Kinematics of machinery

Q.P CODE: 21791

Sem 4/Mechanical/ Choice based/ May-18

Q.1)A) what is degree of freedom of plane mechanism? Find degree of freedom of single slider crank mechanism using kutzbach criteria. [5]

Ans : Degree of freedom of a mechanism

Mechanism can also have several degree of freedom. The degree of freedom of a mechanism is decided by the degree of freedom of the links constituting that mechanism. Accordingly we can classify mechanism under two general categories as follows :

These two types of mechanism are describe in detail here

1. **Spatial mechanism**
   In this type of mechanism,the complete motions cannot be represented in a single plane.that is to describe the motion of such mechanism is more than one plane would be required. They have three dimensional motion path.
   Examples : robot arms, cranes, Hooke's joint
2. **Planar mechanism**
   These are much simpler mechanism. The complete motion parts of the mechanism could be represented on a single plane or in other words the entire mechanism could be represented to a scale on the sheet of paper.
   during the course of the study majority of the mechanism switch will come across will be planar mechanism

Kutzbach criterion

Degree of freedom of a mechanism in space can be determined as follows :

Let n = total number of links in a mechanism

F = degree of freedom of a mechanism

In a mechanism one ling should be fixed. Therefore total number of movable links in mechanism is (n-1). Therefore total number of degrees of freedom of. (n-1) movable link is

$$F = 6(n-1)$$

Q.1)B) Explain with neat sketch the Watts linkage for generating approximate straight line. [5]

Ans : Watts mechanism

It has four legs as shown in the figure. OA,AB,BQ and OQ. OQ is the fix link OA and QB can oscillate about centres O and Q respectively. P is a point on AB such that

$$\frac{PA}{PB} = \frac{QB}{OA}$$

As 0A oscillates the point P will describe the approximate straight line.

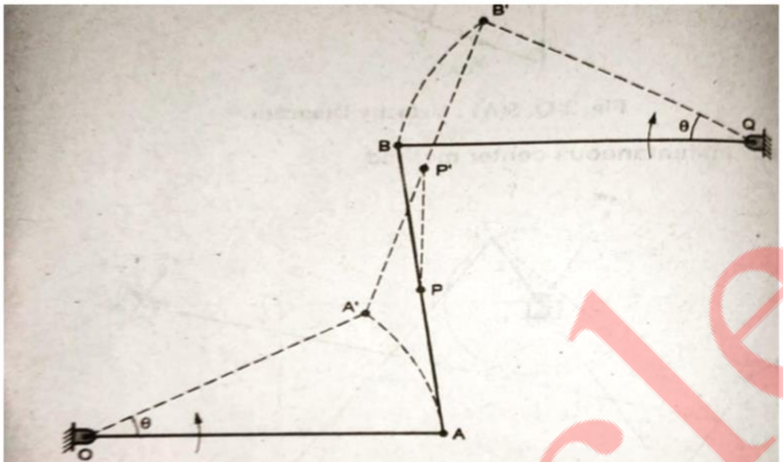


Fig. 1-Q.1(B) : Watt's mechanism

Q.1)C) what is instantaneous center of rotation? How to find number of instantaneous centers in a mechanism? [5]

Ans : Instantaneous center of rotation

The instantaneous center method of analyzing the velocity of various link in a given mechanism is based on the concept that any displacement of body or rigid link having motion in one plane can be considered as a pure rotational motion of a rigid link as a whole about some center called as **instantaneous center.**

Number of instantaneous centers in a mechanism

If two bodies have relative motion between them, there is one instantaneous Centre. Thus the number of instantaneous centers in a mechanism having and links will be equal to possible pairs of two links taken at a time.

Therefore,

Number of instantaneous centers

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

Where n = number of links in a mechanism

Q.1)D) state and derive law of gearing. [5]

Ans: Law of gearing

Consider the portion of two gear teeth in mesh, let two teeth are in contact at point K and

The teeth are rotating in a direction as shown in the figure

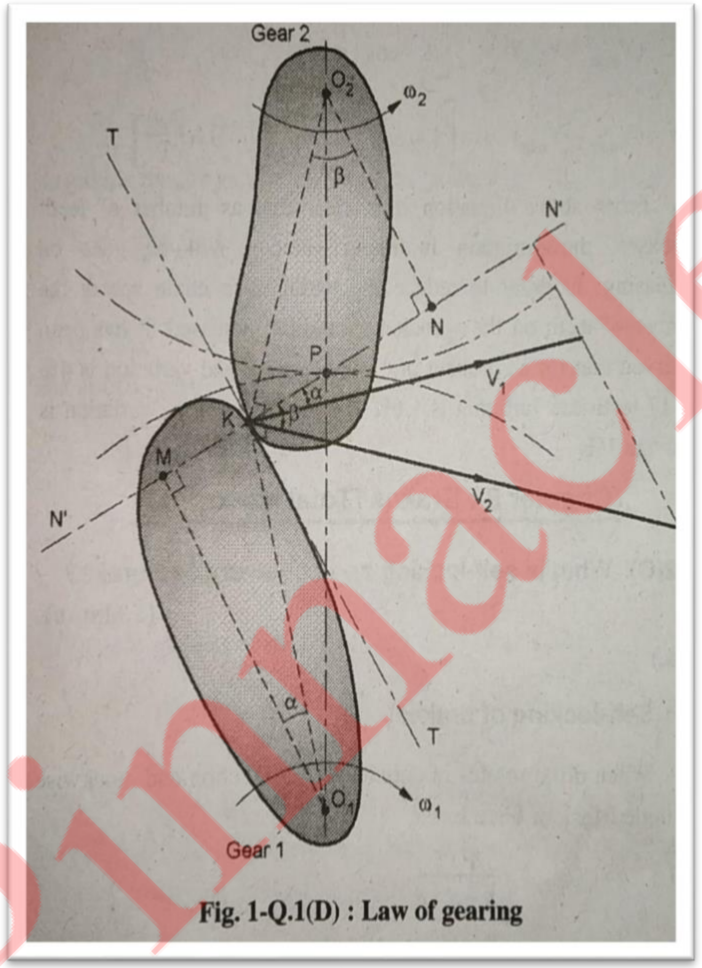


Fig. 1-Q.1(D) : Law of gearing

Fig no.1

Let TT it be common tangent N'Nand in be the common normal to the curves

At the point of contact k of two mating gears from point O_1 and O_2

Draw O_1M and O_2N and perpendicular to common normal N'N'

Let V1 and V2 be the velocity of the point when considered on a gear tooth 1 and 2 respectively then

Component of velocity V1 along N'N'=KN'= $V_1 \cos \alpha$

Component of velocity along N'N' = KN'= $V_2 \cos \beta$

if the mating to remain in contact while transmitting motion then the components of this velocity along normal normal n n must be equal

$V_1 \cos a = V_2 \cos b$

$(\omega_1 * O_1k) \cos a = (\omega_2 * O_2k) \cos b$

$\cos\alpha = \frac{o_1 m}{o_2 k}$ (1)

$\cos\beta = \frac{o_2 n}{o_2 k}$ (2)

On substituting the values of cos alpha cos beta from equation 1 and equation 2 in equation 1 we get

$\omega_1 \times o_1 k \times \frac{o_1 m}{o_1 k} = \omega_2 \times o_2 k \times \frac{o_2 n}{o_1 m}$ (4)

Consider Triangles O_1MP and O_2NP in which each point P lies on intersection of common normal and line joining the centers of gears these two Triangles are similar therefore we can write

$\frac{o_2 n}{o_2 p} = \frac{o_1 m}{o_1 p}$

$\frac{o_2 n}{o_1 m} = \frac{o_2 p}{o_1 p}$ (5)

From eq (4) and (5)

$$\frac{\omega_1}{\omega_2} = \frac{o_2 p}{o_1 p}$$

Thus from equation 1 we can say that the angular velocity ratio is inversely proportional to the ratio of distance of the point P from the gear centers O_1 and O_2

Therefore in order to have constant angular velocity ratio for all position of a meeting near the point P must be a fixed point and it is called **pitch point.**

In other words the common normal at the point of contact between a pair of must be always pass through the beach. For all positions of the mating gears this is fundamental conditions which must be satisfied while designing the profiles of teeth for gears this is called as **law of gearing or condition of correct gearing.**

Q.1)E)what is the effect of centrifugal tension on power transmitted in belt drive? [5]

Ans: A belt running over a pulley experience a centrifugal force similar to the body experiences while moving in a circular path. This centrifugal force is due to mass of the belt of the portion of the belt over the police speed of the belt and radius of the curvature of pulley.

The effect of centrifugal force is to induce additional tension on tight and slack side. Third the tension called in the belt by centrifugal force is called centrifugal tension.

Latest consider strip MN of Belt, substandard an angle Delta theta with the centre of pulley.

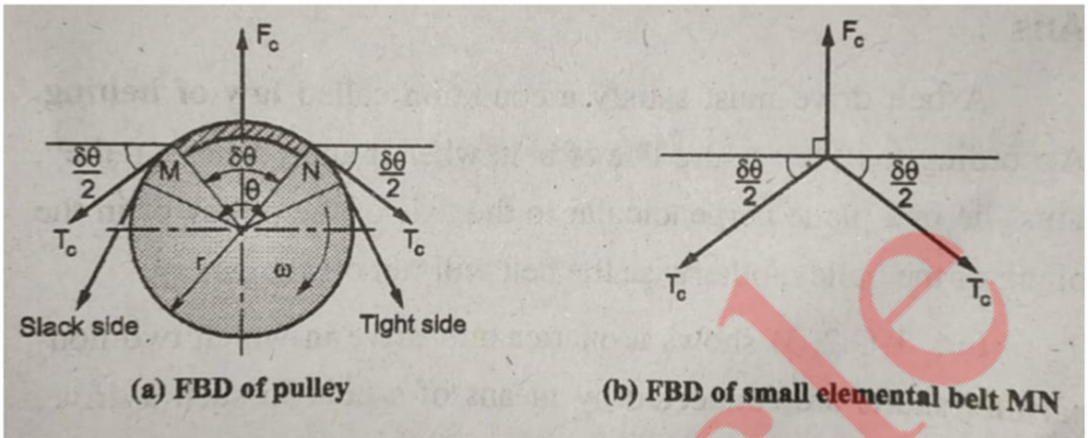


Fig. 1-Q.1(E) : Centrifugal tension in belt

Let v = linear velocity of belt m/s

M= mass of belt per metre length (kg/meter)

r= radius of pulley over which belt runs (m)

T_{c} = centrifugal tension is acting at M and n respectively

F_c = centrifugal force

Length of the belt elements

MN= $r\delta\theta$

Mass of the belt element

MN= Mass per metre length×length of the element MN

= mr $\delta\theta$

Centrifugal force acting on the belt elements MN is given by

$$F_c = (mr\ \delta\theta)\ \frac{v^2}{r}$$

$$F_c = mv^2\ \delta\theta \qquad (1)$$

Resolving the force vertically we get,

$$T_c \sin\frac{\delta\theta}{2} + T_c \sin\frac{\delta\theta}{2} = F_c$$

$$F_c = 2\,T_c \sin\frac{\delta\theta}{2}$$

But as δθ is very small

$$\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$$

$$f_c = 2 \times t_c \times \frac{\delta\theta}{2}$$

$$f_c = T_c\delta\theta$$

Equating equations 1 and 2 we get

$$mv^2\,\delta\theta = T_c\delta\theta$$

$$\boldsymbol{T_c = mv^2}$$

It is noted from equation 1 that centrifugal tension is independent of the tight and slack side tension.

It is only depends on velocity of belt and mass of belt.

When centrifugal tension is considered the total tension on the right side becomes (T_1 + Tc) and total tension on the slack site becomes (T_2+T_c).

Q.2)A) Two 20 degree involute spur gear have a module of 10 mm. The addendum is 1 module. The large gear has 50 and pinion has 13 teeth. Does interference occur?if it occur to what value the pressure angle be changed to eliminate interference? [10]

Ans :

number of teeth on wheel, T= 50

number of teeth on pinion,. T = 13

module m= 10 mm

pressure angle

addendum of pinionn and wheel a = one module = 10 mm

Pitch Circle radius of pinion is, r= $\frac{m.t}{2} = \frac{10\times13}{2} = 65\ mm$

,Pitch Circle radius of wheel is, R= $\frac{mT}{2} = \frac{10\times50}{2} = 250\ mm$

Addendum circle radius of the wheel, R_a= R+a = 260 mm

addendum radius of pinion is, r_a = r+a = 65+10 =75 mm

maximum or limiting radius of addendum circle of to avoid interference is given by

$$O_2M = \frac{M.T}{2}\sqrt{1+\frac{r}{R}\left(\frac{r}{R}+2\right)Sin^2\phi}$$

$$(R_A)\ \text{max} = \frac{10\times 50}{2}\sqrt{1+\frac{65}{250}\left(\frac{65}{250}+2\right)\sin^2 20^\circ}$$

$$(R_A)\ \text{max} = 258.44\ mm$$

the maximum for limiting radius of circle of wheel is (R_A) Max = 25 8.44 mm which is less than actual radius of abandoned circle R_A = 2260 mm therefore interference occurs

the value of pressure angle should be increased to avoid interference which can be determined by considering (R_A)MAX equal to R_A

$$(R_A)max = \frac{M.T}{2}\sqrt{1+\frac{r}{R}\left(\frac{r}{R}+2\right)Sin^2\phi}$$

$$1.04 = \sqrt{1+0.26(2.26)\text{sin }\hat{}2\ \phi}$$

Squaring both the sides

$$(1.04)^2 = 1+0.58\sin^2\phi$$

$$\phi = 22.02\quad say\ 22^\circ$$

Thus if the pressure angle increase from 20° to 22° the interference is avoided.

Q.2)B) State and explain the law of belting. [5]

Ans : A belt drive must satisfy the condition called of building according to get the center line of felt when it approaches a Pulley must lie in a plane perpendicular to the axis of a pulley or in the Plane of the otherwise the belt will run of the pulley

Figure 1 shows a quarter turn drive in which two non parallel shafts are connected by means of a belt in such a drive when the driven Pulley rotates in anticlockwise direction the centerline of the belt approaching the pulley lies in the plane perpendicular to axis of the pulley does the bill transmits power

If the direction of the drive is reversed the belt of centerline of the belt would not approach in the Plane of the pulley

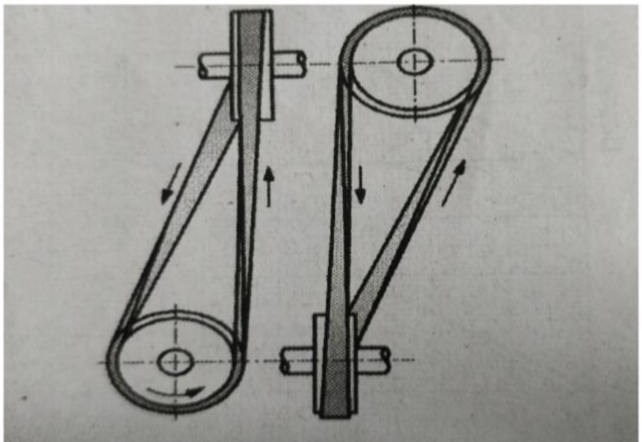


fig No. 1

Q.2)C) what is self locking and self energizing brake? [5]

Ans: a) self locking of brakes

A self locking when drum rotates in anticlockwise direction and clockwise in single block shoe brake

$$R_N = \frac{p.l}{x - \mu.a}$$

$$p = \frac{R_N(x-\mu..a)}{l} \quad (1)$$

In equation 1 if x is less than equals to the effort becomes negative or zero but no effort is required to applied brakes break in self locking

Therefore condition for self locking is

X < μ.a

Bi self energizing brakes self actuating brakes

$$p = \frac{R_N(x - \mu..a)}{l}$$

$$R_n.x = p.l + \mu\ R_n.a \quad (2)$$

From equation to we can say that moment of frictional force $\mu R_n.a$ and moment force (P.l) is other words frictional force helps to apply the brakes. such type of brakes are called **self energizing** brakes for this P > 0,

Q.3)A) An open belt drive is required to transmit 10 kilowatt of power from a motor running at 600 RPM. Diameter of driving pulley is 250 mm the speed of the drive pulley is 220 rpm.

The belt is 12 mm thick and has mass density of 0.001 gm/mm^3. Safe stress in the belt is not to exceed 2.5 N/mm^2. The two shaft are 1.25 mm apart. The coefficient of friction is 0.25 mm. Determined width of belt. [10]

Ans: Given : P = 10kw

T= 12 mm

ρ = 0.001 gm/mm^3

D_1 = 250 mm

N_1 = 600 rpm

C = 1.25 m

N_2 = 220 rpm

σ = 2.5 n/ mm^2

Velocity of belt,

$$v = \omega\left(\frac{d_1}{2}+\frac{t}{2}\right) = \frac{2\pi N}{60}\left(\frac{d_1}{2}+\frac{t}{2}\right)$$

$$v = 8230\ mm/s$$

Power translated is

$$p = (T_1 - T_2)V$$

$$10 \times 10^3 = (T_1 - T_2)8.23$$

$$T_1 - T_2 = 1215$$

Now,

$$\theta = 180\,^\circ - 2\,A = 180 - 2\,[\sin^{-1}\frac{(r_1 - r_2)}{c}]$$

$$\theta = 2.79\ rad$$

Now,

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$= e^{0.25\times 2.79}$$

$$= 2.01$$

From equation 1 and 2 we get

$$T_1 = 2418\ N\ T_2 = 1203N$$

$$T_C = MV^2$$

$$T_C = 812.8\ b$$

Now,

$$T_{MAX} = T_1 + T_C$$

$$\sigma \times B \times ty = 2418 + 812.8\ b$$

$$\boldsymbol{b = 0.0828\ m}$$

Q.3)B) A cam is to give following motion to knife edge follow [10]

(i) To raise the follower through 30 mm with uniform acceleration and deceleration during 120 degree notation of the cam

(ii) Dwell for next 30 CAM rotation

(iii)To lower the rotation with simple harmonic motion during 90 degree of CAM rotation

(iv)Dwell for rest of CAM rotation.

The CAM rotates in Counter clockwise direction with uniform speed of 800 RPM and radius of 30 mm find and draw maximum velocity and maximum acceleration during outward and return stroke

Ans:- cam speed N= 800rpm

ω = 83.77 rad/sec

Out stroke S= 30mm

Angle of out stroke $\theta_{\circ}$ = 120°

Angle of return θ_r = 90°

Angle of out dwell θ_d = 30°

Follower moves with UARM for out stroke

Displacement during outstroke 120° of cam rotation

$$y_o^{\circ} = 0^{\circ}$$

$$y_{60}^{\circ} = \frac{S}{2} = \frac{30}{2} 15\ mm$$

$$y_{120}^{\circ} = S = 30mm$$

Velocity will be

$$V_o = 0^\circ$$

$$v_{60^\circ} = \frac{2s\omega}{\theta_\circ} = 2399.83\ mm/sec$$

$$v_{120^\circ} = 0^\circ$$

Acceleration is constant

$$f_o = \pm 4\frac{s\omega^2}{(\theta_\circ)^2} = 191.97\ m/sec$$

Follower moves with stern for return stroke

displacement using return stroke of cam angle.

$$y_{150^\circ} = s = 30\ mm$$

$$y_{195^\circ} = \frac{s}{2} = \frac{30}{2} 15\ mm$$

$$y_{240^\circ} = 0\ \text{mm}$$

Velocity will be

$$V_{150^\circ} = 0$$

$$V_{195^\circ} = -2513.1\ mm/\sec^2$$

$$V_{240^\circ} = 0$$

Acceleration will be

$$F_{150^\circ} = -\frac{\pi}{\theta_r^2}\frac{s}{2}\omega^2$$

$$= \boldsymbol{-421.04 \times 10^3 mm/sec^2}$$

$$\boldsymbol{f_{195^\circ} = 0}$$

$$\boldsymbol{f_{240^\circ}} = -\frac{\pi}{\theta_r^2}\frac{s}{2}\omega^2$$

$$= \boldsymbol{421.04 \times 10^3 \frac{mm}{sec^2}}$$

$$= \boldsymbol{421.04\ m/sec^2}$$

Q.4)A) The annulus a in gear train shown in figure 1 rotates at 300 RPM about the axis of the fixed wheel S which has 80 teeth the three armed spider is driven at 180 RPM determine the number of teeth required on wheel P. [10]

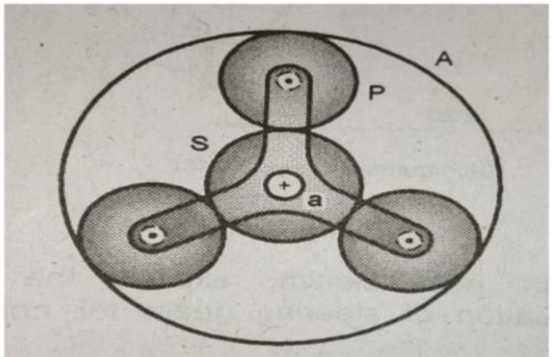


Fig. 1-Q. 4(A) : Gear Train

Ans : given

$t_s = 80 \;\; N_6 = 180\, rpm, N_A = 300, N_S = 0$

$r_s + 2r_p = r_A$

$D_s + 2D_p = D_A$

Since module is same it follows that,

$t_s + 2t_p = t_A$

From figure it follows

Steps	Operation	Arm C	Gear s	Gear p	Gear a
1.	Fix the arm C and give +1 Revolution to S	0	+1	$-\frac{t_s}{t_p}$	$-\frac{t_s}{t_p}\times\frac{t_p}{t_A}$ $-\frac{t_s}{t_A}$
2.	Multiply m	0	M	$-m.\frac{t_s}{t_p}$	$-m.\frac{t_s}{t_p}\times\frac{t_p}{t_A}$
3.	Add n Revolution to all element	n	N	n	N
4.	Total motion	n	m+n	$-m.\frac{t_s}{t_p}+n$	$-m\frac{t_s}{t_p}+n$

Since N_c = 180 rpm

Therefore n= 180

N_S = 0. M+n = 0

M= -180

Since. $N_A = 300$ mm

Therefore

$$-m\frac{t_s}{t_A} + n = 300$$

$$-(-180) \times \frac{80}{t_A} + 180 = 300$$

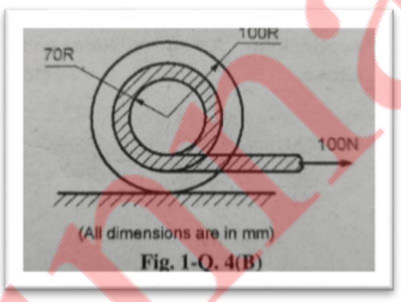
$$\mathbf{t_a = 120}$$

Put this value in equation 1

$$80 + 2T_P = 120$$

$$\mathbf{t_p = 20}$$

Q.4(B) wheel of mass 30 kg is horizontally with a force of 100 N applied through a cord wrapped around in a drum of wheel as shown in figure 1 the wheel has a radius of gyration of 75 mm determine linear acceleration of mass center and angular acceleration of wheel. [10]



(All dimensions are in mm)
Fig. 1-Q. 4(B)

Ans : as the disc does not slide a= r α= 0.1α

Add mass M.I I= mk^2 = 30(0.07)= 0.147kg.m^2

Dynamic equilibrium of drum.

$$I.\alpha - 100 \times 0.07 + ma(0.1) = 0$$

$$0.147\alpha - 1.4 + 30a(0.1) = 0$$

$$0.147\alpha - 1.4 + 30 \times (0.1\alpha)(0.1) = 0$$

$$\alpha = 313\, rad/s^2$$

$$a = r.a$$

$$= 0.1 \times 3.13$$

$$\mathbf{a = 0.313\ m/s^2}$$

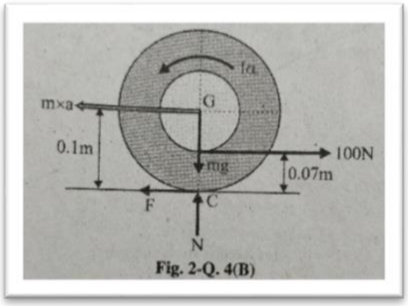


Fig. 2-Q. 4(B)

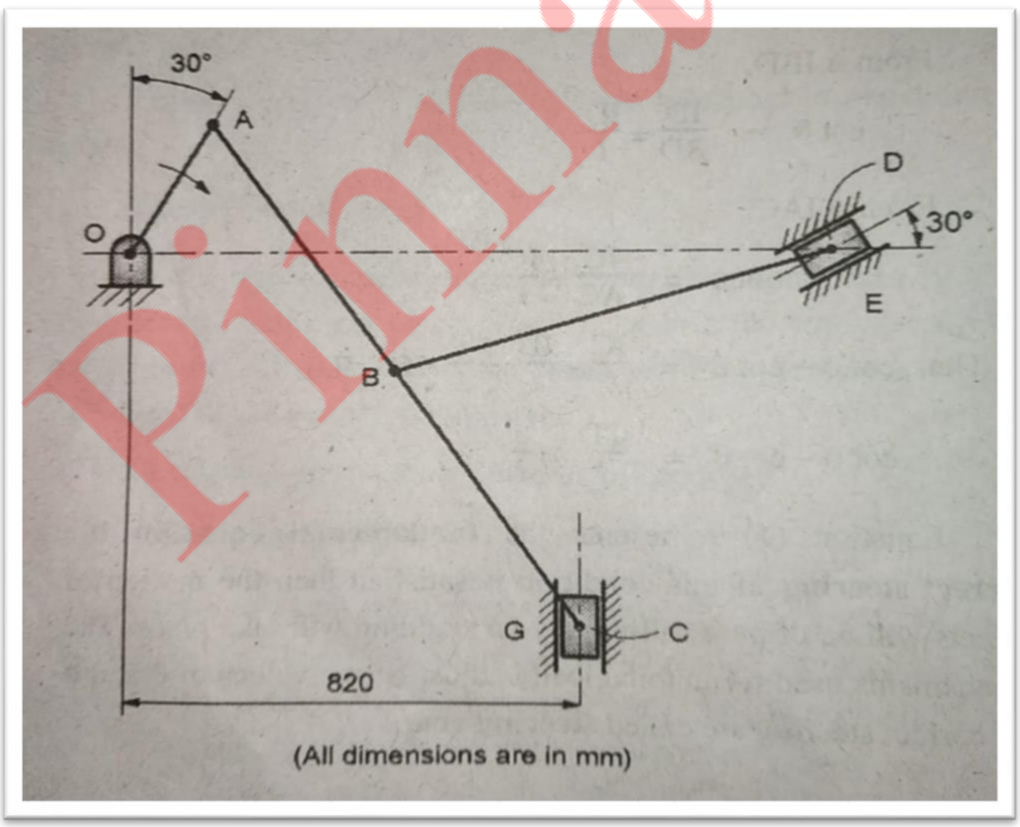
Q.5)A) for the mechanism shown in the figure has following dimensions

OA = 300 mm AB= 600 MM AC=BD= 1.2 M

OD is horizontal forgiven configuration **[14]**

If a rotates at 200 RPM in clockwise direction, find the velocity of slider D by

1) **relative velocity method**
2) **Instantaneous centre method**



Ans :

1) relative velocity method
   From velocity diagram velocity of slider D is
   V_D = od= 2.1

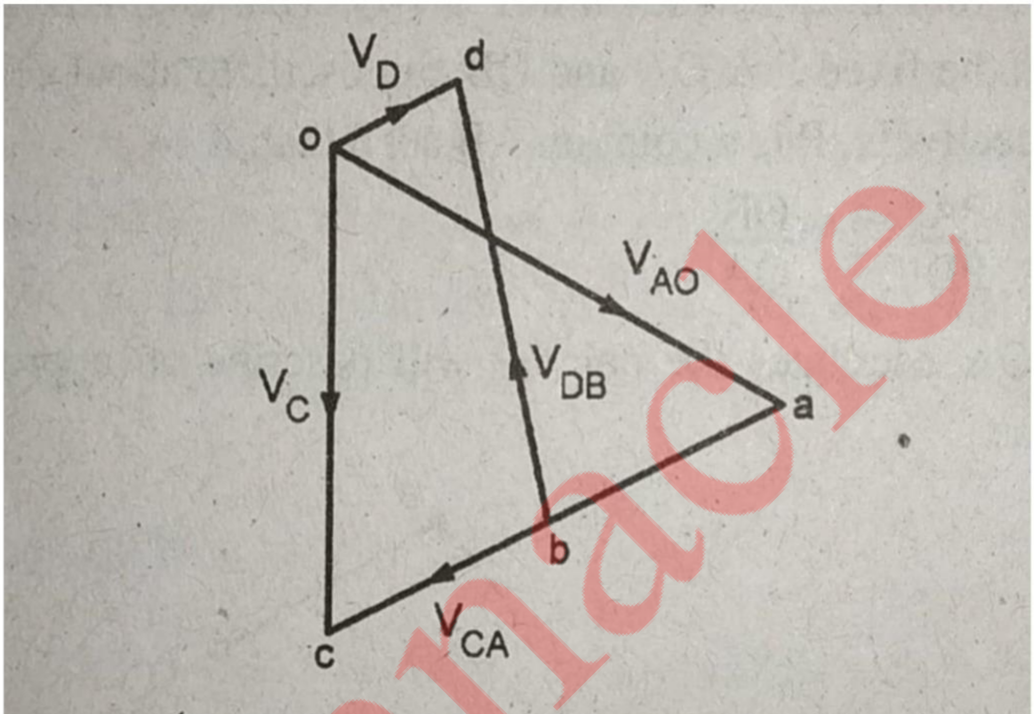


Fig. 2-Q. 5(A) : Velocity Diagram

Fig 1

2) Instantaneous centre method

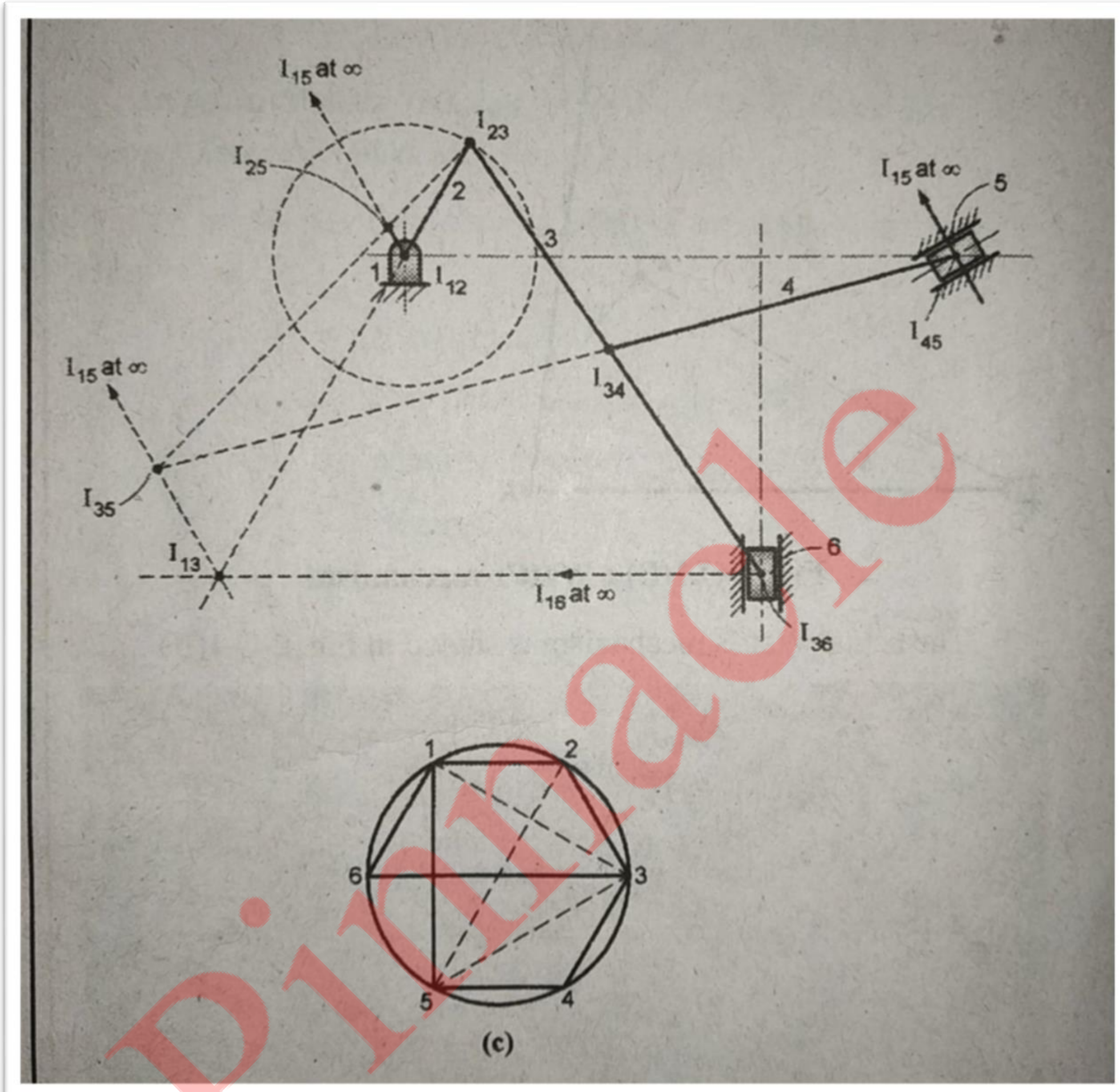


fig 2

$\omega_2 = \frac{2\pi NA\circ}{60}$

$= \frac{2\pi\times200}{60} = 2094\; rad/sec$

$V_D = V_5$

$= \omega_2(I_{12}I_{25})$

$= 2094\; mm/sec$

$= \mathbf{2.094 m/sec}$

Q.5)B)with neat sketch explain the fundamental equation of steering gears for correct gearing. [6]

Ans: the steering gear mechanism is used for changing the direction of wheel, so as to be of pure rolling. It is essential to prevent wear of tyres.move the automobile in desired path. the motion between the wheels of an automobile with road surface should

rolling motion of the wheel's example without skidding is only possible if the parts of the point of contact of the wheels with road surface are concentric circular sharks while automobile is turning on the road.

in order to turn the vehicle the front wheels are mounted on the short axles called stop axles. Usually the back wheels have the same common axis which is fix in a direction with reference to chassis and the steering is achieved by the front wheel.

Front wheels are pivoted at the points A and B of front axle.

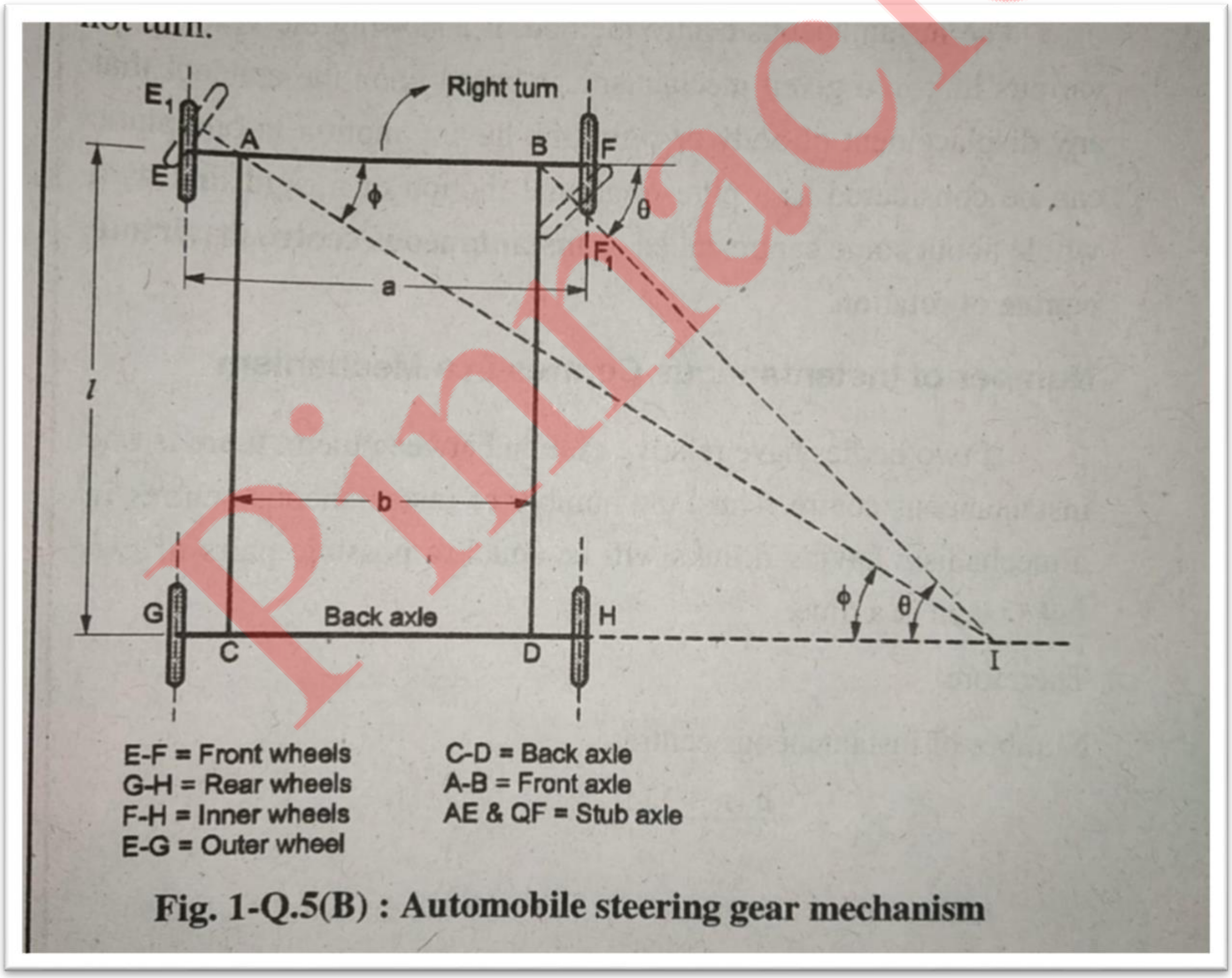


Fig no. 1

for pure rolling motion the two front wheels must about the same instantaneous center I which lies on the axis of the back wheels are shown in the figure. The axis of inner wheels makes a larger angle theta then the angle turned by the outer wheels.

Let l = wheelbase

a=distance between two wheels

b=distance between the pivots of front axle

from IBD

$\cot\theta = \frac{ID}{BD} = \frac{ID}{L}$ ……(i)

From IAC

$\cot\theta = \frac{IC}{AC} = \frac{IC}{l}$ …………..(ii)

Thus $cot\phi - cot\theta = \frac{IC}{l} - \frac{ID}{l} = \frac{1}{l}(Ic - ID)$

$\boldsymbol{\cot\phi - cot\theta = \frac{CD}{l} = \frac{b}{l}}$ **(1)**

Equation 1 represents the fundamental equation for correct steering. If this condition is satisfied then the motion of wheels will be of pure rolling and no skidding will take place. The mechanism used for automatically adjust the values of theta and phi for correct steering are called steering gears.

Q.6)A) figure shows a link mechanism of a quick return mechanism of slotted lever type. The dimensions of lynx are as follows

OA = 400, 0P =200AR=700, RS=300 for the configuration shown determine the acceleration of cutting tool S and angular acceleration of link RS. The crank OP rotates at 210 rpm. [14]

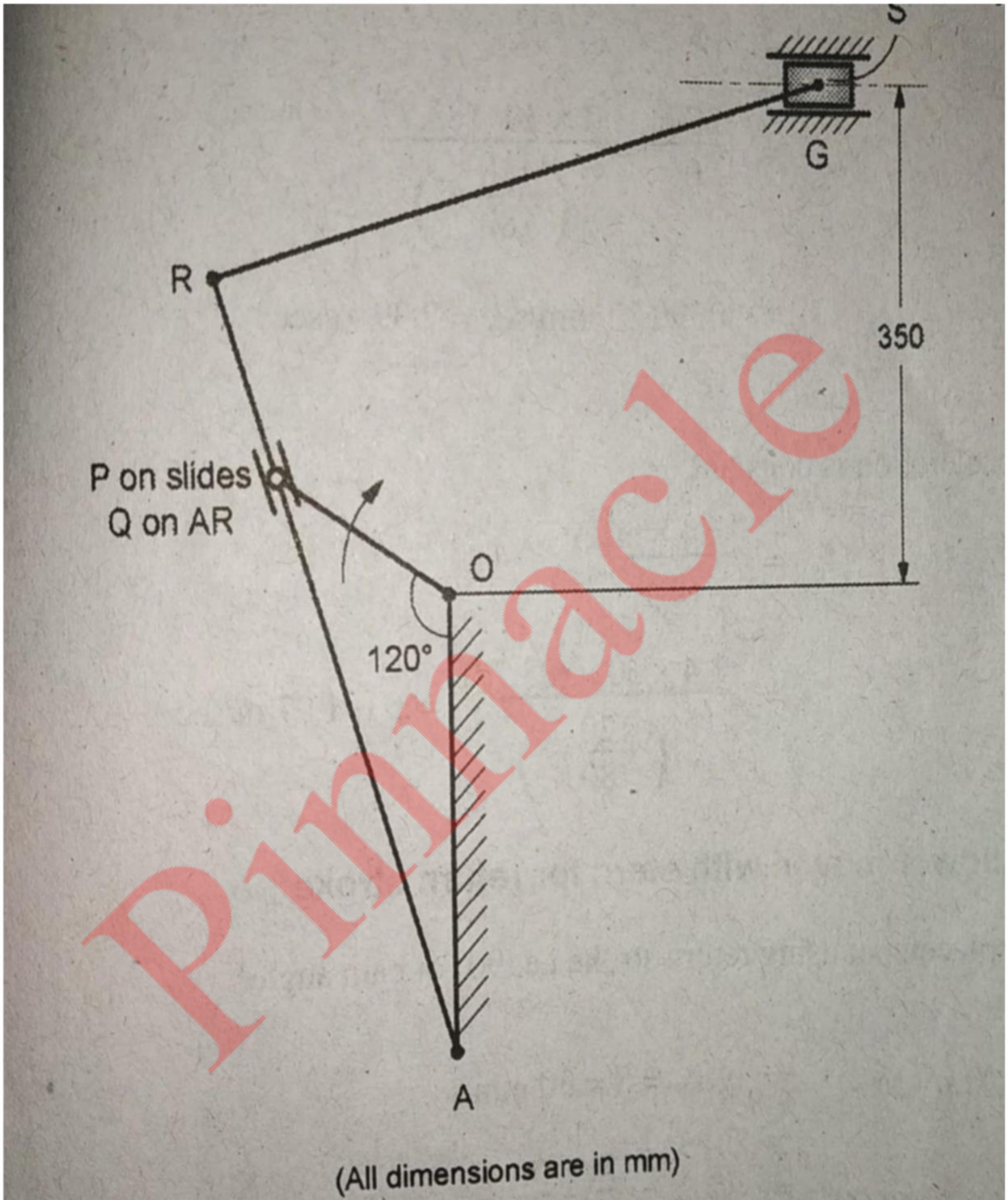
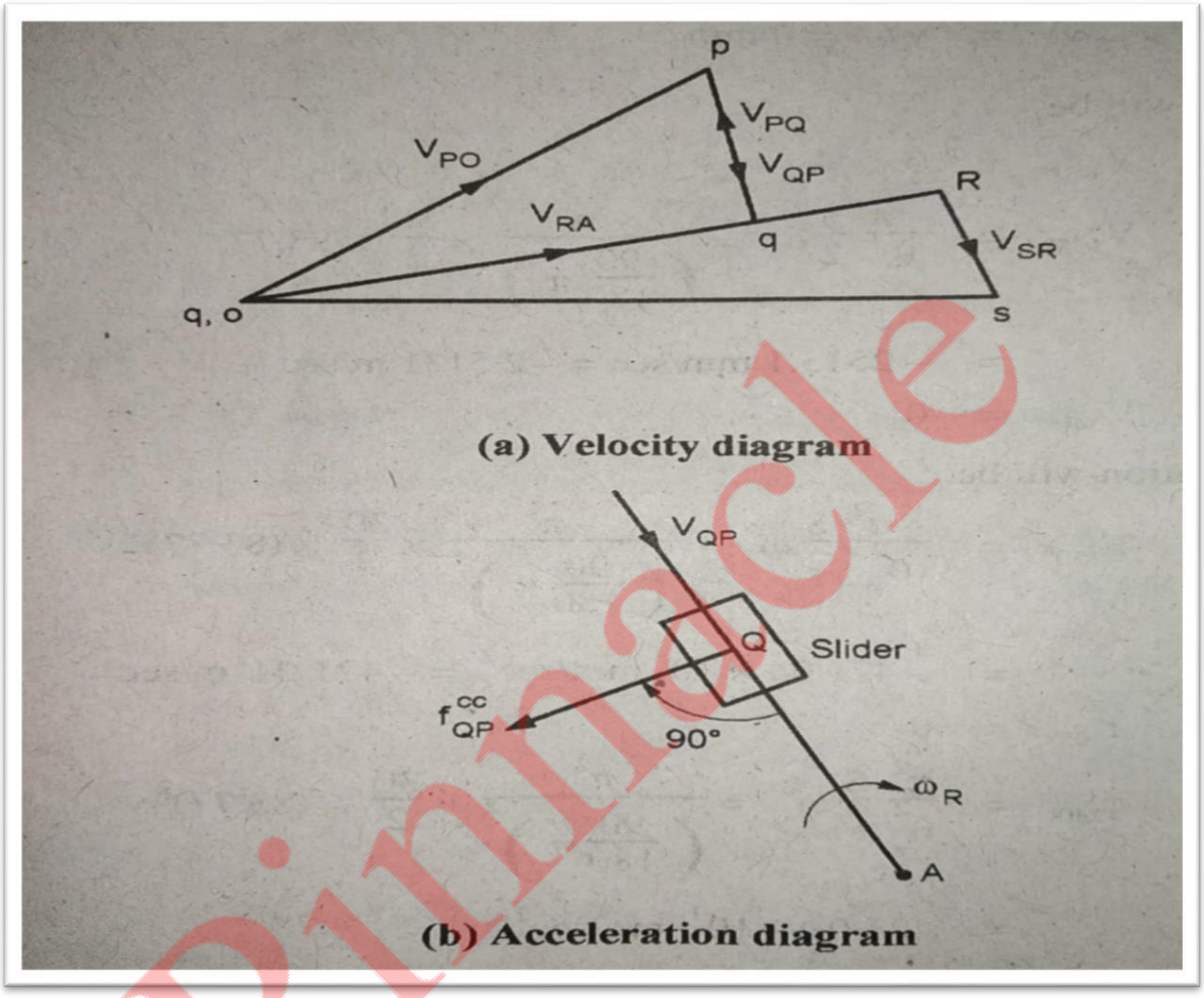


Fig. 1-Q. 6(A)

Ans:


p
V_{PQ}
V_{PO}
V_{QP}
R
V_{RA}
q
V_{SR}
q, o
s
(a) Velocity diagram
V_{QP}
Q
Slider
f^{cc}_{QP}
90°
ω_R
A
(b) Acceleration diagram

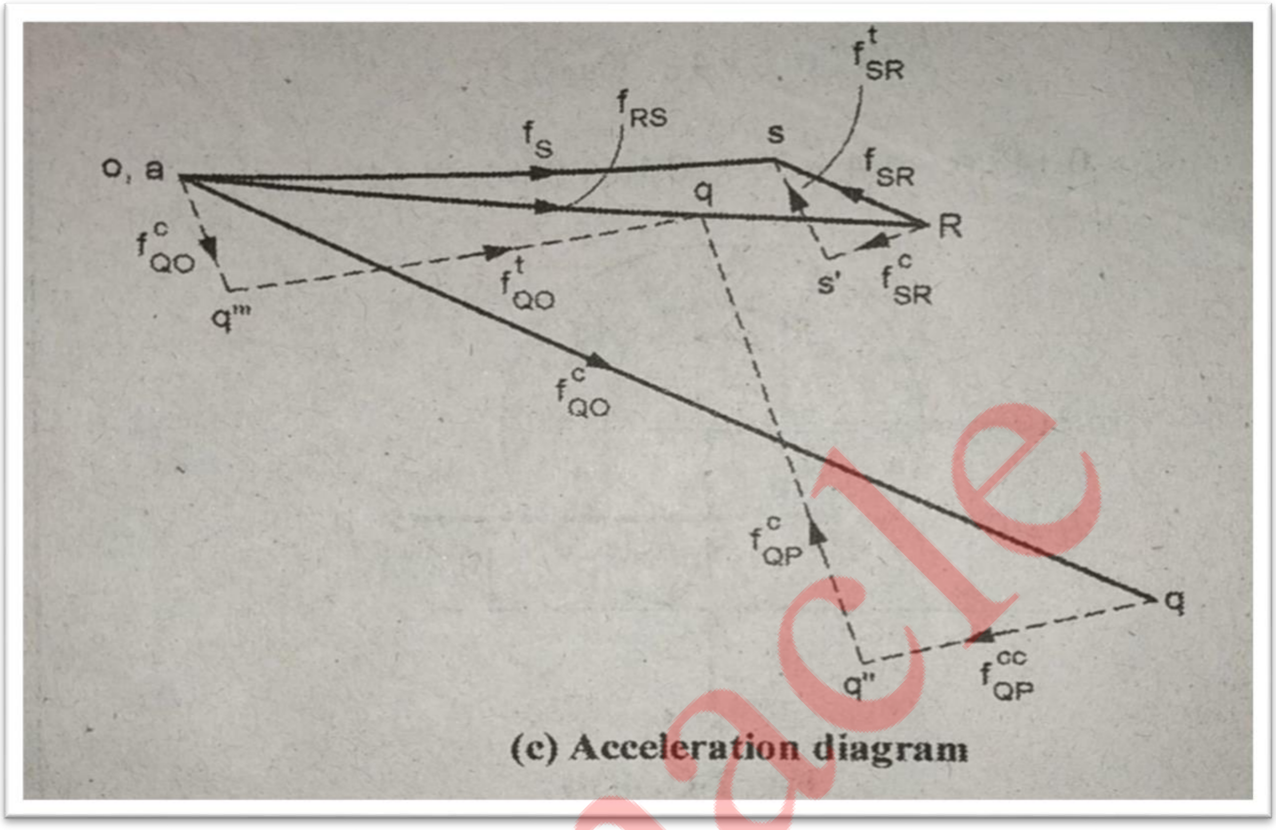


fig no. 2

From acceleration diagram

Acceleration of cutting tool s is

$$f_s = os = 32.80\frac{m}{s^2}$$

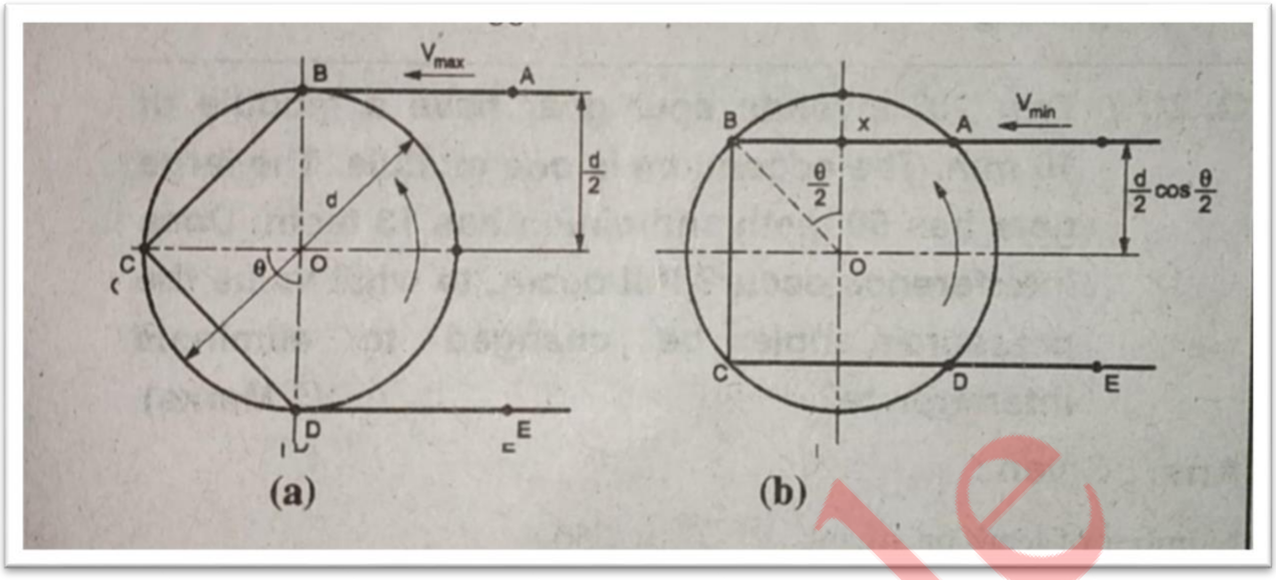
Angular acceleration of the cutting tool is

$$\alpha_{RS} = \frac{f^t\,RS}{RS} = \frac{ss}{RS}$$

$$= \frac{15.7}{0.3} = \mathbf{52.3}\ \boldsymbol{rad/s}$$

Q.6)B) Explain chordal action in chain drive . **[6]**

Ans : The change passes around the sprocket is a series of chordal links. this action is similar to that of non-slipping belt wrapped around a rotating polygon. The coordination is shown in figure where the sprocket has only for teeth. Assume that the sprocket is rotating at a constant speed of an RPM,



the chain ab is at a distance of d/2 from the center of sprocket as shown in the figure its linear velocity is given by

$$v = \omega \times OB = \omega \times \frac{d}{2}$$

$$v\_max = \frac{\pi dn}{60} m/s$$

is this located to the angle the position of the chain link ab shown in the figure in this case the link is at a distance of from the centre of sprocket and its linear velocity is given by

$$v = \omega \times Ox = \omega \times \frac{d}{2} \cos\frac{\theta}{2}$$

$$v\_\min = = \frac{\pi dn}{60} \cos\frac{\theta}{2} m/s$$

the linear speed of chain is not uniform but where is from V_{max} to be minimum during every cycle of tooth engagement. This results in jerky motion the variation in linear velocity is given by.

$$v_{max} - v_{min} = \frac{\pi dn}{60} - \frac{\pi dn}{60} \cos\frac{\theta}{2}$$

$$= \frac{\pi dn}{60} [1 - \cos\theta/2]$$

The variation in linear velocity is directly proportional to

from above equation it is clear that as number of teeth increases the variation in linear velocity will be goes on decreasing.

in order to reduce the variation in chain speed the number of teeth on the sprocket should be increased.

It has been observed that for a sprocket of 11 teeth the speed variation is 4% for 17th the variation is 1.6% and for 24th the variation is less than 1%.