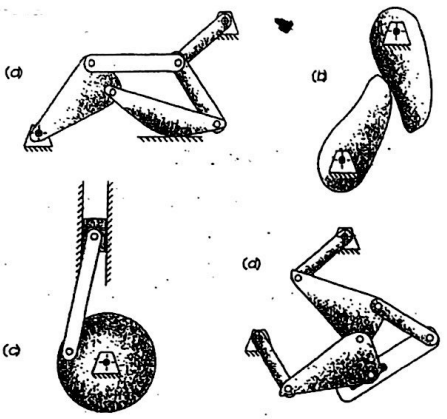

FIGURE P2-1 part 1
Linkages for Problems 2-7 to 2-10

*2-7 Calculate the mobility of the linkages assigned from Figure P2-1 part 1 and part 2.

*2-8 Identify the items in Figure P2-1 as mechanisms, structures, or preloaded structures.

2-9 Use linkage transformation on the linkage of Figure P2-1a to make it a 1-*DOF* mechanism.

2-10 Use linkage transformation on the linkage of Figure P2-1d to make it a 2-*DOF* mechanism.

* Answers in Appendix F.

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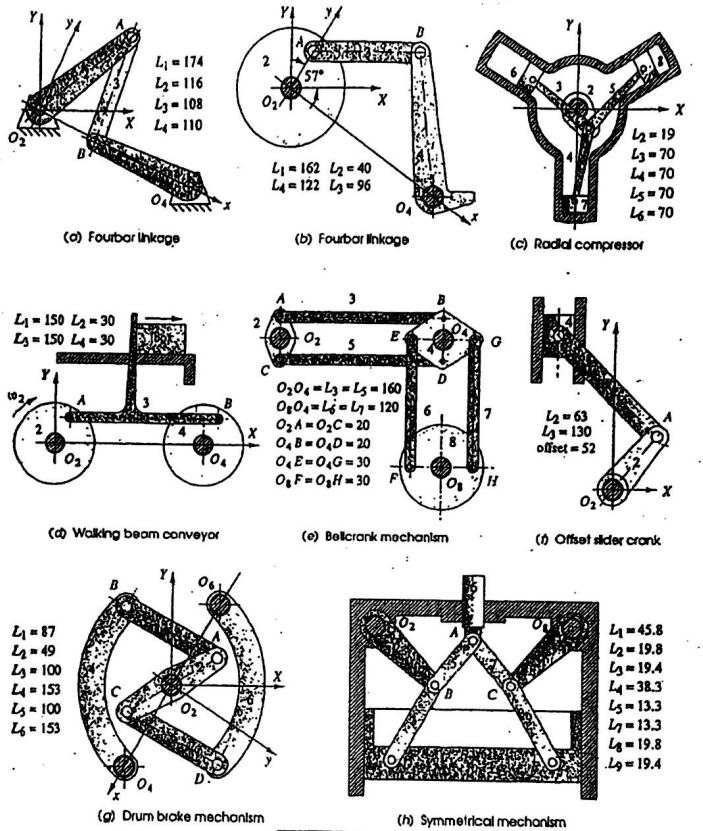

FIGURE P2-4

Problems 2-21 to 2-23 *Adapted from P. H. Hill and W. P. Rule. (1960) Mechanisms: Analysis and Design, with permission*

*2-21 Find the mobility of the mechanisms in Figure P2-4.

2-22 Find the Grashof condition and Barker classifications of the mechanisms in Figure P2-4a, b, and d.

2-23 Find the rotatability of each loop of the mechanisms in Figure P2-4e, f, and g.

* Answers in Appendix P.

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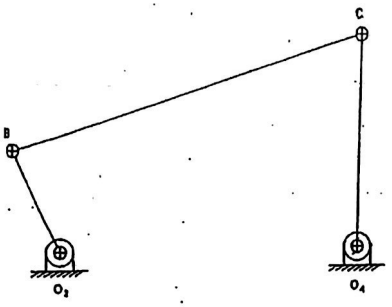

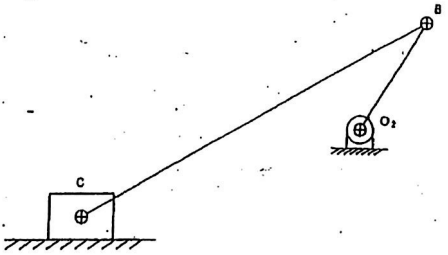

With OB as the input link, determine the stroke and time ratio.

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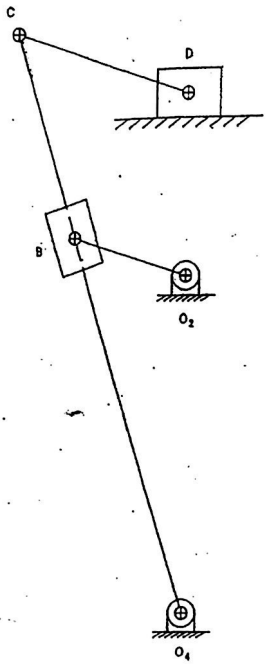

Crank-Shaper:
The crank rotates at 150 rpm, and the forward stroke is to the right
Determine the stroke, time ratio, direction of rotation of the input crank, and the average speed of the forward and return stroke.

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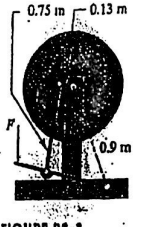

FIGURE P3-3
Problem 3-14. Treadle operated grinding wheel

3-14 Figure P3-3 shows a treadle operated grinding wheel driven by a fourbar linkage. Make a cardboard model of the linkage to any convenient scale. Determine its minimum transmission angles from the model. Comment on its operation. Will it work? If so, explain how it does.

* This figure is provided as an animated Working Model file on the CD-ROM. Its filename is the same as the figure number.

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1) **Mobility**

- Number the links
- Mark the pairing elements with appropriate symbols.
- Calculate the mobility..

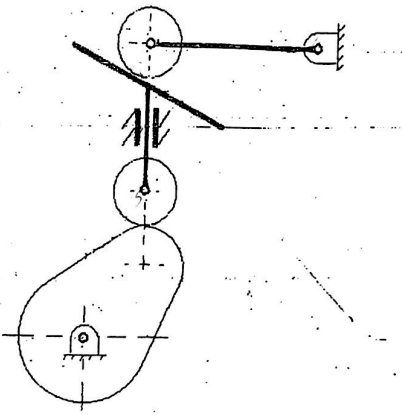
N =

J_1 =

J_2 =

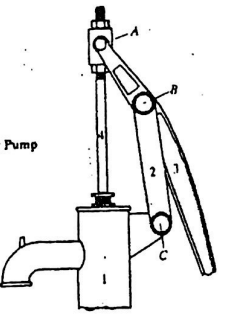
M =

- Comment :



2) **Kinematic Drawing**

Sketch a neat kinematic drawing of the underling mechanism for the shown water pump.



Water Pump

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H.W. 1 (2/5)

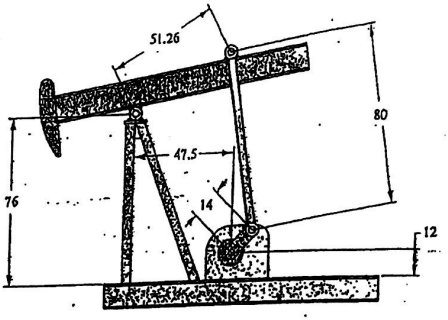

FIGURE P2-18
Problem 2-42 An oil field pump - dimensions in inches

2-42 Find the mobility, the Grashof condition, [redacted] of the oil field pump shown in Figure P2-18.

* This figure is provided as an animated Working Model file on the CD-ROM. Its filename is the same as the figure number.

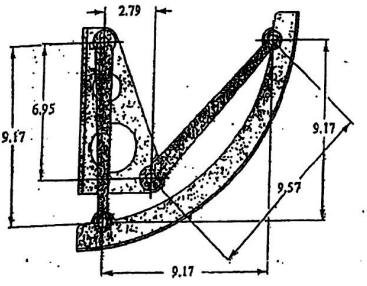

FIGURE P2-19
Problem 2-43 An aircraft overhead bin mechanism - dimensions in inches

2-43 Find the mobility, the Grashof condition, [redacted] of the aircraft overhead bin shown in Figure P2-19. Make a cardboard model and investigate its motions.

Due: at end of 4th Week

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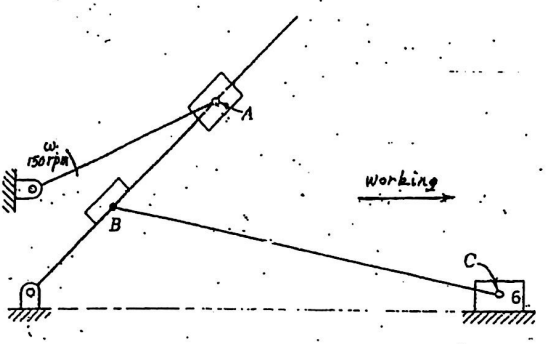
H.W. 1 - (3/5)

Determine:

- The stroke
- Time ratio
- Direction of crank rotation
- Times of the forward and return strokes
- Average speeds of the output link during the forward and return strokes
- The number of cycles of the output link per minute



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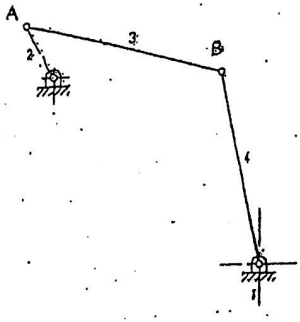
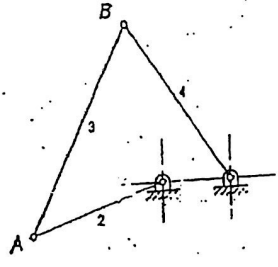
H.W. 1 (4/5)





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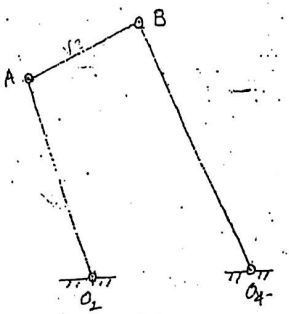
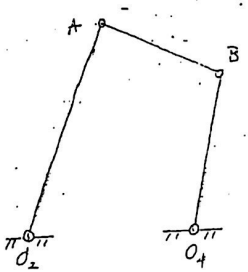
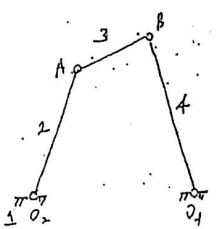
H.W. 1 (5/5)







Determine the limiting positions of the input link (O_2A)

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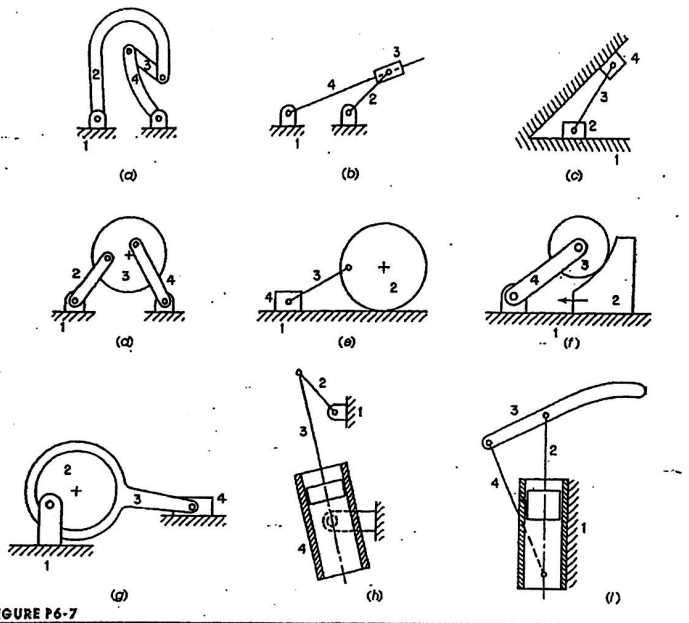

FIGURE P6-7

Problems 6-14 and 6-23. *From R. T. Hinkle, Problems in Kinematics, Prentice-Hall, Englewood Cliffs, N.J., 1954*

6-14 Find all the instant centers of the linkages shown in Figure P6-7.

†6-23 Generate and draw the fixed and moving centrodes of links 1 and 3 for the linkage in Figure P6-7a.

† These problems are suited to solution using *Mathcad*, *Matlab*, or *TKSolver* equation solver programs. In most cases, your solution can be checked with program FOURBAR.

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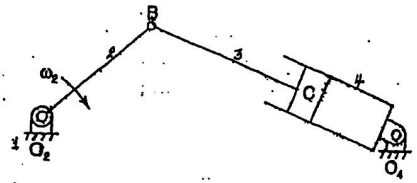
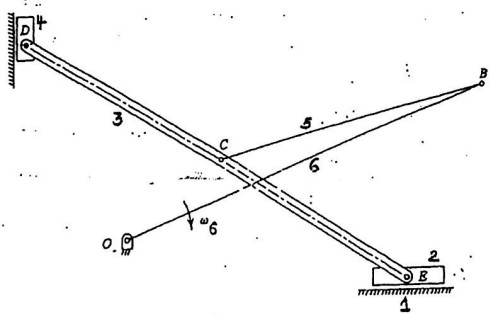
Instantaneous Centers of Velocity

1) With $\omega_2 = 10$ rad/sec, determine:
- All the instantaneous centers
- The angular velocity of link-4 (ω_4)



2) Locate the necessary instantaneous centers to determine the velocity of point D (link-4). The angular velocity of link-2 is $\omega_2 = 10$ rad/sec. The space scale is 1:1



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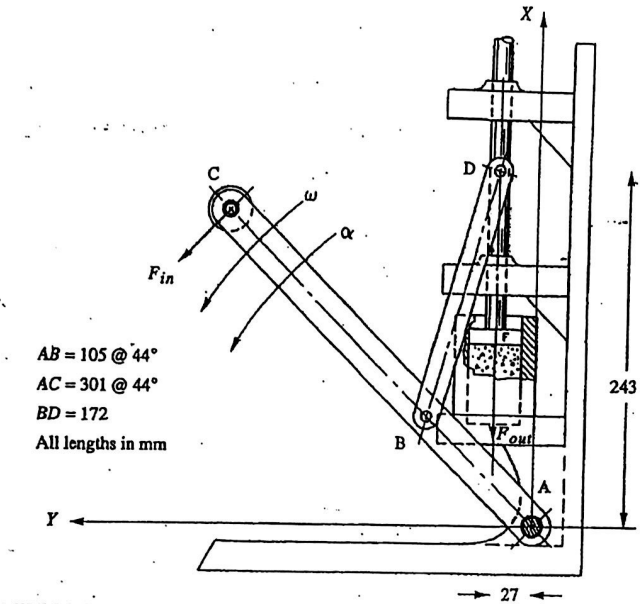

FIGURE P6-18

Problem 6-55 *From P. H. Hill and W. P. Rule. (1960). Mechanisms: Analysis and Design, with permission*

†6-55 Figure P6-18 shows a powder compaction mechanism.

a. Calculate its mechanical advantage for the position shown.

b. Calculate and plot its mechanical advantage as a function of the angle of link *AC* as it rotates from 15 to 60°.

† These problems are suited to solution using *Mathcad*, *Matlab*, or *TKSolver* equation solver programs.

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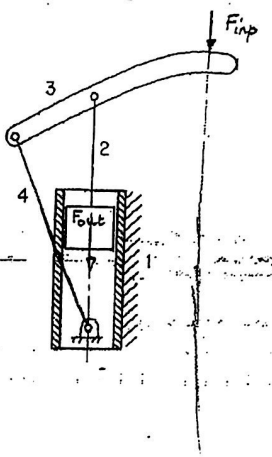
Instantaneous Centers of Velocity and Mechanical Advantage

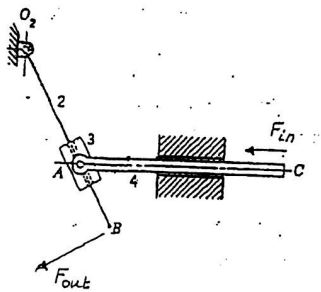
1) For the shown water pump mechanism:

a) Find all the instantaneous centers
b) Find the mechanical advantage



2) At the shown position of Rapson mechanism:

a. Locate all the instantaneous centers of zero velocities
b. Determine the mechanical advantage.



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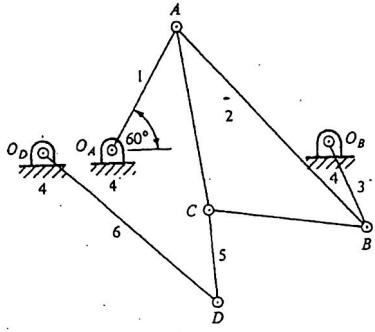
① (a) Locate all the instant centers for velocity.
(b) If $\omega_1 = 3$ rad/s CCW, determine ω_2, ω_3, ω_5, ω_6.

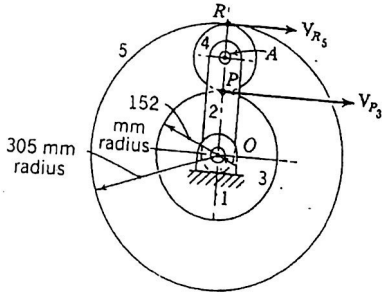
$O_A A = 1.50$ $O_B B = 1.00$ $O_D D = 2.50$

$AB = 3.00$ $AC = 2.00$ $BC = 1.75$ $CD = 1.00$



(8-54)

② In the epicyclic gear train shown, the sun gear (link 3) and the internal gear (link 5) have the same sense of rotation; V_{R_5} is one-half the length of V_{P_3}. Determine the location of instantaneous center 14. Determine the angular-velocity ratios ω_1/ω_3 and ω_2/ω_3.



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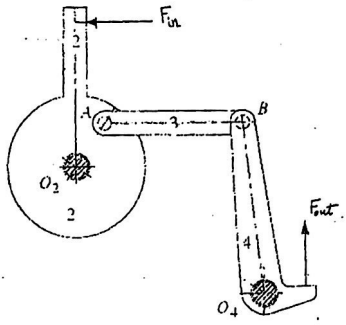
3) **Instantaneous Centers of Velocity and Mechanical Advantage:**

a) Show the instantaneous centers of zero relative velocity.

b) Determine the mechanical advantage.

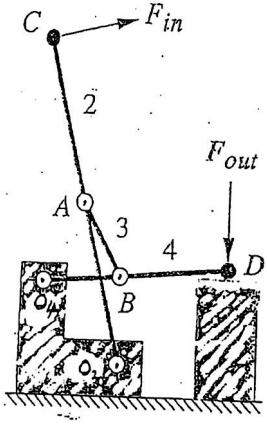
Note: the mechanism is drawn to scale.



4) **Instantaneous Centers and Mechanical Advantage**

For the shown fourbar mechanism determine:

- All the instantaneous centers of zero relative velocity
- The mechanical advantage



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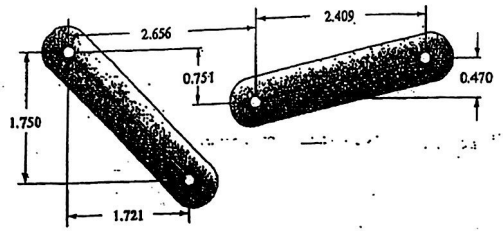

FIGURE P3-1
Problems 3-3 to 3-4

*3-3 Design a fourbar mechanism to give the two positions shown in Figure P3-1 of output rocker motion with no quick-return. (See Example 3-2.) Build a cardboard model and determine the toggle positions and the minimum transmission angle from the model.

3-4 Design a fourbar mechanism to give the two positions shown in Figure P3-1 of coupler motion. (See Example 3-3.) Build a cardboard model and determine the toggle positions and the minimum transmission angle from the model. Add a driver dyad. (See Example 3-4.)

* Answers in Appendix F.

3-2 Design a fourbar Grashof crank-rocker for 90° of output rocker motion with no quick-return. (See Example 3-1, p. 93.) Build a cardboard model and determine the toggle positions and the minimum transmission angle from the model.

3-7 Repeat Problem 3-2 with a quick-return time ratio of 1:1.4. (See Example 3-9, p. 108.)

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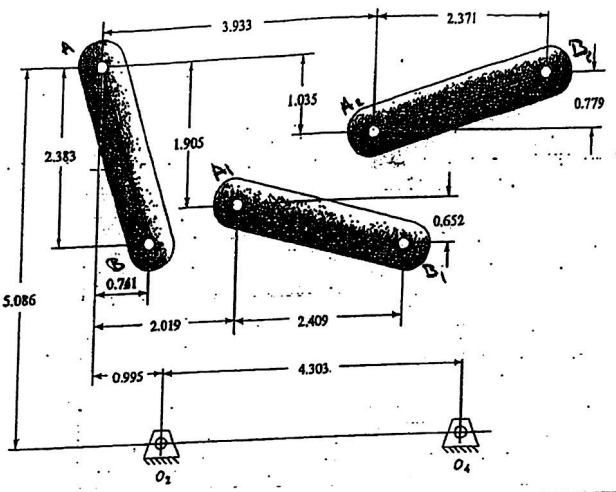

FIGURE P3-2

Problems 3-5 to 3-6

*3-5 Design a fourbar mechanism to give the three positions of coupler motion with no quick-return shown in Figure P3-2. (See also Example 3-5.) Ignore the points O_2 and O_4 shown. Build a cardboard model and determine the toggle positions and the minimum transmission angle from the model. Add a driver dyad. (See Example 3-4.)

*3-6 Design a fourbar mechanism to give the three positions shown in Figure P3-2 using the fixed pivots O_2 and O_4 shown. Build a cardboard model and determine the toggle positions and the minimum transmission angle from the model. Add a driver dyad.

*3-8 Design a sixbar drag link quick-return linkage for a time ratio of 1:2, and output rocker motion of 60°.

3-9 Design a crank-shaper quick-return mechanism for a time ratio of 1:3 (Figure 3-14, p. 112).

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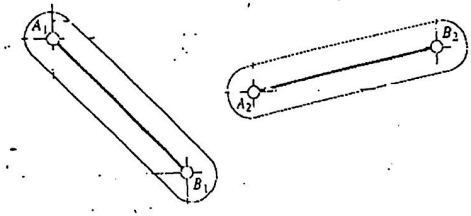
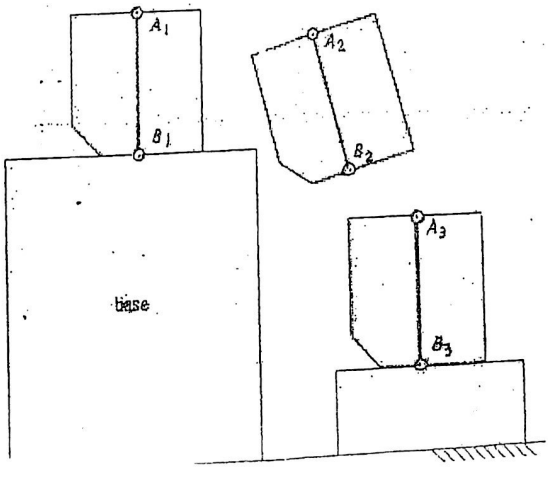
(3-3)



Linkage Synthesis

Design a fourbar linkage to move the object through the three positions shown using points A and B for attachment (AB is the coupler). Add a driver dyad to limit its motion to the range of positions designed making it a sixbar. All pivots should be on the base.



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H.W. 3 (2/2)

Synthesis of Quick-Return Mechanisms

1. Design a fourbar crank rocker to have a stroke of 45° and time ratio of 7/5
2. Design an offset-slider crank mechanism to have a 12 cm stroke and 5/4 time ratio
3. Design a Whitworth quick-return mechanism to have a length of stroke of 12 cm and a time ratio of 11/7.
4. Design a crank-shaper quick-return mechanism to have a length of stroke of 12 cm and a time ratio of 11/7.
5. Design a sixbar drag-link quick-return linkage mechanism for a time ratio of 1.5 and an output rocker of 60°.

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H.W. 4 (1/2)

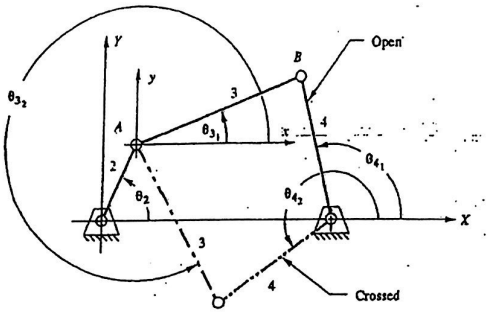

FIGURE P4-1
Problems 4-6 to 4-7. General configuration and terminology for the fourbar linkage

* This figure is provided as an animated Working Model file and as a Matlab file on the CD-ROM. Its filename is the same as the figure number.

*4-6 The link lengths and the value of θ_2 for some fourbar linkages are defined in Table P4-1. The linkage configuration and terminology are shown in Figure P4-1. For the rows assigned, draw the linkage to scale and graphically find all possible solutions (both open and crossed) for angles θ_3 and θ_4. Determine the Grashof condition.

*†4-7 Repeat Problem 4-6 except solve by the vector loop method.

TABLE P4-1 Data for Problems 4-6, 4-7 and 4-13 to 4-15

Row	Link 1	Link 2	Link 3	Link 4	θ_2
a	6	2	7	9	30
b	7	9	3	8	85
c	3	10	6	8	45
d	8	5	7	6	25
e	8	5	8	6	75
f	5	8	8	9	15
g	6	8	8	9	25
h	20	10	10	10	50
i	4	5	2	5	80
j	20	10	5	10	33
k	4	6	10	7	88
l	9	7	10	7	60
m	9	7	11	8	50
n	9	7	11	6	120

* Answers in Appendix F.

† These problems are suited to solution using *Mathcad*, *Matlab*, or *TKSolver* equation solver programs. In most cases, your solution can be checked with program FOURBAR, SLIDER, or SIXBAR.

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HW4 (2/2)

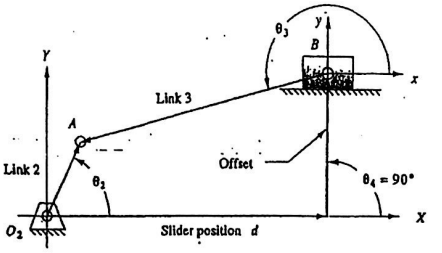

FIGURE P4-2
Problems 4-9 to 4-10 Open configuration and terminology for a fourbar slider-crank linkage

* This figure is provided as an animated Working Model file and as a Matlab file on the CD-ROM. Its filename is the same as the figure number.

*4-9 The link lengths and the value of θ_2 and offset for some fourbar slider-crank linkages are defined in Table P4-2. The linkage configuration and terminology are shown in Figure P4-2. For the rows assigned, draw the linkage to scale and graphically find all possible solutions (both open and crossed) for angle θ_3 and slider position d.

*†4-10 Repeat Problem 4-9 except solve by the vector loop method.

TABLE P4-2 Data for Problems 4-9 to 4-10

Row	Link 2	Link 3	Offset	θ_2
a	1.4	4	1	45
b	2	6	−3	60
c	3	8	2	−30
d	3.5	10	1	120
e	5	20	−5	225
f	3	13	0	100
g	7	25	10	330

* Answers in Appendix F.

† These problems are suited to solution using *Mathcad*, *Matlab*, or *TKSolver* equation solver programs. In most cases, your solution can be checked with program FOURBAR, SLIDER, or SIXBAR.

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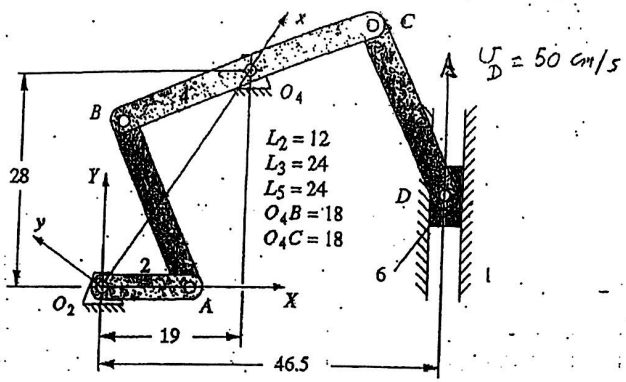
Draw the Vel. & Acc. Polygons



(d) Sixbar linkage

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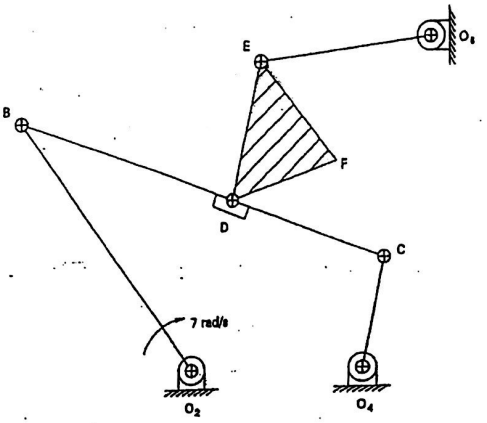

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Velocity and Acceleration Polygons (20 marks)

For the shown mechanism, determine the angular velocity and acceleration of link 6 (ω_6, α_6)

Given:

$O_2A = 5$ cm,

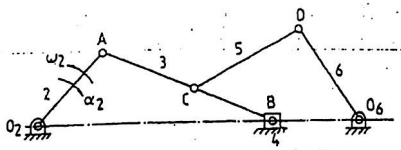
$AB = 10$ cm,

$CD = 6.5$ cm,

$O_6D = 5.8$ cm

$\omega_2 = 8$ rad/s,

$\alpha_2 = 25$ rad/s^2.



$+ O_A$

$+ O_v$

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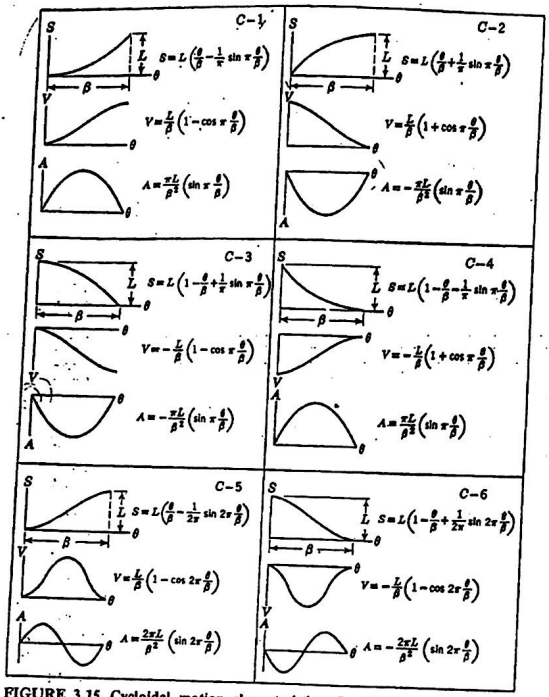

FIGURE 3.15 Cycloidal motion characteristics: S = displacement, inches; V = velocity, inches per degree; A = acceleration, inches per degree squared. (M. Kloomok and R. V. Muffley, "Plate Cam Design—with Emphasis on Dynamic Effects," *Prod. Eng.*, February 1955.) *N. B.* For SI units, S = displacement, millimeters; V = velocity, millimeters per degree; A = acceleration, millimeters per degree squared.

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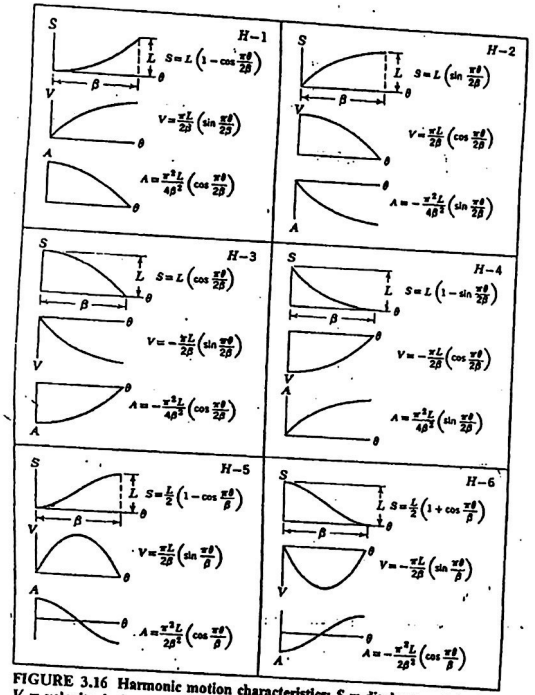

FIGURE 3.16 Harmonic motion characteristics: S = displacement, inches; V = velocity, inches per degree; A = acceleration, inches per degree squared. (M. Kloomok and R. V. Muffley, "Plate Cam Design—with Emphasis on Dynamic Effects," *Prod. Eng.*, February 1955.) *N. B.* For SI units, S = displacement, millimeters; V = velocity, millimeters per degree; A = acceleration, millimeters per degree squared.

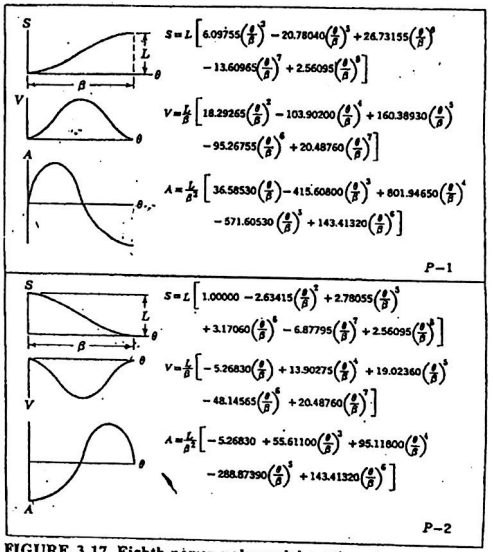

FIGURE 3.17 Eighth-power polynomial motion characteristics: S = displacement, inches; V = velocity, inches per degree; A = acceleration, inches per degree squared. (M. Kloomok and R. V. Muffley, "Plate Cam Design—with Emphasis on Dynamic Effects," *Prod. Eng.*, February 1955.) *N. B.* For SI units, S = displacements, millimeters; V = velocity, millimeters per degree; A = acceleration, millimeters per degree squared.

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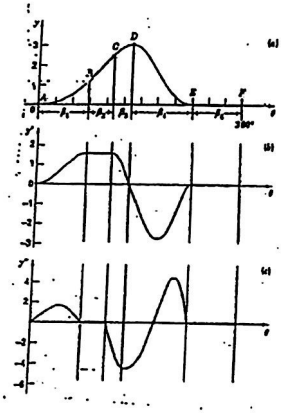

given $\dot{\theta} = 5$ rad/s

$\dot{y}_C =$

$\ddot{y}_D =$

Time from E to F =

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A cam rotates at 100 rpm. If the follower is to be lifted 5 cm with uniformly accelerated motion at 300 cm/sec^2, how many cam degrees will be required.

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A cam follower to be dropped 7.5 cm from its highest position to its lowest position by simple harmonic motion in 90 deg of cam rotation. If the maximum allowable acceleration of the follower is 150 cm/sec^2, what is the maximum allowable cam rpm.

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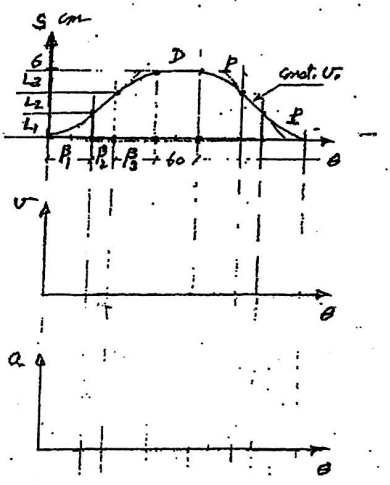
Follower Motion Synthesis

Motion Type	Equation
Const. Acceleration Rise	$s = L\theta^2/\beta^2$
Const. Deceleration Rise	$s = -L\theta^2/\beta^2 + 2L\theta/\beta$

A 7-segments symmetric displacement curve is shown in the figure.

(a) With $\beta_1 = 2\beta_2 = \beta_3$, determine β_1, β_2, and β_3
(b) Prove that the relation to match the velocities are $2L_1/\beta_1 = L_2/\beta_2 = 2L_3/\beta_3$.
(c) Determine L_1, L_2, and L_3.
(d) Sketch the velocity and acceleration curves.



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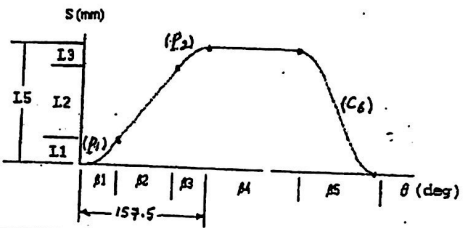
Follower Motion Synthesis

A 5-segments symmetric displacement curve is shown in the figure and the table.

1. Write the displacement, velocity and acceleration equations (symbolic) for each segment
2. Prove that the relation to match the velocities between segments 1 and 2 and between segments 2 and 3 are: $2L_1/\beta_1 = L_2/\beta_2 = 2L_3/\beta_3$.
3. Calculate the values of β_1, β_2, and β_3 to match the velocities.
4. Complete the values missing in the table: β_5, L_4, and L_5
5. Determine the follower maximum velocity during its rise and return
6. Determine the follower maximum acceleration during its rise and return
7. Sketch the velocity and acceleration curves showing the max and min values.

Cam rotates at constant angular velocity
$\omega = 100$ rpm



Segment number	Motion Type Equation	Displacement (mm)	Cam Rotation (deg.)
1	Const. acceleration rise (P_1) $s = L\theta^2/\beta^2$	$L_1 = 10$	$\beta_1 =$
2	Const. Velocity rise	$L_2 = 30$	$\beta_2 =$
3	Const. deceleration rise (P_2) $s = -L\theta^2/\beta^2 + 2L\theta/\beta$	$L_3 = 10$	$\beta_3 =$
4	Dwell	$L_4 =$	$\beta_4 = 90$
5	Cycloid return (C_6) $s = -L(1 - \theta/\beta + 1/2\pi \sin 2\pi\theta/\beta)$	$L_6 =$	$\beta_6 =$

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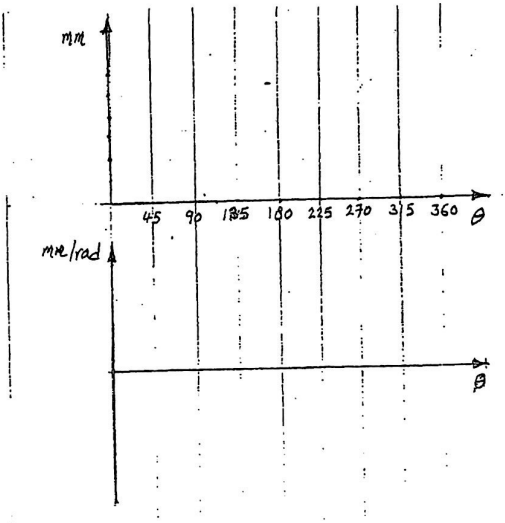
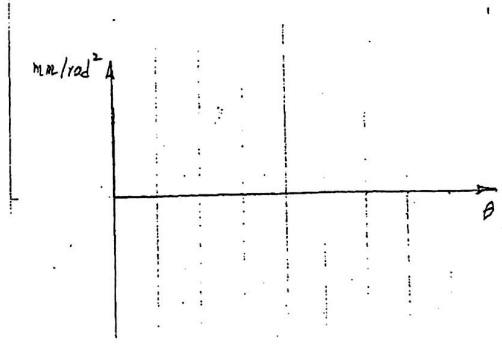
Cam-Follower Motion Synthesis (20 marks)

A 4-kg radial roller follower is to rise with constant acceleration (L_1, $\beta_1 = 90^o$) followed by a constant deceleration (L_2, $\beta_2 = 45^o$). The total rise for the parabolic motion ($L_1 + L_2$) is 60 mm. The follower returns with simple harmonic motion (L_3, β_3) 30 mm in 90°, dwell (0, β_4) for 45°, and returns with cycloid motion (L_5, β_5) the remaining 30 mm in 90° of cam rotation.

a) Determine L_1 and L_2.
b) Sketch the follower displacement, velocity, and acceleration for one complete cycle and calculate and show the key values (max and min).
c) Determine the stiffness of a suitable spring to keep the follower in contact with a disk cam rotating at 300 rpm.





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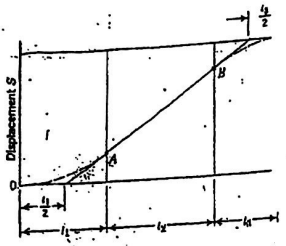
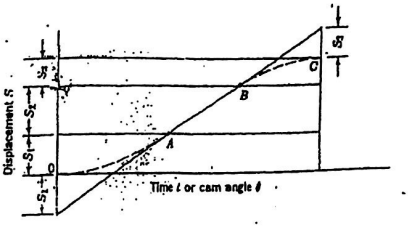
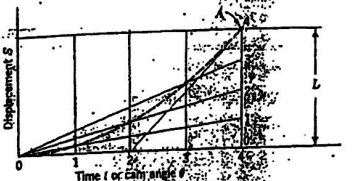
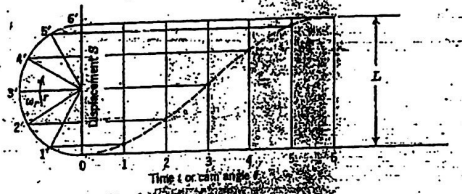


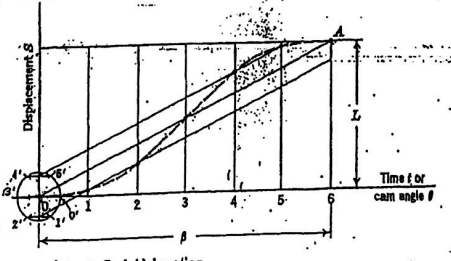




Parabolic motion.



Simple-harmonic motion.



Cycloidal motion.

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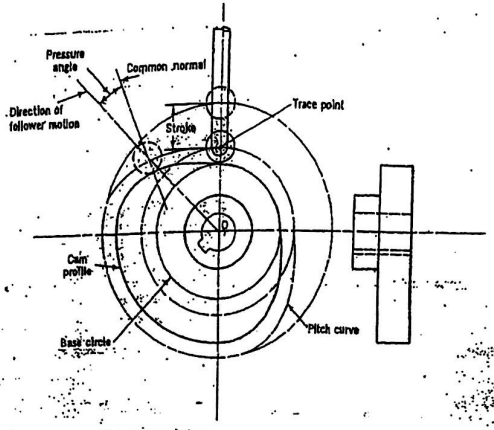
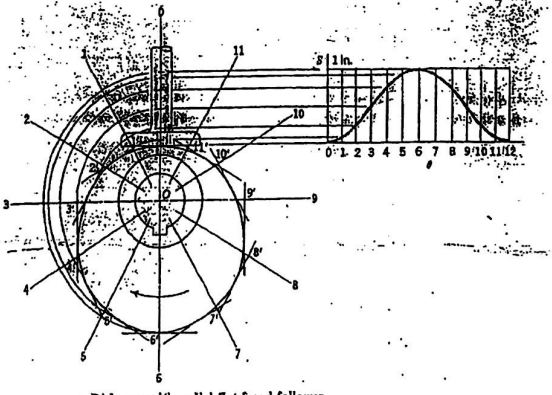


Cam nomenclature.



Disk cam with radial flat-faced-follower.

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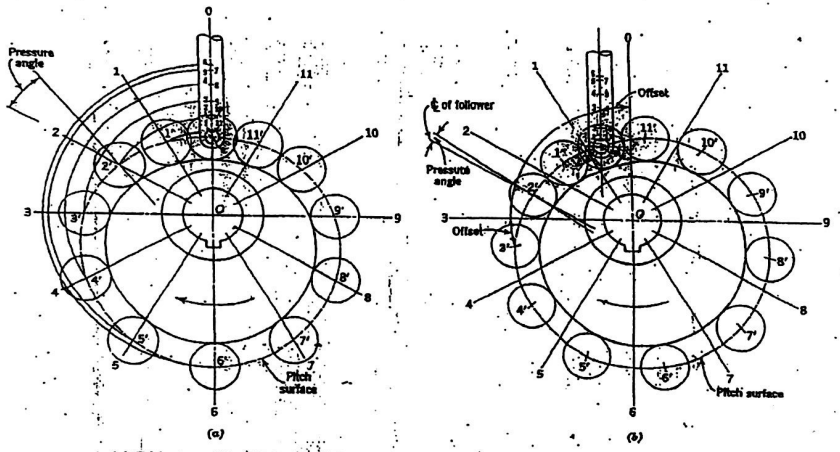

(a) Disk cam with radial roller follower. (b) Disk cam with offset roller follower.

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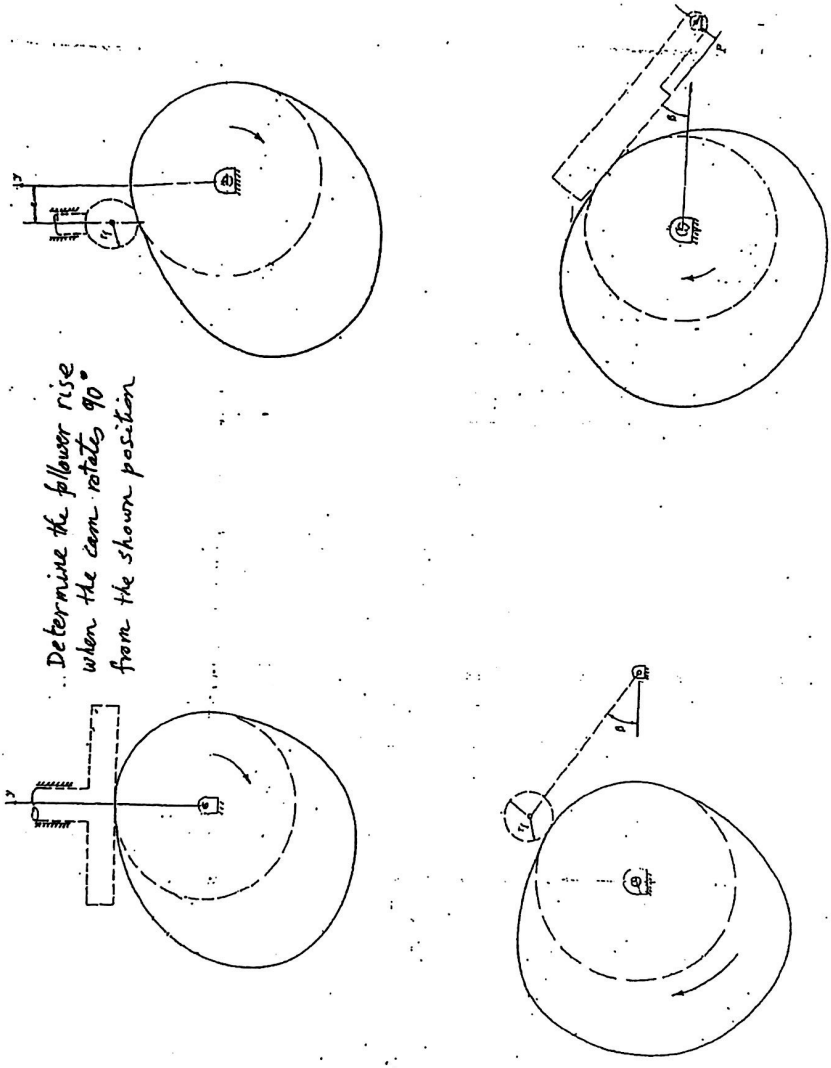
Determine the follower rise when the cam rotates 90° from the shown position



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In the preceding discussions, it was assumed that the cam being generated was the cam to be used in the final application. Where several machines of the same model are being produced and many copies of a cam are needed, it is generally more practical to generate what is known as a master cam and to use this master with a cam duplicating machine. The master cam is often made several times the actual size.

Problems

3.1. A disk cam rotating clockwise drives a radial flat-faced follower through a total displacement of 1½ in. with the following lift figures:

CAM ANGLE, deg	LIFT, in.	m
0	0.00	0
30	0.10	3
60	0.37	11
90	0.75	22
120	1.13	34
150	1.40	42
180	1.50	45
210	1.40	
240	1.13	
270	0.75	
300	0.37	
330	0.10	
360	0.00	

base circle radius 30 mm

roller radius 7 mm

Determine min face width or ϕ_{max}

Lay out the cam using a minimum radius of 1 in. Determine the length of the follower face (symmetrical). After the length has been found by trial, add ½ in. to each end to positively ensure proper contact.

3.2. A disk cam rotating counterclockwise drives a radial roller follower through a total displacement of 1½ in. Lay out the cam using the lift figures from Problem 3.1 and a minimum radius of 1 in. The roller diameter is to be ½ in. By trial determine the magnitude and position of the maximum pressure angle. Draw the

3.3. A disk cam rotating clockwise drives an offset flat-faced follower through a total displacement of 1½ in. Lay out the cam using the lift figures from Problem 3.1. The centerline of the follower is offset ½ in. to the left of and parallel to the vertical centerline of the cam. The minimum radius of the cam is to be 1 in. Determine the length of the follower face (symmetrical). After the length has been found by trial, add ½ in. to each end to positively ensure proper contact.

3.4. A disk cam rotating counterclockwise drives an offset roller follower through a total displacement of 1½ in. Lay out the cam using the lift figures in Problem 3.1. The centerline of the follower is offset ½ in. to the right of and parallel to the vertical centerline of the cam. The minimum radius of the cam is to be 1 in. and the roller diameter ½ in. By trial determine the maximum pressure angle during the outward motion and during the return motion.

3.9. An oscillating roller follower moving through a cam as shown in Fig. 3.9, with the following displacement figures:

FOLLOWER ANGLE, deg	CAM DISPLACEMENT, in.
0.0	0.00
4.5	0.06
16.0	0.24
30.0	0.50
44.0	0.76
55.5	0.94
60.0	1.00

Lay out the groove in the cam block if the cam is to move upward and to the right at an angle of 45° as the follower moves counterclockwise. The follower moves symmetrically about the vertical centerline. The distance from the center of the roller follower to the center of oscillation is 3 in., and the diameter of the roller is ½ in. The cam block is 3 × 4 in.

3.10. Prove that the method for finding inflection points when the time intervals are known as shown in Fig. 3.10 is correct.

3.11. Prove that the method for finding inflection points when the displacement intervals are known as shown in Fig. 3.11 is correct.

3.12. Prove that the method of construction for parabolic motion shown in Fig. 3.12 is correct.

3.13. Draw the displacement–time graph for a follower that rises through a total displacement of 1½ in. with constant acceleration for a three-sixteenth revolution, constant velocity for a quarter revolution, and constant deceleration for a quarter revolution of the cam. After dwelling for a sixteenth revolution, the follower returns with simple harmonic motion in a quarter revolution of the cam. Use an abscissa 4 in. long.

3.14. Draw the displacement–time graph for a follower that rises 19 mm with simple harmonic motion in a quarter revolution, dwells for an eighth revolution, and then rises 19 mm with simple harmonic motion in a quarter revolution of the cam. The follower dwells for a sixteenth revolution and then returns 38 mm with parabolic motion in a quarter revolution, followed by a dwell for a sixteenth revolution of the cam. Use an abscissa 160 mm long.

3.15. Draw the displacement–time graph for a follower that rises 1½ in. in a half revolution of the cam such that the first ¾ in. is constant acceleration, constant velocity for the next ½ in., and constant deceleration for the remaining ¾ in. The return motion is simple harmonic in a half revolution of the cam. Use an abscissa 6 in. long.

H.W.

3.16. Draw the displacement–time graph for a follower that moves through a total displacement of 32 mm with constant acceleration for 90° and constant deceleration for 45° of cam rotation. The follower returns 16 mm with simple harmonic motion in 90°, dwells for 45°, and returns the remaining 16 mm with simple harmonic motion in 90° of cam rotation. Use an abscissa 160 mm long.

3.17. The radial flat-faced follower shown in Fig. 3.43 is made to reciprocate by the action of a circular disk cam rotating about the axis at O_1. (a) Derive expressions for the follower displacement R and for the distance l to the point of contact in terms of the cam angle θ, the radius r of the cam, and the offset distance h. (b) Make a sketch of the displacement R versus cam angle θ for one cycle of the cam. Label the lift L of the follower as the

38

H.W. 7 (2/2)

52

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3.9

O_1 (pinion)

Spur Gears

An 8-module, 20° pinion of 18-tooth drives a 36-tooth gear. The pinion is the driver and rotates counterclockwise

(a) Calculate:

Addendum $a =$

Pitch radii $r_1 =$

$r_2 =$

Outer radii $r_{o1} =$

$r_{o2} =$

Pitch $p =$

Base pitch $p_b =$

(b) Draw a full-scale schematic of the pinion and gear in mesh showing the pitch point P, start and end of contacts A and B, and the length of contact Z

Contact length Z =

Contact ratio $m_p =$

(c) Calculate:

- Tooth thickness at pitch $t =$
- Tooth thickness at base $t_b =$
- Maximum pressure angle Φ_{max} for both the pinion and gear

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Spur Gears

A 12-module, 20° pinion of 20-tooth drives a rack. The pinion rotates counterclockwise at 100 rpm.

a) Calculate:

Addendum $a =$

Dedendum $b =$

Pitch $p =$

Base pitch $p_b =$

Pitch radii $r =$

Outer radii $r_o =$

Base radii $r_b =$

Max pressure angle $\Phi_{max} =$

Max tooth thickness $t_{max} =$

b) Draw a full-scale schematic of the pinion and rack in mesh showing the pitch point P, start and end of contacts A and B, the length of contact Z, and the limit of interference point E.

Contact length $Z =$

Contact ratio $m_p =$

c) Graphically determine the sliding velocity between the pinion tooth and the gear tooth at the beginning of contact.

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H.W. 8 (1/1)

7) **Spur Gears (12 marks)**

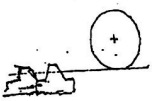
A 5-module, 20° pinion of 20-tooth drives a rack. The pinion rotates counterclockwise.

a. Calculate:

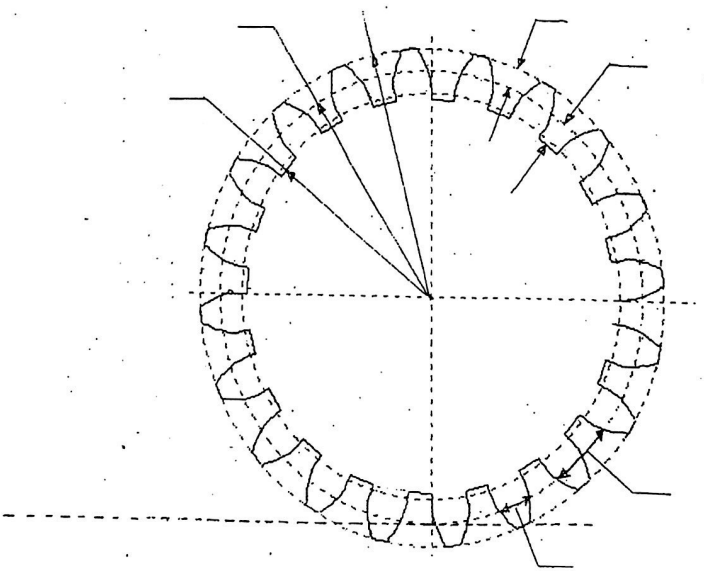
Addendum	a =	Base pitch	p_b =
Dedendum	b =	Tooth thickness at pitch	t =
Pitch radius	r =	Max pressure angle	Φ_{max} =
Base radii	r_b =	Tooth thickness at base	t_b =
Outer radius	r_o =	Contact length	Z =
Inner radius	r_i =	Contact ratio	m_p =
Pitch	p =		

b. Symbolically name the parts of the gear shown in the Figure

c. Complete the Figure to show the rack in mesh with the pinion, the pitch point "P", the start of contact "A", the end of contact "B", and the length of contact "Z".



d. Draw ~~one~~ two tooth of the rack to scale showing the pressure angle, the base pitch, and the addendum and dedendum distances a and b.



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7) **Spur Gears (12 marks)**

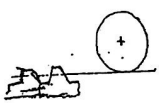
A 5-module, 20° pinion of 20-tooth drives a rack. The pinion rotates counterclockwise.

a. Calculate:

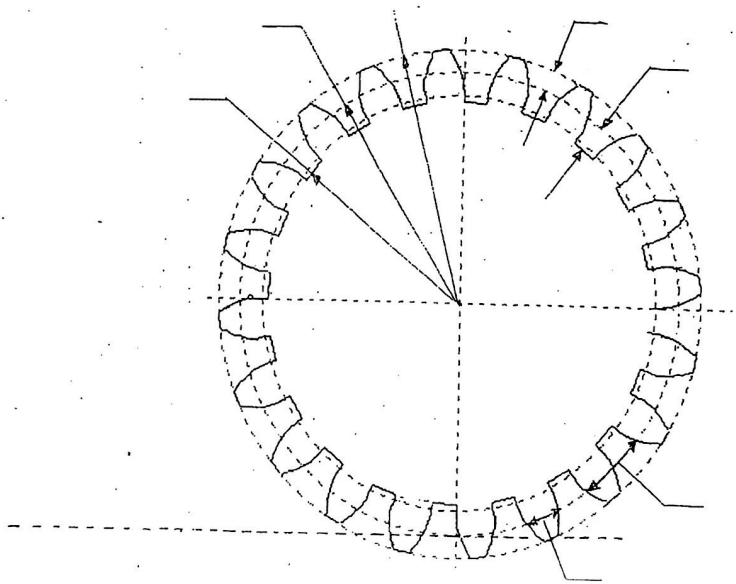
Addendum	a =	Base pitch	p_b =
Dedendum	b =	Tooth thickness at pitch	t =
Pitch radius	r =	Max pressure angle	Φ_{max} =
Base radii	r_b =	Tooth thickness at base	t_b =
Outer radius	r_o =	Contact length	Z =
Inner radius	r_i =	Contact ratio	m_p =
Pitch	p =		

b. Symbolically name the parts of the gear shown in the Figure

c. Complete the Figure to show the rack in mesh with the pinion, the pitch point "P", the start of contact "A", the end of contact "B", and the length of contact "Z".



d. Draw ~~one~~ Two tooth of the rack to scale showing the pressure angle, the base pitch, and the addendum and dedendum distances a and b.



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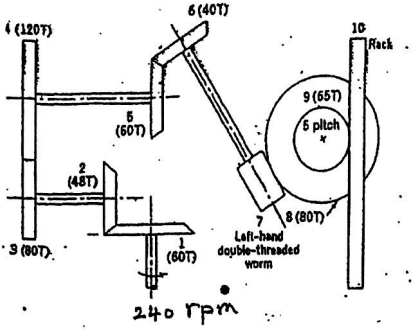
n_1 rpm

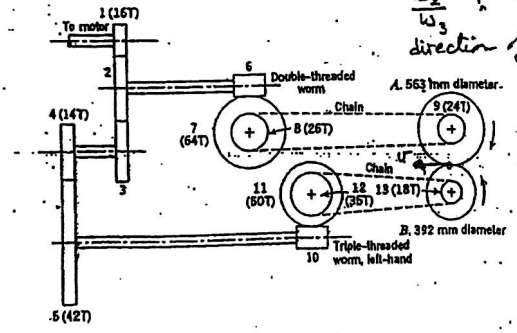
speed & direction of rack (fpm)



1800 rpm

$\frac{\omega_2}{\omega_3}$?

direction of ω_1 & hand of 6 ?



$v = 1150$ M/s

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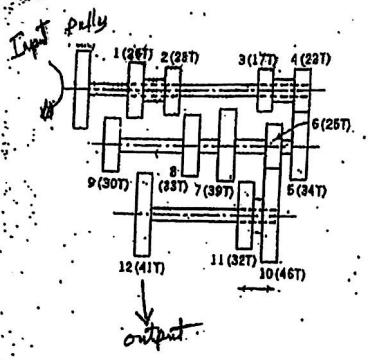
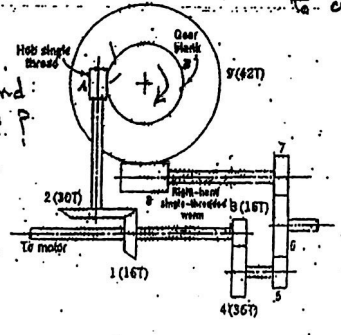
All train values possible?



Gear hobbing

to cut 7 & teeth $\frac{\omega_4}{\omega_5}$?

hand of A.P.



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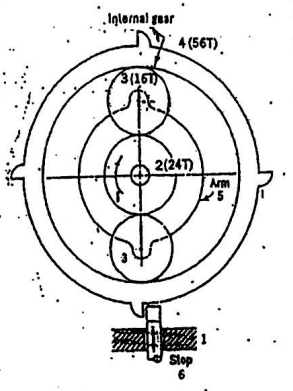
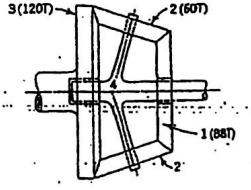
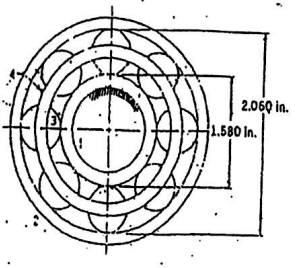
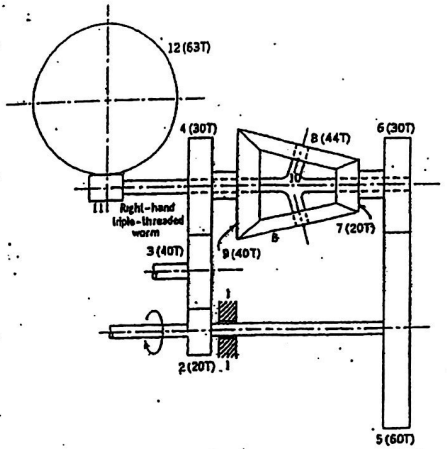






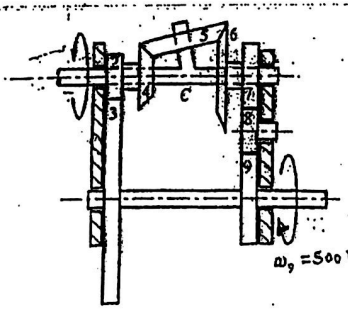
Scanned with CamScanner

In the mechanism shown in the figure, gear 2 rotates at 90 rpm in the direction shown. Determine the speed and direction of rotation of gear 12.



Planetary Gear Train

Determine the angular velocity ω_C of the carrier.



$N_2 = 20$ T
$N_3 = 90$ T
$N_4 = 30$ T
$N_5 = 90$ T
$N_6 = 50$ T
$N_7 = 30$ T
$N_8 = 20$ T
$N_9 = 40$ T

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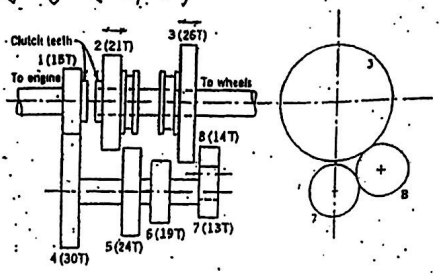
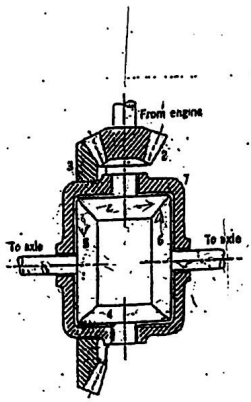
H.W.9 (1/1)

Gear Trains

a) Shown is a conventional automotive transmission discussed in class. Determine ω_B/ω_D when the transmission is on low gear



b) For the shown automotive differential, prove that the angular velocity of the differential carrier (arm) is equal to the average angular velocity of the two axles.



c) A car equipped with transmission and differential as those of parts (a) and (b) above is travelling on low gear at 35 km/hr. Determine the engine speed in rpm if the outside diameter of the car tires is 650 mm.

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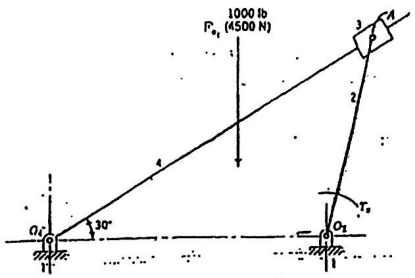
Determine the shaft torque T_s at O_2 in static equilibrium with the shown external force. (S.S. 1;1)



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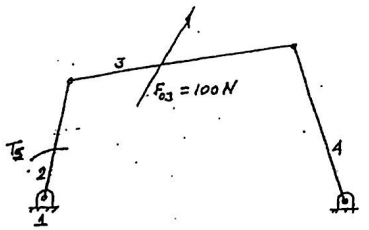
Determine the shaft torque T_s at O_2 in static equilibrium with the shown external force. (S.S. 1:2)



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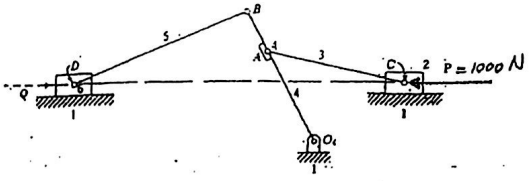
Determine the force Q in static equilibrium with the shown external force. (S.S. 1:1)



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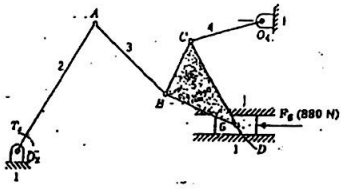
Determine the shaft torque T_2 at O_2 in static equilibrium with the shown external force. (S.S. 1:5)



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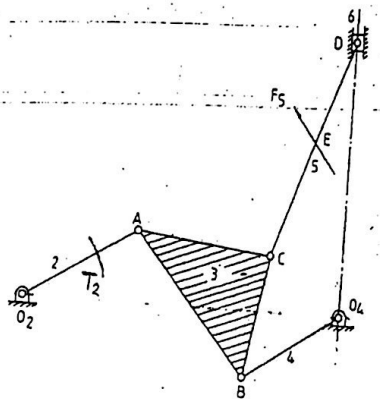
H.W. 10

3) Static Force Analysis (10 marks)

Determine the driving torque in magnitude and direction available on link 2, if a force F_5 of 2000 N is applied on link 5 as shown.

The space scale is: 1:10



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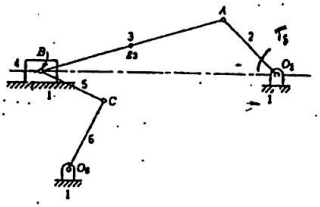
Shown are a linkage mechanism and the associated acceleration polygon

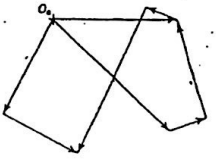
- Complete the acceleration polygon by labeling its vertices and sides
- Determine the shaft torque T_s in equilibrium with the inertia forces of link-3.



Space scale
1:20

$W_3 = 18\ N$

$I_3 = 0.02\ kg.m^2$



Acc. Scale
1 cm = 20 m/s²

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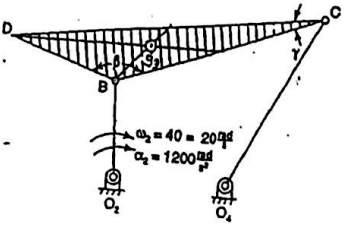
Dynamic Force Analysis

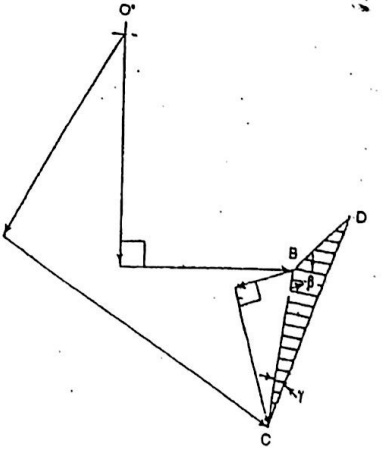
Determine the motor torque T_5 on link-2 which in equilibrium with inertial force of link-4.

$w_3 = 98.1$ N, $I_3 = 0.012$ kg.m^2

The space scale is 1:1.

The acceleration scale is 1 cm = 1000 cm/sec^2





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H.W. 11 (1/1)

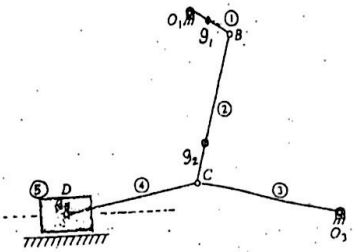
5) **Dynamic Forces (8 marks)**

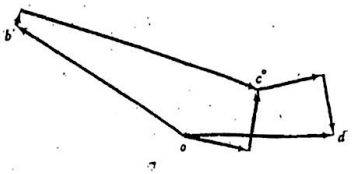
For the shown toggle mechanism, crank 2 has a constant angular velocity. Shown is the acceleration polygon. Calculate and show, on the configuration diagram, the lines of action and directions of the inertia forces F_{01}, F_{02} and F_{05} of links 1, 2 and 5 respectively.

$W_1 = 10$ N, $W_3 = 30$ N, and $I_3 = 0.002$ kg.m^2 and $W_5 = 50$ N,

The space scale is: 1:5

The acceleration scale is: 1cm =25 m/s^2





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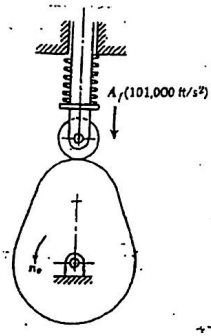
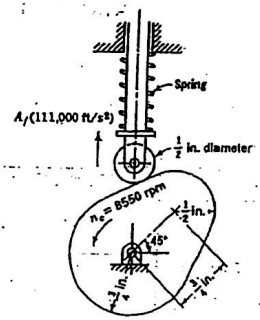
- Spring constant
- Cam force
- Cam Torque

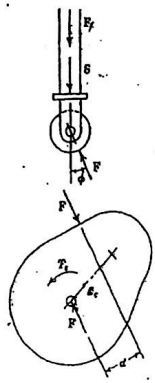
$W_f = 4.45\,N$

$1\ ft/s^2 = 0.35\ m/s^2$

$1\ in = 0.0254\ m$







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A spring-loaded radial roller follower of a disk cam is lifted through a distance of 50 mm with simple harmonic motion. The weight of the follower including the weight of the spring is 45 N. Because of its very low spring constant, the spring is assumed to apply a constant force of 25 N. Determine the maximum speed of the cam so that the follower does not lose contact with the cam.

Scanned with CamScanner

H.W. 12 (1/1)

Cam-Follower Motion Synthesis

A follower is to rise a total $L_1 = 50$ mm with cycloid motion for $\beta_1 = 90$ deg of cam rotation. Afterwards the follower dwells for $\beta_2 = 30^0$, and then it returns with modified parabolic motion, i.e., constant acceleration ($L_3 = 10$ mm, β_3), constant velocity ($L_4 = 30$ mm, β_4), constant deceleration ($L_5 = 10$ mm, β_5).

a) Determine the value of β_3, β_4 and β_5.
b) Sketch the displacement, velocity and acceleration diagrams and show the key values.
c) With the cam rotates at 300 rpm and the follower weight $W_f = 30$ N, determine the spring stiffness.

Cycloid rise: $$s = L\left(\frac{\theta}{\beta} - \frac{1}{2\pi}\sin\frac{2\pi\theta}{\beta}\right)$$

Constant acceleration return: $$s = L(1 - \theta^2/\beta^2)$$

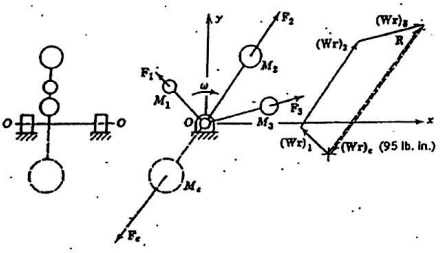
Constant deceleration return: $$s = L(1 - 2\theta/\beta + \theta^2/\beta^2)$$

Due at end of 11th week

Scanned with CamScanner

$$\Sigma F = \Sigma (Mr\omega^2) = \Sigma \left(\frac{W}{g} r\omega^2\right) = \frac{\omega^2}{g} \Sigma (Wr) = 0$$

$$\Sigma (Wr) = 0 \qquad (10.1)$$



Number	W, lb	r, in.	Wr, lb · in.	θ°	Wr_x, lb · in.	Wr_y, lb · in.
1	3	8	24	134	−16.67	+17.26
2	5	12	60	58	+31.80	+50.88
3	4	10	40	15	+38.64	+10.35
					+53.77	+78.49

$$R = \sqrt{(\Sigma Wr_x)^2 + (\Sigma Wr_y)^2}$$

$$= \sqrt{53.77^2 + 78.49^2}$$

$$= 95.14 \text{ lb} \cdot \text{in. (versus 95 lb} \cdot \text{in. by polygon)}$$

$$\theta_R = \tan^{-1}\left[\frac{\Sigma Wr_y}{\Sigma Wr_x}\right] = \tan^{-1}\left(\frac{78.49}{53.77}\right)$$

$$= 55.6° \text{ (versus 56° by polygon)}$$

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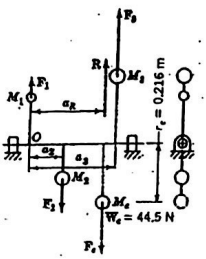
$$\Sigma\,(Fa) = \Sigma\left(\frac{W}{g}\,r\omega^2 a\right) = \frac{\omega^2}{g}\,\Sigma\,(Wra) = 0$$

$$\Sigma\,(Wra) = 0 \quad \neq \quad \Sigma\,Wr = 0 \qquad (10.2)$$



Number	W, N	r, m	Wr, N · m	a, m	Wra, N · m²
1	22.3	0.178	+3.9694	0	0
2	44.5	0.127	−5.6515	0.127	−0.7177
3	44.5	0.254	+11.303	0.305	+3.4474
			+9.6209		+2.7297

$$R = \Sigma(Wr) = 9.6209 \text{ N} \cdot \text{m}$$

$$W_e r_e = -R = -9.6209 \text{ N} \cdot \text{m}$$

$$a_R = \frac{\Sigma(Wra)}{\Sigma(Wr)} = \frac{2.7297}{9.6209} = 0.2837 \text{ m} = 284 \text{ mm}$$

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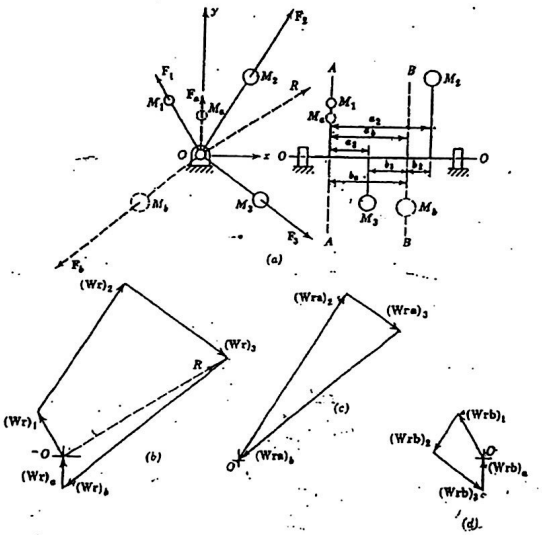
$\Sigma W\bar{r} = 0$ & $\Sigma\,(Wra) = 0$ (10.3)



Number	W, lb	r, in.	Wr, lb · in.	a, in.	Wra, lb · in.²	b, in.	Wrb, lb. in.²
1	5	8	40	0	0	10	400
2	10	12	120	13	1560	−3	−360
3	10	10	100	5	500	5	500
a	5*	5	25*	0	0	10	250*
b	16.3*	10	163*	10	1630*	0	0

$$(Wr)_b = \frac{(Wra)_b}{a_b} = \frac{1630}{10} = 163 \text{ lb} \cdot \text{in.}$$

$$(Wr)_a = \frac{(Wrb)_a}{b_a} = \frac{250}{10} = 25 \text{ lb} \cdot \text{in.}$$

*From polygons and calculations.

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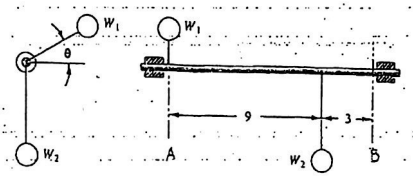
H.W. 13 (11)

11) Balancing of Rigid Rotor (10 marks)

Determine the weights W_A and W_B in the planes A and B, respectively, which put the rotor in dynamic balance. Draw the balancing weights to show their proper angular positions.

–	W	r	W r	θ deg								
1	15	4		30								
2	20	6		270								
A		5										
B		5										



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Velocity and Acceleration Polygons

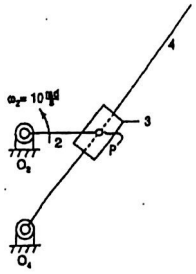
Determine the magnitude and direction of the angular velocity ω_4, and angular acceleration α_4, of link 4; for a constant $\omega_2 = 10$ rad/sec.

Use:

Velocity scale of 1 om = 4 cm/sec,

Acceleration scale of 1 cm = 20 cm/sec^2

The space scale is 1:1.



$+ O_V$

$+ O_A$

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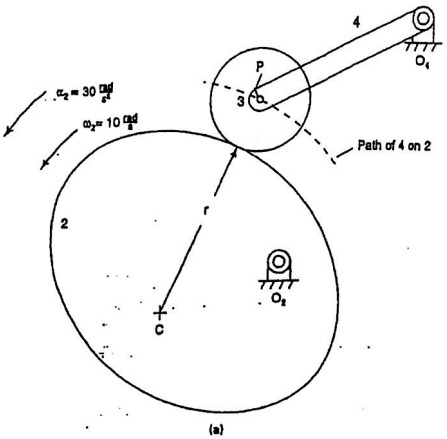
Velocity and Acceleration Polygons

Determine the magnitude and direction of the angular velocity ω_4, and angular acceleration α_4, of link 4. Use velocity scale of 1 cm = 10 cm/sec, and acceleration scale of 1 cm = 100 cm/sec.



(a)

O_A

O_r

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Report I
Introduction to Mechanisms
Part I: Working Model

Objective

Classification of mechanisms and identifying their topology, terminology and motion; including mechanism name, type, skeleton, components, mobility, parameters, inversions, and I/O motion

Procedure

Using Working Model, computer-simulate the motion of the following simple linkage mechanisms. Number the links, and show the type of pairing elements.

a) Grashof Four-Bar RRRR inversions
b) Slide-Crank—Four-Bar RRRP inversions: inline slider-crank, rotating cylinder, reciprocating cylinder, and water pump.
c) Double-Slider-Crank—Four-Bar RRPP inversions: elliptic trammel, Oldham coupling, and Scotch yoke.
d) Cam-follower
e) Pinion and Gear.

Report is due in 2 week

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Report II

Introduction to Mechanisms

Part-2: Lab Mechanisms

Objective

Classification of mechanisms and identifying their topology, terminology and motion; including mechanism name, type, skeleton, components, mobility, parameters, inversions, and I/O motion

Procedure

Study the mechanisms in the lab. Include in your report the mechanism name, type, kinematic skeleton, links, pairing elements, mobility, constant parameters, and show the I/O motion type—reciprocating, oscillating, continuous, or intermittent.

1. Four-bar crank-rocker.
2. In-line slider-crank.
3. Scotch-Yoke Mechanism.
4. Oldham coupler.
5. Whitworth mechanism
6. Cam-follower.
7. Geneva mechanism
8. Ordinary gear train
9. Warm and warm-wheel
10. Ackerman steering mechanism
11. Hooks joint

Report is due in 2 week

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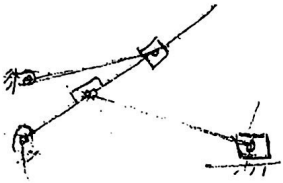
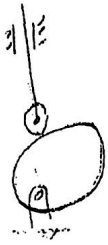
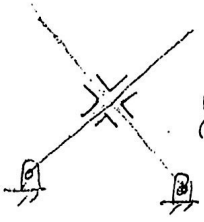
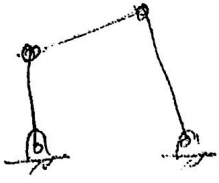
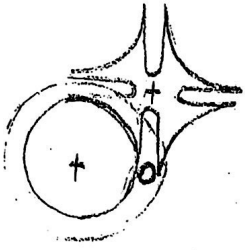


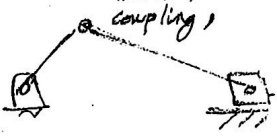




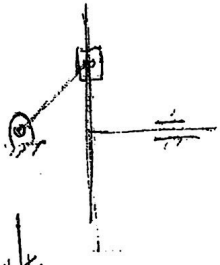
Peaucellier, fourbar Crank Ro
In line Slider-Cr
Scotch Yoke
Whitworth (rotating Slider/ rotating slotted li
driving
inline/offset slider-crank

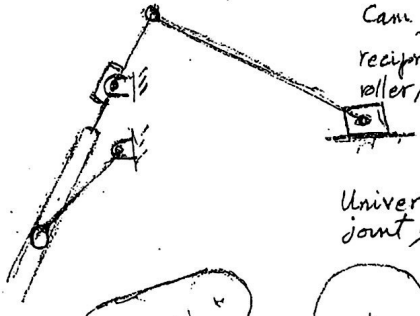




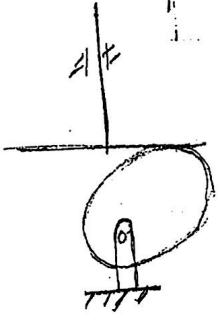


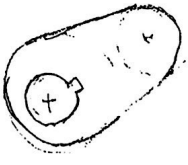
Geneva, old han
coupling,

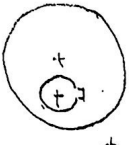




Standard Cam,
tangent/circular
Cam,
reciprocating
roller/flat face
follower

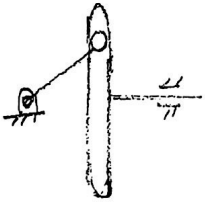


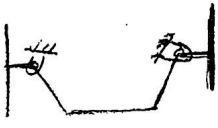


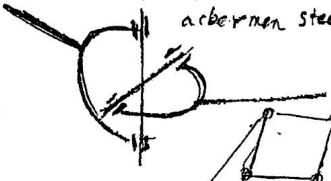


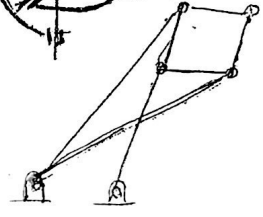
Universal (Hook
joint,

gear train,









ackermen steering

Scanned with CamScanner

Name	Sketch	Design (constatnt) Parameters
Whitworth driver		
Oldham coupler		
Pinion and gear/gear train		

Scanned with CamScanner