**SUMMER – 2022 EXAMINATION**

**Subject Name: Fundamentals of Electrical Engineering** **Model Answer:** **22212: FEE**

**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.

| Q. No. | Sub Q. N. | Answer | Marking Scheme |
|---|---|---|---|
| **1.** | | **Attempt any FIVE of the following:** | **10 Marks** |
| | a) | Define the term resistance and state its unit. | |
| | | **Ans:** | |
| | | **Resistance:** It is defined as the opposition offered by electrical device or material or circuit to the flow of electric current. | 1 Mark |
| | | **Unit:** SI unit of resistance is ohm (Ω) | 1 Mark |
| | b) | State Ohm's law applied to an electrical circuit and expresses it in the form of equation. | |
| | | **Ans:** | |
| | | **Ohm's law:** | |
| | | As long as physical conditions (such as dimensions, pressure and temperature) are constant, the potential difference or voltage applied across the conductor is directly proportional to current flowing through it. | 1 Mark for law |
| | | OR | |
| | | As long as physical conditions (such as dimensions, pressure and temperature) are constant, the current flowing through the conductor is directly proportional to the potential difference or voltage applied across it. | 1 Mark for equation |
| | | $V \alpha I$ Or $I \alpha V$ | |
| | | i. e. $V = RI$ Or $I = V/R$ | |
| | | where, R = constant of proportionality, called as the resistance of the conductor. | |
| | c) | Define dielectric strength and breakdown voltage. | |
| | | **Ans:** | |
| | | **Di-electric Strength:** The voltage which a dielectric material can withstand without breaking down (without losing its dielectric property) is called its dielectric strength. | 1 Mark |
| | | **Breakdown Voltage:** The voltage at which the dielectric material breaks down (Starts conducting or is no longer remains as an insulator) for a specified thickness, is called its breakdown voltage. | 1 Mark |
| | d) | State the values of permeability of free space and permeability of air. | |
| | | **Ans:** | |
| | | Permeability of free space and air is same, given by, | 2 Marks |
| | | $\mu_0 = 4\pi \times 10^{-7}$ **H/m** | |

e) Define the following terms:
   (i) MMF (ii) Reluctance

**Ans:**

(i) **MMF:** Magneto-motive force is defined as the force which sets up the magnetic flux in the magnetic circuit.

(ii) **Reluctance:** Reluctance is the opposition offered by the magnetic circuit to the magnetic flux which is set up through it.

1 Mark for each definition = 2 Marks

f) List two types of induced emf.

**Ans:**

Types of Induced emfs:

i) Statically induced emf
ii) Dynamically induced emf

1 Mark each = 2 Marks

g) State Faraday's laws of electromagnetic induction.

**Ans:**

**Faraday's laws of electromagnetic induction:**

**First law:** When a conductor cuts the magnetic flux or a changing magnetic field links with a conductor, an emf is induced in the conductor.

**Second law:** The magnitude of emf induced in the conductor is directly proportional to the rate of change of flux linking with conductor or rate of flux cutting by the conductor.

1 Mark for each law = 2 Marks

**2. Attempt any <u>THREE</u> of the following:** **12 Marks**

a) List any four types of resistors. Give one application of each.

**Ans:**

**Types of resistors with their applications:**

**i) Carbon composition resistor**: Potential divider, welding control circuits, power supplies, H. V. and high impulse circuits as switching spark circuits, radio/TV receiver circuit, biasing circuits of transistor, amplifier circuits, zener voltage regulator.

**ii) Metal film resistor**: Transmitter circuits, Oscillator, telecommunication circuits, testing circuits, measurement circuits, audio amplifier circuits, Modulator and De-modulator circuits.

**iii) Wire wound resistor**: Power amplifiers, Zener voltage regulators, radio / TV receiver circuit, High power resistance in DC power supplies, measurement circuits.

**iv) H V Ink Film type resistor**: C R O circuits, Radar, medical electronics.

**v) Carbon film resistors:** used for electronic circuits

**vi) Cermet resistors:** used in printers, automotive, computers, cell phones & battery chargers.

1 Mark for each of any 4 resistors with one application = 4 Marks

b) Find the equivalent resistance between terminals A and B shown in Figure No. 1 given below:

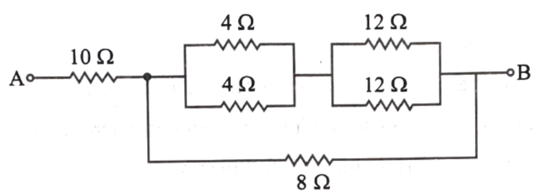
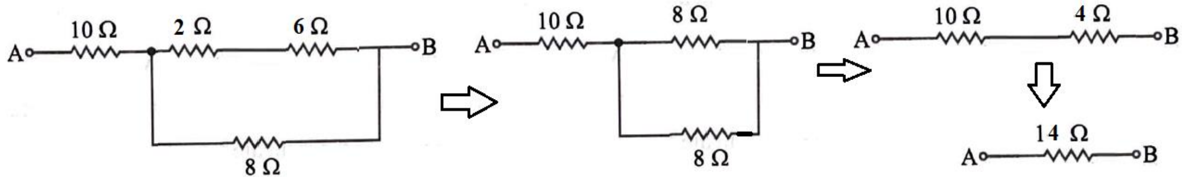



**Figure No. 1**

**Ans:**

Referring to Figure No. 1, it is seen that two 4 Ω resistors are in parallel and also two 12 Ω resistors are in parallel.




1 Mark for each of four steps = 4 Marks

Their equivalent resistance is given by,
4||4 = (4 x 4) / (4+4) = 16/8 = 2 Ω
12||12 = (12 x 12) / (12+12) = 144/24 = 6 Ω
Then 2Ω and 6Ω are in series, their equivalent resistance will be (2+6) = 8Ω
Now two 8Ω resistances are in parallel, their equivalent resistance is
8||8 = (8x8)/(8+8) = 64/16 = 4Ω
Now 10Ω and 4Ω appears in series. So final equivalent resistance between terminals A and B is given by,
$R_{AB}$ = 10 + 4 = **14 Ω**

c) (i) State the equation for energy stored in a capacitor.
**Ans:**
The energy stored in capacitor is given by,

$$E=\frac{1}{2}\ Cv^2=\frac{1}{2}Qv=\frac{1}{2}\frac{Q^2}{C}\text{ joules}$$

1 Mark for equation with terminology

where, $C$ is the capacitance in farad,
$Q$ is the charge on capacitor in coulomb.
$v$ is the voltage across capacitor in volt

c) (ii) If 200V source is applied to parallel combination of 3 capacitors of 4 μF, 8 μF and 12 μF. Calculate energy stored in each capacitor.
**Ans:**
Energy stored in capacitor is given by, $E_C = \frac{1}{2} C v^2$ joule.
Where, C is the capacitance of capacitor in farad
v is the voltage across capacitor in volt.
Here all capacitors are in parallel, so voltage across each capacitor is same and equal to 200V.

i) Energy stored in 4 μF capacitor, $E_1 = \frac{1}{2} (4 \times 10^{-6})(200)^2 = 0.08$ J
ii) Energy stored in 8 μF capacitor, $E_2 = \frac{1}{2} (8 \times 10^{-6})(200)^2 = 0.16$ J
iii) Energy stored in 12 μF capacitor, $E_1 = \frac{1}{2} (12 \times 10^{-6})(200)^2 = 0.24$ J

1 Mark each = 3 Marks

d) Compare statically induced emf with dynamically induced emf on following four points:
(i) Movement of coil or magnet
(ii) Current
(iii) Expression of induced emf
(iv) Application
**Ans:**

| Sr. No. | Particulars | Statically induced EMF | Dynamically induced EMF |
|---|---|---|---|
| 1. | Movement of coil or magnet | Neither coil nor magnet | Either coil moves or magnet |
| 2. | Current | Must vary with respect to time | Can remain constant. |

1 Mark for each point = 4 Marks

| | | | |
|---|---|---|---|
| 3. | Expression of induced emf | $e = -L\left(\frac{di}{dt}\right)$ or $-N\left(\frac{d\phi}{dt}\right)$ | e = Blv sinθ |
| 4. | Application | Transformers, choke coil of fluorescent tube | DC Generator, Back EMF in DC motor, induction motors |

**3. Attempt any THREE of the following:** **12 Marks**

a) State & explain Kirchhoff's voltage law.

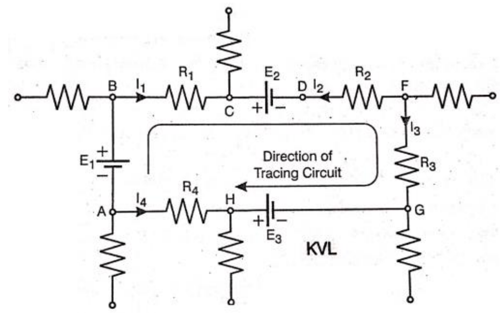
**Ans:**

**Kirchhoff's Voltage Law (KVL):**

It states that, in any closed path in an electric circuit, the algebraic sum of the emfs and products of the currents and resistances is zero.

i.e $\Sigma E - \Sigma IR = 0$ or $\Sigma E = \Sigma IR$

2 Marks for statement




1 Mark for example

OR

It states that, in any closed path in an electrical circuit, the total voltage rise is equal to the total voltage drop.

i.e Voltage rise = Voltage drop

e.g. Referring to the circuit, by KVL we can write,

$\Sigma E = \Sigma IR$

$(E_1 - E_2 + E_3) = (I_1R_1 - I_2R_2 + I_3R_3 - I_4R_4)$

1 Mark for sign convention

**Sign convention:**

While tracing the loop or mesh, the voltage rise is considered as positive and voltage drop is considered as negative.

b) A furnace takes a current of 10 ampere from 200V DC supply for 8 hours. Calculate energy consumed in kWh.

**Ans:**

**Data Given:**

4 Marks for stepwise solution

Voltage V = 200V DC

Current I = 10 A

Time of energy flow t = 8 hours.

Energy = Power x Time = V I t = 200 x 10 x 8 = **16000 watt-hour = 16 kWh**

c) Find the current flowing through 8Ω resistor using KVL. Refer Figure No. 2

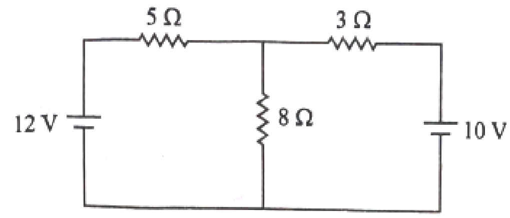
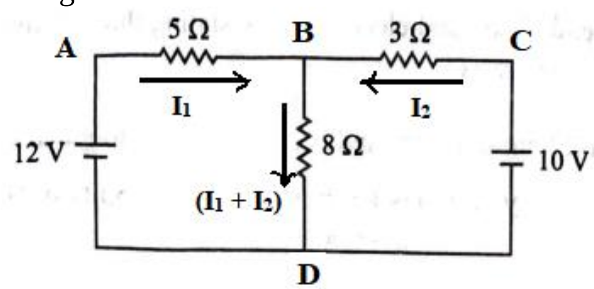



**Figure No. 2**

**Ans:**
Mark the currents on the diagram.




1 Mark for current marking

Write KCL and KVL based equations
Consider loop ABDA,
$-(5)I_1 - 8(I_1 + I_2) + 12 = 0$
$\therefore 13I_1 + 8I_2 = 12 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$
Consider loop CBDC,
$-(3)I_2 - 8(I_1 + I_2) + 10 = 0$
$\therefore 8I_1 + 11I_2 = 10 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

1 Mark for writing correct KVL equations

Multiplying eq. (2) by 13, we get,
$104I_1 + 143I_2 = 130 \ldots\ldots\ldots\ldots\ldots\ldots (3)$
Multiplying eq. (1) by 8, we get,
$104I_1 + 64I_2 = 96 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$
Subtracting eq.(4) from eq. (3),
$79I_2 = 34 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$
$\therefore \boldsymbol{I_2 = 0.43\ A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$
Substituting $eq^n$ (6) in $eq^n$ (1), we get
$13I_1 + (8)(0.43) = 12$
$\therefore \boldsymbol{I_1 = 0.66\ A} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$

1 Mark for currents $I_1$ and $I_2$

Final answer
The current through 8Ω resistance is,
$= I_1 + I_2 = 0.43 + 0.66 = \boldsymbol{1.09\ A}$ flowing in **downward direction** as shown in the figure.

1 Mark for final answer

d) List four factors affecting capacitance of capacitor.
**Ans**:
**Factors affecting the capacitance of capacitor:**
The capacitance of a capacitor is given by,

$$C = \frac{\epsilon_0 \epsilon_r\ A}{d}$$

1 Mark for each factor = 4 Marks

**i) Area of Plates**: Greater the area (A) of capacitor plates, more is the value of capacitance and vice versa.

**ii) Thickness of dielectric:** Smaller the thickness (d) of dielectric, more is the value of capacitance and vice versa.

**iii) Relative permittivity of dielectric:** Greater the relative permittivity ($\in_r$) of dielectric material more is the value of capacitance and vice versa.

**iv) Permittivity of free space:** Capacitance depends upon permittivity of free space $\in_0$, which is constant.

**4. Attempt any THREE of the following:** **12 Marks**

a) Define electrical work and electrical energy. Give SI units of each.

**Ans:**

1. **Electrical Work:** It is defined as the effect of consumption or transformation of electrical energy. SI unit of electrical work is "joule" (J).
2. **Electrical Energy:** It is defined as the capacity to do the electrical work. SI unit of electrical energy is "joule" (J).

1 Mark for each definition
1 Mark for each unit
= 4 Marks

b) Calculate resistance between terminals A and B using star-delta conversion. Refer Figure No. 3

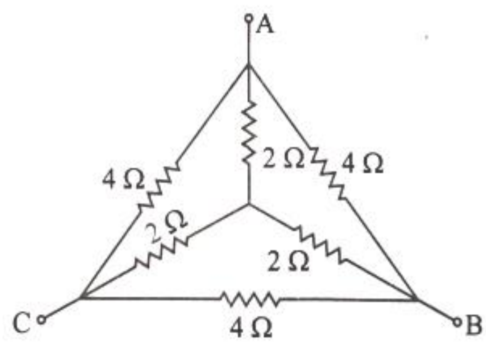
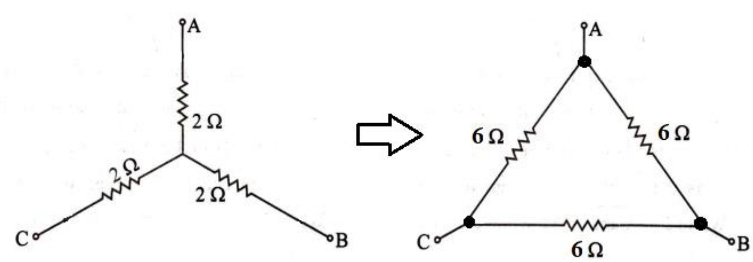



**Figure No. 3**

**Ans:**

**Step 1: Converting Inner Star into equivalent Delta**




$R_{AB} = R_A + R_B + \frac{R_A R_B}{R_C}$

$= 2 + 2 + \frac{2\times2}{2} = 6\,\Omega$ Since all star connected resistors are equal, the delta equivalent resistors will also be equal.

$R_{BC} = R_B + R_C + \frac{R_B R_C}{R_A}$

1 Mark for inner star to delta conversion

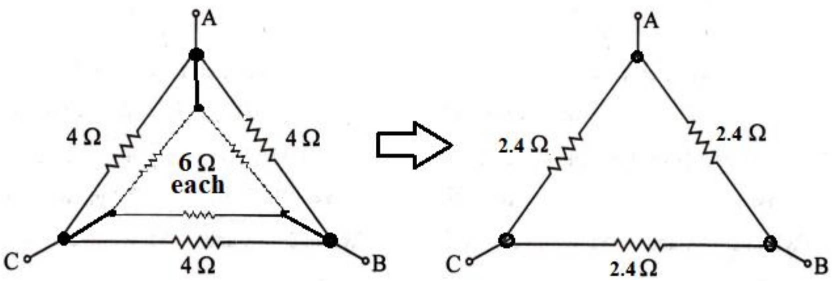
$$= 2 + 2 + \frac{2 \times 2}{2} = 6\,\Omega$$

$$R_{CA} = R_C + R_A + \frac{R_C R_A}{R_B}$$

$$= 2 + 2 + \frac{2 \times 2}{2} = 6\,\Omega$$

**Step 2**: **Modified Network**

Inner equivalent delta appears in parallel with outer delta.




1 Mark for final single delta

**Step 3**: **Solving Parallel Combinations of 4Ω and 6Ω**

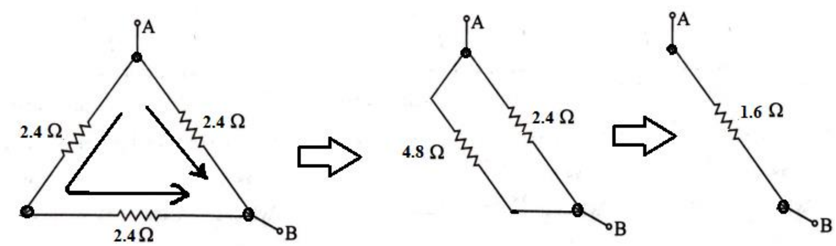
Resistance between AB $= \frac{6 \times 4}{6+4} = 2.4\,\Omega$, Since other combinations are also same,

Resistance between BC $= 2.4\,\Omega$

Resistance between CA $= 2.4\,\Omega$

1 Mark for final simplification

**Step 4**:




1 Mark for final answer

Between A and B, we have two parallel branches:

One has 2.4Ω in series with 2.4Ω and other branch has only one resistor of 2.4Ω.

Thus $R_{AB}$ = (2.4+2.4) || 2.4 = 4.8 || 2.4 = **1.6 Ω**

c) The resistance of copper coil increases from 70Ω at 12°C to 95.5Ω at 60°C. Find the temperature co-efficient of the material at 0°C.

**Ans**:

The resistance at t°C is given by standard equation $R_t = R_0 (1 + \alpha_0 t)$ — 1 Mark

$\therefore R_{12} = 70 = R_0 (1 + 12\,\alpha_0)$ ……………………………..(i)

$\therefore R_{60} = 95.5 = R_0 (1 + 60\,\alpha_0)$ ……………………(ii)

1 Mark for eq. (i) & (ii)

Take ratio, $\frac{70}{95.5} = \frac{(1 + 12\,\alpha_0)}{(1 + 60\,\alpha_0)}$, solving it we get,

$70\,(1 + 60\,\alpha_0) = 95.5(1 + 12\,\alpha_0)$

1 Marks for steps

$\therefore$ (4200-1146)$\alpha_0$ = 95.5 - 70

$\therefore$ $\alpha_0 = 25.5/3054 = 8.35 \times 10^{-3}$

The temperature coefficient of resistance at 0°C is,

$\therefore$ **$\alpha_0$ = 0.00835 /°C**

1 Mark for final answer

d) Three capacitors have capacitances 2μf, 3μf, 5μf. What is the effective capacitance when

connected in –
1) Series
2) Parallel

**Ans:**

**Value of equivalent capacitance:**

Given: $C_1$= 2μF, $C_2$= 3 μF, $C_3$= 5μF

1 Mark for each formula = 2 Marks

i) For Series combination of capacitors:

$1/C_s = (1/C_1)+( 1/C_2) +(1/C_3)$
$= (1/2)+( 1/3)+( 1/5)$
$1/C_s = 0.5+0.33+0.2$
$1/C_s = 1.033$
$\therefore C_s =$ **0.968 μF**

1 Mark for each final correct solution = 2 Marks

ii) For parallel combination of capacitors:

$C_p = C_1 + C_2 + C_3 = 2 + 3 + 5 =$ **10 μF**

e) Derive an expression for capacitance of the parallel plate capacitor with medium partly air.

**Ans:**

**Capacitance of the parallel plate capacitor with medium partly air:**

As shown in figure, the medium consists partly air with parallel sided dielectric slab of thickness 't' and relative permittivity $\in_r$.

The electric flux density D = Q/A is the same in both media.

But electric intensities are different.

$E_1 = \frac{D}{\in_o \in_r}$ ………………………….. in the dielectric medium

$E_2 = \frac{D}{\in_o}$ ………………………….. in the air

1 Mark for $E_1$ and $E_2$

P.D. between plates,

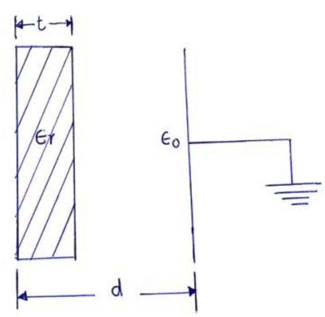
$V = E_1.t + E_2(d - t)$

$= \frac{D}{\in_o \in_r} \times t + \frac{D}{\in_o} \times (d - t)$

1 Mark for V

$= \frac{D}{\in_o} (\frac{t}{\in_r} + d - t)$

$= \frac{Q}{\in_o A} [d - (t - \frac{t}{\in_r})]$




1 Mark for diagram

$\therefore \frac{Q}{V} = \frac{\in_o.A}{[d-(t-\frac{t}{\in_r})]}$

$\therefore$ Capacitance $C = \frac{Q}{V} = \frac{\in_o.A}{[d-(t-\frac{t}{\in_r})]}$

1 Mark for C

**5 Attempt any TWO of the following:** **12 Marks**

5 a) Compare magnetic circuit and electric circuit stating three similarities and three dissimilarities.

**Ans:**

**Similarities between Electric and Magnetic Circuits:**

| Sr. No. | Electric circuit | Magnetic circuit |
|---|---|---|
| 1 | Current: flow of electrons through conductor is current, It is measured in amp. | Flux: lines of force through medium from N pole to S pole form flux. It is measured in weber. |

1 Mark for each of any 3

| | | | |
|---|---|---|---|
| 2 | EMF: It is driving force for current, measured in volts. | MMF: It is driving force for flux, measured in amp-turn. | similarities = 3 Marks |
| 3 | Resistance: It is opposition of conductor to current, measured in ohms | Reluctance: It is opposition offered by magnetic path to flux, measured in AT/wb. | |
| 4 | Resistance is directly proportional to length of conductor. | Reluctance is directly proportional to length of magnetic path. | |
| 5 | For electric circuit we define the conductivity. | For magnetic circuit we define permeability. | |
| 6 | Electric circuit is closed path for current. | Magnetic circuit is closed path for magnetic flux. | |
| 7 | For electric circuit<br>I = EMF/resistance | For magnetic circuit<br>Φ = MMF/reluctance | |
| 8 | Voltage = IR | M M F = Φ S | |
| 9 | Resistivity | Reluctivity | |

**Dissimilarities between Electric and Magnetic Circuits:**

| Sr. No. | Electric circuit | Magnetic circuit |
|---|---|---|
| 1 | Electric current flows | Flux does not actually flow (it only gets established or set up) |
| 2 | Energy is needed continuously for the flow of current. | Energy is only needed for establishment of field (flux) but not needed to maintain it. |
| 3 | Current cannot pass through the insulators. | Flux can pass through almost all things including air. |
| 4 | Electrical Insulator is available | Magnetic Insulator does not exist. |

1 Mark for each of any 3 dissimilarities = 3 Marks

5 b) An iron ring of 20 cm in diameter, 5 $cm^2$ in cross sectional area is wound with 300 turns. Flux density of iron is 1 $Wb/m^2$ and permeability of 500, find:

i) Reluctance
ii) Flux
iii) MMF
iv) Current

**Ans:**

**Given data :**

Area of cross section of core, a = 5 $cm^2$ =$5 \times 10^{-4}$ $m^2$,
No. of turns, N = 300,
Flux Density B = 1 $Wb/m^2$ ,
Relative permeability, $\mu r$ = 500
Diameter d = 20 cm = $20\times10^{-2}$ m
Hence length of magnetic circuit = $l = \pi d = \pi \times 20 \times 10^{-2} = 0.6283$ meter 1 Mark for $l$

**i) Reluctance (S):**

$$\therefore \text{ Reluctance of ring (S)} = \frac{l}{\mu_0 . \mu_r . a}$$

1 Mark for a

$$= \frac{0.6283}{4\times\pi\times10^{-7}\times500\times5\times10^{-4}}$$

**S = 1999941.015 AT/Wb** — 1 Mark for S

**ii) Flux (ϕ):**

Flux Density B = 1 $Wb/m^2$ = ϕ/a

Flux **ϕ** = B × a= 1 ×5 × $10^{-4}$ = 5×$10^{-4}$ = **0.5 mWb** — 1 Mark for ϕ

**iii) MMF:**

∴ MMF = Flux × Reluctance

= 0.5 × $10^{-3}$ × 1999941.015

= **999.97 ≅ 1000 AT** — 1 Mark for MMF

**iv) Current (I):**

Magnetizing current / Current for excitation:

∴ MMF = N × I

∴ I = MMF / N

= 1000 / 300 — 1 Mark for I

= **3.33 A**.

5 c) Calculate the inductance and energy stored in magnetic field of air cored coil of 300 cm long, 60 cm diameter and wound with 5000 turns and carrying 8 A current.

**Ans:**

**Given:**

No. of turns N = 5000,

Length of air cored coil, *l* = 300 cm = 3 m,

Diameter of the coil, d = 60cm = 0.6 m

**Step 1:** Calculate reluctance S — 2 Marks for each step = 6 Marks

Cross sectional area of the air core is , a = $\pi\frac{d^2}{4} = \pi\times\left(\frac{0.6}{2}\right)^2$

a = **0.283 $m^2$**

Reluctance S = $\frac{l}{\mu_o\,\mu_r\,a} = \frac{3}{4\pi\times10^{-7}\times1\times0.283}$ = 8435774.369 **= 8.44× $10^6$ AT/Wb**

**Step 2:** Calculate Inductance:

$$L = \frac{N^2}{S} = \frac{(5000)^2}{8.44\times10^6}$$

= **2.96 H**

**Step 3:** Energy stored in magnetic field of air cored coil, E = $\frac{1}{2}Li^2$

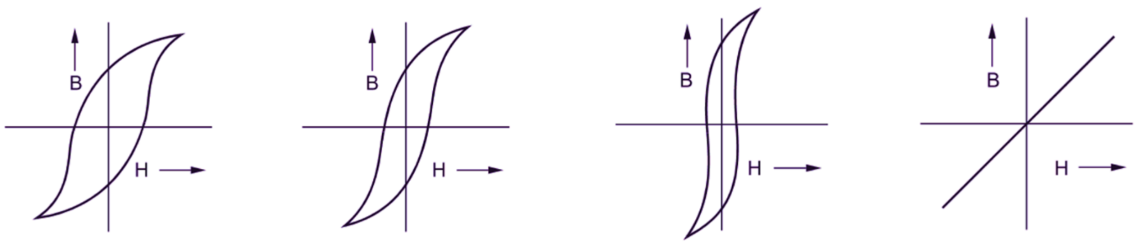
$$E = \frac{1}{2}(2.96)(8)^2 = \mathbf{94.72\ joule}$$

**6 Attempt any <u>TWO</u> of the following: 12 Marks**

6 a) Draw hysteresis loop for hard steel, cast steel, sheet steel and non-magnetic material. Also write application of each material.

**Ans:**

**Hysteresis Loops:**



(a) Hard Steel (b) Cast Steel (c) Sheet Steel (d) Non-magnetic Material

1 Mark for each diagram = 4 Marks

**Applications:**

**i) Hard Steel:** It is used for making permanent magnets as it has large hysteresis loop to give both high remanence and high coercive force.

**ii) Cast Steel:** It is used for making those parts of electrical equipment which are subjected to steady magnetic field, such as yoke of DC machine.

**iii) Sheet Steel:** It is used for making those parts of electrical equipment which are subjected to rapid reversals of magnetization, such as transformer core, as it has high permeability and low hysteresis loss.

**iv) Non-magnetic Material:** It is used for making insulation over conductor.

½ Mark application of each = 2 Marks

6 b) Two coils A of 1500 turns and B of 1200 turns are such that 70% of flux produced by coil A links with coil B. A current of 5A in coil A produces a flux of 0.04 Wb in coil A and 0.085 Wb in coil B. Find:

(i) $L_1$ (ii) $L_2$ (iii) M (iv) K

**Ans:**

i) Inductance of Coil A:

$$L_1 = \frac{N_1 \emptyset_1}{I_1} = \frac{1500 \times 0.04}{5} = \mathbf{12\ H}$$

ii) Inductance of Coil B:

$$L_2 = \frac{N_2 \emptyset_2}{I_2} = \frac{1200 \times 0.085}{5} = \mathbf{20.4\ H}$$

iii) Coefficient of coupling

$$K = \frac{\emptyset_{12}}{\emptyset_1} = \mathbf{0.7}$$

where, $\emptyset_1$ is the flux produced by coil A

$\emptyset_{12}$ is the flux produced by coil A and linking with coil B

iv) Mutual Inductance

$$M = K\sqrt{L_1 L_2} = 0.7\sqrt{12 \times 20.4} = \mathbf{10.95\ H}$$

1½ Mark for each bit = 6 Marks

**6** c) Related to electromagnetic induction:

(i) Define Self-inductance & Mutual inductance.

(ii) Write one equation of each of the above.

(iii) State the values of coupling factor for tight coupling and loose coupling.

**Ans:**

**(i) Self-inductance**: It is the property by virtue of which a coil opposes change in current flowing through it by inducing an emf in it so as to oppose the cause of its production i.e

1 Mark each

changing current flowing through the coil. = 2 Marks

**Mutual inductance**: The ability of the coil 1 carrying changing current to induce an emf in a neighbouring coil 2 is called as mutual inductance.

**(ii) Expression for self indutance (L):**

$$L = N\frac{d\emptyset}{di} \quad \text{OR} \quad L = \frac{N\emptyset}{I} \quad \text{OR} \quad L = \frac{N^2}{S}$$

where, L is the coefficient of self-inductance,
N is the no. of turns of coil,
$d\emptyset$ is the change in the flux,
di is the change in current,
S is the reluctance of magnetic path,
. I is the current flowing in the coil,

**Expression for mutual indutance:**

1 mark for each equation = 2 Marks

$$M = N_2\frac{d\emptyset_{12}}{di_1} \quad \text{OR} \quad M = \frac{N_2\emptyset_{12}}{I_1} \quad \text{OR} \quad M = \frac{N_1N_2}{S}$$

where, M is the coefficient of mutual inductance,
$N_1$ is the no. of turns of coil 1,
$N_2$ is the no. of turns of coil 2,
$d\emptyset_{12}$ is the change in the flux produced by coil 1 and linking with coil 2,
$di_1$ is the change in current in coil 1,
S is the reluctance of magnetic path
$I_1$ is the current flowing in the first coil.

**(iii) Coupling factor:**

1 Mark each = 2 Marks

For tight coupling, Coupling factor $K > 0.5$
For loose coupling, Coupling factor $K < 0.5$