ELECTRICAL DRIVES AND CONTROL
QUESTION BANK

UNIT I
INTRODUCTION

1. Define Drive and Electric Drive. NOV/DEC 2013, NOV/DEC 2015, NOV/DEC 2016

Drive: A combination of prime mover, transmission equipment and mechanical working load is called a drive.

Electric drive: An Electric Drive can be defined as an electromechanical device for converting electrical energy to mechanical energy to impart motion to different machines and mechanisms for various kinds of process control.

2. List out some examples of prime movers.

I.C Engines, Steam engine, Turbine or electric motors

3. List out some advantages of electric drives.

i. Availability of electric drives over a wide range of power a few watts to mega watts.
ii. Ability to provide a wide range of torques over wide range of speeds.
iii Electric motors are available in a variety of design in order to make them compatible to any type of load.

4. Give some examples of Electric Drives.

i. Driving fans, ventilators, compressors and pumps.
ii. Lifting goods by hoists and cranes.
iii. Imparting motion to conveyors in factories, mines and Warehouses
iv. Running excavators & escalators, electric locomotives trains, Cars trolley buses, lifts & drum winders etc.

5. What are the types of electric drives? NOV/DEC 2009, NOV/DEC 2014

Group electric drives (Shaft drive),
Individual Drives,
Multi motor electric drives.

6. Classify electric drives based on the means of control.

Manual, Semi automatic, Automatic.

7. What is a Group Electric Drive (Shaft Drive)? APRIL/MAY 2010

- This drive consists of single motor, which drives one or more line shafts supported on bearings.
- The line shaft may be fitted with either pulleys & belts or gears, by means of which a group of machines or mechanisms may be operated.

8. What are the advantages and disadvantages of Group drive(Shaft drive)? NOV/DEC 2014

Advantages:

- A single large motor can be used instead of a number of small motors.
- The rating of the single motor may be appropriately reduced taking into account the diversity factor of loads.

Disadvantages:

- There is no flexibility, Addition of an extra machine to the main shaft is difficult.
- The efficiency of the drive is low, because of the losses occurring in several transmitting mechanisms.
- The complete drive system requires shutdown if the motor, requires servicing or repair.

- The system is not very safe to operate
- The noise level at the work spot is very high.

9. What is an individual electric drive? Give some examples.

In this drive, each individual machine is driven by a separate motor. This motor also imparts motion to various other parts of the machine. Single spindle drilling machine, Lathe machines etc.

10. What is a multi motor electric drive? Give some examples.

In this drive, there are several drives, each of which serves to activate on of the working parts of the driven mechanisms. Metal cutting machine tools, paper making machines, rolling mills, traction drive, Traveling cranes etc.,

11. What are the types Drive systems?

Electric Drives Mechanical Drives Electromechanical Drives Hydraulic drives.

12. Give an expression for the losses occurring in a machine.

The losses occurring in a machine is given by W = Wc + x2
Wv Where Wc = Constant losses
Wv = Variable losses at full load
X = load on the motor expressed as a function of rated load.

13. What are the assumptions made while performing heating & cooling calculation of an electric motor?

i. The machine is considered to be a homogeneous body having a uniform temperature gradient. All the points at which heat generated have the same temperature. All the points at which heat is dissipated are also at same temperature.

ii. Heat dissipation taking place is proportional to the difference of temperature of the body and surrounding medium. No heat is radiated.

iii. The rate of dissipation of heat is constant at all temperatures.

14. Indicate the importance of power rating & heating of electric drives. NOV/DEC 2016

Power rating: Correct selection of power rating of electric motor is of economic interest as it is associated with capital cost and running cost of drives.

Heating : For proper selection of power rating the most important consideration is the heating effect of load. In this connection various forms of loading or duty cycles have to be considered.

15. How heating occurs in motor drives?

The heating of motor due to losses occurring inside the motor while converting the electrical power into mechanical power and these losses occur in steel core, motor winding & bearing friction.

16. What are the classes of duties?

1. Continuous duty
2. Short time duty operation of motor Main classes of duties
3. Intermittent periodic duty
4. Intermittent periodic duty with starting
5. Intermittent periodic duty with starting & braking
6. Continuous duty with intermittent periodic loading
7. Continuous duty with starting & braking
8. Continuous duty with periodic load changes

20. How will you classify electric drives based on the method of speed control?

1. Reversible &non reversible in controlled constant speed
2. Reversible and non reversible step speed control
3. Reversible and non reversible smooth speed control
4. Constant predetermined position control

5. Variable position control
6. Composite control.

21. List out some applications for which continuous duty is required. NOV/DEC 2013

Centrifugal pumps, fans, conveyors & compressors

22. Why the losses at starting is not a factor of consideration in a continuous duty motor?

While selecting a motor for this type of duty it is not necessary to give importance to the heating caused by losses at starting even though they are more than the losses at rated load. This is because the motor does not require frequent starting it is started only once in its duty cycle and the losses during starting do not have much influence on heating.

23. What is meant by "short time rating of motor"?

Any electric motor that is rated for a power rating P for continuous operation can be loaded for a short time duty (Psh) that is much higher than P, if the temperature rise is the consideration.

24. What is meant by "load equalization"?

In the method of "load Equalization" intentionally the motor inertia is increased by adding a flywheel on the motor shaft, if the motor is not to be reversed. For effectiveness of the flywheel, the motor should have a prominent drooping characteristic so that on load there is a considerable speed drop.

25. How a motor rating is determined in a continuous duty and variable load ?

1. Method of Average losses
2. Method of equivalent power
3. Method of equivalent current
4. Method of equivalent Torque

26. Define heating time constant & cooling time constant?

The time required to heat the machine parts to 63.3% of its final temperature rise is called as heating time constant. The time required to cool the machine parts to 36.6% of its final temperature fall is called as cooling time constant. **NOV/DEC 2012**

27. What are the various function performed by an electric drive?

1. Driving fans, ventilators, compressors & pumps etc.,
2. Lifting goods by hoists & cranes
3. Imparting motion to conveyors in factories, mines & warehouses and
4. Running excavators & escalators, electric locomotives, trains, cars, trolley buses and lifts etc.

28. What is duty factor?

The ratio of ON time (Ton) of the drive to total time period(Ton +Toff) is called duty factor.

29. Mention the necessity of power rating? NOV/DEC 2009, NOV/DEC 2012

Power rating of electric drives for particular operation is important since, following reasons.

1. To get economy with reliability
2. To obtain the maximum efficiency on their full load without any damaging.

30. Define four – quadrant operation?

A motor operate in two modes and braking. In motoring, it converts electrical energy into mechanical energy, which support its motion. In braking it works as a generator converting mathematical energy into electrical energy and thus, opposes the motion. Motor can provide motoring and braking operations for both forward and reverse directions.

PART – B

1. Explain the factors governing the selection of motors. **NOV/DEC 2009, APRIL/MAY 2010, NOV/DEC 2016**
2. Discuss in detail the determination of power rating of motors. **NOV/DEC 2015**
3. Write a brief note on classes of duty for an electric motor. **APRIL/MAY 2010, NOV/DEC 2013, NOV/DEC 2015, NOV/DEC 2016**
4. Draw the typical temperature rise-time curve and derive the equation for temperature rise in an electric drive. **NOV/DEC 2013, NOV/DEC 2014**
5. Explain in detail about the various types of electric drives. **NOV/DEC 2009, NOV/DEC 2015**
6. Compare the D.C and A.C drives.
7. Explain the different types of loading of drives. **NOV/DEC 2012**
8. Explain the choice of selection of the motor for different loads.
9. Draw the block diagram and explain the basic elements of an electric drive system.
10. Explain the four quadrant operation of motor applicable for hoist.

UNIT – II
DRIVE MOTOR CHARACTERISTICS

1. Why a single phase induction motor does not self start?

When a single phase supply is fed to the single phase induction motor. Its stator winding produces a flux which only alternates along one space axis. It is not a synchronously revolving field, as in the case of a 2 or 3phase stator winding, fed from 2 or 3 phase supply.

2. What is meant by plugging?

The plugging operation can be achieved by changing the polarity of the motor there by reversing the direction of rotation of the motor. This can be achieved in ac motors by changing the phase sequence and in dc motors by changing the polarity.

3. Give some applications of DC motor.

Shunt : driving constant speed, lathes, centrifugal pumps, machine tools, blowers and fans, reciprocating pumps

Series : electric locomotives, rapid transit systems, trolley cars, cranes and hoists, conveyors **Compound :** elevators, air compressors, rolling mills, heavy planners.

4. What are the different types of electric braking? APRIL/MAY 2010, NOV/DEC 2013, NOV/DEC 2014, NOV/DEC 2015

Dynamic or Rheostatic braking, Counter current or plugging and Regenerative braking

5. What is the effect of variation of armature voltage on N-T curve and how it can be achieved?

The N-T curve moves towards the right when the voltage is increased. This can be achieved by means of additional resistance in the armature circuit or by using thyristor power converter.

6. Compare electrical and mechanical braking

Brakes require frequent maintenance very little maintenance not smooth can be applied to hold the system at any position cannot produce holding torque.

7. When does an induction motor behave to run off as a generator?

When the rotor of an induction motor runs faster than the stator field, the slip becomes negative. Regenerative braking occurs and the K.E. of the rotating parts is return back to the supply as electrical energy and thus the machine generates power.

8. Define slip.

S = Ns – Nr

Where, Ns = synchronous speed in
rpm. Nr = rotor speed in rpm
S = Slip

9. Define synchronous speed.

It is given by Ns = 120f / p rpm. Where Ns = synchronous speed, p = no. of stator poles=supply frequency in Hz

10. Why a single phase induction motor does not self start?

When a single phase supply is fed to the single phase induction motor. Its stator winding produces a flux which only alternates along one space axis. It is not a synchronously revolving field, as in the case of a 2 or 3phase stator winding, fed from 2 or 3 phase supply.

11. What is meant by regenerative braking?

In the regenerative braking operation, the motor operates as a generator, while it is still connected to the supply here,the motor speed is grater that the synchronous speed. Mechanical energy is converter into electrical energy, part of which is returned to the supply and rest as heat in the winding and bearing.

12. Give some applications of DC motor.

Shunt: driving constant speed, lathes, centrifugal pumps, machine tools, blowers and fans, reciprocating pumps

Series: electric locomotives, rapid transit systems, trolley cars, cranes and hoists, conveyors
Compound: elevators, air compressors, rolling mills, heavy planners.

13. Compare electrical and mechanical braking.

Brakes require frequent maintenance very little maintenance not smooth can be applied to hold the system at any position cannot produce holding torque.

14. Differentiate cumulative and differential compound motors.

Cumulative

The orientation of the series flux **aids** the shunt flux

Differential

Series flux opposes shunt flux

15. What is meant by mechanical characteristics? NOV/DEC 2009, APRIL/MAY 2010, NOV/DEC 2013

A curve drawn between the parameters speed and torque.

16. What is meant by electrical characteristics?

A curve drawn between the armature current and armature torque.

17. What is meant by performance characteristics?

The graph drawn between the output power Vs speed, efficiency, current and torque.

18. What do you mean by Rheostatic braking? NOV/DEC 2016

In this braking armature is removed and connected across a variable rheostat.

19. Is Induction motor runs with synchronous speed or not.

Induction motor never runs with synchronous speed. It will stop if it tries to achieve synchronous speed.

20. Why the armature core in d.c machines is constructed with laminated steel sheets instead of solid steel sheets?

Lamination highly reduces the eddy current loss and steel sheets provide low reluctance path to magnetic field.

21. Why commutator is employed in d.c.machines?

Conduct electricity between rotating armature and fixed brushes, convert alternating emf into unidirectional emf (mechanical rectifier).

22. Distinguish between shunt and series field coil construction?

Shunt field coils are wound with wires of small section and have more no of turns. Series field coils are wound with wires of larger cross section and have less no of turns.

23. How will you change the direction of rotation of d.c. Motor?

Either the field direction or direction of current through armature conductor is reversed.

24. What is back emf in d.c. motor? NOV/DEC 2012

As the motor armature rotates, the system of conductor come across alternate north and South pole magnetic fields causing an emf induced in the conductors. The direction of the emf induced in the conductor is in opposite to current. As this emf always opposes the flow of current in motor operation it is called as back emf.

25. Compare Slip ring and squirrel cage motor

Slip Ring Rotor
Squirrel cage Rotor

26. Induction motor as a transformer?

Transformer is a device in which two windings are magnetically coupled and when one winding is excited by a.c. supply of certain frequency, the e.m.f gets induced in the second winding having same frequency as that of supply given given to the first winding. The winding of which supply is given is called primary winding while winding in which e.m.f gets induced is called secondary winding.

27. What are the types of Single phase induction motors? NOV/DEC 2012

Split phase induction motor
Capacitor start induction motor
Capacitor start capacitors run induction motor
Shaded pole induction motor

28. List the advantage of squirrel cage I.M?

Cheaper
Light in weight
Rugged in construction
More efficient
Require less maintenance
Can be operated in dirty and explosive environments

29. What is back e.m.f in a D.C. Motor? State its expression.

Armature starts rotating, the main flux gets cut by the armature winding and an e.m.f gets induced in the armature. This e.m.f opposes the applied d.c voltage and is called back e.m.f denoted as Eb.

30. Write the voltage equation of D.C. Motor.

$V=E_b+I_aR_a$. The back e.m.f is always less than supply voltage (Eb)

PART – B

1. Explain the Speed-Torque characteristics of three phase induction motor with neat diagrams. **NOV/DEC 2012, NOV/DEC 2014, NOV/DEC 2016**
2. Explain about the speed-torque characteristics of a DC Shunt Motor with Suitable graphs and diagrams. **APRIL/MAY 2010, NOV/DEC 2015**
3. Explain the various methods of braking of induction motors. **NOV/DEC 2009**
4. Draw and explain various load characteristics of DC Shunt Motor. **NOV/DEC 2013**
5. Explain various methods of braking of DC Shunt Motors with neat diagrams. **NOV/DEC 2012, NOV/DEC 2014, NOV/DEC 2015, NOV/DEC 2016**
6. Explain various methods of braking of DC Series Motors with neat diagrams.
7. Explain the Speed-Torque characteristics of Single phase induction motor with neat diagrams. **NOV/DEC 2009**
8. Single phase motor is not a self starting motor. Why? **APRIL/MAY 2010**

UNIT – III
STARTING METHODS

1. Mention the Starters used to start a DC motor.

Two point Starter
Three point Starter
Four point Starter

2. Mention the Starters used to start an Induction motor. NOV/DEC 2009

D.O.L Starter (Direct Online Starter)
Star-Delta Starter
Auto Transformer Starter
Reactance or Resistance starter
Stator Rotor Starter (Rotor Resistance Starter)

3. What are the protective devices in a DC/AC motor Starter? NOV/DEC 2016

Over load Release (O.L.R) or No volt coil
Hold on Coil
Thermal Relays
Fuses
(Starting /Running)
Over load relay

4. Is it possible to include/ Exclude external resistance in the rotor of a Squirrel cage induction motor?. Justify

No it is not possible to include/ Exclude external resistance in the rotor of a Squirrel cage induction motor because, the rotors bars are permanently short circuited by means of circuiting rings (end rings) at both the ends. i.e. no slip rings to do so.

5. Give the prime purpose of a starter for motors. NOV/DEC 2012, NOV/DEC 2015, NOV/DEC 2016

when induction motor is switched on to the supply, it takes about 5 to 8 times full load current at starting. This starting current may be of such a magnitude as to cause objectionable voltage drop in the lines. So Starters are necessary

6. Why motor take heavy current at starting?

When 3 phase supply is given to the stator of an induction motor, magnetic field rotating in space at synchronous speed is produced. This magnetic field is cut by the rotor conductors, which are short circuited. This gives to induced current in them. Since rotor of an induction motor behaves as a short circuited secondary of a transformer whose primary is stator winding, heavy rotor current will require corresponding heavy stator balancing currents. Thus motor draws heavy current at starting

7. What are the methods to reduce the magnitude of rotor current (rotor induced current) at starting?

By increasing the resistance in the rotor circuit by reducing the magnitude of rotating magnetic field i.e. by reducing the applied voltage to the stator windings

8. What is the objective of rotor resistance starter (stator rotor starter)?

To include resistance in the rotor circuit there by reducing the induced rotor current at starting. This can be implemented only on a slip ring induction motor.

9. Why squirrel cage induction motors are not used for loads requiring high starting torque?

Squirrel cage motors are started only by reduced voltage starting methods which lead to the development of low starting torque at starting. This is the reason why squirrel cage induction motors are not used for loads requiring high starting torque.

10. How reduced voltage starting of Induction motor is achieved? APRIL/MAY 2010

D.O.L Starter (Direct Online Starter)
Star-Delta Starter
Auto Transformer Starter
Reactance or Resistance starter

11. Give the relation between line voltage and phase voltage in a

(i) Delta connected network (ii) Star connected network

Delta connected network:

Vphase = Vline

Star connected network:

Vphase = Vline / _3

12. Give some advantages and disadvantages of D.O.L starter.

Advantages:

Highest starting torque
Low cost
Greatest simplicity

Disadvantages:

The inrush current of large motors may cause excessive voltage drop in the weak power system The torque may be limited to protect certain types of loads.

13. What is the function of no-voltage release coil in d.c. motor starter?

As long as the supply voltage is on healthy condition the current through the NVR coil produce enough magnetic force of attraction and retain the starter handle in ON position against spring force. When the supply voltage fails or becomes lower than a prescribed value then electromagnet may not have enough force to retain so handle will come back to OFF position due to spring force automatically.

14. Enumerate the factors on which speed of a d.c.motor depends?

$N = (V - I_a R_a)/\Phi$ so speed depends on air gap flux, resistance of armature, voltage applied to armature.

16. Define critical field resistance of dc shunt generator?

Critical field resistance is defined as the resistance of the field circuit which will cause the shunt generator just to build up its emf at a specified field.

17. Why is the emf not zero when the field current is reduced to zero in dc generator?

Even after the field current is reduced to zero, the machine is left out with some flux as residue so emf is available due to residual flux.

18. On what occasion dc generator may not have residual flux?

The generator may be put for its operation after its construction, in previous operation, the generator would have been fully demagnetized.

19. What are the conditions to be fulfilled by for a dc shunt generator to build back emf?

The generator should have residual flux, the field winding should be connected in such a manner that the flux setup by field in same direction as residual flux, the field resistance should be less than critical field resistance, load circuit resistance should be above critical resistance.

20. Name any two starters which can be used with only slip-ring induction motor

Rotor resistance starter

Solid state rotor resistance starter

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21. What is the Necessity of starter? NOV/DEC 2014

Both d.c motors as well as three phase induction motors are self starting but these motors show the tendency to draw very high current at the time of starting. Such a current is very high and can cause demage to the motor windings. Hence there is a need of a certain device which can limit such a high stating current. Such a device which limits the high starting current is called a starter.

22. What is meant by starting resistance?

To restrict this high starting armature current, a variable resistance is connected in series with the armature at start. This resistance is called starter or a starting resistance.

23. What are the main parts of three point starter?

L = line terminal to be connected to positive of supply

A = to be connected to the armature winding

F= to be connected to the field winding

24. What are the disadvantages of three point starter? NOV/DEC 2009, APRIL/MAY 2010, NOV/DEC 2015

Here NVC and the field winding are in series. so while controlling the speed of the motor above rated, field current is reduced by adding an extra resistance in series with the field winding. To avoid the dependency of NVC and the field winding, four point starter is used in which NVC and the field winding are connected in parallel.

25. What is automatic starter? NOV/DEC 2013, NOV/DEC 2014

Upon pressing ON-push button (start button), current limiting stating resistors get connected in series with armature circuit in DC motor. Then, some form of automatic control progressively disconnects these resistors until full-line voltage is available to the armature circuit. On pressing an OFF push button the system should get back to its original position.

26. Why starts are used for DC motors?

In DC motors starters are used to limit the starting current within about 2 to 3 times the rated current by adding resistance in series with the armature circuit. Other than this starting resistances starters are variable fitted with protective devices like no –voltage protection and over-load protection.

27. Why stator resistance rarely used?

Due to addition of resistance in the stator side cause the voltage available to the motor X times the normal voltage i.e. The starting current drawn by the motor as well as the current drawn from the supply get reduced by X times where as the starting torque developed gets reduced by X2 times.

28. What are the effects of increasing rotor resistance in the rotor circuit of a 3-phase induction motor as starting?

Due to addition of resistance in rotor circuit by the stator not only reduces the staring current, in addition to that the starting torque developed than those given by DOL starting.

29. What are the advantages of Electronic starter?

The moving parts and contacts get completely eliminated.

- The arcing problem gets eliminated.
- Minimum maintenance is required as there are no moving parts.
- The operation is reliable
- Starting time also gets reduced.

30. What is autotransformer starter?

A three phase star connected autotransformer can be used to reduce the voltage applied to the stator. Such a starter is called as autotransformer starter.

<u>PART – B</u>

1. Draw a neat schematic diagram of a three point starter and explain its working. **NOV/DEC 2012, NOV/DEC 2015, NOV/DEC 2016**

2.Draw a neat schematic diagram of a four point starter and explain its working. **APRIL/MAY 2010**

3. Explain with neat circuit diagram, the star-delta starter method of starting squirrel cage induction motor. **NOV/DEC 2012, NOV/DEC 2014, NOV/DEC 2016**
4. Explain the typical control circuits for DC Series and Shunt motors. **NOV/DEC 2009**
5. Explain with neat diagram the starting of three phase slip ring induction motor. **NOV/DEC 2009, NOV/DEC 2013, NOV/DEC 2014, NOV/DEC 2015**
6. Draw and explain the push-button operated direct-on line starter for three phase induction motor. **APRIL/MAY 2010**
7. Draw and explain the manual auto-transformer starter for three phase induction motor. **NOV/DEC 2016**

UNIT – IV
CONVENTIONAL AND SOLID STATE SPEED CONTROL OF D.C.DRIVES

1. Give the expression for speed for a DC motor.

Speed N = k (V-IaRa)j

Where V = Terminal Voltage in volts
Ia = Armature current in Amps
Ra = Armature resistance in ohms
j= flux per pole.

2. What are the ways of speed control in dc motors? NOV/DEC 2014, NOV/DEC 2016

Field control - by varying the flux per pole. -for above rated speed
Armature control- by varying the terminal voltage -for below rated speed

3. Give the Limitation of field control NOV/DEC 2012

a. Speed lower than the rated speed cannot be obtained.
b. It can cope with constant kW drives only.
c. This control is not suitable to application needing speed reversal.

4. What are the 3 ways of field control in DC series motor?

- Field diverter control
- Armature diverter control
- Motor diverter control
- Field coil taps control
- Series-parallel control

5. What are the main applications of Ward-Leonard system?

- It is used for colliery winders.
- Electric excavators
- In elevators
- Main drives in steel mills and blooming and paper mills.

6. What are the merits and demerits of Rheostatic control method?

- Impossible to keep the speed constant on rapidly changing loads.
- A large amount of power is wasted in the controller resistance.
- Loss of power is directly proportional to the reduction in speed. Hence efficiency is decreased.
- Maximum power developed is diminished in the same ratio as speed.
- It needs expensive arrangements for dissipation of heat produced in the controller resistance.
- It gives speed below normal, not above.

7. What are the advantages of field control method? NOV/DEC 2015

- More economical, more efficient and convenient.
- It can give speeds above normal speed.

8. Compare the values of speed and torque in case of motors when ii parallel and in series.

- The speed is one fourth the speed of the motor when in parallel.
- The torque is four times that produced by the motor when in parallel.

9. What is the effect of inserting resistance in the field circuit of a dc shunt motor on its speed and torque?

For a constant supply voltage, flux will decrease, speed will increase and torque will increase.

10. While controlling the speed of a dc shunt motor what should be done to achieve a constant torque drive?

Applied voltage should be maintained constant so as to maintain field strength

11. State the advantages of dc chopper drive. APRIL/MAY 2010, NOV/DEC 2015

- Dc chopper drive s has the advantages of
- High efficiency
- Flexibility in control
- Light weight
- Small size
- Quick response

12. Why chopper based DC drives give better performance than rectifier controlled drives.

- Less harmonic
- Low ripple content
- High efficiency

14.Name the solid state controllers used for the speed control of DC shunt motor and series motor,

- Phase controlled rectifier fed DC drives
- Chopper fed DC drives

15. Give application of Ward-Leonard system of speed control

It is used for elevators, hoist control and for main drive in steel mills where motor of ratings 750KW to 3750KW are required.

16. What is the principle of the field control method of speed control of DC shunt motors?

The speed of the DC motor can be controlled by varying the field flux. This method of speed control can be used for increasing the speed of motor above its rated speed, because the speed of the motor is inversely proportional to the field flux.

17. What is the effect of inserting resistance in the field circuit of of DC shunt motor on its speed and torque?

- Speed increases above base speed.
- Torque decreases.

18. What are the two main methods adopted for speed control of DC motors?

Armature resistance control
Flux control

19. What are the electrical parameters affecting the speed of the DC motors?

Armature voltage
Field current

20. State the types of controlled rectifier Dc drives NOV/DEC 2016

1. Single phase controlled rectifier DC drives
   (a)Half wave controlled rectifier Dc drives
   (b)Half controlled rectifier DC drives
   (c)Full controlled rectifier DC drives
2. Thee phase controlled rectifier fed DC drives

21. How can speed be controlled in a DC shunt motor? NOV/DEC 2013

- The DC shunt motor speed controlled by
  (a) Armature voltage control (below rated speed)
  (b)Flux control method (above rated speed)

22. List the advantages of DC six pulse converter compared with three pulse converter

- Current should be continuous •
Requires less filter circuits
- It gives two quadrant operation

23.What factors limit the maximum speed of field control Dc motor?

Field flux
Armature voltage

24. State control strategies of choppers NOV/DEC 2012

Time ratio control
Current limit control

25. What is meant by V/F control? NOV/DEC 2012, NOV/DEC 2013

When the frequency is reduced the input voltage must be reduced proportionally so as to maintain constant flux. Otherwise the core will get saturated resulting in excessive iron loss and magnetizing current. This type of induction motor behavior is similar to the working of dc series motors.

26. What is static Ward – Leonard drive? NOV/DEC 2009

Controlled rectifiers are used to get variable dc voltage from an ac source of fixed voltage. Controlled rectifiers fed dc drives are known as “static Ward – Leonard drive”.

27. What is meant by voltage control in induction motor? and where it is applicable?

In Induction motor speed can be controlled by varying the stator voltage. This can be done by using transformer. This method is called voltage control. This is suitable only for controlling the speed below rated value.

28. What is meant by armature control? NOV/DEC 2016

The armature having controller resistance in series during the speed control by varying the controller resistance R, the potential drop across the armature is varied. Hence the speed of the motor also varied. This method of speed control is applicable for speed less than no load speed.

29. What is meant by flux control (or) field control method?

By varying the field flux the speed can be controlled is called flux control. This method can be used for increasing the speed of the motor is inversely proportional to the field flux

30. In which type of control the field current and armature current control?

i).For armature control method (or) voltage control method the field current is kept constant

ii).For field control (or) flux control the armature current kept constant

31. What is Slip-Power recovery system? NOV/DEC 2009, APRIL/MAY 2010

The slip power can be recovered to the supply source can be used to supply an additional motor which is mechanically coupled to the main motor. This type of drive is known as slip-power recovery system

PART –B

1. Discuss the Ward-Leonard speed control system with a neat circuit diagram. Also mention its advantages and disadvantages. **NOV/DEC 2012, NOV/DEC 2014, NOV/DEC 2015, NOV/DEC 2016**
2. Explain how the speed of a DC Shunt Motor can be varied both above and below the rated speed at which it runs with full field current. **APRIL/MAY 2010**
3. Explain the speed control schemes of DC Series Motor. **NOV/DEC 2009, APRIL/MAY 2010**
4. Explain the single phase half wave converter drive speed control for DC drive with waveforms.
5. Explain with neat sketch the chopper control method of speed control of DC motors. **APRIL/MAY 2010, NOV/DEC 2012, NOV/DEC 2013, NOV/DEC 2015, NOV/DEC 2016**
6. Explain with neat sketches about the DC Shunt Motor speed control by using single phase fully controlled bridge converter **NOV/DEC 2009, NOV/DEC 2013, NOV/DEC 2014**

UNIT – V

CONVENTIONAL AND SOLID STATE SPEED CONTROL OF A.C. DRIVES

1. What is a controlled rectifier?

A controlled rectifier is a device which is used for converting controlled dc power from a control voltage ac supply.

2. What is firing angle?

The control of dc voltage is achieved by firing the thyristor at an adjustable angle with respect to the applied voltage. This angle is known as firing angle.

3. Give some applications of phase control converters.

Phase control converters are used in the speed control of fractional kW dc motors as well as in large motors employed in variable speed reversing drives for rolling mills. With motors ratings as large as several MW's.

4. What is the main purpose of free wheeling diode?

Free wheeling diode is connected across the motor terminal to allow for the dissipation of energy stored in motor inductance and to provide for continuity of motor current when the thyristors are blocked.

5. What is a full converter?

A full converter is a tow quadrant converter in which the voltage polarity of the output can reverse, but the current remains unidirectional because of unidirectional thyristors.

6. What is natural or line commutation?

The commutation which occurs without any action of external force is called natural or line commutation.

7. What is forced commutation?

The commutation process which takes place by the action of an external force is called forced commutation.

8. What is a chopper?

A chopper is essentially an electronic switch that turns on the fixed-voltage dc source for a short time interval and applies the source potential to motor terminals in series of pulses.

9. What are the two main difficulties of variable frequency system?

Control of Va requires variation of chopper frequency over a wide range. Filter design for variable frequency operation is difficult. At low voltage, a large value of t_{off} makes the motor current discontinuous.

11. What is voltage commutation?

A charged capacitor momentarily reverse-bias the conducting thyristor to turn it off. This is known as voltage commutation.

12. What is current commutation?

A current pulse is forced in the reverse direction through the conducting thyristor. As the net current becomes zero, the thyristor is turned OFF. This is known as current commutation.

13. What is load commutation?

The load current flowing through the thyristor either becomes zero (as in natural or line commutation employed in converters) or is transferred to another device from the conducting thyristor. This is known as load commutation.

14. What are the different means of controlling induction motor? NOV/DEC 2009, NOV/DEC 2013, NOV/DEC 2014, NOV/DEC 2015

- Stator voltage control.
- Frequency control
- Pole changing control.
- Slip power recovery control.

15. What are the two ways of controlling the RMS value of stator voltage?

- Phase control
- Integral cycle control

16. Mention the two slip-power recovery schemes. APRIL/MAY 2010, NOV/DEC 2012, NOV/DEC 2015

- Static Scherbius scheme
- Static Kramer drive scheme.

17. Give the basic difference between the two slip-power recovery schemes.

The slip is returned to the supply network in scherbius scheme and in Kramer scheme, it is used to drive an auxiliary motor which is mechanically coupled to the induction motor shaft.

18. Write short notes on inverter rectifier.

The dc source could be converted to ac form by an inverter, transformed to a suitable voltage and then rectified to dc form. Because of two stage of conversion, the setup is bulky, costly and less efficient.

19. Give the special features of static scherbius scheme.

- The scheme has applications in large power fan and pump drives which requires speed control in narrow range only.
- If max. Slip is denoted by S_{max}, then power rating of diode, inverter and transformer can be just S_{max} times motor power rating resulting in a low cost drive.
- This drive provides a constant torque control.

20. What are the advantages of static Kramer system,, over static scherbius system?

- Since a static Kramer system possesses no line commutated inverter, it causes bless reactive power and smaller harmonic contents of current than a static scherbius.
- What is electrical power supply system?
- The generation, transmission and distribution system of electrical power is called electrical power supply system.

21. What are the 4 main parts of distribution system?

- Feeders,
- Distributors and
- Service mains.

22. What are feeders?

Feeders are conductors which connect the stations (in some cases generating stations) to the areas to be fed by those stations.

23. What are the advantages of high voltage dc system over high voltage ac system?

- It requires only tow conductors for transmission and it is also possible to transmit the power through only one conductor by using earth as returning conductor, hence much copper is saved.
- No inductance, capacitance, phase displacement and surge problem.
- There is no skin effect in dc, cross section of line conductor is fully utilized.

24. What are the limitations of cyclo converter method of speed control?

1. It requires more semiconductor devices like thyristors, MOSFETs compared with inverters
2. Harmonic contents more with low power factor.

25. What are the classifications of PWM technique?

1. Single pulse width modulation
2. Multiple pulse PWM modulation
3. Sinusoidal Pulse PWM

26. Why do we go for PWM inverter control?

The output from inverter is square with some harmonic contents so we have to remove or reducing the harmonic contents by using some voltage control technique called PWM

27. Compare static Kramer and scherbius system. NOV/DEC 2016

Kramer: The system consists or SRIM,diode bridge rectifier and line commutated inverter The slip power can flow in one direction This is applicable for below synchronous speed operation

Scherbius: This system consists of SRIM,two SCR bridge (or) cyclo converter The slip power can flow in both direction Applicable for both below and above synchronous speed operation

28. What are the possible methods of speed control available by using inverters? NOV/DEC 2014

- Current controlled inverter.
- Pulse width modulated (PWM) inverter control
- Variable voltage output(VVO) inverter control
- Variable voltage input(VVI) inverter control

29. What is the function of freewheeling diode?

Free wheeling diodes are introduced to maintain the continuous current flow to the load when ever all thyistors are turned off condition.

30. What is meant by stator frequency control? NOV/DEC 2016

The three phase induction motor speed can be controlled by varying the stator frequency. The variable stator frequency can be obtained by inverters circuit.

31. What is meant by ac voltage controller?

AC voltage controller is nothing but, which is used to converters fixed ac voltage into variable ac voltage without changing supply frequency.

PART – B

1. Explain the V/f control method of AC drive with neat sketches.
2. Explain the speed control schemes of phase wound induction motors. **APRIL/MAY 2010, NOV/DEC 2012, NOV/DEC 2015**
3. Explain in detail about Slip power recovery scheme. **APRIL/MAY 2010, NOV/DEC 2015, NOV/DEC 2016**
4. Explain with neat diagram the method of speed control of dc drives using rectifiers. **NOV/DEC 2009**
5. Explain the different methods of speed control used in three phase induction motors. **NOV/DEC 2014**
6. Explain the Kramer system and Scherbius system. **NOV/DEC 2012**
7. Draw the power circuit arrangement of three phase variable frequency inverter for the speed control of three phase induction motor and explain its working. **NOV/DEC 2016**
8. Discuss the speed control of AC motors by using three phase AC Voltage regulators.
9. Explain the static Kramer method and static Scherbius method of speed control of three phase induction motor. **NOV/DEC 2013**

Explain in detail about the various methods of solid state speed control techniques by using inverters. **NOV/DEC 2013**

Reg. No. :

Question Paper Code : C 1248

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2010.

Third Semester

Mechanical Engineering

EE 1213 — ELECTRICAL DRIVES AND CONTROLS

(Common to B.Tech. Production Technology)

(Regulation 2004)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Define Group drive system.

2. Give the formulae for computing power requirement for a linear movement.

3. Sketch the mechanical characteristics of DC shunt and Series motor in the same graph.

4. What is meant by dynamic braking?

5. State the difference between three point and four point starters.

6. Why is rotor resistance starter only suitable for slip ring induction motor?

7. How the speed of induction motor is more than its synchronous speed in static Kramer system?

8. How is the variable armature voltage obtained in Chopper based DC motor control? Sketch the speed torque characteristics of an induction motor for stator voltage control.

9. List out the advantages of slip power recovery scheme speed control of AC motor.

10. Draw the block diagram of soft starter.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Briefly explain the various factors that will influence the choice of an electrical drive. (8)

(ii) Explain the method of estimating equivalent continuous power rating of a motor for short time load applications. (8)

Or

(b) (i) Explain the different classes of Motor duty with the equations. (12)

(ii) The temperature rise of motor after operating for 30 minute on full load is 20°C and after another 30 minute it become 30°C on the same load. Find the final temperature rise and time constant. (4)

12. (a) (i) From electrical characteristics, derive the mechanical characteristic of DC series motor. (8)

(ii) Why is a 1-phase induction motor not self starting? Also describe any one method of starting a 1-phase induction motor. (8)

Or

(b) (i) Describe the operation of dynamic braking for 3-phase squirrel cage Induction motor. (8)

(ii) How are loads classified based on their speed – torque characteristic? Explain different characteristics. (8)

13. (a) With the neat diagram explain the operation of four point starter. Also mention the advantages of this over a three point starter. (16)

Or

(b) (i) Describe the operation of suitable starter for 3-phase slip ring Induction motor. (10)

(ii) Draw the control circuit for DOL starter. (6)

14. (a) (i) Explain the operation of armature control of a DC shunt motor. (8)

(ii) Draw and explain the speed control of DC motor using chopper drive. (8)

Or

(b) (i) With the block diagram explain the operation of armature and field control of DC motor drive using controlled rectifiers. (12)

(ii) Name the different flux control methods adopted for DC series motor. (4)

15. (a) Explain the operation of different speed control techniques employed for 3-phase squirrel cage induction motor. (16)

Or

(b) What is meant by slip power recovery scheme? Explain with the necessary diagram. (16)

K 4280

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2009.

Third Semester

Mechanical Engineering

EE 1213 — ELECTRICAL DRIVES AND CONTROLS

(Common to B.Tech. Production Technology)

(Regulation 2004)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Draw the block diagram of electric drive.

2. What is meant by intermittent duty?

3. Draw the speed torque characteristics of a DC series motor for different values of armature resistances.

4. When plugging is employed for stopping an induction motor, why is it necessary to disconnect it from supply when the speed reaches close to zero?

5. What do you understand by soft start?

6. What are the advantages of squirrel cage induction motor over dc motors?

7. Field control is employed For getting speeds higher than rated and armature voltage control is employed for getting speeds less than rated. Why?

8. What is time ratio control?

9. Mention the advantages of solid state control of ac drives?

10. Mention the usage of different types of motors with applications in a textile mill.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Explain the various factors influencing the choice of electrical drive. (10)

(ii) State and explain the disadvantages of using a motor of wrong rating with an illustration. (6)

Or

(b) (i) What are heating and cooling curves? Starting from the basic principles derive the expressions for heating and cooling curves for a electrical machine. Also mention the assumptions made. (10)

(ii) The 10 minutes rating of a motor used in domestic mixer is 200 watts. The heating time constant is 40 minutes and the maximum efficiency occurs at full load (continuous). Determine the continuous rating. (6)

12. (a) (i) Explain the speed torque characteristics of three phase induction motor with neat diagram. (8)

(ii) Explain why a dc series motor is more suited to deal with torque over load than other dc motors. (8)

Or

(b) (i) State and explain the important features of various braking methods of DC motors. (12)

(ii) Discuss how the dynamic braking can be made in a single phase induction motor. (4)

13. (a) (i) With a neat sketch, explain the operation of a three point starter used for starting a dc shunt motor. (10)

(ii) Explain the operation of a rotor resistance starter used in slip ring induction motor. (6)

Or

(b) Explain the different starting methods employed in a three phase squirrel cage induction motor. (16)

14. (a) (i) State and explain how armature current and speed of a dc separately excited motor will be affected when halving the armature voltage and field current with load torque remaining constant. (6)

(ii) Explain the operation of a conventional ward Leonard speed control system for a dc separately excited motor. (10)

Or

(b) (i) Draw and explain the operation of a speed control of a dc shunt motor by a single phase fully controlled converter for the continuous motor current. (10)

(ii) Describe the operation of a two quadrant type A chopper fed separately excited dc motor drive. (6)

15. (a) (i) Explain how the speed of a three phase induction can be controlled by varying its stator voltage. (8)

(ii) Write short notes on slip power recovery scheme. (8)

Or

(b) (i) With a simple block diagram explain the operation of a variable voltage variable frequency (VVVF) inverter fed three phase induction motor drive. (10)

(ii) Mention the advantages and disadvantages of ac voltage controller fed three phase induction motor drive when compared to inverter fed drives. (6)

Question Paper Code : 57311

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2016

Third Semester

Mechanical Engineering

EE 6351 – ELECTRICAL DRIVES AND CONTROLS

(Common to Mechanical and Automation Engineering, Production Engineering, Manufacturing Engineering, Petrochemical Engineering, Chemical Engineering and Petrochemical Technology)

(Regulations 2013)

Time : Three Hours | Maximum : 100 Marks

Answer ALL questions.

PART – A ($10 \times 2 = 20$ Marks)

1. List the basic elements of electrical drives.
2. Define thermal overloading.
3. Draw speed-torque characteristics of a traction load.
4. What is meant by 'braking of electrical motor' ?
5. Why starter is necessary to start a electrical motor ?
6. State the difference between three phase squirrel cage and slip-ring induction motors.
7. List the advantages and disadvantages of D.C. Choppers.
8. Give the applications of controlled rectifier circuit.
9. List the types of speed control methods in three phase induction motor.
10. What is AC voltage Regulator ?

PART – B (5 × 16 = 80 Marks)

11. (a) Discuss the following :

    (i) Heating and cooling curves **(8)**

    (ii) Classes of duty **(8)**

    OR

    (b) (i) Discribe the factors influencing the choice of electrical drives. **(8)**

    (ii) Discuss about selection of power rating for drive motors. **(8)**

12. (a) (i) Draw and explain the Speed-Torque Characteristics of DC shunt, series and compound motors with necessary equations. **(10)**

    (ii) Draw and explain the Speed-Torque Characteristics of three phase induction motor. **(6)**

    OR

    (b) What are the different methods used for braking of electrical motors ? Explain all the methods with neat diagrams. Also explain which method is suitable for which electrical motor. **(16)**

13. (a) Explain typical control circuits in starter for shunt and series motors. **(16)**

    OR

    (b) Explain typical control circuits in starters for the three phase slip ring induction motors. **(16)**

14. (a) Explain armature and field control of D.C. motors using controlled rectifiers. **(16)**

    OR

    (b) Explain armature and field control of D.C. Motors using D.C. Choppers. **(16)**

15. (a) Explain speed control of three phase induction by combined voltage/frequency control. **(16)**

    OR

    (b) Explain slip power recovery scheme for the speed control of 3 phase induction motor. **(16)**

Reg. No. :

Question Paper Code : 51626

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2014.

Third Semester

Mechanical Engineering

ME 2205/ME 36/EE 1205 A/080120013/10122 ME 306 — ELECTRICAL DRIVES AND CONTROL

(Common to Production Engineering, Chemical Engineering, Petrochemical Engineering, Petrochemical Technology and Mechanical (sandwich) Engineering)

(Regulation 2008/2010)

(Also common to PTME 2205 Electrical Drives and Control for B.E. (Part-Time) Third Semester – Production Engineering – Regulation 2009)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the basic elements of electric drives?

2. What are the factors to be considered for the selection of electrical drives.

3. Draw speed-torque characteristic of constant torque type load.

4. Draw speed-armature current characteristic of DC series motor.

5. What are the types of DC motor starter?

6. What is the basic principle of primary resistance starter used in 3-phase induction motor?

7. Define armature control method of DC shunt motor.

8. Define duty cycle in DC chopper.

9. What are the conventional methods of speed control of three phase induction motor from stator side.

10. What is the basic principle in v/f control?

PART B — (5 × 16 = 80 marks)

11. (a) List and explain various classes of motor duty. (16)

Or

(b) Explain the selection of power rating for drive motor with regard to continuous duty load.

12. (a) With circuit diagram explain plugging method of braking of D.C. shunt motor and its torque speed characteristics. (16)

Or

(b) Describe speed-torque characteristics for DC dynamic braking of three-phase induction motor.

13. (a) Explain construction and operation of 4-point starter. (16)

Or

(b) Explain with diagram construction and working of rotor resistance starter.

14. (a) Describe with diagram Ward-Leonard speed control system for DC motor. (16)

Or

(b) With diagram describe working of single phase fully controlled rectifier drive.

15. (a) Explain various method of conventional speed control of three-phase induction motor from rotor-side. (16)

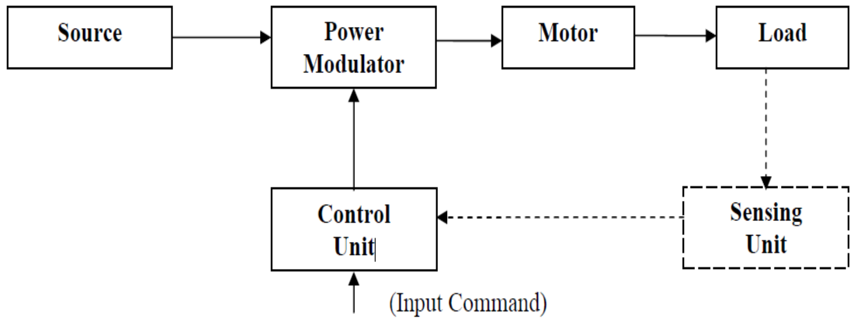
Or

(b) Explain working of conventional Kramer slip power recovery system.

UNIT I

INTRODUCTION TO ELECTRICAL DRIVES

Basic Elements:



A modern variable speed electrical drive system has the following components

- Electrical machines and loads
- Power Modulator
- Sources
- Control unit
- Sensing unit

Electrical Machines:

Most commonly used electrical machines for speed control applications are the following

DC Machines

- Shunt, series, compound, separately excited DC motors and switched reluctance machines.

AC Machines

- Induction, wound rotor, synchronous, PM synchronous and synchronous reluctance machines.

Special Machines

- Brush less DC motors, stepper motors, switched reluctance motors are used.

Power Modulators:

- Modulates flow of power from the source to the motor in such a manner that motor is imparted speed-torque characteristics required by the load
- During transient operation, such as starting, braking and speed reversal, it restricts source and motor currents with in permissible limits.
- It converts electrical energy of the source in the form of suitable to the motor
- Selects the mode of operation of the motor (i.e.) Motoring and Braking.

Types of Power Modulators

In the electric drive system, the power modulators can be any one of the following

- Controlled rectifiers (ac to dc converters)
- Inverters (dc to ac converters)
- AC voltage controllers (AC to AC converters)
- DC choppers (DC to DC converters)
- Cyclo converters (Frequency conversion)

Electrical Sources:

- Very low power drives are generally fed from single phase sources. Rest of the drives is powered from a 3 phase source. Low and medium power motors are fed from a 400v supply. For higher ratings, motors may be rated at 3.3KV, 6.6KV and 11 KV. Some drives are powered from battery.

Sensing Unit:

- Speed Sensing
- Torque Sensing
- Position Sensing
- Current sensing and Voltage Sensing from Lines or from motor terminals
- Torque sensing
- Temperature Sensing

Control Unit:

- Control unit for a power modulator are provided in the control unit. It matches the motor and power converter to meet the load requirements

TYPES OF ELECTRIC DRIVES:

According to Mode of Operation

- Continuous duty drives
- Short time duty drives
- Intermittent duty drives

According to Means of Control

- Manual
- Semi automatic
- Automatic

According to Number of machines

- Individual drive
- Group drive
- Multi-motor drive

According to Dynamics and Transients

- Uncontrolled transient period
- Controlled transient period

Another main classification:

- DC drive
- AC drive

DC DRIVES	AC DRIVES
The power circuit and control circuit is simple and inexpensive	The power circuit and control circuit are complex
It requires frequent maintenance	Less Maintenance
The commutator makes the motor bulky, costly and heavy	These problems are not there in these motors and are inexpensive, particularly squirrel cage induction motors
Fast response and wide speed range of control, can be achieved smoothly by conventional and solid state control	In solid state control the speed range is wide and conventional method is stepped and limited
Speed and design ratings are limited due to commutations	Speed and design ratings have upper limits

FACTORS INFLUENCING THE CHOICE OF ELECTRICAL DRIVES:

- **The limits of Speed range:** The range over which the speed control is necessary for the load.
- **The efficiency:** The motor efficiency varies as load varies so the efficiency consideration under variable speed operation affects the choice of the motor.
- **The braking:** The braking requirements from the load point of view. Easy and effective braking are the requirements of a good drive.
- **Starting requirements:** The starting torque necessary for the load, the corresponding starting current drawn by the motor also affects the selection of drive.
- **Power factor:** The running motor with low power factor value is not economical. The power factor of the motor affects the selection of drive.
- **Load factors:** There are varieties of types of load conditions possible like continuous, intermittent and impact. Such load variation factor and duty cycle of the motor influences the selection of drive.
- **Availability of supply:** The motors available are AC or DC. But the availability of supply decides the type of motor to be selected for the drive.
- **Effects of supply variations:** There is a possibility of frequent supply variations. The selected motor should be able to withstand such supply variations.
- **Economical aspects:** The size and rating of the motor decides its initial cost while the various losses and temperature rise decides its running cost. These economical aspects must be considered while selecting a drive.
- **Reliability of operation:** It is important to study the conditions of stable operation of an electric drive. This includes the investigation of reliability of operation of an electric drive.
- **Environmental effects:** Chemical gases, fumes, humidity etc. may affect the motor. It should be considered when we select a drive.

LOADING CONDITIONS:

- **Continuous or Constant loads:** In this type load occurs for a long time under the same conditions.

Eg. Fan, Paper making machine

- **Continuous variable loads:** The load is variable over a period of time but occurs repetitively for a long duration.

Eg. Metal cutting lathes, conveyors.

- **Pulsating loads:** The load is continuously variable.

Eg. Reciprocating pumps, compressors

- **Impact loads:** These are peak loads occur at regular intervals of time.

Eg. Rolling mils, Presses, Shearing machine, Forging hammers

- **Short time intermittent loads:** The load appears periodically identical duty cycles, each consisting of a period of applications of load.

Eg. Cranes, Hoists, Elevators

- **Short time loads:** A constant load appears on the drive and the system rests for the remaining period of cycle.

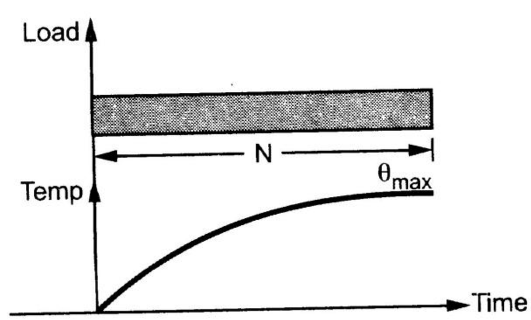
Eg. Motor – generator sets for charging batteries, house hold equipments.

CLASSES OF DUTY:

- Continuous duty
- Continuous duty, variable load
- Short time duty
- Intermittent periodic duty
- Intermittent periodic duty with starting
- Intermittent periodic duty with starting and braking

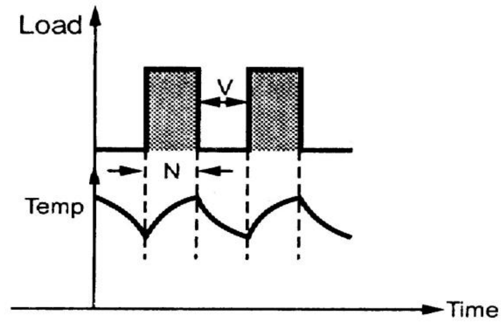
Continuous duty:

- Operation at constant load for a long duration of time
- 'N' indicates duration of operation.



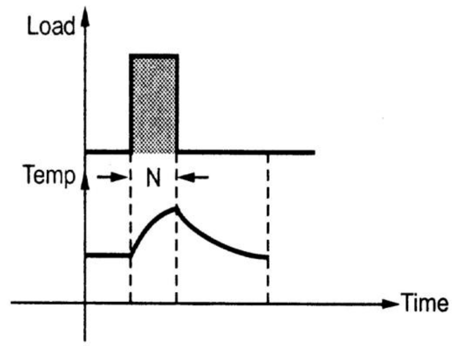
Continuous duty, variable load:

- It denotes a sequence of identical duty cycles each consisting of a period of operation at load and period of no load.



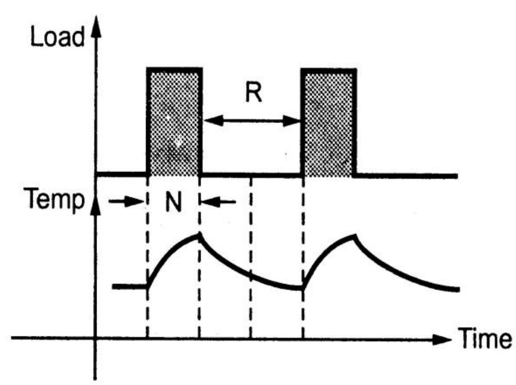
Short time duty:

It denotes operation at constant load during a given time, then followed by rest of sufficient duration



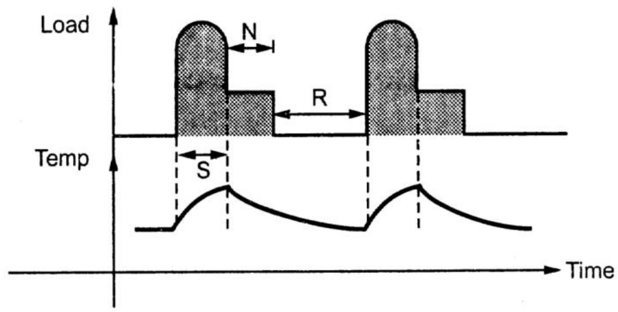
Intermittent periodic duty:

- Sequence of identical duty cycles each consisting of a period of operation at a constant load and then a period of rest.



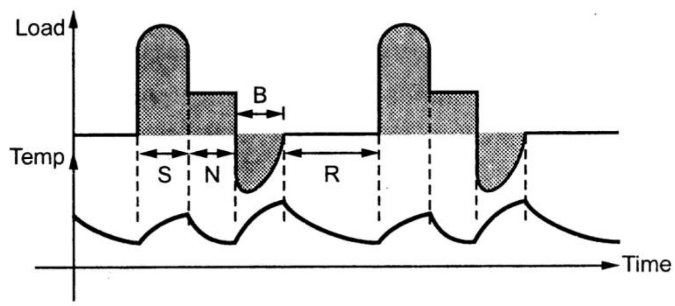
Intermittent periodic duty with starting:

- This consists of a load at start, then constant load and then a period of rest.



Intermittent periodic duty with starting and braking:

- This indicates a load as ‘Intermittent periodic duty with starting’ along with a period of braking and then a rest period.



Heating and Cooling Curves:

<u>Heating Curve:</u>

W – Loss taking place in a machine in watts
G – Mass of the machine in kg
S – Specific heat in watt-sec/kg degree Celsius
θ – Rise in temperature
θ_F – Final temperature rise
A – Area of cooling surface
λ – Rate of heat dissipation

Heat developed = Heat obserbed + Heat dissipated

Heat developed = Wdt
Heat Obserbed = $GSd\theta$
Heat dissipated = $A\,\lambda\,\theta dt$
$Wdt = GSd\theta + A\,\lambda\,\theta dt$
$Wdt - A\,\lambda\,\theta dt = GSd\theta$
$(W - A\,\lambda\,\theta)dt = GSd\theta$

$$\frac{dt}{GS} = \frac{d\theta}{W - A\lambda\lambda}$$

$$\frac{dt}{\left(\frac{GS}{A\lambda}\right)} = \frac{d\theta}{\left(\frac{W}{A\lambda} - \theta\right)}$$

When final temperature is reached, no heat obserbed
$Wdt = A\,\lambda\,\theta_F dt$
$W = A\,\lambda\,\theta_F$

$$\theta_F = \frac{W}{A\lambda}$$

$$\frac{dt}{\left(\frac{GS}{A\lambda}\right)} = \frac{d\theta}{(\theta_F - \theta)}$$

Integrating both sides of equation

$$\int \frac{dt}{\left(\frac{GS}{A\lambda}\right)} = \int \frac{d\theta}{(\theta_F - \theta)}$$

$$\frac{A\lambda}{GS} \times t = -\ln(\theta_F - \theta) + K$$

Where K is constant

To find out value of K, We can use initial condition

At t=0, $\theta = \theta_1$

$$0 = -\ln(\theta_F - \theta_1) + K$$

$$K = \ln(\theta_F - \theta_1)$$

Substitute K value

$$\frac{A\lambda}{GS} \times t = -\ln(\theta_F - \theta) + \ln(\theta_F - \theta_1)$$

$$\frac{A\lambda}{GS} \times t = \ln\left(\frac{\theta_F - \theta_1}{\theta_F - \theta}\right)$$

$$e^{\left(\frac{A\lambda}{GS} \times t\right)} = \frac{\theta_F - \theta_1}{\theta_F - \theta}$$

$$\theta_F - \theta = \left(\theta_F - \theta_1\right) e^{\left(-\frac{A\lambda}{GS} \times t\right)}$$

$\frac{GS}{A\lambda}$ is called heating time constant τ

$$\theta = \theta_F - \left(\theta_F - \theta_1\right) e^{\left(-t/\tau\right)}$$

If the machine is started from ambient temperature $\theta_1 = 0^0C$

$$\theta = \theta_F (1 - e^{\left(-t/\tau\right)})$$

Let us consider the time period t = τ then

$$\theta = \theta_F(1 - e^{-1})$$

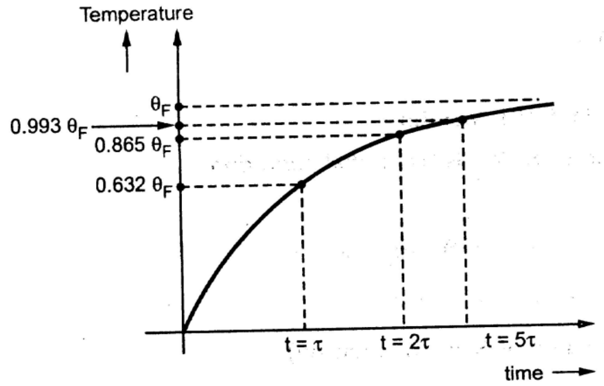
$\theta = 0.632\theta_F$

Similarly, at $t = 2\tau$, $\theta = 0.865\theta_F$

$t = 3\tau$, $\theta = 0.95\theta_F$

$t = 4\tau$, $\theta = 0.982\theta_F$

$t = 5\tau$, $\theta = 0.993\theta_F$



COOLING CURVE:

W – Loss taking place in a machine in watts

G – Mass of the machine in kg

S – Specific heat in watt-sec/kg degree Celsius

θ – Drop in temperature

θ_F' – Final temperature drop

A – Area of cooling surface

λ' – Rate of heat dissipation

Heat developed + Heat emitted = Heat dissipated

Heat developed = Wdt

Heat emitted = -GSdθ

Heat dissipated = A λ’ θdt

Wdt - GSdθ = A λ’ θdt

-GSdθ = A λ’ θdt - Wdt

$$-GSd\theta = \left(A\lambda'\theta - W\right)dt$$

$$-\frac{GS}{A\lambda'}d\theta = \left(\theta - \frac{W}{A\lambda'}\right)dt$$

$$-\frac{d\theta}{\left(\theta - \frac{W}{A\lambda'}\right)} = \frac{dt}{\left(\frac{GS}{A\lambda'}\right)}$$

If θ_F' is final temperature drop, then heat generated is equal to heat dissipated

$$Wdt = A\lambda'\theta_F'dt$$

$$\theta'_F = \frac{W}{A\lambda'}$$

$$-\int \frac{d\theta}{\left(\theta - \frac{W}{A\lambda'}\right)} = \int \frac{dt}{\left(\frac{GS}{A\lambda'}\right)}$$

$$-\int \frac{d\theta}{\left(\theta - \theta'_F\right)} = \int \left(\frac{A\lambda'}{GS}\right) dt$$

$$-\left[\ln\left(\theta - \theta'_F\right)\right] = \frac{A\lambda'}{GS} \times t + K$$

$$\ln\left(\theta - \theta'_F\right) = -\frac{A\lambda'}{GS} \times t + K$$

Where K is constant of integration which can be found by using initial conditions

At $t = 0$, $\theta = \theta_0$

$$\ln\left(\theta_0 - \theta'_F\right) = K$$

$$\ln\left(\theta - \theta'_F\right) = -\frac{A\lambda'}{GS} \times t + \ln\left(\theta_0 - \theta'_F\right)$$

$$\ln\left(\theta - \theta'_F\right) - \ln\left(\theta_0 - \theta'_F\right) = -\frac{A\lambda'}{GS} \times t$$

$$\ln\left(\frac{\theta - \theta'_F}{\theta_0 - \theta'_F}\right) = -\frac{A\lambda'}{GS} \times t$$

$$\frac{\theta - \theta'_F}{\theta_0 - \theta'_F} = e^{-\frac{A\lambda'}{GS} \times t}$$

$$\theta - \theta'_F = \left(\theta_0 - \theta'_F\right) e^{-\frac{A\lambda'}{GS} \times t}$$

$$\theta = \theta'_F + \left(\theta_0 - \theta'_F\right) e^{-\frac{A\lambda'}{GS} \times t}$$

$$\frac{GS}{A\lambda'} = \tau'$$

$$\theta = \theta'_F + \left(\theta_0 - \theta'_F\right)e^{-t/\tau'}$$

The final temperature is ambient temperature ie, $\theta'_F = 0$

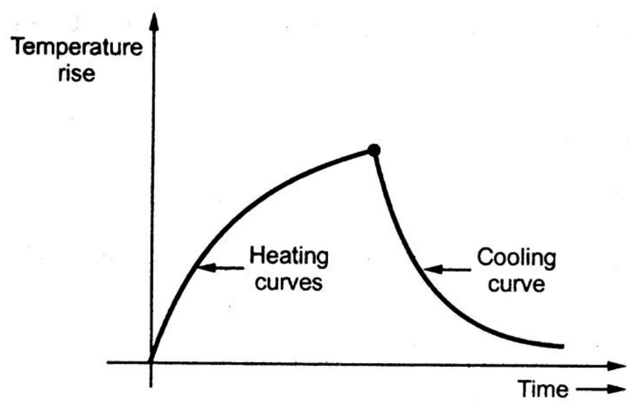
At t = τ', $\theta = 0.367\ \theta_0$

At t =2 τ', $\theta = 0.135\ \theta_0$

At t =3 τ', $\theta = 0.05\ \theta_0$

At t =4 τ', $\theta = 0.018\ \theta_0$

At t =5 τ', $\theta = 0.007\ \theta_0$



UNIT II
DRIVE MOTOR CHARACTERISTICS

Characteristics of DC motor

1. Torque Vs Armature Current Characteristics
2. Speed Vs Armature Current Characteristics
3. Speed Vs Torque Characteristics

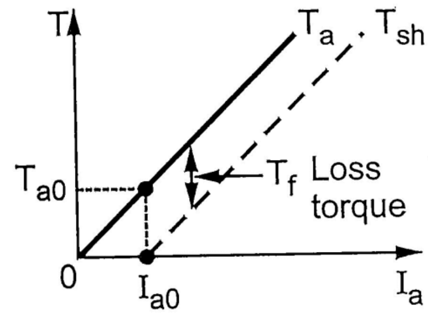
DC Shunt Motor

1. Torque Vs Armature Current Characteristics

$$T_a \propto \phi I_a$$

- For DC Shunt motor, φ is constant.
- Armature torque is directly proportional to Armature current.
- Torque increases linearly with armature current.
- Torque spent to rotate armature is loss.

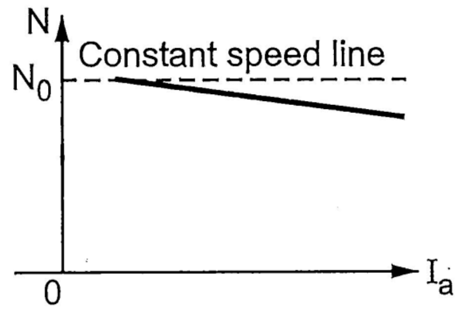
- The torque used to operate the load is called Shaft torque.



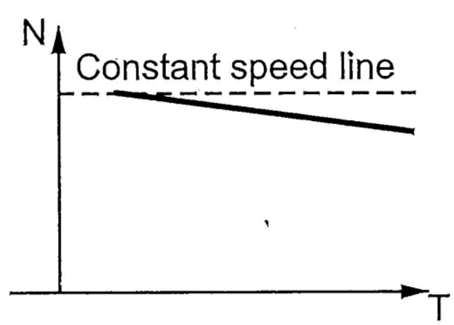
2. **Speed Vs Armature Current Characteristics**

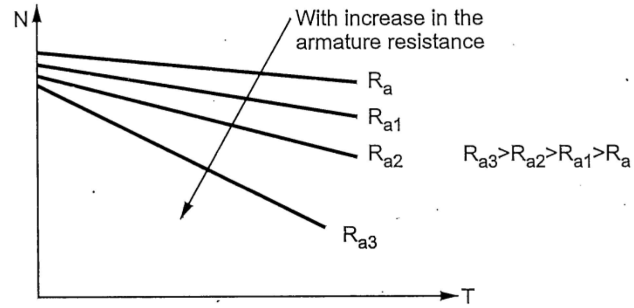
$$N \propto \frac{V - I_a R_a}{\Phi}$$

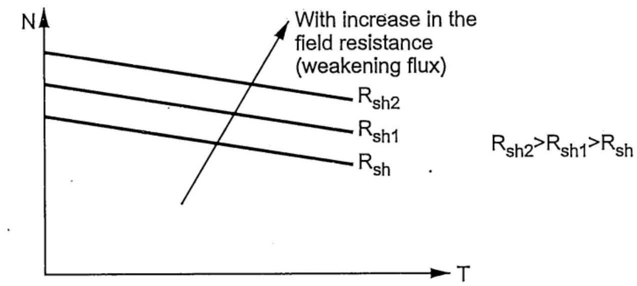
- When load increases, armature current increases.
- When armature current increases, drop increases.
- When drop increases, speed reduces.

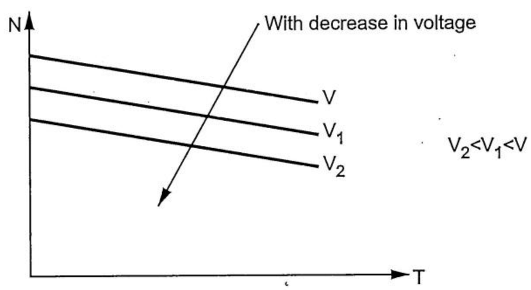


3. **Speed Vs Torque Characteristics**
   - This characteristic is similar to speed-armature current characteristics.
   - When torque increases, speed reduces.
   - The characteristic also varies with respect to armature current value, field resistance value and supply voltage.







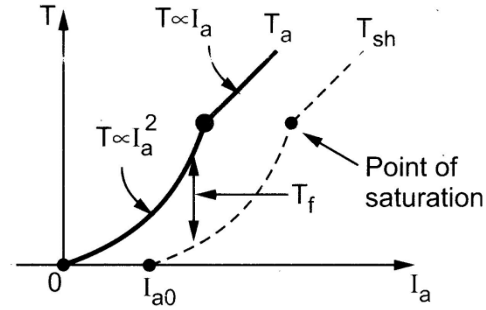


<u>DC Series Motor</u>

1. **Torque Vs Armature Current Characteristics**

$$T \propto I_a^2$$

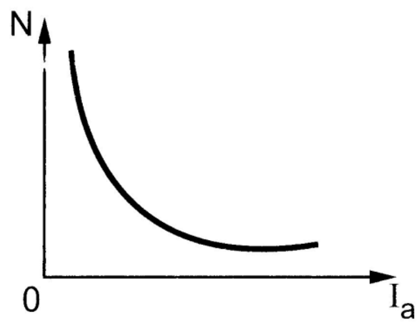
- Armature current and field current are same.
- At starting time, torque is proportional to square value of armature current and then torque is proportional to armature current.
- It can be used for high torque applications.



2. **Speed Vs Armature Current Characteristics**

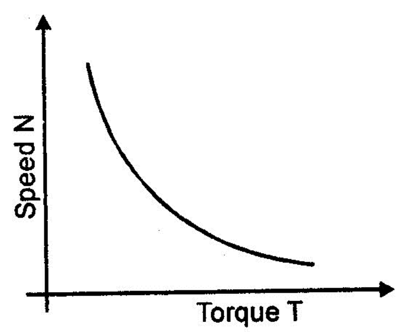
$$N \propto \frac{V - I_a R_a}{\Phi}$$

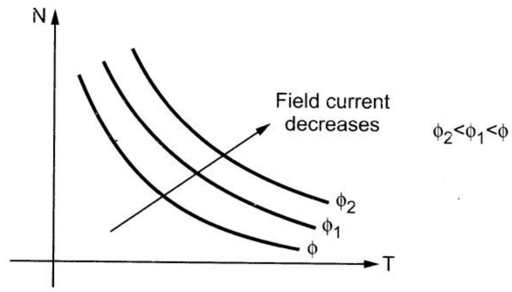
- For series motor, speed is inversely proportional to flux.
- Flux is directly proportional to armature current.
- When armature current increases, speed reduces.

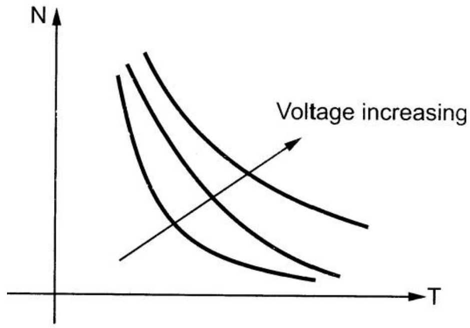


3. **Speed Vs Torque Characteristics**

- This characteristic is similar to speed-armature current characteristics.
- When torque increases, speed reduces.
- The characteristic also varies with respect to field current value and supply voltage.

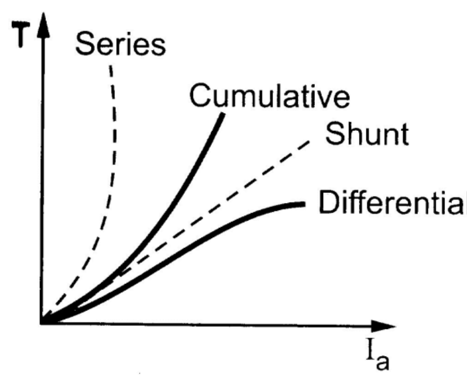


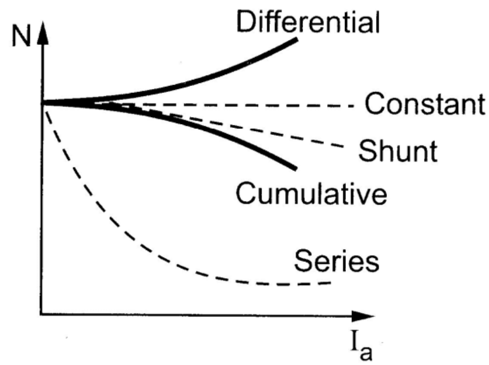


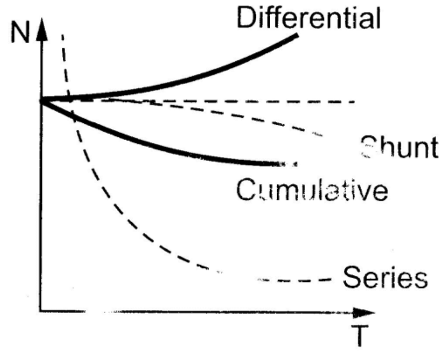


DC Compound Motor

- The characteristic of this motor is depending on flux produced by shunt winding and series winding.
- For cumulative compound motor, the total flux is the sum of shunt field coil flux and series field flux.
- For differential compound motor, the total flux is the difference of shunt field coil flux and series field flux.
- Cumulative compound motor has capability of developing large amount of torque compared to differential compound motor.







BRAKING OF ELECTRICAL MOTORS:

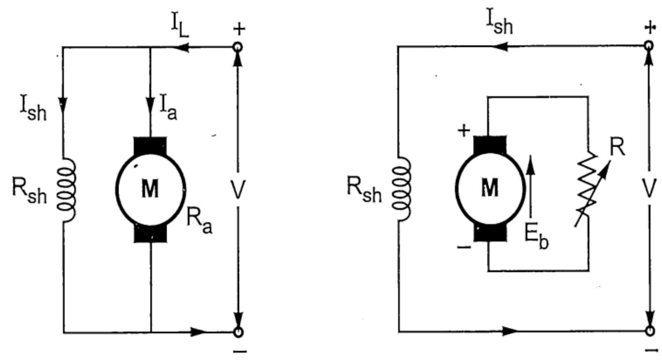
- The term braking comes from the term brake
- The process of reducing speed of any rotating machine

Types of Braking

- Rheostatic or Dynamic Braking
- Plugging or Counter Current Braking
- Regenerative Braking

DC Shunt Motor:

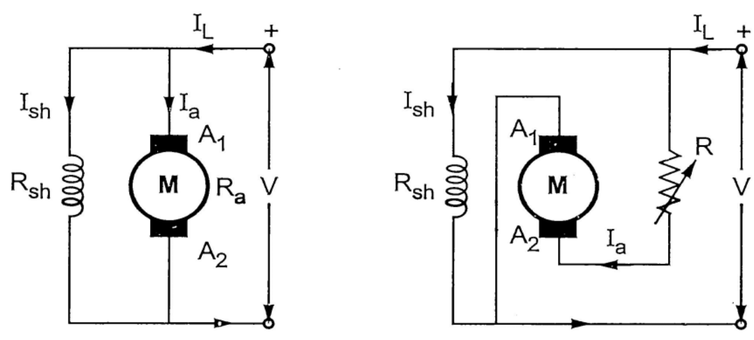
Rheostatic or Dynamic Braking:



(a) Running (b) Braking

- The method of reversing the direction of torque and braking the motor is **dynamic braking**
- In this method of braking the motor which is at a running condition is disconnected from the source and connected across a resistance
- When the motor is disconnected from the source, the rotor keeps rotating due to inertia and it works as a self –excited generator
- When the motor works as a generator the flow of the electric current and torque reverses
- During braking to maintain the steady torque sectional resistances are cut out one by one.

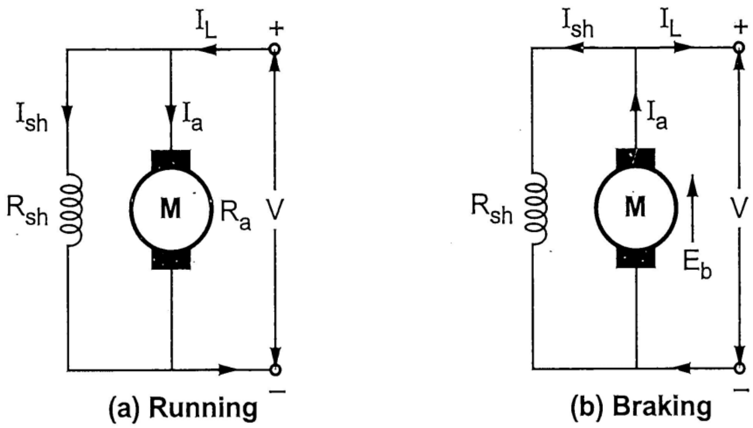
Plugging or Counter Current Braking:



(a) Running (b) Braking

- In this method the terminals of supply are reversed, as a result the generator torque also reverses which resists the normal rotation of the motor and as a result the speed decreases
- During plugging external resistance is also introduced into the circuit to limit the flowing current
- The main disadvantage of this method is that here power is wasted

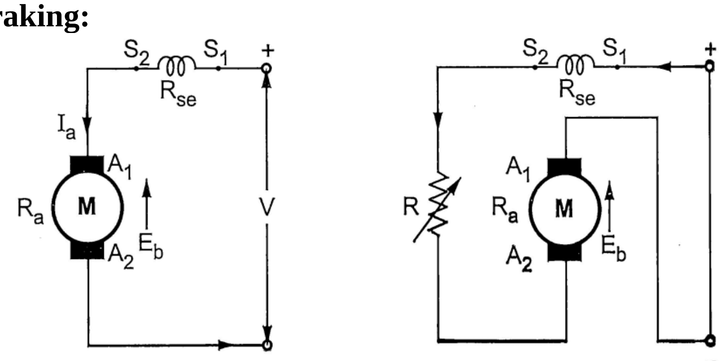
Regenerative Braking:



- **Regenerative braking** takes place whenever the speed of the motor exceeds the synchronous speed
- This baking method is called regenerative braking because here the motor works as generator and supply the voltage to main
- The main criteria for regenerative braking is that the rotor has to rotate at a speed higher than synchronous speed
- The motor will act as a generator and the direction of electric current flow through the circuit and direction of the torque reverses and braking takes place
- The only disadvantage of this type of braking is that the motor has to run at super synchronous speed which may damage the motor mechanically and electrically

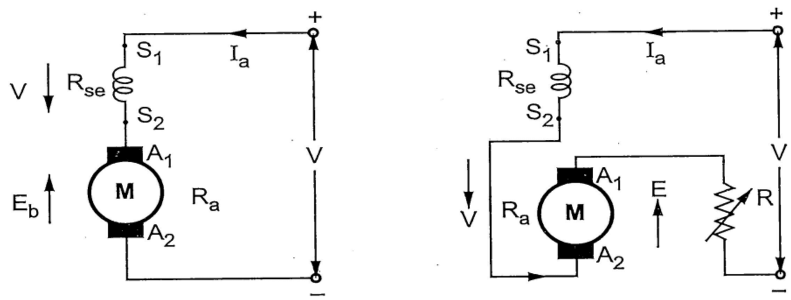
<u>DC SERIES MOTOR</u>:

Rheostatic or Dynamic Braking:



(Theory is same as DC shunt motor braking)

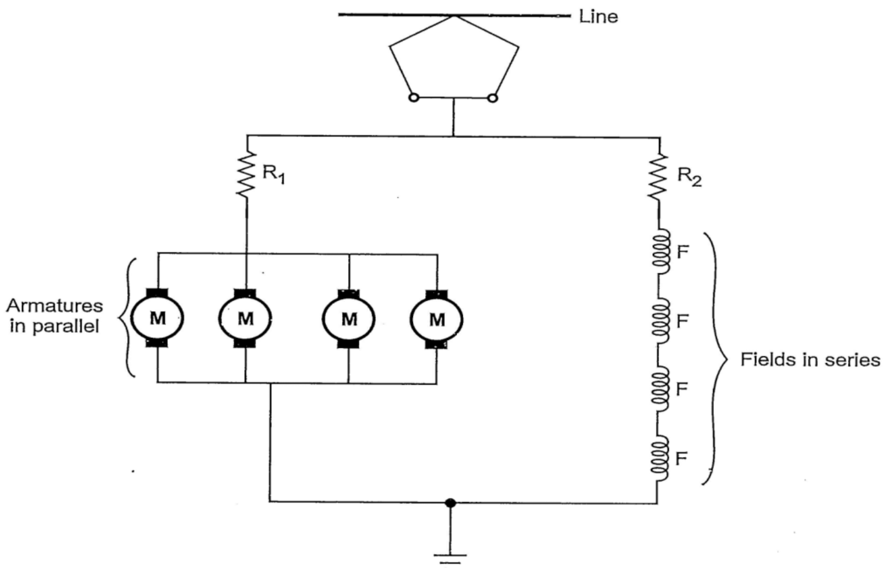
Plugging or Counter Current Braking:



(a) Running (b) Braking

(Theory is same as DC shunt motor braking)

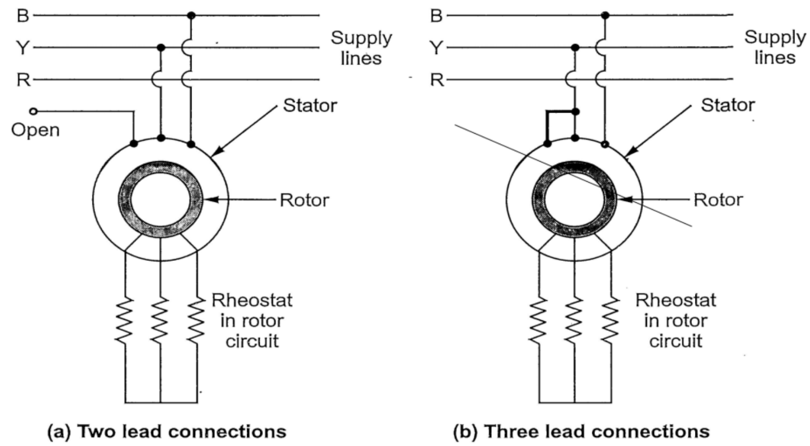
Regenerative Braking:



(Theory is same as DC shunt motor braking)

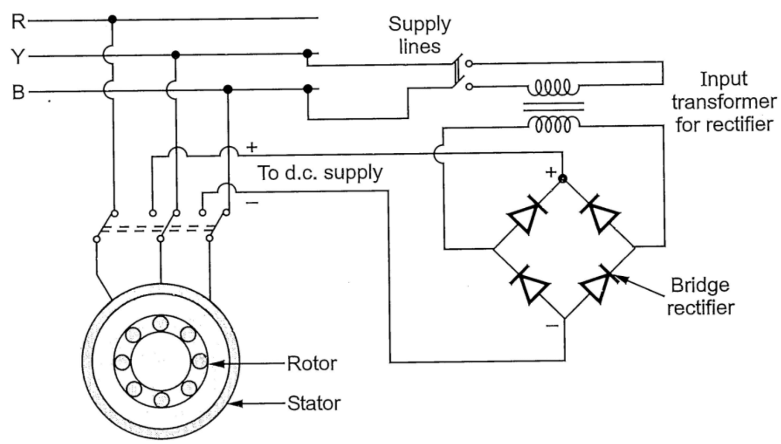
BRAKING OF INDUCTION MOTOR

Dynamic or Rheostatic Braking:



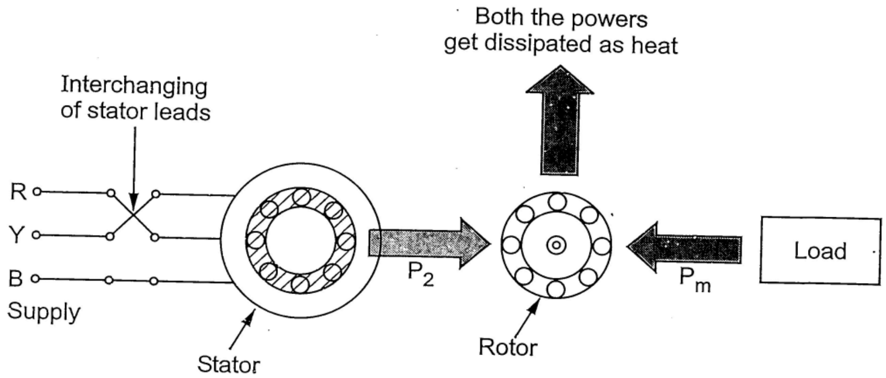
- This type of induction motor braking is obtained when the motor is made to run on a single phase supply by disconnecting any one of the three phase from the source
- The disconnected terminal is connected with another phase or the disconnected phase is left open
- When the disconnected phase is left open, it is called two lead connection
- When the disconnected phase is connected to another machine phase it is known as three lead connection
- The torque of three phase induction motor is reduced when motor runs with two phase supply
- Now the resistance value of rheostat can be adjusted to stop the motor

DC Dynamic Braking:



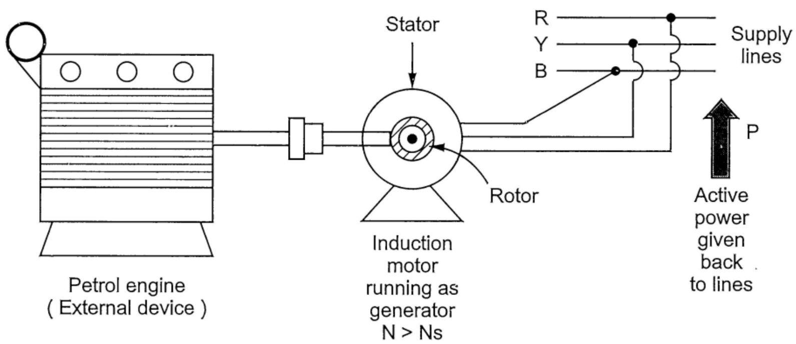
- To obtain this type of braking the stator of a running induction motor is connected to a dc supply
- The moment when AC supply is disconnected and DC supply is introduced across the terminals of the induction motor
- The stationery magnetic field is generated due to the DC electric current flow
- The machine works as a generator and the generated energy dissipates in the rotor circuit resistance and dynamic braking of induction motor occurs

Plugging or Counter Current Braking:



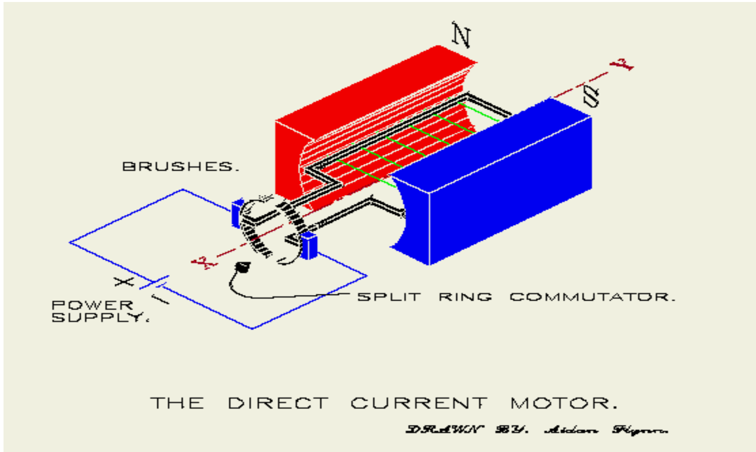
- Plugging **induction motor braking** is done by reversing the phase sequence of the motor
- The phase sequence of the motor can be changed by interchanging connections of any two phases of stator with respect of supply terminals
- When the phase sequence is changed, the direction of current flow is changed
- The counter current produces the opposite torque and then motor is stopped

Regenerative Braking:

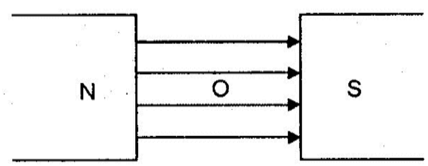


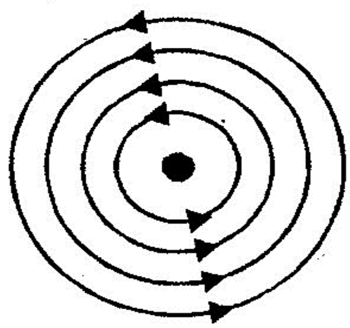
- The **regenerative braking of induction motor** can only take place if the speed of the motor is greater than synchronous speed
- The above synchronous speed is obtained by using Petrol engine
- This baking method is called regenerative braking because here the motor works as generator and supply the voltage to main
- The main criteria for regenerative braking is that the rotor has to rotate at a speed higher than synchronous speed
- The motor will act as a generator and the direction of electric current flow through the circuit and direction of the torque reverses and braking takes place

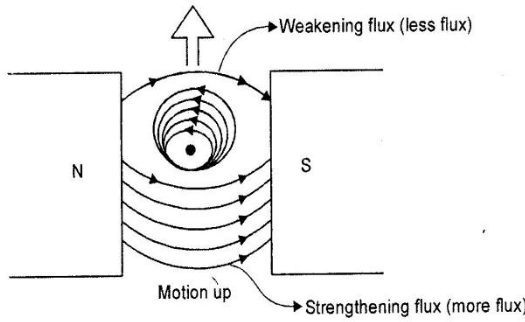
OPERATING PRINCIPLE OF DC MOTORS:

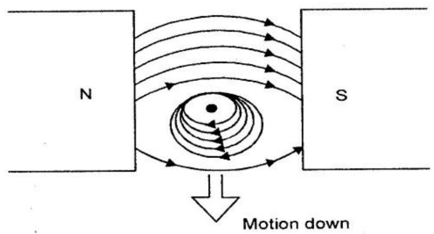


- This is a device that converts DC electrical energy to a mechanical energy
- Structurally and construction wise a direct electric current motor is exactly similar to a DC generator, but electrically it is just the opposite
- This DC or **direct electric current motor** works on the principal, when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move
- This is known as motoring action
- If the direction of electric current in the wire is reversed, the direction of rotation also reverses
- When magnetic field and electric field interact they produce a mechanical force, and based on that the working principle of **dc motor** established
- The direction of rotation of a this motor is given by Fleming's left hand rule
- **Fleming's left hand rule:** if the index finger, middle finger and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of magnetic field, middle finger indicates the direction of electric current, then the thumb represents the direction in which force is experienced by the shaft of the **dc motor**

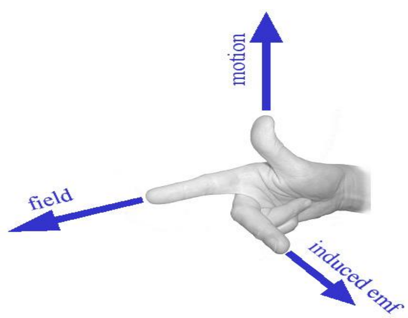


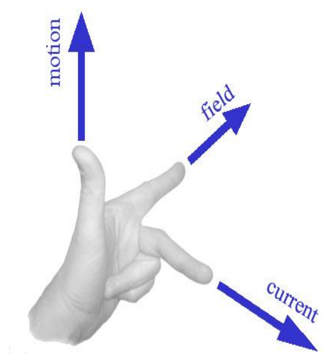




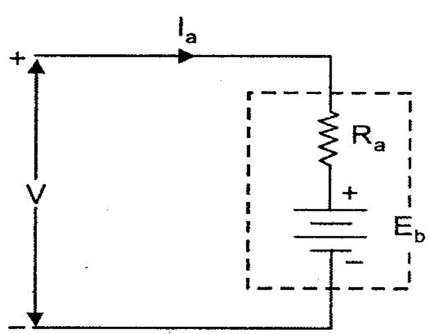


Fleming's Right & Left Hand Rule





Equivalent Circuit



TYPES OF DC MOTORS

- **Separately Excited DC motor.**
- **Self-excited DC motor.**

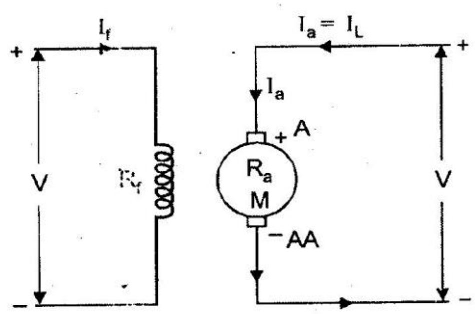
1. **Series motor.**
2. **Shunt motor.**
3. **Compound motor.**

a. **Cumulative compound** b. **Differential compound**

i. Long Shunt compound motor.
ii. Short Shunt compound motor.

Separately Excited DC motor:

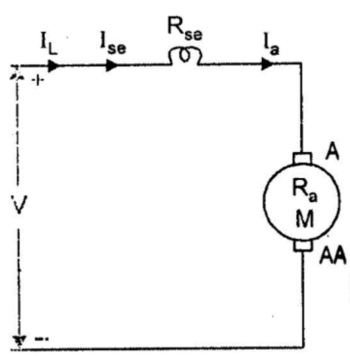
- The supply is given separately to the field and armature windings
- The main distinguishing fact in these types of dc motor is that, the armature electric current does not flow through the field windings, as the field winding is energized from a separate external source of dc electric current



Self-excited DC motor

Series motor:

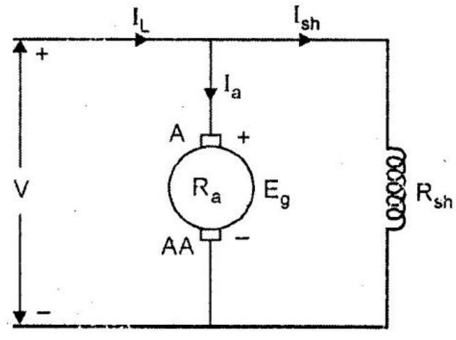
- The armature winding and field winding are connected in series
- The entire armature electric current flows through the field winding as its connected in series to the armature winding
- In a series wound dc motor, the speed varies with load



Shunt motor:

- The field winding is connected in parallel to the armature winding

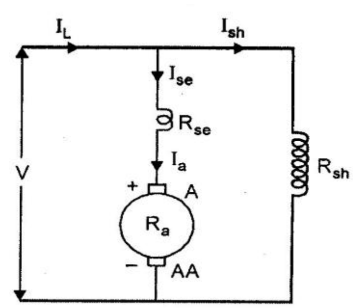
- The voltage is same across field winding and armature winding
- The line current is the sum of armature current and field current
- The shunt wound dc motor is a constant speed motor, as the speed does not vary here with the variation of mechanical load on the output.



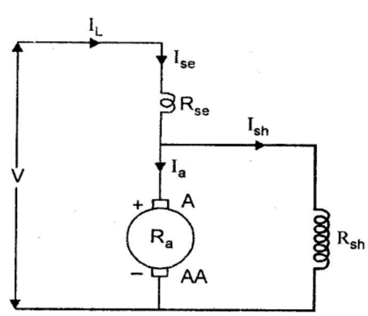
Compound Motor:

- The compound excitation characteristic in a dc motor can be obtained by combining the operational characteristic of both the shunt and series excited dc motor
- It contains the field winding connected both in series and in parallel to the armature winding
- If the shunt field winding is only parallel to the armature winding and not the series field winding then its known as short shunt dc motor
- If the shunt field winding is parallel to both the armature winding and the series field winding then it's known as long shunt type compounded wound dc motor
- When the shunt field flux assists the main field flux, produced by the main field connected in series to the armature winding then it's called cumulative compound dc motor
- In case of a differentially compounded self excited dc, the arrangement of shunt and series winding is such that the field flux produced by the shunt field winding diminishes the effect of flux by the main series field winding

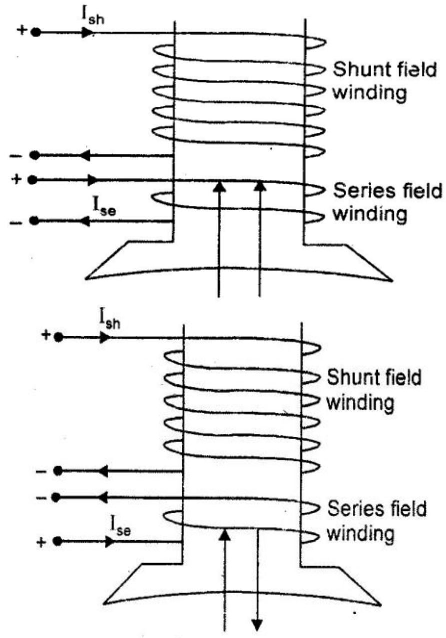
Long Shunt compound motor



Short Shunt compound motor



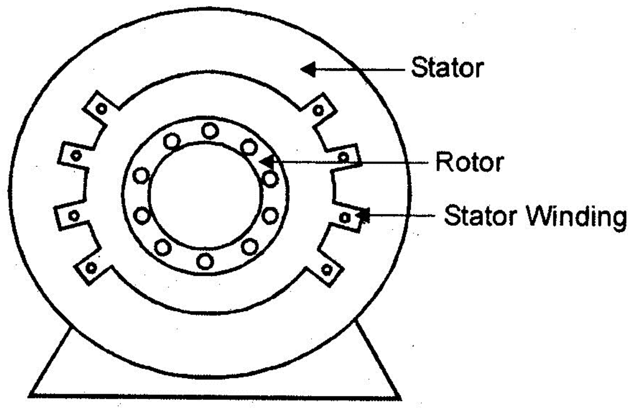
Cumulative & Differential compound

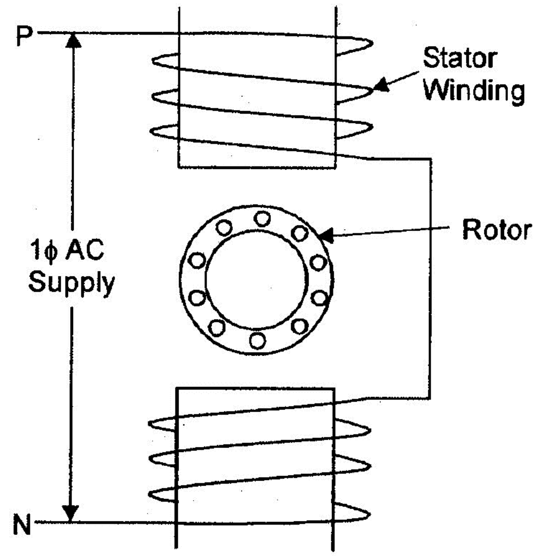


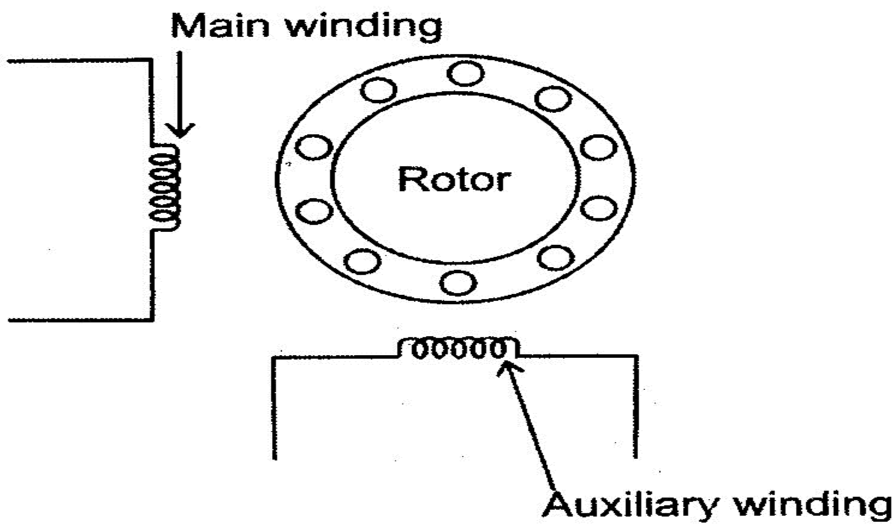
SINGLE PHASE INDUCTION MOTORS:

- Single phase motors are small motors.
- They have a power rating in fractional HP range.
- These motors are used in homes, offices, shops and factories.
- Disadvantages:
  1. Lack of starting torque.
  2. Reduced power factor.
  3. Low efficiency.

CONSTRUCTION:







- The construction of a single phase induction motor is similar to 3φ squirrel cage induction motor.
- Stator has a single phase distributed winding.
- Rotor → Squirrel cage rotor.
- It has no self starting torque.

PRINCIPLE OF OPERATION:

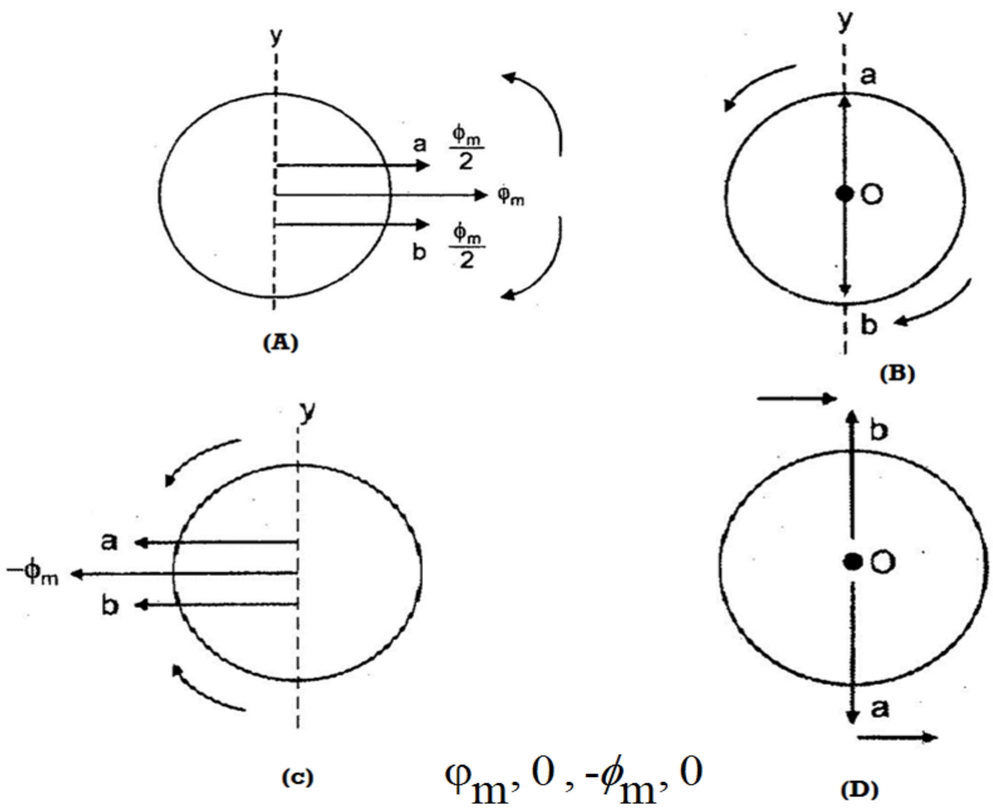
- The starting torque can be produced by using auxiliary winding.
- The angle between main winding and auxiliary winding should be 90 electrical degrees.

- The current passing through main winding and auxiliary winding should have some electrical angle to produce a rotating magnetic field.
- Rotating magnetic field produces high starting torque.
- The single-phase induction motor operation can be described by two methods:

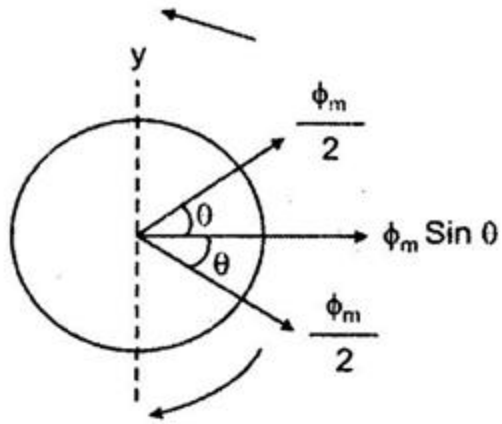
  – Double revolving field theory; and
  – Cross-field theory.

DOUBLE REVOLVING FIELD THEORY:

- A single-phase AC current supplies the main winding that produces a pulsating magnetic field.
- Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.
- The pulsating filed is divided a forward and reverse rotating field.
- The components ‘a’ and ‘b’ are forward and reverse rotating field respectively



Rotation of vector by an angle +φ and –φ



The flux variation with respect to φ:

The forward slip of the rotor is given by

$$s_f = \frac{N_s - N}{N_s}$$

$$s_f = 1 - \frac{N}{N_s}$$

$$\frac{N}{N_s} = 1 - s_f$$

The backward slip of the rotor is given by

$$s_b = \frac{N_s - (-N)}{N_s}$$

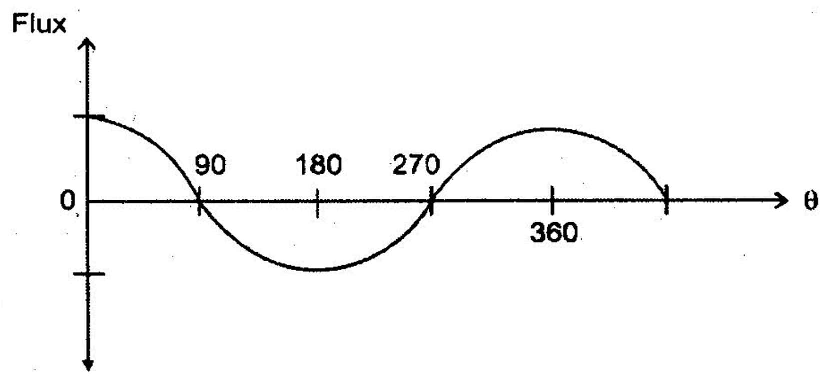
$$s_b = \frac{N_s + N}{N_s}$$

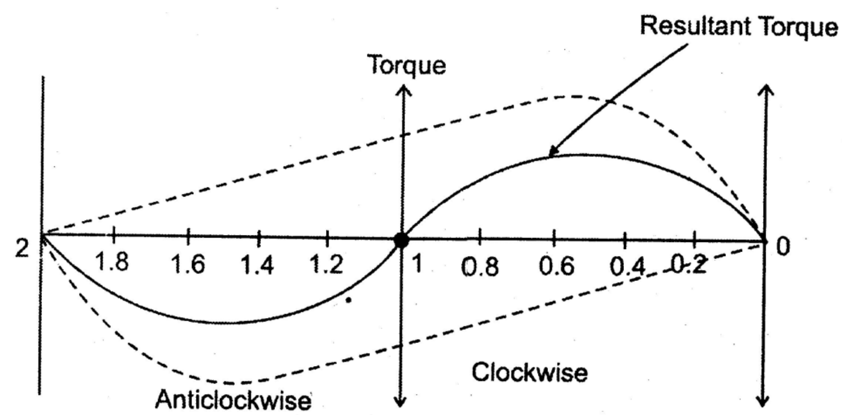
$$s_b = 1 + \frac{N}{N_s}$$

$$s_b = 1 + 1 - s_f$$

$$s_b = 2 - s_f$$

Flux versus time:



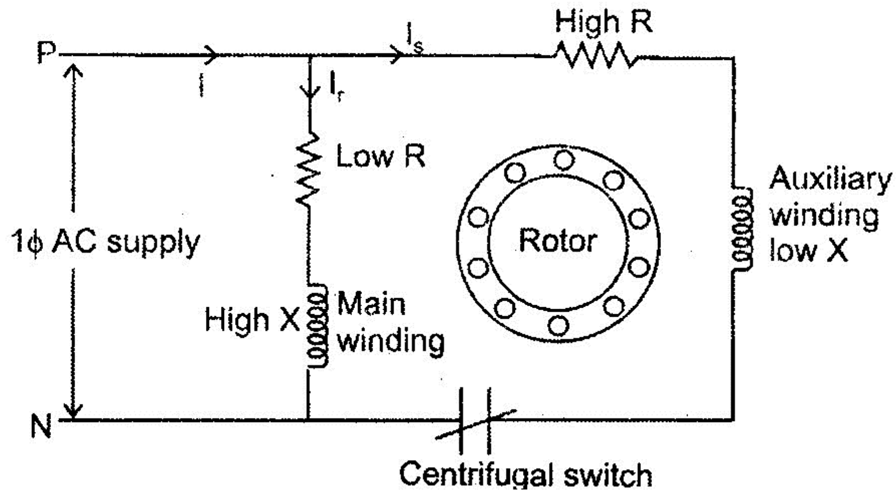


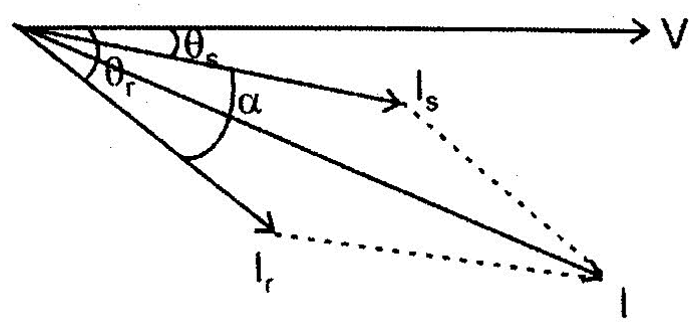
- At starting, the slip value of 1φ induction motor is '1'.
- When slip is 1, the components 'a' and 'b' are producing equal and opposite torque.
- The resulting torque is zero.
- This motor has no starting torque.

TYPES OF 1Φ IM (STARTING METHODS):

- Resistance – Start (Split phase) motor.
- Capacitor – Start induction motor.
- Capacitor – Run induction motor.
- Capacitor – Start and Capacitor – Run IM.
- Shaded – pole motor.

Resistance – Start (Split phase) motor:



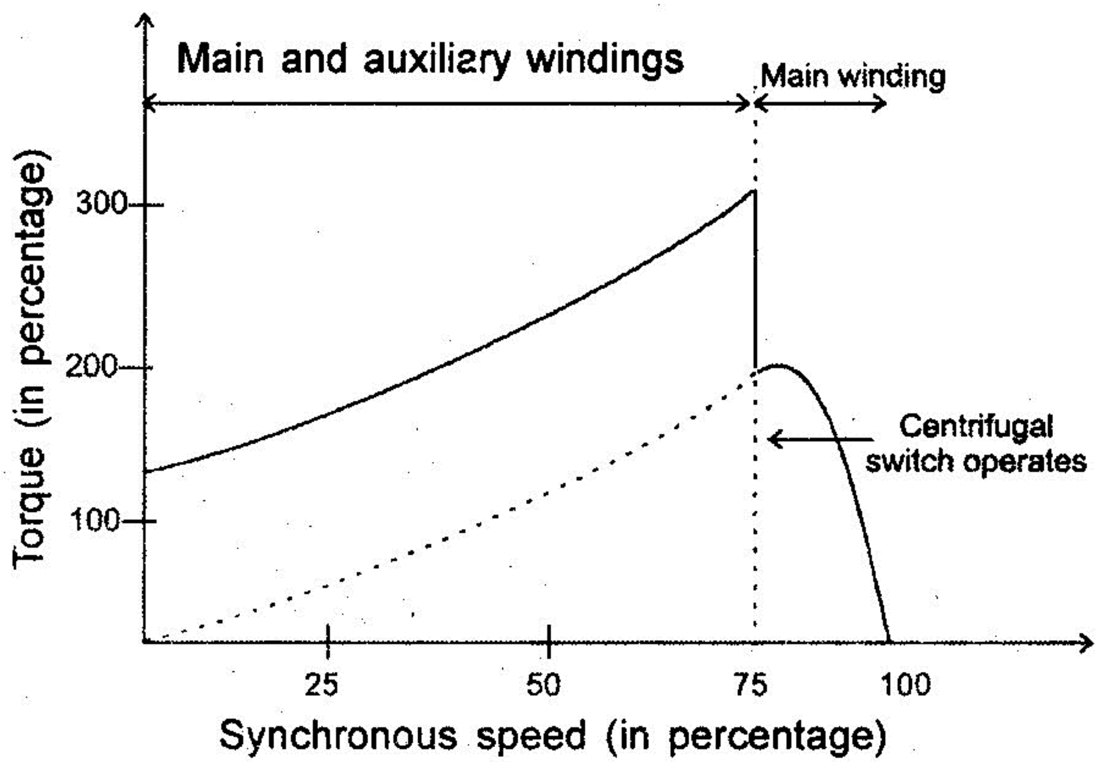


- It has two windings:

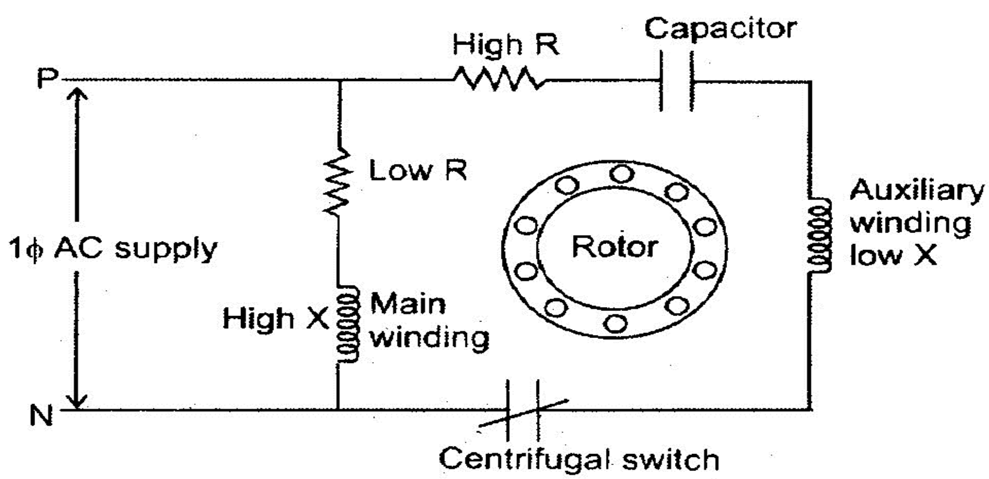
  1. Main winding or Running winding
  2. Auxiliary winding.
- These two winding axes are displaced by 90 electrical degrees.
- The main winding has high X (reactance) value and low R (resistance) value.
- The auxiliary winding has Low X value and High R value.
- This variation in the reactance makes two different phases.
- Two phase supply constructs rotating magnetic field.
- The rotating magnetic field produces high torque at the starting time.
- The centrifugal switch disconnects the auxiliary winding from the circuit after the motor reaches synchronous speed.
- **Applications:**

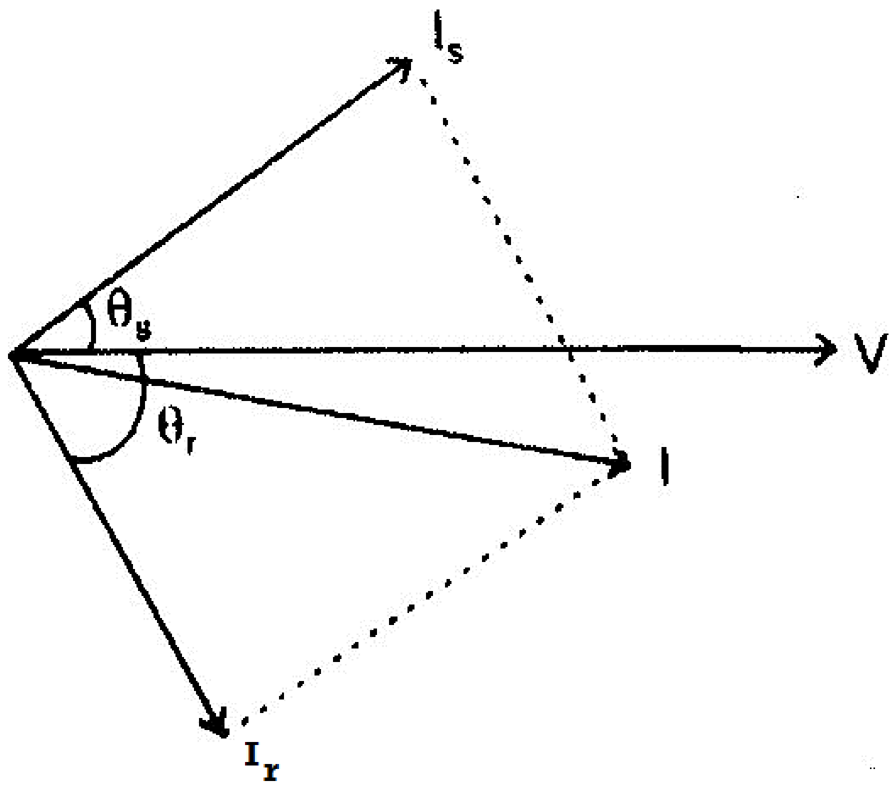
  Fans, Blowers, Centrifugal pumps, washing machines

Torque Vs Speed:



Capacitor – Start induction motor:

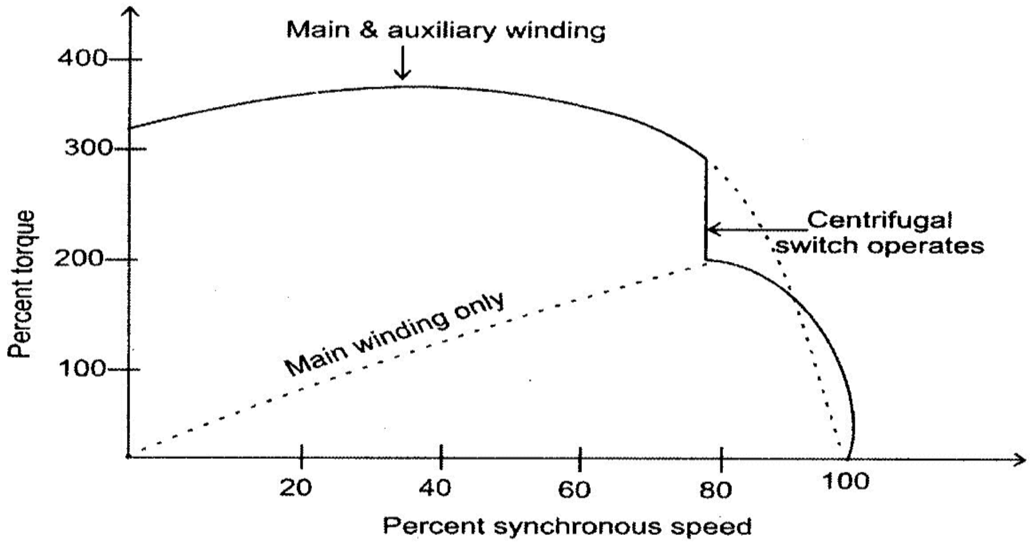




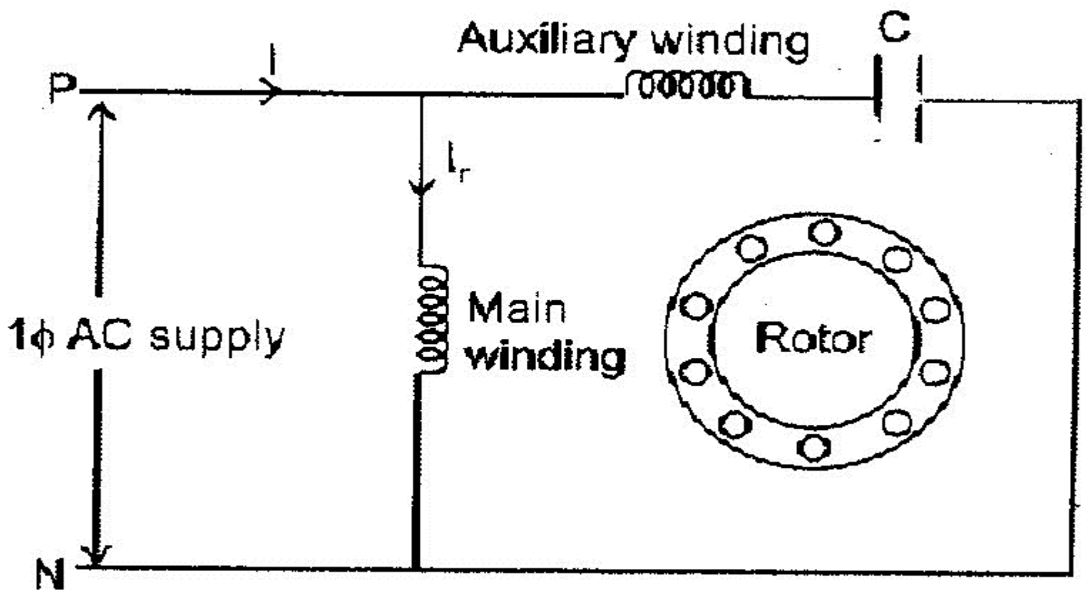
- A capacitor is connected in series with auxiliary winding to produce leading current in auxiliary winding.
- The high X value of main winding produces lagging current.
- Voltage across two windings produces two different phases.
- Two phase supply constructs rotating magnetic field.
- The rotating magnetic field produces high torque at the starting time.
- The centrifugal switch disconnects the auxiliary winding and capacitor from the circuit after the motor reaches 75% of synchronous speed.
- **Applications:**

Compressors, Pumps, Conveyors, Refrigerators, Air conditioning Equipments, Washing machines

Speed Vs Torque:



Capacitor – Run induction motor:

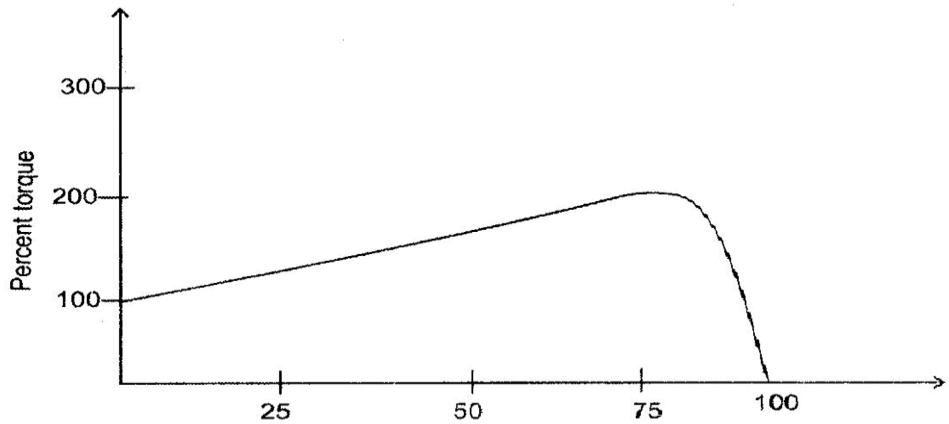


- A capacitor is connected in series with auxiliary winding to produce leading current in auxiliary winding.
- The high X value of main winding produces lagging current.
- Voltage across two windings produces two different phases.
- Two phase supply constructs rotating magnetic field.
- The rotating magnetic field produces high torque at the starting time.
- It does not use centrifugal switch.
- The capacitor is always connected with auxiliary winding so that the starting and running torque is high.

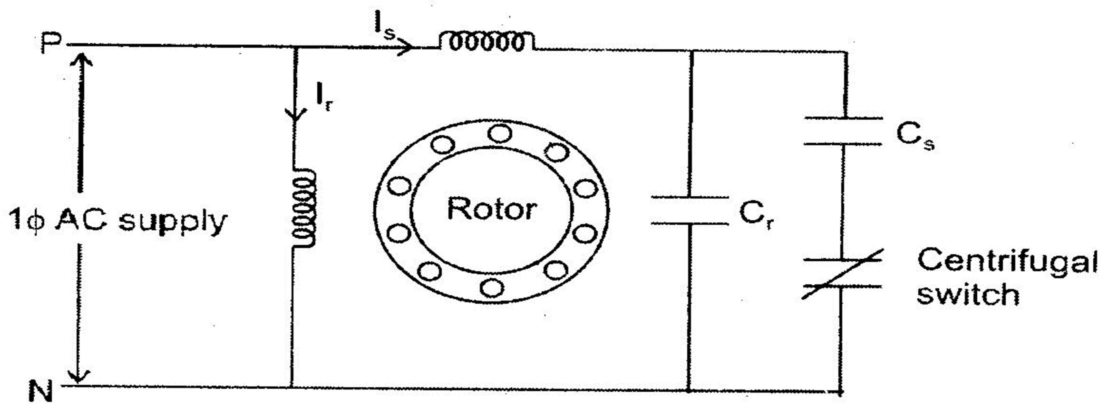
- **Applications:**

  Fans, Blowers, Centrifugal pumps

Speed Vs Torque:



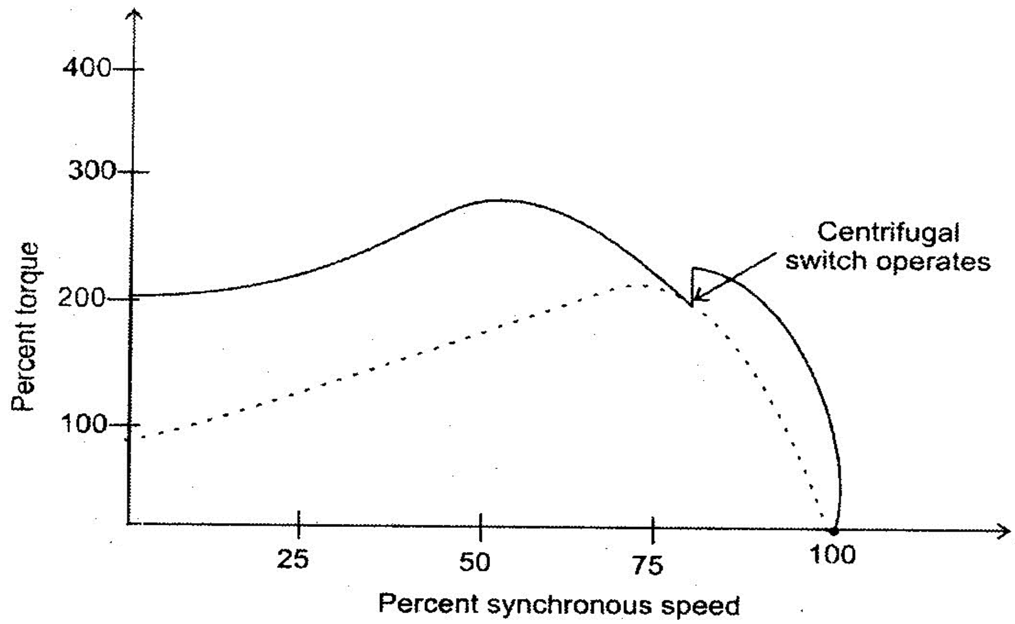
Capacitor – Start and Capacitor – Run IM:



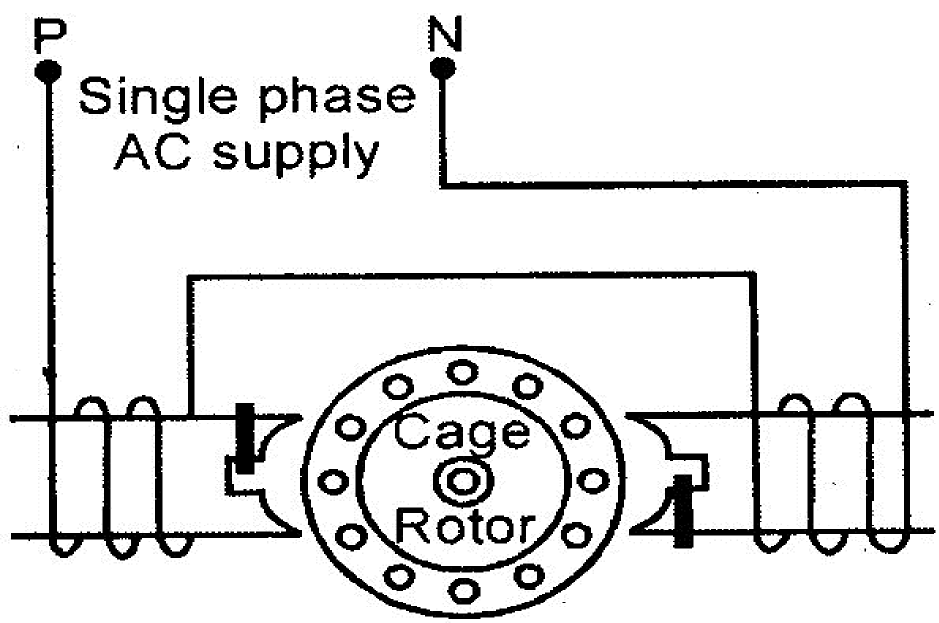
- It uses two capacitors, Running capacitor (Cr) and starting capacitor (Cs).
- Running capacitor always connected in series with auxiliary winding.
- Starting capacitor is disconnected from the circuit after the motor reaches 75% of synchronous speed by the help of Centrifugal switch.
- Starting torque and efficiency can be improved.
- **Applications:**

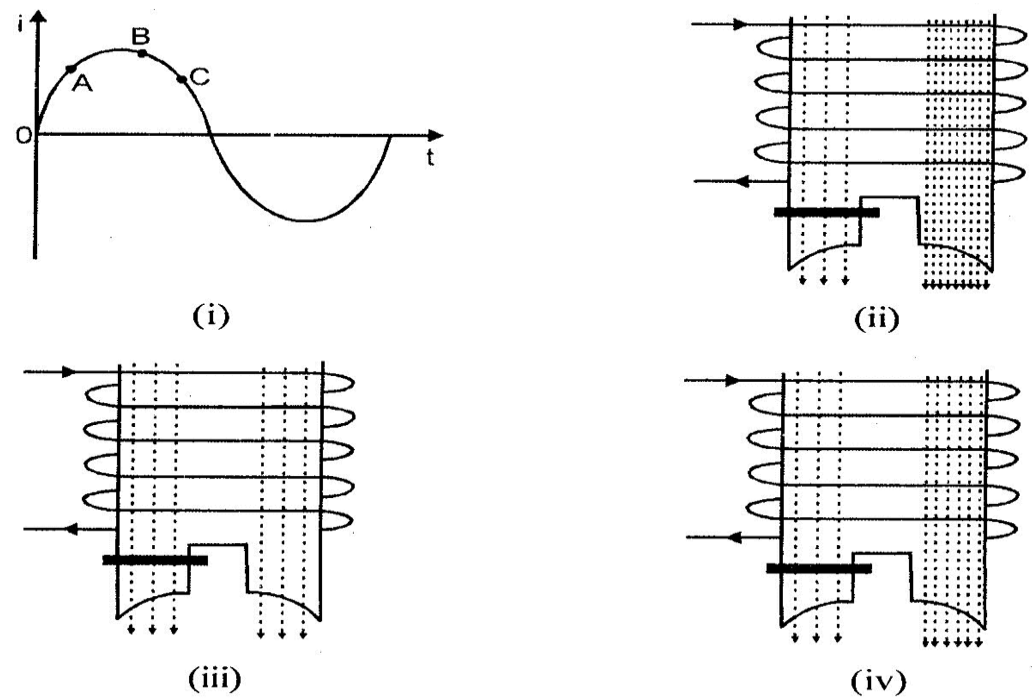
  Compressors, Pumps, Conveyors, Refrigerators

Speed Vs Torque:



Shaded – pole motor:



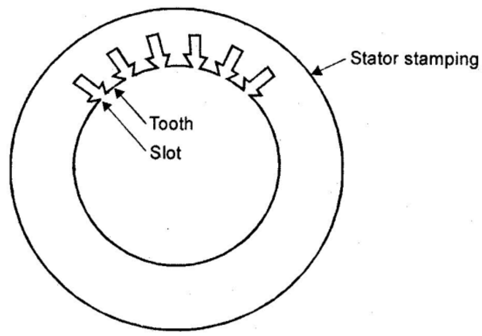


- During the portion OA of the alternating current cycle, the emf is induced in the shading coil. The induced emf produces magnetic flux in the shaded portion. This flux opposes the main field flux, so that the flux under shaded portion is weakened and flux under unshaded portion is strengthened .
- During the portion AB of the alternating current cycle, the flux under shaded portion and unshaded portion is uniform.
- During the portion BC of the alternative current cycle , the emf is induced in the shading coil. The induced emf produces magnetic flux in the shaded portion. This flux is added to the main field flux, so that the flux under shaded portion is strengthened and flux under unshaded portion is weakened.
- Alternatively it is producing strengthened and weakened magnetic flux under pole faces, so that it constructs rotating magnetic field.
- The rotating magnetic field produces high torque at the starting time.
- Low efficiency, Low power factor and Very low starting torque.
- **Applications:**

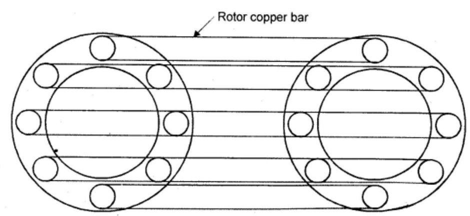
  Fans, Blowers, Turn tables, Hair driers, Motion picture projectors

PRINCIPLE OF OPERATION OF THREE-PHASE INDUCTION MOTORS:

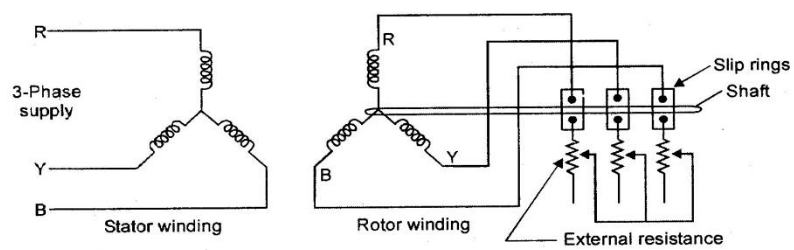
STATOR



Squirrel cage rotor



Slip ring or Wound Rotor



Principle of operation:

- Rotating magnetic field cuts the rotor windings and produces an induced voltage in the rotor windings.
- Due to the fact that the rotor windings are short circuited, for both squirrel cage and wound-rotor, and induced current flows in the rotor windings.
- The rotor current produces another magnetic field.
- A torque is produced as a result of the interaction of those two magnetic fields. This torque makes the rotation of the rotor.
- The IM will always run at a speed lower than the synchronous speed.
- The difference between the motor speed and the synchronous speed is called the Slip speed.

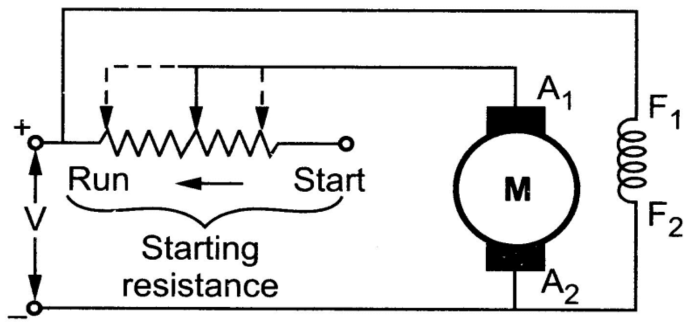
UNIT III

STARTING METHODS

STARTER:

- Starter is used to reduce starting current because armature consumes 15-20 times more than the full load current at starting time.
- High current blows out the fuses.
- It affects insulation of the coil.
- It also creates very high torque and very high torque causes mechanical damage to the motor.

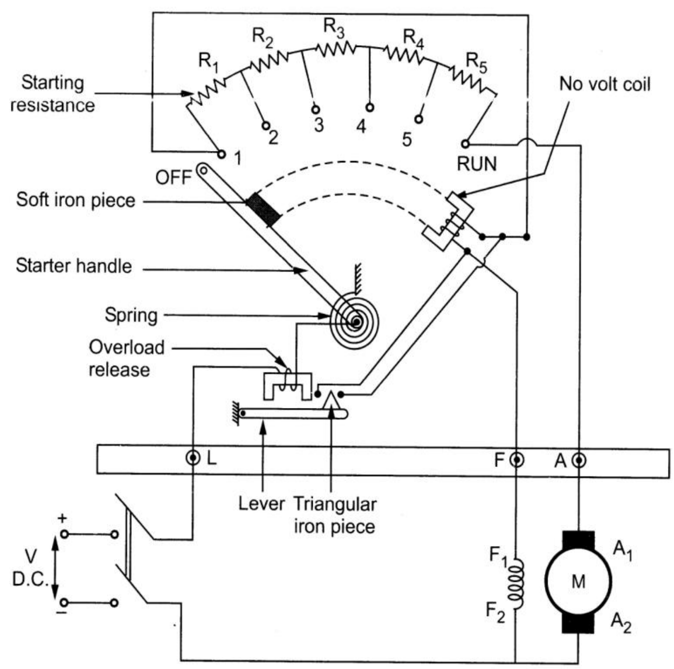
Basic Arrangement:



DC SHUNT MOTOR:

- Three Point Starter
- Four Point Starter

Three Point Starter:

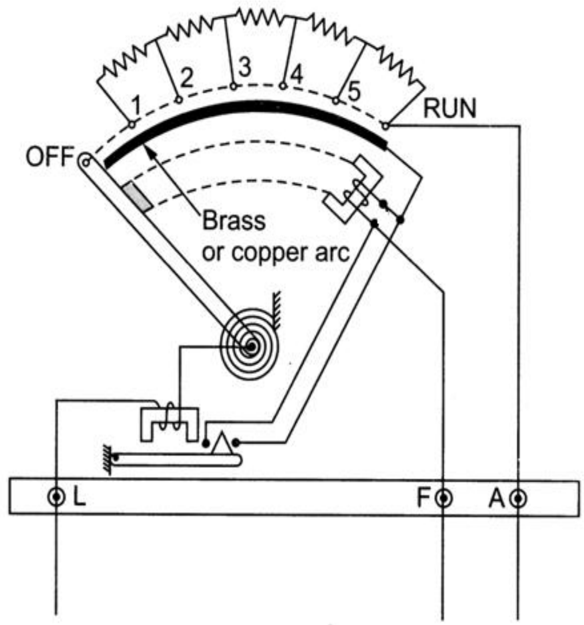


- The electric current will be dangerously high at starting (as armature resistance R_a is small) and hence its important that we make use of a device like the **3 point starter** to limit the starting electric current to an allowable lower value
- Construction wise a starter is a variable resistance, integrated into number of sections as shown in the figure beside
- The contact points of these sections are called studs and are shown separately as **OFF, 1, 2,3,4,5, RUN**
- There are 3 main points
  'L' Line terminal (Connected to positive of supply)
  'A' Armature terminal (Connected to the armature winding)
  'F' Field terminal (Connected to the field winding)
- The point 'L' is connected to an electromagnet called overload release (OLR)
- The other end of 'OLR' is connected to the lower end of conducting lever of starter handle where a spring is also attached with it and the starter handle contains also a soft iron piece housed on it
- This handle is free to move to the other side RUN against the force of the spring
- This spring brings back the handle to its original OFF position under the influence of its own force
- Another parallel path is derived from the stud '1', given to the another electromagnet called No Volt Coil (NVC)
- Which is further connected to terminal 'F'. The starting resistance at starting is entirely in series with the armature
- The OLR and NVC acts as the two protecting devices of the starter

Working of the 3 point starter:

- The supply to the DC motor is switched ON
- Then handle is slowly moved against the spring force to make a contact with stud No. 1
- At this point, field winding of the shunt or the compound motor gets supply through the parallel path provided to starting resistance, through No Voltage Coil
- While entire starting resistance comes in series with the armature, the high starting armature electric current thus gets limited as the electric current equation at this stage becomes $I_a = E/(R_a+R_{st})$
- As the handle is moved further, it goes on making contact with studs 2, 3, 4 etc., thus gradually cutting off the series resistance from the armature circuit as the motor gathers speed
- Finally when the starter handle is in 'RUN' position, the entire starting resistance is eliminated and the motor runs with normal speed
- when field electric current flows, the NVC is magnetized
- Now when the handle is in the 'RUN' position, soft iron piece connected to the handle and gets attracted by the magnetic force produced by NVC, because of flow of electric current through it
- The NVC is designed in such a way that it holds the handle in 'RUN' position against the force of the spring as long as supply is given to the motor
- Thus NVC holds the handle in the 'RUN' position and hence also called **hold on coil**
- when there is any kind of supply failure, the electric current flow through NVC is affected and it immediately loses its magnetic property and is unable to keep the soft iron piece on the handle, attracted
- At this point under the action of the spring force, the handle comes back to OFF position, opening the circuit and thus switching off the motor
- Thus it also acts as a protective device safeguarding the motor from any kind of abnormality

3 Point Starter with brass Arc



FOUR POINT STARTER:

- The 4 point starter has a lot of constructional and functional similarity to a three point starter, but this special device has an additional point
- A 4 point starter as the name suggests has 4 main operational points, namely

1. 'L' Line terminal. (Connected to positive of supply)

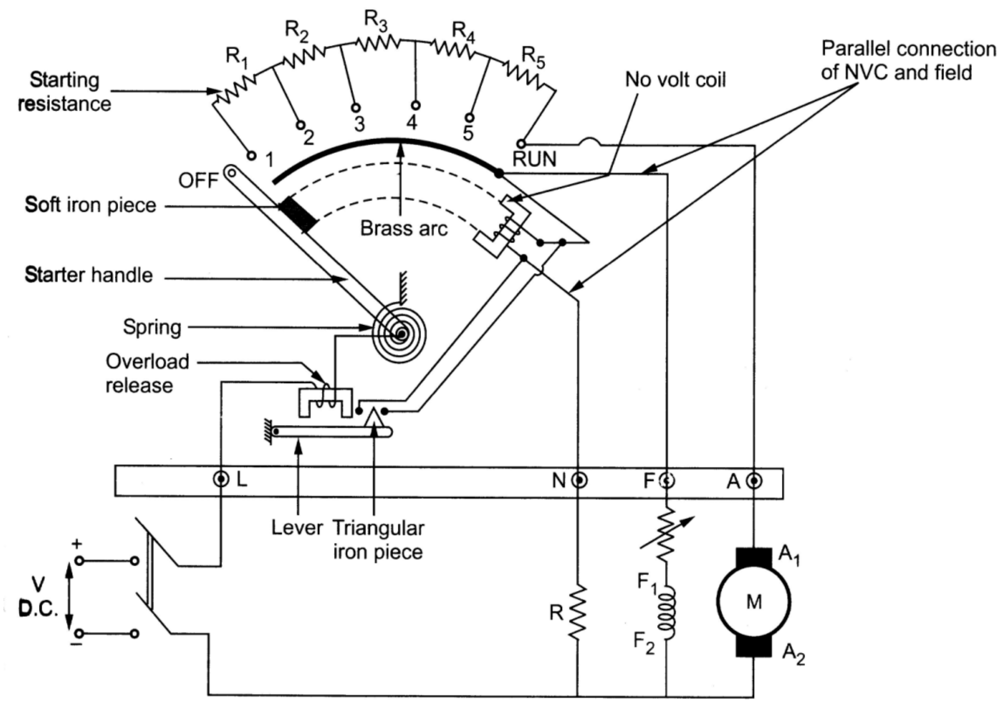
2. 'A' Armature terminal. (Connected to the armature winding)

3. 'F' Field terminal. (Connected to the field winding)

Like in the case of the 3 point starter, and in addition to it there is,

4. A 4th point N. (Connected to the No Voltage Coil)

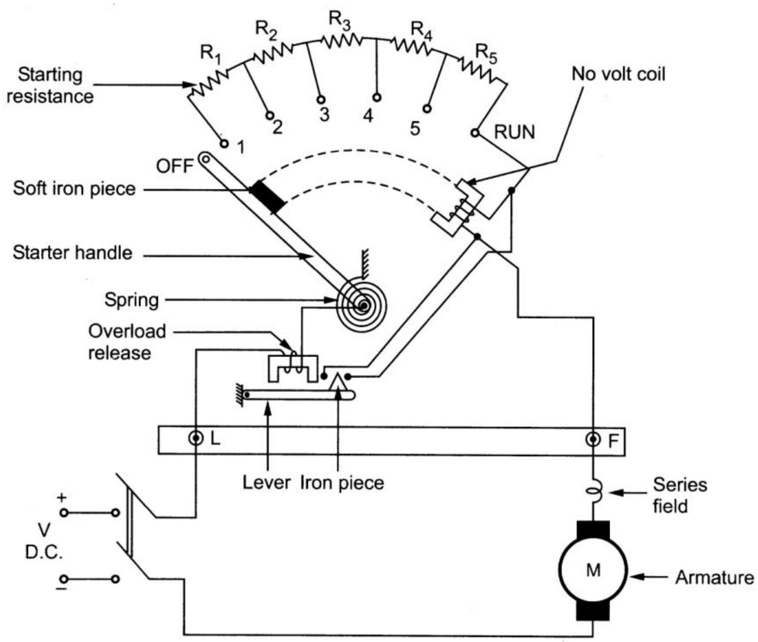
- The remarkable difference in case of a 4 point starter is that the No Voltage Coil is connected independently across the supply through the fourth terminal called 'N'
- The change in the field supply does affect the performance of the NVC
- Apart from this above mentioned fact, the 4 point and 3 point starters are similar in all other ways



<u>**DC Series Motor**</u>

TWO POINT STARTER:

- This starter is only for D.C. series motor only. The basic construction of two point starter is similar to that of three point starter except the fact that it has only two terminals namely line (L) and field (F)
- The F terminal is one end of the series combination of field and the armature winding. The action of the starter is similar to that of three phase starter.
- The main problem in case of D.C. series motor is it’s over speeding action when the load is less
- This can be prevented using two point starters. The no-volt coil is connecting in series with the motor so both current are equal.
- At no load situation load current drawn by the motor decreases causes no-volt coil losses its required magnetism and releases the handle to OFF position.

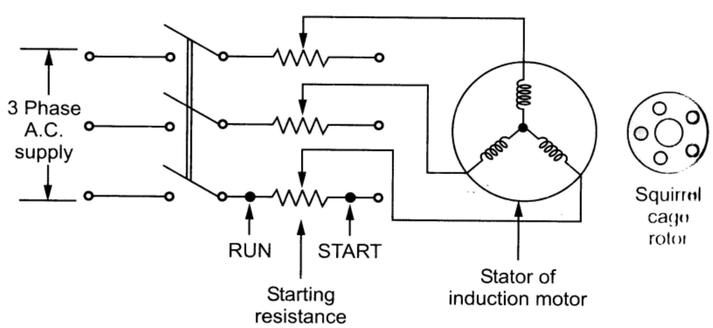


INDUCTION MOTOR STARTERS

- Stator Resistance Starter
- Autotransformer Starter
- Star – Delta Starter
- Rotor Resistance Starter
- Direct On Line Starter

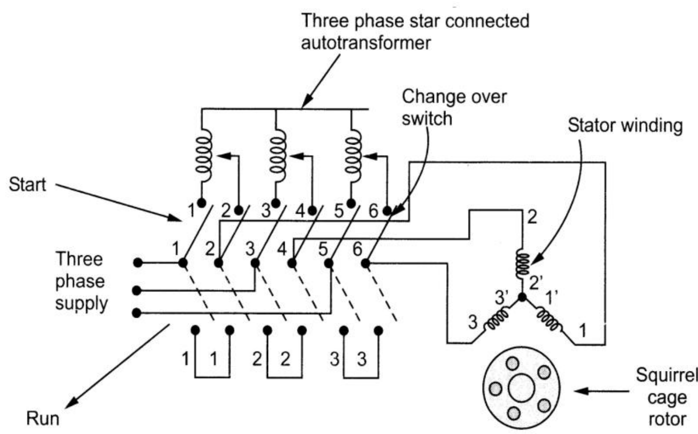
Stator Resistance Starter:

- ➢ The variable resistor connected in series with stator winding reduces the starting current
- ➢ The resistance value is varied from high to low by using sliding contacts of variable resistor
- ➢ Very simple speed control method
- ➢ Low maintenance
- ➢ Low cost



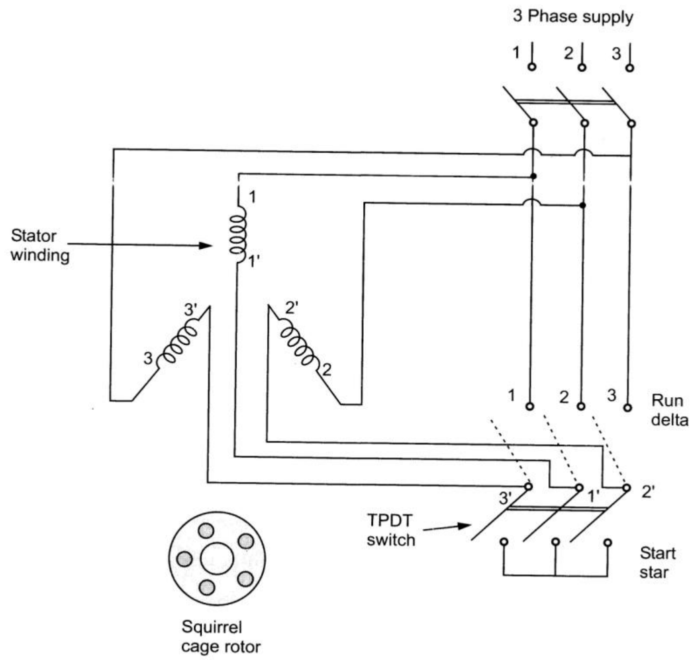
Autotransformer Starter:

- The operation principle of auto transformer method is similar to the star delta starter method
- The starting current is limited by (using a three phase auto transformer) reduce the initial stator applied voltage
- The auto transformer starter is more expensive, more complicated in operation and bulkier in construction when compared with the star – delta starter method
- The starting current and torque can be adjusted to a desired value by taking the correct tapping from the auto transformer



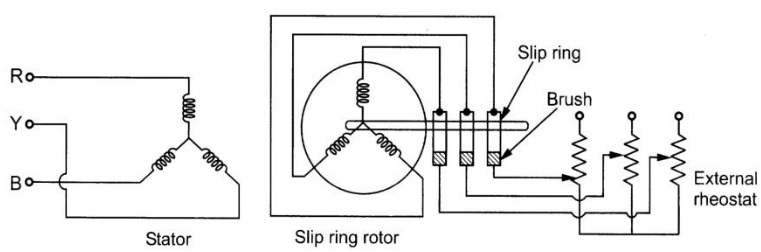
Star – Delta Starter:

- The star delta starting is a very common type of starter and extensively used, compared to the other types of the starters
- This method uses reduced supply voltage in starting
- Figure shows the connection of a 3phase induction motor with a star –delta starter
- The method achieved low starting current by first connecting the stator winding in star configuration
- After the motor reaches a certain speed, throw switch changes the winding arrangements from star to delta configuration
- At the time of starting when the stator windings are start connected, each stator phase gets voltage $\frac{V_L}{\sqrt{3}}$ where V_L is the line voltage
- As the voltage is reduced, the starting current also reduced
- Since the torque developed by an induction motor is proportional to the square of the applied voltage, star-delta starting reduced the starting torque to one – third that obtainable by direct delta starting



Rotor Resistance Starter:

- This method allows external resistance to be connected to the rotor through slip rings and brushes
- Initially, the rotor resistance is set to maximum and is then gradually decreased as the motor speed increases, until it becomes zero
- The rotor resistance starting mechanism is usually very bulky and expensive when compared with other methods
- It also has very high maintenance costs
- Also, a considerable amount of heat is generated through the resistors when current runs through them
- The starting frequency is also limited in this method
- However, the rotor resistance method allows the motor to be started while on load



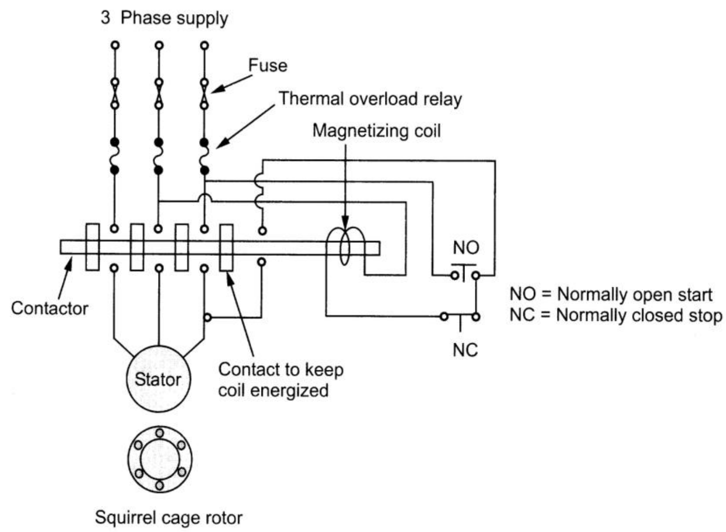
Direct On Line Starter:

- The Direct On-Line (DOL) starter is the simplest and the most inexpensive of all starting methods and is usually used for squirrel cage induction motors
- It directly connects the contacts of the motor to the full supply voltage
- The starting current is very large, normally 6 to 8 times the rated current

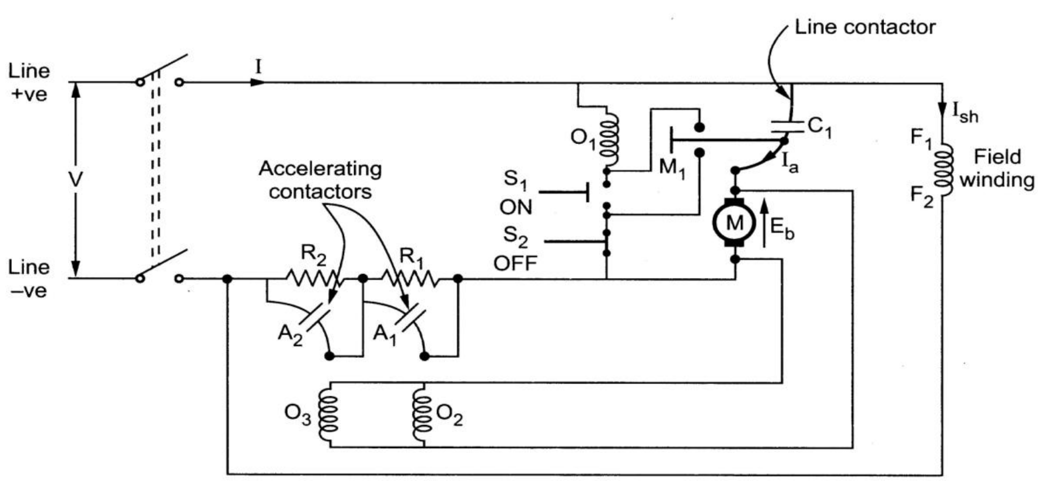
- The starting torque is likely to be 0.75 to 2 times the full load torque
- In order to avoid excessive voltage drops in the supply line due to high starting currents, the DOL starter is used only for motors with a rating of less than 5KW
- There are safety mechanisms inside the DOL starter which provides protection to the motor as well as the operator of the motor

Operation:

- The DOL starter consists of a coil operated contactors controlled by start and stop push buttons
- On pressing the start push button NO, the contactor coil is energized from line
- The three mains contacts and an auxiliary contact are closed
- The motor is thus connected to the supply
- When the stop push button NC is pressed, the supply through the contactor is Disconnected
- Since the coil is de-energized, the main contacts are opened. The supply to motor is disconnected and the motor stops



AUTOMATIC STARTER



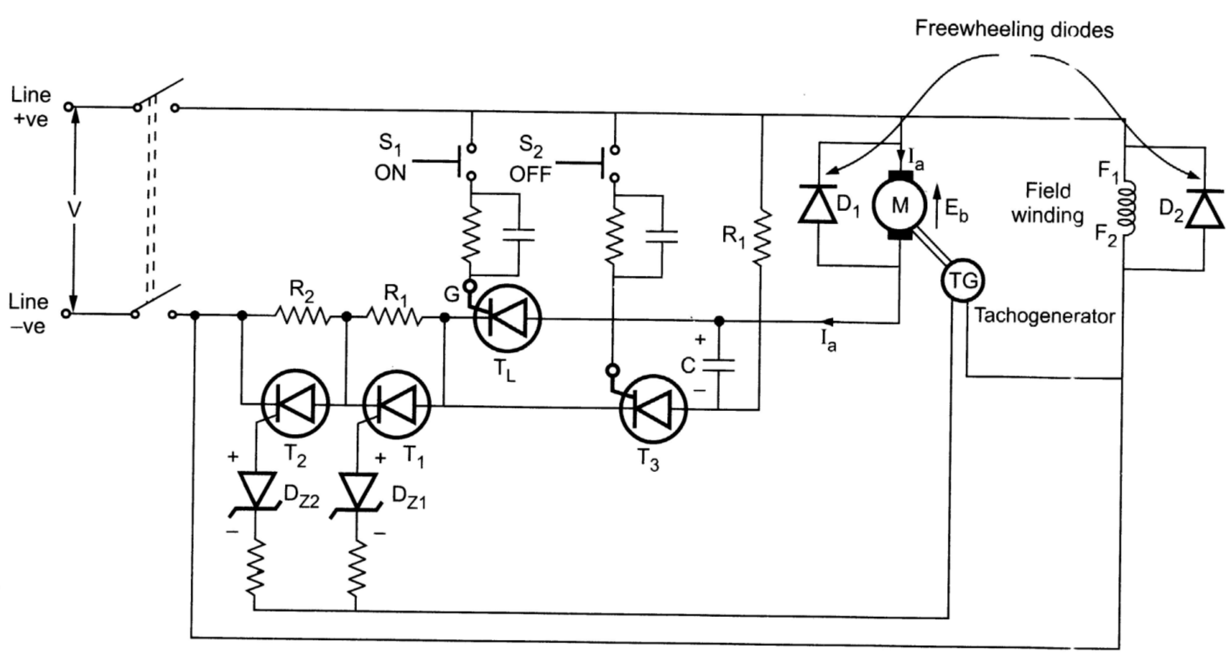
PARTS:

1. Magnetising coil O_1, O_2, O_3
2. Contacts M_1, C_1, A_1, A_2
3. ON switch, OFF switch
4. Resistors
5. DPST switch

WORKING:

- DPST switch is ON
- Press ON switch
- As soon as ON switch is pressed, Coil O_1 gets energised and Contacts M_1, $C_1$are closed
- When Contacts M_1, $C_1$are closed, the armature current flows through R_1 and R_2 and hence the starting current is reduced
- When the motor reaches above 60% speed, the coil O_2 gets energised and hence the contact A_1 is closed
- When the contact A_1 is closed, resistor R_1 is disconnected from armature circuit
- When the motor reaches above 80% speed, the coil O_2 and O_3 gets energised and hence the contact A_1 and A_2 are closed
- When the contacts A_1 and A_2 are closed, resistors R_1 and R_2 are disconnected from the armature circuit
- Finally, the motor rotates at normal speed
- To stop the motor, the OFF button should be pressed
- As soon as the OFF button is pressed, the coil gets reenergized and motor is stopped.

<u>ELECTRONIC STARTER – SHUNT MOTOR</u>



PARTS:

- Thyristor
- Freewheeling diodes

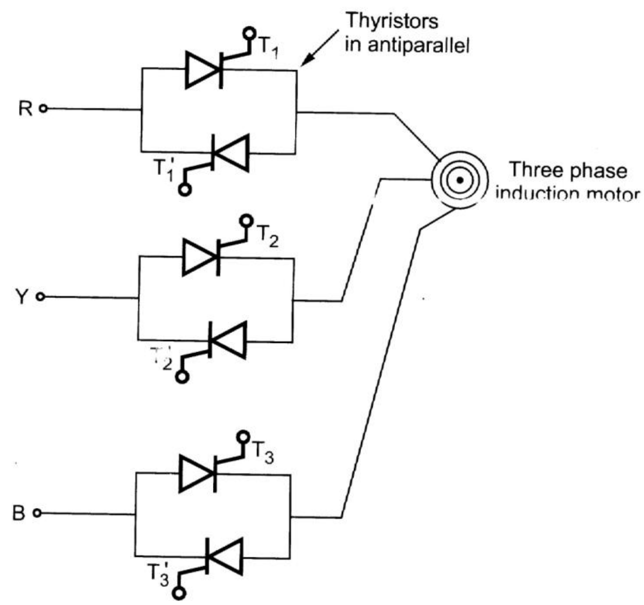
- Tachogenerator
- Zener diode
- Capacitor
- Resistors R_1 and R_2
- Switch S_1 and S_2

WORKING:

- The thyristor is an electronic switch
- It acts as a closed switch, when it conducts
- Resistors R_1 and R_2 are used to reduce starting current
- As soon as the ON button S_1 is pressed, thyristor T_L acts as closed switch, the supply is given to the armature of the motor
- Motor starts to rotate with low starting current because resistors R_1 and R_2 are connected in series with armature winding
- At the same time the capacitor C starts charging with the voltage polarities as shown in figure.
- To cut-off resistors R_1 and R_2, the tachogenerator is used
- When the motor reaches the speed above 60%, the zenerdiode D_{z1} starts conduction and hence the thyristor T_1 acts as a closed switch
- Resistor R_1 is disconnected from the armature circuit
- When the motor reaches the speed above 80%, the zenerdiode D_{z2} starts conduction and hence the thyristor T1andT2 act as a closed switch
- Resistors R_1 and R_2 are disconnected from the armature circuit and the motor runs with normal current
- To stop the motor, the OFF button S_2 should be pressed
- As soon as the OFF button S_2 is pressed, the thyristor T_L stops conduction because the capacitor starts discharging through the thyristor T_L by the aid of thyristor T_3

ELECTRONIC STARTER – IM (Soft Starter)

- The thyristor voltage control method is used in the soft starter
- Resistors are not used in soft starter to reduce the starting current
- The thyristors T_1, T_1', T_2, T_2' and T_3, T_3' are used in the soft starter
- Two thyristors are connected in antiparallel in each line
- Now the antiparallel connection acts as triac
- To control the voltage, the firing angle of triac is controlled
- The voltage and the current are directly proportional
- When the voltage reduces, the current reduces and vice versa
- The starting current is controlled by controlling the starting voltage



UNIT IV
SPEED CONTROL OF DC DRIVES

SPEED CONTROL OF DC MOTORS

- **Speed Control of Shunt Motor**

  ***** Flux Control
  * Armature Voltage Control (Rheostatic Control)
  * Applied Voltage Control

- **Speed Control of Series Motor**

  ***** Flux Control
  * Rheostatic Control
  * Applied Voltage Control

- **Ward- Leonard System of Speed Control**

1. **Speed Control of Dc Shunt Motor:**

Flux Control

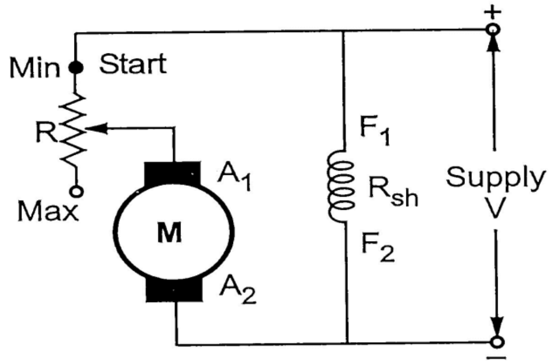
$$N \infty \frac{E_b}{\varphi}$$

$$N \infty \frac{V - I_a R_a}{\varphi}$$

- ➢ speed of the motor is inversely proportional to flux
- ➢ The speed can be controlled by varying flux
- ➢ To vary the flux, a rheostat is added in series with the field winding
- ➢ Adding more resistance in series with field winding will increase the speed, as it will decrease the flux

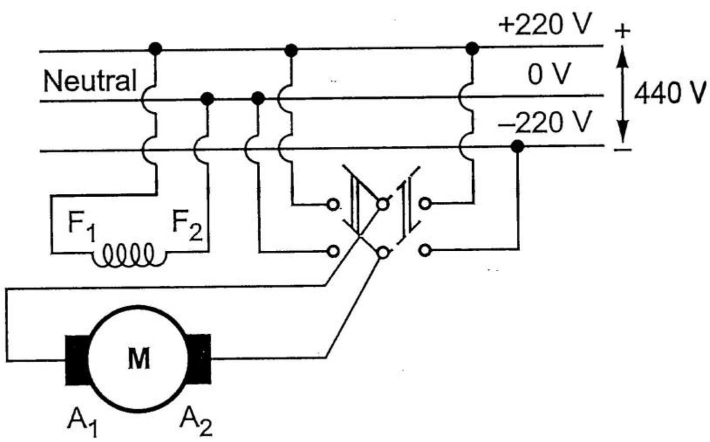
- Field current is relatively small and hence I^2R loss is small
- This method is quiet efficient
- The speed can be reduced by using this method.

Armature Voltage Control



- Speed of the motor is directly proportional to the armature voltage
- When armature voltage varies, the armature current varies
- Speed is directly proportional to armature current I_a
- If we add resistance in series with armature, I_a decreases and hence speed decreases.
- The speed can be reduced by using this method.

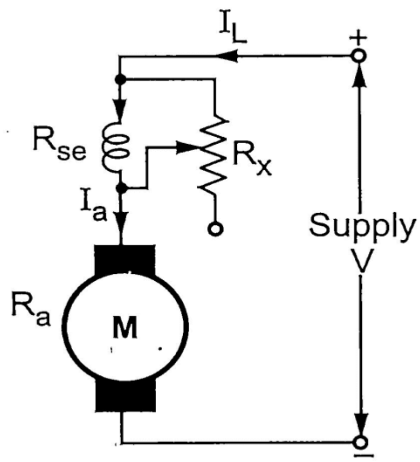
Applied Voltage Control:



- The speed is approximately proportional to the voltage across the armature.
- Voltage across armature is changed with the help of a suitable switchgear
- Armature is supplied with different voltages to get varies speed
- The shunt filed is connected to a fixed exciting voltage

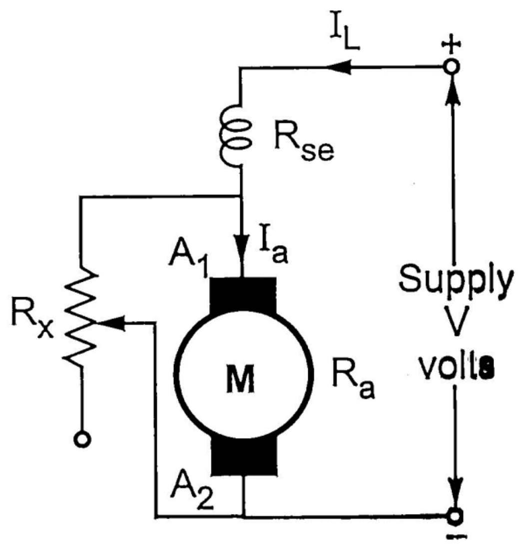
2. <u>**Speed Control of Series Motor:**</u>

Field Diverter Method:



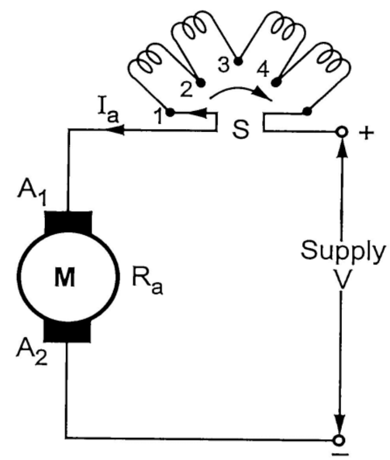
- A veritable resistance is connected parallel to the series field
- This variable resistor is called as diverter
- The desired amount of current can be diverted through this resistor and hence current through field coil can be decreased
- The flux can be decreased to desired amount and speed can be increased

Armature Diverter Method:



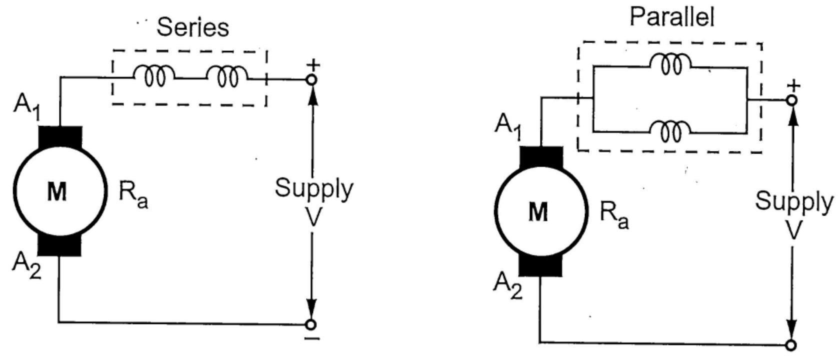
- The diverter is connected across the armature
- The desired amount of armature current can be diverted through this resistor and hence current through field coil and armature can be varied
- The flux is varied and speed can be increased

Tapped Field Method:



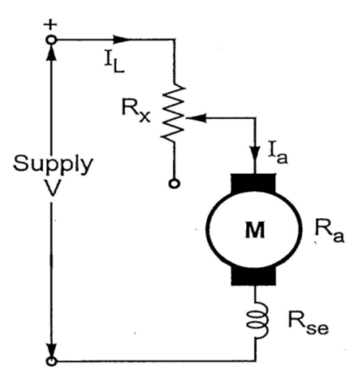
- The field coil is tapped
- The number of turns can be changed and hence the flux can be changed
- We can select different value of Ø by selecting different number of turns.
- The speed inversely proportional to flux Ø

Series – Parallel Connection of Field:



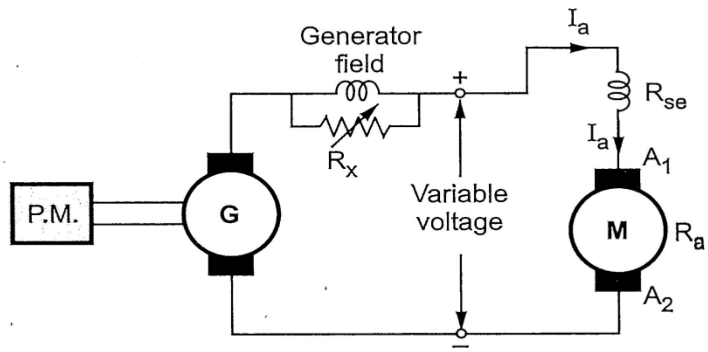
- This system is widely used in electric traction
- In this method, several speeds can be obtained by regrouping coils in parallel and series
- When the coils are in series, the same current passing through them and flux increases
- When the coils are in parallel, the current gets divided and flux reduces

3. Rheostatic Control



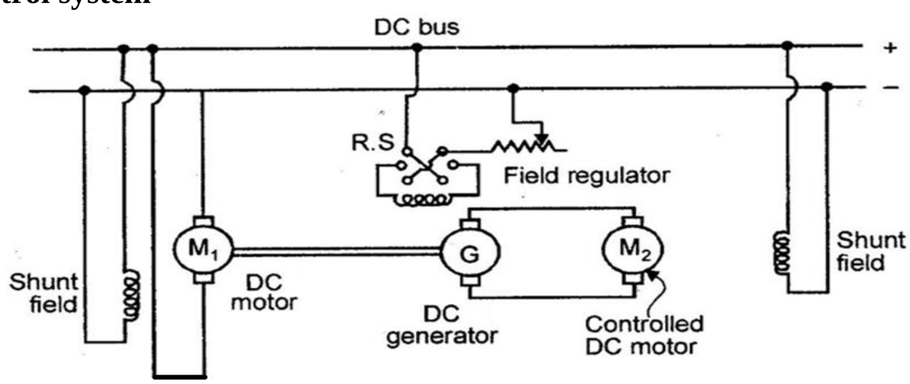
- By introducing resistance in series with armature, voltage across the armature can be reduced. And hence, speed reduces in proportion with it.

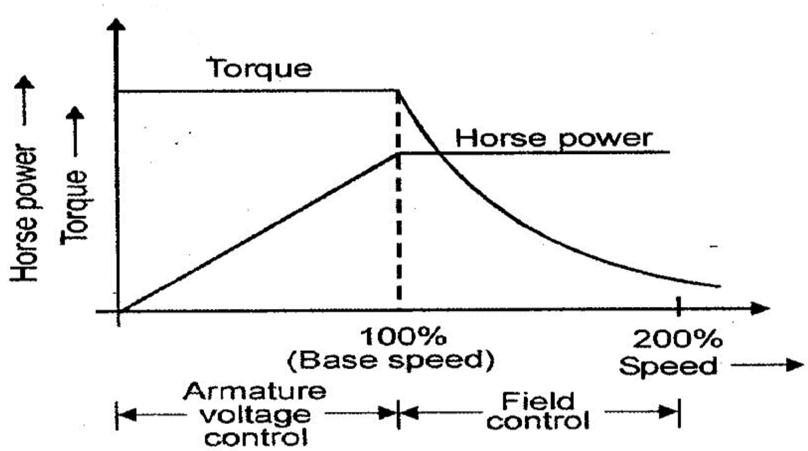
4. Applied Voltage Control



- The speed is approximately proportional to the voltage across the armature and field winding
- Voltage across the armature and field is changed with the help of a Dc motor generator set
- Armature and field is supplied with different voltages to get varies speed

Ward-Leonard control system



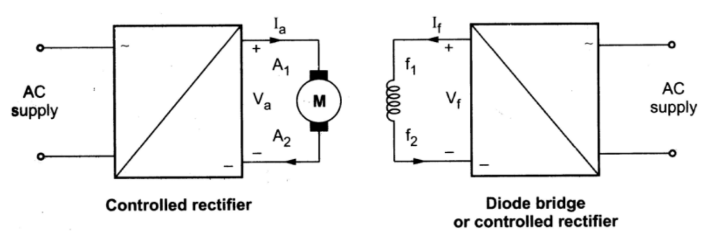


- This system is used where very sensitive speed control of motor is required (e.g electric excavators, elevators etc.)
- M_2 is the motor whose speed control is required

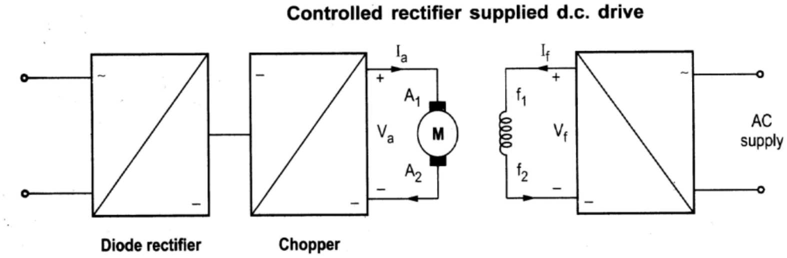
- M_1 may be any AC motor or DC motor with constant speed
- M_1 acts as prime mover to DC generator
- G is the generator directly coupled to M_1
- The output from the generator G is fed to the armature of the motor M_2 whose speed is to be controlled
- The output voltage of the generator G can be varied from zero to its maximum value, and hence the armature voltage of the motor M_2 is varied very smoothly
- Very smooth speed control of motor can be obtained by this method.

SPEED CONTROL DC MOTOR – USING CONVERTERS

- Direct current (dc) motors have variable characteristics and are used extensively in variable-speed drives.
- DC motors can provide a high starting torque and it is also possible to obtain speed control over a wide range.
- The methods of speed control are normally simpler and less expensive than those of AC drives.
- DC motors play a significant role in modern industrial drives.
- Both series and separately excited DC motors are normally used in variable-speed drives, but series motors are traditionally employed for traction applications.
- Due to commutator, DC motors are not suitable for very high speed applications and require more maintenance than do AC motors.
- With the recent advancements in power conversions, control techniques, and microcomputers, the ac motor drives are becoming increasingly competitive with DC motor drives.
- Although the future trend is toward AC drives, DC drives are currently used in many industries. It might be a few decades before the DC drives are completely replaced by AC drives.



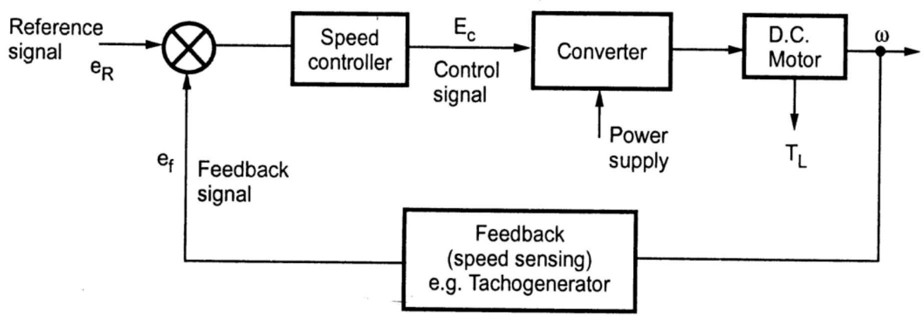
Controlled rectifier supplied d.c. drive



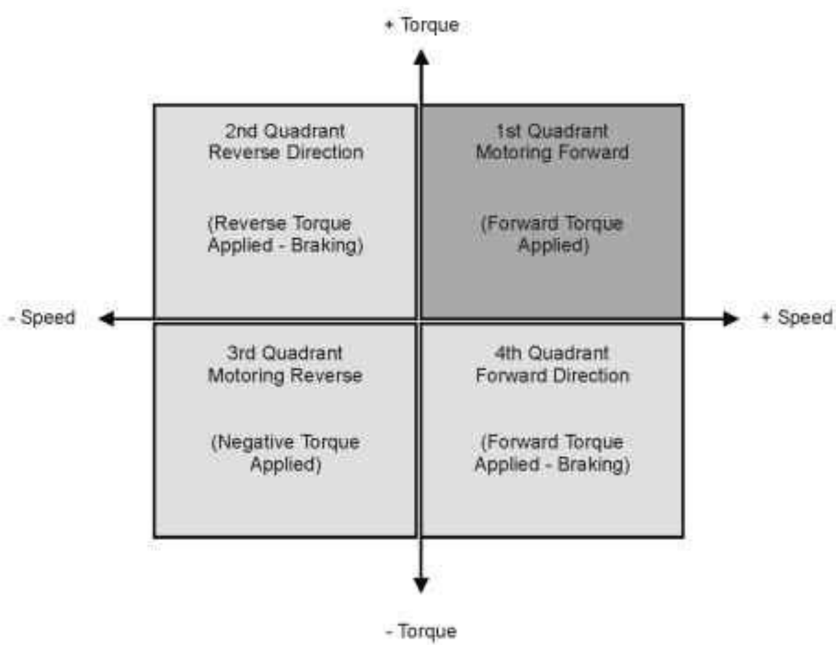
Chopper fed d.c. drive

CLOSED LOOP CONTROL OF DC DRIVES:

- The speed of dc motors changes with the load torque.
- To maintain a constant speed, the armature (and or field) voltage should be varied continuously by varying the delay angle of ac-dc converters or duty cycle of dc-dc converters.
- In practical drive systems it is required to operate the drive at a constant torque or constant power; in addition, controlled acceleration and deceleration are required.
- Most industrial drives operate as closed-loop feedback systems.
- A closed-loop control system has the advantages of improved accuracy, fast dynamic response, and reduced effects of load disturbances and system nonlinearities.
- The block diagram of a closed-loop converter-fed separately excited dc drive is shown in Figure
- If the speed of the motor decreases due to the application of additional load torque, the speed error V_e increases.
- The speed controller responses with an increased control signal V_c, change the delay angle or duty cycle of the converter, and increase the armature voltage of the motor.
- An increased armature voltage develops more torque to restore the motor speed to the original value.
- The drive normally passes through a transient period until the developed torque is equal to the load torque.



FOUR QUADRANT OPERATIONS



DRIVES CLASSIFICATION:

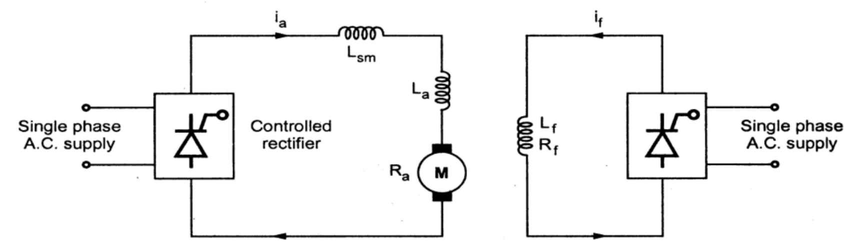
- Single phase drives
- Three phase drives
- Chopper drives

Single phase drives:

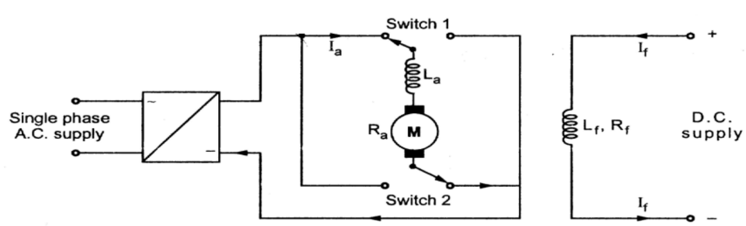
- The motor speed can be varied by
  - controlling the armature voltage V_a, known as voltage control;
  - controlling the field current I_f, known as field control; or
  - torque demand, which corresponds to an armature current I_a, for a fixed field current I_f.

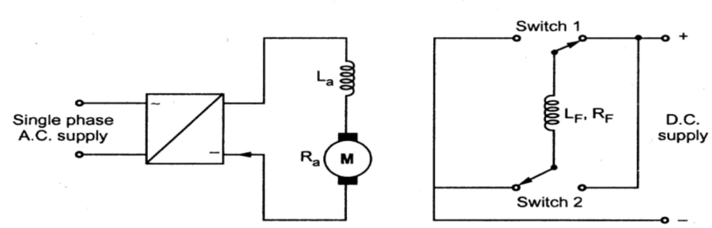
The speed, which corresponds to the rated armature voltage, rated field current and rated armature current, is known as the rated (or base) speed

- In practice, for a speed less than the base speed, the armature current and field currents are maintained constant to meet the torque demand, and the armature voltage V_a is varied to control the speed.
- For speed higher than the base speed, the armature voltage is maintained at the rated value and the field current is varied to control the speed.
- However, the power developed by the motor (= torque X speed) remains constant.
- Figure below shows the characteristics of torque, power, armature current, and field current against the speed.



Single phase drives with contactor:





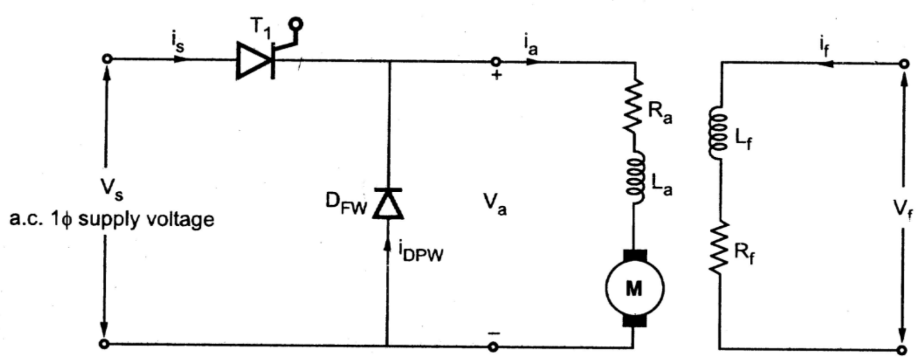
TYPES of Single Phase Drives:

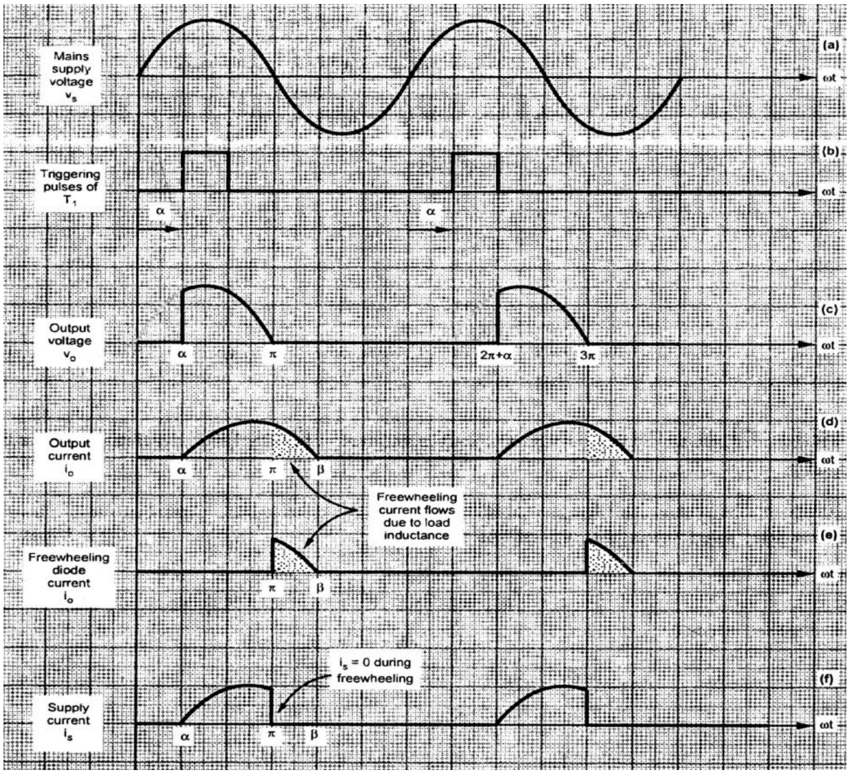
- Single phase half wave converter drive
- Single phase semi converter drive
- Single phase full converter drive
- Single phase dual converter drive

Single Phase Half Wave Converter Drive:

- A single-phase half-wave converter feeds a dc motor, as shown below.
- The armature current is normally discontinuous unless a very large inductor is connected in the armature circuit.
- A freewheeling diode is always required for a dc motor load and it is a one-quadrant drive.
- The applications of this drive are limited to the 0.5 kW power level.
- Figure shows the waveforms for a highly inductive load.
- A half-wave converter in the field circuit would increase the magnetic losses of the motor due to high ripple content on the field excitation current.
- The voltage across the armature $V_a = \frac{V_m}{2\Pi}(1+\cos\alpha)$ for $0 \le \alpha \le \Pi$

  V_a – Armature voltage
  V_m – Maximum voltage
  α - Firing angle

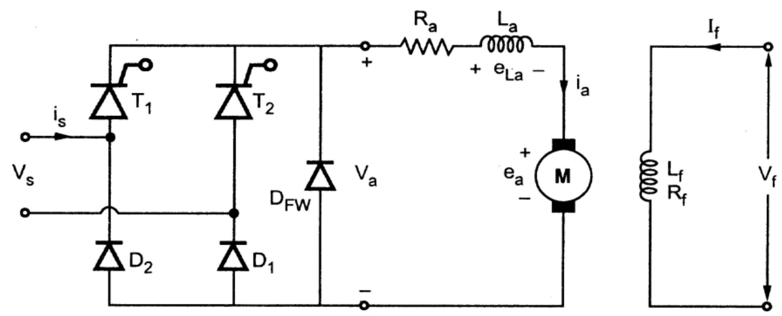


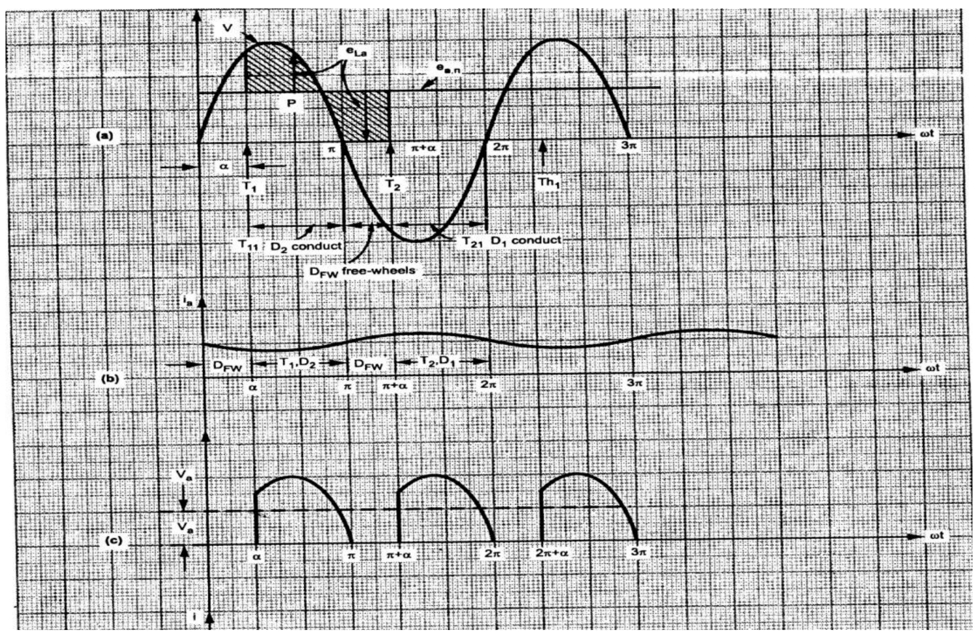


Single Phase Semi Converter Drive:

- It is one quadrant converter which gives current and voltage of one polarity
- Regenerative braking is not possible
- When T_1 and D_1 conducts, the positive cycle of input is transferred to armature of the motor
- When T_2 and D_2 conducts, the negative cycle of input is transferred to armature of the motor but the direction is the same
- Freewheeling diode is used to get continuous current flow through the armature winding.
- When thyristors off, the stored energy in the coil is discharging through diode.
- The voltage across the armature $V_a = \frac{V_m}{\Pi}(1+\cos\alpha)$ for $0 \le \alpha \le \Pi$

  V_a – Armature voltage
  V_m – Maximum voltage
  α - Firing angle

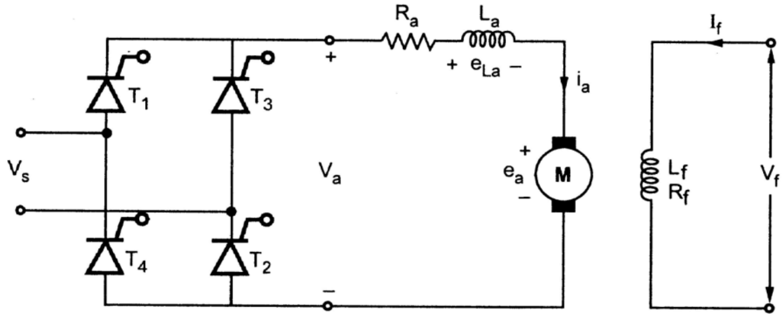


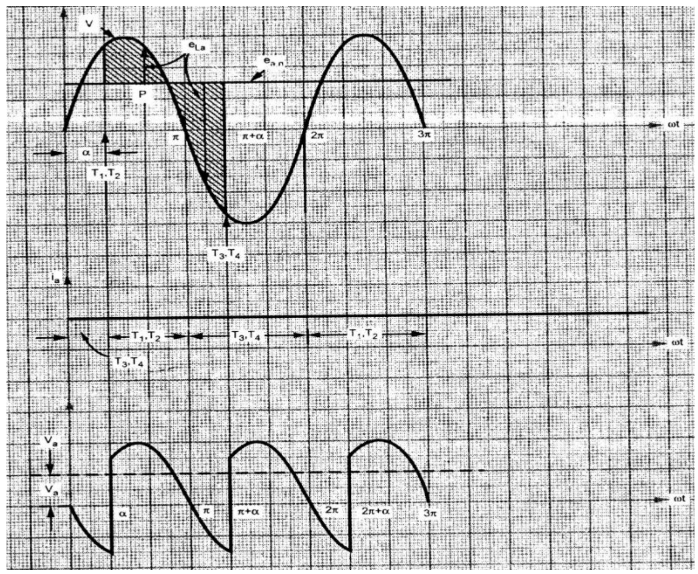


Single Phase Full Converter Drive:

- The armature voltage is varied by a single-phase full-wave converter, as shown in Figure
- It is a two-quadrant drive, as shown in Figure, and is limited to applications up to 15 kW.
- The armature converter gives + V_a or - V_a, and allows operation in the first and fourth quadrants.
- During regeneration for reversing the direction of power flow, the back emf of the motor can be reversed by reversing the field excitation.
- The converter in the field circuit could be a full, or even a dual converter.
- The reversal of the armature or field allows operation in the second and third quadrants.
- The current waveforms for a highly inductive load are shown in Figure for powering action.
- Freewheeling diode is not necessary
- The voltage across the armature $V_a = \frac{2V_m}{\Pi}\cos\alpha$ for $0 \le \alpha \le \Pi$

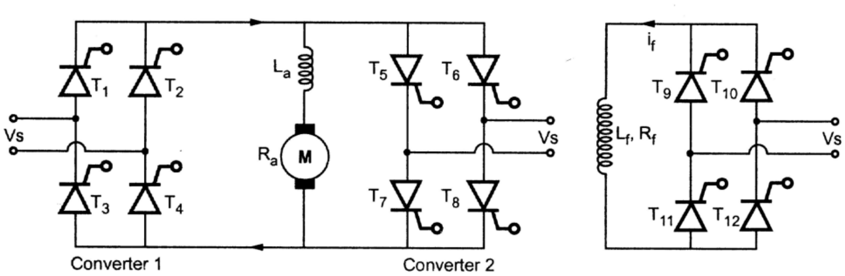
  V_a – Armature voltage
  V_m – Maximum voltage
  α - Firing angle





Single Phase Dual Converter Drive:

- Two single-phase full-wave converters are connected.
- Either converter 1 operates to supply a positive armature voltage, V_a, or converter 2 operates to supply a negative armature voltage, - V_a.
- Converter 1 provides operation in the first and fourth quadrants, and converter 2, in the second and third quadrants.
- It is a four-quadrant drive and permits four modes of operation: forward powering, forward braking (regeneration), reverse powering, and reverse braking (regeneration).
- It is limited to applications up to 15 kW. The field converter could be a full-wave or a dual converter.



THREE PHASE DRIVES

- The armature circuit is connected to the output of a three-phase controlled rectifier.
- Three-phase drives are used for high-power applications up to megawatt power levels.
- The ripple frequency of the armature voltage is higher than that of single-phase drives and it requires less inductance in the armature circuit to reduce the armature ripple current.
- The armature current is mostly continuous, and therefore the motor performance is better compared with that of single-phase drives.

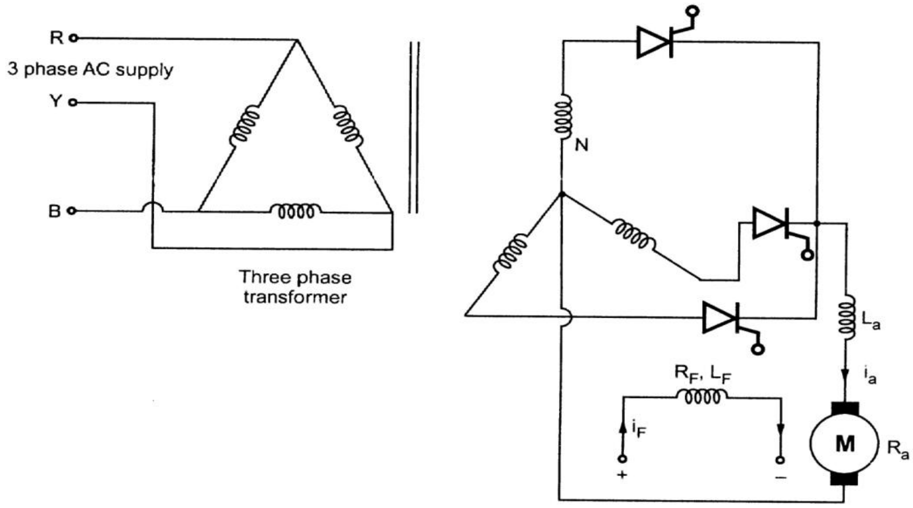
TYPES:

- Three phase Half converter drive
- Three Phase semi converter drive
- Three Phase full converter drive
- Three phase dual converter drive

Three Phase Half Converter Drive:

- Three **single phase half-wave converters** are connected together to form a **three phase half-wave converter**
- The thyristor T_1 in series with one of the supply phase windings *'a-n'* acts as one half wave controlled rectifier
- The second thyristor T_2 in series with the supply phase winding *'b-n'* acts as the second half wave controlled rectifier
- The third thyristor T_3 in series with the supply phase winding acts as the third half wave controlled rectifier
- The 3-phase input supply is applied through the star connected supply transformer as shown in the figure
- The common neutral point of the supply is connected to one end of the load while the other end of the load connected to the common cathode point.
- When the thyristor T_1 is triggered, the phase voltage V_{an} appears across the load when T_1 conducts
- The load current flows through the supply phase winding *'a-n'* and through thyristor T_1 as long as T_1 conducts
- When thyristor T_2 is triggered, T_1 becomes reverse biased and turns-off. The load current flows through the thyristor and through the supply phase winding *'b-n'* . When T_2 conducts the phase voltage v_{bn} appears across the load until the thyristor T_3 is triggered
- When the thyristor T_3 is triggered, T_2 is reversed biased and hence T_2 turns-off. The phase voltage V_{an} appears across the load when T_3 conducts
- The voltage across the armature $V_a = \frac{3\sqrt{3}V_m}{2\Pi}\cos\alpha$ for $0 \le \alpha \le \Pi$

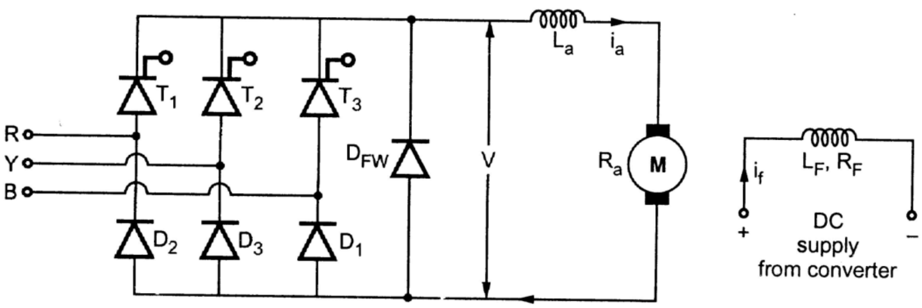
  V_a – Armature voltage
  V_m – Maximum voltage
  α - Firing angle

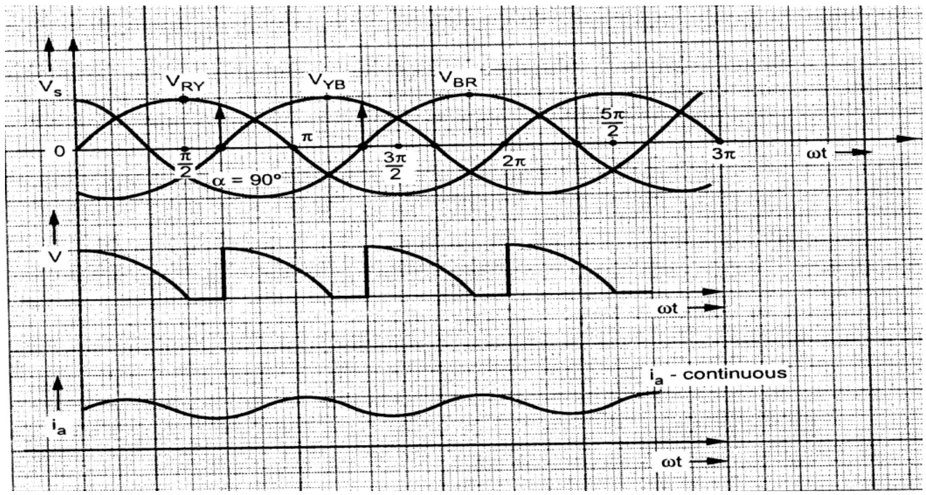


Three Phase Semi Converter Drive:

- 3-phase semi-converters are three phase half controlled bridge controlled rectifiers
- which employ three thyristors and three diodes connected in the form of a bridge configuration
- Three thyristors are controlled switches which are turned on at appropriate times by applying appropriate gating signals
- The three diodes conduct when they are forward biased by the corresponding phase supply voltages
- 3-phase semi-converters are used in industrial power applications up to about 120kW output power level
- The power factor of 3-phase semi-converter decreases as the trigger angle increases
- The power factor of a 3-phase semi-converter is better than three phase half wave converter
- The voltage across the armature $V_a = \frac{3\sqrt{3}V_m}{2\Pi}(1+\cos\alpha)$ for $0 \le \alpha \le \Pi$

V_a – Armature voltage
V_m – Maximum voltage
α - Firing angle

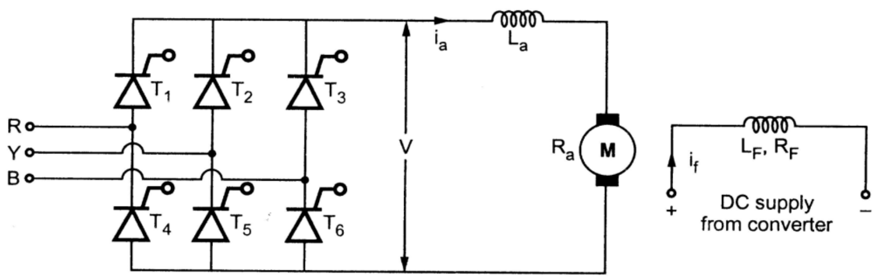


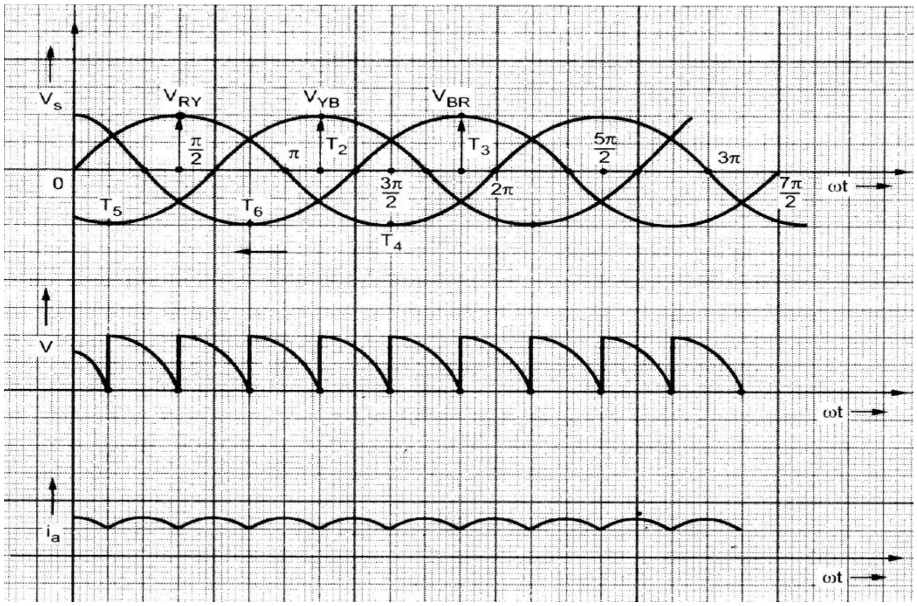


Three Phase Full Converter Drive:

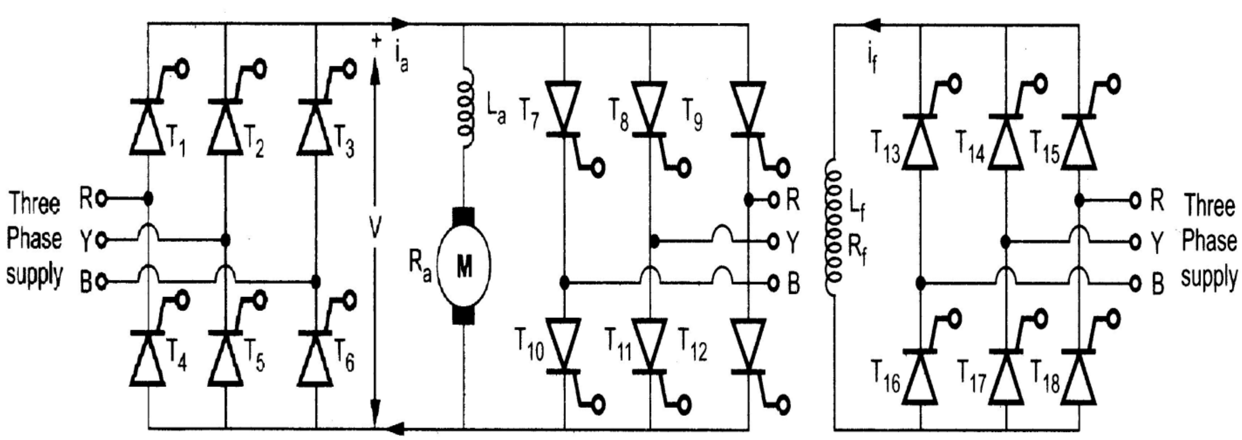
- A three-phase full-wave-converter drive is a two-quadrant drive without any field reversal, and is limited to applications up to 1500 kW.
- During regeneration for reversing the direction of power
- However, the back emf of the motor is reversed by reversing the field excitation.
- The converter in the field circuit should be a single- or three-phase full converter.
- Two three-phase full-wave converters are connected in an arrangement similar to Figure
- Either converter 1 operates to supply a positive armature voltage, V_a or converter 2 operates to supply a negative armature voltage, $-V_a$.
- It is a four-quadrant drive and is limited to applications up to 1500 kW.
- The field converter can be a full-wave converter.
- The voltage across the armature $V_a = \frac{3\sqrt{3}V_m}{\Pi}\cos\alpha$ for $0 \le \alpha \le \Pi$

  V_a – Armature voltage
  V_m – Maximum voltage
  α - Firing angle





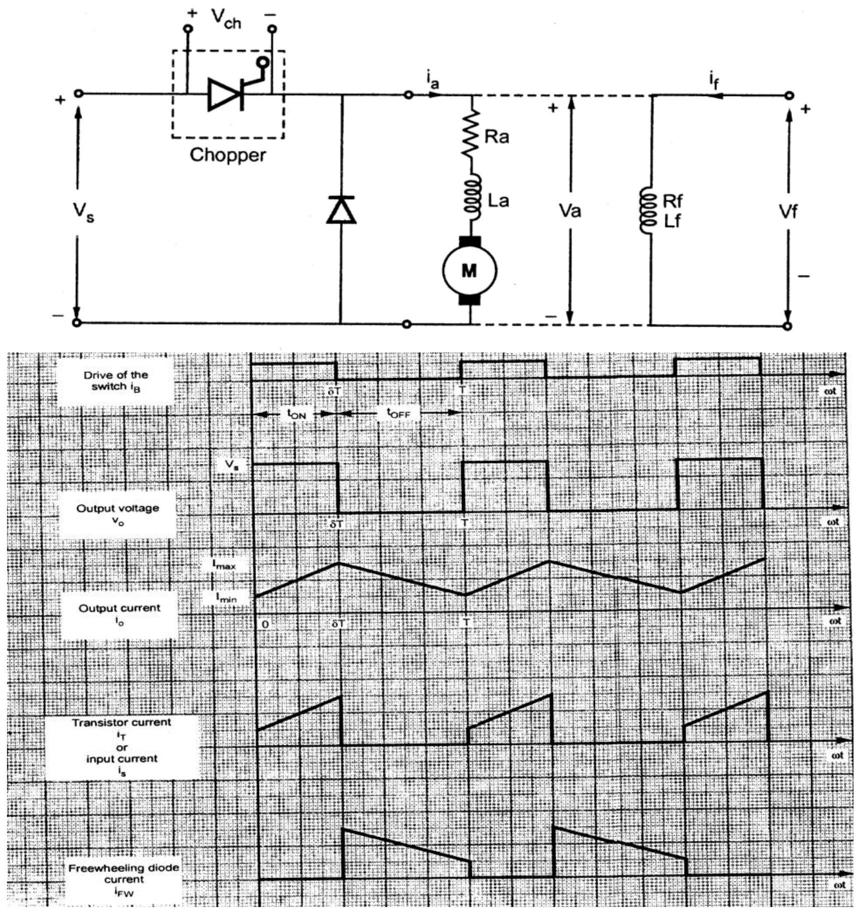
Three Phase Dual Converter Drive:



CHOPPER DC MOTOR CONTROL

- Chopper: The variable dc voltage is controlled by varying the on- and off-times of a converter
- Chopper: DC ⇒ DC (different voltage)
- Its frequency of operation is $f_c = \frac{1}{(t_{on} + t_{off})} = \frac{1}{T}$ and its duty cycle is defined as $d = \frac{t_{on}}{T}$
- Assuming that the switch is ideal, the average output is $V_{dc} = \frac{t_{on}}{T} V_s = dV_s$
- varying the duty cycle changes the output voltage
- The duty cycle d can be changed in two ways:
  (i) Varying the on-time (constant switching frequency).
  (ii) Varying the chopping frequency.

➢ Constant switching frequency has many advantages in practice



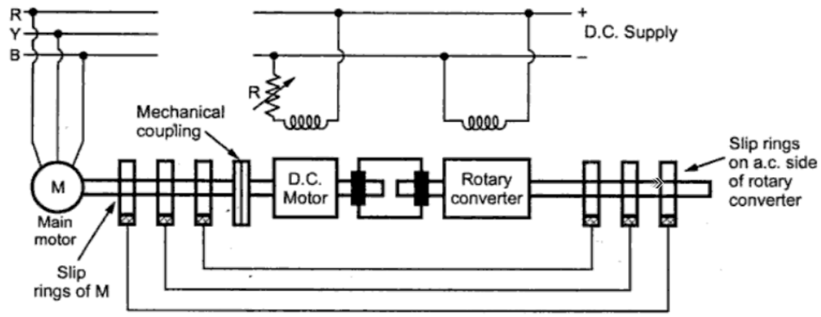
<u>UNIT V</u>

CONVENTIONAL AND SOLID STATE SPEED CONTROL OF A.C. DRIVES

Slip power recovery scheme:

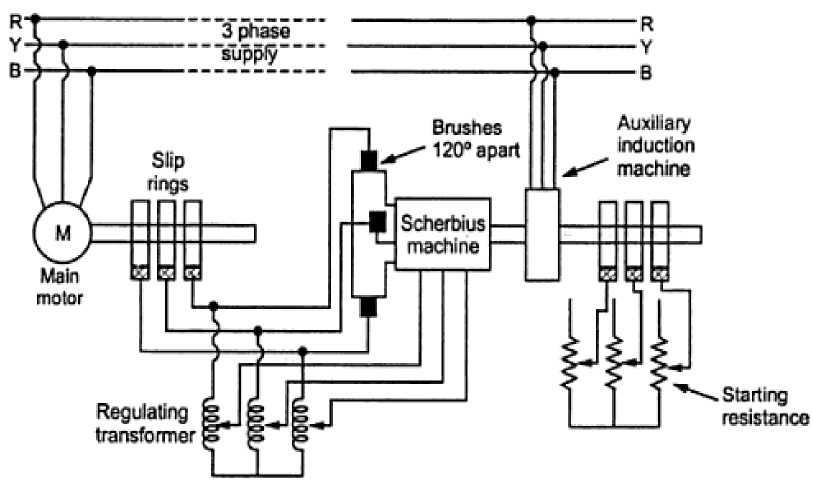
- The slip power recovery (SPR) drive is an external system connected to the rotor circuit in place of the external resistors.
- The SPR provides speed and torque control like the resistors but can also recover the power taken off the rotor and feed it back into the power system to avoid energy waste.
- The speed control of slip ring induction motor is achieved by Injecting E.M.F in Rotor Circuit
- The e.m.f injected in the rotor circuit must have the same frequency as the slip frequency
- When the injected voltage is in phase opposition with the induced rotor e.m.f, then the rotor resistance increases
- when the injected voltage is in phase with the induced rotor e.m.f, then the rotor resistance decreases
- By changing the direction of phase rotation, the resistance of the rotor circuit is varied and thus speed of the slip ring motor is controlled.

Conventional Kramer System:



- This system is basically used for the speed control of large motors of rating more than 4000Kw or above
- The main motor M has slip rings mounted on its shaft
- The induced e.m.f is supplied to the slip rings of a rotary converter by slip rings of main motor.
- The rotary converter converts the low-slip frequency a.c. power into d.c. power
- Which is used to drive a d.c. shunt motor
- The main motor "M" is directly coupled with the d.c. shunt motor .
- The d.c. output of the rotary converter is used to drive the d.c. shunt motor
- Both the rotary converter and the d.c. shunt motor are excited from a separate d.c exciter or d.c bus bar.
- The field regulator governs the back e.m.f Eb of the d.c. shunt motor
- The d.c. potential at the commutator of the rotary converter which controls the slip ring voltage and thus the speed of motor "M."

Conventional Scherbius System:

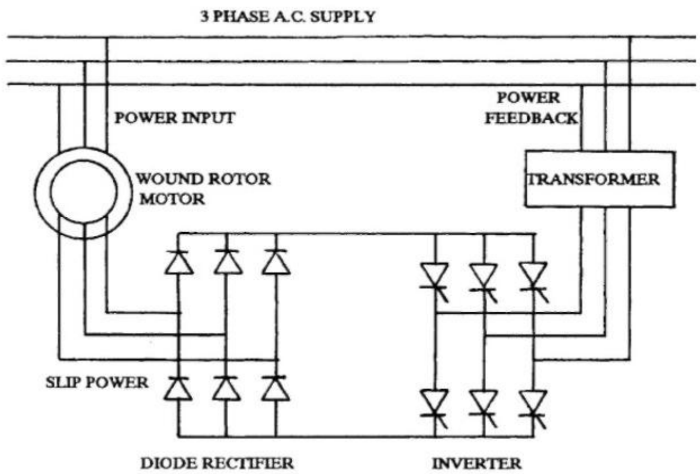


- In this system, the slip energy is not converted into d.c and then fed to a d.c. motor
- It is fed directly to a three phase or six phase a.c. commutator motor called as Scherbius machine.
- The low frequency output of the machine M is fed to the poly phase winding of the machine C through a regulating transformer RT.
- The commutator motor C is a variable speed machine and is controlled by the tapping on RT.

Advantages:

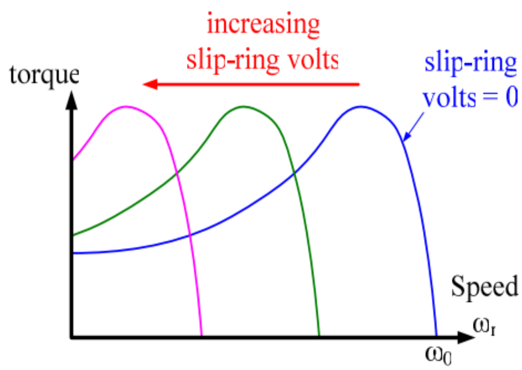
- Better efficiency than earlier methods
- Speed regulation is independent of load conditions
- It can be controlled manually by operator
- Disadvantages:
- Complex, Extra induction motor is needed
- Huge size, costly
- Require well-trained staff
- Can't adjust speed at no-load condition.

Static Kramer System:



- The resistors are replaced by a rectifier-inverter system
- It takes the energy that previously was dissipated in the resistors and feeds it back into the mains supply
- It uses a step-up transformer to increase the voltage level.
- The frequency of the rotor current fr = sfs
- Rotor frequency set by speed of rotation
- Diode rectifier accepts any frequency
- The rotor current is rectified in a diode bridge, and then converted to 3-phase, 50 Hz by a line commutated inverter
- The magnitude of the voltage at the slip-rings is set by the rectifier-inverter link, and controlled by the delay angle α of the line-commutated inverter.

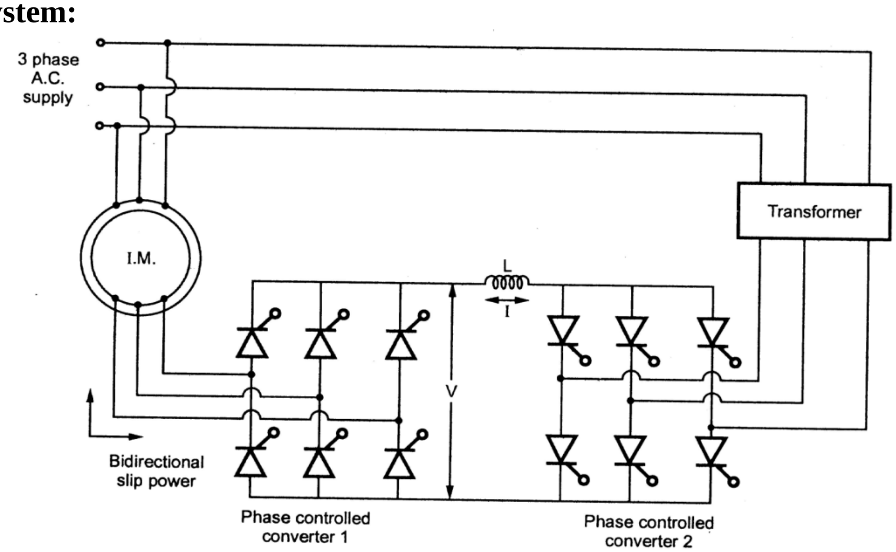
$$V_{dc} = \frac{3}{\pi}.\sqrt{2}.V_{rms}.\cos\alpha$$



Instead of wasting the slip power in the rotor circuit resistance, a better approach is to convert it to ac line power and return it back to the line. Two types of converter provide this approach:

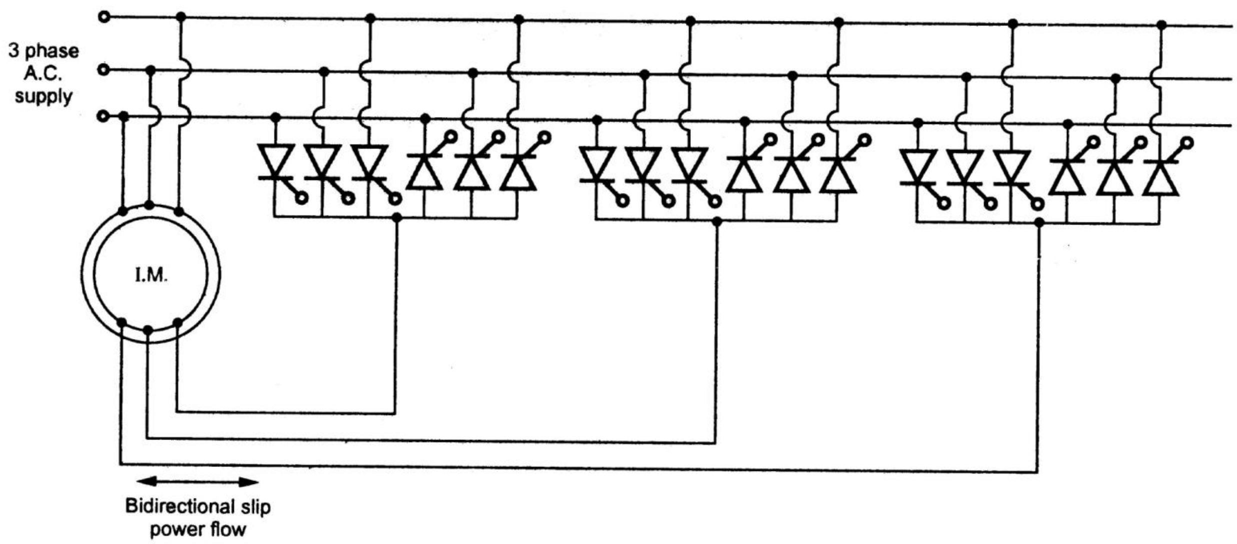
1) Static Kramer Drive - only allows operation at sub-synchronous speed.
2) Static Scherbius Drive – allows operation above and below synchronous speed.

Static Scherbius System:



- The static Scherbius drive overcomes the forward motoring only limitation of the static Kramer drive.
- Regenerative mode operation requires the slip power in the rotor to flow in the reverse direction.
- This can be achieved by replacing the diode bridge rectifier with a thyristor bridge.
- This is the basic topology change for the static Scherbius drive from the static Kramer drive.
- One of the limitations of the previous topology is that line commutation of the machine-side converter becomes difficult near synchronous speed because of excessive commutation angle overlap.
- A line commutated cycloconverter can overcome this limitation but adds substantial cost and complexity to the drive.
- At sub synchronous speeds, the slip power sP_m is supplied to the rotor by the exciter.
- At super synchronous speeds, the rotor output power flows in the opposite direction so that the total shaft power increases to $(1+s)P_m$.

Cycloconverter Scherbius System:



Cycloconverters: Converts single-phase or three-phase ac to variable magnitude and variable frequency, single-phase or three-phase ac

SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

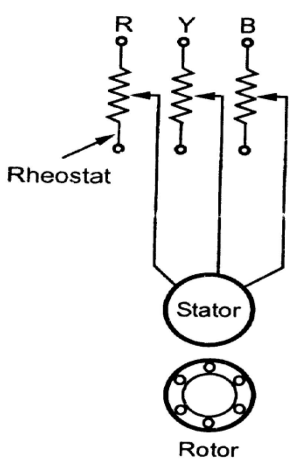
Speed Control from Stator Side:

1. By changing the applied voltage
2. By changing the applied frequency (or) V/f Control
3. Changing the number of stator poles

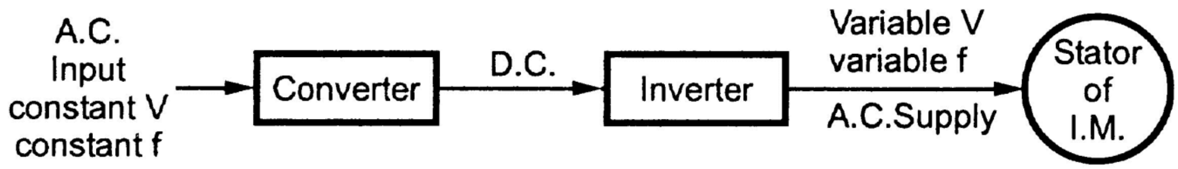
Speed Control from Rotor Side:

1. Rotor rheostat control
2. Cascade operation
3. By injecting EMF in rotor circuit

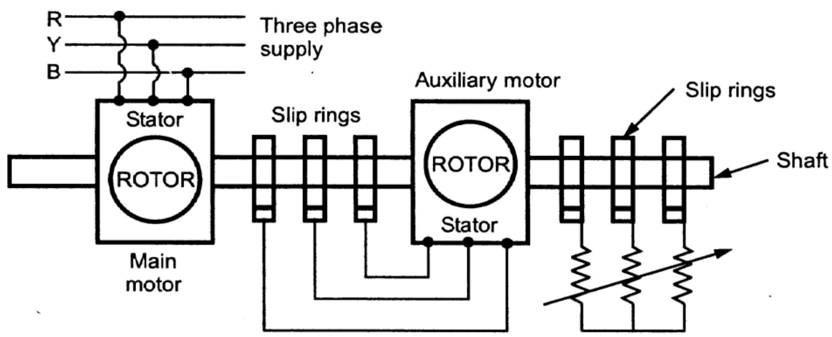
By Changing the Applied Voltage:



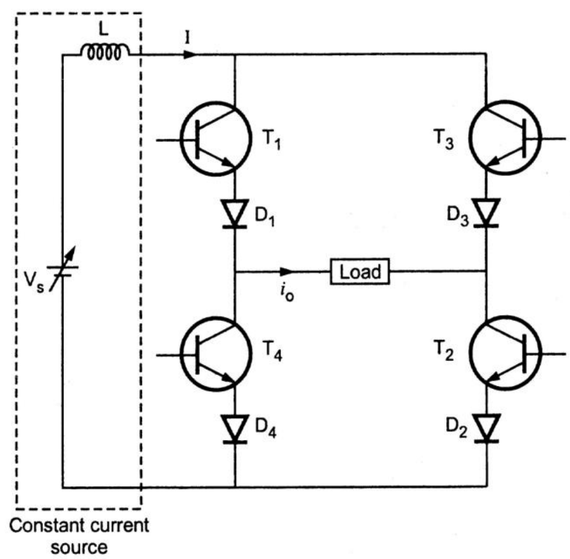
V/f Control:

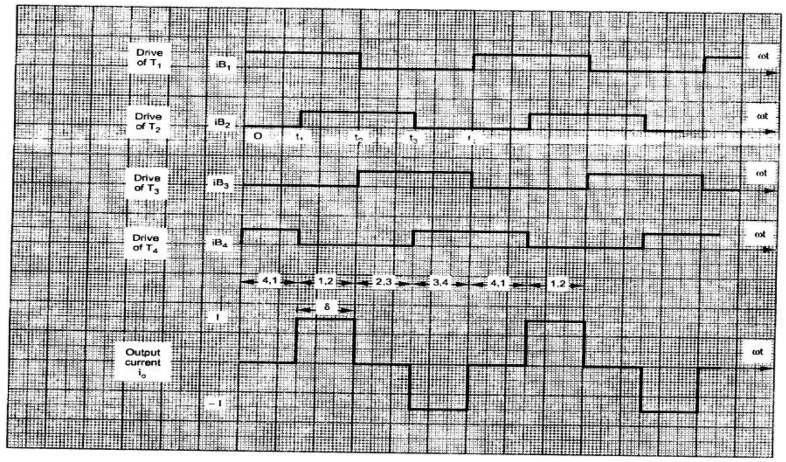


Cascade operation:

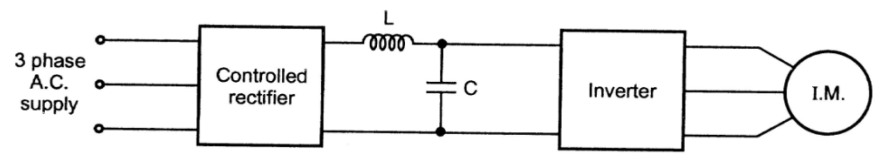


SPEED CONTROL – CURRENT SOURCE INVERTER

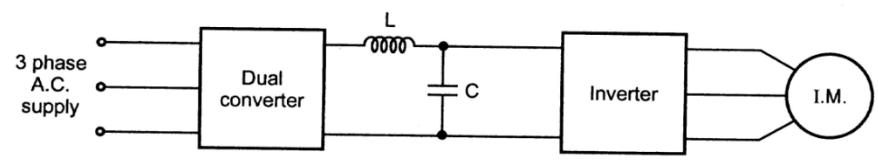




SPEED CONTROL – VOLTAGE SOURCE INVERTER



(a)



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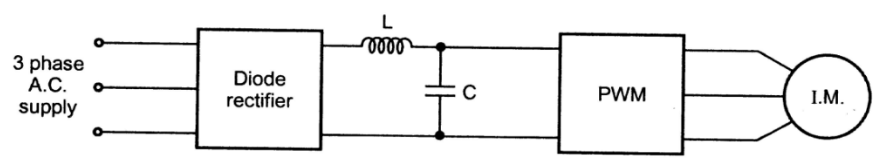

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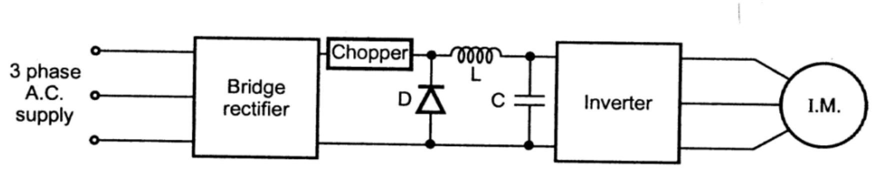
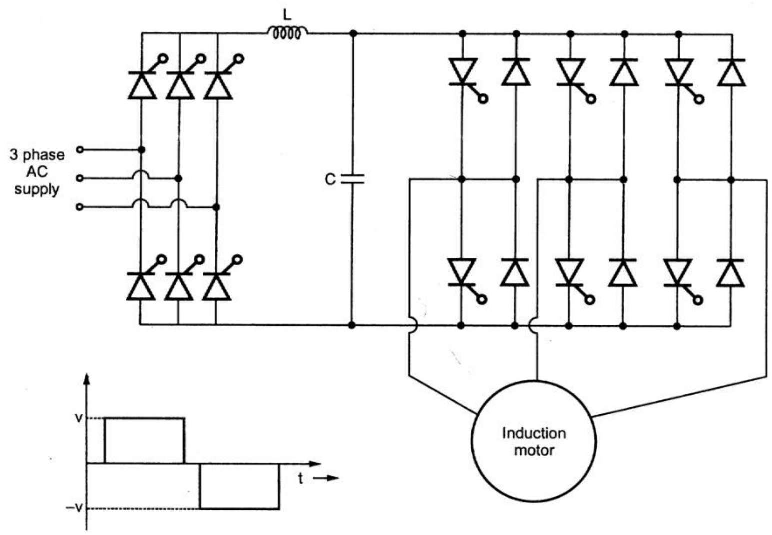




Square wave output

JEPPIAAR ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT TEST I

YEAR / SEM: II /III TIME: 2.00 hrs SUB:
EE6351 ELECTRIC DRIVES AND CONTROL TOTAL MARKS: 100

PART A (10*2=20)

1.What is dynamic braking?
2.Draw the slip – torque characteristics of a single phase induction motor.
3.Define plugging of 3 phase induction motor
4.Why DC series motors should never be started on no-load
5.Define torque.
6.List the types of rotors in induction motor.
7.Give the types of braking used for dc motor.
8.Draw the mechanical characteristics of DC series motor with different input voltage values.
9.How the starting torque of capacitor-start induction motor can be varied?
10. Single phase motor is not a self starting motor. Why?

PART B (4*20=80)

1.Draw and explain the characteristics of a DC shunt Motor with Suitable graphs and diagrams.
2.Explain the various methods of braking of induction motors.
3.Explain the construction and working principle of 3-phase induction motor with neat diagrams.
4.Explain the starting methods of single induction motors with neat diagrams.

JEPPIAAR ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

ASSESSMENT TEST II

YEAR / SEM: II /III TIME: 2.15 hrs
SUB: EE6351 ELECTRIC DRIVES AND CONTROL TOTAL
MARKS: 60

PART A (3*2=6)

1.What are the protective devices in a DC/AC motor Starter?
2.Give some advantages and disadvantages of D.O.L
3.What is the Necessity of starter?

PART B (3*13=39)

5.Draw a neat schematic diagram of a three point starter and explain its working.
6.Explain with neat diagram the starting of three phase slip ring induction motor.
7.Draw and explain the push-button operated direct-on line starter for three phase induction motor.

PART C (1*15=15)

1 .Draw and explain the manual auto-transformer starter for three phase induction motor.

JEPPIAAR ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

ASSESSMENT TEST III

EE6351 ELECTRICAL DRIVES AND CONTROL

YEAR / SEM: II /III TIME: 3.00 hrs

PART A (10*2=20)

1. Draw the block diagram of an electrical drive.
2. Give the examples where continuous duty at constant load is occurred.
3. Name the power modulators used for V/f control of 3 phase induction motor.
4. State the applications where stator voltage control is employed for three phase induction motors.
5. What are the factors to be considered for the selection of electrical drives?
6. What are the conventional methods of speed control of three phase induction motor from stator side?
7. What are the types of electrical drive?
8. Define cooling time constant of an electrical machine.
9. Define voltage source inverter and current source inverter.
10. Mention the advantages of slip power recovery system.

PART B (5*13=65)

11. (a) Explain the various factors that influence the choice of electric drives. (13)

(OR)

(b)List and explain various classes of motor duty. (13)

12. (a) Draw and explain the mechanical characteristic of DC drive. (13)

(OR)

(b) With neat diagram, explain braking methods of a DC Drive. (13)

13. (a) Explain the construction and operation of 3 point starter. (13)

(OR)

(b) With neat diagram, explain the construction and operation of an automatic starter. (13)

14. (a) Explain various methods of conventional speed control of a DC drive. (13)

(OR)

(b) Explain the working of ward-Leonard method of speed control. (13)

15. (a) Explain working of conventional Kramer slip power recovery system. (13)

(OR)

(b) Explain with neat diagram the method of speed control of AC drives using current source inverter. (13)

PART C (1*15=15)

16. Explain the static Scherbius drive which provides speed below and above synchronous speed.

JEPPIAAR ENGINEERING COLLEGE

DEPARTMENT OF MECHANICAL ENGINEERING

MODEL EXAM

EE6351 ELECTRICAL DRIVES AND CONTROL

YEAR / SEM: II /III **TIME: 3.00 hrs**

PART A **(10*2=20)**

1. Draw the block diagram of an electrical drive.
2. Give the examples where continuous duty at constant load is occurred.
3. Define mechanical characteristics.
4. Write any five applications of single phase induction motor.
5. How the starting current of three phase IM can be reduced?
6. Differentiate three point starter and four point starter.
7. Differentiate uncontrolled and controlled rectifiers?
8. What is tapped control method?
9. Define voltage source inverter and current source inverter.
10. Mention the advantages of slip power recovery system.

PART B **(5*13=65)**

11. **(a)** Explain the different factors influencing the choice of electrical drives? (13)

(OR)

(b) Draw the typical temperature rise-time curve and derive the equation for temperature rise in an electric drive. (13)

12. (a) Draw and explain the characteristics of DC motor. (13)

(OR)

(b) Explain the various methods of braking of induction motors. (13)

13. (a) Draw a neat schematic diagram of a three point starter and explain its working. (13)

(OR)

(b) Draw the neat schematic diagram of Induction motor and explain its working. (13)

14. (a) Discuss the Ward-Leonard speed control system with a neat circuit diagram. Also mention its advantages and disadvantages. (13)

(OR)

(b) Explain with neat sketches about the DC Shunt Motor speed control by using single phase fully controlled bridge converter (13)

15. (a) Explain in detail about Slip power recovery scheme. (13)

(OR)

(b) Discuss the speed control of AC motors by using three phase AC Voltage regulators. (13)

PART C (1*15=15)

16. (a) List and explain various classes of motor duty.

(OR)

(b) Explain in detail the construction and operating principle of an automatic starter.

Solved Problems

As mentioned above, while guessing the value of I_{a2}, the proportion of armature-power should be 1.5.

$$\frac{E_{b2}\ I_{a2}}{E_{b1}\ I_{a1}} = \frac{206.56 \times 33.75}{211.2 \times 22} = 1.50$$

Thus, the results obtained are confirmed.

Example 30.17. *A 250 V, 25 kW d.c. shunt motor has an efficiency of 85% when running at 1000 r.p.m. on full load. The armature resistance is 0.1 ohm and field resistance is 125 ohms. Find the starting resistance required to limit the starting current to 150% of the rated current.*

(Amravati Univ., 1999)

Solution.

Output power = 25 kW, at full-load.

$$\text{Input power} = \frac{25{,}000}{0.85} = 29412 \text{ watts}$$

At Full load, Input Current = 29412/250 = 117.65 amp

Field Current = 250/125 = 2 amp

F.L. Armature Current = 117.65 − 2 = 115.65 amp

Limit of starting current = 1.50 × 115.65 = 173.5 amp

Total resistance in armature circuit at starting

$$= \frac{250}{173.5} = 1.441 \text{ ohms}$$

External resistance to be added to armature circuit

= 1.441 − 0.1 = 1.341 ohm.

ASSIGNMENT TOPICS:

1. Draw the typical temperature rise-time curve and derive the equation for temperature rise in an electric drive.
2. Explain various methods of braking of DC Shunt Motors with neat diagrams.
3. Explain with neat circuit diagram, the star-delta starter method of starting squirrel cage induction motor.
4. Explain with neat sketches about the DC Shunt Motor speed control by using single phase fully controlled bridge converter.

QUIZ QUESTIONS

1. The consideration involved in the selection of the type of electric drive for a particular application depends on

(A) Speed control range and its nature

(B) Starting torque

(C) Environmental conditions

(D) All of the above.

Answer: D

2. Which of the following is preferred for automatic drives ?

(A) Synchronous motors

(B) Squirrel cage induction motor

(C) Ward Leonard controlled dc motors

(D) Any of the above.

Answer: C

3. Which type of drive can be used for hoisting machinery

(A) AC slip ring motor

(B) Ward Leonard controlled DC shunt motor

(C) DC compound motor

(D) Any of the above.

Answer: D

4. The motor normally used for crane travel is

(A) AC slip ring motor

(B) Ward Leonard controlled DC shunt motor

(C) Synchronous motor

(D) DC differentially compound motor.

Answer: A

5. A wound rotor induction motor is preferred over squirrel cage induction motor when the major consideration involved is

(A) high starting torque

(B) low starting current

(C) speed control over limited range

(D) all of the above.

Answer:D

6. When smooth and precise speed control over a wide range is desired, the motor preferred is

(A) synchronous motor

(B) squirrel cage induction motor

(C) wound rotor induction motor

(D) dc motor.

Answer:D

7. When quick speed reversal is a consideration, the motor preferred is

(A) synchronous motor

(B) squirrel cage induction motor

(C) wound rotor induction motor

(D) dc motor.

Answer:D

8. Stator voltage control for speed control of induction motors is suitable for

(A) fan and pump drives

(B) drive of a crane

(C) running it as generator

(D) constant load drive.

Answer:A

9. The selection of control gear for a particular application is based on the consideration of

(A) duty

(B) starting torque

(C) limitations on starting current

(D) all of the above.

Answer:D

10. As compared to squirrel cage induction motor, a wound rotor induction motor is preferred when the major consideration is

(A) high starting torque

(B) low windage losses

(C) slow speed operation

(D) all of the above.

Answer:A

11. A synchronous motor is found to be more economical when the load is above

(A) 1 kW

(B) 10 kW

(C) 20 kW

(D)100kW.

Answer:D

12. The advantage of a synchronous motor in addition to its constant speed is

(A) high power factor

(B) better efficiency

(C) lower cost

(D) all of the above.

Answer:A

13. In motor circuit static frequency changers are used for

(A) power factor improvement

(B) improved cooling

(C) reversal of direction

(D) speed regulation.

Answer:D

14. In case of traveling cranes, the motor preferred for boom hoist is

(A) AC slip ring motor

(B) Ward Leonard controlled DC shunt motor

(C) Synchronous motor

(D) Single phase motor.

Answer:A

15. The characteristics of drive for. crane hoisting and lowering is

(A) smooth movement

(B) precise control

(C) fast speed control

(D) all of the above.

Answer:D

16. Belt conveyors offer

(A) zero starting torque

(B) low starting torque

(C) medium starting torque

(D) high starting torque.

Answer:D

17. In case belt conveyors

(A) squirrel cage motors with direct-on-line starters are used

(B) single phase induction motors are used

(C) dc shunt motors are used

(D) induction motors with star-delta starters are used.

Answer:A

18. Which of the following motor is preferred for blowers ?

(A) wound rotor induction motor

(B) squirrel cage induction motor

(C) dc shunt motor

(D) dc series motor.

Answer:B

19. Centrifugal pumps are usually driven by

(A) dc shunt motors

(B) dc series motors

(C) squirrel cage induction motors

(D) any of the above.

Answer:C

20. In a centrifugal pump if the liquid to be pumped has density twice that of water, then the horse power required (as compared to that while pumping water) will be

(A) half

(B) same

(C) double

(D) four times.

Answer:C

21. Wound rotor and squirrel-cage motors with high slip which develop maximum torque at stand still are used for

(A) machine tools

(B) presses and punches

(C) elevators

(D) all of the above.

Answer:B

22. Belted slip ring induction motor is almost invariably used for

(A) centrifugal blowers

(B) jaw crushers

(C) water pumps

(D) screw pumps.

Answer:B

23. In jaw crushers, a motor has to often start against

(A) low load

(B) medium load

(C) normal load

(D) heavy load.

Answer:D

24. Motor used for elevators is generally

(A) synchronous motor

(B) induction motor

(C) capacitor start single phase motor

(D) any of the above.

Answer:B

25. In synthetic fibre mills motor with

(A) constant speeds are preferred

(B) high starting torque are preferred

(C) variable speed are preferred

(D) low starting torque are preferred.

Answer:A

26. Which of the following motor is preferred for synthetic fibre mills ?

(A) series motor

(B) reluctance motor

(C) shunt motor

(D) synchronous motor.

Answer:B

27. Reluctance motor is a

(A) self-starting type synchronous motors

(B) low torque variable speed motor

(C) variable torque motor

(D) low noise, slow speed motor.

Answer:A

28. Power factor in case of reluctance motor is

(A) nearly unity

(B) always leading

(C) 0.8

(D) 0.3 to 0.4.

Answer:D

29. The efficiency of reluctance motor is around

(A) 95%

(B) 90%

(C) 75 to 85%

(D) 60 to 75%.

Answer:D

30. The size of a excavator is usually expressed in terms of

(A) cubic meters

(B) travel in meters

(C) angle of swing

(D) 'crowd' motion

Answer:A

31. Ward-Leonard controlled dc drives are generally used for

(A) light duty excavators

(B) medium duty excavators

(C) heavy duty excavators

(D) all of the above.

Answer:C

32. In case of contactors, the contacts are generally made of

(A) copper

(B) silver

(C) cadmium copper

(D) any of the above.

Answer:D

33. Which electromagnet is preferred for noiseless operation ?

(A) DC operated

(B) AC operated

(C) Any of the above.

Answer:A

34. For high frequency choppers the device that is preferred is

(A) Thyristor

(B) TRIAC

(C) Transistor

(D) GTO.

Answer:C

35. The number of operations per hour in case of class IV contactor will be around

(A) 100

(B) 600

(C) 900

(D) 1200.

Answer:D

36. In case of contactors, the duty in which the main contacts remain closed for a period bearing a definition relation to the no-load periods, is known as

(A) Standard duty

(B) Intermittent duty

(C) Temporary duty

(D) Un-interrupted duty.

Answer:B

37. n case of contactors the ratio of the in service period to the entire period, expressed as a percentage is known as

(A) duty

(B) load factor

(C) class of contact

(D) none of the above.

Answer:B

38. Heat control switches find applications on

(A) three phase induction motors

(B) single phase motors

(C) transformers

(D) cooling ranges.

Answer:D

39. A saturable core reactor is basically a

(A) variable resistor

(B) step down transformer

(C) thermal relay

(D) variable impedance.

Answer:D

40. The earth wire should not be thinner than a

(A) 20 SWG wire

(B) 16 SWG wire

(C) 10 SWG wire

(D) 8 SWG wire.

Answer:D

41. In automobiles the sound is produced by horn due to

(A) magnetostriction

(B) vibrating diaphragm

(C) moving coil

(D) oscillating coil.

Answer:B

42. The current drawn by a 6 V horn is roughly

(A) 0.1 A

(B)1A

(C) 2 A

(D) 20 A.

Answer:D

43. The hours are rated for

(A) continuous operation

(B) intermittent operation

(C) both (A) and (B) above

(D) none of the above.

Answer:B

44. Continuous operation of automobile horn will

(A) help in charging the battery

(B) improve mileage

(C) damage the operating coil

(D) change the tone.

Answer:C

45. In a constant power type load

(A) torque is proportional to speed

(B) torque is proportional to square of speed

(C) torque is inversely proportional to speed

(D) torque is independent of speed.

Answer:C

46. Which of the following pair is used for frequency converters ?

(A) Squirrel cage induction motor and synchronous motor

(B) Wound rotor induction motor and synchronous motor

(C) Wound rotor induction motor and squirrel cage induction motor

(D) Any of the above.

Answer:A

47. Belted wound rotor induction motors are preferred for

(A) machine tools

(B) gyratory crushers

(C) belt conveyor

(D) water pumps.

Answer:B

48. The cooling time constant is usually

(A) equal to the heating time constant

(B) more than heating time constant

(C) none of these.

Answer:B

49. A motor of less than full load power rating can be used if the load is

(A) continuous duty

(B) short time duty

(C) intermittent periodic duty

(D) none of these.

Answer:B

50. Pole changing method of speed control is used in

(A) slip ring induction motor

(B) dc shunt motor

(C) dc series motor

(D) squirrel cage induction motor.

Answer:D

NPTEL website:

**www.nptelvideos.in/2012/11/advanced-electric-drives.html

**www.eps-technology.blogspot.com/2011/02/online-video-courses-electric-drives.html

**https://www.btechguru.com/courses--nptel--electrical-engineering-video-lecture--ee.ht...

**https://play.google.com/store/apps/details?id=com.education.nptelee

**https://www.pannam.com/blog/free-resources-to-learn-electrical-engineering/

Real world Examples

S.No	**Applications**	**Significance of the application Example**
1	Linear Time invariant systems	These are special case of proposed general design principle
2	Control of Robot Manipulators	Robust control of rigid-body robots under parameter uncertainties
3	Pulse width modulation for electric drives	Design philosophy of integral slidding mode can be directly applied to practical systems
4	Robust current control for permanent magnet synchronous motor	Utilisation of proposed perturbations estimator to achieve advanced performance.

V S B Engineering Collge
Department of Mechanical Engineering
Engineering Thermodynamics Question Bank

UNIT I BASIC CONCEPTS AND FIRST LAW
Basic concepts - concept of continuum, comparison of microscopic and macroscopic approach. Path and point functions. Intensive and extensive, total and specific quantities. System and their types. Thermodynamic Equilibrium State, path and process. Quasi-static, reversible and irreversible processes. Heat and work transfer, definition and comparison, sign convention. Displacement work and other modes of work.P-V diagram. Zeroth law of thermodynamics – concept of temperature and thermal equilibrium– relationship between temperature scales –new temperature scales. First law of thermodynamics –application to closed and open systems – steady and unsteady flow processes.
PART-A
1. Define thermodynamic system. A thermodynamic system is defined as a quantity of matter or a region in space, on which the analysisof the problem is concentrated.
2. Name the different types of system. 1. Closed system (only energy transfer and no mass transfer) 2. Open system (Both energy and mass transfer) 3. Isolated system (No mass and energy transfer)
3. Should the automobile radiator be analyzed as a closed system or as an open system? Explain. (Nov/Dec 2016) Automobile radiator system is analyzed as closed system. In this no mass (water) cross the boundary.
4. Define thermodynamic equilibrium. (Nov/Dec 2014) (May/June 2014) If a system is in Mechanical, Thermal and Chemical Equilibrium then the system is in

Thermodynamically equilibrium. (or)
If the system is isolated from its surrounding there will be no change in the macroscopic property, thenthe system is said to exist in a state of thermodynamic equilibrium.

5. What do you mean by quasi-static process? (Nov/Dec 2012)
Infinite slowness is the characteristic feature of a quasi-static process. A quasi-static process is that asuccession of equilibrium states. A quasi-static process is also called as reversible process.

6. Differentiate between point function and path function. (May/June 2014)

Point Function	Path Function
1. Any quantity whose change is independent of the path is known as point function.	1. Any quantity, the value of which depends on the path followed during a change of state is known as path function.
2. The magnitude of such quantity in a process depends on the state.	2. The magnitude of such quantity in a process is equal to the area under the curve on a property diagram.
3. These are exact differential.	3.These are inexact differential. Inexact differential is denoted by δ
4. Properties are the examples of point function like pressure(P), volume(V),Temp.(T),Energy etc.	4. Ex: Heat and work

7. Name and explain the two types of properties. (Nov/Dec 2013)(Nov/Dec 2016)
The two types of properties are intensive property and extensive property.
Intensive Property: It is independent of the mass of the system.
Example: pressure, temperature, specific volume, specific energy, density.
Extensive Property: It is dependent on the mass of the system.
Example: Volume, energy. If the mass is increased the values of the extensive properties also Increase.

8. Explain homogeneous and heterogeneous system.
The system consist of single phase is called homogeneous system and the system consist of more thanone phase is called heterogeneous system.

9. What is a steady flow process?
Steady flow means that the rates of flow of mass and energy across the control surface are constant.

10. Prove that for an isolated system, there is no change in internal energy.
In isolated system there is no interaction between the system and the surroundings. There is no masstransfer and energy transfer. According to first law of thermodynamics as dQ = dU + dW; dU = dQ –dW; dQ = 0, dW = 0, Therefore dU = 0 by integrating the above equation U = constant, therefore the internal energy isconstant for isolated system.

11. Indicate the practical application of steady flow energy equation.
1. Turbine, 2. Nozzle, 3. Condenser, 4. Compressor.

12. Define system.
It is defined as the quantity of the matter or a region in space upon which we focus attention to studyits property.

13. Define cycle.
It is defined as a series of state changes such that the final state is identical with the initial state.

14. Explain Mechanical equilibrium.
If the forces are balanced between the system and surroundings are called Mechanical equilibrium

15. Explain Chemical equilibrium. If there is no chemical reaction or transfer of matter form one part of the system to another is calledChemical equilibrium.
16. Explain Thermal equilibrium. If the temperature difference between the system and surroundings is zero then it is in Thermal Equilibrium.
17. Define Zeroth law of Thermodynamics. (Nov/Dec 2014) When two systems are separately in thermal equilibrium with a third system then they themselves is inthermal equilibrium with each other.
18. What are the limitations of first law of thermodynamics? (Nov/Dec 2012) 1. According to first law of thermodynamics heat and work are mutually convertible during any cycleof a closed system. But this law does not specify the possible conditions under which the heat isconverted into work. 2. According to the first law of thermodynamics it is impossible to transfer heat from lowertemperature to higher temperature. 3. It does not give any information regarding change of state or whether the process is possible or not. 4. The law does not specify the direction of heat and work.
19. What is perpetual motion machine of first kind? It is defined as a machine, which produces work energy without consuming an equivalent of energyfrom other source. It is impossible to obtain in actual practice, because no machine can produce energyof its own without consuming any other form of energy.
20. Define: Specific heat capacity at constant pressure. It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of thesubstance through one degree when the pressure kept constant. It is denoted by Cp.
21. Define: Specific heat capacity at constant volume. It is defined as the amount of heat energy required to raise or lower the temperature of unit mass of thesubstance through one degree when volume kept constant.
22. Define the term enthalpy? The Combination of internal energy and flow energy is known as enthalpy of the system. It may alsobe defined as the total heat of the substance. Mathematically, enthalpy (H) = U + pv KJ) Where, U – internal energy p – Pressure v – Volume In terms of Cp& T → H = mCp (T2-T1) KJ
23. Define the term internal energy Internal energy of a gas is the energy stored in a gas due to its molecular interactions. It is also definedas the energy possessed by a gas at a given temperature.
24. What is meant by thermodynamic work? It is the work done by the system when the energy transferred across the boundary of the system. It ismainly due to intensive property difference between the system and surroundings.
25. What is meant by reversible and irreversible process? A process is said to be reversible, it should trace the same path in the reverse direction when the process is reversed. It is possible only when the system passes through a continuous series of equilibrium state.
26. Enlist the similarities between work and heat. (Nov/Dec 2014)

Heat	Work
Form of energy	Form of energy

Across a boundary	Across a boundary
Cross the boundary whenever there is a change of state of a body	Cross the boundary whenever there is a change of state of a body
It is a path function and hence is an exact differential	It is a path function and hence is an exact differential

27. Why does free expansion have zero work transfer? (April/May 2015)

In free expansion there is no external force acting on the gas so that the energy given to the gas can be utilized to produce heat and to overcome the repulsions between the gases which does not happen in free expansion therefore there is no work transfer.

28. Distinguish between 'Macroscopic energy' and 'Microscopic energy'. (Nov/Dec 2012)

Statistical Thermodynamics is microscopic approach in which, the matter is assumed to be made of numerous individual molecules. Hence, it can be regarded as a branch of statistical mechanics dealing with the average behaviour of a large number of molecules.

Classical thermodynamics is macroscopic approach. Here, the matter is considered to be a continuum without any concern to its atomic structure.

29. Show that the energy of an isolated system remains constant. (Nov/Dec 2015)

A system which does not exchange energy with its surroundings through work and heat interactions is called an isolated system. That is for an isolated system dW = 0 and dQ=0.
The first law of thermodynamics gives dE = dQ – dW
Hence, for an isolated system, the first law of thermodynamics reduces to dE = 0 or $E_2 = E_1$. In other words, the energy of an isolated thermodynamic system remains constant.

30. What are the conditions for steady flow process? (May/June 2013)

- No properties within the control volume change with time. That is
  m_{cv} = constant E_{cv} = constant
- No properties change at the boundaries with time. Thus, the fluid properties at an inlet or exit will remain the same during the whole process. They can be different at different opens.
- The heat and work interactions between a steady-flow system and its surroundings do not change with time.

PART-B

1. **A gas of mass 1.5 kg undergoes a quasi-static expansion, which follows a relationship p=a+bV, where 'a' and 'b' are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively and the corresponding volumes are 0.2 m^3 and 1.2 m^3. The specific internal energy of the gas is given by the relation U = (1.5pV – 85) kJ/kg, where p is in kPa and V is in m^3. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion. (Nov/Dec 2012).**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

2. **A piston – cylinder device contains 0.15 kg of air initially at 2 MPa and 3500C. The air is first expanded isothermally to 500 kPa, then compressed polytropically with a polytrophic exponent of 1.2 to the initial pressure, and finally compressed at the constant pressure to the initial state. Determine the boundary work for each process and the network of the cycle. (Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

3. A gas undergoes a thermodynamic cycle consisting of the following processes:

(i) Process 1-2: Constant Pressure P_1=1.4 bar, V_1=0.028 m^3, W_{1-2}=10.5 kJ.

(ii) Process 2-3: Compression with pV=constant, $U_3=U_2$.

(iii) Process 3-1: Constant volume, U_1-U_3= - 26.4 kJ.

There are no significant changes in KE and PE

1. Sketch the cycle on a p-V diagram.
2. Calculate the network for the cycle in kJ.
3. Calculate the heat transfer for process 1-2.
4. Show that $Q_{cycle}=W_{cycle.}$ **(April/May 2015)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

4. A three cycle operating with nitrogen as the working substance has constant temperature compression at 34^0C with initial pressure 100kPa. Then the gas undergoes a constant volume heating and then polytropic expansion with 1.35 as index of compression. The isothermal compression requires - 67 kJ/kg of work. Determine: (i) p,v and T around the cycle (ii) Heat in and out (iii) Network. For nitrogen gas Cv = 0.731 kJ/kgK.**(May/June 2013)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

5. (i) Air enters the compressor of a gas-turbine plant at ambient conditions of 100 kPa and 25^0C with a low velocity and exists at 1 MPa and 347^0C with a velocity of 90 m/s. The compressor is cooled at the rate of 1500 kJ/min, and the power input to the compressor is 250 kW. Determine the mass flow rate of air through the compressor. Assume Cp=1.005 kJ/kg K.

(ii) Derive steady flow energy equation.**(Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

6. In a gas turbine installation air is heated inside heat exchanger up to 750^OC from ambient temperature of 27^OC. Hot air then enters into gas turbine with the velocity of 50 m/sec and leaves at 600^OC. Air leaving the turbine enters a nozzle at 60 m/sec velocity and leaves nozzle at temperature of 500^OC. For unit mass flow rate of air, determine the following assumptions adiabatic expansion in turbine and nozzle, (i) heat transfer to air in heat exchanger (ii) power output from turbine (iii) velocity at exit of nozzle. Take Cp for air as 1.005 kJ/kgK. **(May/June 2014).**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

7. Air flows steadily at the rate of 0.4 kg/s though an air compressor, entering at 6 m/s with a pressure of 1 bar and specific volume of 0.85 m^3/kg and leaving at 4.5 m/s with a pressure of 6.9 bar and a specific volume of 0.16 m^3/kg. The internal energy of air leaving is 88 kJ/kg greater than that of air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 59 kW. Calculate the power required to drive the compressor and the ratio of inlet and outlet cross sectional area. **(May/June 2012)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

8. Derive the steady flow energy equation and stating the assumptions made.**(May/June 2014).**

Refer: "P.K NAG Engineering Thermodynamics for derivation"

UNIT II SECOND LAW AND AVAILABILITY ANALYSIS

Heat Reservoir, source and sink. Heat Engine, Refrigerator, Heat pump. Statements of second law and its corollaries. Carnot cycle Reversed Carnot cycle, Performance. Clausius inequality. Concept of entropy, T-s diagram, Tds Equations, entropy change for - pure substance, ideal gases - different processes, principle of increase in entropy. Applications of II Law. High and low grade energy. Available and non-available energy of a source and finite body. Energy and irreversibility. Expressions for the energy of a closed system and open systems. Energy balance and entropy generation. Irreversibility. I and II law Efficiency.

PART-A

1. Define Clausius statement. (Nov/Dec 2013)

It is impossible for a self-acting machine working in a cyclic process, to transfer heat from a body atlower temperature to a body at a higher temperature without the aid of an external agency.

2. What is Perpetual motion machine of the second kind?

A heat engine, which converts whole of the heat energy into mechanical work is known as Perpetualmotion machine of the second kind.

3. Define Kelvin Planck Statement. (May/June 2014) (Nov/Dec 2014) (May/June 2013)

It is impossible to construct a heat engine to produce network in a complete cycle if it exchanges heatfrom a single reservoir at single fixed temperature.

4. Define Heat pump.

A heat pump is a device, which is working in a cycle and transfers heat from lower temperature tohigher temperature.

5. Define Heat engine.

Heat engine is a machine, which is used to convert the heat energy into mechanical work in a cyclicprocess.

6. A heat engine with a thermal efficiency of 45 percent rejects 500 kJ/kg of heat. How much heat does it receive? (Nov/Dec 2016)

Thermal efficiency=(Qs-Qr)/Qs

0.45=(Qs-500)/Qs

Qs=909 kJ/kg

7. What is a reversed heat engine? (April/May 2015)

The reversed heat engine works on the principle of reversed Carnot cycle. The heat engine produces work by absorbing heat from source and liberating some heat to sink. The reversed heat engine transfers the heat from sink to the source with the help of external work.

8. What are the assumptions made on heat engine?

1. The source and sink are maintained at constant temperature.
2. The source and sink has infinite heat capacity.

9. State Carnot theorem. (May/June 2014)

It states that no heat engine operating in a cycle between two constant temperature heat reservoir canbe more efficient than a reversible engine operating between the same reservoir.

10. What is meant by reversible process?

A reversible process is one, which is performed in such a way that at the conclusion of process, bothsystem and surroundings may be restored to their initial state, without producing any changes in rest ofthe universe.

11. What is meant by irreversible process?

The mixing of two substances and combustion also leads to irreversibility. All spontaneous process isirreversible.

12. Explain entropy?(Nov/Dec 2014) (Nov/Dec 2015)

It is an important thermodynamic property of the substance. It is the measure of molecular disorder. Itis denoted by S. The measurement of change in entropy for reversible process is obtained by thequantity of heat received or rejected to absolute temperature.

13. What is absolute entropy?

The entropy measured for all perfect crystalline solids at absolute zero temperature is known asabsolute entropy.

14. When a system is adiabatic, what can be said about the entropy change of the substance in the system? (Nov/Dec 2016)

Entropy change of the substance in a adiabatic system is always constant. (S=C)

$S_1=S_2$

15. Define availability.

The maximum useful work obtained during a process in which the final condition of the system is thesame as that of the surrounding is called availability of the system.

16. Define available energy and unavailable energy.

Available energy is the maximum thermal useful work under ideal condition. The remaining part,which cannot be converted into work, is known as unavailable energy.

17. What is a thermal energy reservoir? Explain the term source and sink. (April/May 2015)

A thermal reservoir, a short-form of thermal energy reservoir, or thermal bath is a thermodynamic system with a heat capacity that is large enough that when it is in thermal contact with another system of interest or its environment, its temperature remains effectively constant.

Source is a thermal reservoir, which supplies heat to the system and sink is a thermal reservoir, which takes the heat from the system.

18. What do you understand by the entropy principle?

The entropy of an isolated system can never decrease. It always increases and remains constant onlywhen the process is reversible. This is known as principle of increase in entropy or entropy principle.

19. What are the important characteristics of entropy?

1. If the heat is supplied to the system then the entropy will increase.
2. If the heat is rejected to the system then the entropy will decrease.
3. The entropy is constant for all adiabatic frictionless process.
4. The entropy increases if temperature of heat is lowered without work being done as in throttlingprocess.
5. If the entropy is maximum, then there is a minimum availability for conversion in to work.
6. If the entropy is minimum then there is a maximum availability for conversion into work.

20. What is reversed Carnot heat engine? What are the limitations of Carnot cycle?

1. No friction is considered for moving parts of the engine.
2. There should not be any heat loss.

21. Define an isentropic process.

Isentropic process is also called as reversible adiabatic process. It is a process which follows the lawof $pV^y= C$ is known as isentropic process. During this process entropy remains constant and no heatenters or leaves the gas.

22. Explain the throttling process.

When a gas or vapour expands and flows through an aperture of small size, the process is called asthrottling process.

23. What are the Corollaries of Carnot theorem? (May/June 2014)

(i) In the entire reversible engine operating between the two given thermal reservoirs with fixedtemperature, have the same efficiency.

(ii) The efficiency of any reversible heat engine operating between two reservoirs is independent of thenature of the working fluid and depends only on the temperature of the reservoirs.

24. Define – PMM of second kind.

Perpetual motion machine of second kind draws heat continuously from single reservoir and convertsit into equivalent amount of work. Thus it gives 100% efficiency.
25. What is the difference between a heat pump and a refrigerator? Heat pump is a device which operating in cyclic process, maintains the temperature of a hot body at atemperature higher than the temperature of surroundings. A refrigerator is a device which operating in a cyclic process, maintains the temperature of a cold bodyat a temperature lower than the temperature of the surroundings.
26. Define the term COP? Co-efficient of performance is defined as the ratio of heat extracted or rejected to work input. $COP = \frac{\text{Heat extracted or rejected}}{\text{Work input}}$
27. Write the expression for COP of a heat pump and a refrigerator? COP of heat pump, $COP_{HP} = \frac{\text{Heat Supplied}}{\text{Work input}} = \frac{T2}{T2-T1}$ COP of Refrigerator, $COP_{Ref} = \frac{\text{Heat extracted}}{\text{Work input}} = \frac{T1}{T2-T1}$
28. Why Carnot cycle cannot be realized in practical? (i) In a Carnot cycle all the four process are reversible but in actual practice there is no process isreversible. (ii) There are two processes to be carried out during compression and expansion. For isothermalprocess the piston moves very slowly and for adiabatic process the piston moves as fast as possible.This speed variation during the same stroke of the piston is not possible. (iii) It is not possible to avoid friction moving parts completely.
29. Why a heat engine cannot have 100% efficiency? For all the heat engines there will be a heat loss between system and surroundings. Therefore we can'tconvert all the heat input into useful work.
30. What are the processes involved in Carnot cycle. Carnot cycle consist of i) Reversible isothermal compression ii) Isentropic compression iii) Reversible isothermal expansion iv) Isentropic expansion
31. What are the causes of irreversibility? (Nov/Dec 2015) Four of the most common causes of irreversibility are friction, unrestrained expansion of a fluid, heat transfer through a finite temperature difference, and mixing of two different substances.
32. State Clausius statement of II law of thermodynamics. (Nov/Dec 2013) Clausius statement states "it is impossible for a self-acting machine working in a cyclic process without any external force, to transfer heat from a body at a lower temperature to a body at a higher temperature. It considers transformation of heat

between two heat reservoirs.

PART-B& PART-C

1. (i) A heat pump operates on a Carnot heat pump cycle with a COP of 8.7. It keeps a space at 24^0C by consuming 2.15 kW of power. Determine the temperature of the reservoir from which the heat is absorbed and the heating load provided by the heat pump.

(ii) An inventor claims to have developed a refrigeration system that removes heat from the closed region at -12^0C and transfers it to the surrounding air at 25^0C while maintaining a COP of 6.5. Is this claim reasonable? Why? **(Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

2. A reversible heat engine operates between two reservoirs at temperature of 600^0C and 40^0C. The engine drives a reversible refrigerator which operates between reservoirs at temperatures of 40^0C and -20^0C. The heat transfer to the heat engine is 2000kJ and the network output for the combined engine refrigerator is 360kJ. Calculate the heat transfer to the refrigerant and the net heat transfer to the reservoir at 40^0C. **(April/May 2015)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

3. (a) Two Carnot engines A and B are operated in series. The first one receives heat at 870 K and rejects to a reservoir at T. B receives heat rejected by the first engine and in turn rejects to a sink at 300 K. Find the temperature T for (i) Equal work outputs of both engines (ii) Same Efficiencies.

(b) Mention the Clausius inequality for open, closed and isolated systems. **(Nov/Dec 2013)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"228.

4. (i) A 30 kg iron block and a 40 kg copper block, both initially at 80^0C, are dropped into a large lake at 15^0C. Thermal equilibrium is established after a while as a result of heat transfer between the blocks and the lake water. Determine the total entropy change for this process.

(ii) How much of the 100 kJ of thermal energy at 650 K can be converted to useful work? Assume the environment to be at 25^0C. **(Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

5. 5 m^3 of air at 2 bar, 27^OC is compressed up to 6 bar pressure following $Pv^{1.3}$= constant. It is subsequently expanded adiabatically to 2 bar. Considering the two processes to be reversible, determine the network, net heat transfer and change in entropy. Also plot the processes on T-s and p-V diagrams. **(May/June 2014)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

6. One kg of air is contained in a piston cylinder assembly at 10 bar pressure and 500 K temperature. The piston moves outwards and the air expands to 2 bar pressure and 350K temperature. Determine the maximum work obtainable. Assume the environmental conditions to be 1 bar and 290 K. Also make calculations for the availability in the initial and final states. **(Nov/Dec 2009)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

7. (i) State and Prove Clausius inequality.

(ii) Prove Entropy-A property of the system. **(Nov/Dec 2012)**

Refer: "P.K NAG Engineering Thermodynamics for derivation"

8. 3 kg of air at 500 kPa, 90^0C expands adiabatically in a closed system until its volume doubled and its temperature becomes equal to that of surroundings at 100 kPa and 10^0C. Find the maximum work, change in availability and the irreversibility. **(Nov/Dec 2013)**

Refer: Refer: "P.K NAG Engineering Thermodynamics for similar problems"

UNIT III PROPERTIES OF PURE SUBSTANCE AND STEAM POWER CYCLE

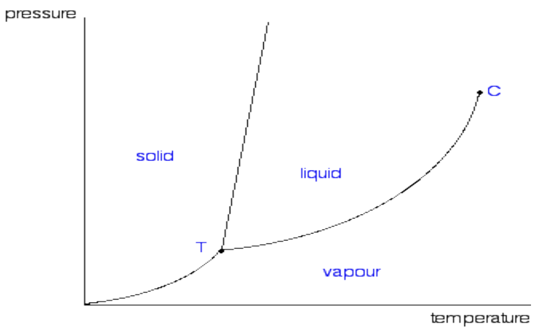
Formation of steam and its thermodynamic properties, p-v, p-T, T-v, T-s, h-s diagrams. p-v-T surface. Use of Steam Table and Mollier Chart. Determination of dryness fraction. Application of I and II law for pure substances. Ideal and actual Rankine cycles, Cycle Improvement Methods - Reheat and Regenerative cycles, Economizer, preheater, Binary and Combined cycles.

PART-A

1. What do you understand by pure substance? (Nov/Dec 2013)

A pure substance is defined as one that is homogeneous and invariable in chemical compositionthroughout its mass.

2. Draw a p-T diagram for a pure substance? (May/June 2014)



3. Is iced water a pure substance? Why?(Nov/Dec 2016)

Yes iced water is a pure substance.

Explanation:
Both ice and liquid water are the same substance. H2O Though ice water is a mixture of both solid and liquid it is a pure substance, based on the molecular structure of its components.

4. Distinguish between flow process and non-flow process. (Nov/Dec 2012)

Flow process : It is one in which fluid enters the system and leaves it after work interaction, which means that such processes occur in the systems having open boundary permitting mass interaction across the system boundary.
Non flow process: It is the one in which there is no mass interaction across the system boundaries during the occurrence of process.

5. Why Rankine cycle is modified?

The work obtained at the end of the expansion is very less. The work is too inadequate to overcomethe friction.

Therefore the adiabatic expansion is terminated at the point before the end of theexpansion in the turbine and pressure decreases suddenly, while the volume remains constant.

6. Why Rankine cycle is modified?

The work obtained at the end of the expansion is very less. The work is too inadequate to overcomethe friction. Therefore the adiabatic expansion is terminated at the point before the end of theexpansion in the turbine and pressure decreases suddenly, while the volume remains constant.

7. Define efficiency ratio.

The ratio of actual cycle efficiency to that of the ideal cycle efficiency is termed as efficiency ratio.

8. Define overall efficiency.

It is the ratio of the mechanical work to the energy supplied in the fuel. It is also defined as the productof combustion efficiency and the cycle efficiency.

9. Define specific steam consumption of an ideal Rankine cycle.

It is defined as the mass flow of steam required per unit power output.

10. Name the different components in steam power plant working on Rankine cycle.

Boiler, Turbine, Cooling Tower or Condenser and Pump.

11. What are the effects of condenser pressure on the Rankine Cycle?

By lowering the condenser pressure, we can increase the cycle efficiency. The main disadvantage islowering the back pressure in release the wetness of steam. Isentropic compression of a very wetvapour is very difficult.

12. Mention the improvements made to increase the ideal efficiency of Rankine cycle. (Nov/Dec 2014) (May/June 2014)

1. Lowering the condenser pressure.
2. Superheated steam is supplied to the turbine.
3. Increasing the boiler pressure to certain limit.
4. Implementing reheat and regeneration in the cycle.

13. What is the effect of reheat on (a) the network output, (b) the cycle efficiency and (c) steam rate of a steam power plant? (Nov/Dec 2016)

(a) The network output - increase
(b) The cycle efficiency - increase
(c) Steam rate of a steam power plant – decrease

14. Why reheat cycle is not used for low boiler pressure?

At the low reheat pressure the heat cycle efficiency may be less than the Rankine cycle efficiency.Since the average temperature during heating will then be low.

15. What are the disadvantages of reheating?

Reheating increases the condenser capacity due to increased dryness fraction, increases the cost of theplant due to the reheats and its very long connections.

16. What are the advantages of reheat cycle?

1. It increases the turbine work.
2. It increases the heat supply.
3. It increases the efficiency of the plant.
4. It reduces the wear on the blade because of low moisture content in LP state of the turbine.

17. Define latent heat of evaporation or Enthalpy of evaporation.

The amount of heat added during heating of water up to dry steam from boiling point is known asLatent heat of evaporation or enthalpy of evaporation.

18. Explain the term super-heated steam and super heating.

The dry steam is further heated its temperature raises, this process is called as superheating and thesteam obtained is known as superheated steam.

19. Explain heat of super heat or super heat enthalpy.

The heat added to dry steam at 100oC to convert it into super-heated steam at the temperature Tsup iscalled as heat of superheat or super heat enthalpy.

20. Explain the term critical point, critical temperature and critical pressure.

In the T-S diagram the region left of the waterline, the water exists as liquid. In right of the dry steamline, the water exists as a super-heated steam. In between water and dry steam line the water exists as awet steam. At a particular point, the water is directly converted into dry steam without formation ofwet steam. The point is called critical point. The critical temperature is the temperature above which asubstance cannot exist as a liquid; the critical temperature of water is 374.15^{o}C. The correspondingpressure is called critical pressure.

21. Define dryness fraction (or) what is the quality of steam?

It is defined as the ratio of mass of the dry steam to the mass of the total steam.

22. Define enthalpy of steam.

It is the sum of heat added to water from freezing point to saturation temperature and the heat absorbed during evaporation.

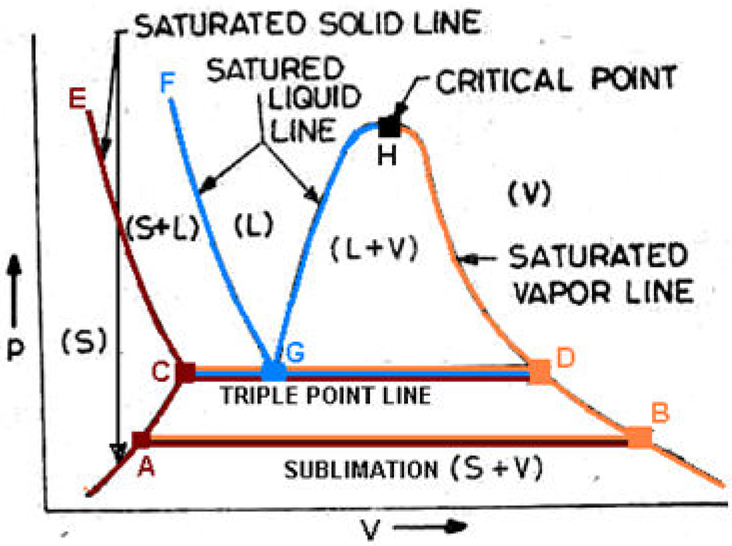
23. How do you determine the state of steam?

If V>vg then super-heated steam, V= vg then dry steam and V< vg then wet steam.

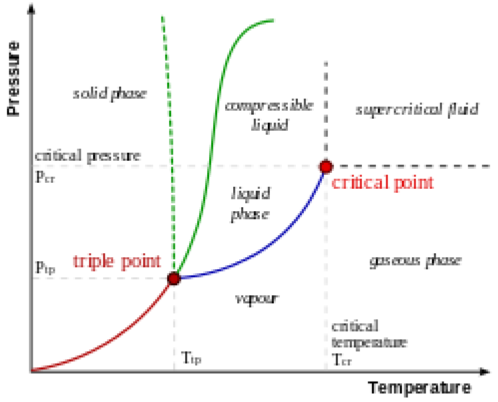
24. Define triple point.

The triple point is merely the point of intersection of sublimation and vaporization curves.

25. How is Triple point represented in the p-V diagram? (Nov/Dec 2013)



26. Define heat of vaporization. The amount of heat required to convert the liquid water completely into vapour under this condition iscalled the heat of vaporization.
27. Explain the terms, Degree of super heat, degree of sub-cooling. The difference between the temperature of the superheated vapour and the saturation temperature atthe same pressure. The temperature between the saturation temperature and the temperature in the subcooled region of liquid.
28. When is reheat recommended in a steam power plant? (Nov/Dec 2015) The purpose of reheating is to increase the dryness fraction of the steam passing out of the later stages of the turbine.
29. What are the processes that constitute a Rankine cycle? Process 1–2: Isentropic expansion of the working fluid through the turbine from saturated vapor atstate 1 to the condenser pressure. Process 2–3: Heat transfer from the working fluid as it flows at constant pressure through thecondenser with saturated liquid at state 3. Process 3–4: Isentropic compression in the pump to state 4 in the compressed liquid region. Process 4–1: Heat transfer to the working fluid as it flows at constant pressure through the boiler tocomplete the cycle.
30. State the advantages of using superheated steam in turbines. (Nov/Dec 2014) Superheated steam is a steam at a temperature higher than its vaporization (boiling) point at the absolute pressure where the temperature is measured. The steam can therefore cool (lose internal energy) by some amount, resulting in a lowering of its temperature without changing state (i.e., condensing) from a gas, to a mixture of saturated vapor and liquid.
31. Draw the p-T diagram for water and label all salient points. (Nov/Dec 2014)



PART-B& PART-C

1. Explain steam formation with relevant sketch and label all salient points and explain every point in detail. **(Nov/Dec 2014)**

Refer: "P.K NAG Engineering Thermodynamics for the description"

2. (a) Define specific steam consumption, specific heat rate and work ratio. **(Nov/Dec 2012)**
(b) A vessel of volume 0.04 m^3 contains a mixture of saturated water and saturated steam at a temperature of 250°C. The mass of the liquid present is 9 kg. Find the pressure, the mass, the specific volume, the enthalpy, and entropy, and the internal energy of the mixture. **(Apr/May 2015)**

Refer: "P.K NAG Engineering Thermodynamics for description"

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

3. Steam at a pressure of 15 bar and 250°C expands according to the law $PV^{1.25}=C$ to a pressure of 1.5 bar. Evaluate the final conditions, work done, heat transfer and change in entropy. The mass of the system is 0.8 kg. **(Nov /Dec 2008)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

4. A steam power plant operates on a theoretical reheat cycle. Steam at boiler at 150 bar, 550°C expands through the high pressure turbine. It is reheated at a constant pressure of 40 bar to 550°C and expands through the low pressure turbine to a condenser at 0.1 bar. Draw T-s and h-s diagrams. Find (i) Quality of steam at turbine exhaust (ii) Cycle efficiency (iii) Steam rate in kg/kWh. **(May/June 2014)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

5. Consider a steam power plant operating on the Ideal Rankine cycle. Steam enters the turbine at 3 MPa and 623 K and is condensed in the condenser at a pressure of 10 kPa. Determine (i) the thermal efficiency of this power plant (ii) the thermal efficiency, if steam is super-heated to 873 K instead of 623 K, and (iii) the thermal efficiency, if the boiler pressure is raised to 15 MPa while the turbine inlet temperature is maintained at 873 K. **(Nov/Dec 2009)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

6. In a Rankine cycle, the steam at inlet to turbine is saturated at a pressure of 35 bar and the exhaust pressure is 0.2 bar. The flow rate of steam is 0.2 kg/s. Determine (i) the pimp work (ii) the turbine work (iii) Rankine efficiency (iv) Condenser heat flow (v) work ratio and (vi) specific steam consumption. **(Nov/Dec 2011)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

7. A steam power plant operates on an ideal regenerative Rankine cycle, Steam enters the turbine at 6 MPa and 450°C and is condensed in the condenser at 20 kPa. Steam is extracted from the turbine at 0.4 MPa to heat the feed water in an open feed water heater. Water leaves the feed water heater. Water leaves the feed water heater as a saturated liquid. Show the cycle on a T-s diagram, and determine (i) The network output per kilogram of steam flowing through the boiler and (ii) the thermal efficiency of the cycle. **(Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for similar problems"

UNIT IV IDEAL AND REAL GASES, THERMODYNAMIC RELATIONS

Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases-Reduced properties-.Compressibility factor-.Principle of Corresponding states. -Generalised Compressibility Chart and its use-. Maxwell relations, Tds Equations, Difference and ratio of heat capacities, Energy equation, Joule-Thomson Coefficient, Clausius Clapeyron equation, Phase Change Processes. Simple Calculations.

PART-A

1. Define Ideal gas.

It is defined as a gas having no forces of intermolecular attraction. These gases will follow the gaslaws at all ranges of pressures and temperatures.

2. What are the properties of ideal gas? (Nov/Dec 2014)

1. An ideal gas consists of a large number of identical molecules.
2. The volume occupied by the molecules themselves is negligible compared to the volume occupied by the gas.
3. The molecules obey Newton's laws of motion, and they move in random motion.

. The molecules experience forces only during collisions; any collisions are completely elastic, and take a negligible amount of time.

3. Define Real gas. (Nov/Dec 2013)

It is defined, as a gas having the forces of attraction between molecules tends to be very small atreduced pressures and elevated temperatures.

4. What is equation of state? (Nov/Dec 2012)

The relation between the independent properties such as pressure, specific volume and temperature fora pure substance is known as the equation of state.

5. State the Vander Waal's equation of state. (Nov/Dec 2014)

The van der Waals equation (or van der Waals equation of state) is an equation relating the density of gases and liquids (fluids) to the pressure (*p*), volume (*V*), and temperature (*T*) conditions (*i.e.*, it is a thermodynamic equation of state).

6. State Boyle's law.

It states that volume of a given mass of a perfect gas varies inversely as the absolute pressure whentemperature is constant.

7. State Charle's law.

It states that if any gas is heated at constant pressure, its volume changes directly as its absolutetemperature.

8. Explain the construction and give the use of generalized compressibility chart.

The general compressibility chart is plotted with Z versus Pr for various values of Tr. This isconstructed by plotting the known data of one of mole gases and can be used for any gas. This chartgives best results for the regions well removed from the critical state for all gases.

9. What do you mean by reduced properties? (Nov/Dec 2016)

The ratios of pressure, temperature and specific volume of a real gas to the corresponding criticalvalues are called the reduced properties.

10. Explain law of corresponding states.

If any two gases have equal values of reduced pressure and reduced temperature, then they have samevalues of reduced volume.

11. Explain Dalton's law of partial pressure.

The pressure of a mixture of gases is equal to the sum of the partial pressures of the constituents. Thepartial

pressure of each constituent is that pressure which the gas would expect if it occupied alone thatvolume occupied by the mixtures at the same temperatures. m = mA+mB+mC+……. = mi
mi = mass of the constituent.
P=PA+PB+PC+……. = Pi, Pi – the partial pressure of a constituent.

12. State Avogadro's Law.

The number of moles of any gas is proportional to the volume of gas at a given pressure andtemperature.

13. What is compressibility factor?

The gas equation for an ideal gas is given by (PV/RT) = 1, for real gas (PV/RT) is not equal to 1
(PV/RT) = Z for real gas is called the compressibility factor.

14. What is partial pressure?

The partial pressure of each constituent is that pressure which the gas would exert if it occupied alonethat volume occupied by the mixtures at the same temperature.

15. Define Dalton's law of partial pressure.

The total pressure exerted in a closed vessel containing a number of gases is equal to the sum of thepressures of each gas and the volume of each gas equal to the volume of the vessel.

16. How does the Vander Waal's equation differ from the ideal gas equation of state?

The ideal gas equation pV=mRT has two important assumptions,
1. There is little or no attraction between the molecules of the gas.
2. That the volume occupied by the molecules themselves is negligibly small compared to the volumeof the gas.
This equation holds good for low pressure and high temperature ranges as the
Intermolecular attraction and the volume of the molecules are not of much significance.
As the pressure increases, the inter molecular forces of attraction and repulsion increases and the
volume of the molecules are not negligible. The real gas deviates considerably from the ideal gas
equation $[p+(a/V2)](V-b) = RT$

17. Explain Joule-Kelvin effect. What is inversion temperature?(April/May 2015)

When a gas (not ideal gas) is throttled, the temperature increases up to a point and then decreases. Thisis known as Joule Kelvin effect. The temperature at which the slope of a throttling curve in T-pdiagram is zero is inversion temperature.

18. What is the law of corresponding states? (April/May 2015)

According to Vander Waals, the theorem of corresponding states (or principle of corresponding states) indicates that all fluids, when compared at the same reduced temperature and reduced pressure, have approximately the same compressibility factor and all deviate from ideal gas behaviour to about the same degree.

19. In what way the Clausius Clapeyron equations is useful? (Nov/Dec 2012)

- Apply the Clausius-Clapeyron equation to estimate the vapor pressure at any temperature.
- Estimate the heat of phase transition from the vapor pressures measured at two temperatures.

20. What are the assumptions made to derive ideal gas equation analytically using the kinetic theory of gases? (May/June 2014)

The assumptions are:

- Gases are made up of molecules which are in constant motion in straight lines.
- The molecules behave as rigid spheres.

- Pressure is due to collisions between the molecules and the walls of the container.
- All collisions, both between the molecules themselves, and between the molecules and the walls of the container, are perfectly elastic.
- The temperature of the gas is proportional to the average kinetic energy of the molecules.

21. Write down the two Tds equations. (Nov/Dec 2016)

$$TdS = C_V dT + T\left(\frac{\partial p}{\partial T}\right)_V dV \quad \text{(first } TdS \text{ equation)}$$

$$TdS = C_P dT - T\left(\frac{\partial V}{\partial T}\right)_P dP \quad \text{(second } TdS \text{ equation)}$$

22. What is Clausius Clapeyron Equation?

Clapeyron equation which involves in the relationship between the saturation pressure, saturation temperature, the enthalpy of evaporation and the specific volume of the two phases involved.

$$\frac{d_p}{d_T} = \frac{h_{fg}}{Tv_{fg}}$$

23. State Helmholtz function.

Helmholtz function is property of system and it is given by subtracting the product of absolute temperature (T) and entropy (s) from the internal energy u.

i.e. Helmholtz function = u-Ts

24. State Gibbs Function.

Gibbs function is property of system and is given by

G = u – Ts + pv = h – Ts {since h=u+pv}

Where h = enthalpy

T = Temperature

S = Entropy

25. Have you ever encountered any ideal gas? If so, where?(Apr/May 2008)

No. In actual practice, there is no ideal gas which strictly follows the gas laws over the entire range of temperature and pressure. However, hydrogen, oxygen, nitrogen and air behave as an ideal gas under certain temperature and pressure limits.

26. What are Maxwell relations? (Nov/Dec 2006, Nov/Dec 2008)

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v$$

$$\left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$$

$$\left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T \text{ and } \left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T$$

These are known as Maxwell relations. These equations are derived by using first law of thermodynamics,

Helmholtz function(a=u-Ts) and Gibbs function (G=h-Ts)
27. What is meant by equation of state? Write the same for an ideal gas. (Nov/Dec 2007, 2011 & 2012) The relationship which exists for the state variables of the system in equilibrium is called equation of state. The equation of state for ideal is given by pV=mRT Where p – Pressure of gas, V – Volume of gas, m- Mass of gas, R – Gas constant, T – Temperature.
28. Determine the molecular volume of any perfect gas at 600 N/m^2 and 30^{0}C. Universal gas constant may be taken as 8314 kJ/kg mole-k. Given: P = 600 N/m^2 T = 30^{0}C = 303 K R = 8314 kJ/kg mole-k Solution: Ideal Gas equation, pV=mRT V=mRT/p=1 x 8314 x 303/600= 4198 m^3/kg-mole.
29. State Charle's law. Charle's law states that "the volume of a given mass of a gas varies directly as its absolute temperature, when the pressure remains constant". $v\ \alpha\ T$
30. State Regnault's law. Regnault's law states that specific heats of a gas always remains constant.
PART-B& PART-C
1. (i) What is joule – Thomson co-efficient? Why is it zero for an ideal gas? **(ii)** Derive an expression for Clausius Clapeyron equation applicable to fusion and vaporization. **(Nov/Dec 2016)** *Refer: "P.K NAG Engineering Thermodynamics for the derivation"*
2. Derive the Maxwell relations and explain their importance in thermodynamics. **(May/June 2014)** *Refer: "P.K NAG Engineering Thermodynamics for the derivation"*
3. (i) Derive the Clausius – Clapeyron equation and discuss its significance. (ii) Draw a neat sketch of a compressibility chart and indicate its salient features. **(Nov/Dec 2013)** *Refer: "P.K NAG Engineering Thermodynamics for the derivation"*
4. (a) From the basic principles, prove the following $C_p - C_v = -T\left(\frac{\partial v}{\partial T}\right)^2_p \left(\frac{\partial P}{\partial v}\right)_T$ **(May/June 2013)** (b) Derive the TdS equation taking T and C as independent variables. **(Nov/Dec 2012)** *Refer: "P.K NAG Engineering Thermodynamics for the derivation"*
5. (a) Explain the physical significance of the compressibility factor Z. **(Nov/Dec 2012)** (b) Derive the Joule – Thomson co-efficient equation and draw the inversion curve.**(Nov/Dec 2014)** *Refer: "P.K NAG Engineering Thermodynamics for the description and derivation"*
6. Determine the pressure of nitrogen gas at T=175 K and v=0.00375 m^3/kg on the basis of (i) The ideal-gas equation of state (ii) the Vander Waals equation of state. The vanderwaals constants for nitrogen are a=0.175 m^{6}kPa/kg^2, b=0.00138 m^3/kg. **(April/May 2015)** *Refer: "P.K NAG Engineering Thermodynamics for the similar problem"*
7. (i) State the conditions under which the equation of state will hold good for gas. (ii) State the main reasons for the deviation of behavior of real gases from ideal gases.

(iii)Explain irreversibility with respect to flow and non-flow process.
(iv) Explain the effectiveness of a system. **(Nov/Dec 2014)**

Refer: Refer: "P.K NAG Engineering Thermodynamics for the description"

8. **(i)** One kg of CO_2 has a volume of 1 m^3 at 100^0C. Compute the pressure by (1) Van der Waals' equation (2) Perfect gas equation. The Van der Waals' constants a=362850 $Nm^4/(kg\text{-}mol)^2$ and b=0.0423 $m^3/(kg\text{-}mol)$.
(ii) Write the Berthelot and Dieterici equations of state. **(Nov/Dec 2016)**

Refer: "P.K NAG Engineering Thermodynamics for the problem"

UNIT V GAS MIXTURES AND PSYCHROMETRY

Mole and Mass fraction, Dalton's and Amaga's Law. Properties of gas mixture – Molar mass, gas constant, density, and change in internal energy, enthalpy, entropy and Gibbs function. Psychrometric properties, Psychrometric charts. Property calculations of air vapour mixtures by using chart and expressions. Psychrometric process – adiabatic saturation, sensible heating and cooling, humidification, dehumidification, evaporative cooling and adiabatic mixing. Simple Applications

PART-A

1. What is humidification and dehumidification?

The addition of water vapour into air is humidification and the removal of watervapour from air is dehumidification.

2. Differentiate absolute humidity and relative humidity.

Absolute humidity is the mass of water vapour present in one kg of dry air.
Relative humidity is the ratio of the actual mass of water vapour present in one kg of dry air at thegiven temperature to the maximum mass of water vapour it can withhold at the same temperature.Absolute humidity is expressed in terms of kg/kg of dry air. Relative humidity is expressed in terms ofpercentage.

3. What is effective temperature?

The effective temperature is a measure of feeling warmth or cold to the human body in response to theair temperature, moisture content and air motion. If the air at different DBT and RH condition carriesthe same amount of heat as the heat carried by the air at temperature T and 100% RH, then thetemperature T is known as effective temperature.

4. Define Relative humidity.

It is defined as the ratio of partial pressure of water vapour (pw) in a mixture to the saturation pressure(ps) of pure water at the same temperature of mixture.

5. Define specific humidity.

It is defined as the ratio of the mass of water vapour (ms) in a given volume to the mass of dry air in agiven volume (ma).

6. Define degree of saturation. (Nov/Dec 2013)

It is the ratio of the actual specific humidity and the saturated specific humidity at the sametemperature of the mixture.

7. What is dew point temperature? (Nov/Dec 2015)(Nov/Dec 2016)

The temperature at which the vapour starts condensing is called dew point temperature. It is also equalto the saturation temperature at the partial pressure of water vapour in the mixture. The dew pointtemperature is an indication of specific humidity.

8. What is meant by dry bulb temperature (DBT)?

The temperature recorded by the thermometer with a dry bulb. The dry bulb thermometer cannot affectby the moisture present in the air. It is the measure of sensible heat of the air.

9. What is meant by wet bulb temperature (WBT)?

It is the temperature recorded by a thermometer whose bulb is covered with cotton wick (wet)saturated with water. The wet bulb temperature may be the measure of enthalpy of air. WBT is thelowest temperature recorded by moistened bulb.
10. Define dew point depression. It is the difference between dry bulb temperature and dew point temperature of air vapour mixture.
11. What is meant by adiabatic saturation temperature (or) thermodynamic wet bulb?Temperature? (May/June 2014) It is the temperature at which the outlet air can be brought into saturation state by passing through thewater in the long insulated duct (adiabatic) by the evaporation of water due to latent heat ofvaporization.
12. What is psychrometer? (Nov/Dec 2014) Psychrometer is an instrument which measures both dry bulb temperature and wet bulb temperature.
13. What is Psychrometric chart? It is the graphical plot with specific humidity and partial pressure of water vapour in y axis and drybulb temperature along x axis. The specific volume of mixture, wet bulb temperature, relativehumidity and enthalpy are the properties appeared in the Psychrometric chart.
14. Define sensible heat and latent heat. (April/May 2015) Sensible heat is the heat that changes the temperature of the substance when added to it or whenabstracted from it. Latent heat is the heat that does not affect the temperature but change of stateoccurred by adding the heat or by abstracting the heat.
15. What are the important Psychrometric processes? 1. Sensible heating and sensible cooling, 2. Cooling and dehumidification, 3. Heating and humidification, 4. Mixing of air streams, 5. Chemical dehumidification, 6. Adiabatic evaporative cooling.
16. What is meant by adiabatic mixing? The process of mixing two or more stream of air without any heat transfer to the surrounding is knownas adiabatic mixing. It is happened in air conditioning system.
17. What are the assumptions made in Vander Waal's equation of state? 1. There is no inter molecular forces between particles. 2. The volume of molecules is negligible in comparison with the gas.
18. Define coefficient of volume expansion. The coefficient of volume expansion is defined as the change in volume with the change intemperature per unit volume.
19. State Helmholtz function. Helmholtz function is the property of a system and is given by subtracting the product of absolutetemperature (T) and entropy (S) from the internal energy (U). Helmholtz function = U – TS
20. What are thermodynamic properties? Thermodynamic properties are pressure (p), temperature (T), volume (V), internal energy (U), Enthalpy(H), entropy (S), Helmholtz function and Gibbs function.
21. Define throttling process. When a fluid expands through a minute orifice or slightly opened valve, the process is called asthrottling process. During this process, pressure and velocity are reduced.
22. Define Molecular mass. Molecular mass is defined as the ratio between total mass of the mixture to the total number of molesavailable in

the mixture.

23. Define isothermal compressibility.

Isothermal compressibility is defined as the change in volume with change in pressure per unit volumekeeping the temperature constant.

24. Define psychrometry.

The science which deals with the study of behavior of moist air (mixture of dry air and water vapour)is known as Psychrometry.

25. What is by-pass factor? (May/June 2014)

The ratio of the amount of air which does not contact the cooling coil (amount of bypassing air) to the amount of supply air is called BPF.

26. **Define Apparatus Dew Point (ADP) of cooling coil?**

For dehumidification, the cooling coil is to be kept at a mean temperature which is below the dew point temperature (DPT) of the entering. This temperature of the coil is called ADP Temperature.

27. **Explain the following terms: (a) Mole fraction (b) Mass fraction.**

(a) Mole fraction:
It is the ratio of the mole number of a component to the mole number of the mixture. The total number of moles of mixture is the sum of its components.
$N_m=N_1+N_2+N_3+\ldots\ldots N_i=\sum_{i=1}^{k} N_i$

(b) Mass fraction
If a gas mixture consists of gases 1,2,3 and so, on, the mass of the mixture is the sum of the masses of the component gases
$M_m=m_1+m_2+m_3+\ldots\ldots m_i=\sum_{i=1}^{k} m_i$

28. **What is compressibility factor? What does it signify? What is its value for Vander Waals at critical point?**

We know that perfect equation is Pv = RT. But for real gas, a correction factor had to be introduced in the perfect gas equation to take into account the deviation of real gas from the perfect gas equation. This factor is known as compressibility factor (Z) and is defined by

$$Z = \frac{pv}{RT}$$

It signifies (i) Intermolecular attractive study is made. (ii) Shape factor is considered.
At critical point, the Vander Waals equation

$$\frac{pv}{RT} = 1 \; for\ ideal\ gases.$$

29. **State Dalton's law of partial pressure.(Nov/Dec 2016)**

Dalton's law of partial pressure states that "the pressure of a gas mixture is equal to the sum of pressures of its each components if each component is exerted alone of the temperature and volume of the mixture".

30. **What is the significance of compressibility factor?**

The gases deviate from ideal gas behavior significantly at high pressures and low temperatures. This deviation from ideal gas behavior at a given temperature and pressure can be determined by the introduction of a correction factor called the compressibility factor, defined as

$$Z = \frac{Pv}{RT}$$

PART-B& PART-C

1. An air-water vapour mixture enters an air-conditioning unit at a pressure of 1.0 bar, 38^{O}C DBT, and a relative humidity of 75%. The mass of dry air entering is 1 kg/s. The air-vapour mixture leaves the air-conditioning unit at 1.0 bar, 18^{O}C, 85% relative humidity. The moisture condensed leaves at 18^{O}C. Determine the heat transfer rate for the process. (May/June 2014)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

2. (a) One kg of air at $40^{O}C$ dry bulb temperature and 50% relative humidity is mixed with 2 kg of air at $20^{O}C$ dry bulb temperature and $20^{O}C$ dew point temperature. Calculate the temperature and specific humidity of the mixture.

(b) With the aid of model psychrometric chart explain the following processes.(i) Adiabatic mixing (ii) Evaporative cooling. (May /June 2013)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

3. **Atmospheric air at 1.0132 bar has $20^{0}C$ DBT and 65% RH. Find the humidity ratio, wet bulb temperature, dew point temperature, degree of saturation, enthalpy of the mixture, density of air and density of vapour in the mixture. (Nov/Dec 2012)**

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

4. It is required to design an air-conditioning plant for a small office room for following winter conditions:

Outdoor conditions…..$14^{0}C$ DBT and $10^{0}C$ WBT
Required conditions……$20^{0}C$ DBT and 60% RH
Amount of air circulation…0.30 m^3/min/person.
Seating capacity of office….60.

The required condition is achieved first by heating and then by adiabatic humidifying. Determine the following:

(i) Heating capacity of the coil in kW and the surface temperature required if the by pass factor of coil is 0.4.
(ii) The capacity of the humidifier. (Nov/Dec 2016)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

5. A perfect gas mixture consists of 4 kg of N_2 and 6 kg of CO_2 at a pressure of 4 bar and a temperature of $25^{0}C$. For N_2; C_v=0.745 kJ/kg K and C_p=1.041 kJ/kg K. For CO_2; C_v=0.653 kJ/kg K and C_p=0.842 kJ/kg. Find C_p, C_v and R of the mixture. If the mixture is heated at constant volume to $50^{0}C$, find the changes in internal energy, enthalpy and entropy of the mixture. (Nov/Dec 2011)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

6. An insulated rigid tank is divided into two compartments by a partition. One compartment contains 7kg of oxygen gas at $40^{O}C$ and 100 kPa and the other compartment contains 4kg of nitrogen gas at $20^{O}C$ and 150kPa. C_V, N_2=0.743 kJ/kgK and C_V, O_2=0.658 kJ/kgK. If the partition is removed and the two gases are allowed to mix, determine (i) The mixture temperature (ii) The mixture pressure after equilibrium has been established. (Nov/Dec 2012)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

7. A mixture of hydrogen (H_2) and Oxygen (O_2) is to be made so that the ratio of H_2 to O_2 is 2:1 by volume. If the pressure and temperature are 1 bar and $25^{0}C$ respectively, Calculate: (i) The mass of O_2 required (ii) The volume of the container. (Nov/Dec 2014)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

8. A rigid tank that contains 2kg of N_2 at $25^{0}C$ and 550 kPa is connected to another rigid tank that contains 4kg of O_2 at $25^{0}C$ and 150 kPa. The valve connecting the two tanks is opened, and the two gases are allowed to mix. If the final mixture temperature is $25^{0}C$, determine the volume of each tank and the final mixture pressure. (Nov/Dec 2016)

Refer: "P.K NAG Engineering Thermodynamics for similar problem"

MANUFACTURING TECHNOLOGY
QUESTION BANK

UNIT- I METAL CASTING PROCESSES

Sand Casting : Sand Mould – Type of patterns - Pattern Materials – Pattern allowances –Moulding sand Properties and testing – Cores –Types and applications – Moulding machines– Types and applications; **Melting furnaces** : Blast and Cupola Furnaces; **Principle of special casting processes :** Shell - investment – Ceramic mould – Pressure die casting - Centrifugal Casting - CO2 process – Stir casting; **Defects in Sand casting**.

PART – A

1. State any four types of patterns. **(May 2006)**

The various types of patterns which are commonly used are as follows:

1) Single piece or solid pattern
2) Two piece or split pattern
3) Loose piece pattern
4) Cope and drag pattern
5) Gated pattern

2. What are chaplets? **(May 2008)**

Chaplets are supports that are provided with cores which are slender or too long to be Properly supported in core prints.

3. Define casting. **(May 2014)**

Casting is the process of forming objects by putting molten metal in moulds and letting it solidify.

4. Mention any two advantages and disadvantages of die casting. **(May 2006)**

Advantages:

- It is a very fast process.
- Moulds have longer life.
- Better surface can be obtained.

Limitations:

- Moulds are much costlier.
- This method is not suitable for small quantity production.
- Shape and weight of the casting is limited.

5. Write the requirements of good pattern. **(May 2007)**

- Simple in design
- Cheap and readily available
- Light in mass
- Surface id smooth
- Have high strength

6. What is core venting? **(May 2007)**

While pouring the mould with molten metal mould walls and cores heat up rapidly and releases large amount of gases. In order to prevent casting defects these gases must be vented out. For this purpose core venting are used. Core venting is incorporated in the core box itself.

7. What function of core? **(May 2008)**

Functions of core are:

- Core provides a means of forming the main internal cavity for hollow casting.
- Core provides external undercut feature.
- Cores can be inserted to obtain deep recesses in the casting.

- Cores can be used to increase the strength of the mould.

8. Which process is called lost waxing method? Why? (May 2008)

Ans: Investment casting process is also known as **Lost-wax** process. The term investment refers to a clock or special covering apparel. In investment casting, the clock is a refractory mould which surrounds the pre-coated wax pattern.

9. What is the function of core print? (Dec 2008, 2012, May 2014)

- Core prints are basically extra projections provided on the pattern.
- They form core seats in the mould when pattern is embedded in the sand for mould making.
- Core seats are provided to support all the types of cores.
- Though the core prints are the part of pattern, they do not appear on the cast part.

10. What are the advantages and applications of ceramic moulds? (Dec 2008)

Advantages:

- It is less expensive
- Intricate objects can be casted.
- Castings of thin sections and which do not require machining can be produced.

Applications:

- It is mainly used for all material using better ingredient in slurry.

11. What are the pattern materials? (Dec 2008)

1) Wood 2) Metal 3) Plastic
4) Plaster 5) Wax

12. Explain the term fettling. (Dec 2009)

Fettling is the name given to cover all those operations which help the casting to give a good appearance. It includes the removal of cores, sand, gates, risers, runners and other unwanted projections from the casting.

13. Name the steps involved in making a casting.

Steps involved in making a casting are

(1) Pattern making (2) Sand mixing and preparation
(3) Core making (4) Melting
(5) Pouring (6) Finishing
(7) Testing (8) Heat treatment
(9) Re-testing

14. What are the applications of casting? (Nov 2014)

- Transportation vehicles (in automobile engine and tractors)
- Machine tool structures
- Turbine vanes and power generators
- Mill housing
- Pump filter and valve

15. Define pattern. (May 2014)

A pattern is defined as a model or replica of the object to be cast.
A pattern exactly resembles the casting to be made except for the various allowances.

16. List the allowances of pattern.

The following allowances are provided on the pattern :

- Shrinkage or contraction allowance
- Machining allowance
- Draft or taper allowance
- Distortion allowance
- Rapping or shake allowance

17. What are the factors on which amount of machining depends?

Factors affecting machining are

(1) Metal of casting
(2) Machining method used

(3) Casting method used
(4) Shape and size of the casting
(5) Amount of finish required on the machined portion

18. Why is a taper allowance used?

Draft allowance or taper allowance is given to all vertical faces of a pattern for their easy. Removal from sand without damaging the mould.

19. What is meant by grain fineness number? (Nov 2014)

A.F.S number is a number proposed by American Foundry men's Society as a measure of the sand texture. Sands are classified into coarse, medium or fine depending on the cumulative percentage of sand reained on a set of sieves and pan of a sifter.

20. How do you eliminate warpage ?

To eliminate this defect, an opposite distortion is provided on the pattern, so that the effect is balanced and correct shape of the casting is produced

21. Write the significance of loose moulding.

Some patterns embedded in the moulding sand cannot be withdrawn, hence such patterns are made with one or more loose pieces for their easy removal from the moulding box.

22. What are the types of moulding sand?

All types of sands used in the foundry can be grouped as:
1. Natural sand 2. Synthetic sand 3. Special sands

23. Why is synthetic sand better than natural sand?

(1) It requires less proportion of binder.
(2) Higher refractoriness and permeability.
(3) Properties can be easily controlled.
(4) Refractory grain size is more uniform.

24. Name the different types of special sand.

(1) Green sand (2) Loam sand (3) Core sand
(4) Parting sand (5) Facing sand (6) Backing sand

24. Define permeability.

The sand must be porous to allow the gases and steam generated within the moulds to be removed freely. This property of sand is known as permeability or porosity

25. Define Muller.

It is a mechanical mixer used for mixing sand ingredients in dry state.

26. Name various methods of sand testing.

(1) Moisture content test (2) Clay content test
(3) Permeability test (4) Grain fineness test

27. Name the factors affecting permeability test

- Grain shape and size
- Grain distribution
- Binder and its contents
- Water amount in the moulding sand
- Degree of ramming

29. Define mould and loam moulding.

When the pattern is removed, a cavity corresponding to the shape of the pattern remains in the sand which is known as mould or mould cavity.
In this, a rough structure of component is made by hand using bricks and loam sand. The sand used is known as loam sand or loam mortar.

30. Explain in short shell moulding.

Shell moulding is suitable for thin walled articles.
It consists of making a mould that has two or more thin shell like parts consisting of thermosetting resin bonded sand.

31. Name defects occurring in casting. (Nov 2013)

(1) Blow holes (2) Porosity (3) Shrinkage

(4) Inclusions (5) Hot tears or hot cracks (6) Misrun and cold shuts
PART – B & C
1. How are the patterns classified? Describe any two types with sketches and state the uses of each of the. (AU-Nov/Dec 2016) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:*
2. Enumerate the casting defects and suggest suitable remedies. (AU-Nov/Dec 2016) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:*
3.Explain the properties required for moulding sand? **Explain the preparation of moulding sand process. (April/May 2015),(AU-Nov/Dec 2016)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:*
4.Explain any one type of centrifugal casting. **Name any five casting defects and explain the remidies. (April/May 2015)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:*
1. What are the pattern making allowances and briefly explain them. (Au-May/June 2006,07) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:292*
2. How green sand mould is prepared? (AU-Nov/Dec 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:294*
3. Explain the properties of moulding sand. (Au-April/May 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:289*
4. Explain the properties of pattern .(Au Nov /Dec 2012) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:292*
5. Briefly explain the carbon dioxide CO2 moulding process and state two important merits and demerits. (Au-May/June 2006) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:301*
6. Explain the Centrifugal casting process Au-May/June 2007) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:318*
7. List any eight casting defects, their causes and remedies (Au-April/May 2007,2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:278*
8. Explain the Ceramic mould casting process. *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:304*
9. Give the sequence of step in pressure die casting process. (AU-Nov/Dec 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:313*
10. Briefly explain the different methods for inspection of casting. (AU-Nov/Dec 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:324*
11. Describe the operation of a cupola furnace for melting cast iron. (AU-Nov/Dec 2009) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:326*

UNIT- II JOINING PROCESSES	
Operating principle, basic equipment, merits and applications of: Fusion welding processes: Gas welding - Types – Flame characteristics; Manual metal arc welding – Gas Tungsten arc welding - Gas metal arc welding – Submerged arc welding – Electro slag welding; **Operating principle and applications of:** Resistance welding - Plasma arc welding – Thermit welding – Electron beam welding – Friction welding and Friction Stir Welding; Brazing and soldering; **Weld defects:** types, causes and cure.	
PART – A	
1.	**List out any four arc welding equipment. (May 2006)** The most commonly used equipments for arc welding are as follows: • A.C or D.C. machine • Wire brush • Cables and connectors • Ear thing clamps • Chipping hammer
2.	**What are the special features of friction welding? (May 2007)**

- Friction welding is a solid state welding process where coalescence is produced by the heat obtained from mechanically induced sliding motion between rubbing surfaces.
- The work parts are held together under pressure.
- Its operating is simple.
- Power required for the operation is low.
- It is used for joining steels, super alloys, non-ferrous metals and combinations of metals.

3. Define resistance welding process. (May 2006, May 2007)

Resistance welding is a process where coalescence is produced by the heat obtained from resistance offered by the workpiece to the flow of electric current in a circuit of which the work piece is a part and by the application of pressure.

4. What is weld porosity? How is it caused? (May 2014)

- Porosity is the formation of small holes or pores in the weld.
- Porosity is caused by entrapment of gases during the solidification process
- The gases so entrapped mostly consists of hydrogen, oxygen and nitrogen of which hydrogen is most prominent for causing porosity

5. How can slag inclusions in welding be an of small voided? (May 2008)

- Avoid multi layer welding
- Reduce arc length
- Increase electrode angle
- Avoid using large electrode

6. How does brazing differ from braze welding? (Dec 2008)

Brazing	Braze Welding
The filler alloy is fed to one or more points in the assembly and it is drawn into the rest of the joint by capillary action.	The filler alloy is deposited directly at the point where it is desired.

7. Why flux is coated on filler rods? (Dec 2008)

- The coating improves penetration and surface finish.
- Suitable coating will improve metal deposition rates.

8. What is the application of carburizing flame? (Dec 2009)

- Carburizing flame is generally used for:
  - Welding of low alloy steel rods
  - Non-ferrous metals
  - High carbon steel

9. What are the diameter and length of the electrodes available in the market? (Dec.2009)

- Standard length of electrodes is 250 mm, 300 mm and 450 mm.
- Standard diameters of electrodes are 1.6,2 ,2.5, 3.2, 4,5,6,7,8, and 9 mm.

10. Define weld ability.

Weld ability is defined as the capacity of a material to be welded under fabrication conditions imposed in a specific and suitably designed structure and to perform satisfactorily in the intended service.

11. State requirement of a good weldability.

A metallic material with adequate weld ability should fulfill the following requirements:

i. Have full strength and toughness after welding.

ii. Contribute to good weld quality even with high dilution.
iii. Have unchanged corrosion resistance after welding.
iv. Should not embrittle after stress relieving.

12. How is welding classified?

- Gas welding
- Arc welding
- Resistance welding
- Solid state welding
- Thermo-chemical welding processes
- Radiant energy welding processes

13. Name the types of flames.

The generated flames are classified into following three types
(a) Neutral flame (Acetylene and oxygen in equal proportion)
(b) Oxidizing flame (Excess of oxygen)
(c) Reducing flame or carburizing flame (Excess of acetylene)

14. Where is oxdizing flame used?

i. Copper-base metals
ii. Zinc-base metals
iii. Ferrous metals such as manganese steel, cast iron, etc.

15. Explain the function of flux in welding. (May 2008, 2016, Nov 2013, 2014)

While welding, if the metal is heated in air then the oxygen from air combines with the metal to form oxides. This results in poor quality, low weld strength hence, to avoid this difficulty a **flux** is employed during welding. It prevents the oxidation of molten metal.

16. Give the applications of gas welding.

Gas welding is most widely used for the following purposes:

- Joining thin materials.
- Joining most ferrous and non-ferrous metals.
- In automobile and aircraft industries.
- In sheet metal fabricating plant.

17. What is arc welding?

Electric arc welding is a fusion welding process in which welding heat is obtained from an electric arc between an electrode and the workpiece.

18. Define arc length and arc crater.

The distance between the centre of arc of the electrode tip and the bottom of arc crater is called as **arc length.** A small depression is formed in the base of the metal which is called as **arc crater.**

19. Define SMAW.

It is an arc welding process where coalescence is produced by heating the workpiece with an electric arc set up between the flux coated electrode and the workpiece.

20. What is submerged arc welding ?

It is an arc welding process where coalescence is produced by heating, with an electric arc set up between bare metal electrode and workpiece.

21. Explain in short plasma arc welding.

It is an arc welding process where coalescence is produced by the heat obtained from a constricted arc set up between a tungsten electrde and the water cooled nozzle or the workpiece. The process employs two inert gases i.e. one forms the plasma arc and the second shields the plasma arc.

Filler rod may or may not be added and pressure is not required for welding.

22. Write about special feature of flux cored welding.

The electrode is **flux cored** i.e. flux is contained within the hollow electrode. The flux cored electrode is coiled and supplied to the arc as a continuous wire. The flux inside the wire provides the necessary shielding of the weld pool.

23. What are the factors affecting resistance welding?

Four factors are involved in operation of resistance welding:

i. Amount of current passing through the work piece.
ii. The pressure that electrodes transfer to the work piece.
iii. Time during which current flows.
iv. Area of electrode tip in contact with the work piece.

24. What is adhesive bonding?

Adhesive bonding is the process of joining materials by using adhesives. The term adhesive includes substances such as glues, cements and other bonding agents.

Main steps in adhesive bonding are

(1) Surface Preparation (2) Applying the primer
(3) Applying the adhesive (4) Assembling adhesive coated components
(5) Curing the assembly (6) Testing of the joints

25. Explain thermoplastic adhesives.

Thermoplastic type adhesives soften at high temperature. They are easy to use and are employed as, air drying dispersions, emulsions or solutions that achieve their strength through the evaporation of the solvent

26. Explain thermosetting adhesives.

Ans: Thermosetting adhesives, once hardened cannot be remelted and a broken joint cannot be rebounded by heating also. These types of adhesives cure or harden by chemical reactions like polymerisation, condensation, vulcanisation or oxidation caused by the addition of a catalyst; heat, pressure, radiations, etc.

27. What is brazing?

It is defined as a group of joining processes where coalescence is produced bu heating to a suitable temperature and by using a filler metal having a liquidus above 470^0 C and below the solids of the base metal.

28. What is thermit welding? (Nov 2012, 2013)

Thermit welding is a fusion welding process that makes use of the intense heat produced when a mixture containing iron oxide and powdered aluminium is ignited. It reduces iron oxide to thermit steel and slag.

29. Name different defects in weld.

(a) Cracks (b) Distortion (c) Inclusions
(d) Porosity and blow holes (e) Undercutting (f) Overlapping
(g) Spatter (h) Poor fusion
(i) Poor weld bead appearance (j) Incomplete penetration

30. What do you mean by bronze welding?

Bronze welding does not mean the welding of bronze , but it is a welding using bronze filler rod

PART – B & C

1. What is a soldering flux? What different types of soldering fluxes are used? (Nov/Dec2016)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:

2. Explain the spot welding process (May 2006) Explain the Arc welding process and its positions (May 2014, 2015)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:892,862

3. Explain the submerged arc welding process (May 2006, 2007, 2013, 2015)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:864

4. Explain the gas (Oxy Acetylene) welding process (Nov 2012, May 2010, 2015)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:859

5. Explain the electron beam welding process with a neat sketch and the merits, limitations and applications.
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:875

6. Distinguish between soldering and brazing. (May 2006, 2007, 2008)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:929,934

7. Explain the features of neutral, reducing and oxidizing flames. Why is a reducing flame so called?
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 859

8. Discuss the sequence of operations in friction welding. (Nov 2008, 2013, 2014)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 888

9. What are the no destructive test used in welding inspection and also explain any two methods. (May

2013) **Explain the TIG and MIG system of welding. Give the applications of each. (Nov 2009, 2012)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:1035*
10. Explain the types of resistance welding process giving the equipment parameters controlled and the applications. (Nov 2009, May 2014) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:891*
11. Sketch the different types of weld defects and mention how they occur. (Nov 2013) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:885*

UNIT III – METAL FORMING PROCESSES

PART – A

1. What are the four major drawbacks of hot working?

- As hot working is carried out at high temperatures, a rapid oxidation or scale formation takes place on the metal surface which leads to poor surface finish and loss of metal.
- Due to the loss of carbon from the surface of the steel piece being worked, the surface layer loses its strength.
- This weakening of the surface layer may give rise to fatigue crack which results in failure of the part.
- Close tolerance cannot be obtained.
- Hot working involves excessive expenditure on account of high tooling cost.

2 Classify the types of extrusion. (May 2006)

- Hot Extrusion
- Cold Extrusion
- Hot Extrusion
- Direct extrusion
- Indirect extrusion
- Tube extrusion

3 What is the difference between a bloom and a billet? (May 2007)

A bloom has a square cross section with minimum size of 150x150 mm and a billet is smaller than bloom and it may have any square section from 38 mm upto the size of a bloom.

4 What is impact extrusion ? (May 2007)

The raw material is in slug form which have been turned from a bar or punched from a strip. By using punch and dies, the operation is performed. The slug is placed in the die and struck from top by the punch opareting at high pressure and speed

5 Why are a number of passes required to roll a steel bar? (May 2008)

To reduce the thickness and to increase the width of the bar number of passes are required.

6 How are seamless tubes produced? (May 2008)

Seamless tubing is a popular and economical raw stock for machining because it saves drilling and boring of parts. The piercing machine consists of two rapered rolls, called as **piercing rolls.**

7 What is Sojourned process? (Dec. 2008)

That extrusion process which is based both on the use of a lubricant in a viscous condition at extrusion temperature and on a separation between the lubrication of the chamber wall and die is called Sojourned process.

8 What is skew rolling? (Dec. 2008)

The rolls are powered and the work piece is in due to frictional force between metal and surface. The torque on the rolls is being zero.

9 Explain the term Extrusion process. (Nov 2009)

Ans: The extrusion process consists of compressing a metal inside a chamber to force it out through a small opening which is called as **die**. Any plastic material can be successfully extruded. A large number of extruded shapes which are commonly used are tubes, rods, structural shapes and lead covered cables. During the process, a heated cylindrical billet is placed in the container and forced out through a steel die with the help of a ram or plunger.

10 What are the disadvantages of forging processes? (Dec. 2009)

- Complicated shapes cannot be produced.
- Generally used for large parts.
- Because of cost of dies, process is costly.

11. What is the purpose of rolling ?

The main purpose of rolling is to convert larger sections such as ingots into smaller sections, which can be used directly in as rolled state or stock for working through other process.

12. What are the types of rolling mills?

According to the number and arrangement of the rolls, rolling mills are classified as follows:

1. Two-high rolling mill
2. Three-high rolling mill
3. Four-high rolling mill
4. Tandem rolling mill
5. Cluster rolling mill
6. Planetary rolling mill

13. Explain cluster rolling mill.

It is a special type of four high rolling mill. In this, each of the two working rolls is backed up by two or more of the larger back up rolls.

14. What is tandem rolling mill?

It is a set of two or three stands of rolls set in parallel alignment. This facilitates a continuous pass through each one successively without change of direction of the metal or pause in the rolling process.

15. What is the main function of planetary rolling mill?

The main feature of this mill is that, it reduces a hot slab to a coiled strip in a single pass.

16. Define Extrusion. (Nov 2013)

The extrusion process consists of compressing a metal inside a chamber to force it out through a small opening which is called as die.

17. Which extrusion requires less force and define it.

As compared to direct extrusion, less total force is required in indirect extrusion.

In this type, the ram or plunger used is hollow and as it presses the billet against the backwall of the closed chamber, the metal is extruded back into the plunger.

18. What is forging? (Nov 2013)

Forging is the process of shaping heated metal by the application of sudden blows (hammer forging) or steady pressure (press forging) and makes use of the characteristic of plasticity of the material.

19. How is forging classified?

According to the equipments utilized for forging, they are classified as follows:

1. Smith die (Open die) forging;
   - (a) Hand forging
   - (b) Power forging
2. Impression die (Closed die) forging:
   - (a) Drop forging
   - (b) Press forging
   - (c) Maching or upset forging
   - (d) Roll forging

20. Define smithing.

Smithing is the act or art of working on forging metals, as iron, into any required shape.

21. Define ball peen hammer.

It is most suitable hammer for hand forging operations. It has a tough cast steel or forged steel head which is fitted to a wooden handle. Once end of the head is flat called as **face** i.e. haedened and polished. It is used for general striking and hammering purpose. Another end is half ball shaped called as **peen** i.e. used for riveting or burring-over purpose.

22. Define angle of bite for rolling. (Nov 2014)

Angle of bite is the angle between the entrance plane and the centre lane of the rolls

23. What is upsetting ? (May 2014)

It is a process through which the cross-section of a metal piece is increased with a corresponding increase in its length.

24. What is setting down?

Ans: Setting down is the operation through which the rounding of a corner is removed, to make it square by uaing a set hammer.

25. Explain fullering. (May 2013)

Fullering is also called as **spreading.** Fullering the metal along the length of the workpiece is done bu working spearate sections. In this, the axis of the work piece is positoned perpendicular to the width of the flat die.

26. Define the term extrusion ratio. (Nov 2011)

It is defined as the ratio of the cross section area of the straight billet to the final cross sectional area of the extruded section.

27. What happens due to swaging?

By swaging, one end of a tube is reduced in diameter and passed through the die, whereas on the other side of the die this end is gripped in tongs which are connected to the draw bench

28. What is cold forging?

Cold forging is a cold upsetting process adapted for large scale production of small cold upset parts from a wire stock. For example, small bolts, rivets, screws, pins, nails and small machine parts, small balls for ball bearings, etc.

29. Define swaging.

Rotary swaging is a process of reducing the cross-sectional shape of bars, rods, tubes or wires by a large number of impacting blows with one or more pairs of opposed dies.

30. Compare hot and cold working.

S. No.	Hot working	Cold working
1.	Hot working is carried out above the recrystallisation temperature but below the melting point, hence deformation of metal and recovery takes place simultaneously.	Cold working is carried out below the recrystallisation temperature and as such there is not appreciable recovery of metal.
2.	During the process, residual stresses are not developed in the metal.	During the process, residual stresses are developed in the metal.
3.	Because of higher deformation temperature used, the stress required for deformation is less.	The stress required to cause deformation is much higher.

PART – B & C

1. (i) Classify the types of rolling mills and sketch them. May 2006, Nov 2009, 2014)
(ii) Explain forging operations. (Nov 2012, 2013)

Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 367

2.List out the various forging defects (May 2006, 2015)

Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 381

3. Describe the indirect extrusion process for solid and hollow work piece and hydrostatic extrusion

process. (May 2006, 2010, Nov 2013) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 419*
4. Explain briefly the wire drawing process. (May 2006, 2008, 2013, Nov 2014) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 418*
5. Describe and specify the merits and limitations of different kinds of rolling mills. (May 2007) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 367*
6.Explain hot working and cold working process (May 2013, Nov 2014) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 57*
7.(i) Describe the difference between a bloom, a slab and a billet. (May 2008) **(ii) Explain ring rolling and thread rolling processes. (May 2008, 2015)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 364,371*
8. Explain briefly with neat sketch, direct and indirect extrusion process. (May 2008, 2015, 2016, Nov 2014) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 419*
9. Explain with neat sketches of upsetting and drawing down operations. (Nov 2009) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 383*
10.What is shape rolling? Mention the products of shape rolling and explain the production of anyone of these products with sketch (Nov 2012) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 358*
11.Distinguish between open die and closed die forging.(Nov 2012) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No:383,388*
12. Distinguish between wire drawing and tube drawing. (Nov 2009, May 2010) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 418*
13.(i) Classify the types of rolling mills and sketch them. May 2006, Nov 2009, 2014) **(ii) Explain forging operations. (Nov 2012, 2013)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 367*

UNIT IV – SHEET METAL PROCESSES

PART – A

1. What is punching operation ? (May 2006)

It is the cutting operation with the help of which various shaped holes are produced in the sheet metal. It is similar to blanking; only the main difference is that, the hole is the desired product and the material punched out to form a hole is considered as a waste.

2. What is super plastic forming operation ? (May 2006)

Superplastic forming is a metalworking process for forming sheet metal. It works upon the theory of superplasticity, which means that a material can elongate beyond 100% of its original size

3.What is press brake? (May 2007)

Press brake (bending brake) is an open frame press used for bending, cutting and forming. Generally, it handless long workpieces in the form of strips. Usually press brake have long dies and suitable and suitable for making long straight line bends.

4.Define hydro forming process. (May 2007, 2008)

Hydro forming is a process which can be carried out in two ways:

1) Hydro - mechanical forming
2) Electro - hydraulic forming

Hydro - mechanical forming: In this method , the blank is placed over the punch whose shape is similar to inner of the find workpiece.

Electro - hydraulic forming : This method involves the conversion of electrical energy into mechanical energy in a liquid medium. Electric spark in a liquid produces shock waves and pressures which can be used for metal forming.

5.Give the difference between punching and blaking. (May 2008)

Blanking : It is the cutting operation of a flat metal sheet. The article punched out is known as **blank**. Blank is the required product of the operation and the metal left behind is considered as a waste.

Punching: It is similliar to blanking; only the main difference is that, the hole is the desired product and the material punched out to form a hole is considered as a waste.

6.How is hydro forming is similar to rubber forming? (May 2008)

In both the sheet metal working processes sheet metal is pressed between a die and rubber block.

Under pressure, the rubber and sheet metal are driven into the die and confirm to its shape by forming the part.

7.What do you mean by minimum bend radius? (Nov 2008)

It is the radius of curvature on inside surface of the bend. If the bend radius is too small, then cracking of a material on the outer tensile surface takes place. To prevent any damage to punch and die, the bend radius should not be less than 0.8mm.

8. Define Embossing. (Nov 2009)

With the help of this operation, specific shapes or figures are produced on the sheet metal. It is used for decorative purpose or giving details like names, tradema rks, specifications, etc. On the sheet metal.

9. Name the operations of sheet metal working

The main operations are as follows:

- Shearing
- Bending
- Drawing
- Forming

10. Explain Shearing

It is process of cutting a straight line across a strip, sheet or bar shearing process has three important stages;

1) Plastic deformation
2) Fracture (Crack propagation)
3) Shear

Shearing is performed either by using hand or by using machines also.

11.Explain Bending

The bending operation involves stretching of metal on the outer surface and compressing it on inner surface along a neutral axis which unchanged. Sheet metal can be bent by hammering on a base by hand or by bending machines.

12. Explain drawing

Drawing operation is used to produce thin walled hollow shapes in sheet metal. It is carried out by using a die and punch on a press machine. If the drawn length is more than the width then the operation is called as **deep drawing.**

13.Explain forming

For safety purpose, the edges of the sheet metal products are formed of folded. Alse, formed edges provide stiffness to the components so that they will not retain their shapes during handling.

14. What is press working?

Press working is a chip less manufacturing process by which various components are produced from sheet metal

15. Why are press machines preferred?

Press machines are preferred for mass production of similar components, because for each component separate tool is required and the cost of every press tool is very high as compared to the cost of other cutting tools.

16. What is the difference between manually and power operated press?

The main difference between manually operated press and power press is that, the former moves by means of a screw and the latter by means of a crankshaft.

17. **Explain press operations.**

Press operations may be grouped into two categories i.e. cutting operations and forming operations. In cutting operations, the workpiece is stressed beyond its ultimate strength whereas; in forming operations, the stresses are below the ultimate strength of the metal.

18. Define trimming.

It is used for cutting unwanted excess material from the perphery of a previously formed workpiece.

19.Define shaving

It is almost similar to trimming, but only small amount of material is removed during the operation as compared to trimming

20. Define lancing

In this operation, there is a cutting of the sheet metal through a small length and bending this small cut portion downwards

21. What is spring back? (May 2010, 2012, 2013, 2014, Nov 2013)

At the end of a metal working process, when the pressure on the metal is released, there is an elastic recovery by the material. Due to this total deformation of metal will get reduced. This phenomenon is called spring back.

22. What is clearance?

During metal cutting, the shape of the punch is similar to die opening except that, it is smaller on each side. This difference in dimensions between die and punch(making members of a die set) is known as **clearance**.

23. Why is angular clearance provided?

Angular clearance is provided to enable the blank to clear the die easily and fall freely out of the die block. If the angular clearance is not provided, the punched blank would remain stuck in the die block.

24. What is tonnage capacity?

The tonnage capacity of a mechanical press is calculated by,

Tonnage capacity = Shear strength of a crankshaft material x Area of crankshaft bearings.

The tonnage capacity of a hydraulic press is calculated by ,Tonnage capacity = Piston area x Oil pressure in the cylinder.

25. What is die space and press adjustment?

Die space: The available surface for mounting the die and punch components in the press.

Press adjustment: The distance through which the ram can be lowered below its shut height position.

26. **Define penetration.**

The distance which the punch enters into the stock to cause rupture is called as **penetration,** and generally it is given in terms of the percentage of the stock thickness. The percentage penetration depends on the mateial being cut and thickness of the material.

27. Explain bend radius.

It is the radius of curvature on inside of the bend. If the bend radius is too small, then cracking of a material on the outer tensile surface takes place. To prevent any damage to punch and die, the bend radius should do not be less than 0.8mm.

28.Define formability. (Nov 2010)

Formability represents the response and suitability of the material for forming processes.

29. What is process of fracturing?

It states that, ductility of the metal is lower if its section size is larger.

It refers to identical metal from which specimens of different section thickness have been machined and tested.

30.What is explosive forming and how is it classified?

Explosive forming makes use of the pressure wave generated by an explosion in a fluid, for applying the pressure against the wall of the die. The explosives are used in the form of rod, sheet, granules, stick, liquid, etc. According to the placement of the explosive (charge) the operations are divided in two categoies:

i. Stand off operation ii. Contact operation.

PART B & C

1. Explain principle of magnetic pulse forming? (May 2006, 2010, 2013)

Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 388

2. Describe the electro hydraulic process? (May 2006, 2008, Nov 2012) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 489*
3. What is drawing operation? Explain with neat sketch (May 2006) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 471*
4. Describe the various test methods used in sheet metal forming (May 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 444*
5. Explain as details the working principles and applications of any two special forming (May 2008) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 353*
6. Explain the super plastic forming process. (May 2010, 2013) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 484*
7. (i) Explain the rubber pad forming? (May 2016, Nov 2014) **(ii) Discuss the characteristics of metal and its importance to sheet metal forming.** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 220,444*
8. Name and describe the common bending operations. (Nov 2012, 2008, May 2010) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 459*
9. What is an explosive forming? Explain with the sketches? (Nov 2008, 2012, 2013) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 487*
10. (i) Write short notes on hydro forming.(Nov 2009, May 2010, 2016) **(ii) Explain with a neat sketch the principle of stretch forming.(Nov 2009, 2014)** **(iii) Explain the principle of metal spinning process. (May 2006, Nov 2009)** *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 480,470,480*

UNIT V – MANUFACTURE OF PLASTIC COMPONENTS
PART – A
1. What are the characteristic of thermoplastics ? (May 2006, Nov 2010) Themoplastics polymers soften when heated and harden, when cooled.These types of polymers are soft and ductile. They have low melting temperature and can be repeatedly moulded and remoulded to the required shapes.
2. List out the material for processing of plastics? (May 2006) The following mentioned are the various polymer additives used in practice: i. Filler material ii. Plasticizers iii. Stabilizers iv. Colorants v. Flame retardants vi. Reinforcements vii. Lubricants
3. List the advantage of cold forming of plastics? (May 2007) • Cold forming can be carried out at room temperature • It is used to produce filament and fibres • It is a simple process.
4. What is film blowing? (May 2007) In this process a heated doughy paste of plastic compound is passed through a series of hot rollers, where it is squeezed into the from of thin sheet of uniform thickness. It is used for making plastic sheets and films.
5. What are the types of plastics? (May 2008) Polymers are classified in two major categories: • Thermoplastic polymers (Soften when heated and harden when cooled) • Thermosetting polymers (Soften when heated and permanently hardened when cooled).
6 What is compression moulding? (May 2008) The main objective is to melt the material due to compression.

7 Name the parts made by rotational moulding. **(Dec 2008)**

Rotational moulding process is mostly used for the production of toys in P.V.C like horse, boats, etc. Larger containers upto 20 m^3 capacity, fuel tanks of automobile are made from polythene and nylon. This process is also used for production of large drums, boat hulls, buckets, housings and carrying cases.

8 What is parison ? **(Dec 2008)**

Blow moulding consists of extrusion of the heated tubular plastic piece called as **parison** which is transferred to the two piece mold.

9 Define degree of polymerization. **(Dec 2009)**

It is the number of repetitive units present in one molecule of a polymer.

$$\text{Degree of polymerization} = \frac{\text{Molecular weight of a polymer}}{\text{Molecular weight of a single monomer}}$$

10 What is rotational mouldig of plastics? **(Dec. 2009)**

- Rotataional moulding also called as **roto-moulding.**
- A measured amount of polyemer power is placed in a thin walled metal mould and the mould is closed.
- Then the mould is rotated about two mutually perpendicular axes as it is heated.

11. Name the characteristic of polymer.(Any Four)

The important characteristic of polymers are

1) Light weight
2) High Corrosion resistance.
3) Low density.
4) Low thermal and electrical properties.
5) Low mechanical properties (can be improved by fibre reinforcement of plastics).

12. Give the mechanism of thermosetting polymers.

These plastics are formed by condensation polymerisation. During initial heating, covalent cross-links are formed which anchor the chains together and resist the vibrational and rotational chain motions at high temperature. If heated to excessively high temperature, there occurs severance of these crosslink bonds leading to polymer degradation.

13. Differentiate thermosetting and thermoplastic polymers

S. No.	**Thermoplastics**	**Thermosetting**
1	They are formed by addition polymerisation	They are formed by condensation.
2	They are linear polymers composed of chain molcules.	They are composed of three dimensional network of cross-linked molecules

14. Define Isomerism.

It is a phenomenon where different atomic configurations are responsible for the formation of same configuration.

15. Define High polymers.

Polymers which have a very high molecular weight ranging between 10,000 and 1,000,000 g/mol. are known as High-polymers. They are mainly solids.

16. Give the three methods of mechanism of polymerisation :

There are three general methods or mechanisms of polymerisation :

(1) Addition Polymerisation

(2) Copolymerization (3) Condensation polymerisation
17. Define addition polymerization. The Polymer is produced by adding a second monomer to the first, a third monomer to this dimmer and so on till the long polymer chain is terminated. This process is called as addition polymerisation.
18. Define condensation polymerisation and give its other name. Condensation polymerisation is also known as **step-growth polymerisation**. It is the formation of polymers by step wise intermolecular chemical reactions that normally involve atleast two different monomers.
19. Why are additives used and enlist its advantages? Additives used to improve the properties and performance of polymers. Advantages of additives when added to the polymers are: • Improve mechanical properties. • Reduce the cost. • Improve the thermal processing such as moldability. • Improve the appearance and aesthetic properties. Improve surface and chemical characteistics of the polymers
20. Give the types of injection moulding. • Ram or Plunger type Injection Moulding • Screw type Injection Moulding
21. What are the applications of injection moulding? Typical parts produced by this process are cups, chairs, toys, containers, knobs, automobile parts (car dash-board, car handles, etc), air conditioner parts, plumbing fittings, electrical fittings, etc. This process is used for making components which consists of complex threads. Production of intricate shapes and thin walled parts like radiator fan can be done by this process.
22. Enlist the types of blow moulding. There are various types of blow moulding process which are as follows : • Injection blow moulding • Extrusion blow moulding • Multi-larger blow moulding
23.What is the difference between rolling and calendering? The main difference between rolling and calendering is that, in calendering there is appreciable thickening after the material has reached minimum thickness at the roll gap and the pre-calendered material is not in the sheet form.
24.Define extrusion moulding . Extrusion process is a continuous process in which the hot plasticized material forced through the die opening of required shape.
25.Explain thermoforming. It is a series of processes for forming thermoplastic sheet or film over a mould with the application of heat and pressure.
26.What are the processes used for thermosetting plastics? For processing of thermosetting plastics following processes are most commonly used: (1) Compression moulding and (2) Transfer moulding
27.Give the application of compression moulding. • Compression moulding is used for making flatware's, gear, buttons, buckles, knobs, handles, dishes, container taps and fittings • Also used for moulding of electrical and electronic components, washing machine agitators and housings.

28.What is gate moulding?

This is the process of forming articles in a closed mould, where the fluid plastic material is conveyed into the mould cavity under pressure from outside of the mould.

29.Name the processing methods of plastics?

i) Plug and ring forming (ii)pressure forming

(iii)Draw forming (iv)Reaction injection moulding (RIM)

(v)Drape forming

30.Define pressure forming?

In this method, the heated plastics sheet is formed into the required shape between a pair of male and female dies. In this process vacuum is not used.

PART B&C

1. Sketch and explain the injection molding process for plastics.(May 2007, 2008, 2015, Nov 2009)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 534

2. Discuss the advantage and application of compression and transfer molding process. (May 2007, 2015)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 543

3. Describe thermoforming and transfer molding process. (May 2008)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 542,544

4. Illustrate with suitable sketch the blow molding process for producing plastics serving bottles. (May 2013, 2015, Nov 2008)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 539

5.Explain the process of compression moulding with neat diagram (May 2016, Nov 2013)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 543

6. Give the sequence of operation in transfer molding for thermosetting plastic process. (Nov 2008)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 544

7. Describe the thermoforming process and thermosetting plastics. (Nov 2008, 2009)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 204

8. Describe the various properties of plastics. (Nov 2009)
Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 198

9. Why is screw injection molding machine better than a ram type injection molding machine. (Nov 2009) *Ref : Manufacturing Engineering and Technology by Kalpakjian, Pg.No: 512*

FLUID MECHANICS AND MACHINERY - QUESTION BANK

UNIT I FLUID PROPERTIES AND FLOW CHARACTERISTICS

Units and dimensions- Properties of fluids- mass density, specific weight, specific volume, specific gravity, viscosity, compressibility, vapor pressure, surface tension and capillarity. Flow characteristics – concept of control volume - application of continuity equation, energy equation and momentum equation.

PART-A

1. Define density or mass density. (May/June2013)

Density of a fluid is defined as the ratio of the mass of a fluid to its volume.

Density, ρ = mass/volume (Kg/m^3)

$\rho_{water} = 1000\ Kg/m^3$

2. Define specific weight or weight density. (May/June2013)

Specific weight or weight density of a fluid is defined as the ratio between the weight of a fluid to its volume.

Specific weight, γ = weight/volume (N/m^3)

$\gamma = \rho g$

$\gamma_{water} = 9810\ N/m^3$

3. Define specific volume. (May/June 2012)

Specific volume of a fluid is defined as the volume of fluid occupied by an unit wt or unit mass of a fluid.

Specific volume vs = volume/ wt = $1/\gamma = 1/\rho g$ ----- for liquids

Specific volume vs = volume/ mass = $1/\rho$ ----- for gases .

4. Define dynamic viscosity. (Nov/Dec 2010)

Viscosity is defined as the property of fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

$$\zeta = \mu \frac{du}{dy}$$

μ – dynamic viscosity or viscosity or coefficient of viscosity ($N\text{-}s/m^2$)

$1\ N\text{-}s/m^2 = 1\ Pa\text{-}s = 10$ Poise

5. Define Kinematic viscosity. (Nov/Dec 2011,14)

It is defined as the ratio between the dynamic viscosity and density of fluid.

$\nu = \mu/\rho\ (m^2/s)$

$1\ m^2/s = 10000$ Stokes (or) 1 stoke = $10^{-4}\ m^2/s$

6. Types of fluids. (May/June2012)

Ideal fluid, Real fluid, Newtonian fluid, Non-Newtonian fluid, Ideal Plastic fluid.

7. Define Compressibility. (May/June 2013)

It is defined as the ratio of volumetric strain to compressive stress.

Compressibility, β = (d Vol/ Vol) / dp (m^2/N)

8. Define Surface Tension. (May/June 2013)

Surface tension is defined as the tensile force acting on the surface of the liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

Surface Tension, σ = Force/Length (N/m)

$\sigma_{water} = 0.0725$ N/m $\sigma_{Mercury} = 0.52$ N/m

9. Surface tension. (Nov/Dec 2013), (May/June 2014)

Surface tension on liquid droplet, $\sigma = pd/4$

Surface tension on a hollow bubble, $\sigma = pd/8$

Surface tension on a liquid jet, $\sigma = pd/2$

σ – surface tension (N/m)

d – diameter (m)

p – pressure inside (N/m^2)

$p_{total} = p_{inside} + p_{atm}$ $p_{atm} = 101.325 \times 10^3$ N/m^2

10. Define Capillarity. (Nov/Dec 2013)

Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid. The rise of liquid surface is known as capillary rise while the fall of liquid surface is known as capillary depression.

Capillary Rise or fall, $h = (4\sigma \cos\theta) / \rho g d$

$\theta = 0$ for glass tube and water $\theta = 130^o$ for glass tube and mercury

11. Define Vapour Pressure.

When vaporization takes place, the molecules start accumulating over the free liquid surface exerting pressure on the liquid surface. This pressure is known as Vapour pressure of the liquid.

12. Define Control Volume. (May/June2012)

A control volume may be defined as an identified volume fixed in space. The boundaries around the control volume are referred to as control surfaces. An open system is also referred to as a control volume.

13. Write the continuity equation. (Nov/Dec 2013)

The equation based on the principle of conservation of mass is called continuity equation.

$\delta u/\delta x + \delta v/\delta y + \delta w/\delta z = 0$ ----- three dimensional flow

$\delta u/\delta x + \delta v/\delta y = 0$ ----- two dimensional flow

$Q = a_1 v_1 = a_2 v_2$ ----- one dimensional flow

14. List the types of fluid flow. (May/June 2014)

Steady and unsteady flow, Uniform and non-uniform flow, Laminar and Turbulent flow

Compressible and incompressible flow, Rotational and ir-rotational flow, One, Two and Three dimensional flow.

15. Define Steady and Unsteady flow. (May/June 2014)

Steady flow

Fluid flow is said to be steady if at any point in the flowing fluid various characteristics such as velocity, density, pressure,etc do not change with time.

$\partial V/\partial t = 0$ $\partial p/\partial t = 0$ $\partial \rho/\partial t = 0$

Unsteady flow

Fluid flow is said to be unsteady if at any point flowing fluid any one or all characteristics which describe the behaviour of the fluid in motion change with time.

$\partial V/\partial t \neq 0$ $\partial p/\partial t \neq 0$ $\partial \rho/\partial t \neq 0$

16. Define Uniform and Non-uniform flow.

Uniform flow

When the velocity of flow of fluid does not change both in direction and magnitude from point to point in the flowing fluid for any given instant of time, the flow is said to be uniform.

$\partial V/\partial s = 0$ $\partial p/\partial s = 0$ $\partial \rho/\partial s = 0$

Non-uniform flow

If the velocity of flow of fluid changes from point to point in the flowing fluid at any instant, the flow is said to be non-uniform flow.

$\partial V/\partial s \neq 0$ $\partial p/\partial s \neq 0$ $\partial \rho/\partial s \neq 0$

17. Compare Laminar and Turbulent flow.

Laminar and Turbulent flow

A flow is said to be laminar if Reynolds number is less than 2000 for pipe flow. Laminar flow is possible only at low velocities and high viscous fluids. In laminar type of flow, fluid particles move in laminas or layers gliding smoothly over the adjacent layer.

Turbulent flow

In Turbulent flow, the flow is possible at both velocities and low viscous fluid. The flow is said to be turbulent if Reynolds number is greater than 4000 for pipe flow. In Turbulent type of flow fluid, particles move in a zig – zag manner.

18. Define Compressible and incompressible flow.

Compressible flow

The compressible flow is that type of flow in which the density of the fluid changes from point to point i.e. the density is not constant for the fluid. It is expressed in kg/sec.

$\rho \neq$ **constant**

Incompressible flow

The incompressible flow is that type of flow in which the density is constant for the fluid flow. Liquids are generally incompressible. It is expressed in m^3/s.

$\rho =$ **constant**

19. Define Rotational and Ir-rotational flow.

Rotational flow

Rotational flow is that type of flow in which the fluid particles while flowing along stream lines and also rotate about their own axis.

Ir-rotational flow

If the fluid particles are flowing along stream lines and do not rotate about their own axis that type of flow is called as ir-rotational flow

20. Define One, Two and Three dimensional flow.

One dimensional flow

The flow parameter such as velocity is a function of time and one space co-ordinate only. $u = f(x), v = 0$ & $w = 0$.

Two dimensional flow

The velocity is a function of time and two rectangular space co-ordinates. $u = f_1(x, y), v = f_2(x, y)$ & $w = 0$.

Three dimensional flow

The velocity is a function of time and three mutually perpendicular directions.

$u = f_1(x, y, z), v = f_2(x, y, z)$ & $w = f_3(x, y, z)$.

21. Write the Bernoulli's equation applied between two sections.

$$p_1/\rho g + v_1^2/2g + Z_1 = p_2/\rho g + v_2^2/2g + Z_2$$

$p/\rho g$ = pressure head

$v^2/2g$ = kinetic head

Z = datum head

22. State the assumptions used in deriving Bernoulli's equation.

Flow is steady; Flow is laminar; Flow is irrotational;

Flow is incompressible; Fluid is ideal.

23. Write the Bernoulli's equation applied between two sections with losses.

$$p_1/\rho g + v_1^2/2g + Z_1 = p_2/\rho g + v_2^2/2g + Z_2 + h_{loss}$$

24. List the instruments works on the basis of Bernoulli's equation.

Venturi meter; Orifice meter; Pitot tube.

25. Define Impulse Momentum Equation (or) Momentum Equation. The total force acting on fluid is equal to rate of change of momentum. According to Newton's second law of motion, **F = ma** **F dt = d(mv)**
26. Write the expression for loss of head at the entrance of the pipe. $\mathbf{h_i = 0.5V^2/2g}$ h_i = Loss of head at entrance of pipe. V = Velocity of liquid at inlet of the pipe.
27. Write the expression for loss of head at exit of the pipe. $\mathbf{h_o = V^2/2g}$ Where, h_o = Loss of head at exit of the pipe. V = Velocity of liquid at inlet and outlet of the pipe.
28. Give an expression for loss of head due to an obstruction in pipe. (May/June 2013) Loss of head due to an obstruction = $\mathbf{V^2 / 2g\ (\ A/\ Cc\ (A\text{-}a\ )\ \text{-}1\ )^2}$ Where, A = area of pipe, a = Max area of obstruction, V = Velocity of liquid in pipe A-a = Area of flow of liquid
29. What is compound pipe or pipes in series? When the pipes of different length and different diameters are connected end to end, then the pipes are called as compound pipes or pipes in series.
30. What is mean by parallel pipe? and write the governing equations. (Nov/Dec 2011) When the pipe divides into two or more branches and again join together downstream to form a single pipe then it is called as pipes in parallel. The governing equations are: $\mathbf{Q_1 = Q_2 + Q_3\ h_{f1} = h_{f2}}$
PART-B
1. State Bernoulli's theorem and assumptions for steady flow of an incompressible fluid. (May/June 2013) *Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
2. The space between two square flat parallel plate is filled with oil. Each side of the plate is 600mm. The thickness of the oil films is 12.5mm. The upper plate, which moves at 2.5m /s, requires a force of 98.1 N to maintain the speed. Determine **(i) The dynamic viscosity of the oil in poise.** **(ii) The kinematic viscosity of the oil in strokes if the specific gravity of the oil is 0.95.** **(May/June 2013)** *Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", Page No from 6 to 7 and from 10 to 11.*
3. A U-tube is made of two capillaries of diameter 1mm and 1.5mm respectively. The tube is kept vertically and partially filled with water of surface tension 0.0736 N/m and zero contact angle. Calculate the difference in the levels of the menisci caused by the capillary. **(May/June 2012)** *Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", Page No from 6 to 7 and from 10 to 11.*
4. A pipe line 60cm in diameter bifurcates at a Y-junction into two branches 40cm and 30cm in diameter. If the rate of flow in the main pipe is 1.5m^3/s and the mean velocity of flow in the 30cm pipe is 7.5m/s. Determine the rate of flow in the 40cm pipe. (May/June 2012) *Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11*
5. Explain in detail the Newton's law of viscosity. Briefly classify the fluids based on the density and viscosity. Give the limitations of applicability of Newton's law of viscosity. (May/June 2014) *Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11*
6. Derive energy equations and state the assumptions made while deriving the equations.May/June 2014)

Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11

UNIT II FLOW THROUGH CIRCULAR CONDUITS

Hydraulic and energy gradient - Laminar flow through circular conduits and circular annuli-Boundary layer concepts – types of boundary layer thickness – Darcy Weisbach equation –friction factor- Moody diagram-commercial pipes- minor losses – Flow through pipes in series and parallel.

PART-A

1. Mention the range of Reynold's number for laminar and turbulent flow in a pipe. (May/June 2014)

If the Reynold's number is less than 2000, the flow is laminar. But if the Reynold's number is greater than 4000, the flow is turbulent flow.

2. What does Haigen-Poiseulle equation refer to? (Nov/Dec 2011)

The equation refers to the value of loss of head in a pipe of length 'L' due to viscosity in a laminar flow.

3. What is Hagen poiseuille's formula? (May/June 2012)

$(P_1-P_2) / \rho g = h_f = 32\ \mu \bar{U} L / \rho g D^2$

The expression is known as Hagen poiseuille formula.

Where $P_1-P_2 / \rho g$ = Loss of pressure head, $\bar{U}$= Average velocity,

μ = Coefficient of viscosity, D = Diameter of pipe,

L = Length of pipe

4. Write the expression for shear stress? (Nov/Dec 2012)

Shear stress $\zeta = - (\partial p/\partial x)(r/2)$

$\zeta max = - (\partial p/\partial x)(R/2)$

5. Give the formula for velocity distribution: - (Nov/Dec 2012)

The formula for velocity distribution is given as

$u = - (\frac{1}{4}\mu)(\partial p/\partial x)(R^2-r^2)$

Where R = Radius of the pipe, r = Radius of the fluid element

6. Give the equation for average velocity : - (May/June 2013)

The equation for average velocity is given as

$\bar{U} = - (1/8\mu)(\partial p/\partial x) R^2$

Where R = Radius of the pipe

7. Write the relation between Umax and Ū? (May/June 2013)

$Umax / \bar{U} = \{ - (\frac{1}{4}\mu)(\partial p/\partial x) R^2 \} / \{ - \frac{1}{8}\mu (\partial p/\partial x) R^2 \}$

$Umax / \bar{U} = 2$

8. Give the expression for the coefficient of friction in viscous flow? (Nov/Dec 2013)

Coefficient of friction between pipe and fluid in viscous flow **f =16/ Re**

Where, f = Re = Reynolds number

9. What are the factors to be determined when viscous fluid flows through the circular pipe? (Nov/Dec 2013)

The factors to be determined are:

i. Velocity distribution across the section.
ii. Ratio of maximum velocity to the average velocity.
iii. Shear stress distribution.
iv. Drop of pressure for a given length.

10. Define kinetic energy correction factor.

Kinetic energy factor is defined as the ratio of the kinetic energy of the flow per sec based on actual velocity across a section to the kinetic energy of the flow per sec based on average velocity across the same section. It is denoted by (α).

K. E factor (α) = K.E per sec based on actual velocity / K.E per sec based on Average velocity

11. Define momentum correction factor (β):

It is defined as the ratio of momentum of the flow per sec based on actual velocity to the momentum of the flow per sec based on average velocity across the section.

β= Momentum per sec based on actual velocity/Momentum Per sec based on average velocity

12. Define Boundary layer.

When a real fluid flow passed a solid boundary, fluid layer is adhered to the solid boundary. Due to adhesion fluid undergoes retardation thereby developing a small region in the immediate vicinity of the boundary. This region is known as boundary layer.

13. What is mean by boundary layer growth?

At subsequent points downstream of the leading edge, the boundary layer region increases because the retarded fluid is further retarded. This is referred as growth of boundary layer.

14. Classification of boundary layer.

(i) Laminar boundary layer, (ii) Transition zone, (iii) Turbulent boundary layer.

15. Define Laminar boundary layer.

Near the leading edge of the surface of the plate the thickness of boundary layer is small and flow is laminar. This layer of fluid is said to be laminar boundary layer.

The length of the plate from the leading edge, upto which laminar boundary layer exists is called as laminar zone. In this zone the velocity profile is parabolic.

16. Define transition zone.

After laminar zone, the laminar boundary layer becomes unstable and the fluid motion transformed to turbulent boundary layer. This short length over which the changes taking place is called as transition zone.

17. Define Turbulent boundary.

Further downstream of transition zone, the boundary layer is turbulent and continuous to grow in thickness. This layer of boundary is called turbulent boundary layer. .

18. Define Laminar sub Layer. (May/June 2013)

In the turbulent boundary layer zone, adjacent to the solid surface of the plate the velocity variation is influenced by viscous effects. Due to very small thickness, the velocity distribution is almost linear. This region is known as laminar sub layer.

19. Define Boundary layer Thickness.

It is defined as the distance from the solid boundary measured in y-direction to the point, where the velocity of fluid is approximately equal to 0.99 times the free stream velocity (U) of the fluid. It is denoted by δ.

20. List the various types of boundary layer thickness.

Displacement thickness(δ*), Momentum thickness(θ), Energy thickness(δ**)

21. Define displacement thickness.

The displacement thickness (δ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in flow rate on account of boundary layer formation.

$$\delta^* = \int [\, 1 - (u/U) \,]\, dy$$

22. Define momentum thickness. (May/June 2013)

The momentum thickness (θ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.

$$\theta = \int [\, (u/U) - (u/U)^2 \,]\, dy$$

23. Define energy thickness.

The energy thickness (δ**) is defined as the distance by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation.

$\delta^{**} = \int [(u/U) - (u/U)^3]\, dy$
24. What is meant by energy loss in a pipe? When the fluid flows through a pipe, it looses some energy or head due to frictional resistance and other reasons. It is called energy loss. The losses are classified as; Major losses and Minor losses.
25. Explain the major losses in a pipe. The major energy losses in a pipe is mainly due to the frictional resistance caused by the shear force between the fluid particles and boundary walls of the pipe and also due to viscosity of the fluid.
26. Explain minor losses in a pipe. The loss of energy or head due to change of velocity of the flowing fluid in magnitude or direction is called minor losses. It includes: sudden expansion of the pipe, sudden contraction of the pipe, bend in a pipe, pipe fittings and obstruction in the pipe, etc.
27. State Darcy-Weisbach equation OR What is the expression for head loss due to friction? $h_f = 4flv^2 / 2gd$ where, h_f = Head loss due to friction (m), L = Length of the pipe (m), d = Diameter of the pipe (m), V = Velocity of flow (m/sec) f = Coefficient of friction
28. What are the factors influencing the frictional loss in pipe flow? Frictional resistance for the turbulent flow is, i. Proportional to v^n where v varies from 1.5 to 2.0. ii. Proportional to the density of fluid. iii. Proportional to the area of surface in contact. iv. Independent of pressure. v. Depend on the nature of the surface in contact.
29. Write the expression for loss of head due to sudden enlargement of the pipe. $h_{exp} = (V_1 - V_2)^2 / 2g$ Where, h_{exp} = Loss of head due to sudden enlargement of pipe. V_1 = Velocity of flow at pipe 1; V_2 = Velocity of flow at pipe 2.
30. Write the expression for loss of head due to sudden contraction. (May/June 2012) $h_{con} = 0.5\, V^2/2g$ h_{con} = Loss of head due to sudden contraction. V = Velocity at outlet of pipe.
PART-B& PART-C
1. Explain the losses of energy in flow through pipes. *Refer: ““Dr.R.KBANSAL, “Fluid Mechanics and Machinery”, ”, Page No from 6 to 7 and from 10 to 11.*
2. For a town water supply, a main pipe line of diameter 0.4m is required. As pipes more than 0.35m diameter are not readily available, two parallel pipes of same diameter are used for water supply. If the total discharge in the parallel pipes is same as in the single main pipe, find the diameter of parallel pipe. Assume coefficient of discharge to be the same for all the pipes. *Refer: ““Dr.R.KBANSAL, “Fluid Mechanics and Machinery”, ”, Page No from 6 to 7 and from 10 to 11.*
3. For a flow a viscous fluid flowing through a circular pipe under laminar flow conditions show that the velocity distribution is a parabola. And also show that the average velocity is half of the maximum velocity. (May/June 2012) *Refer: ““Dr.R.KBANSAL, “Fluid Mechanics and Machinery”, ”, Page No from 6 to 7 and from 10 to 11.*
4. A horizontal pipe line is 40m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end. For the first 25m of its length from the tank, the pipe is 150mm diameter and its diameter is suddenly enlarged to 300mm. The height of water level in the tank is 8m above the

Centre of the pipe. Considering all losses of head which is occur, determine the rate of flow. Take f=0.01 for both sections of the pipe. (May/June 2012)   *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
5. Oil with a density of 900kg/m3 and kinematic viscosity of 6.2 X 10-4 m2/s is being discharged by a 6mm diameter, 40 m long horizontal pipe from a storage tank open to the atmosphere. The height of the liquid level above the center of the pipe is 3m. Neglecting the minor losses, determine the flow rate of oil through the pipe. (Nov/Dec 2012)   *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
6. Two pipes of diameter 40 cm and 20 cm are each 300 m long. When the pipes are connected in series and discharge through the pipe line is 0.10 m3/sec, find the loss of head incurred. What would be the loss of head in the system to pass the same total discharge when the pipes are connected in parallel? Take f = 0.0075 for each pipe. (Nov/Dec 2012)   *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*

UNIT III DIMENSIONAL ANALYSIS
Need for dimensional analysis – methods of dimensional analysis – Similitude –types of similitude - Dimensionless parameters- application of dimensionless parameters – Model analysis.
PART-A
1. Define dimensional analysis. (Nov/Dec 2013)   Dimensional analysis is a mathematical technique which makes use of the study of dimensions as an aid to solution of several engineering problems. It plays an important role in research work.
2. Write the uses of dimension analysis. (May/June 2012)   • It helps in testing the dimensional homogeneity of any equation of fluid motion.   • It helps in deriving equations expressed in terms of non-dimensional parameters.   • It helps in planning model tests and presenting experimental results in a systematic manner.
3. List the primary and derived quantities. (May/June 2012)   **Primary or Fundamental quantities:** The various physical quantities used to describe a given phenomenon can be described by a set of quantities which are independent of each other. These quantities are known as fundamental quantities or primary quantities. Mass (M), Length (L), Time (T) and Temperature (θ) are the fundamental quantities.   **Secondary or Derived quantities:** All other quantities such as area, volume, velocity, acceleration, energy, power, etc are termed as derived quantities or secondary quantities because they can be expressed by primary quantities.
4. Write the dimensions for the followings. (May/June 2012)   Dynamic viscosity (μ) – $ML^{-1}T^{-2}$, Force (F) - MLT^{-2},   Mass density (ρ) – ML^{-3}, Power (P) -$ML^{2}T^{-3}$
5. Define dimensional homogeneity. (Nov/Dec2012)   An equation is said to be dimensionally homogeneous if the dimensions of the terms on its LHS are same as the dimensions of the terms on its RHS.
6. Mention the methods available for dimensional analysis. (Nov/Dec2012)   Rayleigh method, Buckinghum π method
7. State Buckingham's π theorem. May/June 2013)   It states that "if there are 'n' variables (both independent & dependent variables) in a physical phenomenon and if

these variables contain 'm' functional dimensions and are related by a dimensionally homogeneous equation, and then the variables are arranged into n-m dimensionless terms. Each term is called π term".

8. List the repeating variables used in Buckingham π theorem. (May/June 2013)

Geometrical Properties – l, d, H, h, etc,
Flow Properties – v, a, g, ω, Q, etc,
Fluid Properties – ρ, μ, γ, etc.

9. Define model and prototype.

The small scale replica of an actual structure or the machine is known as its Model, while the actual structure or machine is called as its Prototype. Mostly models are much smaller than the corresponding prototype.

10. Write the advantages of model analysis.

- Model test are quite economical and convenient.
- Alterations can be continued until most suitable design is obtained.
- Modification of prototype based on the model results.
- The information about the performance of prototype can be obtained well in advance.

11. List the types of similarities or similitude used in model analysis.

Geometric similarities, Kinematic similarities, Dynamic similarities

12. Define geometric similarities.

It exists between the model and prototype if the ratio of corresponding lengths, dimensions in the model and the prototype are equal. Such a ratio is known as "Scale Ratio".

13. Define kinematic similarities. (May/June 2012)

It exists between the model and prototype if the paths of the homogeneous moving particles are geometrically similar and if the ratio of the flow properties is equal.

14. Define dynamic similarities.

It exits between model and the prototype which are geometrically and kinematically similar and if the ratio of all forces acting on the model and prototype are equal.

15. Mention the various forces considered in fluid flow.

Inertia force, Viscous force, Gravity force,
Pressure force, Surface Tension force, Elasticity force

16. Define model law or similarity law.

The condition for existence of completely dynamic similarity between a model and its prototype are denoted by equation obtained from dimensionless numbers. The laws on which the models are designed for dynamic similarity are called Model laws or Laws of Similarity.

17. List the various model laws applied in model analysis.

Reynold's Model Law, Froude's Model Law,
Euler's Model Law, Weber Model Law, Mach Model Law

18. State Reynold's model law.

For the flow, where in addition to inertia force the viscous force is the only other predominant force, the similarity of flow in the model and its prototype can be established, if the Renold's number is same for both the systems. This is known as Reynold's model law. $\mathbf{Re_{(p)} = Re_{(m)}}$

19. State Froude's model law.

When the forces of gravity can be considered to be the only predominant force which controls the motion in addition to the force of inertia, the dynamic similarities of the flow in any two such systems can be established, if the Froude number for both the system is the same. This is known as Froude Model Law. $\mathbf{Fr_{(p)} = Fr_{(m)}}$

20. State Euler's model law. (May/June 2014)

In a fluid system where supplied pressures are the controlling forces in addition to inertia forces and other forces are either entirely absent or in-significant the Euler's number for both the model and prototype which known as Euler Model Law.

21. State Weber's model law.

When surface tension effect predominates in addition to inertia force then the dynamic similarity is obtained by equating the Weber's number for both model and its prototype, which is called as Weber Model Law.

22. State Mach's model law.

If in any phenomenon only the forces resulting from elastic compression are significant in addition to inertia forces and all other forces may be neglected, then the dynamic similarity between model and its prototype may be achieved by equating the Mach's number for both the systems. This is known Mach Model Law.

23. Classify the hydraulic models.

The hydraulic models are classified as: Undistorted model & Distorted model

24. Define undistorted model.

An undistorted model is that which is geometrically similar to its prototype, i.e. the scale ratio for corresponding linear dimensions of the model and its prototype are same.

25. Define distorted model.

Distorted models are those in which one or more terms of the model are not identical with their counterparts in the prototype.

26. Define Scale effect.

An effect in fluid flow that results from changing the scale, but not the shape, of a body around which the flow passes.

27. List the advantages of distorted model.

- The results in steeper water surface slopes and magnification of wave heights in model can be obtained by providing true vertical structure with accuracy.
- The model size can be reduced to lower down the cast.
- Sufficient tractate force can be developed to produce bed movement with a small model.

28. Write the dimensions for the followings.

Applications of FMS installations are in the following areas.

Quantities	Symbol	Unit	Dimension
Area	**A**	**m^2**	**L^2**
Volume	**V**	**m^3**	**L^3**
Angle	**A**	**Deg. Or Rad**	**$M^0L^0T^0$**
Velocity	**v**	**m/s**	**LT^{-1}**
Angular Velocity	**ω**	**Rad/s**	**T^{-1}**
Speed	**N**	**rpm**	**T^{-1}**
Acceleration	**a**	**m/s^2**	**LT^{-2}**
Gravitational Acceleration	**g**	**m/s^2**	**LT^{-2}**
Discharge	**Q**	**m^3/s**	**L^3T^{-1}**
Discharge per meter run	**q**	**m^2/s**	**L^2T^{-1}**
Mass Density	**ρ**	**Kg/m^3**	**ML^3**
Sp. Weight or Unit Weight	**N/m^3**	**$ML^{-2}T^{-2}$**	
Dynamic Viscosity	**μ**	**$N\text{-}s/m^2$**	**$ML^{-1}T^{-1}$**
Kinematic viscosity	**m^2/s**	**L^2T^{-1}**	
Force or Weight	**F or W**	**N**	**MLT^{-2}**
Pressure or Pressure intensity	**p**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Modulus of Elasticity	**E**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Bulk Modulus	**K**	**N/m^2 or Pa**	**$ML^{-1}T^{-2}$**
Workdone or Energy	**W or E**	**N-m**	**ML^2T^{-2}**

Torque	**T**	**N-m**	ML^2T^{-2}
Power	**P**	**N-m/s or J/s or Watt**	ML^2T^{-3}

29. Give the benefits of FMS.

The benefits that can be expected from an FMS include

• Increased machine utilization
• Fewer machines required
• Reduction in factory floor space required
¨ Greater responsiveness to change
• Reduced inventory requirements
• 1ower manufacturing lead times
• Reduced direct labour requirements and higher labor productivity
• Opportunity for unattended production

30. List any two advantages and disadvantages of FMS implementation.

Advantages

• Faster, lower-cost changes from one part to another which will improve capital utilization.
• 1ower direct labor cost, due to the reduction in number of workers.

Disadvantages

• Substantial pre-planning activity.
• Expensive, costing millions of dollars.

31. How does FMS classified based on level of flexibility?

FMS classified based on level of flexibility as,

• Production flexibility
• Machine flexibility
• Mix flexibility
• Product flexibility

PART-B& PART-C

1. What are the significance and the role of the following parameters?

i. Reynold's number
ii. Froude number
iii. Mach number
iv. Weber number **(May/June 2013)**
v.

Refer: "Mikell "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

2. The resisting force F of a plane during flight can be considered as dependent upon the length of aircraft (l), Velocity (v) air viscosity (μ), air density (ρ) and bulk modulus of air (k). Express the functional relationship between these variables using dimensional analysis. Explain the physical significance of the dimensionless groups arrived. (May/June 2013)

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

3. The efficiency of a fan depends on density, viscosity of the fluid, angular velocity, diameter of rotor and discharge. Express in terms of NON-DIMENSIONAL PARAMETERS. Using Buckingham's theorem. (May/June 2012)

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

4. A geometrically similar model of an air duct is built to 1/25 scale and tested with water which is 50 times more viscous and 800 times denser than air. When tested under dynamically similar conditions, the pressure

drop is 200 kN/m^2 in the model. Find the corresponding pressure drop in the full scale prototype and express in cm of water. (May/June 2012)

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

5. The power developed by hydraulic machines is found to depend on the head h, flow rate Q, density ρ , speed N, runner diameter D, and acceleration due to gravity g. Obtain suitable dimensionless parameters to correlate experimental results. (May/June 2014)

Refer: "Mikell "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

6.The capillary rise h is found to be influenced by the tube diameter D, density ρ , gravitational acceleration gand surface tension σ . Determine the dimensionless parameters for the correlation of experimental results. (May/June 2013)

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

UNIT IV PUMPS

Impact of jets - Euler's equation - Theory of roto-dynamic machines – various efficiencies– velocity components at entry and exit of the rotor- velocity triangles - Centrifugal pumps– working principle - work done by the impeller - performance curves - Reciprocating pump- working principle – Rotary pumps –classification.

PART-A

1. What is meant by Pump? (Nov/Dec 2011)

A pump is device which converts mechanical energy into hydraulic energy.

2. Mention main components of Centrifugal pump. (Nov/Dec 2011)

i) Impeller ii) Casing

iii) Suction pipe,strainer & Foot valve iv) Delivery pipe & Delivery valve

3. What is meant by Priming? (May/June 2014)

The delivery valve is closed and the suction pipe, casing and portion of the delivery pipe upto delivery valve are completely filled with the liquid so that no air pocket is left. This is called as priming.

4. Define Manometric head. (May/June 2012)

It is the head against which a centrifugal pump work.

5. Define Mechanical efficiency.(May/June 2013)

It is defined as the ratio of the power actually delivered by the impeller to the power supplied to the shaft.

6. Define overall efficiency. (Nov/Dec 2012)

It is the ratio of power output of the pump to the power input to the pump.

7. Define speed ratio, flow ratio. (May/June 2013)

Speed ratio: It is the ratio of peripheral speed at outlet to the theoretical velocity of jet corresponding to manometric head.

Flow ratio: It is the ratio of the velocity of flow at exit to the theoretical velocity of jet corresponding to manometric head.

8. Mention main components of Reciprocating pump. (May/June 2013)

- Piton or Plunger
- Suction and delivery pipe
- Crank and Connecting rod

9. Define Slip of reciprocating pump. When the negative slip does occur? (May/june 2013)

The difference between the theoretical discharge and actual discharge is called slip of the pump.

But in sometimes actual discharge may be higher then theoretical discharge, in such a case coefficient of discharge is greater then unity and the slip will be negative called as negative slip.

10. What is indicator diagram? (Nov/Dec 2013)

Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank.

11. What is meant by Cavitations?

It is defined phenomenon of formation of vapor bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapor pressure and the sudden collapsing of theses vapor bubbles in a region of high pressure.

12. What are rotary pumps?

Rotary pumps resemble like a centrifugal pumps in appearance. But the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps, It has the combined advantages of both centrifugal and reciprocating pumps.

13. What is meant by NPSH?

The net positive suction head (NPSH), The minimum pressure required at the suction port of the pump to keep the pump from cavitating. NPSHA is a function of your system and must be calculated, whereas NPSHR is a function of the pump and must be provided by the pump manufacturer.

14. List the losses in centrifugal pump.

- Mechanical friction power loss due to friction between the fixed and rotating parts in the bearing and stuffing boxes.
- Disc friction power loss due to friction between the rotating faces of the impeller (or disc) and the liquid.
- Leakage and recirculation power loss. This is due to loss of liquid from the pump and recirculation of the liquid in the impeller. The pressure difference between impeller tip and eye can cause a recirculation of a small volume of liquid, thus reducing the flow rate at outlet of the impeller.

15. Mention main components of Centrifugal pump.

i) Impeller ii) Casing
iii) Suction pipe, strainer & Foot valve iv) Delivery pipe & Delivery valve

16. Mention main components of Reciprocating pump.

`# Piton or Plunger
Suction and delivery pipe
Crank and Connecting rod

17. What is the role of process planning in CIM architecture?

The process planning function can ensure the profitability or non profitability of a part being manufactured because of the myriad ways in which a part can be produced.

18. What is dispatching?

Dispatching is the function of releasing all required items needed to perform an operation on a part so that part production may be accomplished at the time planned by the scheduling function.

19. What about shop-floor information?

Shop-floor information system is responsible for getting the required information down to the processing equipment local controllers and sequencing controllers as well as capturing real-time status data from the equipment and parts so that the feedback loops can effect corrections or normal continuation of operation as required.

20. Explain PDM.

Product Data Management (PDM) or Product Information Management (PIM) systems provide the tools to control access to and manage all product definition date. It does this by maintaining information (meta-data) about product information. Product Data Management (PDM) systems, when tightly integrated with other product development tools does this transparently and with minimal additional effort on the part of the user.

21. List different types of production monitoring system.

Three types production/ process monitoring systems are:

- Data acquisition systems
- Data logging system

- Multilevel scanning

22. What are the inputs to MRP system? (May/June 2012)

- Master production schedule
- Bill of material file
- Inventory record file

23.Write down three phases of shop floor control.(Nov/Dec 2012)

(i) Order release,
(ii) Order scheduling
(iii) Order progress

24.What is meant by procurement lead time?(Nov/Dec 2012)

The procurement lead time is the interval (usually in months) between the initiation of procurement action and the receipt into the supply system of the material produced.

25. What is meant by fixed order quantity model? (Nov/Dec 2013)

In fixed order quantity model, the size of the order (i,e, order quantity) is predetermined fixed, but the time of its placement (i.e, ordering time) is allowed to vary depending upon the fluctuation of demand.

26. What is foreign key?

A key used in one table to represent the value of a primary key in a related table. While primary keys must contain unique values, foreign keys may have duplicates. For instance, if we use student ID as the primary key in a Students table (each student has a unique ID), we could use student ID as a foreign key.

27. What is normalization?

The process of structuring data to minimize duplication and inconsistencies. The process usually involves breaking down a single table into two or more tables and defining relationships between those tables. Normalization is usually done in stages, with each stage applying more rigorous rules to the types of information which can be stored in a table.

28. Mention the different levels of data modelling.

The Data structures are created within a database. The extent of the relationships among them, plays an important role in determining the effectiveness of DBMS. Therefore the database design becomes a crucial activity in the database environment. The task of Database design is made simpler when data models are used. Models are "Simplified abstractions of real-world events or conditions".

For example, such abstractions will enable us to explore the characteristics of entities and the relationships that can be created among such entities. If the models are not logically sound, the database designs derived from them will not deliver the database system's promise of effective information drawn from an efficient database.

29. What is Network Data Model?

A network data model is simply a graph wherein nodes represent unique records, and links between nodes represent association between the corresponding records.

30. What is Hierarchical Data Model?

The hierarchical data model is similar to the network data model except that the relationships among the records are represented in the form of tree structure.

PART-B& PART-C

1. Explain the working principle of single and double acting reciprocating pumps, centrifugal pump with neat diagram in detail. Also explain the effects of inertia pressure and friction on the performance of the pump using indicator diagrams with and without air vessel.

Refer: "Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

2. Explain the working principle of screw pump, gear pump, lobe pump, and vane pump.

.Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

3. A single acting reciprocatory pump has a plunger of diameter 30cm and stroke of 20cm. If the speed of the pumps is 30rpm and it delivers 6.5lit/s of water, find the coefficient of discharge and the percentage slip of the pump.

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.
4. Explain about indicator diagram & characteristic curves of pumps with neat sketch. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
5. A centrifugal pump with an impeller diameter of 0.4m runs at 1450rpm. The angle at outlet of the backward curved vane is 25° with tangent. The flow velocity remains constant at 3m/s. If the manometric efficiency is 84%. Determine the fraction of the kinetic energy at outlet recovered as static head. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
5. Explain the working principle of double acting reciprocating pump. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*

UNIT V TURBINES

Classification of turbines – heads and efficiencies – velocity triangles. Axial, radial and mixed flow turbines. Pelton wheel, Francis turbine and Kaplan turbines- working principles - work done by water on the runner – draft tube. Specific speed - unit quantities – performance curves for turbines – governing of turbines.

PART-A

1. Define hydraulic machines.

Hydraulic machines which convert the energy of flowing water into mechanical Energy

2. Give example for a low head, medium head and high head turbine.

Low head turbine – Kaplan turbine
Medium head turbine – Modern Francis turbine
High head turbine – Pelton wheel

3. What is impulse turbine? Give example. (May/june 2012)

In impulse turbine all the energy converted into kinetic energy. From these the turbine will develop high kinetic energy power. This turbine is called impulse turbine. **Example:** Pelton turbine

4. What is reaction turbine? Give example.(May/June 2014)

In a reaction turbine, the runner utilizes both potential and kinetic energies. Here portion of potential energy is converted into kinetic energy before entering into the turbine. Example: Francis and Kaplan turbine.

5. What is axial flow turbine? (May/June 2014)

In axial flow turbine water flows parallel to the axis of the turbine shaft. Example: Kaplan turbine

6. What is mixed flow turbine? (Nov/Dec 2013)

In mixed flow water enters the blades radially and comes out axially, parallel to the turbine shaft. Example: Modern Francis turbine.

7. What is the function of spear and nozzle? (May/June 2014)

The nozzle is used to convert whole hydraulic energy into kinetic energy. Thus the nozzle delivers high speed jet. To regulate the water flow through the nozzle and to obtain a good jet of water spear or nozzle is arranged.

8. Define gross head and net or effective head. (Nov 2012)

Gross Head: The gross head is the difference between the water level at the reservoir and the level at the tailstock.
Effective Head: The head available at the inlet of the turbine.

9. Define hydraulic efficiency.

It is defined as the ratio of power developed by the runner to the power supplied by the water jet.

10. Define mechanical efficiency. (May/June 2013)

It is defined as the ratio of power available at the turbine shaft to the power developed by the turbine runner.

11. Define volumetric efficiency.

It is defined as the volume of water actually striking the buckets to the total water supplied by the jet.

12. Define overall efficiency.

It is defined as the ratio of power available at the turbine shaft to the power available from the water jet.

13. State Euler turbine equation.

The equation is based on the concepts of conservation of angular momentum and conservation of energy.

14. What are the methods of robot programming? (or) List out four methods of entering commands into the robot controller memory. (Nov 2014)

- On-line programming
- Lead through programming
- Textual robot languages
- Walk-through programming
- Mechanical programming
- Task programming
- Off-line programming

15. What are the ways of accomplishing lead through programming?

- Powered Lead through
- Manual Lead through

16. What are the components of DDC? (Nov/Dec 2011)

- Transducer , sensors, and associated instrumentation
- Actuators (process interface devices)
- Digital computer
- Analog to digital convertor (ADC)
- Digital to analog convertor (DAC)
- Input and output multiplexers

17. What is direct digital control? Nov/Dec 2013

Direct digital control is a computer process control system in which certain components in a conventional analog control system are replaced by the digital computer.

18. Describe CIM data transmission methods.

- The transmission of binary data across a link can be accomplished either in parallel mode or serial mode,
- In parallel mode multiple data are sent with each clock pulse, while, in serial method , one bit is sent with each clock pulse.

19. What are the two types of channel?

Two basic channel types are used in data communications. They are

i) Analog type ii) Digital type

20. List the characteristics of channel.

The channel characteristics are

i) Electronic noise ii) Signal attenuation

iii) Analog channel capacity iv) Digital channel capacity

21. What is channel bandwidth?

An analog signal can vary from a minimum to maximum frequency. The di (Terence between the lowest and the highest frequency of a single analog is the bandwidth of that signal. The mathematical formula for frequency is,

$$\text{Frequency} = \frac{\text{Velocity}}{\text{Wavelength}}$$

22. What are two types of transmission mode?

There are three transmission modes available. They arc

i) Simplex ii) Half-duplex iii) Duplex.

They can be applied to both analog and digital channels.

23. What is modulation?

The process of varying amplitude or frequency or phase of the carrier signal in accordance with the instantaneous value of the information signal is known as modulation.

24. What is demodulation?

The process of separating the original information signal from the modulated carrier signal is known as demodulation. It is the inverse process of modulation.

25. What are the reasons for using LAN?

1. LAN allows for decentralization of various data processing functions.
2 LAN allows departments to share hardware.
3. LAN allows for the electronic transfer of text.
4. LAN allows for communication between organizations.
5. LAN allows information to be shared.

26. What are the features of LAN?

i) Compatibility ii) Protected Mode Operation
iii) Internetworking iv) Growth Path and Modularity
v) System Reliability

27. Define topology and explain its classification.

The pattern of interconnection of nodes in a network is called topology. Topcigy can also be defined as the geometric arrangement of workstations and the links among them.

The types of LAN topology are i) Bus topology ii) Ring topology iii) Star topology iv) Mesh topology

28. What are the Advantages of LAN?

- LAN is suited to any type of application.
- It provides data integrity.
- Any number of users can be accommodated.
- A LAN can fit any site requirements.
- It is flexible and growth-oriented.
- LAN provides a cost-effective multi user computer environment.
- Data transfer rates are above 10 Mbps.
- It all lows sharing of mass central storage and printers.
- It allows file/record locking.

29. Define OSI.

Open systems interconnection (OSI) reference model is an international standards organization (ISO) standard that specifies the conceptual structure of systems that are to communicate with each other.

30. List out the layers of OSI model.

Seven layers in OSI model
i) Physical layer
ii) Data link layer
iii) Network layer
iv) Transport layer
v) Session layer
vi) Presentation layer
vii) Application layer

PART-B& PART-C

1. A reaction turbine at 450 rpm, head 120 m, diameter at inlet 120 cm, flow area 0.4 m^2 has angles made by absolute and relative velocities at inlet 20° and 60° respectively. Find volume flow rate, H.P and Efficiency. (May/June 2013)

Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.

2. An inward flow reaction turbine having an overall efficiency of 80% is required to deliver 136kw. The head H is 16 m and the peripheral velocity is $3.3\sqrt{H}$. The radial velocity of flow at inlet is $1.1\sqrt{H}$.

The runner rotates at 120rpm. The hydraulic losses in the turbine are 15% of the flow available energy. Determine (i) diameter of the runner (ii) guide vane angle (iii) the runner blade angle at inlet (iv) the discharge through the turbine. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
3. A kaplan turbine delivers 10 MW under a head of 25m. The hub and tip diameters are 1.2m and 3m. Hydraulic and overall efficiencies are 0.90 and 0.85. If both velocity triangles are right angled triangles, determine the speed, guide blade outlet angle and blade outlet angle. (May/June 2014) *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
4. Discuss characteristics curve, load efficiencies of turbines. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
5. Explain the working principle of reaction turbine. **(Nov/ Dec 2013)** *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*
6. Explain the working principle of impulse turbine. *Refer: ""Dr.R.KBANSAL, "Fluid Mechanics and Machinery", ", Page No from 6 to 7 and from 10 to 11.*

SUBJECT : MA6351- TRANSFORMS AND PARTIAL DIFFERENTIAL EQUATIONS

SEMESTER / YEAR: III / II

UNIT I - PARTIAL DIFFERENTIAL EQUATIONS

Formation of partial differential equations – Singular integrals -- Solutions of standard types of first order partial differential equations - Lagrange's linear equation -- Linear partial differential equations of second and higher order with constant coefficients of both homogeneous and non-homogeneous types.

PART- A

Q.No.	Question	Bloom's Taxonomy Level	Domain
1.	Form a partial differential equation by eliminating the arbitrary constants 'a' and 'b' from $z = ax^2 + by^2$. **Solution** p=2ax, q=2by a= p/2x, b=q/2y therefore PDE is 2z=px+qy.	BTL -6	Creating
2.	Eliminate the arbitrary function from $z = f(y/x)$ and form the partial differential equation **MA6351 M/J 2014, N/D '14** **Solution:** px+qy=0	BTL -6	Creating
3.	Form the PDE from $(x-a)^2 + (y-b)^2 + z^2 = r^2$. **Solution** Differentiating the given equation w.r.t x &y, $z^2[p^2+q^2+1]=r^2$.	BTL -3	Applying
4.	Find the complete integral of p+q=pq. **Solution** p=a, q=b therefore z=$ax + \frac{a}{a-1}y + c$.	BTL- 6	Creating
5.	Form the partial differential equation by eliminating the arbitrary constants a, b from the relation $\log(az-1) = x + ay + b$. A/M'15 **Solution:** $\log(az-1) = x + ay + b$ Diff. p.w.r.t x&y, $\frac{ap}{az-1} = 1 - eqn1$ & $\frac{aq}{az-1} = a - eqn2$ $\frac{Eqn1}{Eqn2} \Rightarrow q = ap\ Sub\ in\ a(z-p) = 1 \Rightarrow q(z-p) = p$	BTL -6	Creating
6.	Form the PDE by eliminating the arbitrary constants a,b from the relation $z = ax^3 + by^3$. **MA6351 MAY/JUNE 2014** **Solution:** Differentiate w.r.t x and y $p = 3ax^2$, $q = 3by^2$ therefore 3z = px+qy.	BTL -6	Creating
7.	Form a p.d.e. by eliminating the arbitrary constants from z = $(2x^2+a)(3y-b)$. **Solution:** p = 4x(3y-b), q = $3(2x^2+a)$ 3y – b = p /4x $(2x^2+a)$ = q/3. Therefore 12xz = pq.	BTL -6	Creating
8.	Form the partial differential equation by eliminating arbitrary function ϕ from $\phi(x^2 + y^2, z-xy) = 0$ [MA6351 M/J 2016] **Solution:** $u = x^2+y^2$ and v= z-xy. Then = 2x, $u_y = 2y$; $v_x = p - y$;	BTL -6	Creating

	v_y = q-x. $\begin{vmatrix} u_x & u_y \\ v_x & v_x \end{vmatrix} = 0 \Rightarrow 2xq - 2x^2 - 2yp + 2y^2 = 0$		
9.	Form the partial differential equation by eliminating arbitrary constants a and b from $(x-a)^2 + (y-b)^2 + z^2 = 1$ **Solution**: Differentiating the given equation w.r.t x &y, $z^2[p^2+q^2+1]=1$	BTL -6	Creating
10.	Solve $[D^3-8DD'^2-D^2D'+12D'^3]z = 0$ **[MA6351 M/J 2017]** **Solution:** The auxiliary equation is $m^3-m^2-8m+12=0$; m =2,2,-3 The solution is $z = f_1(y+x)+f_2(y+2x)+xf_3(y+2x)$. [MA6351 NOV/DEC 2014]	BTL -3	Applying
11.	Find the complete solution of $q = 2\,px$ **MA6351 APRIL/MAY 2015** **Solution** Find the complete solution of $q = 2\,px$ **Solution:** Let q= a then p = a/2x dz= pdx +qdy 2z = alogx+2ay+2b.	BTL -3	Applying

12.	Find the complete solution of p+q=1**[MA6351 NOV/DEC 2014]** **Solution** Complete integral is z = ax + F(a) y +c Put p = a, q = 1-a. Therefore z = px + (1-a) y +c	BTL -3	Applying
13.	Find the complete solution of $p^3 - q^3 = 0$ **MA6351 M/J 2016** **Solution** Complete integral is z = ax + F(a) y +c Put p = a, q = a. Therefore z = px + q y +c	BTL -3	Applying
14.	Solve $[D^3+DD'^2-D^2D'-D'^3]z = 0$ **Solution** The auxiliary equation is $m^3-m^2+m-1=0$ m =1,-i, i $\Rightarrow$ The solution is $z = f_1(y+x)+f_2(y+ix)+f_3(y-ix)$.	BTL -3	Applying
15.	Solve (D-1)(D-D'+1)z = 0. **Solution** $z = e^x f_1(y) + e^{-x} f_2(y+x)$	BTL -3	Applying
16.	Solve $\frac{\partial^2 z}{\partial x^2} - \frac{\partial^2 z}{\partial x \partial y} + \frac{\partial z}{\partial x} = 0.$ **Solution:** A.E: D[D-D'+1] = 0 h=0, h=k-1 $z = f_1(y) + e^{-x} f_2(y+x)$	BTL -3	Applying
17.	Solve $(D^4 - D'^4)z = 0$. **[MA6351 MAY/JUNE 2014]** **Solution:** A.E : $m^4-1=0$, m=±1, ±i. $Z=C.F=f_1(y+x)+f_2(y-x)+f_3(y+ix)+f_4(y-ix)$.	BTL -3	Applying
18.	Solve $(D^2 - DD' + D' - 1)Z = 0$. **Solution:** The given equation can be written as $(D-1)(D-D'+1)Z = O$ $z = e^x f_1(y) + e^{-x} f_2(y+x)$	BTL -3	Applying
19.	Solve xdx + ydy = z.	BTL -3	Applying

	Solution The subsidiary equation is $\frac{dx}{x}=\frac{dy}{y}=\frac{dz}{z}$ $\frac{dx}{x}=\frac{dy}{y}\Rightarrow \log x=\log y+\log u$ $u=\frac{x}{y}$ Similarly $v=\frac{x}{z}$.		
20.	Form the p.d.e. by eliminating the arbitrary constants from z= ax +by +ab **Solution:** z= ax+by+ab p = a & q=b The required equation z= px+qy+pq.	BTL -3	Applying

PART – B			
1.(a)	Find the PDE of all planes which are at a constant distance 'k' units from the origin.	BTL -6	Creating
1. (b)	Find the singular integral of $z=px+qy+1+p^2+q^2$	BTL -2	Understanding
2. (a)	Form the partial differential equation by eliminating arbitrary function Φ from $\Phi(x^2+y^2+z^2, ax+by+cz)=0$	BTL -6	Creating
2.(b)	Find the singular integral of $z=px+qy+p^2+pq+q^2$	BTL -2	Understanding
3. (a)	Form the partial differential equation by eliminating arbitrary functions *f* and *g* from z = x f(x/y) + $y\,g(x)$	BTL -6	Creating
3.(b)	Find the singular integral of $z=px+qy+\sqrt{1+p^2+q^2}$. MA6351 M/J 2016	BTL -3	Applying
4. (a)	Solve $(D^3-7DD'^2-6D'^3)z=\sin(x+2y)$.[MA6351 NOV/DEC 2014]	BTL -3	Applying
4.(b)	Form the partial differential equation by eliminating arbitrary function *f* and g from the relation $z = xf(x+t)+g(x+t)$	BTL -6	Creating
5. (a)	Solve $(D^2-2DD')z=x^3y+e^{2x-y}$. [MA6351 NOV/DEC 2014]	BTL -3	Applying
5.(b)	Solve x(y-z)p+y(z-x)q=z(x-y). [MA6351 NOV/DEC 2014]	BTL -3	Applying
6. (a)	Find the singular integral of $px+qy+p^2-q^2$. MA6351 NOV/DEC2014	BTL -2	Understanding
6.(b)	Find the general solution of $z=px+qy+p^2+pq+q^2$. **M/J '17**	BTL -3	Applying
7. (a)	Find the complete solution of $z^2(p^2+q^2+1)=1$	BTL -4	Analyzing

7. (b)	Find the general solution of $(D^2 + 2DD' + D'^2)z = 2\cos y - x\sin y$	BTL -2	Understanding
8. (a)	Find the general solution of $(D^2 + D'^2)z = x^2 y^2$	BTL -2	Understanding
8.(b)	Find the complete solution of $p^2 + x^2 y^2 q^2 = x^2 z^2$ A/M 2015	BTL -2	Understanding
9. (a)	Solve $(D^2 - 3DD' + 2D'^2)\, z = (2 + 4x)e^{x+2y}$	BTL -3	Applying
9.(b)	Obtain the complete solution of $z = px+qy+p^2-q^2$ MA6351 A/M 2015	BTL -2	Understanding
10.(a)	Solve $x(y^2 - z^2)\, p + y(z^2 - x^2)q = z(x^2 - y^2)$	BTL -3	Applying
10.(b)	Solve $(D^2 - 3DD' + 2D'^2)z = \sin(x + 5y)$	BTL -3	Applying
11(a)	Solve the Lagrange's equation $(x + 2z)\, p + (2xz - y)q = x^2 + y$	BTL -3	Applying
11(b)	Solve $(D^2 - DD' - 2D'^2)z = 2x + 3y + e^{2x+4y}$	BTL -3	Applying
12(a)	Solve $(D^2 + DD' - 6D'^2)z = y \cos x$	BTL -3	Applying
12(b)	Solve the partial differential equation $(x^2 - yz)p + (y^2 - xz)q = z^2 - xy$ MA6351 APRIL/MAY 2015, MA6351 M/J 2016	BTL -3	Applying
13(a)	Solve $(D^2 - DD' - 20D'^2)\, z = e^{5s+y} + \sin(4x - y)$.	BTL -3	Applying
13(b)	Solve $(2D^2 - DD' - D'^2 + 6D + 3D')z = xe^{y}$	BTL -3	Applying
14(a)	Solve $(D^2 - 2DD')z = x^3 y + e^{2x-y}$	BTL -3	Applying
14(b)	Solve $(D^3 - 7DD'^2 - 6D'^3)z = \sin(x + 2y)$	BTL -3	Applying
15(a)	Form the PDE by eliminating the arbitrary function from the relation $z = y^2 + 2f\left(\frac{1}{x} + log y\right)$. [MA6351 MAY/JUNE 2014]	BTL -6	Creating
15(b)	Solve the Lagrange's equation (x+2z)p+(2xz-y) = x^2+y.[MA6351 MAY/JUNE 2014]	BTL -3	Applying
16(a)	Solve $x^2p^2+y^2q^2 = z^2$. [MA6351 MAY/JUNE 2014]	BTL -3	Applying
16(b)	Solve $(D^2+DD'-6D'^2)z = y \cos x$. [MA6351 MAY/JUNE 2014]	BTL -3	Applying

UNIT II - FOURIER SERIES: Dirichlet's conditions – General Fourier series – Odd and even functions – Half range sine series – Half range cosine series – Complex form of Fourier series – Parseval's identity – Harmonic analysis.			
PART –A			
Q.No	**Question**	**Bloom's Taxonomy Level**	**Domain**
1.	State the Dirichlet's conditions for a function f(x) to be expanded as a Fourier series. **MA6351 MAY/JUNE 2014, A/M 2017** **<u>Solution:</u>** (i) f(x) is periodic, single valued and finite. (ii) f(x) has a finite number of discontinuities in any one period (iii) f(x) has a finite number of maxima and minima. (iv) f(x) and f′(x) are piecewise continuous.	**BTL -1**	Remembering
2.	Find the value of a_0 in the Fourier series expansion of $f(x)=e^x$ in $(0,2\pi)$. **[MA6351 MAY/JUNE 2014]** **<u>Solution:</u>** $a_0 = \frac{1}{\pi}\int_0^{2\pi} f(x)\,dx = \frac{1}{\pi}\int_0^{2\pi} e^x\,dx = 0$.	**BTL -1**	Remembering
3.	If $(\pi - x)^2 = \frac{\pi^2}{3} + 4\sum_{n=1}^{\infty}\frac{cosnx}{n^2}$ $in\ 0 < x < 2\pi$, then deduce that value of $\sum_{n=1}^{\infty}\frac{1}{n^2}$. **[MA6351 NOV/DEC 2014]** **<u>Solution</u>**: Put x=0, $\sum_{n=1}^{\infty}\frac{1}{n^2} = 6$.	**BTL -1**	Remembering
4.	Does $f(x)$ = tanx posses a Fourier expansion? **<u>Solution</u>** No since tanx has infinite number of infinite discontinuous and not satisfying Dirichlet's condition.	**BTL -2**	Understanding
5.	Determine the value of a_n in the Fourier series expansion of $f(x) = x^3$ in $(-\pi, \pi)$. **<u>Solution:</u>** $a_n = 0$ since f(x) is an odd function	**BTL -5**	Evaluating
6.	Find the constant term in the expansion of $\cos^2 x$ as a Fourier series in the interval $(-\pi, \pi)$. **<u>Solution:</u>** $a_0 = 1$	**BTL -2**	Understanding
7.	If f(x) is an odd function defined in (-l, l). What are the values of a_0 and a_n? **<u>Solution:</u>** $a_n = 0 = a_0$	**BTL -2**	Understanding
8.	If the function f(x) = x in the interval 0<x<2 then find the constant term of the Fourier series expansion of the function f. **<u>Solution:</u>** $a_0 = 4\pi$	**BTL -2**	Understanding

9.	Expand f(x) =1 as a half range sine series in the interval $(0,\pi)$. **[MA6351 MAY/JUNE 2014]** **Solution:** The sine series of f(x) in $(0, \pi)$ is given by $f(x) = \sum_{n=1}^{\infty} b_n \sin nx$ where $b_n = \frac{2}{\pi}\int_0^{\pi} \sin nx dx = -\frac{2}{n\pi}[\cos nx]_0^{\pi} = 0$ if n is even $= \frac{4}{n\pi}$ if n is odd $f(x) = \sum_{n=odd}^{\infty} \frac{4}{n\pi}\sin nx = \frac{4}{\pi}\sum_{n=1}^{\infty}\frac{\sin(2n-1)x}{(2n-1)}$.	**BTL -4**	Analyzing
10.	Find the value of the Fourier Series for f(x) = 0 -c<x<0 = 1 0<x<c at x = 0 **MA6351 M/J 2016** Solution: f(x) at x=0 is a discontinuous point in the middle. f(x) at x = 0 = $\frac{f(0-)+f(0+)}{2}$ $f(0-) = \lim_{h\to 0} f(0-h) = \lim_{h\to 0} 0 = 0$ $f(0+) = \lim_{h\to 0} f(0+h) = \lim_{h\to 0} 1 = 1$ $\therefore$ f(x) at x = 0 ➔ (0 + 1) / 2 = 1 / 2 = 0.5	**BTL -3**	Applying
11.	What is meant by Harmonic Analysis? Solution: The process of finding Euler constant for a tabular function is known as Harmonic Analysis.	**BTL -4**	Analyzing
12.	Find the constant term in the Fourier series corresponding to f (x) = $\cos^2 x$ expressed in the interval $(-\pi,\pi)$. Solution: Given f(x) = $\cos^2 x = \frac{1+\cos 2x}{2}$ W.K.T $f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos nx + \sum_{n=1}^{\infty} b_n \sin nx$ To find $a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi}\cos^2 x dx = \frac{2}{\pi}\int_0^{\pi}\frac{1+\cos 2x}{2}dx = \frac{1}{\pi}\left[x+\frac{\sin 2x}{2}\right]_0^{\pi}$ $= \frac{1}{\pi}[(\pi+0)-(0+0)] = 1$.	**BTL -1**	Remembering
13.	Define Root Mean Square (or) R.M.S value of a function f(x) over the interval (a,b). Solution: The root mean square value of f(x) over the interval (a,b) is defined as	**BTL -3**	Applying

	R.M.S. $= \sqrt{\dfrac{\int_a^b [f(x)]^2 dx}{b-a}}$.		
14.	Find the root mean square value of the function f(x) = x in the interval (0,l). Solution: The sine series of f(x) in (a,b) is given by R.M.S. $= \sqrt{\dfrac{\int_a^b [f(x)]^2 dx}{b-a}} = \sqrt{\dfrac{\int_0^l [x]^2 dx}{l-0}} = \dfrac{l}{\sqrt{3}}$.	**BTL -1**	Remembering
15.	If f(x) = 2x in the interval (0,4), then find the value of a_2 in the Fourier series expansion. Solution: $a_2 = \dfrac{2}{4}\int_0^4 2x\cos[\pi x]dx = 0.$	**BTL -5**	Evaluating
16.	To which value, the half range sine series corresponding to f(x) = x^2 expressed in the interval (0,5) converges at x = 5?. Solution: x = 2 is a point of discontinuity in the extremum. $\therefore [f(x)]_{x=5} = \dfrac{f(0)+f(5)}{2} = \dfrac{[0]+[25]}{2} = \dfrac{25}{2}$.	**BTL -6**	Creating
17.	If the Fourier Series corresponding to f(x) =x in the interval (0, 2 π) is $\dfrac{a_0}{2} + \sum_{n=1}^{\infty}(a_n \cos nx + b_n \sin nx)$ without finding the values of a_0, a_n, b_n find the value of $\dfrac{a_0^2}{2} + \sum_{n=1}^{\infty}(a_n^2 + b_n^2)$. **[MA2211 APR/MAY 2011]** Solution: By Parseval's Theorem $\dfrac{a_0^2}{2} + \sum_{n=1}^{\infty}(a_n^2 + b_n^2) = \dfrac{1}{\pi}\int_0^{2\Pi}[f(x)\}^2 dx = \dfrac{1}{\pi}\int_0^{2\Pi} x^2 dx = \dfrac{1}{\pi}\left[\dfrac{x^3}{3}\right]_0^{2\Pi}$ $= \dfrac{8}{3}\pi^2$	**BTL -4**	Analyzing
18.	Obtain the first term of the Fourier series for the function f(x) =x^2 , -π < x < π. Solution: Given f(x) =x^2 ,is an even functionin -π < x < π. Therefore, $a_o = \dfrac{2}{\pi}\int_0^{\pi} f(x)dx = \dfrac{2}{\pi}\int_0^{\pi} x^2 dx = \dfrac{2}{\pi}\left[\dfrac{x^3}{3}\right]_0^{\pi} = \dfrac{2}{3}\pi^2$.	**BTL -1**	Remembering
19.	Find the co-efficient b_n of the Fourier series for the function f(x) = xsinx in (-2, 2). Solution: xsinx is an even function in (-2,2) . Therefore $b_n = 0$.	**BTL -6**	Creating

20.	Find the sum of the Fourier Series for f(x) = x 0<x<1 = 2 1<x<2 at x = 1. Solution: f(x) at x=1 is a discontinuous point in the middle. $f(x) \text{ at } x = 1 = \dfrac{f(1-)+f(1+)}{2}$ $f(1-) = \lim_{h\to 0} f(1-h) = \lim_{h\to 0} 1-h = 1$ $f(1+) = \lim_{h\to 0} f(1+h) = \lim_{h\to 0} 2 = 2$ $\therefore f(x) \text{ at } x = 1 \Rightarrow (1+2)/2 = 3/2 = 1.5$	**BTL -3**	Applying

PART – B

1.(a)	Obtain the Fourier's series of the function $f(x)=\begin{cases} x & for \quad 0<x<\pi \\ 2\pi - x & for \quad \pi<x<2\pi \end{cases}$. Hence deduce that $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+....=\frac{\pi^2}{8}$ **MA6351A/M 2017**	**BTL -1**	Remembering
1.(b)	Find the Fourier's series of $f(x)=\lvert x\rvert$ in $-\pi<x<\pi$ And deduce that $\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}=\frac{\pi^2}{8}$	**BTL -1**	Remembering
2.(a)	Find the Fourier's series expansion of period $2l$ for $f(x)=(l-x)^2$ in the range $(0,2l)$. Hence deduce that $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+....=\frac{\pi^2}{6}$	**BTL -2**	Understanding
2.(b)	Find the Fourier series of periodicity 2π for f(x) $=x^2$ in $-\pi \le x \le \pi$. Hence deduce that $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\ldots\ldots = \frac{\pi^4}{90}$.	**BTL -2**	Understanding
3.(a)	Find the Fourier series upto second harmonic for the following data: (see table below) **MA6351 APRIL/ MAY 2017**	**BTL -1**	Remembering

X	0	1	2	3	4	5
f(x)	9	18	24	28	26	20

3.(b)	Find the Fourier series of $f(x) = 2x - x^2$ in the interval $0 < x < 2$	**BTL -1**	Remembering
4.(a)	Obtain the half range cosine series of the function $f(x)=\begin{cases} x \;\; in \left(0,\frac{l}{2}\right) \\ l-x \left(\frac{l}{2},l\right) \end{cases}$.	**BTL -5**	Evaluating
4.(b)	Find the half range sine series of the function $f(x)=x(\pi-x)$ in the interval (0 , Л) .	**BTL -3**	Applying
5.(a)	Determine the Fourier series for the function $f(x)=\lvert\sin x\rvert \; in \; -\pi \le x \le \pi.$ MA6351 APRIL/ MAY 2015	**BTL -5**	Evaluating
5.(b)	Find the complex form of the Fourier series of $f(x) = e^{-ax}$ in (-l,l) **MA6351 APRIL/ MAY 2017**	**BTL -1**	Remembering
6.(a)	Find the Fourier series for $f(x) = x\sin x \;\; in \; (-\pi,\pi)$.	**BTL -2**	Remembering
6.(b)	Find the Fourier series expansion of $f(x)=x+x^2 \;\; -2 \le x \le 2.$	**BTL -2**	Remembering
7.(a)	Find the Fourier series for $f(x)=\begin{cases} x & (0,\pi/2) \\ \pi - x & (\pi/2,2\pi) \end{cases}$. MA6351 APRIL/ MAY 2015	**BTL -4**	Analyzing
7.(b)	Find the Fourier series of $f(x) = x + x^2$ in (-l, l) with period 2l.	**BTL -3**	Applying
8.(a)	Find the Fourier series as far as the second harmonic to represent the function f(x) with period 6, given in the following table.	**BTL -6**	Creating

X	**0**	**1**	**2**	**3**	**4**	**5**
f(x)	**9**	**18**	**24**	**28**	**26**	**20**

<table>
<tr><td>8.(b)</td><td>Find the complex form of the Fourier series of $f(x)=e^{-x}$ in $-1<x<1$. MA6351 APRIL/ MAY 2015</td><td>BTL -2</td><td>Remembering</td></tr>
<tr><td>9.(a)</td><td>Find the half range cosine series for the function
$f(x)=x(\pi - x)$ in $0<x<\pi$. Deduce $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\ldots=\frac{\pi^4}{90}$</td><td>BTL -2</td><td>Remembering</td></tr>
<tr><td>9.(b)</td><td>Obtain the Fourier series to represent the function
$f(x)=|x|, -\pi<x<\pi \quad and \quad deduce \sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}=\frac{\pi^2}{8}$
(M/J 2012)</td><td>BTL -3</td><td>Applying</td></tr>
<tr><td>10.(a)</td><td>Find the half range sine series of $f(x) = lx-x^2$ in (0,l) (N/D 2013)</td><td>BTL -1</td><td>Remembering</td></tr>
<tr><td>10.(b)</td><td>Obtain the Fourier cosine series expansion of f(x) = x in 0<x<4.
Hence deduce the value of $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\ldots$</td><td>BTL -1</td><td>Remembering</td></tr>
<tr><td>11.(a)</td><td>By using Cosine series show that $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\ldots=\frac{\pi^4}{96}$ for f(x) = x in $0<x<\pi$</td><td>BTL -4</td><td>Analyzing</td></tr>
<tr><td>11.(b)</td><td>Find the Fourier cosine series up to third harmonic to represent the function given by the following data: MA6351 M/J 2016
<table>
<tr><td>X</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Y</td><td>4</td><td>8</td><td>15</td><td>7</td><td>6</td><td>2</td></tr>
</table></td><td>BTL -6</td><td>Creating</td></tr>
<tr><td>12.(a)</td><td>Show that the complex form of Fourier series for the function
$f(x)=e^{ax}$ $(-\pi,\pi)$)</td><td>BTL -1</td><td>Remembering</td></tr>
<tr><td>12.(b)</td><td>Find the complex form of the Fourier series of
$f(x)=e^{-x}$ in $-1<x<1$. (N/D 2009)</td><td>BTL -4</td><td>Analyzing</td></tr>
<tr><td>13.</td><td>Calculate the first 3 harmonics of the Fourier of f(x) from the following data
<table>
<tr><td>x</td><td>0</td><td>30</td><td>60</td><td>90</td><td>120</td><td>150</td><td>180</td><td>210</td><td>240</td><td>270</td><td>300</td><td>330</td><td>360</td></tr>
<tr><td>f(x)</td><td>1.8</td><td>1.1</td><td>0.3</td><td>0.16</td><td>0.5</td><td>1.3</td><td>2.16</td><td>1.25</td><td>1.3</td><td>1.52</td><td>1.76</td><td>2</td><td>1.8</td></tr>
</table></td><td>BTL -6</td><td>Creating</td></tr>
</table>

14.(a)	Find the complex form of the Fourier series of $f(x) = e^{-S}$ in $-1 < x < 1$.	**BTL -4**	Analyzing
14.(b)	Find the Fourier series up to the second harmonic from the following table.	**BTL -6**	Creating

x	0	1	2	3	4	5
f(x)	9	18	24	28	26	20

UNIT – III APPLICATIONS OF PARTIAL DIFFERENTIAL EQUATIONS

Solution of one dimensional wave equation-One dimensional heat equation-Steady state solution of two dimensional heat equation-Fourier series solutions in Cartesian coordinates .

Textbook : Grewal. B.S., "Higher Engineering Mathematics", 42nd Edition, Khanna Publishers, Delhi, 2012.

PART – A

Q.No	Questions	BT Level	Competence	PO
1	What is the basic difference between the solutions of one dimensional wave equation and one dimensional heat equation. Solution: The correct solution of one dimensional wave equation is of periodic in nature. But the solution of heat equation is not periodic in nature. **(A.U.N/D 2017, N/D 2011,2012, M/J 2013)**	**BTL-4**	**Analyzing**	**PO1**
2	In steady state conditions derive the solution of one dimensional heat flow equations. [Nov / Dec 2005] Solution: one dimensional heat flow equation is $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$ ………..(1) When the steady state conditions exists, put $\frac{\partial u}{\partial t} = 0$ Then (1) becomes, $\frac{\partial^2 u}{\partial x^2} = 0$. Solving, we get u(x)=ax+b. a and b are arbitrary constants.	**BTL-2**	**Understanding**	**PO1,PO2,PO3**

3	What are the possible solution of one dimensional wave equation. Solution: The possible solutions are (i) y(x,t)=($A_1e^{px}+A_2e^{-px})(A_3e^{pat}+A_4e^{-pat})$ (ii) y(x,t)=($B_1\cos px+B_2\sin px)(B_3\cos pat+B_4\sin pat)$ (iii) y(x,t)=($C_1x+C_2)(C_3t+C_4)$. **(A.U. M/J 2014)**	**BTL-1**	**Remembering**	**PO1,PO2**
4	Classify the P.D.E $3u_{xx}+4u_{yy}+3u_y-2u_x=0$. Solution: $B^2-4AC=16-4(3)(0)=16>0$. It is hyperbolic. **(A.U M/J 2008)**	**BTL-1**	**Remembering**	**PO1**
5	The ends A and B of a rod of length 10cm long have their temperatures kept at $20^oC and 70^oC$.Find the Steady state temperature distribution of the rod. Solution: The initial temperature distribution is u(x,0)= $\frac{b-a}{l}x+a$.Here $a=20^oC, b=70^oC, l=10cm.$ $\therefore u(x,t)=\frac{70-20}{10}x+20=5x+20.0<x<10.$ **(A.U M/J 2008, A.U N/D 2012)**	**BTL-1**	**Remembering**	**PO1**
6	Classify the PDE $\frac{\partial^2u}{\partial x^2}+4\frac{\partial^2u}{\partial x\partial y}+4\frac{\partial^2u}{\partial y^2}-12\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}+7u=x^2+y^2$. Solution: The given PDE is $u_{xx}+4u_{xy}+4u_{yy}-12u_x+u_y+7u=x^2+y^2$.A=1;B=4;C=4. $B^2-4AC=16-16=0$. $\therefore$ The given PDE is parabolic. **(A.U M/J 2009)**	**BTL-3**	**Applying**	**PO1**
7	Write down the one dimensional heat equation. Solution: The one dimensional heat equation is $\frac{\partial^2u}{\partial x^2}=\frac{1}{\alpha^2}\frac{\partial u}{\partial t}$. **(A.U M/J 2010,N/D 2012)**	**BTL-1**	**Remembering**	**PO1,PO2**
8	Write down the possible solutions of one dimensional heat flow equation. Solution: The various possible solutions of one dimensional heat equation are (i)u(x,t)= $(Ae^{px}+Be^{-px})e^{\alpha^2p^2t}$ (ii) ($A\cos px+B\sin px)e^{-\alpha^2p^2t}$ (iii) u(x,t)=(Ax+B).	**BTL-1**	**Remembering**	**PO1,PO2**

	(A.U M/J 2009,A.U N/D 2014)			
9	Write the one dimensional wave equation with initial and boundary conditions in which the initial position of the string is f(x) and the initial velocity imparted at each point is g(x). Solution: The wave equation is $\frac{\partial^2 y}{\partial t^2} = \alpha^2 \frac{\partial^2 y}{\partial x^2}$. The boundary conditions are (i) y(0,t)=0, ∀ t>0 (ii) y(0,t)=0, $\forall t > 0$ (iii) $\frac{\partial y}{\partial t}(x,0) = g(x), 0 < x < l.$ (iv) y(x,0)=f(x),0<x<l. **(A.U N/D 2007,M/J 2012,2016)**	**BTL-3**	**Applying**	**PO1**
10	Classify the partial differential equation $\frac{\partial^2 u}{\partial x^2} = \frac{1}{\alpha^2}\frac{\partial u}{\partial t}$ Solution: Given $\frac{\partial^2 u}{\partial x^2} = \frac{1}{\alpha^2}\frac{\partial u}{\partial t}$ $\alpha^2 \frac{\partial^2 u}{\partial x^2} - \frac{\partial u}{\partial t} = 0$ $Here A = \alpha^2; B = 0; C = 0.$ $\therefore B^2 - 4AC = 0 - 4(\alpha^2)(0) = 0.$ **(A.U M/J 2007,M/J2013 ,M/J 2016)**	**BTL-1**	**Remembering**	**PO1**
11	State the two dimensional Laplace equation? Solution : $U_{xx} + U_{yy} = 0$ (**A.U., N/D 2011,2012, M/J 2014)**	**BTL-1**	**Remembering**	**PO1**
12	In an one dimensional heat equation $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$ what does the constant stands for ? Solution : α^2 is called the diffusivity of the material of the body through which the heat flows. If ρ be the density, α the specific heat and k thermal conductivity of the material, we have the relation $k/\rho\alpha = c2$. **(A.U M/J 2013)**	**BTL-1**	**Remembering**	**PO1**
13	What is the basic difference between the solutions of one dimensional wave equation and one dimensional heat equation. Solution: Solution of the one dimensional wave equation is of periodic in nature. But Solution of the one dimensional heat equation is not of periodic in nature.	**BTL-1**	**Remembering**	**PO1,PO2,PO5**

	(A.U A/M 2016)			
14	In the wave equation $\frac{\partial^2 y}{\partial t^2} = \alpha^2 \frac{\partial^2 y}{\partial x^2}$, What does α² stands for ? Solution : α² = $\frac{Tension}{MassperUnitlength}$ **(A.U M/J 2014)**	**BTL-1**	**Remembering**	**PO1**
15	In 2D heat equation or Laplace equation ,What is the basic assumption? Solution : When the heat flow is along curves instead of straight lines,the curves lying in parallel planes the flow is called two dimensional **(A.U M/J 2016)**	**BTL-4**	**Analyzing**	**PO1**
16	Define steady state condition on heat flow. Solution: Steady state condition in heat flow means that the temp at any point in the body does not vary with time. That is, it is independent of t, the time. **(MA2211 A.U M/J 2013)**	**BTL-1**	**Remembering**	**PO1**
17	Write the solution of one dimensional heat flow equation , when the time derivative is absent. Solution : When time derivative is absent the heat flow equation is $U_{xx} = 0$ (**A.U N/D 2009, N/D 2015)**	**BTL-2**	**Understanding**	**PO2**
18	If the solution of one dimensional heat flow equation depends neither on Fourier cosine series nor on Fourier sine series , what would have been the nature of the end conditions? Solution :. One end should be thermally insulated and the other end is at zero temperature. (**A.U M/J 2017)**	**BTL-1**	**Remembering**	**PO1**
19	State any two laws which are assumed to derive one dimensional heat equation? Solution : (i)The sides of the bar are insulated so that the loss or gain of heat from the sides by conduction or radiation is negligible. (ii)The same amount of heat is applied at all points of the face **(A.U M/J 2013)**	**BTL-1**	**Remembering**	**PO1,PO2**
20	What are the assumptions made before deriving the one dimensional heat equation? **Solution : (i)**Heat flows from a higher to lower temperature. (ii)The amount of heat required to produce a given temperature change in a body is proportional to the mass of the body and to the temperature change. (iii)The rate at which heat flows through an area is	**BTL-1**	**Remembering**	**PO1,PO2**

	proportional to the area and to the temperature gradient normal to the area. **(A.U M/J 2014)**			
21	Write down the two dimensional heat equation both in transient and steady states. Solution : Transient state: $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$ Steady state: : $U_{xx} + U_{yy} = 0$ **(A.U M/J 2013)**			
PART-B				
1	A uniform string is stretched and fastened to two points $'l'$ apart. Motion is started by displacing the string into the form of the curve $y = kx(l-x)$ and then releasing it from this position at time $t = 0$. Find the displacement of the point of the string at a distance x from one end at time t. **(A.U.N/D 2017, N/D 2015,2012, M/J 2013)**	**BTL-4**	**Analyzing**	**PO1,PO2,PO5**
2	A tightly stretched string of length l has its ends fastened at $x = 0$ and $x = l$. The midpoint of the string is then taken to a height h and then released from rest in that position. Obtain an expression for the displacement of the string at any subsequent time.	**BTL-4**	**Analyzing**	**PO1,PO2,PO5**
3	A tightly stretched string of length $2l$ is fastened at both ends. The midpoint of the string is displaced by a distance $'b'$ transversely and the string is released from rest in this position. (Find the lateral displacement of a point of the string at time $'t'$ from the instant of release) Find an expression for the transverse displacement of the string at any time during the subsequent motion **(A.U. N/D 2011, M/J 2014)**	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
4	A tightly stretched string of length l is initially at rest in equilibrium position and each point of it is given the velocity $\left(\frac{\partial y}{\partial y}\right)_{t=0} = y_0 \sin^3\left(\frac{\pi x}{l}\right)$. Find the displacement at any time $'t'$. **(A.U N/D 2014)**	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
5	A string is stretched between two fixed points at a distance $2l$ apart and the points of the string are given initial	**BTL-2**	**Understanding**	**PO1,PO2**

	velocities v where $v = \begin{cases} \frac{cx}{l} & 0 < x < l \\ \frac{c}{l}(2l - x) & l < x < 2l \end{cases}$, x being the distance from one end point. Find the displacement of the string at any subsequent time. *(***A.U.N/D 2008***).*			
6	A rod 30cm long has its ends A and B kept at $20^0 c$ and $80^0 c$ respectively until steady state conditions prevails. The temperature at each end is then suddenely reduced to $0^0 c$ and kept so. Find the resulting temperature function $u(x,t)$ taking $x = 0$ at A.*(Nov./Dec. 2009).* **(A.U.N/D 2011, M/J 2014)**	**BTL-2**	**Understanding**	**PO1,PO2**
7	A rod of length l has its ends A and B kept at $0^o c$ and $120^o c$ respectively until steady state conditions prevail. If the temperature at B is reduced to $0^o c$ and so while that of A is maintained, find the temperature distribution of the rod. **(A.U M/J 2012,16)**	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
8	An infinitely long rectangular plate with insulated surface is 10 cm wide. The two long edges and one short edge are kept at zero temperature, while the other short edge x = 0 is kept at temperature given by $u = \begin{cases} 20y, & 0 \le y \le 5 \\ 20(10 - y), & 5 \le y \le 10 \end{cases}$. **(A.U M/J 2011,N/D 2012,M/J 2016)**	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
9	A string is stretched and fastened to two points l apart. Motion is started by displacing the string into the form y = $k(lx-x^2)$ from which it is released at time t = 0. Find the displacement of any point on the string at a distance x from one end at time t. **(A.U M/J 2015,2016)**	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
10	A square plate is bounded by the lines x = 0, x = a, y = 0 and y = b. Its surfaces are insulated and the temperature along y = b is kept at 100° C. Find the steady-state temperature at any point in the plate. [A.U. N/D 2014]	**BTL-5**	**Evaluating**	**PO1,PO2,PO5**
11	A tightly stretched string with fixed end points x = 0 and x = l is initially in a position given by $y(x,0) = y_0 \sin^3\left(\frac{\pi x}{l}\right)$. Find	**BTL-2**	**Understanding**	**PO1,PO2**

	the displacement at any time $'t'$. **(A.U N/D 2012)**			

UNIT – IV FOURIER TRANSFORM				
Fourier integral theorem (without proof) – Fourier transform pair –Sine and Cosine transforms- Properties – Transforms of simple functions – Convolution theorem – Parseval's identity. Textbook : Grewal. B.S., and Grewal. J.S., "Numerical Methods in Engineering and Science", 9th Edition,Khanna Publishers, New Delhi, 2007.				
PART – A				
CO Mapping : C214.2				
Q.No	**Questions**	**BT Level**	**Competence**	**PO**
1	Prove that $F[f(x-a)] = e^{ias}F(s)$ **<u>Proof:</u>** $F(f(x)) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ $F(f(x-a)) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x-a)e^{isx}dx, \quad put\, t = x-a; dt = dx$ $x \to \pm\infty \Rightarrow t \to \pm\infty$ $F(f(x-a)) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{is(t+a)}dt = e^{isa}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{ist}dt = e^{isa}F(s).$ **(A.U.N/D , N/D 2011,2012, M/J 2013)**	**BTL-4**	**Analyzing**	**PO1**
2	Prove that $F(f(x)\cos ax) = \frac{1}{2}[F(s+a)+F(s-a)]$. [MA2211 APR/MAY2011] **<u>Proof:</u>**	**BTL-1**	**Remembering**	**PO1,PO2**

	$F\left(f(x)\cos ax\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)\cos ax\, e^{isx}dx$ $=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)\frac{e^{iax}+e^{-iax}}{2}e^{isx}dx$ $=\frac{1}{2}\left(\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{i(s+a)x}dx+\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{i(s-a)x}dx\right)$ $=\frac{1}{2}\left[F(s+a)+F(s-a)\right].$ **(A.U.N/D 2017, N/D 2015,2012, M/J 2011)**			
3	Prove that $F_c\left(f(x)\sin ax\right)=\frac{1}{2}\left[F_s(s+a)+F_s(s-a)\right]$ **Proof:** $F_c\left(f(x)\cos ax\right)=\sqrt{\frac{2}{\pi}}\int_{0}^{\infty} f(x)\sin ax\cos sx\, dx$ $=\frac{1}{2}\sqrt{\frac{2}{\pi}}\int_{0}^{\infty} f(x)\left(\sin(s+a)x+\sin(s-a)x\right)dx$ $=\frac{1}{2}\left(\sqrt{\frac{2}{\pi}}\int_{-\infty}^{\infty} f(x)\sin(s+a)x\,dx+\sqrt{\frac{2}{\pi}}\int_{-\infty}^{\infty} f(x)\sin(s-a)x\,dx\right)$ $=\frac{1}{2}\left[F_s(s+a)+F_s(s-a)\right].$ **(A.U M/J 2011,2008)**	**BTL-2**	**Understanding**	**PO1,PO2**
4	Find the Fourier sine transform of e^{-x}, $x>0$. **Solution:** $F_s\left(f(x)\right)=\sqrt{\frac{2}{\pi}}\int_{0}^{\infty} f(x)\sin sx\,dx=\sqrt{\frac{2}{\pi}}\int_{0}^{\infty} e^{-x}\sin sx\,dx$ $=\sqrt{\frac{2}{\pi}}\left[\frac{e^{-x}}{1+s^2}\left(-\sin sx-s\cos sx\right)\right]_0^{\infty}=\sqrt{\frac{2}{\pi}}\frac{s}{1+s^2}$ (A.U.N/D 2010)	**BTL-4**	**Analyzing**	**PO2**
5	Write the Fourier transform pair. **Proof:**	**BTL-1**	**Remembering**	**PO1**

	$$F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$$ $$f(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)\,e^{-isx}ds$$ **(A.U N/D 2009,N/D 2012,M/J 2015,2016)**			
6	Find the Fourier sine transform of $\frac{1}{x}$. **Solution:** $$F_s(f(x))=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(x)\sin sx dx=\sqrt{\frac{2}{\pi}}\int_0^{\infty}\frac{1}{x}\sin sx dx$$ $$put\, sx=\theta;\ sdx=d\theta;\qquad =\sqrt{\frac{2}{\pi}}\int_0^{\infty}\frac{\sin\theta}{\theta}d\theta=\sqrt{\frac{2}{\pi}}\frac{\pi}{2}=\sqrt{\frac{\pi}{2}}.$$ **(A.U M/J 2009,N/D 2012,M/J 2015,2016)**	**BTL-2**	**Understanding**	**PO1**
7	Find the Fourier cosine transform of $f(ax)$. **Solution:** $$F_c(f(ax))=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(ax)\cos sx dx$$ $$put\ \ t=ax;\ dt=adx$$ $$=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos\left(\frac{st}{a}\right)\frac{dt}{a}=\frac{1}{a}F_c\left(\frac{s}{a}\right).$$ **(A.U M/J 2013)**	**BTL-2**	**Understanding**	**PO1,PO2**
8	Find the Fourier Cosine transform of e^{-ax}. **Solution:** $$F_c[e^{-ax}]=\sqrt{\frac{2}{\pi}}\int_0^{\infty} e^{-ax}\cos sx dx=\sqrt{\frac{2}{\pi}}\left[\frac{e^{-ax}}{a^2+s^2}(-a\cos sx+s\sin sx)\right]_0^{\infty}$$ $$=\sqrt{\frac{2}{\pi}}\frac{a}{a^2+s^2}.$$ **(A.U M/J 2012 N/D 2015,N/D 2009)**	**BTL-1**	**Remembering**	**PO1**
9	Find the Fourier transform of $f(x)=\begin{cases} e^{ikx}, & a<x<b \\ 0, & x<a, x>b \end{cases}$ **Solution:**	**BTL-1**	**Remembering**	**PO1**

	$F\left[f(x)\right]=\frac{1}{\sqrt{2\pi}}\int_a^b e^{ikx}e^{isx}dx=\frac{1}{\sqrt{2\pi}}\int_a^b e^{i(s+k)x}dx=\frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)x}}{i(s+k)}\right]_a^b$ $=\frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)b}-e^{i(s+k)a}}{i(s+k)}\right].$ **(A.U M/J 2016,N/D 2012,N/D 2009)**			
10	State convolution theorem. Solution : If F(s) and G(s) are fourier transforms of f(x) and g(x) respectively then the fourier transform of the convolutions of f(x) and g(x) is the product of their fourier transform. **(A.U N/D 2012,M/J 2016)**	**BTL-1**	**Remembering**	**PO1**
11	Write the Fourier cosine transform pair? Solution : $F_c(s)=\frac{2}{\sqrt{\pi}}\int_0^\infty f(x)\cos sx dx$ $f(x)=\frac{\sqrt{2}}{\sqrt{\pi}}\int_0^\infty F_c(f(x)\cos sx ds$ **(A.U N/D 2011,N/D 2014)**	**BTL-2**	**Understanding**	**PO1,PO2**
12	Write Fourier sine transform and its inversion formula? Solution : $F_s(s)=\frac{2}{\sqrt{\pi}}\int_0^\infty f(x)\sin sx dx$ $f(x)=\frac{\sqrt{2}}{\sqrt{\pi}}\int_0^\infty F_s(f(x)\sin sx ds$	**BTL-4**	**Analyzing**	**PO1**
13	State the modulation theorem in Fourier transform . Solution : If F(s) is the Fourier transform of f(x) , then F[f(x) cos ax] = 1/2 [F (s+a) +F(s-a). (A.U.N/D 2014)	**BTL-4**	**Analyzing**	**PO1,PO2**
14	State the Parsevals identity on Fourier transform. Solution : If F(s) is the Fourier transform of f(x), then $\int_{-\infty}^{\infty}\left\|f(x)\right\|^2 dx = \int_{-\infty}^{\infty}\left\|F(s)\right\|^2 ds$ **(A.U N/D 2014,M/J 2016)**	**BTL-4**	**Analyzing**	**PO1**
15	State Fourier Integral theorem **.** **Solution :** If f(x) is piecewise continuously differentiable & absolutely integrable in (-∞ , ∞) then f(x) = $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(t)e^{is(x-t)}dtds$ This is known as Fourier integral theorem **(A.U M/J 2014)**	**BTL-1**	**Remembering**	**PO1**
16	Define self-reciprocal with respect to Fourier Transform. Solution: If a transformation of a function f(x) is equal to f(s) then the function f(x) is called self-reciprocal	**BTL-4**	**Analyzing**	**PO1**

	[A.U. N/D 2013]			
	PART – B			
1	Find the Fourier transform of $f(x)=\begin{cases} a^2-x^2, & \lvert x\rvert \le a \\ 0, & \lvert x\rvert \,\phi\, a \end{cases}$. Hence evaluate $\int_0^\infty \frac{x\cos x-\sin x}{x^3}\cos\left(\frac{s}{2}\right)dx.$ **(A.U M/J 2011,A/M 2012,N/D 2015)**	**BTL-5**	**Evaluating**	**PO1,PO2, PO3,PO5**
2	Find the Fourier cosine transform of $f(x)=e^{-ax}, a>0$ and $g(x)=e^{-bx}, b>0.$ Hence evaluate $\int_0^\infty \frac{dx}{(x^2+1)(x^2+9)}.$ (A.UA/M 2009)	**BTL-4**	**Analyzing**	**PO1,PO2**
3	Find the Fourier Transform of f(x) given by $f(x)=\begin{cases} a-\lvert x\rvert, & \lvert x\rvert \le a \\ 0, & \lvert x\rvert \,\phi\, a \end{cases}$. Hence show that $\int_0^\infty \left(\frac{\sin t}{t}\right)^2 dt=\frac{\pi}{2}$ *and* $\int_0^\infty \left(\frac{\sin t}{t}\right)^4 dt=\frac{\pi}{3}.$ **(A.U.N/D 2017, N/D 2011,2012, M/J 2013)**	**BTL-5**	**Evaluating**	**PO1,PO2, PO5,PO12**
4	Find the Fourier transform of $f(x)=\begin{cases} 1, & for\ \lvert x\rvert \le a \\ 0, & for\ \lvert x\rvert \,\phi\, a \,\phi\, 0 \end{cases}$ and using Parseval's identity prove that $\int_0^\infty \left(\frac{\sin t}{t}\right)^2 dt=\frac{\pi}{2}.$ **(A.U.N/D 2017, N/D 2011,2014, M/J 2013)**	**BTL-4**	**Analyzing**	**PO1,PO2, PO5,PO12**
5	Find the Fourier sine and cosine transform of e^{-ax} and hence find the Fourier sine transform of $\frac{x}{x^2+a^2}$ and Fourier cosine transform of $\frac{1}{x^2+a^2}$. (A.U. N/D 2011)	**BTL-5**	**Evaluating**	**PO1,PO2, PO5,PO12**
6	Find the Fourier cosine transform of e^{-x^2}. **(A.U M/J 2016)**	**BTL-4**	**Analyzing**	**PO1,PO2, PO5,PO12**
7	Prove that $\frac{1}{\sqrt{x}}$ is self reciprocal under Fourier sine	**BTL-5**	**Evaluating**	**PO1,PO2, PO5,PO12**

	and cosine transforms. **(A.U N/D 2015,M/J 2014)**			
8	Evaluate $\int_0^\infty \frac{x^2 dx}{(x^2+a^2)(x^2+b^2)}$ using Fourier transforms(MA1201 N/D 2005, M/J 2014,N/D2016)	BTL-5	Evaluating	PO1,PO2, PO5,PO12
9	By finding the Fourier cosine transform of $f(x)=e^{-ax}\ (a \phi 0)$ and using Parseval's identity for cosine transform evaluate $\int_0^\infty \frac{dx}{(a^2+x^2)^2}$. **(A.U A/M 2016)**	BTL-3	Applying	PO1,PO2, PO5,PO12
10	If $F_c(s)\ and\ G_c(s)$ are the Fourier cosine transform of f(x) and g(x) respectively, then prove that $\int_0^\infty f(x)g(x)dx = \int_0^\infty F_c(s)G_c(s)ds.$ (A.U N/D 2008,M/J 2015)	BTL-3	Applying	PO1,PO2, PO5,PO12
11.	Find the Fourier sine transform of $f(x)=\begin{cases} x, & 0 \pi x \pi 1 \\ 2-x, & 1 \pi x \pi 2 \\ 0, & x \phi 2. \end{cases}$ **(A.U.N/D 2016, N/D 2011,2012, M/J 2014)**	BTL-5	Evaluating	PO1,PO2, PO5,PO12
12.	If $F_c(f(x)) = F_c(s)$, prove that $F_c(F_c(x)) = f(s)$. **(A.U M/J 2017)**	BTL-3	Applying	PO1,PO2, PO5,PO12
13	Use transform method to evaluate $\int_0^\infty \frac{dx}{(x^2+a^2)(x^2+b^2)}$	BTL-3	Applying	PO1,PO2, PO5,PO12

UNIT-V Z -TRANSFORMS AND DIFFERENCE EQUATIONS

Z-transforms - Elementary properties – Inverse Z-transform – Convolution theorem -Formation of difference equations – Solution of difference equations using Z-transform.

PART – A

CO Mapping :

Q.No	Questions	BT Level	Competence	PO
1.	Define the unit step sequence. Write its Z- transform. Soln: It is defined as U(k) : {1 ,1 , 1, ………) = $\begin{cases} 1, & k > 0 \\ 0, & k < 0 \end{cases}$	**BTL -1**	**Remembering**	**PO1**

	Hence $Z[u(k)] = 1 + 1/z + 1/z^2 + \ldots + = \frac{1}{1-1/z} = \frac{z}{z-1}$ **(A.U.N/D 2017, N/D 2010,2012, M/J 2013)**			
2.	Form adifference equation by eliminating the arbitrary constant A from $y_n = A.3^n$ Soln: $y_n = A.3^n$,$y_{n+1} = A.3^{n+1} = 3A\ 3^n = 3y_n$ Hence $y_{n+1} - 3y_n\ 0$ **(A.U N/D 2010,M/J 2012,2014)**	**BTL -1**	**Understanding**	**PO1**
3.	Find the Z transform of $\sin\frac{n\pi}{2}$ Soln: We know that , $z[\sin n\theta] = \frac{Z\ sinn\theta}{z2-2zcos\theta+1}$ Put $\theta = \pi/2$ $z[\sin\frac{n\pi}{2}] = \frac{z\sin n\pi/2}{z2-\frac{2zcos\pi}{2}+1} = \frac{z}{z2+1}$ **(A.U.A/M 2010, M/J 2012)**	**BTL -5**	**Understanding**	**PO1**
4.	Find Z(n). Soln: $Z(n) = \frac{z}{(z-1)2}$ **(A.U M/J 2011)**	**BTL -1**	**Remembering**	**PO1**
5.	Express Z{ f(n+1)} in terms of f(z) Soln: Z{ f(n+1)} = zf(z) – zf(0) **(A.U M/J 2011)**	**BTL -1**	**Remembering**	**PO1**
6.	Find the value of z{f(n)] when $f(n) = na^n$ Soln: $z(na^n) = \frac{az}{(z-a)}$ **(A.U M/J 2009)**	**BTL -1**	**Understanding**	**PO2,PO5**
7.	Find $z[e^{-iat}]$ using Z transform. Soln. By shifting property , $z[e^{-iat}] = ze^{iaT}/\ ze^{iaT}{}_{-1}$ **(A.U M/J 2011,N/D 2012)**	**BTL -1**	**Remembering**	**PO1**
8.	Find the Z transform of $a^n/n!$. Soln: $z[a^n/n!] = e^{a/z}$ (By definition) **(A.U M/J 2012,N/D 2014)**	**BTL -1**	**Understanding**	**PO1**
9.	State initial value theorem in Z-transform. Solution : If f(t) = F(z) then $\lim_{t\to 0} f(t) = \lim_{z\to\infty} F(z)$. (A.U.N/D 2015,2013)	**BTL -1**	**Understanding**	**PO1**
10.	State final value theorem in Z-transform. Solution : If f(t) = F(z) then $\lim_{t\to\infty} f(t) = \lim_{z\to 0} F(z)$. State Euler formula. **(A.U M/J 2013)**	**BTL -1**	**Understanding**	**PO1**
11.	State Convolution theorem on Z-transform. Solution : If X(z)) and Y(z) are Z- transforms of x(n) and y(n) respectively then the Z- transform of the convolutions of x(n) and y(n) is the product of their Z- transform. **(A.U M/J 2012,N/D 2014)**	**BTL -1**	**Understanding**	**PO1**
12.	Define Z-tranforms of f(t). Solution : Z-transform for discrete values of t : If f(t) is a	**BTL -1**	**Understanding**	**PO1**

	function defined for discrete values of t where t=nT , n=0,1,2,...T being the sampling period then $Z\{f(t)\} = F(Z) = \sum_{n=0}^{\infty} f(nT)Z^{-n}$			
13.	Define Z- transform of the sequence. Solution : Let {x(n)} be a sequence defined for all integers then its Z-transform is defined to be $Z\{x(n)\} = X(Z) = \sum_{n=0}^{\infty} x(n)Z^{-n}$	**BTL -4**	**Analyzing**	**PO2**
14.	State first shifting theorem. Solution : If $Z\{f(t)\} = F(Z)$ then $Z\{(e^{-at} f(t)\} = F(ze^{at})$	**BTL -2**	**Remembering**	**PO5**
15.	Find the Z-Transform of cos nθ and sin nθ? Solution : $Z(\cos n\theta) = \frac{z(z-\cos\theta)}{(z-\cos\theta)^2 + \sin^2\theta}$ $Z(\sin n\theta) = \frac{z\sin\theta}{(z-\cos\theta)^2 + \sin^2\theta}$ **(A.U N/D 2017)**	**BTL -2**	**Remembering**	**PO5**
16.	Find the Z-transform of unit step sequence. Solution: $u(n) = 1$ for $n \geq 0$ $u(n) = 0$ for $n < 0$. Now $Z[u(n)] = \frac{z}{z-1}$	**BTL -1**	**Remembering**	**PO1**
17.	Find the Z-transform of unit sample sequence. Solution: $\delta(n) = 1$ for n = 0 $\delta(n) = 0$ for n > 0. Now $Z[\delta(n)] = 1$	**BTL -1**	**Understanding**	**PO1**
18.	Form a difference equation by eliminating arbitrary constant from $u_n = a.2^{n+1}$. Solution : Given , $u_n = a.2^{n+1}$ $u_{n+1} = a.2^{n+2}$ Eliminating the constant a, we get $\begin{vmatrix} u_n & 1 \\ u_{n+1} & 2 \end{vmatrix} = 0$ We get $2u_n - u_{n+1} = 0$	**BTL -1**	**Understanding**	**PO1**
19.	Form the difference equation from $y_n = a + b.3^n$ Solution: Given , $y_n = a + b.3^n$ $y_{n+1} = a + b.3^{n+1}$ $= a + 3b.3^n$ $y_{n+2} = a + b.3^{n+2}$ $= a + 9b.3^n$	**BTL -1**	**Understanding**	**PO1**

	Eliminating a and b we get, $\begin{vmatrix} y_n & 1 & 1 \\ y_{n+1} & 1 & 3 \\ y_{n+2} & 1 & 9 \end{vmatrix} = 0$ We get $y_{n+2} - 4y_{n+1} + 3y_n = 0$			
20.	Find $Z[\frac{a^n}{n!}]$ Solution : $Z[\frac{a^n}{n!}] = e^{\frac{a}{z}}$			
PART-B				
1.	Find the Z-transform of cos nθ and sin nθ. Hence deduce the Z-transform of cos (n + 1)θ and a^n sin nθ (A.U.N/D 2012,2015,M/J 2016)	**BTL -1**	**Remembering**	**PO1,PO2,PO5**
2	Use residue theorem find $Z^{-1}\left(\frac{z\ (z+1)}{(z-3)^3}\right)$	**BTL -3**	**Applying**	**PO1,PO2,PO5**
3	Solve $y_{n+2} - 5y_{n+1} + 6y_n = 6^n$, $y_0 = 1$, $y_1 = 0$ (A.U.N/D 2012,2016)	**BTL -1**	**Remembering**	**PO1,PO2,PO5**
4	Solve using Z-Transform $u_{n+2} + 6u_{n+1} + 9u_n = 2^n;\quad given\ u_0 = u_1 = 0$ [NOV/DEC 2010]	**BTL -1**	**Remembering**	**PO1,PO2,PO5**
5	Using convolution theorem find the inverse Z transform of [APRIL/MAY 2010] $\left(\frac{z}{z-4}\right)^3$ (A.U.M/J 2010, N/D2014)	**BTL -2**	**Understanding**	**PO1,PO2,PO5**
6	Solve $y_{n+2} + 6y_{n+1} + 9y_n = 2^n$, $y_0 = 0$, $y_1 = 0$ (A.U.N/D 2014,2017)	**BTL -1**	**Remembering**	**PO1,PO2,PO5**
7	Using convolution theorem find $Z^{-1}\left(\frac{z^2}{(z-4)(z-3)}\right)$ (A.U.N/D 2014,2016, M/J2013)	**BTL -1**	**Remembering**	**PO1,PO2,PO5**
8	Fnd the inverse Z –transform of $\frac{Z^3-20Z}{(Z-2)^3(Z-4)}$ (A.U.N/D 2009)	**BTL -3**	**Applying**	**PO1,PO2,PO12**
9	Find $Z^{-1}\left(\frac{8z^2}{(2z-1)(4z+1)}\right)$ (A.U.N/D 2015,2013)	**BTL -3**	**Applying**	**PO1,PO2,PO12**

10	State and Prove Convolution theorem (A.U.N/D 2016,2011)	**BTL -3**	**Applying**	**PO1,PO2,PO12**
11	Solve $y_{n+2} + 6y_{n+1} + 9y_n = 2^n$, $y_0 = 0$, $y_1 = 0$ (A.U.A/M 2008,2010,N/D2014)	**BTL -5**	**Evaluating**	**PO1,PO2,PO5**
12	Prove that $Z\left(\frac{1}{n}\right) = \log\left(\frac{z}{z-1}\right)$	**BTL -3**	**Applying**	**PO1,PO2,PO12**
13	Using convolution theorem evaluate inverse Z-transform of $\left[\frac{z^2}{(z-1)(z-3)}\right]$ (A.U.N/D 2010,2016)	**BTL -1**	**Remembering**	**PO1,PO2,PO5**