

## Supplement

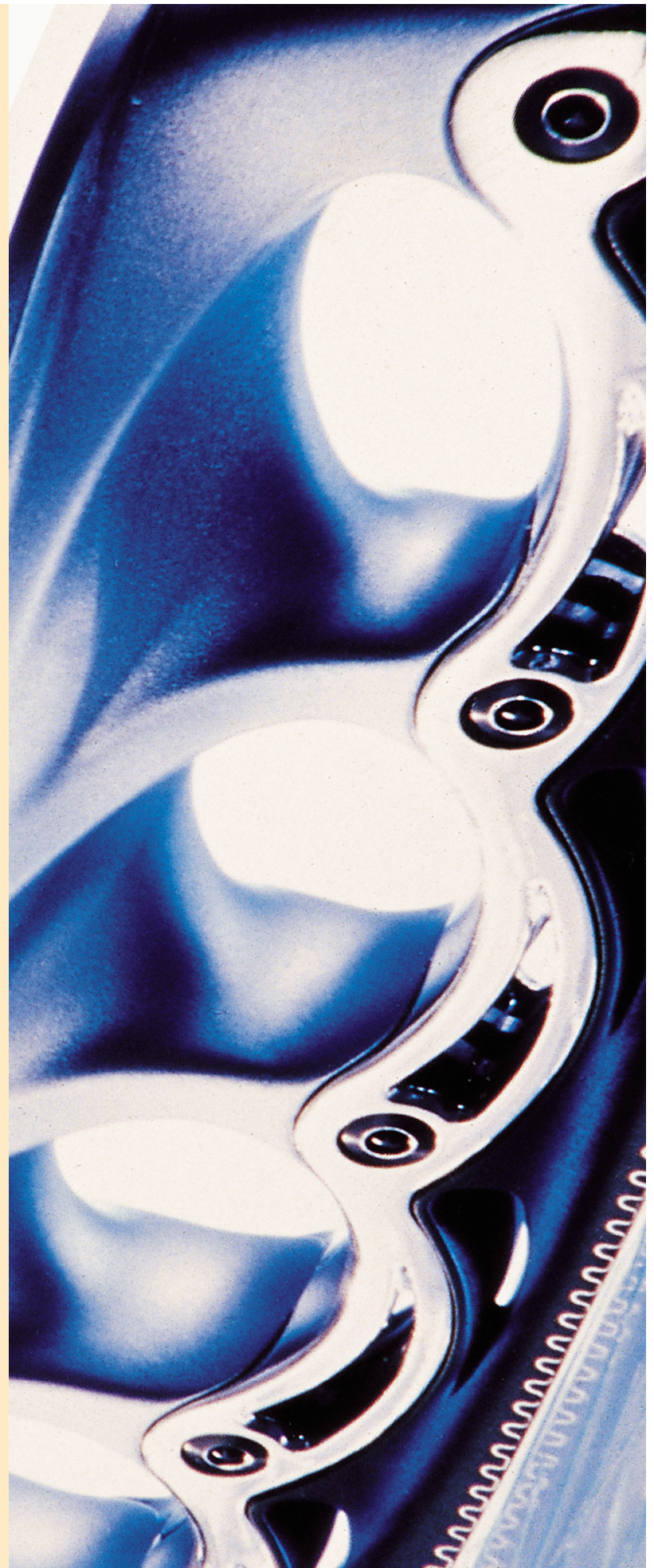
# Design Problems

### General Instructions

The following design problems are intended to challenge you to be creative, individually or in a group. Those problems designed specifically for a group are so labeled. The design problems are not meant to teach the design process, as much as how to represent ideas graphically, using drawings and computer models. Any design problem labeled a concept means that all details of the solution are not necessary. For example, Problem 2 is a concept automobile highway bridge. Obviously, a highway bridge cannot be completely designed in 10, or even 16, weeks by students. However, the basic concept for a highway bridge can be developed and graphically represented in that time frame.

For each project, you must create the engineering drawings and models necessary to communicate your solution to others. The engineering drawings should include the following:

1. Initial design sketches.
2. Multiview drawings, with dimensions. (Concept designs only need critical dimensions and details, where necessary.)
3. Sectioned assembly drawings, with parts list.
4. Pictorial drawings of the final design, with parts list where appropriate.



Group projects use a team approach to solve the design problems. The team should consist of four to eight students, randomly selected. Each team should have a group leader to schedule meetings, assign tasks and deadlines, and make sure the team works together as a group to solve the problem.

## Problems

1. **Concept solar-powered vehicle.** (Group) Design a solar-powered concept vehicle, for one passenger, that can travel up to 20 mph.
2. **Concept automobile highway bridge.** (Group) Design a bridge structure that will carry four lanes of traffic and cross a river. The bridge should be 125 feet across and 78 feet above the water in the center.
3. **Concept multipurpose outdoor stadium.** (Group) Design a multipurpose outdoor stadium for football, baseball, and soccer that will seat 54,000 people.
4. **Concept multipurpose indoor stadium.** (Group) Design a multipurpose indoor stadium for basketball, hockey, and volleyball that will seat 18,000 people.
5. **Concept olympic-sized swimming pool.** (Group) Design an olympic-sized swimming facility that will seat 3500 people.
6. **Ergonomic three-button mouse.** Design an ergonomic computer mouse, with three buttons, that can be used by left- and right-handed people.
7. **Laptop computer case.** Design a hard-plastic carrying case for a notebook computer and mouse that weighs 7 pounds and is 2.25 inches by 8 inches by 11 inches.
8. **Computer disk storage unit.** Design a storage box to hold and organize 100, 3<sup>1</sup>/<sub>2</sub>-inch computer disks.
9. **Computer keyboard tray.** Design a computer keyboard tray that will be fastened to a desk. The keyboard tray must be able to slide under the desk and accommodate a mouse.
10. **Reading lamp.** Design a reading lamp that can be attached to a desk and adjusted to various positions.
11. **Highway interchange.** (Group) Design an interchange between a four-lane highway and a six-lane interstate highway.
12. **Concept airport facility.** (Group) Design an airport facility for a small city to accommodate two airlines and jets no larger than a Boeing 727.
13. **Portable stadium seat.** Design a portable stadium seat, with a backrest that can be folded flat and with storage for a rain poncho.
14. **Cordless telephone.** Design a cordless telephone.
15. **Snow ski carrier.** Design a device that holds four pairs of downhill or cross-country skis and poles and attaches to an automobile.
16. **Computer desk.** Design a desk for a personal computer that uses a 15-inch monitor mounted below the glass top.
17. **Educational toy.** Design an educational toy or game for children ages 3 to 5.
18. **Beverage cooler.** Design a cooler that can accommodate six 12-ounce beverage cans or bottles.
19. **Chair storage device.** Design a portable storage system for 35 folding steel chairs.
20. **Concept railroad bridge.** (Group) Design a railroad bridge that spans a river 100 feet across. It should be 38 feet above the water at the center.
21. **Children's playground.** (Group) Design a neighborhood playground with tennis courts, a basketball court, and playground equipment.
22. **Football/track facility.** (Group) Design a high school football/track facility with concessions and seating for 2500 people.
23. **Packaging for a computer monitor.** Design the packaging for a 15-inch or 17-inch computer monitor.
24. **Solar water heater.** (Group) Design a solar collector to heat water for a 2500-square-foot house.
25. **Solar collector for heat.** (Group) Design a solar collector to heat a 1200-square-foot house located in northern Michigan, at latitude 45 degrees.
26. **Stereo speaker cabinet.** Design compact, three-way stereo speakers for a 40-watt amplifier.
27. **Concept swept-wing aircraft.** (Group) Design a swept-wing combat aircraft.
28. **Concept commercial aircraft.** (Group) Design a high-speed 350-passenger commercial aircraft.
29. **Concept spacecraft.** (Group) Design a three-person space vehicle to be used by a space station for in-space satellite repair missions.
30. **Remote control.** Design a hand-held infrared remote control for an entertainment center that has cable TV, a videocassette player/recorder, and a stereo with cassette tape, tuner, and audio CD player.
31. **Concept mountain bike.** (Group) Design a lightweight frame for a 26-inch mountain bike with a shock-absorbing front fork.
32. **Concept amusement park ride.** (Group) Design an amusement ride for a specific age group for a theme park.
33. **Weightlifting bench.** Design a weightlifting bench that uses a maximum of 600 pounds of free weights.

- The bench should include the following stations: bench press, dual action leg lift, and adjustable inclined bench.
34. **Stair-stepper exerciser.** Design an exercise stair-stepper with dual hydraulic cylinders that can be adjusted for variable resistance. The unit must have a height adjustment for the handlebar and must fold flat for storage.
  35. **Portable basketball hoop.** Design a portable basketball system with a water-filled base that provides 250 pounds of weight for stability. The pole should be adjustable every 6 inches between 7 feet and 10 feet, and the unit must have wheels for easy movement.
  36. **Computer workstation desk.** Design a computer workstation desk for a PC-based CAD system. The workstation must accommodate a 17-inch monitor, desktop computer, keyboard, 18-inch digitizing tablet, and some storage.
  37. **Concept sports car.** (Group) Design a sports car for two passengers.
  38. **Concept electric car.** (Group) Design an electric car to be used by commuters in large metropolitan areas. The car should have a maximum speed of 60 mph and a range of 120 miles.
  39. **Communications device.** Design a communications device that uses pictures, for use by a disabled child. For example, a drawing of a cup with the word “drink” could be used to communicate that the child is thirsty. The communications device must have a minimum of 25 words for basic living functions, such as eat, sleep, open, close, help, etc.
  40. **Propane gas grill.** Design an outdoor propane gas grill with approximately 600 square inches of cooking area.
  41. **Alphabet toy.** Design a toddler-age toy used to teach the alphabet.
  42. **Parking facility.** Design a parking facility to accommodate 100 automobiles, including five spaces for individuals with disabilities. Include a single entrance with a booth for collecting parking fees.
  43. **Logsplitter.** Design a device to split hardwood logs for home fireplaces. The device should use hydraulics to split the logs.
  44. **Aluminum can crusher.** Design a device that will automatically crush aluminum beverage cans for recycling. The device should have a feature that automatically loads, crushes, and discharges the cans.
  45. **Sports car dashboard.** Design a sports car dashboard. Lay out all the standard features on the dashboard so that they are within reach or eyesight of the driver.
  46. **Toothpaste dispenser.** Design a device that will automatically dispense toothpaste from a standard toothpaste tube. This device should be able to mount on a wall.
  47. **Ball return.** Design a device that returns a basketball when a person is practicing free throws. This device must attach to a standard basketball rim, backboard, or pole.
  48. **File cabinet wheels.** Design a wheeled device that attaches to a file cabinet. This device would make the file cabinet easier to move. The device should be adjustable so that it will fit on different-sized cabinets.
  49. **TV/VCR remote control.** Design the controls for a TV/VCR remote control. Take into account the size of an average human finger and its reach. Think of the functions that would be needed and how they could be grouped on the controls. Consider what the overall size and shape should be and what kind of a display it should have, if any.
  50. **Door latch/lock.** Design a door latching/locking system. Define the environment (office, home, industrial, etc.) and the kind of door with which it will be used. Take into consideration the characteristics and abilities of a wide range of people who might be using the door. Include such factors as height, strength, and physical disability.
  51. **Children’s cart/cycle.** Design a children’s outdoor toy that can be propelled by pedaling. The toy should also have the capacity to hold another child, other toys, etc. Consider both cost and safety issues.
  52. **Garden hose sprayer.** Design a hand-held garden hose sprayer. The sprayer must have an on/off control and be able to spray a variety of patterns. Consider how the handle will fit on the sprayer and work the controls. Specify how the sprayer will connect to the hose (standard threaded connection or a quick-release design).
  53. **Hand garden tiller.** Design a garden tiller/weeder that can be used standing up. Define how deep the tiller is meant to penetrate the soil and what kinds of weeds it is meant to remove.
  54. **Casters.** Design furniture casters. They should be able to swivel and lock. They should also be removable from the piece of furniture so that it can sit on the floor without them. Consider the type of flooring for which they are meant and how that might influence their design.
  55. **Workpiece hold-down device.** Design a quick-release hold-down device used for holding down a workpiece in a wood or metal shop. The device must

- be able to hold material up to 3 inches thick and have at least an 8-inch reach. It should have the ability to release the workpiece quickly, and should be easy to position and move to other work surfaces. The holding strength of the device should also be considered.
56. **Wood pellet feeder.** Formed pellets from waste wood are an increasingly popular way of heating both industrial and residential spaces. Design a system that feeds pellets from a hopper into a furnace. Consider the feedback mechanism needed to decide how fast to feed the pellets to generate the required heat. Also consider the high temperatures under which portions of the feeder will have to operate.
  57. **Portable clothesline.** Design a portable clothesline/clothes holder for drying a full load of clothes, including full-length dresses. One person must be able to set up the device quickly, and it must be collapsible to a size no bigger than a large suitcase. Consider out-of-balance situations, that is, when the clothes are not evenly distributed.
  58. **Heavy equipment mover.** Design a system that would attach to stationary machining equipment, such as a lathe or drill press, allowing that equipment to be easily moved around the shop floor. The system may be either permanently attached or attachable just for the move. The system should allow a single person to maneuver a piece of equipment up to 750 pounds and still provide maximum stability when the equipment is stationary.
  59. **Portable light.** Design a battery-powered portable lighting system that leaves the operator's hands free. Define a task for which the operator would need such lighting, and design a light for that situation. Consider the environment in which the operator is working and the amount of light needed for the task.
  60. **Portable bed.** Design a portable bed or cot for camping use. Define the group of people (population) that would be using the cot, and research the range of body dimensions and range of weight in this population. Also consider the space needed to store the bed when not in use and how easy it is to set up.
  61. **Paintbrush dryer/cleaner.** Design a device that can be used for both cleaning and hastening the drying of paintbrushes. The device should be usable with both water- and oil-based paints and brushes of all sizes. Consider a method of containing the volatile solvents used to clean oil-based paint from brushes.
  62. **Bicycle carrier.** Design a bicycle-carrying system that can be used on cars, vans, and trucks. Consider the ease of mounting both the carrier on the vehicle and the bicycle on the carrier. Also consider the aerodynamic qualities of the carrier design, and the methods of securing the bicycle from theft.
  63. **Cellular telephone mount.** Design a system for mounting cellular telephones in cars. The mount should not be permanent and should be adaptable to most makes and models of cars. The design should not compromise the safety of the vehicle operator by impeding the use of controls.
  64. **Home office workstation.** Design a home office workstation with the following items integrated into it:
    - Computer with 17-inch monitor.
    - Phone.
    - Fax machine.
    - Personal-size photocopy machine.

The workstation should also have at least two file drawers, a drawer for office supplies, and clear counter space for paperwork.
  65. **Cooking equipment storage system.** Design a storage system for cooking equipment, including pots, pans, and their lids. Consider a full range of sizes and shapes along with accessibility. The system should fit in industry standard cabinets.
  66. **Compact disk holder.** Design a holder for compact disks. The system should be usable in the home or car and should be able to carry the CDs with or without their original jewel boxes. Define the locations where this holder will be used and how many CDs it should carry.
  67. **School lockers.** Design a modular school locker system made from sheet metal. Consider holding requirements such as books, school supplies, outerwear (wet and dry), and gym clothes. Also consider the locking/latching system that is going to be used. When designing the locker, consider the most efficient use of standard-sized sheet metal.
  68. **Outdoor table.** Design an outdoor table for use on a patio or deck. The table should be a knock-down (KD) design that can be easily assembled and disassembled by the homeowner. The table should also be weatherproof. Consider the seating comfort for both adults and children by researching the range of body dimensions in this population.
  69. **Pallet moving system.** Design a system for moving standard warehouse pallets. Define whether the system will load and unload pallets from trucks or just move within the warehouse. Also decide how high the system will lift the pallets.
  70. **Tool storage system.** Design a tool storage system that can be mounted in a full-sized pickup truck and used for work in the field. Define what profession would be using this system and what kinds of tools

- would be needed. The system should also be relatively easy to remove from the truck and should require no substantial modification of the truck.
71. **Portable welding station.** Design a portable welding station for use by a maintenance crew in a factory. The station should hold equipment for both gas and arc welding and should have clamping surfaces for holding smaller pieces being repaired. Consider safety requirements when working with welding equipment.
  72. **Hazardous environment rescue vehicle.** (Group) Design a vehicle for use in search and rescue operations in hazardous environments, such as a chemical or nuclear plant. Consider how many people the vehicle will hold, what level of medical care will be provided, and what terrain the vehicle will be able to travel over. Once the initial concept is developed by the group, divide the design into smaller components to be worked on by individual team members.
  73. **Space shuttle robot arm.** (Group) Design a robot arm for the space shuttle cargo bay to be used for launching and retrieving satellites. The arm must have considerable reach and maneuverability but must still be able to stow away inside the cargo bay. Consider whether the arm will only be controlled from within the shuttle or by astronauts riding on the arm as well. Once the initial concept is developed by the group, divide the design into smaller components to be worked on by individual team members.
  74. **Computer game joystick.** Design the outside plastic shell for a computer game joystick. The case should be able to be attached to a flat surface or held by the user. The joystick should have all the standard features to control action in a computer game.
  75. **Wheelchair vehicle lift.** Design a device that will lift a child or adult in a wheelchair to a van. The device should be permanently attached to the vehicle.
  76. **Left-foot accelerator.** Design a device that will allow the operation of an automobile through the use of an accelerator pedal for the left foot.
  77. **Hand accelerator.** Design a device that will allow the operation of a vehicle through the use of an accelerator that can be operated by hand.
  78. **Hand brake.** Design a device that will allow the operation of a vehicle through the use of a brake that can be operated by hand.
  79. **Sports wheelchair.** (Group) Design a wheelchair that can be used for sporting activities, such as marathons and basketball.
  80. **Home aquarium feeder.** Design a device that will automatically dispense fish food for a home aquarium.
  81. **Pet watering device.** Design a device that will automatically dispense water for a household pet, such as a dog or cat.
  82. **Pet feeding device.** Design a device that will automatically dispense food for a household pet, such as a dog or cat.
  83. **Horse exercising machine.** Design a device that can be used to assist in the exercising of a horse.
  84. **Automobile safety bumper.** (Group) Design a bumper system that will allow an automobile impact of up to 15 MPH without damage to the vehicle.
  85. **Human-powered vehicle.** (Group) Design a human-powered boat, aircraft, or submarine. These vehicles should be designed for a single person.
  86. **Photographer's blind.** Design a portable, nature photographer's blind. The blind should be lightweight, easy to assemble and disassemble, and small enough to be carried easily when disassembled.
  87. **Home security system.** Design a security system for a single-family home. Use an existing floor plan from a home-planning catalog.
  88. **Router table.** Design a device that can be used to convert an electric hand router into a table router. You must be able to attach and remove the router easily.
  89. **Drillpress.** Design a device that can be used to convert a  $\frac{3}{8}$ -inch electric hand drill into a drillpress. You must be able to attach and remove the drill easily from the device.
  90. **Table saw.** Design a device that can be used to convert a  $7\frac{1}{4}$ -inch hand circular saw into a table saw. You must be able to attach and remove the saw easily from the device.
  91. **Woodworker's vise.** Design a portable woodworker's vise. This vise must be easily attached to a table or other flat surface.
  92. **Router pantograph.** Design a router pantograph that can be used to make oversized signs. This device will use a standard hand router. A pantograph is an instrument used to copy drawings or maps.
  93. **Portable scoreboard.** (Group) Design a portable sports scoreboard that can be used for high school soccer, baseball, football, basketball, and volleyball.
  94. **Jogging shoe.** Design a shoe especially suited for adult joggers who run no more than 10 miles a week.
  95. **Milk carton crusher.** Design a device that will crush a 1-gallon plastic milk carton for recycling.
  96. **Soda bottle crusher.** Design a device that will crush a 2-liter plastic bottle for recycling.
  97. **Mass transit passenger car.** Design a mass transit passenger car for a high-speed commuter rail system to be used in major metropolitan areas in the United States.

98. **Parabolic solar collector.** Design a parabolic solar collector capable of boiling 12 ounces of water in the shortest possible time.
  99. **Pick-and-place robot.** (Group) Design a simple pick-and-place robot that will pick up a 2-inch cube of aluminum from a conveyor belt and place it onto a table located 6 inches above the conveyor line.
  100. **Gear reducer.** Design a gear reduction box that will reduce the speed of an input shaft turning at 1000 RPM to an output shaft turning at 100 RPM.
  101. **Alarm system.** Design a home fire alarm system for warning a deaf person.
  102. **TV support.** Design a 25-inch TV monitor support that can be mounted on a classroom wall. The support needs to allow the TV to be easily repositioned to different viewing angles.
10. Hold-down clamp.
  11. Drillpress vise.
  12. Telephone.
  13. Computer mouse.
  14. Paper stapler.
  15. Paper feeder tray for a laser printer.
  16. Multiple pen holder for a plotter.
  17. Computer game joystick.
  18. Piston and connecting rod for an automobile engine.

### Reverse Engineering Problems

Reverse engineering is a process of taking existing products, evaluating and measuring them, and then creating the CAD database to reproduce them. The following problems can be used as reverse engineering projects. Use a micrometer, scale, and calipers to make measurements. Use manufacturer's catalogs to specify standard parts, such as bearings and fasteners. For each project, the following is required:

1. Disassemble, measure, and sketch each part.
2. Create 3-D models or engineering drawings of each nonstandard part, with dimensions.
3. Specify standard parts, using engineering catalogs.
4. Create an assembly drawing with parts list.
5. Create a written report that summarizes your project, lists the strengths and weaknesses of the product you reverse engineered, comments on the serviceability of the product, and recommends changes to the design, especially as it relates to DFM principles.

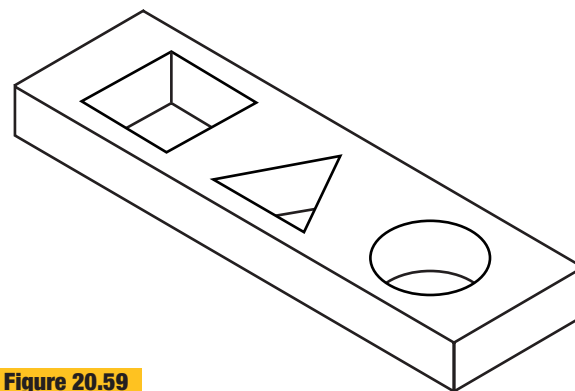
The products to be reverse engineered are as follows:

1.  $\frac{3}{8}$ -inch reversible electric hand drill.
2. Staple gun.
3. Electric kitchen hand mixer.
4. Electric can opener.
5. Electric hair dryer.
6. Electric glue gun.
7. Electric hand jigsaw.
8. Dustbuster.
9. Kant-twist clamp.

### Problem-Solving Activities

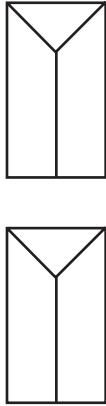
The following problems can be used as individual or group activities. The activities involve the problem-solving process. Some of the activities also involve visualization ability. Most of the problems will require sketches to solve the problem and to communicate the solution.

1. Determine one solid object that will pass completely through the circular, triangular, and square holes (Figure 20.59). The object must pass through each hole one at a time and be tight enough that little or no light passes between it and the sides of the hole. Make an isometric sketch of your solution.
2. Sketch the missing right side view and an isometric view of the two given views in Figure 20.60. The solution cannot have warped surfaces.
3. Create a low-cost lightweight container that will prevent an egg from breaking when dropped from a third-story window onto concrete.
4. Create a method of filling a 2-liter plastic soda bottle resting on the ground, from a third story window.



**Figure 20.59**

Problem solving activity 1

**Figure 20.60****Problem solving activity 2**

- 5.\*A mountain climber starting at sunrise takes a well-worn path from the base of a mountain to its top and completes the trip in one day. The mountain climber camps overnight on the mountain top. At sunrise the climber descends the mountain along the same path. Even though the rates of ascent and descent are different, there is one point along the path which the mountain climber passes at the same time of the day. Prove that there is a single point along the path where this occurs, and make a sketch of your solution.
- 6.\*Build the longest cantilevered structure possible using 20 sticks of spaghetti and 24 inches of clear tape. The base of the cantilever must be taped to an 8-inch-square horizontal area. The cantilever must be constructed in 30 minutes or less. When finished, measure the length of the cantilever section from the point on the base nearest to the overhanging cantilever end to the end of the cantilevered section.

\*Problems 5 and 6 are adapted from *Experiences in Visual Thinking*, R.H. McKim, 1972.