NATIONAL CERTIFICATION EXAMINATION 2005
FOR
ENERGY MANAGERS & ENERGY AUDITORS

Question Papers & Model solutions to the Question Papers

PAPER – 3:	**Energy Efficiency in Electrical Utilities**		
Date: 29.05.2005	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 **65** 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) Put a (√) tick mark in the appropriate box in the answer book

1.	With decrease in design speed of squirrel cage induction motors the required capacitive kVAr for reactive power compensation for the same capacity range will **a) increase**　b) decrease　c) not change　d) none of the above
2.	A six pole induction motor operating at 50 Hz, with 1% slip will run at an actual speed of a) 1000 RPM　b) 1010 RPM　**c) 990 RPM**　d) none of the above
3.	Which of the factors will indicate the performance of a rewound induction motor? a) no load current　b) stator winding resistance c) air gap　**d) all the above**
4.	Which of the following is not a positive displacement compressor a) Roots blower　b) Screw Compressor **c) Centrifugal Compressor**　d) Reciprocating Compressor
5.	If voltage applied to a 415 V rated capacitors drops by 5 %, its VAr output drops by about____. a) 5%　**b) 10%**　c) 19%　d) none of the above

6.	The voltage drops in transmission / distribution line depends on ____. a) reactance and resistance of the line b) current in the line c) length of the line **d) all of the above**
7.	Power factor is the ratio of **a) kW/kVA** b) kVA/kW c) kVAr/kW d) kVAr/kVA
8.	If the reactive power drawn by a particular load is zero, it means the load is operating at a) lagging power factor b) leading power factor **c) unity power factor** d) none of the above
9.	Select the ideal location of installing capacitor banks, which will reduce the distribution loss to the maximum extent. a) main sub-station bus bars **b) motor terminals** c) motor control centre d) distribution transformers
10.	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 at the time of no load test c) lose motor terminal connections **d) very poor power factor as the load is almost reactive**
11.	A battery of two reciprocating 250 cfm belt driven compressors installed in a centralized station, were found to be operating at the same loading period of 60% and unloading period of 40%. The least cost solution to reduce wastage of energy in this case would be a) switching off one compressor **b) reducing appropriately the motors pulley sizes** c) reducing appropriately the compressors pulley sizes d) none of the above
12.	Vertical type reciprocating compressor are used in the cfm capacity range of **a) 50-150** b) 200-500 c) 500-1000 d) 1000 and above
13.	Typical acceptable pressure drop in mains header at the farthest point of an industrial compressed air network is a) 0.5 bar b) 1.0 bar **c) 0.3 bar** d) 0.7bar
14.	For every 4°C rise in the air inlet temperature of an air compressor, the power consumption will normally increase by___ percentage points for the same output. **a) 1** b) 2 c) 3 d) 4
15.	The ratio of current drawn by the induction motor to its rated current does not reflect true loading of the motor at partial loads mainly due to a) increased motor slip **b) decreased operating power factor** c) decreased motor efficiency d) none of the above

16.	The efficiency of backward – inclined fans compared to forward curved fans is__ **a) higher** b) lower c) same d) none of the above
17.	Coefficient of Performance (COP) for a refrigeration compressor is given by **a) Cooling effect (kW) / Power input to compressor (kW)** b) Power input to compressor (kW) / cooling effect (kW) c) Q x C_P x (Ti – To) / 3024 d) none of the above
18.	The refrigeration load in TR when 15 m^3/hr of water is cooled from 21^o C to 15 ^{o} C is about a) 32 b) 7.5 **c) 29.8** d) none of the above
19.	With increase in evaporator temperature in a vapor compression refrigeration system, while maintaining a constant condenser temperature, the specific power consumption of the compressor will a) increase **b) decrease** c) sometime increase and sometime decrease d) remains the same
20.	With increase in condensing temperature in a vapor compression refrigeration system, the specific power consumption of the compressor for a constant evaporator temperature will **a) increases** b) decreases c) sometime increases and sometime decreases d) remains the same
21.	Reducing the fan RPM by 10% decreases the fan power requirement by a) 10% **b) 27%** c) 33% d) none of the above
22.	In centrifugal fans, airflow changes direction a) once **b) twice** c) thrice d) none of the above
23.	The specific ratio as defined by ASME and used in differentiating fans, blowers and compressors, is given by a) suction pressure/ (suction pressure + discharge pressure) b) discharge pressure/ (suction pressure + discharge pressure) **c) discharge pressure/ suction pressure** d) suction pressure/ discharge pressure
24.	A 100 cfm reciprocating compressor was observed to be operating at load - unload pressure setting of 6.0 kg/cm^2g and 7.5 kg/cm^2g respectively. This situation will result in a) increased leakage loss in air distribution system b) increased loading timings of the compressor c) increased energy consumption of the compressor **d) all the above**
25.	_____ fans are known as “non-overloading“ because change in static pressure do not over load the motor a) radial b) foreward- curved **c) backward-inclined** d) tube- axial

26.	If inlet and outlet water temperatures of a cooling tower are 42ºC and 34ºC respectively and atmospheric DBT and WBT are 39 º C and 30 º C respectively, then the approach of cooling tower is a) 3º C b) 4º C c) 5º C d) 8º C
27.	The static pressure of a fan running at 500 RPM is 200 mm wc. If it has to be increased to 250 mmwc then the new speed of the fan would be a) 625 RPM b) 400 RPM c) 1250 RPM d) 750 RPM (One mark was awarded to all, as informed by National Certifying Agency)
28.	Input power to the motor driving a pump is 30 kW. The motor efficiency is 0.9 and pump efficiency is 0.6. The power transmitted to the water is a) 27.0 kW b) 16.2 kW c) 18.0 kW d) none of the above
29.	The operating point in a pumping system is identified by a) point of intersection of system curve and efficiency curve b) point of intersection of pump curve and theoretical power curve c) point of intersection of pump curve and system curve d) none of the above
30.	It is possible to run pumps in parallel provided their_________________ are similar a) suction head b) discharge heads c) closed valve heads d) none of the above
31.	Cycles of concentration in circulating water (C.O.C) is the ratio of a) dissolved solids in circulating water to the dissolved solids in make up water b) dissolved solids in make up water to the dissolved solids in circulating water c) dissolved solids in evaporated water to the dissolved solids in make up water d) none of the above
32.	Small by-pass lines are installed in pumps some times to _____. a) save energy b) control pump delivery head c) prevent pump running at zero flow d) reduce pump power consumption
33.	Which of the following ambient conditions will evaporate minimum amount of water in a cooling tower a) 40ºC DBT and 36ºC WBT b) 38 ºC DBT and 37 ºC WBT c) 35 ºC DBT and 28 ºC WBT d) 35 ºC DBT and 25 ºC WBT
34.	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 = $\frac{\text{Heat load in kCal/ h}}{\text{Water circulation in liters/ h}}$ d) None of the above
35.	Which one from the following types of cooling towers consumes less power? a) Cross-flow splash fill cooling tower b) Counter flow splash fill cooling tower

	c) Counter flow film fill cooling tower d) None of the above
36.	What is the typical frequency of a high frequency electronic ballast? a) 50 Hz b) 50kHz **c) 30 kHz** d) 60 Hz
37.	If voltage is reduced from 230 V to 190 V for a fluorescent tube light, it will result in a) increased power consumption **b) reduced power consumption** c) increased light levels d) no change in power consumption
38.	Which of the following options reduces the electricity consumption in lighting system in a wide spread plant? **a) installing separate lighting transformer and maintaining optimum voltage** b) maintaining 260 V for the lighting circuit with 220 V rated lamps c) replacing 150 W HPSV lamps with 250 W HPMV lamps d) none of the above
39.	Color rendering index of Halogen lamps compared to low pressure sodium vapor lamps is ____. a) poor **b) excellent** c) average d) very poor
40.	One lux is equal to ____. a) one lumen per ft^2 **b) one lumen per m^2** c) one lumen per m^3 d) none of the above
41.	Which of the following losses is the least in DG sets: a) cooling water loss b) exhaust loss c) frictional loss **d) alternator loss**
42.	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
43.	The main precaution to be taken care by the waste heat recovery device manufacturer to prevent the problem in a DG set during operation is: **a) back pressure** b) turbulence of exhaust gases c) over loading of waste heat recovery tubes d) temperature rise
44.	Lower power factor of a DG set demands_____ a) lower excitation currents **b) higher excitation currents** c) no change in excitation currents d) none of the above
45.	Which combination of readings as indicated by the panel mounted instruments of a DG Set would give the indications of proper capacity utilisation of diesel engine and generator a) kW & Voltage b) kVA & kVAr **c) kW & KVA** d) none of the above

46.	Maximum demand controllers are used to a) control the power factor of the plant b) switch off essential loads in a logical sequence **c) switch off non-essential loads in a logical sequence** d) none of the above
47.	Energy savings potential of variable torque applications compared to constant torque application is: **a) higher** b) lower c) equal d) none of the above
48.	Select the feature which does not apply to energy efficient motors by design: a) starting torque for efficient motors may be lower than for standard motors b) energy efficient motors last longer c) energy efficient motors have low slips which results in speeds about 1% higher than standard motors **d) energy efficient motors have high slips which results in speeds about 1% lower than standard motors**
49.	The basic functions of an electronic ballast fitted to a fluorescent tube light exclude one of the following a) to stabilize the gas discharge b) to ignite the tube light c) to supply power to the lamp at very high frequency **d) to supply power to the lamp at supply frequency**
50.	Slip power recovery system is used in a) DC motor b) synchronous motor c) squirrel cage induction motor **d) slipring induction motor**

……. 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. Compute the maximum demand recorded for a plant where the recorded load is as mentioned below in the recording cycle of 30 minutes.

- 500 kVA for 10 minutes
- 300 kVA for 5 minutes
- 50 kVA for 10 minutes
- 400 kVA for 5 minutes

The MD recorder will be computing MD as:

$$\frac{(500 \times 10) + (300 \times 5) + (50 \times 10) + (400 \times 5)}{30} = 300 \text{ kVA}$$

S-2. Briefly explain the impact of power supply quality on the operating performance of induction motors

Motor performance is affected considerably by the quality of input power, that is

- **actual volts and frequency available at motor terminals vis-à-vis rated values**
- **voltage and frequency variations**
- **voltage unbalance across the three phases.**

If voltage supplied is more than rated then (Reverse of below will be the case with under voltage)

1. **Starting torque increases**
2. **% slip reduces**
3. **Full load speed increases**
4. **Efficiency marginally increases at full load but at less than full load the efficiency drops.**
5. **Power factor decreases**
6. **Full load current decreases**
7. **Starting current increases**

If frequency increases (Reverse of below will be the case with under frequency)

1. **Starting torque reduces**
2. **Synchronous speed increases**
3. **Full load speed increases**
4. **Efficiency marginally increases**
5. **Full load current decreases**
6. **Starting current decreases**

S-3 In an engineering industry, while conducting a leakage test in the compressed air system, following data for a reciprocating air compressor was recorded:

Compressor capacity = 50 m^3 per minute
Average load time = 120 seconds
Average unload time = 240 seconds
Find out the leakage quantity in m^3 per day (assume 20 hours per day of operation)

% Leakage in the system

Load time (T)	**:**	**120 seconds**
Un load time (t)	**:**	**240 seconds**
% leakage in the system	**:**	$\frac{T}{(T+t)} x100$
	:	**120 /(120 + 240)**
	:	**33.3 %**
Leakage quantity	**:**	**0.333 x 50**
	:	**16.67 m^3/min X 60 X 20**
	:	**20,000 m^3/ day**

S-4 A process fluid at 23m^3/hr. is flowing in a heat exchanger and is to be cooled from 30^{o}C to 25^{o}C. The fluid specific heat is 0.78 kCal/kg. Find out the chilled water flow rate if the chilled water range across the evaporator is 3^{o}C.

Heat transferred from process fluid	**= 23 x 0.8* x 0.78 x (30 – 25)**
	= 71.76
Chilled water flow rate	**= 71.76 / 3**
	= 23.92 m^3/hr

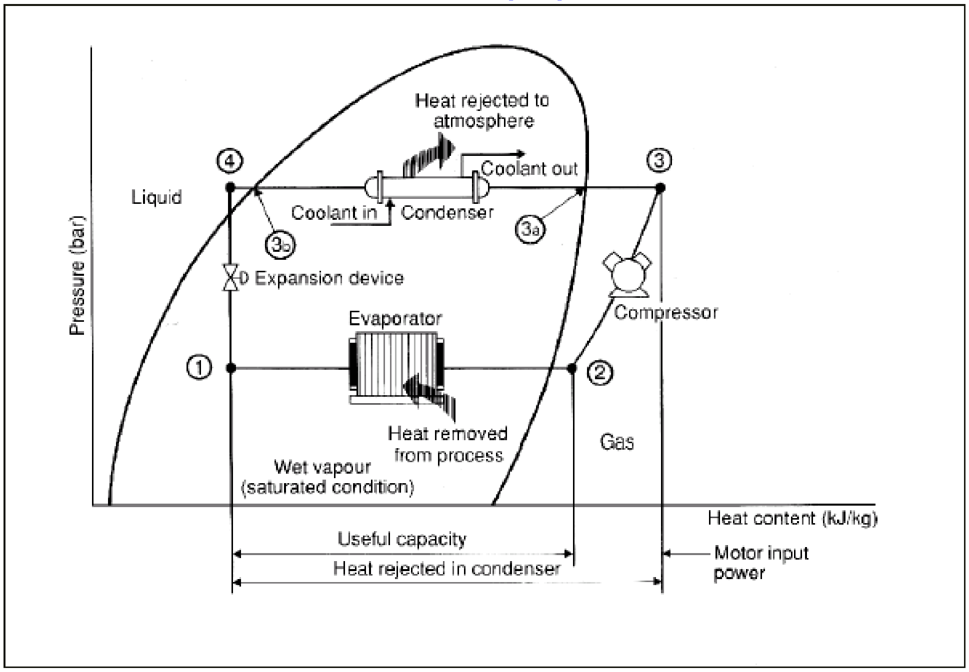
*** This value was not given in the problem. So this figure may vary. Hence full marks were given if the steps are right (as informed by National Certifying Agency).**

S-5 How the heat is absorbed, or removed from a low temperature source and transferred to a high temperature source in a vapour compression system ?

Vapour Compression Refrigeration

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source.

(OR)



1 - 2 Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 - 3 The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy put into the compression process is transferred to the refrigerant.

3 - 4 The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 - 1 The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator

S-6 Find out the blow down rate from the following data: Cooling Water Flow Rate is 700 m^3/hr. The operating range is 7°C. The TDS concentration in circulating water is 1700 ppm and TDS in make up water is 250 ppm.

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 700 x 7

= 7.497 m^3/hr

COC = (TDS in circulating water / TDS in make up water)

= 1700 / 250

= 6.8

Blowdown = Evaporation loss / (COC – 1)

= 7.497 / (6.8 – 1)

= 1.293 m^3/hr

S-7 Briefly explain what is meant by daylight linked controls.

Photoelectric cells can be used either simply to switch lighting on and off, or for dimming.

It is however important to incorporate time delays into the control system to avoid repeated rapid switching caused, for example, by fast moving clouds.

By using an internally mounted photoelectric dimming control system, it is possible to ensure that the sum of daylight and electric lighting always reaches the design level by sensing the total light in the controlled area and adjusting the output of the electric lighting accordingly. If daylight alone is able to meet the design requirements, then the electric lighting can be turned off.

S-8. Explain the term Free Air Delivery.

Free Air Delivery is the **capacity of a compressor at the full rated volume of flow of gas compressed and delivered at conditions of total temperature, total pressure, and composition prevailing at the compressor inlet.**

S-9. A centrifugal pump is pumping 80 m^3/hr of water with a discharge head of 5 kg/cm^2 g and a negative suction head of 5 metres. If the power drawn by the motor is 22 kW, find out the pump efficiency. Assume motor efficiency as 90% and water density as 1000 kg/m^3.

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

Q = 80/3600 m^3/s , h_d - h_s = 50 – (-5) = 55 m

Hydraulic power P_h = (80/3600) x 55 x 1000 x 9.81 / 1000

= 11.99 kW

Pump shaft power = 22 kW x 0.9

= 19.8 kW

Pump efficiency = hydraulic power / pump shaft power

= 11.99 /19.8

= 60.5 %

S-10. A genset is operating at 700 kW loading with 450°C exhaust gas temperature. The DG set generates 8 kg gas/ kWh generated, and specific heat of gas at 0.25 kCal/ kg °C. A heat recovery boiler is installed after which the exhaust gas temperature reduces to 190 °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 80°C.

Quantity of flue gas = 700 x 8

= 5600 kg/hr

Heat recovered = 5600 x 0.25 x (450 – 190)

= 3,64,000 kcal/hr

Quantity of steam generated = 3,64,000 / (650.57 – 80)

= 638 kg/hr

……. 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. (a) A 3 phase, 415 V, 75 kW induction motor is drawing 40 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.

(b) A process plant consumes of 150000 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 = 40 kW (1 – 0.329)

= 26.84 kVAr

Current drawn at 0.7 PF = 40 / $\sqrt{3}$ x 0.415 x 0.7

= 79.5 A

Current drawn at 0.95 PF = 40 / $\sqrt{3}$ x 0.415 x 0.95

= 58.6 A

Reduction in current drawn = 79.5 – 58.6

= 20.9 A

Initial kVA at 0.7 PF = 40 / 0.7

= 57.1 kVA

kVA at 0.95 PF = 40 / 0.95

= 42.1 kVA

Reduction in kVA = 57.1 – 42.1

= 15 kVA

(OR)

Reduction in kVA = $(\sqrt{3}\ VI)_{old} - (\sqrt{3}\ VI)_{new}$
= ($\sqrt{3}$ x 0.415 x 79.5) – ($\sqrt{3}$ x 0.415 x 58.6)
= 57.14 – 42.12
= 15.02 kVA

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

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

= 0.121

= 12.1 %

L-2. a) A V-belt driven reciprocating instrument air compressor was found to be maintaining a distribution system pressure of 7.5 kg/cm^{2}g. 10% of the instrument air was used for control valves installed in a boiler house and requiring 6.5 kg/cm^{2}g, whereas balance 90% of the instrument air was used for other application requiring 4.5 kg/cm^{2}g. What would you like to advise in this situation?

b) An energy auditor observes the following load unload condition on two similar reciprocating air compressor installed in two separate industrial locations (A & B).

	A	B
Load setting (kg/cm^{2}g)	6.5	6.4
Unload setting (kg/cm^{2}g)	7.5	6.8

The energy auditor concludes that at location A, the compressed air system in operation is inefficient. Do you agree with his observation. Justify your reply with atleast two reasons in support of your argument.

1. **Have a separate small compressor operating at 6.5 to 7 kg/cm^{2}g to meet the boiler house control valve requirement near the boiler house.**

2. **The existing compressor can operate with the pressure setting changed to 4.5 to 5 kg/cm^{2}g**

3. **Since 10 % of the load on the existing compressor is transferred to new compressor and with the reduced pressure setting leakage loss will be less. Now this compressor will be unloading for a longer time. Hence reduce motor pulley size to reduce the RPM thus reducing the output and the unloading time.**

b) Energy auditor is right as

a) system A will operate at higher pressure and hence will consume more power

b) leakage loss of the system A will increase due to more header/system pressure

c) Loading time will also be more and hence more unloading power consumption

L-3. List down 10 energy conservation opportunities in fan systems.

1. **Minimising excess air level in combustion systems to reduce FD fan and ID fan load.**
2. **Minimising air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc.**
3. **Avoid cold air in-leaks which increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnace itself.**
4. **Minimizing system resistance and pressure drops by improvements in duct system**
5. **Adopting inlet guide vanes in place of discharge damper control**
6. **Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmission losses**
7. **Option of two speed motors or variable speed drives for variable duty conditions**
8. **Fan speed reduction by pulley dia modifications for derating**
9. **Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy efficient hollow FRP impeller with aerofoil design, in case of axial flow fans**
10. **Impeller derating (by a smaller dia impeller)**
11. **Change of fan assembly as a whole, by a higher efficiency fan**
12. **Change of impeller by a high efficiency impeller along with cone**

L-4. In an air conditioning duct of 0.6 m x 0.6 m size, the average velocity of air measured by vane anemometer is 35 m/s. The static pressure at inlet of the fan is 20 mm WC and at the outlet is 33 mm WC. The motor coupled with fan through belt drive draws 25 A at 410 V at a power factor of 0.82. Find out the efficiency of the fan. Assume motor efficiency = 89% and belt transmission efficiency of 98% (density correction can be neglected).

Ans:

Volume flow rate of the fan, Q = Velocity x Area
= 35 x 0.6 x 0.6
= 12.6 m^3/ Sec

Power input to the fan shaft = Motor input power x motor efficiency x transmission efficiency
= ($\sqrt{3}$ x 0.410 x 25 x 0.82 x 0.89 x 0.98)
= 12.7 kW

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

$$= \frac{12.6 \times 33 - (-20) \times 100}{102 \times 12.7}$$

Fan efficiency = 51.55 %

L -5 An efficiency assessment test was carried out for a standard squirrel cage induction motor in a process plant. The motor specifications are as under.

Motor rated specification: 50 HP/ 415 Volt, 60 Amps, 1475 rpm, 3 phase, delta connected

The following data was collected during the no load test on the motor.

Voltage	= 415 Volts
Current	= 20 Amps
Frequency	= 50 Hz
Stator resistance per phase	= 0.275 Ohms
No load power	= 1110 Watts

Calculate the following:

(i) Iron plus friction and windage losses.
(ii) Stator resistance at 120°C.
(iii) Stator copper loss at operating temperature at 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 power.
(vi) Motor full load efficiency and full load power factor.

(i) Let Iron plus friction and windage loss, P_i + fw

No load power, Pnl = 1110 Watts

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

(This temperature is assumed and hence any temperature used may be given marks)

$= 3 \times (20 / \sqrt{3})^2 \times 0.275$

= 110 Watts

Pi + fw = P_{nl} – Pst.cu

= 1110 – 110

= 1000 W

(ii) Stator Resistance at 120°C,

$$R_{120^0C} = 0.275 \times \frac{120 + 235}{30 + 235}$$

= 0.368 ohms per phase

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

$= 3 \times (60 / \sqrt{3})^2 \times 0.368$

= 1324.88 Watts

(iv) Full load slip

S = (1500 – 1475) / 1500

= 0.0167

Rotor input, Pr = P_{output}/ (1-S)
= 37300 / (1-0.0167)
= 37933.49 Watts

(v) Motor full load input power, P input

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

= 37933.49 + 1324.88 + 1000 + (0.005* × 37300)

= 40444.87 Watts

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

(vi) Motor efficiency at full load

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

= **(37300 / 40444.87) x 100**

= **92.2 %**

Full Load PF = $$\frac{P_{input}}{\sqrt{3} \times V \times I_{fl}}$$

= **(40444.87/ √3 x 415 x 60)**

= **0.938**

……. End of Section – III ……