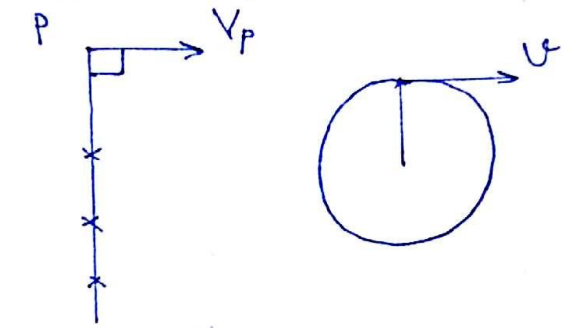
Motion Analysis

* Velocity Analysis *

Instantaneus centre Method App. (Sir Arnhold k.)

Instanteneus centre of Rotation :-

(General Motion)



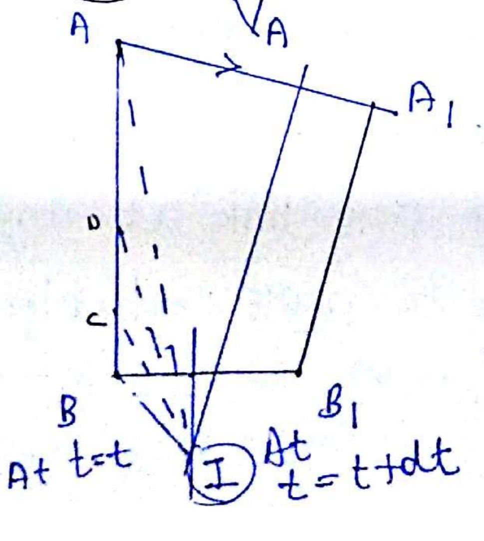
I-centre - Defined for the Relative Motion b/w two links.

for exm.

I_{24} - I - centre for the Relative motion b/w link 2 & link 4

$=$

Same I_{42}



In Reality

$\left.\begin{array}{l} AA_1 \to 0 \\ BB_1 \to 0 \end{array}\right\}$ Differential

The link AB at this instant is in General Motion.

$$\omega_{AB} = \frac{V_A}{AI} = \frac{V_B}{BI} = \frac{V_C}{CI} \dots$$

* In General, when the links move, their Relative Motion IC keeps on changing

* Locous of I - centre for the Relative motion b/w links in centrode.
* Locus of I-axis of rotation for. Relative motion b/w links is Axode.

eg.	Motion	centrode	Axode
1.	General	Curve	Curved surface
2.	Pure translation	Straigth line	Plane Surface
3.	Pure rotation	point	Straigth line

" In General the motion of a link in mechanism is neither in translation or nor in pure rotation It is the combination of translation ~~of~~ and rotation which we ~~Ge~~ normally say link is in General Motion. But any link at any Instant can be asume to be in pure rotation w.r.t. point in the space known as Instanteneus centre of rotation. This centre also knowen as Virtual centre."

Number of I-centre in Mechanism :-

If No. of links : L

$$\text{No. of I-C} = {}^{L}C_2 = \frac{L(L-1)}{2}$$

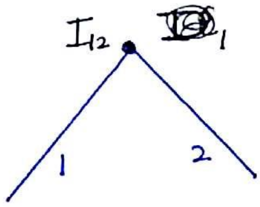
For exm. $l = 5$

$$\# IC = {}^{5}C_2 = 10$$

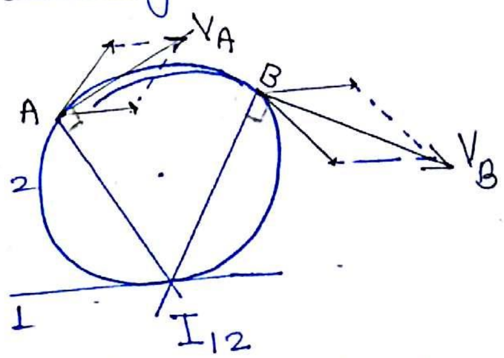
$$\left.\begin{matrix} I_{12} & I_{13} & I_{14} & I_{15} \\ & I_{23} & I_{24} & I_{25} \\ & & I_{34} & I_{35} \\ & & & I_{45} \end{matrix}\right\} 10$$

Basic IC in Mechanism :-

① Turning Pair :-



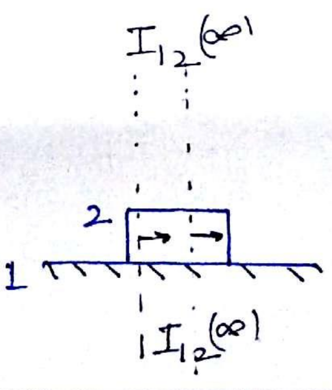
② Rolling Pair



{ take Velocity at any two points and draw ⊥er to Velocities.

③ Sliding Pair

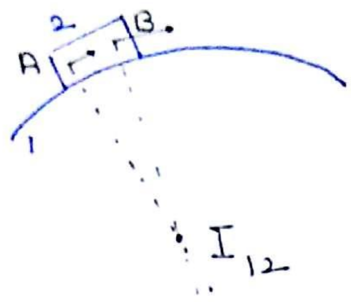
on Plane Surface :-



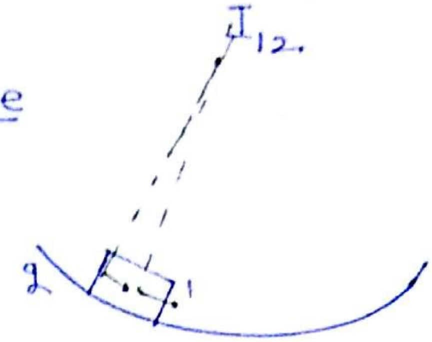
IC will go to ∞, but in the dirn ⊥er to the sliding surface

Curved surface

Convex

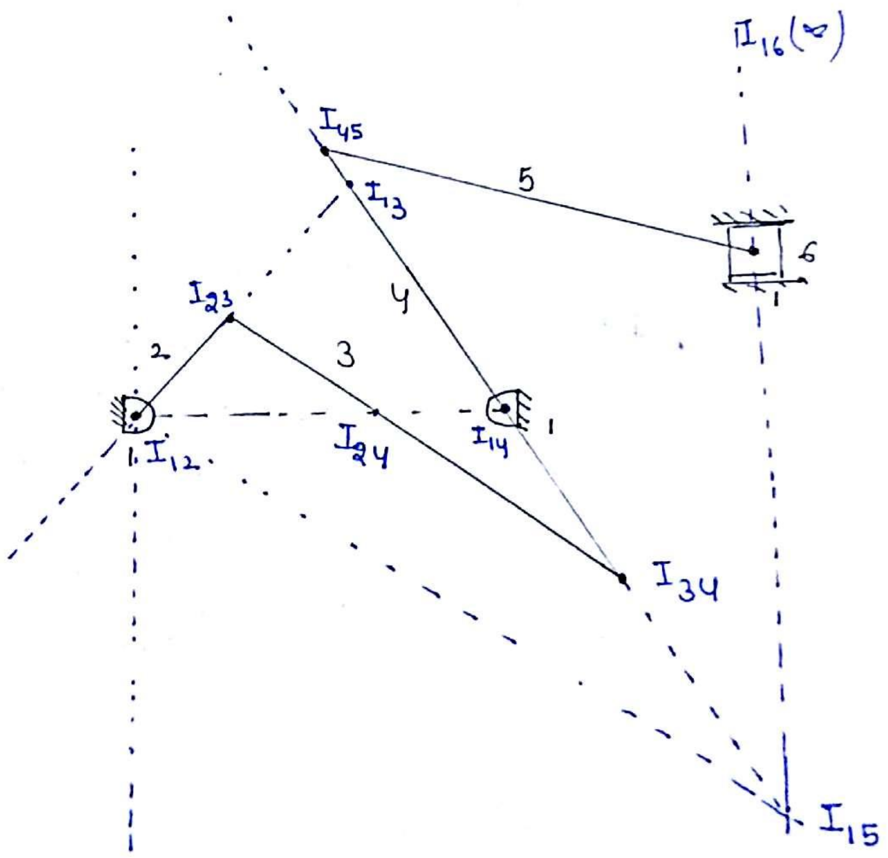


Concave



I-centre lies at centre of radius of curvature for above.

Ques



$l = 6$

$IC = {}^6C_2 = 15$

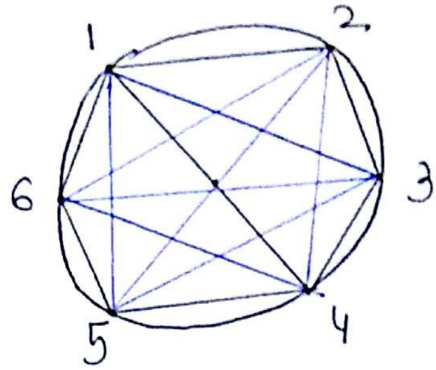
I_{12} I_{13} I_{14} I_{15} I_{16}

I_{23} I_{24} I_{25} I_{26}

I_{34} I_{35} I_{36}

I_{45} I_{46}

I_{56}



13 — 12, 23 ; 14, 43

24 — 23, 34 ; 21, 14

35 — 34, 45 ; 32, 25 ; 31, 15

15 — 14, 45 ; 16, 65

25 — 24, 45 ; 21, 15

36 — 35, 56 ; 32, 26 ; 31, 16

26 — 21, 16 ; 25, 65

46 — 41, 16 ; 42, 26 ; 43, 36 ; 45, 56

Input (Given)

$N_{OA} = 120$ rpm

$\omega = \frac{2\pi \times 120}{60} = 4\pi$ rad/s

$V_A = (OA)\omega_{OA}$

$V_A = 0.2 \times 4\pi$

$V_A = 2.5132$ m/s

link 3 $(A,B)(I_{13})$
for ground

$\omega_3 = \omega_{AB} = \frac{V_A}{I_{13}A} = \frac{V_B}{I_{13}B}$

link 4 $(B,C)(I_{14})$

$\omega_4 = \omega_{BC} = \frac{V_B}{I_{14}B} = \frac{V_c}{I_{14}C}$

link 5 $(C,D)(I_{15})$

$\omega_5 = \omega_{CD} = \frac{V_C}{I_{15}C} = \frac{V_D}{I_{15}D}$

Kennedy's Theorem:-

" For the relative motion b/w the number of links in a mechanism, any three links, their three I-C Must lie in a straigh ~~center~~ line.

Theorem of Angular Velocities:

For any IC I_{mn}

Can be treated on link m

Can also be treated on link n

$$V_{I_{mn}} = \omega_m \left(I_{mn} I_{1m} \right) = \omega_n \left(I_{mn} I_{1n} \right) = V_{I_{mn}}$$

$$\boxed{\omega_m \left(I_{mn} I_{1m} \right) = \omega_n \left(I_{mn} I_{1n} \right)}$$

with Ground.

This is applied at I_{mn}

But total IC's

I_{mn}, I_{1m}, I_{1n} — link 1, link m, link n — in straight line

In Previous question

$\omega_2 \rightarrow$ Given (cw)

$\{$ because I_{15} & I_{12} are in opposite dir^n to $I_{25} \}$

(AC)

apply b/w (25) $\Rightarrow$ $\omega_2(I_{25} I_{12}) = \omega_5(I_{25} I_{15})$

AC

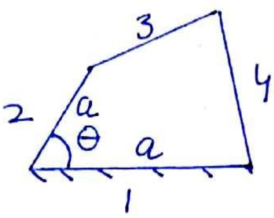
apply b/w (24) $\Rightarrow$ $\omega_2(I_{24} I_{12}) = \omega_4(I_{24} I_{14})$

apply b/w (45) $\omega_4(I_{45} I_{14}) = \omega_5(I_{45} I_{15})$ lie

AC AC (same Side)

Soln

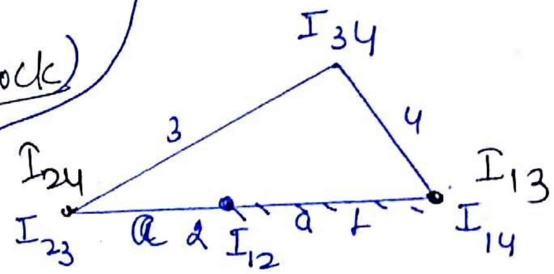
Problem:

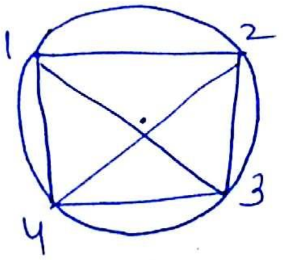


when $\theta = 180°$

$\omega_2 = 5$ rad/s (clock)

$\omega_3 = ?$





I_{13} — 12, 23 / 14, 43

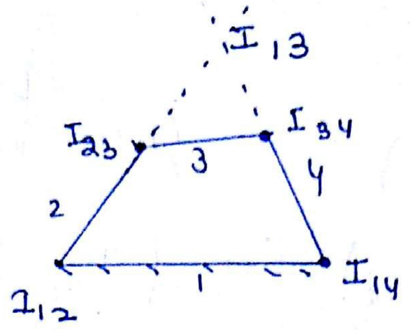
24 — 23, 34 / 21, 14

(23) $\omega_2(I_{23} I_{12}) = \omega_3(I_{23} I_{13})$

$5 \times a = \omega_3 \times 2a$

$\omega_3 = 2.5$ rad/s Clock

Ques



Given $\omega_2 = 5$ rad/se (CW)

$\omega_3 = 14$ rad/s

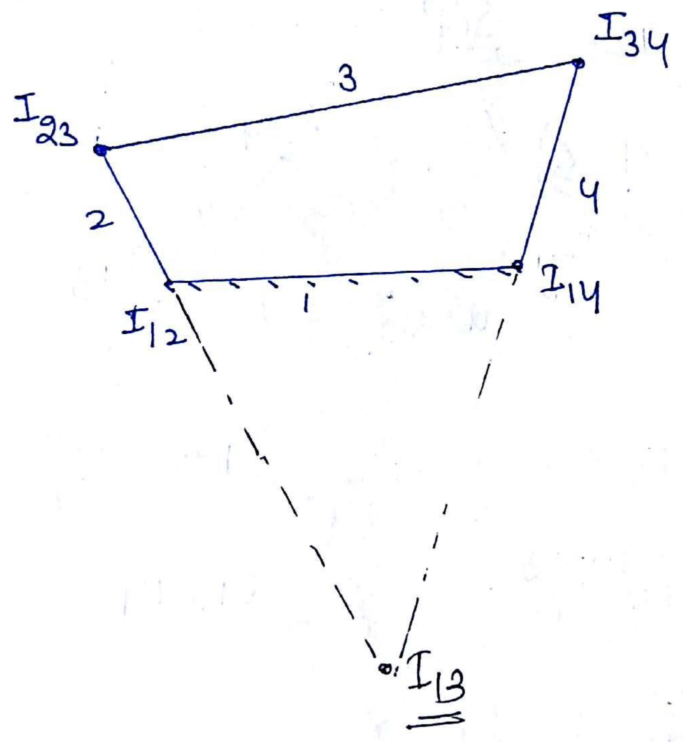
Find Angular Velocity of link 2 wrt 3

$$\vec{\omega}_{23} = \vec{\omega}_2 - \vec{\omega}_3$$

$$= (+5) - (-14)$$

I_{23} (lie b/w I_{12} & I_{13})

Ques:-



$$\vec{\omega}_{23} = \vec{\omega}_2 - \vec{\omega}_3$$

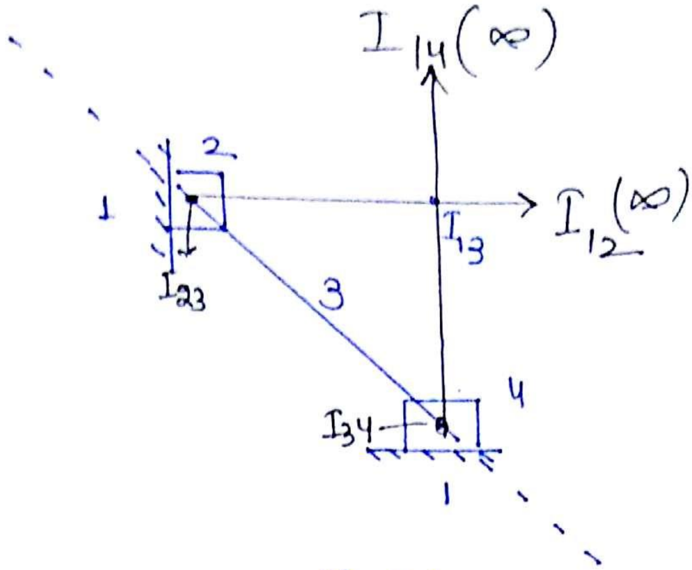
$$= (+5) - (+14)$$

$$= -9 \text{ rad/s}$$

$$= 9 \text{ rad/se (ACW)}$$

ω_3 is CW bcoz I_{23} lie oposite from both.

Ques Gate



find $I_{24} = ?$

I_{13}

$I_{24} \rightarrow$ 23, 34

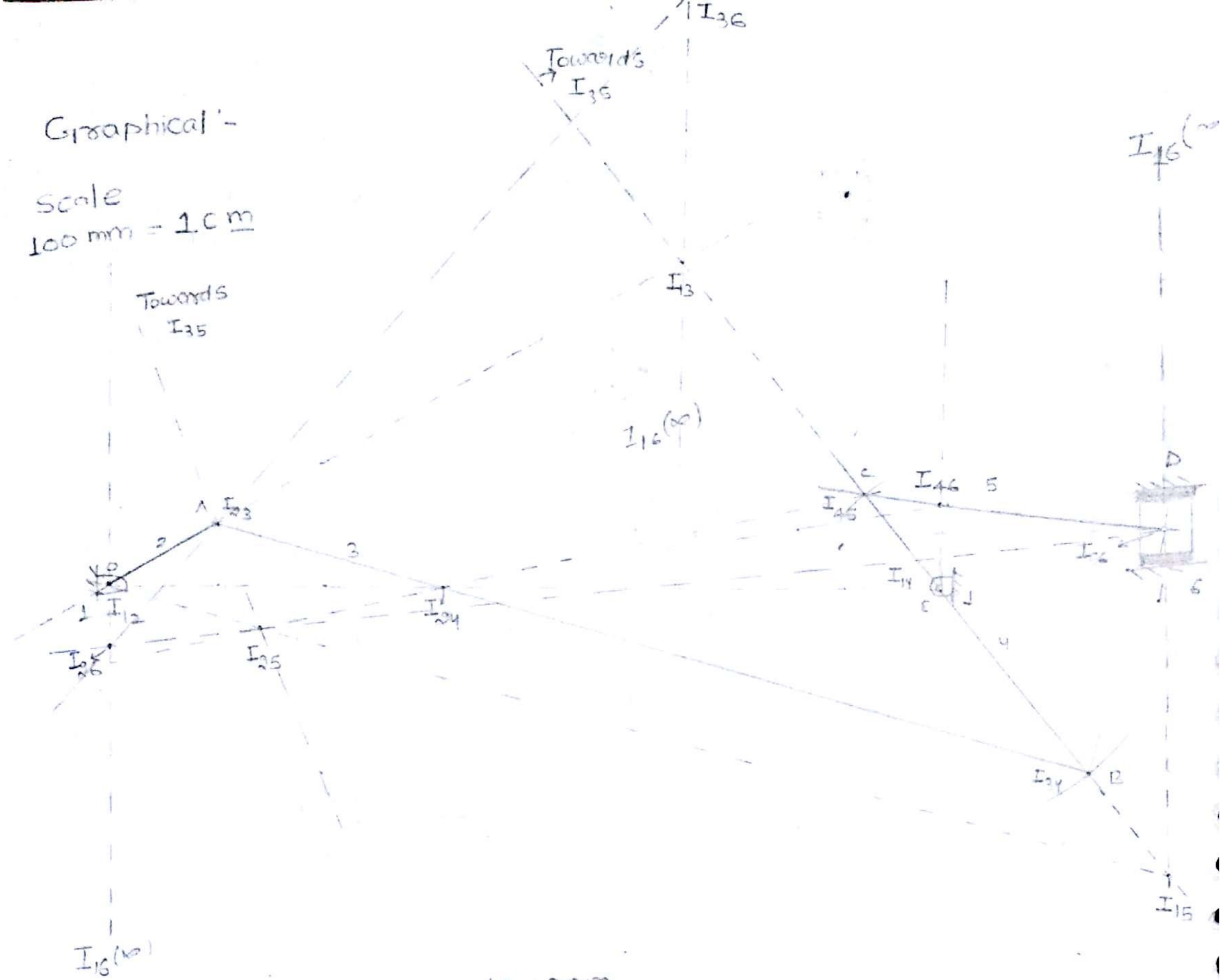
21, 14 ∞ distant line

~~∞ line~~

So I_{24} also lies ∞ Ans

Graphical :-

Scale
100 mm = 1 cm



(2) OA = 200mm

(3) AB = 1500mm

(4) BC = 600mm

(5) CD = 500mm

BE = 400mm

V_B ? ω_{AB} ?

V_C ? ω_{BC} ?

V_D ? ω_{CD} ?

ω_3 ?

ω_4 ?

ω_5 ?

$N_{OA} = 120$ rpm

$\omega_A = \frac{120 \times 2\pi}{60}$

$\omega_A = 4\pi$ rad/s

$\omega_2 = 4\pi$ rad/s (CW)

$V_A = 0.2 \times 4\pi$

$V_A = 2.5132$ m/s

AB

(23)

$\omega_2(I_{23} I_{12}) = \omega_3(I_{23} I_{13})$

$\omega_3 = \frac{4\pi \times (0.2)}{0.860}$

$\boxed{\omega_3 = 0.930\pi \text{ rad/s (ACW)}}$

$\boxed{V_3 = 4.38 \text{ m/s}}$

BC

(24)

$\omega_2(I_{24} I_{12}) = \omega_4(I_{24} I_{14})$

$\omega_4 = \frac{4\pi(0.540)}{(0.810)}$

$\boxed{\omega_4 = 2.66\pi \text{ (ACW)}}$

$\boxed{V_4 = 5.02 \text{ m/s}}$

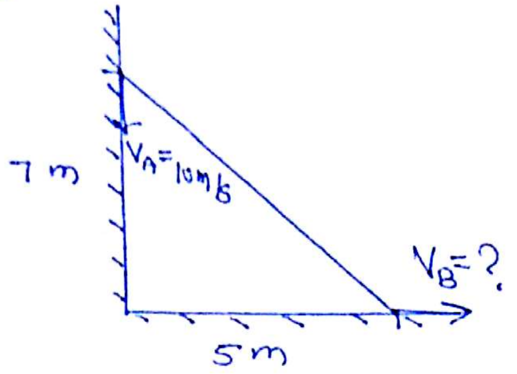
CD

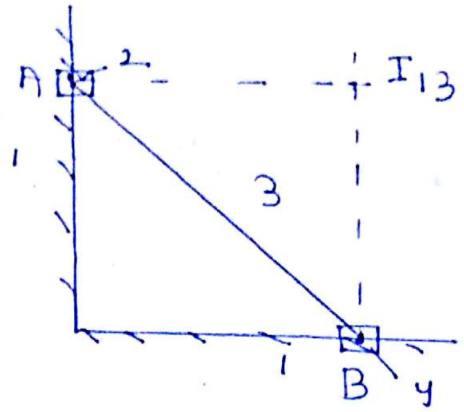
(25) $\omega_2(I_{25} I_{12}) = \omega_5(I_{25} I_{15})$

$\omega_5 = \frac{4\pi(0.250)}{(1.56)} = 0.64\pi$ rad/s (ACW)

$\boxed{V_5 = 1.006 \text{ m/s}}$

Que



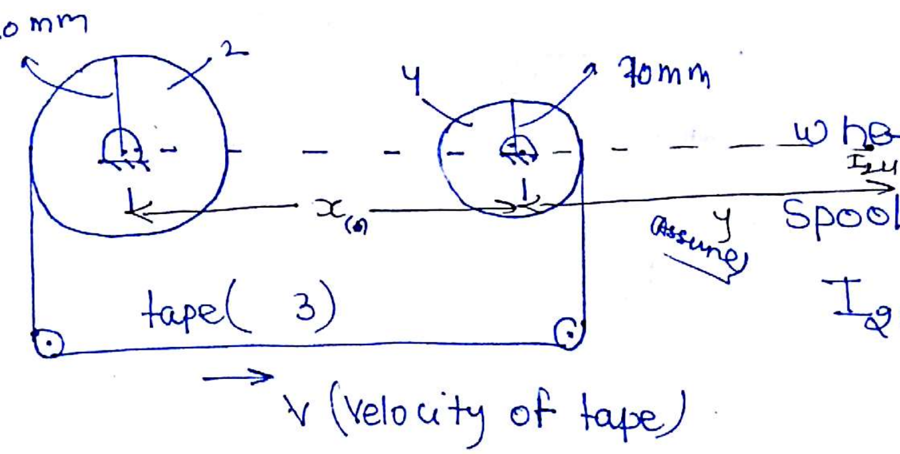


ladder (link 3) (AB) (I_{13})

$$\omega_3 = \frac{V_A}{I_{13}A} = \frac{V_B}{I_{14}B}$$

$$\frac{10}{5} = \frac{V_B}{7} \Rightarrow V_B = 14 \text{ m/s} \quad \text{Ans}$$

Pb-



where is IC of spools

$I_{24} = ?$

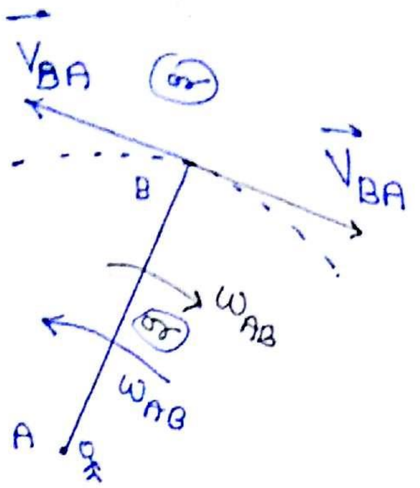
$$\omega_2 (I_{24} I_{12}) = \omega_4 (I_{24} I_{14})$$

$$\frac{v}{0.020} (x+y) = \frac{v}{0.010} (\cancel{x}y)$$

$$\frac{1}{2}(x+y) = y$$

$$y = x$$

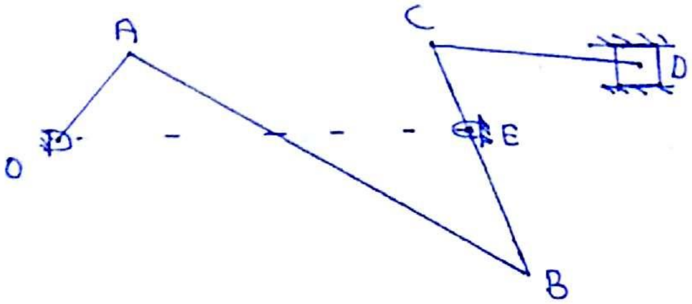
Relative velocity Approach:-



$\underline{\vec{V}_{BA}}$ = The velocity of point B w.r.t. point A will be in the $\perp^{er}$ to the link AB.

Ques

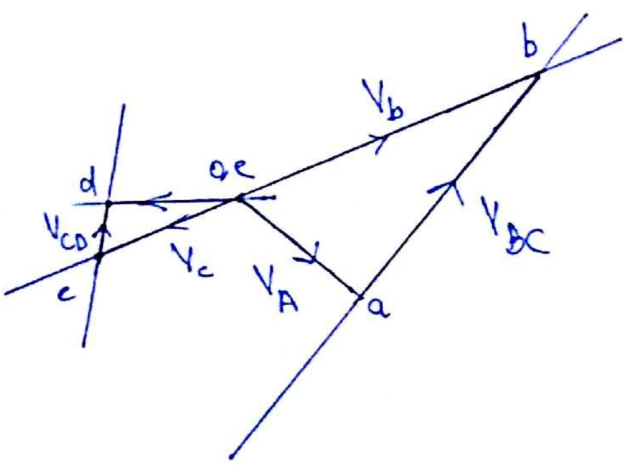
Scale



Velocity dia

$V_A = 2.5132$ m/s

Scale



A से B CW घुमने पर आ रहे हैं

but a से b ACW घुमाने पर आ रहे हैं इसलिए

V_{AB} (ACW)

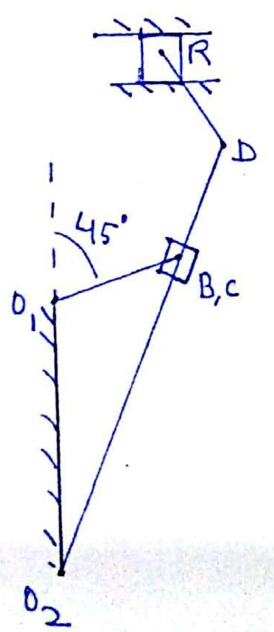
similarlity others

point	w.r.t	procedure
A	O	line $\perp^{er}$ to link OA
B	A	line $\perp^{ar}$ to link AB
B	E	line $\perp^{ar}$ to link BE
C	$\frac{BC}{BE}$	$= \frac{bc}{be}$? $bc = ?$ { if 2 pts on a line (e,b) are know then we can get any pt. in same dirⁿ
D	c	line $\perp^{er}$ to link CD
D	Fixed	line ‖el to the motion of slider.

$$\omega_{AB} = \frac{V_{AB}}{AB} \quad \omega_{BC} = \frac{V_{BC}}{BC} \quad \omega_{CD} = \frac{V_{CD}}{V_{CD}}$$

(AC) (AC) (AC)

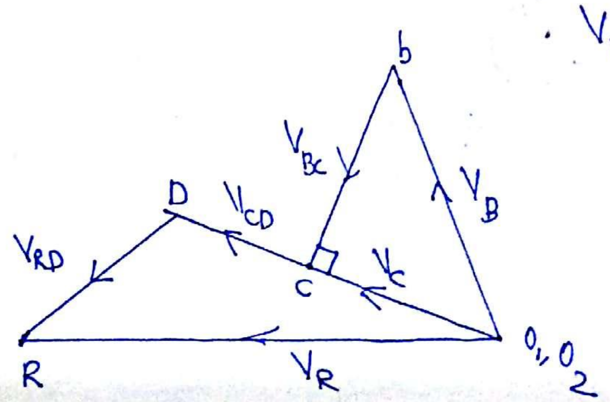
Pb.
IES 2006



If crank O_1B @ $N = 40$ rpm (AC)

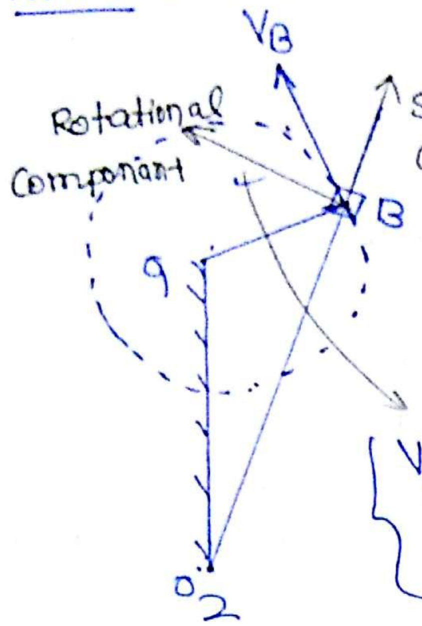
$V_B = (O_1B)(\omega_{O_1B}) = (0.250)\left(40 \times \frac{2\pi}{60}\right)$ m/s

$\therefore V_B =$ —



Point D by intersection after getting c

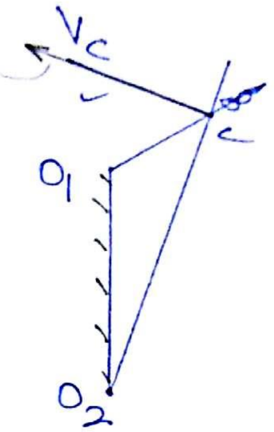
~~B~~ Point B (Slider)



$\left\{ V_c = \text{Rotational Component of } V_B \right\}$

Point (c) :- Coincident point of Slider B, but on Slotted bar

→ slotted bar O_2CD



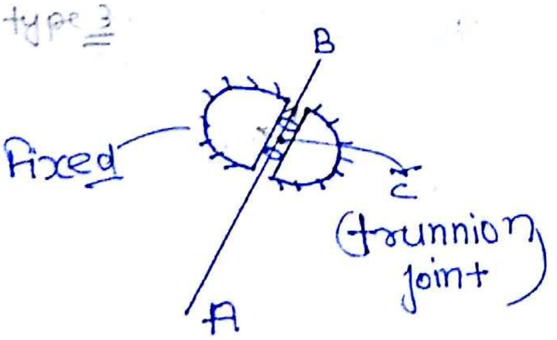
Point c on velocity ~~dai~~ diagram.

type 2

Point	w.r.t.	procedure
c	O_2	line $\perp^{ar}$ to link O_2C
c	B	line $\parallel^{el}$ to link O_2C

Swivel trunnion :- (Trunnion Joint)

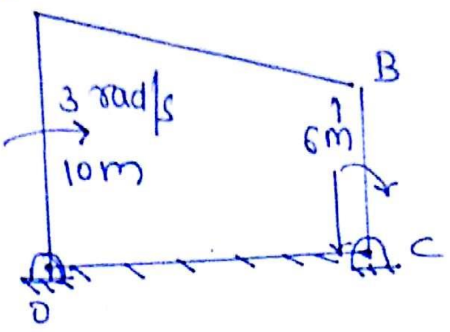
type 3



sliding as well as rotating wrt to fixed

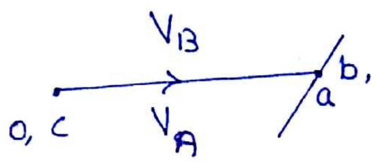
Point	w.r.t.	procedure
c	A	line $\perp^{ar}$ to link AC
c	Fixed	line $\parallel$ to link AC

Problem:-



Pb 1:- The velocity diagram to the given Conf. at this instant.

Velocity dgm.



Pb2 $V_B = ?$ $V_B = V_A = 10 \times 3 = 30$ m/s.

Pb3 $\vec{V}_{BA} = ?$ $V_{BA} = V_B - V_A = 0$

Pb4 The motion of link AB at this moment will be

$$\omega_{AB} = \frac{V_{AB}}{AB} = 0$$

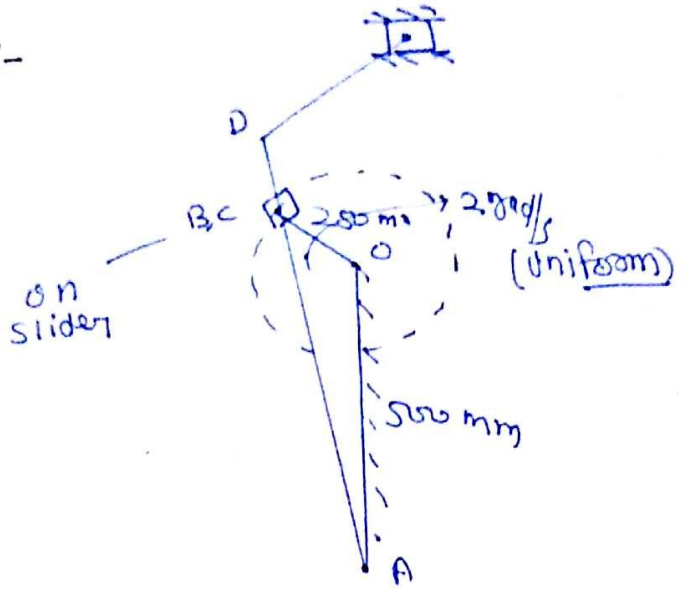
Pb5 $\omega_B = ?$ $V_B = V_A$

$6 \times \omega_{BC} = 10 \times 3$

$\omega_{BC} = 5$ rad/s.

Pb6 Combined All problems.

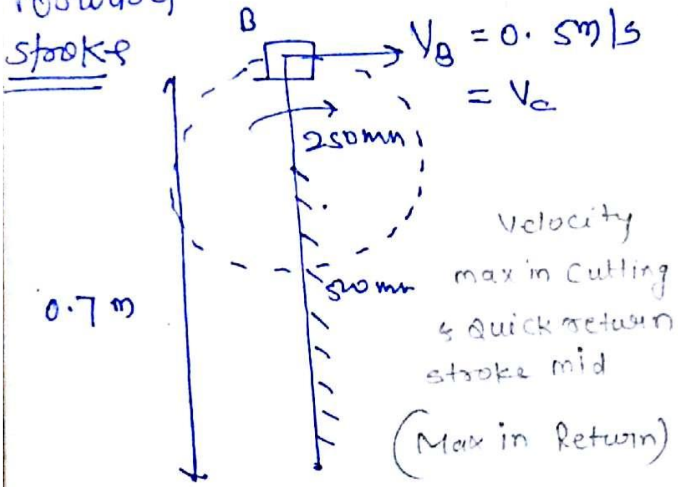
Prob:-
21



Find the Angular Velocity of slotted bar when the Velocity of Ram is max.

Slider velocity $V_B = (0.250) \times 2 = 0.5\ m/s$ (Uniform)

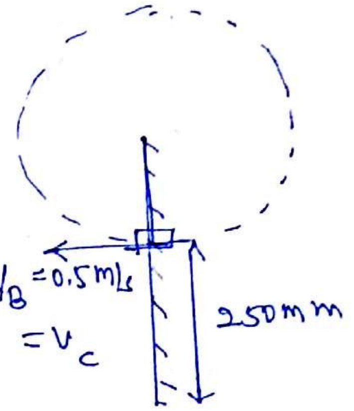
Forward stroke



Velocity max in Cutting & Quick return stroke mid

(Max in Return)

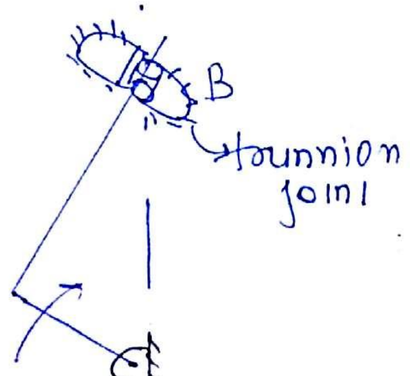
Backward Stroke (Max. here)



$$\omega_{SB} = \frac{V_B}{0.750} = \frac{0.5}{0.750} = 2/3\ rad/sec$$

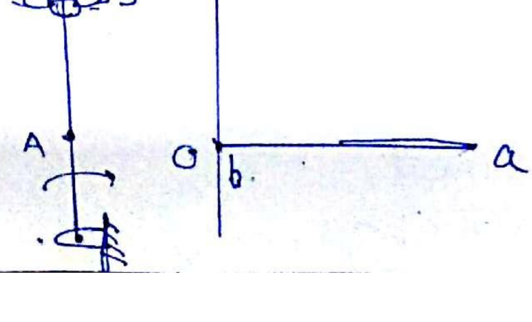
$$\omega_{SB} = \frac{V_c}{0.250} = \frac{0.5}{0.250} = 2\ rad/s$$

Pb:



Find the avg. Velocity of swivel trunmium when the link OA & AB become vertical ?

At that moment



$V_B = 0$

$\omega_{ST} = 0$