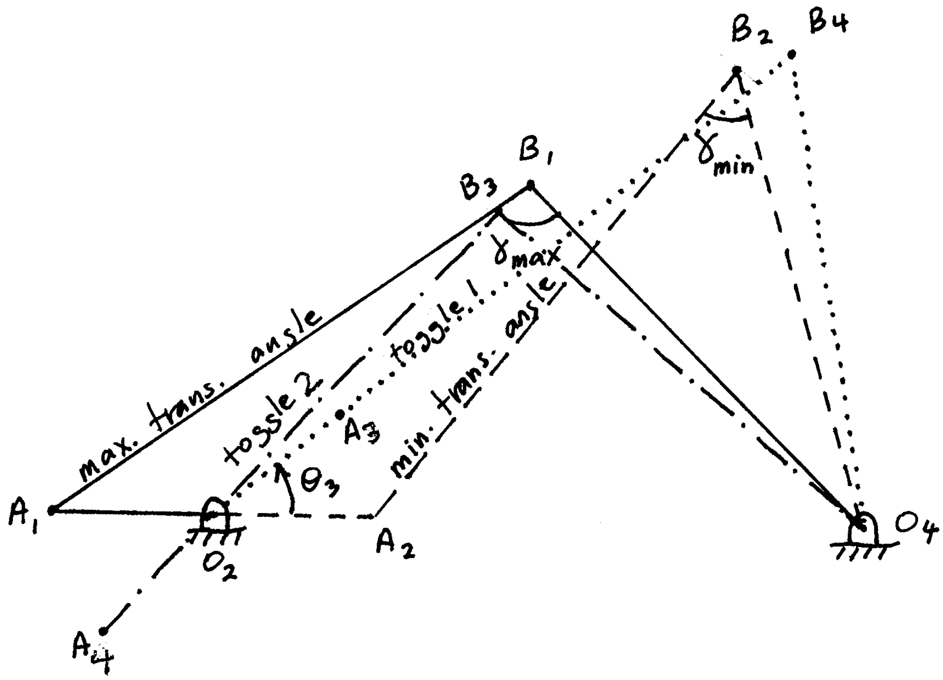
Chapter 1 HW Solution

Problem 1.3: My sketch of Problem 3 is shown below. I used a number of drawing instruments (including an eraser), and only inked it in when I was finished. I labeled the drawing as best I could...



a. Transmission Angle. As stated on text p. 30, the maximum and minimum values of transmission angle γ occur when the crank O_2A lies along the line connecting the frame axes O_2O_4. These are crank positions A_1 and A_2. The values of transmission angle γ I measured with my protractor are:

$$\gamma_{max} \approx 99^\circ \tag{1}$$
$$\gamma_{min} \approx 54^\circ \tag{2}$$

b. Toggle Positions. The toggle positions occur when the crank and coupler are collinear; these are shown as crank positions A_3 and A_4. The corresponding crank angles θ (angle θ_3 shown) and transmission angles are:

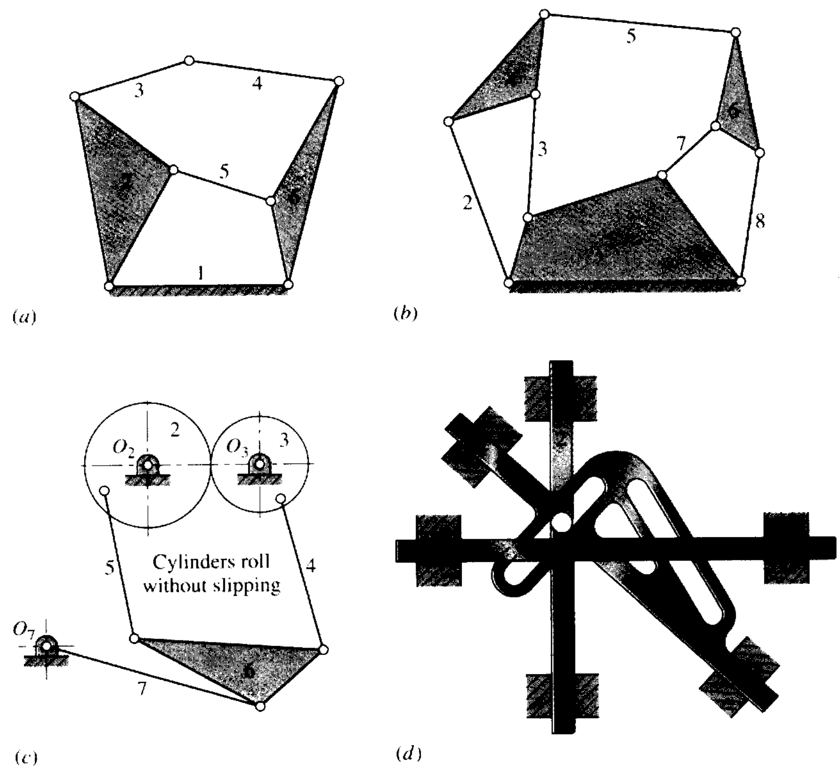
$$\theta_3 \approx 40^\circ, \quad \gamma_3 \approx 60^\circ \tag{3}$$
$$\theta_4 \approx 228^\circ, \quad \gamma_4 \approx 92^\circ \tag{4}$$

Problem 1.5: There are four mechanisms shown here (poorly-scanned figure on the next page); in each case you apply the *Kutzbach criterion*

$$m = 3(n-1) - 2j_1 - j_2 \tag{5}$$

in which

$m =$ mobility (number of mechanism DOF)
$n =$ number of links
$j_1 =$ number of single DOF joints
$j_2 =$ number of two DOF joints



(a) Here $n = 6$, $j_1 = 7$ (7 1DOF pin joints), and $j_2 = 0$, so

$$\boxed{m = 3(n-1) - 2j_1 - j_2 = 3(5) - 2(7) - 0 = 1 \text{ DOF (I can visualize this)}}$$

(b) Here $n = 8$, $j_1 = 10$ (10 1DOF pin joints), and $j_2 = 0$, so

$$\boxed{m = 3(n-1) - 2j_1 - j_2 = 3(7) - 2(10) - 0 = 1 \text{ DOF (I can visualize this one, too)}}$$

(c) Here $n = 7$, $j_1 = 9$ (8 1DOF pin joints plus rolling w/o slipping is 1 DOF), and $j_2 = 0$, so

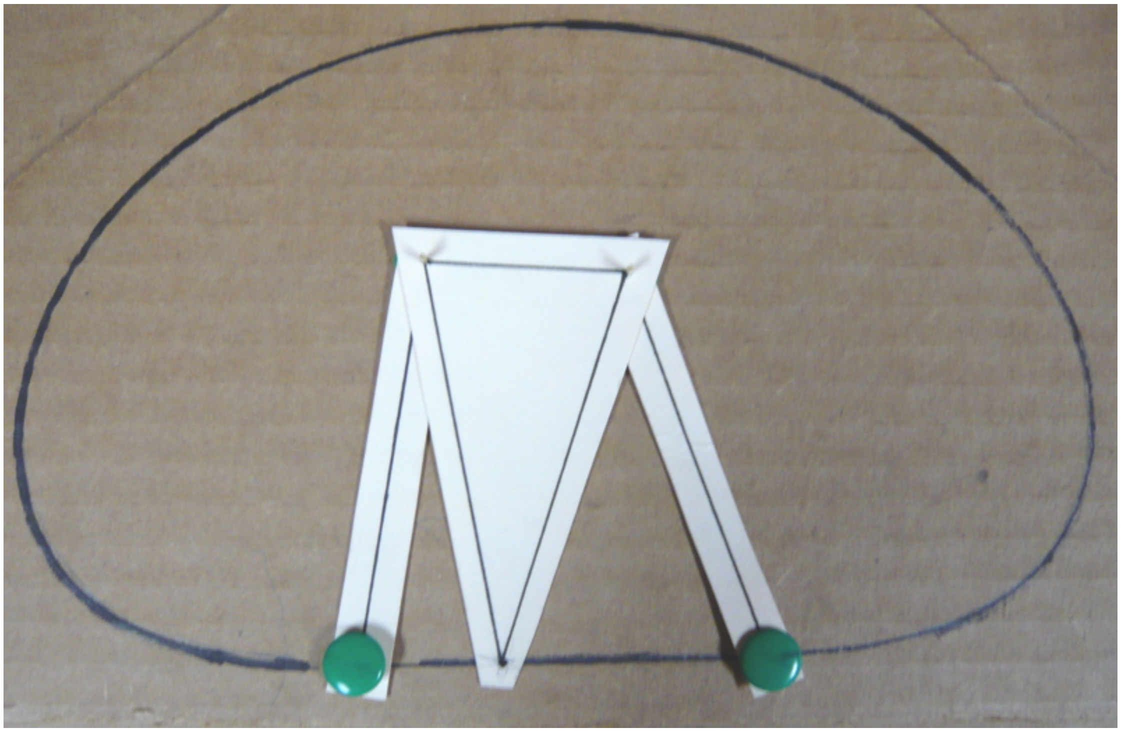
$$\boxed{m = 3(n-1) - 2j_1 - j_2 = 3(6) - 2(9) - 0 = 0 \text{ DOF (this is a little harder to see)}}$$

(d) Here $n = 4$, $j_1 = 3$ (3 1DOF prismatic joints), and $j_2 = 2$ (2 2DOF pin-in-slot joints), so

$$\boxed{m = 3(n-1) - 2j_1 - j_2 = 3(3) - 2(3) - 2 = 1 \text{ DOF (I \textit{definitely} can't visualize this)}}$$

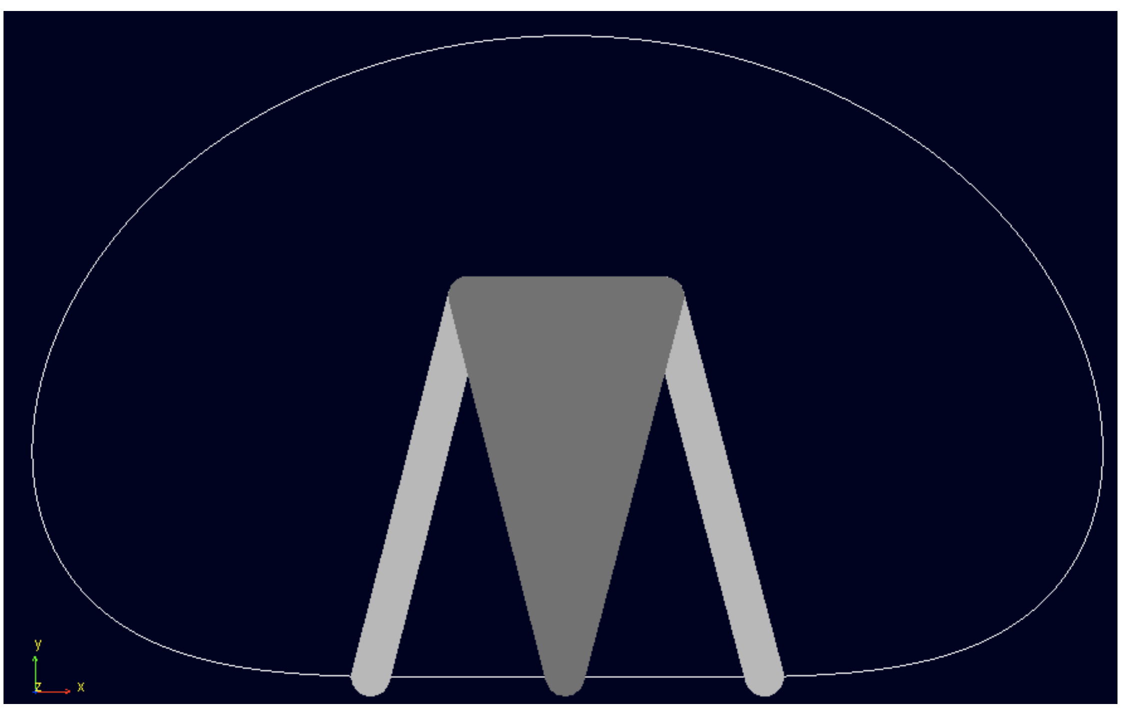
Problem 1.9: REAL MODEL: I built this thing using cardboard and thumbtacks—see the picture below.

My wife and kids loved this model—there's something about actually making a physical model that transcends simulations. Anyway, the complete coupler curve of the Roberts mechanism is shown in the picture—I traced it using a pen stuck through point P. Note that the segment between points A and B is quite straight.



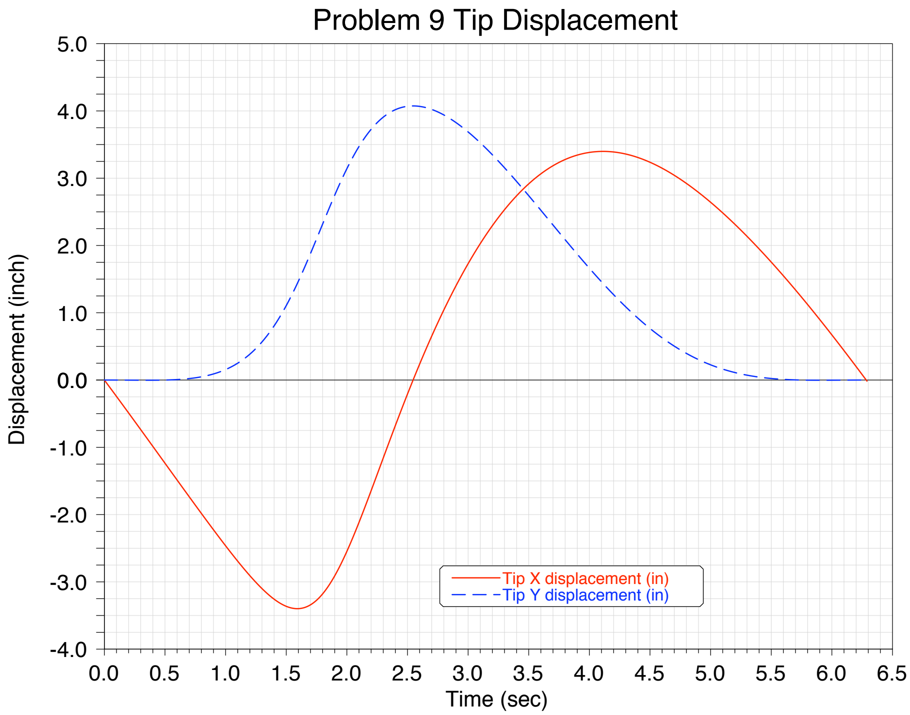
By the way, from Grashof's Law, $1.25 + 2.5 \leq 2.5 + 2.5$ so the coupler should have continuous rotation, and it does (if you maneuver the thumbtacks out of the way).

ADAMS MODEL: I also created an ADAMS model of this mechanism and plotted the path of point P:



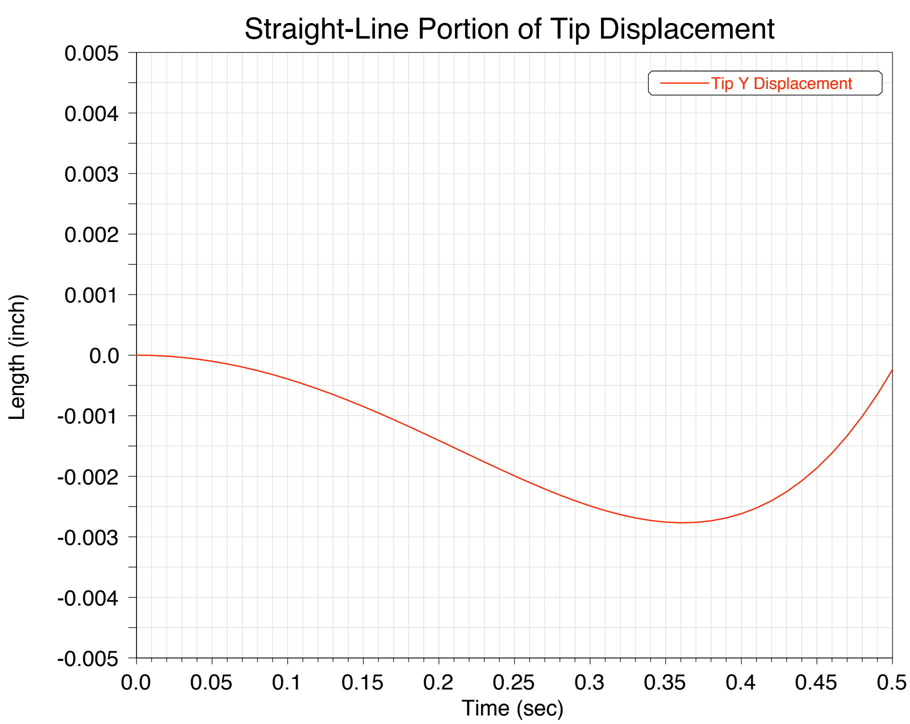
They both look pretty close. But with the ADAMS model one can *really* examine the "straight-line" portion...

Straight-line segment: Below is a plot of the xy motion of point P (I gave joint 23 a constant angular speed of 1 rad/s):



From inspection of the mechanism it is apparent that when point P is (a) at point A, (b) equidistant between A and B, and (c) at point D, it will be on the straight line AD. Moreover, the motion of P to either side is the same.

So below is an expanded plot of one half the motion of point P between the center and the endpoint:



Inspection of the plot shows a maximum deviation of 0.0028 inches—less than three-thousandths of an inch. Pretty good straight line! Note the benefit of using ADAMS to simulate this mechanism.

Problem 1.10: Assume that both threads are right-handed. A thread pitch of 16NF means 16 threads/inch, and 18NF is 18 threads/inch (the diameters 3/4 and 5/8 are not relevant for this problem). Therefore, as the crank is turned 10 revolutions clockwise, the entire screw will advance (move away from the crank) 10/16 inch, while the carriage will retreat (move towards the crank) 10/18 inch. The overall carriage motion is then:

$$\delta x = \frac{10}{16} - \frac{10}{18} = \frac{90 - 80}{144} = \frac{5}{72} = 0.0694 \text{ in} \tag{6}$$

BTW—although not asked for—it is interesting to compute the effective "pitch" of the differential screw. Since 10 revolutions result in 10/144 in displacement, one revolution would cause 1/144 in displacement. The effective pitch would therefore be 144, equivalent the a single screw with 144 threads/in.

This is a pretty "fine" pitch, and would be difficult to obtain with a single thread.