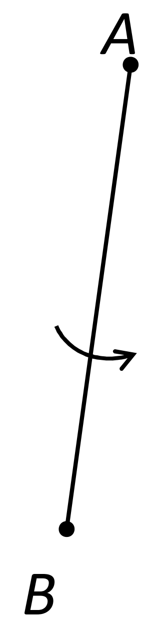
Velocity analysis

- To determine the velocities of different points on links of a mechanism for a given input motion. Determination of the motion characteristics of links in a mechanism is required for the force analysis
- Velocities of links and of points of mechanism can be determined by different methods.
  1. Relative velocity method or velocity polygon method
  2. Instantaneous centre method.

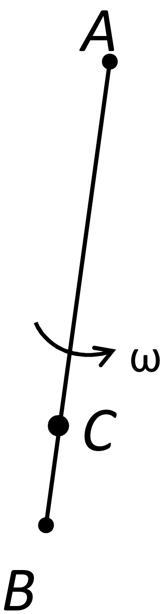
Velocity of link

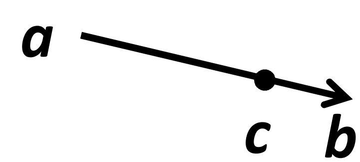
- In order to determine the relative motion of the ends of a link, one of the ends is assumed to be moving relative to the other end.
- Let a link *AB* rotate about *A* in anti-clockwise direction such that the end *B* rotates relative to *A*.
- Then the direction of relative motion of *B* with respect to *A* is perpendicular to *AB*.
- Therefore, the direction of relative velocity of a point w.r.t any other point on a link is always along perpendicular to the straight line joining the two points.



Velocity of link…

- This method is useful in drawing the velocity diagram and finding the relative velocities of points on a link.
- Let the velocity of *B* w.r.t *A* be represented by ab. Then ***ab*** is drawn perpendicular to *AB* to any convenient scale as shown in the velocity diagram.
- If the ω = angular velocity of link AB about its end A, then velocity of *B* w.r.t *A* = $v_{ba} = \omega . AB$
- Similarly, velocity of any intermediate point *C* w.r.t *A* = $v_{ca} = \omega . AC$. It is represented by the vector ***ac*** in the velocity diagram.





$$\frac{v_{ba}}{v_{ca}} = \frac{\omega . AB}{\omega . AC} \qquad \frac{\boldsymbol{ab}}{\boldsymbol{ac}} = \frac{AB}{AC} \qquad \frac{\boldsymbol{ab}}{AB} = \frac{\boldsymbol{ac}}{AC} = \omega \dots \dots (1)$$

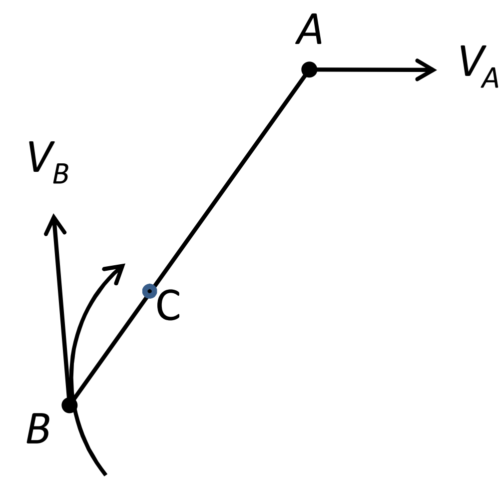
Velocity of link…

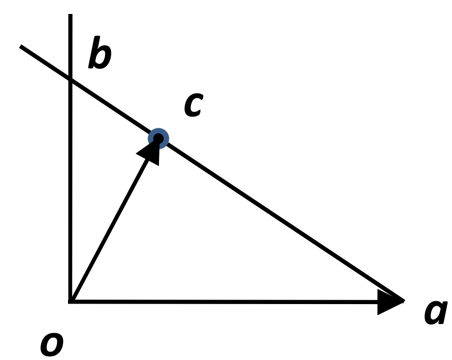
- Hence, the point ***c*** divides the vector ***ab*** in the same ratio as the point *C* divides the link *AB*.

Relative velocity method

Velocity of any point on a link:

Consider a link *AB* where the directions of motion of its ends are shown. The velocity vectors are shown.





oa – velocity of the end *A*

ob- velocity of the end *B*

ab- velocity of B with respect to *A*

ba- velocity of A with respect to *B*

$$v_{ba} = v_b - v_a$$

$$v_b = v_{ba} + v_a$$

$$\mathbf{ob} = \mathbf{ab} + \mathbf{oa}$$

Velocity of any point on a link…

- Velocity of any point *C* on the link can be determined by dividing the vector ***ab*** at ***c*** such that

$$\frac{\mathbf{ab}}{AB} = \frac{\mathbf{ac}}{AC}$$

Then, the velocity of *C* with respect to *A*

$$v_{ca} = v_c - v_a$$

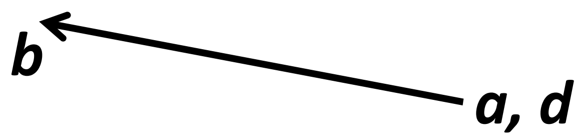
$$v_c = v_{ca} + v_a$$

$$\mathbf{oc} = \mathbf{ac} + \mathbf{oa}$$

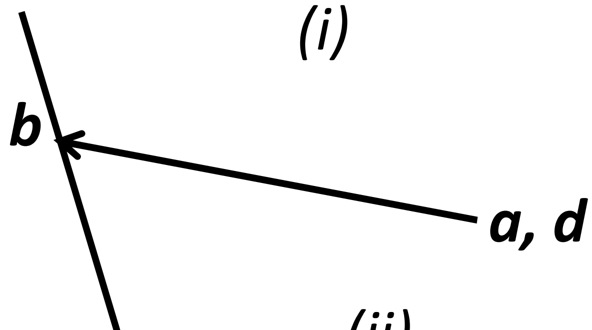
Hence, the vector ***oc*** represents the velocity of point *C*.

Velocity diagram for four bar chain

Given the dimensions of al l the links, angular velocity of the crank AB and position of the crank. Draw configuration diagram.



(i)



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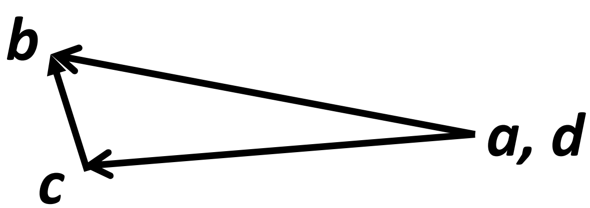

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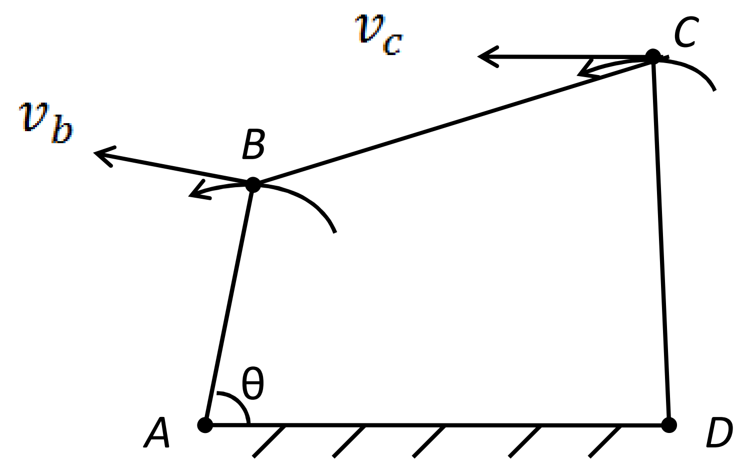


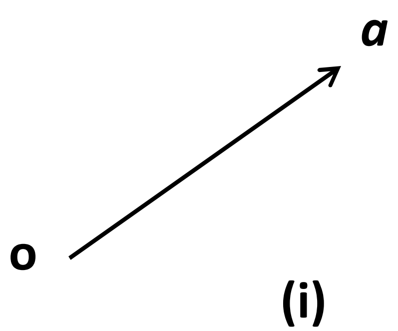
(i) Draw a vector ***ab*** perpendicular to the link *AB* of length *AB x ω* (to a suitable scale).

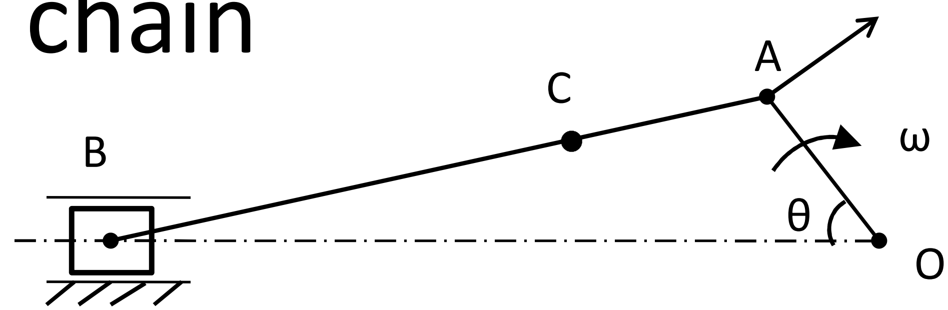
(ii) Draw a vector line through ***b*** in direction perpendicular to the link *BC*.

(iii) Draw a vector through d in a direction perpendicular to the link ***CD.*** This will intersect the vector through in ***c***.

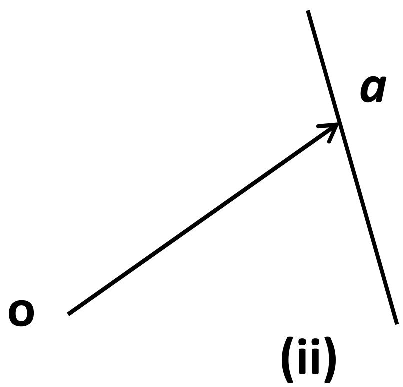
(iv) The vector ***bc*** represents velocity of point C w.r.t point B.

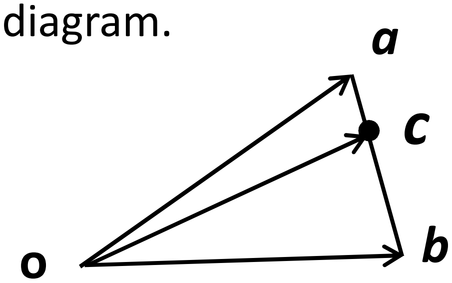
Slider crank chain

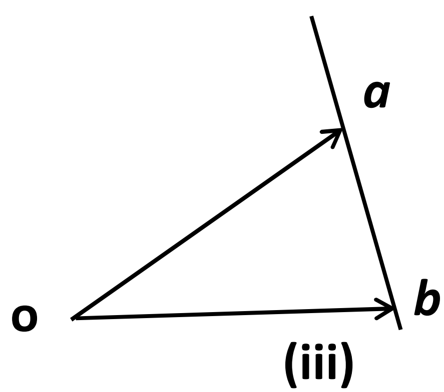




Given the dimensions of al l the links, angular velocity of the crank OA and position of the crank. Draw configuration diagram.







(i) Draw a vector ***oa*** of length OA X *ω* (taking a suitable scale) in a direction perpendicular to *OA*.

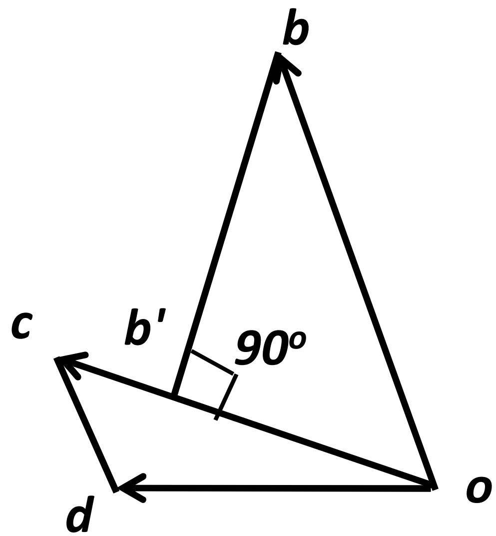
(ii) Draw a vector line through a in a direction perpendicular to the link *AB*. (draw some length on either side of ***a***.)

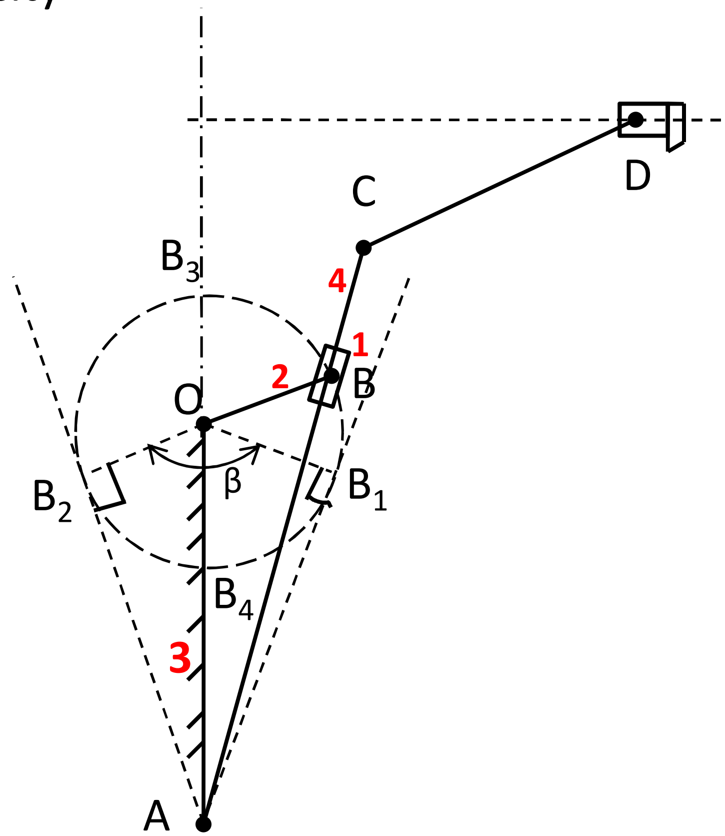
(iii) Draw the vector ob parallel to *OB* to intersect the vector ***ab*** at ***b***.

(iv) Divide the ab vector such that ***ac***:***ab*** = *AC*:*AB*

Crank-slotted lever mechanism

- Given the crank OB rotates with uniform velocity ω about O in the Anti-clock wise direction.
- Dimensions all the links
- Draw the configuration diagram.





Crank and slotted lever type quick return motion mechanism

Note: When the crank pin is at B3 or B4, the component of ob along the lever AC is zero i.e. the velocity of slider at crank pin is zero. Therefore the velocity of the lever at the crank pin = velocity of the crank pin=OB x ω

$$\frac{time\ of\ cutting}{time\ of\ return} = \frac{360-\beta}{\beta}$$

- Since no component of the velocity of the crank pin is used to move the slider, whole the velocity of the crank at crank pin will be used to move the lever and hence, the velocity of lever and velocity of tool at these positions (B_3, B_4) are maximum(neglecting obliquity of link CD).
- Maximum velocity of cutting = maximum velocity of C when crank pin is at B3

$$\frac{v_{max}}{\omega.OB} = \frac{AC}{AB_3}$$

$$Maximum\ velocity\ during\ cutting = \omega.OB.\frac{AC}{AB_3} = \omega.OB.\frac{AC}{AO + OB}$$

$$Maximum\ velocity\ during\ return = \omega.OB.\frac{AC}{AB_4} = \omega.OB.\frac{AC}{AO - OB}$$

$$\frac{Maximum\ velocity\ during\ return}{Maximum\ velocity\ during\ cutting} = \frac{AO + OB}{AO - OB}$$

Questions

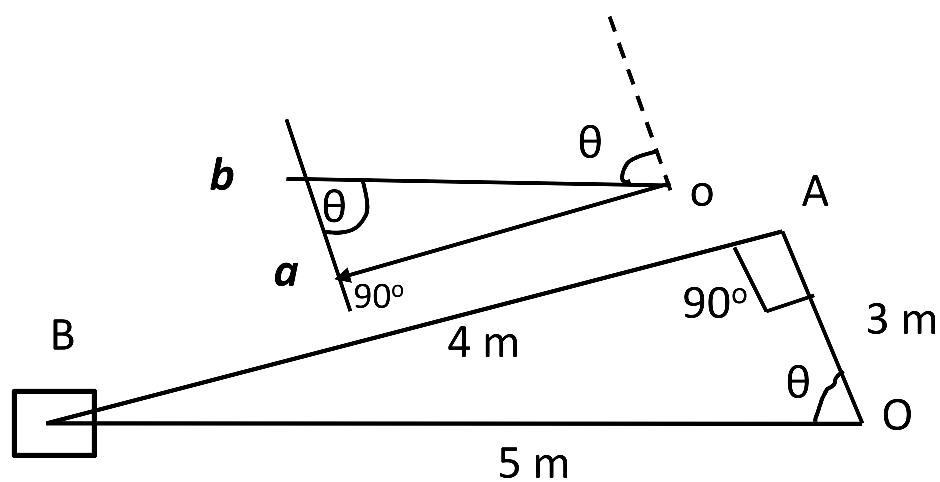
1.For an inline slider-crank mechanism, the length of the crank and connecting rod are 3 m and 4 m, respectively. At the instant when the connecting rod is perpendicular to the crank, if the velocity of the slider is 1 m/s, the magnitude of angular velocity (upto 3 decimal points accuracy) of the crank is __________radian/s. (2017)

Solution:

$$\sin\theta = \frac{oa}{ob}$$

$$\frac{4}{5} = \frac{oa}{1}$$

$$\boldsymbol{oa} = \frac{4}{5} \text{x}1 = 0.8 \text{ m/s}$$

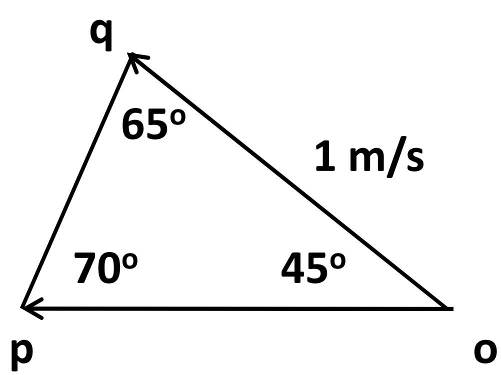


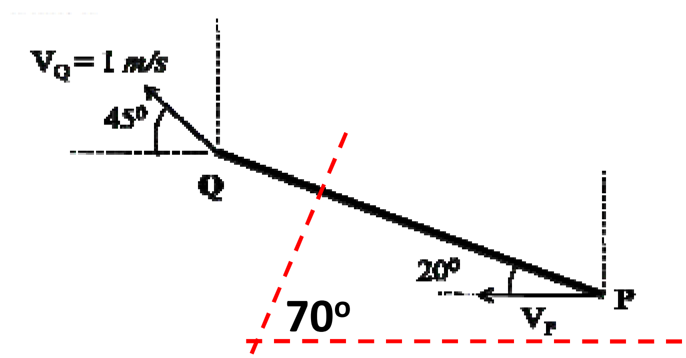
OA x ω=0.8 m/s

ω=0.8/3=0.2667 rad/s

2. A rigid link PQ is 2 m long and oriented at 20° to the horizontal as shown in the figure. The magnitude and direction of velocity V_Q, and the direction of velocity V_P are given. The magnitude of V_P (in m/s) at this instant is

(A) 2.14 (B) 1.89 (C) 1.21 (D) 0.96

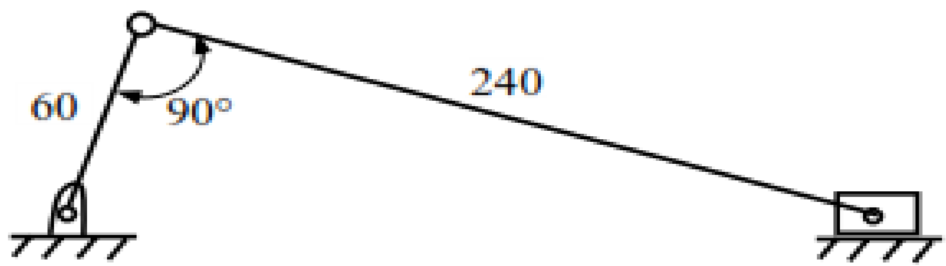




$$\frac{\sin 70}{1} = \frac{\sin 65}{op}$$

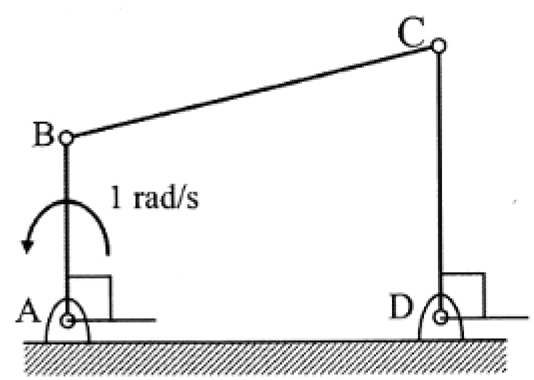
$$op = \frac{\sin 65}{\sin 70} = \frac{0.9063}{0.9397} = 0.9645\ m/s$$

3. A slider-crank mechanism with crank radius 60 mm and connecting rod length 240 mm is shown in figure. The crank is rotating with a uniform angular speed of 10 rad/s, counter clockwise. For the given configuration, the speed (in m/s) of the slider is _______



4. For the four-bar linkage shown in the figure, the angular velocity of link AB is 1 rad/s. The length of link CD is 1.5 times the length of link AB. In the configuration shown, the angular velocity of link CD in rad/s is

(A) 3 (B) 3/2 (C) 1 (D) 2/3



Sol:

Equal velocities

AB x1 =CD x ω

ω=AB/CD=2/3

5. There are two points P and Q on a planar rigid body. The relative velocity between the two points

(A) should always be along PQ

(B) Can be oriented along any direction

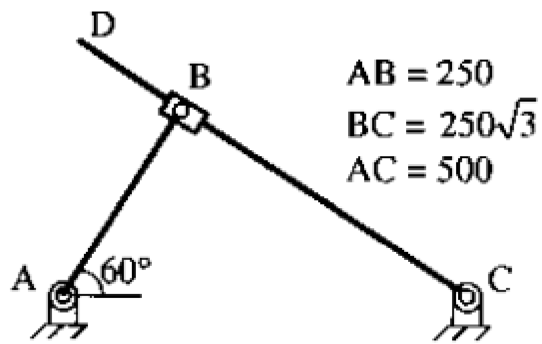
(C) should always be perpendicular to PQ

(D) should be along QP when the body undergoes pure translation

Answer : (C) should always be perpendicular to PQ

6. For the configuration shown, the angular velocity of link AB is 10 rad/s counterclockwise. The magnitude of the relative sliding velocity (in ms^{-1}) of slider B with respect to rigid link CD is

(A) 0 (B) 0.86 (C) 1.25 (D) 2.5



Solution:

From the dimension given,

angle ABC =90°

velocity of crank at B = velocity of slider as AB is perpendicular to CD

Therefore velocity of slider along CD =AB x 10 rad/s

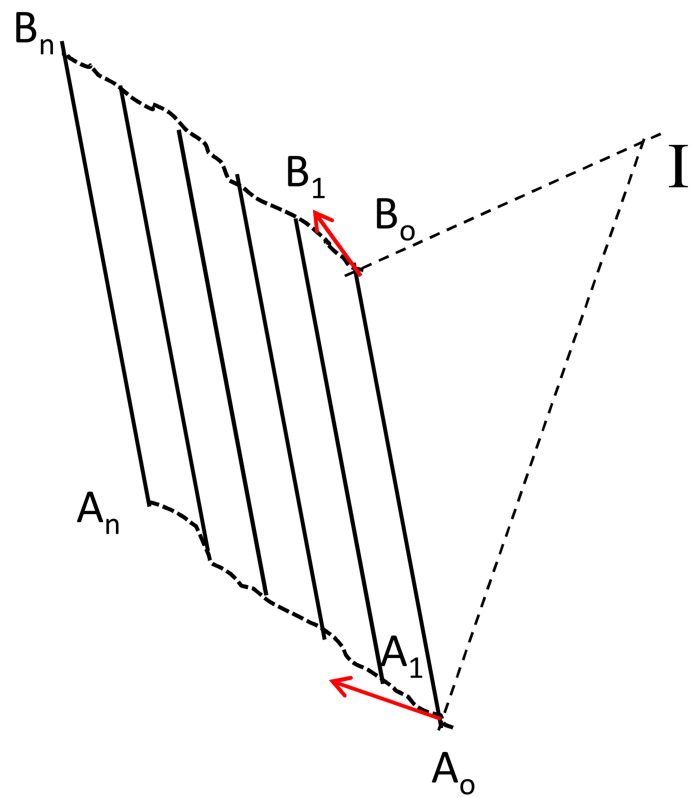
=250 mm x10 rad/s

= 2500 mm/s = 2.5 m/s

Answer : (D) 2.5

Instantaneous center of rotation

- A link AB has moved from A_oB_o to A_nB_n. Its motion can be considered to have taken place in a number of infinitesimally small steps as shown in the figure.
- Its motion from A_oB_o to A_1B_1 can be considered as a pure rotation about a centre I. the location of the centre can be obtained from direction of the velocities of the ends of the link as shown. Such centre is called instantaneous centre of rotation. The location of the centre changes from instant to instant for different positions of the link and locus of these centres is called centrode.

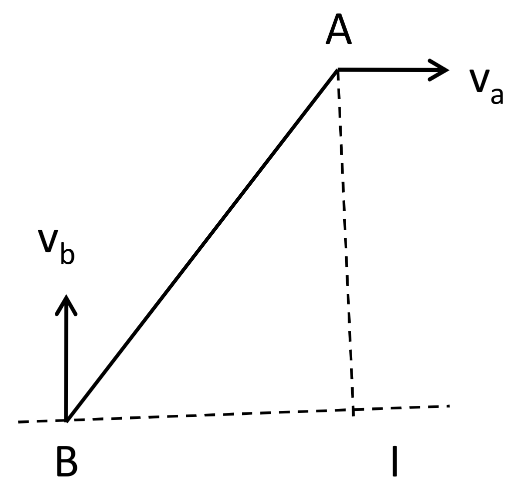


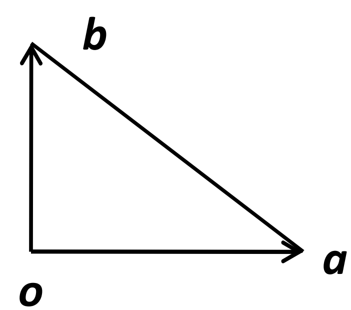
Velocity analysis by instantaneous centre of rotation

- Let the ends of a link AB has velocities as shown in the figure.
- The instantaneous centre of rotation for the given position is located by drawing perpendicular lines to the directions of the velocities at the ends of the line to intersect in I.
- ω= angular velocity of AB at the given instant.
- Velocity of end A = *ω x IA*
- Velocity of end B = *ω x IB*
- From the similarity of triangles IAB and ***oab***

$$\frac{oa}{IA} = \frac{ob}{IB} = \frac{ab}{AB}$$

$$\frac{oa}{IA} = \frac{ob}{IB} = \frac{ab}{AB}$$

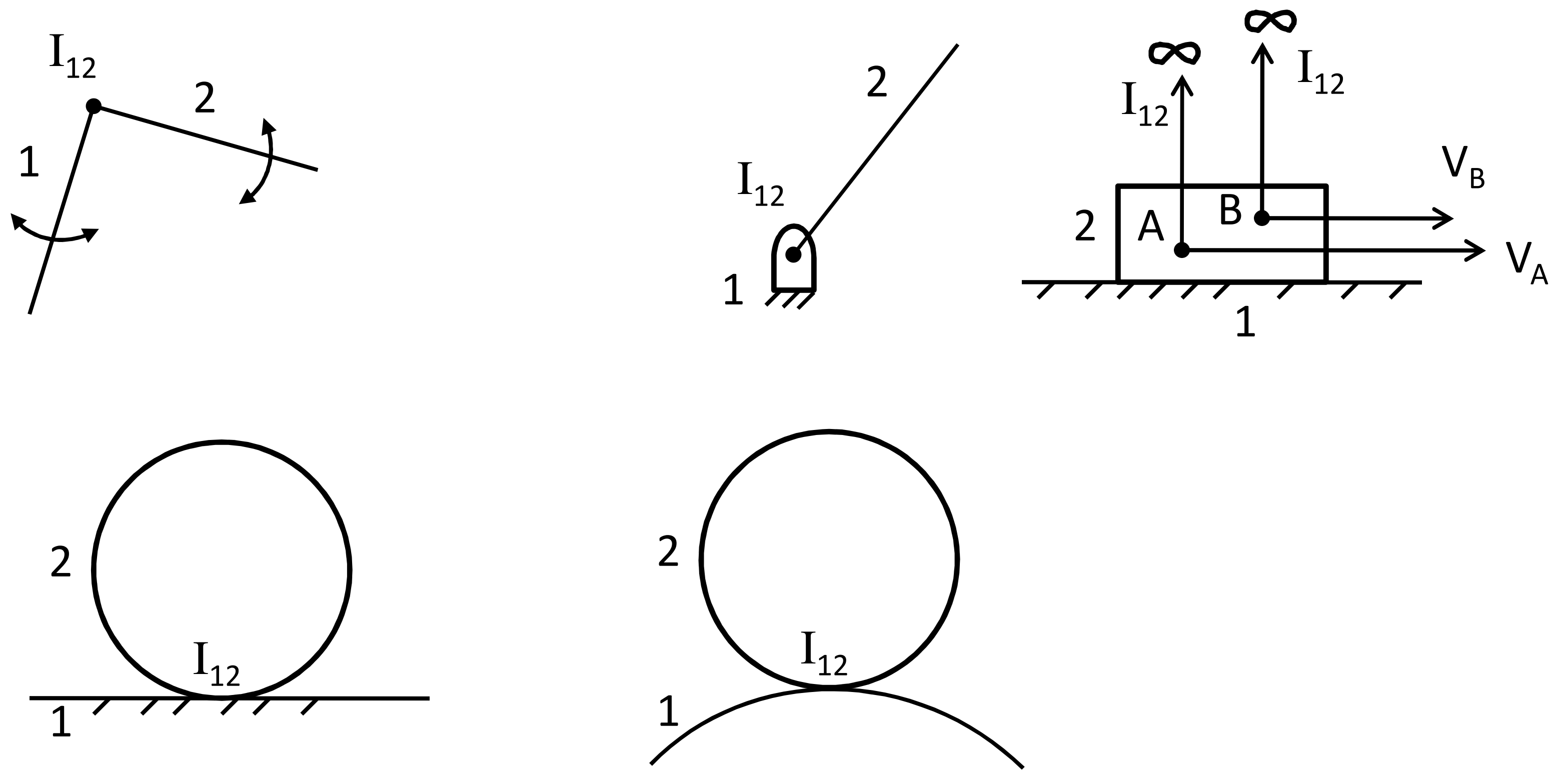




$$\frac{v_a}{IA} = \frac{v_b}{IB} = \frac{v_{ab}}{AB} = \omega = \frac{v_C}{IC}$$

Where C is any point on the link.
The angular velocities of various links can be determined easily using the above equation.
Hence, the instantaneous centre method is simpler than relative velocity method.
when the directions are parallel , it becomes difficult to apply the method. But, relative velocity method is suitable for any configuration.

Instantaneous centres of different moving links

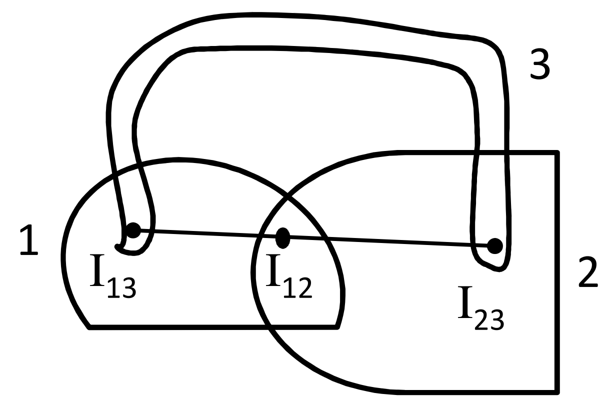


Arnold Kennedy's theorem (Line of three centres theorem)

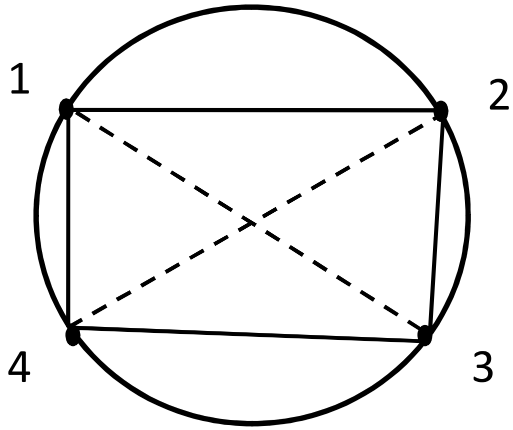
- It states that:

  If three bodies have relative motion with respect to each other, their relative instantaneous centres lie on a straight line.

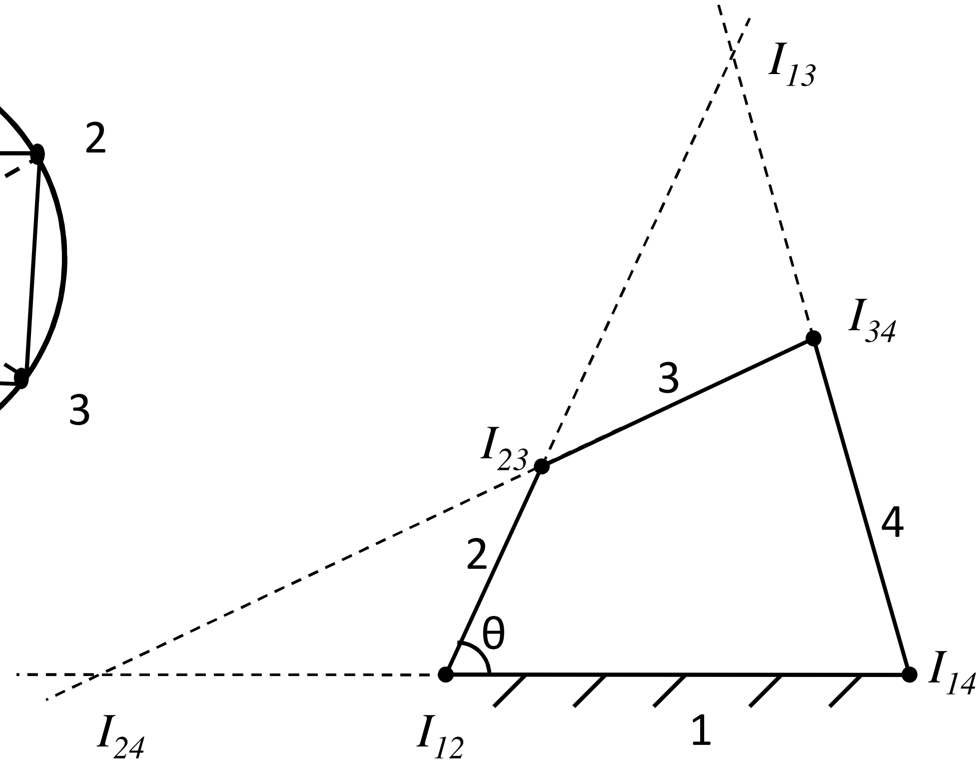
Three bodies 1,2 and 3 are having relative motion with respect to each other. The instantaneous centres of I_{12}, I_{23} and I_{13} lie on a straight line. The location of depends on direction and magnitude of the angular velocities of bodies 1 and 2 relative to the body 3.



Types of instantaneous centres



Circle diagram



- I_{12} , I_{14} : Fixed type
- I_{23} , I_{34} : Permanent type
- I_{24} , I_{13} : Neither fixed nor permanent

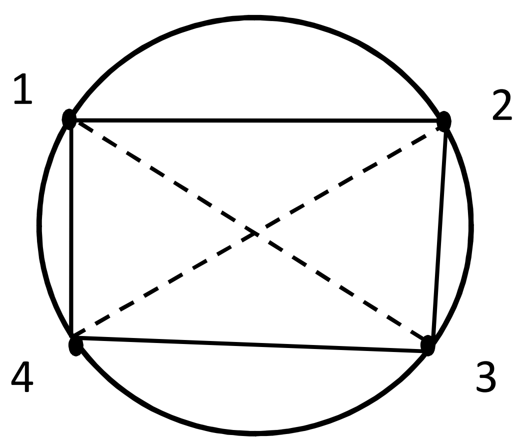
Number of instantaneous centres

- Number of instantaneous centres, N:

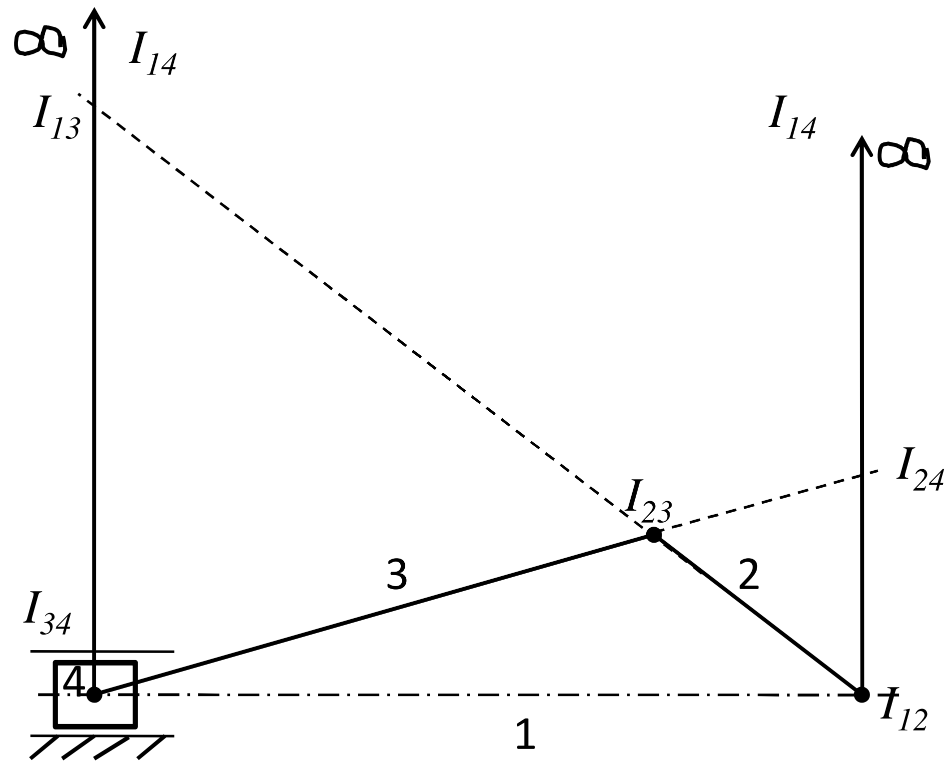
Each pair of links has one instantaneous centre. So, the total number of combinations of n links taken two at a time is

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

Slider-crank chain

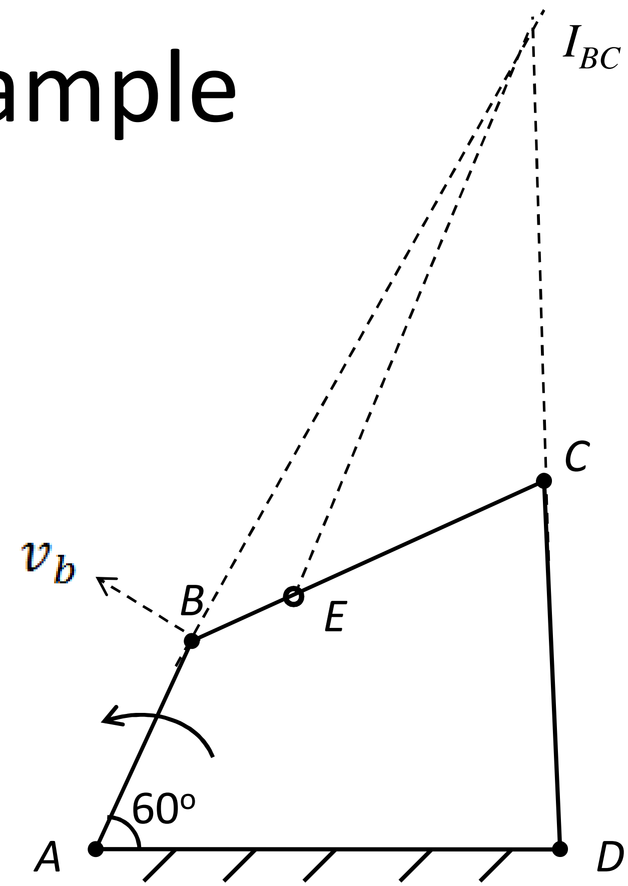


Circle diagram



Numerical example

- Find the angular velocity of BC, velocity of C and velocity of point E on BC using instantaneous centre method. The link AB revolves with angular velocity of π rad/s. Given AB=0.5m, BC=1.5 m, cd=1 m, DA=1.75 m, BE=0.5 m.



$$v_b = \omega_{ba}.AB$$

$$v_b = \omega_{bc}.I_{BC}B$$

$$\omega_{bc} = \omega_{ba}.\frac{AB}{I_{BC}B} = 3.14 \text{ x } \frac{0.5}{2.45} = 0.64\, rad/s$$

$I_{BC}B$ *is to be measured from the configuration diagram*

Numerical example...

- Velocity of point C,

$$v_c = \omega_{bc}.I_{BC}C = 0.64 \text{ x } 1.575 = 1.01\, m/s$$

Velocity of point E on link BC

$$v_e = \omega_{bc}.I_{BC}E = 0.64 \text{ x } 2.1 = 1.344\, m/s$$

Questions

1. The rod *AB*, of length 1 m, shown in the figure is connected to two sliders at each end through pins. The sliders can slide along *QP* and *QR*. If the velocity V_A of the slider at *A* is 2 m/s, the velocity of the midpoint of the rod at this instant is ____________ m/s.

Solution:

$V_A = IA \times \omega$

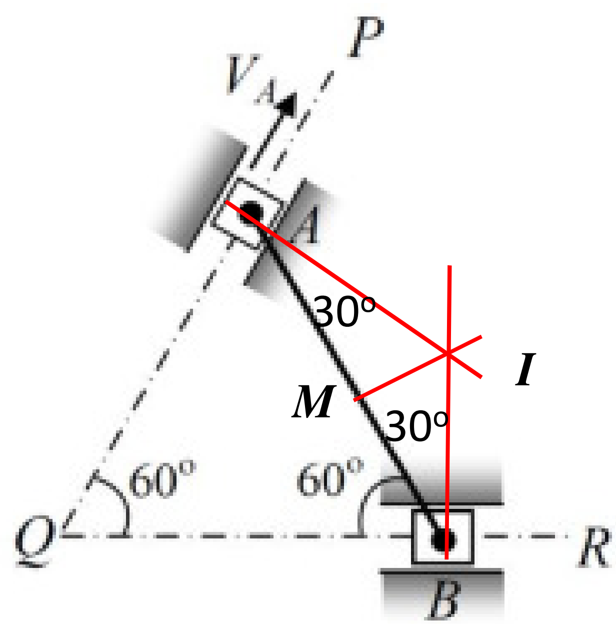
$V_M = IM \times \omega$

$= IA \sin 30^o \times \omega$

$V_M = V_A \sin 30^o$

$= 2 \times 0.5$

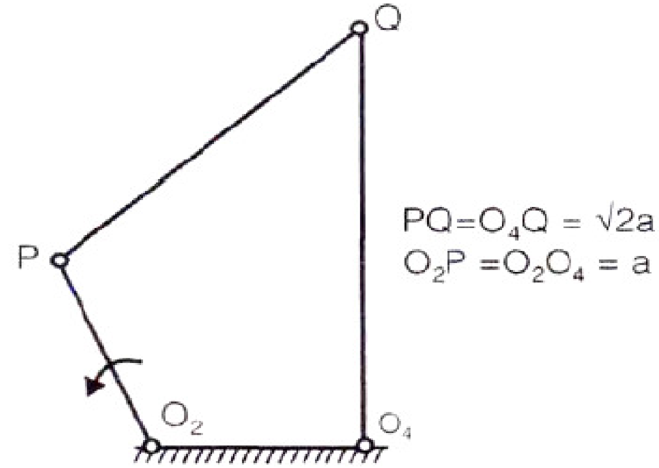
$= 1$ m/s

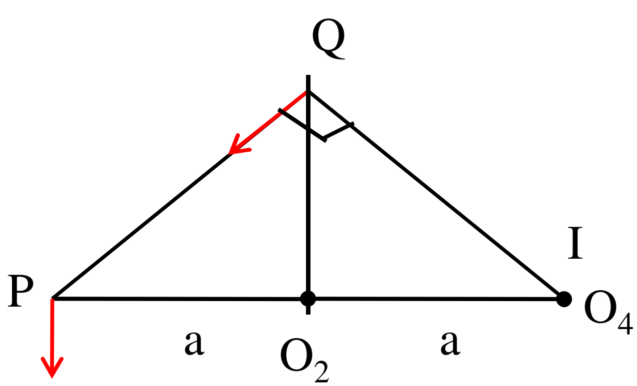


The input link O_2P of a four bar linkage is rotated at 2 rad/s in counter clockwise direction as shown below. The angular velocity of the coupler PQ in rad/s, at an instant when $\angle O_4O_2P = 180°$, is

$PQ = O_4Q = \sqrt{2}\,a$ and $O_2P = O_2O_4 = a$.

(a) 4 (b) $2\sqrt{2}$ (c) 1 (d) $1/\sqrt{2}$





Solution:

$IP \times \omega_{PQ} = O_2P \times \omega$

$\omega_{PQ} = O_2P \times \omega / IP$

$= a \times 2/2a = 1$

For planar mechanisms if no.of links is six ,having lower pairs seven what are all the possible ways to draw the planar mechanism chain.?
Sir,in the gnome engine when crank is fixed and the high-pressure gases exert force on the walls of the cylinder how does that cause the rotation of the cylinder ,the gas may exert equal forces on the walls of the cylinder ??only when an unequal force exists it causes rotation right??
In the question 4 the 2 nd terneray link is connected to a fixed hinge by a link then the number of links will be 7 I think so, please clarify me
sir, from grasshof's linkage if shortest link is made as coupler then also we can achieve double rocker mechanism.so, to question 7 why don't we fix PQ link
What is Indeterminate structure and how would you classify the mobility.?
Actually according to grashoffs law, there exists atleast one crank if it satisfies some condition but my question is "In a mechanism satisfying grashoffs law,by fixing link opposite to shortest how can we get double rocker which do not haveeven a single crank"?
Sir, how will they pose questions on the velocity triangles concept? Do we have to draw diagrams in the examination hall? Please give models of gate questions on velocity triangles and rest of the topics too , if possible.

Clarifications

1. sir,why the velocity of link is always perpendicular from a fixed point on link and why not in other direction
2. In crank slotted lever mechanism, maximum velocity of cutting is velocity of d but not velocity of c right?
3. In Slider crank chain , the velocity of B w.r.t. O is parallel to OB. The slider can move only in to and fro motion so that the velocity of B w.r.t O is parallel to horizontal OB. I think so . is this statement right or not . Please clarify my doubt sir .
   Thankyou sir.......

clarifications

4. sir, in the velocity analysis of slider crank chain while finding velocity of B wrt O why did we draw vector ob parallel to OB and why not perpendicular as done for other links?
5. Sir, In grublers criterion how there is a loss of DOF for lower pair is two and for higher pair is one. Can u pls explain?

clarifications

6. In Crank slotted lever mechanism , the velocity of slider is parallel along AC lever and in the slider crank mechanism , the slider is linked along horizontal OB. In every case,
   the velocity of slider can be given at which the slider is linked along with another link? Is it right or wrong. If it is right,what is the reason?
   OR
   velocity of slider can be given by the movement of slider along with link. please give the clarification .
   Thankyou