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## Subject Code

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- Any - V
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Chapter Name

- Any

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## Examination: 2017 SUMMER

## Que.No Marks

Question:
Define centripetal and tangential acceleration.

## Answer:

Centripetal acceleration:
The centripetal acceleration is the rate of change of tangential velocity.
Q 1 d) 2 When an object is moving with uniform acceleration in circular direction, it is said to be experiencing the centripetal acceleration.
Tangential acceleration:
Tangential acceleration is a measure of how the tangential velocity of a point at a certain radius changes with time. Tangential acceleration is just like linear acceleration, but it's particular to the tangential direction, which is relevant to circular motion.

Question:
Find the velocity of point $B$ and midpoint $C$ of link $A B$ shown in Figure (1).

Q 1 e) 2 Answer:
Velocity of point $B \& C$ :
$\mathrm{Vb}=\mathrm{AB} \times \mathrm{wAB}=0.35 \times 50=17.5 \mathrm{~m} / \mathrm{s}$
$V c=A C \times w A B=0.175 \times 50=8.75 \mathrm{~m} / \mathrm{s}$

## Que.No Marks

Question:
Explain with neat sketch how to find the velocity of a slider in slider crank mechanism by Klein's construction.

Answer:
Velocity of a slider in a slider crank mechanism by Klein's construction method


Let $O C$ be the crank and $P C$ the connecting rod of a reciprocating steam engine, as shown in Fig. below. Let the crank makes an angle $\theta$ with the line of stroke $P O$ and rotates with uniform angular velocity $\omega \mathrm{rad} / \mathrm{s}$ in a clockwise direction.

First of all, draw OM perpendicular to OP; such that it intersects the line PC produced at M . The triangle OCM is known as Klien's velocity diagram.

In this triangle $\mathrm{OCM}, \mathrm{OM}$ may be regarded as a line perpendicular to PO ,
CM may be regarded as a line parallel to PC , (since it is the same line) and CO may be regarded as a line parallel to CO .
$o p_{1}$ represents $v_{\mathrm{PO}}$ (i.e. velocity of $P$ with respect to $O$ or velocity of cross-head or piston $P$ ) and is perpendicular to $O P$, and
$c_{1} p_{1}$ represents $v_{\mathrm{PC}}$ (i.e. velocity of $P$ with respect to $C$ ) and is parallel to $C P$.

Question:
In slider crank mechanism, the length of crank $O B$ and connecting rod $A B$ are 130 mm and 500 mm respectively. The centre of gravity $G$ of the connecting rod is 275 mm from slider $A$. The crank speed is 750 rpm in clockwise. When crank has turned 45 from inner dead centre position determine (i) velocity of slider ' $A$ ' (ii) velocity of centre of gravity of connecting rod ' $\mathbf{G}$ '.

Answer:


Question:
In a four bar mechanism $A B C D$ link $A D$ is fixed and the crank $A B$ rotates at 10 radians per second in clockwise, lengths of the links are $A B=60 \mathrm{~mm}, B C=C D=70 \mathrm{~mm}$, $D A=\mathbf{1 2 0} \mathbf{~ m m}$, when angle $D A B$ $=60 \square$ and both $B$ and $C$ lie on the same side of $A B$, find angular velocities of $B C$ and $C D$ link.

Answer:

Q 4 b) 4


Que.No Marks
Question:
In the toggle mechanism as shown in Fig. (2), D is constrained to move on a horizontal path. The dimensions of various links are $A B=$ $200 \mathrm{~mm}, \mathrm{BC}=300 \mathrm{~mm}, O C=150 \mathrm{~mm}$ and $B D=450 \mathrm{~mm}$. The crank OC is rotating in a counter clockwise direction at a speed of 180 rpm. Find, for given configuration (1) velocity and (2) acceleration of ' $D$ '.

Answer:

(a) Space diagram

(b) Velucity diagram

(c) Acceleration diagram
1.Velocity of slider ' $D$ ' = vector $\mathrm{ad}=1.6 \mathrm{~m} / \mathrm{s}$
2. Acceleration of slider ' $D^{\prime}=$ vector $a^{\prime} d^{\prime}=9.0 \mathrm{~m} / \mathrm{s}^{2}$

Examination: 2017 WINTER

Question:
Define linear velocity, angular velocity, absolute velocity and state the relation between linear velocity and angular velocity

Q 2 c) 4

Q 2 d) 4
Answer:

| Term | Definition | Mathematical/representation <br> (optional) |
| :--- | :--- | :--- |
| Linear <br> velocity | Rate of change of linear <br> displacement per unit time | $V=\frac{d_{x}}{d_{t}} \mathrm{~m} / \mathrm{sec}$ |
| Angular <br> velocity | Rate of change of angular <br> displacement per unit time | $\omega=\frac{d_{\theta}}{d_{t}} \mathrm{rad} / \mathrm{sec}$ |
| Absolute <br> velocity | Velocity of any point with respect <br> any point fixed point | $\mathrm{V}_{\text {ao }} ;$ velocity of point a w.r.t. o |

Relation between linear and angular velocity: $V=\omega \cdot r$

Question:
Explain the Klein's construction to determine velocity and acceleration of single slider crank mechanism

Answer:
klein's construction

1) Draw the basic diagram with the angle made by crank, crank
(AO) and connecting rod (AP) with dimensions and scale.

Acceleration quadrilateral ACNO | 2) Extend the connecting rod upto the vertical line of the crank |
| :--- |
| circle and mark intersection point M , the triangle created |
| $\triangle O A M$ is the velocity triangle. |

If $\omega A O$ is the angular velocity of the crank, then Linear velocity's of the links is given byVAO = $\omega A O \times A O, V A P=\omega A O \times A M, V P O=\omega A O \times M O$ Acceleration of the links is given bya $r A O=\omega 2$ $A O \times A O$, a $\mathrm{AP}=\omega 2 \mathrm{AO} \times \mathrm{AC}$, a $\mathrm{AP}=\omega 2 \mathrm{AO} \times \mathrm{CN}, \mathrm{aPO}=\omega 2 \mathrm{AO} \times \mathrm{NO}$

Question:
In a four bar chain $A B C D, A D$ is fixed and is 150 mm long. The crank $A B$ is 40 mm long and rotates at 120 r.p.m. clockwise, while the link $C D=80 \mathrm{~mm}$ oscillates about $D$. $B C$ and $A B$ are of equal length. Find the angular velocity of link $C D$ when angle $B A D=$ 60].

Answer:


Space diagram (All dimensions in mm ).

$$
\text { Given : } N_{\mathrm{BA}}=120 \text { r.p.m. or } \omega_{\mathrm{BA}}=2 \pi \times 120 / 60=12.568 \mathrm{rad} / \mathrm{s}
$$

Since the length of crank $A B=40 \mathrm{~mm}=0.04 \mathrm{~m}$, therefore velocity of $B$ with respect to $A$ or velocity of $B$, (because $A$ is a fixed point),

$$
v_{\mathrm{BA}}=v_{\mathrm{B}}=\omega_{\mathrm{BA}} \times A B=12.568 \times 0.04=0.503 \mathrm{~m} / \mathrm{s}
$$

$$
\text { vector } a b=v_{\mathrm{BA}}=v_{\mathrm{B}}=0.503 \mathrm{~m} / \mathrm{s}
$$

By measurement, we find that

$$
v_{\mathrm{CD}}=v_{\mathrm{C}}=\text { vector } d c=0.385 \mathrm{~m} / \mathrm{s}
$$

We know that
$C D=80 \mathrm{~mm}=0.08 \mathrm{~m}$
$\therefore$ Angular velocity of link $C D$,

$$
\omega_{\mathrm{CD}}=\frac{v_{\mathrm{CD}}}{C D}=\frac{0.385}{0.08}=4.8 \mathrm{rad} / \mathrm{s}(\text { clockwise about } D)
$$

Question:
In a slider crank mechanism, the length of crank $O B$ and connecting rod AB are 125 mm and 500 mm respectively. The centre of gravity $\mathbf{G}$ of the connecting rod is 275 mm from the slider. The crank speed is $\mathbf{6 0 0} \mathrm{rpm}$ clockwise. When the crank has turned $45 \square$ from the inner dead centre position, determine: (i) Velocity of slider ' $A$ ', (ii) Velocity of the point ' $G$ ' graphically.

Answer:

Q 3b) 4


## Question:

The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 rpm. The crank is 150 mm and the connecting rod is $\mathbf{6 0 0} \mathbf{~ m m}$ long. Determine : (i) linear velocity and acceleration of the mid-point of the connecting rod, and (ii) angular velocity and angular acceleration of the connecting rod, at a crank angle of 45 from inner dead centre position.

Answer:


In order to find the velocity of the midpoint $D$ of the connecting rod $A B$, divide the vector $b a$ at $d$ in the same ratio as $D$ divides $A B$, in the space diagram. In other words,
$b d / b a=B D / B A$
Note: Since $D$ is the midpoint of $A B$, therefore $d$ is also midpoint of vector $b a$.
Join od. Now the vector od represents the velocity of the midpoint $D$ of the connecting $\operatorname{rod}$ i.e. $V_{D}$.

Q 5 a) 8
By measurement, we find that

$$
V_{\mathrm{D}}=\text { vector } o d=4.1 \mathrm{~m} / \mathrm{s}
$$

Acceleration of the midpoint of the connecting rod
We know that the radial component of the acceleration of $B$ with respect to $O$ or the acceleration of $B$,

$$
a_{\mathrm{BO}}^{r}=a_{\mathrm{B}}=\frac{v_{\mathrm{BO}}^{2}}{O B}=\frac{(4.713)^{2}}{0.15}=148.1 \mathrm{~m} / \mathrm{s}^{2}
$$

and the radial component of the acceleraiton of $A$ with respect to $B$,

$$
a_{A B}^{r}=\frac{v_{A B}^{2}}{B A}=\frac{(3.4)^{2}}{0.6}=19.3 \mathrm{~m} / \mathrm{s}^{2}
$$

In order to find the acceleration of the midpoint $D$ of the connecting rod $A B$, divide the vector $a^{\prime} b^{\prime}$ at $d^{\prime}$ in the same ratio as $D$ divides $A B$. In other words

$$
b^{\prime} d^{\prime} / b^{\prime} a^{\prime}=B D / B A
$$

Note: Since $D$ is the midpoint of $A B$, therefore $d^{\prime}$ is also midpoint of vector $b^{\prime} a^{\prime}$. Join o' $d^{\prime}$. The vector $o^{\prime} d^{\prime}$ represents the acceleration of midpoint $D$ of the connecting rod i.e. aD.

By measurement, we find that $\mathrm{aD}=$ vector $\mathrm{o}^{\prime} \mathrm{d}^{\prime}=117 \mathrm{~m} / \mathrm{s} 2$
Angular velocity of the connecting rod
We know that angular velocity of the connecting rod $A B$,

$$
\omega_{A B}=\frac{v_{A B}}{B A}=\frac{3.4}{0.6}=5.67 \mathrm{rad} / \mathrm{s}^{2}(\text { Anticlockwise about } B) \text { Ans. }
$$

Angular acceleration of the connecting rod
From the acceleration diagram, we find that

$$
\left.a_{\mathrm{AB}}^{t}=103 \mathrm{~m} / \mathrm{s}^{2} \quad \text {...(By measurement }\right)
$$

We know that angular acceleration of the connecting rod $A B$,

$$
\alpha_{A B}=\frac{a_{A B}^{t}}{B A}=\frac{103}{0.6}=171.67 \mathrm{rad} / \mathrm{s}^{2}(\text { Clockwise about } B) \text { Ans. }
$$

Given: Lift $=40 \mathrm{~mm}$ Rise $=1 / 4 \times 360=900$ Fall $=1 / 6 \times 360=600$ Dwell $=1 / 10 \times 360=360$

## Examination: 2016 SUMMER

## Que.No Marks

## Question:

Explain single cylinder 4-stroke I.C. engine using turning moment diagram.

## Answer:

A turning moment diagram for a four stroke cycle internal combustion engine, we know that in a four stroke cycle internal combustion engine, there is one working stroke after a crank has turned through two revolution i.e. 7200 . Since the pressure inside the engine cylinder is less than the atmospheric pressure during suction stroke therefore a negative loop is formed. During the compression stroke, the work is done on gases, therefore a higher negative loop is obtained.


During the expansion or working stroke, the fuel burns and the gases expand, therefore a positive loop is obtained. In this stroke the work done is by the gases. During exhaust stroke, the work is done on the gases, therefore negative loop is formed. It may be noted that effect of inertia forces on the piston is taken is account.

## Question:

Define linear velocity, angular velocity, absolute velocity and state the relation between linear velocity and angular velocity.

Answer:
Linear Velocity: It may be defined as the rate of change of linear displacement of a body with respect to Q 2 c) 4 the time. Since velocity is always expressed in a particular direction, therefore it is a vector quantity. Mathematically, linear velocity, $v=d s / d t$
Angular Velocity: It may be defined as the rate of change of angular displacement with respect to time. It is usually expressed by a Greek letter $\omega$ (omega). Mathematically, angular velocity, $\omega=\mathrm{d} \theta / \mathrm{dt}$ Absolute Velocity: It is defined as the velocity of any point on a kinematic link with respect to fixed point. Relation between $v$ and $\omega: V=r$. $\omega$ Where $V=$ Linear velocity. $\omega=$ angular velocity. $r=$ radius of rotation.

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Question:
Explain the Klein's construction to determine velocity and acceleration of single slider crank
mechanism.
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Answer:
Let $O C$ be the crank and $P C$ the connecting rod of a reciprocating steam engine, as shown in
Fig. Let the crank makes an angle $\theta$ with the line of stroke $P O$ and rotates with uniform angular velocity $\omega \mathrm{rad} / \mathrm{s}$ in a clockwise direction. The Klien's velocity and acceleration diagrams are drawn as discussed below:


## Klien's velocity diagram

First of all, draw $O M$ perpendicular to $O P$; such that it intersects the line $P C$ produced at $M$. The triangle OCM is known as Klien's velocity diagram. In this triangle OCM,
$O M$ may be regarded as a line perpendicular to $P O$.
$C M$ may be regarded as a line parallel to $P C$, and $\quad . .(\because$ It is the same line.)
CO may be regarded as a line parallel to CO .
We have already discussed that the velocity diagram for given configuration is a triangle OCP as shown in Fig. If this triangle is rotated through $90^{\circ}$, it will be a triangle oc1 pl , in which oc1 represents VCO (i.e. velocity of $C$ with respect to $O$ or velocity of crank pin C ) and is parallel to OC, op1 represents VPO (i.e. velocity of P with respect to O or velocity of cross-head or piston P ) and is perpendicular to OP , and c1p1 represents VPC (i.e. velocity of P with respect to C ) and is parallel to CP . A little consideration will show that the triangles oc1p1 and OCM are similar. Therefore,

$$
\begin{aligned}
& \frac{o c_{1}}{O C}=\frac{o p_{1}}{O M}=\frac{c_{1} p_{1}}{C M}=\omega(\text { a constant }) \\
& \frac{v_{C O}}{O C}=\frac{v_{\mathrm{PO}}}{O M}=\frac{v_{\mathrm{PC}}}{C M}=\omega \\
& v_{\mathrm{CO}}=\omega \times O C ; v_{\mathrm{PO}}=\omega \times O M, \text { and } v_{\mathrm{PC}}=\omega \times C M
\end{aligned}
$$

Thus, we see that by drawing the Klein's velocity diagram, the velocities of various points may be obtained without drawing a separate velocity diagram. Klien's acceleration diagram: The Klien's acceleration diagram is drawn as discussed below: 1. First of all, draw a circle with C as centre and CM as radius. 2. Draw another circle with PC as diameter. Let this circle intersect the previous circle at $K$ and L. 3. Join KL and produce it to intersect PO at N. Let KL intersect PC at Q. This forms the quadriateral CQNO, which is known as Klien's acceleration diagram. We have already discussed that the acceleration diagram for the given configuration is as shown in Fig. We know that (i) o'c' represents CO ar (i.e. radial component of the acceleration of crank pin C with respect to O ) and is parallel to CO; (ii) c'x represents PC ar (i.e. radial component of the acceleration of crosshead or piston P with respect to crank pin C ) and is parallel to CP or CQ; (iii) xp' represents PC at (i.e. tangential component of the acceleration of P with respect to C ) and is parallel to QN (because QN is perpendicular to CQ); and (iv) o'p' represents aPO (i.e. acceleration of P with respect to O or the acceleration of piston P ) and is parallel to PO or NO. A little consideration will show that the quadrilateral o'c' $\mathrm{x} \mathrm{p}^{\prime}$ is similar to quadrilateral CQNO. Therefore,

$$
\frac{O^{\prime} C^{\prime}}{O C}=\frac{C^{\prime} x}{C Q}=\frac{x p^{\prime}}{Q N}=\frac{O^{\prime} p^{\prime}}{N O}=\omega^{2}(a \text { constant })
$$

Question:
In a slider-crank mechanism, the crank is $\mathbf{4 8 0} \mathbf{~ m m}$ long and rotates at $20 \mathrm{rad} / \mathrm{sec}$ in the counter-clockwise direction. The length of the connecting rod is 1600 mm . when the crank turns 60 from the inner-dead centre. Determine the velocity of the slider by relative velocity method.

Answer:

$$
\begin{aligned}
& \text { Q 3(a) Slider Crank mechanism } \\
& \text { Crank }=480 \mathrm{~mm} \text { long }=0 A=0.480 \mathrm{~m} \\
& \text { connecting rod }=1600 \mathrm{~mm} \text { long }=A P \\
& \left.\omega_{A O}=20 \mathrm{rad} / \mathrm{s}\right)
\end{aligned}
$$

$$
=9.6 \mathrm{~m} / \mathrm{s}
$$



## Question:

In a slider crank mechanism, crank $A B=20 \mathrm{~mm}$ \& connecting rod $B C=80 \mathrm{~mm}$. Crank $A B$ rotates with uniform speed of 1000 rpm in anticlockwise direction. Find (i) Angular velocity of connecting rod BC (ii) Velocity of slider C. When crank AB makes an angle of $\mathbf{6 0}$ degrees with the horizontal. Draw the configuration diagram also. Use analytical method.

## Answer:

Data- Crank $\mathrm{AB}=20 \mathrm{~mm}$; Connecting rod $\mathrm{BC}=80 \mathrm{~mm} ; \mathrm{N}_{\mathrm{BA}}=1000 \mathrm{rpm}$ (anticlockwise) Crank angle $=\theta=60^{\circ} ; n=1 / r=80 / 20=4$

[ 1 Mark ]
Angular velocity of crank $=\omega_{\mathrm{BA}}=2 \pi \mathrm{~N} / 60=\frac{2 X \pi \times 1000}{60}=104.71 \mathrm{rad} / \mathrm{sec}$
Angular velocity of connecting rod $=\omega_{\mathrm{BC}}=\frac{\omega \cos \theta}{n}$
$=\frac{104.71 \mathrm{X} \cos 60^{\circ}}{4}=13.08 \mathrm{rad} / \mathrm{sec} \quad \ldots[1$ Mark ]
Velocity of slider $\mathrm{C}=\mathrm{Vc}=\omega \mathrm{r}\left[\sin \theta+\frac{\sin 2 \theta}{2 n}\right]$

$$
\begin{aligned}
& =104.71 \times .02\left[\sin 60+\frac{\sin 120}{2 \times 4}\right] \\
& =2.04 \mathrm{~m} / \mathrm{s}
\end{aligned}
$$

Question:

Answer:



Velocity Diagram:-
scale
$\mathrm{cm}=3000 \mathrm{~mm} / \mathrm{sec}$


Acceleration Diagram
$1 \mathrm{~cm}=40 \times 10^{3} \mathrm{~mm} / \mathrm{sec}$


Calculations:
i) Velocity of crank AO:
$V_{A O}=(r \times \omega) \times(480 \times 20)$
$\mathrm{V}_{\mathrm{NO}}=9600 \mathrm{~mm} / \mathrm{sec}$
Velocity of connectingrod ( AB )
$V_{A B}=1(\mathrm{ab}) \times$ Scale $=1.6 \mathrm{X} 3000$
$V_{A B}=4800 \mathrm{~mm} / \mathrm{sec}$
Velocity of Slider :
$V_{\mathrm{BO}}=1(\mathrm{bo}) \times$ Scale $=3.2 \times 3000$
$\mathrm{V}_{\mathrm{BO}}=9600 \mathrm{~mm} / \mathrm{sec}$
Velocity of Extended link
$V_{\mathrm{BE}}=1$ (be) $\mathrm{X} \mathrm{Scale}=4.5 \times 3000$
$\mathrm{V}_{\mathrm{BE}}=13500 \mathrm{~mm} / \mathrm{sec}$
Now,
Calculations for acceleration Diagram:
$\mathrm{f}^{\mathrm{c}} \mathrm{os}_{\mathrm{s}}=\frac{\left(\text { velocity of crank }{ }^{2}\right)}{\text { length of crank }}=\frac{(9600)^{2}}{480}=192 \times 10^{3} \mathrm{~mm} / \mathrm{sec}$
$\mathrm{f}^{\mathrm{c}}{ }^{\mathrm{A}} \mathrm{B}=\frac{\left(\text { velocity of } \operatorname{rod}^{2}\right)}{\text { length of rod }}=\frac{(4800)^{2}}{1600}=14.4 \times 10^{3} \mathrm{~mm} / \mathrm{sec}$
$\mathrm{f}^{\mathrm{c}}{ }_{3 E}=\frac{\left(\text { velocity of Extended link }{ }^{2}\right)}{\text { length of crank }}=\frac{(13500)^{2}}{2050}=88.90 \times 10^{3} \mathrm{~mm} / \mathrm{sec}$

## To be find:

1. Acceleration of slider:
$\mathrm{a}_{\mathrm{bo}}=1$ (bo) $\mathrm{XScale}=1.6 \times 40 \times 10^{3}$
$\mathrm{a}_{\mathrm{bo}}=64 \times 10^{3} \mathrm{~mm} / \mathrm{sec}^{2}$
2. The Acceleration of point E:
$\mathrm{a}_{\mathrm{oc}}=1(\mathrm{oe}) \mathrm{XScale}=3.4 \times 40 \times 10^{\circ}$
$\mathrm{a}_{\mathrm{cc}}=136 \times 10^{3} \mathrm{~mm} / \mathrm{sec}^{2}$
3. Acceleration of link $A B$ :

$$
\mathrm{a}_{\mathrm{ab}}=\mathrm{I}(\mathrm{ab}) \times \text { Scale }=4.3 \times 40 \times 10^{3}
$$

$$
\mathrm{a}_{\mathrm{ab}}=172 \times 10 \mathrm{~mm} / \mathrm{sec}^{2}
$$

## Examination: 2016 WINTER

## Que.No Marks

Q 2 c) 4

Q 2d) 4
Question:
Explain Klein's construction to determine velocity and acceleration of different links in single slider crank mechanism.

Answer:
Klein's construction
a) For velocity of different links
b) For acceleration of different links


Question:
Define the terms: (i) Linear velocity (ii) Angular velocity (iii) Absolute velocity (iv) Relative velocity

Answer:

| Term | Definition | Mathematical/representation <br> (optional) |
| :--- | :--- | :--- |
| Linear <br> velocity <br> unit time | Rate of change of linear displacement per <br> Angular <br> velocity | Rate of change of angular displacement per <br> unit time |
| Absolute <br> velocity | Velocity of any point with respect any point <br> fixed point | $\mathrm{V}_{\mathrm{ao}} ;$ velocity of point a w.r.t. o |
| Relad $/ \mathrm{sec}$ <br> velocity | Velocity of any point with respect to any <br> other some point on the same link. | $\mathrm{V}_{\mathrm{ab}} ;$ velocity of point a w.r.t. |

$\qquad$

## Que.No Marks

Question:
The crank and connecting rod of steam engine are 0.5 m and 2 m long respectively. The crank makes $180 \mathrm{r} . \mathrm{p} . \mathrm{m}$. in clockwise direction. When it has turned through $45^{\circ}$ from I.D.C. Find the velocity of piston and angular velocity of connecting rod by relative velocity method.

Answer:
Relative Velocity Method.

## Given Data:

Crank $=0.5 \mathrm{~m}$
Connecting rod $=2 \mathrm{~m}$
$\mathrm{N}=180 \mathrm{rpm}$
$\Theta=45^{\circ}$
A) Space diagram:

Scale:
$1 \mathrm{~cm}=0.25 \mathrm{~m}$

Q 3 b ) 4


$$
\left.\begin{array}{ll}
\omega=\frac{2 \Pi N}{60} \\
\frac{2 \Pi \times 180}{60}
\end{array}\right)
$$

## Calculations:

1) $V_{\mathrm{OA}}=\mathrm{r} \omega$
$=0.5 \mathrm{X} 18.84$
$V_{O A}=9.42 \mathrm{~m} / \mathrm{s} \ldots .1$ mark
B)Velocity diagram: Scale:
$1 \mathrm{~cm}=3 \mathrm{~m} / \mathrm{s}$
2) Velocity of piston:
$\mathrm{Vp}=\mathrm{L}(\mathrm{op}) \mathrm{X}$ scale $=2.8 \mathrm{X} 3$
$\mathbf{V p}=8.4 \mathrm{~m} / \mathrm{s} \ldots .$. ans
3) Angular velocity of connecting rod:

$$
\omega=\frac{V a p}{\text { length of } A P}=\frac{l(a p) X \text { Scale }}{2}=\frac{2.2 \times 3}{2}
$$

$$
\omega=3.3 \mathrm{rad} / \mathrm{sec} . . . . \mathrm{ans}
$$

## Que.No Marks

Question:
In a slider crank mechanism the length of crank and connecting rod are 100 mm and 40 mm respectively. The crank rotates uniformly at 600 rpm clockwise. Then crank has turned through $45^{\circ}$ from I.D.C. Find by analytical method. (i) Velocity and acceleration of slider (ii) Angular velocity and angular acceleration of connecting rod.

Answer:
Radius of crank , $\mathrm{r}=100 \mathrm{~mm}=0.1 \mathrm{~m}$ speed. $\mathrm{N}=600 \mathrm{rpm}, \omega=2 \pi \mathrm{~N} / 60=62.83 \mathrm{rad} / \mathrm{sec}$
Length of connecting rod, $\mathrm{l}=400 \mathrm{~mm}=0.4 \mathrm{~m}$ ( 40 mm is printing mistake)
Obliquity ratio, $n=1 / r=400 / 100=4$, Crank angle , $\theta=45^{\circ}$
Q 5 a ) $8 \quad$ Velocity of slider $\mathrm{Vp}=\omega \mathrm{r}\left(\sin \theta+\frac{\sin 2 \theta}{2 n}\right)=5.225 \mathrm{~m} / \mathrm{s}$
Acceleration of slider $\mathrm{fp}=\omega^{2} \mathrm{r}\left(\cos \theta+\frac{\cos 2 \theta}{n}\right)=279.15 \mathrm{~m} / \mathrm{s}^{2}$
Angular velocity of connecting rod $\omega_{\mathrm{pc}}=(\omega \cos \theta) / \mathrm{n}=11.107 \mathrm{rad} / \mathrm{sec}$
Angular acceleration of connecting rod $\alpha_{\mathrm{pc}}=\left(-\omega^{2} \sin \theta\right) / \mathrm{n}=-697.89 \mathrm{rad} / \mathrm{sec}^{2}$
[Note- If student has taken I=40,(due to printing mistake in QP) which is practically not
possible, but values of answers in that case will be Vp=12.29 m/s;fp=279.15 m/s ${ }^{\mathbf{2}} ; \omega_{p c}=111.07$ $\mathrm{rad} / \mathrm{sec} ; \alpha_{p c}=6978.86 \mathrm{rad} / \mathrm{s}^{2}$, which may be acceptable.]

## Que.No Marks



Examination: 2015 SUMMER

Que.No Marks

> Question:
> Define linear velocity, angular velocity, absolute velocity and state the relation between linear velocity and angular velocity.

Answer:
Linear Velocity It may be defined as the rate of change of linear displacement of a body with respect to the time. Since velocity is always expressed in a particular direction, therefore it is a vector quantity. Mathematically, linear velocity, $v=d s / d t$

Angular Velocity It may be defined as the rate of change of angular displacement with

Q 2 c) 4

Question:
Describe stepwise procedure for determination of velocity and acceleration by Klein's construction with suitable data.

## Answer:

## Steps in Klein's construction :

Klein's construction is a simpler construction to get velocity and acceleration diagrams. For example : for reciprocating engine mechanism OPC. draw a circle with PC as diameter as shown. and obtain velocity diagram OCM ie. produce PC to cut perpendicular to line of stroke in ' $M$ '. Draw another circle with ' C ' as center and "CM" as radius cutting the first circle in points K and L . Join "KL" which is the chord common to both the circles. Let it cuts PC and OP Q 2 d ) 4 in " $Q$ " and " $N$ " respectively. Then "OCQN" is the required quadrilateral which is similar to acceleration diagram.


Que.No Marks
Question:
$P Q R S$ is a four bar chain with $P S$ fixed length of links are $P Q=62.5$ $\mathrm{mm}, \mathrm{QR}=\mathbf{1 7 5} \mathrm{mm}, \mathrm{RS}=\mathbf{1 1 2 . 5} \mathbf{~ m m}, \mathrm{PS}=\mathbf{2 0 0} \mathbf{m m}$. The crank PQ rotate at $10 \mathrm{rad} / \mathrm{sec}$. in clockwise direction. Determine the angular velocity of point $R$, graphically by using relative velocity method.

Answer:
Assume angle $\mathrm{QPS}=60^{\circ}$

(a) Space diagram.

(b) Velocity diagram.

Q 3 e) 4
$\mathrm{V}_{\mathrm{QP}} \quad=\mathrm{PQ} \times \omega_{\mathrm{Pq}}=0.0625 \times 10 \mathrm{rad} / \mathrm{sec}=0.625 \mathrm{~m} / \mathrm{s}$

First of all, draw the space diagram to some suitable scale, as shown in Fig. Now the velocity diagram, as shown in Fig. is drawn as discussed below :

1. Since the link PS is fixed, therefore points $\mathbf{p}$ and $s$ are taken as one point in the velocity diagram. Draw vector $\mathbf{P q}$ perpendicular to QP to some suitable scale, to represent the velocity of Q with respect to P or simply velocity of $\mathrm{Q}\left(i . e \mathrm{Vqp}\right.$ or $\left.\mathrm{Vq}_{\mathrm{q}}\right)$ such that

$$
\text { vector } \mathrm{pq}=\mathrm{Vqp}=\mathrm{Vq}=0.625 \mathrm{~m} / \mathrm{s}
$$

2. Now from point $\mathbf{9}$, draw vector $\mathbf{q r}$ perpendicular to RQ to represent the velocity of R with respect to Q (i.e. Vrq) and from point $s$, draw vector ${ }^{s r}$ perpendicular to RS to represent the velocity of $\mathbf{R}$ with respect to. S or simply velocity of $\mathbf{R}\left(i . e . V_{r s}\right.$, or $\left.\mathrm{Vr}_{\mathrm{r}}\right)$. The vectors qr and sr intersect at $\mathbf{r}$

By measurement, we find that

$$
\begin{aligned}
& \mathrm{Vrs}_{\mathrm{rs}}=\mathrm{V}_{\mathrm{r}}=\text { vector } \mathrm{sr}=0.43 \mathrm{~m} / \mathrm{s} \\
& \mathrm{RS}=112.5 \mathrm{~mm}=0.1125 \mathrm{~m}
\end{aligned}
$$

We know that
$\therefore$ Angular velocity of $\mathrm{R}=$ Ang. Velo. of link RS (clockwise about S )

$$
\omega_{\mathrm{RS}}=\frac{\mathrm{Vrs}}{\mathrm{RS}}=\frac{0.43}{0.1125}=3.82 \mathrm{rad} / \mathrm{s}
$$

Question:
In reciprocating engine the crank is $\mathbf{2 5 0} \mathbf{~ m m}$ long and connecting rod is 1000 mm long. The crank rotate at 150 rpm . Find velocity and acceleration of piston and angular velocity and angular acceleration of connecting rod when the crank makes an angle of $30^{\circ}$ to IDC. Use analytical method.

Answer:
Solution of problem on Reciprocating Engine:
Given : $\mathrm{r}=\mathbf{2 5 0 \mathrm { mm } = \mathbf { 0 . 2 5 } \mathrm { m } , \mathrm { I } = 1 0 0 0 \mathrm { mm } = 1 \mathrm { m } , \quad \theta = \mathbf { 3 0 } 0 ^ { \circ } ; N = \mathbf { 1 5 0 } \mathrm { rpm } , ~}$ $\omega=\pi \times 150 / 60=7.85 \mathrm{rad} / \mathrm{s}$

## 1. Velocity of piston

We know that ratio of the length of connecting rod and crank,

$$
n=l / r=1 / 0.25=4
$$

$\therefore$ Velocity of the slider,

$$
\begin{aligned}
v_{\mathrm{P}} & =\omega r\left(\sin \theta+\frac{\sin 2 \theta}{2 n}\right)=7.85 \times 0.25\left(\sin 30+\frac{\sin 60^{\circ}}{2 \times 4}\right) \mathrm{m} / \mathrm{s} \\
& =1.19 \mathrm{~m} / \mathrm{s} \text { Ans. }
\end{aligned}
$$

and acceleration of the slider,

$$
\begin{aligned}
a_{\mathrm{P}} & =\omega^{2} \cdot r\left(\cos \theta+\frac{\cos 2 \theta}{n}\right)=(7.85)^{2} \times 0.25\left(\cos 30^{\circ}+\frac{\cos 60^{\circ}}{4}\right) \mathrm{m} / \mathrm{s}^{2} \\
& =15.27 \mathrm{~m} / \mathrm{s}^{2} \text { Ans. }
\end{aligned}
$$

## 2. Angular velocity \& Angular acceleration of Con Rod

We know that angular velocity of the connecting rod,

$$
\omega_{\mathrm{PC}}=\frac{\omega \cos \theta}{n}=\frac{7.85 \times \cos 30^{\circ}}{4}=1.67 \mathrm{rad} / \mathrm{s} \text { Ans. }
$$

and angular acceleration of the connecting rod,

$$
\alpha_{\mathrm{PC}}=\frac{\omega^{2} \sin \theta}{n}=\frac{(7.85)^{2} \times \sin 30^{\circ}}{4}=7.7 \mathrm{rad} / \mathrm{s}^{2} \mathrm{Ans}
$$

## Examination: 2015 WINTER

## Question:

Define the terms linear velocity, relative velocity, angular velocity and angular acceleration.

Answer:
Velocity: It may be defined as the rate of change of linear displacement of a body with respect to the time. Since velocity is always expressed in a particular direction, therefore it is a vector quantity. Mathematically, linear velocity,

$$
v=d s / d t
$$

Relative velocity: relative velocity is the velocity of an object or an observer B in the rest frame of another object or an observer A.

Consider two bodies $A$ and $B$ moving along parallel lines in the same direction with absolute velocities $v A$ and $v B$ such that $v A>v B$, as shown in Fig. 7.1 (a). The relative

Q 2 c) 4

Q 2 d ) 4

## Question:

For a single slider crank mechanism , state the formulae to calculate by analytical method - Also state the meaning of each term.

Answer:
i) Velocity of slider:

$$
V p=w . r[\sin \theta+\sin 2 \theta / 2 n]
$$

where,
Vp - velocity of slider
w- angular velocity
$\theta$ - angle of crank to line of stroke 'PO'
$\mathrm{n}-\mathrm{I} / \mathrm{r}=$ ratio of length of connecting rod to crank radius.
ii) Acceleration of slider:
$\mathbf{f p}=\mathbf{w} \mathbf{r}(\cos \theta+\cos 2 \theta / n)$
where, fp - acceleration of slider
iii) Angular velocity of connecting rod.:
$\mathbf{w p c}=\mathbf{w} \boldsymbol{\operatorname { c o s } \theta} \boldsymbol{\theta} /(\mathbf{n} \mathbf{2} \boldsymbol{- \boldsymbol { s }} \mathbf{\operatorname { s i n }} \mathbf{2 \theta}) \mathbf{1 / 2}$
Where, wpc is angular velocity of connecting rod
iv) Angular acceleration of connecting rod.:
$\alpha \mathrm{pc}=-\mathrm{w} 2 \sin \theta(\mathrm{n} 2-1) /(\mathrm{n} 2-\sin 2 \theta) \mathbf{3 / 2}$
Where, $\alpha \mathrm{pc}$ is angular acceleration of connecting rod.

## Que.No Marks

Question:
Space diagram 01 Mark, Velocity Diagram 02 marks, Calculations 01 Mark Note In QP length BC \& AB are equal. Read length AD = length BC = 150 mm

Answer:


Space diagram (All dimensions in mm).


Velocity diagram.

Q 3a) 4

Q 3 b ) 4

$$
\text { Given : } N_{\mathrm{BA}}=120 \text { r.p.m. or } \omega_{\mathrm{BA}}=2 \pi \times 120 / 60=12.568 \mathrm{rad} / \mathrm{s}
$$

Since the length of crank $A B=40 \mathrm{~mm}=0.04 \mathrm{~m}$, therefore velocity of $B$ with respect to $A$ or velocity of $B$, (because $A$ is a fixed point),

$$
v_{\mathrm{BA}}=v_{\mathrm{B}}=\omega_{\mathrm{BA}} \times A B=12.568 \times 0.04=0.503 \mathrm{~m} / \mathrm{s}
$$

vector $a b=v_{\mathrm{BA}}=v_{\mathrm{B}}=0.503 \mathrm{~m} / \mathrm{s}$
By measurement, we find that

$$
v_{\mathrm{CD}}=v_{\mathrm{C}}=\text { vector } d c=0.385 \mathrm{~m} / \mathrm{s}
$$

We know that $\quad C D=80 \mathrm{~mm}=0.08 \mathrm{~m}$
$\therefore$ Angular velocity of link $C D$,

$$
\omega_{\mathrm{CD}}=\frac{v_{\mathrm{CD}}}{C D}=\frac{0.385}{0.08}=4.8 \mathrm{rad} / \mathrm{s}(\text { clockwise about } D)
$$

Question:
In a single slider crank mechanism, crank $A B=20 \mathrm{~mm}$ and connecting rod $B C=80 \mathrm{~mm}$. Crank $A B$ rotates with uniform speed of 1000 rpm in anticlockwise direction. Find (i) angular velocity of connecting rod BC and (ii) Velocity of slider C when crank $A B$ makes angle of $60^{\circ}$ with the horizontal.

Answer:
Given: Crank $A B=20 \mathrm{~mm}=0.02 \mathrm{~m}, \mathrm{C}$. R. $\mathrm{BC}=80 \mathrm{~mm}=0.08 \mathrm{~m}$
$\mathrm{N}=1000 \mathrm{rpm}, \omega B A=2 \pi \mathrm{~N} / 60=2 \pi \times 1000 / 60=104.7 \mathrm{rad} / \mathrm{sec}$
$V B A=\omega B A \times A B=104.7 \times 0.02=2.09 \mathrm{~m} / \mathrm{s}$
From velocty diagram: Velocity of C w.r.t. B -
$\mathrm{VCB}=$ vector $\mathrm{cb}=1.15 \mathrm{~m} / \mathrm{s}$
Angular velocity of Connecting rod ' BC ' $\omega \mathrm{CB}=\mathrm{VCB} / \mathrm{CB}=1.15 / 0.08=14.375 \mathrm{rad}$

## /sec

Velocity of slider ' C '
$\mathrm{VC}=$ vector $\mathrm{ac}=2 \mathrm{~m} / \mathrm{sec}$

## Que.No Marks

Question:
The crank and connecting rod of a reciprocating engine are $\mathbf{2 0 0} \mathbf{~ m m}$ and 700 mm respectively. The crank is rotating in clockwise direction at 120 rad/s. Draw Klein's construction and find (i) Velocity and acceleration of the piston (ii) Angular velocity and angular acceleration of the connecting rod at the instant when the crank is at $30^{\circ}$ to IDC (inner dead centre).

Answer:

## Construction :



1. Velocity and acceleration of the piston

Q 5 a) 4

$$
\text { We know that the velocity of the piston } P \text {, }
$$

$$
v_{p}=\omega \times O M=120 \times 0.127=15.24 \mathrm{~m} / \mathrm{s} \text { Ans. }
$$

and acceleration of the piston $P$,

$$
a_{\mathrm{p}}=\omega^{2} \times N O=(120)^{2} \times 0.2=2880 \mathrm{~m} / \mathrm{s}^{2} \text { Ans }
$$

3. Angular velocity and angular acceleration of the connecting rod

We know that the velocity of the connecting rod $P C$ (i.e. velocity of $P$ with respect to $C$ ),

$$
v_{\mathrm{PC}}=\omega \times C M=120 \times 0.173=20.76 \mathrm{~m} / \mathrm{s}
$$

$\therefore$ Angular acceleration of the connecting rod $P C$,

$$
\omega_{\mathrm{PC}}=\frac{v_{\mathrm{PC}}}{P C}=\frac{20.76}{0.7}=29.66 \mathrm{rad} / \mathrm{s} \text { Ans. }
$$

We know that the tangential component of the acceleration of $P$ with respect to $C$,

$$
a_{P C}^{t}=\omega^{2} \times Q N=(120)^{2} \times 0.093=1339.2 \mathrm{~m} / \mathrm{s}^{2}
$$

$\therefore$ Angular acceleration of the connecting rod $P C$,

$$
\alpha_{P C}=\frac{a_{P C}^{t}}{P C}=\frac{1339.2}{0.7}=1913.14 \mathrm{rad} / \mathrm{s}^{2} \text { Ans. }
$$

