STELLA MARY'S COLLEGE OF ENGINEERING

(Accredited by NAAC, Approved by AICTE - New Delhi, Affiliated to Anna University Chennai)

Aruthenganvilai, Azhikal Post, Kanyalumari District, Tamilnadu - 629202.

ME8492 KINEMATICS OF MACHINERY

(Anna University: R2017)

Prepared By

Mr. P.VIJAYAN

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING

SMCE/IQAC/FM-5D/CF/CBSY

STELLA MARY'S COLLEGE OF ENGINEERING

(Approved by AICTE, New Delhi, Affiliated to Anna University, Chennai
Aruthenganvilai, Kallukatti Junction Azhikal Post, Kanyakumari District-629202, Tamil Nadu.

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIAL

REGULATION	**2017**
YEAR	**II**
SEMESTER	**04**
COURSE NAME	**KINEMATICS OF MACHINERY**
COURSE CODE	**ME 8492**
NAME OF THE COURSE INSTRUCTOR	**Mr. P.VIJAYAN**

SYLLABUS:

UNIT I BASICS OF MECHANISMS **9**

Classification of mechanisms – Basic kinematic concepts and definitions – Degree of freedom, Mobility – Kutzbach criterion, Gruebler's criterion – Grashof's Law – Kinematic inversions of four-bar chain and slider crank chains – Limit positions – Mechanical advantage – Transmission Angle – Description of some common mechanisms – Quick return mechanisms, Straight line generators, Universal Joint – rocker mechanisms.

UNIT II KINEMATICS OF LINKAGE MECHANISMS **9**

Displacement, velocity and acceleration analysis of simple mechanisms – Graphical method– Velocity and acceleration polygons – Velocity analysis using instantaneous centres – kinematic analysis of simple mechanisms – Coincident points – Coriolis component of Acceleration – Introduction to linkage synthesis problem.

UNIT III KINEMATICS OF CAM MECHANISMS **9**

Classification of cams and followers – Terminology and definitions – Displacement diagrams – Uniform velocity, parabolic, simple harmonic and cycloidal motions – Derivatives of follower motions – Layout of plate cam profiles – Specified contour cams – Circular arc and tangent cams – Pressure angle and undercutting – sizing of cams.

UNIT IV GEARS AND GEAR TRAINS **9**

Law of toothed gearing – Involutes and cycloidal tooth profiles –Spur Gear terminology and definitions – Gear tooth action – contact ratio – Interference and undercutting. Helical, Bevel, Worm, Rack and Pinion gears [Basics only]. Gear trains – Speed ratio, train value – Parallel axis gear trains – Epicyclic Gear Trains.

UNIT V FRICTION IN MACHINE ELEMENTS **9**

Surface contacts – Sliding and Rolling friction – Friction drives – Friction in screw threads – Bearings and lubrication – Friction clutches – Belt and rope drives – Friction in brakes- Band and Block brakes.

TEXT BOOKS:

1. F.B. Sayyad, “Kinematics of Machinery”, MacMillan Publishers Pvt Ltd., Tech-max Educational resources, 2011.
2. Rattan, S.S, “Theory of Machines”, 4th Edition, Tata McGraw-Hill, 2014.
3. Uicker, J.J., Pennock G.R and Shigley, J.E., “Theory of Machines and Mechanisms”, 4th Edition, Oxford University Press, 2014

REFERENCES:

1.Allen S. Hall Jr., “Kinematics and Linkage Design”, Prentice Hall, 1961
2. Cleghorn.W. L, “Mechanisms of Machines”, Oxford University Press, 2014
3. Ghosh. A and Mallick, A.K., “Theory of Mechanisms and Machines", 3rd Edit ion Affiliated East-West Pvt. Ltd., New Delhi, 2006.
4. John Hannah and Stephens R.C., "Mechanics of Machines", Viva Low-Prices Student Edition, 1999.
5. Thomas Bevan, "Theory of Machines", 3rd Edition, CBS Publishers and Distributors, 2005.

Course Outcome Articulation Matrix

	Program Outcome												***PSO***		
Course Code / CO No	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***1***	***2***	***3***
ME8492 / C211.1	3	3	3	1	3	2	0	1	2	2	1	3	1	1	3
ME8492 / C211.2	3	3	3	2	3	0	2	0	0	2	0	3	3	1	3
ME8492 / C211.3	3	3	3	0	3	2	0	0	2	1	2	3	3	1	3
ME8492 / C211.4	3	3	3	1	3	1	1	0	0	1	3	3	3	1	3
ME8492 / C211.5	3	3	3	0	3	2	0	1	0	3	0	3	1	1	3
Average	3	3	3	1	3	1	1	0	1	2	1	3	2	1	3

UNIT 1 - BASICS OF MECHANISMS

PART-A

1. Define Kinematic Pair. (May/June 2013)

Kinematic pair is a joint of two links having relative motion between them. The types of kinematic pair are classified according to

- ✓ Nature of contact. (lower pair, higher pair)
- ✓ Nature of mechanical contact. (Closed pair, unclosed pair)
- ✓ Nature of relative motion. (Sliding pair, turning pair, rolling pair, screw pair, spherical pair)

2. Define Kinematic Chain.

When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion it is called a kinematic chain.

Eg: The crank shaft of an engine forms a kinematic pair with the bearings which are fixed in a pair, the connecting rod with the crank forms a second kinematic pair, the piston with the connecting rod forms a third pair and the piston with the cylinder forms the fourth pair. The total combination of these links is a kinematic chain. Eg: Lawn mower.

3. Define Degrees of Freedom. (April/May 2015)

It is defined as the number of input parameters which must be independently controlled in order to bring the mechanism in to useful engineering purposes.

It is also defined as the number of independent relative motions, both translational and rotational, a pair can have.

4. What is meant by transmission angle? (May/June 2012)

In a four bar chain mechanism, the angle between the coupler and the follower (driven) link is called as the transmission angle.

5. Write down the Grashof's law for a four bar mechanism? (Nov/Dec 2012)

Grashof"s law states that the sum of the shortest and longest links cannot be greater than the sum of the remaining two links lengths, if there is to be continuous relative motion between two members.

6. What is indexing mechanism? Where do we use it? (Nov/Dec 2012)

Indexing mechanism is a cam like mechanism which provides intermittent rotary motion. It is used for indexing of a work table in both low and high speed machinery.

7. Define inversion of a mechanism.

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

8. Define Actual Mechanical Advantage.

The Mechanical advantage is defined as the ratio of the output torque to the input torque.It is also defined as the ratio of the load to the effort.

9. Explain Grubler's criteria? (Nov/Dec 2015)

Grubler"s criteria for plane mechanism is obtained by substituting n = 1 and h = 0 in Cutzbach criterion as below

We know that,

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

This equation is known as Grubler"s criterion for plane mechanism.

10. Difference between machine and structure.

S.No	Machine	Structure
1.	Relative motion exist 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.
3.	Links are meant to transmit motion and force.	Members are meant for carrying loads having action.
4.	Examples: Scooter, Car, Bus	Examples: Roof Trusses, bridges.

PART-B

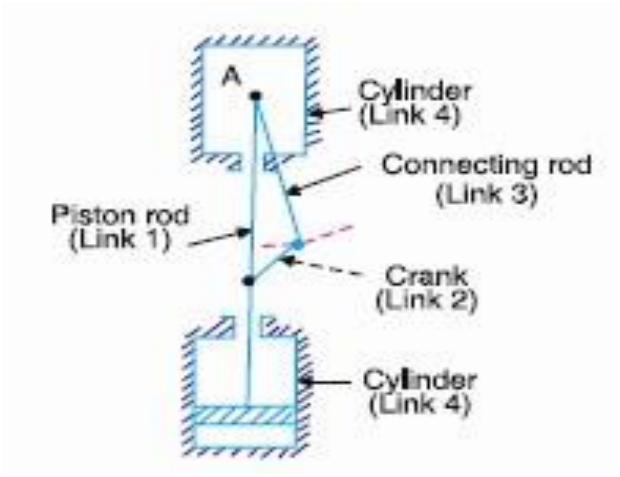
1. Sketch and explain the various inversions of a single slider crank chain. (APR/MAY-13)

A single slider crank chain is a four-link mechanism. We know that by fixing, in turn, different links in a kinematic chain, an inversion is obtained and we can obtain as many mechanisms as the links in a kinematic chain. It is thus obvious, that four inversions of a single slider crank chain are possible. These inversions are found in the following mechanisms.

1. Pendulum pump or Bull engine :

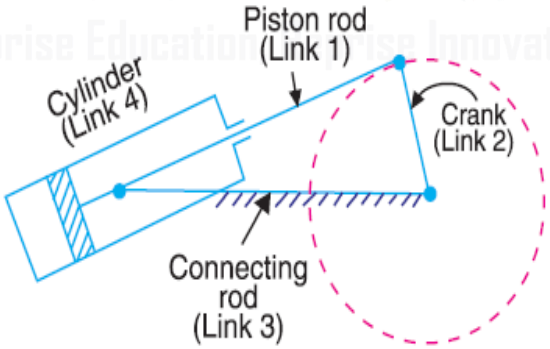
In this mechanism, the inversion is obtained by fixing the Cylinder or link 4 (i.e. sliding pair), as shown in Fig. In this case, when the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at A and the

piston attached to the piston rod (link 1) reciprocates. The duplex pump which is used to supply feed water to boilers has two pistons attached to link 1, as shown in Fig.



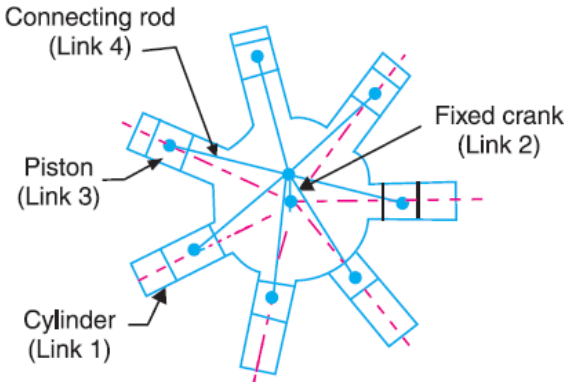
2. Oscillating cylinder engine:

The arrangement of oscillating cylinder engine mechanism, as shown in Fig. It is used to convert reciprocating motion into rotary motion. In this mechanism, the link 3 forming the turning pair is fixed. The link 3 corresponds to the connecting rod of a reciprocating steam engine mechanism. When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at A.



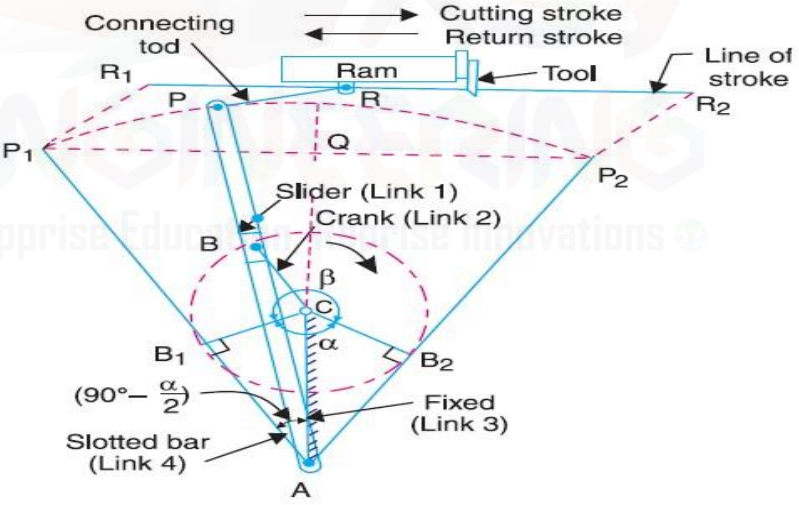
3. Rotary internal combustion engine or Gnome engine:

Rotary internal combustion engines were used in aviation. But now-a-days gas turbines are used in its place. It consists of seven cylinders in one plane and all revolves about fixed centre D, as shown in Fig. While the crank (link 2) is fixed. In this mechanism, when the connecting rod (link4) rotates, the piston (link 3) reciprocates inside the cylinders forming link 1.



4. Crank and slotted lever quick return motion mechanism:

This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link *AC* (*i.e*. link 3) forming the turning pair is fixed, as shown in Fig. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank *CB* revolves with uniform angular speed about the fixed centre *C*. A sliding block attached to the crankpin at *B* slides along the slotted bar *AP* and thus causes *AP* to oscillate about the pivoted point *A*. A short link *PR* transmits the motion from *AP* to the ram which carries the tool and reciprocates along the line of stroke *R*1*R*2. The line of stroke of the ram (*i.e*. *R*1*R*2) is perpendicular to *AC* produced.



`In the extreme positions, AP1 and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB1 to CB2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CB1 (or through angle α) in the clockwise direction. Since the crank has uniform angular speed, therefore

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360^\circ - \beta} \quad \text{or} \quad \frac{360^\circ - \alpha}{\alpha}$$

Since the tool travels a distance of R1 R2 during cutting and return stroke, therefore travel of the tool or length of stroke

$$= R_1R_2 = P_1P_2 = 2P_1Q = 2AP_1 \sin \angle P_1AQ$$

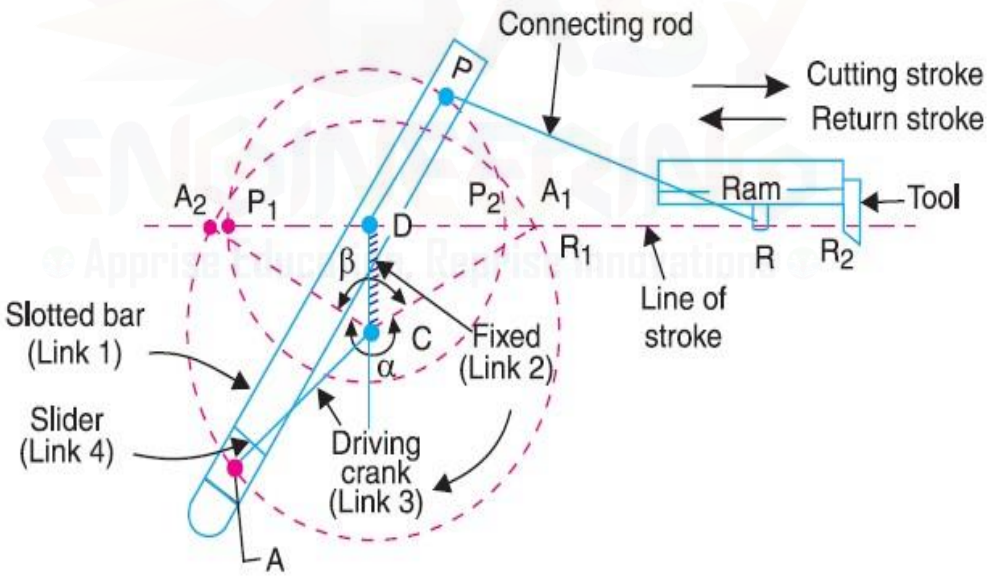
$$= 2AP_1 \sin\left(90^\circ - \frac{\alpha}{2}\right) = 2AP \cos\frac{\alpha}{2} \quad \ldots\ldots (\because AP_1 = AP)$$

$$= 2AP \times \frac{CB_1}{AC} \quad \ldots \left(\because \cos\frac{\alpha}{2} = \frac{CB_1}{AC}\right)$$

$$= 2AP \times \frac{CB}{AC} \quad \ldots (\because CB_1 = CB)$$

5. Whitworth quick return motion mechanism:

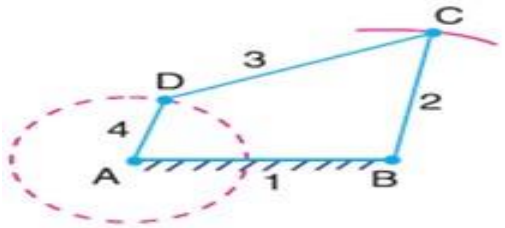
This mechanism is mostly used in shaping and slotting machines. In this mechanism, the link CD (link 2) forming the turning pair is fixed, as shown in Fig.. The link 2 corresponds to a crank in a reciprocating steam engine. The driving crank CA (link 3) rotates at a uniform angular speed. The slider (link 4) attached to the crank pin at A slides along the slotted bar PA (link 1) which oscillates at a pivoted point D. The connecting rod PR carries the ram at R to which a cutting tool is fixed. The motion of the tool is constrained along the line RD produced, i.e. along a line passing through D and perpendicular to CD.



$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360^\circ - \beta} \quad \text{or} \quad \frac{360^\circ - \alpha}{\alpha}$$

2. Describe the mechanism obtained by inversions of four bar chain. (Nov/Dec 2015) (16)

Kinematic chain is a combination of four or more kinematic pairs, such that the relative motion between the links or elements is completely constrained. The simplest and the basic kinematic chain is a four bar chain or quadric cycle chain, as shown in Fig. It consists of four links, each of them forms a turning pair at A, B, C and D. The four links may be of different lengths. According to Grashof "s law for a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths if there is to be continuous relative motion between the two links.



Four bar chain.

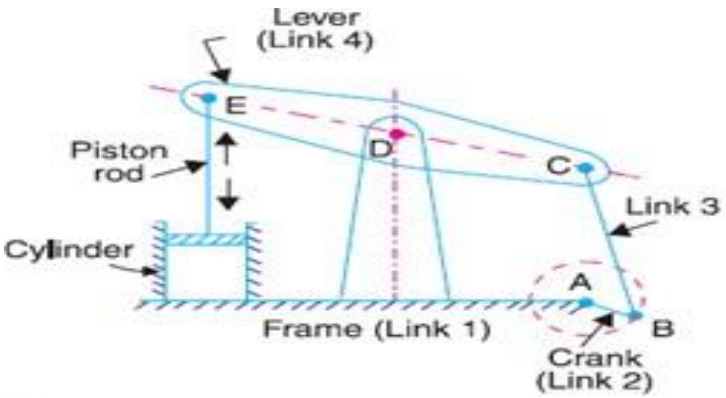
A very important consideration in designing a mechanism is to ensure that the input crank makes a complete revolution relative to the other links. The mechanism in which no link makes a complete revolution will not be useful. In a four bar chain, one of the links, in particular the shortest link, will make a complete revolution relative to the other three links, if it satisfies the Grashof "s law. Such a link is known as crank or driver. In Fig.5.18, AD (link 4) is a crank. The link BC (link 2) which makes a partial rotation or oscillates is known as lever or rocker or follower and the link CD (link 3) which connects the crank and lever is called connecting rod or coupler. The fixed link AB (link 1) is known as frame of the mechanism.

When the crank (link 4) is the driver, the mechanism is transforming rotary motion into oscillating motion.

Inversions of Four Bar Chain

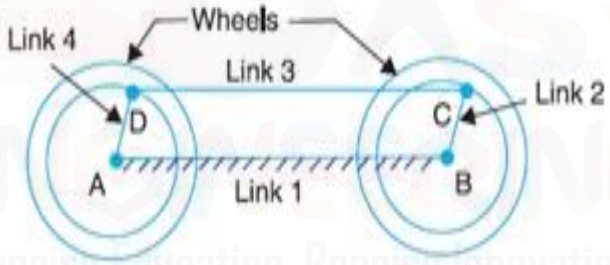
Though there are many inversions of the four bar chain, yet the following are important from the subject Point of view

1. *Beam engine* (*crank and lever mechanism*). A part of the mechanism of a beam engine (also known as crank and lever mechanism) which consists of four links is shown in Fig. In this mechanism, when the crank rotates about the fixed centre *A* lever oscillates about a fixed centre *D*. The end *E* of the lever *CDE* is connected to a piston rod which reciprocates due to the rotation of the crank. In other words, the purpose of this mechanism is to convert rotary motion into reciprocating motion.



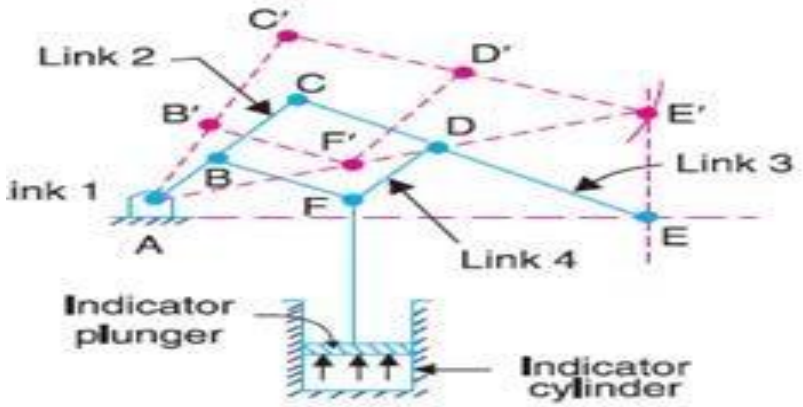
Beam engine.

2. *Coupling rod of a locomotive* (*Double crank mechanism*). The mechanism of a coupling rod of a locomotive (also known as double crank mechanism) which consists of four links is shown in Fig. In this mechanism, the links *AD* and *BC* (having equal length) act as cranks and are connected to the respective wheels. The link *CD* acts as a coupling rod and the link *AB* is fixed in order to maintain a constant centre to centre distance between them. This mechanism is meant for transmitting rotary motion from one wheel to the other wheel.



3. *Watt's indicator mechanism* (*Double lever mechanism*). A *Watt"s indicator mechanism (also known as Watt's straight line mechanism or double lever mechanism) which consists of four links, is shown in Fig. The four links are: fixed link at *A*, link *AC*, link *CE* and link *BFD*. It may be noted that *BF* and *FD* form one link because these two parts have no relative motion between them. The links *CE* and *BFD* act as levers. The displacement of the link *BFD* is directly proportional to the pressure of gas or steam which acts on the indicator plunger. On any small displacement of the mechanism, the tracing point *E* at the end of the link *CE* traces out approximately a straight line.

The initial position of the mechanism is shown in Fig. by full lines whereas the dotted lines show the position of the mechanism when the gas or steam pressure acts on the indicator plunger



Watt's indicator mechanism.

3. (a) Briefly explain the Classification of Kinematic Pairs.(May/June 2015) (10)

Classification of Kinematic Pairs

The kinematic pairs may be classified according to the following considerations:

1. ***According to the type of relative motion between the elements.*** The kinematic pairs according to type of relative motion between the elements may be classified as discussed below:

(a) Sliding pair. When the two elements of a pair are connected in such a way that one can only slide relative to the other, the pair is known as a sliding pair. The piston and cylinder, cross-head and guides of a reciprocating steam engine, ram and its guides in shaper, tail stock on the lathe bed etc. are the examples of a sliding pair. A little consideration will show that a sliding pair has a completely constrained motion.

(b) Turning pair. When the two elements of a pair are connected in such a way that one can only turn or revolve about a fixed axis of another link, the pair is known as turning pair. A shaft with collars at both ends fitted into a circular hole, the crankshaft in a journal bearing in an engine, lathe spindle supported in head stock, cycle wheels turning over their axles etc. are the examples of a turning pair. A turning pair also has a completely constrained motion.

(c) Rolling pair. When the two elements of a pair are connected in such a way that one rolls over another fixed link, the pair is known as rolling pair. Ball and roller bearings are examples of rolling pair.

(d) Screw pair. When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads, the pair is known as screw pair. The lead screw of a lathe with nut, and bolt with a nut are examples of a screw pair.

(d) Spherical pair. When the two elements of a pair are connected in such a way that one element (with spherical shape) turns or swivels about the other fixed element, the pair formed is called a spherical pair. The ball and socket joint, attachment of a car mirror, pen stand etc., are the examples of a spherical pair.

2. *According to the type of contact between the elements*. The kinematic pairs according to the type of contact between the elements may be classified as discussed below :

(a) *Lower pair*. When the two elements of a pair have a surface contact when relative motion takes place and the surface of one element slides over the surface of the other, the pair formed is known as lower pair. It will be seen that sliding pairs, turning pairs and screw pairs form lower pairs.

(b) *Higher pair*. When the two elements of a pair have a line or point contact when relative motion takes place and the motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair. Pair of friction discs, toothed gearing, belt and rope drives, ball and roller bearings and cam and follower are the examples of higher pairs.

2. *According to the type of closure*. The kinematic pairs according to the type of closure between the elements may be classified as discussed below :

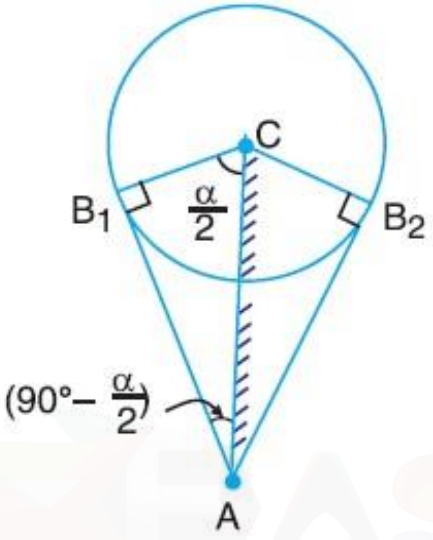
(a) Self closed pair. When the two elements of a pair are connected together mechanically in such a way that only required kind of relative motion occurs, it is then known as self closed pair. The lower pairs are self closed pair.

(b) Force - closed pair. When the two elements of a pair are not connected mechanically but are kept in contact by the action of external forces, the pair is said to be a force-closed pair. The cam and follower is an example of force closed pair, as it is kept in contact by the forces exerted by spring and gravity.

3. (b) A crank and slotted lever mechanism used in a shaper has a centre distance of 300 mm between the centre of oscillation of the slotted lever and the centre of rotation of the crank. The radius of the crank is 120 mm. Find the ratio of the time of cutting to the time of return stroke.

Given : AC = 300 mm ; CB1 = 120 mm

The extreme positions of the crank are shown in Fig. We know that



Solution.

$$\sin \angle CAB_1 = \sin (90° - \alpha/2)$$

$$= \frac{CB_1}{AC} = \frac{120}{300} = 0.4$$

$$\therefore \quad \angle CAB_1 = 90° - \alpha/2$$

$$= \sin^{-1} 0.4 = 23.6°$$

$$\alpha/2 = 90° - 23.6° = 66.4°$$

$$\alpha = 2 \times 66.4 = 132.8°$$

We know that

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360° - \alpha}{\alpha} = \frac{360° - 132.8°}{132.8°} = 1.72$$

4 . Sketch and explain the following mechanisms:

i) **Elliptical trammel**
ii) **Scotch Yoke mechanism**
iii) **Oldham's coupling**

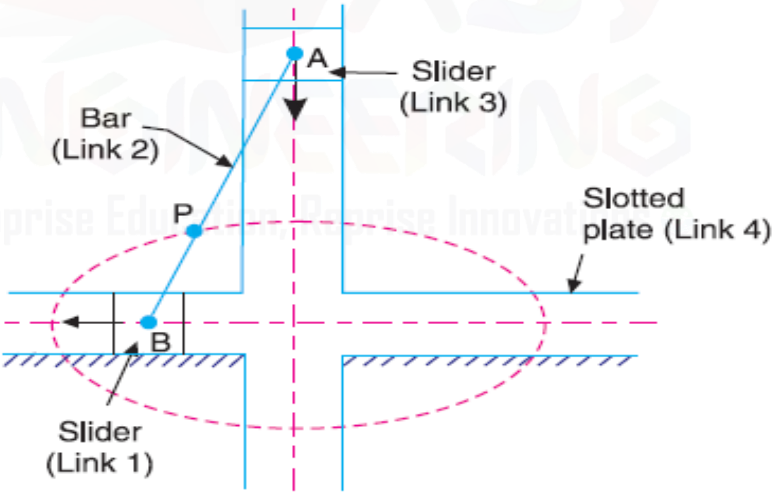
OR

Explain the inversion of double slider crank chain.

- A kinematic chain which consist of two turning pairs and two sliding pairs is known as double slider crank chain.

Elliptical Trammel

1. This inversion can be obtained by fixing the slotted plate.
2. The fixed plate has two straight grooves cut in it at right angles to each other.
3. The link 1 and 3 are known as sliders and form sliding pairs with link 4.
4. The link AB (link 2) is a bar which forms a turning pair with links 1 & 3.
5. When links 1 and 3 slide along their respective grooves, any point on the link 2 such as P traces out the ellipse on the surface of link 4.



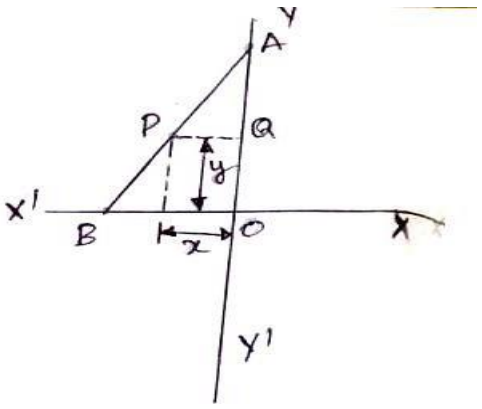
From the geometry

X = PQ = AP Cosθ

Y = PR = BP Sinθ

$$\frac{X}{AP} = Cos\theta$$

$$\frac{Y}{BP} = Sin\theta$$



Squaring and adding

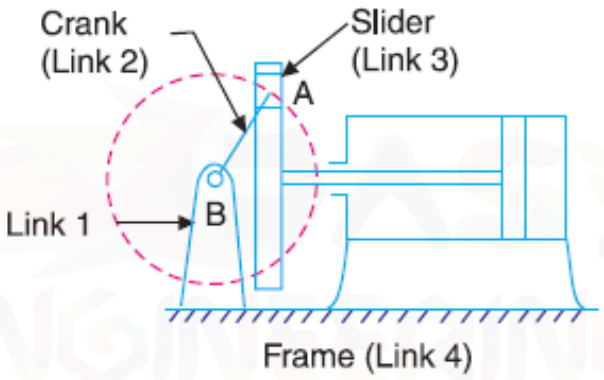
$$\left(\frac{X}{AP}\right)^2 + \left(\frac{Y}{BP}\right)^2 = Sin^2\theta + Cos^2\theta$$

$$\left(\frac{X}{AP}\right)^2 + \left(\frac{Y}{BP}\right)^2 = 1$$

This is an equation of an ellipse. Hence the path traced by the point P is an ellipse whose semi – major axis is AP and semi-minor axis is BP.

SCOTCH YOKE MECHANISM

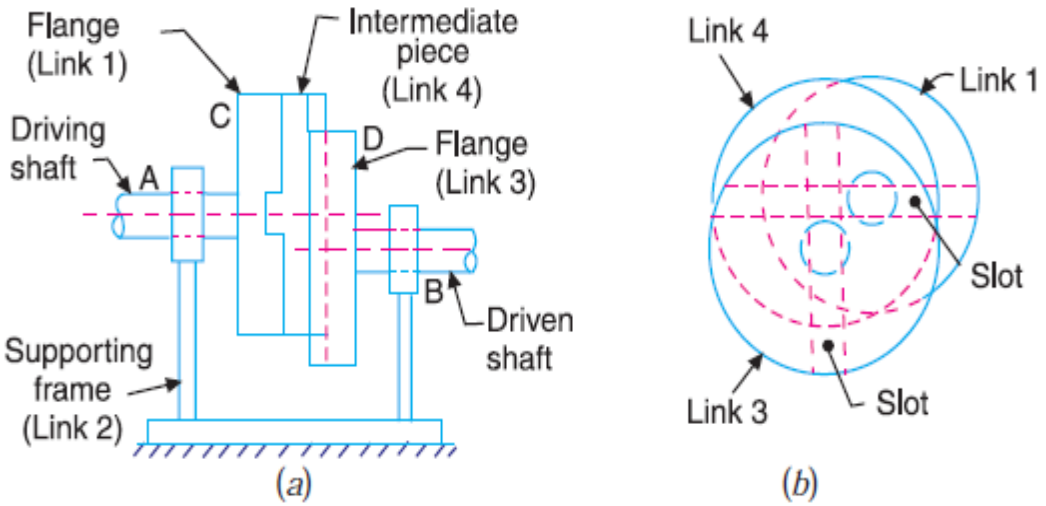
It is obtained by fixing either the link1 or link 3, here the link 1 is fixed. When the link 2 rotates about B as centre the link 4 reciprocates. The fixed link guides the frame.



OLDHAM'S COUPLING

It is obtained by fixing the link 2.

1. The shafts to be connected have two flanges rigidly fastened at their ends by forging.
2. The link 1 and 3 forms turning pairs with link 2.
3. Flanges have diametrical slots cut in their inner faces.
4. The intermediate piece which is a circular disc have two tongues T1 and T2 on each face at right angles to each other.
5. The tongues on the link 4 closely fit into the slots in the two flanges.
6. The link 4 can slide or reciprocate in the slot in the flanges.



The driving shaft A is rotates, the flanges C (L1) causes the intermediate piece to rotate at the same any through which the flange has rotated and it further rotates the flange D (link 3) at the same angle and thus the short rotates. Then the links 1, 3 and 4 have the same angular velocity at every instant.

The maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the centre of the disc along its circular path.

$$V = \omega \times d$$

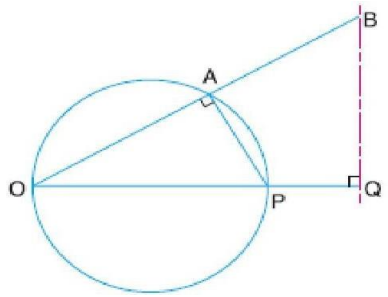
5. a) What is straight line mechanism? Sketch the peaucellier straight line motion mechanism and prove that the generating points moves in a straight line. (10) (Dec 2012)

A mechanism in which straight line motion is obtained by using turning pairs is called as straight line mechanism. In a straight line mechanism one point always moves in a straight line path hence it generates a straight line

Straight line mechanisms: It is a constraint mechanism is that it permits only relative motion of an oscillatory nature along a straight line. Exact straight line motion mechanisms made up of turning pairs: Let O be a point on the circumference of a circle of diameter OP.

Let B is a point on OA (chord), such that

$$OA \times OB = \text{constant}$$

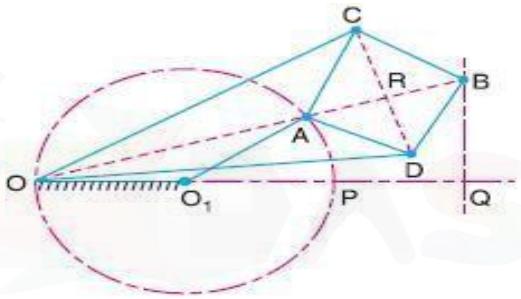


From similar triangles OAP and OBQ,

$$\therefore \quad \frac{OA}{OP} = \frac{OQ}{OB}$$

But OP and OQ are constant then OA X OB = Constant.
Hence the point B moves along a straight path BQ which is perpendicular to OP.

Peaucellier mechanism



1. It consists of 8 links i.e. a fixed link OO_1 and the straight links O_1A, OC, OD, AD, DB, BC and CA are connected by turning pairs.
2. The pin at A is constrained to move along the circumference of a circle.

3. AC = CB = BD = DA; OC = OD; and $OO_1 = O_1A$

From the triangles ORC and BRC

$$OC^2 = OR^2 + RC^2 \qquad ...(i)$$
$$BC^2 = RB^2 + RC^2 \qquad ...(ii)$$

Subtracting equation (*ii*) from (*i*), we have

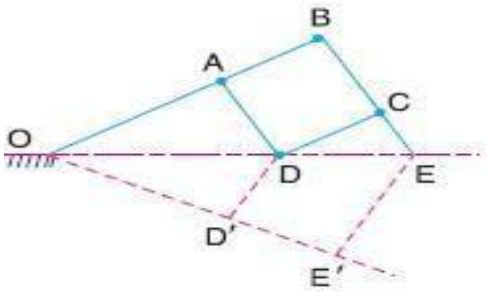
$$OC^2 - BC^2 = OR^2 - RB^2$$
$$= (OR + RB)(OR - RB)$$
$$= OB \times OA$$

Therefore the product OB X OA remains constant. Hence the point B traces a straight path perpendicular to the diameter OP.

5. b) With suitable diagram, explain how a pantograph works. What are its uses? (6)

PANTOGRAPH:

1. It is a four bar linkage used to produce paths exactly similar to the ones traced out by a point on the linkage.
2. The paths so produced are usually on an enlarged or reduced scale and may be straight or curved ones.



1. It consists of a jointed parallelogram ABCD as shown in the figure.
2. It is made up of bars connected by turning pairs.
3. From similar triangles OAD and OBE,

$$OD/OE = AD/BE$$

Let O be fixed and the points D and E move to some new positions D" and E". Then

$$OD/OE = OD'/OE'$$

Therefore the point E traces out the same path as described by point D.

4. A pantograph is mostly used for the reproduction of plane areas and figures such as maps, plans …etc.
5. A modified form of pantograph is used to collect electricity at the top of electric trains.

PART-C

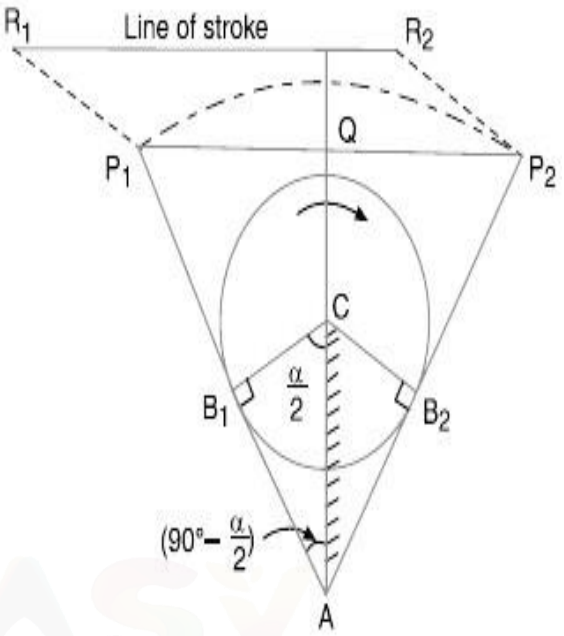
1. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240mm and the length of the driving crank is 120mm. find the inclination of the slotted bar with the vertical in the extreme position and time ratio of cutting stroke to the return storke. If the length of the slotted bar is 450mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever. (Nov/Dec 2015) (16)

Solution. Given : $AC = 240$ mm ; $CB_1 = 120$ mm ; $AP_1 = 450$ mm

Inclination of the slotted bar with the vertical

Let $\angle CAB_1$ = Inclination of the slotted bar with the vertical.

The extreme positions of the crank are shown in Fig. 5.29. We know that



$$\sin \angle CAB_1 = \sin\left(90° - \frac{\alpha}{2}\right)$$

$$= \frac{B_1C}{AC} = \frac{120}{240} = 0.5$$

$$\therefore \angle CAB_1 = 90° - \frac{\alpha}{2}$$

$$= \sin^{-1} 0.5 = 30° \text{ Ans.}$$

Time ratio of cutting stroke to the return stroke

We know that

$$90° - \alpha / 2 = 30°$$

$$\therefore \quad \alpha / 2 = 90° - 30° = 60°$$

or $$\alpha = 2 \times 60° = 120°$$

$$\therefore \quad \frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{360° - \alpha}{\alpha} = \frac{360° - 120°}{120°} = 2 \text{ Ans.}$$

Length of the stroke

We know that length of the stroke,

$$R_1R_2 = P_1P_2 = 2\,P_1Q = 2\,AP_1 \sin (90° - \alpha / 2)$$

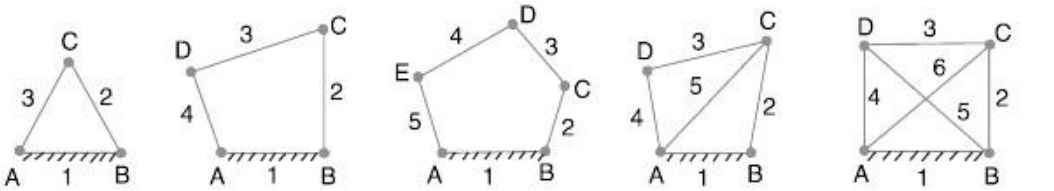
$$= 2 \times 450 \sin (90° - 60°) = 900 \times 0.5 = 450 \text{ mm Ans.}$$

2. Write the application of Kutzbach criterion and Grubler's criterion to plane mechanism. (16)

Application of Kutzbach criterion:

Kutzbach criterion for determining the number of degrees of freedom or movability (n) of a plane mechanism is

$$n = 3\,(l - 1) - 2\,j - h$$



(a) Three-bar mechanism. (b) Four bar mechanism. (c) Five bar mechanism. (d) Five bar mechanism. (e) Six bar mechanism.

Fig. Plane mechanisms.

The number of degrees of freedom or movability (n) for some simple mechanisms having no higher pair (*i.e.* $h = 0$), as shown in Fig. 5.16, are determined as follows :

1. The mechanism, as shown in Fig. (a), has three links and three binary joints, *i.e.* $l = 3$ and $j = 3$.

$$\therefore \quad n = 3\,(3 - 1) - 2 \times 3 = 0$$

2. The mechanism, as shown in Fig. (b), has four links and four binary joints, *i.e.* $l = 4$ and $j = 4$.

$$\therefore \quad n = 3\,(4 - 1) - 2 \times 4 = 1$$

3. The mechanism, as shown in Fig. (c), has five links and five binary joints, *i.e.* $l = 5$, and $j = 5$.

$$\therefore \quad n = 3\,(5 - 1) - 2 \times 5 = 2$$

4. The mechanism, as shown in Fig. (d), has five links and six equivalent binary joints (because there are two binary joints at B and D, and two ternary joints at A and C), *i.e.* $l = 5$ and $j = 6$.

$$\therefore \quad n = 3\,(5 - 1) - 2 \times 6 = 0$$

5. The mechanism, as shown in Fig. (e), has six links and eight equivalent binary joints (because there are four ternary joints at A, B, C and D), *i.e.* $l = 6$ and $j = 8$.

$$\therefore \quad n = 3\,(6 - 1) - 2 \times 8 = -1$$

It may be noted that

(a) When $n = 0$, then the mechanism forms a structure and no relative motion between the links is possible, as shown in Fig. (a) and (d).

(b) When $n = 1$, then the mechanism can be driven by a single input motion, as shown in Fig. (b).

(c) When $n = 2$, then two separate input motions are necessary to produce constrained motion for the mechanism, as shown in Fig. (c).

(d) When $n = -1$ or less, then there are redundant constraints in the chain and it forms a statically indeterminate structure, as shown in Fig. (e).

The application of Kutzbach's criterion applied to mechanisms with a higher pair or two degree of freedom joints is shown in Fig.

Fig. Mechanism with a higher pair.

In Fig. (*a*), there are three links, two binary joints and one higher pair, *i.e.* $l = 3, j = 2$ and $h = 1$.

$$\therefore \quad n = 3\,(3 - 1) - 2 \times 2 - 1 = 1$$

In Fig. (*b*) , there are four links, three binary joints and one higher pair, *i.e.* $l = 4$, $j = 3$ and $h = 1$

$$\therefore \quad n = 3\,(4 - 1) - 2 \times 3 - 1 = 2$$

Here it has been assumed that the slipping is possible between the links (*i.e.* between the wheel and the fixed link). However if the friction at the contact is high enough to prevent slipping, the joint will be counted as one degree of freedom pair, because only one relative motion will be possible between the links.

Application of Grubler's criterion:

The Grubler's criterion applies to mechanisms with only single degree of freedom joints where the overall movability of the mechanism is unity. Substituting $n = 1$ and $h = 0$ in Kutzbach equation, we have

$$1 = 3\,(l - 1) - 2j \quad \text{or} \quad 3l - 2j - 4 = 0$$

This equation is known as the Grubler's criterion for plane mechanisms with constrained motion.

A little consideration will show that a plane mechanism with a movability of 1 and only single degree of freedom joints can not have odd number of links. The simplest possible machanisms of this type are a four bar mechanism and a slider-crank mechanism in which $l = 4$ and $j = 4$.

UNIT-II KINEMATICS OF LINKAGE MECHANISM

PART-A

1. Write the relation between the number of instantaneous centers and the number of links in a mechanism (April/May 15,May/June 13)

N=n (n-1)/2

Where

N-Number of instantaneous centre (May/June 14)

n- Number of links

2. Define instantaneous centre (May/June 14)

The combined motion of rotation & translation of any link may be assumed to be a motion of pure rotation about some centre I which is called instantaneous centre of rotation (or) virtual centre

3. What is a configuration diagram? What are its uses? (Nov/Dec 12)

Drawing the given mechanism with convenient scale is called configuration diagram which is used to draw the velocity and acceleration diagram for a mechanism

4. Define Rubbing velocity. What will be the expression for rubbing velocity at a pin joint when the two links are in opposite direction? (May/June 13)

Rubbing velocity at the pin joint is defined as the algebraic sum between the angular velocities of two links which are connected by using pin joint multiplied by the radius of pin.

$$V_R = (\omega_1+\omega_2)*\text{Radius of pin}$$

5. What is low degree of complexity? (Nov/Dec 13)

By changing the input links a complex mechanism is converted into a simple mechanism is called low degree of complexity.

6. What is coriolis component of acceleration? (May 14)

When the sliding pair itself revolves, its acceleration will include coriolis component of acceleration due to change in its relative distance between two points.

$a_{cc} = 2V_s\omega$

V_s – sliding velocity

a_{cc} – coriolis component of acceleration

7. List out the various methods for finding velocity & acceleration analysis of mechanism?

1. Relative velocity method
2. Instantaneous center
3. Klein"s construction of I.C engine mechanism

8. State the reason for velocity and acceleration analysis

Each particle of every link of a machine is constrained to move along a definite path therefore, to design a machine completely; the velocity and acceleration analysis is needed

9. State Kennedy's theorem

If three bodies move relative to each other then they have three instantaneous centers and lie on a straight line, It is used for locating ICR in the mechanisms such as IC engine mechanism, four bar mechanism, quick return mechanism etc.

10. State the application in which Coriolis components of acceleration occurs.

i) Crank and slotter lever mechanism and

ii) Oscillating cylinder mechanism.

PART - B

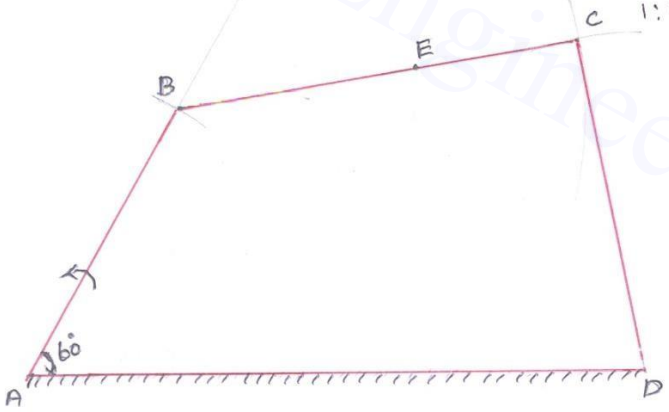
1) The following data refer to the dimensions of the link of a four bar mechanism. AB = 50mm, BC = 66 mm, CD = 56 mm, AD (Fixed link) = 100 mm At the instant when $\angle DAB = 60^\circ$. The link AB has an angular velocity 10.5 rad/s in counter clock wise Determine velocity of Point C, E on link BC while BE = 40mm and the angular velocity link BC & CD ?

May/June : 2013

Ans

i) Space diagram

Scale ratio 1:1



Given

AB = 50mm

BC = 66mm

CD = 56mm

AD = 100mm

$\angle DAB = 60^\circ$

$\omega_{AB} = 10.5$ rad/s

BE = 40mm

To find $V_D, \omega_{BC}, \omega_{CD}$?

ii) Velocity Diagram

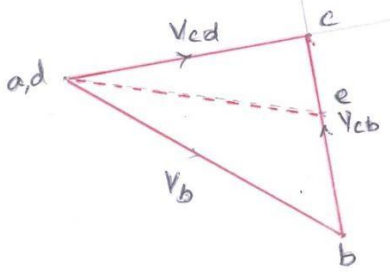
Velocity

$V_{AB} = \omega_{AB} \times AB$

$= 10.5 \times 50 = 525$ mm/s

Scale 1:100

$V_{AB} = 5.25$



From the velocity Triangle By measurement

$V_{ab} = V_B = 525$ mm/s $= 0.525$ m/s

$V_{cb} = 333$ mm/s $= 0.33$ m/s

$V_{cd} = 400$ mm/s $= 0.4$ m/s

$V_e = V_{ab} = 420$ mm/s $= 0.42$ m/s

The Velocity of $V_C = 0.4$ m/s

$V_e = 0.42$ m/s

The angular velocity of BC = 66 mm = 0.06

$$\omega_{BC} = \frac{V_{BC}}{BC} = \frac{0.33}{0.06} = 5.5 \text{ rad/s}$$

The angular velocity of CD

$$\omega_{CD} = \frac{V_{CD}}{CD} = \frac{0.4}{0.056} = 7.1 \text{ rad/s}$$

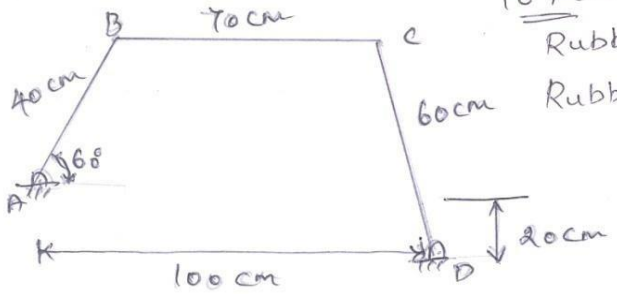
2.

The Crank AB of four bar Mechanism show in fig Rotates at 60 rpm Clockwise, Determine the relative angular Velocities of the Coupler to the Crank and the lever to the Coupler. Find also the rubbing velocities at the Surface of Pins 25mm radius and the joints B & C. (Nov/Dec 2013)

Given Data

$N = 60$ rpm, $r = 25$ mm $= 0.025$ m

Rubbing velocity at joint B & C ?



To Find

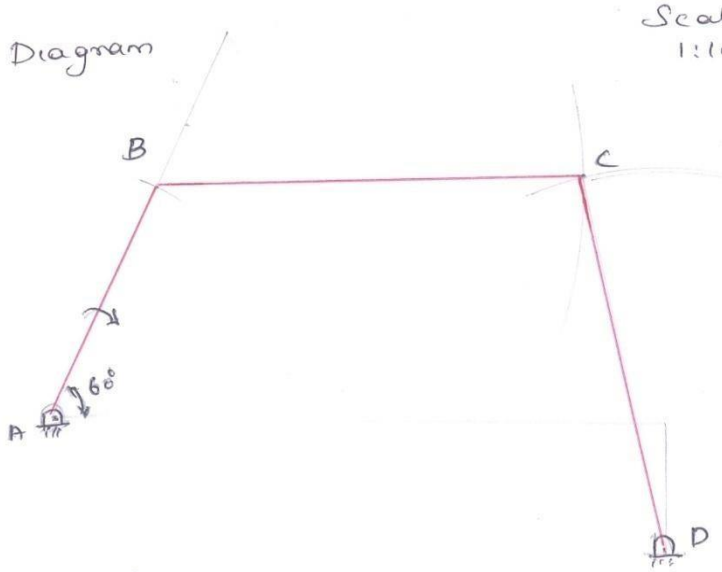
Rubbing at B = $(\omega_{AB} + \omega_{BC}) \times 0.02$

Rubbing at C = $(\omega_{BC} + \omega_{CD}) \times 0.02$

Sol:

Space Diagram

Scale 1:10



Velocity Triangle

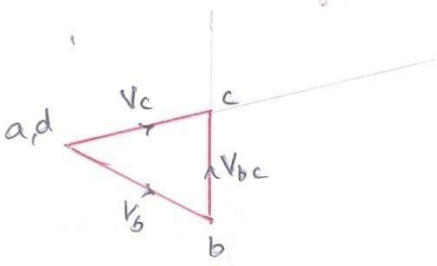
$$N = 60 \text{ rpm}$$

$$\omega_{AB} = \frac{2\pi N}{60} = 6.28 \text{ rad/s}$$

$$V_b = V_{BA} = \omega_{AB} \times BA = 251 \text{ cm/s}$$

Take ~~scale~~ ratio = 1:100

From the ~~@~~ measurement.



$V_c = V_{ac} = 240 \text{ cm/s} = 2.4 \text{ m/s}$

$V_b = V_{ab} = 265 \text{ cm/s} = 2.65 \text{ m/s}$

$V_{bc} = V_{cb} = 170 \text{ cm/s} = 1.7 \text{ m/s}$

The relative velocity of the Coupler $V_c = 2.4 \text{ m/s}$

* relative velocity of lever $V_{bc} = 1.7 \text{ m/s}$

The Rubbing velocity of joint B = $(\omega_{AB} + \omega_{BC}) \times r$

$\omega_{AB} = 6.28 \text{ rad/s}$

$\omega_{BC} = V_{BC} \times BC = 1.7 \times 0.7 = 1.19 \text{ rad/s}$

$\omega_{CD} = V_{CD} \times CD = 1.44 \text{ rad/s}$

Rubbing velocity at B = $(\omega_{AB} + \omega_{BC}) \times r$

$= (6.28 + 1.19) \times 0.095$

$= 0.186$ m/s

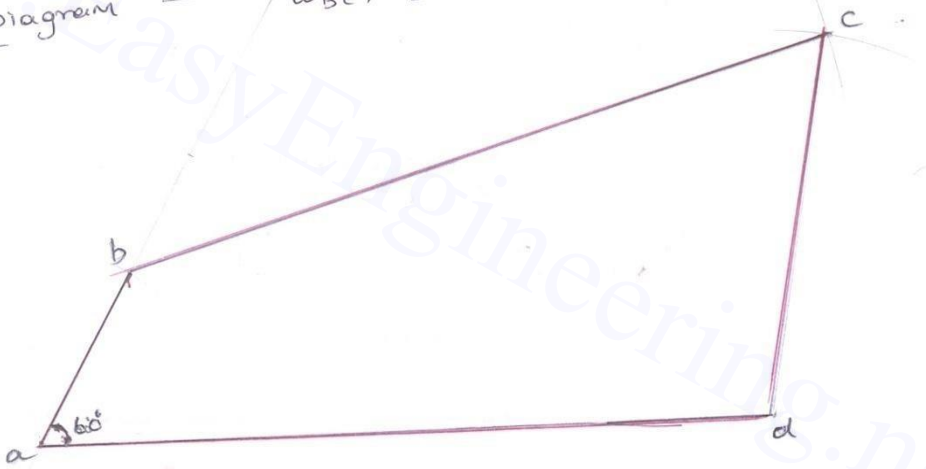
3) In a Fourbar chain ABCD, AD is fixed and is 120 mm long. The crank AB is 30 mm long and rotates at 100 rpm clockwise while the link CD = 60 mm oscillates about D, BC = 120 mm using graphical method. Find angular velocity and angular acceleration of link BC when BAD = 60° Nov/Dec 2012

Given: N = 100 rpm, BAD = 60°

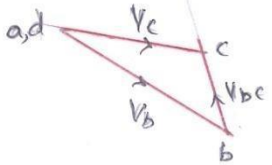
To find: ω_{BC}, a_{BC} = ?.

Space Diagram

Scale 1:10



Velocity triangle



The angular velocity

$\omega_{AB} = \frac{2\pi N}{60} = \frac{2\pi \times 100}{60} = 10.4$ rad/s

$V_{AB} = \omega_{AB} \times BA = 314$ mm/s

Scale 1:100

From the measurement

@ $V_c = 230$ mm/s $= 0.2$ m/s

$V_{bc} = V_{ab} = V_b = 320$ mm/s $= 0.32$ m/s

$V_{cb} = 130$ mm/s $= 0.13$ m/s

Angular velocity $W_{BC} = \frac{V_{BC}}{BC} = \frac{0.132}{0.12} = 1.08$ rad/s ~~1.6 rad/s~~

$$\boxed{W_{BC} = 1.08 \text{ rad/s}}$$

Acceleration diagram

Since the angular acceleration of crank AB is not given, therefore there will be no tangental component of acceleration of Q w.r to P

$$a^r_{BA} = a_{AP} = a^r_{BA} = a_b = \frac{V^2_{BA}}{BA} = 3.41 \text{ M/s}^2$$

Radial Component of acceleration of C with respect to B

$$a^r_{CB} = \frac{V^2_{CB}}{CB} = \frac{0.13^2}{0.12} = 0.140 \text{ M/s}^2$$

Radial Component of acceleration C with respect to P

$$a^r_{CD} = \frac{V^2_{CD}}{CD} = \frac{0.2^2}{0.06} = 0.66 \text{ M/s}^2$$

By measurement from acceleration diagram

$a^n_{CD} = 0.6 \text{ M}^2\text{/s}$, $a^t_{CD} = 2.5 \text{ M}^2\text{/s}$, $a_c = 2.6 \text{ M}^2\text{/s}$

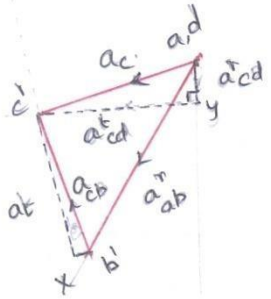
$a^t_{BC} = 2.1 \text{ M}^2\text{/s}$, $BC = 0.12 \text{ M}$

The angular ~~angular~~ acceleration of BC

$$\alpha_{BC} = \frac{a^t_{BC}}{BC} = \frac{2.1}{0.12} = 17.5 \text{ rad/s}^2$$

α

Acceleration Diagram



(a)

4(a) In the Mechanism shown in fig. the Crank OA rotates at a Constant Speed equal to 20 rpm anticlockwise and give motion to the Sliding blocks B & D. The dimensions of Various links are OA = 300 mm; AB = 1200 mm BC = 450 mm, CD = 450 mm. (April may 2008)

Determine

1. Velocities of Slides B & D
2. Angular Velocity link CD
3. Linear Velocity of D
4. Angular Acceleration of CD.

Sol)

G.D

$N = 20 rpm \quad \omega = \frac{2\pi N}{60}, \quad 2.09 \text{ rad/s}$

OA = 30.3m, AB = 1.2m, BC = CD = 0.45m

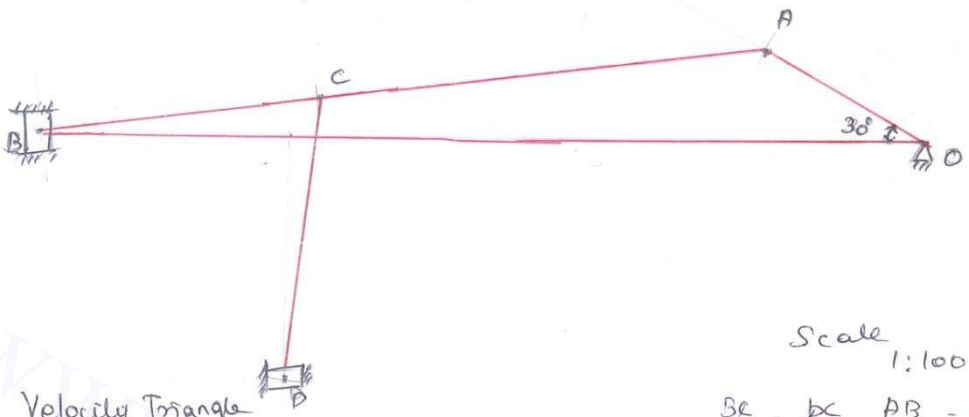
Linear Velocity

$V_{OA} = \omega_{OA} \times OA$

$V_{OA} = 2.09 \times 300 = 6.24 \text{ mm/s}$

Space diagram

Scale
1:100



Velocity Triangle

Scale
1:100

$\frac{BC}{CA} = \frac{bc}{ca}$ $\frac{AB}{BC} = \frac{ab}{bc}$

$\frac{1200}{450} = \frac{5.6}{bc}$

$bc = 2.1$

By measurement

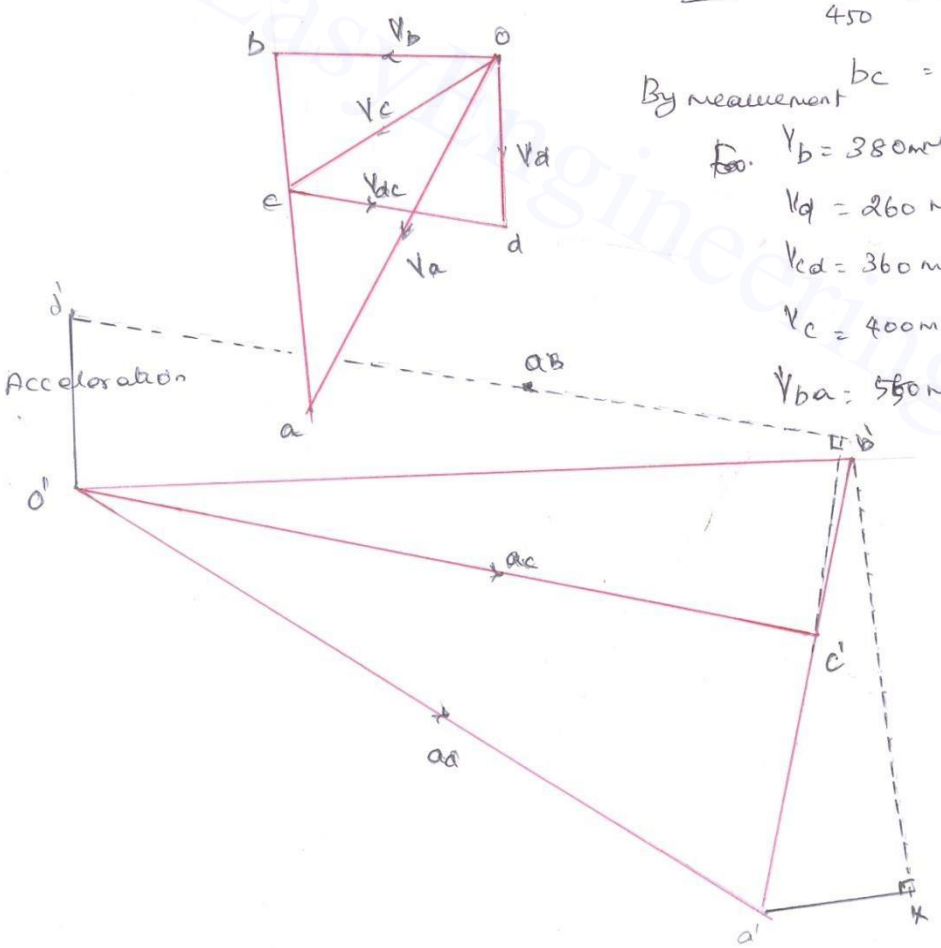
$V_b = 380 mm/s = 0.38 m/s$

$V_d = 260 mm/s = 0.26 m/s$

$V_{cd} = 360 mm/s = 0.36 m/s$

$V_c = 400 mm/s = 0.4 m/s$

$V_{ba} = 550 mm/s = 0.55 m/s$



From the Velocity Triangle

Angular velocity of CD $\omega_{CD} = \frac{V_{CD}}{CD} = \frac{0.36}{0.45}$

$\omega_{CD} = 0.8$ rad/s (anti clock wise)

Acceleration

Radial $a^r_{OA} = a_A = \frac{V^2_{AO}}{OA} = \omega^2_{AO} \times OA = 2.1^2 \times 300$

$a^r = 1323$ mm/s²

Radial Component of accele B with respect to A

$a^r_{BA} = \frac{V^2_{BA}}{BA} = \frac{550^2}{1200} = 252$ mm/s

Radial component acceleration D with respt C

$a^r_{DC} = \frac{V^2_{DC}}{DC} = \frac{360^2}{450} = 288$ mm/s

Divide vector a'b' at c' in the same ratio as c divides AB in the Space diagram

$\frac{AB}{BC} = \frac{a'b'}{b'c'}$ $\quad b'c' = 2.4$

$\frac{1200}{450} = \frac{7.2}{b'c'}$

12.90

Angular Acceleration

$a^t_{DC} = 129$ mm/s² $= 0.129$ m/s²

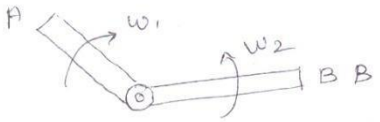
Angular acceleration

$\alpha_{CD} = \frac{a^t_{DC}}{0.45} = 2.84$ rad/s²

Rubbing velocity

The links in a mechanism are mostly connected by means of Pin joints

" 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 O

$= (\omega_1 - \omega_2) r$ - if links move same direction

$= (\omega_1 + \omega_2) r$ if links move opposite direction

5 The Crank & Connecting rod of a theoritical Steam engine are 0.5m & 2m long respectively. The crank makes 180 r.p.m in clockwise direction. when it has turned 45° from the inner dead centre Position. determine May/June 2014

1. Velocity of piston
2. Angular velocity of Connecting rod
3. Velocity of point E on the connecting rod 1.5M from gudgeon Pin.
4. velocities of rubbing at the Pin of Crank Shaft crank, Crosshead when dia of Pins are 50mm, 60mm, 30mm respectively.
5. Position & linear velocity of any point G on the Connecting rod which has least velocity relative to crank shaft.

50)

N_{BO} = 180 r.p.m = $\omega = 2\pi N/60$ = 18.84 rad/s

Crank length OB = 0.5m, linear velocity of B wr to O or velocity of B

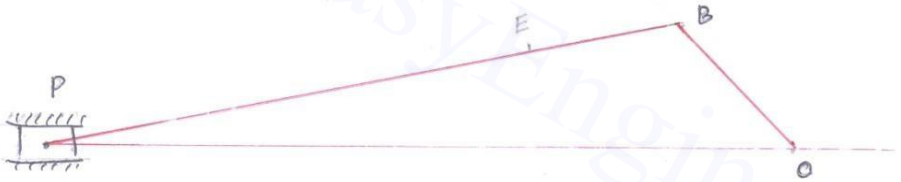
$$V_{BO} = V_B = \omega_{BO} \times OB = 18.84 \times 0.5 = 9.42 \text{ m/s}$$

1. Velocity of piston

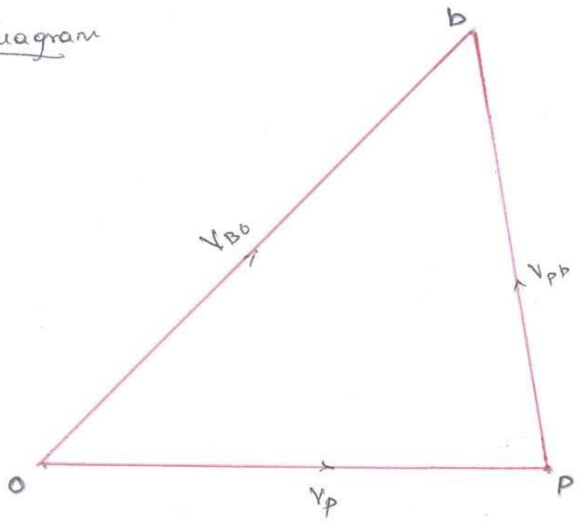
Scale

0.1m = 0.5cm

0.5m = 2.5cm



Velocity diagram



V_{BO} = 9.42 m/s

1 m/s = 1 cm

9.42 m/s = 9.42 cm

B First draw the Space diagram to some Suitable Scale

1. Draw vector ob ⊥r to BO to some Suitable

1. Velocity of piston

First draw the space diagram to some suitable scale

1. Draw vector ob ⊥r to BO to some suitable scale to represent the velocity of B w.r to O or velocity of B

vector ob = V_{BO} = V_B = 9.426 m/s

2. From point b draw vector bp ⊥ to BP to represent velocity of P w.r to B & from point O draw vector op ∥ to PO represent velocity of P w.r to O the vectors intersect bp & op at point P

V_p = vector op = 8.2 m/s

2) Angular velocity

From velocity diagram, Velocity P w.r to B

V_{PB} = vector bp = 7.5 = 6.8

length of connecting rod PB is 2m

$\omega_{PB} = \frac{V_{PB}}{PB} = \frac{6.8}{2} = 3.4$ rad/s (ANTICLOCK)

3) Velocity of Point E or Connecting rod

The point E is 1.5m distance from P is determined by dividing the vector bp at e in the same ratio as E divides PB

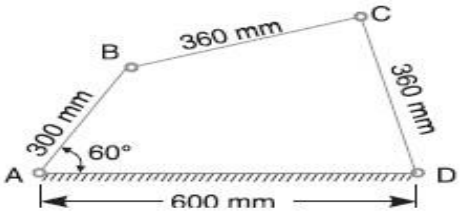
$\frac{BE}{BP} = \frac{Be}{bP}$

$\frac{0.5}{2} = \frac{Be}{6.8}$

$\boxed{be = 1.7 m}$

PART-C

1. In a pin jointed four bar mechanism, as shown in fig, AB=300mm, BC=CD=360mm, and AD= 600mm. The angle of BAD = 60°. The crank AB rotates uniformly at 100rpm. Locate all instantaneous centres and find angular velocity of link BC. (16)



Solution. Given : $N_{AB} = 100$ r.p.m or

$\omega_{AB} = 2\pi \times 100/60 = 10.47$ rad/s

Since the length of crank $AB = 300$ mm $= 0.3$ m, therefore velocity of point B on link AB,

$$v_B = \omega_{AB} \times AB = 10.47 \times 0.3 = 3.141 \text{ m/s}$$

Location of instantaneous centres

The instantaneous centres are located as discussed below:

1. Since the mechanism consists of four links (*i.e.* $n = 4$), therefore number of instantaneous centres,

$$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

2. For a four bar mechanism, the book keeping table may be drawn ·

3. Locate the fixed and permanent instantaneous centres by inspection. These centres are I_{12}, I_{23}, I_{34} and I_{14}, as shown in Fig.

4. Locate the remaining neither fixed nor permanent instantaneous centres by Aronhold Kennedy's theorem. This is done by circle diagram as shown in Fig. Mark four points (equal to the number of links in a mechanism) 1, 2, 3, and 4 on the circle.

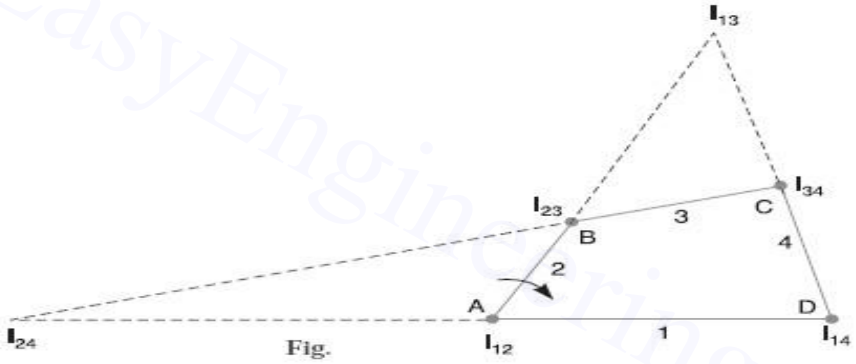


Fig.

5. Join points 1 to 2, 2 to 3, 3 to 4 and 4 to 1 to indicate the instantaneous centres already located *i.e.* I_{12}, I_{23}, I_{34} and I_{14}.

6. Join 1 to 3 to form two triangles 1 2 3 and 3 4 1. The side 13, common to both triangles, is responsible for completing the two triangles. Therefore the instantaneous centre I_{13} lies on the intersection of the lines joining the points I_{12} I_{23} and I_{34} I_{14} as shown in Fig. Thus centre I_{13} is located. Mark number 5 (because four instantaneous centres have already been located) on the dotted line 1 3.

7. Now join 2 to 4 to complete two triangles 2 3 4 and 1 2 4. The side 2 4, common to both triangles, is responsible for completing the two triangles. Therefore centre I_{24} lies on the intersection of the lines joining the points I_{23} I_{34} and I_{12} I_{14} as shown in Fig. Thus centre I_{24} is located. Mark number 6 on the dotted line 2 4. Thus all the six instantaneous centres are located.

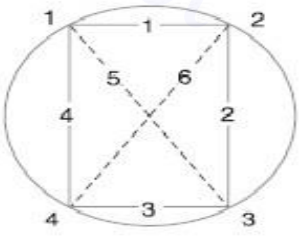


Fig.

Angular velocity of the link BC

Let ω_{BC} = Angular velocity of the link BC.

Since B is also a point on link BC, therefore velocity of point B on link BC,

$$v_B = \omega_{BC} \times I_{13}B$$

By measurement, we find that $I_{13}B = 500$ mm $= 0.5$ m

$$\therefore \quad \omega_{BC} = \frac{v_B}{I_{13}B} = \frac{3.141}{0.5} = 6.282 \text{ rad/s} \quad \text{Ans.}$$

2. Locate the all instantaneous centres of the slider crank mechanism as shown in Fig. The lengths of the crank OB and connecting rod AB are 100mm and 400mm respectively. If the crank rotates clockwise with an angular velocity 10rad/s. find, 1. Velocity of the slider A, and 2. Angular velocity of the connecting rod AB. (16)

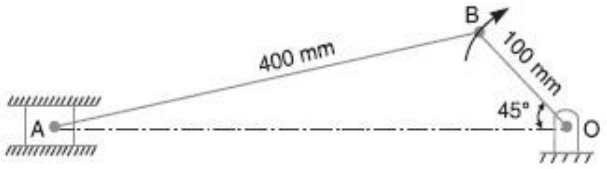


Fig. 6.12

Solution. Given : $\omega_{OB} = 10$ rad/ s; $OB = 100$ mm $= 0.1$ m

We know that linear velocity of the crank OB,

$$v_{OB} = v_B = \omega_{OB} \times OB = 10 \times 0.1 = 1 \text{ m/s}$$

$$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

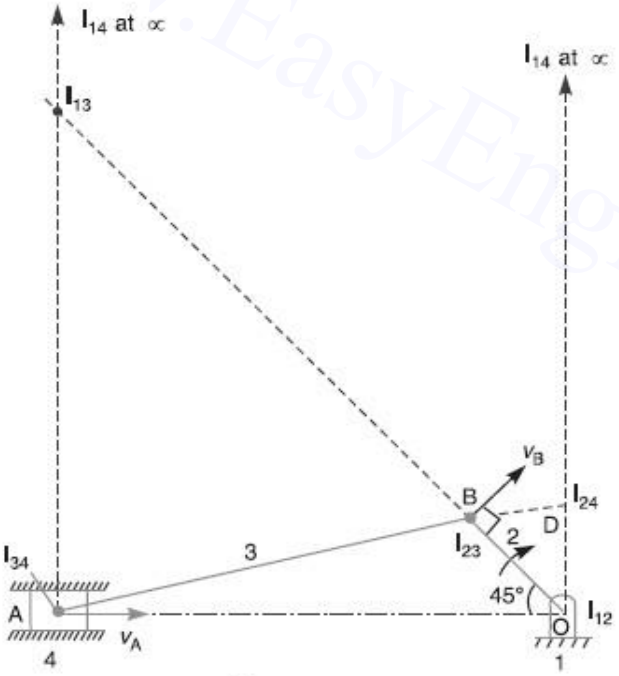


Fig.

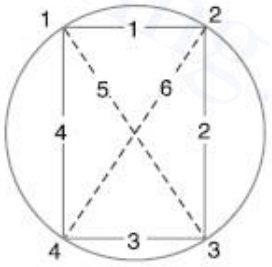


Fig.

By measurement, we find that

$$I_{13}A = 460 \text{ mm} = 0.46 \text{ m} \text{ ; and } I_{13}B = 560 \text{ mm} = 0.56 \text{ m}$$

1. *Velocity of the slider A*

Let v_A = Velocity of the slider A.

We know that $\dfrac{v_A}{I_{13}A} = \dfrac{v_B}{I_{13}B}$

or $v_A = v_B \times \dfrac{I_{13}A}{I_{13}B} = 1 \times \dfrac{0.46}{0.56} = 0.82$ m/s Ans.

2. *Angular velocity of the connecting rod AB*

Let ω_{AB} = Angular velocity of the connecting rod $A B$.

We know that $\dfrac{v_A}{I_{13}A} = \dfrac{v_B}{I_{13}B} = \omega_{AB}$

$\therefore$ $\omega_{AB} = \dfrac{v_B}{I_{13}B} = \dfrac{1}{0.56} = 1.78$ rad/s Ans.

UNIT 3 - KINEMATICS OF CAM MECHANISMS
PART-A

1. Define Lift (or) Stroke in cam.

It is the maximum travel of the follower from its lowest position to the topmost position.

2. State the advantages of cam mechanisms over linkage mechanisms.

Cam mechanisms are simple and inexpensive. They have few moving parts, and occupy a very small space. The versality and flexibility of the cam design are more than that of the linkage mechanisms.

3. What are the different motions of the follower? (April/May 2014)

Uniform motion,

- ✓ Simple harmonic motion,
- ✓ Uniform acceleration and retardation, and
- ✓ Cycloidal motion.

4. State the advantages of tangent cam.

- ✓ Tangent cams are symmetrical and ease to manufacture.
- ✓ They are less costly to manufacture.
- ✓ They are used for operating the inlet and exhaust valves of I.C. engine.

5. List any four types of cam followers.

1. Knife edge follower
2. Roller follower
3. Mushroom or flat faced follower
4. Spherical face follower

6. What are the advantages of roller follower than knife-edge follower?

The rate of wear at the contacting end of the roller follower is comparatively lesser than that of the knife-edge follower.

7. What is the follower motion used for high speed cams? Why?

Cycloidal motion because it results in lower jerks.

8. Define pressure angle in cam and its significance.

It is the angle between the direction of the follower motion and a normal to the pitch curve. This angle is very important in designing a cam profile. If the pressure angle is too large, a reciprocating follower will jam in its bearings.

As the pressure angle increases, the force required to lift the follower increase.

9. Define undercutting in cam. How is occurs?

The cam profile must be continuous curve without any loop. If the curvature of the pitch curve is too sharp, then the part of the cam shape would be lost and thereafter the intended cam motion would not be achieved. Such a cam is said to be undercut. Undercutting occurs in the cam because of attempting to achieve too great a follower lift with very small cam rotation with a smaller cam.

10. Define Prime circle and trace point in cam?

The smallest circle drawn tangent to the pitch curve is known as the prime circle.It is a reference point on the follower and is used to generate the pitch curve. In case of knife edge follower the knife edge represents the trace point and the pitch curve corresponds to the cam profile. In a roller follower the centre of the roller represents the trace point.

PART - B

D Draw the profile of a cam operating a knife edge follower when the axis of the follower passes through the axis of cam shaft from the following data:

(i) Follower to move outwards through 40mm during 60° of cam rotation

(ii) Follower to dwell for the next 45°

(iii) Follower to return its original position during next 90°

(iv) Follower to dwell for the rest of the cam rotation.

the displacement of the follower is to take place with simple harmonic motion during both the outward and Return strokes. the least radius of cam is 50mm. [NOV/DEC 2015]

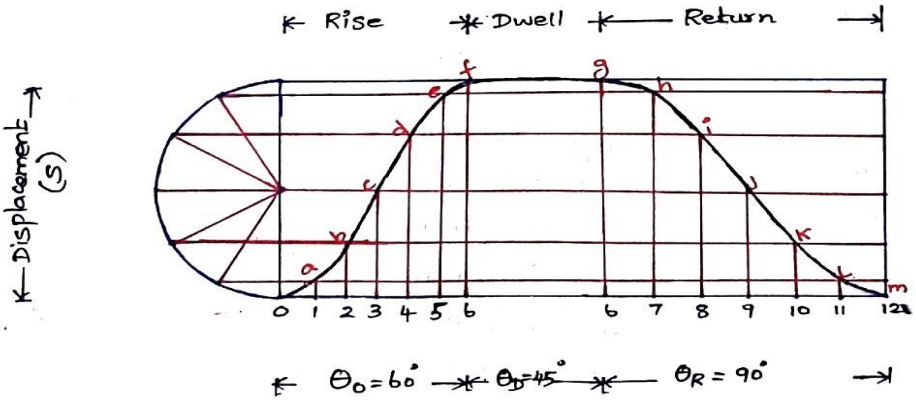
Soln:

given data:

Out stroke, $S = 40mm$, $\theta_O = 60°$, $\theta_D = 45°$, $\theta_R = 90°$

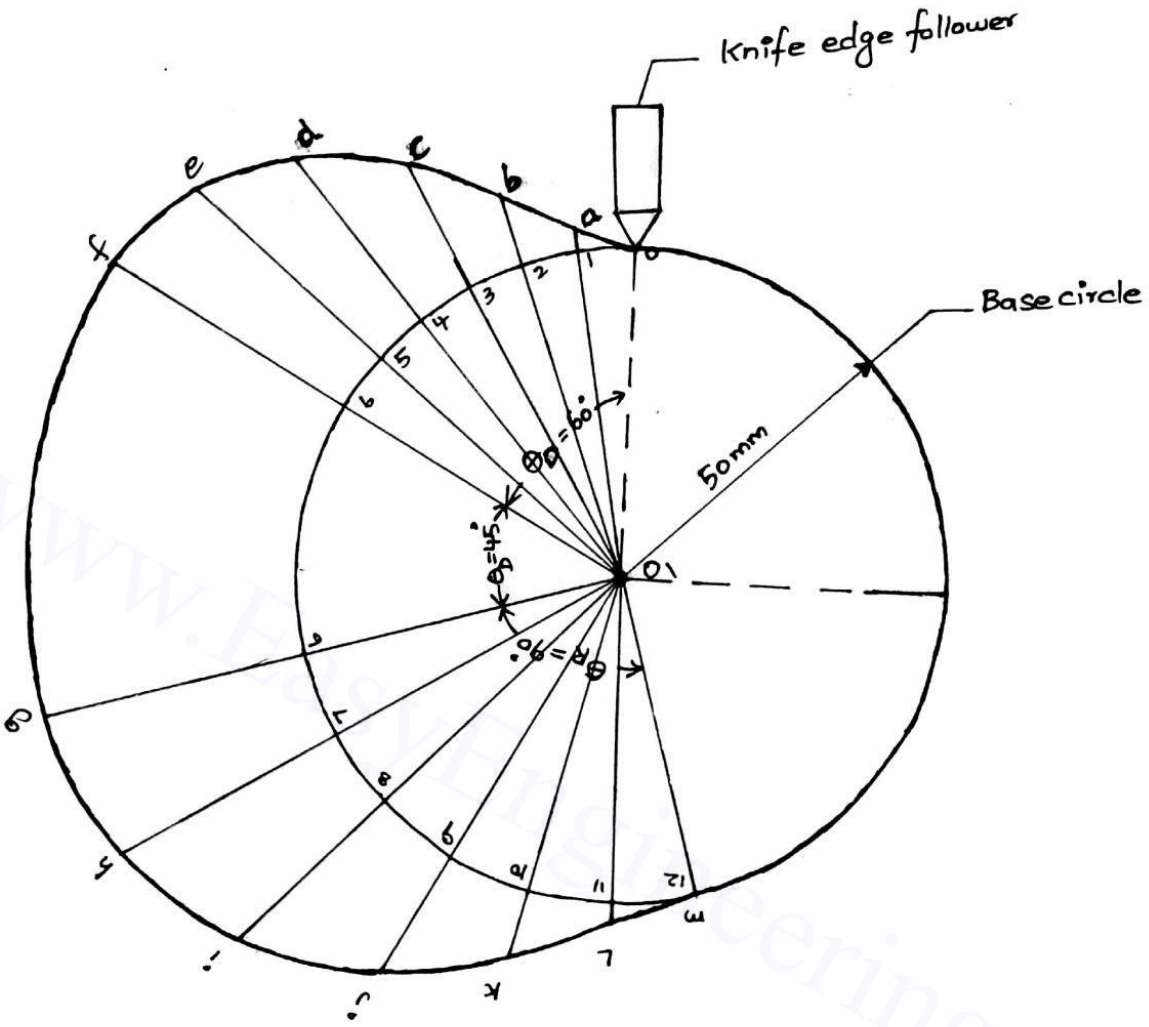
Cam radius = 50mm, Motion type - Simple harmonic motion.

Scale: 1cm = 20°



Displacement curve

Cam profile.



Measurements:

1 to a → 0.3 cm
2 to b → 1.1 cm
3 to c → 2.1 cm
4 to d → 3.1 cm
5 to e → 3.8 cm
6 to f → 4.1 cm
6 to g → 4.1 cm
7 to h → 3.8 cm
8 to i → 3.1 cm
9 to j → 2.1 cm
10 to k → 1.1 cm
11 to L → 0.3 cm

O_1 to 0 & 12 to m → Scale "0"

2) Draw the profile of a cam operating a knife-edge follower (when the axis of the follower passes through the axis of cam shaft) from the following data:

(i) Follower to move outward through 30mm with simple Harmonic motion during 120° of cam rotation,

(ii) Follower to dwell for the next 60°.

(iii) Follower to return to its original position with uniform velocity during 90° of cam rotation.

(iv) Follower to dwell for the rest of the cam rotation. The least radius of cam is 20mm and the cam rotates at 240 rpm. [NOV/DEC 2015]

Soln:

given data:

Out stroke, $S = 30mm$, $\theta_O = 120°$, $\theta_D = 60°$, $\theta_R = 90°$

Cam radius = 20mm,

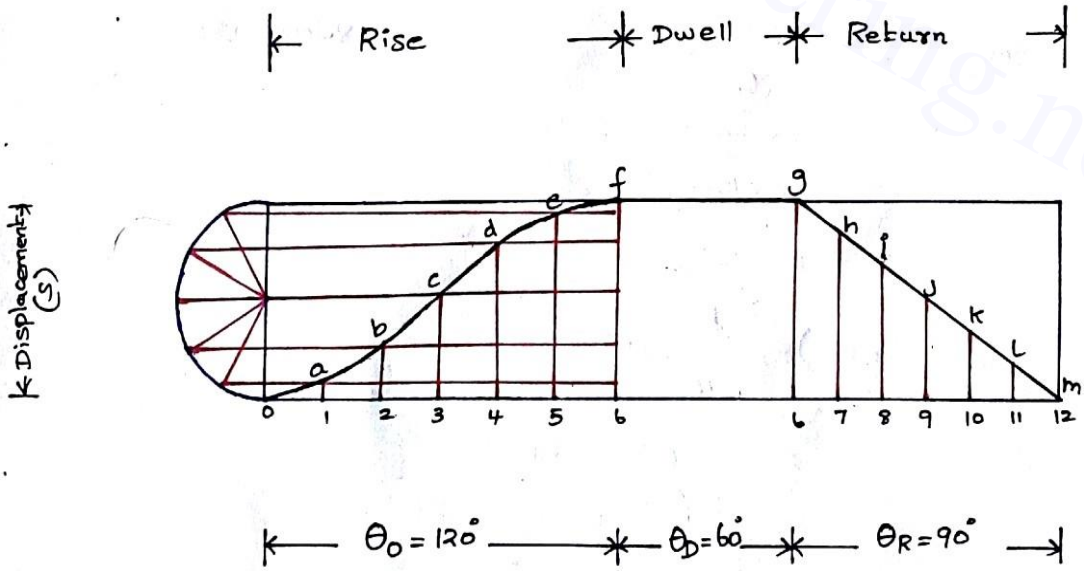
Speed, $N = 240$ rpm

Motion type- Simple harmonic motion (out stroke)

Uniform velocity motion (Return stroke)

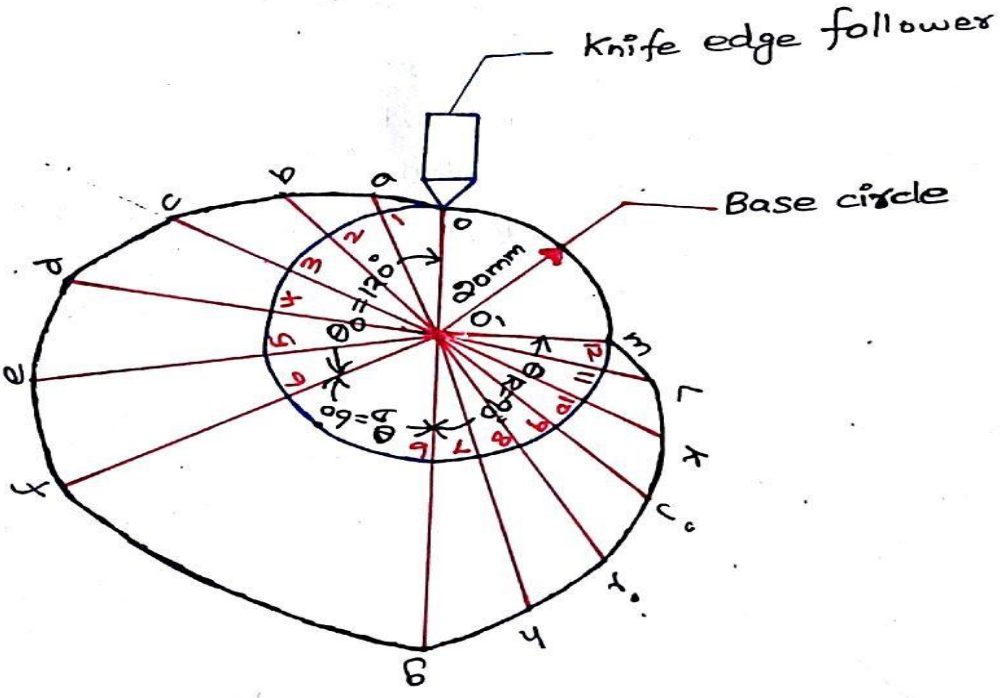
Soln:

$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 240}{60} = 25.13 \text{ rad/s}$$



Displacement curve

Cam profile



Out stroke

$$\text{Velocity } (V_o) = \frac{\pi \cdot S}{2\theta_o} \cdot \omega$$

$$= \frac{\pi \times 30\times10^{-3}}{2\times\left(120\times\frac{\pi}{180}\right)} \times 25.13$$

$$= 0.565 \text{ m/s}$$

$$\text{acceleration } (a_o) = \pm \frac{\pi^2 S}{2(\theta_o)^2} \cdot \omega^2$$

$$= \frac{\pi^2 \times 30\times10^{-3}}{2\times\left(120\times\frac{\pi}{180}\right)^2} \times (25.13)^2$$

$$= \pm 21.31 \text{ m/s}^2$$

3) A cam with 30mm as minimum diameter is rotating clockwise at a uniform speed of 1200 rpm and has to give the following motion to a roller follower 10mm in diameter:

(i) Follower to complete outward stroke of 25mm during 120° of cam rotation with equal uniform acceleration and retardation;

(ii) Follower to dwell for 60° of cam rotation:

(iii) Follower to return to its intial position during 90° of cam rotation with equal uniform acceleration and retardation;

(iv) Follower to dwell for the remaining 90° of cam rotation.

Draw the cam profile if the axis of the roller follower passes through the axis of the cam. Determine the maximum velocity of the follower during the out stroke and return stroke and also the uniform acceleration of the follower on the out stroke and the return stroke. [April/May 2015]

Soln:

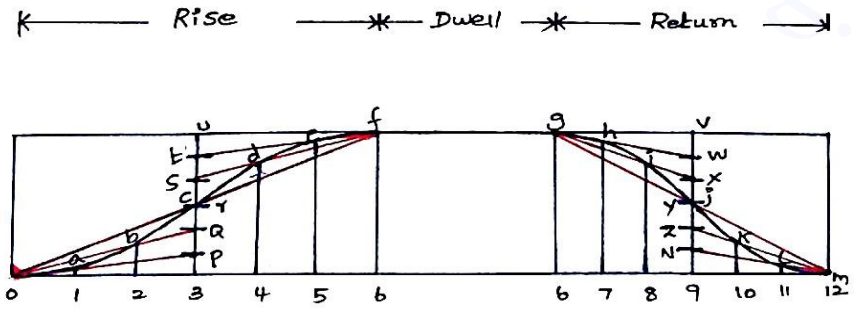
given data:

Outstroke, $S = 25$ mm, $\theta_o = 120°$, $\theta_{D_1} = 60°$, $\theta_R = 90°$, $\theta_{D_2} = 90°$

Cam diameter = 30 mm

Cam radius = $\frac{30}{2} = 15$ mm, Roller diameter = 10mm

Motion type = Uniform acceleration and Retardation, Speed, N = 1200 rpm



$\theta_o = 120°$ — $\theta_D = 60°$ — $\theta_R = 90°$

Displacement curve

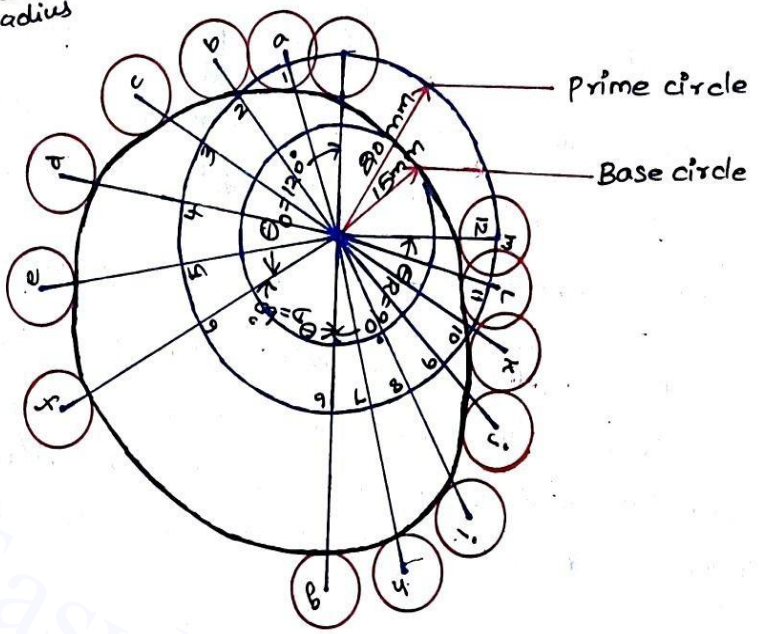
Cam profile

Prime circle radius = Cam radius + Roller radius

$= r_c + r_r$

$= 15 + 5$

$= 20mm$



$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 1200}{60} = 125.66 \text{ rad/sec.}$$

Out stroke:

Velocity $V_o = \frac{2 \cdot S}{\theta_o} \cdot \omega$

$= \frac{2 \times 25 \times 10^{-3}}{120 \times \frac{\pi}{180}} \times 125.66$

$V_o = 3 \text{ m/s}$

Acceleration, $a_o = \pm \frac{4S}{\theta_o^2} \cdot \omega^2$

$= \pm \frac{4 \times 25 \times 10^{-3}}{\left(120 \times \frac{\pi}{180}\right)^2} \times (125.66)^2$

$= \pm 359.97 \text{ m/s}^2$

Return stroke:

Velocity $V_R = \frac{-2S}{\theta_R} \cdot \omega$

$= \frac{-2 \times 25 \times 10^{-3}}{90 \times \frac{\pi}{180}} \times 125.66$

$V_R = -4 \text{ m/s}$

Acceleration, $a_R = \mp \frac{4S}{\theta_R^2} \cdot \omega^2$

$= \mp \frac{4 \times 25 \times 10^{-3}}{\left(90 \times \frac{\pi}{180}\right)^2} \times (125.6$

$= 639.96 \text{ m/s}^2$

4) A cam rotating clockwise at a uniform speed of 200 rpm is required to move an offset roller follower with a uniform and equal acceleration and retardation on both the outward and return strokes. The angle of ascent, the angle of dwell (between ascent and descent) and the angle of descent is 120°, 60° and 90° respectively. The follower dwells for the rest of cam rotation. The least radius of the cam is 50 mm, the lift of the follower is 25 mm and the diameter of the roller is 10 mm. The line of stroke of the follower is offset by 20mm from the axis of the cam. Draw the cam profile and find the maximum velocity and acceleration of the follower during the out stroke. [April/May 2015] R-2008

Gn:

Outstroke, $S = 25$ mm, $\theta_o = 120°$, $\theta_D = 60°$, $\theta_R = 90°$, Cam radius = 50mm

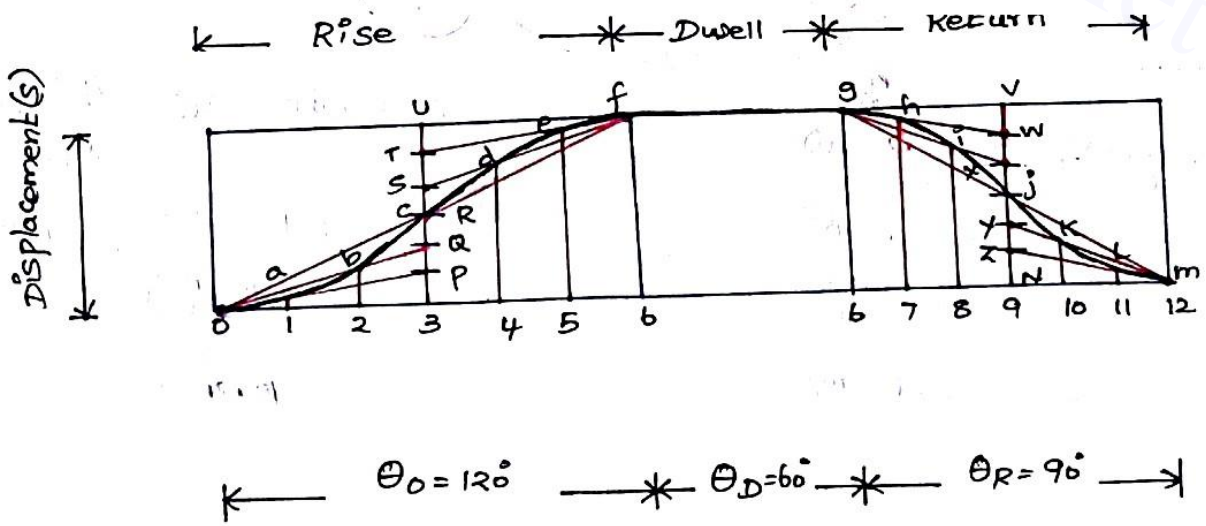
Offset distance = 20mm, Roller diameter = 10mm

Motion type = uniform acceleration and retardation

Speed, $N = 200$ rpm

Soln:

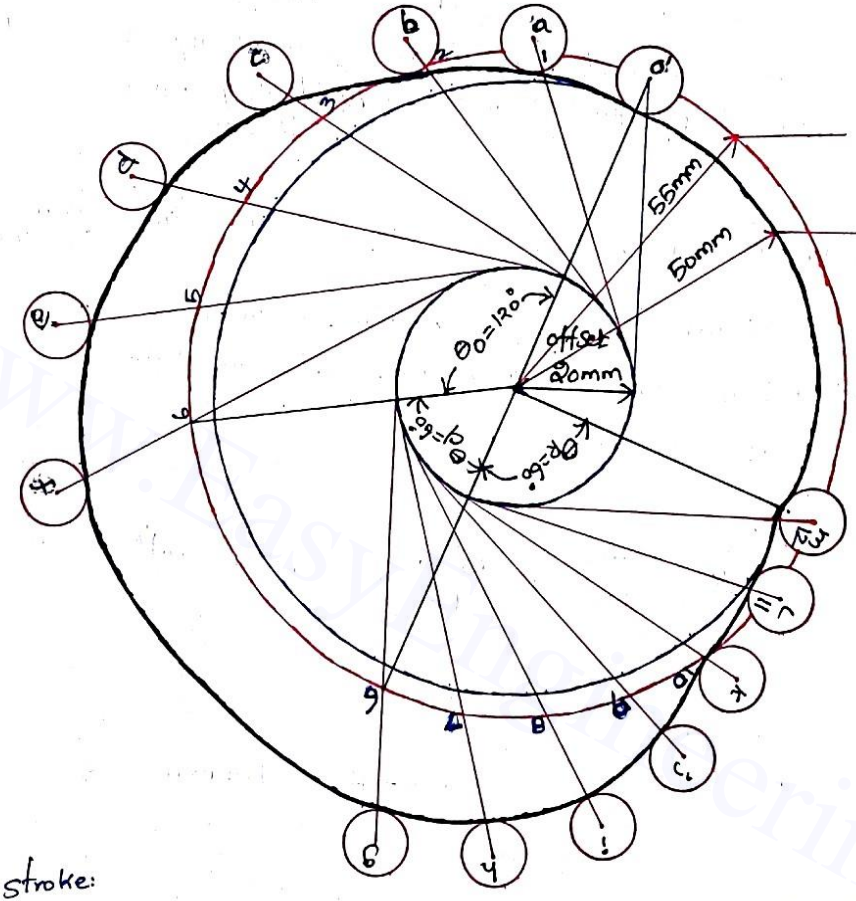
$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 200}{60} = 20.943 \text{ rad/s}$$



$\theta_o = 120°$ — $\theta_D = 60°$ — $\theta_R = 90°$

Displacement curve

Cam profile



Return stroke:

Velocity $(V_R) = -\frac{2S}{\theta_R}\cdot\omega$

$= -\frac{2\times 25\times 10^{-3}}{(90\times \frac{\pi}{180})} \times 20.943$

$V_R = 0.67$ m/s

Acceleration $(a_R) = \mp \frac{4S}{(\theta_R)^2}\cdot\omega^2$

$= \mp \frac{4\times 25\times 10^{-3}}{(90\times \frac{\pi}{180})^2} \times (20.943)^2$

$= 17.78$ m/s^2

5) A cam with a minimum radius of 25 mm, rotating clockwise at uniform speed of 300 rpm is to be designed to give motion to a flat faced mushroom follower as detailed below:

(i) To raise through a distance of 25mm in 120° rotation of the cam

(ii) To remain at rest for the next 30°

(iii) To lower during further 120° rotation of the cam

(iv) To remain in the same position during rest of the revolution.

The raising of the follower takes place with cycloidal motion and the lowering with uniform acceleration and retardation. However, the uniform acceleration is 2/3rd of the uniform retardation. Draw the displacement diagram and profile of the cam. [MAY/JUNE 2013] R-2008

Soln:

Cam radius, $r_b = 25$ mm, $N = 300$ rpm

$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 300}{60} = 31.415$ rad/s, $S = 25$ mm

Out stroke $\theta_o = 120°$, $\theta_D = 30°$, $\theta_R = 120°$ Motion type - Cycloidal motion - Out stroke

Uniform acceleration and retardation - Return stroke

Let θ_{R1} and θ_{R2} be the angle of acceleration and retardation respectively.

$\therefore \theta_{R1} + \theta_{R2} = \theta_R = 120°$

$2/3\ \theta_{R2} + \theta_{R2} = 120°$

$5/3\ \theta_{R2} = 120°$

$\theta_{R2} = 72°$, $\therefore \theta_{R1} = 48°$

Similarly, S_1 and S_2 be the displacement of follower during acceleration and retardation period.

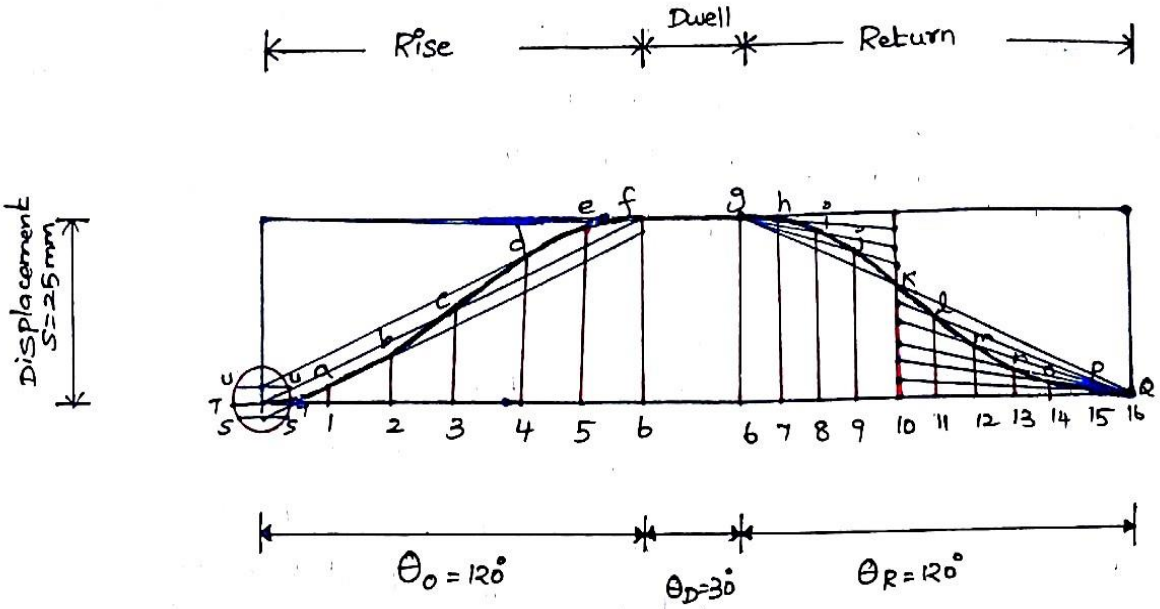
$S_1 + S_2 = S = 25$

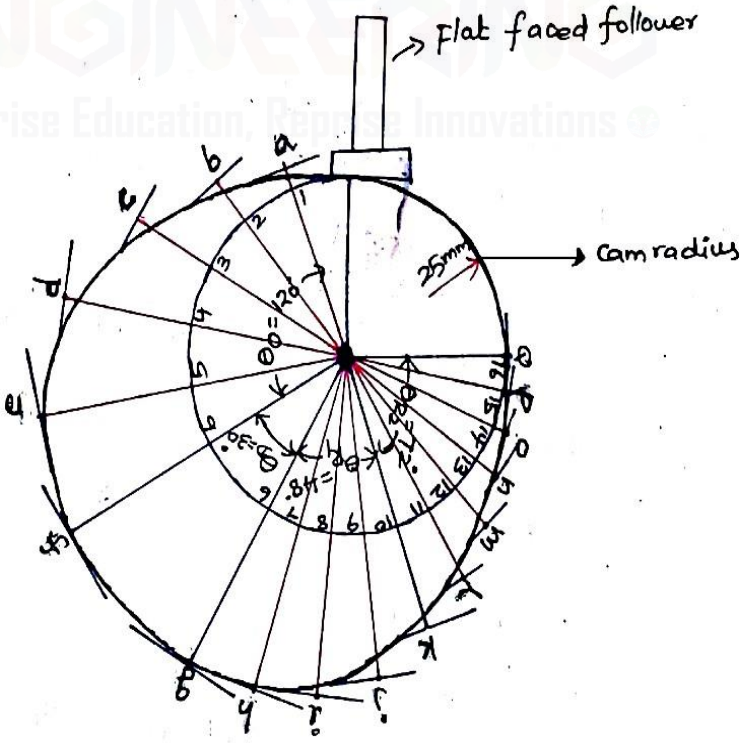
$2/3\ S_2 + S_2 = 25$

$5/3\ S_2 = 25$

$S_2 = 15$ mm

$S_1 = 10$ mm


Rise
Dwell
Return
Displacement
S=25mm
1 2 3 4 5 6 6 7 8 9 10 11 12 13 14 15 16
θo = 120°
θD=30°
θR=120°


Flat faced follower
Cam radius
25mm
θo=120°
θD=30°

PART-C

1. Draw the displacement, velocity and acceleration curves, when the follower moves with SHM and derive the expression for maximum velocity and maximum acceleration. (May/June 2016) (16).

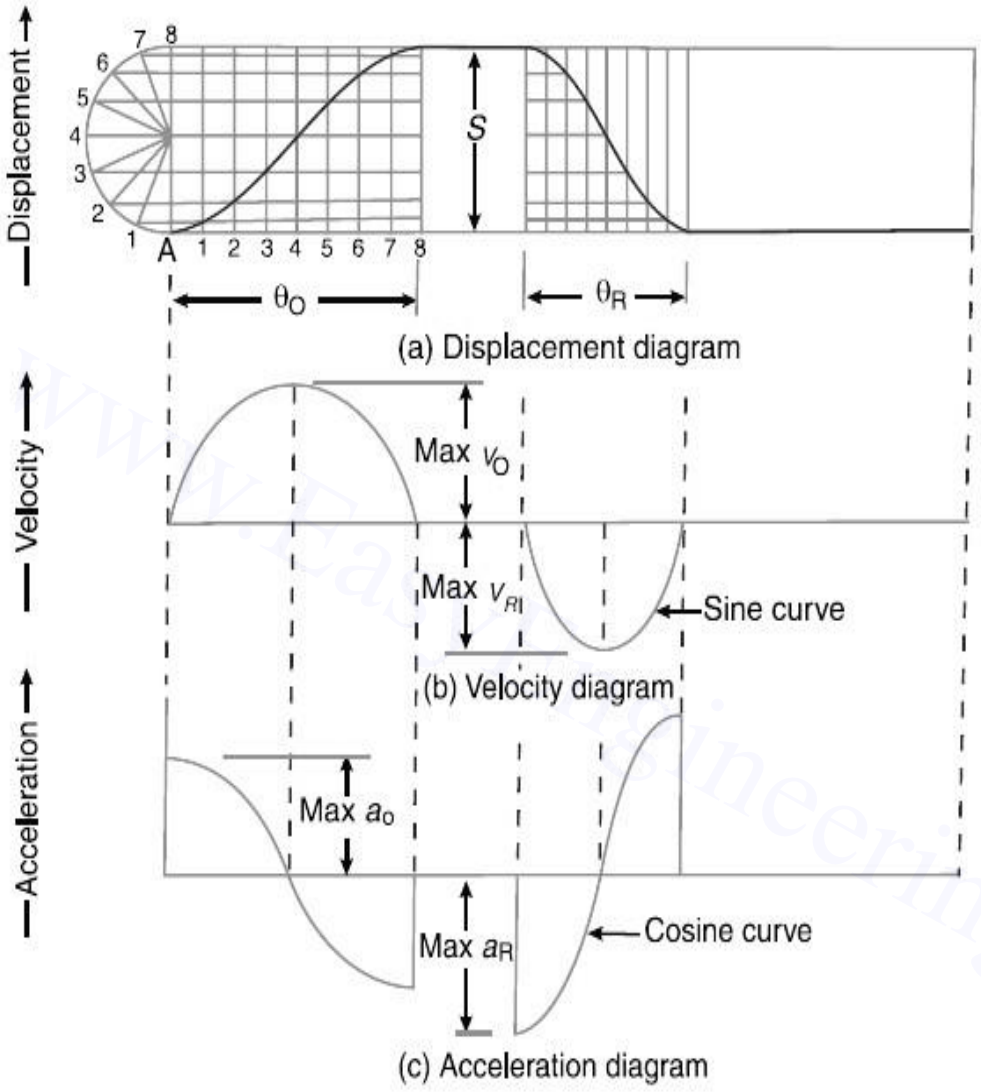


Fig. Displacement, velocity and acceleration diagrams when the follower moves with simple harmonic motion.

Let S = Stroke of the follower,

θ_O and θ_R = Angular displacement of the cam during out stroke and return stroke of the follower respectively, in radians, and

ω = Angular velocity of the cam in rad/s.

∴ Time required for the out stroke of the follower in seconds,

$$t_O = \theta_O / \omega$$

Consider a point P moving at a uniform speed ω_P radians per sec round the circumference of a circle with the stroke S as diameter, as shown in Fig. The point P' (which is the projection of a point P on the diameter) executes a simple harmonic motion as the point P rotates. The motion of the follower is similar to that of point P'.

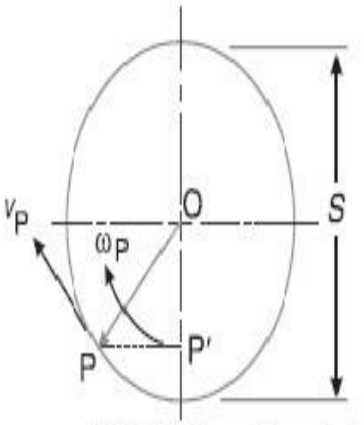


Fig. Motion of a point.

∴ Peripheral speed of the point P',

$$v_P = \frac{\pi S}{2} \times \frac{1}{t_O} = \frac{\pi S}{2} \times \frac{\omega}{\theta_O}$$

and maximum velocity of the follower on the outstroke,

$$v_O = v_P = \frac{\pi S}{2} \times \frac{\omega}{\theta_O} = \frac{\pi \omega . S}{2\theta_O}$$

We know that the centripetal acceleration of the point P,

$$a_P = \frac{(v_P)^2}{OP} = \left(\frac{\pi \omega . S}{2\theta_O}\right)^2 \times \frac{2}{S} = \frac{\pi^2 \omega^2 . S}{2(\theta_O)^2}$$

∴ Maximum acceleration of the follower on the outstroke,

$$a_O = a_P = \frac{\pi^2 \omega^2 . S}{2(\theta_O)^2}$$

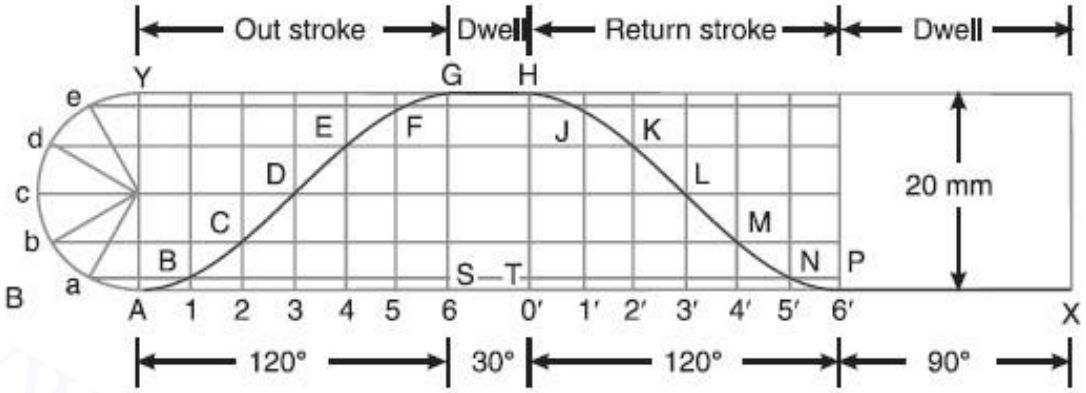
Similarly, maximum velocity of the follower on the return stroke,

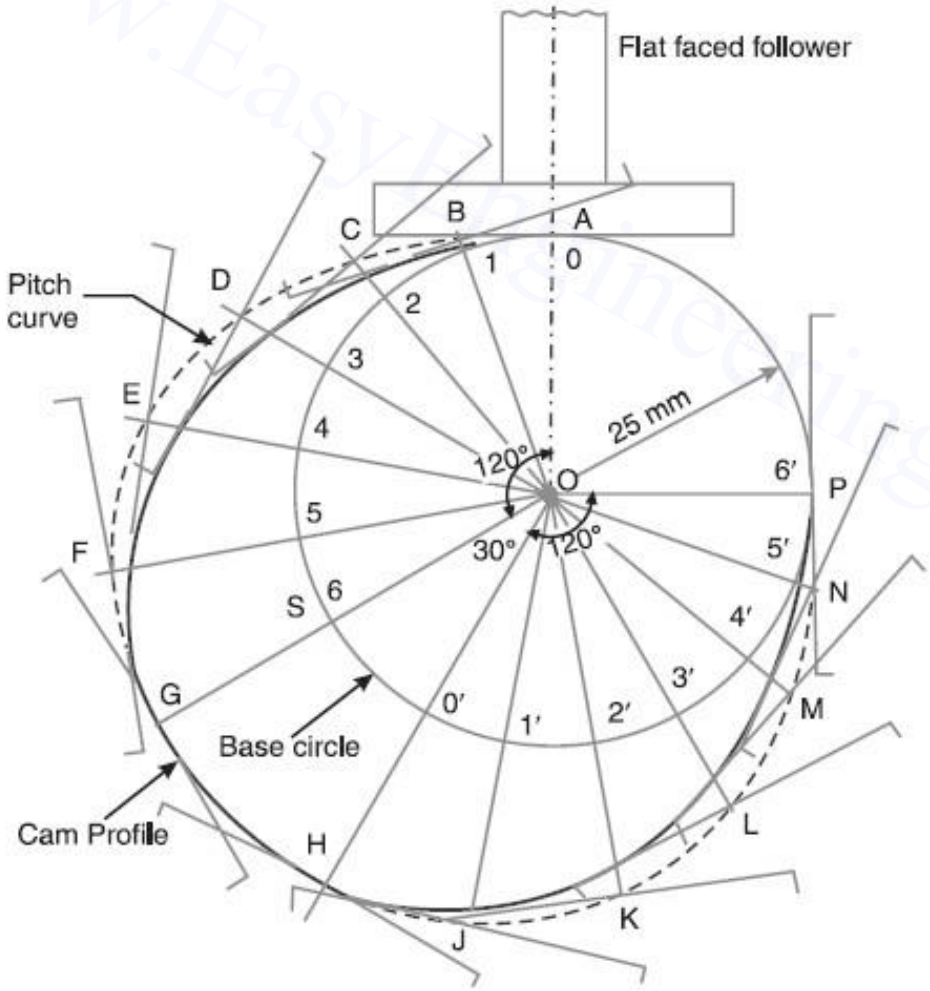
$$v_R = \frac{\pi \omega . S}{2\theta_R}$$

and maximum acceleration of the follower on the return stroke,

$$a_R = \frac{\pi^2 \omega^2 . S}{2(\theta_R)^2}$$

2. A cam drives a flat reciprocating follower in the following manner: During first 120° rotation of the cam, follower moves outwards through a distance of 20mm with SHM. The follower dwells during next 30° of cam rotation. During next 120° of cam rotation, the follower moves inwards with SHM. The follower dwells for the next 90° of cam rotation. The minimum radius of the cam is 25mm. draw the profile of the cam. (16)





UNIT IV GEAR AND GEAR TRAINS

PART-A

1. What is an angle of obliquity in gears? (May 2010)

It is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point. It is also called as pressure angle.

2. What is meant by arc of contact in gears? (Nov 2012)

Arc of contact is the path traced by a point on the pitch circle from the beginning to the end of engagement of a pair of teeth.

3. State law of Gearing. (May 2014)

The law of gearing states that for obtaining a constant velocity ratio, at any instant of teeth the common normal at each point of contact should always pass through a pitch point, situated on the line joining the centre of rotation of the pair of mating gears.

4. Write down the common forms of teeth. (May 2013)

1. Involute Tooth Profile
2. Cycloidal Tooth Profile

5. What are the advantages of gear drive over friction wheels? (Nov 2010)

Advantages:

1. Since there is no slip, so exact velocity ratio is obtained.
2. It is more efficient and effective

6. What do you understand by interference as applied to gears? (May 2015)

The phenomenon when the tip of tooth undercuts the roots on its mating gear is Known as interference.

7. What are the methods to avoid interference? (May 2014)

1. The height of the teeth may be reduced.
2. The pressure angle may be increased.
3. The radial flank of the pinion may be cut back (undercutting).

8. What are the special advantages and applications of epicyclic gear trains? (May 2015)

The epicyclic gear trains are useful in transmitting high velocity ratios in a comparatively lesser space. They are used in the back gear of lathe, differential gears of the automobiles, pulley blocks, wrist watches, etc.

9. Write short notes on differentials (Nov 2013)

The differential gears are used in the rear drive of automobile .Its function is to transmit motion from the engine shaft to the rear driving wheels.

10. Define gear ratio. **(Nov 2013)**

Gear ratio is the ratio of the speed of the driver to the speed of the driven and the ratio of the speeds of any pairs of gears in mesh is the inverse of their number of teeth.

PART-B

1) Calculate:

(i) Length of Path of contact

(ii) Arc of contact and

(iii) the contact ratio when a pinon having 23 teeth drives a gear having teeth 57. The Profile of the gears is involute with pressure angle 20°, module 8 mm and Addendum equal to one Module. [APR/MAY 2015]

Given data:

$t = 23$, $T = 57$, $\phi = 20°$, $m = 8$ mm

Addendum = 1 Module = 8 mm

To find:

(i) Length of Path of Contact (KL).

(ii) Arc of contact.

(iii) Contact ratio.

Solution:

(i) Length of Path of contact:

Pitch circle radius of pinion $r = \frac{mt}{2}$

$= \frac{8 \times 23}{2}$

$= 92$ mm

Pitch circle radius of Wheel $R = \frac{mT}{2}$

$= \frac{8 \times 57}{2}$

$= 228$ mm

Radius of Addendum circle of pinion $r_A = r + \text{Addendum}$

$= 92 + 8$

$= 100$ mm

Radius of Addendum circle of wheel $R_A = R + \text{Addendum}$

$= 228 + 8$

$R_A = 236$ mm

Length of Path of approach (KP):

$$KP = \sqrt{(R_A)^2 - R^2 \cos^2\phi} - R\sin\phi$$

$$KP = \sqrt{(236)^2 - (228)^2 (\cos 20)^2} - 228 \times \sin 20^\circ$$

$$KP = \sqrt{55696 - 45903} - 77.98$$

$$KP = 98.95 - 77.98$$

$$KP = 20.96 \text{ mm}$$

Length of Path of Recess (PL):

$$PL = \sqrt{(r_A)^2 - r^2 \cos^2\phi} - r\sin\phi$$

$$PL = \sqrt{(100)^2 - (92)^2 (\cos 20)^2} - 92 \sin 20^\circ$$

$$PL = \sqrt{10000 - 747.39} - 31.47$$

$$PL = 50.26 - 31.47$$

$$PL = 18.79 \text{ mm}$$

Length of Path of contact $KL = KP + PL$

$= 20.96 + 18.79$

$KL = 39.75$ mm

(ii) Length of Arc of contact:

$$\text{Length of Arc of contact} = \frac{\text{Length of Path of contact}}{\cos\phi}$$

$$= \frac{39.75}{\cos 20^\circ}$$

Length of Arc of contact $= 42.30$ mm

iii) Contact Ratio:

Circular pitch $P_c = \pi \times m = \pi \times 8 = 25.12$ mm

$$\text{Contact Ratio} = \frac{\text{Length of Arc of contact}}{\text{Circular pitch}}$$

$$= \frac{42.30}{25.12}$$

$$= 1.68 \simeq 2$$

Contact Ratio = 2

8) Two gear wheels mesh externally to give a velocity ratio of 3 to 1. The involute teeth has 6 mm module and 20° Pressure angle. Addendum is equal to one module. The pinion rotates at 90 rpm. Determine

(i) Number of teeth on pinion to avoid interference and the corresponding number on the wheel

(ii) The length of path and arc of contact

(iii) Contact ratio and

(iv) The maximum velocity of sliding. [MAY/JUNE 2014]

Given data:

Velocity ratio, $G_1 = \frac{T}{t} = 3$, module $m = 6$ mm

$A_p = A_w = 1$ module $= 6$ mm, $\phi = 20^\circ$, $N_1 = 90$ rpm

Solution:

$$\omega_1 = \frac{2\pi N_1}{60}$$

$$\omega_1 = \frac{2 \times \pi \times 90}{60} = 9.43 \text{ rad/s}$$

(i) Number of teeth on the pinion and wheel:

No. of teeth on pinion to avoid interference

$$t = \frac{2 A_p}{\sqrt{1 + G_1 (G_1 + 2) \sin^2 \phi} - 1}$$

$$= \frac{2 \times 6}{\sqrt{1 + 3 (3+2) \sin^2 20^\circ} - 1}$$

$$= 18.2 \simeq 19$$

$$t = 19$$

No. of teeth on the wheel

$$T = G_1 \cdot t$$

$$= 3 \times 19$$

$$T = 57$$

(ii) Length of path and Arc of contact:

pitch circle radius of pinion $r = \frac{mt}{2}$

$$= \frac{6 \times 19}{2}$$

$$r = 57 \text{ mm}$$

pitch circle radius of wheel $R = \frac{mT}{2}$

$$= \frac{6 \times 57}{2}$$

$$R = 171 \text{ mm}$$

Radius of Addendum circle of Pinion, $r_A = r + Ap$

$= 57 + 6$

$r_A = 63$ mm

Radius of Addendum circle of wheel, $R_A = R + Aw$

$= 171 + 6$

$R_A = 177$ mm

Length of path of Approach (kp):

$$kp = \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi$$

$$= \sqrt{(177)^2 - (171)^2\cos^2 20^\circ} - 171\sin 20^\circ$$

$$= 74.2 - 58.15$$

$$kp = 15.7 \text{ mm}$$

Length of path of Recess (PL):

$$PL = \sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi$$

$$= \sqrt{(63)^2 - (57)^2\cos^2 20^\circ} - 57\sin 20^\circ$$

$$= 33.175 - 19.5$$

$$PL = 13.67 \text{ mm}$$

Length of path of contact $KL = kp + PL$

$= 15.7 + 13.67$

$KL = 29.37$ mm

Length of Arc of contact $= \dfrac{\text{Length of path of contact}}{\cos\phi}$

$= \dfrac{29.37}{\cos 20^\circ}$

$= 31.25$ mm

(iii) Number of pairs of teeth in contact (or) Contact ratio:

Circular pitch = $\pi \times m$ = 18.852 mm

$$\text{Contact ratio} = \frac{\text{Length of Arc of contact}}{\text{circular pitch}}$$

$$= \frac{31.25}{18.852}$$

$$= 1.66 \simeq 2$$

Contact ratio = 2

(iv) Maximum Velocity of sliding (V_s):

Let, ω_1 - Angular speed of pinion

ω_2 - Angular speed of wheel

$$\frac{\omega_1}{\omega_2} = \frac{T}{t}, \quad \omega_2 = \omega_1 \times \frac{t}{T}$$

$$\omega_2 = 9.43 \times \frac{19}{57}$$

$$\omega_2 = 3.14 \text{ rad/s}$$

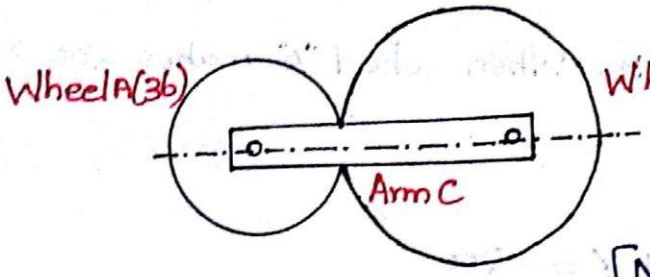
Maximum Velocity of sliding, $V_s = (\omega_1 + \omega_2) \cdot KP$

$$= (9.43 + 3.14) \times 15.7$$

$$V_s = 197.35 \text{ mm/s}$$

3) The arm of an epicyclic gear train rotates at 100 rpm in the anticlockwise direction. The arm carries two wheels A and B having 36 and 45 teeth respectively. The wheel A is fixed and the arm rotates about the centre of wheel A. Find

the speed of wheel B. What will be the speed of B, if the wheel A instead of being fixed, makes 200 rpm clockwise.



[NOV/DEC 2015]

Given data:

$T_A = 36$, $T_B = 45$, $N_C = 100$ rpm [Anticlockwise]

Table of motion.

Step No	Operations	Revolution of Elements (N)		
		Arm C	GEAR A $T_A = 36$	GEAR B $T_B = 45$
1.	Fix the arm C and give Gear A +1 revolution [Anti clockwise]	0	+1	$-\frac{T_A}{T_B}$
2.	Multiply by x	0	+x	$-x \times \frac{T_A}{T_B}$
3.	Add +y revolution to all elements	+y	+y	+y
4.	Total motion	y	x+y	$y - x \times \frac{T_A}{T_B}$

(i) Speed of Gear B, when wheel A is fixed:

Speed of the Arm = 100 rpm [Anticlockwise]

$\therefore y = +100$ rpm

Gear A is fixed, $x + y = 0$

$x = -y$

$x = -100$ rpm

Speed of Gear B = $y - x \times \frac{T_A}{T_B}$

$$= 100 + 100 \times \frac{36}{45}$$

Speed of wheel "B" $= 180$ rpm

(ii) Speed of wheel B, When wheel "A" makes 200 rpm clockwise:

From Table,

$$x + y = -200$$
$$x = -200 - y$$
$$x = -200 - 100$$
$$x = -300 \text{ rpm (clockwise)}$$

Speed of wheel B, $N_B = y - x \times \frac{T_A}{T_B}$

$$= y - (-300) \times \frac{36}{45}$$
$$= 100 + 240$$

$N_B = 340$ rpm (Anticlockwise)

4)(i) An epicyclic gear train consists of three gears 1, 2, 3 as shown in Figure. The internal gear 1 has 72 teeth and gear 3 has 32 teeth. The gear 2 meshes with both gear 1 and gear 3 and is carried on an arm A, which rotates about the centre O_2 at 20 rpm. If the gear 1 is fixed, determine the speed of gears 2 and 3. (12 Marks).

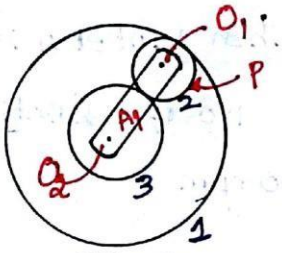


Figure.

(ii) Write short notes on speed ratio of a Planetary gear train. (4 Marks) [NOV/DEC 2013]

Solution:

(i) Table of motion

Step No	Operations	Revolution of Elements (N)			
		Arm A_1	Gear 3 $T_3 = 32$	Gear 2 $T_2 = 20$	Gear 1 $T_1 = 72$
1.	Fix the arm A, and give gear 3 +1 revolution [Anticlockwise]	0	+1	$-\frac{T_3}{T_2}$	$-\frac{T_3}{T_1}$
2.	Multiply by x	0	+x	$-x \times \frac{T_3}{T_2}$	$-x \times \frac{T_3}{T_1}$
3.	Add +y revolution to all elements	+y	+y	+y	+y
4.	Total motion	y	x+y	$y - x \times \frac{T_3}{T_2}$	$y - x \times \frac{T_3}{T_1}$

Speed of Gear 3 (N_3):

Speed of the Arm A_1 is 20 rpm

$y = 20$ rpm

Gear 1 is fixed,

$$y - x \times \frac{T_3}{T_1} = 0$$

$$20 - x \times \frac{32}{72} = 0$$

$$x = \frac{72}{32} \times 20 = 45$$

Speed of Gear 3 $= x + y$

$= 45 + 20$

$N_3 = 65$ rpm [Anticlockwise]

Speed of Gear 2 (N_2):

Let d_1, d_2, d_3 be the pitch circle diameter of the gears 1, 2, 3 respectively.

From the Figure

$$d_2 + \frac{d_3}{2} = \frac{d_1}{2}$$

$$2d_2 + d_3 = d_1$$

Since the no. of teeth are proportional to their pitchcircle diameters. The above eqn can be written as

$$2T_2 + T_3 = T_1$$

$$2T_2 + 32 = T_2$$

$$T_2 = 80$$

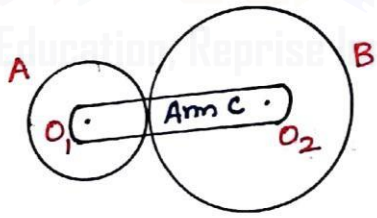
Speed of Gear 2 $= y - x \times \frac{T_3}{T_2}$

$$= 20 - 45 \times \frac{32}{20}$$

$N_2 = -52$ rpm [clockwise]

(ii) Notes on speed ratio of Planetary Gear train:

In the Algebraic method to find the motion of each element of epicyclic gear train relative to the arm is set down in form of eqns



Figure

The Figure shows an epicyclic gear train with gears A & B and Arm C. Let the Arm C be fixed,

∴ Speed of Gear A relative to Arm C $= N_A - N_C$

Also, Speed of Gear B relative to Arm C $= N_B - N_C$

Since the Gears A and B are meshing directly, Therefore

they will revolve in opposite direction.

$$\therefore \frac{N_B - N_C}{N_A - N_C} = -\frac{T_A}{T_B}$$

Since $N_C = 0$ ($\because$ Arm C is fixed)

$$\frac{N_B}{N_A} = -\frac{T_A}{T_B}$$

If Gear A is fixed, then $N_A = 0$

$$\frac{N_B}{N_C} = 1 + \frac{T_A}{T_B}$$

5)(i) Derive an expression to determine the length of path of contact between two spur gears of different size. (10 Marks)

(ii) Briefly explain the sub-classification of compound Gear trains with neat sketches. (6 Marks). [MAY/JUNE 2014].

Solution:

(i)

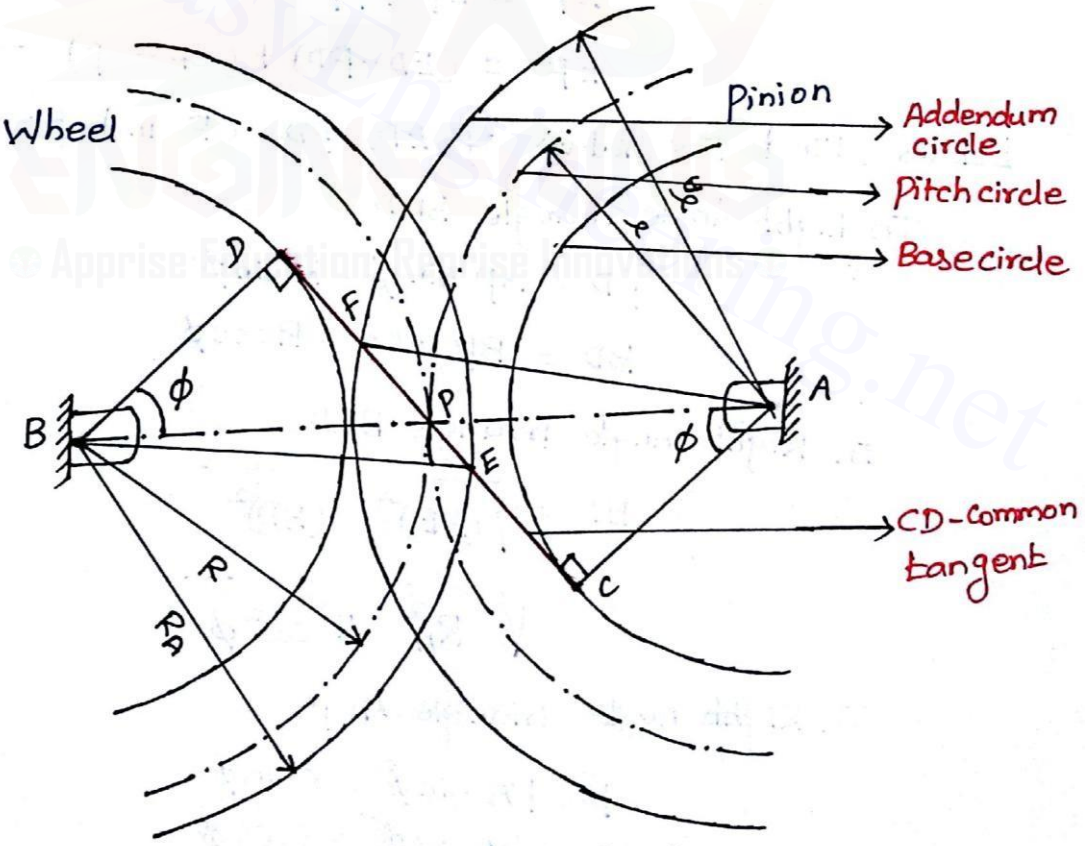


Figure: Line of Action Diagrams for Gears

The pinion is rotating in the clockwise direction and the wheel is driven. The two pitch circles are meeting at the point "P". The line CD is the common tangent of the two base circles. The line is also known as "Line of action".

The point "E" is the intersection of the tangent and the addendum circle of the wheel. The point "F" is the common tangent and the addendum circle of the pinion. The contact of two teeth begins, where the addendum circle of the wheel meets the common tangent (point E) and ends where the addendum circle of the pinion meets the common tangent (point F). The line EF gives the length of path of contact. The length EP is known as "path of approach" where as the length PF is known as "path of recess".

Length of path of contact = Path of approach + Path of Recess

$$EF = EP + PF$$

$$EF = (ED - PD) + (CF - CP) \quad -(1)$$

Let us, Find the values of ED, PD, CF and CD.

In Right Angle Triangle BPD

$$PD = BP \sin\phi = R' \sin\phi$$

$$BD = BP \cos\phi = R \cos\phi$$

In Right Angle Triangle BED.

$$ED = \sqrt{(BE)^2 - (BD)^2}$$

$$= \sqrt{R_A^2 - R^2 \cos^2\phi}$$

In Right Angle Triangle ACP,

$$CP = PA \sin\phi = r \sin\phi$$

$$CA = PA \cos\phi = r \cos\phi$$

In Right Angle Triangle FCA,

$$CF = \sqrt{(AF)^2 - (CA)^2}$$

$$= \sqrt{(r_A)^2 - r^2\cos^2\phi}$$

$\therefore$ Path of Approach = EP = ED − PD

$$= \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi$$

Path of Recess = PF = CF − CD

$$= \sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi$$

Length of Path of Contact = EF = EP + PF

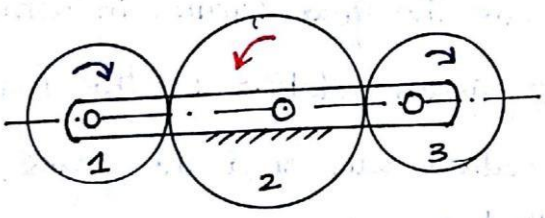
$$= \sqrt{R_A^2 - R^2\cos^2\phi} + \sqrt{r_A^2 - r^2\cos^2\phi} - (R+r)\sin\phi$$

The above equation gives the length of path of contact between two spur gears of different sizes.

(ii) Classification of Gear Trains with sketches:

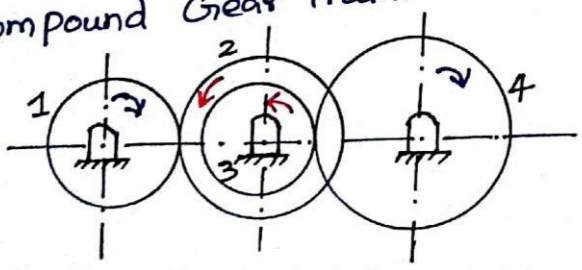
There are Four types of Gear Trains. They are

1) Simple Gear Train:



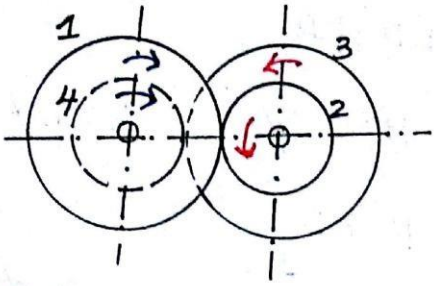
A Simple Gear Train is one in which there is only one gear on each shaft

2) Compound Gear Train:



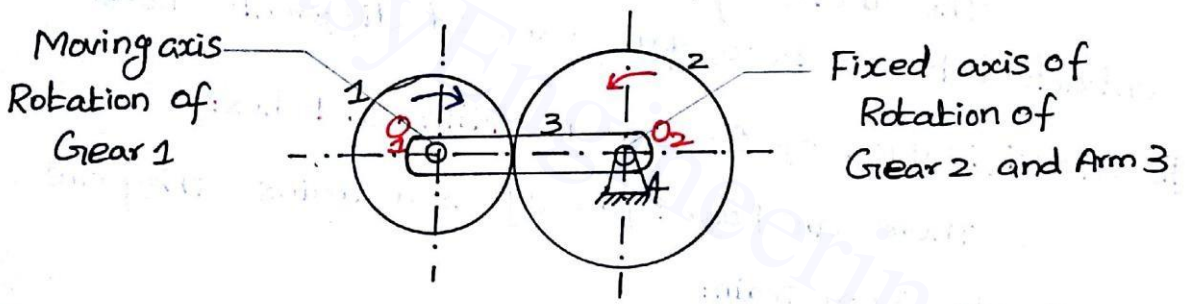
A pair of gears is compound, if they have a common axis are integral, then it is known as compound gear train.

3) Reverted Gear Train:



When the axes of the first gear [Driver] and the last gear (driven) are Co-axial, then the gear train is known as Reverted Gear train.

4) Epicyclic Gear Train:



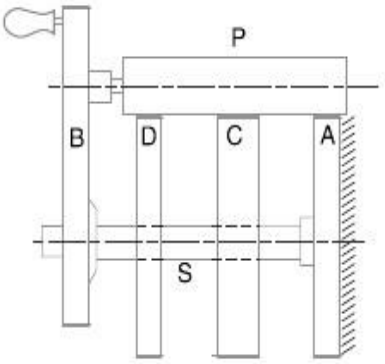
These are the gear trains in which the axis of one (or) more gears relative to the frame. The gear at the centre is called Sun and the gears, whose axes move are called planets.

PART-C

1. Fig shows an epicyclic gear train, Gear A is fixed to the frame and is, therefore, stationary. The arm B and gears C and D are free to rotate on the shaft S. Gears A, C and D have 100, 101 and 99 teeth respectively. The planet gear has 20 teeth. The pitch circle diameters all are the same so that the planet gear P meshes with all of them. Determine the revolutions of gears C and D for one revolution of the arm B. (16)

Solution. Given : $T_A = 100$; $T_C = 101$;

$T_P = 20$ $T_D = 99$



Step No.	Conditions of motion	Revolutions of elements			
		Arm B	Gear A	Gear C	Gear D
1.	Arm B fixed, gear A rotated through + 1 revolution (*i.e.* 1 revolution anticlockwise)	0	+ 1	$+\frac{T_A}{T_C}$	$+\frac{T_A}{T_C}\times\frac{T_C}{T_D}=+\frac{T_A}{T_D}$
2.	Arm B fixed, gear A rotated through + x revolutions	0	$+x$	$+x\times\frac{T_A}{T_C}$	$+x\times\frac{T_A}{T_D}$
3.	Add + y revolutions to all elements	$+y$	$+y$	$+y$	$+y$
4.	Total motion	$+y$	$x+y$	$y+x\times\frac{T_A}{T_C}$	$y+x\times\frac{T_A}{T_D}$

The arm B makes one revolution, therefore

$$y = 1$$

Since the gear A is fixed, therefore from the fourth row of the table,

$$x + y = 0 \quad \text{or} \quad x = -y = -1$$

Let N_C and N_D = Revolutions of gears C and D respectively.

From the fourth row of the table, the revolutions of gear C,

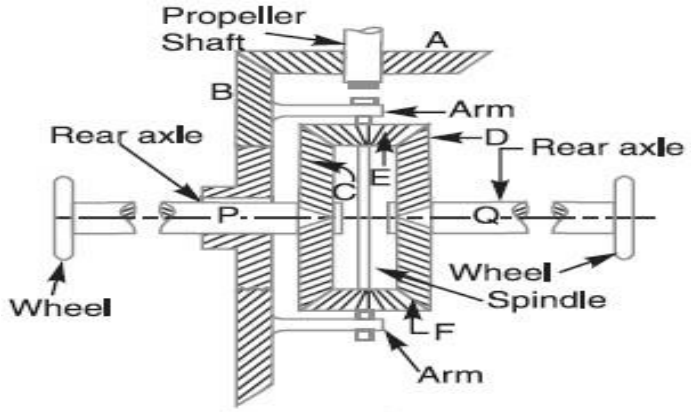
$$N_C = y + x \times \frac{T_A}{T_C} = 1 - 1 \times \frac{100}{101} = +\frac{1}{101} \text{ Ans.}$$

and the revolutions of gear D,

$$N_D = y + x \times \frac{T_A}{T_D} = 1 - \frac{100}{99} = -\frac{1}{99} \text{ Ans.}$$

From above we see that for one revolution of the arm B, the gear C rotates through 1/101 revolutions in the same direction and the gear D rotates through 1/99 revolutions in the opposite direction.

2. Fig shows a differential gear used in a motor car. The pinion A on the propeller shaft has a 12 teeth and gears with crown gear B which has 60 teeth. The shaft P and Q form the rear axles to which the road wheels are attached. If the propeller shaft rotates at 1000 rpm. And the road wheel attached to axle Q has a speed of 210 rpm while taking a turn, find the speed of road wheel attached to axle P. **(May/June 2014) (16)**



Solution. Given : $T_A = 12$; $T_B = 60$; $N_A = 1000$ r.p.m. ; $N_Q = N_D = 210$ r.p.m.

Since the propeller shaft or the pinion A rotates at 1000 r.p.m., therefore speed of crown gear B,

$$N_B = N_A \times \frac{T_A}{T_B} = 1000 \times \frac{12}{60}$$

$$= 200 \text{ r.p.m.}$$

The table of motions is given below :

Step No.	*Conditions of motion*	*Revolutions of elements*			
		Gear B	*Gear C*	*Gear E*	*Gear D*
1.	Gear B fixed-Gear C rotated through + 1 revolution (*i.e.* 1 revolution anticlockwise)	0	+ 1	$+\frac{T_C}{T_E}$	$-\frac{T_C}{T_E} \times \frac{T_E}{T_D} = -1$ $(\because T_C = T_D)$
2.	Gear B fixed-Gear C rotated through + x revolutions	0	$+x$	$+x \times \frac{T_C}{T_E}$	$-x$
3.	Add + y revolutions to all elements	$+y$	$+y$	$+y$	$+y$
4.	Total motion	$+y$	$x+y$	$y + x \times \frac{T_C}{T_E}$	$y-x$

Since the speed of gear B is 200 r.p.m., therefore from the fourth row of the table,

$$y = 200 \qquad \ldots(i)$$

Also, the speed of road wheel attached to axle Q or the speed of gear D is 210 r.p.m., therefore from the fourth row of the table,

$$y - x = 210 \quad \text{or} \quad x = y - 210 = 200 - 210 = -10$$

$\therefore$ Speed of road wheel attached to axle P

$$= \text{Speed of gear } C = x + y$$

$$= -10 + 200 = 190 \text{ r.p.m. Ans.}$$

UNIT-V FRICTION IN MACHINE ELEMENTS

PART-A

1. What are the advantages and disadvantages of V-belt drive over flat belt drive? (May 2011)

i) Power transmitted is more due to wedging action in the grooved pulleys.
ii) V-belt is more compact, quiet and shock absorbing.
iii) The V-belt drive is positive because of negligible slip between the belt and the groove.
iv) High velocity ratio (maximum 10) may be obtained.

2. What is the difference between sliding friction and rolling friction? (May 2011)

Sliding friction	Rolling friction
If the two surface have sliding motion with respect to each other to friction between them. Ex: Nut & bolt	If the two surface rolling motion with respect to each other the friction between them is known as rolling friction. Ex: Ball & Rolling

3. Define the term "Limiting friction".

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

4. Define speed ratio or velocity ratio? (May 2014)

Speed ratio is defined as the ratio between the speed of the driven and the driver shaft.

$$\text{Speed ratio} = \frac{\text{Speed of driven pulley}}{\text{Speed of driving pulley}}$$

5. Differentiate between self locking and overhauling of screw. (May 2012)

S.No	Self locking	Over hauling
1	Condition for self locking ø≥α	Condition for overhauling ø≤α
2	Due to self locking the load will be held in its position without any external brake	Due to overhauling the load continuous to descend under its own weight unless an external brake is applied
3	Used in Screw jack	Used in fly press

6. What are the advantages and disadvantages of V belt drive?

Advantages

1. V-belts have higher power transmitting capacity
2. V-belts can be used for high speed reduction ratio 7:1

Disadvantages

1. They are complex to design and manufacture
2. V-belts have lower efficiency.

7. Distinguish between open and cross belt drive in terms of its application. (May 2013)

1. Open belt drive is used when both the driving and driven shaft are arranged in parallel and rotating in the same direction
2. Cross belt drive is used when both the driving and driven shaft are arranged in parallel, but rotating in opposite direction. It is used for low speed applications

8. What is the role of friction in screw jack?

The role of friction in screw jack is to avoid the descending of load under its own weight or friction is necessary for the self locking condition of the screw.

9. What is creep in the case of belt?

When the belt passes from the slack side to the tight side, a certain portion of the belt extends. And it contracts again when the belt passes from the tight side to slack side .due to these changes of lengths, there is a relative motion.

10. List down the laws of friction. (May 2013)

i) The force of friction is directly proportional to the normal reaction between the surface in contact and always opposes the relative motion between them

ii) The force of friction depends on the nature of materials of the contacting surfaces.

iii) The force of friction is independent of the load

iv) The force of friction reduces with rise in temperature of the lubricant.

PART-B

1) The mean diameter of the screw jack having pitch of 10mm is 50 mm. A load of 20 kN is lifted through a distance of 170 mm. Find the work done in lifting the load and efficiency of the screw jack when

(i) the load rotates with screw and

(ii) the load rests on the loose head which does not rotate with screw.

The external and internal diameter of the bearing surface of the loose head are 60 mm and 10 mm respectively. the coefficient of friction for the screw aswell as the bearing surface may be taken as 0.08. [NOV/DEC 2011]

Given data:

$p = 10\text{ mm} = 10\times10^{-3}\text{ m}$; $d = 50\times10^{-3}\text{ m}$; $W = 20\times10^{3}\text{ N}$;

$D_2 = 60\text{mm}$ or $R_2 = 30\text{mm}$; $D_1 = 10\text{mm}$ or $R_1 = 5\text{ mm}$; $\mu = \tan\phi = \mu_1$;

$\mu_1 = 0.08$.

Solution:

$$\tan\alpha = \frac{p}{\pi d} = \frac{10\times10^{-3}}{\pi\times50\times10^{-3}} = 0.0637$$

Force required at the circumference of the screw to lift the load,

$$P = W\tan(\alpha+\phi) = W\left[\frac{\tan\alpha+\tan\phi}{1-\tan\alpha.\tan\phi}\right]$$

$$= 20\times10^{3}\left[\frac{0.0637+0.08}{1-0.637\times0.08}\right] = 2890\text{N}$$

Torque Required to over come friction at the screw,

$$T = P\times\frac{d}{2} = 2890\times\frac{50\times10^{-3}}{2} = 78.25\text{ N.m}$$

In one complete Revolution of the screwed rod, the load is lifted through a distance equal to pitch.

∴ Number of turns required to lift the load through a distance of 170 mm $= \frac{170}{10} = 17$

(i) When the load rotates with the screw:

Work done in lifting the load,

$W = 2\pi N T = 2\pi \times 17 \times 72.25$

$W = 7718 \text{ N.m}$

Efficiency of the screw Jack,

$$\eta = \frac{\tan\alpha}{\tan(\alpha+\phi)} = \frac{\tan\alpha(1-\tan\alpha\cdot\tan\phi)}{\tan\alpha+\tan\phi}$$

$$= \frac{0.0637(1-0.0637\times0.08)}{0.0637+0.08} = 0.441$$

$\eta = 44.1\%$

(ii) When the load does not rotate with the screw:

Mean Radius of the bearing surface,

$$R = \frac{R_1+R_2}{2} = \frac{30+5}{2} = 17.5 \text{ mm}$$

Torque required to overcome the friction at the screw and the collar,

$$T = P\times\frac{d}{2} + \mu_1 WR$$

$$= 2890 \times \frac{50\times10^{-3}}{2} + 0.08\times2\times10^{3}\times17.5\times10^{-3}$$

$$= 100.25 \text{ N.m}$$

∴ Work done by the torque in lifting the load,

$W = 2\pi NT = 2\pi \times 17 \times 100.25 = 10710 \text{ N.m}$

Torque Required to lift the load, neglecting friction,

$$T_o = P_o \times \frac{d}{2} = W\tan\alpha \times \frac{d}{2}$$

$$= 2\times10^{3}\times0.0637\times\frac{50\times10^{-3}}{2} = 31.85 \text{ N.m}$$

Efficiency of the screw Jack,

$$\eta = \frac{T_o}{T} = \frac{31.85}{100.25} = 0.318 \text{ (or) } 31.8\%$$

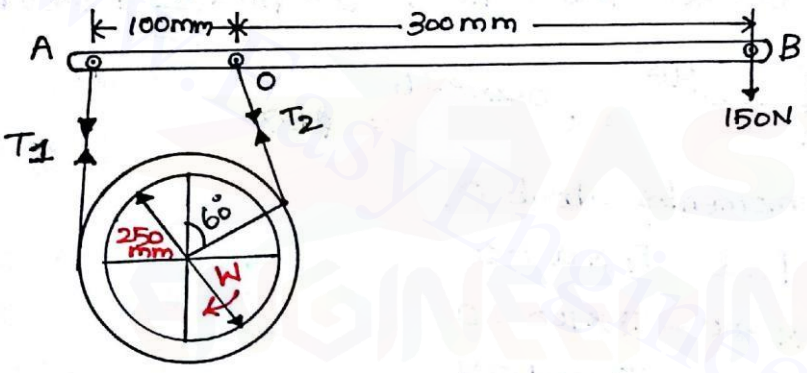
8) (i) Find the power transmitted by a belt running over a pulley 700mm diameter at 300 rpm, $\mu = 0.3$ and angle of lap 160° and maximum tension in the belt is 2.453 KN.

(ii) A simple brake as shown in figure is used on a shaft carrying a flywheel of mass 450 kg. The radius of gyration of the flywheel is 500 mm and runs at 300 rpm. The co-efficient of friction is 0.2 and the diameter of brake drum is 250mm, Determine the following:

(1) Torque applied due to a hand load of 150N.

(2) The number of turns of the wheel before it is brought to rest.

(3) the time required to bring it to rest from the moment of application of the brake. [MAY/JUNE 2013]



Solution:

(i) Given Data:

$d = 700mm = 0.7\ m$; $N = 300$ rpm; $\mu = 0.3$; $\theta = 160° = 2.793$ rad

$T_{max} = 2.453\ KN$

Soln:

velocity of belt, $V = \frac{\pi DN}{60}$

$$V = \frac{\pi \times 0.7 \times 300}{60}$$

$$V = 10.99\ m/s$$

Limiting friction, $\frac{T_{max}}{T_{min}} = e^{\mu\theta}$

$$\frac{2453}{T_{min}} = e^{0.3\times 2.793}$$

$$T_{min} = 1061.21\ N$$

Power Transmitted, $P = (T_1 - T_2) \times V$

$$= (2453 - 1061.2) \times 10.99$$

$$P = 15.303\ KW$$

(ii) Given data:

$m = 450kg$; $\mu = 0.2$; $k = 500mm$; $D = 250mm \Rightarrow r = 125mm$

$N = 320\ rpm$; $a = 100mm$; $\beta = 150°$; $l = 300mm$.

Soln: (1) Brake Torque:

$\theta = 360° - 150° = 210°$, $\theta = 210° \times \frac{\pi}{180} = 3.66\ rad$

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.2\times 3.66} = 2.07$$

Taking moments about O,

$$P \times l - T_1 \times a = 0$$

$$150 \times 300 - T_1 \times 100 = 0$$

$$T_1 = 450\ N$$

$$T_2 = \frac{450}{2.07} = 217.39\ N$$

Brake Torque $= (T_1 - T_2) \times r$

$$= (450 - 217.39) \times 125$$

Brake Torque $= 29\ N.m$

(2) Number of turns:

KE of flywheel $= \frac{1}{2} m k^2 \left(\frac{2\pi N}{60}\right)^2$

$$= \frac{1}{2} \times 450 \times (0.5)^2 \times \left(\frac{2\times\pi\times 320}{60}\right)^2$$

$$= 63,163\ N.m$$

Let the KE be used to overcome the work done by the braking torque in n revolutions.

$T_B \times$ Angular displacement = KE of flywheel

$$2\pi \times 2\pi n = 63,163$$

$$n = 346 \text{ revolutions}$$

(iii) Time Required:

For uniform Retardation, average speed $= \frac{320}{2} = 160$ rpm

$$\text{Time taken} = \frac{n}{N} = \frac{346}{160} = 2.16 \text{ min}$$

$$\text{Time taken} = 2.16 \times 60 = 129.6 \text{ s}$$

3) Two pulleys, one 450 mm diameter and the other 200mm diameter are in parallel shafts 1.95 m apart and are connected by a crossed belt. Find the length of the belt required and the angle of contact between the belt and each pulley. What Power can be transmitted by the belt when the larger pulley rotates at 200 rpm, if the maximum permissible tension in the belt is 1 kN and the co-efficient of friction between the belt and pulley is 0.25? [MAY/JUNE 2014]

Given data:

$D = 450$mm; $R = 225$mm; $d = 200$mm; $r = 100$mm; $C = 1.95$m;

$N = 200$ rpm; $T_1 = 1000$N; $\mu = 0.25$.

Solution: Angle of contact:

$$\beta = \sin^{-1}\left(\frac{R+r}{C}\right) = \sin^{-1}\left(\frac{0.225+0.1}{1.95}\right)$$

$$\beta = 9.59^\circ \text{ (or) } 0.1674 \text{ rad}$$

$$\cos\beta = 0.986$$

Length of belt:

$$L_C = (\pi + 2\beta)(R+r) + 2C\cos\beta$$

$$L_C = (\pi + 2 \times 0.1674)(0.225+0.1) + 2 \times 1.95 \times 0.986$$

$$L_C = 4.97 \text{m}$$

Power Transmitted:

$$V = \frac{\pi DN}{60} = \frac{\pi \times 0.45 \times 200}{60}$$

$$V = 4.71 \text{ m/s}$$

$$\theta = \pi + 2\beta = \pi + 2 \sin^{-1}\left(\frac{R+r}{C}\right)$$

$$= \pi + 2 \times 0.1674$$

$$\theta = 3.476 \text{ rad}$$

$$\frac{T_1}{T_2} = e^{\mu\theta} \quad ; \quad \frac{T_1}{T_2} = e^{0.25 \times 3.476}$$

$$\frac{T_1}{T_2} = 2.384 \quad ; \quad T_1 = 2.384\, T_2$$

$$1000 = 2.384\, T_2$$

$$T_2 = 419.46 \text{ N}$$

$$\text{Power} = (T_1 - T_2) \times V = (1000 - 419.46) \times 4.71$$

$$P = 2734 \text{ W} = 2.734 \text{ KW}$$

4) Determine the maximum power that can be transmitted using a belt of 100mm x 10mm with an angle of lap of 160°. The density of the belt is 1000 kg/m³ and the co-efficient of friction may taken as 0.25. The tension in the belt should not exceed 1.5 N/mm². [NOV/DEC 2015].

Given data:

Area = 100mm x 10mm = 1×10^{-3} m²; $\rho = 1000$ kg/m³

$\theta = 160°$; $\mu = 0.25$; $\sigma = 1.5$ N/mm² = 1.5×10^6 N/m².

Solution:

Mass of belt per metre length = Area x length x density

$= 1 \times 10^{-3} \times 1 \times 1000$

$= 1$ kg

Maximum tension in the belt:

$$= \sigma \cdot b \cdot t$$

$$= 1.5 \times 10^6 \times 0.1 \times 0.01$$

$$T = 1500 N$$

Under maximum power conditions,

$$T_1 = \frac{2}{3} T = \frac{2}{3} \times 1500$$

$$T_1 = 1000 N$$

$$T_c = T - T_1 = 1500 - 1000 = 500 N$$

$$T_c = mV^2 ; \quad 500 = 1 \times V^2$$

$$V = 22.36 m/s$$

$$\frac{T_1}{T_2} = e^{\mu\theta} ; \quad \frac{T_1}{T_2} = e^{0.25 \times (165 \times \frac{\pi}{180})}$$

$$\frac{T_1}{T_2} = 2.05 ; \quad T_1 = 2.05\, T_2$$

$$T_2 = \frac{1000}{2.05} = 486.77 N$$

Maximum Power Transmitted:

$$P = (T_1 - T_2) \times V$$

$$= (1000 - 486.77) \times 22.36$$

$$P = 11,475 W = 11.475 KW$$

5) A Multiplate clutch has three pairs of contact surfaces. The Outer and inner radii of the contact surfaces are 100mm and 50mm respectively. The maximum axial spring force is limited to 1 KN. If the co-efficient of friction is 0.35 and assuming uniform wear, find the power transmitted by the clutch at 1500 rpm. [APR/MAY 2015]

Solution:

Given data:

$n = 3$; $r_1 = 100\ mm$; $r_2 = 50mm = 0.05m$; $W = 1kN = 1000N$;

$N = 1500\ rpm$; $\mu = 0.35$.

For Uniform Wear,

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

$$= \frac{1}{2} \times 3 \times 0.35 \times 1000 (0.1 + 0.05)$$

$$= 78.75\ Nm$$

$$\text{Power Transmitted}, P = \frac{2\pi NT}{60} = \frac{2\pi \times 1500 \times 78.75}{60}$$

$$P = 12.37\ kW$$

b) The external and Internal radii of a friction plate of a single clutch are 120mm and 60mm respectively. the total axial thrust with which the friction surfaces are held together is 1500N. For Uniform Wear, find the maximum, minimum and average pressure on the contact surfaces. [NOV/DEC 2015]

Given data:

$r_1 = 180\ mm$; $r_2 = 60mm = 0.06m$; $W = 1500N$.

Solution:

Maximum Pressure:

Intensity of pressure is maximum at the inner radius (r_2)

$$p_{max} \times r_2 = C\ ;\ C = 0.06\ p_{max}$$

Axial Force exerted on the contact surface

$$W = 2\pi C (r_1 - r_2)$$

$$W = 2 \times \pi \times 0.06\ p_{max} (0.12 - 0.06)$$

$$W = 0.0226\ p_{max}\ ;\ 1500 = 0.0226\ p_{max}$$

$$p_{max} = 66.314\ KN/m^2$$

Minimum pressure:

Intensity of pressure is minimum at outer radius(r_1)

$$p_{min} \times r_1 = C$$

$$C = 0.1\, p_{min}$$

Axial Force exerted on the contact surface

$$W = 2\pi C (r_1 - r_2)$$

$$1500 = 2\pi \times 0.1\, p_{min} (0.1 - 0.06)$$

$$p_{min} = 33.157 \text{ KN/m}^2$$

Average Pressure:

$$p_{av} = \frac{\text{Total normal force on contact surfaces}}{\text{Cross-sectional area of contact surfaces}}$$

$$= \frac{W}{\pi [r_1^2 - r_2^2]}$$

$$= \frac{1500}{\pi [0.1^2 - 0.06^2]}$$

$$p_{av} = 44.21 \text{ KN/m}^2.$$

PART-C

1. Following data is given for a rope pulley transmitting 24 kW: Diameter of pulley = 400mm, speed = 110rpm, Angle of groove=45°, Angle of lap on smaller pulley= 160°, Coefficient of friction = 0.28, Number of ropes = 10, Mass in kg/m length of the rope = $53C^2$, and working tension is limited to $122C^2$ kN, where C is girth of rope in meters. Find initial tension and diameter of the each rope. (16)

Solution. Given : $P_T = 24$ kW ; $d = 400$ mm $= 0.4$ m ; $N = 110$ r.p.m. ; $2\beta = 45°$ or $\beta = 22.5°$; $\theta = 160° = 160 \times \pi / 180 = 2.8$ rad ; $n = 0.28$; $n = 10$; $m = 53\ C^2$ kg/m ; $T = 122\ C^2$ kN $= 122 \times 10^3\ C^2$ N

Initial tension

We know that power transmitted per rope,

$$P = \frac{\text{Total power transmitted}}{\text{No. of ropes}} = \frac{P_T}{n} = \frac{24}{10} = 2.4 \text{ kW} = 2400 \text{ W}$$

and velocity of the rope, $$v = \frac{\pi d . N}{60} = \frac{\pi \times 0.4 \times 110}{60} = 2.3 \text{ m/s}$$

Let T = Tension in the tight side of the rope, and

T_2 = Tension in the slack side of the rope.

We know that power transmitted per rope (P)

$$2400 = (T_1 - T_2)\ v = (T_1 - T_2)\ 2.3$$

$$\therefore \quad T_1 - T_2 = 2400 / 2.3 = 1043.5 \text{ N} \qquad ...(i)$$

We know that

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu . \theta \operatorname{cosec} \beta = 0.28 \times 2.8 \times \operatorname{cosec} 22.5° = 2.05$$

$$\log\left(\frac{T_1}{T_2}\right) = \frac{2.05}{2.3} = 0.8913 \quad \text{or} \quad \frac{T_1}{T_2} = 7.786 \qquad ...(ii)$$

...(Taking antilog of 0.8913)

From equations (i) and (ii),

$$T_1 = 1197.3 \text{ N, and } T_2 = 153.8 \text{ N}$$

We know that initial tension in each rope,

$$T_0 = \frac{T_1 + T_2}{2} = \frac{1197.3 + 153.8}{2} = 675.55 \text{ N} \quad \text{Ans.}$$

Diameter of each rope

Let d_1 = Diameter of each rope,

We know that centrifugal tension,

$$T_C = m . v^2 = 53\ C^2\ (2.3)^2 = 280.4\ C^2 \text{ N}$$

and working tension (T),

$$122 \times 10^3\ C^2 = T_1 + T_C = 1197.3 + 280.4\ C^2$$

$$122 \times 10^3\ C^2 - 280.4\ C^2 = 1197.3$$

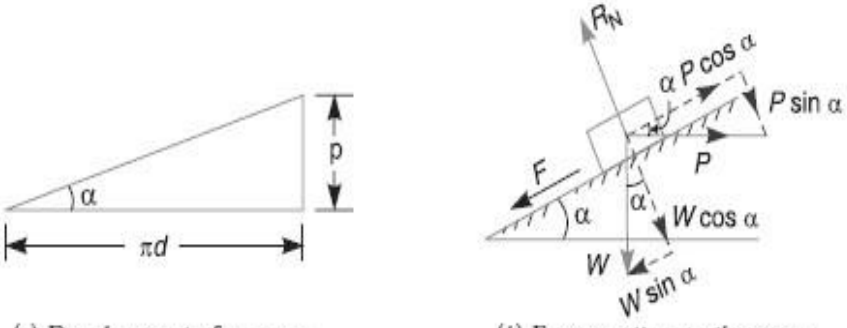
$$\therefore \quad C^2 = 9.836 \times 10^{-3} \text{ or } C = 0.0992 \text{ m} = 99.2 \text{ mm}$$

We know that girth (*i.e.* circumference) of rope (C),

$$99.2 = \pi d_1 \text{ or } d_1 = 99.2 / \pi = 31.57 \text{ mm Ans.}$$

2. Derive an expression for the effort required to raise a load with screw jacking friction into consideration. (MAY/JUNE 2014)

If one complete turn of a screw thread by imagined to be unwound, from the body of the screw and developed, it will form an inclined plane as shown in Fig.(*a*).



(*a*) Development of a screw. (*b*) Forces acting on the screw.

Let p = Pitch of the screw,

d = Mean diameter of the screw,

α = Helix angle,

P = Effort applied at the circumference of the screw to lift the load,

W = Load to be lifted, and

μ = Coefficient of friction, between the screw and nut = tan ϕ, where ϕ is the friction angle.

From the geometry of the Fig. (*a*), we find that

$$\tan \alpha = p/\pi d$$

Since the principle on which a screw jack works is similar to that of an inclined plane, therefore the force applied on the lever of a screw jack may be considered to be horizontal as shown in Fig. (*b*). Since the load is being lifted, therefore the force of friction ($F = \mu.R_N$) will act downwards. All the forces acting on the screw are shown in Fig. (*b*).

Resolving the forces along the plane,

$$P\cos\alpha = W\sin\alpha + F = W\sin\alpha + \mu.R_N \quad \ldots(i)$$

and resolving the forces perpendicular to the plane,

$$R_N = P\sin\alpha + W\cos\alpha \quad \ldots(ii)$$

Substituting this value of R_N in equation (*i*),

$$P\cos\alpha = W\sin\alpha + \mu\,(P\sin\alpha + W\cos\alpha)$$

$$= W\sin\alpha + \mu\,P\sin\alpha + \mu\,W\cos\alpha$$

or $$P\cos\alpha - \mu\,P\sin\alpha = W\sin\alpha + \mu\,W\cos\alpha$$

or $$P\,(\cos\alpha - \mu\sin\alpha) = W\,(\sin\alpha + \mu\cos\alpha)$$

$$\therefore \quad P = W \times \frac{\sin \alpha + \mu \cos \alpha}{\cos \alpha - \mu \sin \alpha}$$

Substituting the value of $\mu = \tan \phi$ in the above equation, we get

$$P = W \times \frac{\sin \alpha + \tan \phi \cos \alpha}{\cos \alpha - \tan \phi \sin \alpha}$$

Multiplying the numerator and denominator by $\cos \phi$,

$$P = W \times \frac{\sin \alpha \cos \phi + \sin \phi \cos \alpha}{\cos \alpha \cos \phi - \sin \alpha \sin \phi} = W \times \frac{\sin (\alpha + \phi)}{\cos (\alpha + \phi)}$$

$$= W \tan (\alpha + \phi)$$

$\therefore$ Torque required to overcome friction between the screw and nut,

$$T_1 = P \times \frac{d}{2} = W \tan (\alpha + \phi) \frac{d}{2}$$

When the axial load is taken up by a thrust collar or a flat surface, as shown in Fig. 10.11 (*b*), so that the load does not rotate with the screw, then the torque required to overcome friction at the collar,

$$T_2 = \mu_1 . W \left(\frac{R_1 + R_2}{2} \right) = \mu_1 . W . R$$

where R_1 and R_2 = Outside and inside radii of the collar,

R = Mean radius of the collar, and

μ_1 = Coefficient of friction for the collar.

$\therefore$ Total torque required to overcome friction (*i.e.* to rotate the screw),

$$T = T_1 + T_2 = P \times \frac{d}{2} + \mu_1 . W . R$$

If an effort P_1 is applied at the end of a lever of arm length l, then the total torque required to overcome friction must be equal to the torque applied at the end of the lever, *i.e.*

$$T = P \times \frac{d}{2} = P_1 . l$$

Notes : 1. When the *nominal diameter (d_0) and the **core diameter (d_c) of the screw thread is given, then the mean diameter of the screw,

$$d = \frac{d_0 + d_c}{2} = d_0 - \frac{p}{2} = d_c + \frac{p}{2}$$

2. Since the mechanical advantage is the ratio of load lifted (W) to the effort applied (P_1) at the end of the lever, therefore mechanical advantage,

$$M.A. = \frac{W}{P_1} = \frac{W \times 2l}{p.d} \qquad \ldots \left(\because P_1 = \frac{P.d}{2l} \right)$$

$$= \frac{W \times 2l}{W \tan (\alpha + \phi) d} = \frac{2l}{d . \tan (\alpha + \phi)}$$

UNIVERSITY QUESTION BANK

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 77212

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Fourth Semester

Mechanical Engineering

ME 6401 — KINEMATICS OF MACHINERY

(Common to Third Semester Mechanical Engineering (Sandwich), Mechatronics Engineering)

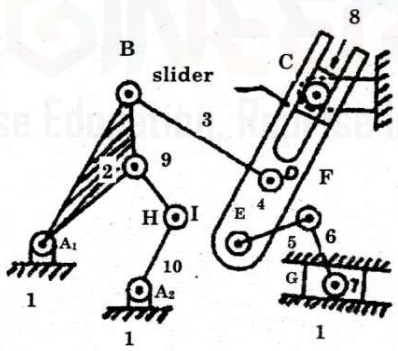
(Regulation 2013)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Determine the number of freedom of the mechanism shown in the figure below :



2. Write a short note on complete and incomplete constraints in lower and higher pairs, depict your answer with neat sketches.
3. Write the relation between the number of instantaneous centres and the number of links in a mechanism.
4. Depict all the directions of Coriolis component of acceleration that arise in a completed cycle of quick return motion of the crank mechanism.
5. Draw the displacement, velocity and acceleration diagrams for a follower when it moves with simple harmonic motion.
6. Why a roller follower is preferred to that of a knife-edged follower?
7. What do you understand by the term 'interference' as applied to gears?
8. What are the special advantages of epicyclic gear trains?

9. What is centrifugal tension in a belt? How does it affect the power transmitted?

10. Distinguish between brakes and dynamometers.

PART B — (5 × 16 = 80 marks)

11. (a) What do you understand by inversion of a kinematic chain? Describe the mechanisms obtained by inversion of the four-bar chain. (16)

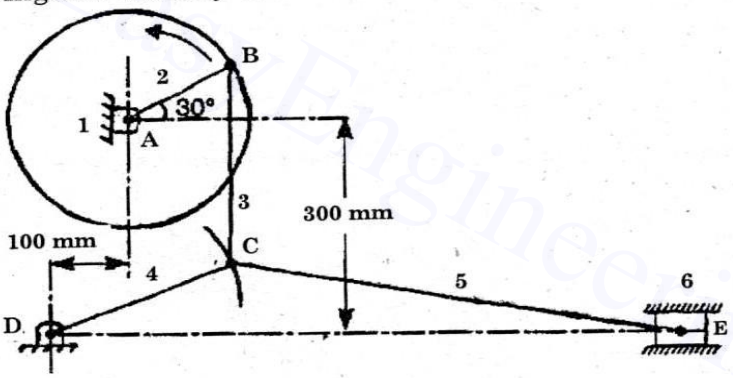
Or

(b) Sketch and describe the working of two different types of quick return mechanisms. Give examples of their applications. Derive an expression for the ratio of times taken in forward and return stroke for one of these mechanisms. (16)

12. (a) Locate all the instantaneous centres of the mechanism as shown in Fig. shown below. The lengths of various links are: AB = 150 mm ; BC = 300 mm ; CD = 225 mm ; and CE = 500 mm. When the crank AB rotates in the anticlockwise direction at a uniform speed of 240 r.p.m. Find

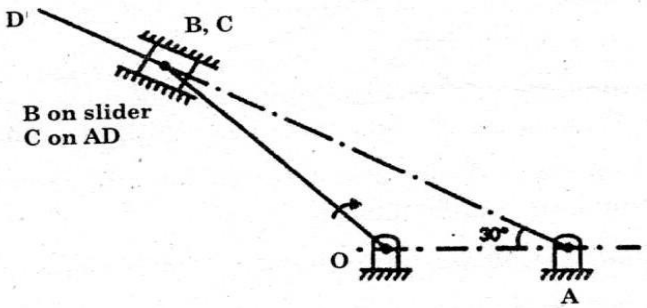
(i) Velocity of the slider E, and

(ii) Angular velocity of the links BC and CE. (16)



Or

(b) A single cylinder rotary engine is shown below. OA is the fixed link, 200 mm long. OB is the connecting rod and is 520 mm long. The line of stroke is along AD and at the instant is inclined at 30° to the vertical. The body of the engine consisting of cylinders rotates at a uniform speed of 400 rpm about fixed centre A. Determine the acceleration of slider B and angular acceleration of connecting rod. (16)



13. (a) The following particulars relate to a symmetrical circular cam operating a flat faced follower :

Least radius = 16 mm, nose radius = 3.2 mm, distance between cam shaft centre and nose centre = 25 mm, angle of action of cam = 150°, and cam shaft speed = 600 r.p.m.

Assuming that there is no dwell between ascent or descent, determine the lift of the valve, the flank radius and the acceleration and retardation of the follower at a point where circular nose merges into Circular flank. (16)

Or

(b) A cam with 30 mm as minimum diameter is rotating clockwise at a uniform speed of 1200 r.p.m. and has to give the following motion to a roller follower 10 mm in diameter :

(i) Follower to complete outward stroke of 25 mm during 120° of cam rotation with equal uniform acceleration and retardation;

(ii) Follower to dwell for 60° of cam rotation;

(iii) Follower to return to its initial position during 90° of cam rotation with equal uniform acceleration and retardation;

(iv) Follower to dwell for the remaining 90° of cam rotation.

Draw the cam profile if the axis of the roller follower passes through the axis of the cam. Determine the maximum velocity of the follower during the outstroke and return stroke and also the uniform acceleration of the follower on the out stroke and the return stoke. (16)

14. (a) Calculate :

(i) Length of path of contact

(ii) Arc of contact and

(iii) The contact ratio when a pinion having 23 teeth drives a gear having teeth 57. The profile of the gears is involute with pressure angle 20°, module 8mm and addendum equal to one module. (16)

Or

(b) In an epicyclic gear train a gear C is keyed to the driving shaft A which rotates at 900 rpm. Gears D and E are fixed together and rotate freely on a pin carried by the arm M which is keyed to the driven shaft B. Gear D is in mesh with gear C while the gear E is in mesh with a fixed annular wheel F. The annular wheel is concentric with the driven shaft B. if the shafts A and B are collinear and number of teeth on gears C, D, E and F are respectively 21, 28, 14 and 84. Determine the speed and sense of rotation of the driven shaft B. (16)

15. (a) A flat belt, 8 mm thick and 100 mm wide transmits power between two pulleys, running at 1600 m/min. The mass of the belt is 0.9 kg/m length. The angle of lap in the smaller pulley is 165° and the coefficient of friction between the belt and pulley is 0.3. If the maximum permissible stress in the belt is 2 MN/m^2,

Find :

(i) Maximum power transmitted; and

(ii) Initial tension in the belt. (16)

Or

(b) The spindle of a screw jack has single start square threads with an outside diameter of 45 mm and a pitch of 10 mm. The spindle moves in a fixed nut. The load is carried on a swivel head but is not free to rotate. The bearing surface of the swivel head has a mean diameter of 60 mm. The coefficient of friction between the nut and screw is 0.12 and that between the swivel head and the spindle is 0.10. Calculate the load which can be raised by efforts of 100 N each applied at the end of two levers each of effective length of 350 mm. Also determine the velocity ratio and the efficiency of the lifting arrangement. (16)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 27357

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Fourth Semester

Mechanical Engineering

ME 6401 — KINEMATICS OF MACHINERY

(Common to Third Semester Mechanical Engineering (Sandwich), Mechatronics Engineering)

(Regulations 2013)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define Grubler's criteria for a mechanism.

2. Name any two inversions of the 4-bar chain.

3. What is the total number of instantaneous centers that are possible for a mechanism consisting 'n' links?

4. Name the mechanism in which Corolis component of acceleration is taken into account.

5. Define the following with respect to cam and follower mechanism

   (a) Pressure angle

   (b) Pitch circle.

6. State the reasons for providing offset in a cam follower mechanism.

7. State the law of gearing.

8. How is the epicyclic gear train works?

9. Write the mathematical expression for the maximum efficiency of a screw jack.

10. Write mathematical expression for the length of the belt required for two pulleys of diameters d_1 and d_2 and at distance x apart are connected by means of an open belt drive.

PART B — (5 × 16 = 80 marks)

11. (a) Describe with neat sketch, the mechanisms obtained by the inversions of 4-bar chain. (16)

Or

(b) In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240 mm and the length of the driving crank is 120 mm. Find the inclination of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke.

If the length of the slotted bar is 450 mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever. (16)

12. (a) In a four bar chain ABCD, AD is fixed and is 15 cm long. The crank AB is 4 cm long and rotates at 120 rpm clockwise, while the link CD (whose length is 8 cm) oscillates about D. BC and AD are of equal length. Find the angular velocity of link CD when angle BAD = 60°. (16)

Or

(b) The crank of a slider crank mechanism is 15 cm and the connecting rod is 60 cm long. The crank makes 300 rpm in the clockwise direction. When it has turned 45° from the inner dead centre position, determine (i) acceleration of the mid-point of the connecting rod and (ii) angular acceleration of the connecting rod. (16)

13. (a) Draw the profile of a cam operating a knife-edge follower when the axis of the follower passes through the axis of cam shaft from the following data:

(i) Follower to move outwards through 40 mm during 60° of cam rotation,

(ii) Follower to dwell for the next 45°,

(iii) Follower to return to its original position during next 90°,

(iv) Follower to dwell for the rest of the cam rotation.

The displacement of the follower is to take place with simple harmonic motion during both the outward and return strokes. The least radius of cam is 50 mm. (16)

Or

(b) Draw the profile of a cam operating a knife-edge follower (when the axis of the follower passes through the axis of cam shaft) from the following data:

(i) Follower to move outward through 30 mm with Simple Harmonic motion during 120° of cam rotation,

(ii) Follower to dwell for the next 60°,

(iii) Follower to return to its original position with uniform velocity during 90° of cam rotation

(iv) Follower to dwell for the rest of the cam rotation. The least radius of cam is 20 mm and the cam rotates at 240 rpm. (16)

14. (a) Calculate (i) the length of path of contact, (ii) arc of contact and (iii) the contact ratio when a pinion having 23 teeth drives a gear having teeth 57. The profile of the gears is involute with pressure angle 20°, module 8 mm and addendum equal to one module.

Or

(b) The arm of an epicyclic gear train rotates at 100 rpm in the anti-clockwise direction. The arm carries two wheels A and B having 36 and 45 teeth respectively. The wheel A is fixed and the arm rotates about the centre of wheel A. Find the speed of wheel B. What will be the speed of B, if the wheel A instead of being fixed, makes 200 rpm clockwise. (16)

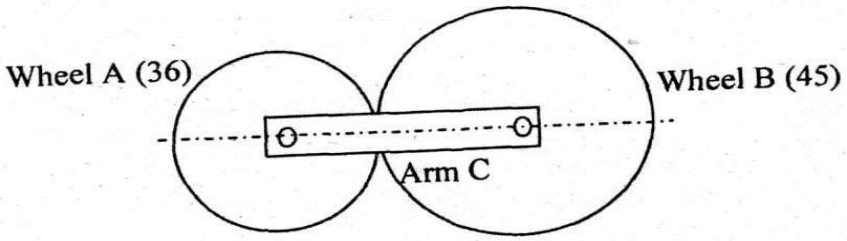


Fig 14(b)

15. (a) The external and internal radii of a friction plate of a single clutch are 120 mm and 60 mm respectively. The total axial thrust with which the friction surfaces are held together is 1500 N. For uniform wear, find the maximum, minimum and average pressure on the contact surfaces. (16)

Or

(b) Determine the maximum power that can be transmitted using a belt of 100 mm × 10 mm with an angle of lap of 160°. The density of the belt is 1000 kg/m^3 and the co-efficient of friction may taken as 0.25. The tension in the belt should not exceed 1.5 N/mm^2. (16)

Reg. No. | | | | | | | | | | | | |

Question Paper Code : 57547

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

Fourth Semester

Mechanical Engineering

ME 6401 – KINEMATICS OF MACHINERY

(Common to Third Semester Mechanical Engineering (Sandwich), Mechatronics Engineering)

(Regulations 2013)

Time : Three Hours **Maximum : 100 Marks**

Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

1. Classify kinematic pairs based on nature of contact. Give examples.
2. When a linkage becomes mechanism ?
3. What is a relative pole, with respect to velocity analysis ?
4. What are the different methods used for finding the velocity ?
5. Define trace point of a cam.
6. Define tangent cam.
7. Define normal and axial pitch in helical gears.
8. What is the advantage when arc of recess is equal to arc of approach in meshing gears ?
9. What are self energizing brakes ?
10. Why self locking screws have lesser efficiency ?

PART – B (5 × 16 = 80 Marks)

11. (a) (i) Classify kinematic pairs based on degrees of freedom. **(10)**

(ii) What is inversion and list its properties. **(2 + 4)**

OR

(b) (i) Find the degrees of freedom of the mechanisms shownin fig. 11 (b). **(10)**

(ii) State the inconsistancies of Grubler's criterion. **(6)**

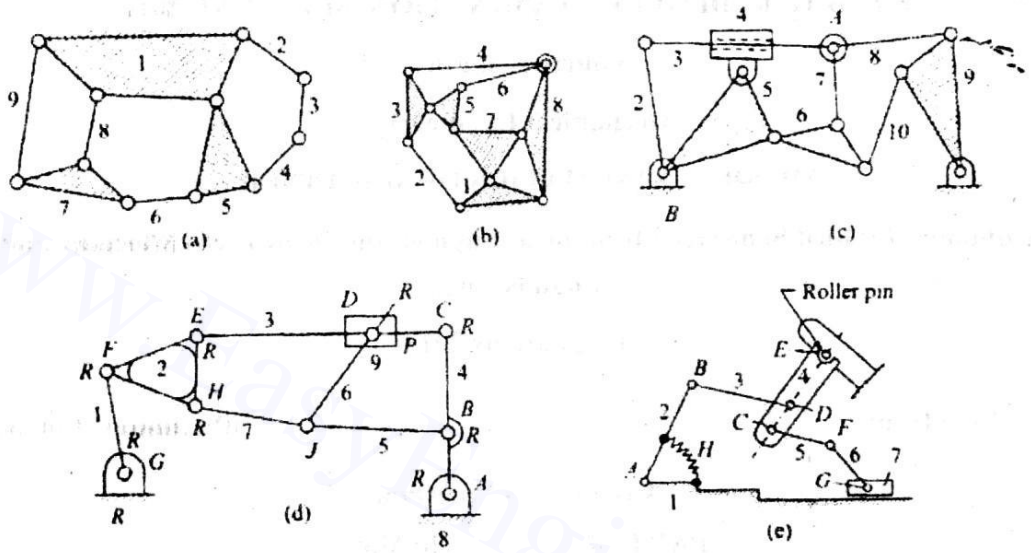


Fig 11 (b)

12. (a)

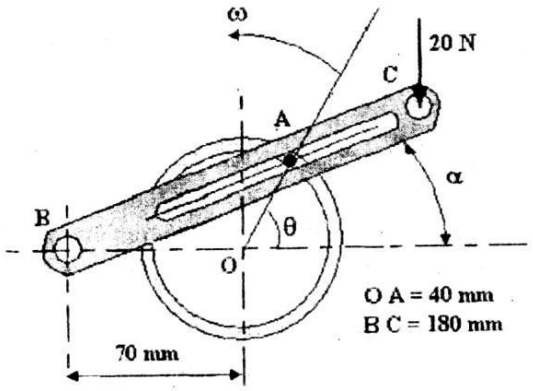


Figure 12 (a)

The diagram shows part of a quick return mechanism. The pin A slides in the slot when the disc is rotated. Calculate the angular velocity and acceleration of link BC when θ = 60° and ω = 100 rad/s. **(16)**

OR

(b) Derive the expression for Coriolis component of acceleration with neat sketch and give its direction for various conditions. **(16)**

13. (a) (i) Draw the displacement, velocity and acceleration curves, when the follower moves with simple harmonic motion and derive the expression for maximum velocity and maximum acceleration. **(10)**

(ii) Depict the types of cams. **(6)**

OR

(b) Follower type = roller follower, lift = 25 mm; base circle radius = 20 mm; roller radius = 5 mm; out stroke with UARM, for 120° cam rotation; dwell for 60° cam rotation; return stroke with UARM, for 90° cam rotation; dwell for the remaining period. Determine max. velocity and acceleration during out stroke and return stroke if the cam rotates at 1200 rpm in counter clockwise direction.

Draw the cam profile for conditions with follower off set to right of cam center by 5 mm. **(16)**

14. (a) The cutter of a broaching machine is pulled by square threaded screw of 55 mm external diameter and 10 mm pitch. The operating nut takes the axial load of 400 N on a flat surface of 60 mm internal diameter and 90 mm external diameter. If the coefficient of friction is 0.15 for all contact surfaces on the nut, determine the power required to rotate the operating nut, when the cutting speed is 6 m/min. **(16)**

OR

(b) Following data is given for a rope pulley transmitting 23.628 kW.

Dia of pulley = 40 cm; speed = 110 rpm, angle of groove = 45°; angle of lap = 60°, co efficient of friction = 0.28, No. of ropes = 10. Mass in kg/m length of ropes = $0.0053 \times C^2$ and working tension is limited $12.2\ C^2$ N where C = girth of rope in cm. Find (i) initial tension, and (ii) diameter of each rope. **(16)**

15. (a) Explain gear nomenclature with neat diagram and define all salient terms pertaining to the gear. **(16)**

OR

(b) Fig. shows a differential gear used in a motor car. The pinion A on the propeller shaft has 12 teeth and gears with the crown gear B which has 60 teeth. The shafts P and Q form the rear axles to which the road wheels are attached. If the propeller shaft rotates at 1000 r.p.m. and the road wheel attached to axle Q has a speed of 210 r.p.m. while taking a turn, find the speed of road wheel attached to axle P. **(16)**

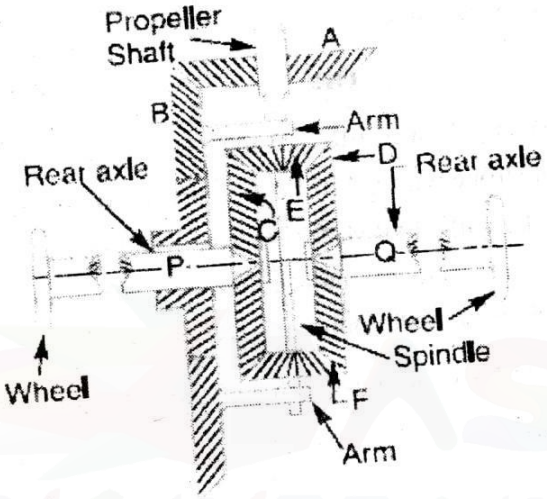


Fig. 15 (b)

575

4

Reg. No. | | | | | | | | | | | |

Question Paper Code : 51846

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

Third Semester

Mechanical Engineering

ME 2203/ME 35/ME 1202 A/080120010/10122/ME 404 – KINEMATICS OF MACHINERY

(Regulations 2008/2010)

(Common to PTME 2203/10122 ME 404 – Kinematics of Machinery for B.E. (Part-Time) Third/Fourth Semester Mechanical Engineering – Regulations 2009/2010)

Time : Three Hours **Maximum : 100 Marks**

Note : A3 drawing sheet is to be supplied to all students.

Answer ALL questions.

PART – A (10 × 2 = 20 Marks)

1. How to determine the given assemblage of links forms the kinematic chain or not ?
2. What is meant by motion adjustment mechanism?
3. Difference between radial component of acceleration and tangential component of acceleration.
4. How are velocity and acceleration of the slider of a single slider crank chain determined analytically ?
5. Differentiate roller and mushroom follower of a cam.
6. What is the maximum acceleration of a follower moving with simple harmonic motion ?

7. What is meant by arc of approach, arc of recess and arc of contact ?

8. How epicyclic gear train differs from the other types of gear trains ?

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

10. What is the condition for transmission of optimum or maximum power in belt drive ?

Part – B (5 × 16 = 80 Marks)

11. (a) (i) Show that the locus of the mid-point of the link connecting the two sliders in an elliptical trammel is a circle. **(8)**

(ii) Explain mechanical advantage and transmission angle related to four- bar mechanisms. **(8)**

OR

(b) (i) The distance between two parallel shafts is 15 mm and they are connected by an Oldham's coupling. The driving shaft revolves at 150 r.p.m, what will be the maximum speed of sliding of the tongue of the intermediate piece along its groove ? **(8)**

(ii) With neat sketches explain any two straight line generator mechanisms. **(8)**

12. (a) In figure, the angular velocity of the crank OA is 600 r.p.m. Determine the linear velocity of the slider D and the angular velocity of the link BD, when the crank is inclined at an angle of 75° to the vertical. The dimensions of various links are: OA = 28 mm; AB = 44 mm; BC = 49 mm; and BD = 46 mm. The centre distance between the centres of rotation O and C is 65 mm. The path of travel of the slider is 11 mm below the fixed point C. The slider moves along a horizontal path and OC is vertical. (Refer fig. 12(a)) **(16)**

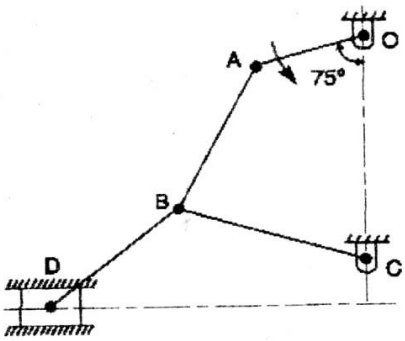


Fig. 12 (a)

OR

(b) In a mechanism shown in figure, the crank OA is 100 mm long and rotates clockwise about O at 120 r.p.m. The connecting rod AB is 400 mm long. At a point C on AB, 150 mm from A, the rod CE 350 mm long is attached. This rod CE slides in a slot in a trunnion at D. The end E is connected by a link EF, 300 mm long to the horizontally moving slider F. For the mechanism in the position shown. find : (Refer fig. 12(b)) **(16)**

(1) Velocity of F,

(2) Velocity of sliding of CE in the trunnion, and

(3) Angular velocity of CE.

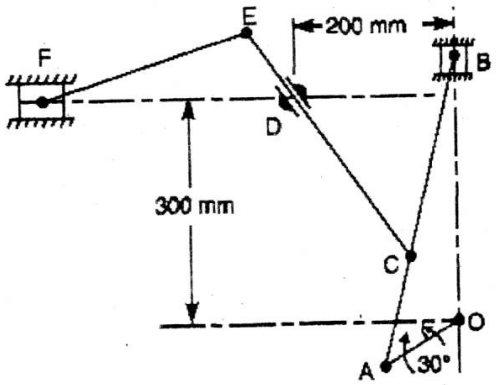


Fig. 12 (b)

13. (a) A cam with 30 mm as minimum diameter is rotating clockwise at a uniform speed of 1200 r.p.m. and has to give the following motion to a follower 10 mm in diameter :

(i) Follower to complete outward stroke of 25 mm during 120° of cam rotation with equal uniform acceleration and retardation;

(ii) Follower to dwell for 60° of cam rotation;

(iii) Follower to return to its initial position during 90° of cam rotation with equal uniform acceleration and retardation;

(iv) Follower to dwell for the remaining 90° of cam rotation.

Draw the cam profile if the axis of the roller follower passes through the axis of the cam. Determine the maximum velocity of the follower during the outstroke and return stroke and also the uniform acceleration of the follower on the out stroke and the return stroke. **(16)**

OR

(b) The following particulars relate to a symmetrical circular cam operating a flat faced follower : Least radius = 16 mm, nose radius = 3.2 mm, distance between cam shaft centre and nose centre = 25 mm, angle of action of cam = 150°, and cam shafts speed = 600 r.p.m. Assuming that there is no dwell between ascent or descent, determine the lift of the valve, the flank radius and the acceleration and retardation of the follower at a point where circular nose merges into circular flank. **(16)**

14. (a) The following data relate to a pair of 20° involute gears in mesh :
Module = 6 mm, Number of teeth on pinion = 17, Number of teeth on gear = 49;
Addenda on pinion and gear wheel = 1 module. Find :

1. The number of pair of teeth in contact;
2. The angle turned through by the pinion and the gear wheel when one pair of teeth is in contact, and
3. The ratio of sliding to rolling motion when the tip of a tooth on the larger wheel,
   (i) is just making contact,
   (ii) is just leaving contact with its mating tooth, and
   (iii) Is at the pitch point. **(16)**

OR

(b) In a gear train, as shown in figure, gear B is connected to the input shaft and gear F is connected to the output shaft. The arm A carrying the compound wheels D and E, turns freely on the output shaft. If the input speed is 1000 r.p.m. counter- clockwise when seen from the right, determine the speed of the output shaft under the following conditions : (1) When gear C is fixed, and (2) When gear C is rotated at 10 r.p.m. counter clockwise. (Refer fig. 14(b) **(16)**

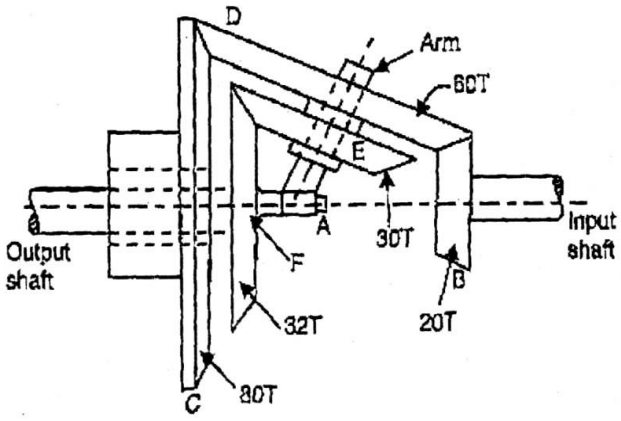


Fig. 14 (b)

15. (a) (i) The pitch of 50 mm mean diameter threaded screw of a screw jack is 12.5 mm. The coefficient of friction between the screw and the nut is 0.13. Determine the torque required on the screw to raise a load of 25 kN, assuming the load to rotate with the screw. Determine the ratio of the torque required to raise the load to the torque required to lower the load and also the efficiency of the machine. **(8)**

(ii) A leather faced conical clutch has a cone angle of 30°. If the intensity of pressure between the contact surfaces is limited to 0.35 × N/mm^2 and the breadth of the conical surface is not to exceed one-third of the mean radius, find the dimensions of the contact surfaces to transmit 22.5 kW at 2000 r.p.m. Assume uniform rate of wear and take coefficient of friction as 0.15. **(8)**

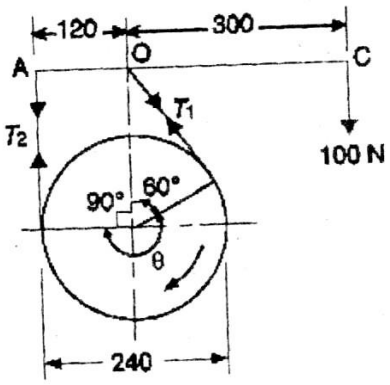
OR

(b) The simple band brake, as shown in figure, is applied to a shaft carrying a flywheel of mass 400 kg. The radius of gyration of the flywheel is 450 mm and runs at 300 r.p.m. If the coefficient of friction is 0.2 and the brake drum diameter is 240 mm, find :

(1) The torque applied due to a hand load of 100 N,

(2) The number of turns of the wheel before it is brought to rest, and

(3) The time required to bring it to rest, from the moment of the application of the brake. (Refer fig. 15(b)) **(16)**



All dimensions in mm

Fig. 15 (b)

Question Paper Code : 71846

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Third Semester

Mechanical Engineering

ME 2203/ME 35/ ME 1202 A/080120010/ 10122 ME 404 — KINEMATICS OF MACHINERY

(Regulation 2008/2010)

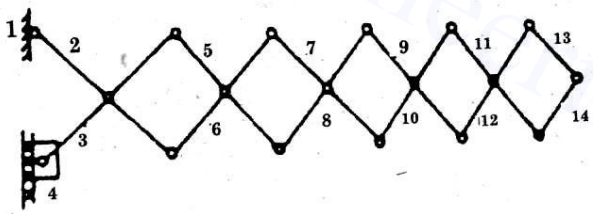
(Common to PTME 2203/ 10122 ME 404 — Kinematics of Machinery for B.E. (Part-Time) Third /Fourth Semester Mechanical Engineering – Regulation 2009/2010)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Determine the number of freedom of the mechanism shown in the figure below:



2. What is the significance of degrees of freedom of a kinematic chain when it functions as a mechanism? Give examples.

3. Explain how the acceleration of a point on a link (whose direction is known) is obtained when the acceleration of some other point on the same link is given in magnitude and direction.

4. Explain how the coriolis component of acceleration arises when a point is rotating about some other fixed point and at the same time its distance from the fixed point varies.

5. Draw the displacement, velocity and acceleration diagrams for a follower when it moves with Cycloidal motion.

6. Which of the displacement diagrams in respect of follower motion should be chosen for better dynamic performance of a cam-follower mechanism?

7. What do you understand by the term 'interference' as applied to gears?

8. In a clock mechanism, what type of gear train used to connect minute hand to hour hand?

9. Which of the two assumptions-uniform intensity of pressure or uniform rate of wear, would you make use of in designing friction clutch and why?

10. Distinguish between brakes and dynamometers.

PART B — (5 × 16 = 80 marks)

11. (a) What is known as kinematic inversion? Sketch and explain the various inversions of a slider crank chain, also stating the actual machines in which these are used in practice. (16)

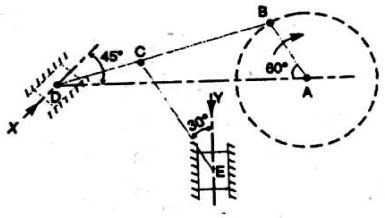
Or

(b) Explain why two Hooke's joints are used to transmit motion from the engine to the differential of an automobile. Two shafts are connected by a universal joint. The driving shaft rotates at a uniform speed of 1200 r.p.m. Determine the greatest permissible angle between the shaft axes so that the total fluctuation of speed does not exceed 100 r.p.m. Also calculate the maximum and minimum speeds of the driven shaft. (16)

12. (a) The dimensions of the mechanism, as shown in Fig. below, are as follows:

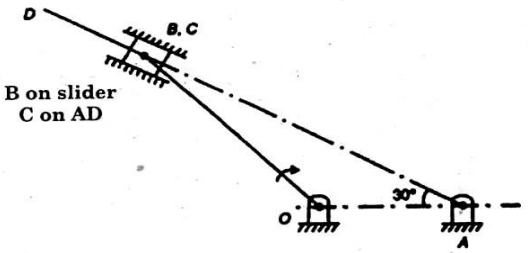
AB = 0.45 m; BD = 1.5 m: BC = CE = 0.9 m.

The crank AB turns uniformly at 180 r.p.m. in the clockwise direction and the blocks at D and E are working in frictionless guides. Draw the velocity diagram for the mechanism and find the velocities of the sliders D and E in their guides. Also determine the turning moment at A if a force of 500 N acts on D in the direction of arrow X and a force of 750 N acts on E in the direction of arrow Y. (16)



Or

(b) A single cylinder rotary engine is shown below. OA is the fixed link, 200 mm long. OB is the connecting rod and is 520 mm long. The line of stroke is along AD and at the instant is inclined at 30° to the vertical. The body of the engine consisting of cylinders rotates at a uniform speed of 400 rpm about fixed centre A. Determine the acceleration of slider B and angular acceleration of connecting rod. (16)



13. (a) The following particulars relate to a symmetrical circular cam operating a flat-faced follower:

Least radius = 25 mm nose radius = 8 mm, lift of the valve = 10 mm, angle of action of cam =120°, cam shaft speed = 1000 r.p.m. Determine the flank radius and the maximum velocity, acceleration and retardation of the follower. If the mass of the follower and valve with which it is in contact is 4 kg, find the minimum force to be exerted by the spring to overcome inertia of the valve parts. (16)

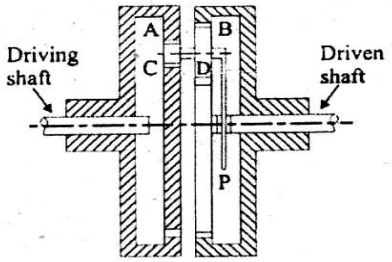
Or

(b) A cam rotating clockwise at a uniform speed of 200 r.p.m. is required to move an offset roller follower with a uniform and equal acceleration and retardation on both the outward and return strokes. The angle of ascent, the angle of dwell (between ascent and descent) and the angle of descent is 120°, 60° and 90° respectively. The follower dwells for the rest of cam rotation. The least radius of the cam is 50 mm, the lift of the follower is 25 mm and the diameter of the roller is 10 mm. The line of stroke of the follower is offset by 20 mm from the axis of the cam. Draw the cam profile and find the maximum velocity and acceleration of the follower during the outstroke. (16)

14. (a) Two spur gears of 24 teeth and 36 teeth of 8 mm module and 20° pressure angle are in mesh. Addendum of each gear is 7.5 mm. The teeth are of involute form. Determine: 1. the angle through which the pinion turns while any pair of teeth are in contact, and 2. the velocity of sliding between the teeth when the contact on the pinion is at a radius of 102 mm. The speed of the pinion is 450 r.p.m. (16)

Or

(b) An epicyclic train is shown in Fig. below. Internal gear A is keyed to the driving shaft and has 30 teeth. Compound wheel C and D of 20 and 22 teeth respectively are free to rotate on the pin fixed to the arm P which is rigidly connected to the driven shaft. Internal gear B which has 32 teeth is fixed. If the driving shaft runs at 60 r.p.m. clockwise, determine the speed of the driven shaft. What is the direction of rotation of driven shaft with reference to driving shaft? (16)



15. (a) The power transmitted between two shafts 3.5 metres apart by a cross belt drive round the two pulleys 600 mm and 300 mm in diameters, is 6 kW. The speed of the larger pulley (driver) is 220 r.p.m. The permissible load on the belt is 25 N/mm which is 5 mm thick. The coefficient of friction between the smaller pulley surface and the belt is 0.35. Determine: 1. necessary length of the belt; 2. width of the belt, and 3. necessary initial tension in the belt. (16)

Or

(b) A multiplate clutch has three pairs of contact surfaces. The outer and inner radii of the contact surfaces are 100 mm and 50 mm respectively. The maximum axial spring force is limited to 1 kN. If the coefficient of friction is 0.35 and assuming uniform wear, find the power transmitted by the clutch at 1500 r.p.m. (16)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 21846

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Third Semester

Mechanical Engineering

ME 2203/ME 35/ME 1202 A/080120010/10122 ME 404 — KINEMATICS OF MACHINERY

(Regulations 2008/2010)

(Common to PTME 2203/10122 ME 404 — Kinematics of Machinery for B.E. (Part-Time) Third/Fourth Semester Mechanical Engineering – Regulations 2009/2010)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are the three conditions to obtain a four bar crank rocker mechanism?

2. Define inversion of kinematic chain.

3. Define the rubbing velocity.

4. Define coriolis component of acceleration.

5. Why sometimes the axes of translating roller followers in cam follower mechanisms are offset from the axis of cam rotating?

6. Define tangential cam.

7. State the law of gearing.

8. What is interference in involute gear and how is it prevented?

9. State the functional difference between a clutch and a brake.

10. What are the advantages of wire ropes over fabric ropes?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Sketch and explain the inversion of a 4 bar mechanism, all the four pairs are turning pairs. (10)

(ii) Sketch and explain any two types of straight line motion generating mechanism. (6)

Or

(b) (i) Explain mechanical advantage and transmission angle related to four bar mechanism. (8)

(ii) Explain the Ratchet and Escapism mechanism with neat diagram. (8)

12. (a) For the configuration of a slider crank mechanism shown in fig.12 (a)

Calculate (i) the acceleration of the slider at B (ii) the acceleration of point E (iii) the angular acceleration of link AB. Link OA rotates at 20 rad/s count er clockwise (16)

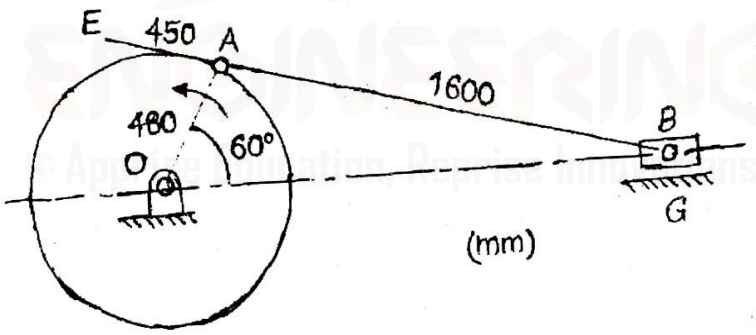


Fig. 12 (a)

Or

(b) One cylinder of a rotary engine is shown in the configuration diagram shown in Fig. 12(b) OA is the fixed crank, 200 mm long. OP is the connecting rod and is 520 mm long. The line of stroke is along AR and at the instant is inclined at 30° to the vertical. The body of the engine consisting of cylinders rotates at a uniform speed of 400 rpm about the fixed centre A.

Determine :

(i) Acceleration of piston (slider) inside the cylinder

(ii) Angular acceleration of the connecting rod. (16)

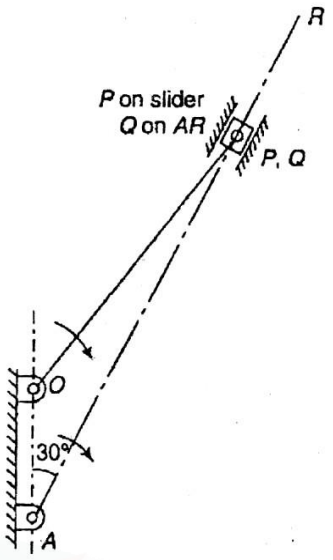


Fig. 12 (b)

13. (a) A cam with a minimum radius of 25 mm is to be designed for a knife-edge follower with the following data :

– To raise the follower through 35 mm during 60° rotation of the cam.

– Dwell for next 40° of the cam rotation.

– Descending of the follower during the next 90° of the cam rotation.

– Dwell during the rest of the cam rotation.

Draw the profile of the cam if the ascending and descending of the cam is with simple harmonic motion and the line of stroke of the follower is offset 10mm from axis of rotation of the cam. (16)

Or

(b) Draw the profile of a cam operating a roller reciprocating follower and with the following data :

Minimum radius of cam = 25 mm, Lift = 30 mm, Roller diameter = 15 mm. The cam lifts the follower for 120° with SHM followed by a dwell period of 30°. Then the follower lowers down during 150° of the cam rotation with uniform acceleration and deceleration followed by a dwell period. If the cam rotates at a uniform speed of 150 rpm, calculate the maximum velocity and acceleration of the follower during the descent period. (16)

14. (a) The following data relate to a pair of 20° involute gears in mesh :

Module = 6 mm, Number of teeth on pinion = 17. Number of teeth on gear = 49; Addenda on pinion and gear wheel = 1 module.

Find :

(i) The number of pairs of teeth in contact;

(ii) The angle turned through by the pinion and the gear wheel when one pair of the teeth is in contact and

(iii) The ratio of the sliding to rolling motion when the tip of a tooth on the larger wheel (1) is just making contact (2) is just leaving contact with its mating tooth and (3) is at the pitch point. (16)

Or

(b) In a reverted epicyclic gear train, the arm A carries two gears B and C and a compound gear D, E. The gear B meshes with gear E and the gear C meshes with gear D. The number of teeth on gears B, C, and D are 75, 30 and 90 respectively. Find the speed and direction of gear C when gear B is fixed and the arm A makes 100 rpm clockwise. (16)

15. (a) (i) The following data relate to screw jack, Pitch of the thread screw = 8 mm, Diameter of the thread screw = 40 mm, Coefficient of friction between screw and nut = 0.1, Load = 20 kN Assuming that the load rotates with the screw, determine (1) the ratio of torque required to raise and lower the load (2) the efficiency of the machine. (6)

(ii) A friction clutch is used to rotate a machine from a shaft rotating at a uniform speed of 250 rpm. The disc type clutch has both of its sides effective, the coefficient of friction being 0.3. The outer and the inner diameters of the friction plate are 200 mm and 120 mm respectively. Assuming uniform wear of the clutch, the intensity of pressure is not to be more than 100 kN/m^2. If the moment of inertia of the rotating parts of the machine is 60.5 kg-m^2, determine the time to attain the full speed by the machine and the energy lost in slipping of the clutch.

What will be the intensity of pressure, if the condition of uniform pressure of the clutch is considered? Also, determine the ratio of power transmitted with uniform wear to that with uniform pressure. (10)

Or

(b) 2.5 kW of powers is transmitted by an open-belt drive. The linear velocity, of the belt is 2.5 m/s. The angle of lap on the smaller pulley is 165° The coefficient of friction is 0.3. Determine the effect on power transmission in the following cases;

(i) Initial tension in the belt is increased by 8%

(ii) Initial tension in the belt is decreased by 8%

(iii) Angle of lap is increased by 8% by the use of an idler pulley, for the same speed and the tension on the tight side, and

(iv) Coefficient of friction is increased by 8% by suitable dressing to the friction surface of the belt. (16)

Reg. No. | | | | | | | | | | | | |

Question Paper Code : 51622

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

Third Semester

Mechanical Engineering

ME 2203/ME 35/ME 1202 A/080120010/10122 ME 404 — KINEMATICS OF MACHINERY

(Regulation 2008/2010)

(Common to PTME 2203–Kinematics of Machinery for B.E. (Part–Time) Third Semester – Mechanical Engineering – Regulation 2009)

Time : Three hours Maximum : 100 marks

Note : A–3 Drawing Sheet is to be Supplied to the Examination

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Differentiate the machine and structure.
2. Classify the constrained motion.
3. Define instantaneous centre.
4. What is the expression for coriolis component of acceleration?
5. Define tangent cam.
6. What are the different motions of the follower?
7. State the law of gearing.
8. What are the methods to avoid interference?
9. Define velocity ratio.
10. What is the maximum efficiency of the screw jack?

PART B — (5 × 16 = 80 marks)

11. (a) Explain the working of two different types of quick return mechanisms. Derive an expression for the ratio of time taken in forward and return stroke for one of these mechanisms. (16)

Or

(b) Sketch and explain any three kinematic inversion of four–bar chain.

12. (a) (i) Derive an expression for the relationship between the angular velocities of links in terms of known link lengths, angular positions of links and angular velocity of input link, for a four–bar linkage. (6)

(ii) In a slider crank mechanism, the length of crank OB and connecting rod AB are 125 mm and 500 mm respectively. The centre of gravity G of the connecting rod is 275 mm from the slider A. The crank speed is 600 rpm clockwise. When the crank has turned 45° from the inner dead centre position, determine velocity of the slider A, Velocity of the point G and Angular velocity of the connecting rod AB (10)

Or

(b) By analytical method, Derive the velocity and acceleration for the reciprocating steam engine mechanism.

13. (a) A cam is designed for a knife edge follower with following data:

(i) Cam lift = 40 mm during 90° of cam rotation with SHM

(ii) Dwell for the next 30°

(iii) During the next 60° of cam rotation, the follower returns to original position with SHM

(iv) Dwell for the remaining 180°

Draw the profile of the cam when the line of stroke is offset 20 mm from the axis of the cam shaft.

Or

(b) In a cam with translating roller follower, the follower axis is offset to the right of Cam hinge by 12 mm. The roller radius is 10 mm and the cam rotates in the counter clock–wise direction. Layout the rise portion of the cam profile to meet the following specifications: Rise takes place during 180° of cam rotation of which for the first 90° the rise is with constant acceleration and the rest is with constant retardation. Take seven station points only. The lift of the cam is 30 mm and the least radius of the cam is 25 mm.

14. (a) Two gear wheels mesh externally to give a velocity ratio of 3 to 1. The involute teeth has 6 mm module and 20° pressure angle. Addendum is equal to one module. The pinion rotates at 90 rpm. Determine

(i) Number of teeth on pinion to avoid interference and the corresponding number on the wheel; (4)

(ii) The length of path and are of contact (4)

(iii) Contact ratio and (4)

(iv) The maximum velocity of sliding. (4)

Or

(b) (i) Derive an expression to determine the length of path of contact between two spur gears of different size. (10)

(ii) Briefly explain the sub–classification of compound gear trains with neat sketches. (6)

15. (a) Two pulleys, one 450 mm diameter and the other 200 mm diameter are in parallel shafts 1.95 m apart and are connected by a crossed belt. Find the length of the belt required and the angle of contact between the belt and each pulley. What power can be transmitted by the belt when the larger pulley rotates at 200 rpm if the maximum permissible tension in the belt is 1 kN and the co–efficient of friction between the belt and pulley is 0.25? (16)

Or

(b) (i) Derive an expression for the effort required to raise a load with screw jack taking friction into consideration. (8)

(ii) A 150 mm diameter value, against a steam pressure of 2 MN/m^2 is acting, is closed by means of a square threaded screw 50 mm in external diameter with 6 mm pitch. If the co–efficient of friction is 0.12, find torque required to turn the handle. (8)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 31559

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Third Semester

Mechanical Engineering

ME 2203/ME 35/10122 ME 404/ME 1202 A/080120010 — KINEMATICS OF MACHINERY

(Regulation 2008/2010)

(Common to PTME 2203 – Kinematics of Machinery for B.E. (Part-Time) Third Semester – Mechanical Engineering – Regulation 2009)

Time : Three hours Maximum : 100 marks

Answer ALL questions

PART A — (10 × 2 = 20 marks)

1. Define sliding connectors.
2. Differentiate rotation and translation.
3. Define number of instantaneous centre.
4. What is low degree of complexity?
5. Define pressure angle.
6. Write the procedure to draw the cam profile.
7. Define gear ratio.
8. Write short notes on differentials.
9. Define anti -friction bearing.
10. Differentiate multiplate clutch and cone clutch.

PART B — (5 × 16 = 80 marks)

11. (a) (i) What is kinematic inversion? Explain the four different inversions of slider crank mechanism. (10)

(ii) Determine the degree of freedom for following linkages. (Fig.1) (6)

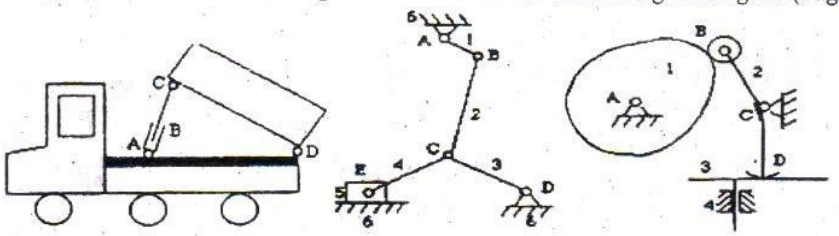


Fig.1

Or

(b) (i) Find the maximum and minimum transmission angles for the mechanisms shown in fig.2. The figures indicate the dimensions in standard units of length. (8)

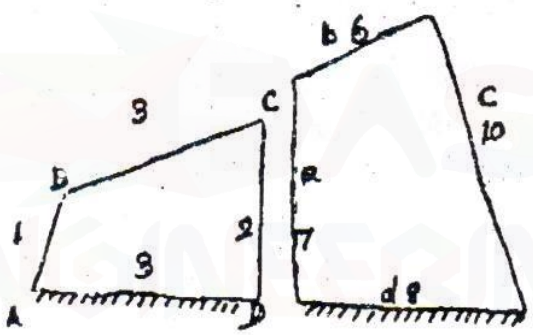


Fig. 2

(ii) Write short notes on toggle mechanism. (8)

12. (a) (i) The crank AB of four bar mechanism shown in figure. 3. Rotates at 60 rpm clockwise. Determine the relative angular velocities of the coupler to the crank and the lever to the coupler. Find also the rubbing velocities al the surface of pins 25 mm radius and the joints B and C. (8)

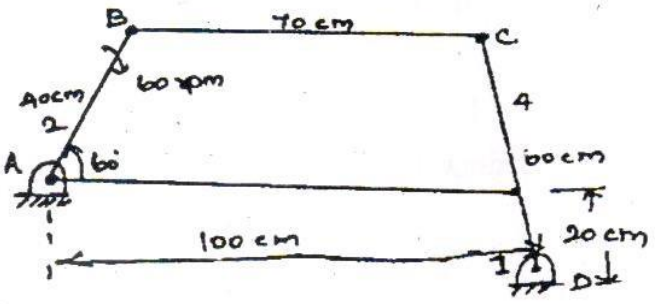


Fig. 3

(ii) Locate the instantaneous centre's of the slider crank mechanism shown in fig.4. Find the velocity of the slider. (8)

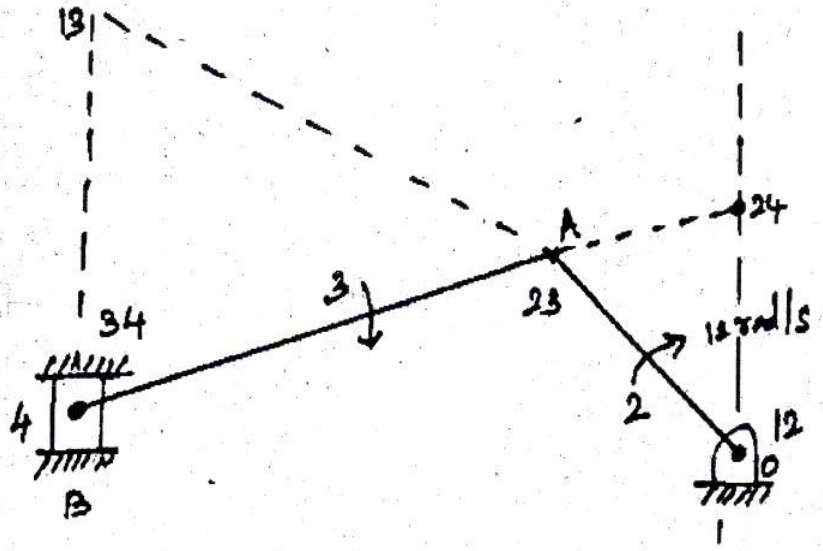


Fig. 4

Or

(b) (i) Fig.5 shows the configuration of a whit worth quick return mechanism. The lengths of the fixed link OA and the crank OP are 200 mm and 300mm respectively. Other lengths are AR=200 mm and RS=400 mm. Find the velocity of the ram using instantaneous centre method when the crank makes a angle of 120° with the fixed link and rotates at 10 rad/s.

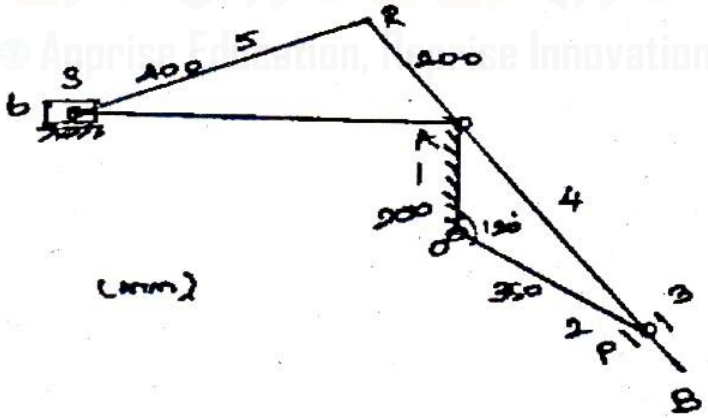


Fig. 5

(ii) Differentiate low degree and high degree of complexity with suitable sketch. (6)

13. (a) A cam operates on offset roller follower. The least radius of the cam is 50 mm, roller diameter is 30 mm, and offset is 20 mm, the cam rotates at 360 rpm. The angle of ascent is 48°, angle of dwell is 42°, and angle of descent is 60°. The motion is to be SHM during ascent and uniform acceleration and deceleration during decent. Draw the cam profile. (16)

Or

(b) (i) A flat faced mushroom follower is operated by a symmetrical cam with circular arc flank and nose profile the axis of tappet passed through the cam axis. Total angle of action is 162°, lift 10 mm and base circle diameter 40 mm. period of acceleration is half the period of retardation during the lift. The cam rotates at 1200 rpm. Determine

(1) The nose and flank radii and

(2) The maximum acceleration and retardation during lift. (12)

(ii) List the various methods to be used to reduce the pressure angle. (4)

14. (a) (i) Explain the various pitches of helical gears with sketch. (10)

(ii) Two 15 mm module 20° pressure angle spur gears have addendum equal to one module. The pinion has 25 teeth and the gear 50 teeth. Determine whether interference will occur or not. If it occurs, to what valve should the pressure angle be changed to eliminate interference? (6)

Or

(b) (i) An epicyclic gear train consists of three gears 1, 2 and 3 as shown in fig.6 the internal gear 1 has 72 teeth and gear 3 has 32 teeth. The gear 2 meshes with both gear 1 and gear 3 and is carried on an arm A. which rotates about the centre O_2 at 20 rpm. If the gear 1 is fixed, determine the speed of gears 2 and 3. (12)

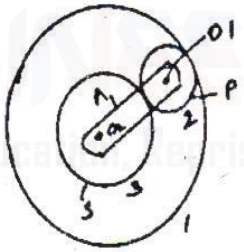


Fig. 6

(ii) Write short notes on speed ratio of a planetary gear train. (4)

15. (a) (i) Derive the force analysis of a body resting on an inclined plane with force inclined to the plane. (12)

(ii) List the various types of friction. (4)

Or

(b) (i) A vertical shaft 140 mm diameter rotating at 120 rpm rests on a flat end foot step bearing. The shaft carries a vertical load of 30 KN. The coefficient of friction is 0.06. Estimate the power lost is friction, assuming uniform pressure and uniform wear. (8)

(ii) A multi-plate disc clutch transmits 55 KW of power at 1800 rpm. Coefficient of friction for the friction surface is 0.1. Axial intensity of pressure is not to exceed 160 KN/m^2. The internal radius is 80 mm and 0.7 times the external radius. Find the number of plates needed to transmit the required torque. (8)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 11519

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2012.

Third Semester

Mechanical Engineering

ME 2203/113302/ME 35/10122 ME 404/ME 1202 A/080120010 — KINEMATICS OF MACHINERY

(Common to PTME 2203 — Kinematics of Machinery for B.E. (Part-Time) Third Semester Mech. – Regulations 2009)

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Write Grashoff's law for 4-bar mechanism.

2. What is meant by indexing mechanism? Where do we use it?

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

4. Define rubbing velocity. What will be the expression for rubbing velocity at a pin joint when the two links rotate in opposite direction?

5. State the expressions for maximum acceleration of a follower moving with cycloidal motion.

6. Why sometimes the axes of translating roller followers in cam follower mechanisms are offset from the axis of rotation of cam?

7. Define the term 'arc of contact' in gears.

8. Name two applications of reverted gear train.

9. Why self locking screws have lesser efficiency?

10. What is meant by a self-locking and a self-energised brake?

PART B — (5 × 16 = 80 marks)

11. (a) Sketch and explain the four inversions of Single-slider crank chain. (16)

Or

(b) (i) What are straight-line mechanisms? Sketch the Peaucellier straight-line motion mechanism and prove that the generating point moves in straight line. (8)

(ii) Sketch a Hooke's joint and derive the condition for equal speeds of driving and driven shafts. (8)

12. (a) In a four bar chain ABCD, AD is fixed and is 120 mm long. The crank AB is 30 mm long and rotates at 100 rpm clockwise while the link CD = 60 mm oscillates about D; BC = 120 mm. Using graphical method, find the angular velocity and angular acceleration of link BC when angle BAD = 60°. (16)

Or

(b) (i) Derive the expressions for the velocity and acceleration of the piston of a reciprocating engine mechanism. (8)

(ii) In a reciprocating engine mechanism, the lengths of the crank and connecting rod are 150 mm and 600 mm respectively. The crank position is 60° from inner dead centre. The crank shaft speed is 450 r.p.m. (clockwise). Using analytical method, determine

(1) velocity of the piston (2)

(2) acceleration of the piston (2)

(3) crank angle for maximum velocity of the piston and the corresponding velocity. (4)

13. (a) A cam with a minimum radius of 25 mm, rotating clockwise at a uniform speed is to be designed to give motion to a roller follower, at the end of a valve rod, as described below :

(i) To raise the valve through 50 mm during 120° rotation of the cam.

(ii) To keep the valve fully raised through next 30°.

(iii) To lower the valve during next 60° and

(iv) To keep the valve closed during rest of the revolution.

The diameter of the roller is 20 mm and the diameter of the cam shaft is 25 mm. The line of the stroke is offset by 15 mm from the axis of the cam shaft. The displacement of the valve, while being raised and lowered is to take place with SHM.

(1) Draw the displacement diagram. Sketch roughly the shapes of velocity and acceleration diagrams. (6)

(2) Draw the profile of the cam. (10)

Or

(b) In a symmetrical tangent cam operating a roller follower, the least radius of the cam is 30 mm and roller radius is 17.5 mm. The angle of ascent is 75° and the total lift is 17.5 mm. The speed of the cam shaft is 600 rpm. Assume that there is no dwell between ascent and descent.

(i) Calculate the principal dimensions of the cam. (6)

(ii) Find the acceleration of the follower at the beginning of the lift. (2)

(iii) Draw the profile of the cam. (8)

14. (a) (i) State and prove the law of gearing. (10)

(ii) Show that the involute curves as the profiles of mating gears satisfy the law of gearing. (6)

Or

(b) A compound gear train using spur gears is required to give a total reduction ratio of 250 to 1 in four steps. The modules of the gears are 5 mm for the first step, 7 mm for the second, 10 mm for the third and 16 mm for the fourth.

(i) Arrive at the individual speed ratios, if a tolerance of ±0.2% is allowed in the total reduction ratio. (4)

(ii) Find the numbers of teeth of all gears, if the minimum number of teeth for any pinion is 20. (4)

(iii) Find the pitch circle diameters of all gears and the centre distances. (4)

(iv) Sketch a line diagram showing the gear train. (4)

15. (a) (i) In a thrust bearing, the external and internal diameters of the contacting surfaces are 320 mm and 200 mm respectively. The total axial load is 80 kN and the intensity of pressure is 350 kN/m^2. The shaft rotates at 400 rpm. Taking the coefficient of friction as 0.06, calculate the power lost in overcoming the friction and the number of collars required. (8)

(ii) A screw-jack has a square thread of mean diameter 60 mm and pitch 8 mm. The co-efficient of friction at the screw thread is 0.09. A load of 3 kN is to be lifted through 120 mm. Determine the torque required and the work done in lifting the load through 120 mm. Find also the efficiency of the jack. (8)

Or

(b) (i) Derive an expression for the centrifugal tension in a belt passing round a pulley rim. (6)

(ii) A leather belt is required to transmit 7.5 kW from a pulley 1.2 m in diameter, running at 250 rpm. The angle embraced is 165° and the coefficient of friction between the belt and the pulley is 0.3. The safe working stress for the leather belt is 1.5 MPa; the density of leather is 1000 kg/m^3 and thickness of belt is 10 mm. Determine the width of the belt taking centrifugal tension into account. (10)