DEPARTMENT OF MECHANICAL ENGINEERING

UNIVERSITY INSTITUTE OF ENGINEERINGAND TECHNOLOGY, CSJM UNIVERSITY, KANPUR

Kinematics and Mechanism (MEE –S203T)

Semester: 2021-22 (Odd Semester) **Year: 2nd Year (2K21)**

Mid Semester Examination

Time: 1.5 h **Maximum marks: 30**

All questions are compulsory

Section A

9 marks (9 questions of 1 mark each)

1. ABCD is a four-link Mechanism. AB = 100 mm, BC = 150 mm, CD = 200 mm and AD = 175 mm. Can it act as a double-crank mechanism?

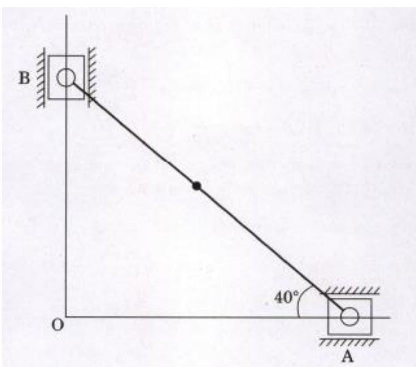
(a) No.

(b) Yes, if AB is fixed

(c) Yes, if BC is fixed

(d) Yes, if AD is fixed

2. The slider A, of an elliptical trammel shown in the figure moves towards O with a velocity of 3 m/s at the instant when AB makes an angle of 40^0 with the horizontal. Determine the velocity of the mid point of the link AB at this instant



3. The number of instantaneous centres of rotation in a slider crank quick –return mechanism is ________.

4. A planer mechanism has 10 links and 12 rotary joints. Using Grubler's criterion, the number of degrees of freedom of the mechanism is _______.

5. The magnitude of the velocity of any point on the kinematic link relative to the other point on the same kinematic link is the product of

(a) A square root of an angular velocity of the link and the distance between the two points under consideration

(b) An angular velocity of the link and the square of distance between the two points under consideration

(c) A square of an angular velocity of the link and the distance between the two points under consideration

(d) An angular velocity of the link and the distance between the two points under consideration

6. Match the degree of freedom of kinematic pair

List-1	List-II
1. Spherical pair	A. 1
2. Cylindrical pair	B. 2
3. Screw pair	C. 3
4. Ball and socket joint	

7. For a crank and slotted lever quick return mechanism, α = 150°. Find the ratio of time of cutting stroke to time of return stroke.

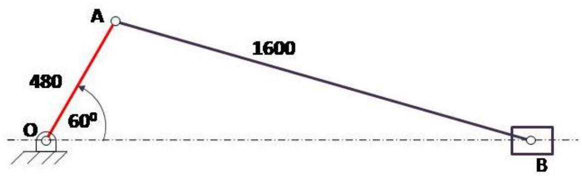
8. Define: kinematic link, kinematic pair, kinematic chain.

9. Distinguish between mechanism and machine.

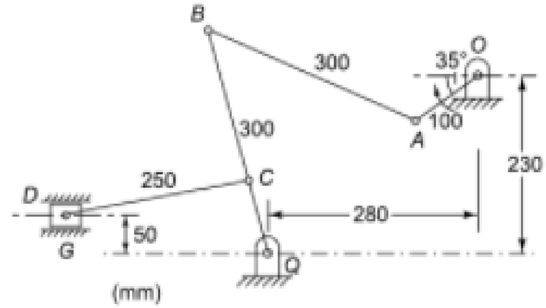
Section B

9 marks (3 questions of 3 marks each)

1. For the configuration of a slider –crank mechanism, calculate the
(a) acceleration of the slider at B
(b) angular acceleration of the link AB
OA rotates at 20 rad/s counter-clockwise



2. A mechanism in which OA = QC = 100 mm, AB = QB = 300 mm and CD = 250 mm. The crank OA rotates at 150 rpm in the clockwise direction. Determine the velocity of the slider at D.



(a)

(c) State kennedy theorem. Locate all instantaneous centre of rotation for a four-bar mechanism.

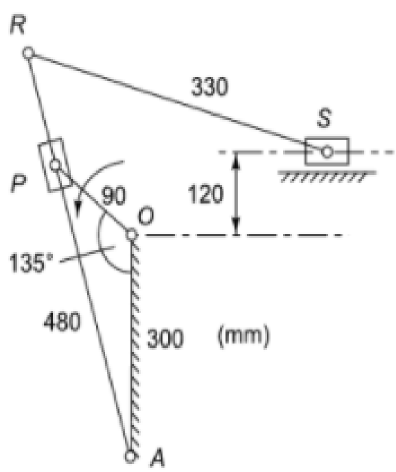
Section C

12 marks (2 questions of 6 marks each, Each question can have parts)

1. The crank OP of a crank- and slotted-lever mechanism rotates at 100 rpm in the counter-clockwise direction. Various lengths of the links are OP = 90 mm, OA = 300 mm, AR = 480 mm and RS = 330 mm. The slider moves along an axis perpendicular to AO and is 120 mm from O.

(a) Determine velocity of the slider when the AOP is 135^0 and quick return ratio.

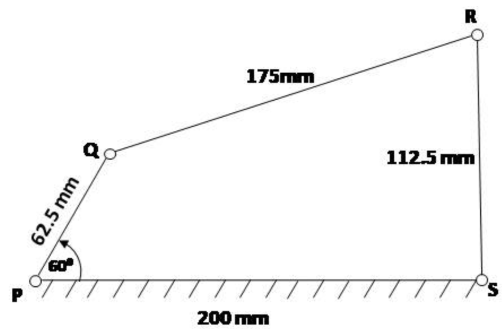
(b) Determine angular velocity of link AR, RS.



2. PQRS is a four bar chain with link PS fixed. The lengths of the links are PQ = 62.5 mm ; QR = 175 mm ; RS = 112.5 mm and PS = 200 mm. The crank PQ rotates at 10 rad/s clockwise. Draw the velocity and acceleration diagram when angle QPS = 60^0 and Q and R lie on the same side of PS.

(a) Find the angular velocity links QR and RS.

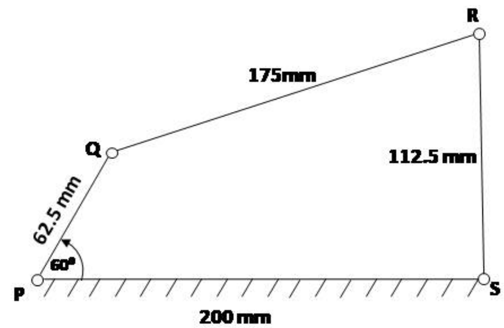
(b) Find the angular acceleration of links QR and RS



Q2. PQRS is a four bar chain with link PS fixed. The lengths of the links are PQ = 62.5 mm ; QR = 175 mm ; RS = 112.5 mm and PS = 200 mm. The crank PQ rotates at 10 rad/s clockwise. Draw the velocity and acceleration diagram when angle QPS = 60^0 and Q and R lie on the same side of PS.

(a) **Find the angular velocity links** QR and **RS**.

(b) Find the angular acceleration of links QR and RS



In Δ PQS,

$$\cos 60^0 = \frac{PQ^2 + PS^2 - QS^2}{2 \times PQ \times PS} = \frac{62.5^2 + 200^2 - QS^2}{2 \times 62.5 \times 200}$$

$QS = 177.2$ mm

$$\cos \angle PQS = \frac{PQ^2 + QS^2 - PS^2}{2 \times PQ \times QS} = \frac{62.5^2 + 177.2^2 - 200^2}{2 \times 62.5 \times 177.2}$$

$\angle PQS = 102.2^0$

$$\frac{177.2}{\sin 60^0} = \frac{62.5}{\sin \angle PSQ}$$

$\angle PSQ = 17.79^0$

In ΔQSR

$$\cos \angle R = \frac{QR^2 + RS^2 - QS^2}{2 \times QR \times RS} = \frac{175^2 + 112.5^2 - 177.2^2}{2 \times 175 \times 112.5}$$

$\angle R = 72.44^0$

$$\frac{QS}{\sin \angle R} = \frac{112.5}{\sin \angle SQR} = \frac{175}{\sin \angle QSR}$$

$$\frac{177.2}{\sin 72.44^0} = \frac{112.5}{\sin \angle SQR}$$

$\angle SQR = 37.25^0$

$$\angle QSR + \angle SQR + \angle R = 180^0$$

$\angle QSR + 37.25 + 72.44 = 180^0$

$\angle QSR = 70.31^0$

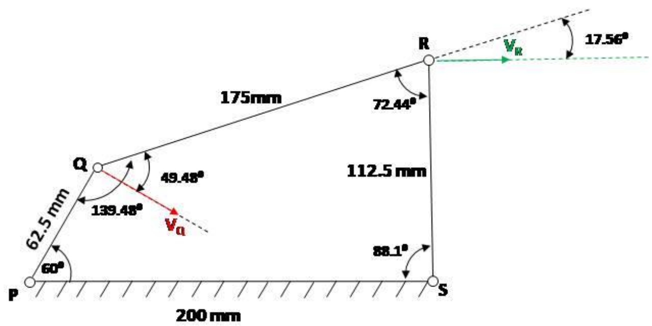
$\angle Q = \angle PQS + \angle SQR$

$\angle Q = 102.23^0 + 37.25^0 = 139.48^0$

$\angle S = \angle PSQ + \angle QSR$

$\angle S = 17.79 + 70.31 = 88.1$

$\angle P = 60^0 , \angle Q = 139.48^0, \angle R = 72.44^0 \; and \; \angle S = 88.1^0$



$V_Q \cos 49.48^0 = V_R \cos 17.56^0$

$V_R = \frac{\omega_{PQ} \times PQ \times \cos 49.48^0}{\cos 17.56^0} = \frac{10 \times 0.0625 \times \cos 49.48^0}{\cos 17.56^0} = 0.426$ m/s

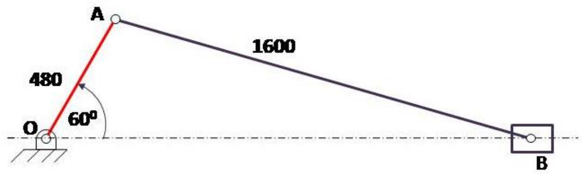
$V_R = 0.426 \; m/s$

$V_R = \omega_{RS} \times RS$

$\omega_{RS} = \frac{V_R}{RS} = \frac{0.426}{0.1125} = 3.79$ rad/s

$\omega_{RS} = 3.79$ rad/s (1.5 marks)

Q1. For the configuration of a slider –crank mechanism, calculate the
(a) acceleration of the slider at B
(b) angular acceleration of the link AB
OA rotates at 20 rad/s counter-clockwise



Acceleration of slider B:

$$\vec{a}_B = \vec{a}_A + \vec{a}_{B/A}$$

$$|\vec{a}_A| = \omega_{OA}^2 \times OA$$

$$= 20^2 \times 0.48$$

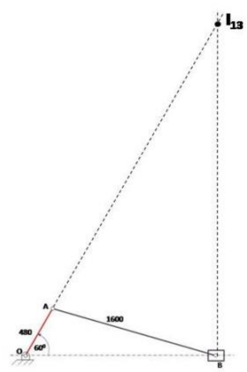
$$= 192 \text{ m/s}^2$$

$$\vec{a}_{B/A} = \bar{a}_{B/A}^r + \bar{a}_{B/A}^t$$

$$|\bar{a}_{B/A}^r| = \omega_{AB}^2 \times AB$$

Find ω_{AB}

Let AB is link -3, locate I_{13}.



$V_A = \omega_{AB} \times AP$ (P is point I_{13})

$$\omega_{AB} = \frac{V_A}{AP} = \frac{\omega_{OA} \times OA}{AP}$$

Find AP,

In Δ OPB

$$\cos 60^0 = \frac{OB}{OP}$$

OP = 2 x OB.

In ΔOAB,

$$\cos 60^0 = \frac{OA^2 + OB^2 - AB^2}{2 \times OA \times OB} = \frac{480^2 + OB^2 - 1600^2}{2 \times 480 \times OB}$$

OB = 1785 mm (0.25 mm)

OP = 2 x 1785 mm

OA + AP = 3570 mm

480 + AP = 3570 mm

AP = 3090 mm

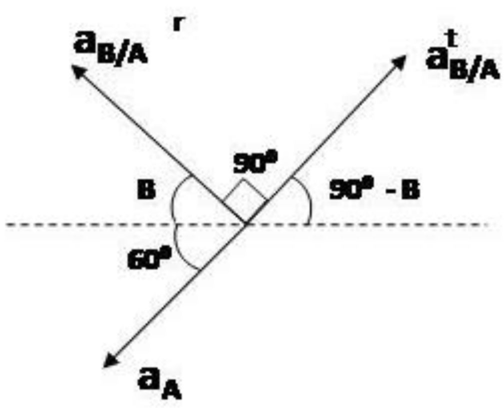
$$\omega_{AB} = \frac{V_A}{AP} = \frac{\omega_{OA} \times OA}{AP} = \frac{20 \times 480}{3090}$$

ω_{AB} = 3.11 rad/s (0.25 marks)

$|\bar{a}^r_{B/A}| = \omega^2_{AB} \times AB =$ $3.11^2 \times 1.6 = 15.48$ m/s^2 (0.25 marks)

$|\bar{a}^t_{B/A}| = \alpha_{AB} \times AB = \alpha_{AB} \times 1.6$

$\vec{a}_B = \vec{a}_A + \vec{a}_{B/A}$



Acceleration of B along horizontal direction. Therefore summation of these three vector along y-direction should be equal to zero.

$$a^r_{B/A} \sin B + a^t_{B/A} \sin(90^0 - B) = a_A \sin 60^0$$

$$15.48 \times \sin B + 1.6 \times \alpha_{AB} \sin(90^0 - B) = 192 \sin 60^0$$

Section-B (Q-1)

Find angle B,

$$\frac{1600}{\sin 60^0} = \frac{480}{\sin B}$$

$\sin B = 0.26$

$\cos B = 0.97$ (0.25 marks)

$15.48 \times 0.26 + 1.6 \times \alpha_{AB} \times 0.97 = 192 \sin 60^0$

$\alpha_{AB} = 104.6$ rad/s^2 (1 marks)

$a_B = a^r_{B/A} \cos B - a^t_{B/A} \cos(90^0 - B) + a_A \cos 60^0$

$a_B = 15.48 \times 0.97 - 1.6 \times 104.6 \times 0.26 + 192 \times 0.5$

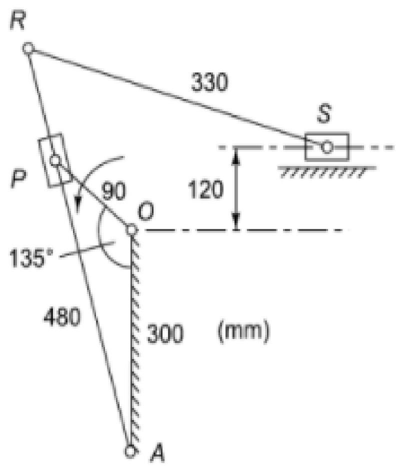
$a_B = 67.502$ m/s^2 (1 marks)

Quick return mechanism

1. The crank OP of a crank- and slotted-lever mechanism rotates at 100 rpm in the counter-clockwise direction. Various lengths of the links are OP = 90 mm, OA = 300 mm, AR = 480 mm and RS = 330 mm. The slider moves along an axis perpendicular to AO and is 120 mm from O.

(a) Determine velocity of the slider when the AOP is 135^0 and quick return ratio.

(b) Determine **angular velocity of link AR**, RS.



Velocity approach method

Step-1: Find the length AP

In Δ OPA,

$$\cos 135^0 = \frac{OP^2 + OA^2 - AP^2}{2 \times OP \times OA}$$

$$\cos 135^0 = \frac{90^2 + 300^2 - AP^2}{2 \times 90 \times 300}$$

$$AP^2 = 90^2 + 300^2 - 2 \times 90 \times 300 \cos 135^0$$

$AP = 369.16$ mm (0.25 marks)

In Δ OPA,

Let $\angle$OPA = θ

$$\cos\theta = \frac{AP^2 + OP^2 - AO^2}{2 \times AP \times OP}$$

$$\cos\theta = \frac{369.16^2 + 90^2 - 300^2}{2 \times 369.16 \times 90}$$

$\theta = 35.07^0$ (0.25 marks)

Velocity of P perpendicular to AP = $V_{P/0} \cos\theta$

Velocity of P perpendicular to AP = Velocity of point Q (coincident to point P, point Q lie on link AR)

Velocity of point Q = angular velocity of link AR x AQ [AQ = AP]

$$V_{P/0} \cos\theta = \omega_{AR} \times AP$$

$$\omega_{oP} \times OP \times \cos 35.07^0 = \omega_{AR} \times AP$$

$$\omega_{AR} = \frac{\omega_{oP} \times OP \times \cos 35.07^0}{AP}$$

$$\omega_{AR} = \frac{\frac{2\pi \times 100}{60} \times 90 \times \cos 35.07^0}{369.16} = 2.08\ rad/s$$ (1 marks)