1. ***Differentiate between analysis of mechanisms and synthesis of mechanisms.***

Study of mechanisms

1. Analysis of mechanisms

- Analysis involves the study of motion and forces concerning different parts of the mechanism.
- In the analysis, the kinematic quantities, i.e., displacement, velocity and acceleration of the parts are determined.

2. Synthesis of mechanisms

- Synthesis involves the design of various parts of machine concerning (i) its shape and size, (ii) materials to be used, and (iii) the arrangement of parts so that the resulting machine can perform the desired tasks.

2. ***Differentiate between rigid body and resistant body.***
   - ✓ Rigid body means a body with no deformation when the required force is transmitted.
   - ✓ A body is said to be a resistant if it is capable of transmitting the required force with negligible deformation.
3. ***Define kinematic link (or element).*** *[A.U., Nov/Dec 2011]*

   A kinematic link, also known as an element, is defined as a single part (or an assembly of rigidly connected parts) of a machine which has motion relative to some other part of the machine.
4. ***What are the different types of links?***
   1. Rigid link
   2. Flexible link
   3. Fluid link
5. ***A spring used in a machine/mechanism is not treated as a kinematic link. Why?***

   Because a kinematic link must be a resistant body. As spring deforms in the direction of applied force, it is not a resistant body and hence it is not treated as a link.
6. ***Differentiate between a machine and a structure.***

   [A.U., Oct/Nov 2002; Apr/May 2005; May/June 2007; Nov/Dec 2010; May/June 2013; May/June 2014]

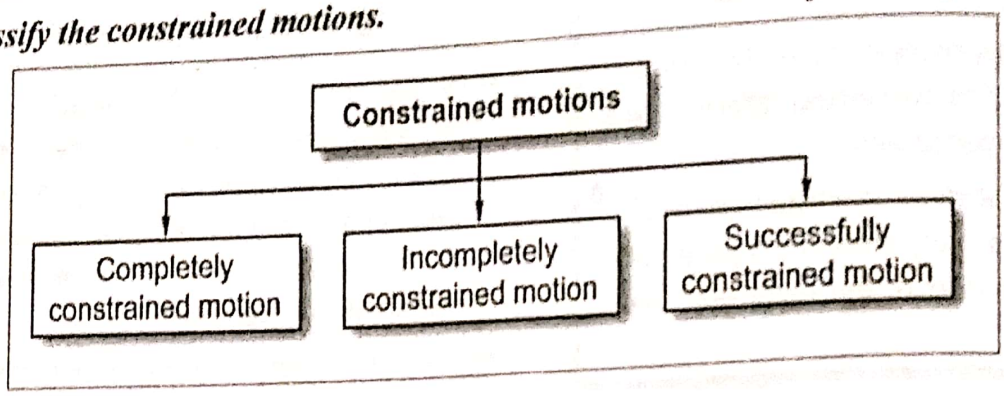
S.No.	Machine	Structure
1.	Relative motion exists between its parts.	No relative motion exists between its members.
2.	It transforms available energy into useful work.	It does not convert the available energy into work.

T.2

S.No.	Machine	Structure
3.	Links are meant to transmit motion and forces.	Members are meant for carrying forces (*i.e.*, loads) only.
4.	***Examples:*** Washing machines, cars, toys, lathes, shapers, *etc.*	***Examples:*** Roof trusses, bridges, *etc.*

[A.U., May/June 2014]

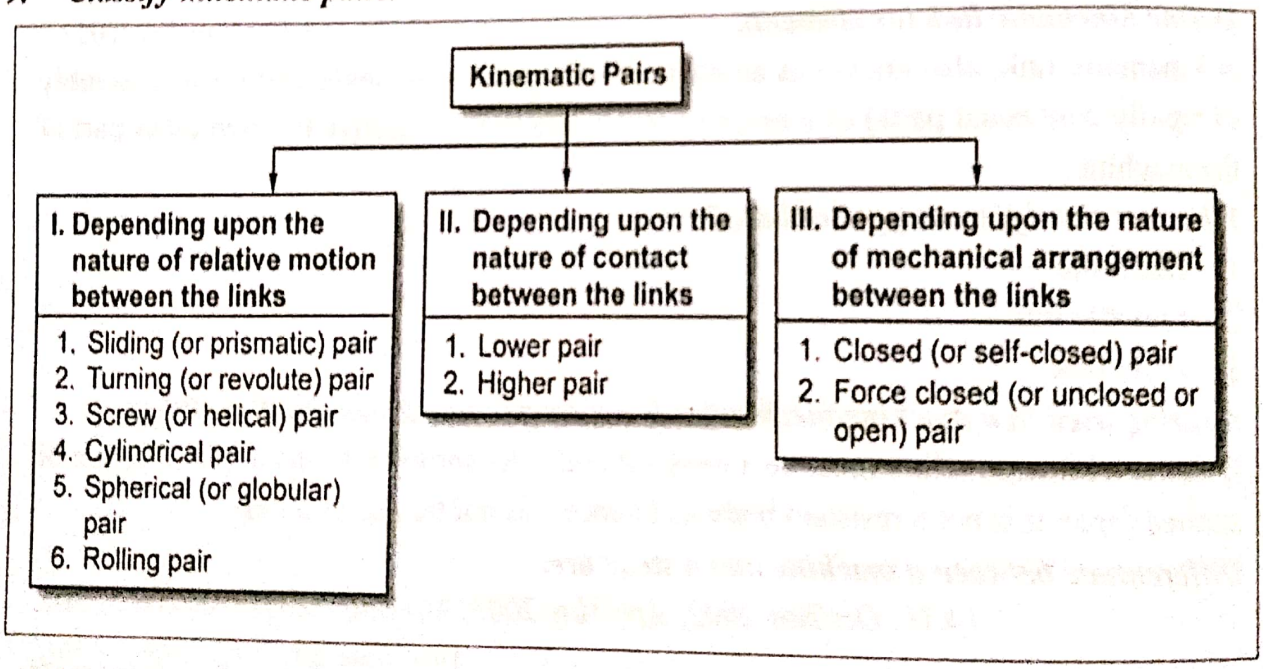
7. *Classify the constrained motions.*



8. *Define kinematic pair.* *[A.U., Nov/Dec 2006; Apr/May 2010; May/June 2013]*

When any two links are connected in such a way that their relative motion is completely or successfully constrained, they form a kinematic pair.

9. *Classify kinematic pairs.*



10. *State any four types of kinematic pairs according to the types of relative motion between them.*

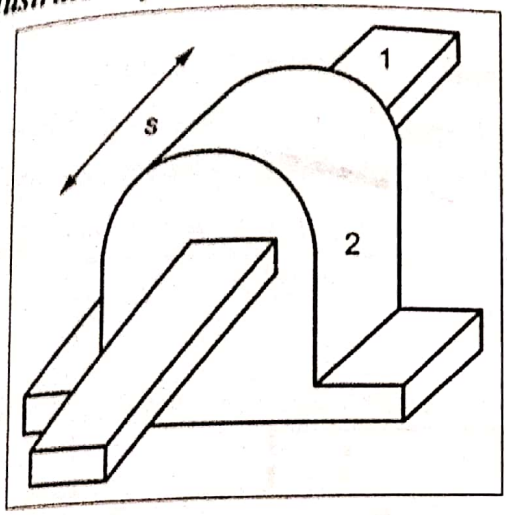
[A.U., Nov/Dec 2004]

1. Sliding (or prismatic) pair
2. Turning (or revolute) pair
3. Screen (or helical) pair
4. Cylindrical pair
5. Spherical (or globular) pair
6. Rolling pair

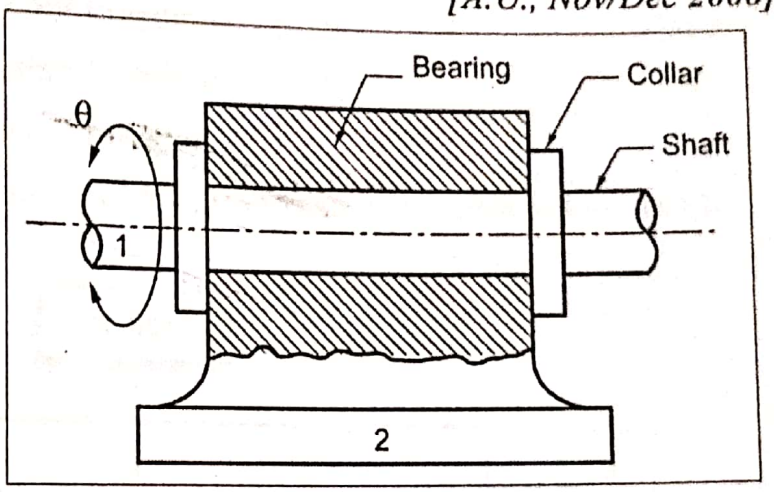
11. ***Differentiate between lower pair and higher pair with examples.***
[A.U., Nov/Dec 2005; Apr/May 2008; Nov/Dec 2011]

Lower Pair	Higher Pair
✓ If a kinematic pair has a surface or area contact between the two links, it is called a lower pair.	✓ If a kinematic pair in motion has a line or point contact between the two links, it is called a higher pair.
✓ ***Examples:*** Nut and bolt, ball and socket joints, shaft rotating in bearings, *etc.*	✓ ***Examples:*** Cam and follower, roller bearings, ball bearings, *etc.*

12. ***Illustrate any two types of constrained pair.*** *[A.U., Nov/Dec 2006]*



(a) Sliding pair



(b) Turning pair

13. ***Identify the possible motion and name of the following combinations:***

(a) Members of a scissor.

(b) A two pin plug inserted in a two pin socket. *[A.U., May/June 2006]*

(a) Members of a scissor:

Types of motion: Incompletely constrained motion.

Types of pair: Lower pair (and also closed pair)

(b) A two pin plug inserted in a two pin socket:

Types of motion: Completely constrained motion.

Types of pair: Lower pair (and also unclosed pair)

14. ***State atleast one similarity and one difference between a helical pair and a cylindrical pair.*** *[A.U., Nov/Dec 2003]*

Similarity: Both are lower pairs.

Difference: Helical pair has one degree of freedom, whereas the cylindrical pair has two degrees of freedom.

15. *Define kinematic chain.* *[A.U., Nov/Dec 2005; Apr/May 2010]*

A kinematic chain is defined as the combination of kinematic pairs in which each link forms a part of two kinematic pairs and the relative motion between the links is either completely constrained or successfully constrained.

16. *How can you determine the given assemblage of links forms the kinematic chain or not?*

If the given assemblage satisfies the following two equations (for lower pair), then it forms the kinematic chain.

$$n = 2p - 4$$

and

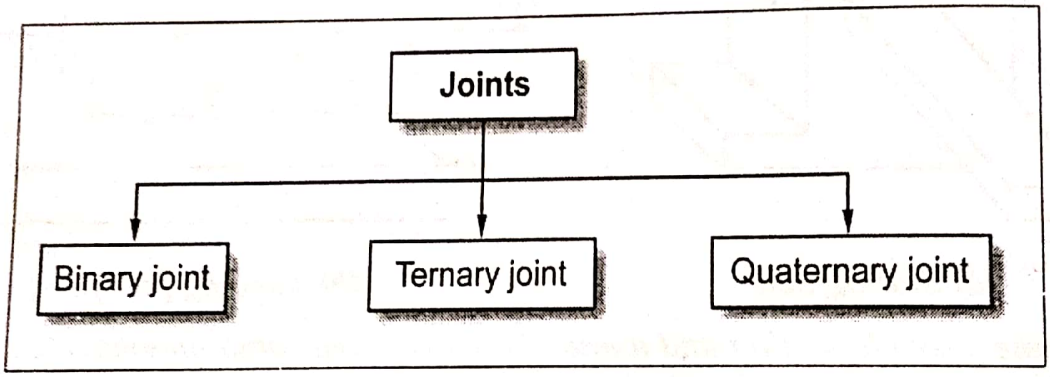
$$j = \frac{3}{2}n - 2$$

where n = Number of links,

p = Number of pairs, and

j = Number of binary joints.

17. *What are the different types of joints in a chain?*



18. *Differentiate between a mechanism and a machine.*

Sl.No.	Mechanism	Machine
1.	Mechanism is an assemblage of links used to transmit and modify motion (without considering forces involved).	Machine is an assemblage of links used to transmit motion, and energy.
2.	A mechanism is the skeleton outline of the machine primarily to transmit definite motion between various links.	A machine may consist of one or more mechanisms to transmit the available energy into useful work.
3.	***Examples:*** Drafter, typewriter, clocks, spring toys, *etc.*	***Examples:*** Sewing machine, shaper and planar in workshop, IC engine, *etc.*

18. ***Define degrees of freedom of a mechanism.***

[A.U., Nov/Dec 2007; Apr/May 2008; Nov/Dec 2008; Apr/May 2010]

The degree of freedom of a mechanism is the number of independent parameters required to specify the location of every link within the mechanism.

19. ***Define mobility of a mechanism.***

The mobility of a mechanism is defined as the number of inputs required to produce the constrained motion of the mechanism.

20. ***What is the number of DOF of a cricket ball (or a body) when it is in air?***

For a cricket ball (or a body) when it is in air, six independent co-ordinates, (three translatory—x, y, z and three rotational—θ_x, θ_y, θ_z) are required to define its motion, therefore DOF for this ball is equal to six.

21. ***Give the DOF for a shaft in a circular hole.***

[A.U., Nov/Dec 2007]

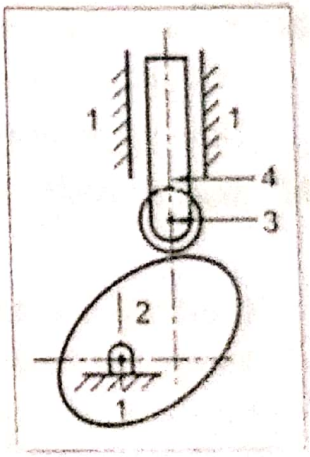
Since a circular shaft moving in a circular hole have both rotations and sliding, it has 2 degrees of freedom.

22. ***Give the DOF for a cam with roller follower.***

[A.U., Apr/May 2010]

Solution: $n = 4; j = 3; l = j = 3; h = 1$

$$\therefore \text{DOF} = 3(r-1) - 2l - h$$
$$= 3(4-1) - 2(3) - 1 = 2 \quad \textbf{Ans.}$$



23. ***What is Kutzbach criterion for planar mechanism?***

[A.U., Nov/Dec 2006; May/June 2007]

The Kutzbach criterion for planar mechanisms is given by

$$\text{DOF} = 3(n-1) - 2l - h$$

where n = Number of links,

l = Number of lower pairs, and

h = Number of higher pairs.

24. ***State Kutzbach equation for spatial mechanisms.***

Kutzbach equation for spatial mechanism is given by

$$\text{DOF} = 6(n-1) - 5p_1 - 4p_2 - 3p_3 - 2p_4 - 1p_5$$

where n = Number of links in the mechanism,

p_1 = Number of pairs having 1 DOF,

p_2 = Number of pairs having 2 DOF and so on.

25. ***State Grubbler's criterion for planar mechanisms.***

[A.U., Apr/May 2005; Nov/Dec 2005; Nov/Dec 2008; Nov/Dec 2010]

Grubler's criterion for planar mechanisms is given by

$$3n - 2l - 4 = 0$$

where n = Number of links, and

l = Number of lower pairs.

27. *State Grubler's criterion for spatial mechanisms.* *[A.U., Nov/Dec 2009]*

Grubler's criterion for spatial mechanisms is given by

$$6n - 5p_1 - 7 = 0$$

where n = Number of links, and

p_1 = Number of pairs having 1 DOF

28. *Draw a four-bar mechanism and show that it has one degree of freedom.* *[A.U., May/June 2006]*

✓ The four-bar mechanism is shown in Fig.1. It has four links and four binary joints. *i.e.*, $n = 4; j = l = 4; h = 0$.

✓ ***DOF:*** We know that

$$\text{DOF} = 3(n-1) - 2l - h$$
$$= 3(4-1) - 2(4) - 0 = \mathbf{1} \quad \textbf{Ans.}$$

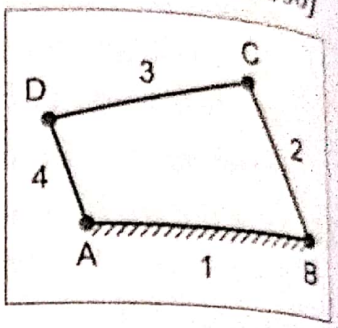


Fig. 1.

29. *What do you mean by inversion of mechanism?* *[A.U., May/June 2006]*

The process of obtaining different mechanisms by fixing different links in a kinematic chain is known as inversion of the mechanism.

30. *State Grashof's law for a four-bar linkage.*

[A.U., Nov/Dec 2007; Apr/May 2008; May/June 2009; Nov/Dec 2012]

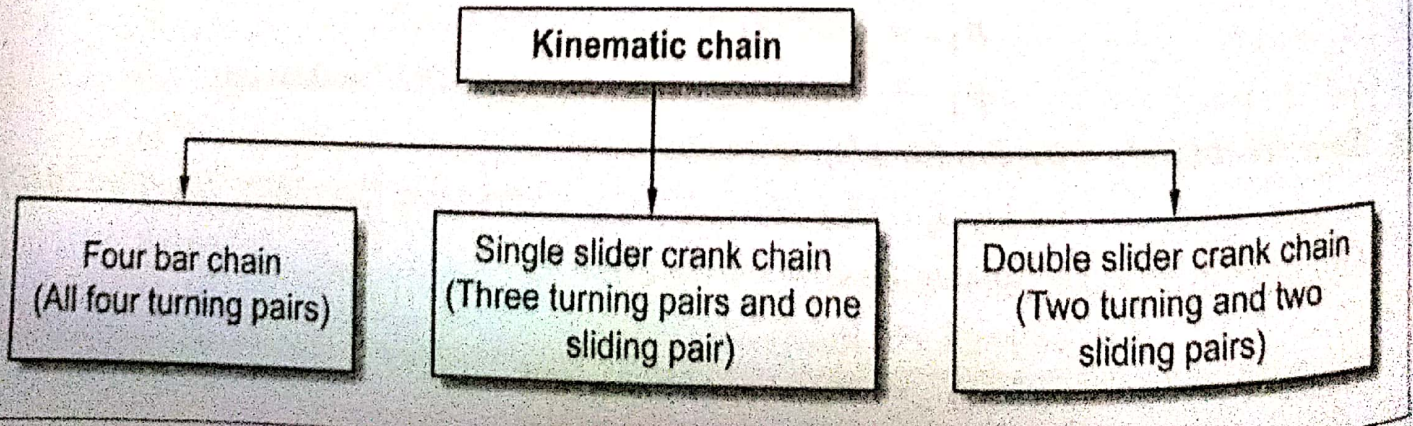
Grashof's law states that for a planar four-bar mechanism, the sum of the shortest and longest links must be less than or equal to the sum of the lengths of two other links, if there is to be continuous relative rotation between two members.

31. *What is the significance of Grashof's law for a four-bar mechanism?*

[A.U., Nov/Dec 2011]

For four-bar chain, Grashof's law is used to test whether any of the links in the chain can be a crank.

32. *Write down the different types of kinematic chain.*



33. ***What are the conditions to obtain a four-bar double-crank mechanism?***

When (*i*) $s + l \leq p + q$, and (*ii*) the shortest link is fixed, then a double-crank mechanism is obtained.

34. ***What are the conditions to obtain a four-bar crank-rocker mechanism?*** *[A.U., Apr/May 2003]*

When (*i*) $s + l \leq p + q$, and (*ii*) any one of the links adjacent to the shortest link is fixed, then a crank-rocker mechanism is obtained.

35. ***What are the conditions to obtain a four-bar double-rocker mechanism?***

When (*i*) $s + l \leq p + q$, and (*ii*) the link opposite to the shortest link is fixed, then a double-rocker mechanism is obtained.

36. ***State the difference between a crank-rocker mechanism and a drag-link mechanism.*** *[A.U., May/June 2006]*

✓ In a ***crank-rocker mechanism,*** one link oscillates while the other link rotates about the fixed link, as shown in Fig.2.

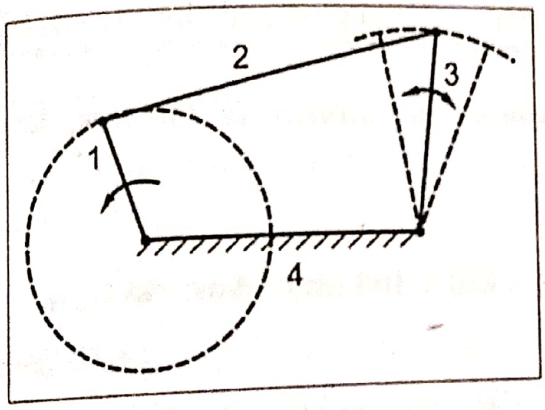


Fig. 2

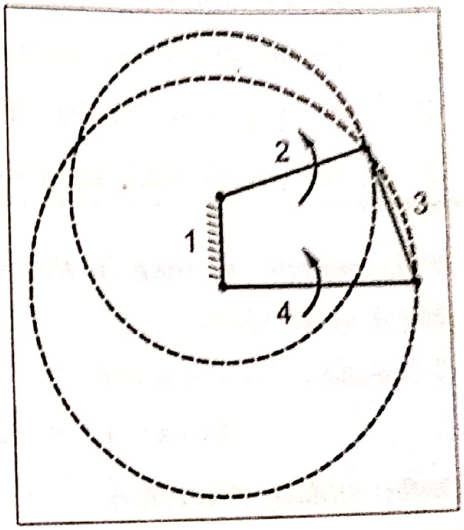


Fig. 3

✓ In a ***drag-link mechanism*** (also known as ***double-crank mechanism***), the shortest link is fixed and the adjacent links would complete revolutions, as shown in Fig.3.

37. ***How many inversions are possible from a four-bar kinematic chain? Name them based on their input-output motions.*** *[A.U., Apr/May 2003]*

✓ Theoretically, four inversions are possible from a four-bar mechanism.

✓ First and second inversions form crank-rocker mechanism.

✓ Third inversion forms double-crank mechanism.

✓ Fourth inversion forms double-rocker mechanism.

38. ***Give any four inversions of four-bar chain.***

1. Beam engine
2. All rotary oscillating converters
3. Coupled wheels of a locomotive
4. Watt's indicator mechanism

39. *Give any four inversions of a single slider chain.* *[A.U., May/June 2009]*

1. Internal combustion engine
2. Reciprocation compressor/pump
3. Whitworth quick return mechanism
4. Oscillating cylinder engine
5. Pendulum pump

40. *Give any two inversions of a double slider crank chain.* *[A.U., May/June 2007]*

1. Elliptical trammel
2. Scotch yoke mechanism
3. Oldham's coupling

41. *Name any four common mechanisms with specific applications.* *[A.U., May/June 2007]*

Sl.No.	Mechanism	Application
1.	Crank-lever mechanism	Beam engine
2.	Double-crank mechanism	Coupled wheels of a locomotive
3.	Double-rocker mechanism	Watt's indicator diagram
4.	Whitworth quick return mechanism	Shaping and slotting machines

42. *If the length of crank in the reciprocating mechanism is 150 mm, find the stroke length of the slider.*

☺ ***Solution:*** We know that

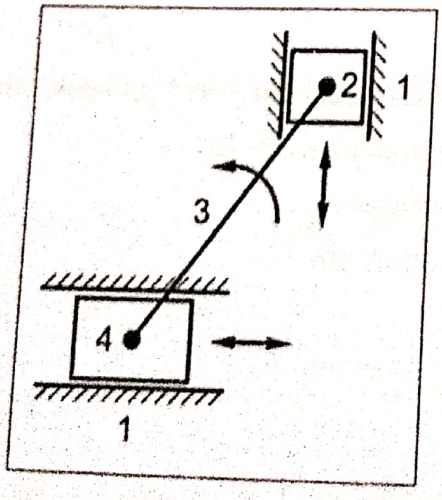
Stroke, $L = 2r = 2 \times 150 = \mathbf{300\ mm}$ **Ans.**

43. *Define sliding connectors.* *[A.U., Nov/Dec 2013]*

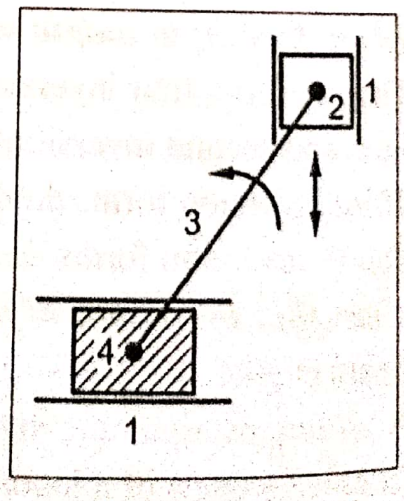
Sliding connectors are used when one slider (the input) is to drive another slider (the output). Usually the two sliders operate in the same plane but in different directions.

44. *State and sketch any two inversions of a double-slider mechanism.*

[A.U., Oct/Nov 2002]



Elliptical trammel



Scotch yoke mechanism

45. ***If an ellipse of semi-major axis 300 mm and semi-minor axis 200 mm is to be drawn what should be the length of link ABC in elliptical trammel?***

☹ *Given data:* AC = 300 mm; BC = 200 mm

☺ *Solution:* Referring to Fig.1.55 in Chapter 1, we can write

$\therefore$ ABC = **300 mm** **Ans.**

46. ***If the length of fixed link and crank in crank and slotted lever quick return quick motion mechanism are 300 mm and 150 mm respectively, determine quick return ratio.***

☺ *Solution:*

$$\cos\frac{\theta}{2} = \frac{15}{30} = \frac{1}{2}$$

$$\therefore \quad \frac{\theta}{2} = 60^\circ = \theta = 120^\circ$$

$$\text{Quick return ratio} = \frac{360^\circ - 120^\circ}{120^\circ} = \frac{240^\circ}{120^\circ} = 2 \quad \textbf{Ans.}$$

47. ***What is the use of elliptical trammel?***

Elliptical trammel is an instrument used for drawing ellipses.

48. ***What is the purpose of scotch yoke mechanism?***

The scotch yoke mechanism is used for converting rotary motion into reciprocating motion.

49. ***When do you use Oldham's coupling?***

Oldham's coupling is used for transmitting motion between two shafts when (*i*) the shafts are parallel, but not coaxial; and (*ii*) the centre distance between their centre lines is small.

50. ***Define mechanical advantage of a mechanism.*** *[A.U., Nov/Dec 2008; Nov/Dec 2009]*

The mechanical advantage of a mechanism is defined as the ratio of the output torque exerted by the driven link to the required input torque at the driver link.

51. ***Define transmission angle of a four-bar mechanism. What are the worst value of transmission angle?*** *[A.U., Nov/Dec 2003; Nov/Dec 2011; May/June 2012]*

✓ The angle between the coupler link and the driven link (or follower) is known as transmission angle (γ).

✓ The worst value of transmission angle is less than 45°.

63. ***What is the condition of correct steering of an automobile?*** *[A.U., May/June 2012]*

The condition of correct steering is that the relative motion between the wheels and the road surface should be that of pure rolling while taking a turn, avoiding any lateral slip (skidding).

64. ***What is the use of a Hooke's joint (or universal joint or universal coupling)?***

A Hooke's joint, also known as universal joint or universal coupling, is used for connecting two shafts whose axes are non-parallel but intersecting.

65. ***List any two applications of Hooke's joints.***

- In automobiles, Hooke's joints are used for power transmission from the gear box to the back axle.
- In multi-spindle drilling machines, Hooke's joints are used for the transmission of power to different spindles.

66. ***What are ratchets and escapements?***

- ✓ ***Ratchets*** are used to ensure that the motion of the output device is allowed in only one direction.
- ✓ ***Escapements*** are used to control continuous motion to produce a highly controlled step motion (*i.e.*, intermittent motion) at a fixed rate.

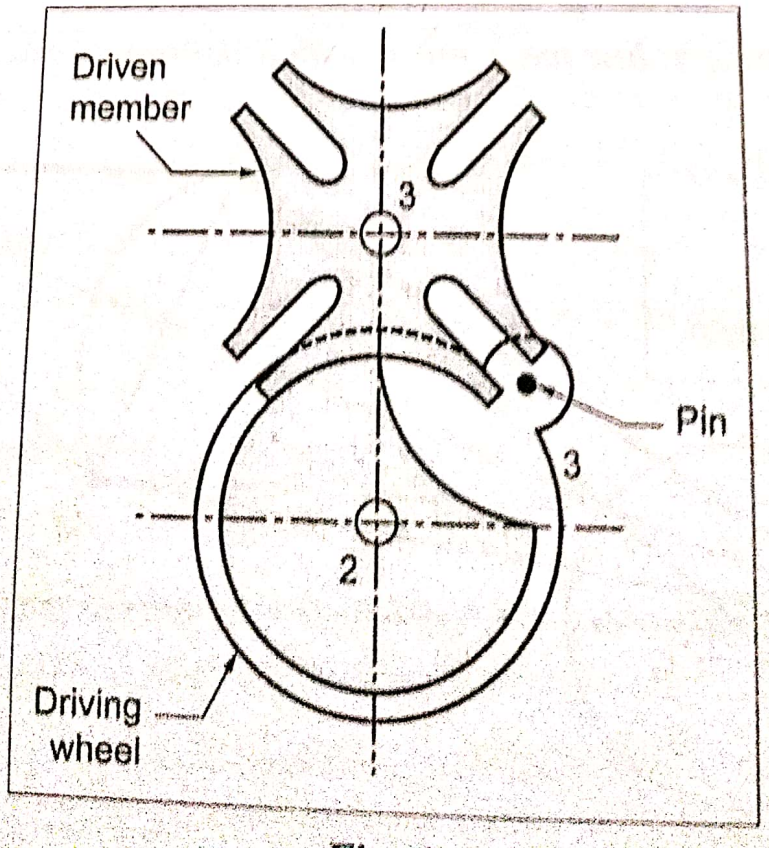
67. ***What are indexing mechanisms?*** *[A.U., Nov/Dec 2012]*

Indexing mechanisms are generally used to convert a rotary or oscillating motion to a series of step movements (*i.e.*, intermittent motion) of the output link or shaft.

68. ***Sketch the Geneva wheel indexing mechanism and state its applications.***

[A.U., Apr/May 2003; Nov/Dec 2012]

- ✓ The arrangement of Geneva mechanism is shown in Fig.4.
- ✓ Geneva mechanisms are used in machine tools for indexing the turret or work table.



69. ***What is low degree of complexity?*** *[A.U., Nov/Dec 2013]*

In a complex mechanism, if only one radius of path curvature of one motion transfer point is not known, such a mechanism is called a mechanism with low degree of complexity.

CHAPTER 2: VELOCITY AND ACCELERATION IN MECHANISMS

1. ***Differentiate between rotation and translation.*** *[A.U., Nov/Dec 2013]*

✓ ***Translation*** is defined as a state of motion of body for which the displacement difference between any two points is zero.

✓ ***Rotation*** is a state of motion of the body for which different points of the body are equal.

2. ***How to represent the direction of linear velocity of any point on a link with respect to another point on the same link?***

The direction of linear velocity of any point on a link with respect to another point on the same link is perpendicular to the line joining the points.

3. ***What is a configuration diagram? What is its use?***

[A.U., May/June 2012; Nov/Dec 2012]

✓ Configuration diagram is a line sketch of a given mechanism drawn to a suitable scale.

✓ The configuration diagram forms the basis for the construction of both velocity and acceleration diagrams.

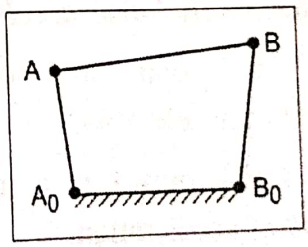
4. ***A four-bar mechanism has coupler pin centres at A and B, and fixed pivot centres at A_0 and B_0. Write the two vector equations involving the output velocity vector of B.***

[A.U., May/June 2006]

$$\overrightarrow{v_{BA}} = \omega_{BA} \cdot BA$$

$$\overrightarrow{v_{BB_0}} = \omega_{BB_0} \cdot BB_0$$

$$\overrightarrow{v_{BB_0}} = \overrightarrow{v_A} + \overrightarrow{v_{BA}}$$



5. ***Define rubbing velocity at a pin joint. What will be the rubbing velocity at pin joint when the two links move in the same and opposite directions?***

[A.U., Oct/Nov 2002; Nov/Dec 2004; Nov/Dec 2005; May/June 2007; Apr/May 2010; May/June 2012; Nov/Dec 2012]

✓ ***Definition:*** The rubbing velocity is defined as the algebraic sum between the angular velocities of the two links which are connected by pin joints, multiplied by the radius of the pin.

✓ Rubbing velocity at pin joint when the two links move in opposite direction $= (\omega_1 + \omega_2) r$

✓ Rubbing velocity at pin joint when the two links move in opposite direction $= (\omega_1 - \omega_2) r$

where ω_1 and ω_2 = Angular velocities of two links, and

r = Radius of the pin.

6. ***How the direction of the angular velocity is found out during velocity analysis of a mechanism by graphical method?*** *[A.U., Apr/May 2010]*

By using right hand screw rule.

7. ***Explain normal component of acceleration.*** *[A.U., Nov/Dec 2006]*

Normal or radial component of acceleration is perpendicular to the velocity of the particle at the given instant. The magnitude is given by $a^r_{BA} = \omega^2 \cdot AB = \frac{v^2_{BA}}{AB}$.

8. ***Distinguish normal component of acceleration and tangential component of acceleration.*** *[A.U., Apr/May 2003]*

✓ ***Normal (or radial or centripetal) component*** is perpendicular to the velocity of the particle at the given instant. In other words, the normal component acts parallel to the link.

$$a^r_{link} = \omega^2 \times \text{Length of the link} = \frac{v^2_{link}}{\text{Length of the link}}$$

✓ ***Tangential component*** is parallel to the velocity of the particle at the given instant. In other words, it acts perpendicular to the link.

$$a^t_{link} = \alpha \times \text{Length of the link}$$

9. ***What type of link will have only centripetal component of acceleration and what types of link will have only linear acceleration?*** *[A.U., Apr/May 2005]*

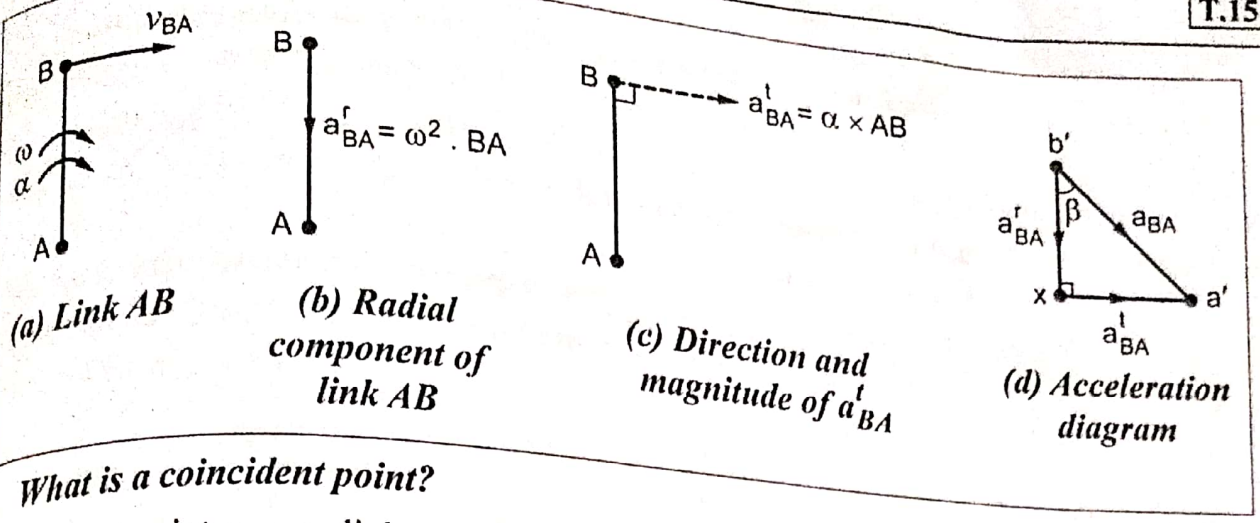
✓ The link which rotates at a constant velocity will have only centripetal i.e., radial component of acceleration.

✓ The link which moves in a linear direction will have only linear i.e., tangential component of acceleration.

10. ***How will you determine the total acceleration of a point on a link, when the normal component of acceleration and the tangential component of acceleration are known?*** *[A.U., May/June 2006]*

The total acceleration of a point on a link is the vector sum of their components of the radial acceleration and tangential acceleration.

11. ***Draw an acceleration polygon for a crank rotating at an angular speed of 'ω' rad/s and angular acceleration of 'α' rad/s².*** *[A.U., May/June 2009; Nov/Dec 2010]*



(a) Link AB *(b) Radial component of link AB* *(c) Direction and magnitude of a^t_{BA}* *(d) Acceleration diagram*

12. *What is a coincident point?*

When a point on one link is sliding along another rotating link, then the point is known as coincident point.

13. *State Coriolis law.*

[A.U., Nov/Dec 2006]

Whenever a point on one link is sliding along another rotating link, then the total acceleration will have one additional acceleration component known as Coriolis component.

14. *What is Coriolis component of acceleration?*

[A.U., Nov/Dec 2007; May/June 2007; Nov/Dec 2009; Nov/Dec 2010; Nov/Dec 2011]

Coriolis component of acceleration occurs when a point on one link is sliding along another rotating link, such as in quick return mechanism.

15. *When Coriolis component of acceleration occur?*

[A.U., Nov/Dec 2004]

Coriolis component of acceleration occurs when a point on one link is sliding along another rotating link, such as in quick return mechanism.

16. *Name two mechanisms: one where Coriolis acceleration is encountered and another where Coriolis acceleration is not encountered.*

[A.U., Apr/May 2010]

- ✓ In the mechanisms such as crank and slotted lever mechanism, Whitworth quick return mechanism and oscillating cylinder mechanism, Coriolis acceleration is encountered.
- ✓ In the mechanisms such as four-bar chain, slider-crank mechanism and toggle mechanisms, Coriolis is not encountered.

17. *State the condition for a link to experience Coriolis acceleration (or for what kind of relative motion, the Coriolis component of acceleration occurs?)*

[A.U., May/June 2006; Nov/Dec 2006; Nov/Dec 2011]

Coriolis acceleration occurs when a point on one link is sliding along another rotating link, such as in quick return mechanism.

18. Give the relation to find the magnitude of Coriolis component of acceleration. *[A.U., Apr/May 2008; May/June 2014]*

$$\boxed{a^c = 2 v^s \omega}$$

where ω = Angular velocity of OA, and
v^s = Velocity of sliding.

19. In a revolving stage with a speed of 3 rpm, a person is walking with a speed of 0.5 m/s along a radial path. Determine the magnitude of the Coriolis component of acceleration in this motion. *[A.U., Nov/Dec 2003]*

☹ ***Given data:*** N = 3 rpm; $\omega = \frac{2\pi(3)}{60} = 0.314$ rad/s; $v^s = 0.5$ m/s.

☺ ***Solution:*** Coriolis acceleration, $a^c = 2 v^s \omega$
$= 2 \times 0.5 \times 0.314 = \mathbf{0.314\ m/s^2}$ **Ans.** ☜

20. A slider sliding at 100 mm/s on link, which is rotating at 60 rpm is subjected to Coriolis acceleration. Find its magnitude. *[A.U., Apr/May 2010]*

Given Data: $v^s = 100$ mm/s = 0.1 m/s; N = 60 rpm on $\omega = 2\pi(60)/60 = 6.28$ rad/s

☺ ***Solution:*** Coriolis acceleration, $a^c = 2 v^s \omega$
$= 2 \times 0.1 \times 6.28 = \mathbf{1.256\ m/s^2}$ **Ans.** ☜

21. How the direction of Coriolis component of acceleration is determined? *[A.U., May/June 2009]*

The direction of Coriolis component is the direction of relative velocity vector for the two coincident points rotated at 90° in the direction of angular velocity of rotation of link.

22. On rotating link with a speed of 15 rpm, a slider is moving with a linear velocity, v. The linear velocity vector is acting in north-east direction and the Coriolis acceleration vector of magnitude 125.67 mm/s^2 acts in south-east direction. Sketch the vectors, and determine the sense of rotation of the rotating link, and the magnitude of linear velocity vector, v. *[A.U., May/June 2006]*

☹ ***Given data:*** N = 15 rpm; $a^c = 125.67$ mm/s^2 = 0.12567 m/s^2

☺ ***Solution:*** $\omega = \frac{2\pi N}{60} = \frac{2\pi(15)}{60} = 1.571$ rad/s

We know that the Coriolis component of acceleration,

$$a^c = 2 v^s \omega$$

$$0.12567 = 2 v^s (1.571)$$

or Magnitude of linear velocity, $v^s = \mathbf{0.04\ m/s}$ **Ans.** ☜

The directions of v^s and a^c are given and are shown in Fig.5. Therefore the sense of rotation of the rotating link is ***clockwise direction.*** **Ans.** ☜

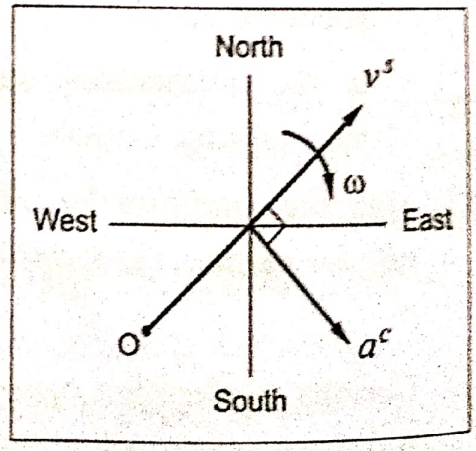


Fig. 5.

23. What is meant by virtual centre or instantaneous centre? *[A.U., Nov/Dec 2002; Nov/Dec 2003; Nov/Dec 2009; May/June 2014]*

The combined motion of rotation and translation of the link may be assumed to be a motion of pure rotation about some centre known as virtual centre or instantaneous centre.

24. Write the equation to determine the number of instantaneous centres of a mechanism. *[A.U., Nov/Dec 2003; May/June 2007; May/June 2013; Nov/Dec 2013]*

✓ Number of instantaneous centres, $N = \frac{n(n-1)}{2}$, where n = Number of links.

25. How many instantaneous centres are possible in a four bar chain mechanism?

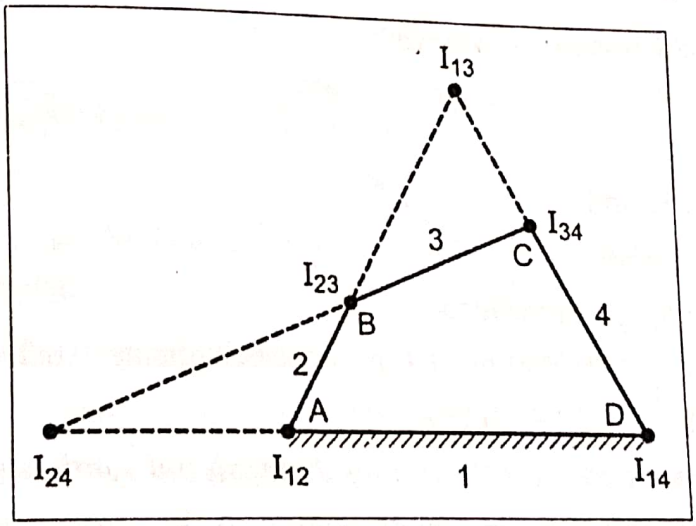
Number of instantaneous centres, $N = \frac{n(n-1)}{2}$

where n = Number of links.

In four bar chain mechanism, $n = 4$

$\therefore$ $N = \frac{4(4-1)}{2} = 6$ centres are possible.

26. Illustrate the instantaneous centres of a typical four bar. *[A.U., May/June 2006]*



27. How many instantaneous centres are in a single slider crank mechanism?

[A.U., Oct/Nov 2002]

✓ In a single slider crank mechanism, there are four links.

$\therefore$ Number of instantaneous centres, $N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$ **Ans.**

28. What are the types of instantaneous centres? *[A.U., Apr/May 2005]*

Three types of instantaneous centres are:

1. Fixed instantaneous centres,
2. Permanent instantaneous centres, and
3. Neither fixed nor permanent centres.

29. *Define Aronhold-Kennedy's theorem.*

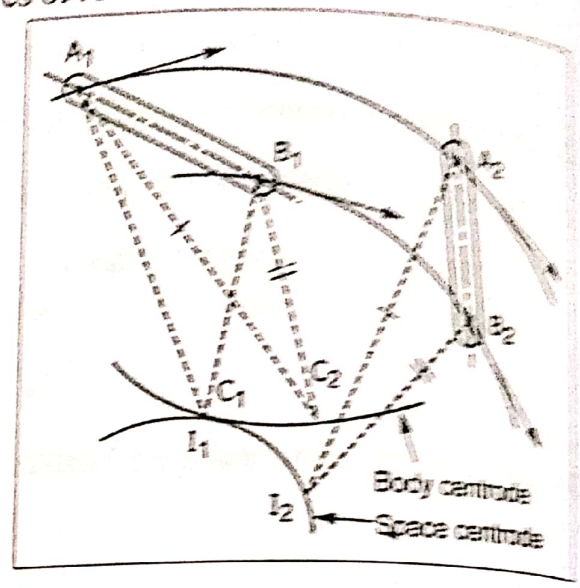
The Kennedy's theorem states that if three bodies have relative motion with each other, then their relative instantaneous centres lie on a straight line.

30. *Define angular velocity ratio theorem.*

The angular velocity ratio theorem states that the angular velocity ratio of two links relative to a third link is inversely proportional to the distances of their common instantaneous centre from their respective centres of rotation.

31. *Explain with a neat sketch, the space centrode and body centrode.*

[A.U., Nov/Dec 2004; Nov/Dec 2006]



✓ The locus of the instantaneous centre in space during a definite motion of the body is called the ***space centrode.***

✓ The locus of the instantaneous centre relative to the body itself is called the ***body centrode.***

32. *What the stages of kinematic synthesis?*

The three stages of the kinematic synthesis are:

1. Type synthesis,
2. Number synthesis, and
3. Dimensional synthesis.

33. *What do you mean by type synthesis?*

Type synthesis refers to selection of type of mechanisms (such as gears, cams, belts, *etc.*) to be employed for a given application.

34. *Distinguish between number synthesis and dimensional synthesis.*

✓ ***Number synthesis*** refers to the determination of the number and order of links and joints required for a specified motion.

✓ ***Dimensional synthesis*** refers to the determination of the dimensions of parts (i.e. lengths and angles) so as to accomplish specified task and desired motion characteristics.

35. *What are the tasks of kinematic synthesis?*

1. Function generation,
2. Path generation, and
3. Motion generation.

36. *Differentiate between path generation and motion generation.*

✓ In ***path generation,*** a point on the coupler link is constrained to describe a path with reference to a fixed frame.

✓ In **motion generation,** a mechanism is designed to guide a rigid body in a specified path.

37. ***What do you mean by coupler curve?*** *[A.U., May/June 2007]*

When the linkage is put into motion, any point attached to the plane of coupler generates some path/curve with respect to frame link. This path or curve is called coupler curve.

38. ***State the Freudenstein's equation for a four-bar mechanism.*** *[A.U., Nov/Dec 2007]*

Freudenstein's equation is given by

$$k_1 \cos\phi + k_2 \cos\theta + k_3 = \cos(\theta - \phi)$$

where $k_1 = \frac{d}{a}$; $k_2 = \frac{-d}{c}$; and $k_3 = \frac{a^2 - b^2 + c^2 + d^2}{2ac}$

a, b, c and d are magnitudes of four links.

θ and ϕ are the angles made with horizontal by the input and follower links respectively.

39. ***State the relationship between crank angle θ and connecting rod angle ϕ of single slider-crank mechanism.***

[A.U., Nov/Dec 2011]

$$\sin\phi = \frac{r}{l}\sin\theta = \frac{\sin\theta}{n}$$

CHAPTER 3: KINEMATICS OF CAM

1. ***What is a cam?***

A cam is a rotating mechanical member used for transmitting desired motion to a follower by direct contact.

2. ***What are the three necessary elements of a cam mechanism?***

1. Cam: The driving member is known as the cam.

2. Follower: The driven member is known as the follower.

3. Frame: It supports the cam and guides the follower.

3. ***State the advantages of cam mechanisms over linkage mechanisms.***

[A.U., Apr/May 2003]

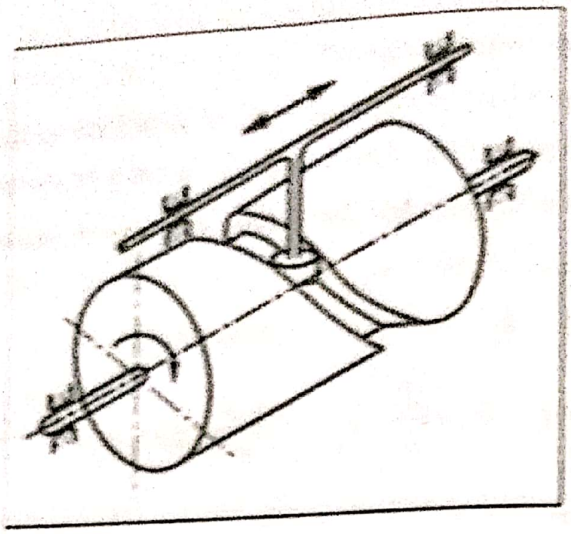
The cam mechanisms are preferred over linkage mechanisms in applications that require complex or irregular motion and work function requirements.

4. ***What are the classifications of cams based on contact surfaces?***

[A.U., Nov/Dec 2006, May/June 2013]

1. Radial (or disc or plate) cams,
2. Wedge (or flat) cams,
3. Cylindrical (or barrel) cams,
4. Conical cams,
5. Globoidal cams, and
6. End (or face) cams.

5. *Sketch a cylindrical cam with the follower reciprocates in a direction parallel to the cam axis.* [A.U., Apr/May 2005]



6. *List any four types of cam followers.* [A.U., Nov/Dec 2004]

(*i*) Knife-edge follower; (*ii*) Roller follower;

(*iii*) Flat-faced (or mushroom) follower; and (*iv*) Spherical-faced follower.

7. *Classify followers according to the follower shape or surface in contact.*

(*i*) Knife-edge follower; (*ii*) Roller follower;

(*iii*) Flat-faced (or mushroom) follower; and (*iv*) Spherical-faced follower.

8. *Classify followers according to the motion of the follower.*

1. Reciprocating (or translating) follower
2. Oscillating (or rotating) follower

9. *Classify followers according to the path of motion of the follower.*

1. Radial follower
2. Offset follower

10. *Why is a roller follower preferred to knife-edge follower?* [A.U., Nov/Dec 2006; Nov/Dec 2009]

In roller followers, the wear rate is considerably reduced because of rolling motion between contacting surfaces.

11. *State, atleast, one advantage and one disadvantage of flat-faced follower over roller follower in a cam mechanism.* [A.U., May/June 2006]

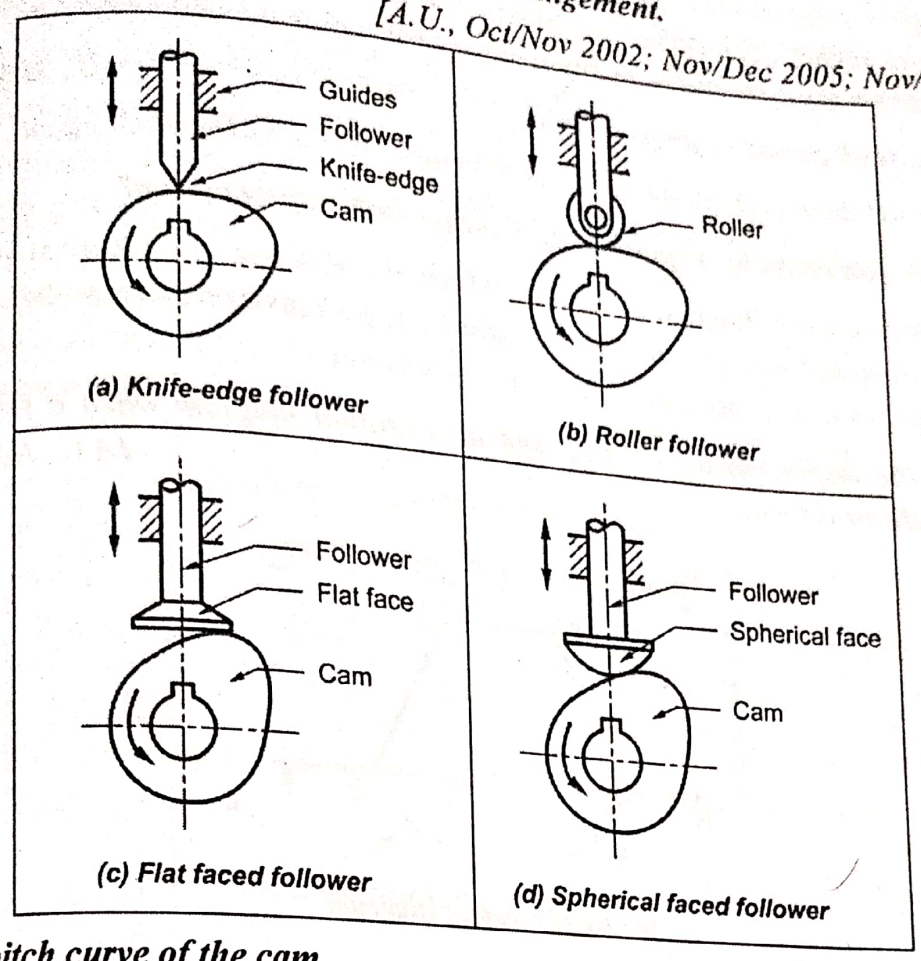
✓ *Advantage:* The thrust at the bearing is less as compared roller followers.

✓ *Disadvantage:* It causes high surface stresses.

12. *Why sometimes the axes of translating roller followers in cam follower mechanisms are offset from the axis of rotation of cam?* [A.U., Nov/Dec 2011; Nov/Dec 2012]

An offset is usually provided on a side so as to decrease pressure angle at the point of maximum velocity during outstroke in order to reduce the side thrust in guides of followers.

13. ***Sketch any four types of follower with cam arrangement.*** *[A.U., Oct/Nov 2002; Nov/Dec 2005; Nov/Dec 2008]*



14. ***Define pitch curve of the cam.*** *[A.U., Apr/May 2008]*

The locus or path of the tracing point is known as the pitch curve.

15. ***What is prime circle of a cam? What is the radial distance between the prime circle and base circle for a cam with knife-edge follower?*** *[A.U., May/June 2007]*

✓ The smallest circle drawn tangent to the pitch curve is known as the prime circle.

✓ The radial distance between the prime circle and base circle for a cam with knife-edge follower is zero.

16. ***Define pressure angle of a cam mechanism and state the best value of the pressure angle.*** *[A.U., Nov/Dec 2003; Apr/May 2010; Nov/Dec 2011; Nov/Dec 2013]*

✓ ***Definition:*** Pressure angle is the angle between the line of action of the follower and corresponding normal to the pitch curve through trace point.

✓ The maximum pressure angle should be less than 30° for cams with reciprocating followers.

17. ***What is the significance of pressure angle in cam? (or why large pressure angle is not preferred in cam curves?)*** *[A.U., May/June 2009; May/June 2012]*

✓ The pressure angle is very important in cam design as it measures the effectiveness of cam to transfer driving force to the follower.

✓ Higher value of pressure angle results in higher value of side thrust at the guides and hence higher the chances of jamming the translating follower in its guide ways. The pressure angle should be as small as possible within the limits of design.

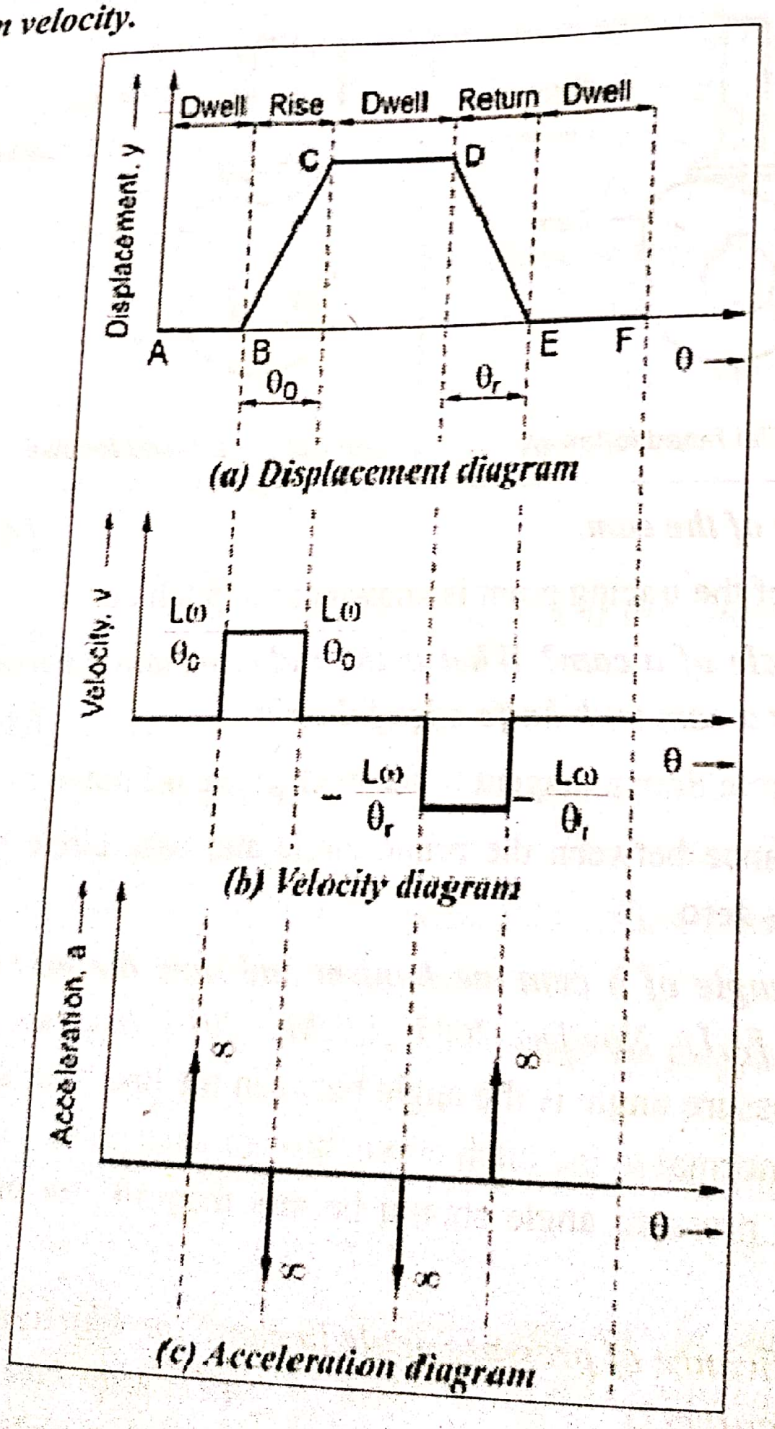
18. *Define dwell period or angle of dwell.* [A.U., May/June 2013]

The period during which the follower remains at rest is called dwell period.

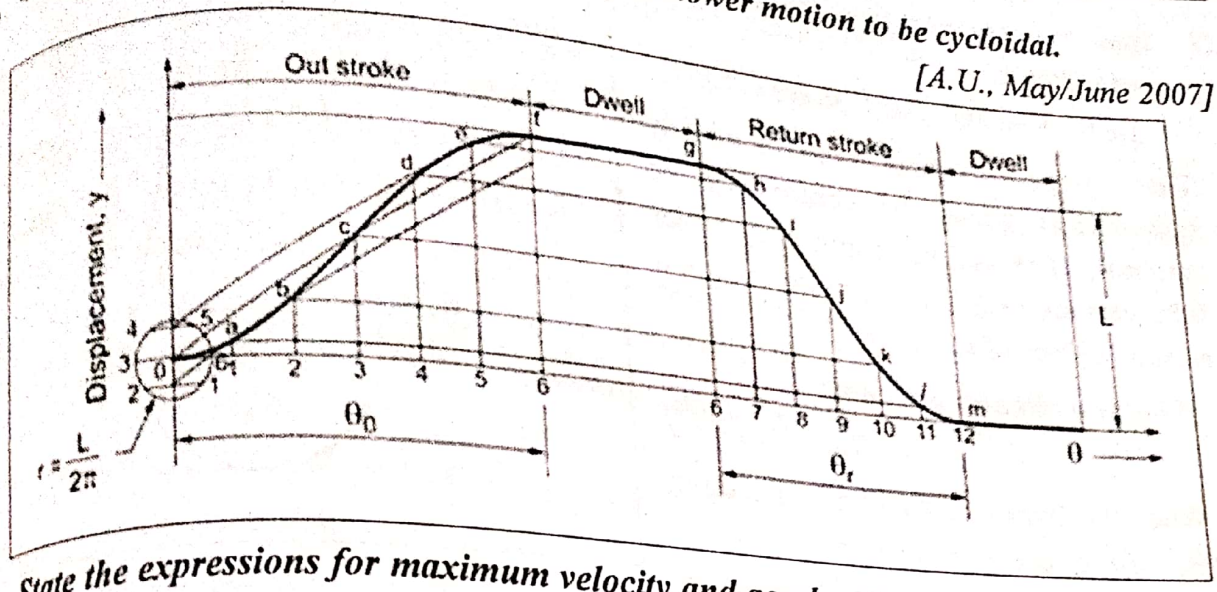
19. *What do you mean by displacement diagram with respect to cam?*

The displacement diagram is one in which the abscissa (*i.e.*, X-axis) represents the angular displacement of cam and the ordinate (*i.e.*, Y-axis) represents the corresponding displacement of the follower from its initial position.

20. *Sketch the displacement, velocity and acceleration diagram when a follower moves with uniform velocity.* [A.U., Nov/Dec 2006]



25. ***Construct the displacement diagram for the follower motion to be cycloidal.*** *[A.U., May/June 2007]*



26. ***State the expressions for maximum velocity and acceleration of a follower moves with cycloidal motion.*** *[A.U., May/June 2007; Nov/Dec 2007; Nov/Dec 2012]*

$$(v_o)_{max} = \frac{2 L \omega}{\theta_o} \qquad (v_r)_{max} = \frac{2 L \omega}{\theta_r}$$

$$(a_o)_{max} = \frac{2\pi L \omega^2}{\theta_o^2} \qquad (a_r)_{max} = \frac{2\pi L \omega^2}{\theta_r^2}$$

where L = Stroke of the follower,

ω = Angular velocity of the cam in rad/s, and

θ_0 and θ_r = Angle of ascent and angle of descent.

27. ***What is the follower motion used for high speed cams? Why?*** *[A.U., May/June 2009; May/June 2012]*

The cams with cycloidal motion for followers are recommended for higher speeds. Because the acceleration curve is continuous and the value of jerk is not infinite anywhere.

28. ***Why cams with specified contours are used?***

In actual practice, in order to achieve ease of manufacturing and cheaper cost of production of cams, the cams with specified contours are used. *[A.U., Apr/May 2010]*

29. ***Name the types of cams with specified contours.***

1. Tangent cams, and
2. Circular arc cams. *[A.U., May/June 2014]*

30. ***Define tangent cam.***

When the flanks of the cam are straight and tangential to the base circle and nose circle, the cam is known as tangent cam.

CHAPTER 4: TOOTHED GEARING

1. ***What are the advantages of gear drive over other drives?***

(i) Since there is no slip, so gear drive obtains exact velocity ratio.

(ii) It is capable of transmitting larger power (than that of the belt and chain drives).

(iii) It is more efficient and effective means of power transmission.

(iv) It requires less space (as compared to belt and rope drives).

2. ***Under what situations, (a) spur gears, (b) bevel gears, and (c) worm gears, are used?***

(a) ***Spur gears*** are used when the power and motion are to be transmitted between two parallel shafts.

(b) ***Bevel gears*** are used when the power and motion are to be transmitted between two intersecting shafts.

(c) ***Worm and worm wheel*** are used when the power and motion are to be transmitted between two non-parallel and non-intersecting shafts.

3. ***State the advantages of helical gears over spur gears.*** *[A.U., Nov/Dec 2003]*

(i) Helical gears operate smoother and quieter than spur gears.

(ii) Helical gears have a greater load carrying capacity.

4. ***Define: (a) normal pitch and (b) axial pitch relating to helical gears.***

[A.U., Nov/Dec 2004; May/June 2007; Apr/May 2010]

✓ ***Normal pitch*** is the distance between similar faces of adjacent teeth, along a helix on the pitch cylinder normal to the teeth.

✓ ***Axial pitch*** is the distance measured parallel to the axis, between similar faces of adjacent teeth.

5. ***What are herringbone gears? State its advantage.***

✓ Herringbone gears, also known as double-helical gears, consists of teeth having a right and a left handed helix cut on the same blank.

✓ In Herringbone gears, the problem of axial thrust is eliminated.

6. ***What is the use of rack and pinion arrangement?***

The rack and pinion is used to convert rotary motion into translatory motion or vice versa.

7. ***Differentiate between a straight bevel gear and a spiral bevel gear.***

✓ If the teeth on the bevel gears are parallel to the lines generating the pitch cones, then they are called ***straight bevel gears.***

✓ When the teeth of a bevel gear are inclined at an angle to the face of the bevel gears, they are known as ***spiral bevel gears.***

[A.U., Apr/May 2010]

8. *What is a worm gear drive?*

A worm gear drive is used to transmit power from one shaft to another which are non-intersecting and their axes are normally right angles to each other.

9. *State the advantages of worm gear drive over other gear drives.* *[A.U., May/June 2006]*

(i) The worm gears can be used for high speed reductions upto 400 : 1.

(ii) The operation is smooth and quite.

(iii) The worm gear drives are irreversible.

10. *Which type of gear pair is to be used to get very large speed reduction in a stage? State the reason.* *[A.U., Nov/Dec 2003]*

✓ The worm and worm wheel are used for large speed reduction in a stage upto 400 : 1.

✓ As the worm (similar to screw) drives the larger worm wheel, it is used in a very large speed reduction applications.

11. *Define the following terms used in gears: (a) Pitch circle, (b) Circular pitch, (c) Diametral pitch and (d) Module.* *[A.U., May/June 2006]*

(a) Pitch circle: Pitch circle is an imaginary circle on gear, by which pure rolling action would give the same motion as the actual gear.

(b) Circular pitch: Circular pitch is the distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.

(c) Diametral pitch: Diametral pitch is the number of teeth per unit pitch circle diameter of the gear.

(d) Module: Module is the ratio of the pitch circle diameter to the number of teeth on the gear.

12. *Differentiate diametral pitch and circular pitch of a friction wheel.*

[A.U., Nov/Dec 2007]

✓ ***Diametral pitch:*** Diametral pitch is the number of teeth per unit pitch circle diameter of the gear.

✓ ***Circular pitch:*** Circular pitch is the distance measured along the circumference of the pitch circle from a point on one tooth to the corresponding point on the adjacent tooth.

13. *Define module of gears and its relation to circular pitch.*

[A.U., Apr/May 2003; Nov/Dec 2006]

✓ Module is the ratio of the pitch circle diameter to the number of teeth on the gear.

✓ Relation between circular pitch and module:

$$\text{Circular pitch, } p_c = \pi \times \text{Module}$$

14. ***Define the following terms used in gears: (a) Pressure angle, (b) Module.***

[A.U., Nov/Dec 2011; May/June 2012]

(a) ***Pressure angle*** is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point.

(b) ***Module*** is defined as the ratio of pitch circle diameter to the number of teeth on the gear.

15. ***Define the term 'arc of contact' in gears.*** *[A.U., Nov/Dec 2012]*

The arc of contact is the path traced by a point on the pitch circle from the beginning to the end of engagement of two meshing teeth.

16. ***What do you mean by backlash?***

Backlash is the difference between the tooth thickness of one gear and the tooth space of the mating gear.

17. ***State the law of gearing.***

[A.U., Oct/Nov 2002; Nov/Dec 2004; Nov/Dec 2005; May/June 2007; Nov/Dec 2008; Nov/Dec 2009; May/June 2013; May/June 2014]

The law of gearing states that for maintaining constant velocity ratio between two meshing gears, the common normal of the tooth profiles, at all contact points with in mesh, must always pass through a fixed point on the lines of centres, called pitch point.

18. ***Prove or disprove that pure rolling is possible at one point only, on the line of action, between two meshing gear teeth profiles.*** *[A.U., Nov/Dec 2003; May/June 2006]*

We know that in a spur gear pair, at the pitch point there is no sliding. The action is pure rolling. We also know that the path of contact should always pass through the pitch point. Thus the pure rolling occurs only at one point along the path of contact.

19. ***State the condition for constant velocity ratio of toothed wheels.*** *[A.U., Nov/Dec 2006]*

- ✓ The condition for constant velocity ratio of toothed wheels is nothing but the law of gearing.
- ✓ The law of gearing states that for maintaining constant velocity ratio between two meshing gears, the common normal of the tooth profiles, at all contact points with in mesh, must always pass through a fixed point on the lines of centres, called pitch point.

20. ***Define the terms velocity ratio and sliding velocity in a spur gear pair.***

[A.U., May/June 2006; Nov/Dec 2013; May/June 2014]

- ✓ ***Velocity ratio:*** Velocity ratio is the ratio of speed of driving gear to the speed of the driven gear.
- ✓ ***Sliding velocity:*** Sliding velocity or velocity of sliding is the velocity of one tooth relative to its mating tooth along the common tangent at the point of contact.

21. *Name two curves for use as gear profile, which satisfy the law of gearing (or) Lay down the common forms of gear teeth.* *[A.U., Apr/May 2010; May/June 2013]*

1. Involute curve
2. Cycloidal curve

22. *What are the advantages and disadvantages of involute gear tooth profile?* *[A.U., Nov/Dec 2003; Nov/Dec 2006; May/June 2007]*

✓ ***Advantages:*** Variable centre distance; Constant pressure angle; Easy manufacturing.

✓ ***Disadvantages:*** Interference occurs; Weaker teeth; More wear and tear.

23. *What are the standard interchangeable tooth profiles commonly used?*

1. $14^1/_2°$ composite system,
2. $14^1/_2°$ full depth involute system,
3. 20° full depth involute system,
4. 20° stub involute system,
5. 25° full depth involute system, and
6. 25° stub involute system.

24. *Define pressure angle in gears and explain the effect of different pressure angle.* *[A.U., Apr/May 2008]*

✓ ***Pressure angle*** is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point.

✓ ***Effect of pressure angle:***

- The gears with smaller pressure angles efficiently transfer torque and apply lower radial loads onto the shaft and supporting bearings. However as the pressure angles are reduced, a greater tendency exists for gear tooth to interfere as they engage.
- The larger pressure angle makes teeth with a much larger base, which makes these teeth much stronger and also allows the production of gears with fewer teeth.

25. *What is meant by contact ratio in gear? And write the equation to determine this value.* *[A.U., Apr/May 2005]*

✓ The contact ratio in gear refers to the average number of teeth that are in contact at any instant.

✓ Mathematically, $\text{Contact ratio} = \dfrac{\text{Length of arc of contact}}{\text{Circular pitch}}$

26. *What is the significance of contact ratio in gears?* *[A.U., Nov/Dec 2010]*

✓ The greater contact ratio values result in smoother action because another gear tooth shares the load for a longer duration during the engaging/disengaging process.

✓ The contact ratio should exceed 1 because contact between gears must not be lost.

27. ***Explain the term interference as applied to gears.*** *[A.U., Nov/Dec 2004; Apr/May 2008]*

The phenomenon when the tip of tooth will dig out or interfere with the flank portion of the tooth portion of the mating gear is known as interference.

28. ***Define undercutting in gears.*** *[A.U., Apr/May 2008]*

When the tip of the gear tooth undercuts the root (flank) of the mating gear tooth, some portion of the flank will be removed. This process of removal of material due to interference phenomenon is called undercutting.

29. ***Explain any two methods of reducing or eliminating interference in gears.*** *[A.U., Oct/Nov 2002; May/June 2014]*

1. By modifying addendum of gear teeth.
2. By increasing the pressure angle.
3. By modifying tooth profile or profile shifting.
4. By increasing the centre distance.

30. ***Determine the minimum number of teeth to avoid interference in worst case of meshing with 14½° pressure angle.*** *[A.U., Nov/Dec 2003]*

☺ ***Solution:*** Assuming the pinion and gear wheel have equal teeth *i.e.*, G = 1, the minimum number of teeth on the gear wheel is given by

$$T_{G\,(min)} = \frac{2A_n}{\sqrt{(1+3\sin^2\phi)} - 1}$$

$$= \frac{2 \times 1}{\sqrt{1+3\sin^2 14.5^\circ} - 1} = 22.22 \text{ say } 23$$

$$\therefore \quad T_{P\,(min)} = \frac{T_G}{G} = \frac{23}{1} = \mathbf{23} \quad \textbf{Ans.}$$

31. ***What are non-standard gears?***

The gear teeth obtained by modifying the standard proportions of gear teeth parameters, is known as non-standard gear teeth.

32. ***What are the principal reasons for the use of non-standard gears?*** *[A.U., May/June 2007]*

The principal reasons for employing non-standard gears are: (i) to prevent interference, (ii) to maintain reasonable contact ratio, and (iii) to attain predetermined centre distance.

33. ***What do you mean by tumbler gears?***

Tumbler gears are those which are used, in lathes for reversing the direction of rotation of driven gears.

CHAPTER 5: GEAR TRAIN

1. ***What is a gear train?***

   A gear train is a combination of gears that is used for transmitting motion from one shaft to another.

2. ***Define the term train value of gear train.***

   Train value is the ratio of the speed of the driven gear to the speed of the driving gear.

3. ***What are the types of gear trains?***

   (i) Simple gear train,
   (ii) Compound gear train,
   (iii) Reverted gear train, and
   (iv) Epicyclic gear train.

4. ***Define simple gear train.***

   When there is only one gear on each shaft, it is known as simple gear train.

5. ***What is meant by compound gear train?***

   When a gear train having one or more compound gears is known as compound gear train.

6. ***What is the advantage of a compound gear train over a simple gear train?***

   The advantage of a compound gear train over a simple gear train is that it can provide higher speed reductions, for the given centre distance between the input and output shafts, using smaller gears.

7. ***Mention two methods to transmit power between two wheels when the distance between them is more.***

   (i) By providing the large sized wheels, or
   (ii) By providing one or more intermediate wheels.

8. ***How to change the direction of rotation of the output gear in simple gear train without changing the direction of rotation of input gear?*** *[A.U., Apr/May 2005]*

   By using intermediate idle gears.

9. ***What are the roles of idlers in gear trains? [or what are the uses of intermediate gears in a gear train?]*** *[A.U., Apr/May 2010; May/June 2012]*

   Intermediate gears, also known as idler gears, are necessary:

   (i) to change the direction of rotation of the driven gear without changing its angular velocity, and
   (ii) to bridge the gap between first and last gears, when the centre distance is large.

10. ***What is the effect of intermediate gears on train value in a gear train?***

    The intermediate gears do not affect the train value of the gear train.

11. ***What is the advantage of a compound gear train over a simple gear train?***

The advantage of a compound gear train over a simple gear train is that it can provide higher speed reductions, for the given centre distance between the input and output shafts.

12. ***In a compound gear train, the drivers have 25, 50, 75 and 100 teeth and the followers have 15, 30, 40 and 65 teeth. What is the velocity ratio of the compound gear train?***

Solution: We know that velocity ratio of compound gear train,

$$\text{Velocity ratio} = \frac{\text{Product of number of teeth on drivers}}{\text{Product of number of teeth on followers}}$$

$$= \frac{25 \times 50 \times 75 \times 100}{15 \times 30 \times 40 \times 65} = 8 \text{ Ans.}$$

13. ***Briefly write about reverted gear train with suitable sketch.***

[A.U., Apr/May 2003; Nov/Dec 2007]

A compound gear train in which the first and last gears are coaxial is called as reverted gear as shown in Fig.1.

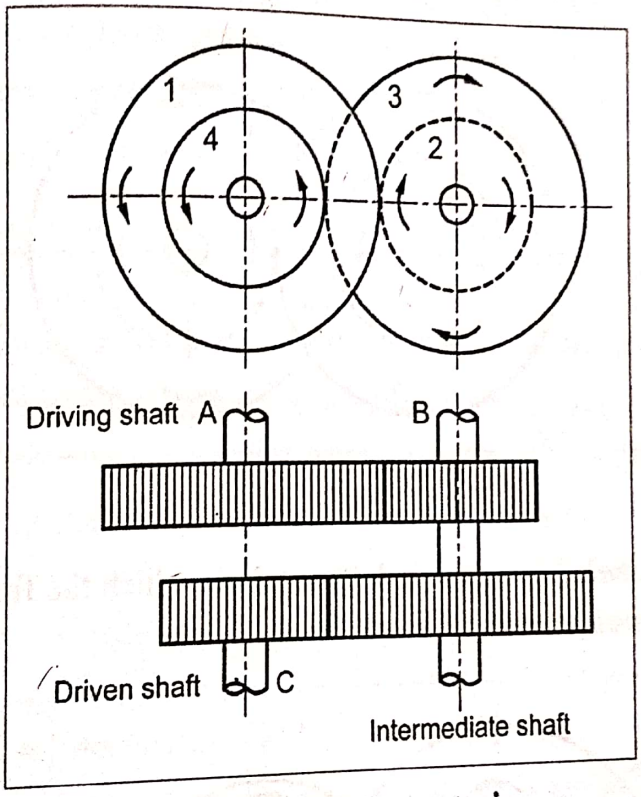


Fig. 1. Reverted gear train

14. ***What are the applications of reverted gear trains?***

[A.U., May/June 2009; Nov/Dec 2012]

The reverted gear trains are used in automobile gear boxes, lathe back gears, clocks, etc.

15. ***What is meant by an epicyclic gear train? Give a practical example.***

[A.U., Nov/Dec 2003; Nov/Dec 2011]

- ✓ When the axis of rotation of one or more gears is allowed to rotate about another axis, then the gear train is known as epicyclic gear train.
- ✓ ***Examples:*** Automobile differentials, machine tools, hoists, pulley blocks, etc.

19. ***List out the applications of epicyclic gear train.*** *[A.U., May/June 2007]*

The epicyclic gear trains find many applications in automobile differentials, machine tools, hoists, pulley blocks, wrist watches, aircraft propeller reduction drives, automatic transmissions, *etc.*

20. ***State the methods to find the velocity ratio of epicyclic gear train.***

Two methods are: 1. Tabulation method, and 2. Algebraic method.

21. ***What are the various types of torques in an epicyclic gear train? [or what are the externally applied torques used to keep the gear train in equilibrium?]***

[A.U., Nov/Dec 2008]

1. Input torque on the driving member.
2. Output or resisting or load torque on the driven member.
3. Holding or braking or fixing torque on the fixed gear.

22. ***Explain briefly the use of differential in an automobile.***

[A.U., Nov/Dec 2006; Nov/Dec 2011]

The function of a differential gear in an automobile is to:

(i) transmit motion from engine to rear wheels, and

(ii) rotate the rear wheels at different speeds while the automobile is taking a turn.

23. ***What are the advantages of epicyclic (or planetary) gear trains?***

[A.U., Nov/Dec 2010; Nov/Dec 2011]

The advantage of epicyclic gear trains over simple or compound gear trains is that it can achieve high speed reductions within a very limited space.

24. ***What is the degree of freedom of a differential mechanism?*** *[A.U., Nov/Dec 2009]*

DOF of a differential mechanism = 2

CHAPTER 6: FRICTION

1. ***Why friction is called as 'necessary evil'?***

Friction is the important factor in engineering and physical applications such as belt and ropes, jibs, clutches and brakes, nut and bolts, so it is the necessary one. If the friction exceeds certain value it will cause heat, damage and wear when applied. So it is called 'necessary evil'.

2. ***Differentiate between dry friction and fluid friction.***

- ✓ The friction that exists between two unlubricated surfaces is known as dry friction.
- ✓ The friction that exists when the contacting surfaces are separated by a film of fluid is known as fluid friction.

3. ***Distinguish between sliding and rolling friction.*** *[A.U., May/June 2009; Apr/May 2010; Nov/Dec 2011; Nov/Dec 2012]*

✓ The friction that exists when one surface slides over another surface is known as ***sliding friction.***

✓ The friction that exists when one surface slides over another surface is known as ***rolling friction.***

4. ***State the laws of dry friction.*** *[A.U., Apr/May 2003; May/June 2013]*

1. The frictional force is directly proportional to the normal reaction between the surfaces.
2. The frictional force depends upon the nature of the surfaces in contact.
3. The frictional force is independent of the area and the shape of the contacting surfaces.
4. The frictional force is independent of the velocity of sliding of one body relative to the other body.

5. ***Define the term limiting friction.*** *[A.U., Nov/Dec 2008]*

The maximum value of frictional force, which comes into play, when a body just tends to move, is known as limiting force of friction or limiting friction.

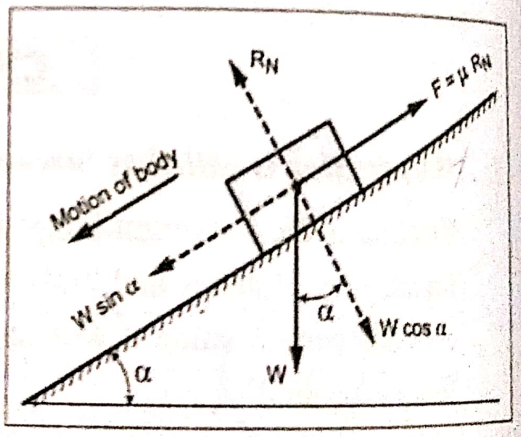
6. ***What do you mean by friction angle?*** *[A.U., May/June 2007; Nov/Dec 2011]*

The limiting angle of friction (ϕ) is defined as the angle at which the resultant reaction R makes with the normal reaction R_N.

7. ***What do you mean by angle of repose?***

The angle of repose is the maximum inclination of a plane at which a body remains in equilibrium over the inclined plane by the assistance of friction only.

8. ***With a neat sketch show that angle of repose α is equal to the limiting angle of friction.*** *[A.U., May/June 2006]*



From the geometry of figure,

$$W \sin\theta = F$$
$$= \mu \cdot R_N$$
$$= \mu W \cos\alpha$$

or $$\tan\alpha = \mu = \tan\phi$$

Thus, $$\alpha = \phi$$

Hence the angle of repose α is equal to the limiting angle of friction ϕ.

11. *A block of 50 N rests on a horizontal plane and whose coefficient of friction is 0.25. What is the force required to pull the block at an angle 30° to the horizontal?*

☹ ***Given data:*** $W = 50$ N; $\mu = 0.25$; $\theta = 30°$

☺ ***Solution:*** We know that $\phi = \tan^{-1}(\mu) = 14.04°$

We know that the force required to pull a body at an angle θ on a horizontal plane,

$$P = \frac{W \sin \phi}{\cos(\theta - \phi)} = \frac{50 \sin 14.04°}{\cos(30° - 14.04°)} = \mathbf{12.62\ N}\ \textbf{Ans.}$$

12. *A block of 50 N rests on a horizontal plane and whose coefficient of friction is 0.25. What is the minimum force required to just pull the block at an angle θ to the horizontal.*

☹ ***Given data:*** $W = 50$ N; $\mu = 0.25$.

☺ ***Solution:*** Friction angle, $\phi = \tan^{-1}(\mu) = 14.04°$

We know that the minimum force required to just pull a body at an angle θ on a horizontal plane,

$$P_{min} = W \sin \phi = 50 \sin 14.04° = \mathbf{12.13\ N}\ \textbf{Ans.}$$

13. *A body of 50 N is placed on a 20° inclined plane whose coefficient of friction μ = 0.3. What is the force required to hold the body at its position in the horizontal direction.*

☹ ***Given data:*** $W = 50$ N; $\mu = 0.3$; $\alpha = 20°$

☺ ***Solution:*** Friction angle, $\phi = \tan^{-1}(\mu) = 16.69°$

We know that the holding force i.e., the force required to move the body up the plane,

$$P = \frac{W \sin(\alpha + \phi)}{\sin[\theta - (\alpha + \phi)]}$$ [Here $\theta = 90°$, because of the horizontal force]

$$= \frac{50 \sin(20° + 16.69°)}{\sin(90° - 20° - 16.69°)} = \mathbf{37.25\ N}\ \textbf{Ans.}$$

14. *For the above problem, find the mechanical advantage.*

Mechanical advantage, $M.A = \frac{W}{P} = \frac{50\ N}{37.255\ N} = 1.342$

15. *What is the mechanical efficiency of an inclined plane which needs 50 N of force to raise a block on its surface when it is purely lubricated and 65 N when the surface is dry.*

☹ ***Given data:*** $P_0 = 50$ N (without friction); $P = 65$ N (with considering friction)

☺ ***Solution:*** Efficiency of the inclined surface is given by

$$\eta = \frac{P_0}{P} = \frac{50}{65} = 0.769 \text{ or } \mathbf{76.92\%}\ \textbf{Ans.}$$

30. What is the condition of maximum efficiency of a screw jack? *[A.U., May/June 2007]*

$$\alpha = \frac{\pi}{4} - \frac{\phi}{2}$$

31. What is the maximum efficiency of a screw jack? *[A.U., May/June 2014]*

$$\eta_{max} = \frac{1 - \sin\phi}{1 + \sin\phi}$$

32. Why square threads are preferred to V-threads for lifting loads?

Square threads require lesser force to lift the given load as compared to V-threads.

33. Define virtual coefficient of friction. *[A.U., Apr/May 2010]*

In the friction of a V-thread, $\mu_1 = \frac{\mu}{\cos\beta}$ is known as virtual coefficient of friction.

34. Define antifriction bearing. *[A.U., Nov/Dec 2013]*

An antifriction bearing, also known as a rolling contact bearing, is used when very little friction is needed for low differential surface speeds.

35. Differentiate the terms pivots and collars, with respect to bearing.

- ✓ The bearing surfaces provided at the end of a shaft are known as pivots.
- ✓ The bearing surfaces provided at any place along the length of the shaft are known as collars.

36. State the assumptions of uniform pressure theory and uniform wear theory.

- ✓ ***Assumption of uniform pressure theory:*** Intensity of pressure is uniform over the bearing surface *i.e.*, p = constant. *This assumption holds good only for newly fitted bearings* and also the fit between the shaft and bearing surfaces should be perfect.
- ✓ ***Assumption of uniform wear theory:*** The rate of wear is uniform, *i.e.*, $p \cdot r$ = constant. *This assumption holds good for old (used) bearings.*

CHAPTER 7: FRICTION CLUTCH

1. What is the function of a clutch?

A clutch is a mechanical device used to connect or disconnect the driven shaft from the driving shaft at the will of the operator while power is transmitted from driving to driven shaft.

2. What are the significance of friction with regard to power transmission devices like clutches and bearings? *[A.U., May/June 2007]*

The power transmission devices like clutches and bearings work on the principle of friction. When two friction surfaces are brought in contact with each other and pressed, they are united due to the friction between them.

(a) Cone clutches
(b) Disc or plate clutches
(c) Plate clutches
(d) Centrifugal clutches

4. *In cone clutch problems, it is assumed that 'old clutch' works under uniform _____ and the 'new clutch' works under uniform _____.*

[Axial wear, pressure]

5. *Clutches are usually designed on the basis of uniform wear. Why?*

In clutches, the value of normal pressure, axial load for the given clutch is limited by the rate of wear that can be tolerated in the brake linings. Moreover, the assumption of uniform wear rate gives a lower calculated clutch capacity than the assumption of uniform pressure. Hence clutches are usually designed on the basis of uniform wear.

6. *In a five plate clutch drive, the inner and outer radii of friction plate are 100 mm and 200 mm respectively. The coefficient of friction is 0.25 and the axial force is 15 kN. What is the frictional torque acting on the plate using uniform wear principle.*

Given data: $n_p = 5$ or $n = 5 - 1 = 4$; $r_2 = 100$ mm $= 0.2$ m; $r_1 = 200$ mm $= 0.2$ m; $\mu = 0.25$; $W = 15$ kN $= 15000$ N

Solution: For uniform wear, torque transmitted is given by

$$T = \frac{1}{2} n \mu W (r_1 + r_2)$$

$$= \frac{1}{2} \times 4 \times 0.25 \times 15000 (0.2 + 0.1) = \mathbf{2250\ N.m} \quad \textbf{Ans.}$$

7. *Differentiate between multiplate clutch and cone clutch.* *[A.U., Nov/Dec 2013]*

- In disc clutches, friction lined flat plates are used.
- In cone clutches, friction lined frustum of cone is used.

8. *What is the difference between cone clutch and centrifugal clutch?*

Cone clutch works on the principle of friction alone. But centrifugal clutch uses principle of centrifugal force in addition with it.

CHAPTER 8: BELT AND ROPE DRIVES

1. *Name any four belt materials that are commonly used?*

1. Leather, 2. Cotton or fabric, 3. Rubber, 4. Balata, and 5. Nylon.

2. *Give examples for flexible and non-flexible drives.*

Flexible drives: Belt drive, rope drive, and chain drive.

Non-flexible drives: Cam drive, gear drive, and clutches.

3. ***Distinguish between open and cross belt drives in terms of its applications.*** *[A.U., May/June 2013]*

✓ The open belt drive is used with shafts arranged parallel and rotating in same direction.

✓ The crossed belt drive is used with shafts arranged parallel and rotating in the opposite direction.

4. ***Why the slack side of the belt of a horizontal belt drive is preferable to place on the top side?***

The slack side of the belt is preferably placed on the top side because, the slack side of the belt, due to its self-weight, will sag. For this reason the angle of contact between the belt and the pulleys will increase. However, the tight side will not sag to that extent. Hence, the net effect will be an increase in the angle of contact or angle of wrap. Thus, due to the increase in angle of contact, the power transmission capacity of the drive system will increase.

5. ***What is the purpose of idler pulley in a flat belt drive?***

Idler pulley, also known as jockey pulley, is a tensioner that helps provide the right level of tension on the belt and ensures correct operation.

6. ***When is quarter twist drive used?***

The quarter twist drive is used with shafts arranged at right angles and rotating in one definite direction.

7. ***What is the use of a cone pulley drive?***

A stepped or cone pulley drive is used for changing the speed of the driven shaft while the main or driving shaft runs at constant speed.

8. ***When do you use fast and loose pulley drive?***

A fast and loose pulley drive is used when the driven or machine shaft is to be started or stopped whenever desired without stopping the driving shaft.

9. ***What you meant by 'crowning' in pulley?***

The rim of the pulley is given camber (i.e., taper) on the surface, so that the belt will not slip off the pulley when it rotates. This process is known as crowning of pulley.

10. ***Define velocity ratio of the belt drive.***

Velocity ratio is the ratio of velocity of the driven pulley to velocity of the driver pulley.

11. ***Define the term slip in relation to belt drive.***

Slip is defined as the relative motion between belt and pulley, due to insufficient grip between belt and pulley.

12. ***Whether the thickness of belt affects the velocity ratio?***

Yes, but it is negligible.

28. *What is the ratio of driving tension in flat belt, V belt and in rope drives?*

(a) $\frac{T_1}{T_2} = e^{\mu\theta}$ [For flat belt drive]

(b) $\frac{T_1}{T_2} = e^{\mu\theta \operatorname{cosec} \beta}$ [For V belt and rope drive]

where T_1 = Tension in tight side,

T_2 = Tension in loose side,

θ = Angle of contact, and

2β = Angle of V-groove

29. *What are the advantages and disadvantages of V-belt drive over flat belt drive?*

[A.U., Apr/May 2010; Nov/Dec 2011]

Advantages:

(i) Power transmitted is more due to wedging action in the grooved pulleys.

(ii) V-belt is more compact, quiet and shock absorbing.

Disadvantages:

(i) It cannot be used with large centre distances.

(ii) It is not as durable as flat drive.

CHAPTER 9: BRAKES

1. *What is the function of a brake?*

Brake is a mechanical device by means of which motion of a body is retarded for slowing down or to bring it to rest, by applying artificial frictional resistance.

2. *State the functional difference between a brake and a clutch.*

[A.U., Nov/Dec 2011; May/June 2012]

A clutch connects two moving members of a machine, whereas a brake connects a moving member to a stationary member.

3. *Differentiate a brake and a dynamometer.*

A dynamometer is a brake incorporating a device to measure the frictional resistance applied.

4. *Give examples for radial and axial brakes.*

✓ ***Radial brakes:*** Band brakes, block brakes, and internal expanding rim.

✓ ***Axial brakes:*** Cone brakes and disc brakes.

5. *List out any four desirable characteristics of brake lining material.*

[A.U., Nov/Dec 2007]

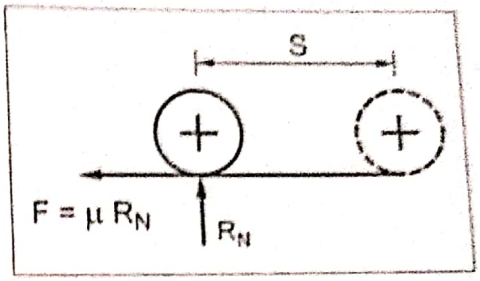
(i) A high and uniform coefficient of friction.

(ii) Ability to withstand high temperatures, together with high heat dissipation capacity.

(iii) Adequate mechanical and thermal strengths.

(iv) High resistance to wear.

6. ***A force of 80 N is applied to the brake of a bicycle rear wheel and the distance covered by the bicycle before coming to rest is 12.5 metres. If the coefficient of friction is 0.6, find the work done against the friction.*** *[A.U., May/June 2006]*



☹ ***Given data:*** F = 80 N; S = 12.5 m; μ = 0.6.

☺ ***Solution:*** $F = \mu R_N$ or $R_N = 80/0.6$

$= 133.33$ N

Work done $= R_N \times S = 133.33 \times 12.5$

$= 1666.6$ N.m **Ans.**

7. ***Explain briefly significance of friction in braking.*** *[A.U., Nov/Dec 2006]*

The capacity of any brake depends upon the unit pressure between braking surfaces, the coefficient of friction between them, velocity of brake drum, heat dissipation capacity of the brake, etc.

8. ***What is a self-locking brake?*** *[A.U., Nov/Dec 2012]*

When the frictional force is sufficient enough to apply the brake with no external force, then the brake is said to be self-locking brake.

9. ***What you meant by self-energizing (or self-actuating) brake?***

[A.U., Nov/Dec 2010; Nov/Dec 2012]

When the moment of applied force ($F \cdot l$) and the moment of the frictional force ($\mu \cdot R_N \cdot c$) are in the same direction, then frictional force helps in applying the brake. This type of brake is known as a self-energizing brake.

❑❑❑