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REVISION

# DIPLOMA EXAMINATION IN ELECTRICAL &ELECTRONICS ENGINEERING
## SECOND SEMESTER
## BASIC ELECTRICAL ENGINEERING

Scheme of Evaluation

PART A

I

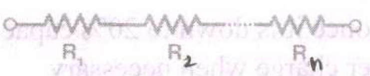
1. Ohms law states that the potential difference across the terminals of a conductor is directly proportional to the current flowing through it at constant temperature
2. The maximum power transferred to the load whenever load resistance equals the source resistance in DC circuit
3. Electric flux density D at any section in an electric field is the electric flux crossing normally per unit area of that section.
   $D=\Psi/A \ \ C/m^2$
4. The ability of a dielectric material to concentrate electric lines of force between the plates of a capacitor is called dielectric constant or relative permittivity of that material
5. Unit of magnetic flux is weber (Wb) and mmf is Ampere turns (AT)

PART B

II

1. **Resistors in series** (3)

   Two or more resistors are said to be connected in series when the same amount of current flows through all the resistors. In such circuits, the voltage across each resistor is different



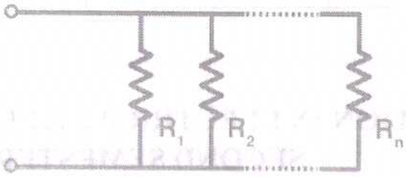

For the above circuit, the total resistance is given as:

$R_{total} = R_1 + R_2 + \ldots\ldots + R_n$

The total resistance of the system is just the total sum of individual resistances

**Resistors in parallel** (3)

Two or more resistors are said to be connected in parallel when the voltage is the same across all the resistors. In such circuits, the current is branched out and recombined when branches meet at a common point.




$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} \ldots\ldots \frac{1}{R_n}$$

The sum of reciprocals of resistance of an individual resistor is the total reciprocal resistance of the system.

2. **Effect of temperature on resistance** (1 mark for each points)

a. In certain pure metals such as gold, copper, silver, aluminium etc. the resistance increases with increasing temperature at fairly regular manner. Such metals possess positive temperature coefficient of resistance.

b. In certain materials (alloys) such as eureka, nichrome etc. the change in resistance due to increasing temperature is irregular and negligible for a considerable range of temperature.

c. In case of certain materials belongs to insulators, electrolytes such as paper, rubber, glass, mica, carbon, acids, alkalies etc. the resistance decreases with increasing temperature at fairly regular manner. Such materials posses negative coefficient of resistance

The resistivities of metallic conductors within a limited range of temperature are given by the following equation:

$$\mathbf{R_T = R_0\,[1 + \alpha(T - T_0)]} \qquad \text{(2 marks)}$$

$R_T$ = resistivity at a temperature T

$T_0$ = resistivity at a reference temperature T0

$\alpha$ = temperature coefficient of resistivity; the dimension of a is $(\text{Temperature})^{-1}$ (1 mark)

3. Maintenance of batteries (6 marks)

- Charge battery once it is down to 20% capacity.
- Deliver equalizer charge when necessary.
- Turn power off and allow battery to cool before removing.
- When water/electrolytes are needed, be sure to water battery after charging and disconnecting
- If battery is overfilled, clean battery immediately following overflow.
- Clean battery with a neutralizing detergent solution on a regular basis

4. **Steps in Thevenin's theorem** **( 6 Marks)**

1.Open or remove the load resistor.

2.Calculate / measure the open circuit voltage. This is the Thevenin Voltage ($V_{TH}$).

3.Open current sources and short voltage sources.

4.Calculate /measure the Open Circuit Resistance. This is the Thevenin Resistance ($R_{TH}$).

5.Now, redraw the circuit with measured open circuit Voltage ($V_{TH}$) in Step (2) as voltage source and measured open circuit resistance ($R_{TH}$) in step (4) as a series resistance and connect the load resistor which we had removed in Step (1). This is the equivalent

Thevenin circuit of that linear electric network or complex circuit which had to be simplified and analyzed by Thevenin's Theorem.

6. Now find the Total current flowing through the load resistor by using the Ohm's Law:

$$I_{th} = \frac{V_{th}}{R_{th} + R_L}$$

5. **Applications of Capacitor (any six points)**

- The fundamental use of a capacitor is to store energy in the form of electricity.
- Also, it works as a temporary battery that maintains the power supply while the power is cut off.
- In domestic as well as commercial appliances like as batteries, fans, cameras, coolers, electronic chargers, LED lights, audio equipment, etc., the capacitor is needed.
- Also, the capacitor is widely used in computers in cases of an emergency shutdown of the system.
- In the power system, capacitor banks are widely used for regulating voltage and improving the quality of the power supply.
- The capacitor includes AC to DC converters (for example, Chargers).
- In audio equipment and gadgets such as loudspeakers, microphones, woofers, tweeters, etc., capacitors are inbuilt to filter and manipulate signals.
- Also, capacitors are used in electrical measuring equipment (for example- sensors).
- This device is very useful for decoupling or smoothing the output voltage in the rectifier circuits. Especially, a smoothing capacitor is used.
- In electronics and telecommunication devices (such as television receivers, transmitter circuits, and radio), it is widely used.

6. **Energy Stored in Inductor**

Suppose that an inductor of inductance Lis connected to a variable DC voltage supply. The supply is adjusted so as to increase the current i flowing through the inductor from zero to some final value I. As the current through the inductor is ramped up, an emf **e=L di/dt** is generated, which acts to oppose the increase in the current. Clearly, work must be done against this emf by the voltage source in order to establish the current in the inductor. The work done by the voltage source during a time interval dt is

$dW = Pdt = \ -eidi = i\,L\frac{di}{dt}\,dt = i\,L\,di$ (4 marks)

Here, P==ei is the instantaneous rate at which the voltage source performs work. To find the total work $W$ done in establishing the final current I in the inductor, we must integrate the above expression. Thus

$$W = L\int_0^I i\,di$$

$W = \frac{1}{2}LI^2$ (2 marks)

This energy is actually stored in the magnetic field generated by the current flowing through the inductor

7. Comparison of electric and magnetic circuit (any six points)

Table 10.1 Analogy between magnetic and electric circuit

| Electric circuit | Magnetic circuit |
|---|---|
| Exciting force = emf in volts | mmf in AT |
| Response = current in amps | flux in webers |
| Voltage drop = $VI$ volts | mmf drop = $\Re\phi$ AT |
| Electric field density = $\frac{V}{l}$ volt/m | Magnetic field Intensity = $\frac{\Im}{l}$ AT/m |
| Current$(I) = \frac{E}{R}$ A | Flux $(\phi) = \frac{\Im}{R}$ Web |
| Current density$(J) = \frac{I}{a}$ Amp/m$^2$ | Flux density$(B) = \frac{\phi}{A}$ Web/m$^2$ |
| Resistance $(R) = \frac{\rho_l}{a}$ ohm | Reluctance $(\Re) = \frac{1}{\mu}\frac{l}{a}$ AT/Web |
| Conductance $(G) = \frac{1}{R}$ Mho | Permeance = $\frac{1}{\Re} = \frac{\mu a}{\mu}\frac{l}{a}$ Web/AT |

## PART C

III a) Resistance 12 Ω and 6 Ω are connected in parallel and this combination is connected in series with 4Ω.

The equivalent resistance, $R_{eq} = 4 + \left(\frac{12*6}{12+6}\right) = 8\Omega$

The total current in the circuit is $I = \frac{V}{R} = \frac{16}{8} = 2A$

(2 marks)

Current through 12 Ω

$$I_{12\Omega} = 2 * \frac{6}{6+12} = 0.66A$$

(2 marks)

Current through 6 Ω

$$I_{6\Omega} = 2 * \frac{12}{6+12} = 1.33A$$

(2 marks)

III b)

(i) $R_{18} = R_0(1+\alpha_0 * 18)$

$R_{50} = R_0(1+\alpha_0 * 50)$

$$\frac{R_{18}}{R_{50}} = \frac{1+18\alpha_0}{1+50\alpha_0}$$

On solving

$$\alpha_0 = \frac{1}{236} / ℃$$

(3 marks)

(ii) $R_{18} = R_0(1+\alpha_0 * 18)$

$$R_{18} = R_0(1 + 18\alpha_0)$$

$$R_0 = \frac{R_{18}}{1+18\alpha_0} = \frac{12.7}{1 + 18 * \left(\frac{1}{236}\right)} = 11.8\Omega$$

(3 marks)

(iii) $\alpha_{18} = \alpha_0 (1+\alpha_0 * 18) = \frac{1}{236+18}$

$$\alpha_{18} = \frac{1}{254} / ℃$$

(3 marks)

IV a) For lamp A, $R_A$ =110/0.8=137.5 Ω

For lamp B, $R_B$=110/0.9=122.2 Ω

When lamps are connected in series, total resistance $R_T$=137.5+122.2 =259.7 Ω (2 marks)

Voltage across lamp A=$IR_A$=0.847*137.5 =116.5V (2 marks)

Voltage across lamp B=$IR_B$=0.847*122.2 =103.5V (2 marks)

IV b) Total wattage of lamps =40*6 =240 watts

Total wattage of tubes =125*2=250 watts

Wattage of heater=1000 watts

Energy consumed by the appliances per day

=(240*4)+(250*2)+(1000*3)

=4460 watt hour =4.46 KWh (3 marks)

Total energy consumed in the month of June (i.e . in 30 days)

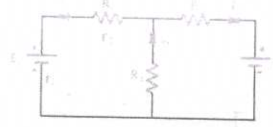
=4.46* 30 =133.8 KWh (2 marks)

Bill for the month of June = Rs.4 *133.8 = Rs.535.2 (1 mark)

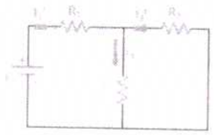
V a) **Superposition Theorem**

In any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately and all other sources are replaced by their internal resistance. The superposition theorem is used to solve the network where two or more sources are present and connected. (2 marks)

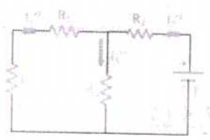
Considering the circuit diagram A, let us see the various steps to solve the superposition theorem:



Circuit Diagram A



Circuit Diagram B



Circuit Diagram C

(1mark)

1. Take only one independent source of voltage or current and deactivate the other sources.

2. In the circuit diagram b shown above, consider the source e1 and replace the other source e2 by its internal resistance. If its internal resistance is not given, then it is taken as zero and the source is short-circuited.

3. If there is a voltage source than short circuit it and if there is a current source then just open circuit it.

4. Thus, by activating one source and deactivating the other source find the current in each branch of the network. Taking the above example find the current i1', i2'and i3'.

5. Now consider the other source e2 and replace the source e1 by its internal resistance r1 as shown in the circuit diagram c.

6. Determine the current in various sections, i1", i2" and i3".

7. Now to determine the net branch current utilizing the superposition theorem, add the currents obtained from each individual source for each branch.

8. If the current obtained by each branch is in the same direction then add them and if it is in the opposite direction, subtract them to obtain the net current in each branch. The actual flow of current in the circuit c is given by

$$I_1 = I_1' - I_1''$$

$$I_2 = I_2' - I_2''$$

$$I_3 = I_3' - I_3''$$

(5 marks)

V b) Applying KVL to the loop formed by A ,B and C

$$5-2I_1-3I_3=0$$

$$2I_1+3I_3=5 \qquad (1) \qquad (1\ \text{mark})$$

Applying KCL to node C

$$I_1 = I_2 + I_3 \qquad (2) \qquad (1\ \text{mark})$$

Sub eq (2) in eq(1)

$$2(I_2+I_3)+3I_3=5$$

$$2I_2+5I_3=5 \qquad (3) \qquad (1\ \text{mark})$$

Apply KVL to the loop formed by the nodes A,B,C and D, we get

$$2I_1+5I_2=5+3$$

$$2I_1+5I_2=8 \qquad (4) \qquad (1\ \text{mark})$$

Sub eq (2) in eq(4)

$$2(I_2+I_3)+5I_2=8$$

$$7I_2+2I_3=8 \qquad (5) \qquad (1\ \text{mark})$$

Solving eq(3) and eq(5)

$$I_3 = \mathbf{0.613\Omega} \qquad (2\ \text{marks})$$

$$I_2 = 0.968\Omega$$

Therefore current through 3Ω resistor is 0.613Ω

VI a) With load removed (i.e. 8Ω) and terminals AB are short circuited, the current flows through AB is equal to $I_N$

Load on source =4Ω+5Ω||6Ω

=4+ (5*6)/(5+6)

=6.727Ω (1 mark)

Source current I' =40/6.727 =5.94A

Short circuit current in AB $I_N$ =I' * 6/(6+5) =3.24A (2 marks)

To find Norton's resistance, battery is replaced by short circuit and resistance at terminals AB is equal to $R_N$

$R_N$= 5Ω+4Ω||6Ω =5+ (4*6)/(4+6)

$R_N$=7.4 Ω (2 marks)

Current in 8Ω =3.24 *7.4/(8+7.4) =1.55A (2 marks)

VI b) **Charging mode** (4 marks)

When the battery is in the charged state, then every cell contains the negative plate of the element Pb or lead and the positive plate of PbO2 or lead(IV) oxide. The electrolyte contains approximately 4.2M of H2SO4 or sulfuric acid.

In the recharging process, the electrons are forcibly removed from the positive plate, and they are introduced forcibly in the negative plate. This is done by the source of charging.

Here are the chemical reactions that occur in the respective plates.

Negative plate reaction

$PbSO_4(s) + H+(aq) + 2e– \rightarrow Pb(s) + HSO_4–(aq)$

Positive plate reaction

$PbSO_4(s) + 2H2O(l) \rightarrow PbO_2(s) + HSO_4–(aq) + 3H+(aq) + 2e–$

The overall reaction when the negative and the positive plate reactions are combined is:

$2PbSO_4(s) + 2H_2O(l) \rightarrow Pb(s) + PbO_2(s) + 2H+(aq) + 2HSO_4–(aq)$

This is the reverse of the discharge reaction.

It is important to note that if the battery is overcharged, then this will lead to the formation of oxygen gas and hydrogen gas, which are the byproducts. These gases cause a loss of the reactants because of these escapes from the battery.

**Discharging mode** (4 marks)

When the battery is in the discharged state, then the positive, as well as the negative plate, becomes lead (II) sulphate (PbSO4). The electrolyte loses the dissolved sulphuric acid, and this is now mostly water. The discharge process gets driven by the electron conduction that occurs from the negative plate back to the cell in the positive plate. This happens in the external circuit.

Here is the Negative plate reaction:

$Pb(s) + HSO4–(aq) \rightarrow PbSO_4(s) + H+(aq) + 2e–$

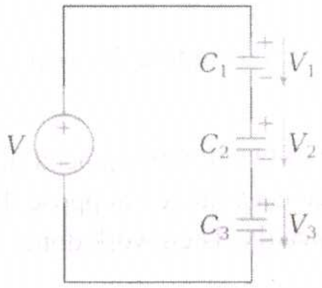
Here is the Positive plate reaction:

$PbO_2(s) + HSO_4–(aq) + 3H+(aq) + 2e– \rightarrow PbSO_4(s) + 2H_2O(l)$

The overall reaction occurs before combining the positive and negative reactions:

$Pb(s) + PbO_2(s) + 2H+(aq) + 2HSO_4–(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$

VII **a) Capacitor in series**




(2 marks)

A circuit consisting of a number of capacitors in series is similar in some respects to one containing several resistors in series. In a series capacitive circuit the same displacement current flows through each part of the circuit and the applied voltage will divide across the individual capacitors. he sum of the capacitor voltages must equal the source voltage (Kirchhoff's voltage law)

$$V=V_1+V_2+V_3$$

The charges on all capacitors must be the same, since the capacitors are connected in series and any charge movement in one part of the circuit must take place in all parts of the series circuit. Solving the equation C=Q/V for voltage in terms of capacitance and charge (V=Q/C), the following results are obtained for each of the series capacitors and the total capacitance (Ct)

$$V=\frac{Q}{C_t} \quad V_1=\frac{Q}{C_1} \quad V_2=\frac{Q}{C_2} \quad V_3=\frac{Q}{C_3}$$

(2 marks)

Substituting these results into the above Kirchhoff's voltage law equation

$$\frac{Q}{C_t}=\frac{Q}{C_1}+\frac{Q}{C_2}+\frac{Q}{C_3}$$

Dividing both sides of the above equation by the common factor Q

$$\frac{1}{C_t}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}$$

(2 marks)

Taking the reciprocal of both sides and assuming any number of capacitors

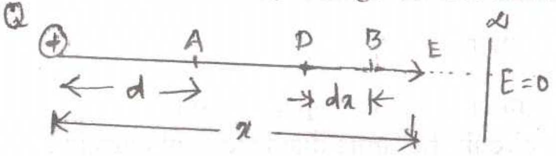
$$C_t=\frac{1}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}+\ldots+\frac{1}{C_n}}$$

$$C_t=\frac{C_1C_2}{C_1+C_2}$$

(2 marks)

This equation is the general equation used to compute the total capacitance of capacitors connected in series.

VII b) Consider a positive point charge of Q coloumbs placed in air. At a point x meters from it, the force on one coloumb positive charge is $Q/4\pi\varepsilon_0 x^2$. Suppose this one coloumb charge is moved towards Q through a small distance dx. Then work done




$$= \frac{Q}{4\pi\varepsilon_0 x^2} * (-dx)$$

(2 marks)

The negative sign is taken because dx is measured alond the negative direction of x.The total work done in bringing this coloumb of positive charge from infinity to any point d meters from Q is given by

$$W = \int_{x=\infty}^{x=d} -Q.\frac{dx}{4\pi\varepsilon_0 x^2}$$

$$= \frac{-Q}{4\pi\varepsilon_0}\int_{x=\infty}^{x=d}\frac{dx}{x^2}$$

$$= \frac{-Q}{4\pi\varepsilon_0}\left[\frac{-1}{x}\right] = \frac{-Q}{4\pi\varepsilon_0}\left[\frac{-1}{d} - \left(\frac{-1}{\infty}\right)\right] = \frac{-Q}{4\pi\varepsilon_0 d}\ Joules$$

(3 marks)

By definition, this work in joule is numerically equal to the potential of that point in volts

$$V = \frac{Q}{4\pi\varepsilon_0 d} = 9 * 10^9 \frac{Q}{d}\ volt$$

$$V = \frac{Q}{4\pi\varepsilon_0\varepsilon_r d} = 9 * 10^9 \frac{Q}{\varepsilon_r d}\ volt$$

(2 marks)

VIII a) **Laws of electrostatics**

**First Law**

It states that like charges of electricity repel each other, whereas unlike charges attract each other.

(2 marks)

**Second Law**

The second law of electrostatic states that the force exerted between two small charged bodies (point charges) is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

(2 marks)

In other words, the electric force of attraction or repulsion between two charged points varies directly as the product of the charged points and inversely as the square of the distance between those charge points.
Coulomb's Laws of electrostatic can be mathematically represented as follows.

$$F \propto \frac{Q_1 Q_2}{d^2}$$

$$F = K \frac{Q_1 Q_2}{d^2}$$

Where:

(2 marks)

- F = Force
- Q1, Q2 = Two charged bodies or points
- d = Distance between the two charged bodies
- K = Constant which values depends on the measurement units of F, Q1 and Q2 and characteristics of the dielectric insulating medium between two charged bodies. The constant K is also represented by the symbol of λ (Lambda). The value of constant K = 1 / 4πεοεr in both SI and MKS systems.

VIII b) Area of parallel plates=7.6 $cm^2$ =7.6 $*10^{-4}$ $m^2$

Distance, d=1.8mm =1.8 $*10^{-3}$ m

Potential difference V=20V

a) E=V/d

E=20/1.8 $*10^{-3}$ =11.11$*10^3$ N/C (3 marks)

b) Capacitance, C

$$C = \frac{\varepsilon_0 A}{d} = \frac{8.85 * 10^{-12} * 7.6 * 10^{-4}}{1.8 * 10^{-3}}$$

$$C = 37.367 * 10^{-13} F$$

(3 marks)

c) The charge on plate be Q,

$Q = CV = 37.367 * 10^{-13} * 20$

$$Q = 74.734 * 10^{-12} C$$

(3 marks)

IX a)

The fraction of magnetic flux produced by the current in one coil that links with the other coil is called the coefficient of coupling between the two coils. It is denoted by (k). (2 marks)

Consider two magnetic coils A and B.

When current I1 flows through coil A.

$$L_1 = \frac{N_1 \varphi_1}{I_1} \; and \; M = \frac{N_2 \varphi_{12}}{I_1} \dots\dots(1) \; as \; (\varphi_{12} = k\varphi_1)$$

4

Considering coil B in which current I2 flows

$$L_2 = \frac{N_{2\varphi_2}}{I_2} \; and \; M = \frac{N_{1\varphi_{21}}}{I_2} = \frac{N_1 k\varphi_2}{I_2} \;\ldots\ldots.(2) \quad as\,(\varphi_2 = k\varphi_2)$$

(2 marks)

Multiplying equation (1) and (2)

$$MxM = \frac{N_{2k\varphi_1}}{I_1} \, x \frac{N_{1k\varphi_2}}{I_2}$$

$$M^2 = k^2 \frac{N_{1\varphi_1}}{I_1} \, x \, \frac{N_{2\varphi_2}}{I_2} = k^2 L_1 L_2$$

$$\text{M} = \sqrt{L_1 L_2} \quad \ldots\ldots\ldots.(A)$$

(2 marks)

The above equation (A) shows the relationship between mutual inductance and self-inductance between the two coils

IX b) **First law of Faraday's electromagnetic induction**

When the Magnetic Flux linked with closed-circuit changes, an EMF is induced in it which lasts only as long as the change in flux is taking place. If the circuit is closed then current also gets induced inside the circuit which is called Induced current. Changing the magnetic field changes the induced current in the circuit.

(2 marks)

**Second law of Faraday's electromagnetic induction**

The magnitude of the induced emf is equal to the rate of change of magnetic flux linked with the coil. (2 marks)

Consider a coil having N conductors and a magnetic is moving towards the coil, then

At the initial position, the flux linkage with the coil is $\psi_1 = N\phi_1 \quad \ldots(1)$

At the final condition, the flux linkage with the coil is $\psi_2 = N\phi_2 \quad \ldots(2)$

Hence, the change in the flux linkage is,

$$\Delta\psi = \psi_2 - \psi_1$$

$$\Rightarrow \Delta\psi = N(\phi_2 - \phi_1)$$

Now, the rate of change of this flux linkage is

$$\frac{\Delta\psi}{t} = \frac{N(\phi_2 - \phi_1)}{t}$$

(3 marks)

According to Faraday's second law of electromagnetic induction, the EMF induced in the conductor is equal to the rate of change of flux linkage.

$$\therefore e = \frac{N(\phi_2 - \phi_1)}{t} \quad \ldots(3)$$

In differential form,

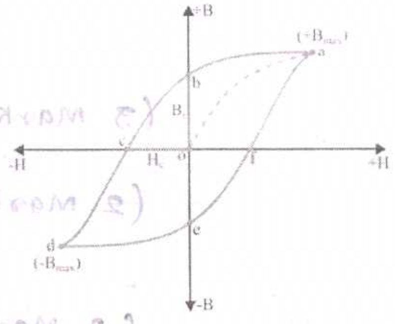
$$e = N\frac{d\phi}{dt} \quad \ldots(4)$$

(2 marks)

Where, $\phi = \phi_2 - \phi_1$, the total change in magnetic flux.

X a) B-H Curve

Consider a coil of N turns wound on an un-magnetised iron bar AB (see the figure). The magnetising force (H = NI/l) produced by the coil can be changed by varying the current through the coil. It can be seen that when the iron bar is subjected to one complete cycle of magnetisation, the resultant B-H curve traces a loop abcdefa called as hysteresis loop.




(2 marks)

- When the current in the coil is zero, the H is zero and hence B in the iron bar is zero. When H is increased by increasing the coil current, the magnetic flux density also increases until the point of maximum magnetic flux density (+Bmax) is reached. At this point, the material is saturated and beyond this point, the magnetic flux density will not increase regardless of any increase of magnetising force (H). For this, the B-H curve follows the path **oa** (see the hysteresis loop).
- Now, if the H is gradually decreased by decreasing the coil current, it is found that the magnetic flux density does not decrease along the path oa but follows the path **ab**. At point **b**, the magnetising force is zero but magnetic flux density in the material has a finite value (equal to **ob**) called residual flux density (+Br). The ability of retaining residual magnetism by a magnetic material is called as retentivity of the material.
- In order to demagnetise the iron bar i.e. to remove the residual magnetism **(ob)**, the magnetising force is reversed by reversing the coil current. When H is gradually increased in the reversed direction, the B-H curve follows the path bc so that when H = oc, the residual magnetism is zero. The values of H = oc required to completely remove the residual magnetism is known as coercive force (Hc).
- Now, if H is further increased in reverse direction, the material again saturates in the reverse direction (point **d**). Reducing H to zero and then increasing it in the positive direction traces the curve defa. Therefore, when an iron bar is subjected to one complete cycle of magnetisation, the B-H curve traces a closed loop abcdefa called hysteresis loop.

X b)

Given that, reluctance = 3000 A-turns/Wb

Number of turns (N) = 400

Current (I) = 2 A

Magnetic flux $\phi = \frac{mmf}{relucatnce} = \frac{400 \times 2}{3000} = 0.267\ Wb$ (3 Marks)

Inductance $L = \frac{N\phi}{I} = \frac{400 \times 0.267}{2} = 53.33$ (2 Marks)

$\frac{di}{dt} = \frac{2-(-2)}{15} = \frac{4}{15}$

Average emf induced $V = L\frac{di}{dt} = 53.33 \times \frac{4}{15} = 14.22$ ( 2 Marks)