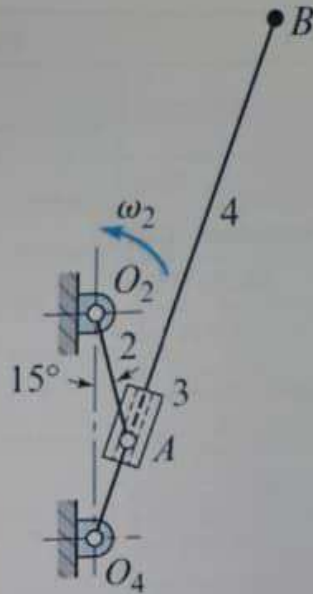


Problem 1: (12 points)

For the inverted slider-crank linkage shown in the Figure, crank 2 has a constant angular velocity of 60 rev/min CCW, where $R_{O_2O_4} = 300$, $AO_2 = 175$ mm, $BO_4 = 700$ mm. By the graphical method

- (2-points) Find the Mobility of the mechanism shown.
- (2-points) Find the position of link 4, and the slider link 3
- (4-points) From the velocity diagram find the velocity of B and the angular velocity of link 4
- (4-points) From the acceleration diagram find the acceleration of point B, and the angular acceleration of link 4.



Problem 2: (18 points)

for the linkage in Figure in the position shown. Assume that $\theta_4 = 60.472^\circ$, $\theta_2 = -20^\circ$ in the x-y coordinate system, $\omega_2 = 1$ rad/sec CCW increasing at the rate of 10 rad/sec^2 . The position of the coupler point P on link 3 with respect to point A is: $p = 15.00$, $\delta_3 = 0^\circ$. Using an analytical method:

- (6-points) In terms of all parameters (a, b, c, d, θ_1 , θ_2 , θ_3 , and θ_4) derive the position, velocity and acceleration equations for the loop of the four-bar mechanism.
- (4-points) Analytically find the angular velocity of links 3 and 4,
- (4-points) Analytically find the angular accelerations of links 3 and 4,
- (4-points) Find the acceleration of point P in the x-y coordinate system.

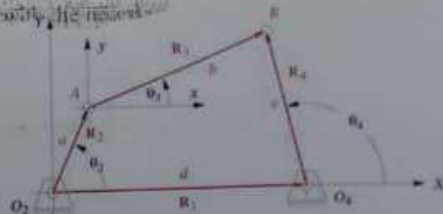
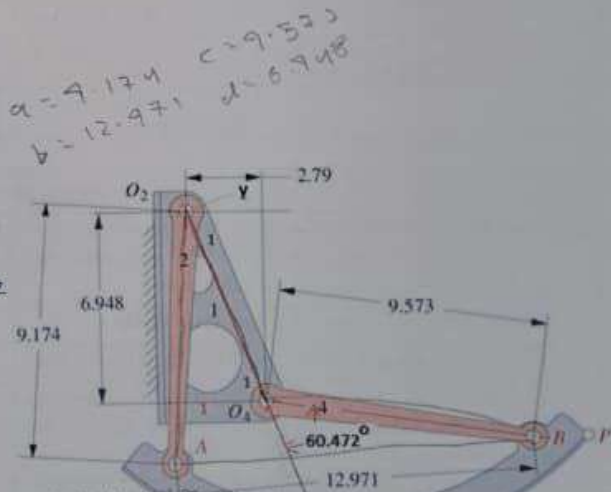


TABLE 9-1 AGMA Full-Depth Gear Tooth Specifications

Parameter	Coarse Pitch ($p_d < 20$)	Fine Pitch ($p_d \geq 20$)
Pressure angle ϕ	20° or 25°	20°
Addendum a	$1.000 / p_d$	$1.000 / p_d$
Dedendum b	$1.250 / p_d$	$1.250 / p_d$
Working depth	$2.000 / p_d$	$2.000 / p_d$
Whole depth	$2.250 / p_d$	$2.200 / p_d + 0.002$ in
Circular tooth thickness	$1.571 / p_d$	$1.571 / p_d$
Fillet radius—basic rack	$0.300 / p_d$	Not standardized
Minimum basic clearance	$0.250 / p_d$	$0.200 / p_d + 0.002$ in
Minimum width of top land	$0.250 / p_d$	Not standardized
Clearance (shaved or ground teeth)	$0.350 / p_d$	$0.350 / p_d + 0.002$ in

$$Z = \sqrt{(r_p + a_p)^2 - (r_p \cos \phi)^2} + \sqrt{(r_g + a_g)^2 - (r_g \cos \phi)^2} - c \sin \phi$$

$c = r_1 + r_2$

Backlash

$$P_B = 43200 (\Delta C) \frac{\tan \phi}{\pi d}, \quad P_c = \frac{\pi d}{N}, \quad P_b = P_c \cos \phi$$

$$P_d = N/d, \quad P_d = \frac{\pi}{P_c}, \quad M = d/N, \quad \frac{P_c}{M} = \pi$$

$$M = 25.4 / P_d$$

$$M_V = \frac{W_{out}}{W_{in}} = \frac{d_{out}}{d_{in}} = \frac{N_{in}}{N_{out}}$$

$$M_p = \frac{Z}{P_b}$$

↓
contact ratio

$$M_T = \frac{W_{in}}{W_{out}} = \frac{d_{out}}{d_{in}} = \frac{N_{out}}{N_{in}}$$

Simple Gear Train

$$M_V = -\frac{N_2}{N_3} \cdot -\frac{N_3}{N_4} \cdot -\frac{N_4}{N_5} \cdot -\frac{N_5}{N_6} = \frac{N_2}{N_6}$$

Compound

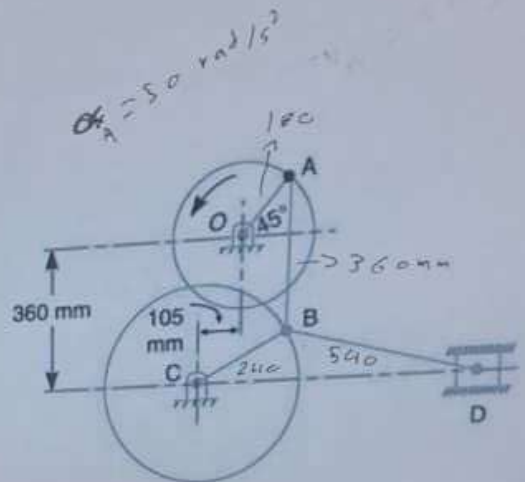
$$M_V = -\frac{N_2}{N_3} \cdot -\frac{N_4}{N_5} \quad M_V = \frac{W_5}{W_2}$$

$$\frac{W_2 - W_{arm}}{W_T - W_{arm}} = \pm \frac{M_F}{N_L} R$$

$$\pi = 9550 \frac{P}{N}$$

Q1. In the toggle mechanism shown, the slider D is constrained to move on a horizontal path. The crank OA is rotating in the counter-clockwise direction at a speed of 180 rpm, increasing at the rate of 50 rad/s². The dimensions of the various links are as follows: OA = 180 mm; CB = 240 mm; AB = 360 mm; and BD = 540 mm. For the given configuration,

- Draw the mechanism and find the positions of AB, BD, and BC. (1-point)
- Draw the velocity diagram to find the velocity of BA, BC, DB and the slider D. (2-points)
- Draw the acceleration diagram to find the acceleration of A, the slider D, and the angular acceleration of BD. (7-points)



$$\omega_A = 180 \frac{(2\pi)}{60} = 18.85 \frac{\text{rad}}{\text{s}} \rightarrow v_A = \omega_A r_A = 3.393 \text{ m/s}$$

$$\alpha_A = 50 \text{ rad/s}^2 \rightarrow a_t = \alpha_A r_A = (50)(180 \times 10^{-3}) = 9 \text{ m/s}^2$$

$$a_n = \omega^2 r \quad \alpha_c = \omega^2 r$$

$$a_n^A = 1 \text{ m/s}^2 \quad // \quad a_n^A = 18.85^2 \cdot 0.18 = 63.95805 \text{ m/s}^2$$

$$a_{bc}^C = \omega_{bc}^2 r_{bc} = 12.2525^2 (0.24) = 36.0297 \text{ m/s}^2$$

$$v_{bd}^D = \omega_{bd}^2 r_{bd} = 4.184^2 (0.54) = 12.65 \text{ m/s}^2$$

$$a_{ab}^B = \omega_{ab}^2 r_{ab} = 2.1992^2 (0.36) = 1.7411 \text{ m/s}^2$$

$$b) \quad v_{BA} = 0.7917 \text{ m/s} \quad // \quad v_{BC} = 2.9406 \text{ m/s} \quad // \quad v_{DB} = 2.6013 \text{ m/s}$$

$$v_D = 2.1489 \text{ m/s}$$

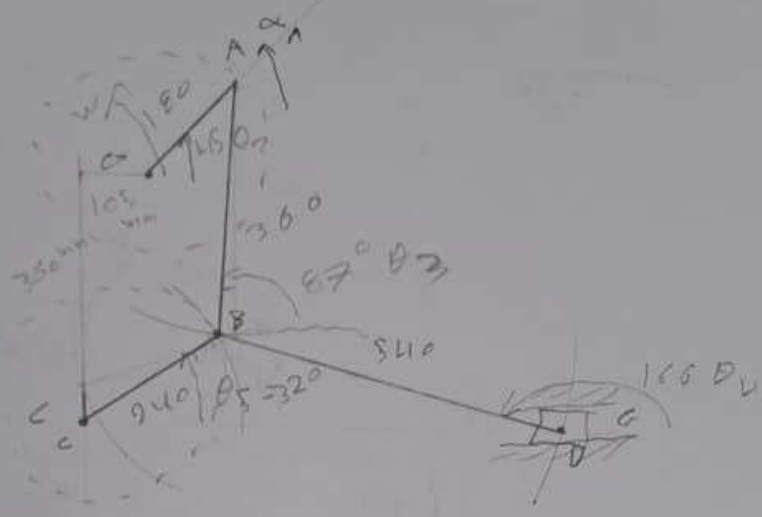
$$c) \quad a_A = 63.96 \text{ m/s}^2$$

$$\alpha_{BD} = 11.841 \text{ rad/s}^2$$

$$a_D = 38.376 \text{ m/s}^2$$

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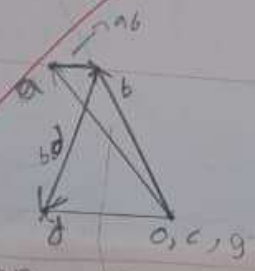
positions diagram. Scale 100mm = 1cm



Velocity diagram

Scale 3.393 m/s : 30 mm → 0.1131 m/s : 1 mm

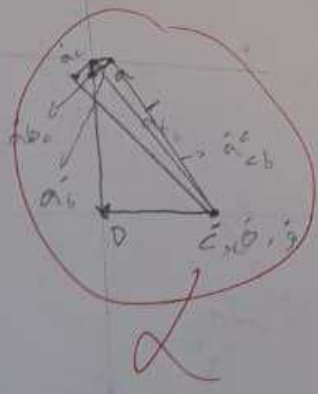
$w = \frac{v}{r}$
 $w_{bd} = \frac{2.613}{0.23} = 11.36 \text{ rad/s}$
 $w_{cb} = 12.2525 \text{ rad/s}$



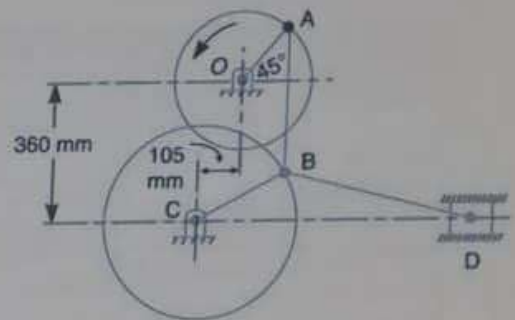
$ob = 26 \text{ mm} \rightarrow v_b = 2.9406 \text{ m/s}$
 $bd = 23 \text{ mm} \rightarrow v_{bd} = 2.6013 \text{ m/s}$
 $cd = 19 \text{ mm} \rightarrow v_d = 2.1499 \text{ m/s}$
 $ab = 7 \text{ mm} \rightarrow v_{ab} = 0.7917 \text{ m/s}$
 $w_{ab} = 2.1492 \text{ rad/s}$

acceleration diagram

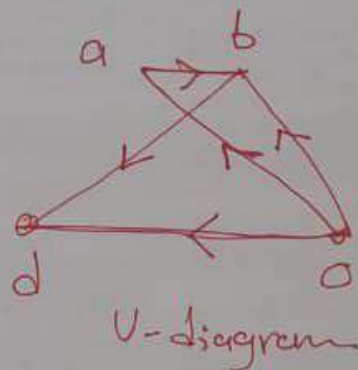
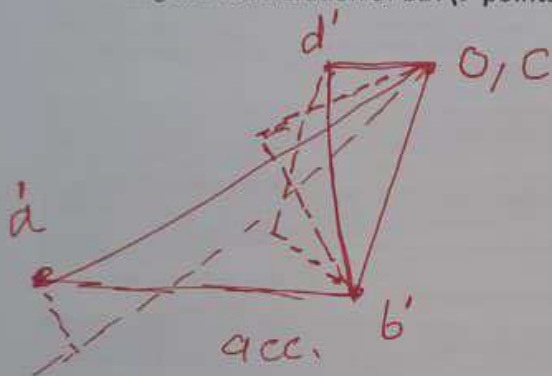
Scale: 63.96 m/s² : 30 mm → 2.132 m/s² : 1 mm
 $1 \text{ m/s}^2 = 0.4169$



Q1. In the toggle mechanism shown, the slider D is constrained to move on a horizontal path. The crank OA is rotating in the counter-clockwise direction at a speed of 180 rpm, increasing at the rate of 50 rad/s^2 . The dimensions of the various links are as follows: $OA = 180 \text{ mm}$; $CB = 240 \text{ mm}$; $AB = 360 \text{ mm}$; and $BD = 540 \text{ mm}$. For the given configuration,



- Draw the mechanism and find the positions of AB, BD, and BC. (1-point)
- Draw the velocity diagram to find the velocity of BA, BC, DB and the slider D. (2-points)
- Draw the acceleration diagram to find the acceleration of A, the slider D, and the angular acceleration of BD. (7-points)



$$a_{AO}^r = \frac{v_A^2}{OA} = 63.9 \text{ m/s}^2$$

$$a_{BA}^r = \frac{0.9^2}{0.36} = 2.25 \text{ m/s}^2$$

$$a_{BC}^r = 32.5 \text{ m/s}^2$$

$$a_{DB}^r = \frac{(2.4)^2}{0.54} = 10.8 \text{ m/s}^2$$

$$a_D = 13.3 \text{ m/s}^2$$

$$a_{DB}^t = 38.5 \text{ m/s}^2$$

$$\alpha_{DB} = \frac{38.5}{0.54} = 71.3 \text{ rad/s}^2 \text{ CW}$$

$$v_A = 3.4 \text{ m/s}$$

$$v_{BA} = 0.9 \text{ m/s}$$

$$v_{BC} = 2.8 \text{ m/s}$$

$$v_{DB} = 2.4 \text{ m/s}$$

$$v_D = 2.05 \text{ m/s}$$