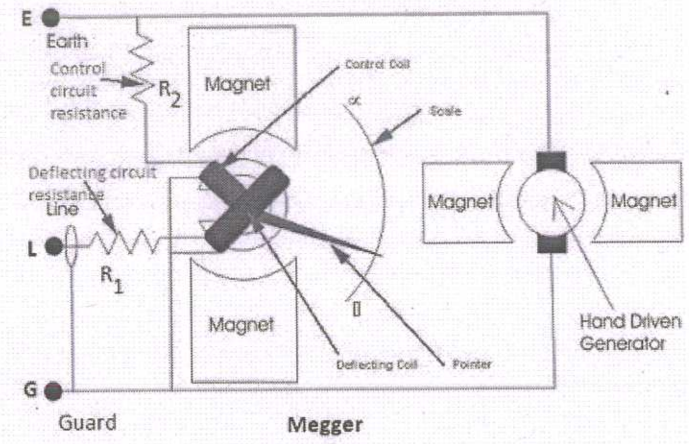
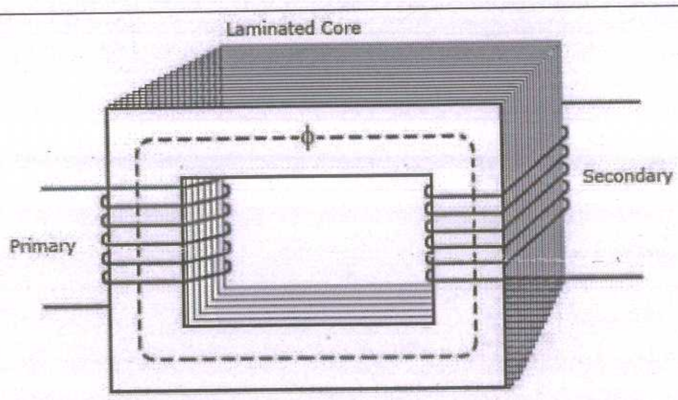
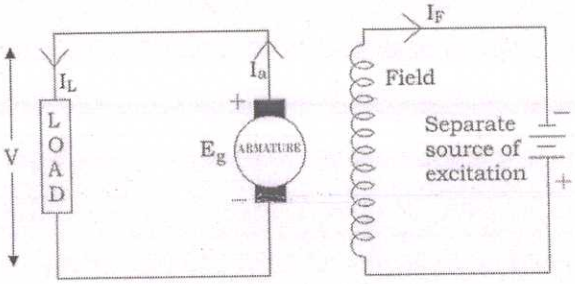
SCHEME OF VALUATION

Scoring Indicators

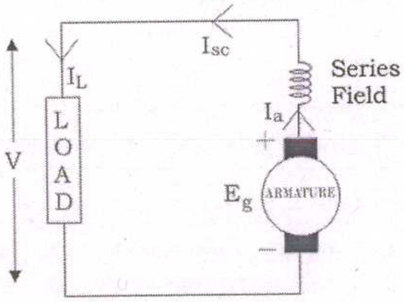
Revision : 2015 **Course Title : ELECTRICAL TECHNOLOGY**		**Course Code : 3043**		
Qst. No.	Scoring Indicator	Splitup score	Sub total	Total
I	**PART A**			
1	For protection of human life from shock and also protection of equipment. It provides alternate path for high current to flow during faulty conditions	2	2	2
2	Step up transformers –transformers which are used to increase the input voltage of a system Step down transformers – they reduce the input voltage	1+1	2	2
3	$Eg = P\Phi NZ / 60A$ P = number of field poles Ø = flux produced per pole in Wb (weber) Z = total no. of armature conductors A = no. of parallel paths in armature N = rotational speed of armature in revolutions per min. (rpm)	2	2	2
4	I=V/R, when temperature remains constant the current through a conductor is proportional to the voltage and inversely proportional to the resistance.	2	2	2
5	The servo motor is used in robotics to activate movements, giving the arm to its precise angle. The servo motor is used in robotic vehicle to control the robot wheels, producing plenty torque to move, start and stop the vehicle and control its speed	1 + 1	2	2

II	**PART B**			
1	 The resistance under test is connected between test terminals (L and G) the generator handle is then steadily turned at a uniform speed till the pointer gives a steady reading. The **working of megger** insulation tester can be fully understood from the following steps: **Step 1.** When the test terminals are open, the resistance to be measured is infinite. In case the generator handle is rotated, the generated voltage sends current through the potential coil and no current flows in the current coil. Therefore, the moving system rotates in such a direction that the pointer rests at infinity end of the scale. **Step 2.** If the test terminals are short-circuited and the generator is operated, it sends a large current through the current coil and a very small current flows through the potential coil. Therefore, the resultant torque so produced turns the pointer to zero end of the scale. **Step 3.** If the unknown resistance to be measured is connected between test terminals, an appreciable amount of current flows in both the coils. The actual position taken up by the pointer depends upon the ratio of currents in the two coils i.e. upon the unknown resistance.	Fig 2 + Exp (2 + 2)	6	6

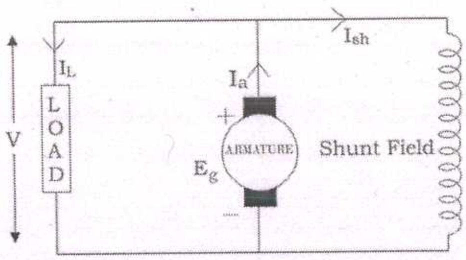
2	 As shown above the electrical transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as $e=M*dI/dt$ If the second coil circuit is closed, a current flows in it and thus electrical energy is transferred magnetically from the first to the second coil. The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding. In short, a transformer carries the operations shown below: Transfer of electric power from one circuit to another. Transfer of electric power without any change in frequency. Transfer with the principle of electromagnetic induction. The two electrical circuits are linked by mutual induction	Fig (2) + Exp 4	6	6
3	The answer should include the circuit diagrams for series, shunt, separately excited and compound DC generators	6	6	6



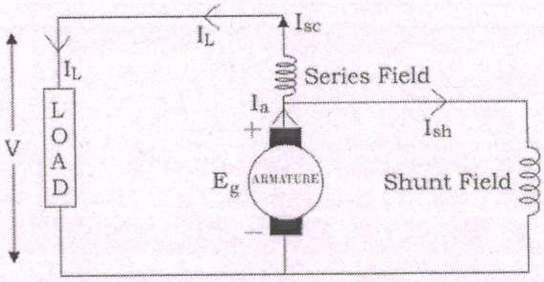
Separately Excited DC Generator



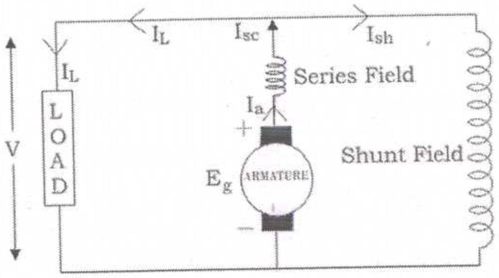
Series Wound Generator

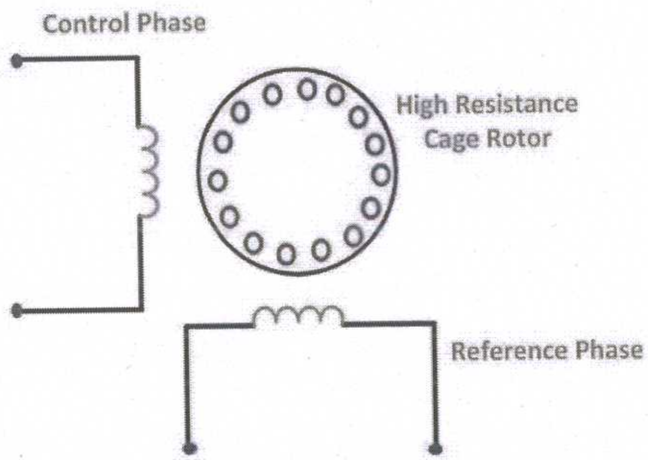


Shunt Wound Generator



Short Shunt Compound Wound Generator

	 Long Shunt Compound Wound Generator			
4	P= No. of poles Z= No. of Conductors or Coil sides in series/phase i.e. Z= 2T…Where T is the number of coils or turns per phase (Note that one turn or coil has two ends or sides) f = frequency of induced e.m.f in Hz ϕ = Flux per pole (Weber) N = rotor speed (RPM) If induced e.m.f is assumed sinusoidal then, Kf= Form factor = 1.11 In one revolution of the rotor i.e. in 60/N seconds, each conductor is cut by a flux of Pϕ Webers. dϕ= ϕP and also dt= secionds60/N then induced e.m.f per conductor (average) = dϕ/ dt= Pϕ/(60/N) =P N ϕ/60…..(a) But We know that f = PN/120 or N= 120f/P Putting the value of N in Equation (a)… We get the average value of e.m.f per conductor is = Pϕ/60 x 120 f/P = **2f ϕ Volts.** —à{N= 120f/P} If there are Z conductors in series per phase, then average e.m.f per phase = 2fϕZ Volts= ***4fϕT***	2 +3+1	6	6

	Volts ….{Z=2T} Also we know that Form factor= RMS Value/Average Value… = RMS value= Form factor x Average Value, = 1.11 x 4fϕT = 4.44fϕT Volts.			
5	Ac servomotor is a two phase induction motor. A reference phase and a control phase is used. The voltage applied to control phase is having a phase difference of + or – 90 degrees with the reference phase The speed and torque of the machine is controlled by the phase difference between the control phase and reference phase  	4+2	6	6
6	Root Mean Square (RMS) value of AC current is defined as the steady or DC current which when flowing through a circuit for a given time period produces the same heat as produced by the AC current flowing through the same circuit for the same time period Derivation Put wt= θ	2 + 4	6	6

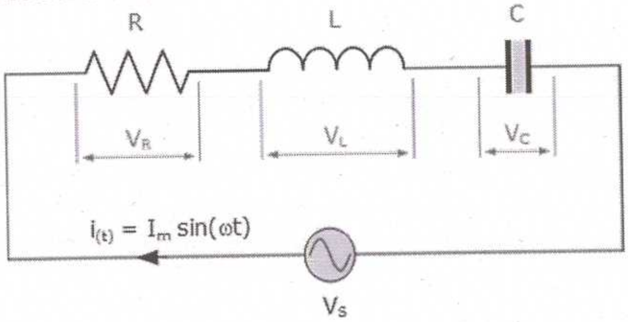
	$\therefore \quad I_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2 . d\theta}$ $I_{rms}^2 = \frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2\theta \, d\theta = \frac{I_m^2}{\pi}\int_0^{\pi} \sin^2\theta . d\theta$ $= \frac{I_m^2}{\pi}\int_0^{\pi}\left(\frac{1-\cos 2\theta}{2}\right).d\theta = \frac{I_m^2}{2\pi}\int_0^{\pi}(1-\cos 2\theta).d\theta$ $= \frac{I_m^2}{2\pi}\left\| \theta - \frac{1}{2}\sin 2\theta \right\|_0^{\pi}$ $= \frac{I_m^2}{2\pi}\left\| \left(\pi - \frac{1}{2}\sin 2\pi\right) - \left(0 - \frac{1}{2}\sin 2\times 0\right) \right\|$ $= \frac{I_m^2}{2\pi}\,\|\pi - 0 - 0 + 0\| = \frac{\pi}{2\pi} I_m^2 = \frac{I_m^2}{2}$ $\therefore \quad I_{rms} = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}} = 0.707\, I_m$			
7	The presence of back emf makes the d.c. motor a *self-regulating machine* i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load. Armature current (Ia), $I_a = \frac{V - E_b}{R_a}$ When the motor is running on no load, small torque is required to overcome the friction and windage losses. Therefore, the armature current Ia is small and the back emf is nearly equal to the applied voltage. If the motor is suddenly loaded, the first effect is to cause the armature to slow down. Therefore, the speed at which the armature conductors move through the field is reduced and hence the back emf Eb falls. The decreased back emf allows a larger current to flow through the armature and larger current means increased driving torque. Thus, the driving torque increases as the motor slows down. The motor will stop slowing down when the armature current is just sufficient to produce the increased torque required by the load. If the load on the motor is decreased, the driving torque is momentarily in excess of the requirement so that armature is accelerated. As the armature speed increases, the back emf Eb also increases and causes the armature current Ia to decrease. The motor will stop accelerating when the armature	6	6	6

<table>
<tr><td></td><td>current is just sufficient to produce the reduced torque required by the load.
Therefore, the back emf in a DC motor regulates the flow of armature current i.e., it automatically changes the armature current to meet the load requirement.</td><td></td><td></td><td></td></tr>
<tr><td>III
(a)</td><td>

PART – C

Power factor is defined as the cosine of angle between the voltage phasor and current phasor in an AC circuit. It is denoted as pf. For an AC circuit, $0 \leq pf \leq 1$ whereas for DC circuit power factor is always 1.

Series RLC Circuit



The series RLC circuit above has a single loop with the instantaneous current flowing through the loop being the same for each circuit element. Since the inductive and capacitive reactance's X_L and X_C are a function of the supply frequency, the sinusoidal response of a series RLC circuit will therefore vary with frequency, f. Then the individual voltage drops across each circuit element of R, L and C element will be "out-of-phase" with each other as defined by:

$i_{(t)} = I_{max} \sin(\omega t)$

The instantaneous voltage across a pure resistor, V_R is "in-phase" with current

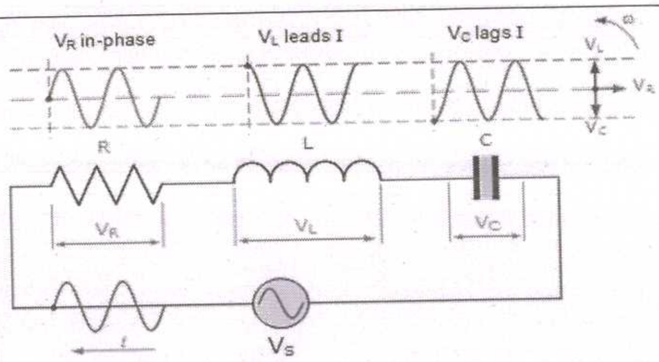
The instantaneous voltage across a pure inductor, V_L "leads" the current by 90°

The instantaneous voltage across a pure capacitor, V_C "lags" the current by 90°

Therefore, V_L and V_C are 180° "out-of-phase" and in opposition to each other.

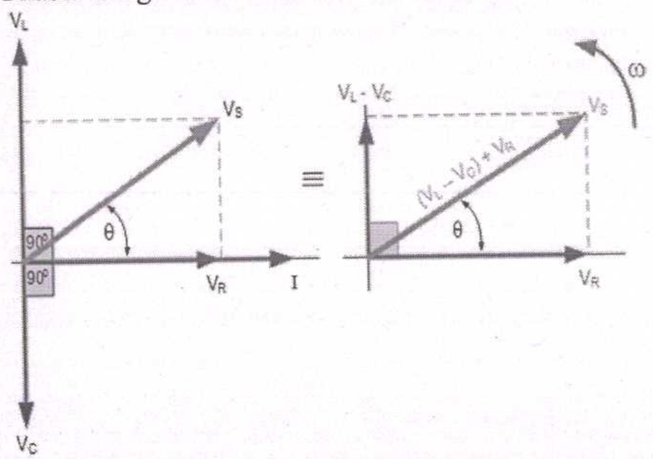
For the series RLC circuit above, this can be shown as:

</td><td>Fig 4 +
Exp 6</td><td>10</td><td>15</td></tr>
</table>



The amplitude of the source voltage across all three components in a series RLC circuit is made up of the three individual component voltages, V_R, V_L and V_C with the current common to all three components. The vector diagrams will therefore have the current vector as their reference with the three voltage vectors being plotted with respect to this reference as shown below.

Phasor Diagram for a Series RLC Circuit



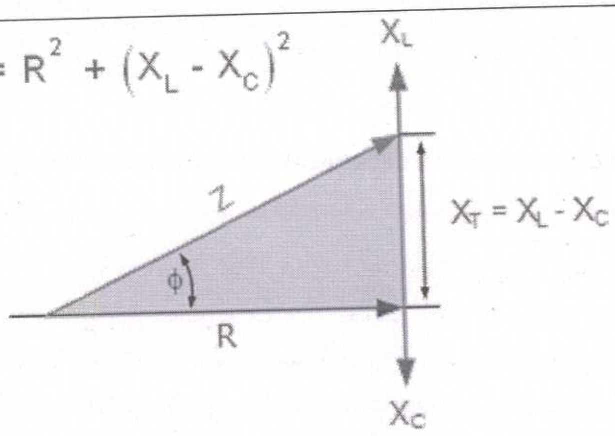
We can see from the phasor diagram above that the voltage vectors produce a rectangular triangle, comprising of hypotenuse VS, horizontal axis VR and vertical axis VL – VC Hopefully you will notice then, that this forms our old favourite the Voltage Triangle and we can therefore use Pythagoras's theorem on this voltage triangle to mathematically obtain the value of VS as shown.

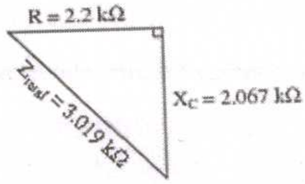
(b)

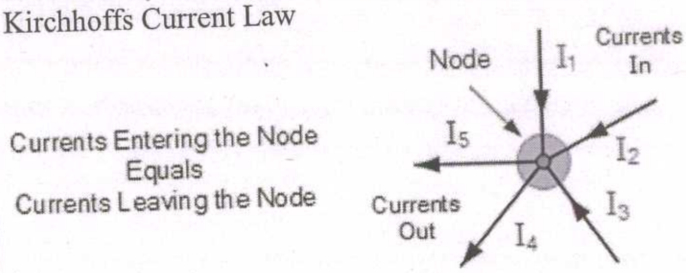
$$V_S^2 = V_R^2 + (V_L - V_C)^2$$

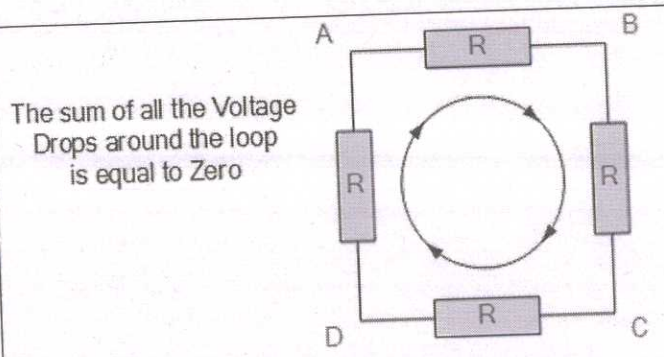
$$V_S = \sqrt{V_R^2 + (V_L - V_C)^2}$$

The Impedance Triangle for a Series RLC Circuit

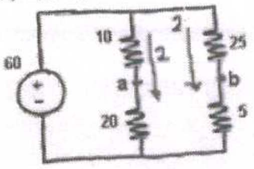
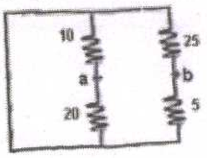
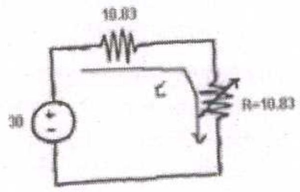
	$Z^2 = R^2 + (X_L - X_C)^2$  The impedance Z of a series RLC circuit depends upon the angular frequency, ω as do XL and XC If the capacitive reactance is greater than the inductive reactance, XC > XL then the overall circuit reactance is capacitive giving a leading phase angle. Likewise, if the inductive reactance is greater than the capacitive reactance, XL > XC then the overall circuit reactance is inductive giving the series circuit a lagging phase angle. If the two reactance's are the same and XL = XC then the angular frequency at which this occurs is called the resonant frequency and produces the effect of resonance which we will look at in more detail in another tutorial. Then the magnitude of the current depends upon the frequency applied to the series RLC circuit. When impedance, Z is at its maximum, the current is a minimum and likewise, when Z is at its minimum, the current is at maximum. So the above equation for impedance can be re-written as: $\text{Impedance, } Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ The phase angle, θ between the source voltage, VS and the current, i is the same as for the angle between Z and R in the impedance triangle. This phase angle may be positive or negative in value depending on whether the source voltage leads or lags the circuit current and can be calculated mathematically from the ohmic values of the impedance triangle as: The power factor of the circuit is defined as the cosine of the angle between the source voltage and current Ie. Pf = Cos θ =R/Z	3+2	5	

IV **(a)**	 Xc= 1/(2pi fC) $R = 2.2\ k\Omega\ X_C = 2.067\ k\Omega$ $Z_{series} = \sqrt{R^2 + X_C^2}$ $Z_{series} = \sqrt{2200^2 + 2067^2} = 3019\ \Omega$	Fig 3 + Exp 5	8	15
(b)	$I_r = \frac{V}{R} = \frac{5}{100} = 0.05\ A$ $I_c = \frac{V}{-jX_C} = \frac{5}{-j200} = j0.025\ A$ $I_t = (I_r^2 + I_c^2)^{1/2} = (0.0025 + 0.000625)^{1/2} = 0.0559$ $Z = \frac{V}{I_T} = \frac{5}{0.0559} = 89.44\Omega$	7	7	
V **(a)**	Kirchhoffs Circuit Laws with one of Kirchhoffs laws dealing with the current flowing around a closed circuit, Kirchhoffs Current Law, (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoffs Voltage Law, (KVL). Kirchhoffs First Law – The Current Law, (KCL)			

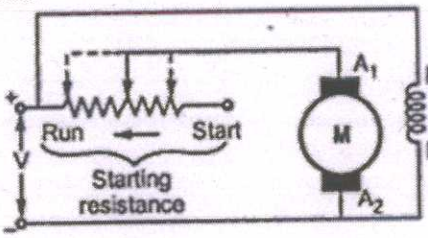
	Kirchhoffs Current Law or KCL, states that the "total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, I(exiting) + I(entering) = 0. This idea by Kirchhoff is commonly known as the Conservation of Charge. Kirchhoffs Current Law  $I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$ Here, the three currents entering the node, I1, I2, I3 are all positive in value and the two currents leaving the node, I4 and I5 are negative in value. Then this means we can also rewrite the equation as; I1 + I2 + I3 – I4 – I5 = 0 The term Node in an electrical circuit generally refers to a connection or junction of two or more current carrying paths or elements such as cables and components. Also for current to flow either in or out of a node a closed circuit path must exist. We can use Kirchhoff's current law when analysing parallel circuits. Kirchhoffs Second Law – The Voltage Law, (KVL) Kirchhoffs Voltage Law or KVL, states that "in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop" which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the Conservation of Energy. Kirchhoffs Voltage Law	4+4	8	15

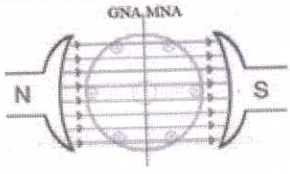
		 $V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$ Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero. We can use Kirchhoff's voltage law when analysing series circuits. When analysing either DC circuits or AC circuits using Kirchhoffs Circuit Laws a number of definitions and terminologies are used to describe the parts of the circuit being analysed such as: node, paths, branches, loops and meshes. These terms are used frequently in circuit analysis so it is important to understand them.			
	(b)	Let, N1 = Number of turns in primary winding N2 = Number of turns in secondary winding Φm = Maximum flux in the core (in Wb) = (Bm x A) f = frequency of the AC supply (in Hz) the flux rises sinusoidally to its maximum value Φm from 0. It reaches to the maximum value in one quarter of the cycle i.e in T/4 sec (where, T is time period of the sin wave of the supply = 1/f). Therefore, average rate of change of flux = Φm /(T/4) = Φm /(1/4f) Therefore, average rate of change of flux = 4f Φm .... (Wb/s). Now, Induced emf per turn = rate of change of flux per turn Therefore, average emf per turn = 4f Φm ....(Volts). Now, we know, Form factor = RMS value / average value Therefore, RMS value of emf per turn = Form	7	7	

	factor X average emf per turn. As, the flux Φ varies sinusoidally, form factor of a sine wave is 1.11 Therefore, RMS value of emf per turn = $1.11 \times 4f\,\Phi m = 4.44f\,\Phi m$. RMS value of induced emf in whole primary winding (E1) = RMS value of emf per turn X Number of turns in primary winding $E1 = 4.44f\,N1\,\Phi m$ .... eq 1 Similarly, RMS induced emf in secondary winding (E2) can be given as $E2 = 4.44f\,N2\,\Phi m$. .... eq 2			
VI (a)	In electrical engineering, the maximum power transfer theorem states that, " to obtain maximum external power from a source with a finite internal resistance, the resistance of the load must equal the resistance of the source as viewed from its output terminals"	3+5	8	

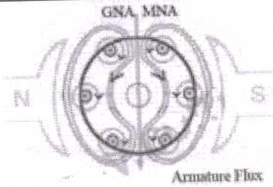
	SOLUTION: (a) V_{th}: Open circuit voltage  From the circuit, $V_{ab}=V_{th}=40-10=30$ [V] (b) R_{th}: Let's apply Input Resistance Method:  Then $R_{ab}=(10//20)+(25//5)=6.67+4.16=10.83=R_{th}$. (c) Thevenin circuit:  $P_{max}=\left(\frac{30}{2\times10.83}\right)^2\cdot(10.83)=20.77$ [W]			15
(b)	Iron Losses Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as Core loss. Iron loss is further divided into hysteresis and eddy current loss. Hysteresis Loss The core of the transformer is subjected to an alternating magnetising force, and for each cycle of emf, a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss and given by the equation shown below $P_h = K\eta B_{max}^{1.6} f V$ watts Where $K\eta$ is a proportionality constant which depends upon the volume and quality of the material of the core used in the transformer. f is the supply frequency Bmax is the maximum or peak value of the flux density The iron or core losses can be minimised by using silicon steel material for the construction of the core of the transformer.	1+2+2+2	7	

	Eddy Current Loss When the flux links with a closed circuit, an emf is induced in the circuit and the current flows, the value of the current depends upon the amount of emf around the circuit and the resistance of the circuit. Since the core is made of conducting material, these EMFs circulates currents within the body of the material. These circulating currents are called Eddy Currents. They will occur when the conductor experiences a changing magnetic field. As these currents are not responsible for doing any useful work, and it produces a loss (I^2R loss) in the magnetic material known as an Eddy Current Loss. The eddy current loss is minimised by making the core with thin laminations. The equation of the eddy current loss is given as $$P_e = K_e B_m^2 t^2 f^2 V \quad \text{watts}$$ Where, K_e – co-efficient of eddy current. Its value depends upon the nature of magnetic material like volume and resistivity of core material, thickness of laminations B_m – maximum value of flux density in wb/m^2 T – thickness of lamination in meters F – frequency of reversal of magnetic field in Hz V – volume of magnetic material in m^3 Copper Loss Or Ohmic Loss These losses occur due to ohmic resistance of the transformer windings. If I_1 and I_2 are the primary and the secondary current. R_1 and R_2 are the resistance of primary and secondary winding then the copper losses occurring in the primary and secondary winding will be $I_1^2R_1$ and $I_2^2R_2$ respectively. Therefore, the total copper losses will be $$P_c = I_1^2R_1 + I_2^2R_2$$			
VII (a)	At starting, heavy current is drawn by the dc motor from the supply as some time is required by the motor to gain speed and hence to built up back emf. If the starter is not present then there will be overheating of armature and voltage drop in supply takes place. So starters are required to limit this initial heavy inrush current to stop the overheating of the armature. Hence the main functions of starter are to limit functions			

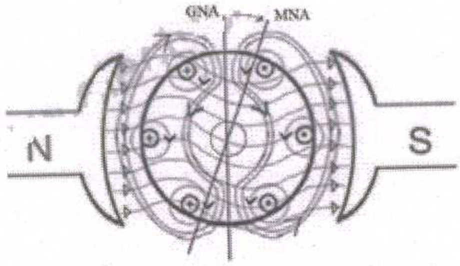
	of starter is to limit the starting current in armature circuit during starting. The necessity of starter: -we know that in case of dc motor $I_a=(V-E_b)/(R_a)$ and $E_b=(\emptyset ZNP)/60$ So during starting, speed(N) is zero. Hence back emf E_b is zero. If the armature resistances is very small then armature current will be very large. This excess armature current may damage the winding. To avoid this excessive starting current, the starter is needed in the circuits of the armature. In the starter, additional resistance is connected in series with armature at the time of starting. When motor attains its full speed, this resistance gets disconnected. 	2 + 5 (Fig 2 +exp 5)	7	15
(b)	In a DC machine, two kinds of magnetic fluxes are present; 'armature flux' and 'main field flux'. The effect of armature flux on the main field flux is called as armature reaction. MNA And GNA EMF is induced in the armature conductors when they cut the magnetic field lines. There is an axis (or, you may say, a plane) along which armature conductors move parallel to the flux lines and, hence, they do not cut the flux lines while on that plane. MNA (Magnetic Neutral Axis) may be defined as the axis along which no emf is generated in the armature conductors as they move parallel to the flux lines. Brushes are always placed along the MNA because reversal of current in the armature conductors takes place along this axis. GNA (Geometrical Neutral Axis) may be defined as the axis which is perpendicular to the stator field axis. Armature Reaction The effect of armature reaction is well illustrated in the figure below.	fig 3 + Exp 3+adv effect 2	8	



Main field flux



Armature Flux



Distortion of main field flux due to armature flux - Armature reaction

Consider, no current is flowing in the armature conductors and only the field winding is energized (as shown in the first figure of the above image). In this case, magnetic flux lines of the field poles are uniform and symmetrical to the polar axis. The 'Magnetic Neutral Axis' (M.N.A.) coincides with the 'Geometric Neutral Axis' (G.N.A.).

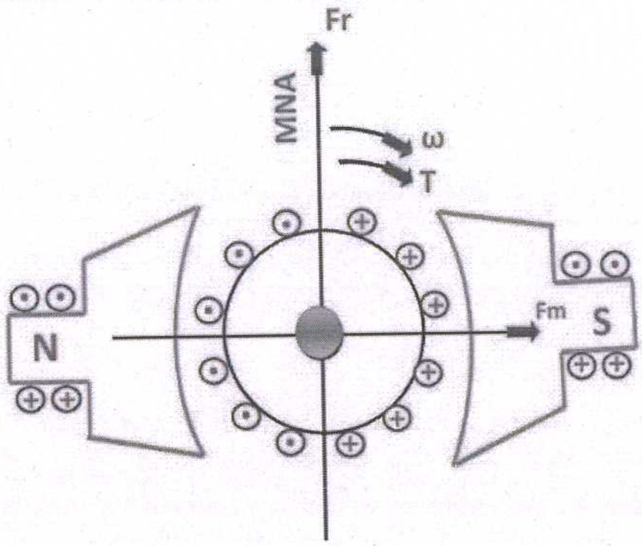
The second figure in the above image shows armature flux lines due to the armature current. Field poles are de-energised.

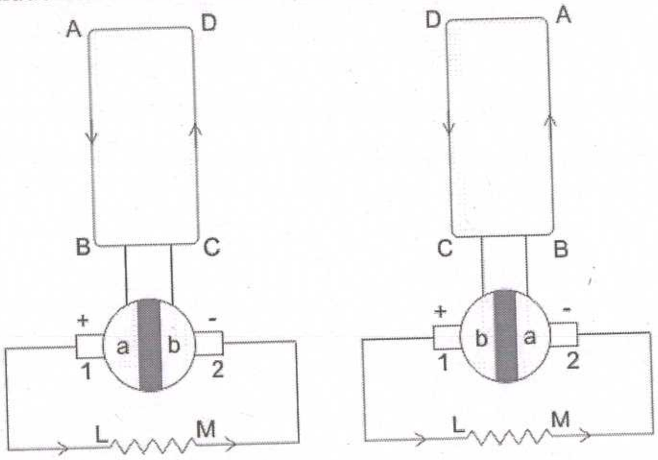
Now, when a DC machine is running, both the fluxes (flux due to the armature conductors and flux due to the field winding) will be present at a time. The armature flux superimposes with the main field flux and, hence, disturbs the main field flux (as shown in third figure the of above image). This effect is called as armature reaction in DC machines.

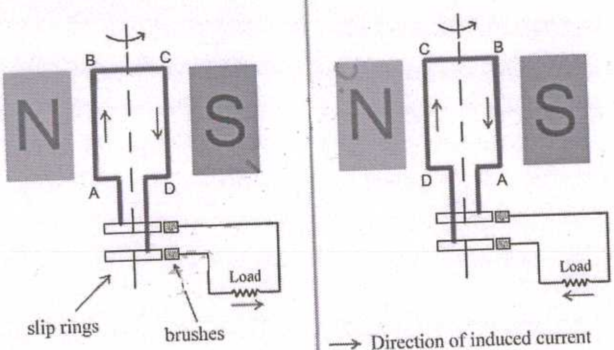
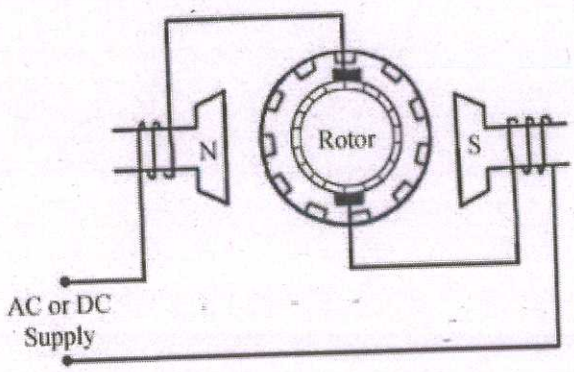
The Adverse Effects Of Armature Reaction:

Armature reaction weakens the main flux. In case of a dc generator, weakening of the main flux reduces the generated voltage.

Armature reaction distorts the main flux, hence the position of M.N.A. gets shifted (M.N.A. is perpendicular to the flux lines of main field flux). Brushes should be placed on the M.N.A., otherwise, it will lead to sparking at the surface of brushes. So, due to armature reaction, it is hard to determine the exact position of the MNA

VIII (a)	An electric motor is an electrical machine which converts electrical energy into mechanical energy. The basic working principle of a DC motor is: "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". The direction of this force is given by Fleming's left-hand rule and its magnitude is given by F = BIL. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field. Fleming's left hand rule: If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other, and the direction of magnetic field is represented by the first finger, direction of the current is represented by the second finger, then the thumb represents direction of the force experienced by the current carrying conductor When armature windings are connected to a DC supply, an electric current sets up in the winding. Magnetic field may be provided by field winding (electromagnetism) or by using permanent magnets. In this case, current carrying armature conductors experience a force due to the magnetic field, according to the principle stated above. Commutator is made segmented to achieve unidirectional torque. Otherwise, the direction of force would have reversed every time when the direction of movement of conductor is reversed in the magnetic field.  	Exp(5) +fig(3)	8	15
(b)	Generators produce electrical power based on the principle of Faraday's law of electromagnetic induction. This law states that when a conductor moves in a magnetic field it cuts magnetic lines of force, which induces an electromagnetic force (EMF) in the conductor. The magnitude of this induced EMF depends upon the			

	rate of change of flux (magnetic line force) linkage with the conductor. This EMF will cause a current to flow if the conductor circuit is closed. Hence the most basic two essential parts of a generator are: The magnetic field Conductors which move inside that magnetic field.  We can see that in the first half of the revolution current always flows along ABLMCD, i.e., brush no 1 in contact with segment a. In the next half revolution, in the figure, the direction of the induced current in the coil is reversed. But at the same time the position of the segments a and b are also reversed which results that brush no 1 comes in touch with the segment b. Hence, the current in the load resistance again flows from L to M. The waveform of the current through the load circuit is as shown in the figure. This current is unidirectional. This is the basic working principle of DC generator, explained by single loop generator model.	Fig(3)+ exp(4)	7	
IX (a)	According to the Faraday's law of electromagnetic induction, whenever a conductor moves in a magnetic field EMF gets induced across the conductor. If the close path is provided to the conductor, induced emf causes current to flow in the circuit. Now, see the above figure. Let the conductor coil ABCD is placed in a magnetic field. The direction of magnetic flux will be form N pole to S pole. The coil is connected to slip rings, and the load is connected through brushes resting on the slip rings. Now, consider the case 1 from above figure. The coil is rotating clockwise, in this case the direction of induced	Fig(3)+ exp(5)	8	

	current can be given by Fleming's right hand rule, and it will be along A-B-C-D. As the coil is rotating clockwise, after half of the time period, the position of the coil will be as in second case of above figure. In this case, the direction of the induced current according to Fleming's right hand rule will be along D-C-B-A. It shows that, the direction of the current changes after half of the time period, that means we get an alternating current.  case 1 case 2 **Main parts of the alternator**, obviously, consists of stator and rotor. But, the unlike other machines, in most of the alternators, field exciters are rotating and the armature coil is stationary. Stator: Unlike in DC machine stator of an alternator is not meant to serve path for magnetic flux. Instead, the stator is used for holding armature winding.			
(b)	A universal motor is a special type of motor which is designed to run on either DC or single phase AC supply. These motors are generally series wound (armature and field winding are in series), and hence produce high starting torque .That is why, universal motors generally comes built into the device they are meant to drive. Most of the universal motors are designed to operate at higher speeds, exceeding 3500 RPM  When the universal motor is fed with a DC supply, it	2+2+3	7	15

	works as a DC series motor.. When current flows in the field winding, it produces an electromagnetic field. The same current also flows from the armature conductors. When a current carrying conductor is placed in an electromagnetic field, it experiences a mechanical force. Due to this mechanical force, or torque, the rotor starts to rotate. The direction of this force is given by Fleming's left hand rule. When fed with AC supply, it still produces unidirectional torque. Because, armature winding and field winding are connected in series, they are in same phase. Hence, as polarity of AC changes periodically, the direction of current in armature and field winding reverses at the same time. Thus, direction of magnetic field and the direction of armature current reverses in such a way that the direction of force experienced by armature conductors remains same. Thus, regardless of AC or DC supply, universal motor works on the same principle that DC series motor works			
X **(a)**	An electrical motor is an electromechanical device which converts electrical energy into mechanical energy. In the case of three phase AC (Alternating Current) operation, the most widely used motor is a 3 phase induction motor, as this type of motor does not require an additional starting device. These types of motors are known as self-starting induction motors. A 3 phase induction motor consists of two major parts: **A stator** **A rotor** The **stator** of three phase induction motor is made up of numbers of slots to construct a 3 phase winding circuit which we connect with 3 phase AC source. We arrange the three-phase winding in such a manner in the slots that they produce one rotating magnetic field when we switch on the three-phase AC supply source. The **rotor** of three phase induction motor consists of a cylindrical laminated core with parallel slots that can carry conductors. The conductors are heavy copper or aluminum bars fitted in each slot and short-circuited by the end rings. The slots are not exactly made parallel to the axis of the shaft but are slotted a little skewed because this arrangement reduces magnetic humming noise and can avoid stalling of the motor. The stator of the motor consists of overlapping winding offset by an electrical angle of 120o. When we connect	1+3+3	7	15

	the primary winding, or the stator to a 3 phase AC source, it establishes rotating magnetic field which rotates at the synchronous speed. prniciple Behind the Rotation: According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit. As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, an emf is induced in the rotor copper bar and due to this emf a current flows through the rotor conductor. Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation; hence as per Lenz's law, the rotor will rotate in the same direction to reduce the cause, i.e., the relative velocity.			
(b)	Construction of a single phase induction motor is similar to the construction of three phase induction motor having squirrel cage rotor, except that the stator is wound for single phase supply. Stator is also provided with a 'starting winding' which is used only for starting purpose.. **Working Principle Of Single Phase Induction Motor** When the stator of a single phase motor is fed with single phase supply, it produces alternating flux in the stator winding. The alternating current flowing through stator winding causes induced current in the rotor bars (of the squirrel cage rotor) according to Faraday's law of electromagnetic induction. This induced current in the rotor will also produce alternating flux. Even after both alternating fluxes are set up, the motor fails to start (the reason is explained below). However, if the rotor is given a initial start by external force in either direction, then motor accelerates to its final speed and keeps running with its rated speed. This behavior of a single phase motor can be explained by double-field revolving theory. **Double-Field Revolving Theory** The double-field revolving theory states that, any alternating quantity (here, alternating flux) can be resolved into two components having magnitude half of the maximum magnitude of the alternating quantity, and both these components rotating in opposite direction. The stator of a single phase induction motor is wound with single phase winding. When the stator is fed with a single phase supply, it produces alternating flux (which alternates along one space axis only). Alternating flux acting on a squirrel cage rotor can not produce rotation,	Double field revolving theory (3)+working(5)	8	

	only revolving flux can. That is why a single phase induction motor is not self starting. to make it self-starting, it can be temporarily converted into a two-phase motor while starting. This can be achieved by introducing an additional 'starting winding' also called as auxillary winding. Hence, stator of a single phase motor has two windings: (i) Main winding and (ii) Starting winding (auxillary winding). These two windings are connected in parallel across a single phase supply and are spaced 90 electrical degrees apart. Phase difference of 90 degree can be achieved by connecting a capacitor in series with the starting winding. Hence the motor behaves like a two-phase motor and the stator produces revolving magnetic field which causes rotor to run. Once motor gathers speed, say upto 80 or 90% of its normal speed, the starting winding gets disconnected form the circuit by means of a centrifugal switch, and the motor runs only on main winding.			