USN

18ME44

Fourth Semester B.E. Degree Examination, July/August 2022
Kinematics of Machines

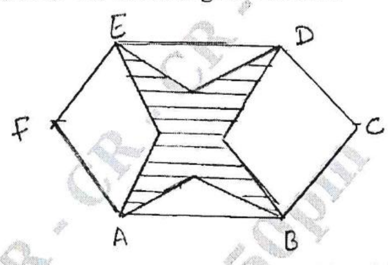
Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Module-1

1 a. Define the following :
   i) Kinematic chain.
   ii) Structure.
   iii) Machine.
   iv) Mechanism. **(08 Marks)**

b. Find the degrees of freedom for the following mechanism. **(04 Marks)**



c. What is Inversion? Explain any one Inversion of double slider crank mechanism with the help of a neat sketch. **(08 Marks)**

OR

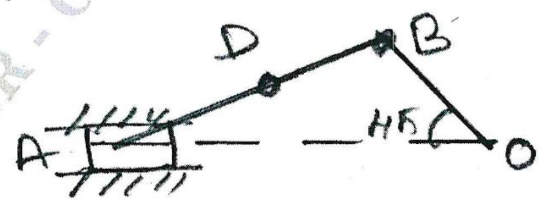
2 a. Explain the construction and working of Peaucillieri Mechanism with a neat sketch. Prove that it generates an exact straight line. **(08 Marks)**

b. What are the field applications and advantages of Quick return motion mechanism? Explain the crank and slotted lever mechanism using a neat sketch. **(12 Marks)**

Module-2

3 The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 rpm. The crank is 150mm and connecting rod is 600mm. Determine
   i) Linear velocity and acceleration of the midpoint of the connecting rod and
   ii) Angular velocity and angular acceleration of the connecting rod, at a crank angle of 45° from the Inner dead centre position. **(20 Marks)**

Fig. Q3



OR

4 a. State and prove Arnold Kennedy theorem. **(06 Marks)**

b. Locate all the Instantaneous centres of the slider crank mechanism as shown in Fig. Q4(b). The lengths of crank OB and connecting rod AB are 100mm and 400mm respectively. If the crank rotates clockwise with an angular velocity of 10 rad/s. Find

i) Velocity of the slider A ii) Angular velocity of the connecting rod AB. **(14 Marks)**

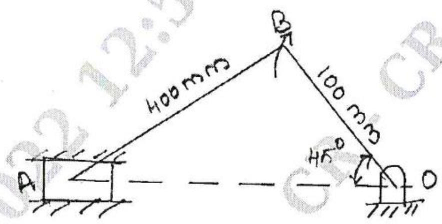


Fig. Q4(b)

Module-3

5 a. Derive analytical expressions for the determination of velocity and acceleration of Piston of a reciprocating engine. **(12 Marks)**

b. If the crank and connecting rod are 150mm and 600mm long respectively and the crank rotates at a constant speed of 100 rpm, determine the velocity and acceleration of Piston. The angle which the crank makes with the Inner dead centre is 30°. **(08 Marks)**

OR

6 a. Derive Freudensteins equation for slider bar Mechanism. **(10 Marks)**

b. Design a four bar mechanism to co-ordinate three positions of the Input and Output links as follows :

$\theta_1 = 20°$	$\phi_1 = 35°$
$\theta_2 = 35°$	$\phi_2 = 45°$
$\theta_3 = 50°$	$\phi_3 = 60°$

Using Freudenstein's equation for four bar mechanism. **(10 Marks)**

Module-4

7 a. State the different types of Cam's and follower and explain. **(04 Marks)**

b. A cam, with a minimum radius of 25mm rotating clockwise at a uniform speed is to be designed to give a roller follower, at the end of a valve rod, motion described below.

i) To raise the valve through 50mm during 120° rotation of the cam.

ii) To keep the valve fully raised through next 30°.

iii) To lower the valve during next 60° and

iv) To keep the valve closed during rest of the revolution is 150°.

The diameter of the roller is 20mm and the diameter of the cam shaft is 25mm. Draw the profile of a cam when the line of stroke is offset 15mm from the axis of the cam shaft. The displacement of the valve, while being raised and lowered, is to take place with SHM. **(16 Marks)**

OR

8 a. Define the following terms related to cam :

i) Base circle.

ii) Pressure angle.

iii) Cam profile.

iv) Lift. **(04 Marks)**

b. Design a cam for operating the exhaust valve of an oil engine. It is required to give equal uniform acceleration and retardation during opening and closing of the valve each of which corresponds to 60° of cam rotation. The valve must remain in the fully open position for 20° of cam rotation.

The lift of the valve is 37.5mm and the least radius of the cam is 40mm. The follower is provided with a roller of radius 20mm and its line of stroke passes through the axis of the cam. **(16 Marks)**

Module-5

9 a. Derive the expression for length of path of contact and arc of contact for a pair of involute gear's in contact. **(08 Marks)**

b. Two gear wheel mesh externally and are to give a velocity ratio of 3. The teeth are of involute form of module 6mm and standard addendum of one module. Pressure angle = 18° , Pinion rotates at 90 rpm.

Find i) Number of teeth on each wheel so that interference is just avoided.

ii) Length of path of contact iii) Length of arc of contact

iv) Maximum velocity of sliding between teeth v) Number of pairs of teeth in contact. **(12 Marks)**

OR

10 a. Explain with neat sketch : i) Simple gear Train ii) Compound gear Train iii) Epicyclic gear Train. **(06 Marks)**

b. An epicyclic gear train consists of sun wheel (S), a stationary internal gear (E) and three identical planet wheels (P) carried on a star shaped planet carrier (C). The size of different toothed wheels are such that the planet carrier 'C' rotates at 1/5 of the speed of the sun wheel. The minimum number of teeth on any wheel is 6. The driving torque on the sun wheel is 100 N/m. Determine :

i) Number of teeth on different wheels of train.

ii) Torque necessary to keep the internal gear stationary. **(14 Marks)**

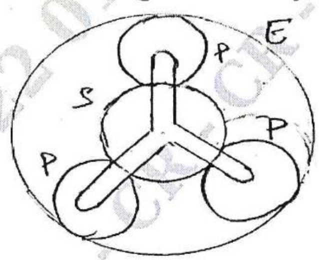


Fig. Q10(b)

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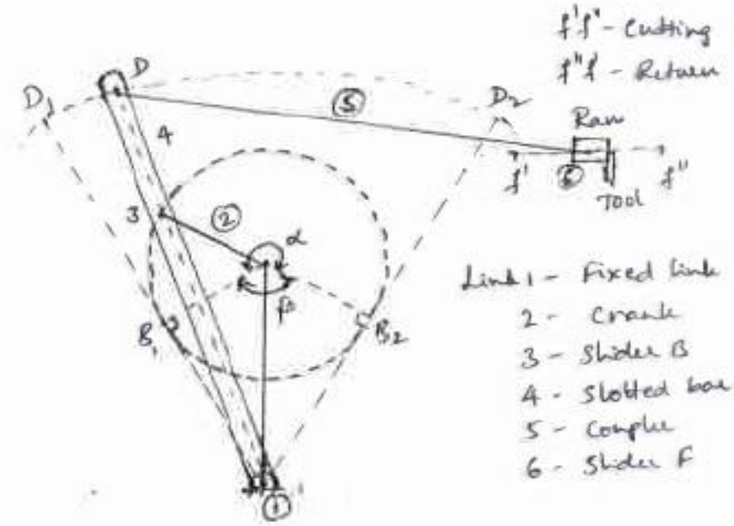
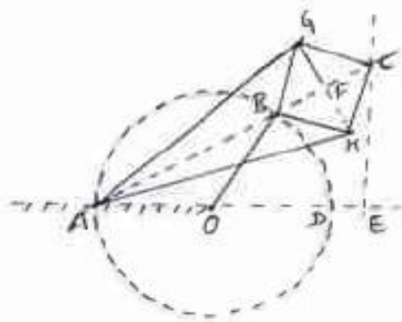
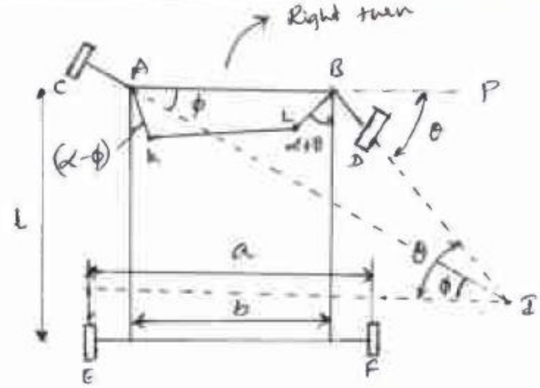
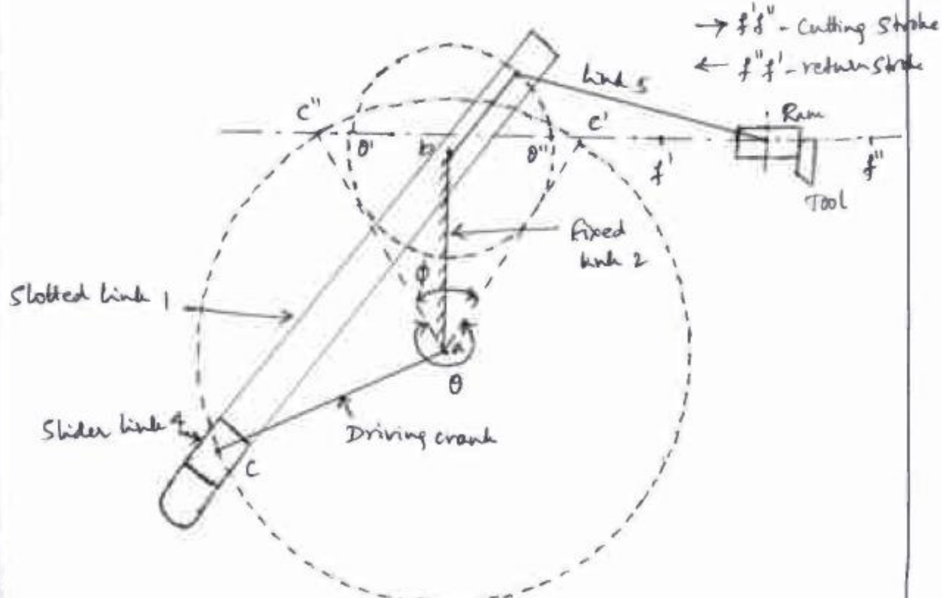
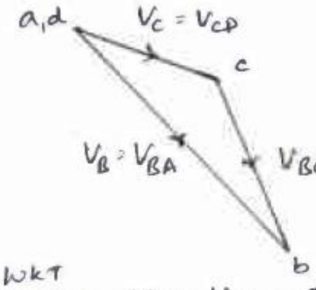
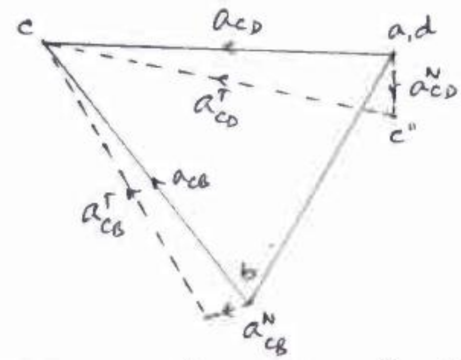
Signature of Scrutinizer

Scheme & Solutions

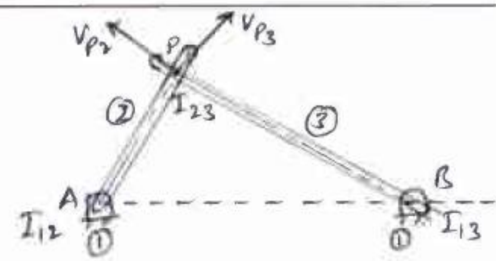
Subject Title : KINEMATICS OF MACHINES

Question Number	Solution	Marks Allocated
1.a	Definitions 1 marks each	
1.b	 Sketch - 4 marks Explanation / $\alpha > \beta$ - 2 marks	
1.c	 Sketch - 04 marks Derivation → $AG^2 - GC^2 = (AC)(AB)$ - 04 marks	08

Question Number	Solution	Marks Allocated
2. a	 Sketch - 05 marks Explanation indicating all the conditions for correct steering	05 05 } 10 marks
2. b	 Sketch - 06 marks Explanation stating cutting stroke greater than return stroke i.e. $\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\text{Angle } \theta}{\text{Angle } \phi} = \frac{\theta}{(360-\theta)}$	06 04 } 10 marks

Question Number	Solution	Marks Allocated
3.	$N_{AB} = 200$ Rpm. $\omega_{AB} = 20.943$ rad/sec. CW	01
	Velocity diagram 	05
	~~From diagram~~ WKT $V_B = V_{BA} = 0.8377$ m/sec ($V_B = BA \times \omega_{AB}$)	
	From diagram $V_C = V_{CD} = 0.51$ m/sec. $V_{BC} = 0.45$ m/sec.	02
	$\omega_{CD} = 6.375$ rad/sec (CW) $\omega_{BC} = 3$ rad/sec (CCW)	02
	Acceleration diagram 	05
	$a^N_{AB} = 17.514$, $a^N_{BC} = 1.35$ $a^N_{CD} = 3.25$ m/sec^2	01
	From acc^n diagram. $a^T_{CD} = 16.8$ m/sec^2 $a^T_{CB} = 15.4$ m/sec^2	02
	$\alpha_{CD} = 210$ rad/sec^2 (CCW about D) $\alpha_{CB} = 102.67$ rad/sec^2 (CCW about B)	02
		20

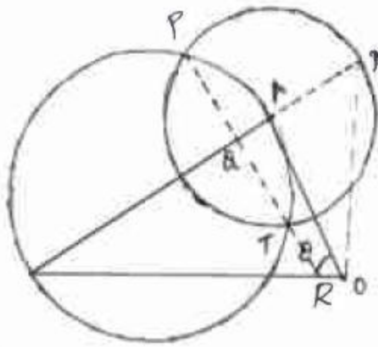
<table>
<tr><th>Question Number</th><th>Solution</th><th>Marks Allocated</th></tr>
<tr><td>4.a.</td><td>

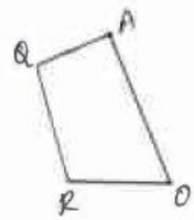


Sketch -

Def^n & Proof: I_{12}, I_{23} & I_{13} must lie on the same line

</td><td>04 marks
04 marks
08 marks</td></tr>
<tr><td>4.b</td><td>





Velocity

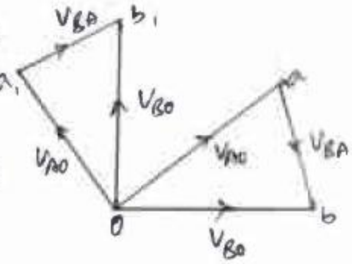
$$\frac{a_1b_1}{AM} = \frac{ob_1}{OM} = \frac{oa_1}{OA} = \omega$$

$a_1b_1 = \omega \cdot AM \quad ob_1 = OM \cdot \omega$

$V_{BA} = \omega \cdot AM \quad V_{BO} = \omega \cdot OM$

$oa_1 = OA \cdot \omega$

$\boxed{V_{AO} = \omega \cdot OA}$



Velocity diagram rotated by 90°

Acceleration:

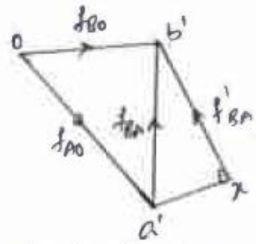
$$\frac{oa'}{OA} = \frac{a'x}{AQ} = \frac{xb'}{QR} = \frac{ob'}{OR} = \omega^2$$

$oa' = f_{AO} = \omega^2 OA$

$a'x = f^r_{BA} = \omega^2 . AQ$

$xb' = f^t_{BA} = \omega^2 . QR$

$ob' = f_{BO} = \omega^2 . OR$



Acceleration diagram

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04 marks
04 marks
12 marks</td></tr>
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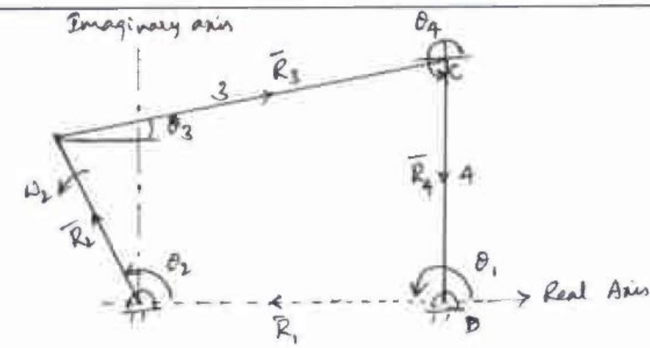
Question Number	Solution	Marks Allocated
5.		



— 02

Loop closure eqn in complex number form is given by

$$\bar{BA} + \bar{CB} + \bar{DC} + \bar{AD} = 0$$

where $\bar{BA} = \bar{R}_2 = r_2 \cdot e^{i\theta_2}$, $\bar{CB} = r_3 \cdot e^{i\theta_3}$, $\bar{DC} = r_4 \cdot e^{i\theta_4}$, $\bar{AD} = r_1 e^{i\theta_1}$

i.e. $r_2 e^{i\theta_2} + r_3 e^{i\theta_3} + r_4 e^{i\theta_4} + r_1 e^{i\theta_1} = 0$ — 08

i.e. $(r_2 \cos\theta_2 + r_3 \cos\theta_3 + r_4 \cos\theta_4 + r_1 \cos\theta_1) + i(r_2 \sin\theta_2 + r_3 \sin\theta_3 + r_4 \sin\theta_4 + r_1 \sin\theta_1) = 0$

Substituting $r_3 \cos\theta_3 = 0.3$ & $r_3 \sin\theta_3 = 0.213$.

$\theta_3 = 35.374°$ & $r_3 = 0.368$ m.

Angular velocity of link 3

$$\frac{d}{dt}\left(r_2 e^{i\theta_2} + r_3 \cdot e^{i\theta_3} + r_4 e^{i\theta_4} + r_1 e^{i\theta_1}\right) = 0$$

$\Rightarrow r_2 \omega_2 i(\cos\theta_2 + i\sin\theta_2) + r_3 \omega_3 i(\cos\theta_3 + i\sin\theta_3) + r_4 \cdot \omega_4 \cdot i(\cos\theta_4 + i\sin\theta_4) = 0$ — 04

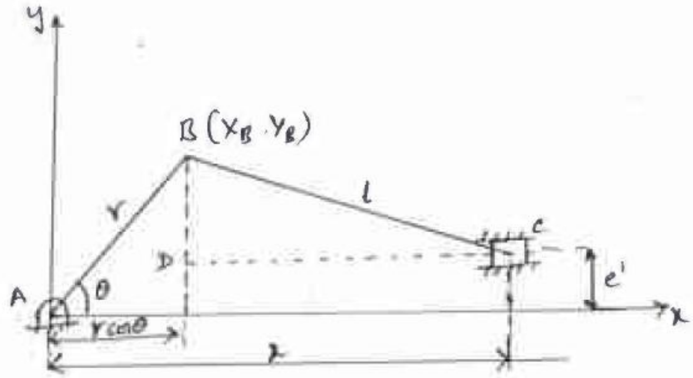
$\Rightarrow (-r_2 \omega_2 \sin\theta_2 - r_3 \omega_3 \sin\theta_3 - r_4 \omega_4 \sin\theta_4) + i(r_2 \omega_2 \cos\theta_2 + r_3 \omega_3 \cos\theta_3 + r_4 \omega_4 \cos\theta_4) = 0$ — ①

$\Rightarrow \omega_3 = 7.5$ rad/sec (ccw) — 01

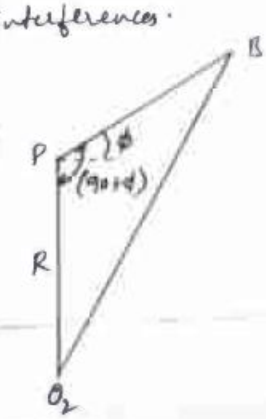
Angular velocity of link 4

Sub. values in eqn ① $\omega_4 = 18.313$ rad/sec (ccw) — 05 (4 for eqn, 1 for Ans)

20 marks

Question Number	Solution	Marks Allocated
6.a.	Frendenstein equation	
		— Skech-03
	Slider movement is Proportional to movement of crank	
	i.e $\Delta x \propto \Delta\theta$	
	$\Delta x = C \cdot \Delta\theta$	
	$C = \dfrac{x_F - x_S}{\theta_F - \theta_S}$	
	From fig. $x_B = r\cos\theta$, $Y_B = r\sin\theta$ $x_c = x$ & $Y_c = e'$	05
	From Δ^{le} BCD. $BC^2 = CD^2 + BD^2$	
	$l^2 = (x - \cos\theta . r)^2 + (r\sin\theta - e')^2$	
	i.e $x^2 = (l^2 - r^2 - e'^2) + 2xr\cos\theta + 2re'\sin\theta$	
	(or) $x^2 = k_1 x\cos\theta + k_2\sin\theta + k_3$	— 01
	where $k_1 = 2r$, $k_2 = 2re'$ & $k_3 = l^2 - r^2 - e'^2$	08 marks
6.b	To Calculate x_1, x_2 & x_3.	
	$x_j = \dfrac{x_F + x_S}{2} - \dfrac{x_F - x_S}{2}\cos\left[\dfrac{\pi(2j-1)}{2n}\right]$	
	$x_1 = 1.2009$. $x_2 = 2.5$ $x_3 = 3.799$	— 02
	To calculate Y_1 Y_2 Y_3	
	$Y = x^{1.5}$	
	$Y_1 = 1.316$ $Y_2 = 3.9528$ $Y_3 = 7.404$	— 02
	$\Delta Y = Y_F - Y_S = 7$	

Question Number	Solution	Marks Allocated
	Calculate angle relationship	
	$\theta_j = \theta_s + \frac{\Delta\theta}{\Delta x}(x_j - x_s)$	
	$\theta_1 = 36.027^\circ$, $\theta_2 = 75^\circ$ $\theta_3 = 113.97^\circ$	02
	$\phi_j = \phi_j + \frac{\Delta\phi}{\Delta y}(y_j - y_s)$	
	$\phi_1 = 63.16^\circ$ $\phi_2 = 89.528$ $\phi_3 = 124.046$	02
	Calculate k_1 k_2 k_3	
	$k_1 \cos\phi - k_2 \cos\theta + k_3 = \cos(\theta - \phi)$	
	$k_1 = 2.4326$. $k_2 = 2.1027$ $k_3 = 1.4922$	02
	To calculate length of links:	
	$l_1 = 30mm$ $l_2 = 12.332$ mm $l_3 = 27.028$. $l_4 = 14.267$ mm	02
		12 marks
7.a.	Terminologies showing in the sketch. 02 marks each	2x4 = 08
7.b	Minimum number of teeth to avoid interferences.	
	From Δ^{le} O_2PB.	Sketch-02
	$(O_2B)^2 = (O_2P)^2 + (PB)^2 - 2O_2P \times PB \times \cos(90+\phi)$	
	i.e. $(O_2B)^2 = R^2\left[1 + \frac{r}{R}\sin^2\phi\left(\frac{r}{R}+2\right)\right]$	
	$\therefore O_2B = \frac{m \cdot Z_G}{2}\sqrt{1 + \frac{Z_P}{Z_G}\cdot\sin^2\phi\left(\frac{Z_P}{Z_G}+2\right)}$	04
	But $O_2B = O_2P + a_w$	
	$O_2P + A_w \cdot m = \frac{m \cdot Z_G}{2}\sqrt{1 + \frac{Z_P}{Z_G}\sin^2\phi\left(\frac{Z_P}{Z_G}+2\right)}$	
	on solving $Z_G = \frac{2 \cdot A_w}{\sqrt{1 + \sin^2\phi \cdot \frac{1}{G}\left(\frac{1}{G}+2\right) - 1}}$	04
	$\therefore$ Min no of teeth on Pinion to avoid interference $Z_P = \frac{2 \cdot A_P}{\sqrt{1 + \sin^2\phi \cdot G(G+2) - 1}}$	02
		12 marks



Question Number	Solution	Marks Allocated
8.a.	Explanation with Simple Sketch - 2 marks each	2x4 = 8
8.b.		

Step	Motion	Arm C	Gear A	Gear B
1	Fix arm, give +1 revolution to A	0	+1	$-\frac{Z_A}{Z_B}$
2	Multiply by x	0	x	$-\frac{Z_A}{Z_B} \cdot x$
3	Add y	y	x+y	$y - \frac{Z_A}{Z_B} \cdot x$

— 06

Given $N_A = 0$, $N_C = -100 = y$

$N_A = x + y = 0$ ∴ $x = 100$ Rpm.

$N_B = y - \frac{Z_A}{Z_B} \cdot x = -180$ Rpm (ccw) — 03

Speed of Gear B if A is not fixed

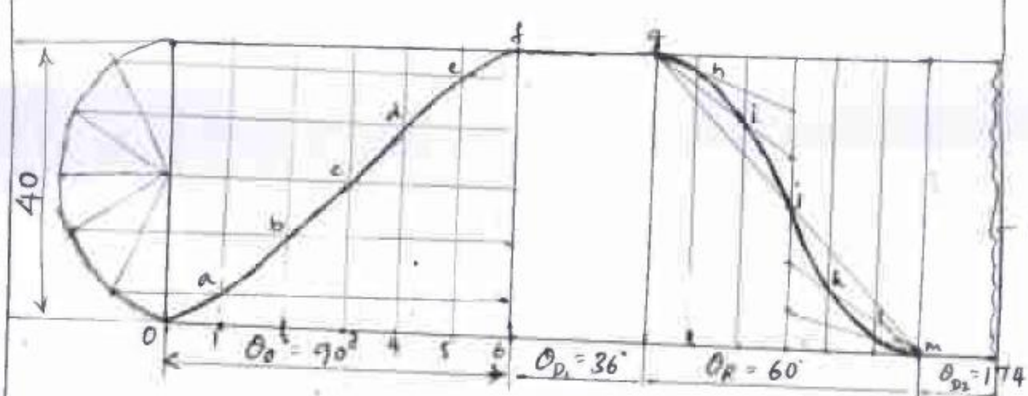
$N_A = 200$ Rpm. $N_C = -100$ Rpm $= y$

$N_A = x + y = 200$; $x = 300$ — 03

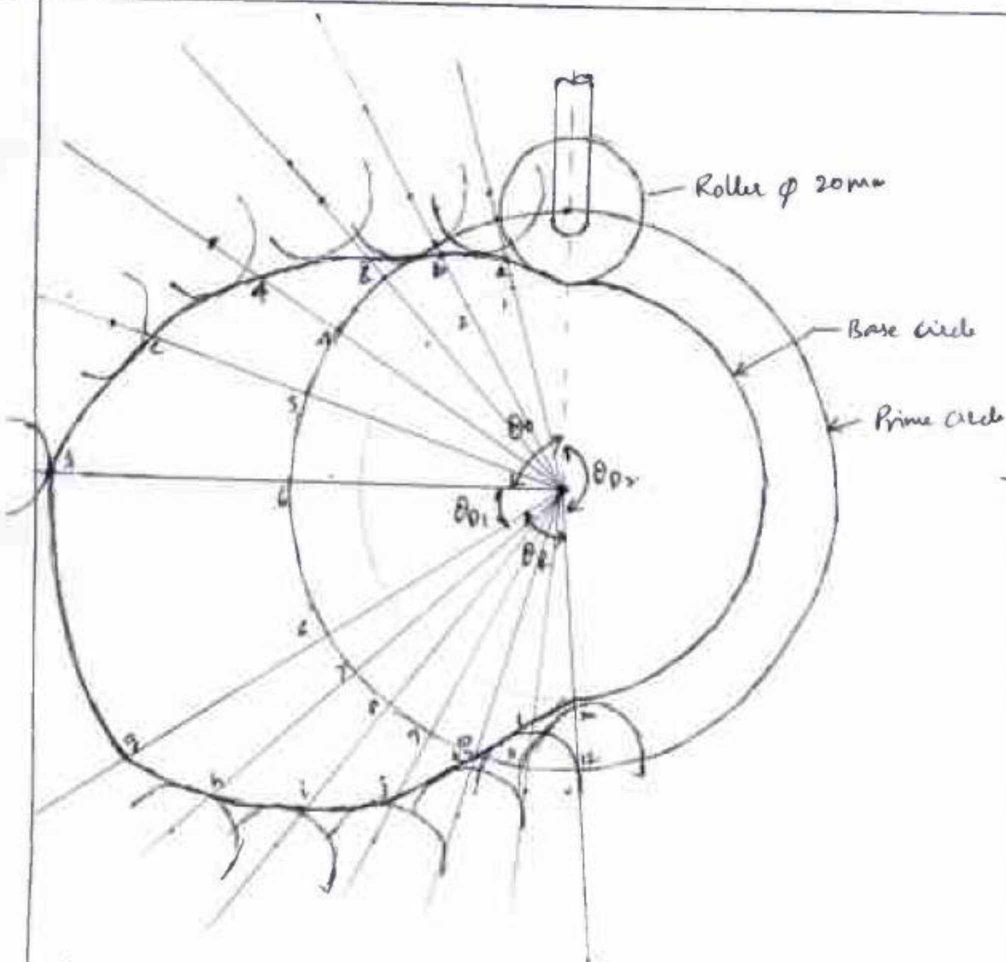
$N_B = y - \frac{Z_A}{Z_B} \cdot x = -340$ Rpm (ccw)

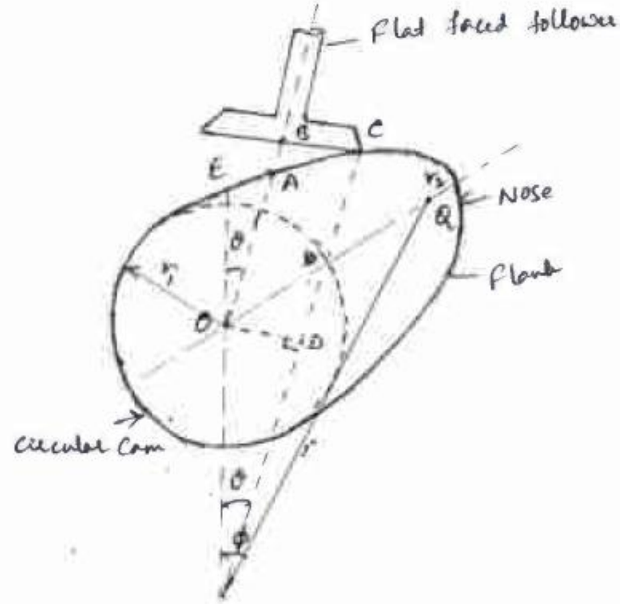
12 marks

9. Displacement diagram



— 06 marks

Question Number	Solution	Marks Allocated
		10
	During outstroke Max. velocity : $V_{omax} = \frac{\pi S}{2\theta_o} \cdot \omega = 1.5079$ m/sec Max. Acceleration $a_{omax} = \pm \frac{\pi^2 S}{2\theta_o^2} \cdot \omega^2 = \pm 113.69$ m/sec^2	02
	During return $V_{Rmax} = -2.879$ m/sec $\quad a_{Rmax} = \mp 207.35$ m/sec^2	02
		20
10.a.	Definitions of each showing in the sketch - 2 marks each	08 marks

Question Number	Solution	Marks Allocated
10.b		06 marks
	From fig. $x = OB - OA = CD - OA = CD - OE$	
	$x = OP - OP\cos\theta$	
	$x = OP(1-\cos\theta)$	02
	Velocity $v = \frac{dx}{dt} = \frac{dx}{d\theta}\cdot\left(\frac{d\theta}{dt}\right) = OP\,\sin\theta\cdot\omega$	
	$V = OP.\,\omega.\,\sin\theta$	02
	Acceleration $a = \frac{dv}{dt} = \frac{dv}{d\theta}\cdot\frac{d\theta}{dt} = OP.\,\omega^2\cos\theta$	
	$f_{max} = OP.\,\omega^2 = (R - r_1)\cdot\omega^2$	02
	when $\cos\theta = 1$ i.e. $\theta = 0$	
		12 marks