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 $O_A$ and $O_B$ shown. Build a cardboard model and determine the toggle positions and the minimum transmission angle. 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 $O_A$ and $O_B$ shown. Build a cardboard model and determine the toggle positions and the minimum transmission angle. Add a driver dyad. (See Example 3-4).

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

3-8 Design a sixbar drag link quick-return linkage for a time ratio of 1 : 2, and output rocker motion of 60 degrees. (See Example 3-10.)

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

3-10 Select a linkage from the Hrones and Nelson atlas (or use Figure 3-17), and manually find its two cognates. Draw the Cayley and Roberts diagrams. Check your results with program FOURBAR.
3.11 Find the three equivalent geared fivebar linkages for the three fourbar cognates in Figure 3-22a. Check your results by comparing the coupler curves with programs FOURBAR and FIVEBAR.

3.12 Design a sixbar single-dwell linkage for a dwell of 90 degrees of crank motion, with an output rocker motion of 45 degrees. (See Example 3-11.)

3.13 Design a sixbar double-dwell linkage for a dwell of 90 degrees of crank motion, with an output rocker motion of 60 degrees, followed by a second dwell of about 60 degrees of crank motion. (See Examples 3-11 and 3-12.)

3.14 Complete Example 3-5 by adding a driver dyad to link 3, and build a working cardboard model. Scale the diagram carefully for dimensions. (Hint: Use stiff cardboard and tacks. Dimensions must be very accurate in this example for it to work.)

3.13 PROJECTS

These larger-scale project statements deliberately lack detail and structure and are loosely defined. Thus, they are similar to the kind of "identification of need" problem statement commonly encountered in engineering practice. It is left to the student to structure the problem through background research and to create a clear goal statement and set of task specifications before attempting to design a solution. This design process is spelled out in Chapter 1 and should be followed in all of these examples. These projects can be done as an exercise in mechanism synthesis alone or can be revisited and thoroughly analyzed by the methods presented in later chapters as well. All results should be documented in a professional engineering report.

P3-1 The tennis coach needs a better tennis ball server for practice. This device must fire a sequence of standard tennis balls from one side of a standard tennis court over the net such that they land and bounce within each of the three court areas defined by the court's white lines. The order and frequency of a ball's landing in any one of the three court areas must be random. The device should operate automatically and unattended except for the refill of balls. It should be capable of firing 50 balls between reloads. The timing of ball releases should vary. For simplicity, a motor driven pin-jointed linkage design is preferred.

P3-2 A quadriplegic patient has lost all motion except that of her head. She can only move a small "mouth stick" to effect a switch closure. She was an avid reader before her injury, and would like again to be able to read standard hardcover books without the need of a person to turn pages for her. Thus, a reliable, simple, and inexpensive automatic page turner is needed. The book may be placed in the device by an assistant. It should accommodate a wide range of book sizes as possible. Book damage is to be avoided and safety of the user is paramount.

P3-3 Grandma's off her rocker again! Junior's run down to the Bingo parlor to fetch her, but we've got to do something about her rocking chair before she gets back. She's been complaining that her arthritis makes it too painful to push the rocker. So, for her 100th birthday in 2 weeks, we're going to surprise her with a new, automated, motorized rocking chair. The only constraints placed on the problem are that the device must be safe and must provide interesting and pleasant motions, similar to those of her present Boston rocker, to all parts of the occupant's body. Since simplicity is the mark of good design, a linkage solution with only full pin joints is preferred.
P3-4 The local amusement park’s business is suffering as a result of the proliferation of computer game parlors. They need a new and more exciting ride which will attract new customers. The only constraints are that it must be safe, provide excitement, and not subject the occupants to excessive accelerations or velocities. Also it must be as compact as possible, since space is limited. Continuous rotary input and full pin joints are preferred.

P3-5 The student section of ASME is sponsoring a spring fling on campus. They need a mechanism for their “Dunk the Professor” booth which will carry the unfortunate (untutor) volunteer into and out of the water tub. The contestants will provide the inputs to a multiple DOF mechanism. If they know their kinematics, they can provide a combination of inputs which will dunk the victim.

P3-6 The National House of Flapjacks wants to automate their flapjack production. They need a mechanism which will automatically flip the flapjacks “on the fly” as they travel through the griddle on a continuously moving conveyor. This mechanism must track the constant velocity of the conveyor, pick up a pancake, flip it over and place it back onto the conveyor.

P3-7 Many varieties and shapes of computer video monitors now exist. Their long-term use leads to eyestrain and body fatigue. There is a need for an adjustable stand which will hold the video monitor and the separate keyboard at any position the user deems comfortable. The computer’s Central Processor Unit (CPU) can be remotely located. This device should be free standing to allow use with a comfortable chair, couch, or lounge of the user’s choice. It should not require the user to assume the conventional “seated at a desk” posture to use the computer. It must be stable in all positions and safely support the equipment’s weight.

P3-8 Most small boat trailers must be submerged in the water to launch or retrieve the boat. This greatly reduces the life of the trailer, especially in salt water. A need exists for a trailer that will remain on dry land while it launches or retrieves the boat. No part of the trailer should get wet. User safety is of greatest concern, as is protection of the boat from damage.

P3-9 The “Save the Skeet” foundation has requested a more humane skeet launcher be designed. While they have not yet succeeded in passing legislation to prevent the wholesale slaughter of these little devils, they are concerned about the inhumane aspects of the large accelerations imparted to the skeet as it is launched into the sky for the sportsman to shoot it down. The need is for a skeet launcher that will smoothly accelerate the clay pigeon onto its desired trajectory.

P3-10 The coin operated “kid bouncer” machines found outside supermarkets typically provide a very unimaginative rocking motion to the occupant. There is a need for a superior “bouncer” which will give more interesting motions while remaining safe for small children.

P3-11 Horseback riding is a very expensive hobby or sport. There is a need for a horseback riding simulator to train prospective riders sans the expensive horse. This device should provide similar motions to the occupant as she would feel in the saddle under various gaits such as a walk, canter, gallop etc. A more advanced version might contain jumping motions as well. User safety is most important.
P3-12 The nation is on a fitness craze. Many exercise machines have been devised. There is still room for improvement to these devices. They are typically designed for the young, strong athlete. There is also a need for an ergonomically optimum exercise machine for the older person who needs gentler exercise.

P3-13 A paraplegic patient needs a device to get himself from his wheelchair into the Jacuzzi with no assistance. He has good upper body and arm strength. Safety is paramount.

P3-14 The Army has requested a mechanical walking device to test army boots for durability. It should mimic a person’s walking motion and provide forces similar to an average soldier’s foot.

P3-15 NASA wants a zero-G machine for astronaut training. It must carry one person and provide a negative 1 G acceleration for as long as possible.

P3-16 The Amusement Machine Co. Inc. wants a portable “Whip” ride which will give two or four passengers a thrilling but safe ride, and which can be trailed behind a pickup truck from one location to another.

P3-17 The Air Force has requested a pilot training simulator which will give potential pilots exposure to G forces similar to those they will experience in dogfight maneuvers.

P3-18 Cheers needs a better “Mechanical Bull” simulator for their “yuppie” bar in Boston. It must give a thrilling “bucking bronco” ride but be safe.

P3-19 Despite the improvements in handicap access, many curbs block wheelchairs from public places. Design an attachment for a conventional wheelchair which will allow it to get up over a curb.

P3-20 A carpenter needs a dumping attachment to fit in her pickup truck so she can dump building materials. She can’t afford to buy a dump truck.

P3-21 The same carpenter wants an inexpensive lift gate designed to fit her full-sized pickup truck, in order to lift and lower heavy cargo to the truck bed.

P3-22 This carpenter is very demanding (and lazy). She also wants a device to lift sheets of “sheet rock” into place on ceiling or walls to hold it while nailing.

P3-23 Click and Clack, the tappet brothers, need a better transmission jack for their Good News Garage. This device should position a transmission under a car (on a lift) and allow it to be maneuvered into place safely and quickly.

P3-24 A paraplegic who was an avid golfer before his injury, wants a mechanism to allow him to stand up in his wheelchair in order to once again play golf. It must not interfere with normal wheelchair use, though it could be removed from the chair when he is not golfing.

P3-25 A wheelchair lift is needed to raise chair and person 3 feet from the garage floor to the level of the first floor of the house. Safety and reliability are of major concern, as is cost.
FIGURE 11-35
Geneva wheel driven by a four-bar linkage synthesized by the Hrones-Nelson method. Link 2 is the driving crank.

FIGURE 11-36
The inverse Geneva mechanism.

PROBLEMS

11-1 A function varies from 0 to 10. Find the Chebychev spacing for two, three, four, five, and six precision points.

11-2 Determine the link lengths of a slider-crank linkage to have a stroke of 600 mm and a time ratio of 1.20.

11-3 Determine a set of link lengths for a slider-crank linkage such that the stroke is 16 in and the time ratio is 1.25.
11-4 The rocker of a crank-rocker linkage is to have a length of 500 mm and swing through a total angle of 45° with a time ratio of 1.25. Determine a suitable set of dimensions for \( r_1 \), \( r_2 \), and \( r_3 \).

11-5 A crank-and-rocker mechanism is to have a rocker 6 ft in length and a rocking angle of 75°. If the time ratio is to be 1.32, what are a suitable set of link lengths for the remaining three links?

11-6 Design a crank and coupler to drive rocker 4 in the figure such that slider 6 will reciprocate through a distance of 16 in with a time ratio of 1.20. Use \( a = r_4 = 16 \) in and \( r_5 = 24 \) in with \( r_4 \) vertical at midstroke. Record the location of \( O_2 \) and the dimensions \( r_2 \) and \( r_3 \).

![FIGURE P11-6]

11-7 Design a crank and rocker for a six-link mechanism such that the slider in the figure for Prob. 11-6 reciprocates through a distance of 800 mm with a time ratio of 1.12. Use \( a = r_4 = 1200 \) mm and \( r_5 = 1800 \) mm. Locate \( O_4 \) such that rocker 4 is vertical when the slider is at midstroke. Find suitable coordinates for \( O_2 \) and lengths for \( r_2 \) and \( r_3 \).

11-8 Design a crank-rocker mechanism with optimum transmission angle, a unit time ratio, and a rocker angle of 45° using a rocker 250 mm in length. Use the chart of Fig. 11-5 and \( \gamma_{\text{min}} = 50^\circ \). Make a drawing of the linkage to find and verify \( \gamma_{\text{min}} \), \( \gamma_{\text{max}} \), and \( \phi \).

11-9 The figure shows two positions of a folding seat used in the aisles of buses to accommodate extra seated passengers. Design a four-bar linkage to support the

![FIGURE P11-9]
seat so that it will lock in the open position and fold to a stable closing position along the side of the aisle.

11-10 Design a spring-operated four-bar linkage to support a heavy lid like the trunk lid of an automobile. The lid is to swing through an angle of 80° from the closed to the open position. The springs are to be mounted so that the lid will be held closed against a stop, and they should also hold the lid in a stable open position without the use of a stop.

11-11 For part (a) of the figure, synthesize a linkage to move \( AB \) from position 1 to position 2 and return.

![Diagram](a)

![Diagram](b)

**FIGURE P11-11 and P11-12**

11-12 For part (b) of the figure synthesize a mechanism to move \( AB \) successively through positions 1, 2, and 3.

11-13 through 11-22\(^{17}\) The figure shows a function-generator linkage in which the motion of rocker 2 corresponds to \( x \) and the motion of rocker 4 to the function \( y = f(x) \). Use four precision points and Chebychev spacing and synthesize a linkage to generate the functions shown in the accompanying table. Plot a curve of the desired function and a curve of the actual function which the linkage generates. Compute the maximum error between them in percent.

![Diagram](Diagram)

**FIGURE P11-13 through P11-22**

\(^{17}\)This example is adapted from a similar problem solved graphically in Hartenberg and Denavit, op. cit., pp. 244-248 and pp. 274-278.
11-33 The figure illustrates a coupler curve which can be generated by a four-bar linkage (not shown). Link 5 is to be attached to the coupler point, and link 6 is to be a rotating member with $O_6$ as the frame connection. In this problem we wish to find a coupler curve from the Hrones and Nelson atlas or by point-position reduction, such that, for an appreciable distance, point $C$ moves through an arc of a circle. Link 5 is then proportioned so that $D$ lies at the center of curvature of this arc. The result is then called a *hesitation motion* because link 6 will hesitate in its rotation for the period during which point $C$ traverse the approximate circle arc. Make a drawing of the complete linkage and plot the velocity-displacement diagram for 360° of displacement of the input link.

![Coupler curve](image)

**FIGURE P11-33**

11-34 Synthesize a four-bar linkage to obtain a coupler curve having an approximate straight-line segment. Then, using the suggestion included in Fig. 11-29b or 11-31b, synthesize a dwell motion. Using an input crank angular velocity of unity, plot the velocity of rocker 6 versus the input crank displacement.

11-35 Synthesize a dwell mechanism using the idea suggested in Fig. 11-29a and the Hrones and Nelson atlas. Rocker 6 is to have a total angular displacement of 60°. Using this displacement as the abscissa, plot a velocity diagram of the motion of the rocker to illustrate the dwell motion.