel engine is true? a) **<u>operates using energy of exhaust gases</u>** b) decreases supply air pressure to engine c) preheats the combustion air using energy from exhaust gases d) all of the above
47.	The refrigerant which can be used both in vapour compression chillers and vapour absorption chiller is a) R22 b) R21 **<u>c) ammonia</u>** d) pure water
48.	Energy efficient distribution transformer core is made up of ______. a) silicon alloyed iron (grain oriented) b) copper c**<u>) amorphous core - metallic glass alloy</u>** d) none of the above
49.	In a transformer on load, if the secondary voltage is one-fourth the primary voltage, then the secondary current will be a) **<u>four times the primary current</u>** b) equal to the primary current c) one-fourth the primary current d) two times the primary current
50.	If V_1 is actual supply voltage and V_2 is the rated voltage of a capacitor, the reactive KVAr produced would be in the ratio of a) V_2^2/V_1^2 **<u>b) V_1^2/V_2^2</u>** c) 1 - V_2^2/V_1^2 d) 1 + V_2^2/V_1^2

……. End of Section – I …….

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

(i) Answer all **<u>Eight</u>** questions
(ii) Each question carries **<u>Five</u>** marks

S-1	**A 15 kW, 415 V, 4 pole, 50 Hz, 3 Phase squirrel cage induction motor has a full load efficiency of 92% and power factor of 0.89. Find the following if the motor operates at full load rated values.** **a) input power in kW** **b) current drawn by the motor** **c) RPM at a full load slip of 0.8%**
Ans:	a) P_{in} (Input power) = 15 / 0.92 = 16.304 kW b) I(Input current) = 16.304 / ($\sqrt{3}$ x 0.415 x 0.89) = 25.48 A c) Ns = 120 x f / p = 120 x 50 / 4 = 1500 RPM N = Ns (1- S) = 1500 (1- 0.008) = 1488 RPM
S-2	**In a pumping system the water level is 4 m below the pump centerline. The discharge**

pressure is 2.60 kg/cm^2. The flow rate of water is 1.5 m^3 /min. Find out the pump efficiency if the actual power drawn by the pump motor is 14 kW at a motor operating efficiency of 0.88.

Ans

Discharge Head	=	2.60 kg/cm^2
	=	26 metre head.
Suction Head	=	- 4 metre.
Total Head	=	26 – (-4) = 30 metre
Hydraulic Power	=	(1.5/60) x 1000 x 9.81 x 30/1000
	=	7.36 kW
Shaft input	=	14x.88=12.32
Pump Efficiency	=	100 x 7.36/12.32 = 59.74 %

S-3

Harmonic measurements in an electrical system of an industry gave the following results.

Current at 50 Hz : 300 A

Current at 150 Hz : 42 A

Current at 250 Hz : 33 A

Calculate the Total Harmonic Distortion in current for the system.

Ans

$$I_{THD} = \sqrt{\left[\left(\frac{42}{300}\right)^2 + \left(\frac{33}{300}\right)^2\right]} \, x100$$

$$\sqrt{(0.0196 + 0.0121)} \, x100 = 17.8\%$$

S-4

Air flow measurements using the pitot tube, in the primary air fan of a coal fired boiler gave the following data

Air temperature	**= 38°C**
Velocity pressure	**= 47 mmWC**
Pitot tube constant, Cp	**= 0.9**
Air density at 0°C (standard data)	**= 1.293 kg /m^3**

Find out the velocity of air in m/sec.

Ans

Corrected air density	273 x 1.293 /(273+38)
	1.135 kg/m^3
Velocity m/s	Cp x √2 x 9.81 x Δp x γ / γ
	0.9 x √2 x 9.81 x 4

		x 1.135 / 1.135	25.6 m/s

S-5	**List five measures to reduce energy consumption in lighting system for buildings, industry and street lighting**
Ans	• Reduce excessive illumination levels to standard levels using switching, delamping, etc. (Know the electrical effects before doing delamping.) • Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors. • Install efficient alternatives to incandescent lighting, mercury vapor lighting, etc. Efficiency (lumens/watt) of various technologies range from best to worst approximately as follows: low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapor, incandescent. • Select ballasts and lamps carefully with high power factor and long-term efficiency in mind. • Upgrade obsolete fluorescent systems to Compact fluorescents and electronic ballasts • Consider lowering the fixtures to enable using less of them. • Consider daylighting, skylights, etc. • Consider painting the walls a lighter color and using less lighting fixtures or lower wattages. • Use task lighting and reduce background illumination. • Re-evaluate exterior lighting strategy, type, and control. Control it aggressively. • Change exit signs from incandescent to LED.
S-6	**Identify each of the following statement as applicable to Vapor Compression Refrigeration System (VCR) and to Vapor Absorption Refrigeration System(VAR).** **(Need not copy and write the following statements in the Answer book; only write against the statements A, B, C, D etc. whether it is applicable to VCR or VAR)** **A. No effect of reducing the load on performance.** **B. Uses low grade energy** **C. Liquid traces in suction line may damage the compressor.** **D. Moving parts are only in the pump and hence operation is smooth.** **E. The system can work on lower evaporator pressures also without affecting the COP.** **F. Performance is adversely affected at partial loads.** **G. Liquid traces of refrigerant present in piping at the exit of evaporator** **H. Using high-grade energy like mechanical work** **I. Moving parts are more; therefore, more equipment maintenance and noise** **J. The COP decreases considerably with decrease in evaporator pressure**
Ans	**A. VAR** **B. VAR** **C. VCR** **D. VAR** **E. VAR** **F. VCR** **G. VAR** **H. VCR**

	I. **VCR** J. **VCR**
S-7	**List any five factors that affect the rate of evaporation of water in cooling towers**
	- Amount of water surface area exposed - The time of exposure - The relative velocity of air passing over the droplets - The RH of air - The direction of airflow relative to water. **Any other relevant point to be considered**
S-8	**Estimate the cooling tower capacity (TR) and approach with the following parameters** **Water flow rate through CT = 2 m^3/min** **Specific heat of water = 1 kcal/kg °C** **Inlet water temperature = 43 °C** **Outlet water temperature = 35 °C** **Ambient WBT = 30°C**
Ans	Cooling tower capacity (TR) = (flow rate x density x sp.heat x diff. temp)/ 3024 = (2X60) x 1000 x 1.0 x (43-35)/ 3024 = 317.5TR Approach = 35- 30 = 5°C

……. End of Section - II …….

Section – III: LONG DESCRIPTIVE QUESTIONS **Marks: 6 x 10 = 60**

(i) Answer all **<u>Six</u>** questions
(ii) Each question carries **<u>Ten</u>** marks

L-1	**An efficiency assessment test was carried out for a standard 4 pole squirrel cage induction motor in a chemical plant. The motor specifications are as under:** **Motor rated specification: 3 phase delta connected,37 kW, 415 Volt, 63 Amps, 1475 rpm,** **The following data was collected during the no- load test on the motor:** **Voltage= 415 Volts** **Current = 17 Amps** **Frequency = 50 Hz** **Stator resistance per phase = 0.260 Ohms at 30°C** **No load power= 1152 Watts** **Calculate the following:** **(i) Iron plus friction and windage losses.** **(ii) Stator resistance at 120°C.** **(iii) Stator copper loss at full load at operating temperature of 120°C.**

(iv) Full load slip and rotor input assuming rotor losses are slip times rotor input.
(v) Motor input assuming that stray losses are 0.5% of the motor rated output power.
(vi) Motor full load efficiency

Ans

Let Iron plus friction and windage loss, P_i + fw

No load power, Pnl = 1152 Watts

Stator Copper loss, P st-30^0C (Pst.cu)

$= 3 \times (17 / \sqrt{3})^2 \times 0.260$

= 75.13Watts

$P_i + fw = P_{nl} - Pst.cu$

= 1152 – 75.13

= 1076.87 W

(ii) Stator Resistance at 120^0C,

$$R_{120^0C} = 0.260 \times \frac{120 + 235}{30 + 235}$$

= 0.3483 ohms per phase

(iii) Stator copper losses at full load, Pst.cu 120^0C

$= 3 \times (63 / \sqrt{3})^2 \times 0.3483$

= 1382.3 Watts

(iv) Full load slip

S = (1500 – 1475) / 1500

= 0.01666 or 1.66%

Rotor input, Pr = P_{output}/ (1-S)
= 37000 / (1-0.01666)
= 37000/0.98334
= 37626.86 Watts

(v) Motor full load input power, P input

$= P_r + Pst.cu\ 120^0C + (P_i + fw) + P_{stray}$

$= 37626.86 + 1382.3 + 1076.87 + (0.005^* \times 37000)$

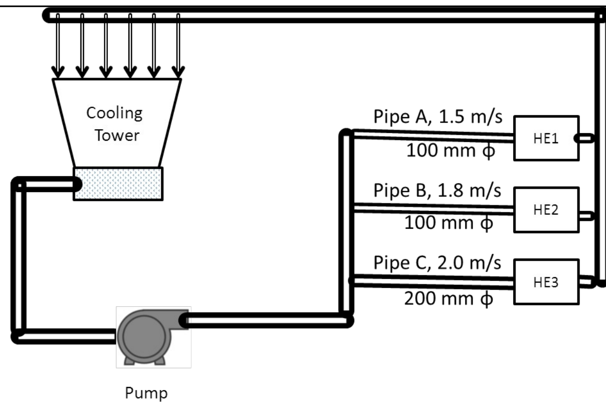
= 40271.03 Watts

*where, stray losses = 0.5% of rated output (assumed)

(vi) Motor efficiency at full load

$$\text{Efficiency} = \frac{P_{output}}{P_{input}} \times 100$$

	= (37000 / 40271.03) x 100 = 91.87 %
L2	**Fill in the blanks:** **1. Cavitation may occur in a pump when the local static pressure in a fluid reaches a level below the _________pressure of the liquid at the actual temperature.** **2. In a vapour absorption system using ammonia as refrigerant, the absorbent is _______** **3. The system resistance of a fan system is proportional to the ______of flow rate or velocity** **4. If the dry bulb temp.is 30^{0}C and the wet bulb temp. is 30^{0}C, then the % relative humidity will be _______** **5. Slip ring induction motors are comparatively ________efficient than of the squirrel cage motors of same ratings.** **6. In a pumping system with a horizontal discharge, the suction static head is 3 m and the friction head is 21 m. The total head developed by the pump will be ___________** **7. The lowest theoretical temperature to which water can be cooled in a cooling tower is the _________ of atmospheric air** **8. The measure of illuminance of a surface in metric units is ________** **9. It is acceptable to run pumps in parallel provided their__ ________heads are similar** **10. When heat load, range and wet bulb temperature are held constant, the cooling tower size is ________proportional to the approach.**
Ans	1. Vapour 2. Water 3. Square 4. 100% 5. Less 6. 18 m 7. Wet bulb temperature 8. Lux 9. Closed valve heads 10. Inversely
L-3	**The cooling water circuit of a process industry is depicted in the figure below. Cooling water is pumped to three heat exchangers via pipes A,B and C where flow is throttled depending upon the requirement. The diameter of pipes and measured velocities with non-contact ultrasonic flow meter in each pipe are indicated in the figure.**

	 **<u>The following are the other data:</u>** **Measured motor power : 50.7 kW** **Motor efficiency at operating load: 90%** **Pump discharge pressure : 3.4 kg/cm^2** **Suction head : 2 meters** **Determine the efficiency of the pump**
Ans	

Flow in pipe A	22/7 x (0.1)^2/4 x 1.5
	0.011786 m^3/s
Flow in pipe B	22/7 x (0.1)^2/4 x 1.8
	0.014143 m^3/s
Flow in pipe C	22/7 x (0.2)^2/4 x 2.0
	0.062857 m^3/s
Total flow	0.088786 m^3/s
Total head	34 m – 2 m = 32 m
Pump hydraulic power	0.088786 x 32 x 9.81
	27.9 kW
	27.9 x 100/50.7 x 0.9
Pump efficiency	61 %

L4	**a) The size of an engine room to be ventilated is 30 m x 20 m x 5 m. The number of air changes per hour is designed to be 20. If the static pressure rise across the ventilator fan is 15 mm WC and fan efficiency is 70 % find out the motor power drawn at a motor efficiency of 90%.**

	b) A seal air fan for a coal mill is operating with suction damper in 25 % open condition. The power drawn at 50 Hz by fan motor is 120 kW. A VFD is to be installed eliminating the damper operation. It is found that the damper can be completely opened and the fan motor can be operated at 33 Hz. Calculated the power drawn by the fan motor at 33 Hz, assuming that motor and fan efficiency remains constant.
	a) Flow rate - 30 x 20 x 5 x 20 = 60,000 m^3/hr Motor power - (60,000/3600) x 15/ (102 x 0.7x0.9) - 3.89 kW b) Power at 50 Hz - 120 kW Power at 33 Hz - 120 x $(33/50)^3$ - 34.5 kW
L-5	**a) In an automobile industry a pump-up test was conducted to determine the free air delivery (FAD) of a reciprocating compressor and the following data were obtained:** **Receiver capacity and additional holdup volume in piping and after-cooler : 4100 litres** **Initial pressure: : 1 kg/cm^2 (g)** **Final pressure: : 8.5 kg/cm^2 (g)** **Atmospheric Pressure: : 1.026 kg/cm^2 (a)** **Ambient air temperature: : 32 °C** **Final compressed air temperature: : 52 °C** **Compressor pump up time : 65 secs** **Calculate the FAD of the compressor in cubic foot per minute.** **b) Further a leakage test was carried out in the same compressed air system and with the same compressor as in problem a) above and following were the observations:** - **Compressor was on load for 03 minutes** - **Compressor was unloaded for 13 minutes** - **Compressor was drawing 145 kW during load** **Calculate the following:** **i. % leakage in compressed air system** **ii. Leakage quantity** **iii. Specific power consumption** **iv. Power lost due to leakage**
Ans	**a)** Q $= \dfrac{P_2 - P_1}{P_0} \times \dfrac{V}{t} \times \left(\dfrac{273 + t_1}{273 + t_2}\right)$ Time = 65 sec=1.0833 secs

= (8.5 - 1)/1.026X 4.1 /1.0833) X (305/325)

= 25.96 m^3/min

= 25.96 x $(3.28)^3$

= 916 cfm

b)

i) % Leakage in the system

Load time (T) : 03 minutes

Un load time (t) : 13 minutes

% leakage in the system $\frac{T}{(T + t)} x100$

$\frac{3}{(3 + 13)} x100$ = 18.75 %

ii) Leakage quantity : 0.1875 x 916

: 171.75 cfm

iii)

Operating capacity (FAD) : 916 cfm

Actual power consumption : 145 kW

Specific power consumption : 145/916

= 0.1583 kW/cfm

iv)

Power lost due to leakage : leakage quantity x sp power consumption

: 171.75 x 0.1583

: 27.19 kW

L-6 **Answer any two of the following :**

(i) In a throttle valve-controlled pumping system with oversized pump list any five options to improve energy efficiency? (Note: Name only options, no explanation required)

(ii) Define one 'Ton of Refrigeration (TR)'. How do you calculate TR across the Air Handling Units?

(iii) List five energy conservation opportunities in fan system.

Ans

i) Trim impeller, replace with smaller impeller, install variable speed drive, change pulley if it is belt driven, change to two speed drive, and lower rpm drive

ii) A ton of refrigeration is defined as the quantity of heat to be removed in order to form one ton of ice in 24 hours when the initial temperature of water is 0 °C. This is equivalent to 50.4 Kcal/min or 3024 Kcal/h in metric system

Refrigeration load in TR is assessed as ;

	$$TR = \frac{Q \times \rho \times (h_{in} - h_{out})}{3024}$$ Where Q is the air flow in CMH ρ is density of air kg/m^3 h_{in} is enthalpy of inlet air kCal/kg h_{out} is enthalpy of outlet air kCal/kg iii) **Energy conservation opportunities in fan system** • Use smooth, well-rounded air inlet cones for fan air intakes. • Avoid poor flow distribution at the fan inlet. • Minimize fan inlet and outlet obstructions. • Clean screens, filters, and fan blades regularly. • Use aerofoil-shaped fan blades. • Minimize fan speed. • Use low-slip or flat belts. • Check belt tension regularly. • Eliminate variable pitch pulleys. • Use variable speed drives for large variable fan loads. • Use energy-efficient motors for continuous or near-continuous operation • Eliminate leaks in ductwork. • Minimise bends in ductwork • Turn fans off when not needed.

……. End of Section – III ……

13th NATIONAL CERTIFICATION EXAMINATION – September, 2012 FOR ENERGY MANAGERS & ENERGY AUDITORS

PAPER – 3:	**Energy Efficiency in Electrical Utilities**	
Date: 16.9.2012	Timings: 0930-1230 HRS	Duration: 3 HRS
Max. Marks: 150		

Section – I: OBJECTIVE TYPE **Marks: 50 x 1 = 50**

(i) Answer all **50** questions
(ii) Each question carries **one** mark

1	In a 22 kV feeder, if the voltage is raised from 22 kV to 66 kV for the same loading conditions, the voltage drop in the same feeder system would be lowered to a) 1/2 b) 1/3 c) 1/9 d) unpredictable value
2	Normally, the efficiency of distribution transformer at full load varies anywhere between a) 96 to 99 % b) 80 to 85 % c) 60 to 70% d) 50%- 60%
3	What is the reduction in distribution loss if the current flowing through the distribution line is reduced by 10%? a)10% b) 90% c) **19%** d) 81%
4	Power factor is the ratio of a) kVAr/kW b) $(kW^2+kVAr^2)^{1/2}/kW$ c) $kW/(kW^2+kVAr^2)^{1/2}$ d) $kVAr/(kW^2+kVAr^2)^{1/2}$
5	The electricity bill shows an average power factor of 0.72 with an average kW demand of 627. How much kVAr is required to improve the power factor to 0.95? (Given Data: tan Φ1 = 0.964, tan Φ2 = 0.329) a) 398 b) 144 c) 95 d) 627
6	Where transformer loading is known, the actual transformer loss at a given load can be computed as: a) No Load Loss+ (Actual kVA Load/rated kVA) X Load Loss b) No Load Loss+ $(\text{Actual kVA Load/rated kVA})^2$ X Load Loss c) No Load Loss+ (Actual kVA Load/rated kVA) X Load Loss^2 d) $[\text{No Load Loss+\{ (Actual kVA Load/rated kVA) X Load Loss\}}]^2$

7	Direct current motors are used in special applications where a) high torque starting or where smooth acceleration over a broad speed range is required. b) low torque starting or where steady acceleration over a narrow speed range is required. c) normal torque starting or where high acceleration over a broad speed range is required. d) low torque starting or where smooth acceleration over a broad speed range is required.
8	A 3-phase, 415 volts, 50 Hz, 100 kW, 6 pole squirrel cage induction motor with a rated slip of 2% will have a full load rotor speed of (a) 1470 rpm (b) 980 rpm (c) 1020 rpm (d) none of the above
9	In an induction motor the loss which is independent of motor load a) I^2R loss of stator b) I^2R loss of rotor c) friction and windage loss d) all of the above
10	Rewinding can affect which of the following factors that contribute to deterioration in motor efficiency: a) winding and slot design and winding material selection b) heat applied to strip windings, damage the insulation between laminations, thereby increasing eddy current losses c) change in the air gap may affect power factor and output torque d) all the above
11	If measured Line Current of a 3 phase induction motor is 25.98 A, what will be the Phase Current? **a)** 15 A **b)** 45 A **c)** 8.96 A d) 30 A
12	The efficiency of compressed air system is around a) 90% b) 60% c) 50% d) **10%**
13	The basic function of air dryer in a compressed air system is to a) remove remaining traces of moisture after the aftercooler b) store and smoothen pulsating air output c) reduce the temperature of the air before it enters the next state to increase efficiency d) prevent dust from entering compressor
14	Select the correct statement for reciprocating air compressors: a) for every 4°C drop in the inlet air temperature, the increase in energy consumption is by 1%. b) for every 4 °C rise in the inlet air temperature, the decrease in energy consumption is by 1% c) for every 4 °C rise in the inlet air temperature, the increase in energy consumption is by 1% d) the energy consumption remains same irrespective of inlet air temperature

15	Which of the following parameters is not required for evaluating volumetric efficiency of the compressor? a) FAD b) Cylinder bore diameter c) Stroke length d) <u>Power input</u>
16	Which of the following will not occur if a reciprocating compressor is operated at a lower discharge pressure? a) lower power consumption b) less load on the piston rods and hence reduced maintenance costs c) lower leakage losses d) <u>lower free air delivery than rated</u>
17	Which type of energy efficient dryer can be opted if a user in a plant requires compressed air at a dew point of -40°C ? a) heatless purge type dryer b) <u>heat of compression dryer</u> c) aftercooler d) refrigerant dryers
18	A 1.5 TR room air conditioner having EER (W/W) of 3.0 , will draw input power of______ kW a) <u>1.75</u> b) 3.00 c) 1.50 d) 2.00
19	Identify the wrong statement from the following regarding Vapour Compression Refrigeration system a) condenser rejects heat to atmosphere b) evaporator removes heat from process or space c) compressor sends superheated vapor to condenser **<u>d) high pressure sub-cooled liquid refrigerant returns back to evaporator</u>**
20	The head developed by a centrifugal pump is not directly proportional to a) Impeller diameter b) Shaft speed c) Number of impellers d) **<u>Diameter of discharge port</u>**
21	Which of the following is incorrect in the case of cooling towers a)"Range" is the difference between the cooling tower water inlet and outlet temperature. b) "Approach" is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. <u>d)'Range' is a better indicator of cooling tower performance.</u> e) Cooling capacity is the heat rejected in kCal/hr or TR
22	Identify the correct statement: **<u>a) the Specific Ratio of Compressors is higher than Blowers</u>** b) the Specific Ratio of Fans is higher than Blowers c) the Specific Ratio of Compressors is lower than Fans d) the Specific Ratio of Blowers is higher than Compressors
23	Two energy auditors made following statements regarding Vapour compressor Refrigeration system and what will be your judgement?

	Statement A: Reducing condensing temperature by 5.5°C, results in a 20 – 25% decrease in compressor power consumption Statement B: 5.5°C increase in evaporator temperature reduces compressor power consumption by 20 – 25% a) statements A & B are TRUE b) statements A & B are FALSE c) statement A is TRUE & B is FALSE d) statement A is FALSE & B is TRUE
24	Decreasing the rpm of a fan at partial loading by 10% results in: **a) decrease of 10% in flow rate and decrease of 27% in power requirement** b) decrease of 10% in flow rate and decrease of 19% in power requirement c) decrease of 10% in flow rate and increase of 10% in power requirement d) increase of 10% in flow rate and no appreciable change in power requirement
25	The power drawn by a centrifugal fan is a) inversely proportional to fan efficiency b) directly proportional to fan efficiency c) inversely proportional to static pressure d) inversely proportional to flow rate
26	The frictional loss in a piping system is proportional to a) flow **b) flow^2** c) 1/flow d) 1/flow^2
27	For the same flow, through which of the following diameter pipes, the pump will work with maximum pressure? **a) 100 mm** b) 150 mm c) 200 mm d) 250 mm
28	It is possible to run pumps in parallel if their __________________ are similar. a) suction heads b) discharge heads c) closed valve heads d) none of the above
29	Input power to the motor driving a pump is 20 kW. The motor efficiency is 0.9 and pump efficiency is 0.7. The power transmitted to the water is a) 12.6 kW b) 18.0 kW c) 14.0 kW d) 31.75 kW
30	Small by-pass lines are installed in pumps some times to _____. a) increase flow b) control pump delivery head c) prevent pump running at zero flow d) reduce pump power consumption
31	The refrigeration load in TR when 10 m^3/hr of water is cooled from a 15 ^{o}C to 7 ^{o}C is about a) 10 b) 8 c) 26.5 d) none of the above
32	The order of movement of thermal energy in HVAC system is: a) Indoor air - Chilled water - Refrigerant-Condenser water- Cooling tower b) Chilled water - Indoor air - Refrigerant-Cooling tower - Condenser water c) Indoor air - Condenser water - Chilled water - Cooling tower - Refrigerant d) Indoor air - Chilled water – Refrigerant - Cooling tower - Condenser water
33	In a cooling tower, Statement A: Surface of heat exchange is the surface area of the water droplets, which is in

	contact with air. Statement B: Area of heat exchange is the surface area of the fill sheets, which is in contact with air. a) statements A & B are false b) statement A is True & B is false c) statements A & B are True d) statement A is false & B is True
34	If the evaporation loss is 16 m^3 /hr per cell and Cycles of Concentration is 3, the blow down requirement in m^3 /hr per cell of a cooling tower: **a) 8** b) 5.33 c) 4 d) 2
35	Cycles of Concentration (C.O.C) of a cooling tower will depend on a) TDS in circulating water b) TDS in make-up water c) both a & b d) none of the above
36	The Solar Heat Gain Coefficient (SHGC) of window of a building is 0.30. This means: a) That the window allows 70 % of the sun's heat to pass through into interior of the buildings **b) That the window allows 30 % of the sun's heat to pass through into the building interior** c) That 70 % of the sun's heat is incident on the window d) That the window reflects back to exterior a minimum of 30 % of the sun's heat
37	FRP fans consume less energy than aluminium fans because a) they are lighter b) they have better efficiencies c) they encounter less system resistance d) they deliver less air flow
38	The hydraulic power in a pumping system depends on a) motor efficiency b) pump efficiency c) both motor and pump efficiency d) none of the above
39	The most energy intensive heat transfer loop of a Vapour Compression Refrigeration System is: a) Indoor air loop b) Chilled water loop c) Refrigerant loop d) Condenser water loop
40	The efficiency of a pump does not depend on a) suction head b) discharge head c) motor efficiency d) density of fluid
41	The power factor of a squirrel cage induction motor a) decreases at low motor loading b) decreases at high motor loading c) remains constant and is independent of load d) cannot be predicted
42	The slip of a synchronous motor will be a) more than the induction motor b) less than the induction motor c) zero d) load dependent

43	In BEE Star labeled distribution transformers, which of following losses are defined? a) total loss at 50% and 100% loading b) total loss at 75 % loading c) total loss at 75% and 100% loading d) total loss at 100% loading
44	To optimize the voltage level fed to the lighting feeder, the best option is to install. a) servo stabilizer for lighting feeder b) "exclusive" transformer for lighting c) microprocessor based controllers d) high frequency (HF) electronic ballasts
45	Which one of the following device will help to eliminate the hunting problems normally associated with capacitor switching? a) Intelligent Power Factor Controller b) maximum demand controller c) soft starter d) eddy current drives
46	Which one of the following is an incorrect statement? a) fluorescent lamp is an electric discharge lamp b) electronic ballasts make use of semi-conductor devices c) electronic ballasts have very low internal loss d) fluorescent lamps can produce light by direct connection to the power source
47	A 2500 MW super thermal power station generated 15786 million units in the year 2011-12. Its Plant Load Factor (PLF) is: a) 60% b) 65% c) 72% d) 79%
48	Which of the following statements is not true of maximum demand controller a) switches off non-essential loads in Logical sequence. b) alarm is sounded when demand approaches a preset value. c) voltage level is closely regulated d) plant equipment selected for the load management can be programmed
49	The main reason for using Variable Frequency Drive (VFD) for capacity control in electrical motor driven centrifugal fans with fluctuating load is : a) improved power quality **b) fan capacity is proportional to its speed whereas the power drawn by the fan is proportional to the cube of its speed** c) improved power factor d) precise closed loop process control
50	Select the incorrect statement: a) harmonics occur as spikes at intervals which are multiples of the supply frequency b) harmonics are multiples of the fundamental frequency c) induction motors are the major sources of harmonics d) transformers operating near saturation level create harmonics

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

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

S-1	List any five industrial applications of a heat pump.
Ans	Industrial heat pumps are mainly used for: 1. Space heating 2. Heating of process streams 3. Water heating for washing, sanitation and cleaning 4. Steam production 5. Drying/dehumidification 6. Evaporation 7. Distillation 8. Concentration
S-2	A pump is delivering 64 m^3/hr of water with a discharge head of 26 metres. The water is drawn from a sump where water level is 3 metres below the pump centerline. The power drawn by the motor is 8.89 kW at 88% motor efficiency. Find out the pump efficiency
Ans	Hydraulic power P_h = Q (m^3/s) xTotal head, $h_d - h_s$ (m) x r (kg/m^3) x g (m/s^2) / 1000 Q = 64/3600 m^3/s , $h_d - h_s$ = 26 – (-3) = 29 m Hydraulic power P_h = (64/3600) x 29 x 1000 x 9.81 / 1000 = 5.0576 kW Pump shaft power = 8.89 kW x 0.88 = 7.8232 kW Pump efficiency = hydraulic power / pump shaft power = 5.0576 / 7.8232 = 64.65 %
S-3	How do the Time-Of-Day (TOD) metering and billing benefit the utilities as well as consumers?
Ans	ToD meter records demand, time, and energy and the ToD tariff are set in such a way that higher rates at peak load periods and lower rates at off-peak load periods. The billing as per ToD tariff benefits the consumers to avail maximum power and energy at off-peak hours at lowest tariff ; and the higher peak period tariff dis-incentivise for increased drawl at peak period. This results effective maximum demand reduction to the utility, and in turn savings in peak time power procurement at higher rate as well as maximising the load factor for resulting better financials to the utility.
S-4	Explain briefly the difference between static and dynamic head of a centrifugal pumping system.
	Static head is simply the difference in height of the supply and destination reservoirs and it is independent of flow. Dynamic head is the friction loss, on the liquid being moved, in pipes, valves and equipment in the system. The friction losses are proportional to the square of the flow rate.

S-5

Compute AT & C (Aggregate Technical and Commercial) Losses for the following data:

S. No.	Description	Annual Data
1	Input Energy = (Import-Export), MU	11
2a	Energy Billed (Metered), MU	7
2b	Energy Billed (Un-Metered), MU	1
2c	Total Energy Billed	8
3	Amount Billed (Rs. lakhs)	450
4a	Gross Amount Collected (Rs. lakhs)	460
4b	Arrears Collected (Rs. lakhs)	40

Ans

Estimation of AT & C Losses

S. No.	Description		Annual Data
1	Input Energy = (Import-Export), MU	Ei	11
2a	Energy Billed (Metered), MU	E1	7
2b	Energy Billed (Un-Metered), MU	E2	1
2c	Total Energy Billed (E1 + E2)	Eb	8
3	Amount Billed (Rs. lakhs)	Ab	450
4a	Gross Amount Collected (Rs. lakhs)	AG	460
4b	Arrears Collected (Rs. lakhs)	Ar	40
4c	Amount Collected without Arrears (Rs. lakhs)	Ac=AG-Ar	420
5	Billing Efficiency (BE)	= Eb/Ei *100%	72.7%
6	Collection Efficiency(CE)	=Ac/Ab *100%	93.3%
7	AT& C Loss	{1- (BE *CE) *100%	32.17%

S-6

A DG set is operating at 700 kW load with 450^{O}C exhaust gas temperature. The DG set generates 7.8 kg of exhaust gas/ kWh generated. The specific heat of gas at 430^{o}C is 0.25 kCal/ kg^{O}C. A heat recovery boiler is installed after which the exhaust temperature drops to 220^{O}C. How much steam will be generated at 3 kg/ cm^{2} with enthalpy of 650.57 kcal/ kg. Assume boiler feed water temperature as 65^{o}C.

Ans

= 700 kWh x 7.8 kg gas generated/ kWh output x 0.25 kCal/ kg ^{o}C x (450^{o}C-220 ^{o}C) =3,13,950 kCal/hr

Steam generation = 3,13,950 kCal/hr / (650.57 – 65) = 536.14 kg/ hr.

S-7

An energy audit of a fan was carried out. It was observed that the fan was delivering 18,500 Nm^{3}/hr of air with static pressure rise of 45 mm WC. The power measurement of the 3-phase induction motor coupled with the fan recorded 2.9 kW/ phase on an average. The motor operating efficiency was assessed as 88% from the motor performance curves. What would be the fan static efficiency?

Ans

Q = 18,500 Nm^{3} / hr.= 5.13888 m^{3}/sec ,
SP = 45 mmWC,
η_{St} = ?,

	Power input to motor= 2.9x3=8.7 kW Power input to fan shaft=8.7 x0.88=7.656 kW $\text{Fan static } \eta = \dfrac{\text{Volume in } m^3/\text{sec} \times \Delta P_{st} \text{ in mmWc}}{102 \times \text{Power input to shaft}}$ $= \dfrac{5.13888 \times 45}{102 \times 7.656}$ = 0.296 = 29.6%
S-8	List down any 5 energy conservation opportunities in compressed air system
Ans	§ Ensure air intake to compressor is not warm and humid by locating compressors in well-ventilated area or by drawing cold air from outside. Every 4^0C rise in air inlet temperature will increase power consumption by 1 percent. § Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter. § Keep compressor valves in good condition by removing and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50 percent. § Install manometers across the filter and monitor the pressure drop as a guide to replacement of element. § Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors. § Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture. § Fouled inter-coolers reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting in increased corrosion. Periodic cleaning of inter-coolers must be ensured. § Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken if required. § If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at full load. Any other relevant point

-------- 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) In a cooling tower, the cooling water circulation rate is 1200 m^3/hr. The water enters the cooling tower at 38°C. The ambient wet bulb temperature is 26°C. The cooling tower operates with an approach of 4°C. If the blowdown rate of the cooling tower is 1 % of the circulation rate, calculate the evaporation loss and COC. b) A medium scale industry has a load of 450 kVA. It has installed two transformers of 500 kVA each. The no load loss and full load copper loss are 760 W and 5400 W respectively. From the energy efficiency point of view the management wants to take a decision on whether to operate a single transformer on full load or two transformers equally sharing the load. What is your recommendation ? Why?
Ans	a) Leaving cold water temperature = 26 + 4 = 30°C Evaporation Loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T_1 –T_2) = 0.00085 x 1.8 x 1200 x 8 = 14.69 m^3/hr Blowdown = 12 m^3/hr Blowdown = Evaporation loss / (COC – 1) 12 = 14.69 / (COC – 1) COC = 2.224 b) (see table below) **Two transformers are better because the losses are the least.**

1 x 500 kVA	
Transformer loss at 450	No load loss + [kVA load/Rated kVA]^2 x full load loss
	760 + 4374
	5134 W
2 x 500 at 50% load	2 x {760 + [225/500]^2 x 5400}
	3707 W

Two transformers are better because the losses are the least.

L-2	Fill in the blanks for the following 1. A motor which can conveniently be operated at lagging as well as leading power factors is the___________ motor 2. A 50 Hz, 3-phase induction motor has a full load speed of 1440 r.p.m. The number of poles of the motor are______ 3. In a centrifugal pump the velocity energy is converted to pressure energy by _____ 4. In a centrifugal pump if the liquid to be pumped has density twice that of water, then the horse power required (as compared to that while pumping water) will be______ times 5. The friction loss in a pipe carrying a fluid is proportional to the fifth power of _________ 6. A 10 MVA generator has power factor 0.866 lagging. The reactive power produced will be ______ MVAR 7. Totally-enclosed, fan cooled (TEFC) motors are______ efficient than Screen – protected, drip-proof (SPDP) induction motors 8. Low speed Squirrel cage induction motors are normally ______efficient than high speed squirrel cage induction motors 9. Harmonics in electricity supply are multiples of the ________frequency 10. For the same rating, slip ring induction motors are normally _________efficient than squirrel cage induction motors
Ans	1. Synchronous 2. 4 3. volute or diffuser 4. 2 5. pipe diameter 6. 5 7. more 8. less 9 fundamental 10 less
L-3	a) Calculate the free air delivery (FAD) in m^3/min of a compressor for the following observed data: Receiver capacity: 0.25 m^3 Initial pressure: 1 kg/cm^2 (g) Final pressure: 7 kg/cm^2 (g) Initial temperature: 32 ^oC Final temperature: 52 ^oC Additional holdup volume: 0.05 m^3 Compressor pump up time: 2.1 minutes b) Identify the following statements as applicable to Vapor Compression Refrigeration System

	(VCR) or to Vapor Absorption Refrigeration System(VAR). I. The system operates under vacuum - ________(VCR/VAR) II. Uses water as a refrigerant - ________(VCR/VAR) III. Uses large amount of high-grade energy - ________(VCR/VAR) IV. COP decreases considerably with decrease in evaporator pressure - ________(VCR/VAR) V. The system can work on lower evaporator pressures also without affecting the COP - ________(VCR/VAR)
Ans	Q $= \frac{P_2 - P_1}{P_0} \times \frac{V}{t} \times \left(\frac{273+t_1}{273+t_2}\right)$ $= \frac{7-1}{1.026} \times \frac{(0.25+0.05)}{2.1} \times \left(\frac{273+32}{273+52}\right)$ **= 0.784 m^3/min** I. The system operates under vacuum VAR II. Uses water as a refrigerant VAR III. Using large amount of high-grade energy VCR IV. The COP decreases considerably with decrease in evaporator pressure. VCR V. The system can work on lower evaporator pressures also without affecting the COP VAR
L-4	The measured values of a water cooled 20 TR package air conditioning plant are given below: Average air velocity across suction side filter: 2.5 m/s Cross Sectional area of suction: 2.4 m^2 Inlet air : Dry Bulb:20 deg. C, Wet Bulb: 14 deg. C; Enthalpy: 9.37 k Cal per kg Outlet air: Dry Bulb: 12.7 deg. C, Wet Bulb: 11.3 deg. C; Enthalpy: 7.45 k Cal per kg Specific volume of Air: 0.85 m^3/kg Power drawn: by Compressor : 18.42 k W by Pump : 2.1 k W by Evaporator Fan : 1.25 k W Calculate the following: i. Air Flow rate ii. Cooling effect delivered iii. Compressor kW/TR iv. Overall kW/TR v. Overall Energy Efficiency ratio in W/W
Ans	i. Air flow rate = 2.5*2.4 = 6 m^3/sec = 21600 m^3/hr ii. Cooling Effect delivered = [(9.37-7.45)*21600]/(0.85*3024) = 16.13 TR = 56.73 kW iii. Compressor kW/TR = 18.42 /16.13 = 1.13 iv. Overall kW/TR = (18.42+2.1+1.25)/16.13 = 1.35 v. Energy Efficiency Ratio(EER) in W/W = 56.73/21.77 = 2.606

L-5	**a)** How do you calculate the velocity of air/gas in a duct using the average differential pressure and density of the air/gas? b) A no load test was conducted in a delta connected 37 kW induction motor. Nameplate data- 3 Phase, 415 V, 50 Hz, 55 Amp Measured data at no load: Voltage, V = 415 Volts; Current, I = 17 Amps; Frequency, F = 50 Hz; Stator phase resistance at 30°C = 0.24 Ohms/ phase No load power = 955 Watts i. Find out Iron Loss plus Friction Loss plus Windage Loss ii. Stator Copper Loss at name plate ratings(full load), considering stator temperature =120 °C iii. No load power factor of the motor
Ans	a) **Ans:** **Velocity V, m/s =** $\mathbf{\dfrac{C_P \times (2 \times 9.81\, \Delta p \times \gamma)^{1/2}}{\gamma}}$ **C_p = Pitot tube constant, 0.85 (or) as given by the manufacturer** **Δp = Average differential pressure measured by pitot tube by taking** **measurement at number of points over the entire cross section of the duct.** **γ = Density at air/ gas at test condition** **b)** Let Iron Loss plus Friction Loss plus Windage Loss be P_i+fw Stator Copper Loss, P_{st}, 30°C = 3X $(17/\sqrt{3})^2$X0.24 = 69.36 Watt P_i+fw = P_{nl} - P_{st}= 955 – 69.36 = 885 .64 Stator resistance at 120 °C = 0.24x[(120+235)/[(30+235)] = 0.322 Ohms Stator Copper Loss at name plate ratings = 3x$(55/\sqrt{3})^2$ X0.322 = 974.05 Watt No load power factor= 955/(1.7321x415x17)=0.078
L-6	Answer any **two** of the following : (i) two most important electrical parameters, which are to be monitored for safe operation of Diesel Generator set (ii) Slip method of motor load assessment (iii) Five options for electricity distribution loss optimization (iii) Five energy conservation opportunities in pumping system
Ans	**(i)** two most important electrical parameters, which are to be monitored for safe operation of Diesel Generator set are **KVA and kW**
	(ii) Slip method of motor load assessment
	In the absence of a power meter, the slip method can be used which requires a tachometer. The percentage loading can be calculated as follows:

	$$Load = \frac{Slip}{S_s - S_r} * 100\%$$ Where: Load = Output power as a % of rated power Slip = Synchronous speed - Measured speed in rpm S_s = Synchronous speed in rpm at the operating frequency S_r = Nameplate full-load speed Slip also varies inversely with respect to the motor terminal voltage squared. A voltage correction factor can, also, be inserted into the slip load equation. The voltage compensated load can be calculated as shown $$Load = \frac{Slip}{(S_s - S_r)\ x\ (V_r / V)^2}\ x\ 100\%$$ Where: Load = Output power as a % of rated power Slip = Synchronous speed - Measured speed in rpm S_s = Synchronous speed in rpm S_r = Nameplate full-load speed V = RMS voltage, mean line to line of 3 phases V_r = Nameplate rated voltage
	iii) **Five options for electricity distribution loss optimization**
	• minimising length of distribution lines • adequate Size of Conductors • installaing Distribution Transformers (DTR) at load center on the Secondary Distribution System • Maintaining high Power Factor • High Voltage Distribution System (HVDS) • Incorporating Amorphous Core Transformers Any other relevant point
	iv) **Five energy conservation opportunities in pumping system**
	• Ensure adequate NPSH at site of installation • Operate pumps near best efficiency point. • Modify pumping system/pumps losses to minimize throttling. • Adapt to wide load variation with variable speed drives • Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area. • Conduct water balance to minimise water consumption • Replace old pumps by energy efficient pumps Any other relevant point

……. End of Section – III ………….…