ME 213
MACHINE
DYNAMICS

MACSITHIGH

ME 213— MACHINE DYNAMICS

Assignments– FALL 2010

TEXT: *Design of machinery*, by R.L. Norton, Fourth Edition, McGraw Hill, 2008.

COURSE OUTLINE

CORE TOPICS

CHAPTER 1. Introduction.

CHAPTER 2. Kinematics Fundamentals. 2.0–2.7, 2.11, 2.14–2.17.

4–BAR LINKAGES. 2.12, 3.0–3.4, 3.6, 4.10–4.11, supplementary materials.

TEST 1

CHAPTER 4. Position Analysis. 4.0–4.2, 4.5–4.6, 4.8–4.8, 4.13.

CHAPTER 6. Velocity Analysis. 6.0–6.1, 6.3–6.4, 6.6–6.7, 6.9.

TEST 2

CHAPTER 7. Acceleration Analysis. 7.0–7.5.

CHAPTER 10. Dynamics Fundamentals. 10.0–10.8, 10.15.

CHAPTER 11. Force Analysis. 11.0–11.5, 11.11.

APPLICATIONS

CHAPTER 12. Balancing.

TEST 3

CHAPTER 8. Cams.

CHAPTER 9. Gears.

Final Exam 10 problems, 2 hours
all tests covered, 1 cam prob, 1 gears prob.

BARKER CLASSIFICATION

Table 2. Complete classification of four-bar planar mechanisms

Number	$s + l \; \begin{matrix} < \\ = \\ > \end{matrix} \; p + q$	Category	Characteristic bar length	Class	Proposed name	Symbol
1	$<$	Grashof	frame, $R_1 = s$	1	Grashof crank-crank-crank	*GCCC*
2	$<$	Grashof	input, $R_2 = s$	2	Grashof crank-rocker-rocker	*GCRR*
3	$<$	Grashof	coupler, $R_3 = s$	3	Grashof rocker-crank-rocker	*GRCR*
4	$<$	Grashof	output, $R_4 = s$	4	Grashof rocker-rocker-crank	*GRRC*
5	$>$	non-Grashof	frame, $R_1 = l$	1	Class 1 rocker-rocker-rocker	*RRR1*
6	$>$	non-Grashof	input, $R_2 = l$	2	Class 2 rocker-rocker-rocker	*RRR2*
7	$>$	non-Grashof	coupler, $R_3 = l$	3	Class 3 rocker-rocker-rocker	*RRR3*
8	$>$	non-Grashof	output, $R_4 = l$	4	Class 4 rocker-rocker-rocker	*RRR4*
9	$=$	change point	frame, $R_1 = s$	1	change point crank-crank-crank	*CPCCC*
10	$=$	change point	input, $R_2 = s$	2	change point crank-rocker-rocker	*CPCRR*
11	$=$	change point	coupler, $R_3 = s$	3	change point rocker-crank-rocker	*CPRCR*
12	$=$	change point	output, $R_4 = s$	4	change point rocker-rocker-crank	*CPRRC*
13	$=$	change point	two equal pairs	5	double change point	*CP2X*
14	$=$	change point	$R_1 = R_2 = R_3 = R_4$	6	triple change point	*CP3X*

213 Final Exam Reference Sheet

- Mobility:
    - Test 1 prob1
    - Labeling joints and mobility, homework 1
- 4-Bar configurations:
    - Grashof/Barker classification pg61
    - Examples, homework #2
- Mechanism synthesis:
    - Definitions, test 1 p3
    - Examples –p 158
- Instant Centers:
    - LOTS on homework 7
    - Review 2 pg2
- Vector loops:
    - Exam 2 problem1
- Acceleration:
    - With vslip: Homework 9,
    - Acceleration difference, homework 8, test 2 p5
    - Find ang. Velocity of a bar: test2 p4
- Mechanical Advantage:
    - Crimper tool: homework 8, review 3 pg 13
    - Complex problem:
- Force Analysis:
    - Kinetic eqn's, **numerically explicit form**: SPRING2010TEST3
    - Draw FBD and write kinetic eqns: Test3 prob2
- Dynamic Balancing:
    - Lollipops example: exam 3 p4
    - Tire balancing : practice exam SPRING2010TEST3
- Design a 4bar to give positions
    - Homework 3 prob2
- Cams:
    - Pitch curve p453
    - Pressure angle p445, review2 p13
    - Undercutting p450
    - Transmission angle review 3 p12,
- Gears:
    - Equation for Z: p476
    - Equation for m_p p484
    - Interference & undercutting p482
    - Teeth anatomy p480
    - Involute profile p478 -center distance does not affect the velocity ratio

Exams

ME 213 FALL 2010 TEST 3

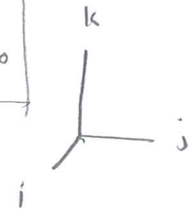
NAME: David Malawey

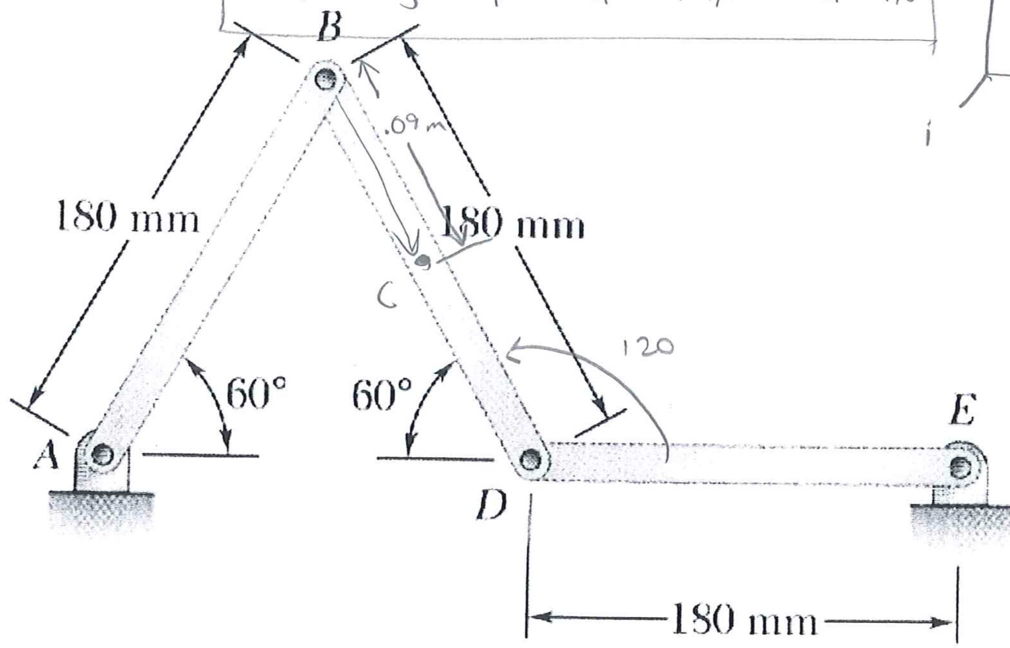
1	23
2	16
3	25
4	21
4	
Total	85

formulas

relative $a_p = a_o + a_{p/o}$

rotating $a_p = \alpha_{op} \times R_{p/o} - \omega_{op}^2 R_{p/o}$





1.(25%) The link-lengths for the four-bar mechanism shown are given above. At the instant shown, the angular velocities, and angular accelerations of the links are given to be $\omega_{AB} = 5\,\text{rad/s}\curvearrowleft$, $\omega_{BD} = 5\,\text{rad/s}\curvearrowleft$, $\omega_{DE} = 5\,\text{rad/s}\curvearrowright$, $\alpha_{AB} = \frac{50}{\sqrt{3}}\,\text{rad/s}^2\curvearrowright$, $\alpha_{BD} = \frac{50}{\sqrt{3}}\,\text{rad/s}^2\curvearrowleft$, $\alpha_{DE} = 0\,\text{rad/s}^2$. Find the horizontal and vertical components of the acceleration $\boxed{\mathbf{a}_C}$ of the mid-point C of the coupler BD.

(1) $\underline{a_C = a_B + a_{C/B}}$

$R_{B/A} = (.18\,m)(\cos 60 i + \sin 60 j)$
$= (.09 i + .1559 j)$

23

$a_B = \alpha_{ab} \times R_{B/A} - \omega_{AB}^2 R_{B/A}$

$= -\frac{50}{\sqrt{3}}\hat{k} \times (.09 i + .1559 j)\,m - \left(5 \frac{rad}{s}\right)^2 (.09, .1559)$

$= -2.598 j + 45.00 i \frac{m}{s^2} - (2.25 i + 7.795 j) \frac{m}{s^2}$

$= (42.75 i - 10.39 j) \frac{m}{s^2}$

$R_{C/B} = (.09\,m)(\cos 120 i + \sin 120 j)$
$= (.045 i - .7795 j)$

$a_{C/B} = \alpha_{BD} \times R_{C/B} - \omega_{BD}^2 R_{C/B}$

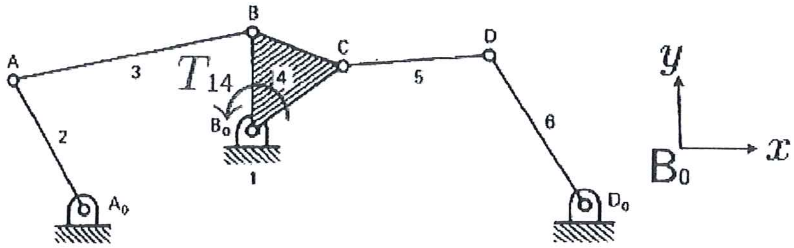
$= +\frac{50}{\sqrt{3}}\hat{k} \times (.045 i - .7795 j) - 5^2 (.045 i - .7795 j)$

$= (+1.299 j + 22.50 i) + (-1.125 i + 19.49 j)$

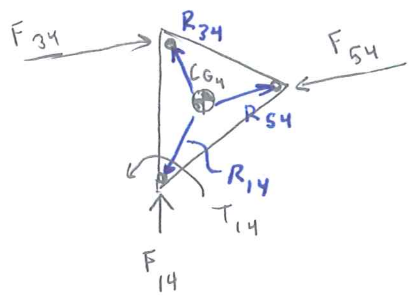
ARITHMETIC

$= (21.38 i + 20.79 j)\, m/s^2$

$a_C = a_B + a_{C/B} = \boxed{(64.13 i + 10.4 j)\, m/s^2}$



2.(25%) The six-bar mechanism shown is driven by a couple T_{14} applied to link 4. Draw free-body diagrams for links 3 and 4, labeled in accordance with the conventions of Norton's textbook. Write out the three kinetic equations for each of these links. Use the coordinate system shown.



$$\Sigma F_x = M_4 a_{CG_4,x}$$

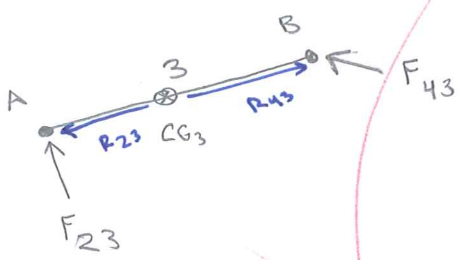
$$F_{ABx} + F_{DCx} + F_{14x} = M_4 a_{CG_4x}$$

$$F_{ABy} + F_{DCy} + F_{14y} = M_4 a_{CG_4y}$$

$$\circlearrowleft + \Sigma T_{G4} = I_{G4} \alpha \cancel{\hat{k}}$$

$$T_{14}\hat{k} + R_{34} \times F_{34} + R_{54} \times F_{54} + R_{14} \times F_{14} = I_{G4} \alpha \cancel{\hat{k}}$$

$F_{34} = -F_{43}$!



$$F_{Ax} + F_{Bx} = M_3 a_{CG_3x}$$

$$F_{Ay} + F_{By} = M_3 a_{CG_3y}$$

$$+\circlearrowleft \Sigma T_{G3} = I_{G3} \alpha \cancel{\hat{k}}$$

$$R_{23} \times F_{23} + R_{43} \times F_{43} = I_{G3} \alpha \cancel{\hat{k}}$$

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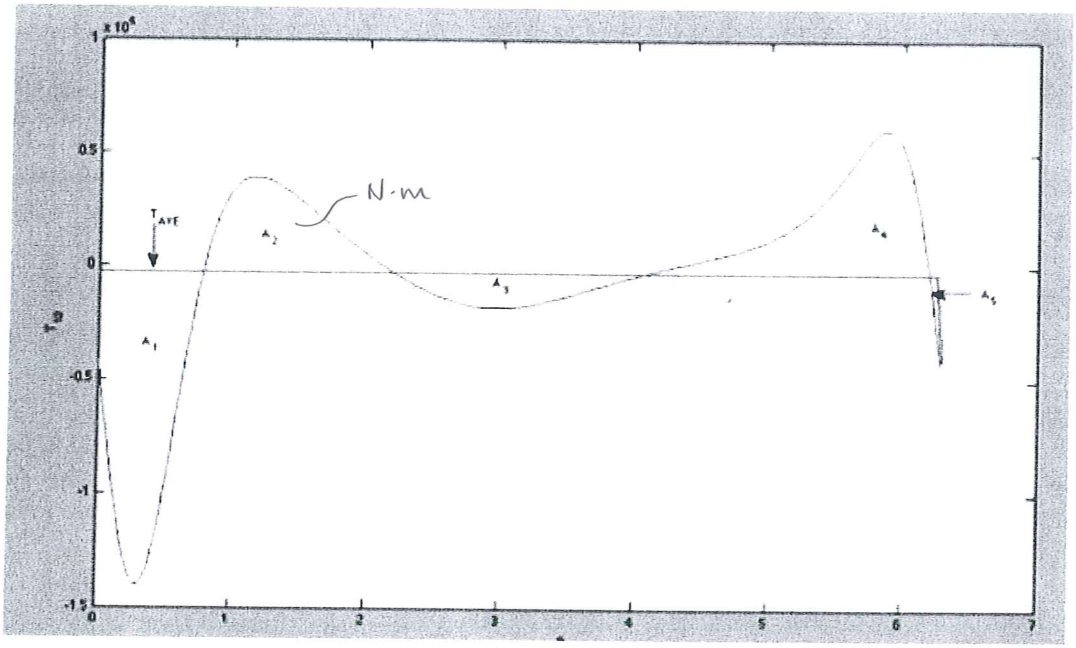
SCALAR EQTS ?

$$R_{23x}F_{23y} - R_{23y}F_{23x} + R_{43x}F_{43y} - R_{43y}F_{43x} = I_{G3}\alpha_3$$

$$T_{14} + R_{34x}F_{34y} - R_{34y}F_{34x} + R_{54x}F_{54y} - R_{54y}F_{54x} = I_{G4}\alpha_4$$



3.(25%) The above plot shows the torque T_{12} required to drive a certain four-bar mechanism at a constant input-link angular velocity $\omega_2 = 50\,\text{rad/s}$. The average torque is $T_{AVE} = -2.694{\times}10^3$ N·m, and the areas of the lobes between the T_{12} plot and the T_{AVE} line are $A_1 = -6.791{\times}10^4$ N·m, $A_2 = 3.458{\times}10^4$ N·m, $A_3 = -1.767{\times}10^4$ N·m, $A_4 = 5.268{\times}10^4$ N·m, $A_5 = -1.686{\times}10^3$ N·m. It is desired to drive this system by means of a motor operating near constant torque T_{AVE} at approximately constant angular velocity $\omega_{avg} = 50\,\text{rad/s}$. Given a value $k = 0.025$ of the coefficient of fluctuation, estimate the moment of inertia of a flywheel that will accomplish this.

Find ΔE_{max}

A (N·m 10^4)	Net A (N·m 10^4)
-6.791	-6.791
3.458	-3.333
-1.767	-5.10
5.268	0.168
-1.686	-1.518

$$\Delta E = -6.791 - (0.168)$$

$$= 6.959 \text{ N·m } (10^4)$$

25

$$I_s = \frac{\Delta E}{k\,\omega_{avg}^2} = \frac{6.959(10^4)\text{ N·m}}{0.025\,(50\text{ rad/s})^2} = \frac{69.59\text{ kN m}}{.025(50^2)\,1/s^2}$$

$$= 1.113 \text{ kN·m s}^2$$

$$\boxed{I_s = 1.113 \text{ kg·m}^2}$$

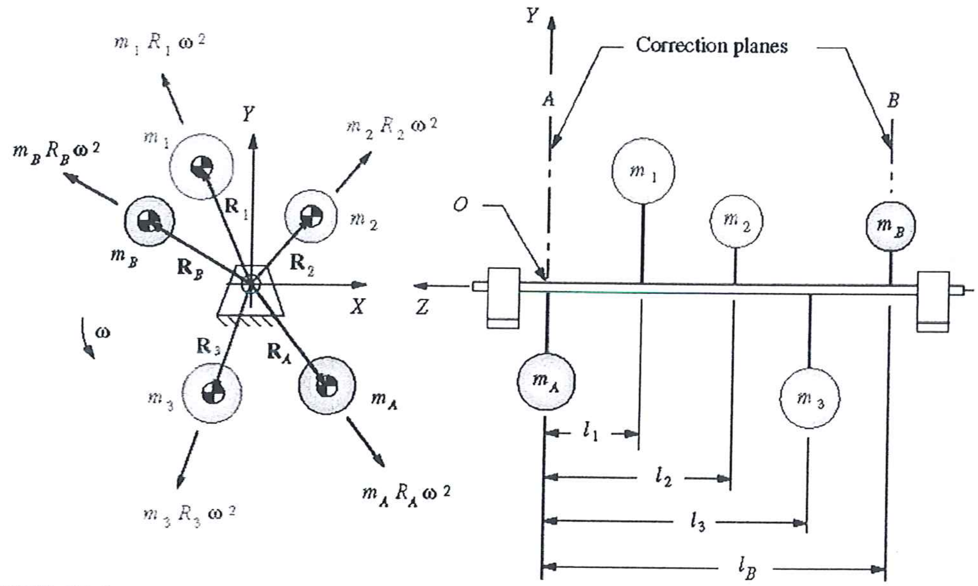


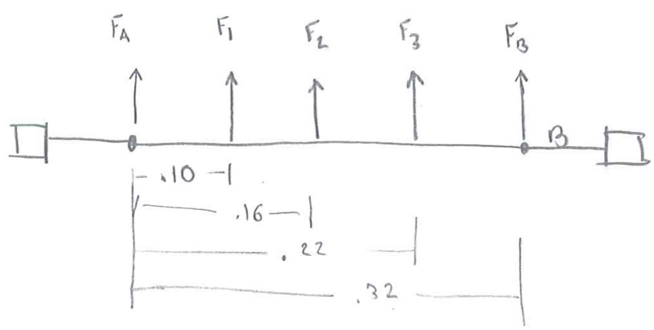
FIGURE 12-3

4.(25%) Three lumped masses are attached to the axle as shown. Balance masses are to be attached in planes A and B at a radial distance from the axle of $\boxed{8\text{ cm}}$ in order to dynamically balance the rotor. Find their magnitudes and angles relative to a reference line θ_A, θ_B for given values

$m_1 = 5\,\text{kg} @ \theta = 90°$, radius=12 cm, $l_1 = 10$ cm;
$m_2 = 5\,\text{kg} @ \theta = 225°$, radius=8 cm, $l_2 = 16$ cm;
$m_3 = 10\,\text{kg} @ \theta = 315°$, radius=16 cm, $l_3 = 22$ cm; $\boxed{l_B = 32\text{ cm.}}$

$\Sigma T_o = 0$

$F = MR\omega^2(\cos\theta\, i + \sin\theta\, j)$



$F_1 = 5(.12)(\omega^2)(\cos 90 i + \sin 90 j)$
$= (0.6\,\omega^2 j)$

$F_2 = 5(.08)\omega^2(\cos 225 i + \sin 225 j)$
$= (-.2828\,\omega^2 i - .2828\,\omega^2 j)$

$F_3 = 10(.16)\omega^2(\cos 315 i + \sin 315 j)$
$= (1.131\,\omega^2 i - 1.131\,\omega^2 j)$

$F_B = m_B R_B \omega^2(\cos\theta_B i + \sin\theta_B j)$

$\Sigma T_o = 0 \qquad \sum_i l_i \hat{k} \times F_i = 0$

$0.1\hat{k} \times (.6w^2 j) + .16\hat{k} \times (-.282w^2 i - .282w^2 j) + .22\hat{k} \times (1.131w^2 i - 1.131w^2 j)$

$+ 0.32\hat{k} \times (m_B R_B w^2 (\cos\theta_B i + \sin\theta_B j)) = 0$

$w^2 \hat{k} \times \left[(.1)(.6)j + .16(-.2828i - .2828j) + .22(1.131i - 1.131j) + .32 m_B R_B (\cos\theta_B i + \sin\theta_B j) \right] = 0$

$i: \cancel{0.06}\ 0 - .0452 + .2488 + .32 m_B \cos\theta_B = 0$

$.32 m_B \cos\theta_B = -.2036$

$R_B m_B \cos\theta_B = -.6363$

$j: .06 - .0452 - .2488 + .32 m_B \sin\theta_B = 0$

$R_B m_B \sin\theta_B = .234$

$m_B \cos\theta_B = -7.954$

$m_B \sin\theta_B = 2.925$

$\frac{\sin\theta_B}{\cos\theta_B} = -.3678$

$\theta_B = \cancel{-20.19}$

$\boxed{\theta_B = 159.8^\circ \quad m_B = 8.475\ kg}$

$\Sigma F_x = 0$

$m_A(.08)\cancel{w^2}\cos\theta_A - .2828\cancel{w^2} + 1.131\cancel{w^2} + 8.475(.08)\cancel{w^2}\cos 159.8 = 0$

$.08\, m_A \cos\theta_A = -.2119$

$m_A \cos\theta_A = -2.649$

$\Sigma F_y = 0$

$m_a(.08)\sin\theta_A + .6 - .2828 - 1.131 + 8.475(.08)\sin 159.8 = 0$

$m_a(.08)\sin\theta_A = .5797$

$m_a \sin\theta_A = 7.246$

$\frac{\sin\theta_A}{\cos\theta_A} = -2.735$

$\theta_A = -69.92^\circ + 180$

$\boxed{\theta_A = 110.08^\circ \quad m_a = 7.715\ kg}$

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#4 Solution

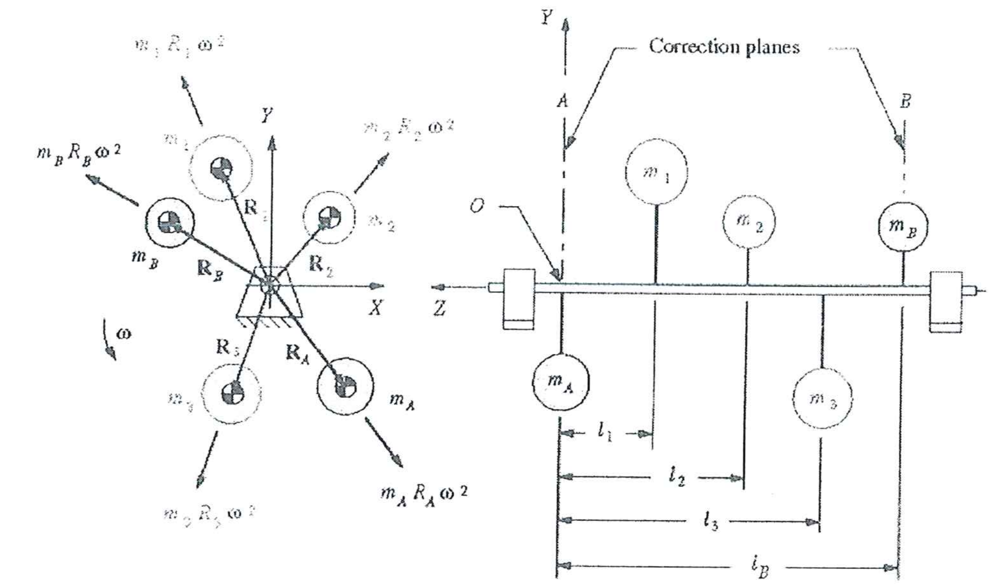

FIGURE 12-3

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$m_2 = 5\,\text{kg} @ \theta = 225°$, radius=8 cm, $l_2 = 16$ cm;
$m_3 = 10\,\text{kg} @ \theta = 315°$, radius=16 cm, $l_3 = 22$ cm; $l_B = 32$ cm.

	A	1	2	3	B
m	m_A	5	5	10	m_B
x	$8\cos\theta_A$	0	$-\frac{8}{\sqrt{2}}$	$\frac{16}{\sqrt{2}}$	$8\cos\theta_B$
y	$8\sin\theta_A$	12	$-\frac{8}{\sqrt{2}}$	$-\frac{16}{\sqrt{2}}$	$8\sin\theta_B$
z_A	0	10	16	22	32
z_B	-32	-22	-16	-10	0

1

$$\sum M_{Z_A x} = 0$$

(4)

$$0 = m_B(32)(8\cos\theta_B) + 10(22)\left(\frac{16}{\sqrt{2}}\right) + 5(16)\left(\frac{-8}{\sqrt{2}}\right) + 5(10)(0) + m_A(0)(8\cos\theta_A)$$

$$256\, m_B \cos\theta_B = \frac{8}{\sqrt{2}}(80 - 440) \quad ; \quad m_B \cos\theta_B = -7.955$$

$$\sum M_{Z_A y} = 0$$

(4)

$$0 = m_B(32)(8)\sin\theta_B + 10(22)\left(\frac{-16}{\sqrt{2}}\right) + 5(16)\left(\frac{-8}{\sqrt{2}}\right) + 5(10)(12) + m_A(0)(8\sin\theta_A)$$

$$256\, m_B \sin\theta_B = \frac{8}{\sqrt{2}}(80 + 440) - 600 \quad ; \quad m_B \sin\theta_B = 9.1467$$

$$m_B = \sqrt{(7.955)^2 + (9.1467)^2} \quad \boxed{m_B = 12.122\text{ kg}}$$ (2)

$$\cos\theta_B = -.6562 \quad ; \quad \sin\theta_B = .7546 \quad ; \quad \boxed{\theta_B = 131.01^\circ}$$ (2)

$$\sum M_{Z_B x} = 0$$

(4)

$$0 = (-32)(8)\, m_A \cos\theta_A + 5(-22)(0) + 5(-16)\left(\frac{-8}{\sqrt{2}}\right) + 10(-10)\left(\frac{16}{\sqrt{2}}\right) + m_B(0)(8)\cos\theta_B$$

$$256\, m_A \cos\theta_A = (80 - 200)\left(\frac{8}{\sqrt{2}}\right) \quad ; \quad m_A \cos\theta_A = -2.6517$$

$$\sum M_{Z_B y} = 0$$

(4)

$$0 = (-32)m_A(8)\sin\theta_A + 5(-22)(12) + 5(-16)\left(\frac{-8}{\sqrt{2}}\right) + 10(-10)\left(\frac{-16}{\sqrt{2}}\right) + m_B(0)(8)\sin\theta_B$$

$$256\, m_A \sin\theta_A = (80 + 200)\frac{8}{\sqrt{2}} - 1320 \quad ; \quad m_A \sin\theta_A = 1.0309$$

$$m_A = \sqrt{(2.6517)^2 + (1.0309)^2} \quad \boxed{m_A = 2.845\text{ kg}}$$ (2)

$$\cos\theta_A = -.9320 \qquad \sin\theta_A = .3624 \qquad \boxed{\theta_A = 158.75^\circ}$$ (2)

ME 213 FALL 2010 TEST 2

NAME: David Malawey

David Malawey

1	20
2	20
3	20
4	20
5	20
Total	100

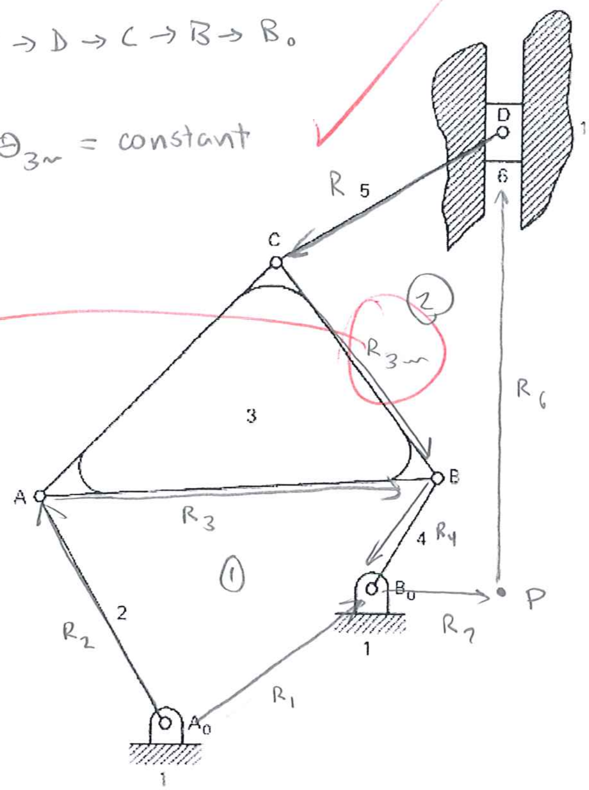
\# use 3'

loop 1: $A_0 \to A \to B \to B_0 \to A_0$

loop 2: $B_0 \to P \to D \to C \to B \to B_0$

c) constraints $\theta_3 - \theta_{3\sim} = \text{constant}$

UGLY NOTATION!



b)

	d	θ
1	c	c
2	c	v
3	c	v
3~	c	v
4	c	v
5	c	v
6	v	c
7	c	c

} constrained

Vars: 6 total

20

1.(20%) For the mechanism shown:

√ (a) Develop vector-loop equations. Explicitly specify the loop or loops being used.

√ (b) Consider each vector used in some vector-loop. Is its magnitude constant or variable? Is its orientation constant or variable?

√ (c) What, if any, geometric constraints exist among vectors used in some vector-loop?

√ (d) Write the vector-loop equations in components and (if any exist) the constraint equations. Count equations and variables. How many of the variable quantities must be specified to make the system solvable?

loop 1 $R_2 + R_3 + R_4 - R_1 = 0$

x: $R_2\cos\theta_2 + R_3\cos\theta_3 + R_4\cos\theta_4 - R_1\cos\theta_1 = 0$

y: $R_1\sin\theta_1 + R_3\sin\theta_3 + R_4\sin\theta_4 - R_1\sin\theta_1 = 0$

Loop 2 $R_7 + R_6 + R_5 + R_{3\sim} + R_4 = 0$

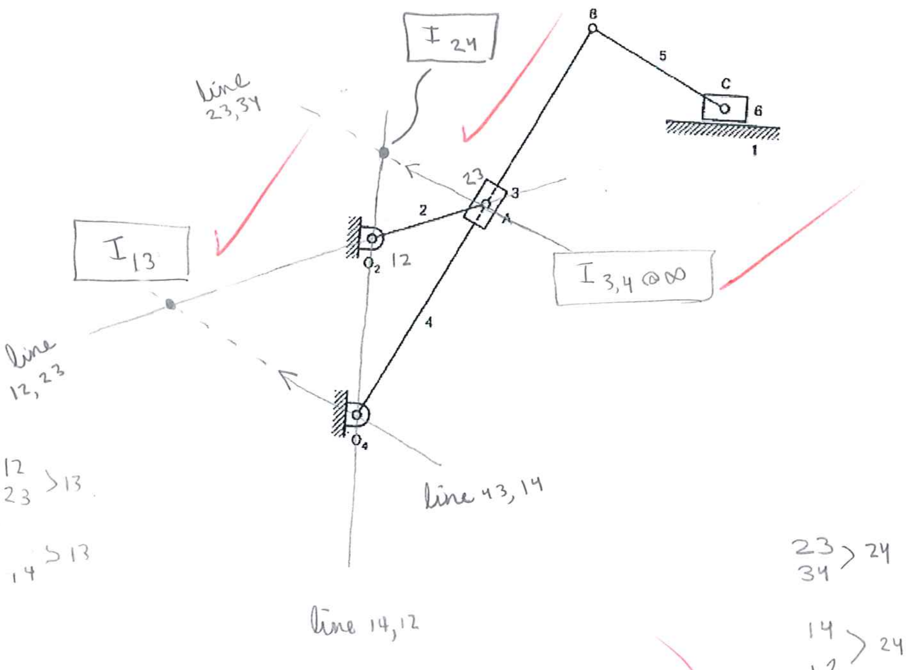
x: $R_7 + R_5\cos\theta_5 + R_{3\sim}\cos\theta_{3\sim} + R_4\cos\theta_4 = 0$

y: $R_6 + R_5\sin\theta_5 + R_{3\sim}\sin\theta_{3\sim} + R_4\sin\theta_4 = 0$

4 eq's + 1 constraint eq.

5 eq's, 6 vars, 1 DOF

d) $\boxed{\text{1 variable must be specified}}$



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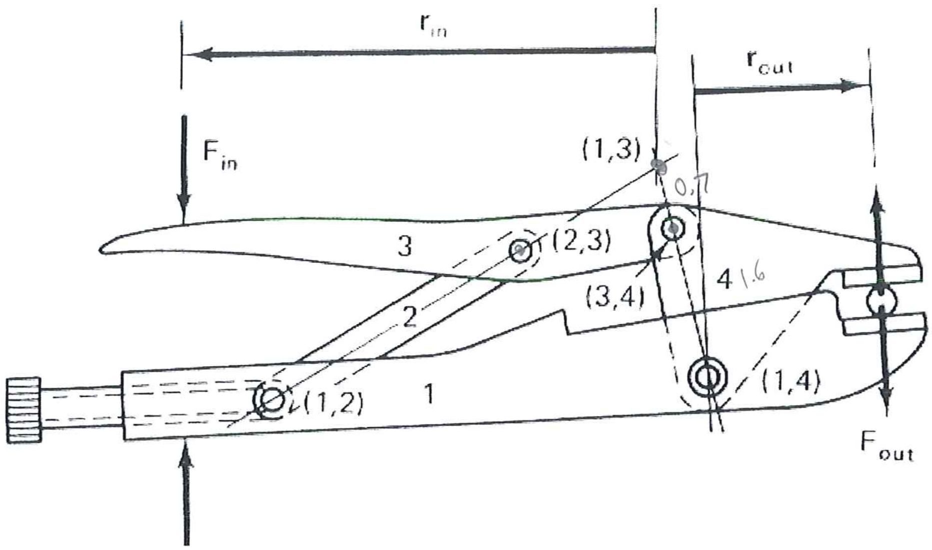
2.(20%) For the six-bar mechanism shown, using Kennedy's Rule as needed, locate the instant centers $I_{3,4}$ $I_{1,3}$ and $I_{2,4}$.

at I_{34}; $V_3 = V_4 = \omega_3 r_{3,IC} = \omega_4 r_{4,IC}$

$$\frac{\omega_3}{\omega_4} = \frac{r_{4,IC}}{r_{3,IC}} = \frac{1.6}{0.7}$$



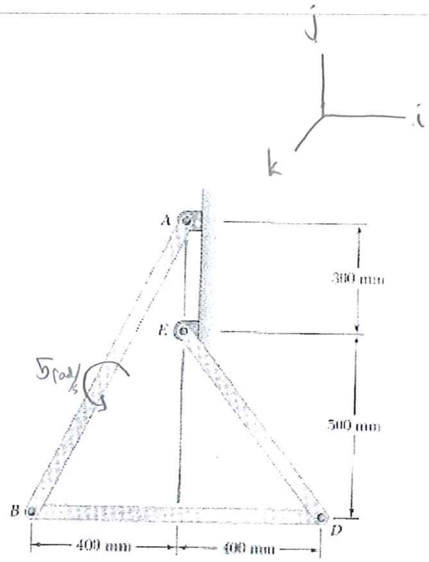
3.(20%) A four-bar tool and its instant centers are shown. In a consistent system of units, $r_{in} = 5.1$, $r_{out} = 1.9$, the distance from $I_{1,3}$ to $I_{3,4}$ is 0.7, and that from $I_{1,4}$ to $I_{3,4}$ is 1.6. Write down the power identity for the mechanism, and use the foregoing information to determine its mechanical advantage.

$F_{in} r_{in} \omega_{in} = F_{out} r_{out} \omega_{out}$

$$MA = \frac{F_{out}}{F_{in}} = \frac{r_{in}\omega_{in}}{r_{out}\omega_{out}} = \frac{5.1}{1.9}\left(\frac{\omega_{in}}{\omega_{out}}\right)$$

$$= \frac{5.1}{1.9}\left(\frac{1.6}{0.7}\right) = \boxed{MA = 6.135}$$

20



4.(20%) The dimensions of the four-bar mechanism shown are given. In the current configuration, link AB has angular velocity $\omega_{AB} = 5\,\text{rad/s}$ counter-clockwise. Find the angular velocities of links DE and BD.

HINT:- $\omega_{AB} \times \mathbf{R}_{B/A} + \omega_{BD} \times \mathbf{R}_{D/B} - \omega_{DE} \times \mathbf{R}_{D/E} = \mathbf{0}.$

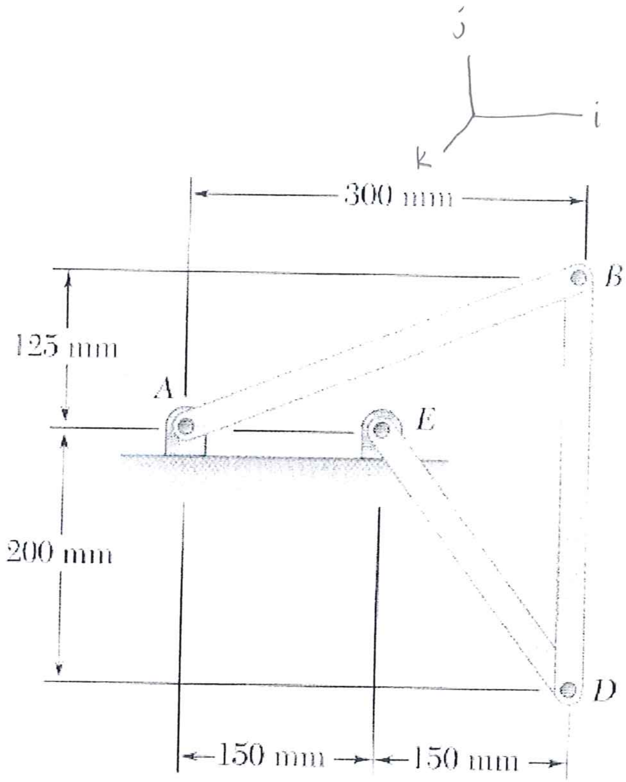
$$5\hat{k} \times (-0.4\hat{i} - 0.8\hat{j}) + \omega_{BD} \times (0.8\hat{i}) - \omega_{DE} \times (0.4\hat{i} - 0.5\hat{j}) = 0$$

$$-2\hat{j} + 4\hat{i} + 0.8\,\omega_{BD}\,\hat{j} - [\,.4\omega_{DE}\,\hat{j} + .5\omega_{DE}\,\hat{i}\,] = 0$$

$\hat{i}$: $4 - .5\omega_{DE} = 0 \Rightarrow \boxed{\omega_{DE} = 8\hat{k}\ \text{rad/s}}$

$\hat{j}$: $-2 + .8\omega_{BD} - .4\omega_{DE} = 0 \Rightarrow \boxed{\omega_{BD} = 6.5\hat{k}\ \text{rad/s}}$

20



$A_{QP} = \alpha_3 \times \vec{R}_{QP} - \vec{\omega}_3^{\,2} R_{QP}$

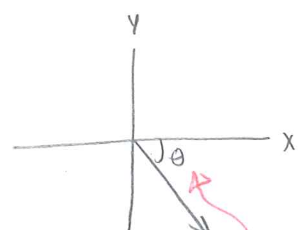
5.(20%) The dimensions of the four-bar mechanism shown are given. In the current configuration, link BD has angular velocity $\omega_{BD} = 4\,\text{rad/s}$ counter-clockwise, angular acceleration $\alpha_{BD} = 5\,\text{rad/s}^2$ clockwise. Find the acceleration difference vector $\mathbf{A}_{BD}$. Magnitude & angle

$\alpha_{BD} = -5\hat{k} \qquad \omega_{BD} = 4\hat{k}$

$A_{BD} = \vec{\alpha}_{BD} \times \vec{R}_{BD} - \omega_{BD}^2 R_{BD}$

$= -5\hat{k}\,(.325\,j) - 16\,(.325\,j)$

$A_{BD} = 1.625\,i - 5.2\,\hat{j}$



$= \sqrt{1.625^2 + 5.2^2}$

$\theta = \tan^{-1}\left(\frac{5.2}{1.625}\right)$

$\boxed{A_{BD} = \text{Magnitude } 5.448\ \text{m/s}^2 \qquad \theta = 72.65^\circ}$

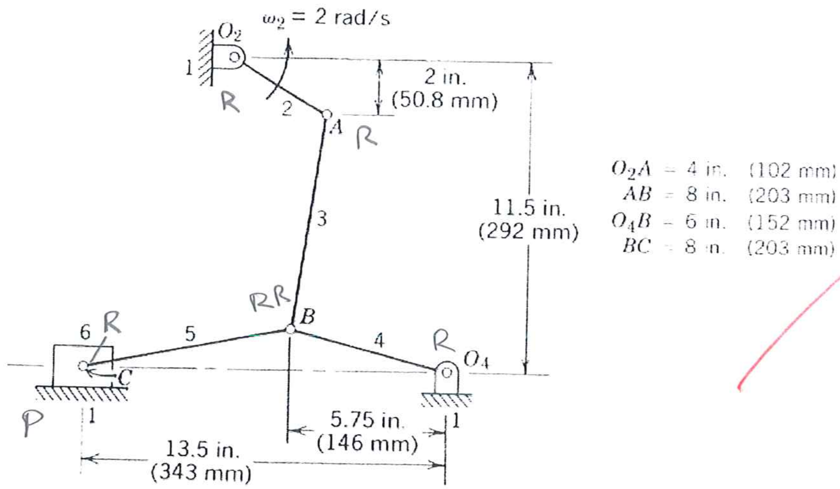
OK

20

ME 213 FALL 2010 TEST 1

NAME: David Malawey

1	10
2	8
3	10
4	30
5	32
Total	90



1.(10%) For the 6-link - **the slider is a link** - mechanism shown:
(i) Label all joints,
(ii) Compute the mobility.

$L = 6$

$J_1 = 7$

$J_2 = 0$

$M = 3(6-1) - 2(7) - 1(0)$

$15 - 14$

$\boxed{\text{Mobility} = 1 \text{ dof}}$

10

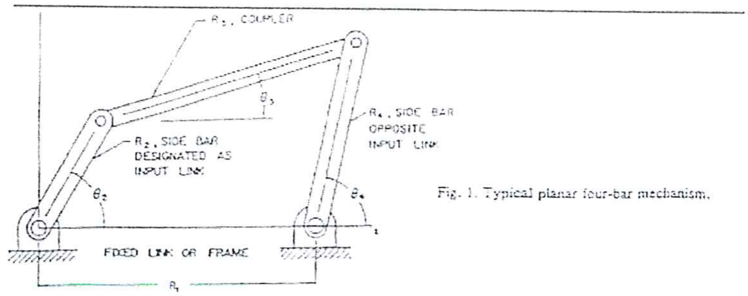


Fig. 1. Typical planar four-bar mechanism.

2. (10%) For each of the following hypothetical 4-bars: (a) Determine whether it can be assembled, (b) if so, determine its type according to the Barker classification.

assembleable?

a)

$$\{R_1, R_2, R_3, R_4\} = \{6, 10, 4, 7\} \quad \boxed{\text{yes}} \tag{1}$$

$$\{R_1, R_2, R_3, R_4\} = \{8, 5, 9, 12\} \quad \boxed{\text{yes}} \tag{2}$$

$$\{R_1, R_2, R_3, R_4\} = \{3, 5, 16, 7\} \quad \boxed{\text{No, } 16 > 3+5+7} \tag{3}$$

b)

1) $s + l = 10 + 4 = 14$ $\quad L_2 = l \Rightarrow \boxed{\text{type 6, RRR2}}$

$p + q = 6 + 7 = 13$

2) $s + l = 5 + 12 = 17$ $\quad L_1 = s \Rightarrow \boxed{\text{type 9 SCCC}}$ X

$p + q = 8 + 9 = 17$

SCRR / CPCRR

8

3.(10%)

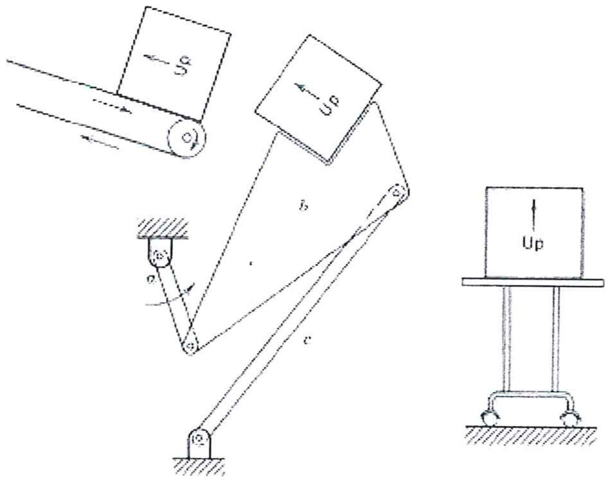
give definitions

(a) Define the following types of mechanism synthesis:

(i) Function generation. gives a detailed math output from detailed math input (analog computer)

(ii) Path generation. drives a particular point of a link along a specified path in plane of motion

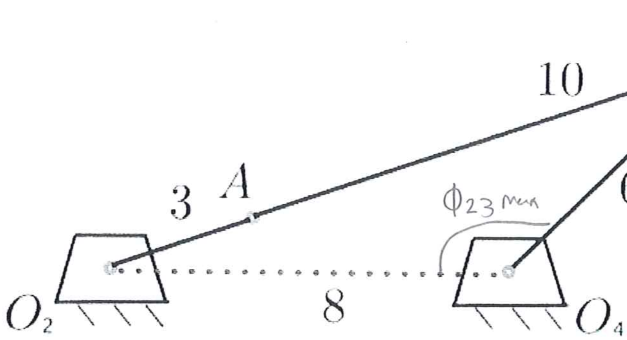
(iii) Motion generation. design task that requires one to control all 3 D.O.F. of a link



10

(b) A four-bar mechanism is designed to transfer packages from the conveyer belt to the trolley, as shown. Which of the above types is this mechanism?

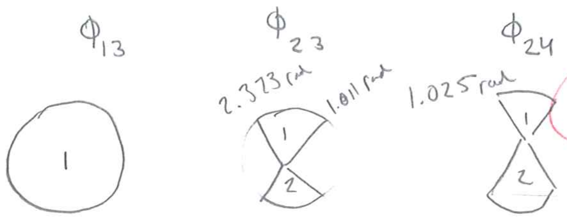
Motion generation



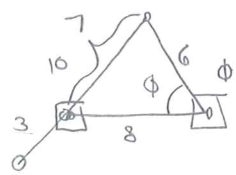
$$\phi_{23\,max} = \cos^{-1}\left[\frac{64+36-169}{2(48)}\right]$$

$$= 2.373 \text{ rad}$$

4.(35%) A GCRR 4-bar mechanism has lengths $\{R_1, R_2, R_3, R_4\} = \{8, 3, 10, 6\}$, and is assembled, as shown, in a configuration with $\phi_{12} > 0$.
Find, and illustrate on suitable pie-charts (with numerical values), the ranges of the fundamental position angles ϕ_{23}, ϕ_{24}, and ϕ_{13}. Sketch the configurations of the mechanism that correspond to any extreme values computed.

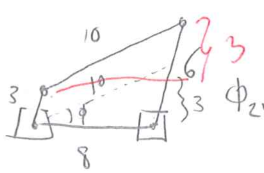


30



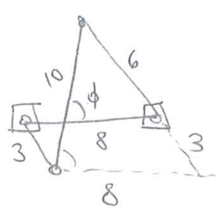
$$\phi_{23\,min} = \cos^{-1}\left[\frac{64+36-49}{2(48)}\right] = 1.011 \text{ rad}$$

8



$$\phi_{24\,min} = \cos^{-1}\left[\frac{100+64-36}{2(80)}\right] = .6435 \text{ rad}$$

0.2507



$$\phi_{24\,max} = \cos^{-1}\left[\frac{100+64-81}{2(80)}\right] = 1.025 \text{ rad}$$

5.(35%) The $x - y$ coordinates of three configurations of link CD are $C_1 = (0,0)$ $D_1 = (7.6248, 4.7814)$, $C_2 = (-.2156, 1.2837)$ $D_2 = (8.3124, 4.1720)$, $C_3 = (-2.3768, 3.6550)$ $D_3 = (6.4378, 5.4825)$.

A four-bar mechanism with CD as coupler, such that CD passes through these configurations is required. Find the pivot-point at which the link attached at C must be grounded.

	X	Y
C_1	0	0
C_2	-.2156	1.2837
C_3	-2.3768	3.6550

	Slope $= \frac{Y_2 - Y_1}{X_2 - X_1}$	midpoint $\left(\frac{X_1+X_2}{2}, \frac{Y_2+Y_1}{2}\right)$	perpen. slope
C_1 to C_2	-5.102	(.1078, .6419)	.1960
C_2 to C_3	-1.0972	(-1.2962, 2.4694)	.9114

32

SHOW YOUR WORK !!

Perp. bisector eq'n

1) $Y - 2.4694 = .9114 \left[X + 1.2962 \right]$ $\Rightarrow$ $.9114x + .9114(1.2962) + 2.4694$

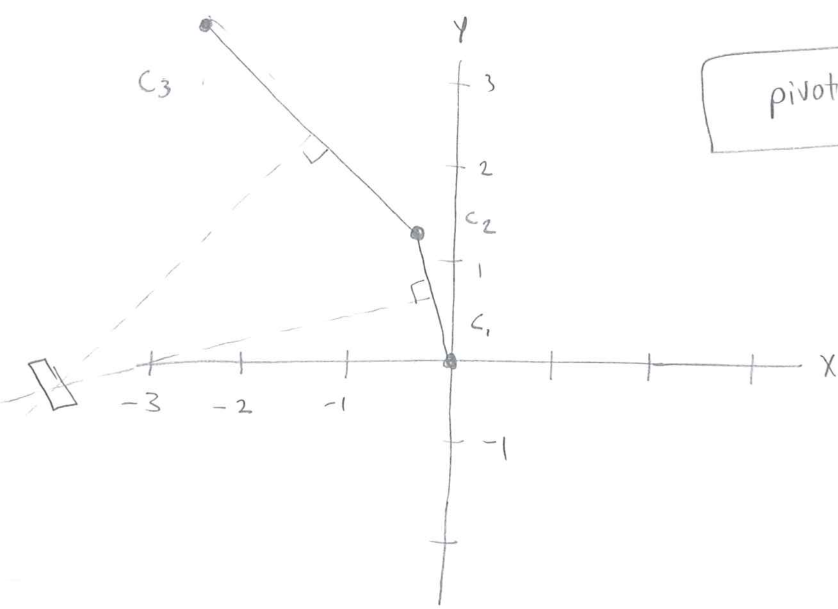
$\quad Y_2 \qquad M_2 \qquad X - X_2$

2) $Y - .6419 = .1960 \left[X - .1078 \right]$ $= .1960x + .1960(-.1078) + .6419$

$3.6508 + .7154x = .6208$

$\boxed{X = -4.235}$

$\boxed{Y = -.2093}$

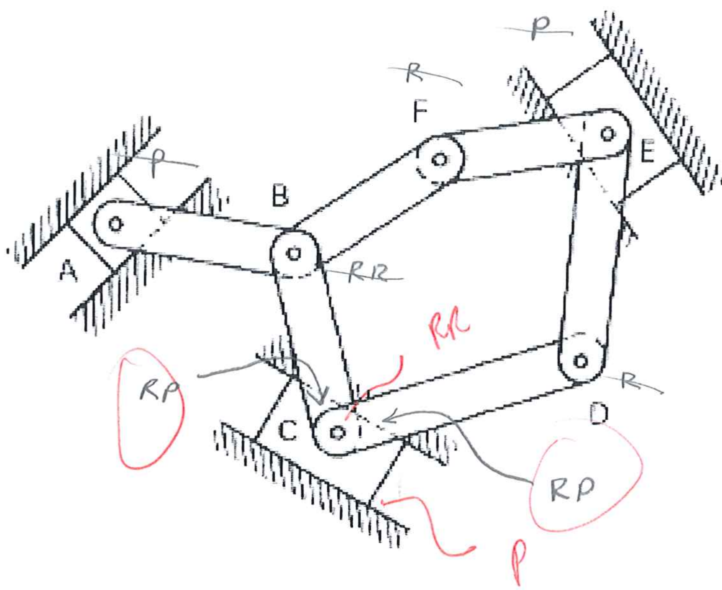


$\boxed{\text{pivot point} = (-4.235, -.2093)}$

Quizzes

ME 213 B CONCEPT QUIZ 1

NAME: David Malawey



Treat the slider at C as a link. Label all joints that involve this slider.

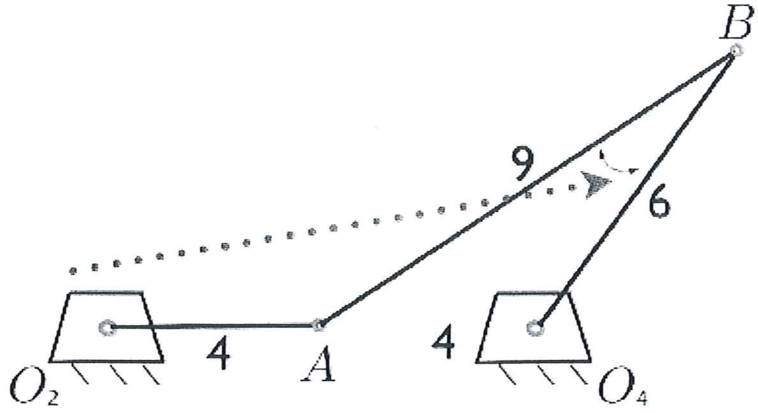
2

double revolute has 3 ~~joints~~ links, RR

C is prismatic

ME 213 B CONCEPT QUIZ 2

NAME: David Malawey



In its current configuration, the four-bar mechanism shown experiences a (circle one) **MAXIMUM** **MINIMUM** of the fundamental position angle (circle one)

ϕ_{12} ϕ_{13} ϕ_{14} ϕ_{23} ϕ_{24} ϕ_{34}

Homework

— David Malawey — Big Computer assignment

100

```
format long e;
R1=2.22;
R2=1;
R3=2.06;
R4=2.33;
FPX=0;
FPY=-100;
M2=9.75;
M3=113.6331;
M4=22.7175;
IG2=.8145;
IG3=51.7916;
IG4=10.2823;
T4=0;

TH2=0:0.001:2*pi;
TH3=zeros(size(TH2));
TH4=zeros(size(TH2));
TH31=zeros(size(TH2));
TH41=zeros(size(TH2));
TH32=zeros(size(TH2));
TH42=zeros(size(TH2));
OM2=zeros(size(TH2));
OM3=zeros(size(TH2));
OM4=zeros(size(TH2));
AL3=zeros(size(TH2));
AL4=zeros(size(TH2));

A=zeros(2,2);
g=zeros(2,1);
h=zeros(2,1);
q=zeros(2,1);
p=zeros(2,1);
B=zeros(9,9);
H=zeros(9,1);
V=zeros(9,1);

psi=(31-12.401)*(pi/180);
d=(1.6470);

RPX=zeros(size(TH2));
RPY=zeros(size(TH2));

R12X=zeros(size(TH2));
R12Y=zeros(size(TH2));
R32X=zeros(size(TH2));
R32Y=zeros(size(TH2));
R23X=zeros(size(TH2));
R23Y=zeros(size(TH2));
R43X=zeros(size(TH2));
R43Y=zeros(size(TH2));
```

```
R34X=zeros(size(TH2));
R34Y=zeros(size(TH2));
R14X=zeros(size(TH2));
R14Y=zeros(size(TH2));

F12X=zeros(size(TH2));
F12Y=zeros(size(TH2));
F32X=zeros(size(TH2));
F32Y=zeros(size(TH2));
F43X=zeros(size(TH2));
F43Y=zeros(size(TH2));
F14X=zeros(size(TH2));
F14Y=zeros(size(TH2));
T12=zeros(size(TH2));

AG2X=zeros(size(TH2));
AG2Y=zeros(size(TH2));
AG3X=zeros(size(TH2));
AG3Y=zeros(size(TH2));
AG4X=zeros(size(TH2));
AG4Y=zeros(size(TH2));

n=max(size(TH2));



for k=1:n;

    theta2=TH2(k);
    K1=R1/R2;
    K2=R1/R4;
    K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
    K4=R1/R3;
    K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);

    D=(1+K4)*cos(theta2)+K5-K1;
    F=(K4-1)*cos(theta2)+K5+K1;
    A=cos(theta2)-K1-K2*cos(theta2)+K3;
    B=-2*sin(theta2);
    C=K1-(K2+1)*cos(theta2)+K3;

    z1=(-B+sqrt(B^2-4*A*C))/(2*A);
    z2=(-B-sqrt(B^2-4*A*C))/(2*A);
    w1=(-B+sqrt(B^2-4*D*F))/(2*D);
    w2=(-B-sqrt(B^2-4*D*F))/(2*D);

    L1=2*z1/(1+z1^2);
    M1=(1-z1^2)/(1+z1^2);
    L2=2*z2/(1+z2^2);
    M2=(1-z2^2)/(1+z2^2);
    N1=2*w1/(1+w1^2);
```

```
    P1=(1-w1^2)/(1+w1^2);
    N2=2*w2/(1+w2^2);
    P2=(1-w2^2)/(1+w2^2);

    TH41(k)=atan2(L1,M1);
    TH42(k)=atan2(L2,M2);
    TH31(k)=atan2(N1,P1);
    TH32(k)=atan2(N2,P2);

end

OM2(1)=40;
AL2=-2;

for k=2:n;

    OM2(k)=sqrt(OM2(1)^2+2*AL2*TH2(k));

end

for k=1:n;

    TH3(k)=TH32(k);
    TH4(k)=TH42(k);

end
for k=1:n;

    A(1,1)=R3*cos(TH3(k));
    A(1,2)=-R4*cos(TH4(k));
    A(2,1)=R3*sin(TH3(k));
    A(2,2)=-R4*sin(TH4(k));

    g(1)= -R2*OM2(k)*cos(TH2(k));
    g(2)= -R2*OM2(k)*sin(TH2(k));

    h=A\g;

    OM3(k)=h(1);
    OM4(k)=h(2);

    q(1)=-R2*AL2*cos(TH2(k))+R2*((OM2(k))^2)*sin(TH2(k))+R3*((OM3(k))^2)*sin(TH3(k))-R4*↙
((OM4(k))^2)*sin(TH4(k));
    q(2)=-R2*AL2*sin(TH2(k))-R2*((OM2(k))^2)*cos(TH2(k))-R3*((OM3(k))^2)*cos(TH3(k))+R4*↙
((OM4(k))^2)*cos(TH4(k));

    p=A\q;

    AL3(k)=p(1);
    AL4(k)=p(2);
```

```
end

for k=1:n;

     R12X(k)=-R2*cos(TH2(k))/2;
     R12Y(k)=-R2*sin(TH2(k))/2;
     R32X(k)=-R12X(k);
     R32Y(k)=-R12Y(k);
     R23X(k)=-d*cos(TH3(k)-psi);
     R23Y(k)=-d*sin(TH3(k)-psi);
     R43X(k)=R3*cos(TH3(k))+R23X(k);
     R43Y(k)=R3*sin(TH3(k))+R23Y(k);
     R34X(k)=.5*R4*cos(TH4(k));
     R34Y(k)=.5*R4*sin(TH4(k));
     R14X(k)=-R34X(k);
     R14Y(k)=-R34Y(k);

     AG2X(k)=AL2*R12Y(k)+OM2(k)^2*R12X(k);
     AG2Y(k)=AL2*R12X(k)+OM2(k)^2*R12Y(k);
     AG3X(k)=AL2*-(R32Y(k)-R12Y(k))-OM2(k)^2*(R32X(k)-R12X(k))-AL3(k)*-R23Y(k)+OM3(k)↙
^2*R23X(k);
     AG3Y(k)=AL2*(R32X(k)-R12X(k))-OM2(k)^2*(R32Y(k)-R12Y(k))-AL3(k)*R23X(k)+OM3(k)↙
^2*R23Y(k);
     AG4X(k)=AL4(k)*R14Y(k)+OM4(k)^2*R14X(k);
     AG4Y(k)=-AL4(k)*R14X(k)+OM4(k)^2*R14Y(k);

     RPX(k)=3.06*cos(TH3(k)-psi)-R23X(k);
     RPY(k)=3.06*sin(TH3(k)-psi)-R23Y(k);

end

for k=1:n;

     B(1,1)=(1);
     B(1,3)=(1);
     B(2,2)=(1);
     B(2,4)=(1);
     B(3,1)=(-R12Y(k));
     B(3,2)=(R12X(k));
     B(3,3)=(-R32Y(k));
     B(3,4)=(R32X(k));
     B(3,9)=(1);
     B(4,3)=(-1);
     B(4,5)=(1);
     B(5,4)=(-1);
     B(5,6)=(1);
     B(6,3)=(R23Y(k));
     B(6,4)=(-R23X(k));
     B(6,5)=(-R43Y(k));
     B(6,6)=(R43X(k));
     B(7,5)=(-1);
```

```
    B(7,7)=(1);
    B(8,6)=(-1);
    B(8,8)=(1);
    B(9,5)=(R34Y(k));
    B(9,6)=(-R34X(k));
    B(9,7)=(-R14Y(k));
    B(9,8)=(R14X(k));

    H(1,1)=(M2*AG2X(k));
    H(2,1)=(M2*AG2Y(k));
    H(3,1)=(IG2*AL2);
    H(4,1)=(M3*AG4X(k)-FPX);
    H(5,1)=(M3*AG4Y(k)-FPY);
    H(6,1)=(IG3*AL3(k)-RPX(k)*FPY+RPY(k)*FPX);
    H(7,1)=(M4*AG4X(k));
    H(8,1)=(M4*AG4Y(k));
    H(9,1)=(IG4*AL4(k)-T4);

    V=B\H;

    F12X(k)=V(1);
    F12Y(k)=V(2);
    F32X(k)=V(3);
    F32Y(k)=V(4);
    F43X(k)=V(5);
    F43Y(k)=V(6);
    F14X(k)=V(7);
    F14Y(k)=V(8);
    T12(k)=V(9);

end
```

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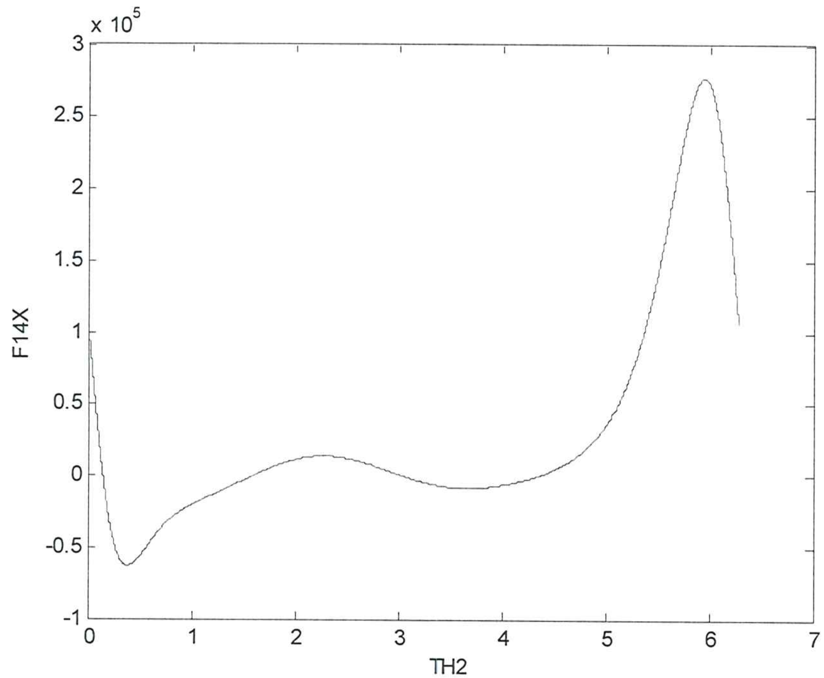

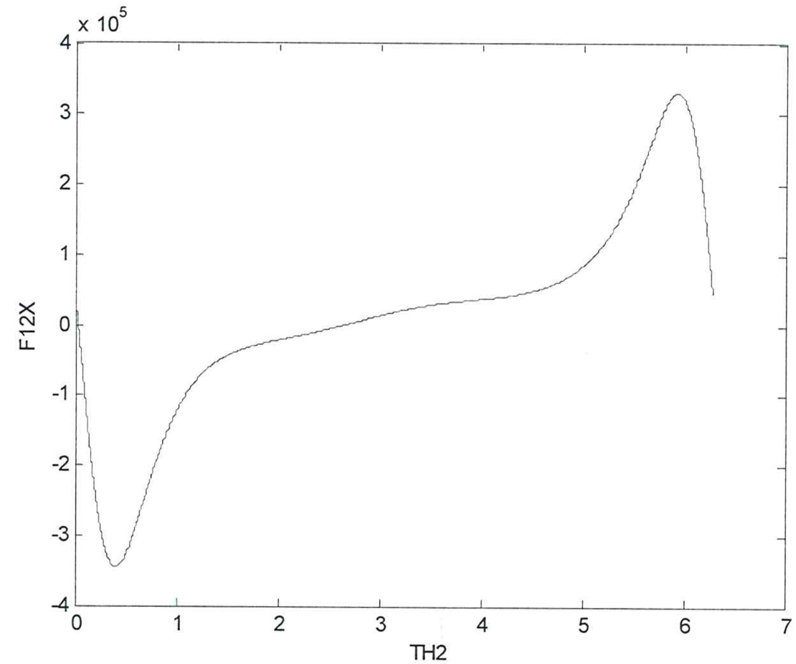

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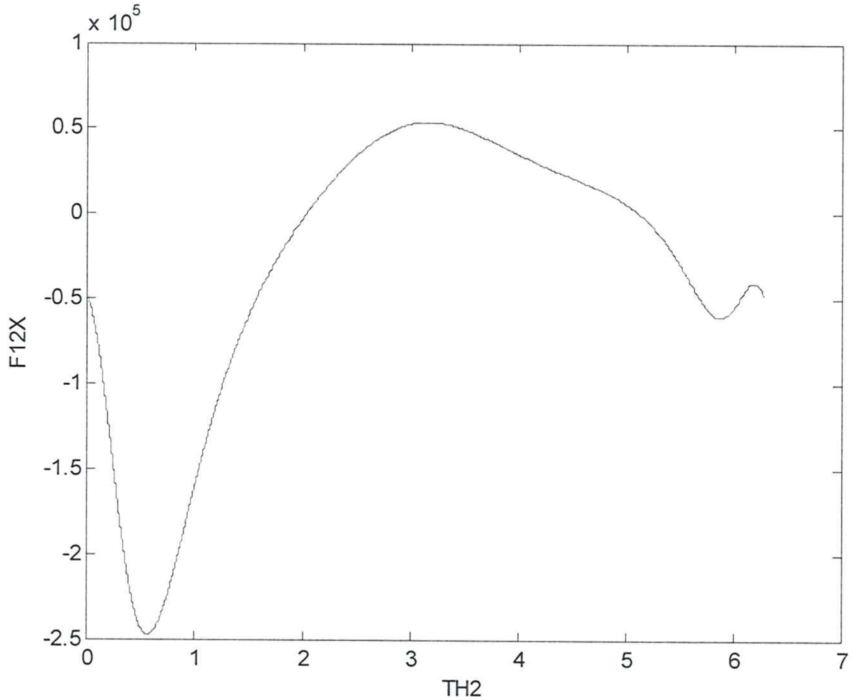

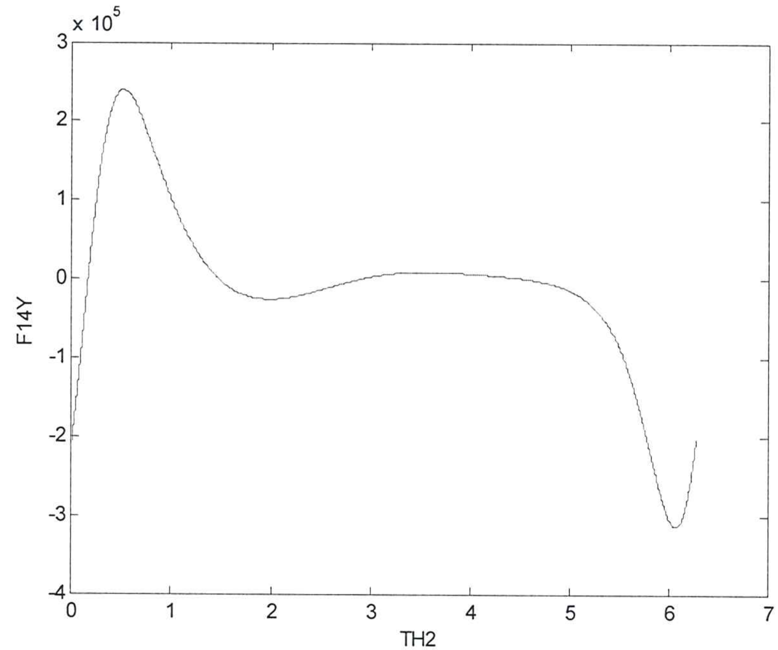

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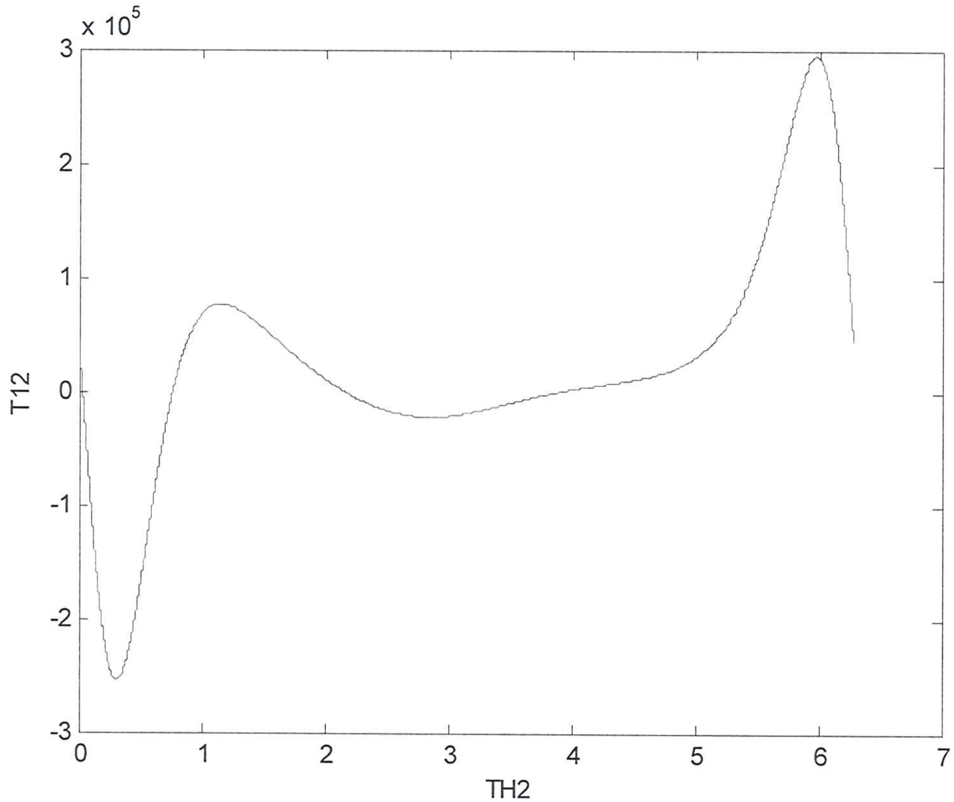
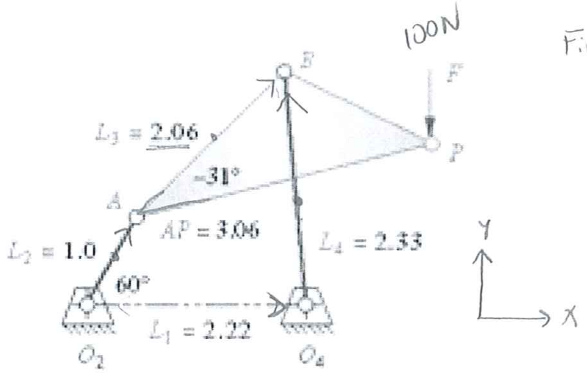


David Malaway

ME 213 A/B HOMEWORK SET 10

(Due 11/05/10)



Find θ's, ω's, α's given only θ_2 ω_2,

$\omega_2 = 10 \text{ rad } \hat{k}$ G

$\alpha_2 = 5 \text{ rad}/s^2$

Norton, Problem 11-9.

$2\text{mm} = .002\text{ m}$

$a = \alpha \times r - \omega^2 r$

$\underline{(4) = 5.979}$

$4.524\hat{k} \times (+1.22\cos(96)\hat{i} + 1.22\sin(96)\hat{j})$

$- 1.44^2(1.22\cos(96)\hat{i} + 1.22\sin(96))$

$-3.09\hat{i} + 5.225\hat{j}$

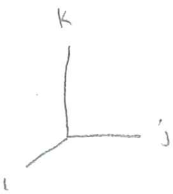
HW Set 10

Vector loop $O_4 \to O_2 \to A \to B \to O_4$ $\quad \vec{R}_1 + \vec{R}_4 - \vec{R}_2 - \vec{R}_3 = 0$

$x]$ $\quad l_1 + l_4 \cos\theta_4 - l_3\cos\theta_3 - l_2\cos\theta_2 = 0$ $\qquad \theta_2 = 60°$

$y]$ $\quad l_4 \sin\theta_4 - l_3 \sin\theta_3 - l_2 \sin\theta_2 = 0$

$l_1 = 2.22$	$\theta_1 = 0°$	$\omega_1 = 0$	$\alpha_1 = 0$
$l_2 = 1.0$	$\theta_2 = 60°$	$\omega_2 = 10$	$\alpha_2 = 5$
$l_3 = 2.06$	$\theta_3 = 44.67°$	$\omega_3 = -3.68$	$\alpha_3 = 6.137$
$l_4 = 2.33$	$\theta_4 = 96.58°$	$\omega_4 = 1.44$	$\alpha_4 = 4.524$



$x]$ $\quad -\dot\theta_4 l_4 \sin\theta_4 + \dot\theta_3 l_3 \sin\theta_3 + \dot\theta_2 l_2 \sin\theta_2 = 0$

$y]$ $\quad \dot\theta_4 l_4 \cos\theta_4 - \dot\theta_3 l_3 \cos\theta_3 - \dot\theta_2 l_2 \cos\theta_2 = 0$

$\frac{d}{dt}$

$x]$ $\quad 0 = -\ddot\theta_4 l_4 \sin\theta_4 - \dot\theta_4^2 l_4 \cos\theta_4 + \ddot\theta_3 l_3 \sin\theta_3 + \dot\theta_3^2 l_3 \cos\theta_3 + \ddot\theta_2 l_2 \sin\theta_2 + \dot\theta_2^2 l_2 \cos\theta_2$

$y]$ $\quad 0 = \ddot\theta_4 l_4 \cos\theta_4 - \dot\theta_4^2 l_4 \sin\theta_4 - \ddot\theta_3 l_3 \cos\theta_3 + \dot\theta_3^2 l_3 \sin\theta_3 - \ddot\theta_2 l_2 \cos\theta_2 + \dot\theta_2 l_2 \sin\theta_2$

$-\alpha_4\, 2.315 - 2.074(-.2670) + \alpha_3(1.448) + 13.54(1.465) + 4.33 + 5 = 0$

$\alpha_4(-.2670) - 2.074(2.315) - \alpha_3(1.448) + 13.54(1.448) - 5(\tfrac{1}{2}) + 10(\sin 60) = 0$

midpoint of L_2

$a = \alpha_2 \times r_{P/O} - \omega_2^2 r_{P/O}$

$= 5\hat{k} \times .5\cos 60\,\hat{i} + .5\sin 60\,\hat{j} - 100\,(.5\cos 60\,\hat{i} + .5\sin 60\,\hat{j})$

$1.25\,\hat{j} - 2.165\,\hat{i} - 25\,\hat{i} - 43.30\,\hat{j}$

$\boxed{\vec{a}_2 = -27.17\,\hat{i} - 42.05\,\hat{j}}$

$\boxed{\vec{a}_4 = -3.09\,\hat{i} + 5.225\,\hat{j}}$

$\boxed{\vec{a}_3 = -14.27\,\hat{i} - 14.14\,\hat{j}}$

$\rho_{Al} = 2.7 g/cm^3$

2.5cm × $b = 3.06$

$h = 2.06 \sin 31$

$V = 2.5 \times 2.06 \times 3.06 \times \frac{1}{2} = 7.88$

$m = \frac{1}{2} \rho t h L = 113.63 kg$

$I_G = (6.313)(8.209) = 51.79 \; kg m^2$

ℓt 50mm × 25mm 1.0 ρ = $m_2 = 9.85 kg$

"   " 2.33 ρ = $m_4 = 19.995 kg$

$9.85(-27.17\hat{i} - 42.05\hat{j})$

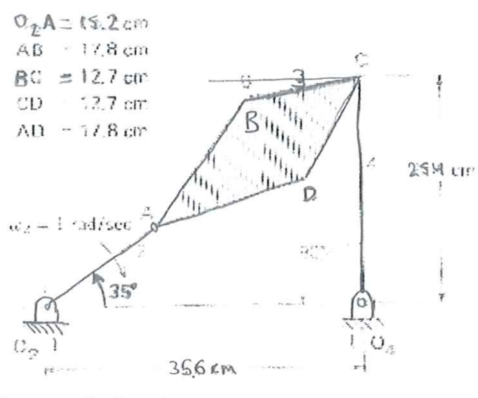
$F_{12x} = -1246$ $F_{14x} = 235 N$ $F_{32x} = -1105 N$

$F_{12y} = 940$ $F_{14y} = -2219 N$ $F_{32y} = 162 N$ $T_{12} = 7.08 N \cdot m$

David Malawey

ME 213 A/B HOMEWORK SET 9

(Due 10/29/10)



$R_{A/B,y} = O_2A_y + BC_y - 25.4 \text{ cm}$

$8.718 + 7.284 - 25.4 = (-9.39)$

$R_{A/B,x} = O_2A_x + BC_x - 35.6 = (-12.75)$

$R_{B/A} = (12.75\hat{i} + 9.39\hat{j})$

$A_{AO_2} = \alpha \times r_{AO_2} - w^2 r_{AO_2}$

$A_{BO_2} = A_{AO_2} + \alpha_3 \times R_{B/A} - \omega_3^2 r_{B/A}$

1. Three of the link-lengths for the four-bar mechanism shown are given above. The fourth is AC = 28.5 cm. At the instant shown, the angles, angular velocities and the angular accelerations of the links are given to be $\theta_2 = \theta_3 = 35°$, $\theta_4 = 90°$, $\omega_2 = 1\,\text{rad/s} \curvearrowright$, $\omega_3 = 0.53\,\text{rad/s} \curvearrowleft$, $\omega_4 = 0$, $\alpha_2 = 2\,\text{rad/s}^2 \curvearrowleft$, $\alpha_3 = .35\,\text{rad/s}^2 \curvearrowright$, $\alpha_4 = 1.2\,\text{rad/s}^2 \curvearrowleft$. AB makes an angle $\phi = 17.5°$ with AC. Find the horizontal and vertical components of the acceleration $\mathbf{a}_B$ of the coupler-point B. Link angles are measured counter-clockwise relative to the ground link.

$R_{A/O_2} = (12.45i + 8.72j)$

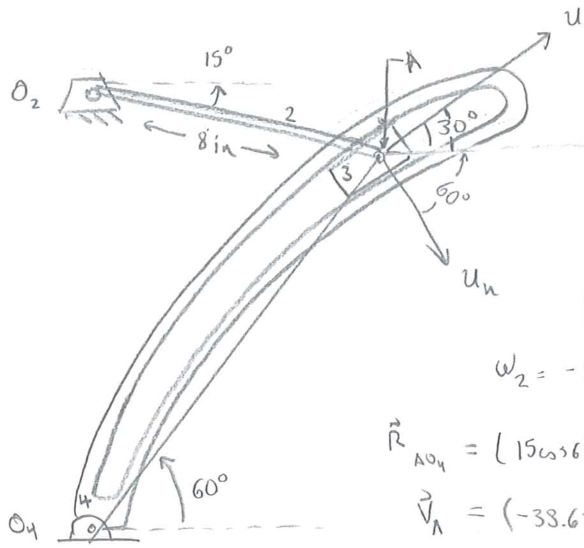
$A_{AO_2} = 2\hat{k} \times (12.45\hat{i} + 8.72\hat{j}) - (-1)^2 \times (12.45i + 8.72j)$

$= (24.9j - 17.44i) - (12.45i + 8.72j)$

$= \boxed{(-29.89i + 16.18\hat{j})\ \text{cm/s}^2}$

$A_{BO_2} = (-29.89i + 16.18j) + \left[\underbrace{-.35\hat{k} \times (12.75i + 9.39j)}\right] \left[\underbrace{(-4.463j + 3.28i) - (3.58i + 2.64\hat{j})}\right]$

$A_{BO_2} = (-30.19\hat{i} + 9.08\hat{j})$



$V_A = V_{slip}\, U_t + \omega_4 \hat{k} \times R_{AO_4}$

$\vec{A}_A = \dot{V}_{slip}\, \vec{U}_t + \frac{V^2_{slip}}{\rho} \vec{U}_n + \alpha \times R_{AO_4} - \omega_4^2 R_{AO_4} + 2\omega_4 \hat{k} \times V_{slip} U_t$

$\vec{V}_A = (-\omega_2 \hat{k}) \times \vec{R}_{AO_2}$

$\vec{A}_A = -\omega_2^2 R_{AO_2}$

$\vec{R}_{AO} = (8\cos 15 i - 8 \sin 15 j) = (7.73 i - 2.07 j)$

$\omega_2 = -5\hat{k} \qquad \vec{V}_A = -5\hat{k} \times (7.73 i - 2.07 \hat{j})$

$\vec{R}_{AO_4} = (15 \cos 60\, i + 15 \sin 60\, \hat{j}) = (7.5 i + 12.9 j)$ $\vec{V}_A$

$\vec{V}_A = (-38.65 \hat{j} - 10.35 i)$

$u_t = (\cos 30 i + \sin 30 \hat{j}) = (\frac{\sqrt{3}}{2} i + .5 j)$

2. In the configuration shown, the 8-inch rotor O_2A is oriented 15° below the horizontal, $\mathbf{R}_{AO_4}$ has magnitude 15 inches and is oriented 60° above the horizontal, the tangent to the slot at A is oriented 30° above the horizontal, and the radius of the circular slot is 16 inches. If O_2A has constant clockwise angular velocity $\omega_2 = 5\,\text{rad/s}$, find the angular velocity and angular acceleration of link 4 in the current configuration.

$\vec{A}_A = -25\,(7.73 i - 2.07 j) \qquad \vec{U}_n = (\cos 60 i - \sin 60) = (.5 i - \frac{\sqrt{3}}{2} j)$

$A_A = (-193.25 i + 51.75 \hat{j}) \qquad \rho = 16$

$(-38.65 j - 10.35 i) = (V_{slip} \frac{\sqrt{3}}{2} i + V_{slip} .5 j) + (\omega_4\, 7.5 j - \omega_4\, 12.9 i)$

$j \quad -38.65 = .5 V_{slip} + \omega_4 (7.5)$

$\hat{i} \quad -10.35 = V_{slip} (\frac{\sqrt{3}}{2}) - \omega_4 (12.9)$

$V_{slip} = -44.512$

$\omega_4 = -2.185$ rad/s

$(-193.25 i + 51.75 \hat{j}) = (\dot{v} \frac{\sqrt{3}}{2} + \dot{v} .5 j) + \underbrace{\frac{(-44.5)^2}{16} \langle .5 i - \frac{\sqrt{3}}{2} \hat{j} \rangle}_{(61.88 i - 107.18 j)}$

$+ \alpha_4 \hat{k} \times (7.5 i + 12.19 j) - (2.135)^2 (7.5 i + 12.95 j) + 2(-2.185)\hat{k} \times \langle -44.5(\frac{\sqrt{3}}{2}) i - 44.5(0.5) j \rangle$

$-4.372\, \hat{k} \times \langle -38.54 i - 22.25 j \rangle$

$+(\alpha_4\, 7.5 j - \alpha_4\, 12.9 i) - (35.77 i + 61.53 j) + (168.48 j - 97.27 i)$

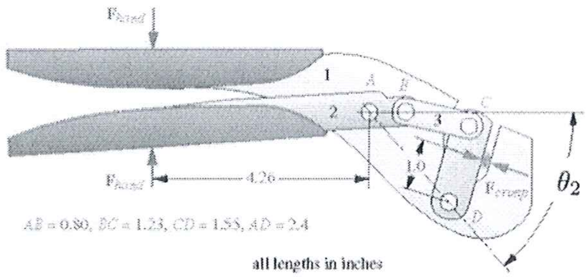
$i \Rightarrow -193.25 = \dot{v}(.866) + 61.88 - \alpha_4 (12.9) - 35.77 - 97.27$

$j \Rightarrow 51.75 = \dot{v}(.5) - 107.2 + \alpha_4 (7.5) - 61.53 + 168.48 \qquad \dot{V} = -18.94$

$\boxed{\alpha_4 = 8.19 \text{ rad/s}^2}$

ME 213 A/B HOMEWORK SET 8

(Due 10/22/10)



1. The crimping tool shown is a four-bar mechanism. When $\theta_2 = 50°$, the corresponding values of the coupler and output angles are $\theta_3 = 33.41°$, $\theta_4 = 123.68°$ respectively.

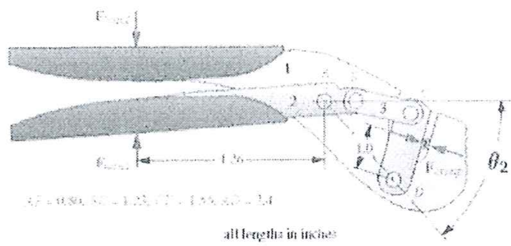
   (a) Write the power identity for the mechanism, and express its mechanical advantage M. A. $= \dfrac{F_{crimp}}{F_{hand}}$ in terms of the ratio $\dfrac{\omega_2}{\omega_4}$.

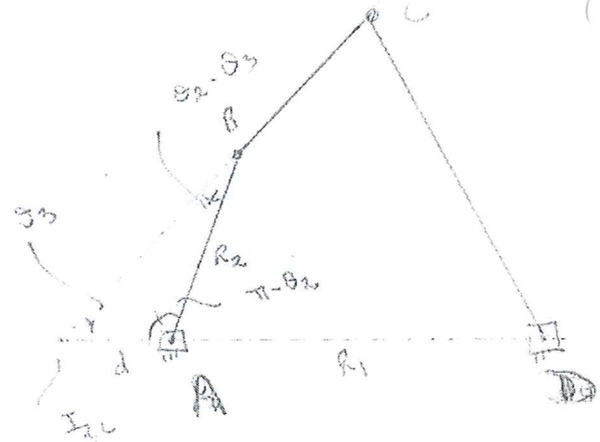
   (b) Sketch the mechanism in the configuration $\theta_2 = 50°$, locate the instant center $I_{2,4}$, and use it to develop a numerical relationship between ω_2 and ω_4.

   (c) Find the mechanical advantage of the tool for this configuration.

2. A GCRR four-bar mechanism has link-lengths $R_1 = 8$, $R_2 = 4$, $R_3 = 7$, $R_4 = 6$. Let θ_2 range from 0 to 2π in increments of .01 rad. Implement the MATLAB code presented in class to find the corresponding values of θ_3 and θ_4, using the direct method. The mechanical advantage of the four-bar mechanism is proportional to $\dfrac{\omega_2}{\omega_4}$. In class, we developed an expression for this quantity, in terms of the link-lengths and θ's. Compute this quantity, and plot it against θ_2. What values of θ_2 correspond to extrema of M.A.? Do your numbers agree with Freudenstein's result?

Ans. on back





3.(20%) The crimping tool shown is a four-bar mechanism. When $\theta_2 = 50°$, the corresponding values of the coupler and output angles are $\theta_3 = 33.41°$, $\theta_4 = 123.68°$ respectively.

(a) Write the power identity for the mechanism, and express its mechanical advantage M. A. $= \dfrac{F_{crimp}}{F_{hand}}$ in terms of the ratio $\dfrac{\omega_2}{\omega_4}$.

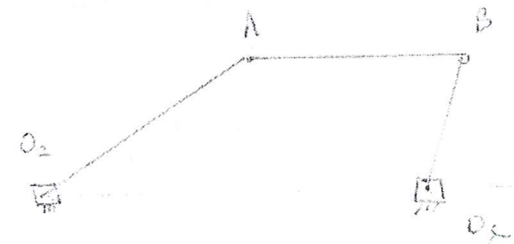
(b) Sketch the mechanism in the configuration $\theta_2 = 50°$, locate the instant center $I_{2,4}$, and use it to develop a numerical relationship between ω_2 and ω_4.

(c) Find the mechanical advantage of the tool for this configuration.

$F_{crimp}(1)\omega_4 = F_{HAND}(4.26)\omega_2$

$d\,\omega_2 = (R_1 + d)\,\omega_4$

$\dfrac{R_2}{\sin\theta_3} = \dfrac{d}{\sin(\theta_2-\theta_3)}$



$MA = \dfrac{F_{crimp}}{F_{HAND}} = \dfrac{4.26\,\omega_2}{\omega_4} = 4.26\left(1 + \dfrac{R_1}{d}\right)$

$d = \dfrac{R_2 \sin(\theta_2-\theta_3)}{\sin\theta_3} = \dfrac{(.8)\sin(16.59)}{\sin(33.41)} = .4148$

$R_1 = 2.4$

$M.A = 4.26)(1 + 5.78...$

$\boxed{MA = 28.906}$

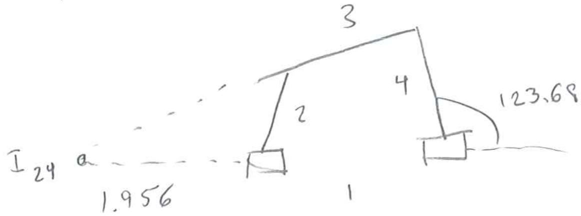
David Mallaway

1) $\dfrac{\omega_2}{\omega_4} = \dfrac{R_4 \sin(\theta_4 - \theta_2)}{R_2 \sin(\theta_2 - \theta_3)}$

a) $F_{in} W_{in} r_{in} = F_{out} W_{out} r_{out}$

$\dfrac{F_{out}}{F_{in}} = \dfrac{W_2 r_2}{W_4 r_4} = \dfrac{4.26}{1} \dfrac{W_2}{W_4}$ $\quad MA = \dfrac{F_{clmp}}{F_{in}}$ $\quad MA = 4.26 \dfrac{W_2}{W_4}$

b)



$l_1 = r_2 \cos S_4 + r_3 \cos 33.41$

$= .8 \cos S_D + 1.23 \cos 33.41$

$= 1.541$

$\tan 33.41 = {}^{n}/_{l_P}$ $\quad l_H = \dfrac{1.956}{\cos 33.41}$ $\quad l_P = 1.29 / \tan 33.41$

$l_P = 1.956$

$l_H = 2.32$

c) $MA = 4.26\ {}^{\omega_2}/_{\omega_4} = 4.26 \dfrac{R_4 \sin(\theta_4 - \theta_3)}{R_2 \sin(\theta_2 - \theta_3)}$

$= 4.26 \dfrac{(1.55 \sin 123.68 - 33.41)}{(.8 \sin 50 - 33.41)} \Rightarrow \boxed{MA = 28.9}$

3) $V_B = \omega_2 r_2$

$V_D = \omega_4 r_4$

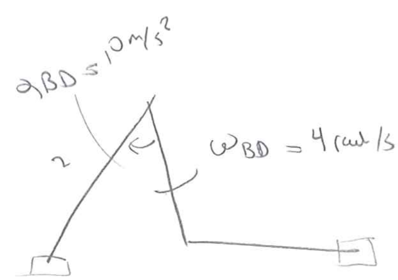
$A_{DB} = \alpha \times R_{DB} - \omega^2 R_{DB}$

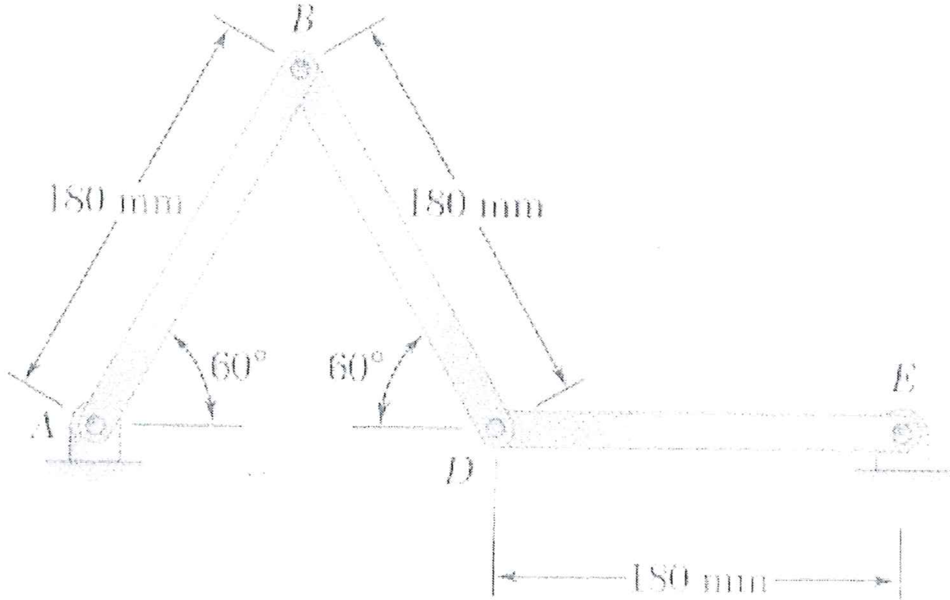
$A_{DB} = -10\ rad/s^2\ \hat{k} \times (-.12 \cos 60 \hat{i} + .18 \sin 60 \hat{j} - 4^2(-.18 \cos 60 \hat{i} + .18 \sin 60 \hat{j})$

$= 1.559 \hat{i} + .9 \hat{j} + 1.442 \hat{i} - 2.494 \hat{j}$

$\boxed{A_{BD} = 2.99 \hat{i} - 1.594 \hat{j}\ m/s^2}$

$\boxed{|A_{DB}| = 3.388\ m/s^2 \quad 28°}$





5.(20%) The dimensions of the four-bar mechanism shown are given. In the current configuration, link BD has angular velocity $\omega_{BD} = 4\,\mathrm{rad/s}$ counter-clockwise, angular acceleration $\alpha_{BD} = 10\,\mathrm{rad/s^2}$ clockwise. Find the acceleration difference $\mathbf{A}_{DB}$. Give your answer as a magnitude and an orientation relative to the horizontal.

$$\vec{R}_{DB} = .18(.5\hat{i} - .866\hat{j}) = (.09\hat{i} - .1559\hat{j})\ \mathrm{m}$$

$$\vec{A}_{DB} = 10\hat{k} \times (.09\hat{i} - .1559\hat{j}) - 16(.09\hat{i} - .1559\hat{j})$$

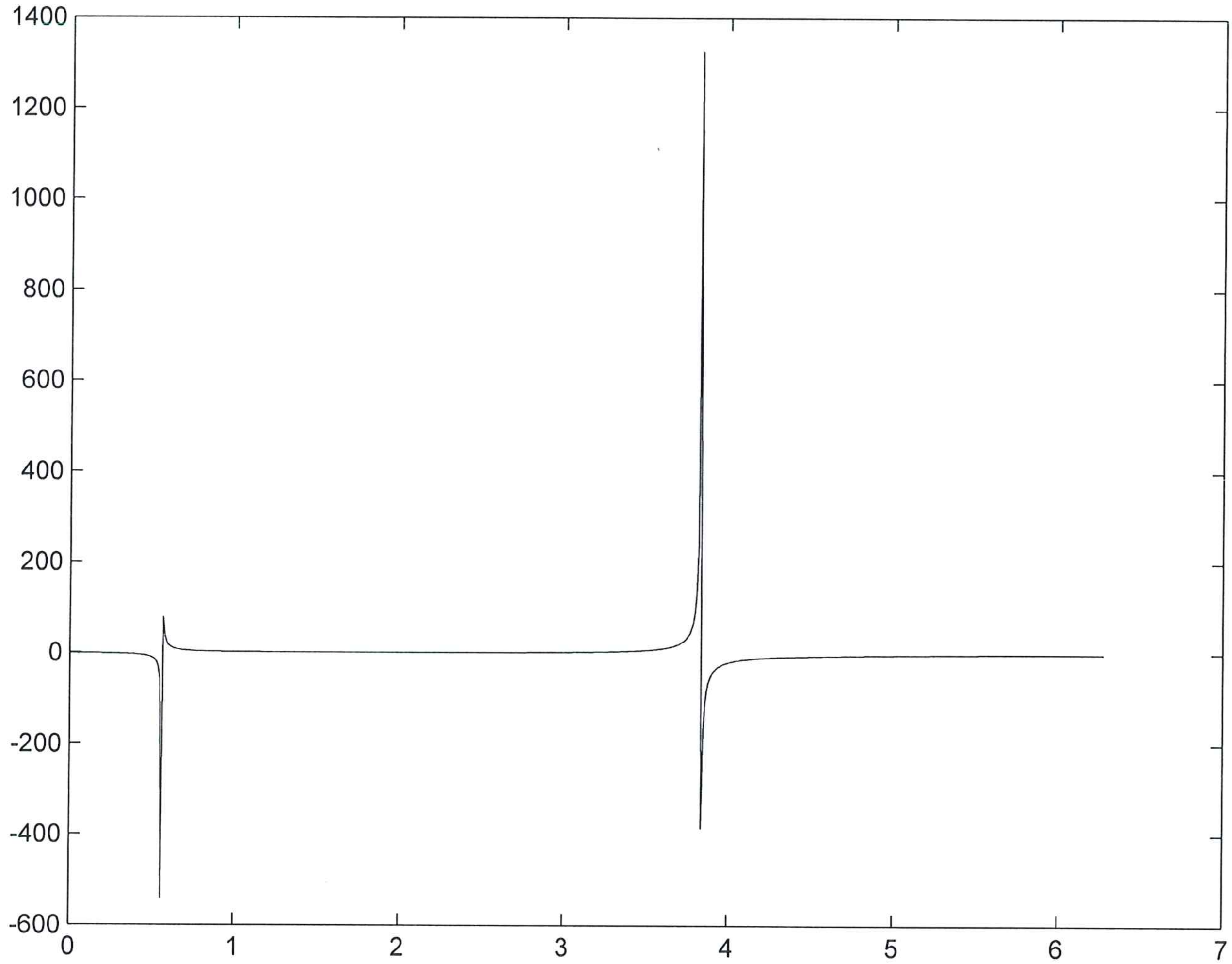
$$= (1.559\hat{i} + .9\hat{j}) - 1.44\hat{i} + 2.4944\hat{j}$$

$$= .119\hat{i} + 3.3944\hat{j}$$

3.3965 m/s²

$\tan^{-1}(28.5244) = 87.99°$

```
format long e;
R1=8;
R2=4;
R3=7;
R4=6;
TH2=0:0.01:2*pi;
TH31=zeros(size(TH2));
TH41=zeros(size(TH2));
TH32=zeros(size(TH2));
TH42=zeros(size(TH2));
M1=zeros(size(TH2));
M2=zeros(size(TH2));
n=max(size(TH2));
for k=1:n;
    theta2=TH2(k);
K1=R1/R2;
K2=R1/R4;
K3=(R1^2+R2^2+R4^2-R3^2)/(2*R2*R4);
K4=R1/R3;
K5=(R4^2-R1^2-R2^2-R3^2)/(2*R2*R3);
D=(1+K4)*cos(theta2)+K5-K1;
F=(K4-1)*cos(theta2)+K5+K1;
A=cos(theta2)-K1-K2*cos(theta2)+K3;
B=-2*sin(theta2);
C=K1-(K2+1)*cos(theta2)+K3;
z1=(-B+sqrt(B^2-4*A*C))/(2*A);
z2=(-B-sqrt(B^2-4*A*C))/(2*A);
w1=(-B+sqrt(B^2-4*D*F))/(2*D);
w2=(-B-sqrt(B^2-4*D*F))/(2*D);
L1=2*z1/(1+z1^2);
M1=(1-z1^2)/(1+z1^2);
L2=2*z2/(1+z2^2);
M2=(1-z2^2)/(1+z2^2);
N1=2*w1/(1+w1^2);
P1=(1-w1^2)/(1+w1^2);
N2=2*w2/(1+w2^2);
P2=(1-w2^2)/(1+w2^2);
TH41(k)=atan2(L1,M1);
TH42(k)=atan2(L2,M2);
TH31(k)=atan2(N1,P1);
TH32(k)=atan2(N2,P2);
end
for k=1:n;
D11=R4*sin(TH41(k)-TH31(k));
D12=R2*sin(TH2(k)-TH31(k));
M1(k)=D11/D12;
D21=R4*sin(TH42(k)-TH32(k));
D22=R2*sin(TH2(k)-TH32(k));
M2(k)=D21/D22;
end
```



1400
1200
1000
800
600
400
200
0
-200
-400
-600
0
1
2
3
4
5
6
7

ME 213 A/B HOMEWORK SET 7

(Due 10/15/09)

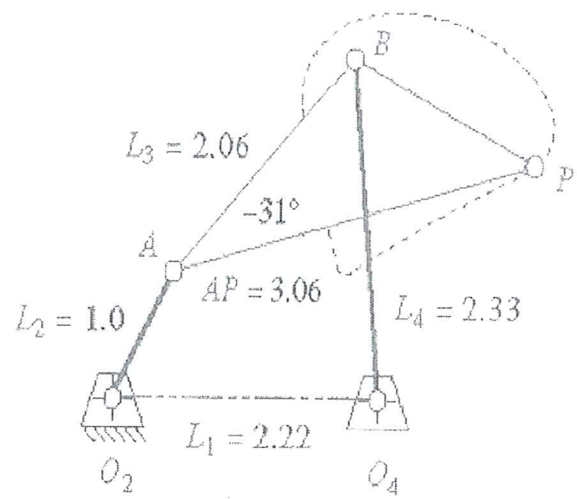
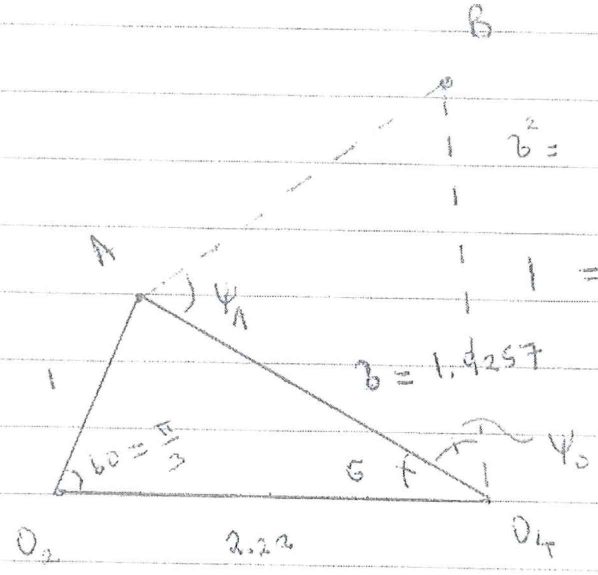


FIGURE P6-10

1. The input link of the GCRR mechanism shown has constant counter-clockwise angular velocity $\omega_2 = 5\,\text{rad/s}$. Find the velocity **vector** of coupler point P when $\theta_2 = 60°$

   (i) analytically,

   (ii) using instant centers.

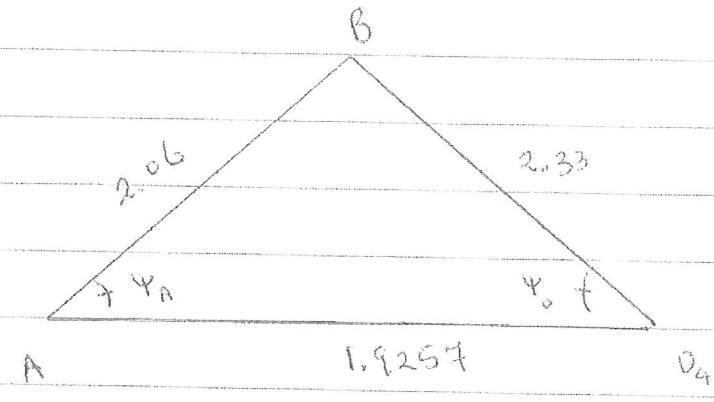


$$b^2 = 1^2 + 2.22^2 - 2(2.22)\cos(60)$$

$$1 = 2.22^2 + 1.9257^2 - 2(2.22)(1.9257)\cos\sigma$$

$$\cos\sigma = .8932$$

$$\sigma = .4664 \text{ radians} = 26.72^\circ$$



$$\cos\psi_A = \frac{2.06^2 + 1.9257^2 - 2.33^2}{2(1.9257)(2.06)} = .3180$$

$$\cos\psi_B = \frac{2.33^2 + 1.9257^2 - 2.06^2}{2(2.33)(1.9257)} = .5453$$

$\psi_A = 1.2472 = 71.45^\circ$ $\quad\quad$ $\theta_3 = .7808 = 44.74^\circ$

$\psi_B = .994 = 56.95^\circ$ $\quad\quad$ $\theta_4 = 1.6812 = 96.33^\circ$

$\boxed{\text{OR}}$

VECTOR LOOP EQT

$$\cos\theta_2 + 2.06\cos\theta_3 - 2.33\cos\theta_4 = 2.22$$
$$\sin\theta_2 + 2.06\sin\theta_3 - 2.33\sin\theta_4 = 0$$

$\theta_2 = \pi/3$

$$2.06\cos\theta_3 - 2.33\cos\theta_4 = 1.72$$
$$2.06\sin\theta_3 - 2.33\sin\theta_4 = -.8660$$

- SOLVE USING YOUR FAVORITE AUTOMATED NONLINEAR EQUATION SOLVER

$$\left\{(\theta_3, \theta_4) = (.7807, 1.6811)\right.$$

or

$$(\theta_3, \theta_4) = (-1.7136, -2.6140)$$

$\rightarrow$ OPEN CONFIGURATION

$$-\sin\theta_2\, \omega_2 - 2.06\sin\theta_3\, \omega_3 + 2.33\sin\theta_4\, \omega_4 = 0$$
$$\cos\theta_2\, \omega_2 + 2.06\cos\theta_3\, \omega_3 - 2.33\cos\theta_4\, \omega_4 = 0$$

$$-1.4498\,\omega_3 + 2.3158\,\omega_4 = 4.3301$$
$$1.4635\,\omega_3 + .2565\,\omega_4 = -2.5$$

$$-3.761\begin{bmatrix}\omega_3\\ \omega_4\end{bmatrix} = \begin{bmatrix}.2565 & -2.3158\\ -1.4635 & -1.4498\end{bmatrix}\begin{bmatrix}4.3301\\ -2.5\end{bmatrix} = \begin{bmatrix}6.9002\\ -2.7126\end{bmatrix}$$

$$\vec{\omega}_3 = -1.8346\,\hat{k} \qquad \vec{\omega}_4 = .7212\,\hat{k}$$

$$31^\circ = .5411$$

$$\theta_3 - .5411 = .2397 \sim 13.73^\circ$$

$$\vec{R}_{PA} = 3.06\left[\cos(.2397)\hat{\imath} + \sin(.2397)\hat{\jmath}\right]$$

$$2.9725\,\hat{\imath} + .7265\,\hat{\jmath}$$

$$\vec{V}_A = 5\hat{k} \times (.5\hat{\imath} + .866\hat{\jmath}) = -4.33\hat{\imath} + 2.5\hat{\jmath}$$

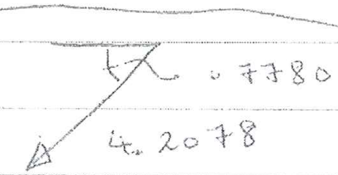
$$\vec{V}_{PA} = \vec{\omega}_3 \times \vec{R}_{PA} = -1.8346\hat{k} \times (2.9725\,\hat{\imath} + .7265\,\hat{\jmath})$$

$$= 1.3328\,\hat{\imath} - 5.4533\,\hat{\jmath}$$

$$\vec{V}_P = \vec{V}_A + \vec{V}_{PA} = -2.9972\hat{\imath} - 2.9533\,\hat{\jmath}$$

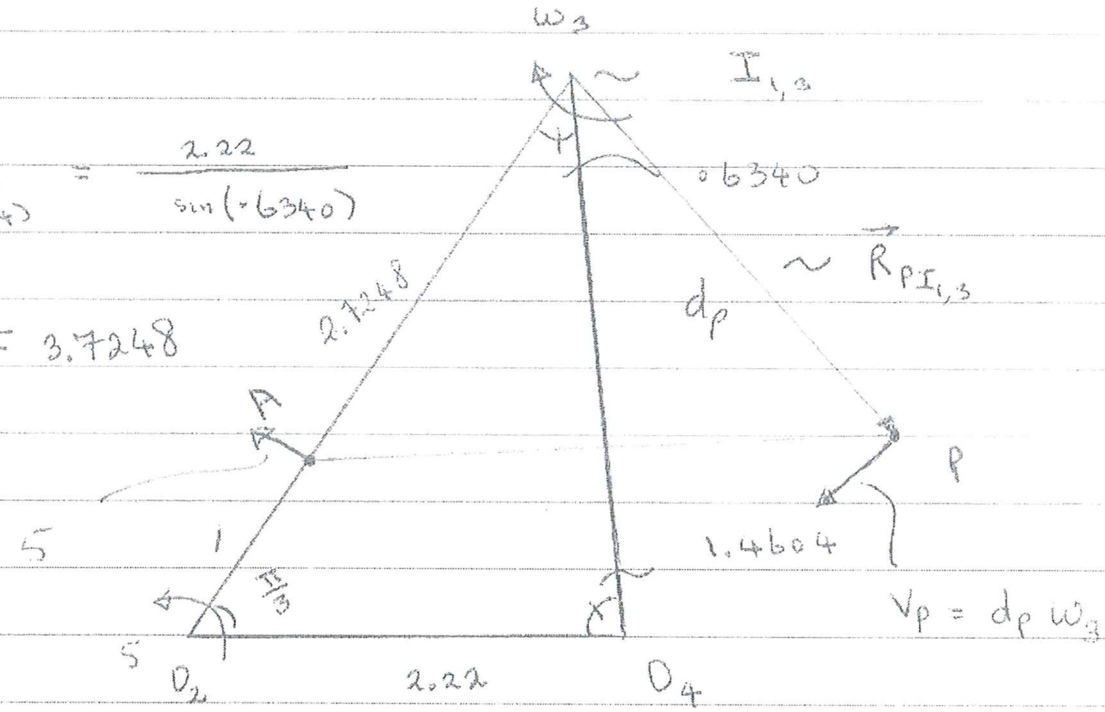
$$|\vec{V}_P| = 4.2078$$

$\vec{V}_P =$



$$\frac{O_2 I_{1,3}}{\sin(1.4604)} = \frac{2.22}{\sin(.6340)}$$

$$O_2 I_3 = 3.7248$$

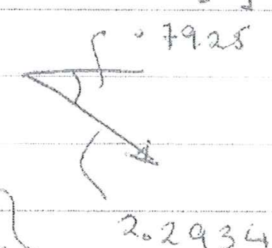


$$2.7248\,\omega_3 = 5 \qquad \omega_3 = 1.835 \text{ rad/s}$$

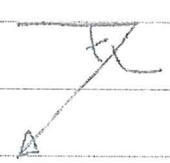
$$\vec{R}_{PI_{1,3}} = \vec{R}_{PA} - \vec{R}_{I_{1,3}A} = \left[2.9725\,\hat{i} + .7265\,\hat{j}\right]$$

$$- 2.7248\left[.5\,\hat{i} + .866\,\hat{j}\right]$$

$$= 1.6101\,\hat{i} - 1.6332\,\hat{j}$$



$$\boxed{\vec{V}_p = 4.2084 \qquad \frac{\pi}{2} - .7925 = .7783}$$



$F_{in} r_2 \omega_{in} =$

$F_{in} r_2 \omega_{in} = F_{out} V_c \qquad V_c = l_6 \left(\frac{r_4}{l_5}\right)\left(\frac{l_2}{h+l_2}\right) \omega_{in}$

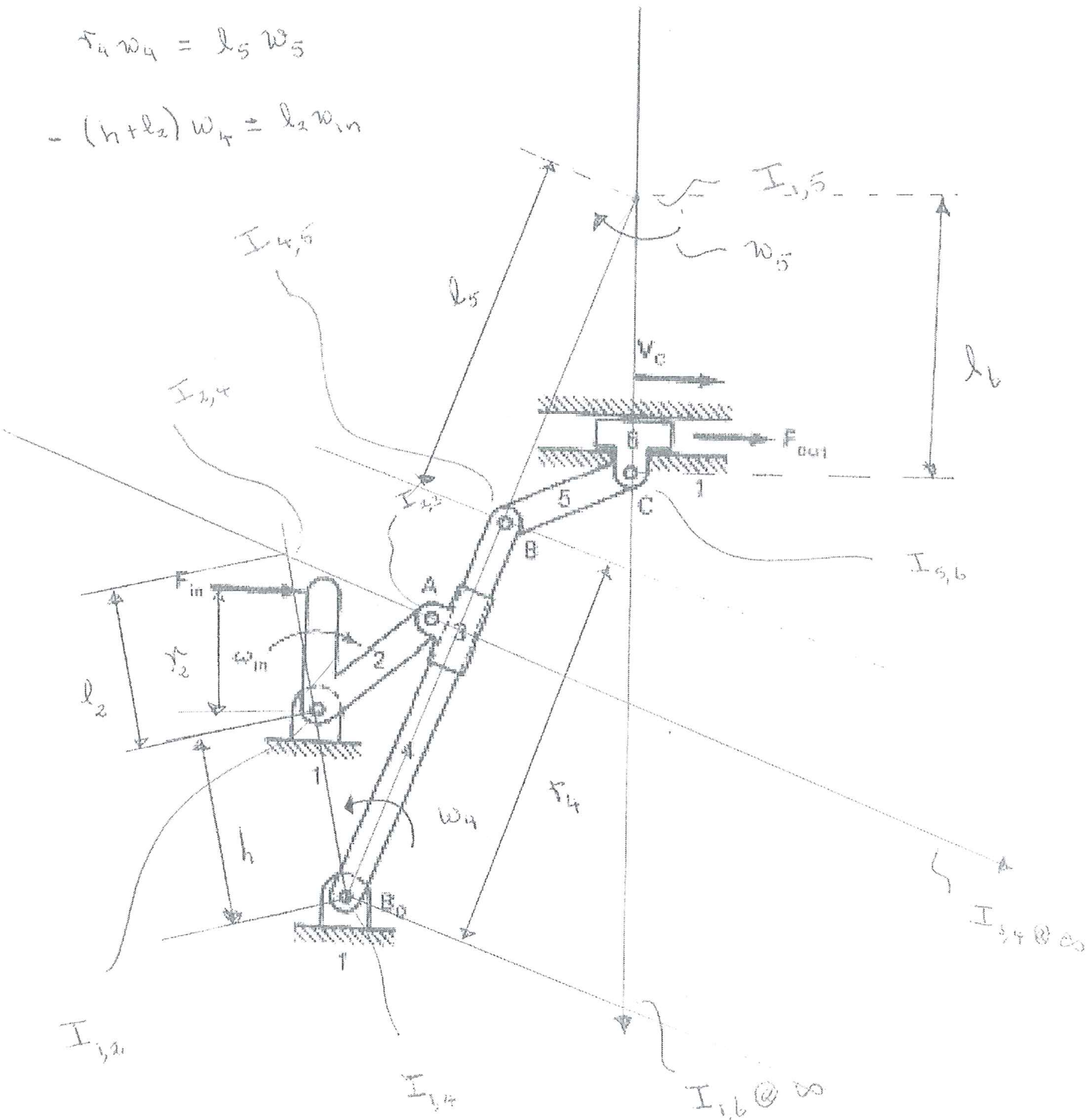
$$M.A. = \frac{r_2 \omega_{in}}{V_c} = \frac{r_2 l_5 (h+l_2)}{l_6 r_4 l_2}$$

2. Using appropriate instant centers, express the mechanical advantage of the mechanism shown in terms of its current geometry.

$V_c = - l_6 \omega_5$

$r_4 \omega_4 = l_5 \omega_5$

$-(h+l_2)\omega_4 = l_2 \omega_{in}$



OR

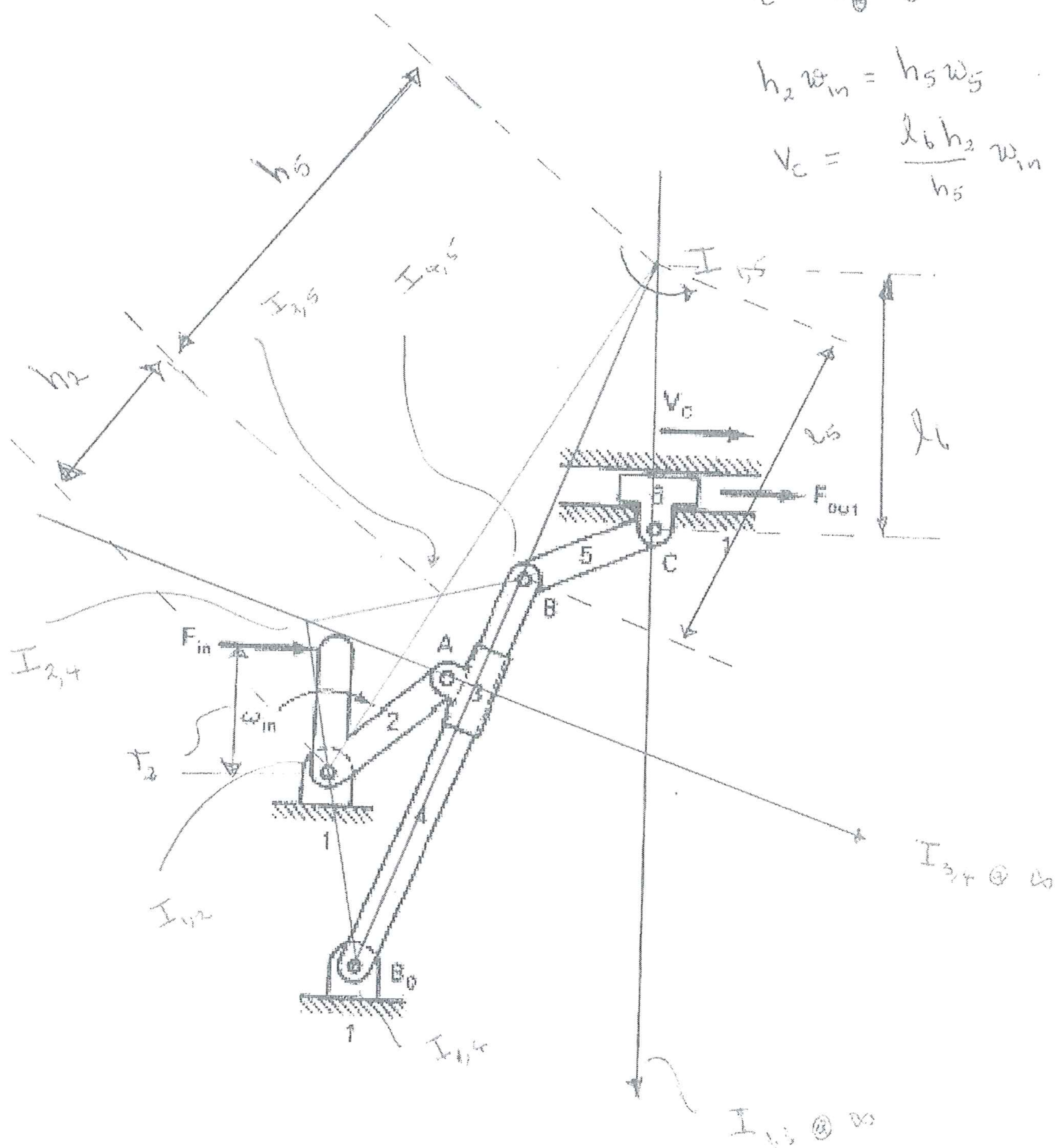
$$M.A. = \frac{T_2 \omega_{in}}{V_c} = \frac{T_2 h_5}{l_6 h_2}$$

2. Using appropriate instant centers, express the mechanical advantage of the mechanism shown in terms of its current geometry.

$V_c = l_6 \omega_5$

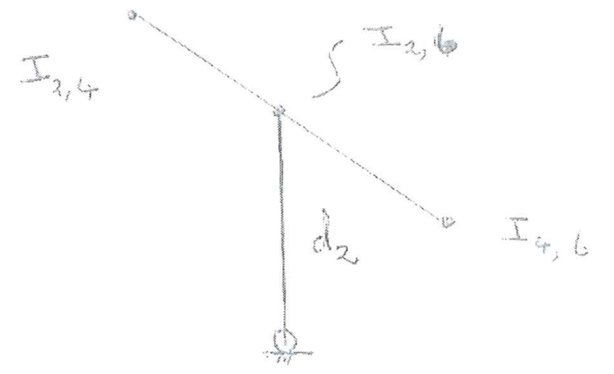
$h_2 \omega_{in} = h_5 \omega_5$

$V_c = \frac{l_6 h_2}{h_5} \omega_{in}$



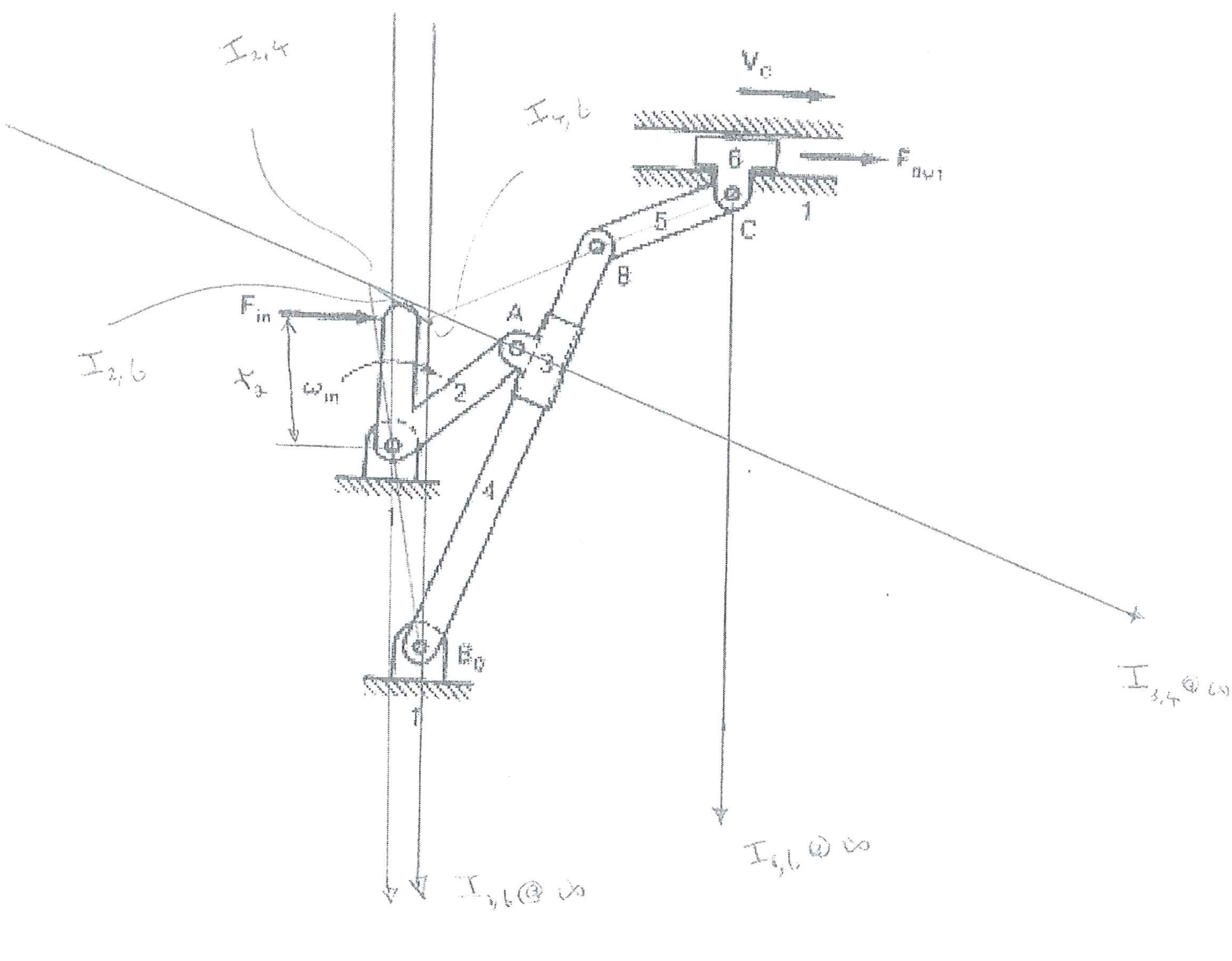
$\boxed{\text{OR}}$

2. Using appropriate instant centers, express the mechanical advantage of the mechanism shown in terms of its current geometry.



$$d_2 \omega_{in} = V_c$$

$$M.A. = \frac{r_2 \omega_{in}}{V_c} = \frac{r_2}{d_2}$$



3. Express the mechanical advantage of the mechanism shown in terms of its current geometry.

(i) Use instant centers $I_{2,5}$, $I_{1,2}$, and $I_{1,5}$.

(ii) Use instant centers $I_{2,6}$, $I_{1,2}$, and $I_{1,6}$.

(iii) Use instant centers $I_{1,2}$, $I_{2,4}$, $I_{1,4}$, and $I_{4,6}$.

$$F_{out} V_c = F_{in} r_2 \omega_2$$

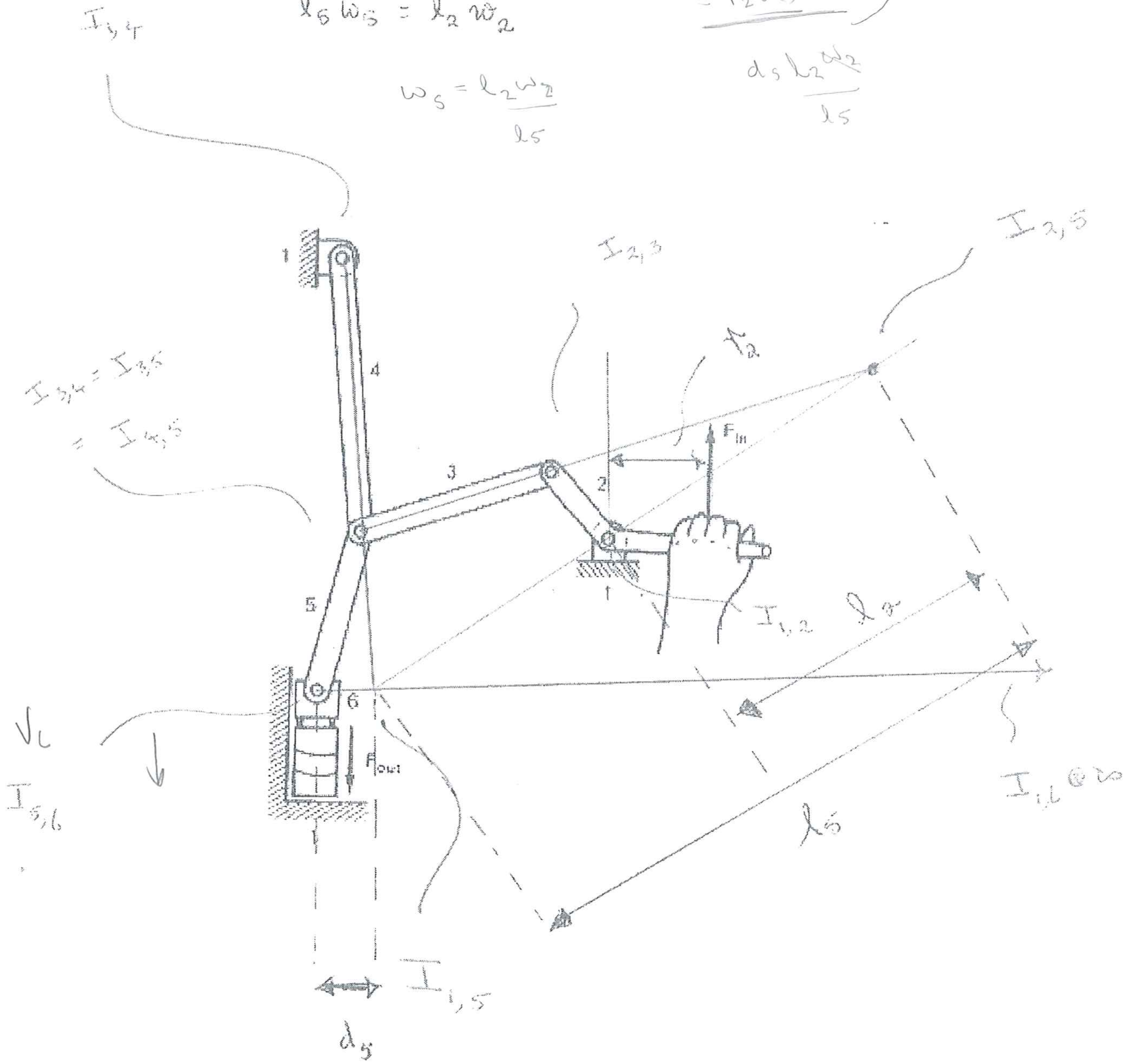
$$M.A. = \frac{r_2 \omega_2}{V_c} = \frac{r_2 l_5}{l_2 d_5}$$

$$V_c = d_5 \omega_5$$

$$l_5 \omega_5 = l_2 \omega_2$$

$$= \frac{r_2 \omega_2}{\frac{d_5 l_2 \omega_2}{l_5}}$$

$$\omega_5 = \frac{l_2 \omega_2}{l_5}$$



3. Express the mechanical advantage of the mechanism shown in terms of its current geometry.

(i) Use instant centers $I_{2,5}$, $I_{1,2}$, and $I_{1,5}$.

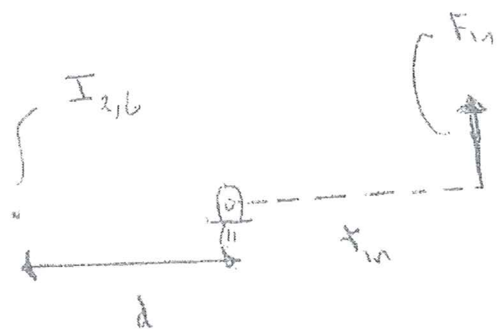
→ (ii) Use instant centers $I_{2,6}$, $I_{1,2}$, and $I_{1,6}$.

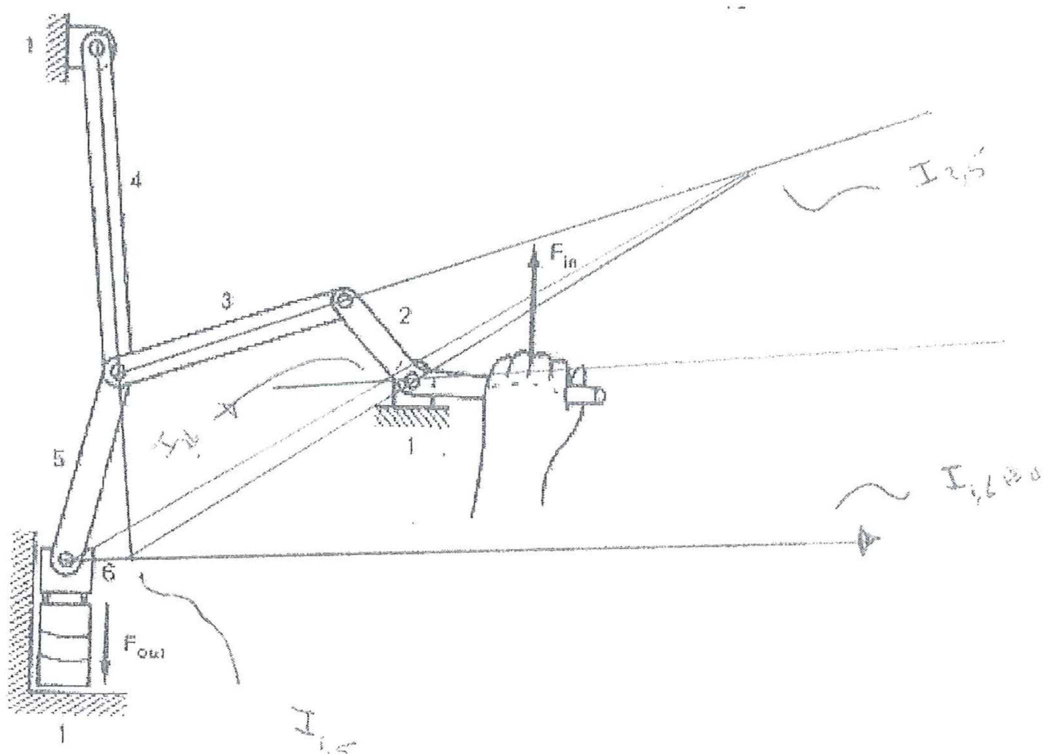
(iii) Use instant centers $I_{1,2}$, $I_{2,4}$, $I_{1,4}$, and $I_{4,6}$.

$$V_{out} = d\omega_2$$

$$MA = (d\omega_2)^{-1}(r_{in}\omega_2)$$

$$= \frac{r_{in}}{d}$$

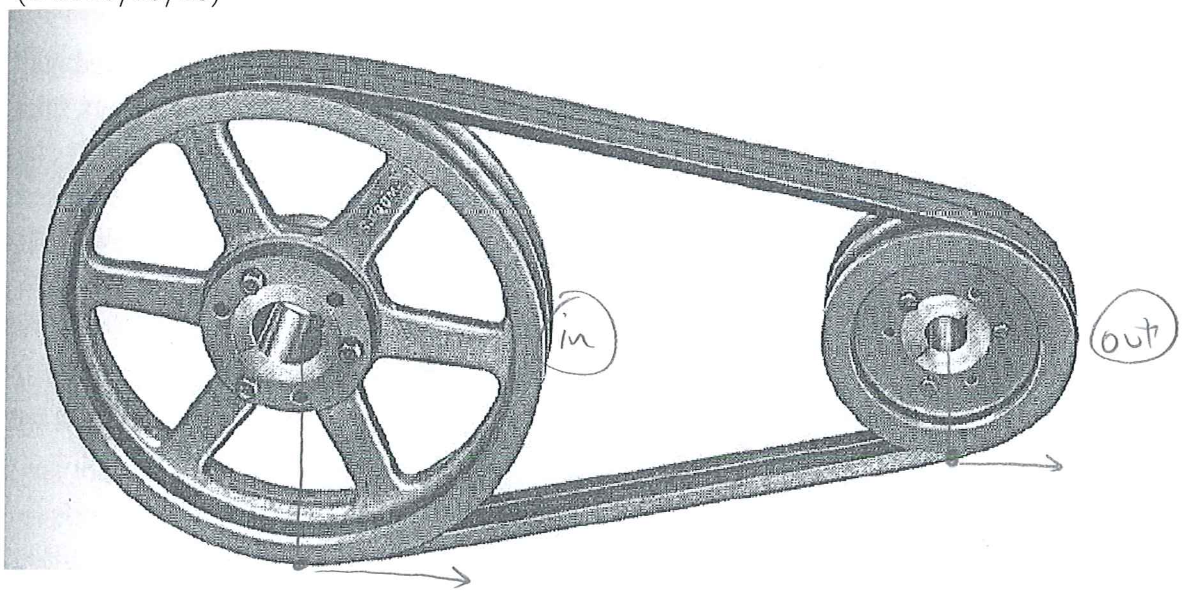




David Malawey

ME 213 A/B HOMEWORK SET 7

(Due 10/15/10)



1. The belt-drive shown transmits torque from the large wheel to the small one via the belt. Develop an expression for the mechanical advantage $\frac{T_{out}}{T_{in}}$ of the belt-drive.

$P_{in} = P_{out}$

$\omega = \frac{v}{r}$ (const)

$T_{in}\,\omega_{in} = T_{out}\,\omega_{out}$

$$\frac{T_{in}}{T_{out}} = \frac{\omega_{in}}{\omega_{out}} = \frac{\frac{\cancel{v}}{r_{in}}}{\frac{\cancel{v}}{r_{out}}} = \boxed{\frac{r_{out}}{r_{in}}}$$

1 2 ✓
1 3 ✓ 2 3 ✓
1 4 ✓ 2 4 ✓ 3 4 ✓
1 5 ✓ 2 5 ✓ 3 5 4 5 ✓
1 6 ✓ 2 6 ✓ 3 6 ✓ 4 6 ✓ 5 6 ✓

12
15 > 25

24
45 > 25

34
45 > 35

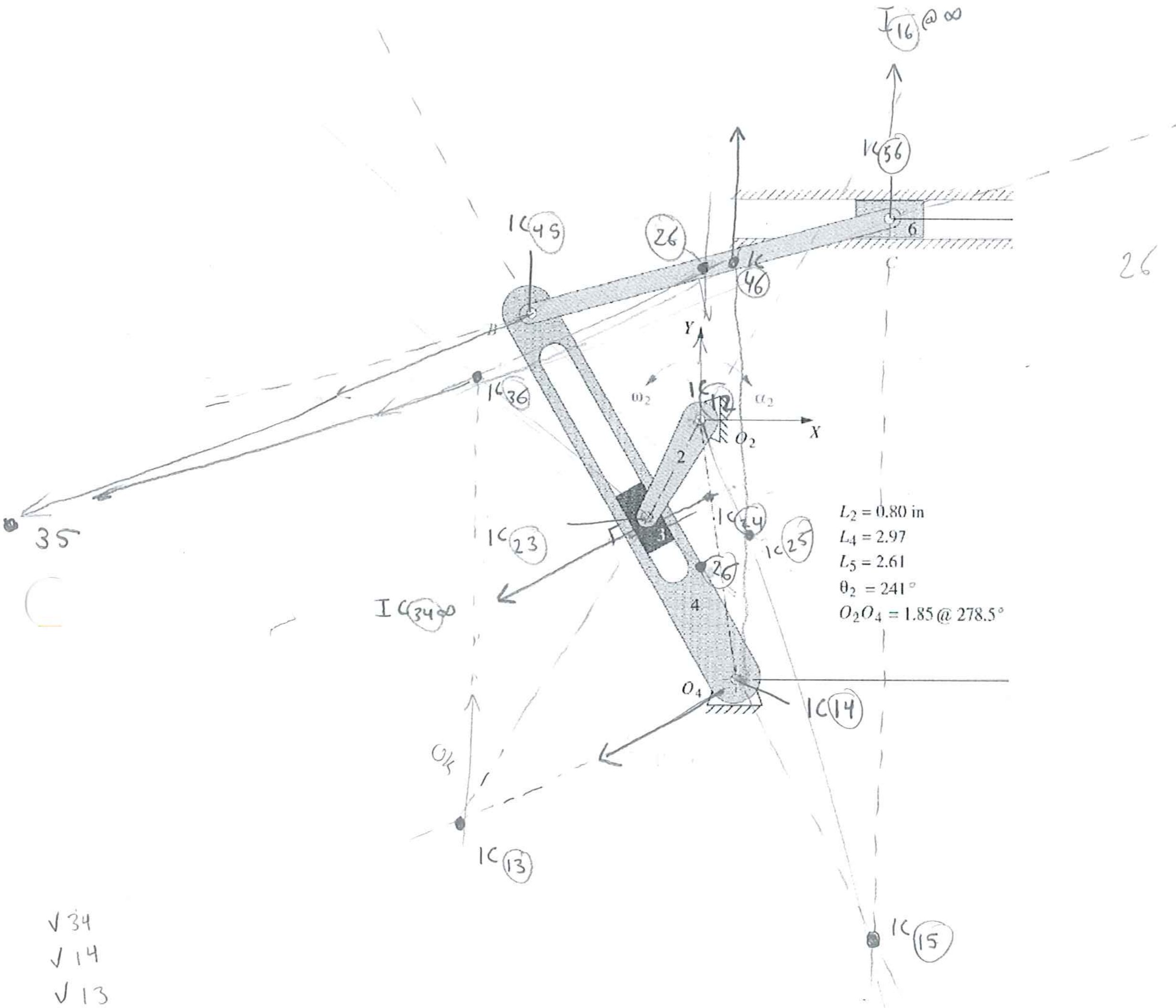
36
65 > 35

16
12 > 26

36
23 > 26

13
16 > 36

43
46 > 36



✓ 34
✓ 14
✓ 13
✓ 21
✓ 23
✓ 45
✓ 46
✓ 15

IC_{61} is @ ∞ along ⊥ to plane of slip

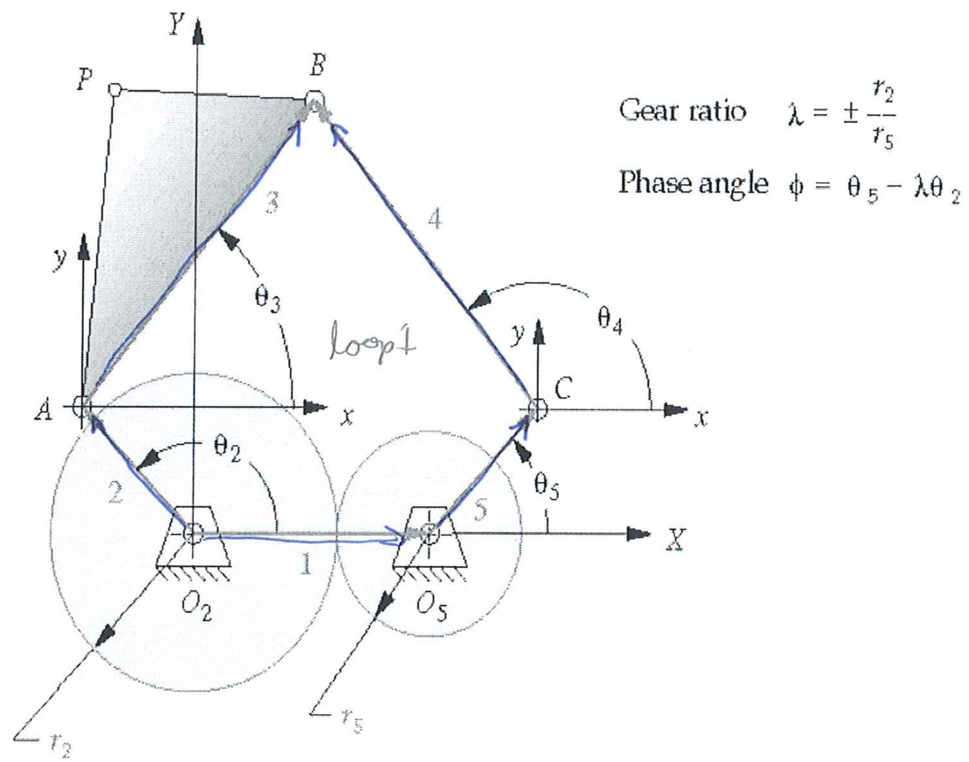
2. For the six-bar mechanism shown, use Kennedy's Rule to locate all 15 instant centers.

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

David Malaway

ME 213 A/B HOMEWORK SET 5

(Due 10/01/10)



1. For the geared five-bar mechanism shown (assuming the lengths of all rigid links are known):

(a) Develop vector-loop equations. Explicitly specify the loop or loops being used.

(b) Consider each vector used in some vector-loop. Is its magnitude constant or variable? Is its orientation constant or variable?

(c) What, if any, geometric constraints exist among vectors used in some vector-loop?

(d) Write the vector-loop equations in components and (if any exist) the constraint equations. Count equations and variables. How many of the variable quantities must be specified to make the system solvable?

David Malawey. Problem #1

1\. a) loop eq'n

$r_2 + r_3 = r_1 + r_5 + r_4$

$\boxed{\text{loop 1: } r_1 + r_5 + r_4 - r_2 - r_3 = 0}$

b)

	dR	θ
r_1	c	c
r_2	c	✓
r_3	c	✓
r_4	c	✓
r_5	c	✓

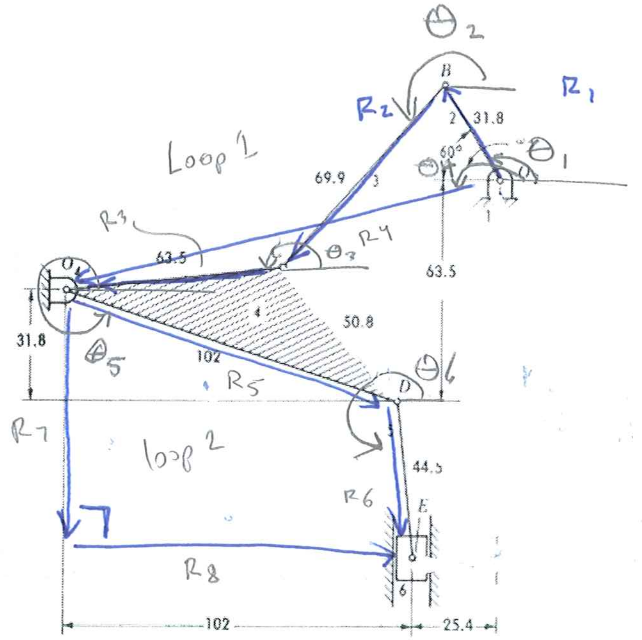
d) $x: \quad r_1 + r_5 \cos\theta_5 + r_4 \cos\theta_4 - r_3 \cos\theta_3 - r_2 \cos\theta_2 = 0$

$y: \quad r_5 \sin\theta_5 + r_4 \sin\theta_4 - r_3 \sin\theta_3 - r_2 \sin\theta_2 = 0$

c) $R_2\theta_2 = -R5\,\theta_5$

$\boxed{R_2\,\theta_2 + R5\,\theta_5 = \text{const}}$

3 equations, 4 variables $\boxed{\text{1 var must be specified to solve}}$



b)

R	d	θ
1	c	V
2	c	V
3	c	V
4	c	c
5	c	V
6	c	V
7	V	c
8	c	c

6 vars

2. For the six-link mechanism shown (the lengths of all rigid links are given in mm.):

(a) Develop vector-loop equations. Explicitly specify the loop or loops being used.

(b) Consider each vector used in some vector-loop. Is its magnitude constant or variable? Is its orientation constant or variable?

(c) What, if any, geometric constraints exist among vectors used in some vector-loop?

(d) Write the vector-loop equations in components and (if any exist) the constraint equations. Count equations and variables. How many of the variable quantities must be specified to make the system solvable?

a) Loop 1

$$R_1 + R_2 + R_3 - R_4 = 0$$

Loop 2

$$R_5 + R_6 - R_7 - R_8 = 0$$

c) $d\theta_5 = d\theta_3$ $\quad \boxed{\theta_5 - \theta_3 = \text{const}}$

d) Loop 1 x: $R_1 \cos\theta_1 + R_2 \cos\theta_2 + R_3 \cos\theta_3 - R_4 \cos\theta_4 = 0$

y: $R_1 \sin\theta_1 + R_2 \sin\theta_2 + R_3 \sin\theta_3 - R_4 \sin\theta_4 = 0$

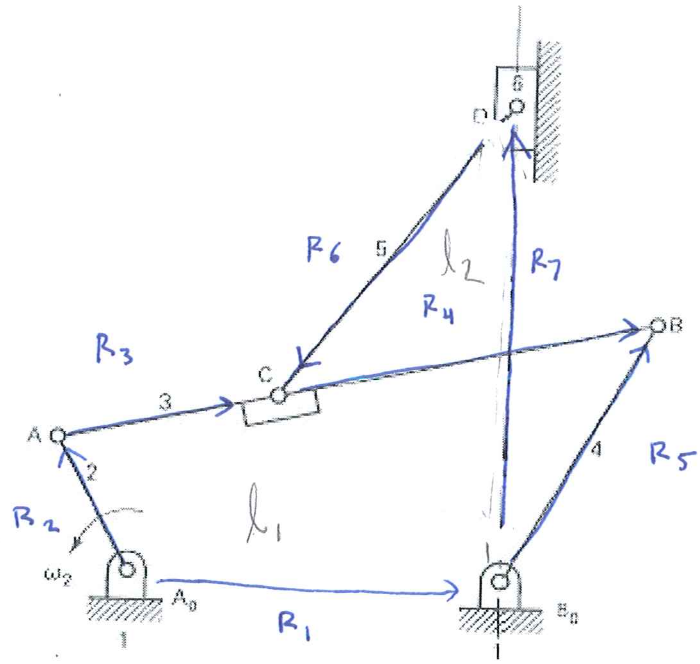
Loop 2 x: $R_5 \cos\theta_5 + R_6 \cos\theta_6 - R_8 = 0$

y: $R_5 \sin\theta_5 + R_6 \sin\theta_6 - R_7 = 0$

$\boxed{\text{5 eq's, 6 unknowns} \quad \text{1 required var specified to solve}}$

1 D.O.F

David Malaney



b)

	d	θ
1	C	C
2	C	V
3	C	V
4	C	V
5	C	V
6	C	V
7	V	C

6 vars

3. For the mechanism shown (assuming the lengths of all rigid links are known):

(a) Develop vector-loop equations. Explicitly specify the loop or loops being used.

(b) Consider each vector used in some vector-loop. Is its magnitude constant or variable? Is its orientation constant or variable?

(c) What, if any, geometric constraints exist among vectors used in some vector-loop?

(d) Write the vector-loop equations in components and (if any exist) the constraint equations. Count equations and variables. How many of the variable quantities must be specified to make the system solvable?

a) $R_2 + R_3 + R_4 - R_1 - R_5 = 0$ (Loop 1)

$R_7 + R_6 + R_4 - R_5 = 0$ (loop 2)

c) $\theta_3 = \theta_4$ $\boxed{\theta_3 - \theta_4 = \text{const}}$

Loop 1 x: $R_2 \cos\theta_2 + R_3 \cos\theta_3 + R_4 \cos\theta_4 - R_1 - R_5 \cos\theta_5 = 0$

y: $R_2 \sin\theta_2 + R_3 \sin\theta_3 + R_4 \sin\theta_4 - R_5 \sin\theta_5 = 0$

Loop 2 x: $R_6 \cos\theta_6 + R_4 \cos\theta_4 - R_5 \cos\theta_5 = 0$

y: $R_7 + R_6 \sin\theta_6 + R_4 \sin\theta_4 - R_5 \sin\theta_5 = 0$

HOMEWOKK 3

ME 213 A/B HOMEWORK SET

David Malawey

(Due 9/17/1[illegible]

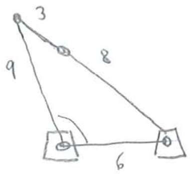
1. The length of the links in a GRCR 4-bar mechanism are $\{R_1, R_2, R_3, R_4\} = \{6, 9, 3,$ [illegible] It is assembled in the Form 1 configuration. Determine any limiting values of the fundamental position angles, and represent their ranges on Barker diagrams.

2. By combining the detailed analysis of problem 1 with the observation that the relative motions of links are frame-independent, generate the Barker tables for the three inversions of that mechanism.

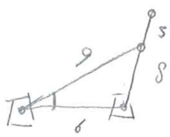
3. Norton, Problem 3-1.

David Malawey HW #3 due 9-17

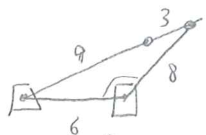
#1)



$$\phi_{34\,max} \quad \cos^{-1}\frac{81+36-121}{2(54)} = 1.608$$

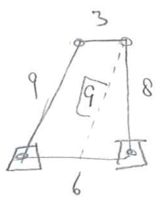


$$\phi_{34\,min} \quad \cos^{-1}\frac{81+36-25}{2(54)} = .5513$$

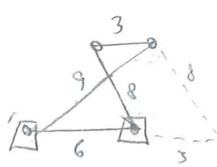


$$\phi_{23\,max} \quad \cos^{-1}\frac{64+36-144}{2(48)} = 2.047$$

$$\phi_{23\,min} \quad \cos^{-1}\frac{64+36-36}{2(48)} = .8411$$



$$\phi_{13\,min} \quad \cos^{-1}\frac{64+81-9}{2(72)} = .3349$$



$$\phi_{13\,max} \quad \cos^{-1}\frac{64+81-81}{2(72)} = 1.110$$

ϕ_{12} ϕ_{13} ϕ_{14} ϕ_{23} ϕ_{24} ϕ_{34}

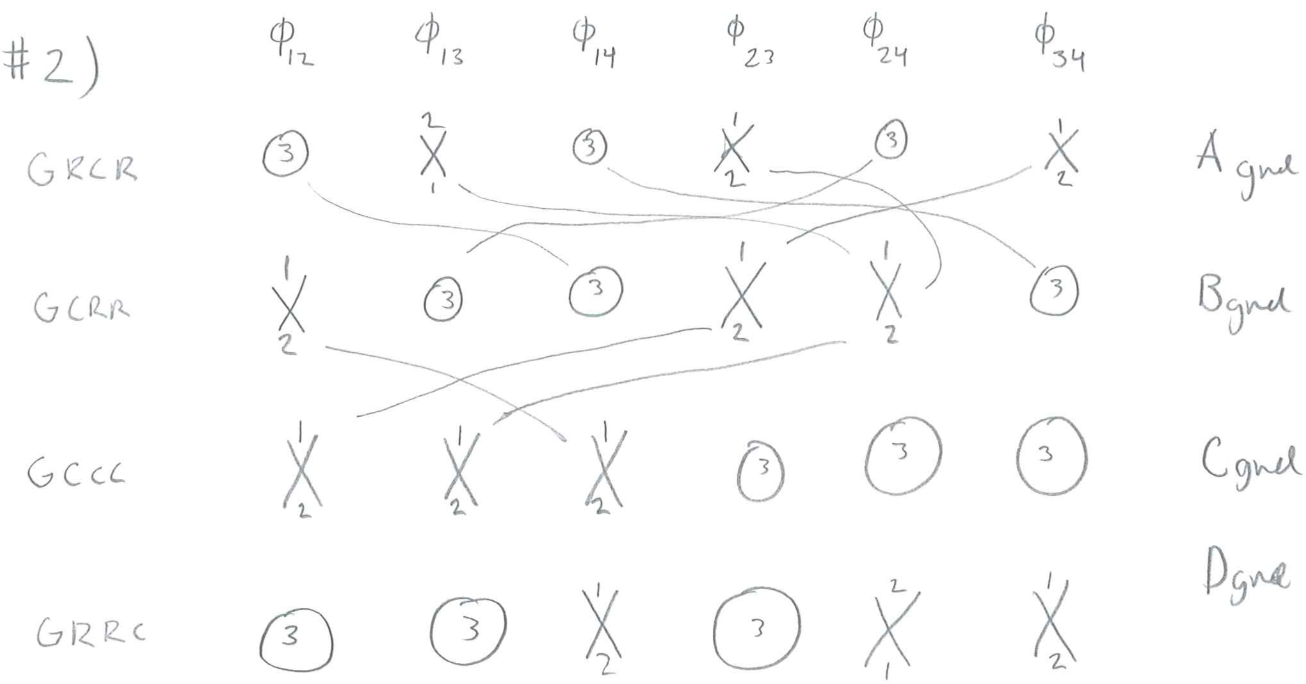
David Malawey

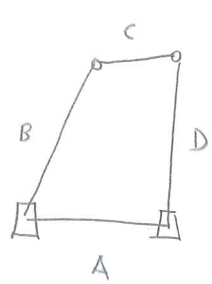
#3)

Norton # 3-1

path	motion	function generation
a		
	b	
		c
d		
e		

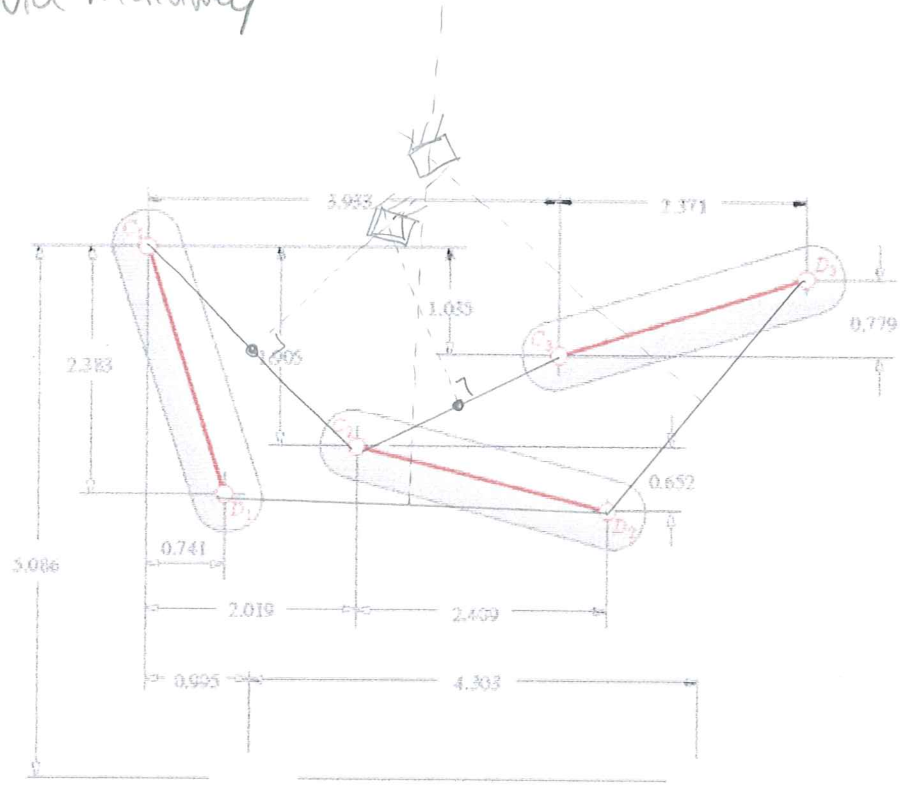
#2)





David Malawey

#4



[Norton. Problem 3-5.] Design a non-quick-return four-bar mechanism to give the three positions of coupler motion shown. Classify this mechanism according to the Barker scheme. Determine the range of ϕ_{12} it attains, and find its minimum transmission angle.

$Y = mx + b$

$b = Y - mx$

$4.13 = 1.06(1.01) + b$

$3.616 = -2.20(2.98) + b$

l_2	2.19
l_4	3.78
Coupler	2.50
gnd	0.78

$s + l = .78 + 3.78 = 4.56$

$p + q = 4.69$

$s + l < p + q \Rightarrow$ Barker type I GCCC

B

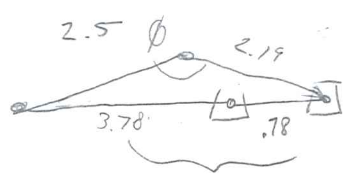
	x	y
c1	0	5.086
c2	2.019	3.181
c3	3.933	4.051
d1	0.741	2.703
d2	4.428	2.529
d3	6.304	4.83

	Midpoint x	Midpoint y	slope	perpendicular slope	b = y - x(m)
c1 & c2	1.010	4.134	-0.944	1.060	3.064
c2& c3	2.976	3.616	0.455	-2.200	10.163
d1&d2	2.585	2.616	-0.047	21.190	-52.149
d2&d3	5.366	3.680	1.227	-0.815	8.054

intersection of lines

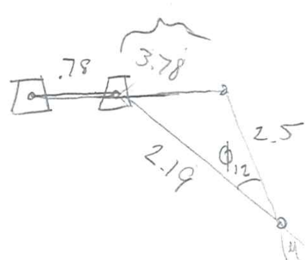
	mx + b = mx + b	x=	y=
C lines	1.06x + 3.06 = -2.20x + 10.16	2.178	5.372
D lines	21.19x -52.15 = -.82x + 8.05	2.740	5.911

length of links	
link 2	2.197
link 4	3.780
coupler	2.496
ground linl	0.779



$$\phi_{12}\ max = \cos^{-1}\left[\frac{2.5^2 + 2.19^2 - 4.56^2}{2(2.5)(2.19)}\right]$$

$$= \boxed{2.67\ rad}$$



$$\phi_{12}\ min = \cos^{-1}\left[\frac{2.5^2 + 2.19^2 - 3^2}{2(2.5)(2.19)}\right]$$

$$= \boxed{1.38\ rad}$$

Minimum transmission angle, μ

$\mu = \pi - 2.67$ rad

$\boxed{\mu_{(min)} = .476}$ rad

ME 213 A/B HOMEWORK SET 2

(Due 9/10/10)

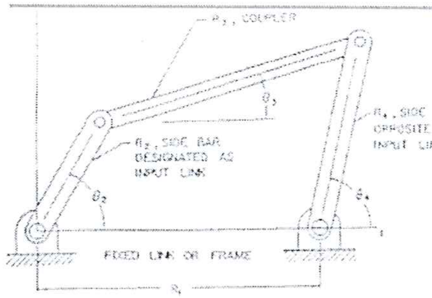


Fig. 1. Typical planar four-bar mechanism.

1. For each of the following hypothetical 4-bars: (a) Determine whether it can be assembled, (b) if so, determine its type according to the Barker classification.

$$\{R_1, R_2, R_3, R_4\} = \{6, 10, 4, 7\} \tag{1}$$

$$\{R_1, R_2, R_3, R_4\} = \{12, 6, 5, 8\} \tag{2}$$

$$\{R_1, R_2, R_3, R_4\} = \{13, 2, 5, 5\} \tag{3}$$

$$\{R_1, R_2, R_3, R_4\} = \{9, 18, 10, 11\} \tag{4}$$

$$\{R_1, R_2, R_3, R_4\} = \{9, 8, 4, 6\} \tag{5}$$

2. A GCCC 4-bar mechanism has lengths $\{R_1, R_2, R_3, R_4\} = \{4, 9, 6, 8\}$, and is assembled in the Form 1 configuration. Sketch, with numbers, the ranges of the six fundamental position angles for this mechanism.

3. A GCRR 4-bar mechanism has lengths $\{R_1, R_2, R_3, R_4\} = \{8, 4, 9, 6\}$, and is assembled in the Form 2 configuration. Sketch, with numbers, the ranges of the six fundamental position angles for this mechanism.

David Mahoney

Homework Set #2

#1) $\{R_1, R_2, R_3, R_4\} = \{6, 10, 4, 7\}$ assembleable.

1) $s = L_3$ $\quad l = L_2$ $\quad s+L > p+q$ $\quad$ Type 6 Barker RRR2

2) $(12, 6, 5, 8)$ assembleable, $s+L > p+q$ $\quad L_1 = l$ $\quad$ Type 5 RRR1

3) $13, 2, 5, 5$ not assembleable

4) $9, 18, 10, 11$ yes, $s+l > p+q$ $\quad L_2 = l$ $\quad$ Type 6 RRR2

5) $9, 8, 4, 6$ yes, $s+l < p+q$ $\quad L_3 = s$ $\quad$ Type 3 GRCR

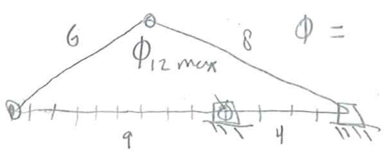
#2

GCCC $\{4, 9, 6, 8\}$ Form 1 configuration

$s+l < p+q$ $\quad s = L_1$ $\quad$ GCCC Type 1

ϕ_{12} $\quad \phi_{13}$ $\quad \phi_{14}$ $\quad \phi_{23}$ $\quad \phi_{24}$ $\quad \phi_{34}$

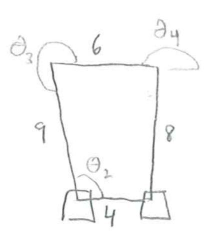
$\phi_{12} = \theta_4 - \theta_3$ $\quad$ form 1, $\quad 0 < \phi_{12} < \pi$



$\phi =$ $\quad 2ab\cos\theta_c = a^2 + b^2 - c^2$

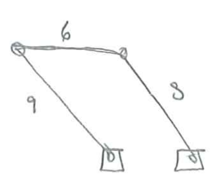
max. $\theta_{12} = 2.373$

min $\theta_{12} = \overset{6}{\underset{5}{\triangle}}{}^{8} \Rightarrow .6741$



$\phi_{13} = \theta_2 - \theta_4$ $\quad$ Min @ sides 9 & 8 parallel

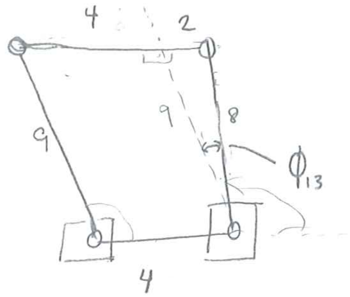
$$\boxed{\phi_{12}\ \text{Max} = 2.37}$$



$$\boxed{\phi_{12}\ \text{min} = .674}$$

2 continued

Note: $-\pi \le \phi \le \pi$

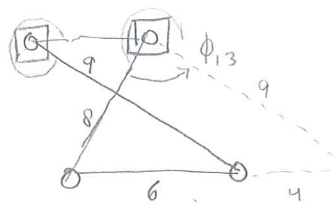


ϕ_{13} min when other 2 parallel

$$\phi_{13\,min} = \cos^{-1}\left[\frac{8^2+9^2-2^2}{2(8\cdot 9)}\right]$$

$$\boxed{\phi_{13\,min} = .2045 \text{ rad}}$$

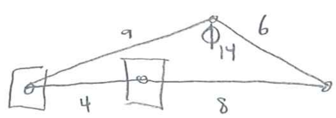
$\theta_2 - \theta_4$



$$2\cdot 8\cdot 9\cos\phi_{13} = 8^2+9^2-10^2$$

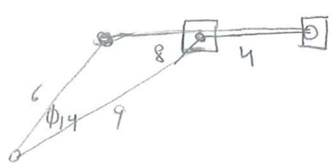
$$\boxed{\phi_{13\,max} = 1.253}$$

ϕ_{14} faces 1 & 4 $= \pi - \theta_2 + \theta_3$



$$\phi_{14} = \cos^{-1}\left[\frac{81+36-144}{2(9\cdot 6)}\right]$$

$$\boxed{\phi_{14\,max} = 1.823 \text{ rad}}$$



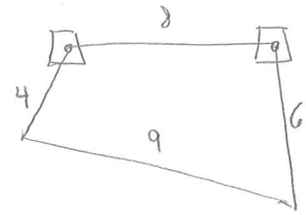
$$\phi_{14} = \cos^{-1}\left[\frac{81+36-16}{2(9\cdot 6)}\right]$$

$$\boxed{\phi_{14\,min} = .362}$$

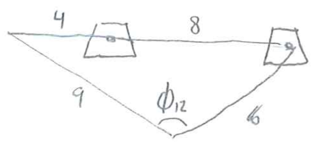
\#3

GCRR $\{8,4,9,6\}$

ϕ_{12} ϕ_{13} ϕ_{14} ϕ_{23} ϕ_{24} ϕ_{34}



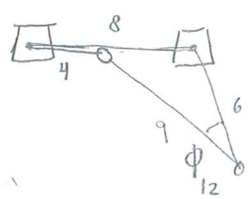
1 & 2 parallel



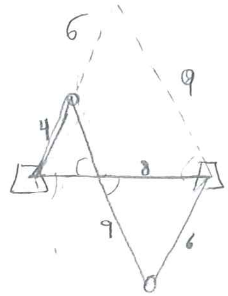
$$\phi_{12\,max} = \cos^{-1}\left[\frac{36+81-144}{2\cdot 9\cdot 6}\right]$$

$$\boxed{\phi_{12\,max} = 1.823 \text{ rad}}\ \checkmark$$

1 & 2 parallel



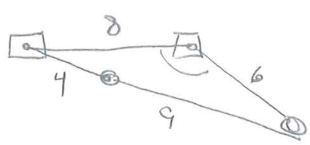
$$\phi_{12\,min} = \cos^{-1}\left[\frac{36+81-16}{2\cdot 6\cdot 9}\right] \quad \boxed{\phi_{12\,min} = .3620 \text{ rad}}\ \checkmark$$



$$\phi_{max} = \cos^{-1}\left[\frac{81+64-100}{2\cdot 72}\right]$$

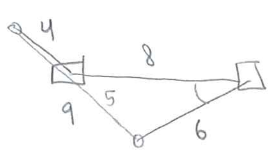
$$\boxed{\phi_{24\,max} = 1.253 \text{ rad}}\ \checkmark$$

2 & 3 parallel



$$\phi_{23} = \cos^{-1}\left[\frac{64+36-13^2}{2\cdot 8\cdot 6}\right]$$

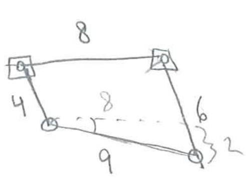
$$\boxed{\phi_{23\,max} = 2.37 \text{ rad}}\ \checkmark$$



$$\phi_{23\,min} = \cos^{-1}\left[\frac{64+36-25}{(2\cdot 8\cdot 6)}\right]$$

$$\boxed{\phi_{23\,min} = .6741 \text{ rad}}\ \checkmark$$

2 & 4 parallel



$$\phi_{24\,min} = \cos^{-1}\left[\frac{81+64-4}{2\cdot 9\cdot 8}\right]$$

$$\boxed{\phi_{24\,min} = .2045}\ \checkmark$$

ME 213 hw, due in class 9/3/10 HOMEWORK 1

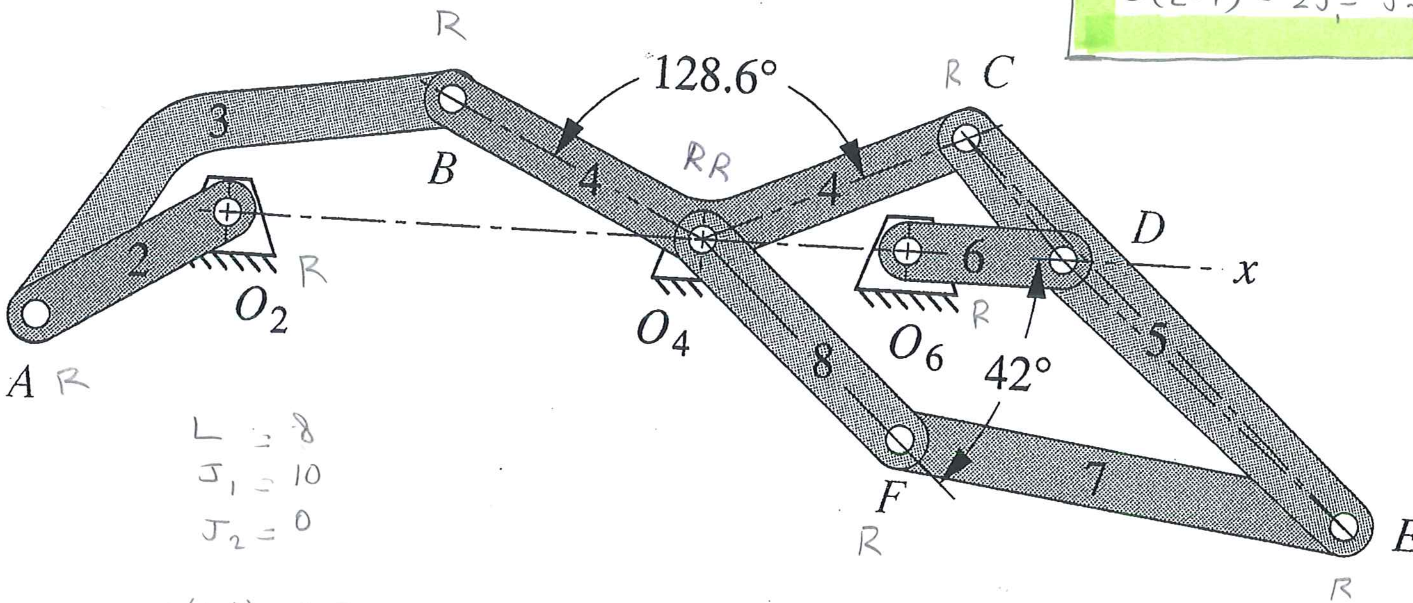
David Malawey

For each of the mechanisms shown:

(1) Identify and label all joints. (2) Calculate the mobility.

MOBILITY =

$3(L-1) - 2J_1 - J_2$



$L = 8$

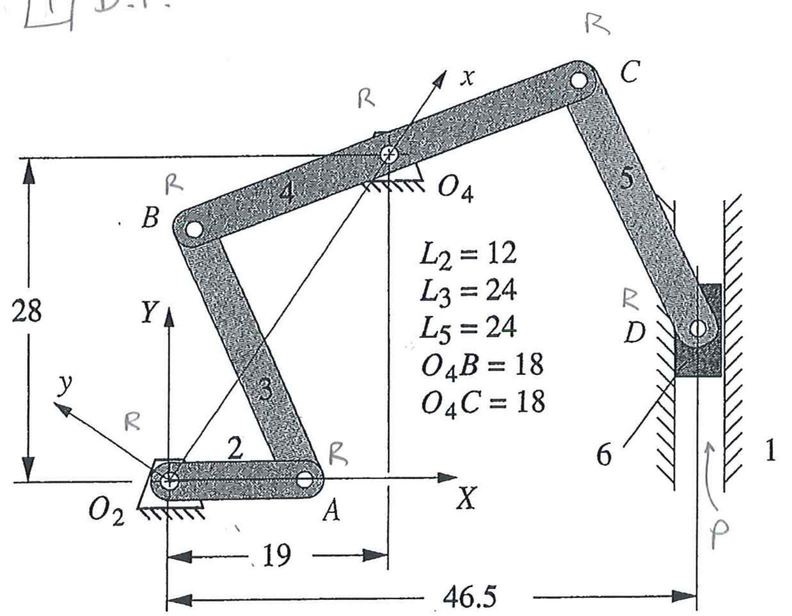
$J_1 = 10$

$J_2 = 0$

$M = 3(L-1) - 2J_1 - J_2 =$

$= 3(7) - 2(10)$

$= 21 - 20 = \boxed{1}$ D.F.



$L = 6$

$J_1 = 7$

$J_2 = 0$

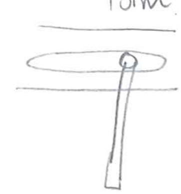
$M = 3(6-1) - 2(7) - 0$

$= 15 - 14$

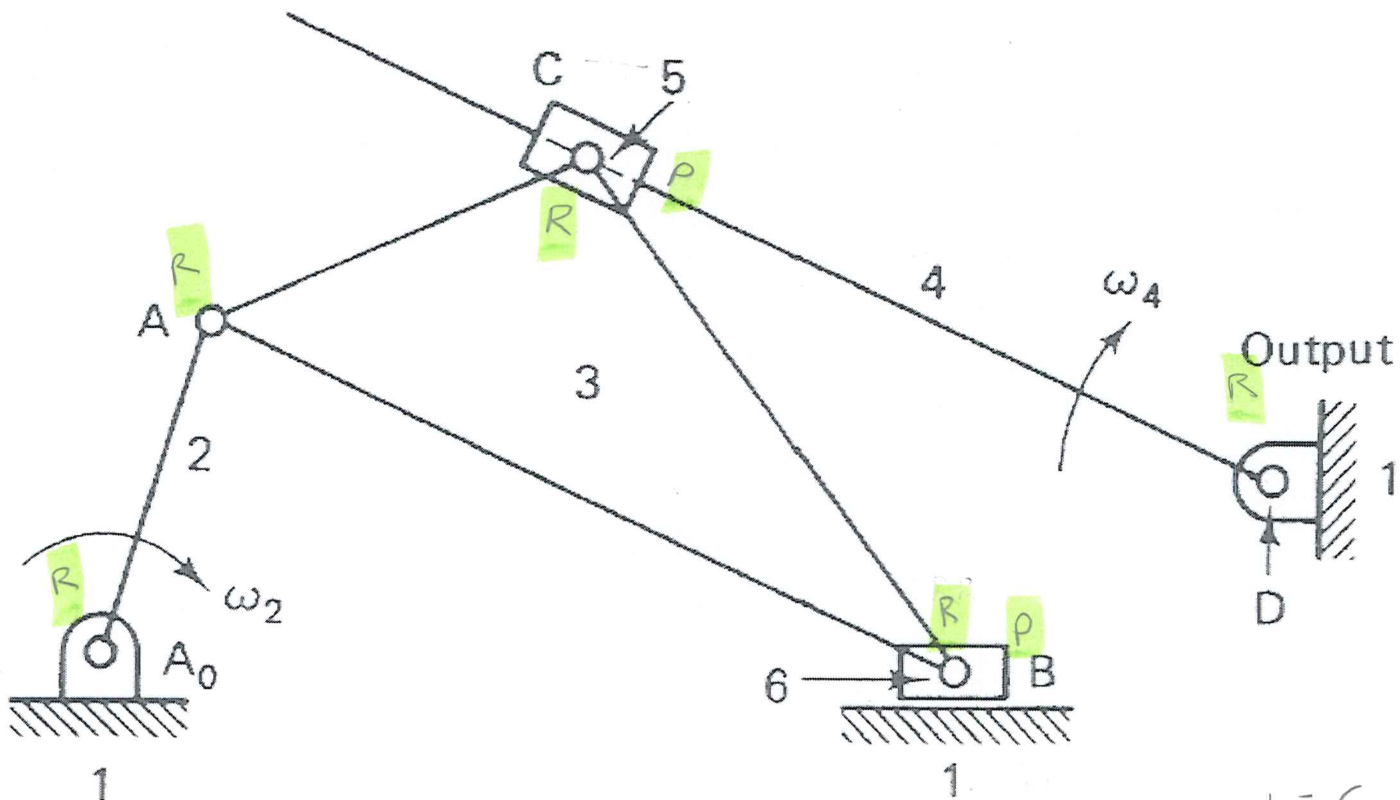
$= \boxed{1}$ DOF

these half joints only

2 Form closed



Force closed

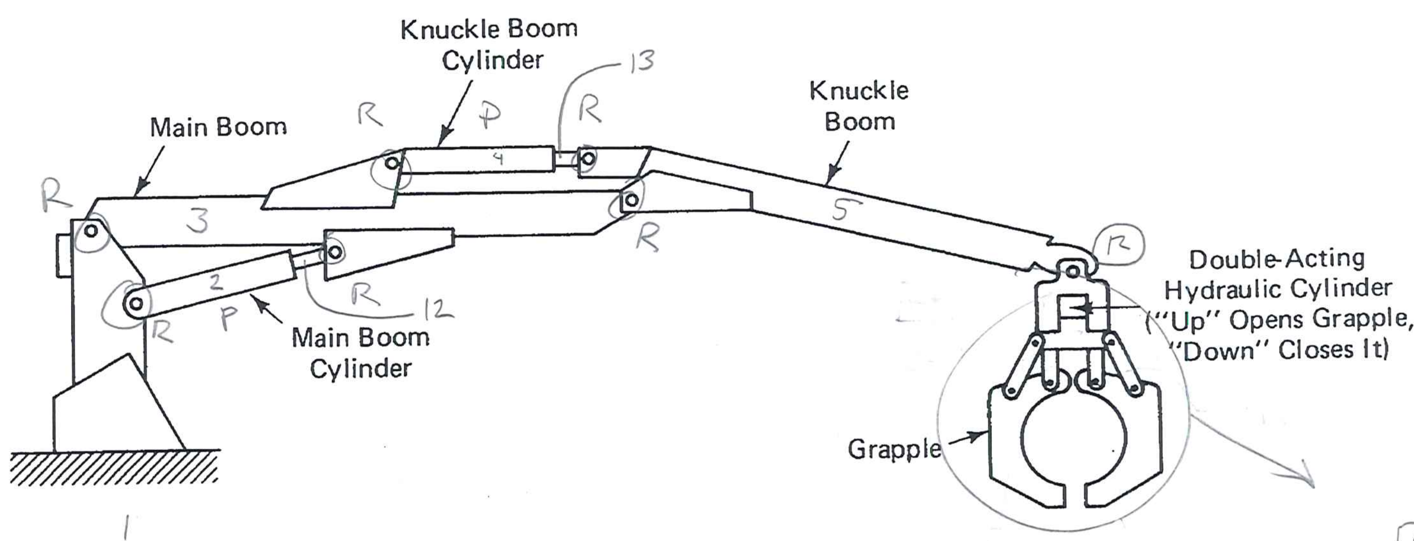


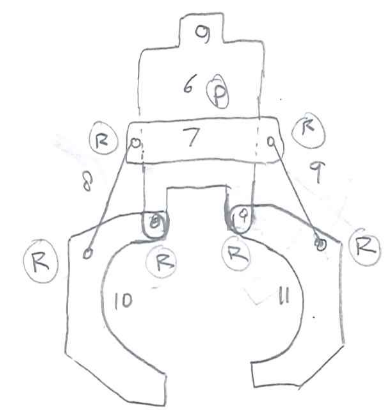
$L = 6$
$J_1 = 7$
$J_2 = 0$

$M = 3(6-1) - 2(\ ) - 0$
$= 15 - 14$
$= \boxed{1}$ D.O.F.

$L = 6$
$J_1 = 7$

$M = 3(6-1) - 2(7)$
$= 15 - 14 = \boxed{1}$ DOF





$\# L = 13$

$J_1 = 16$

$M = 3(12) - 2(16) - 0$

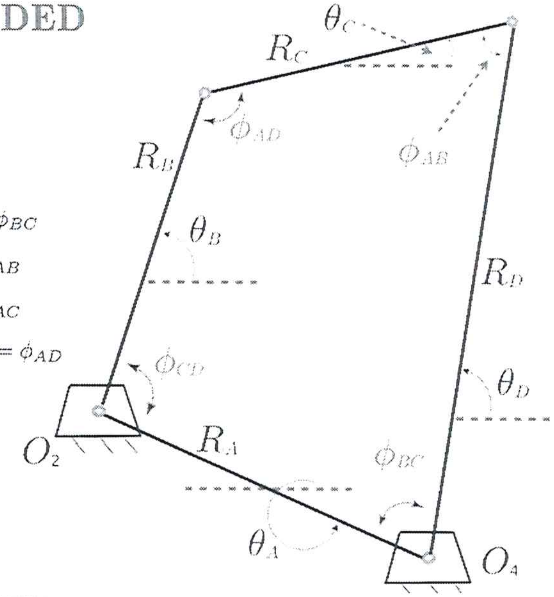
$= 36 - 32$

$= \boxed{4 \text{ D.O.F.}}$

Exam practice

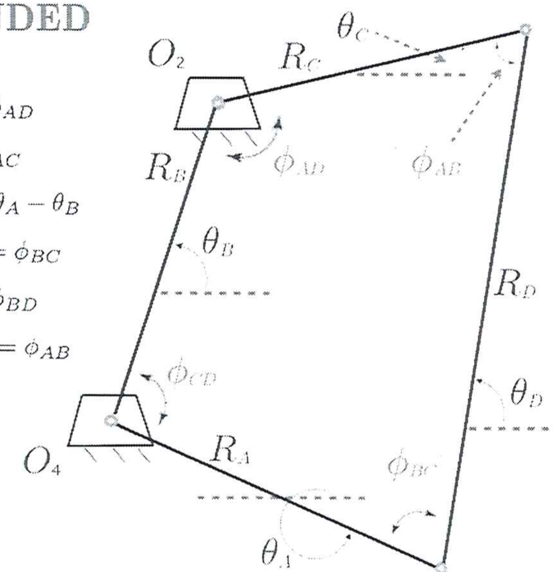
LINK A GROUNDED

$$\theta_2 = \theta_B - \theta_A = \phi_{34} = \phi_{CD}$$
$$\theta_3 = \theta_C - \theta_A = \phi_{24} = \phi_{BD}$$
$$\theta_4 = \theta_D - \theta_A = \pi - \phi_{23} = \pi - \phi_{BC}$$
$$\phi_{12} = \theta_4 - \theta_3 = \theta_D - \theta_C = \phi_{AB}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_B - \theta_D = \phi_{AC}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = \pi - \theta_B + \theta_C = \phi_{AD}$$



LINK B GROUNDED

$$\theta_2 = \pi + \theta_C - \theta_B = \phi_{34} = \phi_{AD}$$
$$\theta_3 = \theta_D - \theta_B = \phi_{24} = -\phi_{AC}$$
$$\theta_4 = \pi - \phi_{23} = \pi - \phi_{CD} = \pi + \theta_A - \theta_B$$
$$\phi_{12} = \theta_4 - \theta_3 = \pi + \theta_A - \theta_D = \phi_{BC}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_C - \theta_A = \phi_{BD}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = -\theta_C + \theta_D = \phi_{AB}$$

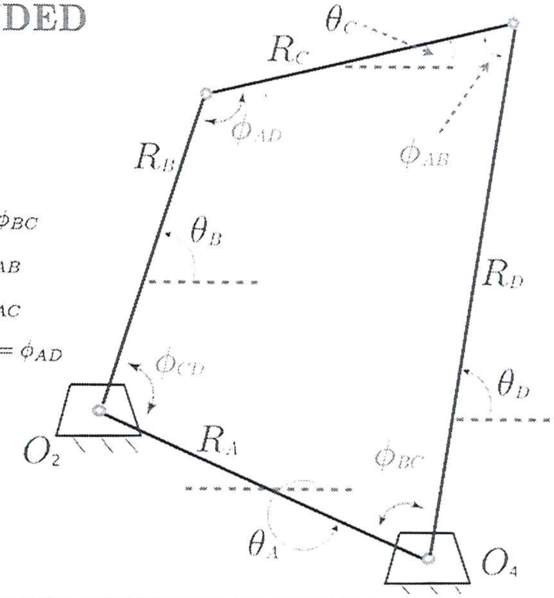


LINK A GROUNDED	LINK B GROUNDED
$\theta_2 = \theta_B - \theta_A = \phi_{34} = \phi_{CD}$	$\theta_2 = \pi + \theta_C - \theta_B = \phi_{34} = \phi_{AD}$
$\theta_3 = \theta_C - \theta_A = \phi_{24} = \phi_{BD}$	$\theta_3 = \theta_D - \theta_B = \phi_{24} = -\phi_{AC}$
$\theta_4 = \theta_D - \theta_A = \pi - \phi_{23} = \pi - \phi_{BC}$	$\theta_4 = \pi - \phi_{23} = \pi - \phi_{CD} = \pi + \theta_A - \theta_B$
$\phi_{12} = \theta_4 - \theta_3 = \theta_D - \theta_C = \phi_{AB}$	$\phi_{12} = \theta_4 - \theta_3 = \pi + \theta_A - \theta_D = \phi_{BC}$
$\phi_{13} = \theta_2 - \theta_4 = \theta_B - \theta_D = \phi_{AC}$	$\phi_{13} = \theta_2 - \theta_4 = \theta_C - \theta_A = \phi_{BD}$
$\phi_{14} = \pi - \theta_2 + \theta_3 = \pi - \theta_B + \theta_C = \phi_{AD}$	$\phi_{14} = \pi - \theta_2 + \theta_3 = -\theta_C + \theta_D = \phi_{AB}$

CAN GENERATE THE BARKER DIAGRAMS FOR CASE 2 FROM THOSE FOR CASE 1.

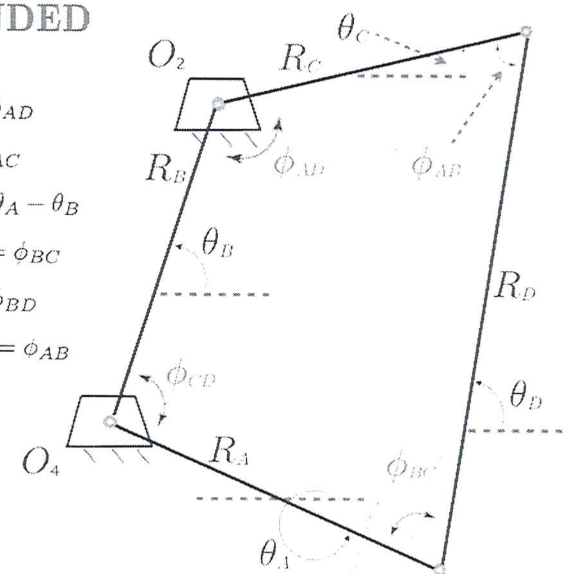
LINK A GROUNDED

$$\theta_2 = \theta_B - \theta_A = \phi_{34} = \phi_{CD}$$
$$\theta_3 = \theta_C - \theta_A = \phi_{24} = \phi_{BD}$$
$$\theta_4 = \theta_D - \theta_A = \pi - \phi_{23} = \pi - \phi_{BC}$$
$$\phi_{12} = \theta_4 - \theta_3 = \theta_D - \theta_C = \phi_{AB}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_B - \theta_D = \phi_{AC}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = \pi - \theta_B + \theta_C = \phi_{AD}$$



LINK B GROUNDED

$$\theta_2 = \pi + \theta_C - \theta_B = \phi_{34} = \phi_{AD}$$
$$\theta_3 = \theta_D - \theta_B = \phi_{24} = -\phi_{AC}$$
$$\theta_4 = \pi - \phi_{23} = \pi - \phi_{CD} = \pi + \theta_A - \theta_B$$
$$\phi_{12} = \theta_4 - \theta_3 = \pi + \theta_A - \theta_D = \phi_{BC}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_C - \theta_A = \phi_{BD}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = -\theta_C + \theta_D = \phi_{AB}$$



LINK A GROUNDED

$$\theta_2 = \theta_B - \theta_A = \phi_{34} = \phi_{CD}$$
$$\theta_3 = \theta_C - \theta_A = \phi_{24} = \phi_{BD}$$
$$\theta_4 = \theta_D - \theta_A = \pi - \phi_{23} = \pi - \phi_{BC}$$
$$\phi_{12} = \theta_4 - \theta_3 = \theta_D - \theta_C = \phi_{AB}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_B - \theta_D = \phi_{AC}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = \pi - \theta_B + \theta_C = \phi_{AD}$$

LINK B GROUNDED

$$\theta_2 = \pi + \theta_C - \theta_B = \phi_{34} = \phi_{AD}$$
$$\theta_3 = \theta_D - \theta_B = \phi_{24} = -\phi_{AC}$$
$$\theta_4 = \pi - \phi_{23} = \pi - \phi_{CD} = \pi + \theta_A - \theta_B$$
$$\phi_{12} = \theta_4 - \theta_3 = \pi + \theta_A - \theta_D = \phi_{BC}$$
$$\phi_{13} = \theta_2 - \theta_4 = \theta_C - \theta_A = \phi_{BD}$$
$$\phi_{14} = \pi - \theta_2 + \theta_3 = -\theta_C + \theta_D = \phi_{AB}$$

CAN GENERATE THE BARKER DIAGRAMS FOR CASE 2 FROM THOSE FOR CASE 1.

4. **(15 pts)** Circle the atom or ion **WITHIN EACH PAIR** that has (according to the general trend)
… the larger atomic radius:

a) Ge Sn **b)** Tl Pb **c)** Cl Ne

… the larger ionic radius:

ME 213 B SPRING 2010 TEST 3

d) As^{3-} Se^{2-} **e)** Co^{2+} Rh^{2+} **f)** V^{2+} V^{5+}

… the larger first ionization energy:

g) Ca K **h)** Si Ge **i)** N Si

… the more negative electron affinity:

j) Sb Sn **k)** P N **l)** S F

… the higher electronegativity:

m) Sr Rb **n)** Si N **o)** Ga In

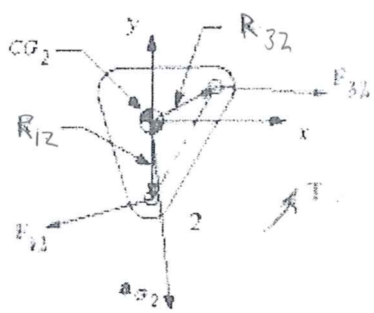
NAME:__________________

5. **(6 pts)** Write the five **IONS** made by the elements As, Se, Rb, Sr and Y that are isoelectronic, have the same number of electrons, as the bromide ion (Br^-) in order of increasing radius.

_____ < _____ < _____ < _____ < _____

6. **(28 pts)** Complete the following table as indicated:

Element or ion	Electron core element	Rest of electrons	Number of valence electrons	Orbital Diagram For non core electrons	Unpaired Electrons
Mg	[Ne]	$3s^2$	1____ 2____ 3 2____ 4____ Total____	*np* __ __ __ *ns* ↑↓ *(n-1)*d __ __ __ __ __	0
Cr				*np* __ __ __ *ns* __ *(n-1)*d __ __ __ __ __	
Cr^{2+}				*np* __ __ __ *ns* __ *(n-1)*d __ __ __ __ __	
Cr^{3+}				*np* __ __ __ *ns* __ *(n-1)*d __ __ __ __ __	
Cr^{7+}				*np* __ __ __ *ns* __ *(n-1)*d __ __ __ __ __	



2.(30%) The FBD for a link in a mechanism is shown above. The link has mass $m = 5\,\text{kg}$, and moment of inertia $I_{G_2} = 6\,\text{kg}\cdot\text{m}^2$. At the instant of concern, $\mathbf{R}_{12} = \{-3.5\,\hat{\imath} - 30\,\hat{\jmath}\}\,\text{cm}$, $\mathbf{R}_{32} = \{30\,\hat{\imath} + 40\,\hat{\jmath}\}\,\text{cm}$, $\mathbf{a}_{G_2} = \{44\,\hat{\imath} - 473\,\hat{\jmath}\}\,\text{cm/s}^2$, $\alpha = 2\,\text{rad/s}^2$ ↶. Using the $x - y$ horizontal-vertical coordinate system, and the quantities $\mathbf{F}_{12}$, $\mathbf{F}_{32}$, $\mathbf{T}_{12}$ named on the diagram, write down the three kinetic equations for the link in numerically explicit form.

$$m_2 \vec{a}_{G2} = 5\vec{a}_{G2} = \vec{F}_{12} + \vec{F}_{32}$$

$$6\vec{\alpha}_2 = 6(2)\hat{k} = \vec{T}_{12} + \vec{R}_{12} \times \vec{F}_{12} + \vec{R}_{32} \times \vec{F}_{32}$$

$$\boxed{F_{12x} + F_{32x} = 2.2 \text{ Newtons}}$$ (8)

$$\boxed{F_{12y} + F_{32y} = -23.65 \text{ Newtons}}$$ (8)

$$T_{12}\hat{k} + (-.035\hat{\imath} - .3\hat{\jmath}) \times (F_{12x}\hat{\imath} + F_{12y}\hat{\jmath}) + (.3\hat{\imath} + .4\hat{\jmath}) \times (F_{32x}\hat{\imath} + F_{32y}\hat{\jmath})$$
$$= 12\hat{k}\ \text{N}\cdot\text{m}$$

$$\boxed{T_{12} + .3F_{12x} - .035F_{12y} - .4F_{32x} + .3F_{32y} = 12\ \text{N}\cdot\text{m}}$$ (14)

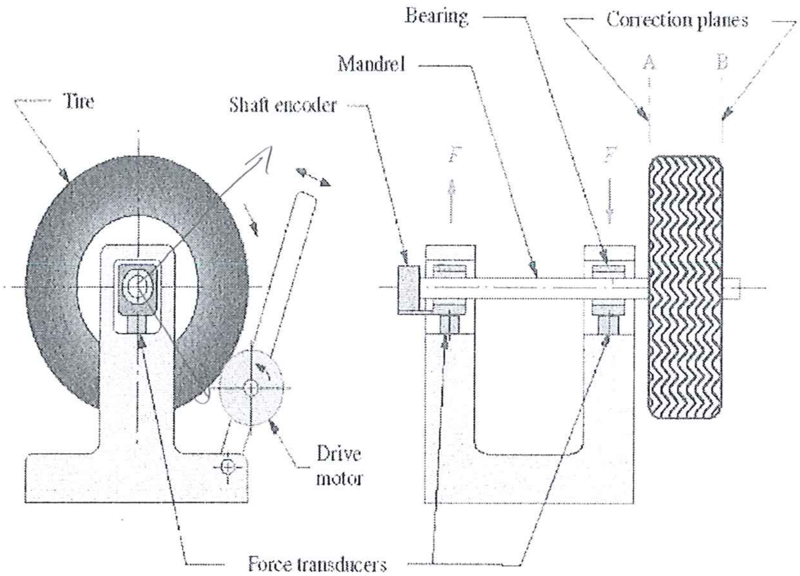
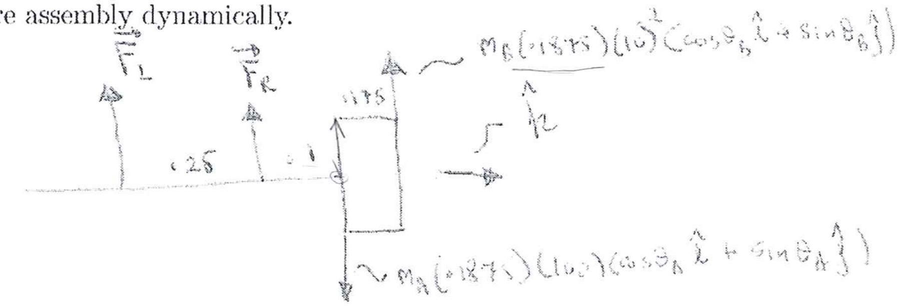


FIGURE 12-12
A dynamic wheel balancer

4.(20%) The wheel and tire assembly shown has been run at 10 rad/s on a dynamic balancing machine. The force measured in the left bearing has a peak of 10 N at a phase angle of 15° with respect to the zero reference line on the tire. The force measured in the right bearing has a peak of 12 N at a phase angle of −60° with respect to the zero reference line on the tire. The center distance between the two bearings on the machine is 25 cm. The left edge of the wheel rim is 10 cm from the centerline of the closest bearing. The wheel is 17.5 cm wide at the rim. The wheel rim diameter is 37.5 cm. Determine the size and location with respect to the tire's zero reference angle of balance masses. needed on each side of the rim to balance the tire assembly dynamically.



$$0 = \sum \vec{T}_A = -.35\hat{k}\times\vec{F}_L - .1\hat{k}\times\vec{F}_R + -.175\hat{k}\times\{18.75\, m_B(\cos\theta_B\,\hat{i} + \sin\theta_B\,\hat{j})\}$$

$$= \hat{k}\times\{(-.175)(18.75)\, m_B(\cos\theta_B\,\hat{i} + \sin\theta_B\,\hat{j}) - (.1)(12)(.5\hat{i} - .866\hat{j})$$

$$- (.35)(10)(\cos 15\,\hat{i} + \sin 15\,\hat{j})\}$$

$$3.2813(m_B\cos\theta_B\,\hat{i} + m_B\sin\theta_B\,\hat{j}) = +3.9807\,\hat{i} - .1334\,\hat{j}$$

ME 213 A SPRING 2010 TEST 2

NAME:____________________

1__________

2__________

3__________

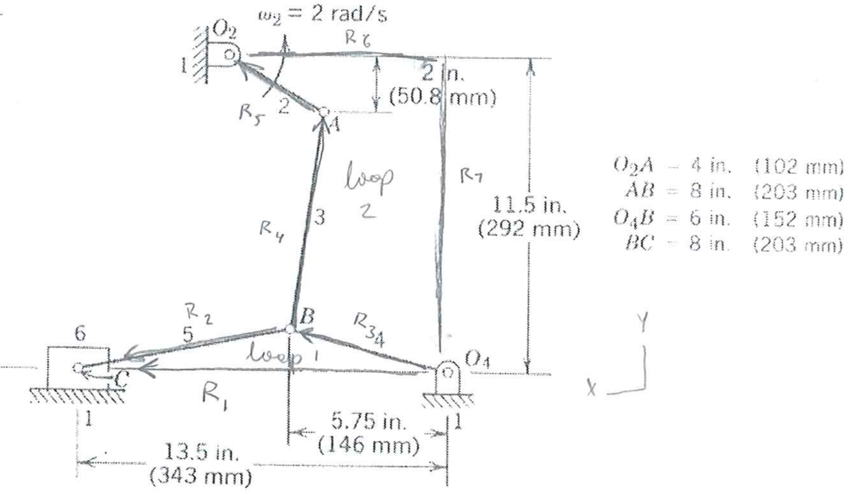
4__________

5__________

Total__________

	d	θ
1	V	C
2	C	V
3	C	V
4	C	V
5	C	V
6	C	C
7	C	C

5 vars



1.(20%) For the mechanism shown (assuming the lengths of all rigid links are known):

(a) Develop vector-loop equations. Explicitly specify the loop or loops being used.

(b) Consider each vector used in some vector-loop. Is its magnitude constant or variable? Is its orientation constant or variable?

(c) What, if any, geometric constraints exist among vectors used in some vector-loop?

(d) Write the vector-loop equations in components and (if any exist) the constraint equations. Count equations and variables. How many of the variable quantities must be specified to make the system solvable?

Loop 1 $\quad R_1 - R_2 - R_3 = 0$

x) $R_1 - R_3 \cos\theta_3 - R_2 \cos\theta_2 = 0$ (1)

y) $R_3 \sin\theta_3 + R_2 \sin\theta_2 = 0$ (2)

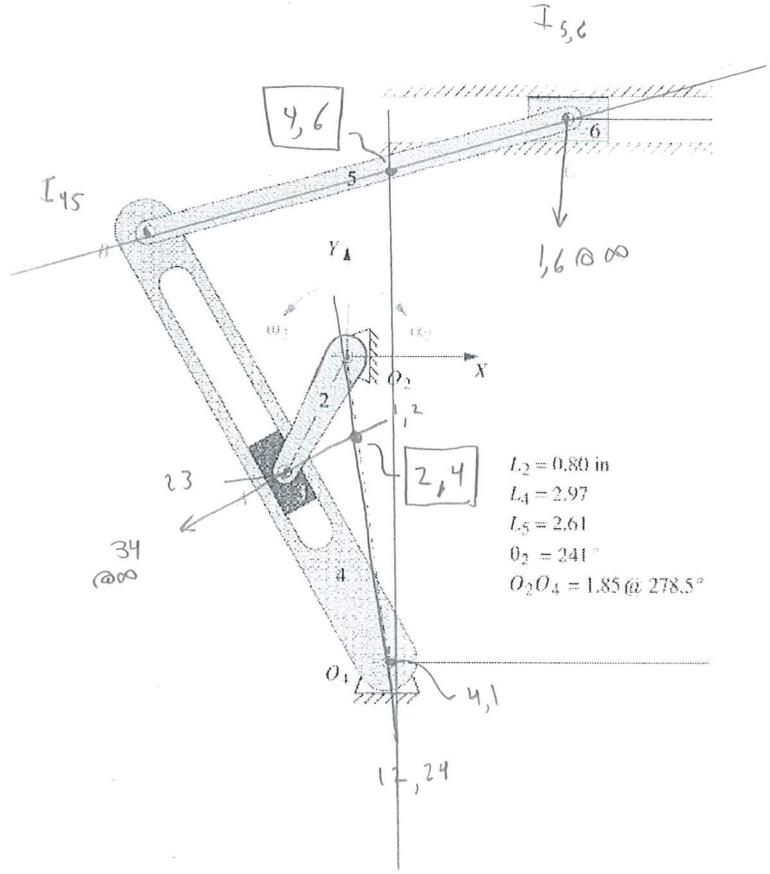
Loop 2 $\quad R_3 + R_4 + R_5 - R_6 - R_7 = 0$

x) $R_3 \sin\theta_3 + R_4 \sin\theta_4 + R_5 \sin\theta_5 - R_6 = 0$ (3)

y) $R_3 \cos\theta_3 + R_4 \cos\theta_4 + R_5 \cos\theta_5 - R_7 = 0$ (4) 4 equations, 5 variables

1 DOF

4,5 > 4,1
5,6 1,6



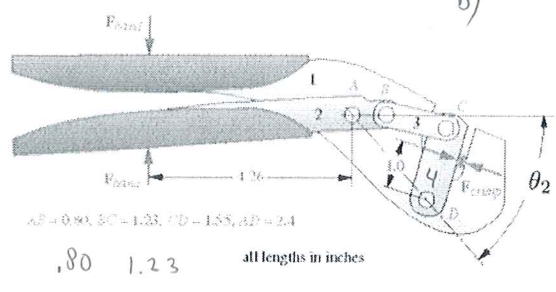
1,2 > 23 >
1,4 34

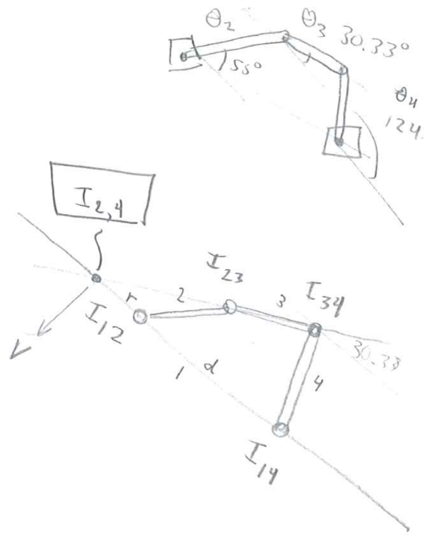
2.(20%) For the six-bar mechanism shown, use Kennedy's Rule to locate the instant centers $I_{2,4}$ and $I_{4,6}$.

23
34

21
14

b)





.80 1.23

AD = 2.4

3.(20%) The crimping tool shown is a four-bar mechanism. When $\theta_2 = 55°$, the corresponding values of the coupler and output angles are $\theta_3 = 30.33°$, $\theta_4 = 124.57°$ respectively.

(a) Write the power identity for the mechanism, and express its mechanical advantage M. A. $= \dfrac{F_{crimp}}{F_{hand}}$ in terms of the ratio $\dfrac{\omega_2}{\omega_4}$.

(b) Sketch the mechanism in the configuration $\theta_2 = 55°$, locate the instant center $I_{2,4}$, and use it to develop a numerical relationship between ω_2 and ω_4.

(c) Find the mechanical advantage of the tool for this configuration.

a) Power Identity $\quad F_i V_i \cos\phi_i = F_o V_o \cos\phi_o$

$V = \omega r$

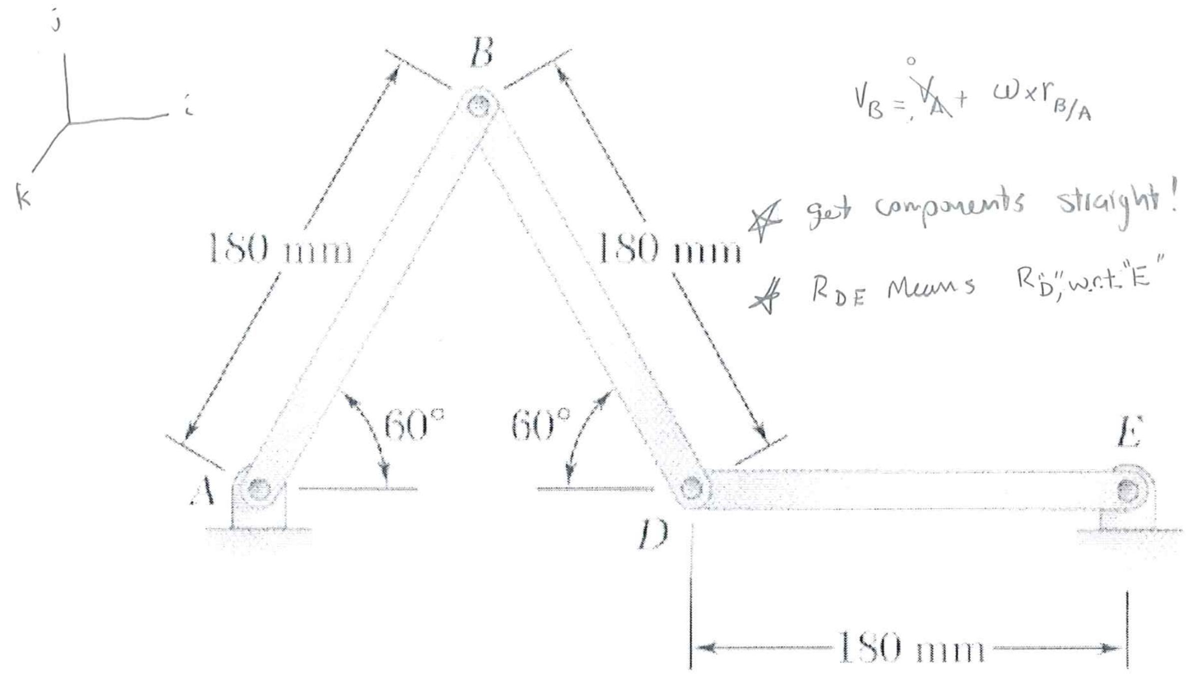
$$\frac{F_o}{F_i} = \frac{V_i \cancel{\cos\phi_i}}{V_o \cancel{\cos\phi_o}} = \frac{\omega_2 r_2}{\omega_4 r_4} = \boxed{\frac{\omega_2}{\omega_4}(4.26)}$$

$V_{I_{24}} = r\omega_2 = (r + d)\,\omega_4$ $\quad$ Find r $\quad \dfrac{a}{\sin a} = \dfrac{b}{\sin b} \quad \dfrac{r_2}{\sin(\theta_3)} = \dfrac{r}{\sin(\theta_2 - \theta_3)}$

$r = .6612 \quad d = 2.4$

$$\frac{\omega_2}{\omega_4} = \frac{(r+d)}{(r)} = 4.630$$

$\boxed{MA = 19.72}$



4.(20%) The dimensions of the four-bar mechanism shown are given. In the current configuration, link AB has angular velocity $\omega_{AB} = 5\,\text{rad/s}$ counter-clockwise. Find the angular velocities of links DE and BD.

$$\text{HINT:-}\quad \underbrace{\boldsymbol{\omega}_{AB} \times \mathbf{R}_{B/A}}_{V_B} + \underbrace{\boldsymbol{\omega}_{BD} \times \mathbf{R}_{D/B}}_{V_D} \underbrace{- \boldsymbol{\omega}_{DE} \times \mathbf{R}_{D/E}}_{-V_E} = \mathbf{0}.$$

$\omega_{AB} = 5\hat{k}$

$5\hat{k} \times (.18\cos 60\,\hat{i} + .18\sin 60\,\hat{j})$

$+\ \omega_{BD}\hat{k} \times (.18\cos 60\,i - .18\sin 60\,\hat{j})$

$-\ \omega_{DE}\hat{k} \times (-.18\,i + 0\,\hat{j})$

$.45\,j - .7794\,i + [\omega_{BD}\,.09\,\hat{j} + \omega_{BD}\,.1559\,\hat{i}]$

$-[-\omega_{DE}\,.18\,\hat{j}] = 0$

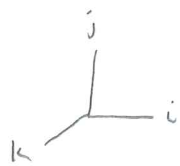
$\underline{i:}\quad -.7794 + .1559\,\omega_{BD} = 0$

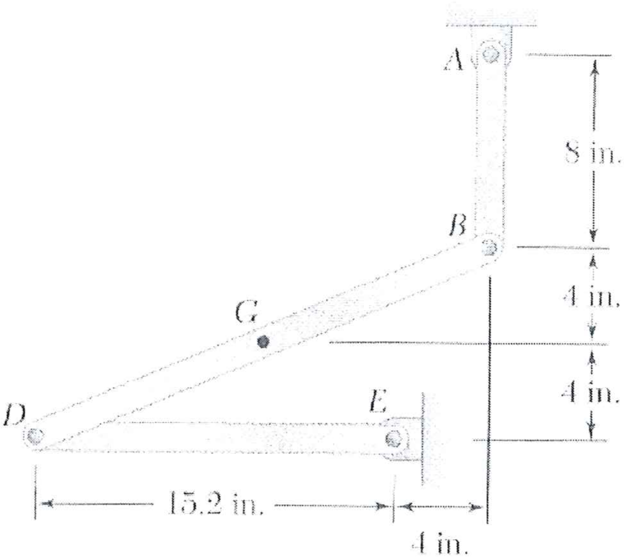
$\underline{j:}\quad .45 + .09\,\omega_{BD} + .18\,\omega_{DE} = 0$

$\boxed{\omega_{BD} = 5.0\ \hat{k}}$ rad/s

$\boxed{\omega_{DE} = -5\,\hat{k}\ \text{rad/s}}$

$A_{DB} = \vec{\alpha}_3 \times \vec{R}_{D/B} - \vec{\omega}_3^{\,2} \vec{R}_{D/B}$





☆ one cross product, one regular product

$\omega_{BD} = 4\hat{k}$

$\alpha_{BD} = -10 \frac{rad}{s^2}\hat{k}$

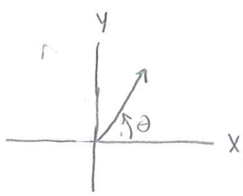
$R_{D/B} = -19.2\hat{i} - 8\hat{j}$

5.(20%) The dimensions of the four-bar mechanism shown are given. In the current configuration, link BD has angular velocity $\omega_{BD} = 4\,\text{rad/s}$ counter-clockwise, angular acceleration $\alpha_{BD} = 10\,\text{rad/s}^2$ clockwise. Find the acceleration difference $\mathbf{A}_{DB}$. Give your answer as a magnitude and an orientation relative to the horizontal.

$A_{DB} = -10k \times (-19.2i - 8j) - 4^2 k\,(-19.2i - 8j)$

$= +192j + (-80i) + [\,307.2i + 128j\,]$

$= 227i + 320j$



$\boxed{A_{DB} = 392 \text{ rad/s}^2 \quad \theta = 54.65^\circ}$

PRACTICE FOR EXAM 2

1.(20%) For the six-bar mechanism shown on the next page, use Kennedy's Rule to locate the instant centers $I_{1,3}$, $I_{1,5}$, and $I_{2,4}$. The connection between links 3 and 5 is a revolute joint.

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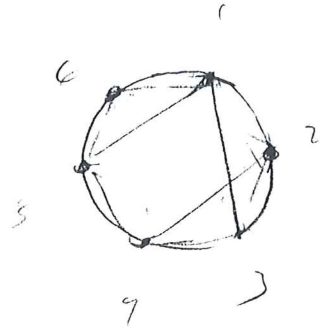
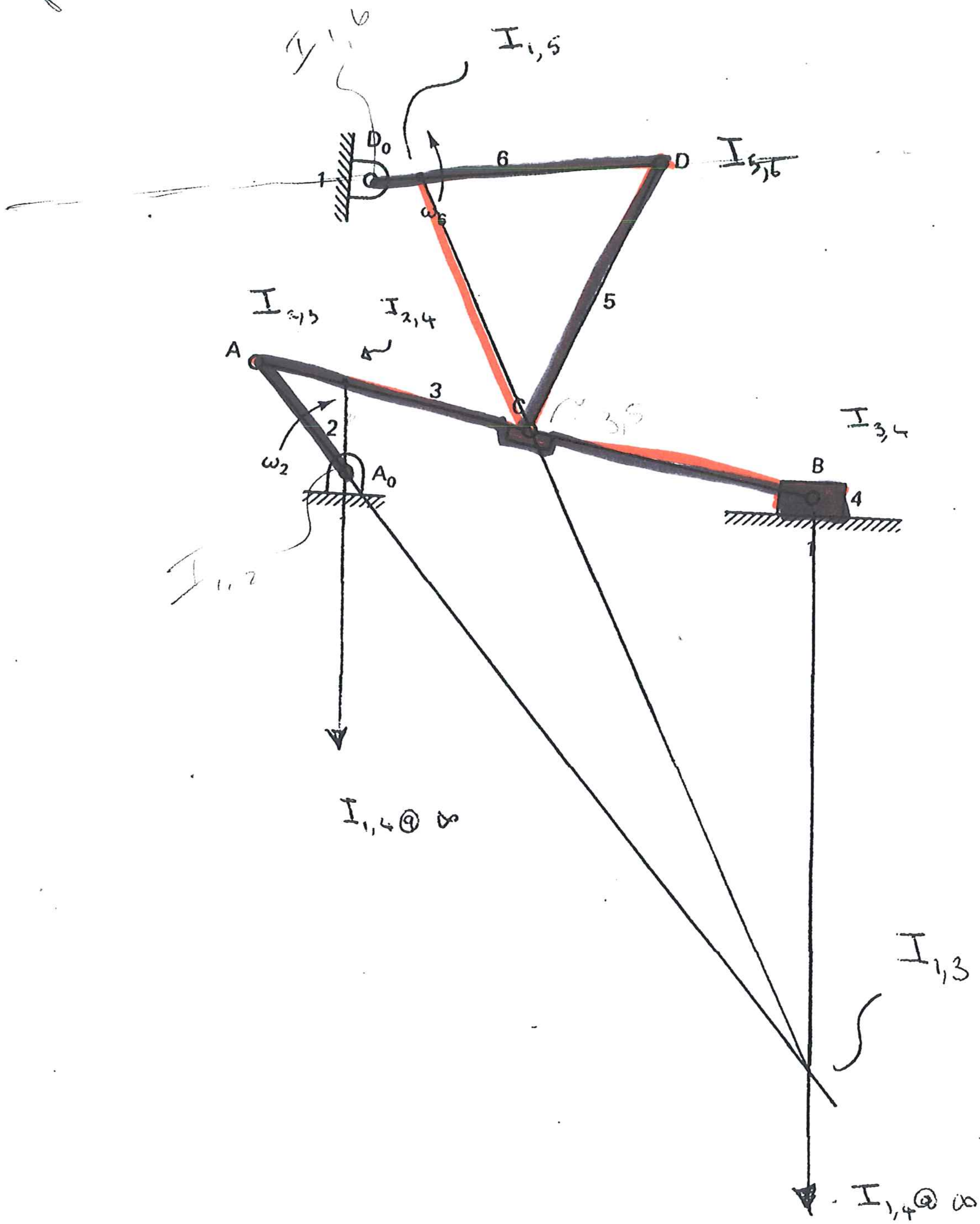


1
2
3
4
5
6

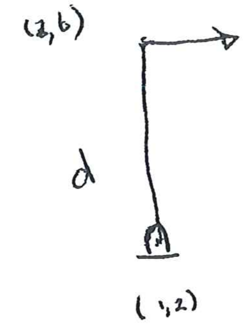


I1,6
I1,5
D0
1
6
D
I5,6
ω6
5
I2,3
I2,4
A
3
C
I3,4
2
ω2
A0
B
4
I1,2
I1,4 @ ∞
I1,3
I1,4 @ ∞

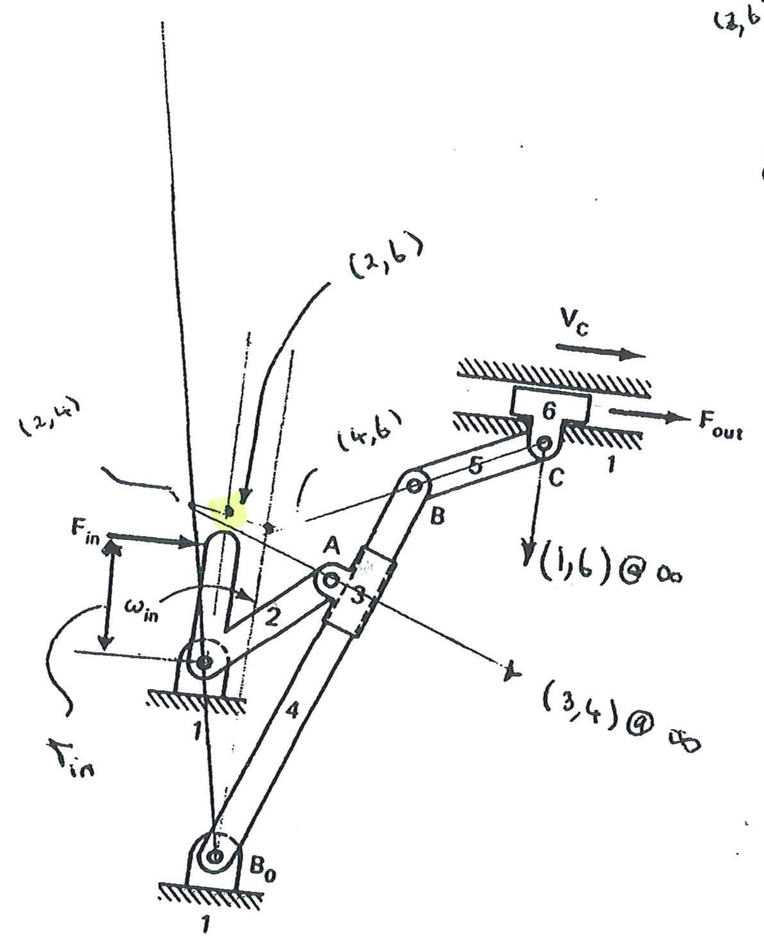
at IC 2,6,

$V_6 = V_2$

$$P_{in} = F_{in}\, r_{in}\, \omega_{in} = P_{out} = F_{out} V_c$$



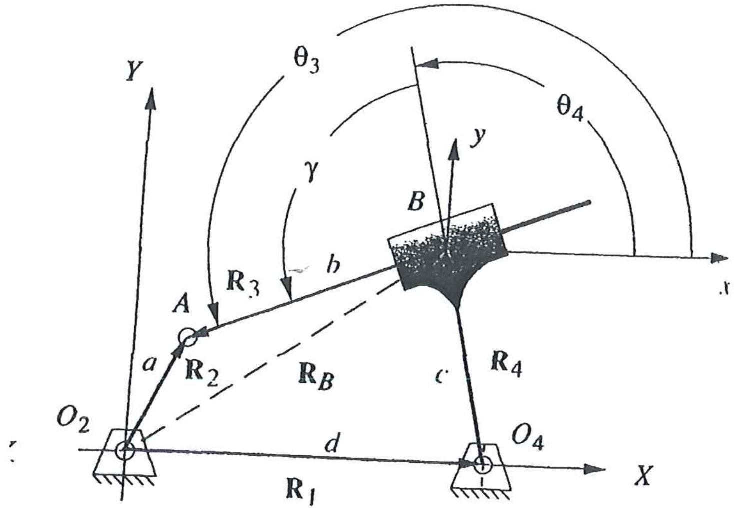
$V_c = d\,\omega_{in}$



$$F_{in}\, r_{in}\, \omega_{in} = F_{out}\, d\, \omega_{in}$$

$$\boxed{MA = \frac{F_{out}}{F_{in}} = \frac{r_{in}}{d}}$$

2. (20%) A six-link mechanism and certain of its instant centers are shown above. Develop a relationship between the input force F_{in} experienced by link 2 and the output force F_{out} in terms of lengths taken from the instant center diagram. Label any lengths used. What is the mechanical advantage of the mechanism?



4.(30%) The inverted slider-crank mechanism shown has lengths $a = 4$, $c = 2$, $d = 8$, and $\gamma = 30°$. For $\theta_2 = 75°$, in an open configuration, $b = 6.17$, $\theta_4 = 128.2°$, $\theta_3 = \theta_4 + \gamma$. In this configuration, $\omega_2 = -45\,\mathrm{k}\,\mathrm{rad/s}$, and $\omega_4 = -2.7\,\mathrm{k}\,\mathrm{rad/s}$, $\dot{b} = -176.0$. If $\alpha_2 = 25\,\mathrm{k}\,\mathrm{rad/s^2}$, develop a set of equations to determine α_4 and $\ddot{b}$. You are **NOT** asked to solve these equations.

$$\theta_3 = \theta_4 + \gamma \;; \quad \omega_3 = \omega_4 \;, \quad \alpha_3 = \alpha_4$$

$$(b e^{j\gamma} + c)\, e^{j\theta_4} + d = a e^{j\theta_2}$$

$$\{\dot b e^{j\gamma} + j\omega_4 (b e^{j\gamma} + c)\} e^{j\theta_4} = j a \omega_2 e^{j\theta_2}$$

$$\{\ddot b e^{j\gamma} + 2j\omega_4 \dot b e^{j\gamma} + j\alpha_4 (b e^{j\gamma} + c) - \omega_4^2 (b e^{j\gamma} + c)\} e^{j\theta_4}$$

$$= (j\alpha_2 - \omega_2^2)\, a e^{j\theta_2}$$

$$\{[(\ddot b - \omega_4^2 b)\cos\gamma - (b\alpha_4 + 2\dot b\omega_4)\sin\gamma - c\omega_4^2]$$

$$+ j[(\ddot b - \omega_4^2 b)\sin\gamma + (b\alpha_4 + 2\dot b\omega_4)\cos\gamma + c\alpha_4]\}(\cos\theta_4 + j\sin\theta_4)$$

$$= a(-\omega_2^2 + j\alpha_2)(\cos\theta_2 + j\sin\theta_2)$$

$$(\ddot{b} - w_4^2 b)\left[\cos\gamma \cos\theta_4 - \sin\gamma \sin\theta_4\right]$$
$$- (b\alpha_4 + 2\dot{b} w_4)\left[\sin\gamma \cos\theta_4 + \cos\gamma \sin\theta_4\right]$$
$$- c w_4^2 \cos\theta_4 - c\alpha_4 \sin\theta_4 = - a w_2^2 \cos\theta_2 - a\alpha_2 \sin\theta_2$$

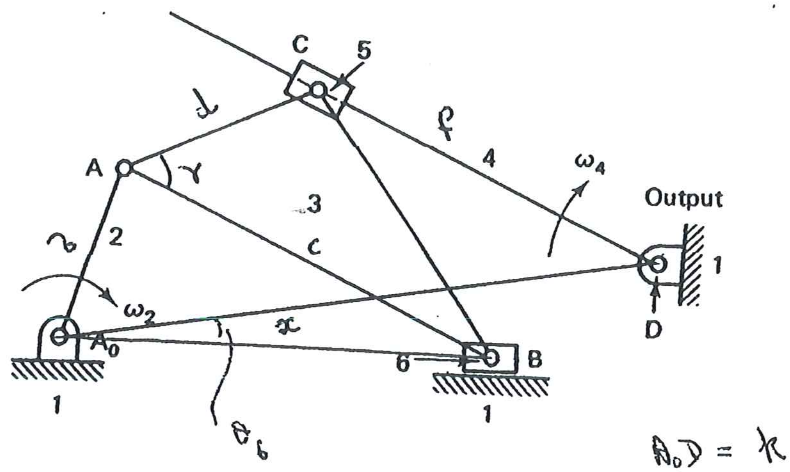
$$(\ddot{b} - w_4^2 b)\left[\cos\gamma \sin\theta_4 + \sin\gamma \cos\theta_4\right]$$
$$+ (b\alpha_4 + 2\dot{b} w_4)\left[- \sin\gamma \sin\theta_4 + \cos\gamma \cos\theta_4\right]$$
$$- c w_4^2 \sin\theta_4 + c\alpha_4 \cos\theta_4 = - a w_2^2 \sin\theta_2 + a\alpha_2 \cos\theta_2$$

$$\ddot{b} \cos(158.2) - (b \sin(158.2) + c \sin(128.2))\alpha_4$$
$$= w_4^2 b \cos(158.2) + 2\dot{b} w_4 \sin(158.2) + c w_4^2 \cos(128.2) - a w_2^2 \cos\theta_2 - a\alpha_2 \sin\theta_2$$

$$\ddot{b} \sin(158.2) + (b \cos(158.2) + c \cos(128.2))\alpha_4$$
$$= w_4^2 b \sin(158.2) - 2\dot{b} w_4 \cos(158.2) + w_4^2 c \sin(128.2) - a w_2^2 \sin\theta_2 + a\alpha_2 \cos\theta_2$$

$a = 4 \quad b = 6.17 \quad c = 2 \quad \dot{b} = -176 \quad w_2 = -45 \quad w_4 = -2.7 \quad \alpha_2 = 25$

$$\boxed{\begin{aligned} -.9285\,\ddot{b} - 3.8631\,\alpha_4 &= -1890.8581 \\ .3714\,\ddot{b} - 6.9656\,\alpha_4 &= 6887.5224 \end{aligned}}$$



3.(30%) Vector loop equations for the single DOF mechanism shown may be written in the complex forms

$$be^{j\theta_2} + ce^{j\theta_3} - x = 0 \qquad \dot{\theta}_2 = -\omega_2$$

$$be^{j\theta_2} + de^{j\theta_5} - fe^{j\theta_4} - ke^{j\theta_6} = 0 \qquad \dot{\theta}_4 = -\omega_4$$

$$\theta_5 - \theta_3 = \gamma \qquad \omega_5 - \omega_3 = 0$$

Note that f and x are variable quantities. Develop equations relating ω_3, ω_4, $\dot{f}$ and $\dot{x}$ to ω_2.

$$jc\omega_3 e^{j\theta_3} - \dot{x} = -jb\dot{\theta}_2 e^{j\theta_2}$$

$$jd\omega_3 e^{j\omega_5} - \dot{f}e^{j\theta_4} - jf\dot{\theta}_4 e^{j\theta_4} = -jb\dot{\theta}_2 e^{j\theta_2}$$

$$-c\omega_3 \sin\theta_3 - \dot{x} = -b\omega_2 \sin\theta_2$$

$$c\omega_3 \cos\theta_3 = b\omega_2 \cos\theta_2$$

$$-d\omega_3 \sin(\theta_3+\gamma) - \dot{f}\cos\theta_4 - f\omega_4 \sin\theta_4 = -b\omega_2 \sin\theta_2$$

$$d\omega_3 \cos(\theta_3+\gamma) - \dot{f}\sin\theta_4 + f\omega_4 \cos\theta_4 = b\omega_2 \cos\theta_2$$

ME 213 A SPRING 2010 TEST 1

Practice test

NAME: David Malaway

1__________

2__________

3__________

4__________

5__________

Total__________

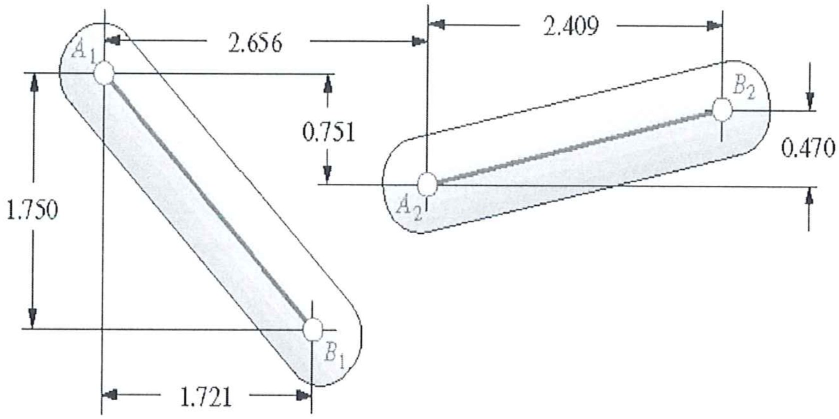


FIGURE P3-1

3.(10%) A design problem calls for the synthesis of a mechanism that will carry link AB between the two configurations shown. Which of the three standard types - ~~function generation, path generation~~, motion generation - of synthesis is this?

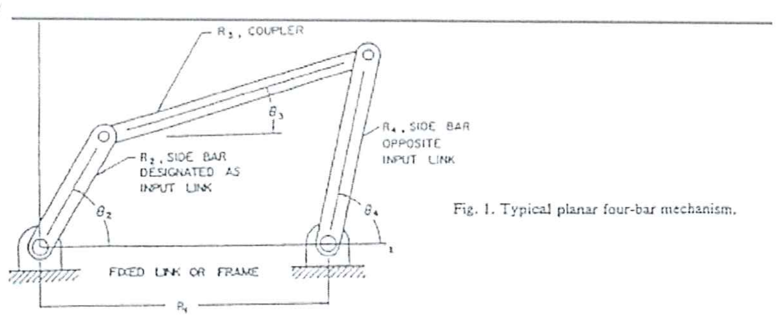


Fig. 1. Typical planar four-bar mechanism.

2. (10%) For each of the following hypothetical 4-bars: (a) Determine whether it can be assembled, (b) if so, determine its type according to the Barker classification.

$$\{R_1, R_2, R_3, R_4\} = \{10, 6, 7, 4\} \quad (1)$$ ✓

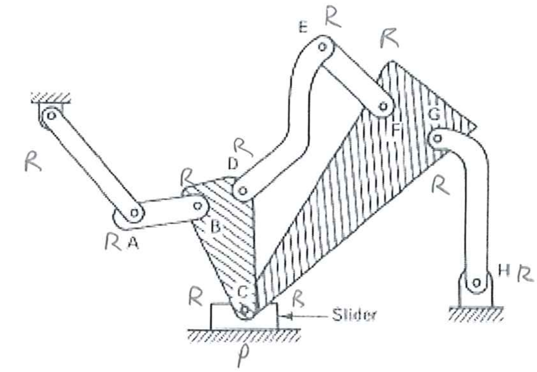
$$\{R_1, R_2, R_3, R_4\} = \{5, 12, 8, 6\} \quad (2)$$ ✓

$$\{R_1, R_2, R_3, R_4\} = \{3, 8, 16, 4\} \quad (3)$$ not assemble able

(1) $s+l = 14$
$p+q = 13$
type 5 GRRR1

(2) $s+l = 17$
$p+q = 14$
type 6 RRR2

(3) ~~$s+l =$~~
~~$p+q =$~~



1.(10%) For the 9-link mechanism shown:
(i) Label all joints,
(ii) Compute the mobility.

$L = 9$

$J_1 = 10$

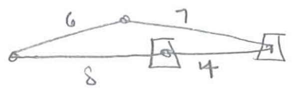
$J_2 = 0$

$M = 3(9-1) - 2(11)$

$= 24 - 22$

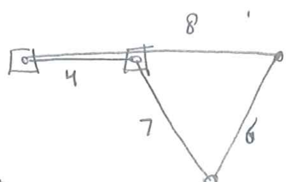
$\boxed{M = 2}$

4.(35%) A GCCC 4-bar mechanism has lengths $\{R_1, R_2, R_3, R_4\} = \{4, 8, 6, 7\}$, and is assembled in Form 1, i.e., with $\phi_{12} > 0$.
Find, and illustrate on suitable pie-charts (with numerical values), the ranges of the fundamental position angles ϕ_{12}, ϕ_{13}, and ϕ_{24}. Sketch the configurations of the mechanism that correspond to any extreme values computed.



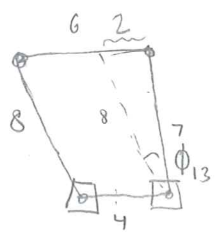
$$\phi_{12\,max} = \cos^{-1}\left[\frac{36+49-144}{2(42)}\right]$$

$$= 2.350 \text{ rad}$$



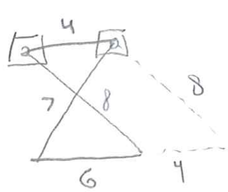
$$\phi_{12\,min} = \cos^{-1}\left[\frac{36+49-16}{2(42)}\right]$$

$$= .6069 \text{ rad}$$



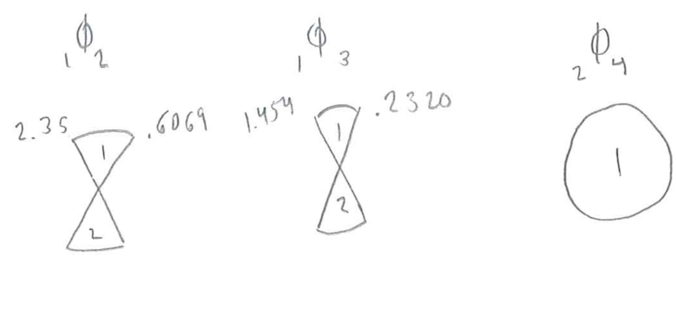
$$\phi_{13\,min} = \cos^{-1}\left[\frac{64+49-4}{2(56)}\right]$$

$$\phi_{13\,min} = .2320 \text{ rad}$$



$$\phi_{13\,max} = \cos^{-1}\left[\frac{64+49-100}{2(56)}\right]$$

$$\phi_{13\,max} = 1.454 \text{ rad}$$



5.(35%) The $x-y$ coordinates of two configurations of link CD are $C_1 = (1,1)$, $D_1 = (1,3)$; $C_2 = (5,1)$, $D_2 = (6.2, 2.6)$. Find the rotopole associated with these two configurations.

	X	Y
C_1	1	1
D_1	1	3
C_2	5	1
D_2	6.2	2.6

slope			inverse slope
C_1 to C_2	$\frac{Y_2 - Y_1}{X_2 - X_1} = \frac{0}{5-4} = 0$		vertical
D_1 to D_2	$'' = \frac{2.6-3}{6.2-1} = -.0769$		13

midpoint	$\frac{X_2+X_1}{2}, \frac{Y_2+Y_1}{2}$
C_1 & C_2	(3, 1)
D_1 & D_2	(3.6, 2.8)

bisector line eq.	
C_1 + C_2	$X = 3$
D_1 & D_2	

$Y - 2.8 = 13(3 - 3.6)$

$\boxed{Y = -5}$

$\boxed{X = 3}$

$\frac{1}{3}$ 3

$\frac{-1}{3}$

$+ 0$