Q.2 a. State and explain Lenz's law and Faraday's law of electromagnetic induction. (8)

Answer:

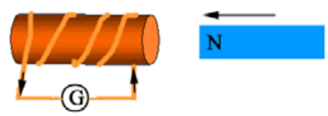
Lenz's law infact describes that in order to produce an induced emf or induced current some external source of energy must be supplied otherwise no current will induce.

Lenz's law states that-

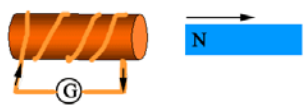
"The direction of induced current is always such as to oppose the cause which produces it".

Consider a bar magnet and a coil of wire.

When the N-pole of magnet is approaching the face of the coil, it becomes a north face by the induction of current in anticlockwise direction to oppose forward motion of the magnet.



b. When the N-pole of the magnet is receding the face of the coil becomes a south pole due to a clockwise induced current to oppose the backward motion.



Faraday's Law states that "When magnetic flux changes through a circuit, an emf is induced in it which lasts only as long as the change in the magnetic flux through the circuit continues".

Quantitatively, induced emf is directly proportional to the rate of change of magnetic flux throughthe coil. i.e.

Average emf = $-Nd\Phi/dt$

Where N = number of turns in the coil.

The negative sign indicates that the induced current is such that the magnetic field due to it opposes the magnetic flux producing it.

b. Describe qualitatively and quantitatively the force between long parallel current carrying conductors. (8)

Answer:

Forces between two parallel conductors

When two conductors are placed within a distance of each other, they will experience a force as the magnetic fields around each conductor will interact with each other.

- When the conductors are parallel, the magnetic fields interact with each other in a way depending on the direction of the current in the conductors.
  - If the conductors are flowing in the same direction, their magnetic fields would join and they would attract each other.
  - If the conductors are flowing in opposite directions, their magnetic fields would repel and the conductors would repel each other.
  - Both of these can be confirmed by the use of the right hand push rule.

Finding the magnitude of the force

Based on the above, we can describe the magnetic interaction of I1 on I2 to be

$$B = kI2 / d$$

We also know that the force provided by wire one can be found as $F = BI1l$

Thus:

$$B = F / I1l$$

Hence, the magnitude of the force can be summed up mathematically as:

$$F = kI1I2 / ld$$

Where:

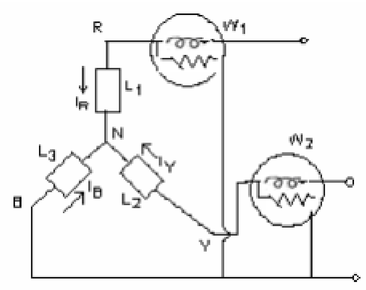
- B is the strength of the External Magnetic Field
- k is Ampere's constant (2.00×10^{-7})
- I1 and I2are the currents in the first conductor and the second conductor respectively(A)
- l is the **common/shared** length of the conductors (m)
- d is the perpendicular distance between the two conductors (m)

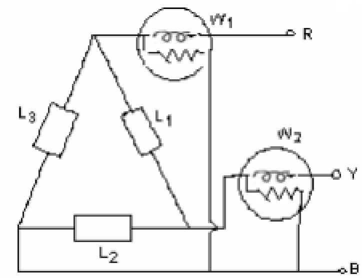
Q.3 a. What are the different methods of measurement of power in 3-phase circuit? Explain the two wattmeter method in brief. (8)

Answer:

Following methods are available for measuring power in 3-phase circuit
i) Three wattmeter method
ii) Two wattmeter method
iii) One wattmeter method

Two wattmeter method: In this method, two wattmeters are used for power measurement. As shown in figure, the current coils of two wattmeters are inserted in any two line and the voltage coil of each joined to the 3rd line. It can be proved that the sum of the instantaneous power indicated by W1 and W2 gives the instantaneous power absorbed by the three loads L1, L2 & L3.





This method can be applied to star connected as well as delta connected load. Considering star connected load

$$\text{Instantaneous current through } W_1 = i_R$$
$$\text{Instantaneous Voltage across } W_1 = e_{RB} = e_R - e_B$$
$$\text{Instantaneous Power read by } W_1 = i_R(e_R - e_B)$$
$$\text{Instantaneous current through } W_2 = i_y$$
$$\text{Instantaneous Voltage across } W_2 = e_{yB} = e_y - e_B$$
$$\text{Instantaneous Power read by } W_2 = i_y(e_y - e_B)$$
$$\text{Therefore } W_1 + W_2 = i_R(e_R - e_B) + i_y(e_y - e_B)$$
$$= i_R e_R + i_y e_y - e_B(i_y + i_R)$$
$$\text{Now } i_R + i_y + i_B = 0 \text{ by kirchoffs point law}$$
$$(i_y + i_R) = -i_B$$
$$W_1 + W_2 = i_R e_R + i_y e_y + i_B e_B = p_1 + p_2 + p_3$$

Where p1 is the power absorbed by L1, p2 that absorbed by L2 and p3 that absorbed by L3

W1 + W2 = total power absorbed.

Hence in two wattmeter method the sum of readings of two wattmeters gives the total power absorbed by 3-Φ circuit.

b. State the following: (8)
(i) Thevenin's Theorem.
(ii) Norton's Theorem.
(iii) Maximum power transfer theorem.
(iv) Kirchoff's laws.

Answer:

(i) Thevenin's Theorem states that the current flowing through a load resistance RL connected across any two terminals A and B of a linear, active bilateral network is given by Voc / (Rin + RL) where Voc is the open circuit voltage (ie. the voltage across the two terminals when RL is removed) and Rin is the internal resistance of the network as viewed back into the open circuited network from terminals A and B with all voltage sources replaced by their internal resistance (if any) and current sources by infinite resistance.

(ii) Norton's Theorem states that any two – terminal active network containing voltage sources and resistances when viewed from its output terminals, is equivalent to a constant current source and parallel resistance. The constant current is equal to the current which would flow in a short circuit placed across the terminals and parallel resistance is the resistance of the network when viewed from these open circuited terminals after all voltage and current sources have been removed and replaced by their internal resistances.

(iii)Maximum power transfer theorem: A resistive load will abstract maximum power from a network when the load resistance is equal to the resistance of the network as viewed from the output terminals, with all energy sources removed leaving behind their internal resistances.

(iv)Kirchoff's first law states that the algebraic sum of all currents meeting at a point is zero.

$\Sigma I = 0.$

Kirchoff's second law states that, in a closed circuit, the algebraic sum of all the emf's plus the algebraic sum of all the voltage drops (i.e. product of current and resistances) is zero.

$\Sigma I R + \Sigma \text{emf} = 0.$

Q.4 a. Give reasons, why the starters are required for starting a motor? (6)

Answer:

In case of DC motors, when the motor is at rest, the induced emf in the armature is zero. Consequently, if full voltage is applied across the motor terminals, the armature will draw heavy current because the armature resistance is relatively very small. This heavy starting current will blow out the fuses and it may also damage the armature winding due to excessive heating effect. Excessive voltage drop will occur in the lines to which the motor is connected. To avoid this heavy current at start, a variable resistance is connected in series with the armature called starting resistance or starter, thus the armature current is limited to a safe value. Once the motor picks up speed, emf is built up and the resistance is gradually reduced. The whole resistance is taken out of circuit when the motor attains normal speed. The starter contains the protective device as overload protection coil (or relay), which provides necessary protection to the motor against overloading.

b. A 240V dc shunt motor has an armature resistance of 0.4 ohm and is running at the full-load speed of 600 r.p.m. with a full load current of 25A. The field current is constant. Find the speed if a resistance of 1 ohm is added in series with the armature (i) at the full-load torque and (ii) at twice the full-load torque. (10)

Answer:

In a DC shunt motor

$V = 240V$

$Ra = 0.4\Omega$

N1 = 600rpm (full load speed)
Ia = 25A and, ISh is constant
R = 1 Ω added in series with armature

Eb1 = V - IaRa
= 240 -25 x 0.4
= 230 volts

Eb2 = V - Ia (Ra+ R)
= 240 -25 (0.4+ 1)
= 201 volts

Now N1 / N2 = Eb1 / Eb2 x Φ2 / Φ1 (Φ1 = Φ2 = constant)
N2 = N1 x Eb2 / Eb1 at full load torque
= 600 x 201/ 230
= 534.78

∴ the speed of motor at full load = 535 rpm

Now,
N3 / N1 = Eb3 / Eb1 x Φ1 / Φ3 (Φ1 = Φ2= Φ3 = constant)

And Eb3 at twice the full load torque

∴ Ia2 = 2 Ia =50 amp.

∴ Eb3 = 240-50 (1 +0.4) = 240 – 70 = 170 volts.

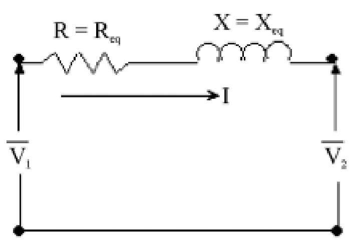
N3 = N1 x Eb3 / Eb1 = 600 x 170 /230 = 443.47 rpm

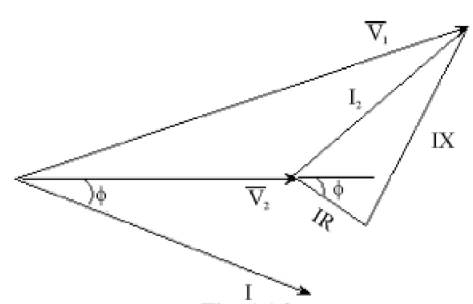
Therefore the speed of motor at twice of the load = 443 rpm

Q.5 a. Draw and explain the phasor diagram of a transformer on load, at a lagging power factor. (8)

Answer:

Figure shows the phase diagram of a transformer on a load at lagging power factor and the corresponding equivalent circuit of transformer in which all quantities are referred to the primary. Thus V2 is the secondary terminal voltage referred to the primary [where over bar implies a phasor].





$$R = R_{eq} = R_1 + R_2' = R_1 + R_2\left(\frac{N_1}{N_2}\right)^2$$

$$X = X_{eq} = X_{l_1} + X_{l_2}' = X_{l_1} + \left(\frac{N_1}{N_2}\right)^2 X_{l_2}$$

$$\overline{V_1} = \overline{V_2} + \overline{I}(R + jX)$$

Where R1 and R2 are primary and secondary resistances, N1 and N2 are primary and secondary number of turns and Xl1 and Xl2 are leakage reactances of primary and secondary windings.

b. A 400V, 4-pole, 50 Hz, 3-phase, 10 hp, star connected induction motor has a no load slip of 1% and full load slip of 4%. Find the following: (i) Synchronous speed (ii) no-load speed (iii) full-load speed and (iv) frequency of rotor current at full-load. (8)

Answer:

Given :

VL = 400 volts; P = 4, f= 50 Hz,

i. Synchronous speed NS = 120 f / p
= 120 x 50 / 4 = 1500 rpm

ii. No load speed at s = 0.01
N0 = NS (1 – s) = 1500 (1- 0.01)
= 1485 rpm

iii. Full load speed at sf
= 0.04
Nfl = NS (1-sf) = 1500 (1-0.04)
= 1440 rpm

iv. Frequency of rotor current (fr) = sf
s.f = 0.04 x 50
= 2.0 Hz

Q.6 a. Discuss the process of doping in a switching diode. What is reverse recovery time? (8)

Answer:

In switching diodes a lightly doped neutral region is made, whose length is shorter than a minority carrier diffusion length. In this case the stored charge for forward conduction is very small, since most of the injected carriers diffuse through the lightly doped region to end contact. When such a diode is switched to reverse conduction, very little time is required to eliminate the stored charge in the narrow neutral region. A second approach is to add efficient recombination centres to the bulk material. For Si diode, Au doping is useful for this purpose. To a good approximation the carrier the carrier lifetime varies with the reciprocal center concentration. The total time required for the reverse current to decay to 10% of its maximum magnitude is defined as recovery time.

b. Distinguish between avalanche and zener breakdown in p-n junction diode.(8)

Answer:

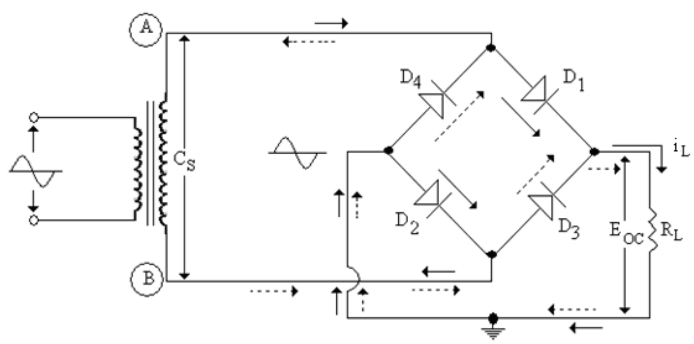
Both avalanche breakdown and zener breakdown occur under reverse biased condition of p-n junction and the common cause is the electric field accelerating a carrier which collides with an ion and breaks the covalent bond releasing one or more extra carriers.

In the case of avalanche breakdown, the carriers are thermally generated ones, accelerating under externally applied large electric field in reverse bias and the process is cumulative giving rise to more and more pairs of carriers by multiple collision of ions. The result is destructive.

On the other hand, in a zener breakdown, the breaking of ionic bond and generation of extra carriers is by the intense electric field across a very narrow depletion region at the junction, mainly due to heavy doping of both p and n regions of the diode. The resulting process gives rise to large reverse current and is reversible. This phenomenon is called 'Zener breakdown'.

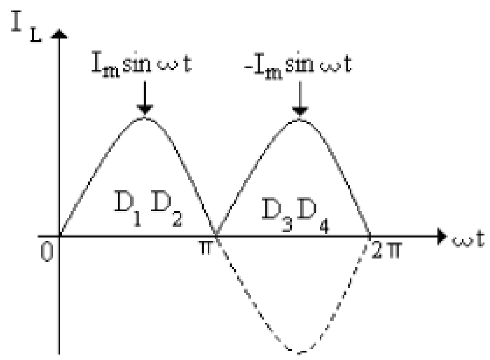
Q.7 a. Explain the working of a Bridge rectifier with a neat circuit diagram. (8)

Answer:



During positive half cycle of the input voltage point A becomes positive. Diodes D1 and D2 will be forward biased and D3 and D4 reverse biased. D1 and D2 conduct in series with the load and the current flows in the direction as shown in figure1 by solid arrows. In the next half cycle, when the polarity of the ac voltage reverses, 'B' becomes positive D3 and D4 are forward biased, while D1 and D2 are reverse biased. D3 and D4 conduct in series with the load and the current flows as shown by dotted arrows.

During both the half cycles of input signal, the current through RL is in same direction and is as shown in Fig.



b. Derive the expressions for rectification efficiency and ripple factor for a bridge rectifier. (8)

Answer:

Expression for efficiency and ripple factor:

$$i_L = I_m \sin \omega t \quad 0 \le \omega t \le \pi$$
$$i_L = -I_m \sin \omega t \quad \pi \le \omega t \le 2\pi$$

$$I_{dc} = (1/\pi) \int_0^{\pi} I_m \sin \omega t \, d(\omega t)$$

$$I_{dc} = 2I_m / \pi \text{ and } E_{dc} = 2E_m / \pi$$

$$I_{RMS} = \sqrt{\left({}^{1}/_{2\pi} \int_0^{2\pi} i_L^2 \, d\omega t \right)} = \sqrt{\left({}^{2}/_{2\pi} \int_0^{\pi} (I_m \sin\omega t) \right)^2 d(\omega t)}$$

$$= \mathbf{I_m} \sqrt{{}^{1}/_{\pi} \int_0^{\pi} [(1 - \cos 2\omega t)/2] \, d(\omega t)} = \mathbf{I_m}/\sqrt{2}$$

In bridge rectifier, in each half cycle two diodes conduct simultaneously. Hence maximum value of load current is

$$I_m = \frac{E_m}{(R_s + 2R_f + R_L)}$$

$$P_{DC} = I_{DC}{}^2 R_L = \left(\frac{2I_m}{\Pi}\right)^2 R_L$$

where Rs = transformer secondary winding resistance.

$$P_{AC} = I_{rms}{}^2 (2R_f + R_s + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (2R_f + R_s + R_L)$$

$$\text{rectification efficiency} = P_{DC}/P_{AC} = \frac{[(4I_m^2/\pi^2)\, R_L]}{I_m^2/2\,(2R_f+R_s+R_L)} \approx \frac{8R_L}{\pi^2 R_L} \quad (\text{since } 2R_f+R_s << R_L)$$

$$= 8/\pi^2 = 81.05\%$$

$= 8/\pi^2 = 81.05\%$

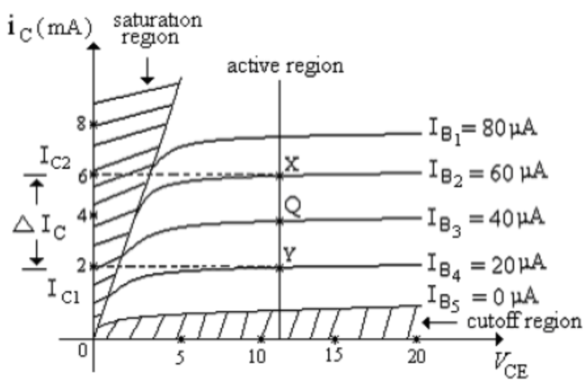
Ripple factor $= \sqrt{(I_{rms}/I_{DC})^2 - 1}$

$= \sqrt{[(I_m/\sqrt{2})/(2I_m/\pi)]^2 - 1} = \sqrt{(\pi^2/8) - 1} = 0.48.$

Q.8 a. Sketch the output V-I characteristic of a BJT in CE configuration. Indicate thereon, the different regions. How one can determine the value of hfe or βF with the help of these characteristics? (8)

Answer:

Fig. shows the characteristics of BJT in CE configuration.



To find hfe, draw a constant VCE line (vertical) going through desired Q point. Choose constant IB lines suitably, which cut the constant VCE line at X and Y. The hfe can be determined as follows

$$h_{fe} = \frac{\Delta I_C}{\Delta I_B}$$

For example, the hfe in the given figure can be determined as below:

$h_{fe} = \Delta I_C / \Delta I_B$. From fig $h_{fe} = (I_{C2} - I_{C1}) / (I_{B4} - I_{B2})$

$= (6-2)$ mA / $(60-20)$ μA $= 100$.

b. Design a series voltage regulator using a transistor having VBE = 0.6V and β=50, which can supply 1A to a load at a constant voltage of 9V. The supply voltage to regulator is 15V±10%. The minimum zener current is 12mA. (8)

Answer:

$I_B = \frac{I_c}{\beta} = \frac{1A}{50} = 20mA$

$V_{out} = V_z - V_{BE}$

$9 = V_z - 0.6$

$V_z = 9.6v$

Voltage drop in resistor $R = V_{in} - V_Z = 15 - 9.6 = 5.4v$

Current through resistor R, $I = I_B + I_Z = 20 + 12 = 32mA$

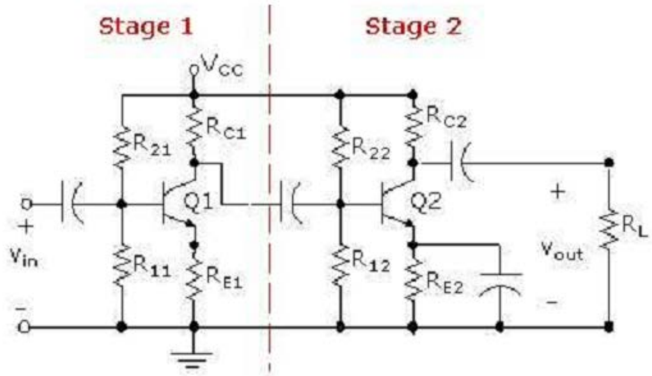
$\therefore \quad R = \frac{\text{Voltage drop in resistor } R}{I} = \frac{5.4}{32mA}$

$R = 168.75\Omega$.

Q.9a. What is the benefit of capacitive coupling? Explain a two stage RC coupled CE amplifier. (8)

Answer:

Capacitive coupling is the simplest and most effective way to remove the effects of any dc levels between amplifier stages, since the capacitor removes the dc component from the ac signal. This is important in multistage amplifiers because we do not want to amplify any dc levels, which may drive the amplifier into saturation and render the output useless. Capacitive coupling allows us to treat each stage as an individual in terms of biasing. A two stage RC coupled CE amplifier is shown in Figure:



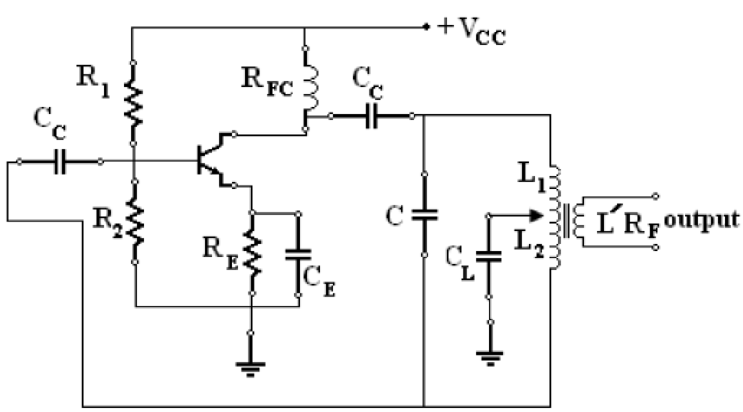
When input AC. signal is applied to the base of the transistor of the 1st stage of RC coupled amplifier, from the function generator, it is then amplified across the output of the 1st stage. This amplified voltage is applied to the base of next stage of the amplifier, through the coupling capacitor Cout where it is further amplified and reappears across the output of the second stage.

Thus the successive stages amplify the signal and the overall gain is raised to the desired level. Much higher gain can be obtained by connecting a number of amplifier stages in succession.

Resistance-capacitance (RC) coupling in amplifiers are most widely used to connect the output of first stage to the input (base) of the second stage and so on. This type of coupling is most popular because it is cheap and provides a constant amplification over a wide range of frequencies.

b. Derive an expression for the frequency of oscillation, in a Hartley oscillator.(8)

Answer:



The Hartley oscillator widely used as a local oscillator in radio receivers.

$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_2 Z_3 = 0 \qquad \text{--------(1)}$$

Here $Z_1 = jwL_1 + jwM$, $Z_2 = jwL_2 + jwM$ and $Z_3 = \frac{1}{jwc} = -j/wc$

Substituting these values in equation (1), we get

$$h_{ie}\left[(jwL_1 + jwM) + (jwL_2 + jwM) - \frac{j}{wc}\right] + (jwL_1 + jwM)(jwL_2 + jwM)(1 + h_{fe}) + (jwL_2 + jwM)\left(-j/wc\right) = 0$$

$$jwh_{ie}\left[L_1 + L_2 + 2M - \frac{1}{w^2 c}\right] - w^2 (L_2 + M)\left[(L_1 + M)(1 + h_{fe}) - \frac{1}{w^2 c}\right] = 0$$

Equating imaginary parts of above equation to zero we get,

While $\left[L_1 + L_2 + 2M - \frac{1}{w^2 c}\right] = 0$

Or $L_1 + L_2 + 2M - \frac{1}{w^2 c} = 0 \quad \therefore wh_{ie} \neq 0$

$$w^2 c = \frac{1}{L_1 + L_2 + 2M}$$

Or $f = \frac{w}{2\pi} = \frac{1}{2\pi\sqrt{c(L_1 + L_2 + 2M)}}$

Text Book

V N Mittle and Arvind Mittle, Basic Electrical Engineering , Tata McGraw-Hill Publishing Company Limited,2nd edition ,2006.
Electronic Devices and Circuits, David A Bell, Fourth Edition ,PHI(2006)