

## Kinematics of Rigid Body (ICR)

- 1)  $V = r \times \omega$   
 $v \rightarrow$  Velocity  
 $r \rightarrow$  Distance between Fixed Point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)

### ICR

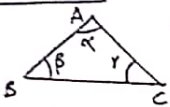
- 1) It is a fixed point i.e. Zero Velocity Point
- 2) It is an imag point
- 3) It may be lie within the body or outside the body.

### Types of Link

- Rotating Link  
(ICR  $\rightarrow$  Inside the body)
- Sliding Link  
(ICR  $\rightarrow$  outside the body)

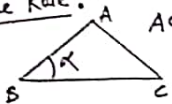
### Type 1:- Sliding Link

### 3) Sine Rule:

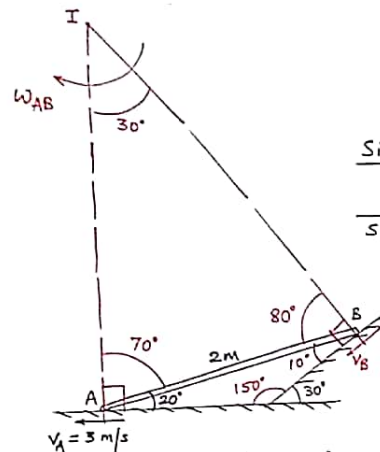


$$\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$$

### 4) Cosine Rule:



$$AC = \sqrt{AB^2 + BC^2 - 2AB \cdot BC \cos \alpha}$$



### Sine Rule

$$\frac{2}{\sin 30^\circ} = \frac{AI}{\sin 80^\circ} = \frac{BI}{\sin 70^\circ}$$

$$AI = 3.93 \text{ m}$$

$$BI = 3.75 \text{ m}$$

Q 15)

### Link AB (Sliding)

pt I is an ICR

$$V_A = AI \times \omega_{AB}$$

$$3 = 3.93 \times \omega_{AB}$$

$$\omega_{AB} = 0.761 \text{ r/sec}$$

$$V_B = BI \times \omega_{AB}$$

$$= 3.75 \times 0.761$$

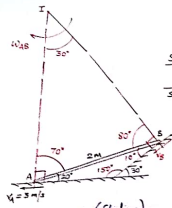
$$V_B = 2.86 \text{ m/s}$$

# Kinematics of Rigid Body (ICR)

- $V = r\omega$
- $r$  → Distance between fixed point and moving point
- $\omega$  → Angular Velocity (rad/sec)

- $\omega = 2\pi N / 60$
- $N$  → No. of revolutions (rpm)
- Sine Rule:  $\frac{AB}{\sin B} = \frac{BC}{\sin A} = \frac{AC}{\sin C}$
- Corollary Rule:  $\frac{AB}{\sin B} = \frac{BC}{\sin A} = \frac{AC}{\sin C}$

- Types of Link
- 1. Revolute Link (ICR inside the body)
- 2. Sliding Link (ICR outside the body)

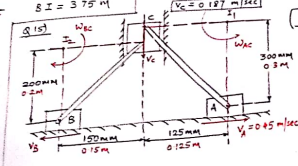


Link AB (Sliding)  
pt I is an ICR  
 $V_A = AI \times \omega_{AB}$   
 $3 = 3.93 \times \omega_{AB}$   
 $\omega_{AB} = 0.761 \text{ rad/sec}$   
 $V_B = BI \times \omega_{AB}$   
 $= 3.75 \times 0.761$   
 $V_B = 2.85 \text{ m/s}$

Sine Rule  
 $\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$   
 $\frac{2}{\sin 30^\circ} = \frac{AI}{\sin 80^\circ} = \frac{BI}{\sin 70^\circ}$   
 $AI = 3.93 \text{ m}$   
 $BI = 3.75 \text{ m}$

Link AC  
pt I is an ICR  
 $V_A = AI \times \omega_{AC}$   
 $0.45 = 3.93 \times \omega_{AC}$   
 $\omega_{AC} = 0.115 \text{ rad/sec}$   
 $V_C = CI \times \omega_{AC}$   
 $= 0.125 \times 0.115$   
 $V_C = 0.0144 \text{ m/sec}$

Link BC  
pt I is an ICR  
 $V_C = CI \times \omega_{BC}$   
 $0.187 = 0.15 \times \omega_{BC}$   
 $\omega_{BC} = 1.246 \text{ rad/sec}$   
 $V_B = BI \times \omega_{BC}$   
 $= 0.2 \times 1.246$   
 $V_B = 0.249 \text{ m/sec}$



## Kinematics of Rigid Body (ICR)

$$v = r \times \omega$$

$v \rightarrow$  Velocity

$r \rightarrow$  Distance between Fixed Point and moving point

$\omega \rightarrow$  Angular Velocity (rad/sec)

### ICR

1) It is a fixed point i.e. zero velocity point

2) It is an imag. point

3) It may be lie within the body or outside the body

### Types of Link

Rotating Link

Sliding Link

(ICR  $\rightarrow$  Inside the body) (ICR  $\rightarrow$  outside the body)

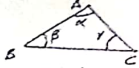
Type 1:- Sliding Link

Type 2:- One Sliding & One Rotating

Type 3:- One Sliding, One Rotating and One Free end

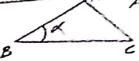
$N \rightarrow$  No of Revolutions (RPM)

3) Sine Rule:

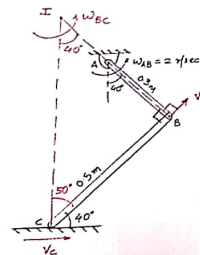


$$\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$$

4) Cosine Rule:



$$AC^2 = AB^2 + BC^2 - 2ABBC \cos \alpha$$



Link AB (Rotating)

Pt A is an ICR

$$V_A = 0$$

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

$$= 0.3 \times 2$$

$$V_B = 0.6 \text{ m/sec}$$

Link BC (Sliding)

Pt I is an ICR

$$V_B = BI \times \omega_{BC}$$

$$0.6 = 0.596 \times \omega_{BC}$$

$$\omega_{BC} = 1 \text{ rad/sec}$$

$$V_C = CI \times \omega_{BC}$$

$$= 0.778 \times 1$$

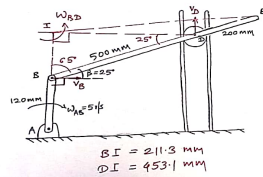
$$V_C = 0.778 \text{ m/sec}$$

## Kinematics of Rigid Body (ICR)

- $V = r \times \omega$   
 $V \rightarrow$  Velocity  
 $r \rightarrow$  Distance between Fixed Point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)  
 $\omega = \frac{2\pi N}{60}$
- ICR**  
 1) It is a fixed point i.e. zero velocity point  
 2) It is an imag. point  
 3) It may be lie within the body or outside the body

### Types of Link

- Rotating Link (ICR  $\rightarrow$  inside the body)  
 Sliding Link (ICR  $\rightarrow$  outside the body)  
 Type 1:- Sliding Link  
 Type 2:- One Sliding & One Rotating  
 Type 3:- One Sliding, One Rotating and One free end



Link AB (Rotating)  
 pt A is an ICR  
 $V_A = 0$   
 $V_B = AB \times \omega_{AB}$   
 $120 = 500 \times \omega_{AB}$   
 $\omega_{AB} = 0.24 \text{ rad/sec}$   
 Link BD (Sliding)  
 pt I is an ICR  
 $V_B = BI \times \omega_{BD}$   
 $600 = 211.3 \times \omega_{BD}$   
 $\omega_{BD} = 2.839 \text{ rad/sec}$

$V_D = DI \times \omega_{BD}$   
 $= 453.1 \times 2.839$   
 $V_D = 1286.49 \text{ mm/sec}$   
 Free end (E)  
 $V_E = EI \times \omega_{BD}$   
 $= 1816.98 \text{ mm/sec}$



# Kinematics of Rigid Body (ICR)

- $V = r \times \omega$
- $V \rightarrow$  Velocity
- $r \rightarrow$  Distance between Fixed Point and moving point
- $\omega \rightarrow$  Angular Velocity (rad/sec)

$$\omega = \frac{2\pi N}{60}$$

$N \rightarrow$  No of Revolutions (RPM)

a) Sine Rule:

$$\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$$

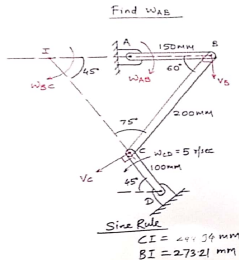
b) Cosine Rule:

$$AC^2 = AB^2 + BC^2 - 2AB \cdot BC \cos \gamma$$

- ICR
- It is a fixed point i.e zero velocity point
  - It is an imaginary point
  - It may be lie within the body or outside the body

## Types of Link

- Rotating Link (ICR  $\rightarrow$  Inside the body)
- Sliding Link (ICR  $\rightarrow$  outside the body)
- Type 1: Sliding Link
- Type 2: One Sliding & One Rotating
- Type 3: One Sliding, One Rotating and One free end
- Type 4: Two Rotating & One Sliding link



## Find $\omega_{AB}$

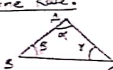
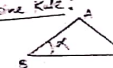
- Link CD (Rotating)  
pt D is an ICR  
 $V_D = 0$   
 $V_C = CD \times \omega_{CD}$   
 $V_C = 500 \text{ mm/sec}$
- Link AB (Rotating)  
pt A is an ICR  
 $V_A = 0$   
 $V_B = AB \times \omega_{AB}$   
 $V_B = 150 \times \omega_{AB}$  — ①

## Link BC (Sliding)

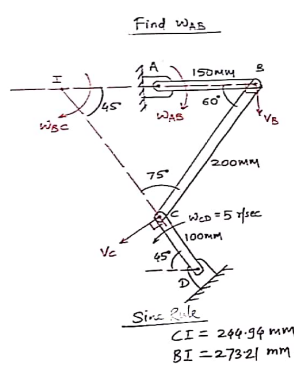
- pt I is an ICR  
 $V_C = CI \times \omega_{BC}$   
 $500 = 244.34 \times \omega_{BC}$   
 $\omega_{BC} = 2.04 \text{ rad/sec}$
- $V_B = BI \times \omega_{BC}$   
 $= 273.21 \times 2.04$   
 $V_B = 557.34 \text{ mm/sec}$
- From eqn ①  
 $557.34 = 150 \times \omega_{AB}$   
 $\omega_{AB} = 3.71 \text{ rad/sec}$

# Kinematics of Rigid Body (ICR)

$V = r \times \omega$   
 $V \rightarrow$  velocity  
 $r \rightarrow$  Distance between fixed point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)  
 $\omega = \frac{2\pi N}{60}$   
 $N \rightarrow$  No. of Revolutions (RPM)

**1) Sine Rule:**  
  
 $\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$   
**2) Cosine Rule:**  
  
 $AC^2 = AB^2 + BC^2 - 2AB \cdot BC \cos \alpha$

**ICR**  
 1) It is a fixed point i.e. zero velocity point  
 2) It is an img. point  
 3) It may be lie within the body or outside the body  
**Types of Link**  
 Rotating Link (ICR  $\rightarrow$  Inside the body)  
 Sliding Link (ICR  $\rightarrow$  outside the body)  
 Type 1:- Sliding link  
 Type 2:- One Sliding & One Rotating  
 Type 3:- One Sliding, One Rotating and one free end  
 Type 4:- Two Rotating & one Sliding link



**Link CD (Rotating)**  
 pt D is an ICR  
 $V_D = 0$   
 $V_C = CD \times \omega_{CD}$   
 $500 = 200 \times \omega_{CD}$   
 $\omega_{CD} = 2.5 \text{ rad/sec}$   
**Link AB (Rotating)**  
 pt A is an ICR  
 $V_A = 0$   
 $V_B = AB \times \omega_{AB}$   
 $V_B = 150 \times \omega_{AB}$

**Link BC (Sliding)**  
 pt I is an ICR  
 $V_C = CI \times \omega_{BC}$   
 $500 = 244.94 \times \omega_{BC}$   
 $\omega_{BC} = 2.04 \text{ rad/sec}$   
 $V_B = BI \times \omega_{BC}$   
 $= 273.21 \times 2.04$   
 $V_B = 557.34 \text{ mm/sec}$   
 From eqn 1  
 $557.34 = 150 \times \omega_{AB}$   
 $\omega_{AB} = 3.71 \text{ rad/sec}$

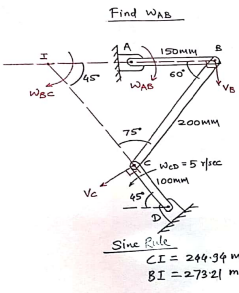


# Kinematics of Rigid Body (ICR)

$V = r \times \omega$   
 $V \rightarrow$  Velocity  
 $r \rightarrow$  Distance between Fixed Point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)  
 $\omega = \frac{2\pi N}{60}$   
 $N \rightarrow$  No of Revolutions (RPM)

**Sine Rule:**  
 $\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$   
**Cosine Rule:**  
 $AC^2 = AB^2 + BC^2 - 2AB \cdot BC \cos \alpha$

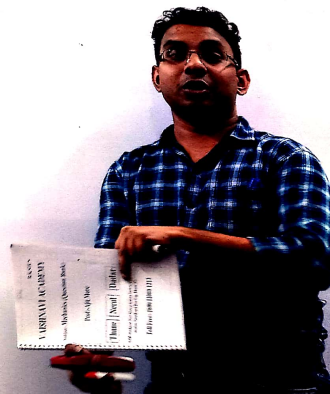
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 Rotating Link (ICR  $\rightarrow$  Inside the body)  
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 Type 1:- Sliding Link  
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 Type 3:- One Sliding, One Rotating and one free end.  
 Type 4:- Two Rotating & one Sliding link



**Find  $\omega_{AB}$**   
**Link CD (Rotating)**  
 pt D is an ICR  
 $V_D = 0$   
 $V_C = CD \times \omega_{CD}$   
 $V_C = 500 \text{ mm/sec}$   
**Link AB (Rotating)**  
 pt A is an ICR  
 $V_A = 0$   
 $V_B = AB \times \omega_{AB}$   
 $V_B = 150 \times \omega_{AB}$

**Link BC (Sliding)**  
 pt I is an ICR  
 $V_C = CI \times \omega_{BC}$   
 $500 = 244.34 \times \omega_{BC}$   
 $\omega_{BC} = 2.04 \text{ rad/sec}$   
 $V_B = BI \times \omega_{BC}$   
 $= 273.21 \times 2.04$   
 $V_B = 557.34 \text{ mm/sec}$   
 from eqn (1)  
 $557.34 = 150 \times \omega_{AB}$   
 $\omega_{AB} = 3.71 \text{ rad/sec}$

**Sine Rule**  
 $CI = 244.34 \text{ mm}$   
 $BI = 273.21 \text{ mm}$



# Kinematics of Rigid Body (ICR)

$V = r \times \omega$   
 $V \rightarrow$  Velocity  
 $r \rightarrow$  Distance between Fixed Point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)

$\omega = \frac{d\theta}{dt}$   
 of Revolutions (Rpm)

1) Same Rule:



2) Same Rule:

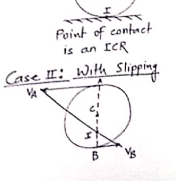


ICR  
 1) It is a fixed point or zero velocity point  
 2) It is an imag. point  
 3) It may be lie within the body or outside the body

Types of Link  
 Rotating Link (ICR Inside the body)  
 Sliding Link (ICR outside the body)  
 Type 1: Sliding Link  
 Type 2: One Sliding & One Rotating  
 Type 3: One Sliding, One Rotating and One free end  
 Type 4: Two Rotating & one Sliding link  
 Type 5: Circular Body

## Circular Body

Case I: Without Slipping

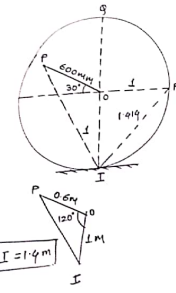


Case II: With Slipping

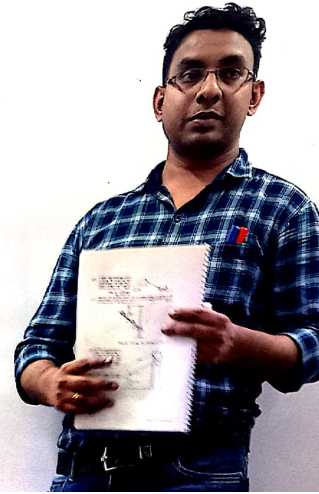


Q.7)

dia = 2m,  $r = 1m$ ,  $V_O = 4m/s$



$$\begin{aligned}
 V_O &= OI \times \omega \\
 4 &= 1 \times \omega \\
 \omega &= 4 \text{ rad/sec} \\
 V_G &= GI \times \omega \\
 &= 2 \times 4 \\
 V_G &= 8 \text{ m/sec} \\
 V_R &= RI \times \omega \\
 &= 1.414 \times 4 \\
 V_R &= 5.65 \text{ m/s}
 \end{aligned}$$

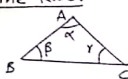





## Kinematics of Rigid Body (ICR)

- 1)  $V = r \times \omega$   
 $V \rightarrow$  Velocity  
 $r \rightarrow$  Distance between Fixed Point and moving point  
 $\omega \rightarrow$  Angular Velocity (rad/sec)
- ICR  
 1) It is a fixed point i.e. Zero Velocity Point  
 2) It is an imag point  
 3) It may be lie within the body or outside the body

2)  $\omega = \frac{2\pi N}{60}$   
 $N \rightarrow$  No. of Revolutions (RPM)

3) Sine Rule:  
  
 $\frac{AB}{\sin \gamma} = \frac{BC}{\sin \alpha} = \frac{AC}{\sin \beta}$

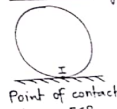
4) Cosine Rule:  
  
 $AC = \sqrt{AB^2 + BC^2 - 2AB \cdot BC \cos \alpha}$

### Types of Link

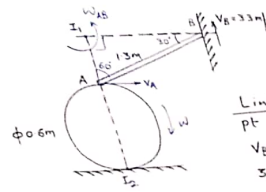
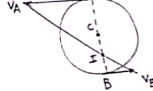
- Rotating Link  
 (ICR  $\rightarrow$  Inside the body)
- Sliding Link  
 (ICR  $\rightarrow$  outside the body)
- Type 1:- Sliding Link  
Type 2:- One Sliding & One Rotating  
Type 3:- One Sliding, One Rotating and one free end  
Type 4:- Two Rotating & one Sliding link  
Type 5:- Circular Body

### Circular Body

#### Case I:- Without Slipping



#### Case II:- With Slipping



Sine Rule  
 $BI_1 = 1.12 \text{ m}$   
 $AI_1 = 0.65 \text{ m}$

#### Link AB (Sliding)

pt  $I_1$  is an ICR

$V_B = BI_1 \times \omega_{AB}$

$3.3 = 1.12 \times \omega_{AB}$

$\omega_{AB} = 2.94 \text{ rad/sec}$

$V_A = AI_1 \times \omega_{AB}$

$= 0.65 \times 2.94$

$V_A = 1.91 \text{ m/sec}$

#### Cylinder (Without Slipping)

pt  $I_2$  is an ICR

$V_A = AI_2 \times \omega$

$1.91 = 0.6 \times \omega$

$\omega = 3.18 \text{ rad/sec}$

$\lambda = 1.5 \times 10^{-6} \text{ m}$   
 $\mu = 1.5$   
 $\theta = 30^\circ$   
 $\phi = 45^\circ$   
 $\alpha = 15^\circ$   
 $\beta = 75^\circ$   
 $\gamma = 90^\circ$   
 $\delta = 105^\circ$   
 $\epsilon = 135^\circ$   
 $\zeta = 165^\circ$   
 $\eta = 195^\circ$   
 $\theta = 225^\circ$   
 $\iota = 255^\circ$   
 $\kappa = 285^\circ$   
 $\lambda = 315^\circ$   
 $\mu = 345^\circ$   
 $\nu = 375^\circ$   
 $\xi = 405^\circ$   
 $\eta = 435^\circ$   
 $\theta = 465^\circ$   
 $\iota = 495^\circ$   
 $\kappa = 525^\circ$   
 $\lambda = 555^\circ$   
 $\mu = 585^\circ$   
 $\nu = 615^\circ$   
 $\xi = 645^\circ$   
 $\eta = 675^\circ$   
 $\theta = 705^\circ$   
 $\iota = 735^\circ$   
 $\kappa = 765^\circ$   
 $\lambda = 795^\circ$   
 $\mu = 825^\circ$   
 $\nu = 855^\circ$   
 $\xi = 885^\circ$   
 $\eta = 915^\circ$   
 $\theta = 945^\circ$   
 $\iota = 975^\circ$   
 $\kappa = 1005^\circ$   
 $\lambda = 1035^\circ$   
 $\mu = 1065^\circ$   
 $\nu = 1095^\circ$   
 $\xi = 1125^\circ$   
 $\eta = 1155^\circ$   
 $\theta = 1185^\circ$   
 $\iota = 1215^\circ$   
 $\kappa = 1245^\circ$   
 $\lambda = 1275^\circ$   
 $\mu = 1305^\circ$   
 $\nu = 1335^\circ$   
 $\xi = 1365^\circ$   
 $\eta = 1395^\circ$   
 $\theta = 1425^\circ$   
 $\iota = 1455^\circ$   
 $\kappa = 1485^\circ$   
 $\lambda = 1515^\circ$   
 $\mu = 1545^\circ$   
 $\nu = 1575^\circ$   
 $\xi = 1605^\circ$   
 $\eta = 1635^\circ$   
 $\theta = 1665^\circ$   
 $\iota = 1695^\circ$   
 $\kappa = 1725^\circ$   
 $\lambda = 1755^\circ$   
 $\mu = 1785^\circ$   
 $\nu = 1815^\circ$   
 $\xi = 1845^\circ$   
 $\eta = 1875^\circ$   
 $\theta = 1905^\circ$   
 $\iota = 1935^\circ$   
 $\kappa = 1965^\circ$   
 $\lambda = 1995^\circ$   
 $\mu = 2025^\circ$   
 $\nu = 2055^\circ$   
 $\xi = 2085^\circ$   
 $\eta = 2115^\circ$   
 $\theta = 2145^\circ$   
 $\iota = 2175^\circ$   
 $\kappa = 2205^\circ$   
 $\lambda = 2235^\circ$   
 $\mu = 2265^\circ$   
 $\nu = 2295^\circ$   
 $\xi = 2325^\circ$   
 $\eta = 2355^\circ$   
 $\theta = 2385^\circ$   
 $\iota = 2415^\circ$   
 $\kappa = 2445^\circ$   
 $\lambda = 2475^\circ$   
 $\mu = 2505^\circ$   
 $\nu = 2535^\circ$   
 $\xi = 2565^\circ$   
 $\eta = 2595^\circ$   
 $\theta = 2625^\circ$   
 $\iota = 2655^\circ$   
 $\kappa = 2685^\circ$   
 $\lambda = 2715^\circ$   
 $\mu = 2745^\circ$   
 $\nu = 2775^\circ$   
 $\xi = 2805^\circ$   
 $\eta = 2835^\circ$   
 $\theta = 2865^\circ$   
 $\iota = 2895^\circ$   
 $\kappa = 2925^\circ$   
 $\lambda = 2955^\circ$   
 $\mu = 2985^\circ$   
 $\nu = 3015^\circ$   
 $\xi = 3045^\circ$   
 $\eta = 3075^\circ$   
 $\theta = 3105^\circ$   
 $\iota = 3135^\circ$   
 $\kappa = 3165^\circ$   
 $\lambda = 3195^\circ$   
 $\mu = 3225^\circ$   
 $\nu = 3255^\circ$   
 $\xi = 3285^\circ$   
 $\eta = 3315^\circ$   
 $\theta = 3345^\circ$   
 $\iota = 3375^\circ$   
 $\kappa = 3405^\circ$   
 $\lambda = 3435^\circ$   
 $\mu = 3465^\circ$   
 $\nu = 3495^\circ$   
 $\xi = 3525^\circ$   
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## Types of Rigid Body (ICR)

- ICR
- 1) It is a fixed point i.e. zero velocity point
  - 2) It is an imaginary point
  - 3) It may be lie within the body or outside the body

Types of Link

Rotating Link (ICR inside the body)      Sliding Link (ICR outside the body)

Type 1:- Sliding link

Type 2:- One Sliding & One Rotating

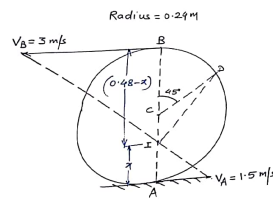
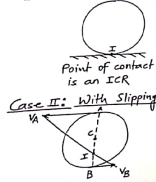
Type 3:- One Sliding, One Rotating and One free end

Type 4:- Two Rotating & One Sliding link

Type 5:- Circular Body

## Circular Body

Case I:- Without Slipping



$$V_A = A I \times \omega$$

$$1.5 = 7 \times \omega \quad \text{--- (1)}$$

$$V_B = B I \times \omega$$

$$3 = (0.48 - 7) \times \omega \quad \text{--- (2)}$$

$$\text{eqn (1) } \div \text{ (2)}$$

$$\frac{1.5}{3} = \frac{7 \times \omega}{(0.48 - 7) \times \omega}$$

$$\frac{1}{2} = \frac{7}{0.48 - 7}$$

$$0.48 - 7 = 14$$

$$0.48 = 14 + 7 = 21$$

$$0.48 = 21 \times \omega$$

$$\omega = \frac{0.48}{21} \text{ rad/s}$$

$$\omega = 0.0228 \text{ rad/s}$$

$$V_C = 0.0228 \times 5.37$$

$$V_C = 0.122 \text{ m/s}$$

$$V_C = C I \times \omega$$

$$C I = C A - A I = 0.08 \text{ m}$$

$$V_C = 0.08 \times 5.37$$

$$V_C = 0.43 \text{ m/s}$$

$$V_D = D I \times \omega$$

$$D I = 0.3 \text{ m}$$

$$V_D = 0.3 \times 5.37$$

$$V_D = 1.61 \text{ m/s}$$