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.	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**
2.	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
3.	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
4.	A parameter that indicates adequacy of lighting for a particular application is

	a) installed load efficacy b) installed power density **c) lux** d) lumens
5.	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%
6.	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
7.	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
8.	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
9.	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
10.	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
11.	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
12.	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
13.	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**
14.	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
15.	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
16.	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
17.	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**
18.	In a vapor compression refrigeration system, the component across which the enthalpy remains constant a) compressor b) condenser **c) expansion valve** d) evaporator
19.	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
20.	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
21.	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
22.	Increasing the suction pipe diameter in a pumping system will a) reduce NPSHa **b) increase NPSHa**

	c) decrease NPSHr d) increase NPSHr
23.	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
24.	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
25.	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**
26.	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
27.	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
28.	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
29.	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
30.	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
31.	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
32.	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**
33.	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
34.	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
35.	When evaporator temperature is increased a) refrigeration capacity decreases **b) refrigeration capacity increases** c) specific power consumption remains same d) power consumption increases
36.	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** b) air with same dry bulb and wet bulb temperature d) air with high dry bulb temperature and high moisture.
37.	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
38.	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

39.	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
40.	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.
41.	Which of the following is an example of variable torque equipment ? **a) centrifugal pump** b) reciprocating compressor c) screw compressor d) roots blower
42.	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
43.	Which of the following is not a climate zone as per ECBC classification? a) Hot - dry b) Warm - humid c) Cold **d) Cold humid**
44.	Which of the following is not an example of lighting controls? a) dimmers b) timers c) photosensors **d) daylight harvesting**
45.	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**
46.	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
47.	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**

48.	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
49.	When the dew point temperature is equal to the air temperature then the relative humidity is a) 0% b) 50% **c) 100%** d) unpredictable
50.	Which of the following flow controls in a fan system will change the system resistance curve: a) Inlet guid vane b) speed change with variable frequency drive c) speed change with hydraulic coupling **d) discharge damper**

…………. 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 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* ……………….5 marks (each relevant point carries one marks)
S-2	A stream of moist air with a mass flow rate of 8.1 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 = $\frac{M_1H_1 + M_2H_2}{\text{Dry air}}$ = $\frac{(0.01x8.1) + (0.1x1)}{(8.1\ x(1 - 0.01))}$ = 0.023 kg per kg of dry air** **Dry air (*can also be calculated as*) = [8.1 kg/s – (moisture i.e. 8.1 x 0.01)]** ……………….5 marks Or Mass of **moist air = 8.1 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) = 8.1 kg/s X + X * (0.01) = 8.1 kg/s On solving, we get X=8.0 kg/s Now, Moisture in moist air is 0.1 kg/s Superheated steam = 0.1 kg/s Humidity ratio of final steam = **H= $\frac{M_1H_1 + M_2H_2}{\text{Dry air}}$ = $\frac{(0.01x8) + (0.1x1)}{(8)}$ = 0.023 kg per kg of dry air** ……………….5 marks
S-3	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 = 7 m/s. • Atmospheric Pressure = 1.013 bar
Ans	**Actual Condition vs NTP Condition** ▪ **P_2 x V_2 / T_2 = P_1 x V_1 / T_1** ▪ **(1.013 + 7) x V_2 / (273 + 35) = 1.013 x 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 / 7 = 0.0057 m^2**

<table>
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- **$A = \pi (d_i^2/4)$ = 0.0057 m^2**
- **Pipe, in mm = d_i = 0.085 m = 85 mm (2 Marks)**

= *say 90 mm*

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<tr><td>S-4</td><td>

The operating boiler load and associated Induced-draft fan power consumption of a boiler is given below.

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.

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Boiler loading	Damper position	Operating hours a day	Fan motor power (with damper operation) (kW)
80%	Position # 1	4	34
70%	Position # 2	12	31
60%	Position # 3	8	28

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	34	17.9	16.1	64.4
70	12	31	12	19	228
60	8	28	7.6	20.4	163.2
Total Daily Savings					**455.6**

……………….5 marks

S-5

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 : 5.3 kW
- Motor efficiency η : 93%
- 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 = 5.3 x 0.93 = 4.93 kW

Pump efficiency = 3.13/4.93 = 63.5%

……………….1 mark

S-6	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 416 V, 419 V & 418 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.
Ans	i) **Additional temperature rise:** Phase / V / Deviation from mean voltage R / 416 / -1.67 Y / 419 / 1.33 B / 418 / 0.33 Mean / 417.67 / 0 Voltage unbalance = Maximum deviation from mean/mean voltage = 1.67*100/417.67 = 0.39.9% --------------------3 Marks Additional temperature rise = 2 X (%voltage unbalance)^2 = 2 X (0.4)^2 = 0.32% ----------------2 Marks
S-7	Briefly explain any three different methods of flow control for fans
	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.

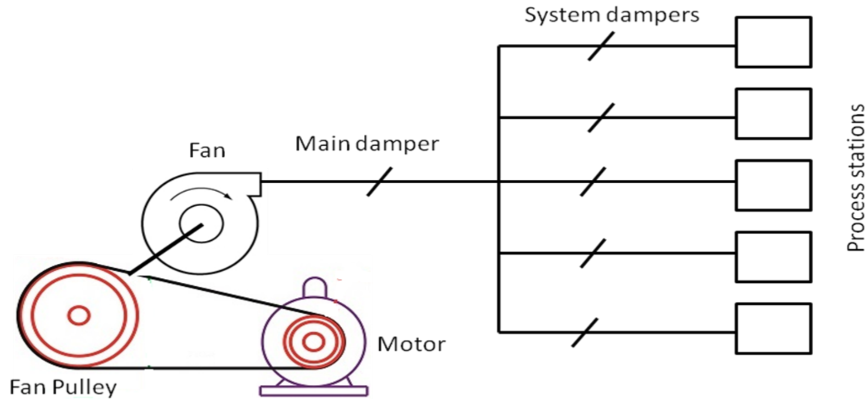
	Variable Speed Drive: Variable speed operation involves reducing the speed of the fan to meet reduced flow requirements. Fan performance can be predicted at different speeds using the fan laws. Since power input to the fan changes as the cube of the flow, this will usually be the most efficient form of capacity control. ……………….5 marks (any of the above three to be considered)
S-8	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'.** **d) Cycles of Concentration (COC)** **e) Lumens** ……………….5 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	a) A 3-Phase, 50 kW rated Induction motor drawing 46 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 = 46kW Original P.F = $\text{Cos}\theta_1$ = 0.75 Final P.F = $\text{Cos}\theta_2$ = 0.96 θ_1 = $\text{Cos}^{-1}(0.75)$ = 41°.41; Tan θ_1 = Tan (41°.41) = 0.88 θ_2 = $\text{Cos}^{-1}(0.96)$ = 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) = 46 kW (0.88 – 0.29) = **27.14 kVAR** ……………….2.5 marks Rating of Capacitors connected in each Phase 27.14/3 = **9.05 kVAR** Current drawn at 0.75 PF = 46 / √3 x 0.415 x 0.75 = 85.3 A Current drawn at 0.96 PF = 46 / √3 x 0.415 x 0.96 = 66.7 A **Reduction in current drawn** = 85.3 – 66.7 = 18.6 A Initial kVA at 0.75 PF = 46 / 0.75 = 61.3 kVA kVA at 0.96 PF = 46 / 0.96 = 47.9 kVA **Reduction in kVA** = 61.3 – 47.9 = 13.42 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-2	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 : 25.2 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 6500 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) = 25.2 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 x 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 x (W_{Th1} / W_{Th2})

= 25.2 x (17.7/20.86) = 21.4 kW

………………..2 marks

Annual Energy saving :

Annual Energy saving = Power Reduction x Op. Hours

= (25.2 kW – 21.4 kW) x 6500 hrs

= 24700 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) x 560 = 608 mm

………………..2 marks

L-3	Write short notes on i) Ice Bank System in refrigeration ii) Vapour Absorption Refrigeration System iii) Harmonics in electrical system and its impacts
Ans	(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 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
L-4	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. In case of centrifugal pumps, impeller diameter changes are generally limited to reducing the diameter to about _______% of maximum size. 3. The dry bulb temperature is 30 0C and the wet bulb temperature is 30 0C. The relative humidity is _________%. 4. 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. 5. In an amorphous core distribution transformer, ______ loss is less than a conventional transformer 6. 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. 7. 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. 8. As the "Approach" decreases, the other parameters remaining constant, the effectiveness of cooling tower will __________. 9. Harmonics in electricity supply are multiples of the ____________ frequency. 10. The ratio of luminous flux emitted by a lamp to the power consumed by the lamp is called_________________.
Ans	**1. Synchronous** **2. 75% (or 80%)** **3. RH = 100%** **4. 12 meter or the same** **5. No load (other correct answers could be : fixed, iron, total)**

	6. **Vapor** 7. **0.10** 8. **Increases** 9. **Fundamental or 50 Hz** 10. **Luminous efficacy** ……………….10 marks **(each one carries one marks)**
L-5	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 77 kJ/kg. At the outlet of AHU, air has an enthalpy of 59 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)** **= (77-59) x 1.3 x 1.5 x 2.2 x 3600 / (4.187x 3024)** **= 21.96 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
L-6	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 3.2 kW and a full load copper loss of 18.1 kW , while Transformer-2 has an iron loss of 2.7 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 3.2 = 76.8 kWh Energy loss per day due to copper loss = $[\left(\frac{500}{1,500}\right)^2 \times 18.1 \times 6] + [\left(\frac{1,000}{1,500}\right)^2 \times 18.1 \times 6] + [\left(\frac{1,500}{1,500}\right)^2 \times 18.1 \times 12]$ = (12.1) + (48.3) + (217.2) = 277.6 kWh Total energy loss per annum = (76.8 +277.6) x 365 = 1,29,356 kWh Annual cost of energy losses = Rs 6 x 129356 kWh = Rs. 7,76,136………… (3 Marks) **Transformer 2** Energy loss per day due to iron loss = 24 x 2.7 = 64.8 kWh Energy loss per day due to copper loss = $[\left(\frac{500}{1,500}\right)^2 \times 19.8 \times 6] + [\left(\frac{1,000}{1,500}\right)^2 \times 19.8 \times 6] + [\left(\frac{1,500}{1,500}\right)^2 \times 19.8 \times 12]$ = (13.2) + (52.3) + (237.6) = 303 kWh Total energy loss per annum = (64.8 + 303) x 365 = 1,34,247 kWh Annual cost of energy losses = Rs.6 x 1,34,247 = Rs. 8,05,482… (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 8,05,482 - Rs 7,76,136) = Rs 29,346 Pay Back of additional investment = (25000 / 29,346) = around 10 months = 0.85 Yrs 4 Marks

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