

**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 **9** 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 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
2.	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>
3.	The unit of specific humidity of air is: a) <u>grams moisture/kg of dry air</u> b) moisture percentage in air c) grams moisture/kg of air d) percentage
4.	The percentage reduction in distribution losses when tail end power factor raised from 0.85 to 0.95 is a) 10.1% b) <u>19.9%</u> c) 71% d) 84%
5.	The nomenclature T2, T5, T8 and T12 for fluorescent lamps are categorized based on a) <u>diameter of the tube</u> b) length of the tube c) both diameter and length of the tube d) power consumption

17.	If the observed temperature in air receiver is higher than ambient air temperature the correction factor for free air delivery will be: a) <u>less than one</u> b) greater than one c) equal to one d) equal to zero
18.	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) <u>34 kW</u> b) 37.8 kW c) 0.36 kW d) none of the above
19.	Higher COP can be achieved with_____. a) lower evaporator temperature and higher condenser temperature b) <u>higher evaporator temperature and Lower condenser temperature</u> c) higher evaporator temperature and higher condenser temperature d) lower evaporator temperature and Lower condenser temperature
20.	Friction losses in a pumping system is a) inversely proportional to flow b) inversely proportional to cube of flow c) <u>proportional to square of flow</u> d) inversely proportional square of flow
21.	Calculate the density of air at 11400 mmWC absolute pressure and 65°C. (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) <u>1.15 kg/m³</u> d) none of the above
22.	A spark ignition engine is used for firing which type of fuels: a) high speed diesel b) light diesel oil c) <u>natural gas</u> d) furnace oil
23.	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) <u>10.75</u> b) 0.09 c) 43 d) data insufficient
24.	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) <u>265 kVA</u> c) 170 kVA d) none of the above
25.	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) <u>85.0%</u> b) 94.5% c) 89.9% d) 88.2%
26.	Which of the following is not a part of vapour compression refrigeration cycle a) compressor b) evaporator c) condenser d) <u>absorber</u>
27.	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) <u>faulty consumer service meters</u> d) undersize conductors
28.	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
29.	What is the function of drift eliminators in cooling towers a) maximize water and air contact b) <u>capture 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
30.	Time of the Day metering (TOD) is a way to a) <u>reduce the peak demand of the distribution company</u> b) increase the revenue of the distribution company c) increase the peak demand d) increase the maximum demand in a industry
31.	The purpose of inter-cooling in a multistage compressor is to a) remove the moisture in the air b) <u>reduce the work of compression</u> c) separate moisture and oil vapour d) none of the above
32.	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) <u>20.41</u> c) 10 d) none of these
33.	The fan system resistance is predominately due to a) more bends used in the duct b) more equipments in the system c) <u>volume of air handled</u> d) density of air
34.	The components of two part tariff structure for HT & EHT category consumers are a) <u>one part for capacity(or demand) drawn and second part for actual energy drawn</u> 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
35.	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) <u>3420 watt</u> d) 13500 watts
36.	The percentage imbalance when line-line voltages are 415 V, 418 V and 408 V is a) <u>1.047%</u> b) 0.32% c) 1.44% d) none of the above
37.	Slip power recovery system is applicable in case of a) squirrel cage induction motor b) <u>wound rotor motor</u> c) synchronous motor d) DC shunt motor
38.	Rotating magnetic field is produced in a _____ a) single- phase induction motor b) <u>three- phase induction motor</u> c) DC series motor d) all of the above

39.	Power factor is highest in case of a) sodium vapour lamps b) mercury vapour lamps c) fluorescent lamps <u>d) incandescent lamps</u>
40.	Power factor Improvement will result in a) reduction in active power b) reduction in active current <u>c) reduction in reactive power</u> d) all the above
41.	Motor efficiency will be improved by <u>a) reducing the slip</u> b) increasing the slip c) reducing the diameter of the motor d) decreasing the length of the motor
42.	In a large compressed air system, about 70% to 80% of moisture in the compressed air is removed at the a) air dryer <u>b) after cooler</u> c) air receiver d) inter cooler
43.	Illuminance of a surface is expressed in a) radians <u>b) lux</u> c) lumens d) LPD
44.	If two identical pumps operate in series, then the combined shutoff head is a) it does not affect head b) more than double <u>c) doubled</u> d) less than double
45.	If EER of One Ton Split AC is 3.5, what is its power rating? <u>a) 1.0 kW</u> b) 1.5 kW c) 0.8 kW d) None of the above
46.	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 <u>d) reducing dry bulb temperature and increasing specific humidity</u>
47.	Flow control by damper operation in fan system will a) increase energy consumption <u>b) reduce energy consumption</u> c) reduce system resistance d) none of the above
48.	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 % <u>c) 24%</u> d) 34 %
49.	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 <u>c) low voltage</u> d) low current
50.	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%
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..... **End of Section – I**

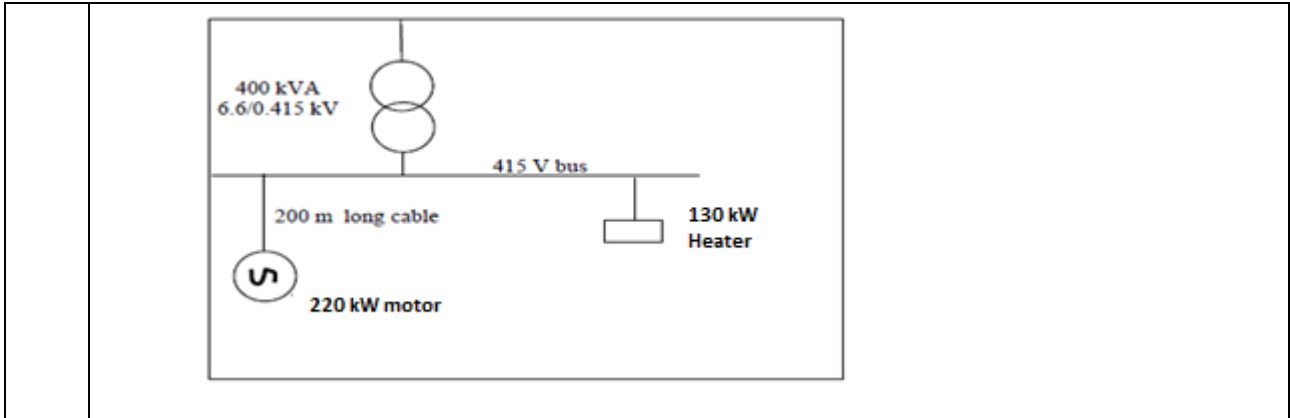
Section – II: SHORT DESCRIPTIVE QUESTIONS

Marks: 8 x 5 = 40

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

S-1	<p>During an energy audit of a power plant cooling tower, the following observations were made.</p> <ul style="list-style-type: none"> • Power plant generation = 500 MW • Circulation rate = 68155 m³/hr • Cooling tower range = 9.5°C • Power plant design COC value = 3.2°C <p>As an auditor find out</p> <ul style="list-style-type: none"> a) The total water consumption per hour, b) Specific water consumption in m³/MW generation. <p>The plant is pursuing an up-gradation treatment plan to increase COC to 6.0.</p> <ul style="list-style-type: none"> c) What would be the potential water savings in m³/hr and m³/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 * 68155 * (9.5) * 1.8	990.6	m ³ /hr	0.5 mark
	2	Blow-down loss	Evaporation loss / (COC - 1)	990.6 / (3.2 - 1)	450.3	m ³ /hr	0.5 mark
	3	Total as run hourly consumption	S.No 1 + S.No 2	(990.6 + 450.3)	1440.9	m ³ /hr	0.5 mark
	4	Specific water consumption	S.No 3 / 785	(1440.9 / 500)	2.88	m ³ /MW	0.5 mark
	5	Blow down at improved COC of 6.0	Evaporation loss / (COC - 1)	(990.6 / (6 - 1))	198.12	m ³ /hr	0.5 mark
	6	Total water consumption at improved COC	S.No 1 + S.No 5	(990.6 + 198.12)	1188.72	m ³ /hr	0.5 mark
	7	Specific water consumption at improved COC	S.No 6 / 500	(1188.72 / 500)	2.37	m ³ /MW	0.5 mark
	8	Total water saving per hour	S.No 3 - S.No 6	(1440.9 - 1188.72)	252.18	m ³ /hr	0.5 mark
	9	Water saving/MW	S.No 8 / 500	(252.18 / 500)	0.504	m ³ /MW	1 mark

	<table border="1"> <tr> <td></td> <td>generation</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </table>		generation										
	generation												
S-2	<p>Explain with equation for COP_{Carnot} that:</p> <p>(a) higher COP_{Carnot} is achieved with higher evaporator temperature and lower condenser temperature.</p> <p>(b) COP_{Carnot} does not take into account the type of compressor</p> <p>(c) How is the COP normally used in the industry given?</p>												
	<p>Ans:</p> <p>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 T_e and condenser temperature T_c with COP being given as: $COP_{Carnot} = T_e / (T_c - T_e)$. 2 mark</p> <p>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 mark</p> <p>c) Hence the COP normally used in the industry is given by $COP = [\text{Cooling effect (kW)}/\text{Power input to compressor (kW)}]$ where the cooling effect is the difference in enthalpy across the evaporator and expressed as kW 1 mark</p>												
S-3	<p>Define Lux and Luminous efficacy.</p>												
	<p>Ans</p> <p>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)</p> <p>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)</p>												
S-4	<p>The following single line diagram depicts the location of a 130 kW heater load and a 220 kW motor (which is 200 metres away from the 415V, LT bus). The main incoming line power factor of the system is 0.82 lag. Calculate the rating of capacitors to improve PF of main incoming line to 0.95 lag.</p>												



Ans:

Total Inductive load requiring PF compensation=220kW (since the other 130 kW is a resistive load)

..... (1 mark)

Operating PF $\cos \phi_1 = 0.82$ lag.

Desired PF $\cos \phi_2 = 0.95$ lag

kVAr required= $kW((\tan(\cos^{-1}\phi_1)-\tan(\cos^{-1}\phi_2)))$

..... (1 mark)

=220($\tan(\cos^{-1}0.82)-\tan(\cos^{-1}0.95)$)

=220($\tan(34.92)-\tan(18.19)$)

=220(0.698-0.329)

=220(0.369)

=81.2 kVAr

..... (3 marks)

S-5 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

	<ul style="list-style-type: none"> Sun film application <p>Minimize the process heat loads by measures involving TR reduction and refrigeration temperature level reduction</p> <ul style="list-style-type: none"> 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 <p>At refrigeration and AC plant area</p> <ul style="list-style-type: none"> 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 component as per manufacturers guide lines. Ensure adequate quantity of chilled water flows, cooling water flows Avoid by pass flow by closing valves of ideal equipments 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 <p style="text-align: right;">..... (5 marks for relevant points as above)</p>																																				
S-6	<p>The input power to a fan is 40kW for a 3125 Nm³/hr fluid flow. The fan pulley diameter is 375mm. 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.</p>																																				
	<p>Solution:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">1</td> <td style="width: 70%;">Input power to fan kW</td> <td style="width: 25%; text-align: center;">40</td> <td></td> </tr> <tr> <td style="text-align: center;">2</td> <td>Fluid flow Nm³/hr</td> <td style="text-align: center;">3125</td> <td></td> </tr> <tr> <td style="text-align: center;">3</td> <td>Diameter of Fan pulley (mm)</td> <td style="text-align: center;">375</td> <td></td> </tr> <tr> <td style="text-align: center;">4</td> <td>Governing Equation is $N_1 D_1 = N_2 D_2$</td> <td style="text-align: center;">Eqn-1</td> <td style="text-align: center;">1 mark</td> </tr> <tr> <td style="text-align: center;">5</td> <td>$N_2 = 0.85 N_1$</td> <td style="text-align: center;">given</td> <td></td> </tr> <tr> <td style="text-align: center;">6</td> <td>From Eqn-1 $D_2 = (D_1) * (N_1 / N_2); = (375) * (N_1 / 0.85 N_1)$</td> <td style="text-align: center;">441.2mm</td> <td style="text-align: center;">2 marks</td> </tr> <tr> <td style="text-align: center;">7</td> <td>$(KW_1 / KW_2) = (N_1^3 / N_2^3);$ Hence, $KW_2 = (N_2 / N_1)^3 * (KW_1) = (0.85 N_1 / N_1)^3 * (40)$</td> <td style="text-align: center;">24.6KW</td> <td style="text-align: center;">2 marks</td> </tr> <tr> <td colspan="3">So Power requirement for fan will be 24.6 kW.</td> <td></td> </tr> <tr> <td colspan="3">Fan pulley to be changed to 441.2 mm diameter.</td> <td></td> </tr> </table>	1	Input power to fan kW	40		2	Fluid flow Nm ³ /hr	3125		3	Diameter of Fan pulley (mm)	375		4	Governing Equation is $N_1 D_1 = N_2 D_2$	Eqn-1	1 mark	5	$N_2 = 0.85 N_1$	given		6	From Eqn-1 $D_2 = (D_1) * (N_1 / N_2); = (375) * (N_1 / 0.85 N_1)$	441.2mm	2 marks	7	$(KW_1 / KW_2) = (N_1^3 / N_2^3);$ Hence, $KW_2 = (N_2 / N_1)^3 * (KW_1) = (0.85 N_1 / N_1)^3 * (40)$	24.6KW	2 marks	So Power requirement for fan will be 24.6 kW.				Fan pulley to be changed to 441.2 mm diameter.			
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S-7	<p>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 3.8 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</p>																																				

	<p>indicated that the waste heat recovery potential is 1.98×10^5 kCal/hr at the existing engine exhaust gas temperature of 483°C.</p> <p>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 °C.</p>																																																
	<p>Solution:</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%;">1</td> <td style="width: 70%;">Rated kVA of Diesel Generator</td> <td style="width: 15%;">1000</td> <td rowspan="4" style="width: 10%; text-align: center; vertical-align: middle;">0.5 mark</td> </tr> <tr> <td>2</td> <td>Rated kW @ 0.8 PF</td> <td>800</td> </tr> <tr> <td>3</td> <td>Specific fuel consumption (kwh/lts)</td> <td>3.8</td> </tr> <tr> <td>4</td> <td>Specific gravity of fuel oil</td> <td>0.86</td> </tr> <tr> <td>5</td> <td>Oil consumption at full load in kg/hr($(2 \times 4)/3$) ($800/3.8$)\times 0.86</td> <td>181</td> <td style="text-align: center; vertical-align: middle;">1 mark</td> </tr> <tr> <td>6</td> <td>Air supplied per kg of fuel (kg)</td> <td>14</td> <td></td> </tr> <tr> <td>7</td> <td>Mass of flue gas (14+1)</td> <td>15</td> <td></td> </tr> <tr> <td>8</td> <td>Mass of flue gas kg per hour (7×5) (15\times 181)</td> <td>2715</td> <td style="text-align: center; vertical-align: middle;">1 mark</td> </tr> <tr> <td>9</td> <td>Waste heat recovery potential kCal/hr</td> <td style="color: red;">198000</td> <td></td> </tr> <tr> <td>10</td> <td>Delta T across waste heat recovery system (Heat kCal/hr)/(mass of flue gas kg/hr\times specific heat, kcal/kg°C) ($198000/(2715 \times 0.25)$)</td> <td style="color: red;">291.71</td> <td style="text-align: center; vertical-align: middle;">1.5 mark</td> </tr> <tr> <td>11</td> <td>Present Flue gas temp. or temp. before waste heat recovery system</td> <td>483</td> <td></td> </tr> <tr> <td>12</td> <td>Exit flue gas temp. after waste heat recovery system (483 – 291.71)</td> <td style="color: red;">191.29</td> <td style="text-align: center; vertical-align: middle;">1 mark</td> </tr> </table>				1	Rated kVA of Diesel Generator	1000	0.5 mark	2	Rated kW @ 0.8 PF	800	3	Specific fuel consumption (kwh/lts)	3.8	4	Specific gravity of fuel oil	0.86	5	Oil consumption at full load in kg/hr($(2 \times 4)/3$) ($800/3.8$) \times 0.86	181	1 mark	6	Air supplied per kg of fuel (kg)	14		7	Mass of flue gas (14+1)	15		8	Mass of flue gas kg per hour (7×5) (15 \times 181)	2715	1 mark	9	Waste heat recovery potential kCal/hr	198000		10	Delta T across waste heat recovery system (Heat kCal/hr)/(mass of flue gas kg/hr \times specific heat, kcal/kg°C) ($198000/(2715 \times 0.25)$)	291.71	1.5 mark	11	Present Flue gas temp. or temp. before waste heat recovery system	483		12	Exit flue gas temp. after waste heat recovery system (483 – 291.71)	191.29	1 mark
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S-8	<p>The total system resistance of a piping loop is 60 meters and the static head is 20 meters at designed water flow. Calculate the system resistance offered at 85%, 65% and 35% of water flow</p>																																																
	<p>Solution:</p> <p>Total System Resistance of piping loop: 60m Static Head :20 m So, Dynamic Head at designed water flow: 40 m</p> <p style="text-align: right;">.....1 mark</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;">Sl. No.</th> <th style="width: 15%;">Flow%</th> <th style="width: 25%;">Dynamic Head (m) = $40 \times (\%flow)^2$</th> <th style="width: 15%;">Static Head (m)</th> <th style="width: 35%;">Total Resistance (m)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>85.0%</td> <td>28.9</td> <td>20</td> <td>48.9</td> </tr> <tr> <td>2</td> <td>65.0%</td> <td>16.9</td> <td>20</td> <td>36.9</td> </tr> <tr> <td>3</td> <td>35.0%</td> <td>4.9</td> <td>20</td> <td>24.9</td> </tr> </tbody> </table> <p style="text-align: right;">.....4 marks</p>				Sl. No.	Flow%	Dynamic Head (m) = $40 \times (\%flow)^2$	Static Head (m)	Total Resistance (m)	1	85.0%	28.9	20	48.9	2	65.0%	16.9	20	36.9	3	35.0%	4.9	20	24.9																									
Sl. No.	Flow%	Dynamic Head (m) = $40 \times (\%flow)^2$	Static Head (m)	Total Resistance (m)																																													
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..... **End of Section - II**

Section – III: LONG DESCRIPTIVE QUESTIONS

Marks: 6 x 10 = 60

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

L-1	<p>a) List five disadvantages of low Power Factor ?</p> <p>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 4 lakhs, calculate the annual cost saving potential if power factor is improved to unity from the current level.</p>
	<p>Answer : (Any five -1 mark each)</p> <p>a) Disadvantages of low power factor are</p> <ol style="list-style-type: none"> 1.) Large Line Losses (Copper Losses): 2.) Large kVA rating and Size of Electrical Equipment: 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 <p>b)</p> <p>Minimum PF required = 0.9 Present penalty = 1.00 % energy bill 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 = 4 lakh x 9.5% = Rs.38000 (2 marks) Annual cost Reduction = 38000x12 = Rs.456000 (1 mark)</p>
L-2	<p>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 is 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 8°C range, calculate the water flow in cooling tower. The design approach temperature of the CT is 5°C.</p>
	<p>Ans. Condenser load = 7 MW Steam rate for condenser = 5 kg/KW</p> <p>Total steam required for condenser power = 7000 X 5 = 35000 kg/hr. 2 marks</p> <p>Condenser heat load = 35000 x 550 = 19250000 kcal/hr. 2 marks</p> <p>Heat load of VAM = 1100 x 127 x 60 = 8382000 kcal/hr. 2 marks</p>

	<p>Total heat load = $19250000 + 8382000 = 27632000$ kcal/hr. 2 marks</p> <p>Range of tower = 8 deg C</p> <p>Cooling water Flow required=$27632000/8=3454000$ lts or 3454 m³. 2 marks</p>																						
L-3	<p>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 25.</p> <p>b) Air at 30,000 m³/hr and at 1.2 kg/m³ 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 26.5 kW with an efficiency of 90%, find out the kW/TR of the refrigeration system. (1 J = 4.18 Cal.).</p>																						
	<p>Solution:</p> <p>a) Ventilation Rate:</p> <table border="1" style="margin-left: 40px; border-collapse: collapse;"> <tr> <td style="padding: 2px;">Room Length (m)</td> <td style="text-align: center; padding: 2px;">20</td> </tr> <tr> <td style="padding: 2px;">Room Height (m)</td> <td style="text-align: center; padding: 2px;">15</td> </tr> <tr> <td style="padding: 2px;">Room Width (m)</td> <td style="text-align: center; padding: 2px;">10.5</td> </tr> <tr> <td style="padding: 2px;">Air Changes per Hr (ACH)</td> <td style="text-align: center; padding: 2px;">25</td> </tr> <tr> <td style="padding: 2px;">ventilation rate (m³/Hr) = Length (m) * Height (m) * Width (m) * ACH</td> <td style="text-align: center; padding: 2px;">78750</td> </tr> </table> <p style="text-align: right; margin-right: 20px;">..... (5 marks)</p> <p>b)</p> <table style="margin-left: 40px; width: 80%;"> <tr> <td style="padding: 5px;">Refrigeration tonnes</td> <td style="padding: 5px;">$Q \times \rho \times (h_2 - h_1)$ $30000 \times 1.2 \times 2.38$ kcal/kg 85680 kcal/hr</td> <td style="text-align: right; padding: 5px;">..... (2 marks)</td> </tr> <tr> <td style="padding: 5px;">TR</td> <td style="padding: 5px;">$85680 / 3024$ 28.3 TR</td> <td style="text-align: right; padding: 5px;">.....(1 mark)</td> </tr> <tr> <td style="padding: 5px;">Power input to the compressor</td> <td style="padding: 5px;">$26.5 \times 0.9 = 23.85$ kW</td> <td style="text-align: right; padding: 5px;">.....(1 mark)</td> </tr> <tr> <td style="padding: 5px;">kW/TR</td> <td style="padding: 5px;">$28.3 / 23.85 = 1.19$</td> <td style="text-align: right; padding: 5px;">.....(1 mark)</td> </tr> </table>	Room Length (m)	20	Room Height (m)	15	Room Width (m)	10.5	Air Changes per Hr (ACH)	25	ventilation rate (m ³ /Hr) = Length (m) * Height (m) * Width (m) * ACH	78750	Refrigeration tonnes	$Q \times \rho \times (h_2 - h_1)$ $30000 \times 1.2 \times 2.38$ kcal/kg 85680 kcal/hr (2 marks)	TR	$85680 / 3024$ 28.3 TR(1 mark)	Power input to the compressor	$26.5 \times 0.9 = 23.85$ kW(1 mark)	kW/TR	$28.3 / 23.85 = 1.19$(1 mark)
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L-4	<p>In a dairy 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/cm² (a). The installed water flow meter at the common header during an energy audit reads the following:</p> <table border="1" style="margin-left: auto; margin-right: auto; border-collapse: collapse;"> <tr> <td style="padding: 5px;">Operating Pump No.</td> <td style="padding: 5px;">Flow Rate (m³/hr)</td> </tr> <tr> <td style="padding: 5px;">Pump No 1 & 2</td> <td style="text-align: center; padding: 5px;">525</td> </tr> </table>	Operating Pump No.	Flow Rate (m ³ /hr)	Pump No 1 & 2	525																		
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<p>The power drawn by motors of cooling water pump 1, 2 & 3 are 30 kW, 33 kW & 31 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:</p> <p>i) Individual pump efficiencies ii) Specific energy consumption (kWh/m³) iii) Which is the best operating pump combination</p>																														
<p>Solution:</p> <p>Let flow of pump 1,2 &3 be X, Y and Z respectively.</p> <p>From given:</p> <p>$X + Y = 525$ -----(1) $Y + Z = 555$------(2) $X + Z = 540$ -----(3)</p> <p>Subtracting eqn (1) from eqn (2):</p> <p>$Z - X = 30$ -----(4)</p> <p>Adding eqn (3) and eqn (4):</p> <p>$2Z = 570$ $Z = 285$</p> <p>Putting Z value in eqn (2) and (3):</p> <p>$Y = 270$ and $X = 255$</p> <p>Therefore, individual pump flow rates are: 255 m³/hr, 270m³/hr and 285 m³/hr respectively.</p> <p style="text-align: right;">.... (3 marks)</p>																														
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L-5	<p>Compare the performance of centrifugal chiller with vapour absorption chiller using the data given below:</p> <table border="1"> <thead> <tr> <th>Sl. No.</th> <th>Parameter</th> <th>Centrifugal Chiller</th> <th>VAM</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Chilled water flow (m³/h)</td> <td>192</td> <td>183</td> </tr> <tr> <td>2</td> <td>Condenser water flow (m³/h)</td> <td>245</td> <td>360</td> </tr> <tr> <td>3</td> <td>Chiller inlet water temperature (°C)</td> <td>13</td> <td>14.5</td> </tr> <tr> <td>4</td> <td>Condenser water inlet temperature (°C)</td> <td>28</td> <td>32</td> </tr> <tr> <td>5</td> <td>Chiller outlet water temperature (°C)</td> <td>7.8</td> <td>9.2</td> </tr> <tr> <td>6</td> <td>Condenser water outlet temperature (°C)</td> <td>36.2</td> <td>40.7</td> </tr> <tr> <td>7</td> <td>Chilled water pump consumption (kW)</td> <td>32</td> <td>31</td> </tr> <tr> <td>8</td> <td>Condenser water pump consumption (kW)</td> <td>38</td> <td>52</td> </tr> <tr> <td>9</td> <td>Cooling tower fan consumption (kW)</td> <td>9</td> <td>22</td> </tr> </tbody> </table> <p>If the compressor of centrifugal chiller consumes 220 kW, the steam consumption for VAM is 1620 kg/Hr. calculate the following:</p> <ul style="list-style-type: none"> 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.5.0/kWh and steam cost is Rs.0.35/kg compare the operating cost for both systems. 	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 (°C)	13	14.5	4	Condenser water inlet temperature (°C)	28	32	5	Chiller outlet water temperature (°C)	7.8	9.2	6	Condenser water outlet temperature (°C)	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
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1	Refrigeration load delivered (TR) = Mass of Chilled water flow x Specific heat * Delta T of Chilled water = [Sl. No.1 m ³ /hr * 1000kg/m ³ * 1	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	664.35	1035.71	2 marks
3	Auxiliary Power Consumption (kW) =	79	105	2 marks
4	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
5	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
6	Operating Energy Cost per Hour of Operation	Rs. 1420/- (284 * 5 = Rs. 1420/-)	Rs 1092/- (105 * 5 = Rs. 525/- plus 1620 * 0.35 = Rs. 1092/-)	2 marks
L-6	<p>a) In a chemical industry, cooling water of 9000 m³/hr and 6000 m³/hr from two independent heat exchangers with temperature of 41°C and 52°C respectively are fed to one cooling tower after proper mixing at top basin. If measured heat rejection by the cooling tower is 45000TR, calculate effectiveness and evaporation loss of the cooling tower at 32°C WBT.</p> <p>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. The 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 = 90% (neglect density correction)</p>			

Solution:

a)

Sl. No.	Particulars	Stream 1	Stream 2	
1	Flow Rate (m ³ /hr)	9000	6000	
2	Temp. °C	41	52	
3	Mix. Flow Rate (m ³ /Hr) (Sl.1 +2)	15000		
4	Mix. Hot Water Temp. °C [(Flow1 * Temp. 1) + (Flow 2 *Temp. 2)]/ (Flow1 + Flow 2)	45.4		1 mark
5	Heat Rejection (TR)	45000		
6	Range of Cooling Tower °C: (Heat Rejection TR * 3024) / (Flow M ³ /hr * 1000)	9.072		1 mark
7	WBT °C	32		
8	Cold Water Temp. °C (Mix. Hot Water Temp. – Range)	36.328		0.5 mark
9	Approach °C (Cold Water Temp. – WBT)	4.328		0.5 mark
10	Effectiveness (Range/ (Range + Approach))	67.7		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)	0.25	
2	Avg. velocity (m/s)	28	
3	Air Flow (m ³ /s) (Sl. 1* Sl. 2)	7	1 mark
4	Suction static Pr. (mmWC)	-20	
5	Discharge Static Pr. (mmWC)	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 90%)	6.29	1 mark
9	Fan Static Eff. (%) = Air Power*100%/Shaft Input	54.57	1 mark

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