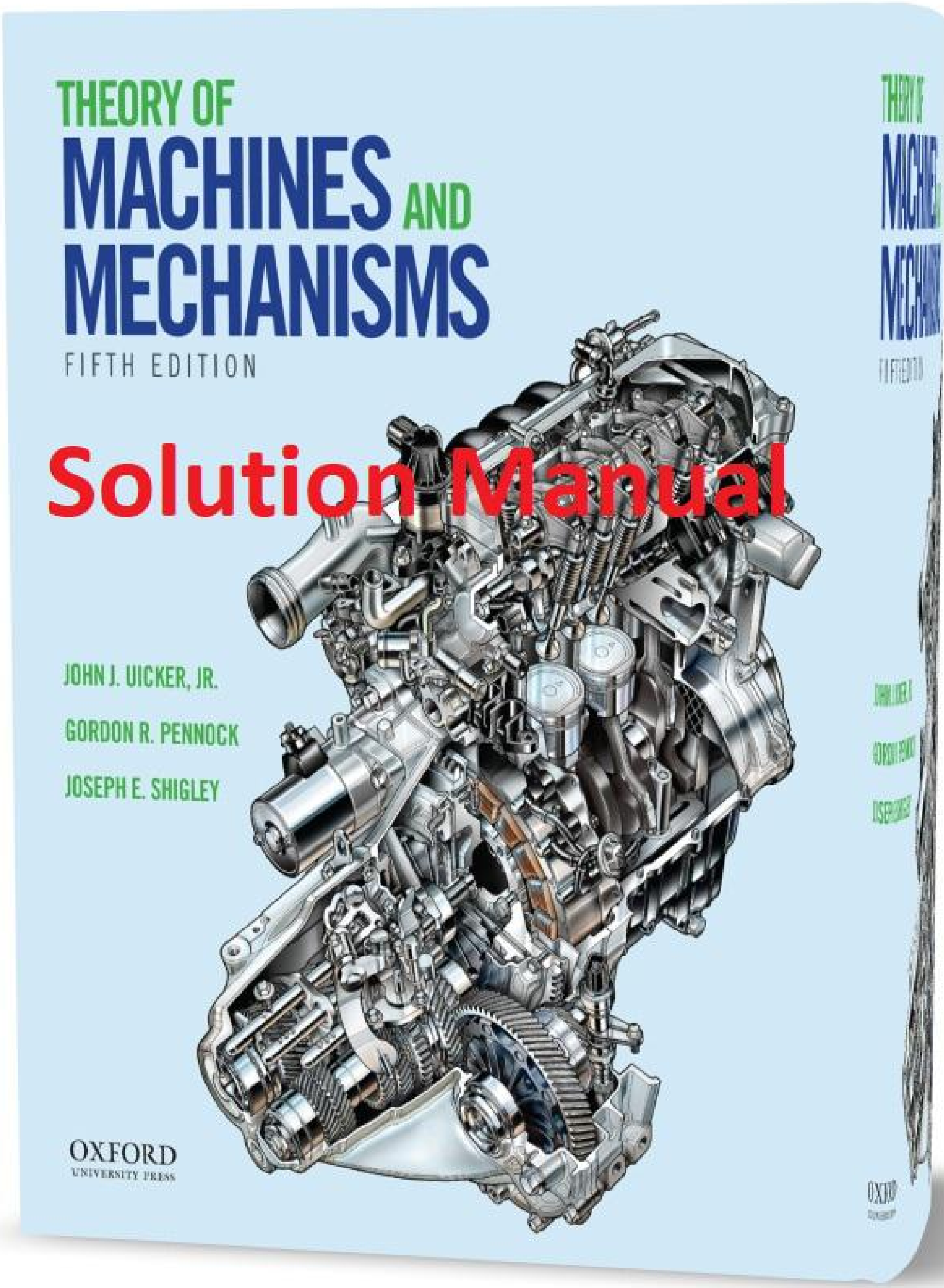
THEORY OF
MACHINES AND
MECHANISMS
FIFTH EDITION
Solution Manual
JOHN J. UICKER, JR.
GORDON R. PENNOCK
JOSEPH E. SHIGLEY
OXFORD
UNIVERSITY PRESS

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Instructors' Manual to accompany

THEORY OF MACHINES AND MECHANISMS

Fifth Edition

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Oxford University Press
NEW YORK OXFORD
2016

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Oxford University Press

Oxford New York
Auckland Bangkok Buenos Aires Cape Town Chennai
Dar es Salaam Delhi Hong Kong Istanbul Kolkata
Kuala Lumpur Madrid Melbourne Mexico City Mumbai
Nairobi Sao Paulo Shanghai Taipei Tokyo Toronto

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198 Madison Avenue, New York, New York, 10016
http://www.oup-usa.org

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Library of Congress Cataloging-in-Publication Data

ISBN: 978-0-19-537124-6

Printing number: 9 8 7 6 5 4 3 2 1

Printed in the United States of America
on acid-free paper

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PART 1

KINEMATICS AND MECHANISMS

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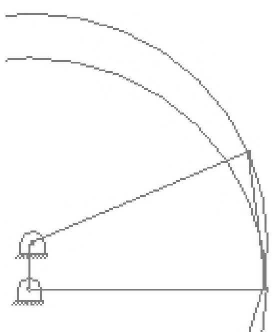
Chapter 1
The World of Mechanisms

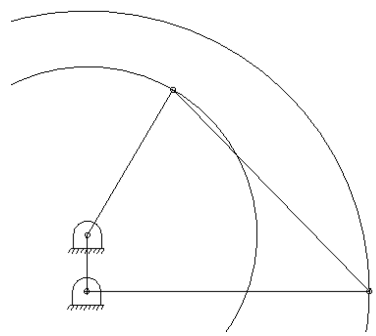
1.1 Sketch at least six different examples of the use of a planar four-bar linkage in practice. These can be found in the workshop, in domestic appliances, on vehicles, on agricultural machines, and so on.

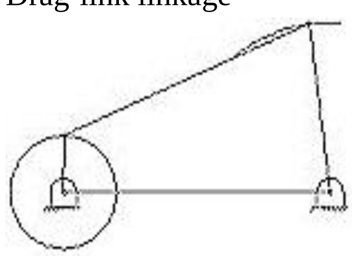
Since the variety is unbounded no standard solutions are provided here.

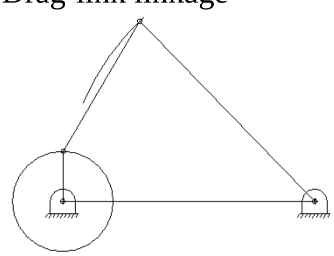
1.2 The link lengths of a planar four-bar linkage are 1 in, 3 in, 5 in, and 5 in. Assemble the links in all possible combinations and sketch the four inversions of each. Do these linkages satisfy Grashof's law? Describe each inversion by name, for example, a crank-rocker linkage or a drag-link linkage.

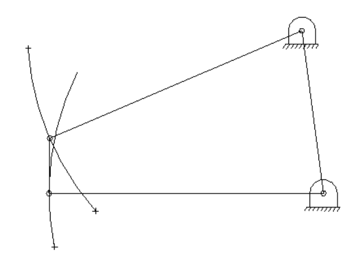
$s = 1$ in, $l = 5$ in, $p = 3$ in, $q = 5$ in; these linkages all satisfy Grashof's law since $1 \text{ in} + 5 \text{ in} < 3 \text{ in} + 5 \text{ in}$. *Ans.*

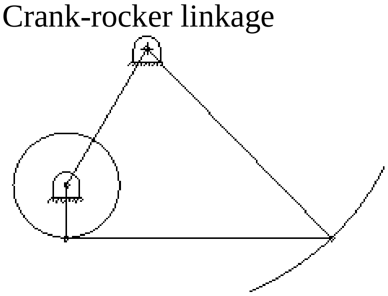

Drag-link linkage


Drag-link linkage *Ans.*


Crank-rocker linkage


Crank-rocker linkage *Ans.*


Double-rocker linkage.


Crank-rocker linkage *Ans.*

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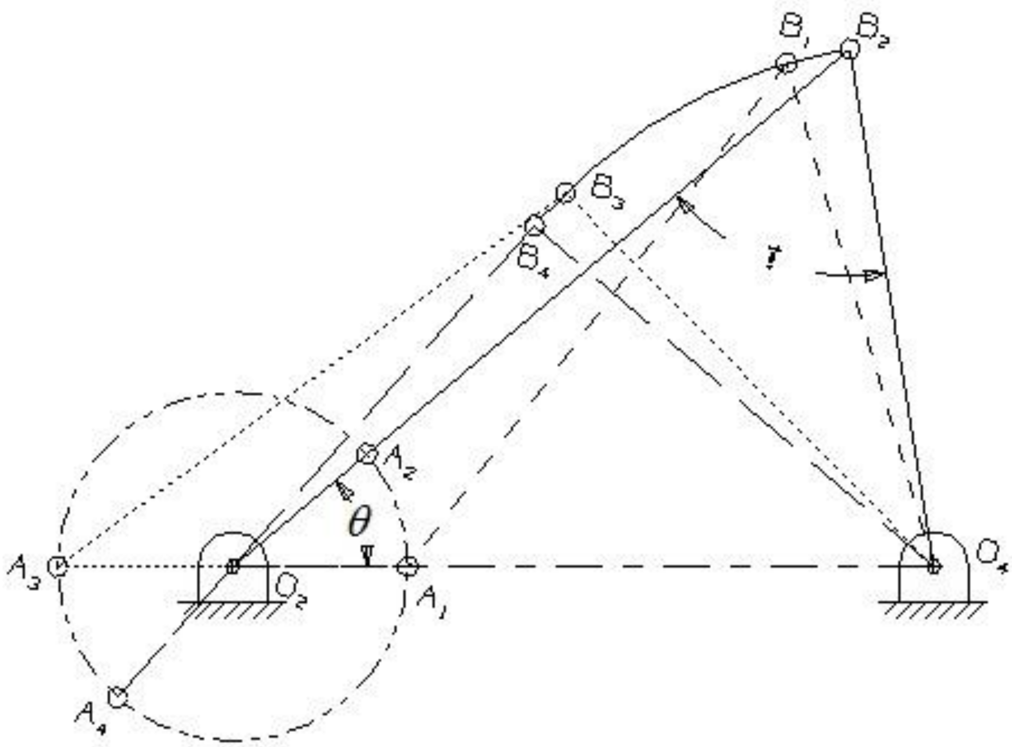
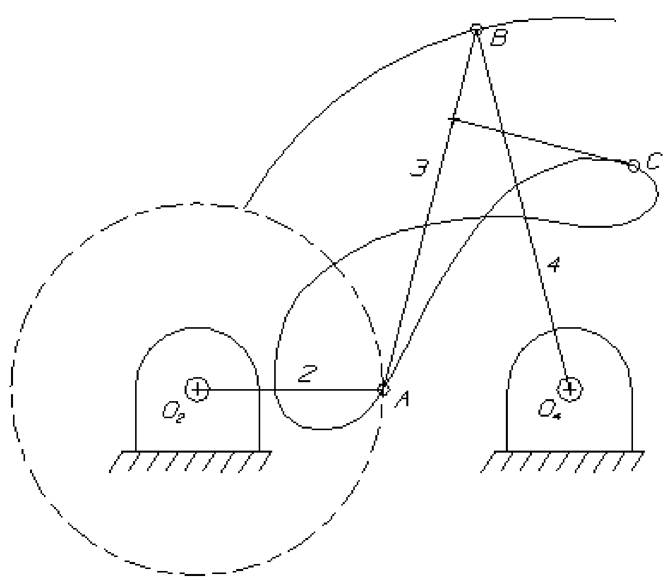
1.3 A crank-rocker linkage has a 100-mm frame, a 25-mm crank, a 90-mm coupler, and a 75-mm rocker. Draw the linkage and find the maximum and minimum values of the transmission angle. Locate both toggle postures and record the corresponding crank angles and transmission angles.



Extremum transmission angles: $\gamma_{\min} = \gamma_1 = 53.1°;\ \gamma_{\max} = \gamma_3 = 98.1°$ *Ans.*

Toggle postures: $\theta_2 = 40.1°; \gamma_2 = 59.1°;\ \theta_4 = 228.6°; \gamma_4 = 90.9°$ *Ans.*

1.4 Plot the complete path of coupler point *C*.



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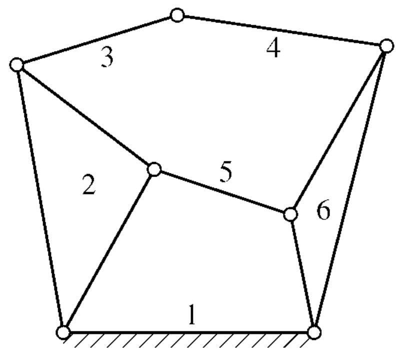
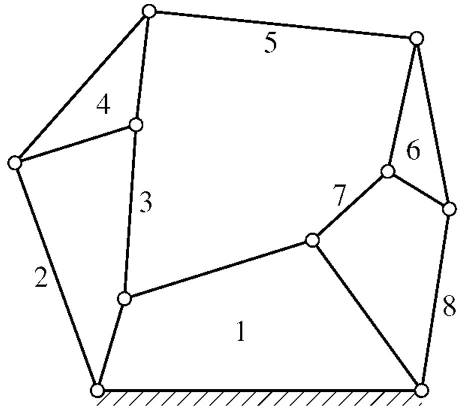
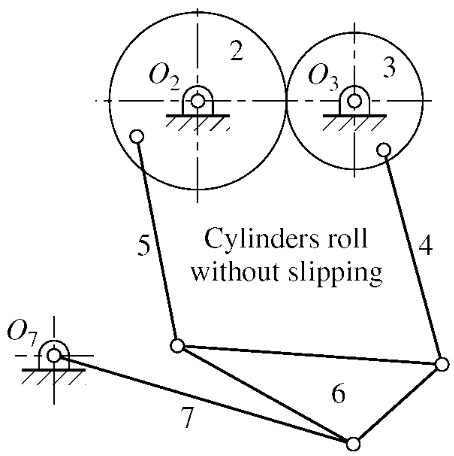
1.5 Find the mobility of each mechanism.



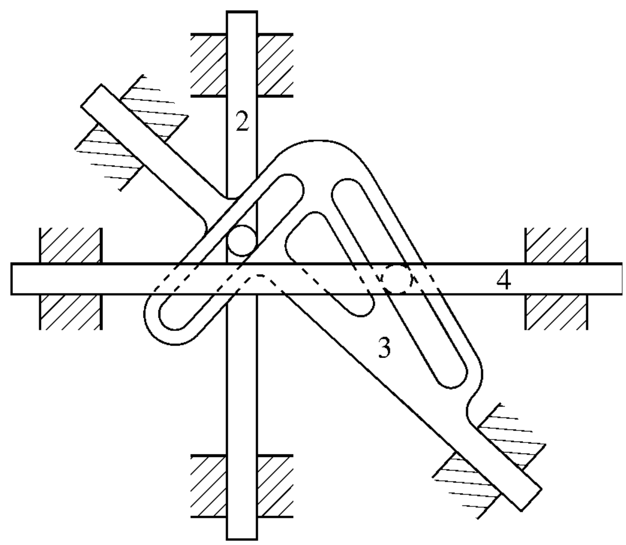
(*a*)



(*b*)



(*c*)



(*d*)

(*a*) $n=6,\ j_1=7,\ j_2=0;$ $m=3(6-1)-2(7)-1(0)=1$ Ans.

(*b*) $n=8,\ j_1=10,\ j_2=0;$ $m=3(8-1)-2(10)-1(0)=1$ Ans.

(*c*) $n=7,\ j_1=9,\ j_2=0;$ $m=3(7-1)-2(9)-1(0)=0$ Ans.

Note that the Kutzbach criterion fails in the case of part (*c*); the true mobility is m=1. The exception is due to a redundant constraint. The assumption that the rolling contact joint does not allow links 2 and 3 to separate duplicates the constraint of the fixed link length O_2O_3.

(*d*) $n=4,\ j_1=3,\ j_2=2;$ $m=3(4-1)-2(3)-1(2)=1$ Ans.

Note in part (*d*) that each pair of coaxial sliding ground joints is counted as only a single prismatic pair.

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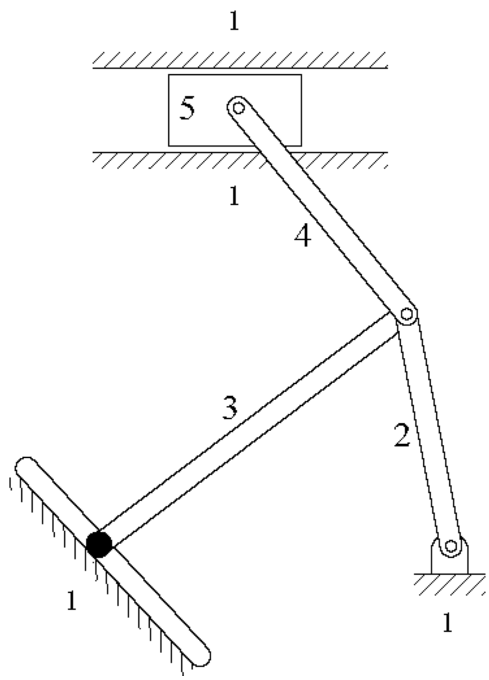
1.6 Use the Kutzbach criterion to determine the mobility of the mechanism.



$n = 5,\ j_1 = 5,\ j_2 = 1;$ $m = 3(5-1) - 2(5) - 1(1) = 1$ *Ans.*

Note that the double pin is counted as two single pin j_1 joints.

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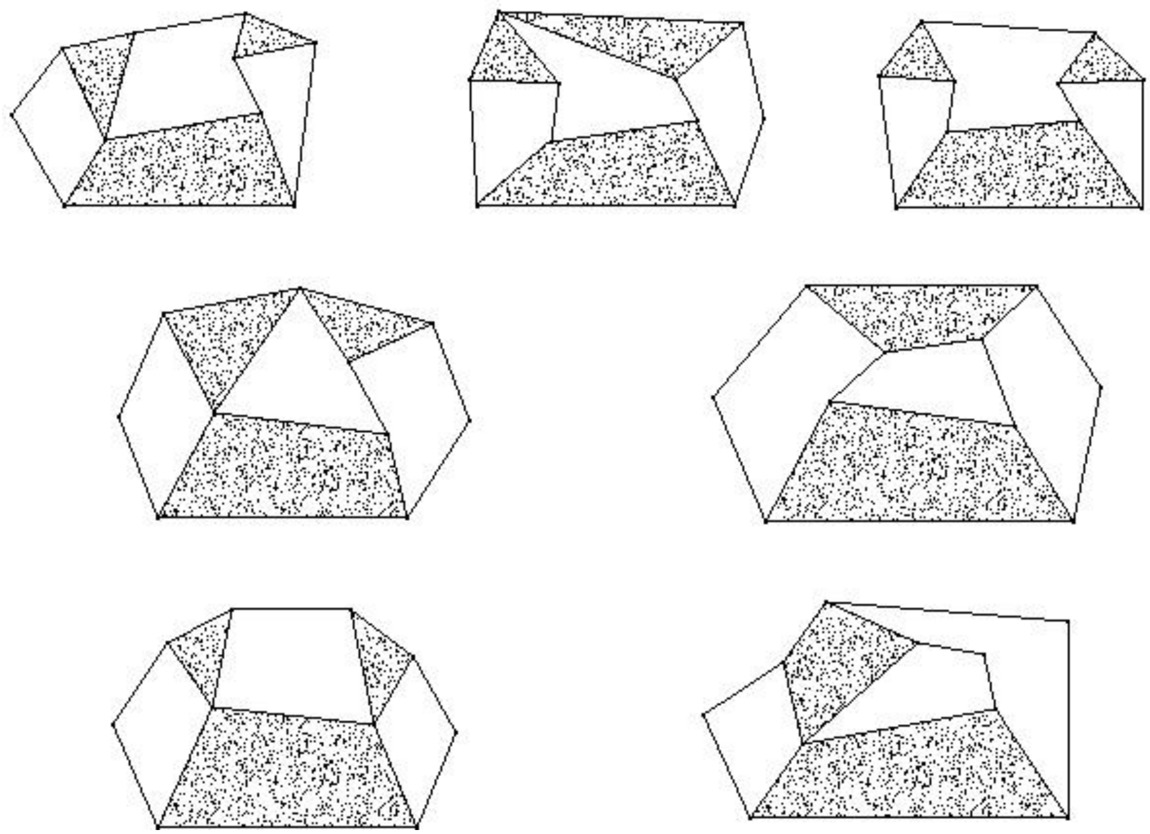
1.7 Sketch a planar linkage with only revolute joints and a mobility of m=1 that contains a moving quaternary link. How many distinct variations of this linkage can you find?

To have at least one quaternary link, a planar linkage must have at least eight links. The Kutzbach criterion then indicates that ten single-freedom joints are required for mobility of m = 1. According to H. Alt, 1955. “Die Analyse und Synthese der achtgleidrigen Gelenkgetriebe”, *VDI-Berichte*, **5**, pp. 81-93, there are a total of sixteen distinct eight-link planar linkages having ten revolute joints, seven of which contain a quaternary link. These seven are illustrated here: <u>*Ans.*</u>



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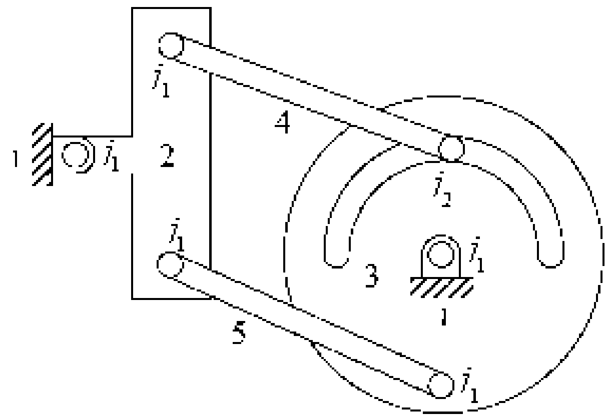
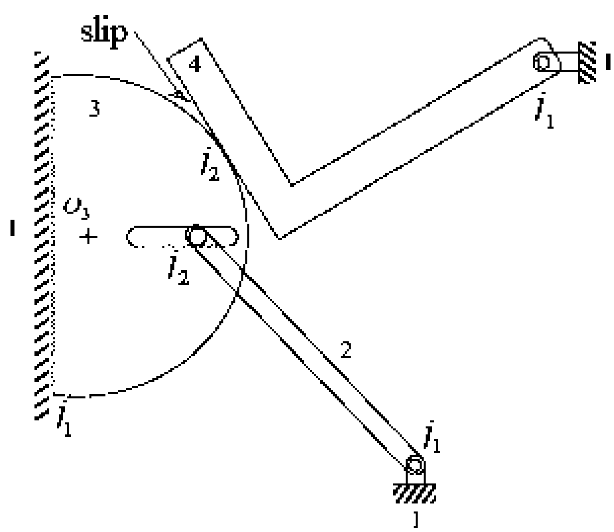
1.8 Use the Kutzbach criterion to detemine the mobility of the mechanism. Clearly number each link and label the lower pairs (j_1 joints) and higher pairs (j_2 joints).



$n = 5,\ j_1 = 5,\ j_2 = 1;$ $m = 3(5-1) - 2(5) - 1(1) = 1$ *Ans.*

1.9 Determine the number of links, the number of lower pairs, and the number of higher pairs. Use the Kutzbach criterion to determine the mobility of the mechanism. Is the answer correct? Briefly explain.



$n = 4,\ j_1 = 3,\ j_2 = 2;$ $m = 3(4-1) - 2(3) - 1(2) = 1$ *Ans.*

If it is not evident visually that link 3 can be incremented upward without jamming, then consider incrementing link 3 downward. Since it is clear visually that this determines the position of all other links, this verifies that mobility of one is correct.

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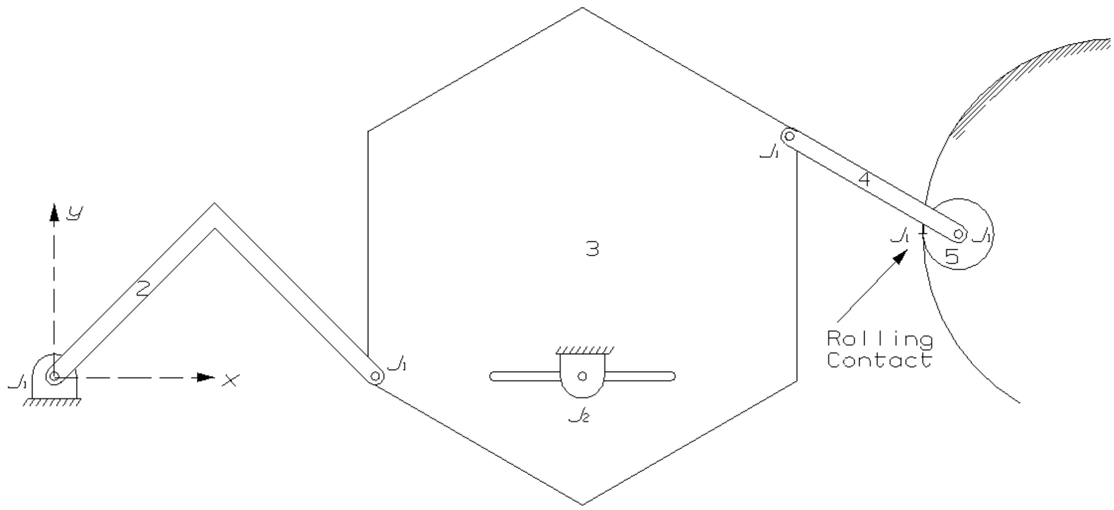
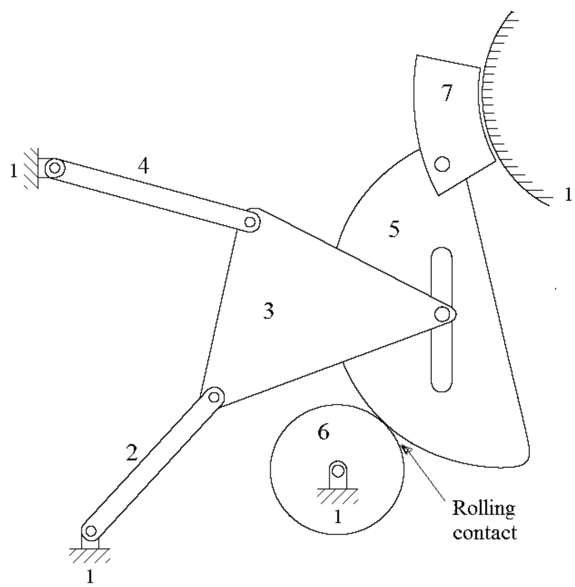
1.10 Use the Kutzbach criterion to detemine the mobility of the mechanism. Clearly number each link and label the lower pairs and higher pairs.



$n = 5,\ j_1 = 5,\ j_2 = 1;$ $m = 3(5-1) - 2(5) - 1(1) = 1$ *Ans.*

1.11 Determine the number of links, the number of lower pairs, and the number of higher pairs. Treat rolling contact to mean rolling with no slipping. Using the Kutzbach criterion determine the mobility. Is the answer correct? Briefly explain.



$n = 7,\ j_1 = 8,\ j_2 = 1;$ $m = 3(7-1) - 2(8) - 1(1) = 1$ *Ans.*

This result appears to be correct. If all parts remain assembled (connected), then within the limits of travel of the joints illustrated, it appears that when any one joint is locked the total system becomes a structure.

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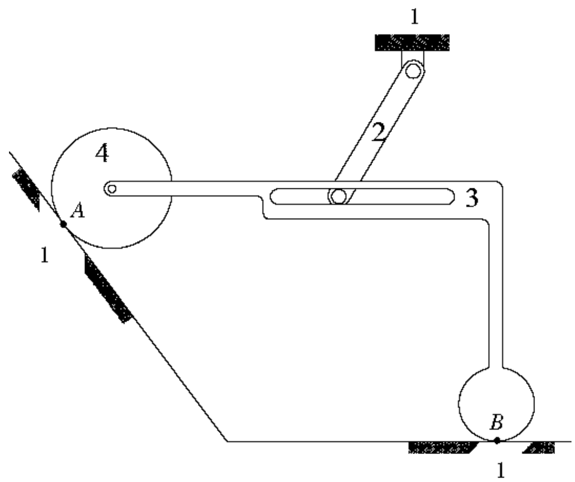
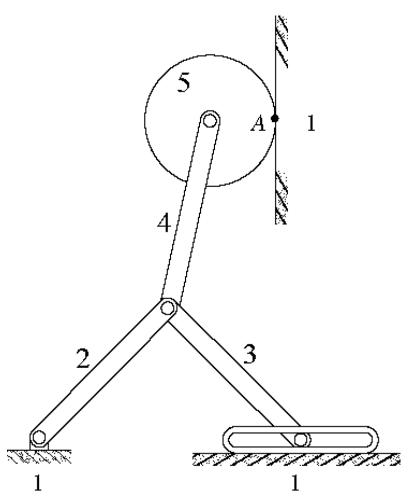
1.12 Does the Kutzbach criterion provide the correct result for this mechanism? Briefly explain why or why not.



$n=4,\ j_1=2,\ j_2=3;$ $m=3(4-1)-2(2)-1(3)=2$ *Ans.*

The joints at *A* and *B* are both assumed to allow slipping and are j_2 joints. This results in *m* = 2 which appears to be correct. If any part except wheel 4 is moved, all other parts are required to follow. However, after all other parts are in a certain posture, wheel 4 is still able to rotate while slipping against the frame at *A*.

1.13 The mobility of the mechanism is *m* = 1. Use the Kutzbach criterion to determine the number of lower pairs and the number of higher pairs. Is the wheel rolling without slipping, or rolling and slipping, at point *A* on the wall?



Suppose that we identify the number of independent freedoms at *A* by the symbol *k*. Then if we account for all links and all other joints as follows, the Kutzbach criterion gives

$n=5;\ j_1=4;\ j_2=1;\ j_k=1;$ $m=3(5-1)-2(4)-1(1)-(3-k)(1)=k;$

Therefore, to have mobility of $m=1$, we must have $k=1$ independent freedom at *A*. The wheel must be rolling without slipping. Then, $n=5;\ j_1=5;\ j_2=1;$ and $m=1;$ *Ans.*

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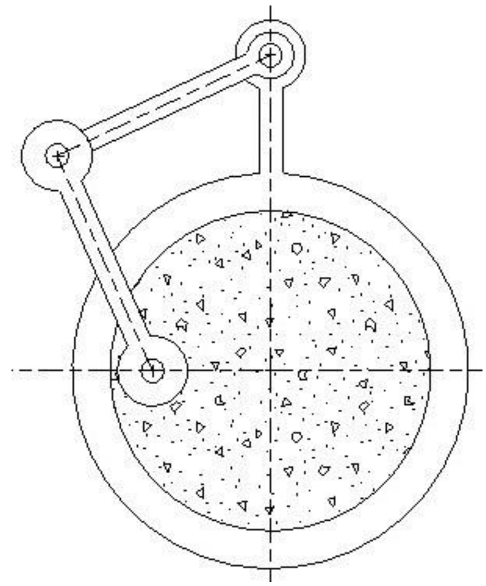
1.14 Devise a practical working model of the drag-link linkage

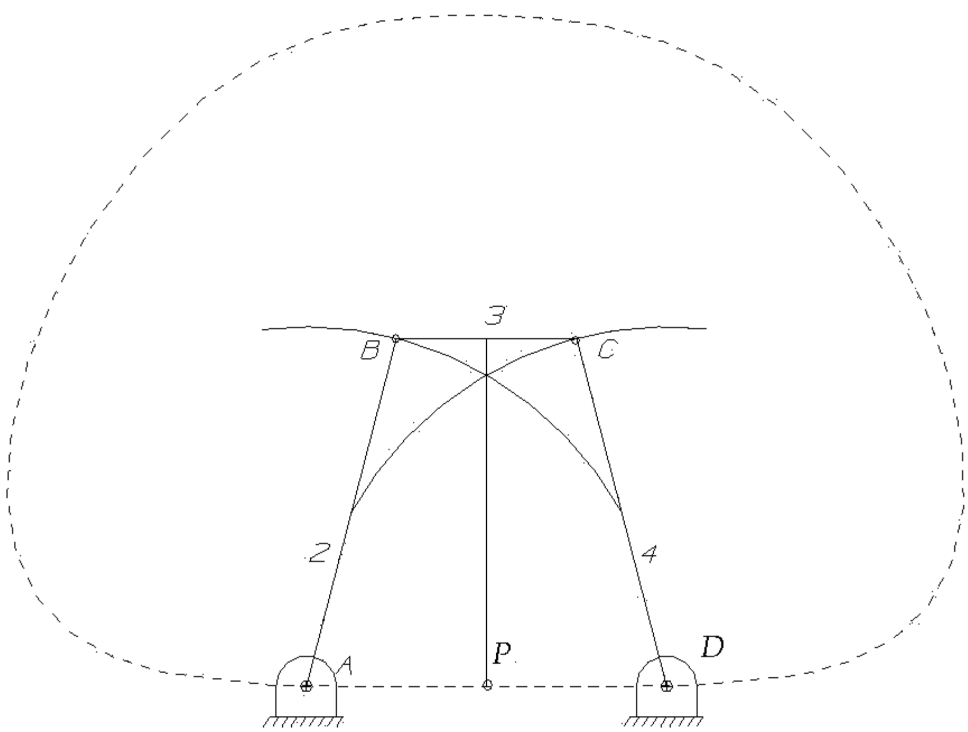


Ans.

1.15 Find the advance-to-return ratio of the linkage of Prob. 1.3.

From the values of θ_2 and θ_4 we find $\alpha = 188.5°$ and $\beta = 171.5°$.
Then, from Eq. (1.5), $Q = \alpha / \beta = 1.099$. *Ans.*

1.16 Plot the complete coupler curve of Roberts' linkage illustrated in Fig. 1.24*b*. Use *AB* = *CD* = *AD* = 2.5 in and *BC* = 1.25 in.



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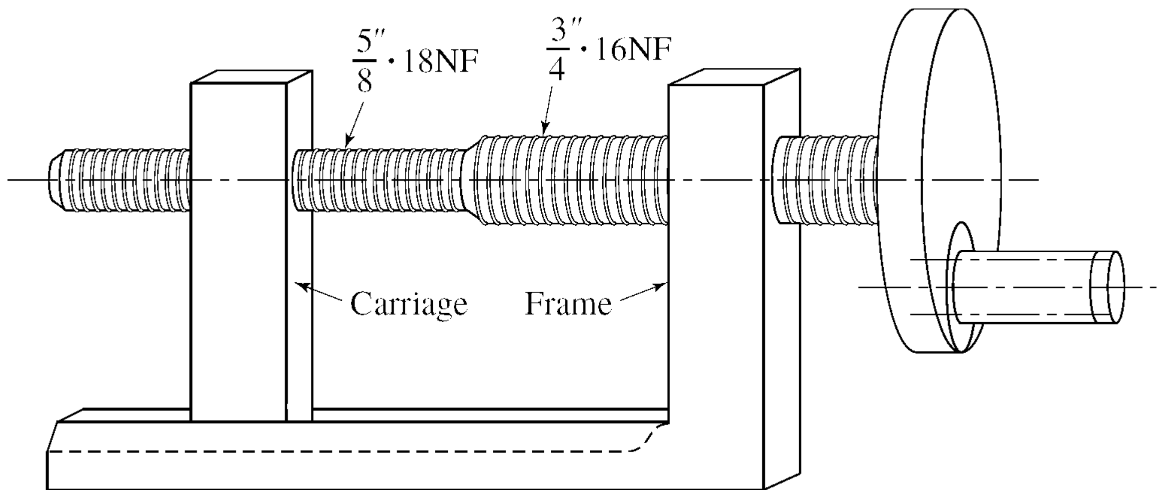
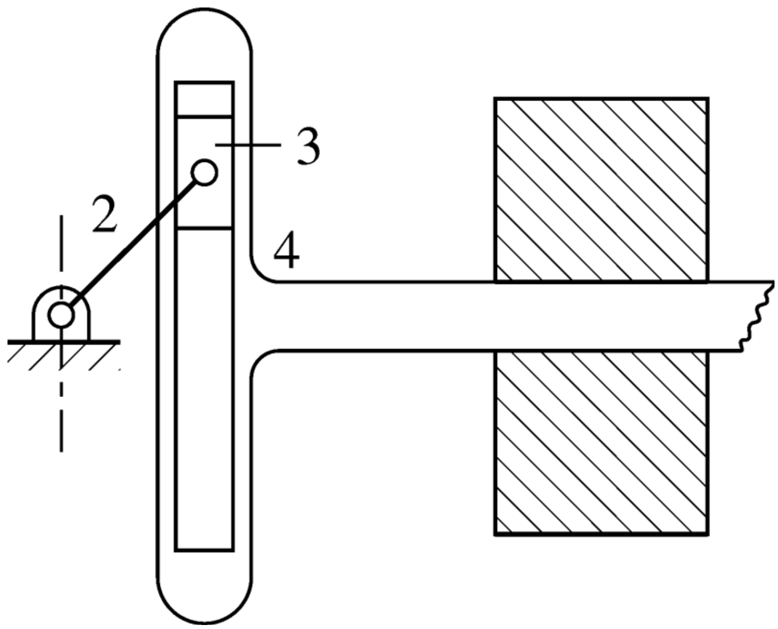
1.17 If the handle of the differential screw in Fig. 1.11 is turned 15 revolutions clockwise, how far and in what direction does the carriage move?



Screw and carriage move by (15 rev)/(16 rev/in) = 0.937 50 in to the left.
Carriage moves (15 rev)/(18 rev/in) = 0.833 33 in to the right with respect to the screw.
Net motion of carriage = 15/16 in – 15/18 in = 15/144 = 0.104 17 in to the left. *Ans.*

1.18 Show how the linkage of Fig. 1.15*b* can be used to generate a sine wave.



With the length and angle of crank 2 designated as R and θ_2, respectively, the horizontal motion of link 4 is $x_4 = R\cos\theta_2 = R\sin(\theta_2 + 90°)$.

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