CHAPTER 8

Engineering Design

8.1 What Is Engineering Design?

Engineers create things. Engineers build things. In order to successfully perform these tasks, engineers must be involved in design or in a design process. So what is engineering *design* and an engineering *design process*? Webster's dictionary defines design as "to create, fashion, execute, or construct according to plan." It defines a natural process as "a natural phenomenon marked by gradual changes that lead toward a particular result: a series of actions or operations conducing to an end; a continuous operation or treatment, especially in manufacture."

This chapter may seem closely related to Chapter 5, "Problem Solving." Indeed, there are many similar topics and themes in Chapter 5 that are important in Design. One of the critical areas which impacts Design is the issue of "external constraints" that can influence the outcome of the process. Appropriate references back to Chapter 5 will be noted throughout this chapter.

In the work of engineers, engineering design is an important and ongoing activity. Students who graduate with an engineering degree from an accredited program have had a significant amount of design experience as part of their education. The Accreditation Board for Engineering and Technology (ABET) has traditionally defined engineering design as follows:

> *Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process . . . in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. . . . it is essential to include a variety of realistic constraints, such as economic factors, safety, reliability, aesthetics, ethics, and social impact.*

ABET then describes the basic educational components for a major engineering design experience that must be included in an engineering program:

> Each educational program must include a meaningful, major engineering design experience that builds upon the fundamental concepts of mathematics, basic sciences, the humanities and social sciences, engineering topics, and communication skills. The scope of the design experience within a program should match the requirements of practice within that discipline. . . . all design work should not be done in isolation by individual students; team efforts are encouraged where appropriate. Design cannot be taught in one course; it is an experience that must grow with the student's development. A meaningful, major design experience means that, at some point when the student's academic development is nearly complete, there should be a design experience that both focuses the student's attention on professional practice and is drawn from past course work. Inevitably, this means a course, or a project, or a thesis that focuses upon design. "Meaningful" implies that the design experience is significant within the student's major and that it draws upon previous course work, but not necessarily upon every course taken by the student.

Many entering engineering students often confuse the "design process" with drafting or art-related work. To clarify this, ABET adds the following:

> Course work devoted to developing computer drafting skills may not be used to satisfy the engineering design requirement.

Most engineering programs concentrate their engineering design coursework in the later part of the student's program, thereby allowing the student to apply much of the prerequisite background in math, science and related fields to the various engineering problems. In most engineering programs, design courses comprise between 20% and 25% of the total curriculum.

8.2 The Design Process

It is important to realize that there is not one uniform approach to engineering design that is followed by practicing engineers. Some firms approach engineering design as a short, simple process with only a few steps, while others use a more complex, multi-step method with several stages. No matter what process is used, it is important to realize that engineering design is always continuous. The completion of one design, or the solution of one problem, may serve to open up opportunities for subsequent designs or modifications.

A design process is used whether a product is being developed for an ongoing manufacturing process, where thousands or even millions of a certain item will be produced, or for a one-time design, such as with the construction of a bridge, dam, or highway exit ramp.

10-Stage Design Process

This chapter will present one design process (the 10-stage process) that is presently in use. This process will then be applied to an existing product to analyze how each of the 10 stages may have been applied in the product's realization.

The 10 stages that make up the process are as follows:

- Stage 1: Identify the problem/product innovation
- Stage 2: Define the working criteria/goals
- Stage 3: Research and gather data
- Stage 4: Brainstorm/generate creative ideas
- Stage 5: Analyze potential solutions
- Stage 6: Develop and test models
- Stage 7: Make the decision
- Stage 8: Communicate and specify
- Stage 9: Implement and commercialize
- Stage 10: Perform post-implementation review and assessment

The actual process begins with the appointment of a project manager or team leader. This individual will be responsible for oversight of the entire process to ensure that certain key elements of each stage have been satisfied before the project moves on to the next stage. This person will also be responsible for recruiting team members of varying backgrounds and expertise for each of the stages. The team will include non-engineers as well as engineers. Some of the team members will be used throughout the process, while others will be needed only for certain parts of the process.

Stage 1: Identify the Problem

Engineers are problem-solvers; and the problems they solve are often identified as the specific needs and problems of customers. For example, a new prosthesis may be required to overcome a particular handicap, or increased gas mileage standards demand higher-efficiency engines, or a new computer program is needed to monitor a modified manufacturing process, or new safety devices are required to better protect infants in automobiles. Therefore, the first stage to problem solving in engineering design is to establish the actual problem clearly, and to identify sources of information to help understand the scope and nature of the problem.

The project manager will call upon the resources of various individuals to assist with these initial stages in the process. There may be a multitude of sources outside as well as within the organization that can assist with solving the problem. Many firms have a research and development unit made up of scientists and engineers who possess the training and expertise to assist with problem evaluation. In addition, sales engineers, who maintain consistent contact with outside individuals, can provide valuable input on problem identification. If the problem is one of expanding a current product line or modifying an existing system to improve it or make it better fit customer needs, management will likely play a role in the definition of the problem. Each group would be represented on the team at this stage.

External resources may come from trade shows, conferences, technical presentations, patent listings, and publications. Ideas generated from existing or prospective clients may also be valuable. Information gathered from external research agencies, private laboratories, and government-funded foundations can be useful as well. In addition, an awareness of the competition and what products and services they are involved with can be beneficial in problem identification. At this early stage in the process, it is helpful to establish a preliminary, formal statement of the problem. For example, the need for a new automobile safety device for infants might evolve into a preliminary statement of the problem as follows: "Develop a better child restraint system that will protect children involved in automobile collisions."

It is important at this point to review the section of Chapter 5 which discusses the "real Problem." Before going ahead with the design process, the team must be certain that the correct issues and background have been thoroughly explored so the most appropriate solutions can be developed.

At this point, if the project manager is satisfied that all necessary issues have been resolved, the project will likely be passed on to the next stage where project criteria and goals will be developed.

Stage 2: Define the Working Criteria and Goals

Once the problem has been identified, it is important for the team to be able to validate it throughout the design process. This requires the establishment of certain working criteria, or standards, which can be used in each of the 10 stages to measure possible solutions. The ultimate objective in this stage is to be able to establish preliminary goals which will act as the focal point of the team as it works through the process. The development of some working criteria provides a means to compare possible solutions. At this stage of the design process, everything is preliminary, so it is still possible for the team to modify the criteria if necessary.

Examples of working criteria could include answers to the following questions:

1. How much will it cost?
2. Will it be difficult to produce?
3. What will be the size, weight, strength?
4. What will it look like?
5. Will it be easy to use?
6. Will it be safe to use?
7. Are there any legal concerns?
8. Will it be reliable and durable?
9. Can it be recycled?
10. Is this what the customer truly wanted?

11. Will our customers want to purchase it?
12. Will customers want to purchase this version instead of a competitor's product?

Once some preliminary working criteria have been established, it is important to try to develop overall goals for the process. This is basically a statement of objectives which can be evaluated as the design process evolves. Using the example of new standards implemented to increase gas mileage and reduce emissions in automobiles, the goals for the design might be: "To develop an automobile engine which produces 25% less emissions while increasing gas mileage by 10%."

Having overall goals established for the project provides a means of evaluating, monitoring, and changing, if necessary, the focus of the process as it evolves through the 10 stages. For the project manager, the criteria and goals become a "checkpoint" for assessing the progress to date, and will help them determine if the project is ready to move to the next stage, or if the process needs to return to Stage 1 for re-evaluation.

Stage 3: Research and Gather Data

This stage is very important to all remaining stages of the design process. Having good, reliable background information is necessary for the team to begin exploring all relevant aspects of the problem. Consistent with the preliminary working criteria and the goals that have been established, the team members selected for this phase of the process must determine what types of information will be needed and the best sources of that information. For example, they may want to know such things as:

1. What information has been published about the problem?
2. Is there a solution to the problem that may already be available?
3. If the answer to the above is yes, who is providing it?
4. What are the advantages of their solution?
5. What are the disadvantages of their solution?
6. What is the cost?
7. Is cost a significant issue?
8. What is the ratio of time spent compared to overall costs?
9. Are there legal issues to consider?
10. Are there environmental concerns which must be considered?

There are many possible resources the team members can utilize to assist them in their research. A good starting point may be a simple search using the Internet. This may provide useful sources of material that can serve as the focus for additional research. Other sources of reference information may come from:

1. libraries
2. professional associations (technical and non-technical)
3. trade journals and publications
4. newspapers and magazines

5. market assessment surveys
6. government publications
7. patent searches and listings (U.S. Patent Office: www.uspto.gov.)
8. technical salespersons and their reference catalogs
9. professional experts including engineers, professors, and other scientists
10. the competition's product (How do they construct it? Disassemble their product and study it.)

Detailed files, notes, pictures, sketches, and other supporting materials will be maintained by the team to assist them as they proceed through the remaining stages of the design process. As new supporting information is discovered by the team, the material will be added as additional reference resources.

Depending on the type of information that has been collected, at this point it may be appropriate to review the established preliminary working criteria and the overall goals. To assist the project manager throughout the process, some modifications may need to be made. For example, it may be determined that one or more of the criteria may not actually apply to the problem. Likewise, new issues may surface which may necessitate the addition of new criteria or a modification of the goals. It is important to have these issues resolved before moving on to the next stage.

Stage 4: Brainstorm/Generate Creative Ideas

The basic concept involved at this stage of the process is to creatively develop as many potential solutions to the problem as possible. The more ideas that can be generated, the better the likelihood of identifying a feasible solution to the problem. The project manager will want to gather a group of individuals from both technical and non-technical backgrounds to provide their unique perspective to the problem. This group may include engineers, scientists, technicians, shop workers, production staff, finance personnel, managers, computer specialists, and perhaps even a few clients.

A major method of generating multiple ideas to a problem is called *Creative Problem Solving*, using a technique called *brainstorming*. (Note: For a thorough discussion of creative problem solving and brainstorming strategies, please refer to Section 5.6 in Chapter 5.) With this method, a large group of individuals with varying backgrounds and training are brought together to attempt to solve a particular problem. Every idea that is spontaneously contributed from the group is recorded. The basic premise is that no idea is deemed too wild or illogical at this stage. No preliminary judgments are made about any member's idea, and no negative comments are allowed. The goal is to develop a long list of possible alternative solutions to the problem at hand. The group leader should be able to encourage participants to suggest random thoughts and ideas.

Some students may have had the opportunity to engage in brainstorming exercises. Brainstorming can be fun and highly stimulating to the creative process. For example: How many ways can you suggest to use a piece of string and a Styrofoam drinking cup? What could be created from a trash bag that contains some old magazines, tape and a ruler? Think of ways your student organization could earn extra funds for a field trip, etc.

It is conceivable that a brainstorming session would be continued on a second occasion to allow members time to consider other possible options. When the group reconvenes, members may have several new ideas or new perspectives for examining the problem.

At the conclusion of this stage, the group should have a long list of potential solutions to the problem. It is important to remember that at this stage of the process no idea has been eliminated from consideration. Each idea will be evaluated eventually, but it is important to keep all options open at this stage.

Once the project manager is satisfied that all possible solutions have been suggested, the project will likely be cleared for the next stage.

Stage 5: Analyze Potential Solutions

Note: Chapter 5.3 discussed the Analytic Method in detail. That information is directly related to this material in this stage. In the early part of the analysis stage (Phase I), it is important to try to narrow the ideas generated in the brainstorming stage to a few ideas which can be subjected to more sophisticated analysis techniques. This early narrowing could include:

- Examine the list and eliminate duplicates. As discussed earlier, it is important not to create limited categories, but only to eliminate repeated ideas. If two are similar, both should remain at this point.
- Allow the group to ask clarifying questions. This could help identify duplicate ideas.
- Ask the group to evaluate the ideas. The group members can vote for their top three ideas, and those that gain the most votes will be retained for more detailed analysis.

At this point, there will probably be a small number of ideas remaining. These can now be analyzed using more technical and perhaps time-consuming analysis techniques (Phase II).

A variety of individuals should be involved at this stage, but the engineer will be of primary importance. The analysis stage requires the engineer's time and background. It is here that one's training in mathematics, science, and general engineering principles are extensively applied to evaluate the various potential solutions. Some of the techniques in this phase can be time consuming, but a thorough and accurate analysis is important before the project moves to the next stage in the process. For example, if the problem under consideration was the development of an automobile bumper that could withstand a 20-mile-per-hour crash into a fixed object barrier, several forms of analysis could be applied, including:

Common sense: Do the results seem reasonable when evaluated in a simple form? Does the solution seem to make sense compared to the goal?

Economic analysis: Are cost factors consistent with predicted outcomes?

Analysis using basic engineering principles and laws: Do each of the proposed solutions satisfy the laws of thermodynamics? Newton's laws of motion? The basic principles of the resistance of a conductor, as in Ohm's law, etc.?

Estimation: How does the performance measure up to the predicted outcomes? If the early prediction was that some of the possible bumper solutions would perform better than others, how did they perform against the estimate? (Review Chapter 5.3 for a more thorough discussion of Estimation.)

Analysis of compatibility: Each of the possible solutions and their related mathematical and scientific principles are compared to the working criteria to determine their degree of compatibility. For example: How would each bumper solution meet the criteria of being cost-effective? What would be the size, weight, and strength of each of the proposed solutions? How easy would each one be to produce?

Computer analysis techniques: One frequently used method is *finite element analysis*. With this method, a device is programmed on a computer and then numerically analyzed in segments. These segments are then compared mathematically to other segments of the concept. In the bumper crash example, the effects of the impact could be analyzed as a head-on crash and then compared to a 45-degree angle collision or a side-impact crash. As each section is analyzed, the "worst-case scenario" can be evaluated.

Conservative Assumptions: As discussed in Chapter 5, this technique can be most useful in analysis. It can build safeguards into the analysis until more data is generated.

After each of the working criteria have been examined and compared to the list of possible solutions, a process eliminates those that have not performed well in the various forms of analysis. It is expected at this point that only three to five options from the original list of prospective solutions will remain. These remaining options will then be reviewed by the project manager, who will likely authorize that the project be cleared for the next stage, assuming that these remaining options meet the working criteria and overall goals. If not, the process will need to be terminated, or return to an earlier stage to correct the problem.

Stage 6: Develop and Test Models

Once each of the prospective solutions has been analyzed and the list of feasible options has been narrowed to a few possibilities, it is time to enter the phase where specific models will be developed and tested. Again, in this stage it is important to have a strong background in engineering coupled with experience and sound judgment. However, this stage will also involve team members who are computer specialists, shop workers, testing technicians, and data analysts.

There are several types of models which are commonly used by engineers and others in this stage. These include:

Mathematical models: Various conditions and properties can be mathematically related as functions and compared to one another. Often these models will be computerized to assist in visualizing the changing parameters in each of the models.

Computer models: There are various types of computer models which can be used. Typically these models allow the user to create on-screen images which can be analyzed prior to the construction of physical models. The most common computer modeling is referred to as CAD (Computer Aided Design) where models are designed and displayed as three-dimensional wire-frame drawings or as shaded and colored pictures. The computer can also be used to control equipment that can generate solid models using techniques such as "stereo-lithography," where quick-hardening liquids are shaped into models or other forms of "rapid prototyping." These on-screen models, or the prototype models they produce, can then be used in the testing process.

Scale models: Typically, these smaller models have been built to simulate the proposed design but may not include all of the particular features or functions. These models are often called prototypes or mock-ups and are useful in helping engineers visualize the actual product. Such models may be used to depict dams, highways, bridges, new parts and components, or perhaps the entire body of a prototype automobile.

Diagrams or graphs: These models provide a tool for visualizing, on a computer or on paper, the basic functions or features of a particular part or product. These diagrams or graphs could be the electrical circuit components of an operating unit of the product, or a visualization of how the components eventually may be assembled.

Once the models have been developed and created, it is time to test each of them. Performing a variety of tests on each of the models allows for comparison and evaluation against the working criteria and the overall goals that have been established. In actuality, tests are done continually throughout a project including early models, prototypes, and the testing of product quality as the product is manufactured or built. However, the results of the testing done in this stage establish the foundation for the decisions that will be made about the future of this project.

Examples of these tests include:

Durability: How long will the product run in testing before failure? If the product is a structure, what is its predicted life span?

Ease of assembly: How easily can it be constructed? How much labor will be required? What possible ergonomic concerns are there for the person operating the equipment or assembling the product?

Reliability: These tests are developed to characterize the reliability of the product over its life cycle, to simulate long-term use by the customer.

Strength: Under what forces or loads is a failure likely, and with what frequency is it likely to occur?

Environmental: Can the parts be recycled?

Quality consistency: Do tests show that product quality is consistent in the various stages? Is the design such that it can be consistently manufactured and assembled? What conditions need to be controlled during manufacture or construction to ensure quality?

Safety: Is it safe for consumer use?

Consistency of testing: This technique examines each of the testing methodologies against the various results obtained to determine the consistency among the various tests. In the bumper design example, the testing methodology might be different for a head-on impact test than for a 45-degree crash test in order to minimize testing inconsistencies.

All of this information will be evaluated by the project manager. If the manager is satisfied that these results consistently meet the working criteria and overall goal, the project will likely be cleared for the next stage.

Stage 7: Make the Decision

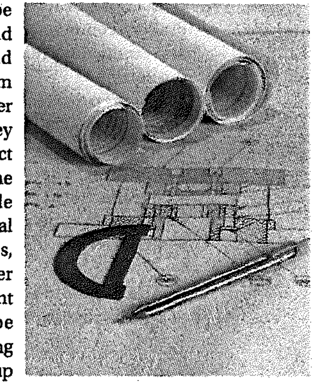
At this stage, it is important for the team members to establish a means to compare and evaluate the results from the testing stage to determine which, if any, of the possible solutions will be implemented. The working criteria that have been used throughout the process are the critical factors which will be used to determine the advantages and disadvantages of each of the remaining potential solutions. One of the ways to evaluate the advantages and disadvantages of each of the proposed solutions is to develop a *decision table* to help the team visualize the merits of each. Typically, a decision table lists the working criteria in one column. A second column assigns a *weighted available point total* for each of the criteria. The team will need to determine the order of priority of each of the criteria. The third column then provides *performance scores* for each of the possible solutions. A sample Decision Table might look like the one that follows.

TABLE 8.1 A Decision Table

Working Criteria	*Points Available*	*#1*	*#2*	*#3*
Cost	20	10	15	18
Production Difficulty	15	8	12	14
Size, Weight, Strength	5	5	4	4
Appearance	10	7	6	8
Convenient to use	5	3	4	4
Safety	10	8	7	8
Legal issues	5	4	4	4
Reliability/Durability	15	7	9	11
Recyclability	5	4	3	4
Customer Appeal	10	7	8	9
Total	**100**	**63**	**72**	**84**

Based on this sample decision table, it appears that while none of the proposed solutions have scored near the "ideal" model, Solution #3 did perform better than the others. Using this information, the project manager and team leaders would make the final decision to "go" or "no-go" with this project. They may decide to pursue Solution #3, to begin a new process, or even to scrap the entire project. Assuming they decide to pursue Solution #3, the team would prepare the appropriate information for the next stage in the process.

Stage 8: Communicate and Specify



Before a part, product or structure can be manufactured, there must be complete and thorough communication, reporting, and specification for all aspects of the item. Team member engineers, skilled craft workers, computer designers, production personnel, and other key individuals associated with the proposed project must work together at this stage to develop the appropriate materials. Such materials include detailed written reports, summaries of technical presentations and memos, relevant e-mails, diagrams, drawings and sketches, computer printouts, charts, graphs, and any other relevant and documented material. This information will be critical for those who will be involved in determining final approval for the project, as well as the group involved in the final implementation of the product. They must have total knowledge of all parts, processes, materials, facilities, components, equipment, machinery, and systems that will be involved in the manufacturing or production of the product.

Communication is an important tool throughout the design process, but especially in this stage. If team members cannot adequately sell their ideas to the rest of the organization, and be able to appropriately describe the exact details and qualities of the product or process, then many good possible solutions might be ignored. At this stage of the process, it also may be important to create training materials, operating manuals, computer programs, or other relevant resources which can be used by the sales team, the legal staff, and prospective clients and customers.

At this point, if the project manager is satisfied that all necessary materials have been adequately prepared and presented, the project will likely be passed on to the next stage, the implementation stage.

Stage 9: Implement and Commercialize

The next-to-last stage of the design process is critical, as it represents the final opportunity for revision or termination of a project. At this point in the process, costs begin to escalate dramatically, so all serious issues should be resolved by this time.

In addition to the project manager and team leaders, there are a number of other individuals involved at this stage, representing a variety of backgrounds and areas of expertise. While engineers are a part of this stage, many of the activities here are performed by others. Some of those involved in this stage may include:

Management and key supervisory personnel. These individuals will make the ultimate decisions concerning the proposed project. They are concerned with the long-term goals and objectives of the organization, determining future policies and programs that support these goals, and making the economic and personnel decisions that affect the overall health of the organization.

Technical representatives. These may include skilled craft workers, technicians, drafters, computer designers, machine operators, and others involved in manufacturing and production. This group will have primary responsibility for getting the product "out the door."

Business representatives. This group may consist of:

- **human resource personnel** if new individuals must be hired
- **financial people** to handle final budget details and financial analysis questions
- **purchasing personnel** who will procure the needed materials and supplies
- **marketing and advertising staff members** who will help promote the product
- **sales people** who will be involved in the actual selling and distribution of the product

Attorneys and legal support staff. The legal representatives who will handle a variety of legal issues including patent applications, insurance, and risk protection analysis.

If all parties are in agreement that all criteria have been satisfied and the overall goal achieved, the actual production and commercialization will begin. However, there is one remaining stage where the project activities and processes will be evaluated and reviewed. (Note: Some stages of the process may be monitored differently depending on whether the project relates to a one-time product, i.e., a bridge or dam, or an ongoing manufacturing process.)

Stage 10: Perform Post-Implementation Review and Assessment

At this point, it is assumed that the project is in full production. The project manager, key supervisory personnel, and team members who had significant input with the project are gathered together for a final project review and assessment. This stage involves the termination of the project team, since the product is now considered to be a regular product offering in the firm's overall product line. The product's performance is reviewed, including the latest data on production efficiency, quality control reports, sales, revenues, costs, expenditures, and profits. An assessment report is prepared which will detail the product's strengths and weaknesses, outline what has been learned from the overall process, and suggest ways that teams can improve the quality of the process in the future. This report will be used as reference for future project managers and teams to consult.

EXERCISES AND ACTIVITIES

8.1 Disassemble one of the devices listed below, and put it back together. Sketch a diagram of all the parts and illustrate how they fit together to make the device operate. List at least three ways you think the design could be improved. Choose one of the following devices: a) flashlight, b) lawn sprinkler, c) sink faucet, d) stapler, e) toaster, f) computer mouse.

8.2 Prepare a list of questions that should be resolved in identifying each of the following problems:

a) Develop an improved manual gearshift for a mountain bike.
b) Develop a better braking system for in-line skates.
c) Develop a recliner chair that incorporates six built-in surround sound speakers in the unit.
d) Develop a hands-free flashlight.
e) Develop a theft-proof bicycle lock.
f) Develop a baseball cap with wireless stereo headphones.
g) Develop a secure storage area on a bike for a helmet.
h) Develop a new idea to reduce overcrowded parking on campus.
i) Develop a hands-free cellphone that can be used when doing activities.
j) Develop a shockproof cellphone carrying case.

8.3 Develop a list of working criteria that could be used in deciding whether to:

a) Accept a co-op job offer from Company A or Company B.
b) Study overseas for the Fall semester or remain on campus.
c) Buy a new car or repair your old one.
d) Purchase a desktop or laptop computer.
e) Change your major or remain in engineering.
f) Purchase a new computer or upgrade your current model.
g) Live in the dormitory or lease an off-campus apartment next year.
h) Pledge a fraternity/sorority.

8.4 Identify five product, structure, or system designs you think can be improved. Pick one and write a preliminary problem statement for the engineering design process.

8.5 Using an item from your list in Exercise 8.4, develop a list of reference materials that would be used in developing possible solutions to the problem. Provide specific examples.

8.6 Get together with three other classmates and brainstorm at least 30 ways to use one of the following objects:

a) Two-foot length of string
b) Ping-pong ball

c) Three plastic pop bottles
d) Page of notebook paper and a 2-inch piece of tape
e) Old telephone directory
f) Trash bag
g) Deck of playing cards
h) Yo-yo
i) Frisbee
j) Metal coat hanger
k) Empty plastic milk container
l) 15 paper clips
m) 2 tubes from paper towel rolls and 2 pages of newspaper
n) Deflated balloon
o) Bag of marshmallows
p) Newspaper and 12" of masking tape

8.7 Using the information you developed in Exercise 8.4, prepare a decision table for three possible alternative solutions.

8.8 Read a current newspaper or magazine article (possibly on the Web) that describes and discusses a new product, device, or system. Prepare a three- to four-page essay which analyzes and explains, in detail, each of the stages of the design process that were probably involved in the engineering of this product or device. Apply each stage of the 10-stage design process discussed in this chapter to your product or device, and use specific examples to support your statements. Make sure you list your sources in the body of the paper or in a bibliography.

8.9 Put together a team of five students from your class. Using the 10-stage design process, have your team develop a portable, garage-like covering for a bicycle that can be stored somewhere on the bike when not in use.

8.10 Put together a team of four or five students from your class. Using the 10-stage design process, build the tallest possible tower that can support a 12-oz can of soda/pop. Materials: one roll of masking tape, one package of straws, and one can of soda/pop. Constraints: Your tower must be free standing. The base must fit on a plate. Your tower must stand for 5 seconds under load for measurement. After the design is complete, 30 minutes will be allowed for tower construction.

8.11 Put together a team of four or five students from your class. Using the 10-stage design process, build a bridge that spans three feet between supports that contact the ground. Materials: one roll of duct tape, ten feet of rope, a 40 inch by 75 inch piece of cardboard, and 14 cardboard slats. After the design is complete, 40 minutes will be allowed for tower construction and testing. The test: one of your team members must walk heel-to-toe across the bridge.

8.12 Put together a team of five students from your class. Using the 10-stage design process, have your team develop a carrying mechanism for Rollerblades and/or your shoes when one is not in use.

CHAPTER 9

Technical Communications

Engineers must possess the technical skills to complete engineering analysis, evaluation, and design. However, these skills are essentially useless if they cannot be communicated to the variety of audiences with whom engineers work. These audiences will have a wide range of technical skills and might come from backgrounds extremely different from yours. To communicate effectively as an engineer, you need to understand your audiences, the desired effects you wish to have on these audiences, and the conventions of communication these audiences will expect you to follow (as shown in Figure 9.1). In other words, you will need to employ a rhetorical strategy to make your attempts at communication with these disparate audiences successful.

The rhetorical triangle shown in Figure 9.1 is an illustration of the considerations to be made in any communication scenario. The triangle represents three questions you can ask yourself to help you to make good choices in any rhetorical context.

- *Who is my audience?* Do I know them personally? What are their attitudes? Needs? Values?
- *What is my purpose?* Am I trying to explain something? Share something? Sell something? How do I want the audience to respond?
- *What is expected of me as a communicator?* Are there conventional approaches to this task? How do I make the desired impression?

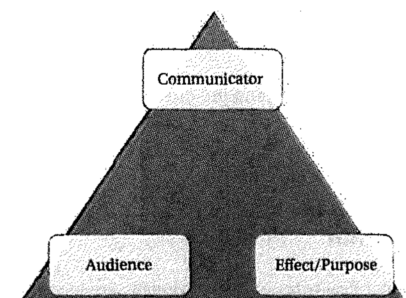


Figure 9.1 The rhetorical triangle.

Of course, these questions overlap; they are parts of an overall context for communicating. For example, is the context professional? Is it technical? What are the time