Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept

1	a)	• Generation • Transmission • Distribution	1 to 2 pts 1 mark, 3 pts 2 marks
1	b)	Frequency: no. of cycles / oscillations of alternating qty. completed in 1 sec. Unit: hertz or cycles / second.	1 mark
		Period: the time for one complete cycle or oscillation, (it is reciprocal of frequency = T = 1/f (sec) if frequency is given in c/s or hertz).	1 mark
1	c)	Voltage: work done in moving unit positive charge between the 2 points. Unit: Volts.	1 mark
		Current: the time rate of flow of charges is current= Q/t. Unit Amperes.	1 mark

1 d) Delta connection: $V_L = V_{Ph}$, and — 1 mark

$I_L = \sqrt{3}\, I_{Ph}$ — 1 mark

1 e) Application of clip on ammeter: used to measure high currents normally greater than about 30 A without inserting the ammeter directly in the series path of the current. The currents are of the order of hundreds to thousands of amperes carried by cables, busbars etc. — 2 marks

1 f) Specifications of DC motor:

Rated Output power in HP/kW;

Rated Input voltage, V.

Rated input current (A) while delivering rated output power at rated speed.

Rated speed (at rated output power with rated input voltage applied)

Type of field winding connection (shunt, series etc.)

Field current in case of shunt type at rated voltage.(A)

Insulation class. Eg. Class B

Rating (duty): continuous, intermittent etc.

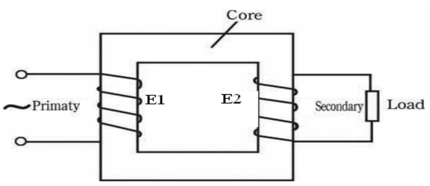
Enclosure: type of enclosure.

Up to 3 pts- ½ mark, 4 to 5 pts 1 mark, 6 pts. and above 2 mark

1 g) Principle of working of single phase transformer:

Mutual induction between two circuits / coils (in ac circuits). — 1 mark

The circuits are linked by a common magnetic field produced in the electromagnetic core by one of the coils/circuits called as the primary winding while the other is the secondary to which the load is connected. The induced emf produced in the secondary winding feeds the load through the terminals of the secondary winding. — 1 mark



(diag. optional)

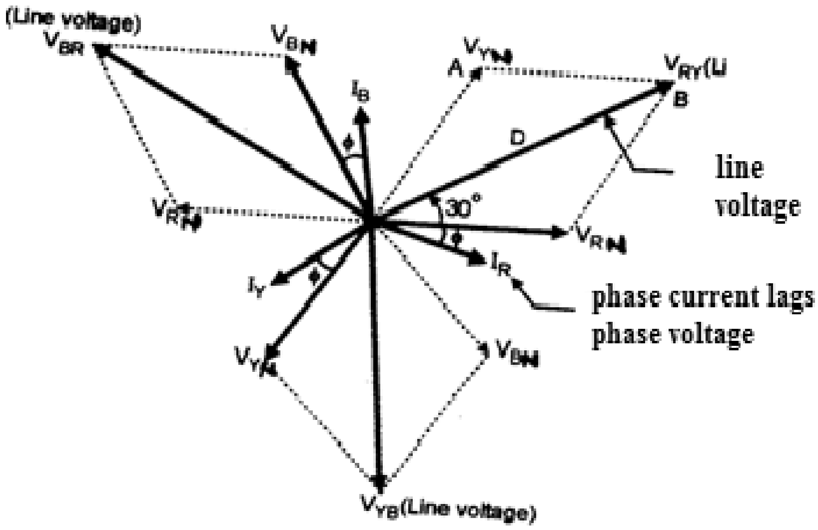
1	h)	Regulation of transformer: The voltage regulation is the percentage of voltage difference between no load and full load voltages of a transformer with respect to its full load voltage.	1 mark
		% Regulation = $[(V_{NL} – V_{FL})/V_{FL}]$ x100. (some students may express this difference as percentage of no load which is acceptable)	1 mark
1	i)	Principle of alternator: A conductor moving relative to a magnetic field has an induced EMF in it (faraday's law) . This emf reverses its polarity (alternates) when it moves under magnetic poles of opposite nature i.e N and S poles.	1 mark 1 mark
1	j)	Direction of three phase induction motor is reversed by interchanging any two phase supply terminals to the motor.	2 marks
1	k)	Classification of drives:	
		Type I: i) individual drives, ii) group drives.	1 mark
		Type II: i) electric drives, ii) mechanical drives.	1 mark
1	m)	MCCB: Moulded Case Circuit Breaker;	1 mark
		ELCB: Earth Leakage Circuit Breaker.	1 mark
1	n)	Types of tariff: 1. Flat rate tariff, 2. Block rate tariff, 3. Two part tariff and 4. Power factor based tariff.	½ mark each max. 2 marks
2	a)	Definition:	
		i) Phase: time related quantity used to state the position an alternating electric quantity such as voltage, current and power with respect to a reference or one another (stated in electrical radians or electrical degrees).	1 mark

ii) Maximum value: it is the magnitude of peak value achieved by an alternating quantity while undergoing one cycle of alternation. 1 mark

iii) Average value: it is the average value of the alternating quantity over half cycle.
It is expressed in terms of the maximum value.
= (2/π) x maximum value (for sinusoidal varying quantity) 1 mark
= 0.637 x Max. value.

iv) RMS value: it is the square root of the mean of squares of the alternating quantity taken over a cycle or half cycle.
$X_{RMS} = \sqrt{[(X_1^2 + X_2^2 + \ldots + X_{(n-1)}^2 + X_n^2)/n]}$ (where X_r = r[th] value of alternating quantity X).
$= X_M/\sqrt{2}$ (for sinusoidal varying quantity) 1 mark

2 b) Consider balanced star connected load and draw phasor diagram:



1 mark

Power in each phase is = $V_{PH}\ I_{PH} \cos Ø$ 1 mark
Power in 3 phases is = $3\ V_{PH}\ I_{PH} \cos Ø$ 1 mark
But here line voltage $V_L = \sqrt{3}\ V_{PH}$ and
line current I_L = phase current I_{PH}
hence three phase power = $\sqrt{3}\ V_L\ I_L \cos Ø$. 1 mark

2 c) List of torques in indicating meters:

1. Deflecting torque: produced in proportion to quantity to be measured. Normally it is the current/voltage proportional to the quantity which is fed to the coil/s when the resulting magnetic field interacts with another magnetic field producing the deflecting torque. $T_D \propto I$ or VI or I^2. — 1 to 2 pts 1 mark, 3 pts 2 marks.
2. Controlling torque: produced by restraining systems (eg. springs in different forms). Opposes the motion of moving member (normally coil producing deflecting torque). Brings the motion to halt when it exerts a torque equal to deflecting torque.
   $T_C \propto$ displacement of moving system or angular displacement.
3. Damping torque: required to bring the moving system to halt as quickly as possible. This torque is present only as long as the system is moving before the deflecting and controlling torques become equal.

2 d) Electrical Insulating materials are classified in to different classes depending on the temperature they can withstand. They are: Y, A, E, B, F, H and C. Class Y has lowest temperature of 90 ^{o}C while class C has 180^{o}C. — 1 mark

List of insulating materials:
Paper, cotton, silk, wood, fibre cellulose, impregnated paper, impregnated cotton, enamels, varnished paper, laminated wood, epoxy resins, polyurethane resins, plastics, mica, glass, ceramics, asbestos, — ½ mark each material any six materials

2 e) Emf equation of transformer:
Consider the sinusoidal varying flux in the core of transformer linking both primary and secondary.

Maximum value of flux is reached in time t= 1/ 4f

Avg. rate of change of flux =Φm/t = Φm/(1/ 4f)= 4Φmf Wb/sec — (1 mark

From faraday's laws of electromagnetic induction

Avg. emf induced in each turn = Avg. rate of change of flux = 4Φmf

Form factor for sinusoidal flux = (RMS value)/(Avg. value) = 1.11

RMS value of emf induced in each turn=1.11 x Avg. value

$= 1.11 \times 4\Phi mf$ Volts. 1 mark

RMS value of emf induced in primary winding,

$=($ RMS emf / turn$) \times N_1$

$E1 = 4.44\ \Phi_m f\ N_1$ volts 1 mark

Similarly, $E2 = 4.44\ \Phi_m f\ N_2$ volts 1 mark)

II[nd] method: OR

$\Phi = \Phi_m \sin\omega t$

According to Faraday's laws of electromagnetic induction;

Instantaneous value of emf/ turn = $- d\Phi/dt$

$= -d/dt\ (\Phi m \sin\omega t)$

$= -\omega\Phi m.\cos\omega t$

$= \omega\Phi m \sin(\omega t - \pi/2)$ volts (1 mark

Maximum value of emf/turn= $\omega\Phi m$

But $\omega = 2\pi f$

Max. value of emf /turn $=2\pi f\ \Phi m$

RMS value of emf /turn = $0.707 \times 2\pi f\ \Phi m$

$= 4.44\Phi mf$ volts 1 mark

RMS value of emf in primary winding

$E_1 = 4.44\Phi m\ f\ N_1$ volts and 1 mark

$E_2 = 4.44\ \Phi m\ f\ N_2$ volts 1 mark)

2 f) Types of lamps:

1. Incandescent lamps: specifications: rated voltage, rated power, lumens, color temp.
2. Fluorescent lamps: rated voltage, rated power, lumens output, color temp.
3. Mercury vapour lamps: high pressure and low pressure, rated voltage, rated power, lumens output, color temp.
4. Sodium vapour lamps: high pressure and low pressure, rated voltage, rated

Any four 1 mark each max 4 marks.

power, lumens output, color temp.

5.Compact fluorescent lamps: rated voltage, rated power, lumens output, power factor.

6.Halogen lamp: rated voltage, rated power, lumens output, color temp.

7.Metal halide lamps: rated voltage, rated power, lumens output, color temp.

8.LED lights: drive current, voltage, power and lumens.

3 a) Definitions:

- Electric power: it is the time rate of work being done in an electric circuit. Given by product of voltage and current. Units: Watts. 1 mark 1 mark
- Electrical energy: it's the energy expended by an electric source by supplying power for a certain time. Given by the product of power and the time for which the power was supplied. Unit: joules, Watt-hour. 1 mark 1 mark

3 b) Series R-L arm of balanced 3 phase delta; $V_{PH} = V_L$ and $I_L = \sqrt{3}\ I_{PH}$.

$R = 10$ ohms. $X_L = 2\pi f\ L = 2\pi \times 50 \times 0.019 = 5.966$ ohms

$Z_{PH} = \sqrt{(R^2 + X_L^2)} = (10^2 + 5.966^2)^{1/2} = 11.64$ ohms.

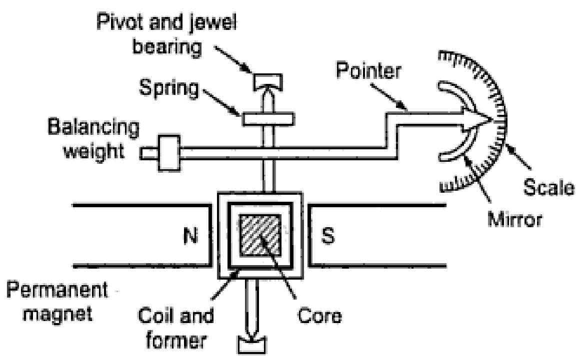
$I_{PH} = V_{PH}/Z_{PH} = 415/11.64 = 35.65$ A., $I_L = \sqrt{3}\ I_{PH} = I_L = \sqrt{3} \times 35.65 = 61.75$ A 1 mark

pf = $\cos Ø = R/Z_{PH} = 10/11.64 = 0.859$ lag. 1 mark

Power input to circuit = $I_L = \sqrt{3}\ V_L\ I_L \cos Ø$ 1 mark

$= \sqrt{3} \times 415 \times 61.75 \times 0.859 = 38132$ W $= 38.13$ kW. 1 mark

3 c) PMMC instrument:



Labeled diag. 4 M, partially labeled (min 6 labels) 3 M, unlabeled 2 M, Incomplete diag. 1 M

3 d) Parts of DC machine:

1. Field system:
- Poles, (provide path for flux, suitable profile at pole faces for armature to cut)
- Windings/coils, create the required MMF and flux for the armature to cut at the pole faces.
- Yoke: provides path for the magnetic flux set up and supports the poles. 3 to 4 parts 1 mark, 5 & more parts 2 marks,

2. Armature system:
- Windings/coils: carry induced /supplied alternating current for generator / motor action.
- Core: provides proper seating arrangement for the windings in the slots.

3. Commutator:
- Rectifies the generated AC to DC in generators.
- Inverts the DC input in motors into AC in motors.

4. Interpoles/commutating poles:
- Ensure sparkles commutation.

5. Brushes and brush holders:
- Provide means to collect (in generators) or supply (in motors) current of the rotating armature windings. 1 function ½ mark, max 2 marks.

6. Bearings:
- Support the armature shaft and ensure minimum friction during rotation.

7. Cooling fan:
- Blows air over the machine during running to maintain its temperature rise in limits.

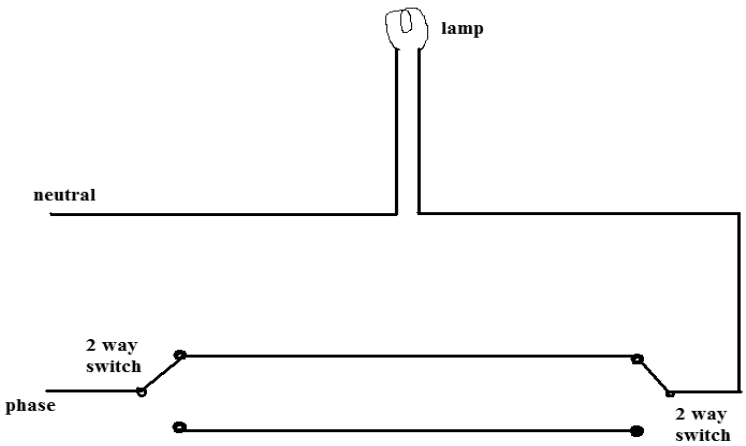
8. Enclosure:
- Protects the internal parts against external physical disturbances depending on the purpose to be served.

3 e)

Sr. No	Two winding transformer	Auto transformer
1	Different primary & secondary winding	primary & secondary on common winding
2	No electrical connection between primary and secondary	Electrical connection between primary and secondary
3	Amount of copper required and weight is more	Amount of copper required and weight is less
4	Size is larger as compared to auto transformer for similar capacity	Size is small as compared to two winding transformer for similar capacity
5	Cost is more	Cost is less
6	More losses hence lower efficiency as compared to auto.	Less losses hence higher efficiency

1 mark each pt. any four pts = 4 mark

3 f) Wiring diagram of 1 lamp control from two pts:



Labeled 4 marks, Unlabeled 3 marks, Incorrect connections no marks.

4 a) $R = 10\ \Omega$, $L = 0.2$ H, $V = 100$ V, $f = 50$ Hz.

ii) Reactance $X_L = 2\pi fL = 2 \times \pi \times 50 \times 0.2 = 62.83\ \Omega$. 1 mark

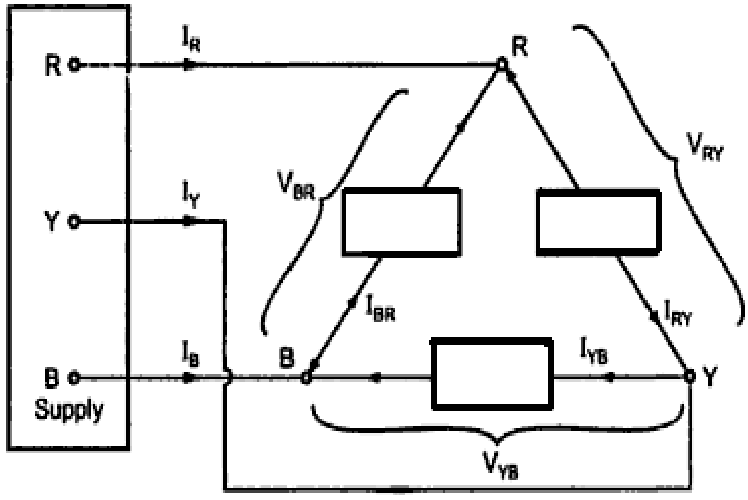
i) Impedance $Z = \sqrt{[R^2 + X_L^2]} = \sqrt{[10^2 + 62.83^2]} = 63.62\ \Omega$. 1 mark

iii) Current $I = V/Z = 100/63.62 = 1.57$ A. 1 mark

iv) Phase angle Ø between current and applied voltage is dependent on the resistance and reactance values,

$Ø = \tan^{-1}(X_L/R) = \tan^{-1}(62.83/10) = 89.95^o$. 1 mark

4 b) 3 phase supply to delta connected load:



Labeled diagram 3 marks, partially labeled 2 marks, unlabeled 1 mark.

Line voltages V_L = Phase voltages V_{PH} = V_{RY}, V_{YB}, and V_{BR},

Phase currents I_{PH} = I_{RY}, I_{YB}, and I_{BR},

Line currents I_L = I_R, I_Y, and I_B,

Power = $\sqrt{3}\ V_L I_L \cos \emptyset$. 1 mark

4 c) Working principle of DC motor:

Current carrying conductor placed in a magnetic field experiences a force given by $F = B\ I\ L \sin \theta$, where B = external magnetic field, I current in conductor, L = length of conductor in magnetic field, θ = physical angle between directions of I and B. 1 mark

Significance of back emf in d.c. motor:-

- As the armature of the DC motor start rotating, the flux which is responsible for their rotation is cut and consequently an e.m.f. is induced in them in accordance with Faraday's law of electromagnetic induction. 1 mark
- This e.m.f. always acts in opposition with the applied voltage (*V*) as per Lenz's law and therefore it is known as back e.m.f. (E_b) or counter e.m.f.
- Since the back e.m.f. opposes the applied voltage across the armature, the

net voltage acting in the armature circuit is the difference between the two (i.e. $V-E_b$). It is, this effective voltage which determines the value of armature current (I_a). 4 — 1 mark

- If R_a is the armature resistance, then from Ohm's law, $I_a = (V-E_b)/R_a$ amperes.

In the running condition, E_b is nearly equal to V. The internal resistance of the armature of a d.c. motor being very low, it is the back e.m.f. which mainly limits the armature current in the running condition of the motor. — 1 mark

4 d) Secondary induced emf = primary voltage (N_2/N_1) = 3000 x 50/500 = 300 V. — 1 mark

Full load primary current I_1 = kVA x 10^3/primary voltage

= 25 x 10^3/3000 = 8.33 A. — 1 mark

Full load secondary current $I_2 = I_1(N_1/N_2)$ = 8.33 x 500/50 = 83.3 A. — 1 mark

Emf equation of transformer E = 4.44 $\varnothing_M$ f N volts.

Taking primary side values 3000 = 4.44 x $\varnothing_M$ x 50 x 500,

$\varnothing_M$ = 3000/(4.44 x 50 x 500) = 0.027 Weber/m^2 or Tesla. — 1 mark

4 e) Enclosures and advantages:

- Open : best cooling by air, no special cooling arrangement required.
- Protected: large ventilation openings in covers, hence good cooling.
- Screen protected: entry of large outer particles not possible.
- Totally enclosed: can be safely used in dusty and dirty atmosphere.
- Flame proof, can be safely used in explosive atmosphere.
- Drip proof: can be used in damp situations where liquids drip from above.
- Splash proof: can be used in situations where liquids (water etc) splash but cannot enter the motor.

½ mark for enclosures any four = 2 marks, ½ mark for advantage any four = 2 marks.

4 f) Earthing is needed for safety of working personnel, safety of animals and property such that any live part touching the body of the equipment must be grounded (connected to zero volts); for protection as under such circumstances the low resistance path results in heavy current drawn from supply which is sensed to trip circuits open or blow fuses. — 2 mark

Earthing is also needed in electrical installations of substations to hold the neutral voltage to very low values so that fault on one phase does not affect the other. (neutral earthing) — 1 mark

Types:

Plate earthing, pipe earthing and earth mat (mesh earthing). — 1 mark

5 a) Applications of three phase transformers:

1. Step up voltage to transmission levels for efficiency of transmission.
2. Step down voltage to distribution levels as required by consumers/loads.
3. Step up or step down as required the voltage for special types of loads such as furnaces, ovens etc.
4. Step up or step down as required the voltage for motional machines such as 22 kV motors etc.

1 mark each, max 4 marks. Other valid applications allowed

5 b) P = 6, f = 50 Hz, N_R = 970 RPM,

N_S = 120f/P = 120 x 50/6 = 1000 RPM. — 1 mark

i) % slip = $[(N_S – N_R)/ N_S]$ x 100 — 1 mark

= [(1000 – 970)/1000] x 100 = 3. — 1 mark

ii) Rotor current frequency

= fractional slip x stator line frequency

= 0.03 x 50 = 1.5 Hz. — 1 mark

5 c) Types of alternators by construction of rotors:

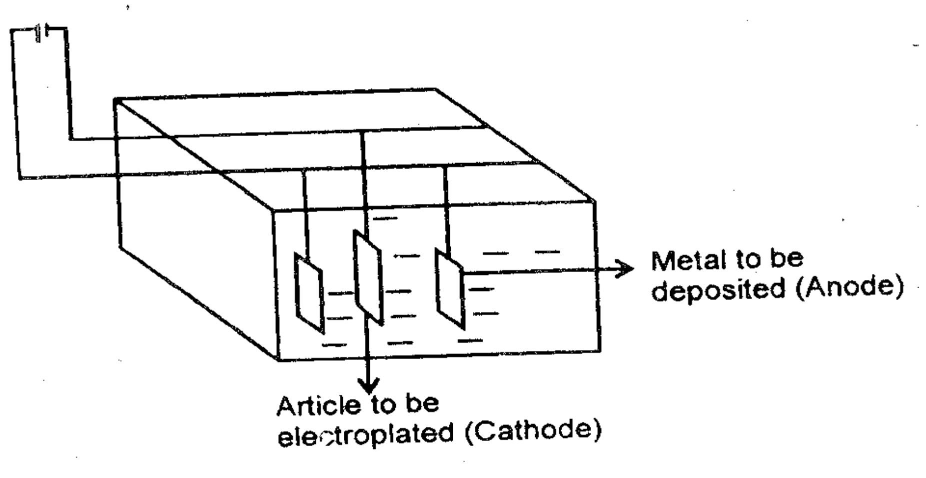
1) Salient pole / projecting pole structure, — 1 mark
2) Non-salient pole / cylindrical rotor. — 1 mark

Alternators used in hydro electric stations are: of the salient pole. 2 marks

5 d) Electrical heating is superior to conventional heating due to following:

1. Very Clean. 1 mark
2. Higher efficiency lesser losses. each point
3. Convenient and user friendly heating systems can be designed for different applications using the different principles of electrical heating. max 4 marks,
4. Fuels not needed, hence fly ash nuisance/disadvantage avoided. Other valid
5. Temperature control is very easy in comparison, quick heating. pts. must be
6. Smaller spaces needed for heat generation and utilization (compact systems), low maintenance required, cheaper. awarded marks.

5 e) Principle of Electroplating:



Diag. 2 marks

- Process of depositing metal on articles for decoration / protective layering using electricity is electroplating. 1 mark
- Electrolysis is used to carry out the coating / deposition as shown in figure.
- Control of current is used to regulate/control of deposition. 1 mark

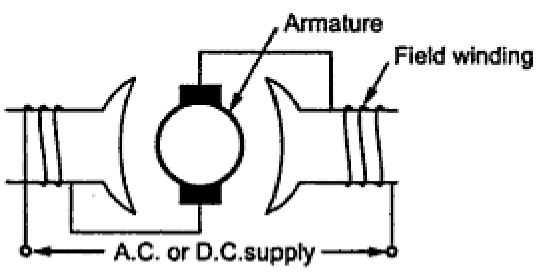
5 f) Methods of energy conservation:

1. Load transformers near the rated value (above 70%)
2. Maintain power factor at unity or nearest to it. 1 mark

3. Use heating machines with proper thermostat control to have the correct temperature; avoid over heating. each pt any 4pts (other pts if valid be awarded marks)
4. Keeping power system losses as low as less than 20%.
5. Use synchronous motors instead of induction motors.
6. For induction motors loaded less than 40 % of their rating use them in star connection.
7. Control illumination levels using low power high lumen lighting devices and combine natural light use.
8. Insulate or plug the heat loss paths properly for boilers etc.
9. Use non-conventional energy sources for daily heating and power needs.

6 a) Universal motor:

- Operating principle is the interaction of the main field and field due to current in the armature conductors to produce force/torque for motion. 1 mark
- The force is directly proportional to the product of main flux and armature current.
- Small motors designed and constructed to operate on either DC or single phase AC supply of same voltage. 1 mark
- Have nearly similar operating characteristics.
- The effect of inductance in AC adversely affects the operating characteristics which can be overcome by compensating winding.
- The armature is similar to that of the DC machine.



1 mark

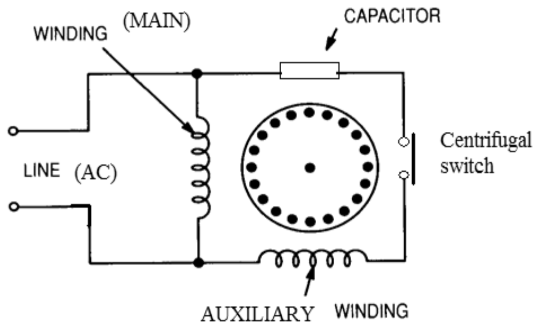
Applications of universal motor:

1) Vacuum cleaners,

2) Mixers, ½ mark
3) Dryers, each, any 2
4) Sewing machines. = 1 mark.

6 b) Working of capacitor start single phase induction motors:

- Have arrangement in the form of two windings placed with axes 90^0 apart in the stator.
- Single phase supply given to these windings results in phase diff. in the currents in these two windings due to the different impedances of the winding circuits.
- Capacitance is added in series to one of the coils (called as starting or auxiliary coil) to create the two currents that result in proportional magnetic fluxes with time phase difference (space phase is already created due to the winding/coil axes relative position) in the air gap resulting in the required starting torque in the required direction. The other coil is called as the main winding. 2 marks
- The centrifugal switch is used to disconnect the starting winding once the motor picks up speed after which the motor continues to run.



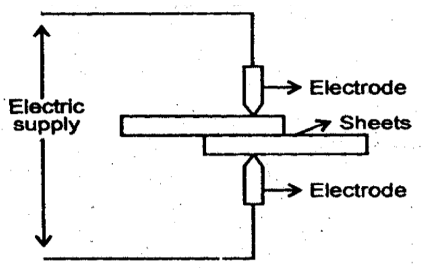
2 marks

6 c) Applications of synchronous motors:

1. Textile mill drives,
2. Paper mill drives,
3. Roller mill drives,
4. Rubber industry drives

1 mark each any other applications if valid be considered

6 d) Electric welding:



Diag. 3 marks

The sheets to be welded are placed between electrodes as shown. The electric supply from the welding transformer passes a heavy current that melts metal at the point of contacts and helps in fusion of the sheets to be welded at that point. 1 mark

6 e) Factors for selection of motors:

1. Availability of type of electric supply / type of industry.
2. Nature of load to be driven: torque/speed requirements of driven load. 1 mark
3. Drive type: group or individual. each Any
4. Speed/torque/output power control needed for motor. four = 4
5. Environment in which to be installed to decide the type of enclosures. marks
6. Efficiency of the various motors suitable for the application.
7. Cost of the various motors suitable for the application.

6 f) Water pumps for irrigation:

- Centrifugal pumps (mono-block), 1 mark
- Submersible pumps, each any
- Positive displacements (diaphragm type) four = 4

Also irrigation pumps include marks

- deep well turbines,
- Submersible and propeller pumps.
- Pumps for sprinkler systems.

Actually, turbine, submersible and propeller pumps are special forms of a centrifugal pump.
