Fundamentals of Mechanical Engineering and Mechatronics

KME 101-T/201-T

One Shot Video
के लिए यहाँ क्लिक करे

Unit-5
Mechatronics

One Shot Video
के लिए यहाँ क्लिक करे

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Syllabus

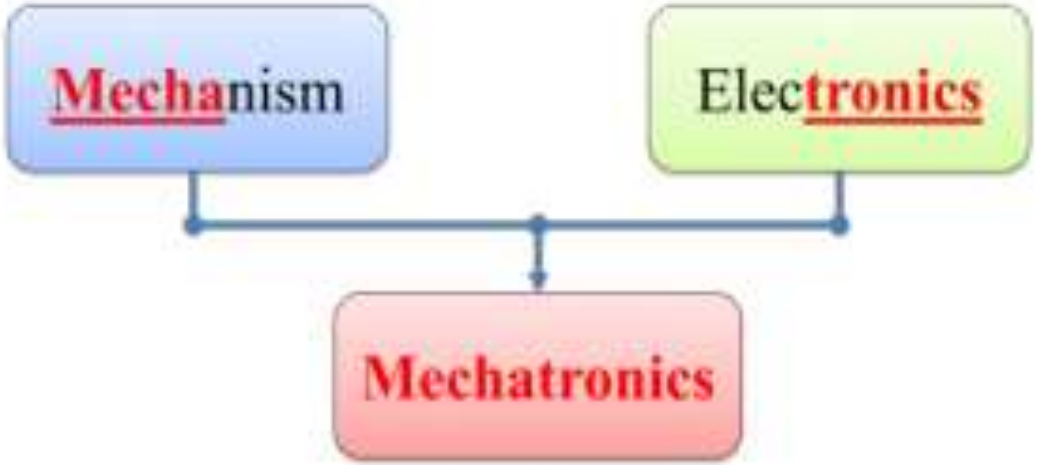
Introduction to Mechatronics: Evolution, Scope, Advantages and disadvantages of Mechatronics, Industrial applications of Mechatronics, Introduction to autotronics, bionics, and avionics and their applications. Sensors and Transducers: Types of sensors, types of transducers and their characteristics.

Overview of Mechanical Actuation System – Kinematic Chains, Cam, Train Ratchet Mechanism, Gears and its type, Belt, Bearing

Hydraulic and Pneumatic Actuation Systems: Overview: Pressure Control Valves, Cylinders, Direction Control Valves, Rotary Actuators, Accumulators, Amplifiers, and Pneumatic Sequencing Problems.

Q.1 What is “Mechatronics”?

- Mechatronics is a concept of Japanese origin (1970’s) and can be defined as the application of electronics and computer technology to control the motions of mechanical systems.

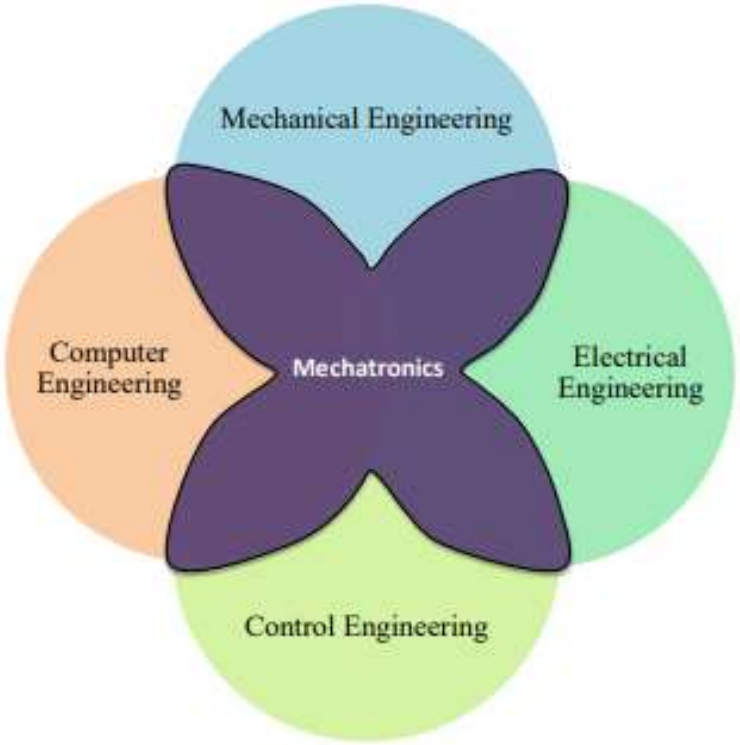


Mechatronics.....

- It is a multidisciplinary approach to product and manufacturing system design (Figure).

- It involves application of electrical, mechanical, control and computer engineering to develop products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming.

- It concurrently includes all these disciplines.



Mechatronics.....

- Mechatronics can also be termed as replacement of mechanics with electronics or enhance mechanics with electronics.

- **For example, in modern automobiles, mechanical fuel injection systems are now replaced with electronic fuel injection systems.**

- This replacement made the automobiles more efficient and less pollutant.

Mechatronics.....

- By employment of reprogrammable microcontrollers/microcomputers, it is now easy to add new functions and capabilities to a product or a system.

- **Today's domestic washing machines are "intelligent" and four-wheel passenger automobiles are equipped with safety installations such as air-bags, parking (proximity) sensors, antitheft electronic keys etc.**

Q.2 What are the Advantages of Mechatronics?

1. Mechatronics enhances functionality and features.
2. It brings more efficiency.
3. Mechatronics adds intelligence to design of the system.
4. Mechatronics solutions are less expensive when compared to mechanical solutions.
5. A mechatronic solution improves design and reliability.
6. It is also more user-friendly and safer to use.
7. Mechatronic uses microcontroller, by which precision, position, speed, flow rate, and variables can be controlled.

Q.3 What are the Dis-advantages of Mechatronics?

1. High initial cost of the system.
2. Imperative to have knowledge of different engineering field for design and implementation.
3. Specific problem for various system would have to be addressed separately and properly.
4. It is expensive to incorporate mechatronic approach to an existing/old system.
5. Maintenance and servicing are costly .

Q.4 What are the Industrial application of Mechatronics?

- Mechatronics based automated systems such as automatic inspection and quality assurance, automatic packaging, record making, and automatic dispatch help to expedite the entire manufacturing operation.
- **It is widely used in aeronautics engineering** for unmanned aerial vehicles and automatic pilots. **In the defense industry it is used for automatically guided vehicles** and mine detection robots.

Q.5 Write short notes on Autotronics.

Definition: Autotronics can be defined as the **combination of automobile and electronics** or we can say that the **use of electronics science in automobile vehicles is called autotronics.**

Major Areas:

- The use of electronics in the automobile field makes the system safe, improved and efficient.
- At present, in the new generation automobiles almost 75%-85% of automobile parts are embedded with electronics system.
- The main areas of automobiles using autotronics are engine controlling system, airbags, antilock braking system, lightening interiors, GPS, music systems etc.
- In the autotronics systems the use of control units like sensors, motors and digital equipment establishes a communication between the various essential system and components of the vehicle.

Q.6 Write short notes on Bionics.

- **Bionics is a field of technology that combines the study of biology in nature and its patterns, with mechatronics, which combines mechanical, electronics and software.**
- Bionics consists of many different subject areas, but one of the most eye-catching and popular is bionic implants.
- **These implants aim to improve the standard of living for people who have damaged body parts such as arms, legs, eyes, or even ears.**

Working of bionic implants

- It’s extremely hard to mimic the actions created by regular limbs. It’s something that software and hardware engineers have a lot of trouble working with.
- To solve this, all the successful bionics systems use machine learning to mimic physical movements.
- **Myoelectric** *(Myo = muscles)* sensors are used in bionic limbs to generate an electrical signal from muscle contractions.
- This is useful because it can get signals from the still functional nerve endings of the amputated limb. This means that the sensors can pick up when the user wants to move that area.
- In some cases, to improve the accuracy of myoelectric sensors, small incisions are made to place them closer to the muscle/nerve endings.

Q.7 Write short notes on Avionics.

- **Avionics are the electronics systems used in aircraft, artificial satellite, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems,** and the hundreds of systems that are fitted to aircraft to perform individual functions.

- Avionics grew in 1950's and 1960 as electronic devices which replaces the mechanical or analog equipment in the aircraft.
- Avionics equipment on a modern military or civil aircraft account for around;

- 30% of the total cost of the aircraft
- 40% in the case of a maritime patrol/antisubmarine aircraft or helicopter.
- Over 75% of the total cost in the case of an airborne early warning aircraft (AWACS).

NEED FOR AVIONICS:

- To enable the flight crew to carry out the aircraft mission safely and efficiently. For civil airliner the mission is carrying passengers to their destination. For military aircraft the mission is intercepting a hostile aircraft, attacking a ground target, reconnaissance or maritime patrol.

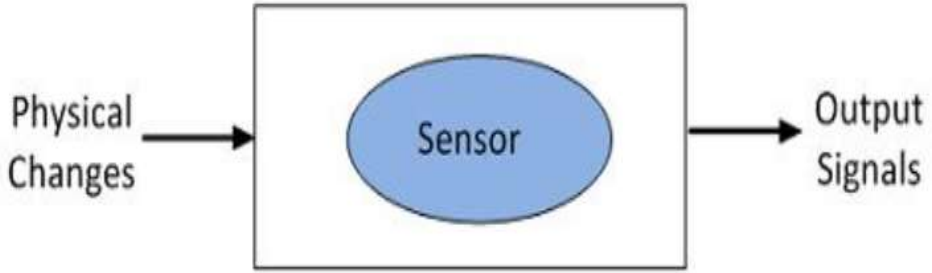
Advantages

- Increased safety
- Air traffic control requirements
- All weather operation
- Reduction in fuel consumption
- Improved aircraft performance and control and handling and reduction in maintenance costs

Q.8 Define Sensor with an example.

- **Sensor:** A sensor is a device that provides usable output in response to change in a specified physical quantity which is measured. A device that receives and responds to a signal .

- The physical quantity may be temperature, force, pressure, displacement, flow etc.
- **For example, the bulb of a thermometer** senses the temperature of the body in contact



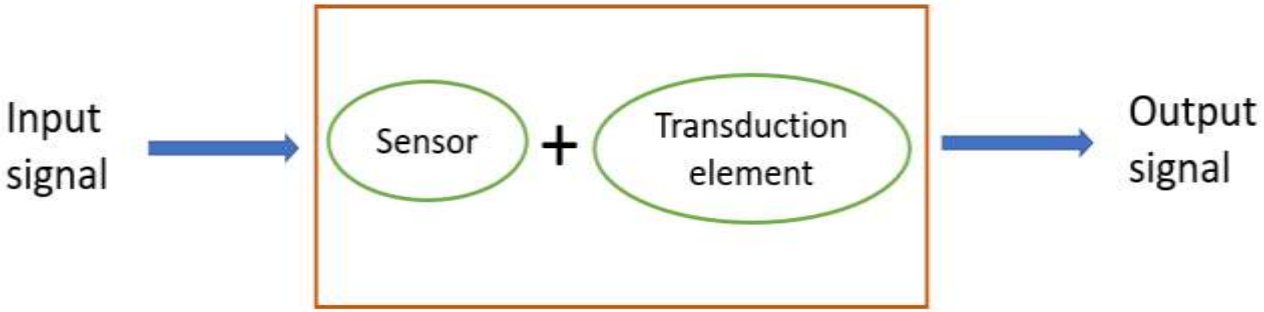
Sensor

Q.9 Define transducer with an example.

- The **transducer** is a device that changes the physical attributes of the non-electrical signal into an electrical signal which is easily measurable. The process of energy conversion in the transducer is known as the transduction(figure). It consists of two parts:

1. Sensing element/detector
2. Transduction element

For example : thermometer



Q.10 List the types of sensors.

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor, colour sensor
- Humidity Sensor
- Flow and Level Sensor

Q.11 List the types of transducers.

Types of transducers:

There are of many different types of transducer, they can be classified based on various criteria as:

1. **Transducer based on Quantity to be Measured**

- Temperature Transducers (e.g thermocouple)
- Pressure transducers (e.g. a diaphragm)
- Displacement transducers (e.g. LVDT)
- Oscillator transducers
- Flow transducers

2. **Transducer based on the Principle of Operation**

- Capacitive
- Inductive
- Resistive
- Photoelectric
- chemical

3. **Transducer based on need of an External Power Source**

❖ **Active Transducer:** Active transducers are those which do not require any power source for their operation. For example, a thermocouple, thermometer etc.

❖ **Passive Transducer:** Transducers which require an external power source for their operation is called as a passive transducer**.** For example, a strain gauge, thermistor etc.

Q.12 Explain Characteristics of sensors and transducers

- The performance characteristics are mainly divided into two categories:

i) Static characteristics ii) Dynamic characteristics

i. Static characteristics:

Static characteristics refer to the characteristics of the system when the input is either held constant or varying very slowly. Range, sensitivity, linearity, resolution, accuracy, precision, response time etc are important static characteristics.

ii. Dynamic characteristics:

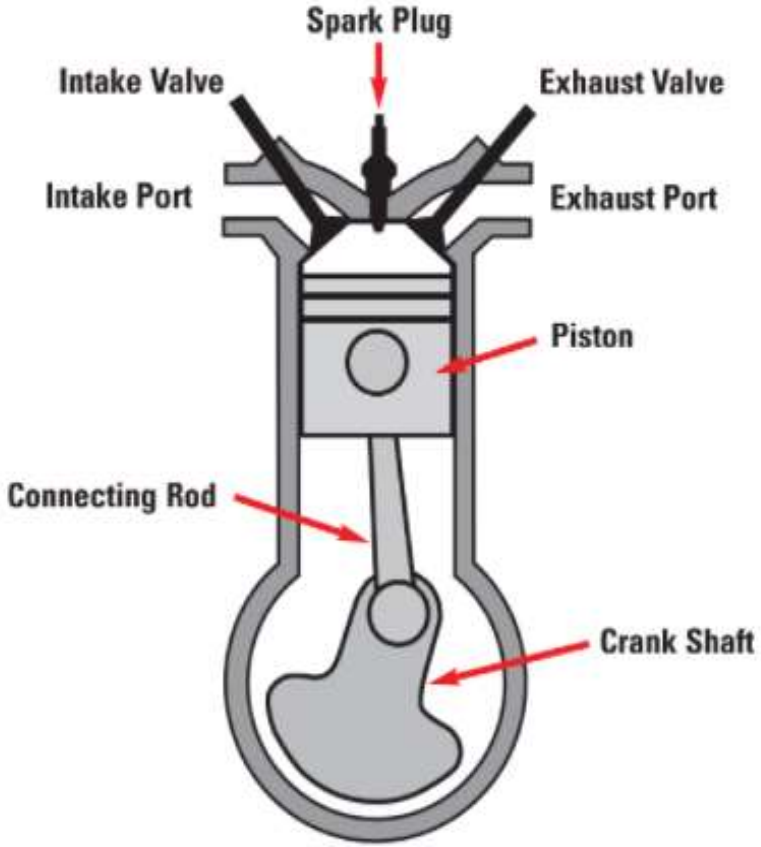
Dynamic characteristics refer to the performance of the instrument when the input variable is changing rapidly with time. For example, human eye cannot detect any event whose duration is more than one-tenth of a second; thus, the dynamic performance of human eye cannot be said to be very satisfactory.
Few important dynamics characteristics are dynamic error, speed of response.

Q.13 Define Kinematic Link or Element with an example.

Kinematic Link or Element:

- Every part of a machine which is having some relative motion with respect to some other parts will be known as kinematic link or element.

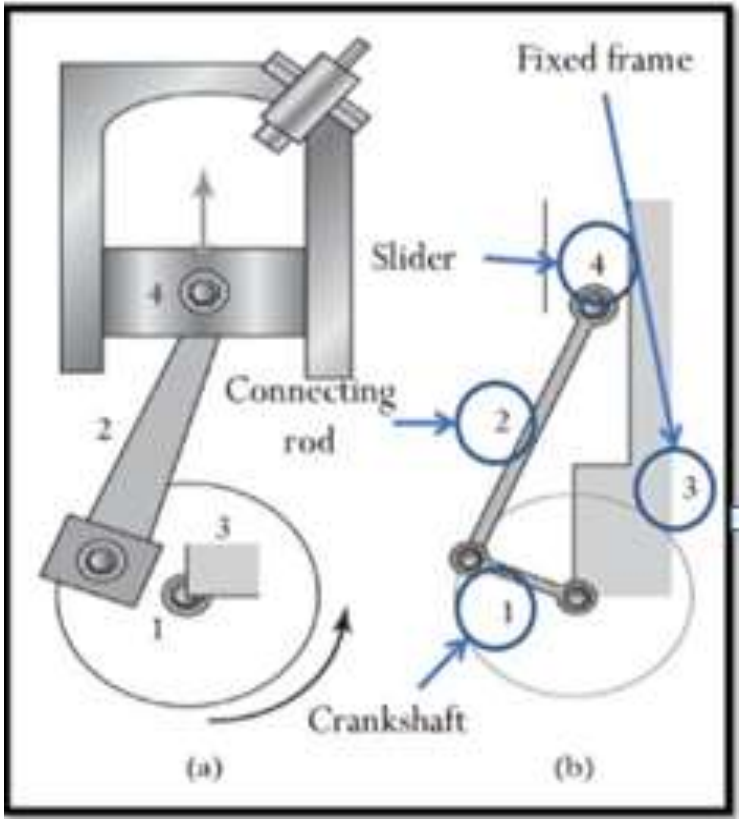
- **Examples** : Piston, Connecting rod, crank, lever etc.



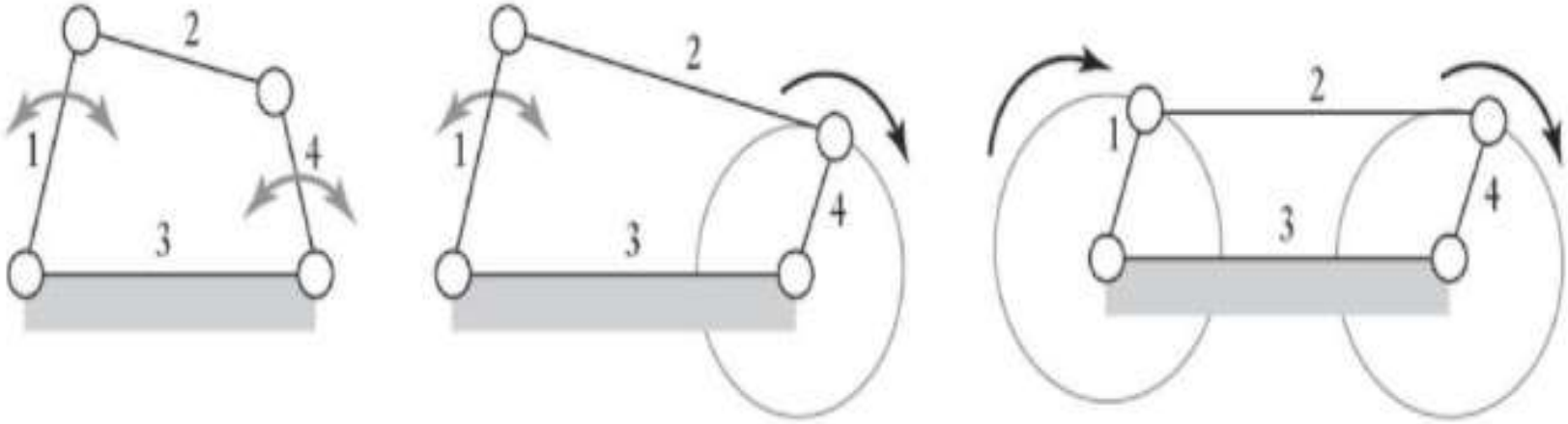
Q.14 Define Kinematic chain with an example.

Kinematic Chain:

- "If all the links are connected in such a way that **first link is connected to last link** in order to get the close chain and if all the relative motion in this close chain are constrained then such a chain is known as kinematic chain".



- **The Four-bar Chain**
  - Consists of 4 links connected to give 4 joints about which turning can occur.



Double-lever mechanism Lever-crank mechanism Double-crank mechanism

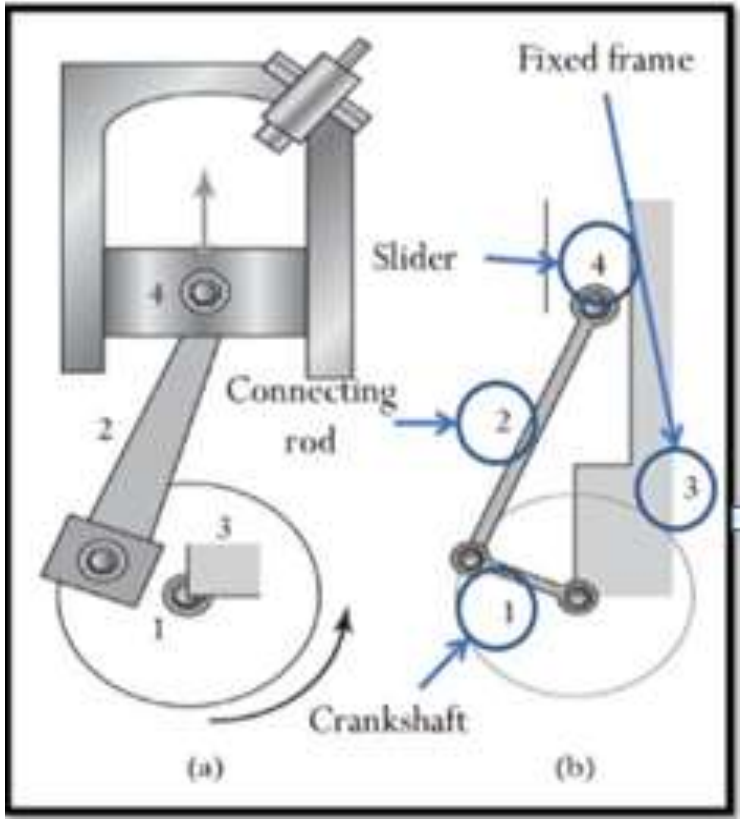
Q.15 Define mechanism and machine.

Mechanism:

- "If one of the links of kinematic chain is fixed then it will be known as mechanism".

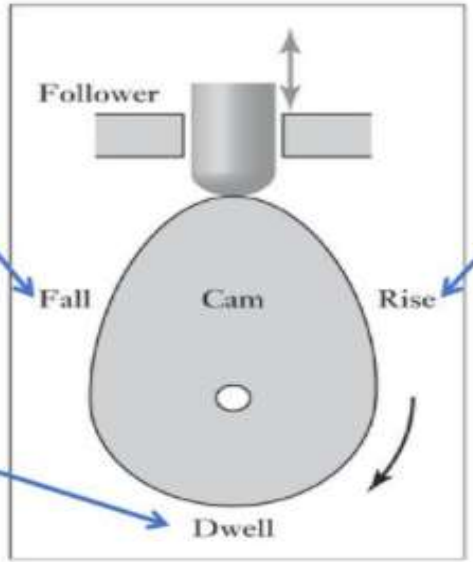
Machine:

- "When a mechanism is utilized in order to get desired output with respect to given input then it will be known as a machine".



Q.16 Define CAM with diagram.

- Cam is a body which rotates or oscillates and in doing so imparts a reciprocating motion to a second body called follower, with which it is in contact.
- The length of times spent for the rotation is depending on the shape of the cam.



Part that lowers the follower, its profile determining how quickly the cam follower will fall.

Part that drives the follower upwards, its profile determining how quickly the cam follower will lifted.

Part that allows the follower to remain at the same lever for a significant period of time and where its circular with a radius that does not change.

Q.17 What are the types of CAM ?.

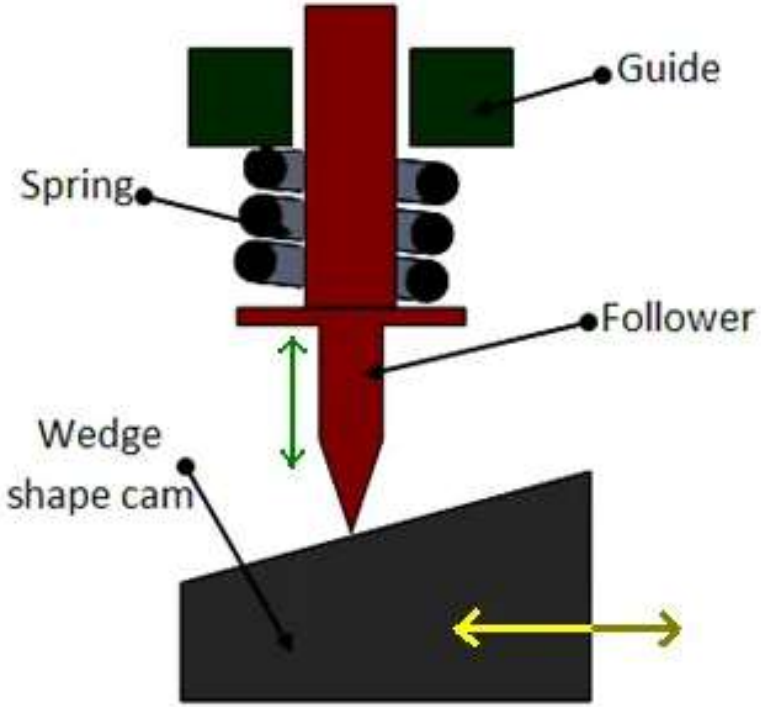
Types of Cams:

Cams can be classified according to

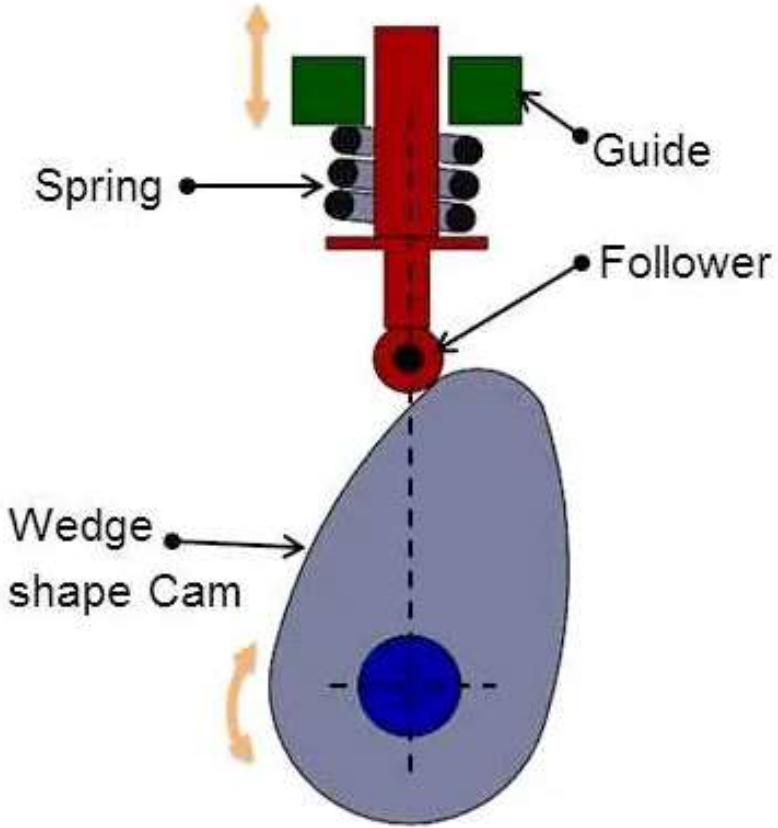
- Shape
- Follower movement
- Manner of constraint of the follower

1. Wedge and flat cams
2. Radial or disc cams
3. Spiral cams
4. Cylindrical cams
5. **Spherical cams**

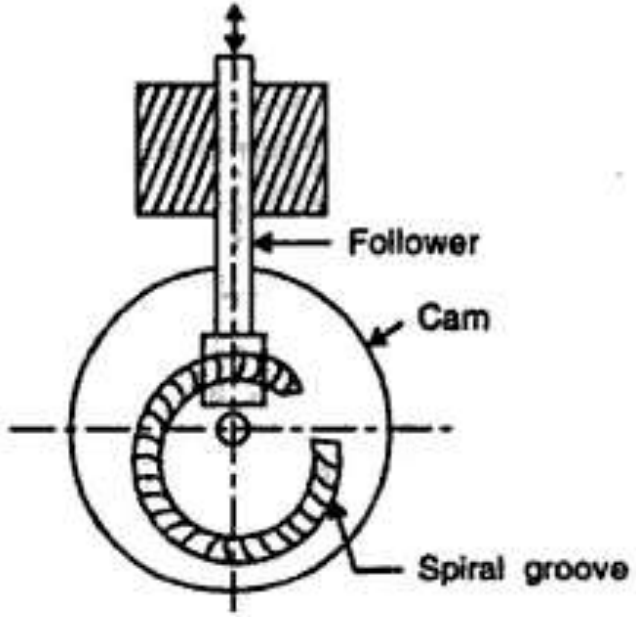
1. Wedge and flat cams



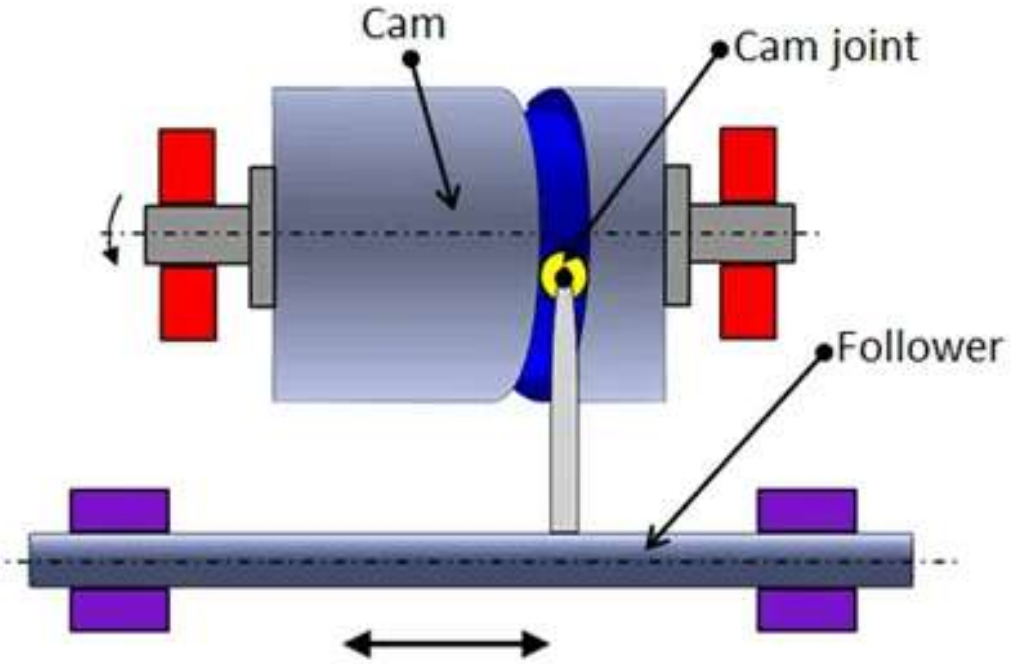
2. Radial or disc cams



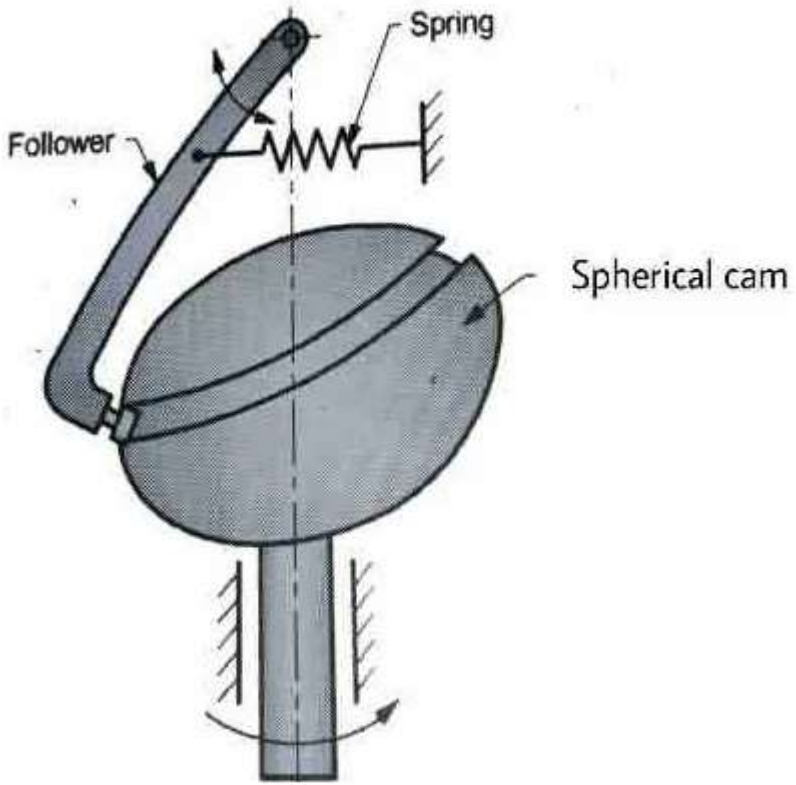
3. Spiral cams



4. Cylindrical cams



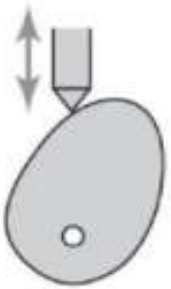
5. Spherical cams



Q.18 What are the types of followers ?.

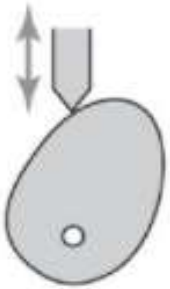
- Figure below shows a number of examples of different types of cam followers.

Point



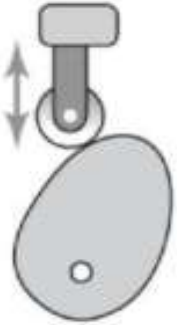
(a)

Knife



(b)

Roller

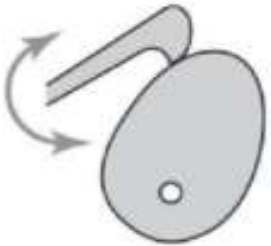


(c)

Lower friction than sliding contact but can be more expensive

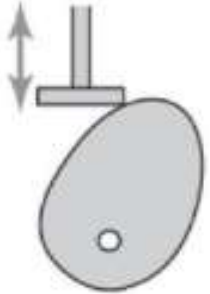
- Figure below shows a number of examples of different types of cam followers.

Sliding and oscillating



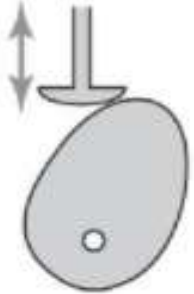
(d)

Flat



(e)

Mushroom



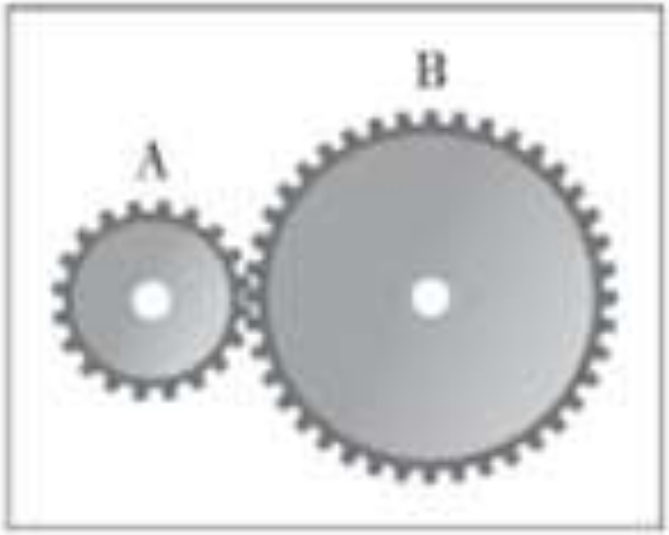
(f)

Often used because – cheaper and can be made smaller than roller follower.

Q.19 What is the use of gears or gear drive ?

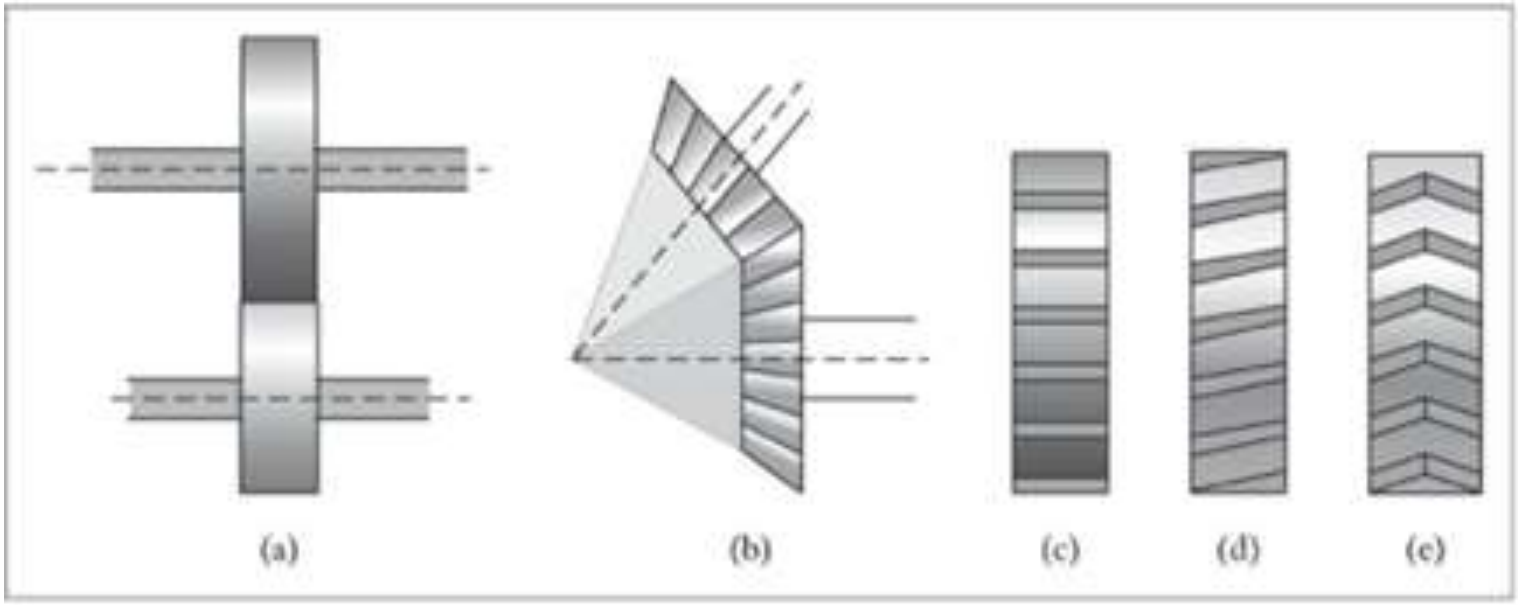
Gears are used to

- Transmit power
- Change the velocity
- Change the direction



Gear Ratio:

Q.20 Explain the types of gears .



(a) Parallel gear axes, (b) axes inclined to one another, (c) axial teeth, (d) helical teeth, (e) double helical teeth

Types of gears

Spur Gears

Helical Gears

Rack and Pinion

Bevel Gears

Miter Gears

Worm and Worm Gear

Screw Gears

Internal Gears

Spur gear : This is Cylindrical gear. Teeth are parallel to axis. This is a highly demanded gear, which is easy to manufacture and to assemble.

Helical gear : This is a Cylindrical gear. Teeth have helix curve. Helical gear provides more strength, less oscillation and lower noise level compared with Spur gears.

Internal gear : This is a cylindrical gear ring with teeth formed at the inner diameter.

Straight bevel (Miter) gear: Miter gear has shaft angle of 90° and gear ratio of 1:1.

Rack and pinion : A rack is a gear whose pitch diameter is infinite, resulting in a straight line pitch circle. Used to convert rotary motion to straight line.

Q.21 What do you mean by gear trains ?.

- The term gear train is defined as a series of intermeshed gear wheels.
- It is required when large distance is there between two gears.
- It is required when very high/very low velocity ratio is required.

- **Gear train may be simple gear train or may be compound gear train.**

40

Any Gear train is a combination of

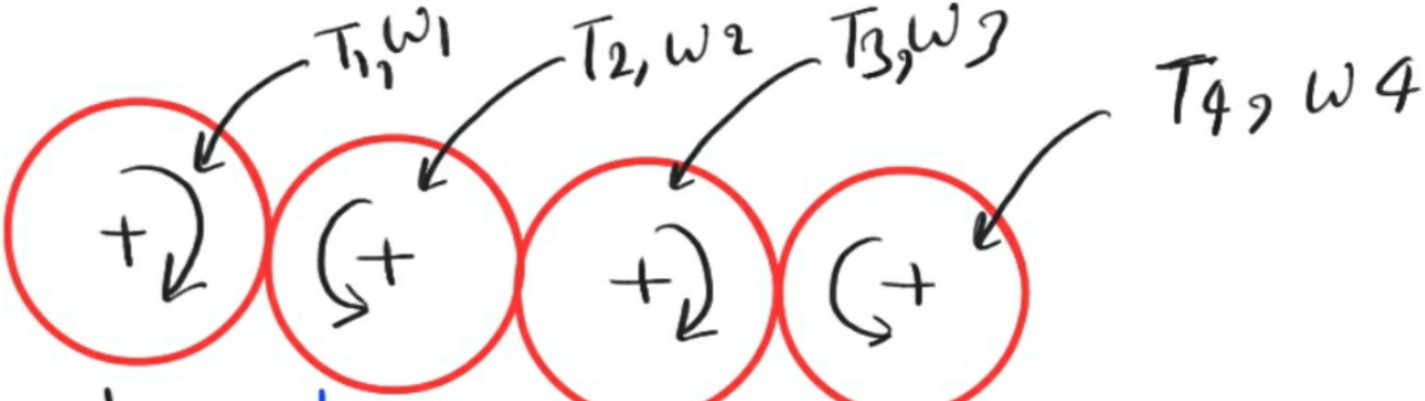
(I) Main DVR (driver)

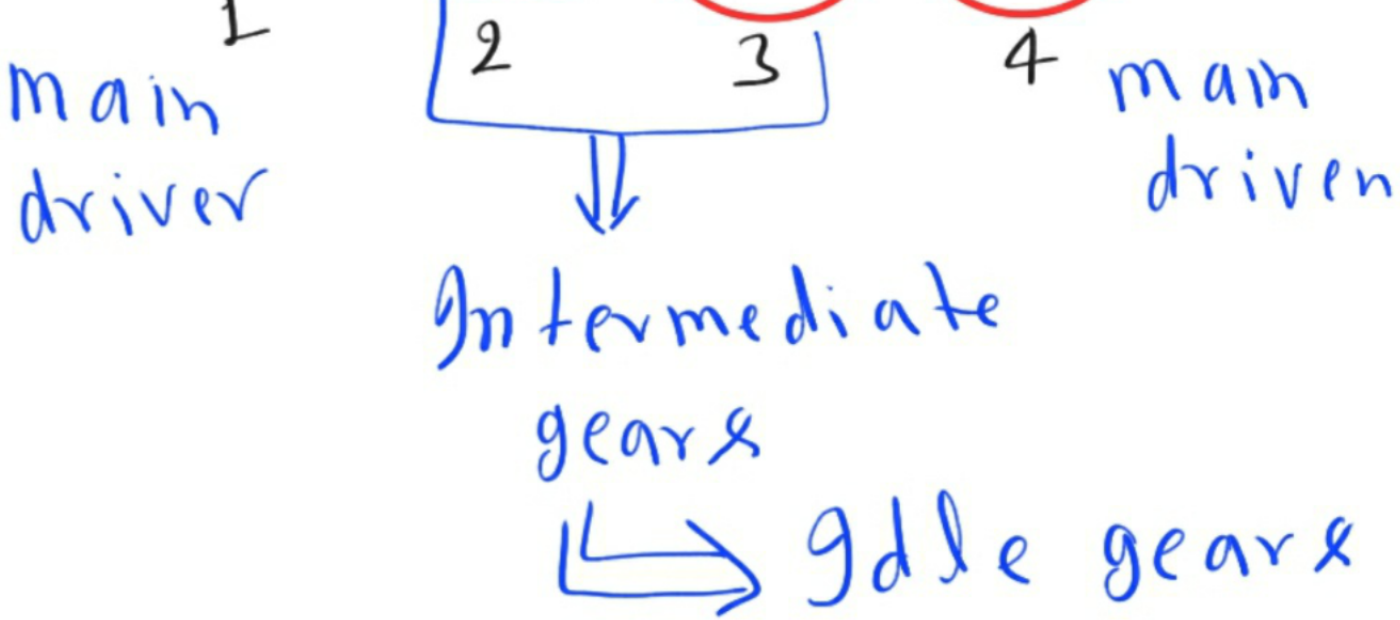
(II) Main DVN (driven)

(III) Intermediate Gears

Q.22 Explain Simple Gears Train.

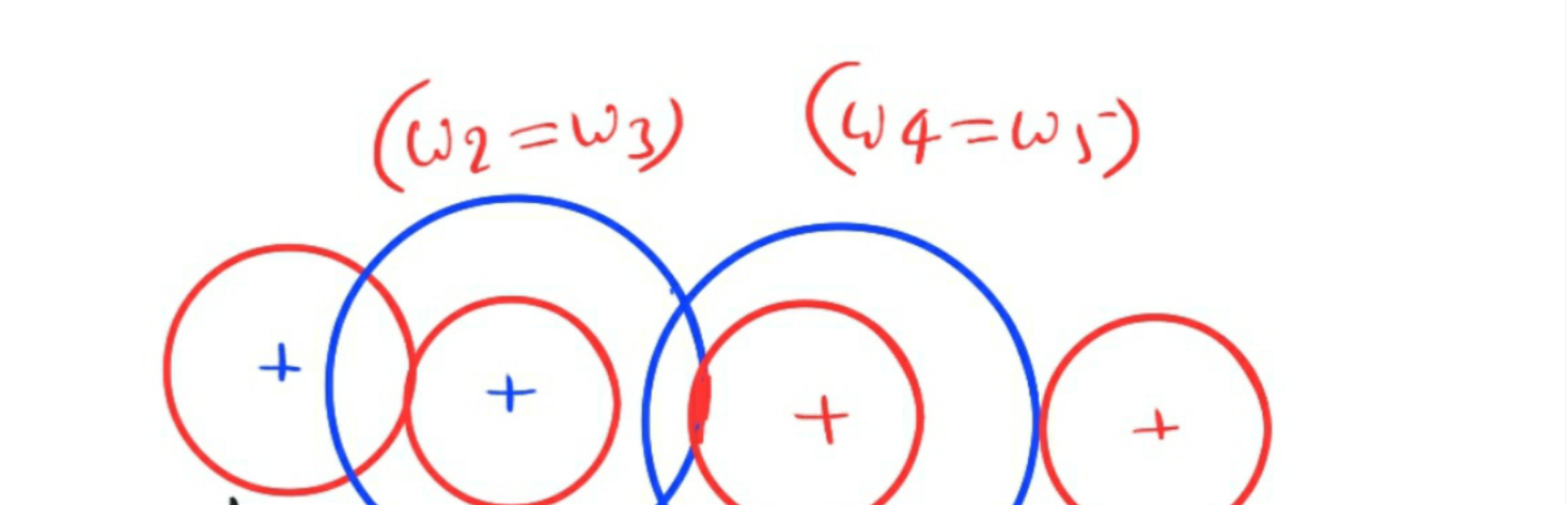
- Every shaft is having only one gear as shown in the fig.
- For such a gear train, the overall gear ratio is the ratio of the angular velocities at the input and output shafts.

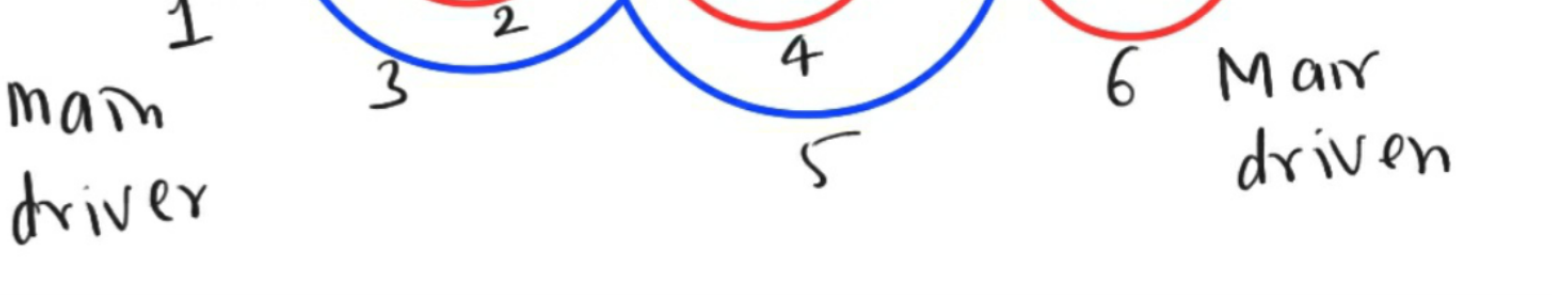



1
2
3
4
main driver
main driven
Intermediate gears
Idle gears

Q.23 Explain Compound Gears Train.

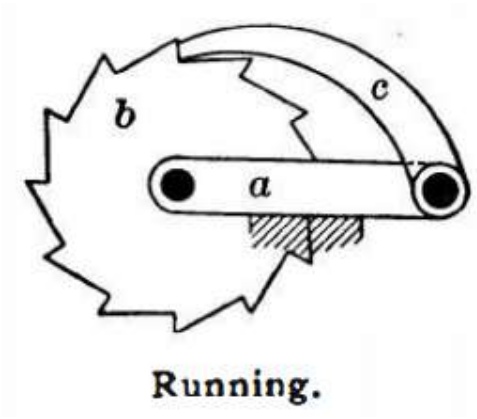
- At least one of the **intermediate shaft must have more than one gear** in use.



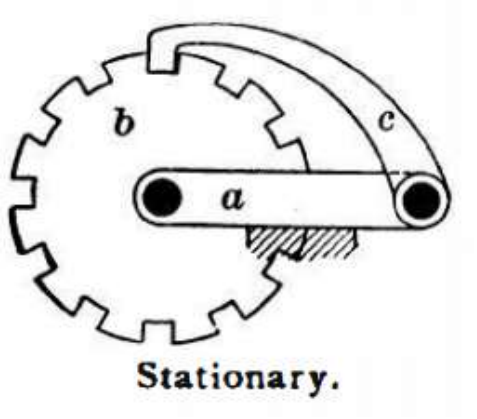

1
2
3
4
5
6
main driver
Main driven

Q.24 What do mean by Ratchet Mechanism

- In Ratchet Mechanism, gearing are arranged in such a way that certain links are temporarily or periodically locked together or connected during the action of the mechanism.
- This locking of relative motion may be so effected that relative motion of the two links is only possible in one sense or direction (when the gear is called by Reuleaux a Running-ratchet Train), or movement in both directions may be rendered impossible when the ratchet acts, in which case the gear is known as a Stationary-ratchet Train.



Running.



Stationary.

- Each consists of a frame or arm **a**, ratchet-wheel **b**, and ratchet or click **c.** In the first figure **b** is evidently capable of left-handed rotation only, so long as the ratchet **c** (sometimes called a pawl) is resting against its teeth.
- In the second figure motion is only possible when the pawl is lifted clear.

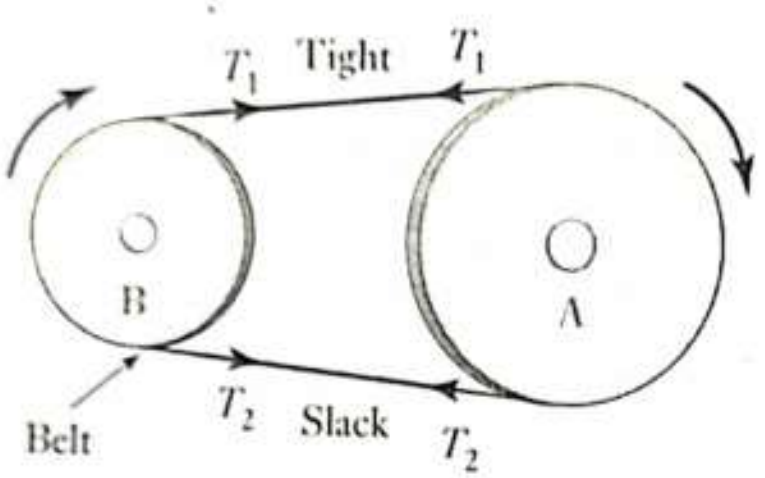
Q.25 What is belt drive?

- Belt drives use the friction that develops between the pulleys attached to the shafts and the belt around the arc of contact in order to transmit a torque.
- The torque is due to the differences in tension that occur in the belt during operation.
- Let T_1 is the tension in the tight side and T_2 is the tension in slack side.

$$\text{torque on A} = (T_1 - T_2)r_A$$

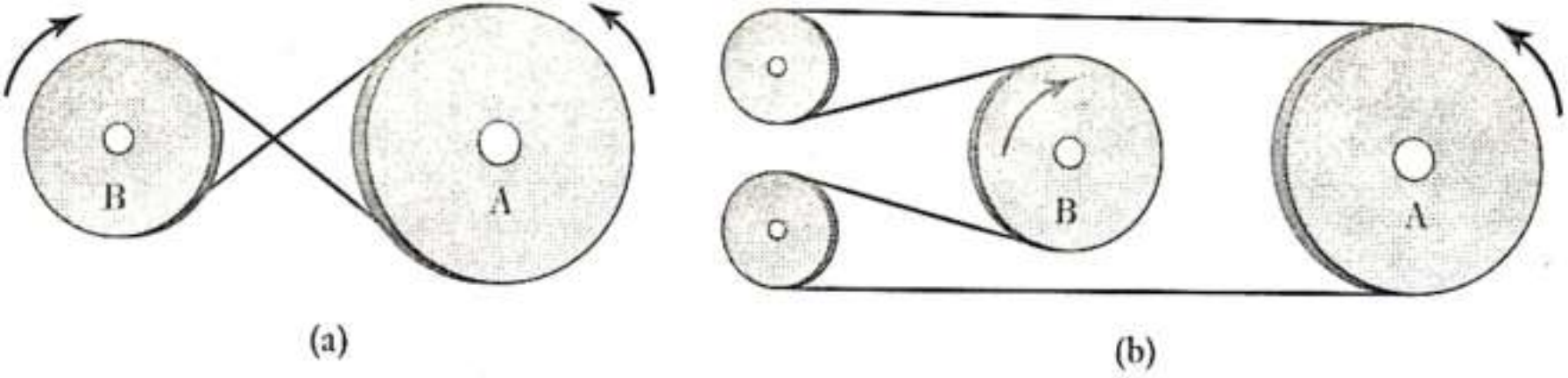
$$\text{torque on B} = (T_1 - T_2)r_B$$

$$\text{power} = (T_1 - T_2)v$$



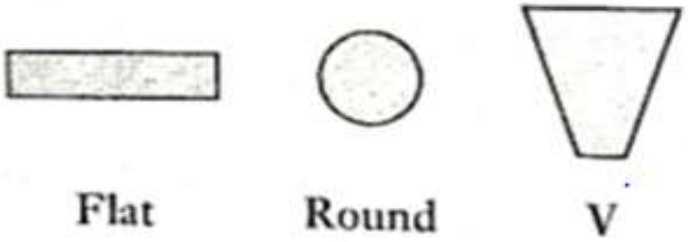
- In previous case driven wheel rotating in the same direction as the driver wheel.

- As shown in the diagrams below driven wheel is rotating in the opposite direction as the driver.



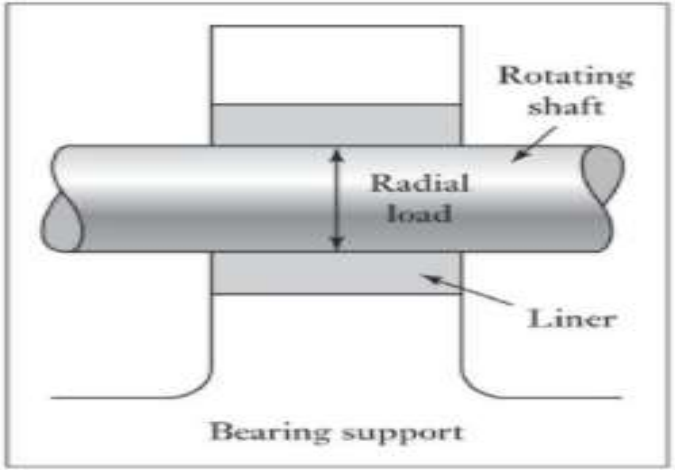
Q.26 What are the various types of belts used for power transmission?

- **Flat :** The belt has a rectangular cross-section and produces less noise. They can transmit power over a long distance between pulley centers
- **Round :** The belt has a circular cross-section and used with grooved pulleys.
- **V :** V-belts are used with grooved pulleys and are less efficient than flat belts.

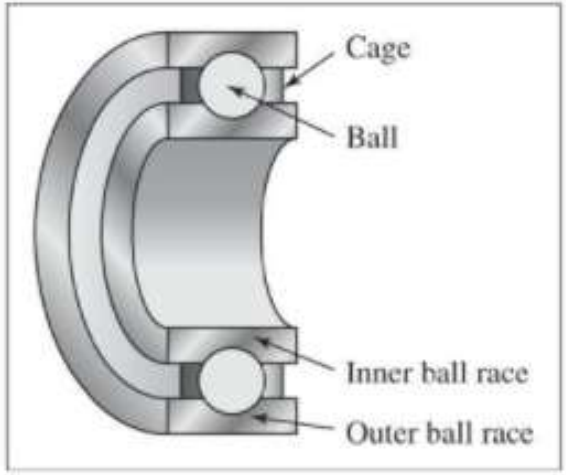


Q.27 Write the definition of bearing and its classification.

- **Plain journal bearings**
  - Used to support rotating shafts which are loaded in a radial direction (journal – shaft).
  - Consists of an insert of some suitable material which is fitted between the shaft and the support.
  - Rotation of the shaft results in its surface sliding over that of the bearing surface.
  - The bearing may be a dry rubbing bearing or lubrication.



- **Ball and roller bearing**
  - With this type of bearing, the main load is transferred from the rotating shaft to its support by rolling contact rather than sliding contact.
  - A rolling element bearing consists of 4 main elements : an inner race, an outer race, the rolling element either balls or rollers, and a cage to keep the rolling elements apart.
  - The inner and outer races contain hardened tracks in which the rolling elements roll.



Q.28 Explain Hydraulic system.

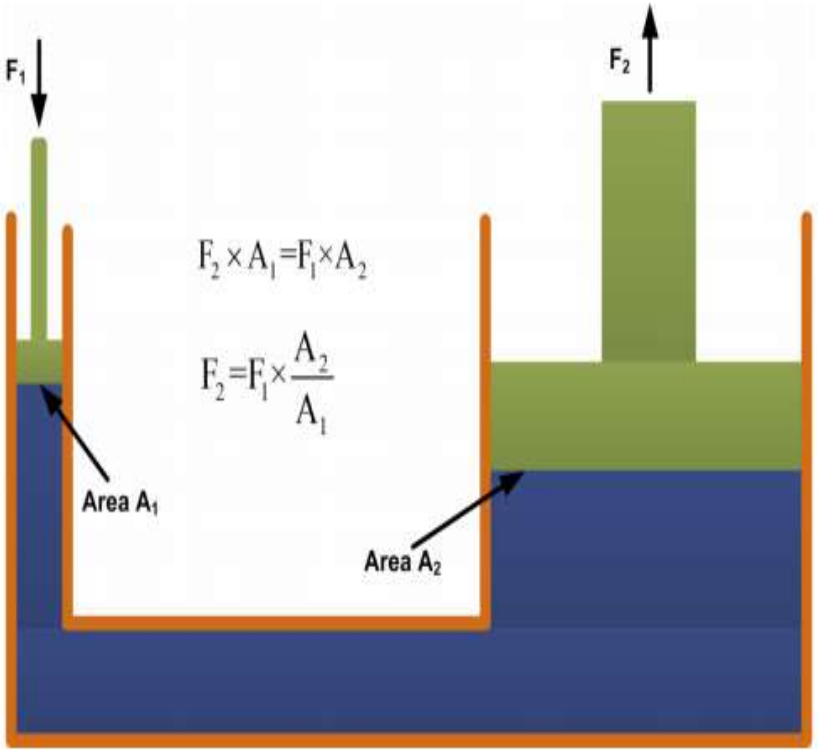
- The controlled movement of parts or a controlled application of force is a common requirement in the industries.
- These operations are performed mainly by using electrical machines or diesel, petrol and steam engines as a prime mover.
- These prime movers can provide various movements to the objects by using some mechanical attachments like screw jack, lever, rack and pinions etc.
- However, these are **not the only** prime movers. The enclosed fluids (**liquids and gases**) can also be used as prime movers to provide controlled motion and force to the objects or substances.

Hydraulic system……

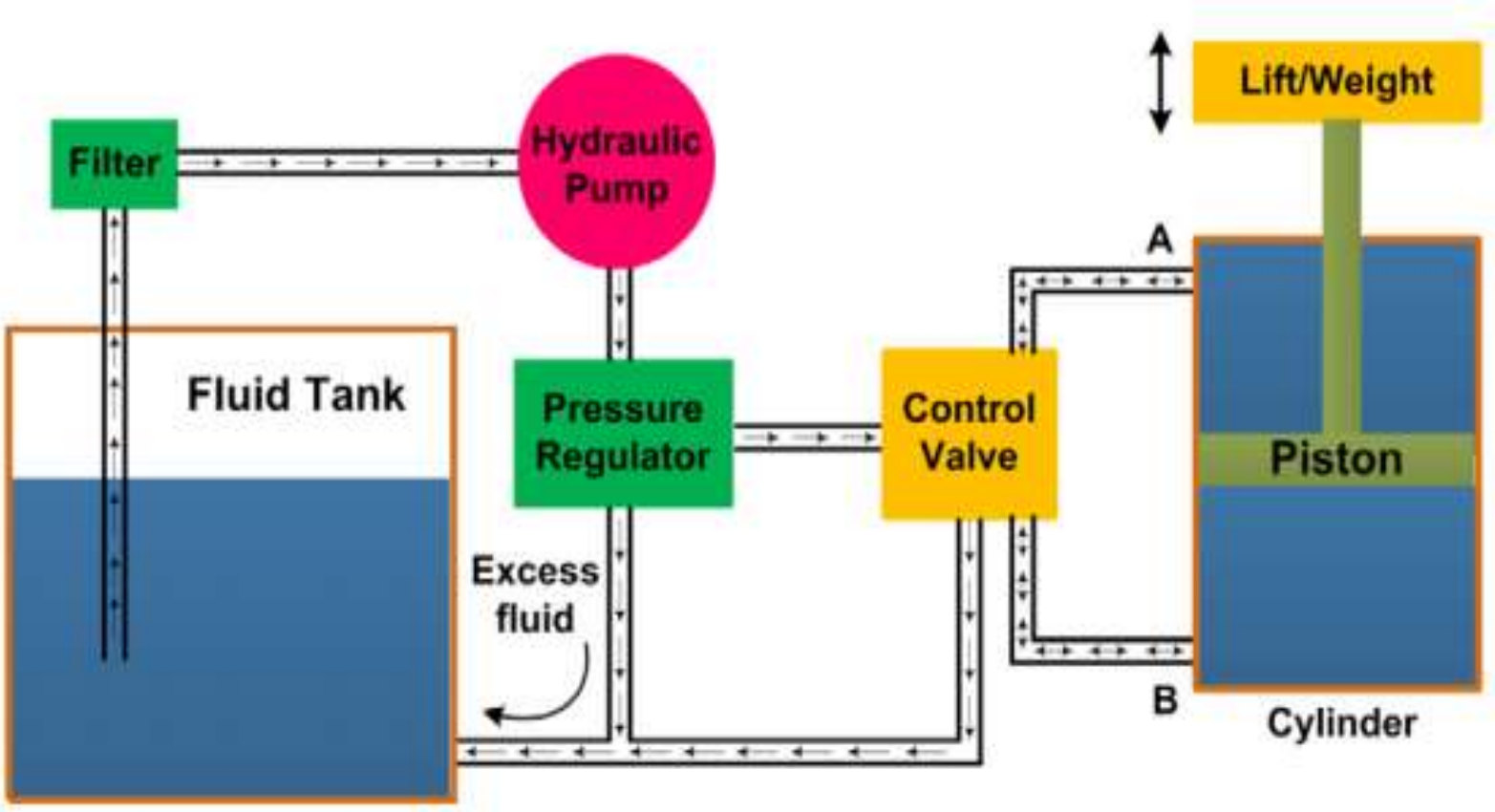
- The specially designed enclosed fluid systems can provide both linear as well as rotary motion.
- The high magnitude controlled force can also be applied by using these systems.
- This kind of enclosed fluid based systems using pressurized incompressible liquids as transmission media are called as hydraulic systems.
- **The hydraulic system works on the principle of Pascal's law which says that the pressure in an enclosed fluid is uniform in all the directions.**

Hydraulic system…….

- The Pascal's law is illustrated in figure.
- As the pressure is same in all the direction, the smaller piston feels a smaller force and a large piston feels a large force.
- Therefore, a large force can be generated with smaller force input by using hydraulic systems.



Q.29 What are the Basic Components of Hydraulic System?



Basic Components of Hydraulic System……..

The hydraulic systems consists a number of parts for its proper functioning. It consists of:

- a movable piston connected to the output shaft in an enclosed cylinder
- storage tank
- filter
- electric pump
- pressure regulator
- control valve
- leak proof closed loop piping.

Q.30 What are the applications of hydraulic systems

The hydraulic systems are mainly used for precise control of larger forces. The main applications of hydraulic system can be classified in five categories:

1. Industrial: Plastic processing machineries, steel making and primary metal extraction applications, automated production lines, machine tool industries, paper industries, loaders, crushes, textile machineries, R & D equipment and robotic systems etc.

2. Mobile hydraulics: Tractors, irrigation system, earthmoving equipment, material handling equipment, commercial vehicles, tunnel boring equipment, rail equipment, building and construction machineries and drilling rigs etc.

3. Automobiles: It is used in the systems like breaks, shock absorbers, steering system, wind shield, lift and cleaning etc.

4. Marine applications: It mostly covers ocean going vessels, fishing boats and navel equipment.

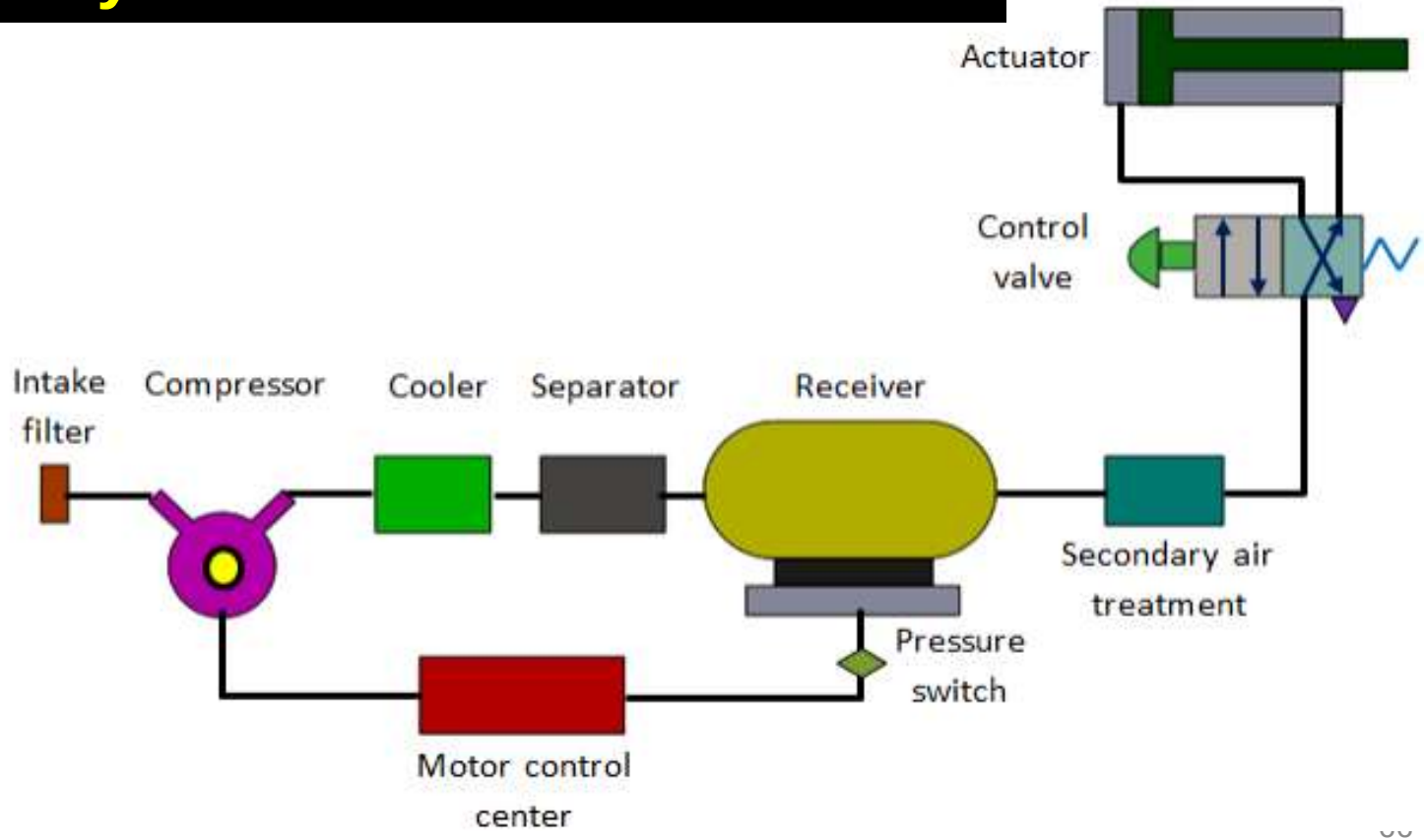
5. Aerospace equipment: There are equipment and systems used for rudder control, landing gear, breaks, flight control and transmission etc. which are used in airplanes, rockets and spaceships.

Q.31 Explain Pneumatic system.

- Pneumatic technology deals with the study of behavior and applications of **compressed air** in our daily life in general and manufacturing automation in particular.

- Pneumatic systems use **air** as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

Q.32 What are the Basic Components of Pneumatic System?



Important components of a pneumatic system are shown in fig.

a) Air filters: These are used to filter out the contaminants from the air.

b) Compressor: Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.

c) Air cooler: During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.

d) Dryer: The water vapor or moisture in the air is separated from the air by using a dryer.

e) Control Valves: Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.

f) Air Actuator: Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.

g) Electric Motor: Transforms electrical energy into mechanical energy. It is used to drive the compressor.

h) Receiver tank: The compressed air coming from the compressor is stored in the air receiver

Q.33 What do you mean by Valves in hydraulic and pneumatic systems.

- Valves are used with hydraulic and pneumatic systems to direct and regulate to fluid flow.

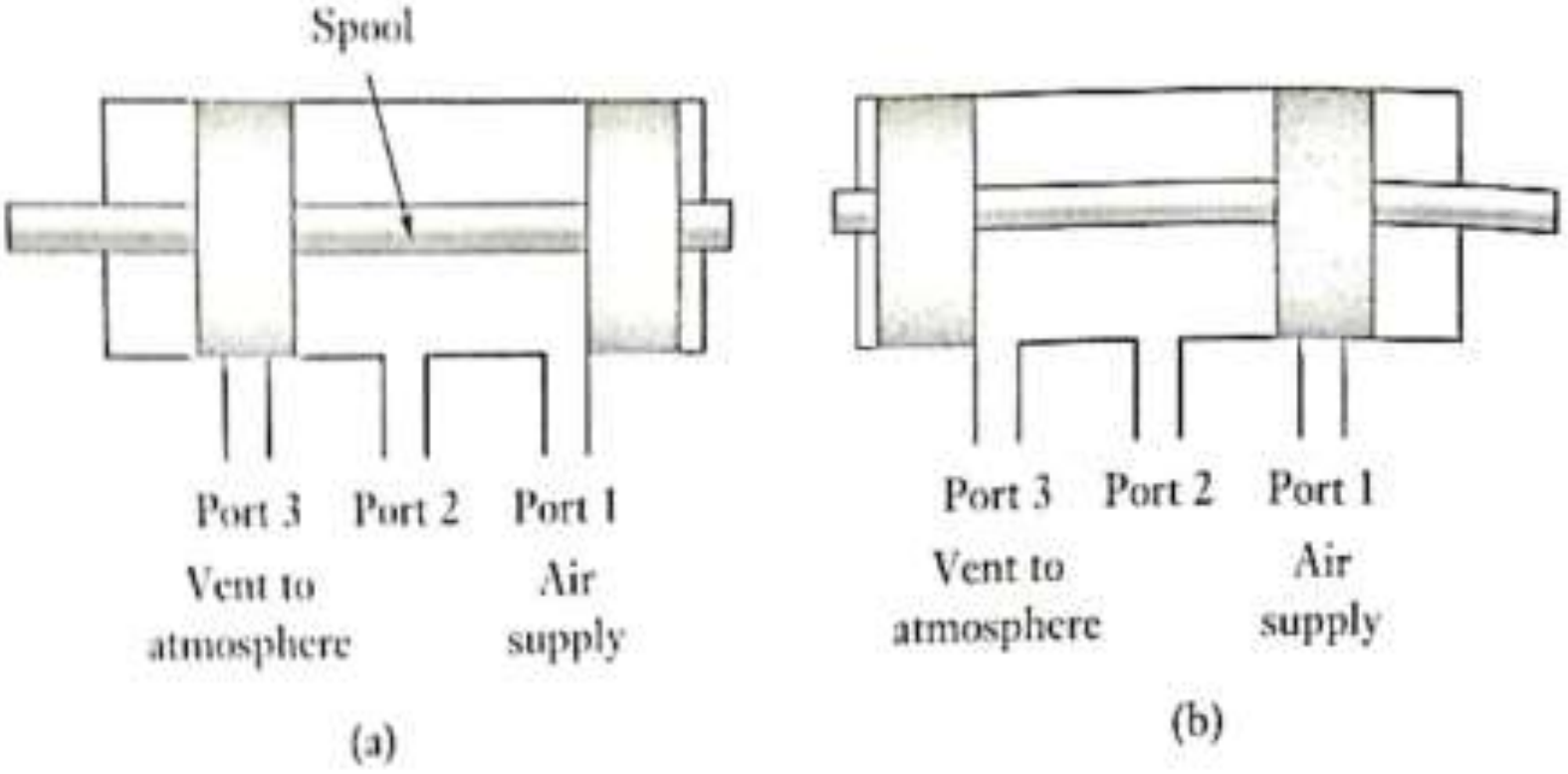
1. Direction Control Valves

2. Pressure Control Valves

Q.34 What do you mean by Direction Control Valves?

- Pneumatic and hydraulic systems use directional control Valves to direct the flow of fluid through a system.
- They do not vary the rate of fluid flow but either completely open or completely closed i.e. ON/OFF devices.
- They might be activated to switch the fluid flow direction by means of mechanical, electrical or fluid pressure signals.
- A common type of directional control valve is the spool valve.

Spool Direction Control Valves



Spool Direction Control Valves…..

- A spool moves horizontally within the valve body to control the flow.
- In fig (a) the air supply is connected to port 1 and port 3 is closed.
- Thus the device connected to port 2 can be pressurized.
- When the spool is moved to the left (in fig b) the air supply is cut off and port 2 is connected to port 3.
- Port 3 is a vent to the atmosphere and so the air pressure in the system attached to port 2 is vented.
- Thus the movement of the spool has the air firstly to flow into the system and then be reversed and flow out of the system.

Q.35 What do you mean by Pressure Control Valves?

- These are used to control the pressure in hydraulic and pneumatic system
- There are three main types of pressure control valves

.

a) Pressure regulating valves

b) Pressure – limiting/relief valves

c) Pressure sequence valves

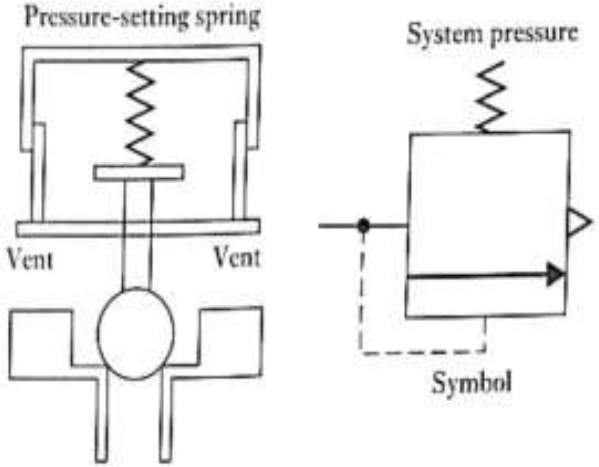
a) Pressure regulating valves

- These are used to control the operating pressure in a circuit and maintain it at a constant value.

b) Pressure – limiting/relief valves

- These are used as safety devices to limit the pressure in a circuit to below some safe value.
- The valve opens and vents to the atmosphere, or back to the sump, if the pressure rises above the safe value.
- It has one orifice which is normally closed.

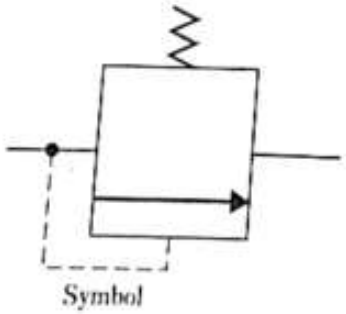
- When the inlet pressure overcomes the force exerted by the spring, the valve opens and vents to the atmosphere, or back to the sump.



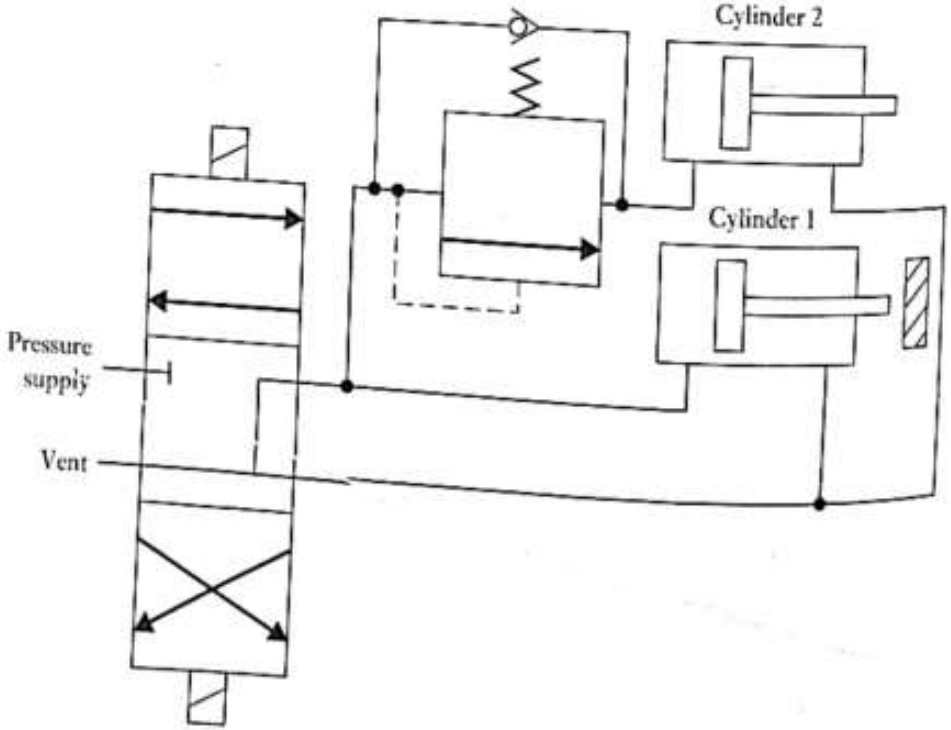
c) Pressure sequence valves

- These are used to sense the pressure of an external line and give a signal when it reaches some pre-set value.
- With the pressure limiting valve, the limiting pressure is set by the pressure at the inlet to the valve.
- We can adapt such a valve to give a sequence valve.
- This can be used to allow to flow occur to some part of the system when the pressure has risen to the required level.
- For example in an automatic machine we might require some operation to start when the clamping pressure applied to a work piece is at some particular value.

Pressure sequence valves



(a)



(b)

Q.36 Define Actuators.

- Actuators are output devices which convert energy from pressurized **hydraulic oil** or **compressed air** into the required type of action or motion.
- In general, hydraulic or pneumatic systems are used for gripping and/or moving operations in industry. These operations are carried out by using actuators.

- In general actuators can be classified into two types.

1. Linear actuators: These devices convert hydraulic/pneumatic energy into linear motion.**(Ex-cylinder)**

2. Rotary actuators: These devices convert hydraulic/pneumatic energy into rotary motion. **(Ex-Gear motor)**

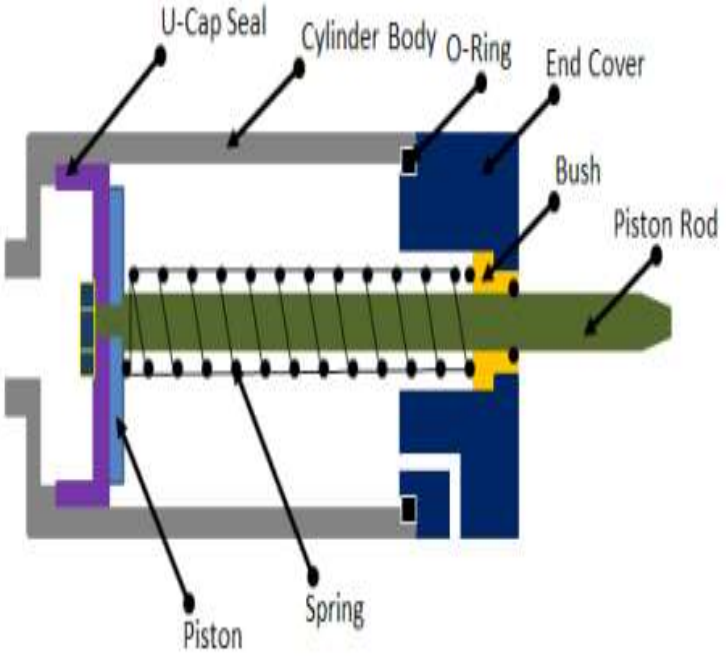
The construction of hydraulic and pneumatic linear actuators is similar.

However they differ at their operating pressure ranges.

Typical pressure of hydraulic cylinders is about 100 bar and of pneumatic system is around 10 bar.

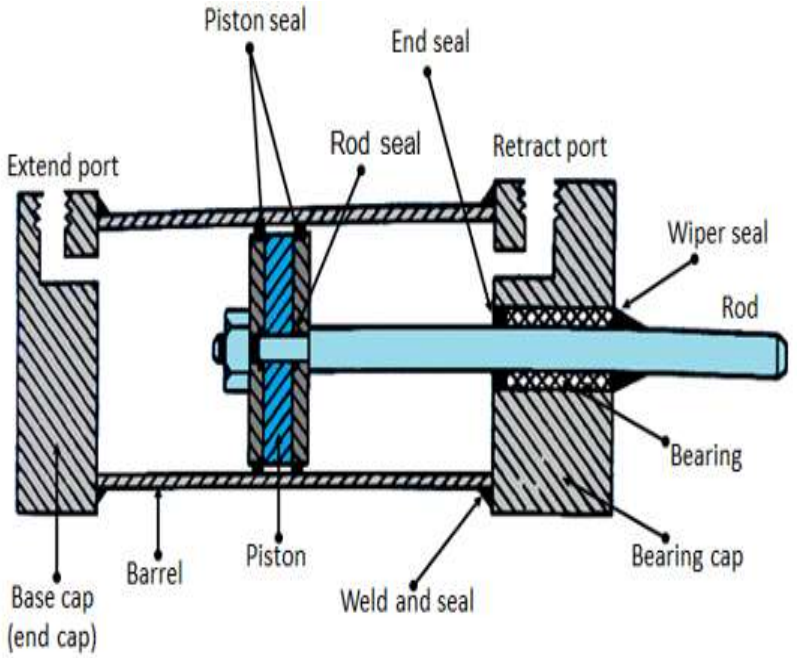
Q.37 Explain working single acting cylinder.

- These cylinders produce work in one direction of motion hence they are named as single acting cylinders.
- Figure shows the construction of a single acting cylinder.
- The compressed air pushes the piston located in the cylindrical barrel causing the desired motion.
- The return stroke takes place by the action of a spring.
- Generally the spring is provided on the rod side of the cylinder.



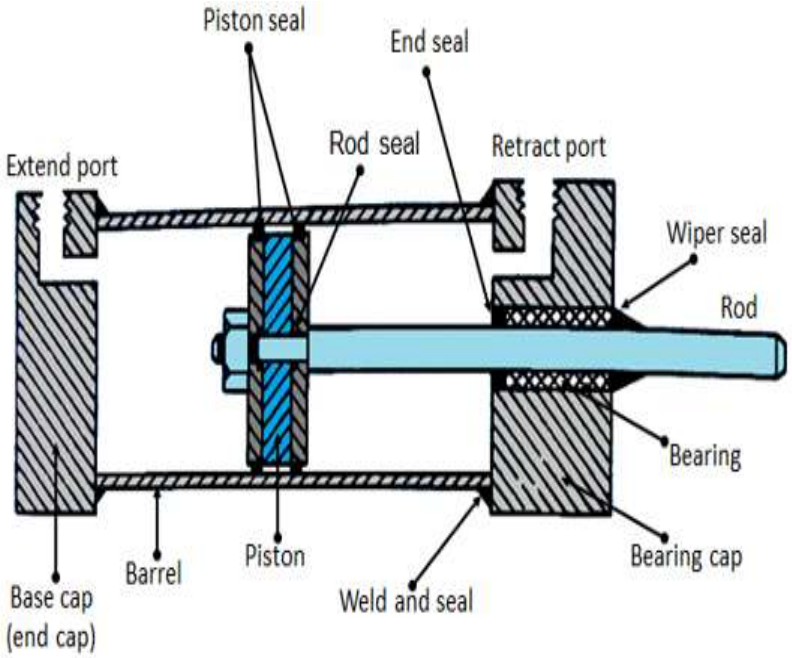
Q.38 Explain working double acting cylinder.

- The main parts of a hydraulic double acting cylinder are: piston, piston rod, cylinder tube, and end caps.
- As shown in the fig. the piston rod is connected to piston head and the other end extends out of the cylinder.
- The piston divides the cylinder into two chambers.
- The seals prevent the leakage of oil between these two chambers.
- The cylindrical tube is fitted with end caps. .



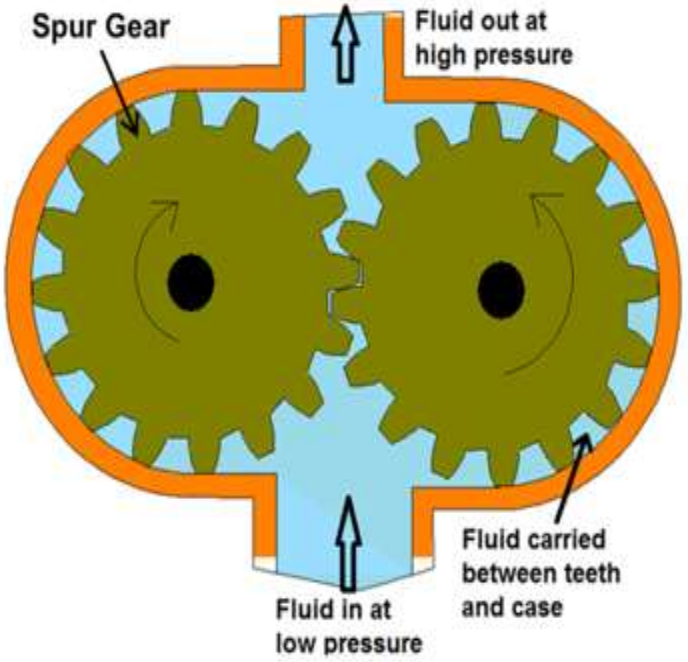
Double acting cylinder…….

- The pressurized oil, air enters the cylinder chamber through the ports provided.
- In the rod end cover plate, a wiper seal is provided to prevent the leakage of oil and entry of the contaminants into the cylinder.
- The piston seal prevents metal to metal contact and wear of piston head and the tube. These seals are replaceable.
- End cushioning is also provided to prevent the impact with end caps.



Q.39 Explain rotary Rotary Actuators.

- Rotary actuators convert energy of pressurized fluid into rotary motion. Rotary actuators are similar to electric motors but are run on hydraulic or pneumatic power.
- It consists of two inter meshing gears inside a housing with one gear attached to the drive shaft.
- Figure shows a schematic diagram of Gear motor.
- The air enters from the inlet, causes the rotation of the meshing gear due to difference in the pressure and produces the torque.
- The air exits from the exhaust port.
- Gear motors tend to leak at low speed, hence are generally used for medium speed applications.



Thank You