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)	Terminal Voltage:	Supply Voltage:	
	- The voltage available at the terminals of sources which is less than EMF.	- The constant voltage available from electricity supply agencies for connecting to different loads.	1 mark
	- For battery $V_T = E - I r$.	- Supply voltage is specified constant. (230 V, 50 Hz AC).	each pt any 2 pts
	- The terminal voltage changes appreciably with the load.	- It is does not change appreciably with the load.	

1 b) i) Node: A point in electrical circuit at which different branches meet. — 1 mark

ii) Loop: A loop is a set of branches, forming a closed path in a network. — 1 mark

c) Active networks: If a network consists of energy source, then it is called as active network. — 1 mark

Linear networks: - A circuit whose parameters are always constant irrespective of changes in voltage. Or current is known as "Linear network." — 1 mark

1 d) Types of capacitors: — Any 4 types ½ mark each

Air capacitors, Paper capacitors, Mica capacitors, Ceramic capacitors, Polycarbonate capacitors Electrolytic capacitors.

1 e) Applications of electromagnet: — ½ mark each application.

1) As Field and armature in DC Machine.
2) In solenoid valves.
3) In electromechanical relays.
4) In all AC Machines.

1 f) Permeance: It is the property of magnetic circuit due to which it permits the passage of magnetic flux through it and it is reciprocal of reluctance. — 1 mark

Permeance = 1/ Reluctance. Unit: Weber / ampere. — 1 mark

1	g)	Faraday's laws of electromagnetic induction:	
		1st law: When a conductor cuts or is cut by the magnetic flux, an EMF is generated in the conductor.	1 mark
		2nd law: The magnitude of EMF induced in the coil depends on rate of change of flux linking with coil.	1 mark
		$\lvert e \rvert \ \alpha$ (change in flux)/(time in which it occurs)	
1	h)	Dynamically induced emf : in AC Generators, DC Generators.	1 mark
		Statically induced emf: Transformers, Choke coil.	1 mark
1	i)	Electrical Characteristics of battery: 1) Electromotive Force 2) Terminal voltage 3) Internal resistance 4) Ampere-hour capacity 5) Ampere-hour efficiency 6) Watt-hour efficiency	Any four characteristics ½ mark each
1	j)	Types of Batteries:	
		A) Non rechargable batteries e.g. Zinc chloride batteries.	1 mark
		B) Rechargable battries. 1) lead acid batteries. 2) Nickel cadmium batteries. 3) Nickel hydride batteries. 4) Sealed maintenace free batteries.	1 mark
1	k)	Classification of insulating materials: A) Solid: Fibrous, Ceramic, Mica, Glass, Rubber, Resins. B) Liquid: Mineral. Synthetic. Special. C) Gaseous: Air, Hydrogen, Nitrogen, Sulfur-hexafluoride.	1 mark each max 2 marks.

1 l) Types of resistors:

A) Carbon composition: used as potential devider, Radio/TV receivers, Amplifiers. — 1 mark each max 2 marks.

B) Wire wound resitors: used as Zener voltage regulator, Power ampilfiers, Radio/TV receiversm, Low/high frequency applications.

C) Metal film resistors: used for millitary apllications, Modulators, Demodulators.

2 a) Current, I= Power(P) / Voltage(V) = 1000/ 230 = 4.3A. — 1 mark

Resistance, $R = V^2 / P = 230^2 / 1000 = 52.9\ \Omega$ — 1 mark

Energy, E = P (kW) x t (hrs) — 1 mark

= 1 x 20 = 20 kWh. — 1 mark

2 b) $R_{20} = 16.5\ \Omega$ & $R_{55} = 18\ \Omega$

$R_{55} = R_{20}\ [1+ \alpha_{20}\ (55 -20)]$ — 1 mark

Therefore $\alpha_{20} = 2.6 \times 10^{-3} / {}^{O}C$ — 1 mark

$R_0 = R_{20}\ [1+ \alpha_{20}\ (0 -20)] = 16.5[1 + 2.6 \times 10^{-3}(-20)] = 15.64\ \Omega$ — 1 mark

$\alpha_0 = [\ (R_{20} – R_0) / (\ 20 – 0)\ ] / R_0 = 2.74 \times 10^{-3} / {}^{O}C.$ — 1 mark

2 c) Duality between series and parallel DC circuit. :-

Series circuit.	Parallel circuit.	
1) $I_T = I_1 = I_2 = I_3 =$……..	$V_T = V_1 = V_2 = V_3 =$	1 mark
2) $V_T = V_1 + V_2 + V_3 +$…..	$I_T = I_1 + I_2 + I_3 +$……..	1 mark
3) $R_T = R_1 + R_2 + R_3 +$….	$G_T = G_1 + G_2 + G_3 +$…..	1 mark
4) $I_T = V_1 / R_1 = V_2 / R_2 = V_3 / R_3$..	$V_T = I_1/G_1 = I_2 /G_2 = I_3/G_3 =$	1 mark

(some students may state in words the dual quantities which must be awarded marks)

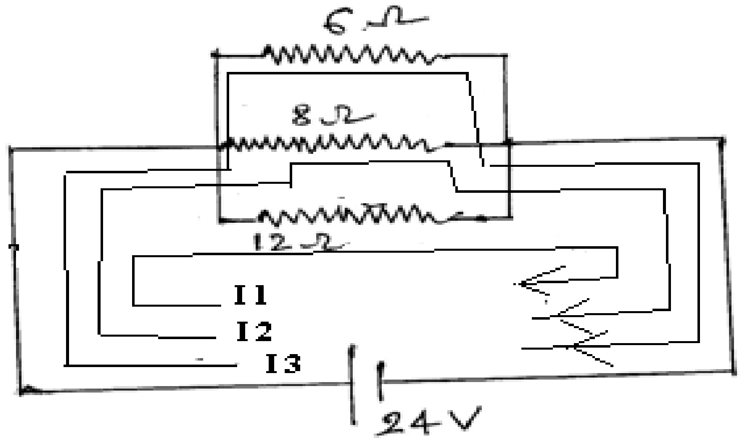
2 d) i) Kirchhoff's current law : - It states that in any electrical network at any node the algebraic sum of current is equal to zero. — 1 mark

i. e. At a node $\sum I = 0$ — 1 mark

ii) Kirchhoff's voltage law : - It states that in algebraic sum of the e.m.f. and the voltage drop (I.R.) across each part of the circuit is zero. 1 mark

i.e. Around aclosed loop $\sum$ e.m.f. + $\sum$ I.R. = 0 1 mark

2 e) Recognise and redraw the circuit as shown, mark the loop currents:



1 mark

Apply KVL to loops 1, 2, 3.

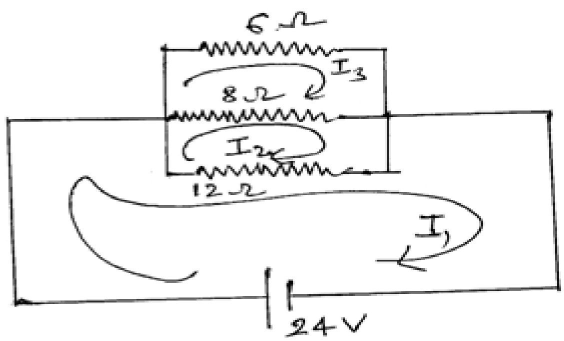
Loop 1, $24 = 12\ I_1$, hence I_1 = current thro 12 ohm = 2 A. 1 mark

Loop 2, $24 = 8\ I_2$, hence I_2 = current thro 8 ohm = 3 A. 1 mark

Loop 3, $24 = 6\ I_3$, hence I_3 = current thro 6 ohm = 4 A. 1 mark

OR

OR



Apply kirchoff's voltage law to loops 1, 2, 3,

Loop 1:

$24 = 12\ I_1 - 12\ I_2 + 0\ I_3$,

$2 = I_1 - I_2 + 0\ I_3$.

Loop 2:

$0 = -12 I_1 + 20 I_2 - 8 I_3,$

$0 = -3 I_1 + 5 I_2 - 2 I_3,$

Loop 3

$0 = 0 I_1 - 8 I_2 + 14 I_3,$

$0 = 0 I_1 - 4 I_2 + 7 I_3.$

Collecting the 3 equations:

$2 = I_1 - I_2 + 0 I_3.$

$0 = -3 I_1 + 5 I_2 - 2 I_3,$

$0 = 0 I_1 - 4 I_2 + 7 I_3.$

Solving them simultaneously:

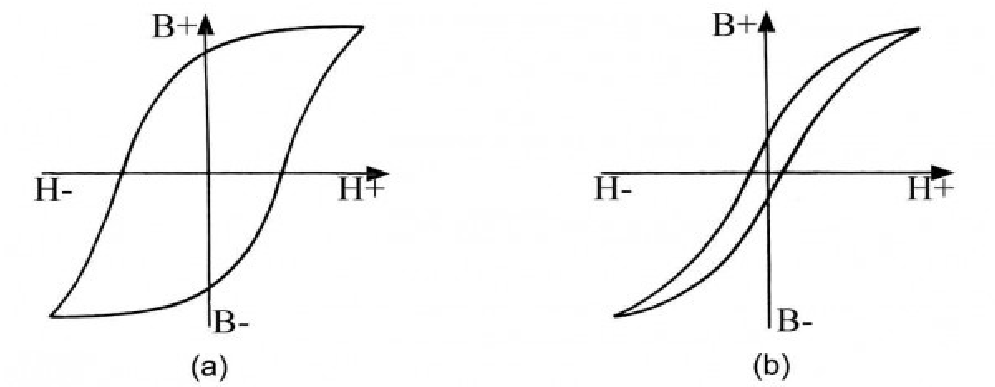
$I_1 = 9$ A, $I_2 = 7$ A, $I_3 = 4$ A. 1 mark

Current in 6 ohms = I_3 = 4 A. 1 mark

Current in 8 ohms = $I_2 - I_3$ = 3 A. 1 mark

Current in 12 ohms = $I_1 - I_2$ = 2 A. 1 mark

2 f)



2 marks

Fig. (a) Shows hysteresis loop for hard steel. Such materials are used for producing permanent magnets. Such a hysteresis loop represents a large residual flux & hence large coercive force. 1 mark

Fig. (b) Shows hysteresis loop for cast steel. Residual flux & coercive force are less. Hence material can be used for making the electromagnets. 1 mark

3 a) Energy stored in Capacitors:

Let C be capacitance of a capacitor in Farad

'*v*' be potential difference across capacitor in volt

Let q be charge on capacitor at a instant — 1 mark

Therefore, Potential, $v = q / C$

The work done in shifting a small charge dq against P. D. of '*v*' volts is

$dW = v \times dq = (q/C) \times dq$. — 1 mark

The work done is stored as potential energy in the electrostatic field by the capacitor.

Therefore, total energy stored by the capacitor — 2 marks

$E = \text{work done } W = \int (q/C)dq = \frac{1}{2} C v^2$ Joules.

3 b) R_C and C are resistance and capacitance of charging.

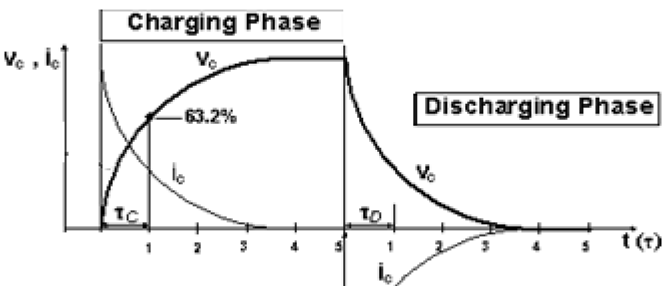
R_O and C are resistance and capacitance of dis-charging.

$\tau_C = R_C \times C$

$v_c = V(1 - e^{-t/\tau_C})$

$i_c = V / R_C \, e^{-t/\tau_C}$

2 marks for correct graphs



$\tau_D = R_0 \times C$

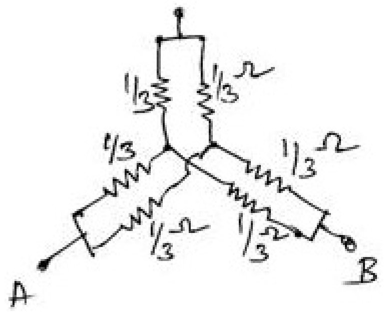
$v_c = V \, e^{-t/\tau_D}$

$i_c = -(V / R_0) \, e^{t/\tau_D}$

2 marks for equation

3 c) Convert both delta networks into equivalent star to get each star arm value as follows $R_1 = R_{12} R_{31}/(R_{12} + R_{23} + R_{31})$ and similarly for other star resistances

$= 1 \times 1(1 + 1 + 1) = 1/3$ ohm. — 1 mark



1 mark

Between A and B we have two branches each containing two 1/3 ohms in series. 1 mark

Hence each branch = (1/3) + (1/3) = 2/3 ohms.

In parallel these 2/3 ohms give equivalent resistance of (2/3)(2/3)/(2/3 + 2/3) 1 mark

= 1/3 ohms.

3 d) Given data : -

$V = 500$ V

$d = 0.5$ mm $= 0.5 \times 10^{-3}$ m

$a = 500$ cm^2 $= 500 \times 10^{-4}$ m^2

$\in r = 1$ for air, $\in o = 8.854 \text{ X } 10^{-12}$ F/m. 1 mark

We have $C = \in o \in r \, A/d$ (F)

$= 8.854 \text{ X } 10^{-12} \text{ X } 1 \text{ X } 500 \text{ X } 10^{-4} / (0.5 \text{ X } 10^{-3})$

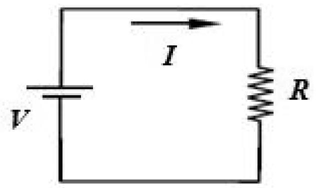
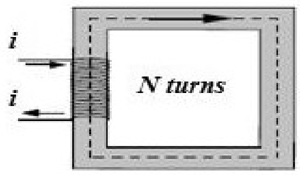
$\therefore C = 8.854 \times 10^{-10}$ F

= 885.4 PF 2 mark

And

Charge on capacitor $Q = CV$

$\therefore Q = 0.4427 \ \mu C$ 1 mark

	Electric circuit:	Magnetic circuit	
3 e) i)			1 mark each pt. max 4 marks. Other pts as electric fields , magnetic field if given must be considered.
ii)	Voltage 'V' (volts)	MMF = Ø S (amperes)	
iii)	Current 'I' (amperes)	Flux 'Ø' (webers)	
iv)	Resistance R = ρl/a ohms.	Reluctance S = l/(μA) amperes/weber	
v)	V = I R (volts)	MMF = Ø S (amperes)	
vi)	Conductance G = 1/R (Siemens)	Permeance P = 1/S (webers/ampere)	

3 f) Important points to be observed during maintenance of battery:

1) Keep the container surface dry.
2) Tighten the terminal connections.
3) Battery should not be discharged below a minimum voltage.
4) Never keep battery in discharged condition.
5) Battrey should not be overcharged
6) Charge battrey at specific rate.
7) During initial charging use fresh electrolyte.

Any 4 points 1 mark each

4 a) **Effects:**

1. Due to leakage flux, amount of useful flux will be decreased. 1 mark
2. Due to fringing, the effective cross sectional area of air gap is increased. 1 mark
3. Will need extra MMF (higher current in coil) to overcome. 1 mark.

Reduction in leakage flux & fringing:

It can be reduced by proper design of the magnetic circuit. ½ mark

Selecting a high quality magnetic material each any 2

Making the air gap as narrow as possible. = 1mark

4 b) Ohm's law of magnetic circuit:

In magnetic circuit (the closed path traversed) flux is directly protional to magnetomotive force and inversely to reluctance of the path 3 marks

Hence, Flux = M.M.F. / Reluctance. 1 mark

4 c) Given data :

$A = 10\ cm^2 \Rightarrow 10 \times 10^{-4}\ m^2$

N = 200, flux density $B = 1\ Wb/\ m^2$.

$l = \pi \times d = 0.15 \times \pi\ m = 0.47\ m.$

$\mu r = 500$

$\therefore$ Reluctance of ring (S) = $l/(\mu_r\ \mu_O\ A) = 7.5 \times 10^5$ AT/Wb 1 mark

Flux $\text{Ø} = B \times A = 1 \times 10^{-3} = 1$ mWb. 1mark

$\therefore$ MMF = Flux × Reluctance

$= 1 \times 10^{-3} \times 7.5 \times 10^5 = 750$ AT 1 mark

We have to find out magnetizing current.

$\therefore$ MMF = I.N

$\therefore$ I = MMF/N

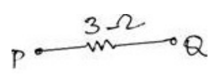
= 750 / 200 = 3.75 A. 1 mark

4 d) Recognize and redraw the network as shown:

2 marks

$1/R_P = (1/10) + (1/15) + (1/6) = 1/3\ ohm^{-1}$. 1 mark

$R_{PQ} = 3$ ohms. 1 mark



4 e) Ampere hour efficiency:
The ratio of the output of a battery, measured in ampere-hours, to the input required to restore the initial state of charge, under specified conditions, it is given as,

$$\eta_{Ah} = \frac{\text{Ampere-hours on discharge}}{\text{Ampere-hours on charge}}$$

$$\% \eta_{Ah} = \left[\frac{\text{Current} \times \text{Time on discharge}}{\text{Current} \times \text{Time on charge}}\right] \times 100$$

2 marks

The ratio of the output of a battery, measured in Watt-hours, to the input required to restore the initial state of charge, under specified conditions, it is given as,

$$\eta_{Wh} = \frac{\text{watt hours during discharge}}{\text{watt hours during charge}}$$

$$\therefore \% \eta_{Wh} = \left\{\frac{[\text{Voltage during discharge (average)}] \times [\text{Current} \times \text{time at discharge}]}{[\text{Voltage during charge (average)}] \times [\text{Current} \times \text{time at charge}]}\right\} \times 100$$

$$= \eta_{Ah} \times \frac{\text{Average voltage during discharge}}{\text{Average voltage during charge}}$$

2 marks

4 f)

Sr. No.	Class	Limiting temp. in ^{O} C	Materials
1	Y	90	Cotton, silk paper.
2	A	105	Impregnated paper , silk, cotton
3	C	120	Enameled wire insulations, Polyurethane, epoxy resins.
4	B	130	Inorganic materials like mica, glass, asbestos impregnated with varnish
5	F	155	Mica, polyester, epoxide varnishes.
6	H	180	Composite materials on mica, fiber glass, and asbestos bases, impregnated with silicon rubber.
7	C	Above 180	Mica, ceramics, glass, Teflon, quartz.

Max 4 marks, (any 4 class with example allowed)

5 a) We know that, coefficient of self inductance $L = N \Phi / I$ henrys 1 mark

If the length of coil l meters and the cross sectional area a sq. meters & if it is wound on a core of absolute permeability μ, then with current of I amperes through it,

Flux, Φ = M.M.F. /Reluctance = NI/ (l/ μ a) = NI/ S Weber's 1 mark

Substituting this in above equation, we have

L = (N/I) x (NI/ S) = N^2 / S. 2 marks

5 b)

Sr. No.	Air cored inductor	Ferrite cored inductor
1	Wire wound on former magnetic, non-conducting core.	Wire wound on former with ferrite (components $xxFe_2O_4$ represents various metals) core
2	Air is non magnetic.	Ferrite is a ceramic ferromagnetic material that is nonconductive, so eddy currents cannot flow within it.
3	Has very low inductance.	Has very high inductance compared to air for equal turns of coil.
4	Has Linear B – H curve with no saturation.($B = \mu_o H$)	Has non-linear B-H curve.
5	Have zero core losses (iron losses).	Have very low iron losses
6	Used where inductance (low losses) low required and high radio frequencies are handled.	Used where high inductance (low losses) required and high are handled.

Any four points of comparison 1 mark each.

5 c) Change of the current in a coil produces an EMF in another (neighbouring) coil by mutual induction. The EMF so induced is mutually induced EMF. 1 mark

Example: In given figure current I_A changes in coil A to produce change in flux due to it. The part of changing flux linking coil B produces EMF in it by mutual induction called as mutually induced EMF. 1 mark

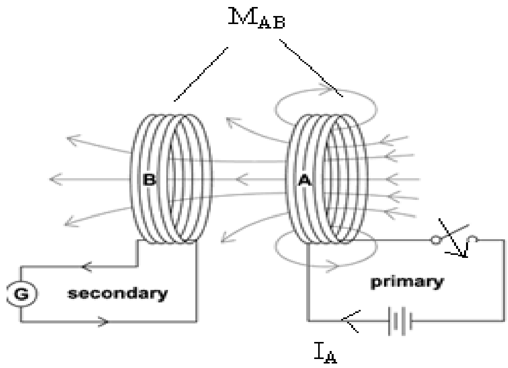
Thus Mutually Induced EMF in coil B due to change in current in coil A is

$$E_{BA} = - M_{AB} (dI_A/dt) \text{ (V)}$$ 1 mark

(where M_{AB} = coefficient of mutual inductance between coils A and B in Henry,

I_A is in amperes, and time t in secs).

Figure: (induced emf can be detected by galvanometer shown) — Fig: 1 mark for any other equivalent fig. also.



5 d) r = radius of coil = 4 cm = 4 x 10^{-2} m, length of magnetic circuit 'l' = 1.5 m.

But μ_0 = 1, A = π r^2 = 5.027 x 10^{-3} sq m

Reluctance, S = l/(μ_O μ_r A),

S = 237.47 x 10^6 AT/wb — 1 mark

Inductance = N^2 / S = 5000^2 / (237.47 x 10^6) = 0.1053 H — 1 mark

Energy stored,

E = ½ L I^2 — 1 mark

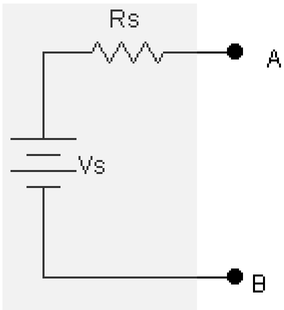
= 0.21 Joules. — 1 mark

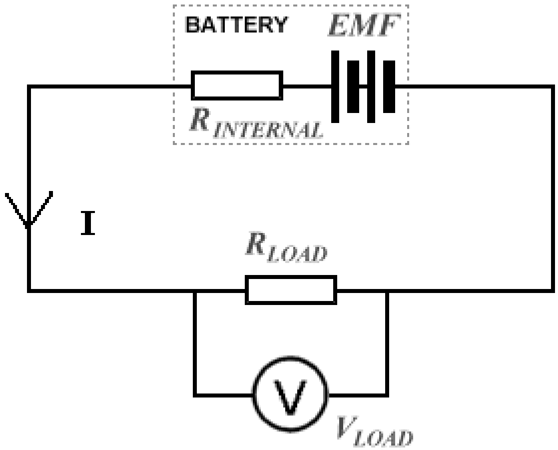
5 e)

Sr.	Parameter	AC supply	DC supply
1	Definition	It is supply system in which AC current flows	It is supply system in which AC current flows
2	Use of transformer	Possible	Not possible
3	Distribution efficiency	High	Low
4	Design of machines	Easy	Not easy
5	Generation	Easy	From the AC waveform using commutator

6	Applications	Ac motors, domestic & industrial loads	DC machines, HVDC

5 f) Internal resistance:



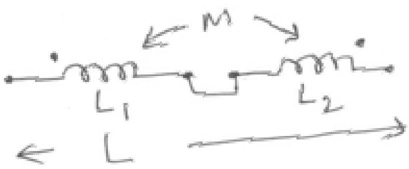


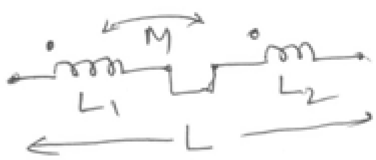
Any one figure or equivalent 2 marks

The internal resistance of sources is the property of the components used to generate the EMF. So it is internal to the source. Hence called internal resistance. It is represented by the symbol of resistance and is measured in ohms. 1 mark

It creates heat loss in the source given by I^2R which reduces the efficiency of the source system. Ideally it must be zero which is practically not possible. 1 mark

6 a) Series connection:





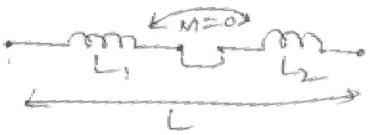
For similar polarity pts connected:

$L = L_1 + L_2 - 2M$.

For opposite polarity pts connected:

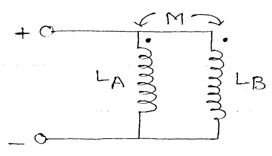
$L = L_1 + L_2 + 2M$ ½ mark

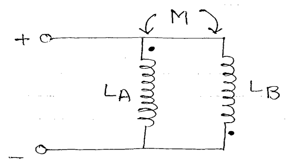
With no mutual inductance:



$L = L_1 + L_2$. ½ mark

Parallel connection:





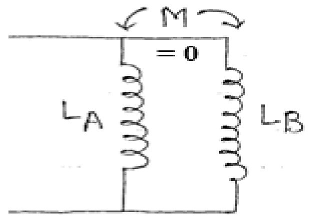
as shown in fig. two mutually coupled coils having inductance L_A and L_B are connected in parallel.

∴ the equivalent inductance of two mutually coupled coils connected in parallel is given by — 1 mark each eqn. = 2 marks

1. $L_1 = \dfrac{L_A.L_B - M^2}{L_A + L_B - 2M}$ 2. $L_2 = \dfrac{L_A.L_B - M^2}{L_A + L_B + 2M}$

Where , M = Mutual inductance in Henry.

With no mutual inductance



½ mark

Resultant inductance $L = L_A L_B/(L_A + L_B)$ — ½ mark

Energy stored in each of above = ½ LI^2 where I is the current drawn by the combination.

6 b) Electric field strength (E):

The mechanical force experienced by unit positive charge placed at any point in the electric field is known as electric field strength at that point. Its unit is Newton per coulomb (N/C) or volt per meter (V/m). — 1 mark

Dielectric constant (μ_r):

Relative permittivity is called as dielectric constant. It is defined as the ratio of electric flux density (D) in a dielectric medium to that produced in vacuum or free space, by the same electric field strength (E) with all other conditions identical. — 1 mark

Dielectric Strength: It is define the dielectric strength of an insulating material as the ability of the insulating medium to resist its breakdown when large voltage is applied across it. Its unit is volts per meter (V/m). 1 mark

Electric flux density (B): the electric flux per unit area measured at right angles to the direction of the flux is known as electric flux density. Its unit is coulomb per square meter (C/m^2). 1 mark

6 c) Reasons for using sinusoidal AC:

1) Use of transformer is possible to change the voltage level.
2) Distribution of AC voltage is more efficient.
3) The construction of AC motors & AC generators is simple.
4) It is possible to obtain a DC voltage from AC by means of rectification.

1 mark each

6 d) Classification of magnetic materials:

A) Paramagnetic materials: Used for as non magnetic materials such as titanium, copper, aluminum.

B) Diamagnetic materials: Not useful for magnetic applications such as Hydrogen, Bismuth.

C) Ferromagnetic materials: Used as magnetic material e.g. Iron & alloy of iron are used in the electrical field for cores of various machines, pole bodies, yokes.

1 mark each max 4 marks

6 e)

Sr. No.	Comparison point	Transformer with Amorphous core	Transformer with steel core
1	Weight(kg)	High(200)	Low(184)
2	Core loss	Low(15.5)	High(57)
3	Temperature rise (K)	Low(48)	High(57)
4	Audible noise(dB)	Less(33)	More(40)
5	Magnetizing current	Less(0.14)	More(0.36)

1 mark for each comparison (Max. 4 points) (figures not compulsory at all)

6 f)

Sr. No.	Aluminum conductor	Copper conductor
1	Resistivity is more	Resistivity is less
2	Low weight	More weight
3	Mechanically weaker	Mechanically strong
4	Specific Gravity Low	Specific Gravity high
5	Difficult to weld & solder	Welding & soldering is easy
6	Oxidizes when open	Affected chemically
7	Breaks when bend	Does not break when bend
8	Tensile strength is half of copper	Tensile strength is double of aluminum
9	Used for overhead lines	Used for winding

½ mark for each comparison (Max. 8 points)