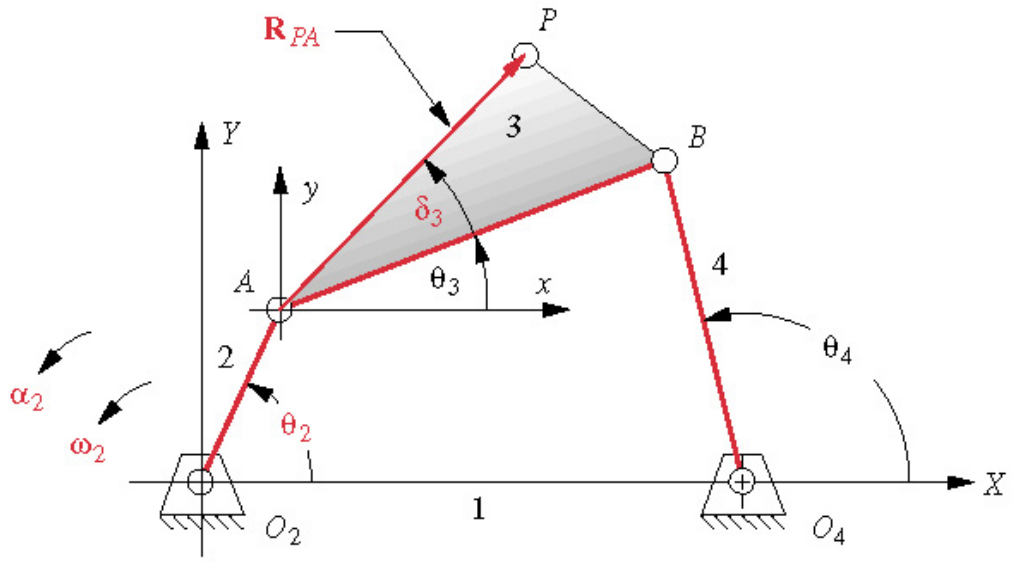
NAME: SOLUTION

PROBLEM 1 (30 pts): A four bar linkage has the following dimensions. All lengths are in inches and all angles are in degrees.

Link 1	Link 2	Link 3	Link 4	θ_2	R_{PA}	δ_3
4	6	10	7	88	10	330

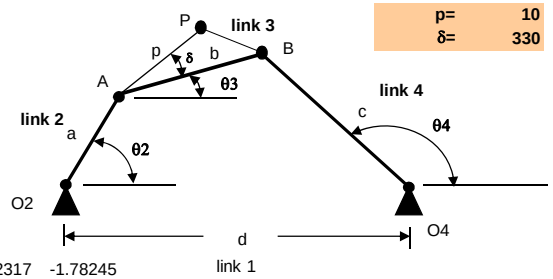
Link 2 is the drive link and it is known to be rotating at $\omega_2 = -80\frac{1}{s}$ and $\alpha_2 = 30\frac{1}{s^2}$. Using the program that you have been developing, calculate all the critical parameters associated with this linkage in both of the possible configurations. Print out the results of your program and staple it directly behind this page.



4-Bar Linkage

a=	**6**	Link 2
b=	**10**	Link 3
c=	**7**	Link 4
d=	**4**	Link 1
$\theta_2 =$	**88**	1.535889742
$\dot{\theta}_2 =$	**-80**	$\frac{1}{s}$
$\ddot{\theta}_2 =$	**30**	$\frac{1}{s^2}$
By=	**3.70**	**-3.78**
Bx=	**9.94**	**-1.89**
$\theta_3 =$	**-13.3**	**-102.1**
$\theta_4 =$	**31.9**	**-147.3**
$\dot{\theta}_3 =$	**-5.6156E+01**	**-5.5638E+01**
$\dot{\theta}_4 =$	**-9.4798E+01**	**-1.6996E+01**
$\ddot{\theta}_3 =$	**-2.6936E+03**	**3.1098E+02**
$\ddot{\theta}_4 =$	**-4.0547E+03**	**1.6721E+03**

K1=	4.0891E+00
K2=	1.5819E+00
K3=	-8.0449E-02
K4=	-1.3988E+01



p=	**10**
δ=	**330**

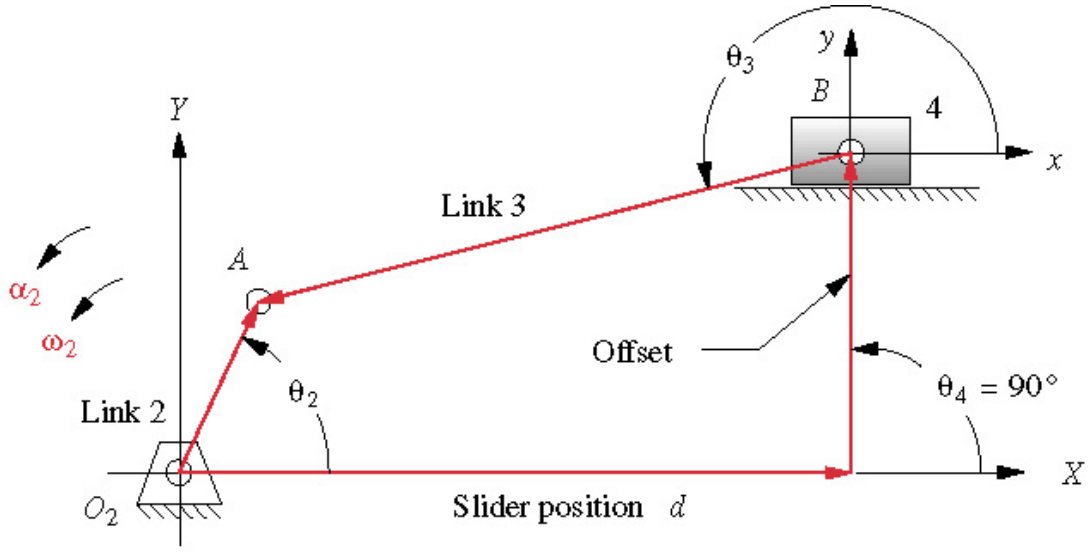
-0.2317	-1.78245	
0.556928	-2.57107	

	x comp	y comp	mag	angle	i	j
r04=	**4.00**	**0.00**	**4.000**	**0.0**	**1.000**	**0.000**
rA=	**0.21**	**6.00**	**6.000**	**88.0**	**0.035**	**0.999**
rBA=	9.73	-2.30	10.000	-13.3	0.973	-0.230
rBO4=	5.94	3.70	7.000	31.9	0.849	0.529
rB=	**9.94**	**3.70**	**10.608**	**20.4**	**0.937**	**0.349**
rPA=	7.28	-6.86	10.000	-43.3	0.728	-0.686
rP=	**7.49**	**-0.86**	**7.539**	**-6.5**	**0.993**	**-0.114**
vA=	**479.71**	**-16.75**	**480.000**	**-2.0**	**0.999**	**-0.035**
vBA=	-128.95	-546.55	561.559	-103.3	-0.230	-0.973
vB=	**350.76**	**-563.31**	**663.584**	**-58.1**	**0.529**	**-0.849**
vPA=	-384.95	-408.85	561.559	-133.3	-0.686	-0.728
vP=	**94.76**	**-425.61**	**436.027**	**-77.4**	**0.217**	**-0.976**
aA=	**-1520.03**	**-38370.33**	**38400.422**	**-92.3**	**-0.040**	**-0.999**
aBA	-36877.40	-18974.51	41472.574	-152.8	-0.889	-0.458
aB	**-38397.43**	**-57344.83**	**69012.986**	**-123.8**	**-0.556**	**-0.831**
aPA=	-41424.02	2006.30	41472.574	177.2	-0.999	0.048
aP=	**-42944.05**	**-36364.03**	**56271.964**	**-139.7**	**-0.763**	**-0.646**
ALT	**x comp**	**y comp**	**mag**	**angle**	**i**	**j**
rO4=	**4.00**	**0.00**	**4.000**	**0.0**	**1.000**	**0.000**
rA=	**0.21**	**6.00**	**6.000**	**88.0**	**0.035**	**0.999**
rBA=	-2.10	-9.78	10.000	-102.1	-0.210	-0.978
rBO4=	-5.89	-3.78	7.000	-147.3	-0.842	-0.540
rB=	**-1.89**	**-3.78**	**4.227**	**-116.6**	**-0.447**	**-0.894**
rPA=	-6.71	-7.42	10.000	-132.1	-0.671	-0.742
rP=	**-6.50**	**-1.42**	**6.652**	**-167.7**	**-0.977**	**-0.214**
vA=	**479.71**	**-16.75**	**480.000**	**-2.0**	**0.999**	**-0.035**
vBA=	-543.96	116.88	556.375	167.9	-0.978	0.210
vB=	**-64.25**	**100.13**	**118.970**	**122.7**	**-0.540**	**0.842**
vPA=	-412.64	373.20	556.375	137.9	-0.742	0.671
vP=	**67.06**	**356.45**	**362.702**	**79.3**	**0.185**	**0.983**
aA=	**-1520.03**	**-38370.33**	**38400.422**	**-92.3**	**FALSE**	**-0.999**
aBA	9543.26	29611.30	31111.140	72.1	0.307	0.952
aB	**8023.23**	**-8759.02**	**11878.243**	**-47.5**	**0.675**	**-0.737**
aPA=	23070.36	20872.51	31111.140	42.1	0.742	0.671
aP=	**21550.32**	**-17497.81**	**27759.503**	**-39.1**	**0.776**	**-0.630**

PROBLEM 2 (30 pts): A slider crank linkage has the following dimensions. All lengths are in inches and all angles are in degrees.

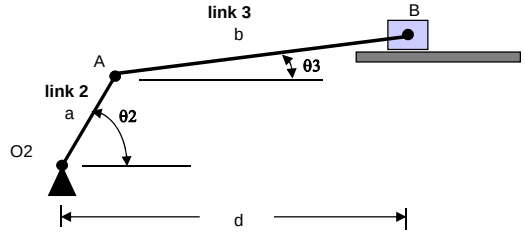
Link 2	Link 3	Offset	θ_2
5	20	-5	225

Link 2 is the drive link and it is known to be rotating at $\omega_2 = -50\frac{1}{s}$ and $\alpha_2 = 10\frac{1}{s^2}$. Using the program that you have been developing, calculate all the critical parameters associated with this linkage in both of the possible configurations. Print out the results of your program and staple it directly behind this page.



Slider Crank

a=	**5**	Link 2
b=	**20**	Link 3
c=	**-5**	Link 1
$\theta_2 =$	**225**	3.926990817
$\dot{\theta}_2 =$	**-50**	$1/s$
$\ddot{\theta}_2 =$	**10**	$1/s^2$
By=	**-5.00**	**-5.00**
Bx=	**16.41**	**-23.48**
$\theta_3 =$	**-4.2**	**-175.8**
$\dot{\theta}_3 =$	**-8.86**	**8.86**
$\ddot{\theta}_3 =$	**-447.13**	**447.13**
vB=	**-189.76**	**-163.80**
aB=	**6652.68**	**11095.70**



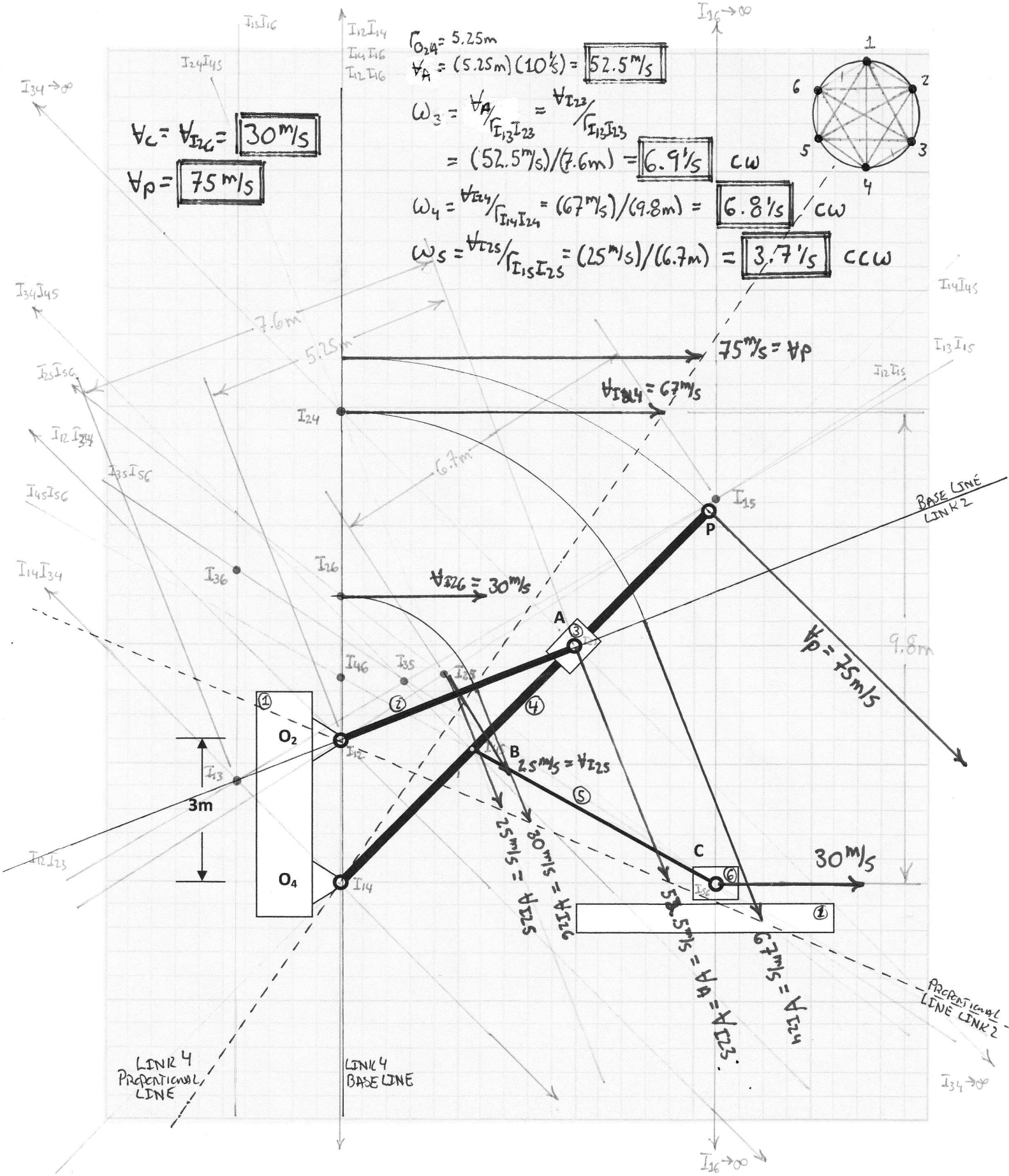
	x comp	y comp	mag	angle	i	j
rB=	**16.41**	**-5.00**	**17.16**	**-16.9**	**0.957**	**-0.291**
rA=	**-3.54**	**-3.54**	**5.00**	**-135.0**	**-0.707**	**-0.707**
rBA=	19.95	-1.46	20.00	-4.2	0.997	-0.073
vB	**-189.76**	**0.00**	**189.76**	**180.0**	**-1.000**	**0.000**
vA	**-176.78**	**176.78**	**250.00**	**135.0**	**-0.707**	**0.707**
vBA	-12.98	-176.78	177.25	-94.2	-0.073	-0.997
aB	**6652.68**	**0.00**	**6652.68**	**0.0**	**1.000**	**0.000**
aA	**8874.19**	**8803.48**	**12500.10**	**44.8**	**0.710**	**0.704**
aBA	-2221.51	-8803.48	9079.45	-104.2	-0.245	-0.970

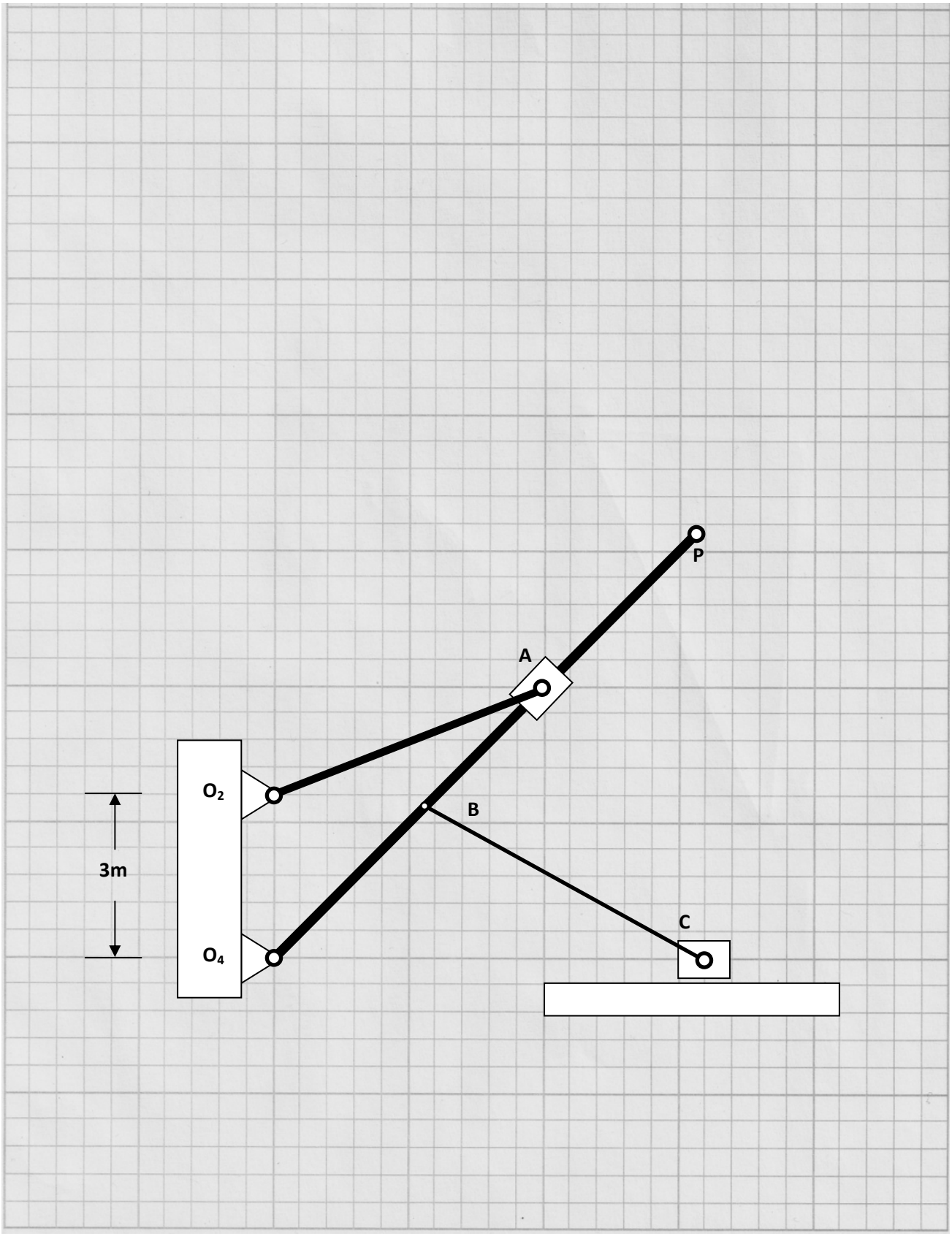
alt	**x comp**	**y comp**	**mag**	**angle**	**i**	**j**
rB=	**-23.48**	**-5.00**	**24.01**	**-168.0**	**-0.978**	**-0.208**
rA=	**-3.54**	**-3.54**	**5.00**	**-135.0**	**-0.707**	**-0.707**
rBA=	-19.95	-1.46	20.00	-175.8	-0.997	-0.073
vB	**-163.80**	**0.00**	**163.80**	**180.0**	**-1.000**	**0.000**
vA	**-176.78**	**176.78**	**250.00**	**135.0**	**-0.707**	**0.707**
vBA	12.98	-176.78	177.25	-85.8	0.073	-0.997
aB	**11095.70**	**0.00**	**11095.70**	**0.0**	**1.000**	**0.000**
aA	**8874.19**	**8803.48**	**12500.10**	**44.8**	**0.710**	**0.704**
aBA	2221.51	-8803.48	9079.45	-75.8	0.245	-0.970

PROBLEM 2 (40 pts): On the following page a linkage has been drawn to scale. It is known that the link O_2A is rotating at the rate of $\omega = -10\frac{1}{s}$.

2a) Find all the instant centers associated with this linkage.

2b) Using the instant center graphical approach, determine the velocity of points C & P, the angular velocities of links O_4P & BC, and the angular velocity of the slider at A.

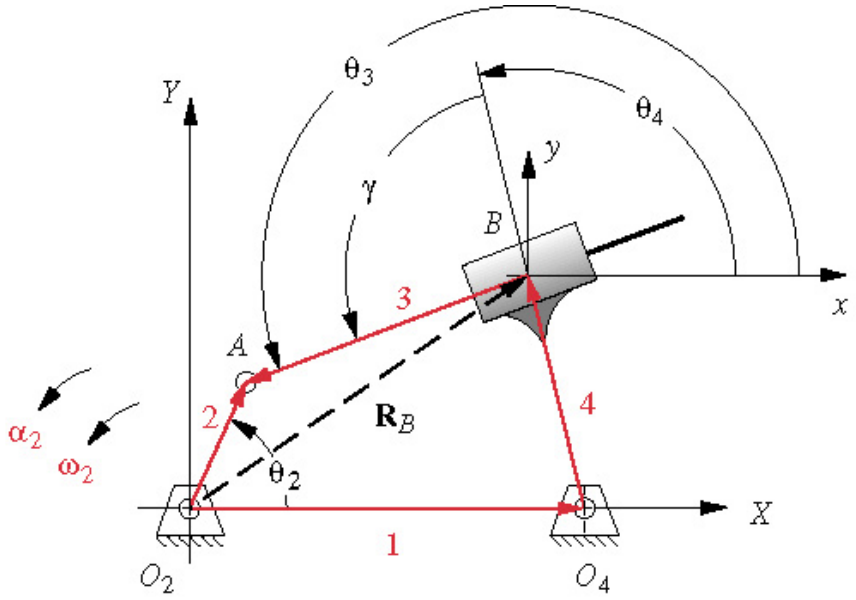

$r_{O_2A} = 5.25m$
$v_A = (5.25m)(10\,1/s) = 52.5\,m/s$
$\omega_3 = v_A / r_{I_{13}I_{23}} = v_{I_{23}} / r_{I_{13}I_{23}}$
$= (52.5\,m/s)/(7.6m) = 6.9\,1/s$ cw
$\omega_4 = v_{I_{24}} / r_{I_{14}I_{24}} = (67\,m/s)/(9.8m) = 6.8\,1/s$ cw
$\omega_5 = v_{I_{25}} / r_{I_{15}I_{25}} = (25\,m/s)/(6.7m) = 3.7\,1/s$ ccw
$v_C = v_{I_{26}} = 30\,m/s$
$v_P = 75\,m/s$
$I_{34} \to \infty$
$I_{16} \to \infty$
$I_{12}I_{14}$
$I_{14}I_{16}$
$I_{12}I_{16}$
$I_{13}I_{16}$
$I_{24}I_{45}$
$I_{34}I_{45}$
$I_{23}I_{56}$
$I_{12}I_{34}$
$I_{35}I_{56}$
$I_{45}I_{56}$
$I_{14}I_{34}$
$I_{14}I_{45}$
$I_{13}I_{15}$
$I_{12}I_{15}$
$I_{12}I_{23}$
7.6m
5.25m
6.7m
9.8m
3m
I_{24}
I_{15}
I_{26}
I_{36}
I_{46}
I_{35}
I_{25}
I_{12}
I_{13}
I_{14}
O_2
O_4
P
A
B
C
BASE LINE LINK 2
PROPORTIONAL LINE LINK 2
LINK 4 PROPORTIONAL LINE
LINK 4 BASE LINE
$v_{I_{24}} = 67\,m/s$
$v_{I_{26}} = 30\,m/s$
$v_P = 75\,m/s$
$25\,m/s = v_{I_{25}}$
$30\,m/s = v_{I_{26}}$
$52.5\,m/s = v_A = v_{I_{23}}$
$67\,m/s = v_{I_{24}}$
1
2
3
4
5
6


P
A
B
C
O_2
O_4
3m

Bonus (5 pts): An inverted slider crank linkage has the following dimensions. All lengths are in inches and all angles are in degrees.

Link 1	Link 2	Link 4	θ_2	γ
5	8	8	150	90

Link 2 is the drive link and it is known to be rotating at $\omega_2 = 100\frac{1}{s}$ and $\alpha_2 = -65\frac{1}{s^2}$. Using the program that you have been developing, calculate all the critical parameters associated with this linkage in both of the possible configurations. Print out the results of your program and staple it directly behind this page.

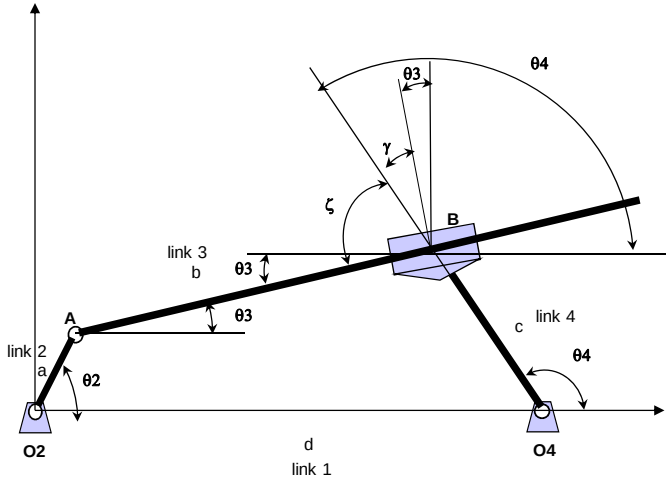


Inverted Slider Crank

a=	**8**	Link 2
c=	**8**	Link 4
d=	**5**	Link 1
$\theta_2 =$	**150**	
γ=	**0**	
$\dot{\theta}_2 =$	**100**	$\frac{1}{s}$
$\ddot{\theta}_2 =$	**-65**	$\frac{1}{s^2}$

b=	**9.71**	**-9.71**
$\theta_4 =$	**110.95**	**-148.02**
$\theta_3 =$	**20.95**	**-238.02**
$\dot{\theta}_4 =$	**51.91**	**72.73**
$\dot{\theta}_3 =$	**51.91**	**72.73**
b-dot=	**205.98**	**-205.98**
$\ddot{\theta}_4 =$	**1942.01**	**-2645.70**
$\ddot{\theta}_3 =$	**1942.01**	**-2645.70**
b-dotdot=	**-40179.23**	**40179.23**

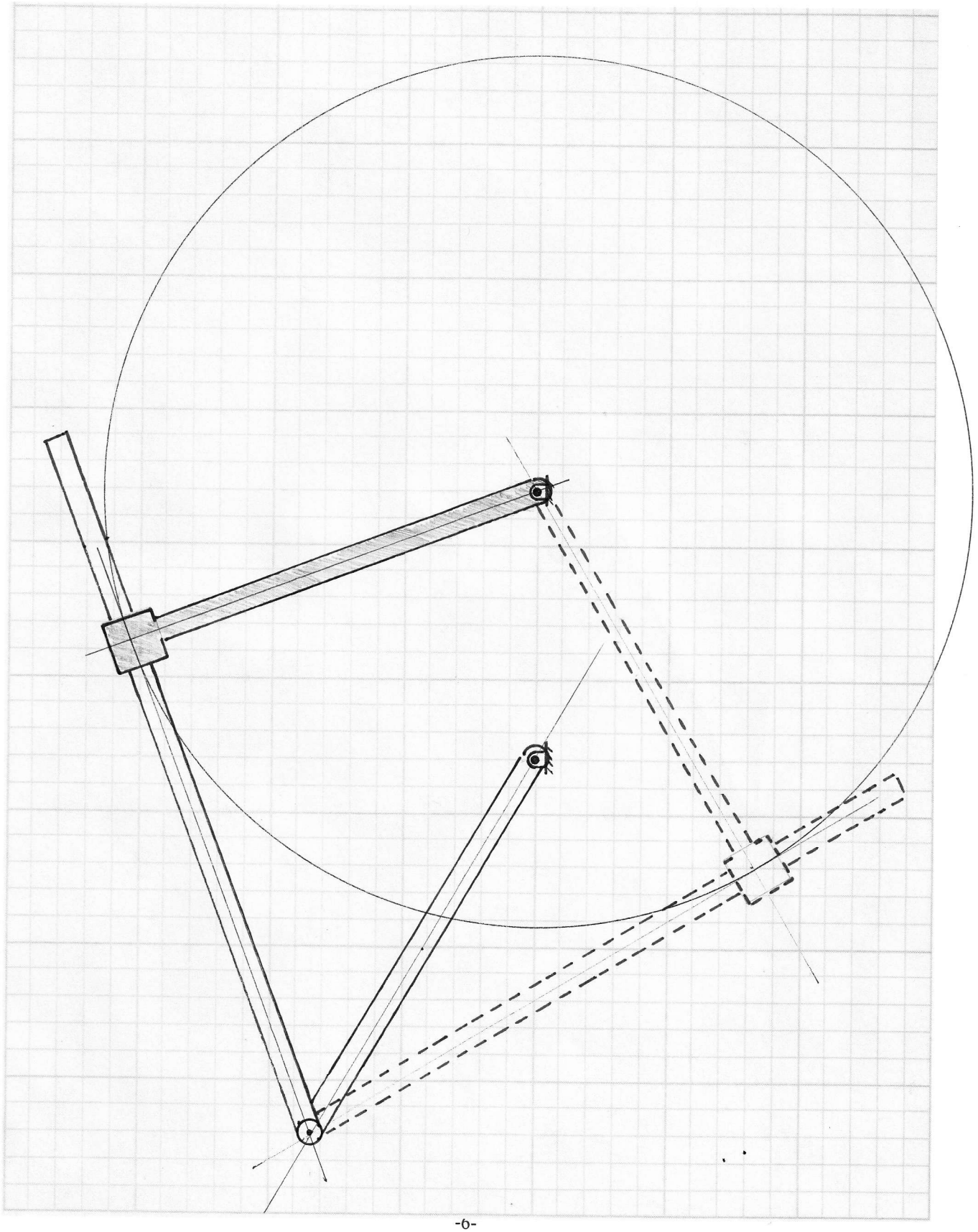
ζ=	90
K1=	-4
K2=	11.92820323
K3=	8



	x comp	y comp	mag	angle	i	j
rO4=	**5.00**	**0.00**	**5.00**	**0.0**	**1.000**	**0.000**
rA=	**-6.93**	**4.00**	**8.00**	**150.0**	**-0.866**	**0.500**
rBA=	9.07	3.47	9.71	20.9	0.934	0.358
rBO4=	-2.86	7.47	8.00	110.9	-0.358	0.934
rB=	**2.14**	**7.47**	**7.77**	**74.0**	**0.275**	**0.961**
vA=	**-400.00**	**-692.82**	**800.00**	**-120.0**	**-0.500**	**-0.866**
vBA=	12.17	544.36	544.50	88.7	0.022	1.000
vB=	**-387.83**	**-148.46**	**415.27**	**-159.1**	**-0.934**	**-0.358**
aA=	**69542.03**	**-39549.67**	**80001.69**	**-29.6**	**0.869**	**-0.494**
aBA=	-76344.88	13863.57	77593.42	169.7	-0.984	0.179
aB=	**-6802.85**	**-25686.10**	**26571.68**	**-104.8**	**-0.256**	**-0.967**

alt	**x comp**	**y comp**	**mag**	**angle**	**i**	**j**
rO4=	**5.00**	**0.00**	**5.00**	**0.0**	**1.000**	**0.000**
rA=	**-6.93**	**4.00**	**8.00**	**150.0**	**-0.866**	**0.500**
rBA=	5.14	-8.24	9.71	-58.0	0.530	-0.848
rB04=	-6.79	-4.24	8.00	-148.0	-0.848	-0.530
rB=	**-1.79**	**-4.24**	4.60	-112.9	-0.388	-0.921
vA=	**-400.00**	**-692.82**	**800.00**	**-120.0**	**-0.500**	**-0.866**
vBA=	708.13	199.26	735.63	15.7	0.963	0.271
vB=	**308.13**	**-493.56**	**581.84**	**-58.0**	**0.530**	**-0.848**
aA=	**69542.03**	**-39549.67**	80001.69	-29.6	0.869	-0.494
aBA=	-44854.15	79913.90	91641.29	119.3	-0.489	0.872
aB=	24687.88	40364.24	47315.57	58.5	0.522	0.853

Bonus (5 pts): Draw the above inverted slider crank linkage in both of its configurations.



Bonus (5 pts): Draw the above inverted slider crank linkage in both of its configurations.