CHAPTER 5

Drawing to Develop Design Ideas

Menu

Before You Begin

Think about these questions as you study the concepts in this chapter:

1. Why is freehand sketching an important skill for designers, scientists, or engineers?
2. Why do engineers and other designers need to document their work?
3. What different abilities do the right and left hemispheres of the brain offer to artists, designers, or engineers?
4. What are the six "visual design elements" that can be integrated into an effective design?
5. How can you use color to better communicate design ideas?
6. What drawing techniques can be used to record and present ideas in engineering notebooks and design portfolios?
7. How are engineering notebooks and design portfolios developed?

INTRODUCTION

In Chapter 2, you were introduced to the *design process*, the central activity of all technological and engineering design. In Chapter 5, we look at some of the communication techniques designers use, especially at the beginning of the process, where ideas are just forming in the mind and need much further development.

Design is derived from the Latin word *designare*, "to mark out," which became the French word, *dessiner*, "to draw." Therefore, design is historically associated with drawing.

Drawing, or making graphic images by some means, is an integral part of being a professional designer or engineer (see Figure 5-1). Drawing can also be very useful to "everyday **technologists**"—homeowners, parents, or businesspeople solving practical problems.

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Figure 5-1:
A young artist showcases a digital sketch of a concept car during an international motor show in Kuala Lumpur, Malaysia.

THE MANY USES OF DRAWING

1

Drawing plays several roles in the design process (see Figure 5-2). These roles fall into three major categories: exploration, idea development, and documentation. For the purposes of this chapter, drawing includes **sketching** (rapid, **freehand** drawings) as well as more exacting depictions such as those required for technical work, possibly using instruments like compasses and straightedges. Sketching is shorthand for artists. It is used to get information down quickly, as in visual brainstorming. Detail drawing, for example, tends to be more careful and time-consuming.

sketching:
Creating a rough drawing representing the main features of an object or scene, often as a preliminary study.

freehand:
Done manually without the aid of instruments such as rulers.

Exploring the Visible World

Exploration is how we gather and make sense of information. The act of drawing requires us to look very hard at a subject, to really focus our attention on the details. Up to 90 percent of the information humans take in is visual, and yet rarely do we take a hard look at the world. Looking with the intention of drawing requires intense concentration. Drawing is an excellent investigative tool; it can help us understand how things work and how parts relate to one another.

Developing Ideas

We develop solutions to design problems by generating and manipulating ideas. Our first ideas for solving problems are usually rather rough. Sketching allows us to give form to ideas and to think more clearly about how to build on those ideas. Creating successive drawings allows us to capture each improvement. Drawing is one of the handiest tools at our disposal for putting down an idea and then changing it until we have something we like.

Exploration and idea development are the building blocks of creativity. The freehand sketching and drawing explained in this chapter provide a direct bridge from what's in our minds to the world of physical objects and products. It is the immediacy of hand drawing that allows us to capture a creative insight or a moment's vision for future use.

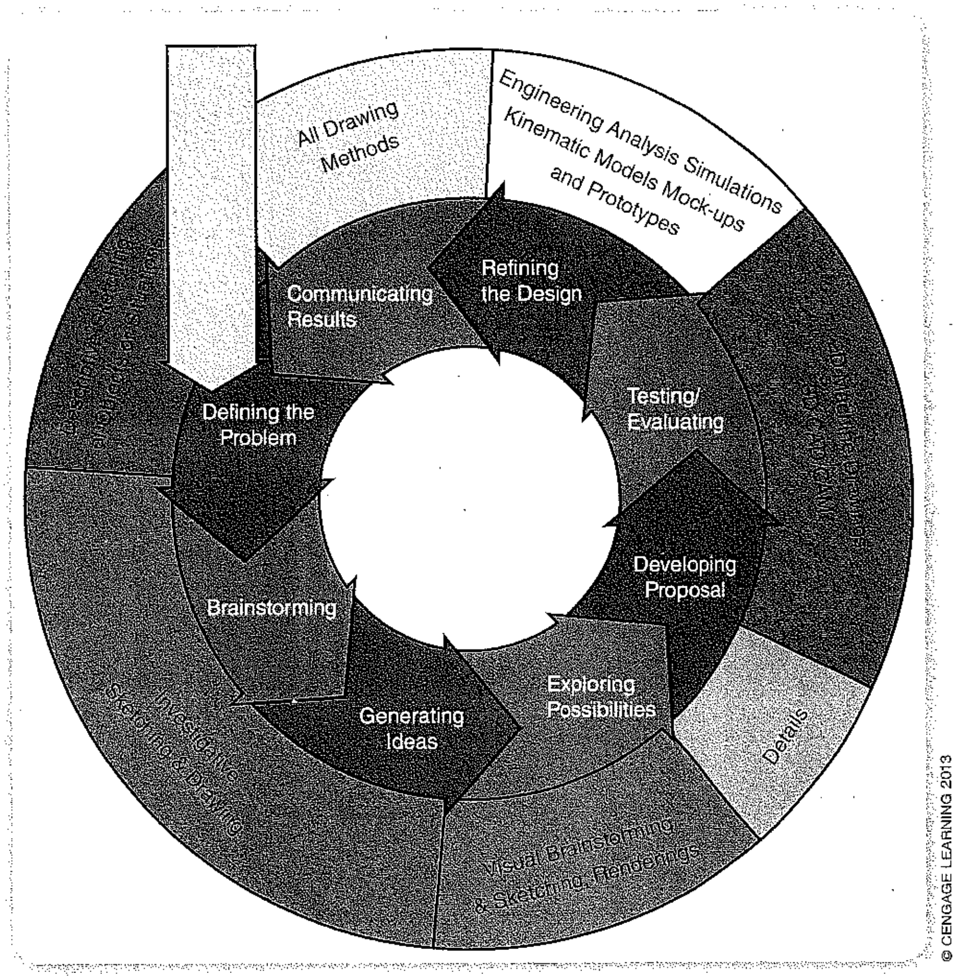

Figure 5-2: *How drawing and modeling support the design process.*

perspective:
A form of pictorial drawing in which vanishing points are used to provide the depth and distortion that is seen with the human eye; perspective drawings can be drawn using one, two, and three vanishing points.

Once an idea is on its way to being a product, we use technology to extend our drawing skills. Not long ago, **draftspersons** labored over drawing boards, hand-inking production drawings and blueprints, measuring precise dimensions, and adding notations. In Chapter 10, we will see that today those drawings are largely done by **computer-aided design or computer-aided drafting (CAD)** programs that allow designers to work in **perspective** using color, lighting effects, and realistic surface renderings.

Documenting the Process

Documentation is the activity of collecting the evidence of the thinking and problem-solving process that has gone into a designed innovation. Figure 5-2 shows how drawing supports the design process. The outer circle suggests different drawing and modeling techniques that allow designers to see and develop their ideas. When you do documentation in a pre-engineering class, you are developing basic design skills and providing your teacher with a window into your mind.

documentation:
(1) The documents required for something, or that give evidence or proof of something; (2) drawings or printed information that contains instructions for assembling, installing, operating, and servicing.

Keeping a record of ideas and development work is an integral part of designing (see Figure 5-3). The term **designer** is used for a wide range of occupations. Engineers do technical designs for the products and systems we use every day, from our cell phones to the water we drink, the games we play, and the vehicles we use to get to school, work, or vacation. Architects and civil engineers are designers of structures; **graphic artists** works with elements on a page, such as typeface, page layout, and photos to design print materials; industrial designers work with physical products; and fashion designers work with clothes and accessories. These and many other occupations involve design, and a record of work is a necessary part of the job.

In the world of business and industry, the **engineer's notebook** is a careful record of ideas, calculations, thoughts, and plans for a particular project (see Figure 5-4). It is not unusual for an engineer to be pulled from the middle of a project, only to pick it up again six months or several years later. The documentation within the engineer's notebook saves countless hours of rediscovery when the engineer returns to a task.

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Figure 5-3: An architect shares concept drawings with a client.

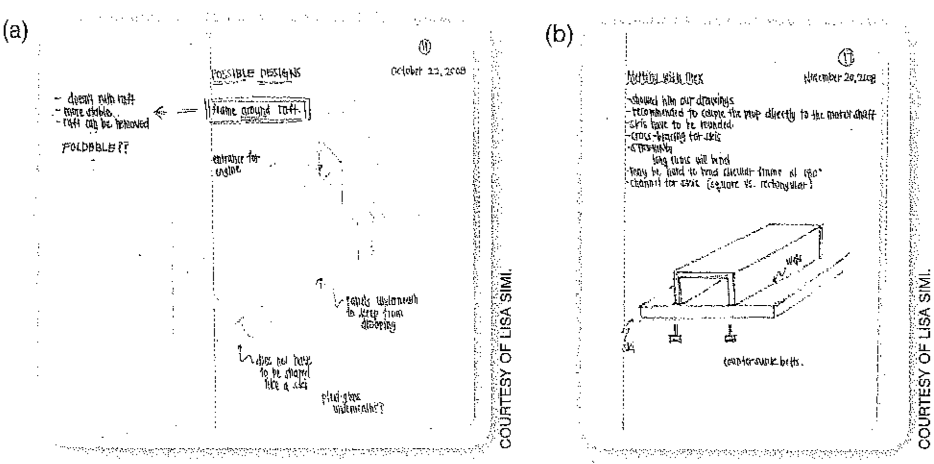
In a similar manner, the records the engineer keeps may well be the legal basis for awarding a **patent** when several similar patent applications are submitted. Questions such as "Which applicant developed a critical idea or design first?" can be answered with documentation evidence. Contrary to popular belief, ideas do not generally blossom forth fully formed; they evolve and grow. The documentation of the development of an idea over time is generally a collection of original sketches, notes, calculations, and other evidence.

engineer's notebook: Also referred to as an engineer's logbook, a design notebook, or designer's notebook. Used as (1) a record of design ideas generated in the course of an engineer's employment that others may not claim as their own, and (2) an archival record of new ideas and engineering research achievements which can provide proof of an idea for patenting purposes.

Engineers must preserve the evidence of that evolution of thought, not just for legal purposes, but perhaps more importantly, so that they can "backtrack" when the inevitable "false trail" is taken. Being sure about where you have been makes future progress possible, because we all are forgetful and designing is a very involved process. Good documentation helps designers keep track of important facts and information, ideas, and the details of design solutions.

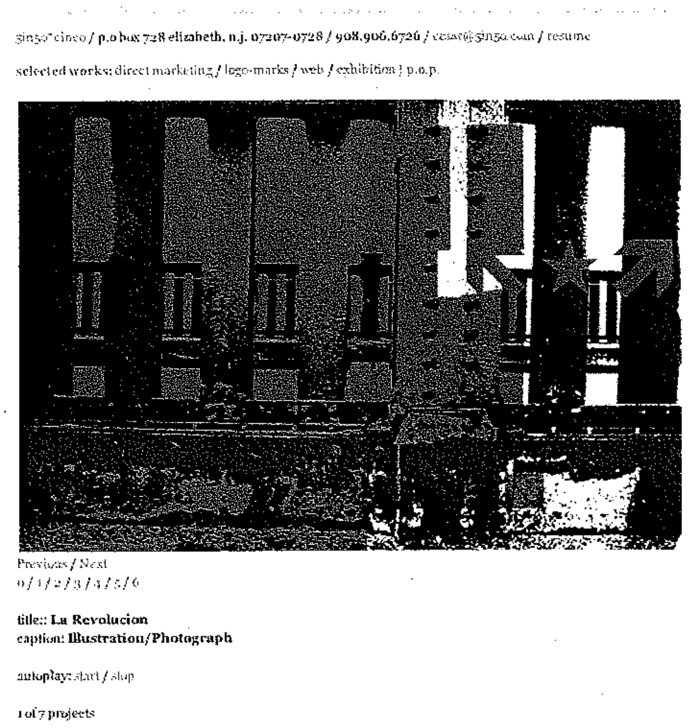
Design Portfolio. People in creative fields and students preparing for work in a creative field should keep records of their work. Although the engineer's notebook serves an important technical and legal role, a **portfolio** consisting of a collection of materials that document the thinking and physical work of an individual may also be created. Architects show a portfolio to prospective clients so that the clients can evaluate their previous projects. If a prospective client sees evidence of quality work and style compatible with the project's requirements, then the deal may be "closed." Throughout a project, an architect will use drawings or photographs

portfolio: A set of pieces of creative work intended to demonstrate a person's ability or to document the development of an idea over time.



(a) COURTESY OF LISA SIMI. (b) COURTESY OF LISA SIMI.

Figure 5-4: Examples of drawings from a bound engineering notebook, a) using sketching to show a possible solution, b) using a sketch to communicate an idea for a meeting with a machinest.



COURTESY OF CAESAR RUBIN, DESIGN DIRECTOR/DESIGNER, WWW.5IN50.COM.

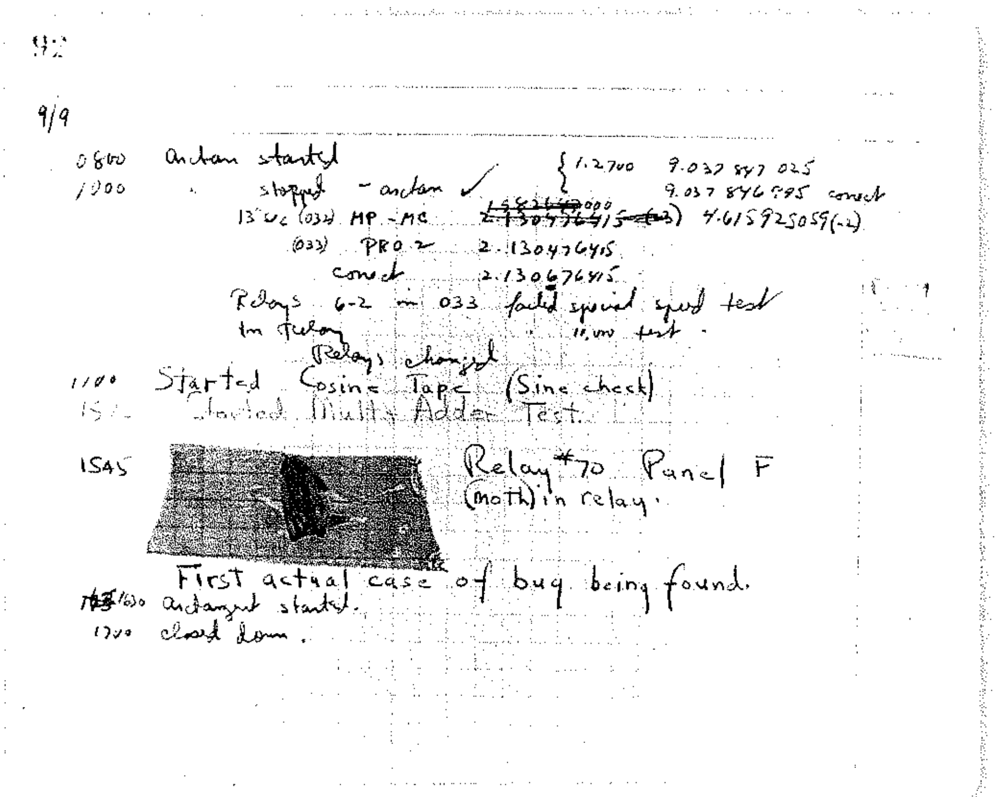
Figure 5-5: *This artist's online portfolio allows visitors to navigate through the portfolio's pages.*

to communicate the progress of the job to the client. The portfolio plays an important role in the designer-client relationship.

Like architects, other design professionals know the importance of portfolios (see Figure 5-5). Designers can show their portfolio to prospective clients interested in commissioning work, or can use it to apply for grants and exhibits. For many years, designers have photographed their work and developed slide portfolios. More and more designers are now documenting their works digitally and posting their portfolios on websites.

Engineer's Notebook. Engineers or other designers may develop a kind of portfolio as well, describing projects and original work through photographs, sketches, illustrations, and publications. These are used for job promotion and job search, and may even be used to obtain funding for a project or to open one's own business.

The patent system in the United States rewards the first person who invents a new product. An engineer's note book or journal helps you prove that you were first (see Figure 5-6). An engineer's



COURTESY OF THE DEPARTMENT OF THE NAVY, NAVAL HISTORICAL CENTER.

Figure 5-6: *Page describing the first computer "bug" from an inventor's log of Rear Admiral Grace Hopper, inventor of COBOL computer language.*

notebook is officially a bound notebook on which each day's activities are recorded, with the date and any drawings that show the evolution of the problem solution. Often major benchmarks are signed and witnessed to prove that the claims for the design and the dates are authentic. An engineer may not be trying to protect new methods for patenting purposes, but may keep a log to record decisions made and benchmarks in the development of a project to replicate the results and evaluate the process and product.

Student Design Portfolio. In education, the portfolio is taking on new importance. Many critics of education are saying that paper and pencil tests are of only limited value when it comes to assessing what students have learned. Because tests only assess a student's knowledge at one point in time, they provide little evidence of what someone actually knows; we have all learned something for a test and then promptly forgotten it when the test was over. Within the portfolio, however, is evidence of what an individual has actually done (applied) over a period of time. This evidence does not simply appear the last week of school; it is accumulated over weeks, months, or even years.

The portfolio is an especially powerful tool in technology and pre-engineering courses (see Figure 5-7). Because much of design and development work is graphic in nature and because the portfolio lends itself to graphic evidence, it becomes a central part of the design process on two levels:

1. Each problem tackled is tracked and documented with a portfolio; and
2. The individual portfolio of each project is incorporated into a cumulative portfolio, which can act as evidence for application to a college or professional training program, for a job, or an award, honor, or competition.

The documentation of your design work is an integral part of both the study and understanding of design. By means of the portfolio, you will gather evidence of your ideas and your creative and developmental work.

(a)

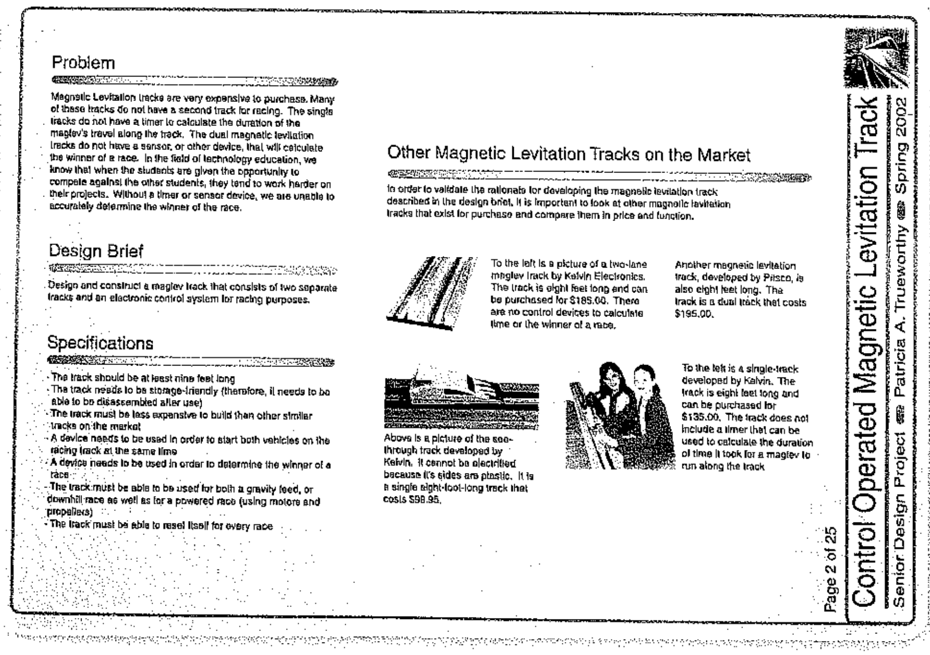


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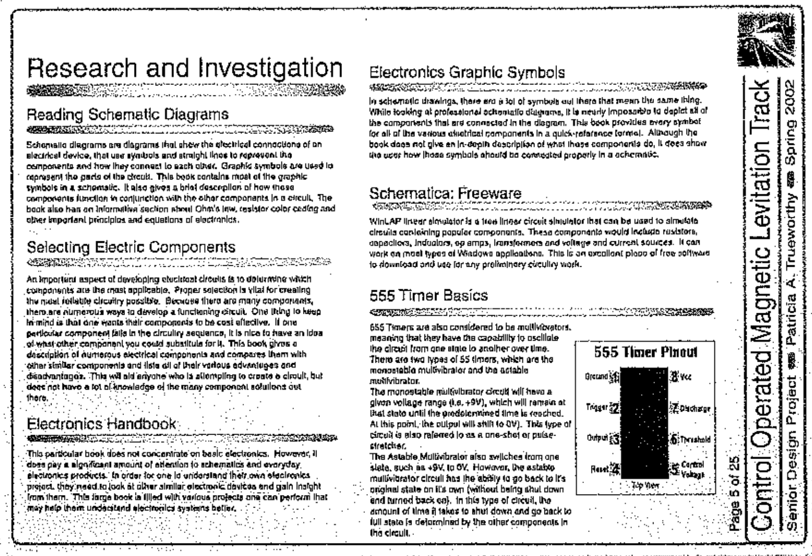
Figure 5-7: *Pages of a student design portfolio.*

Figure 5-7: (*Continued*)

(b)



Research and Investigation

Reading Schematic Diagrams

Schematic diagrams are diagrams that show the electrical connections of an electrical device, that use symbols and straight lines to represent the components and how they connect to each other. Graphic symbols are used to represent the parts of the circuit. This book contains most of the graphic symbols in a schematic. It also gives a brief description of how these components function in conjunction with the other components in a circuit. The book also has an informative section about Ohm's law, resistor color coding and other important principles and equations of electronics.

Selecting Electric Components

An important aspect of developing electrical circuits is to determine which components are the most applicable. Proper selection is vital for creating the most reliable circuitry possible. Because there are many components, there are numerous ways to develop a functioning circuit. One thing to keep in mind is that one wants their components to be cost effective. If one particular component fails in the circuitry sequence, it is nice to have an idea of what other component you could substitute for it. This book gives a description of numerous electrical components and compares them with other similar components and lists all of their various advantages and disadvantages. This will aid anyone who is attempting to create a circuit, but does not have a lot of knowledge of the many component solutions out there.

Electronics Handbook

This particular book does not concentrate on basic electronics. However, it does pay a significant amount of attention to schematics and everyday electronics products. In order for one to understand their own electronics project, they need to look at other similar electronic devices and gain insight from them. This large book is filled with various projects one can perform that may help them understand electronics systems better.

Electronics Graphic Symbols

In schematic drawings, there are a lot of symbols out there that mean the same thing. While looking at professional schematic diagrams, it is nearly impossible to depict all of the components that are connected in the diagram. This book provides every symbol for all of the various electrical components in a quick-reference format. Although the book does not give an in-depth description of what these components do, it does show the user how these symbols should be connected properly in a schematic.

Schematica: Freeware

WinLAP linear simulator is a free linear circuit simulator that can be used to simulate circuits containing popular components. These components would include resistors, capacitors, inductors, op amps, transformers and voltage and current sources. It can work on most types of Windows applications. This is an excellent piece of free software to download and use for any preliminary circuitry work.

555 Timer Basics

555 Timers are also considered to be multivibrators, meaning that they have the capability to oscillate the circuit from one state to another over time. There are two types of 55 timers, which are the monostable multivibrator and the astable multivibrator.
The monostable multivibrator circuit will have a given voltage range (i.e. +9V), which will remain at that state until the predetermined time is reached. At this point, the output will shift to 0V). This type of circuit is also referred to as a one-shot or pulse-stretcher.
The Astable Multivibrator also switches from one state, such as +9V, to 0V. However, the astable multivibrator circuit has the ability to go back to it's original state on it's own (without being shut down and turned back on). In this type of circuit, the amount of time it takes to shut down and go back to full state is determined by the other components in the circuit.

555 Timer Pinout
Ground 1
Trigger 2
Output 3
Reset 4
8 Vcc
7 Discharge
6 Threshold
5 Control Voltage
Top View

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Control Operated Magnetic Levitation Track
Senior Design Project Patricia A. Trueworthy Spring 2002

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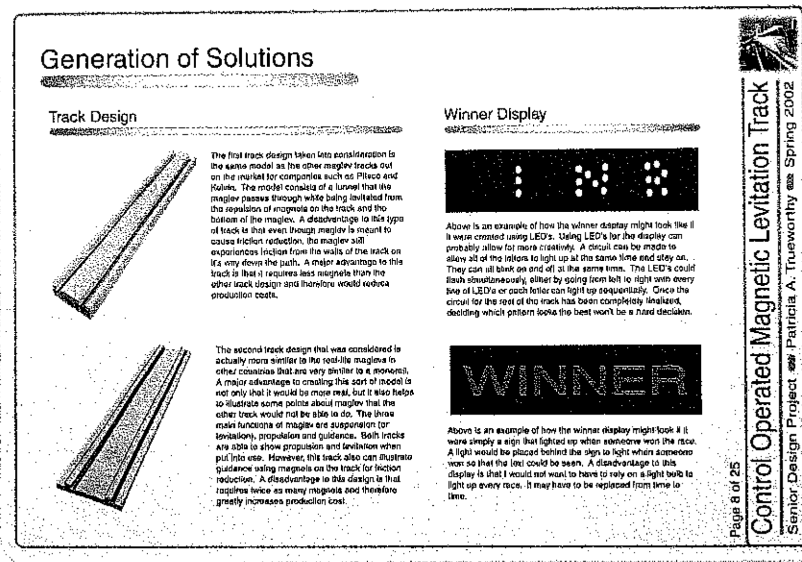

Generation of Solutions

Track Design

The first track design taken into consideration is the same model as the other maglev tracks out on the market for companies such as Pitsco and Kelvin. The model consists of a tunnel that the maglev passes through while being levitated from the repulsion of magnets on the track and the bottom of the maglev. A disadvantage to this type of track is that even though maglev is meant to cause friction reduction, the maglev still experiences friction from the walls of the track on it's way down the path. A major advantage to this track is that it requires less magnets than the other track design and therefore would reduce production costs.

The second track design that was considered is actually more similar to the real-life maglevs in other countries that are very similar to a monorail. A major advantage to creating this sort of model is not only that it would be more real, but it also helps to illustrate some points about maglev that the other track would not be able to do. The three main functions of maglev are suspension (or levitation), propulsion and guidance. Both tracks are able to show propulsion and levitation when put into use. However, this track also can illustrate guidance using magnets on the track for friction reduction. A disadvantage to this design is that requires twice as many magnets and therefore greatly increases production cost.

Winner Display

Above is an example of how the winner display might look like if it were created using LED's. Using LED's for the display can probably allow for more creativity. A circuit can be made to allow all of the letters to light up at the same time and stay on. They can all blink on and off at the same time. The LED's could flash simultaneously, either by going from left to right with every line of LED's or each letter can light up sequentially. Once the circuit for the rest of the track has been completely finalized, deciding which pattern looks the best won't be a hard decision.

WINNER

Above is an example of how the winner display might look if it were simply a sign that lighted up when someone won the race. A light would be placed behind the sign to light when someone won so that the text could be seen. A disadvantage to this display is that I would not want to have to rely on a light bulb to light up every race. It may have to be replaced from time to time.

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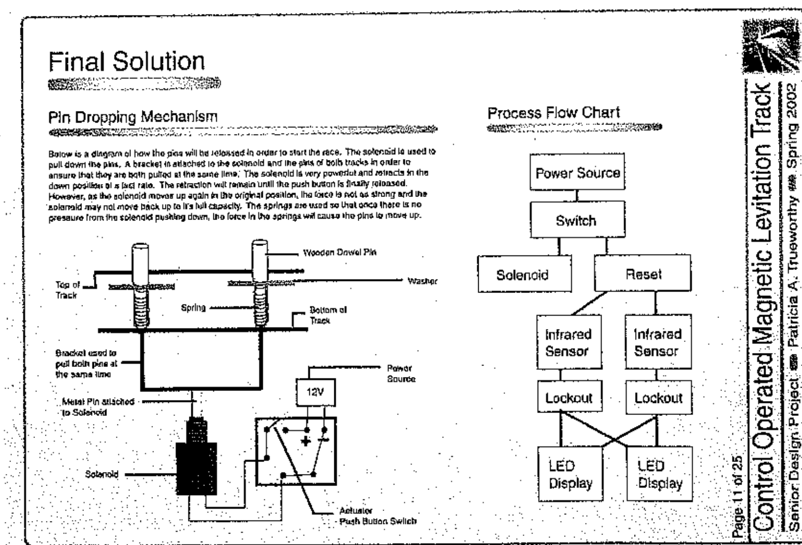

Final Solution

Pin Dropping Mechanism

Below is a diagram of how the pins will be released in order to start the race. The solenoid is used to pull down the pins. A bracket is attached to the solenoid and the pins of both tracks in order to ensure that they are both pulled at the same time. The solenoid is very powerful and retracts in the down position at a fast rate. The retraction will remain until the push button is finally released. However, as the solenoid moves up again in the original position, the force is not as strong and the solenoid may not move back up to it's full capacity. The springs are used so that once there is no pressure from the solenoid pushing down, the force in the springs will cause the pins to move up.

Wooden Dowel Pin
Top of Track
Washer
Spring
Bottom of Track
Bracket used to pull both pins at the same time
Power Source
12V
Metal Pin attached to Solenoid
Solenoid
Actuator Push Button Switch

Process Flow Chart

Power Source
Switch
Solenoid
Reset
Infrared Sensor
Infrared Sensor
Lockout
Lockout
LED Display
LED Display

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Control Operated Magnetic Levitation Track
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Figure 5-7: *(Continued)*

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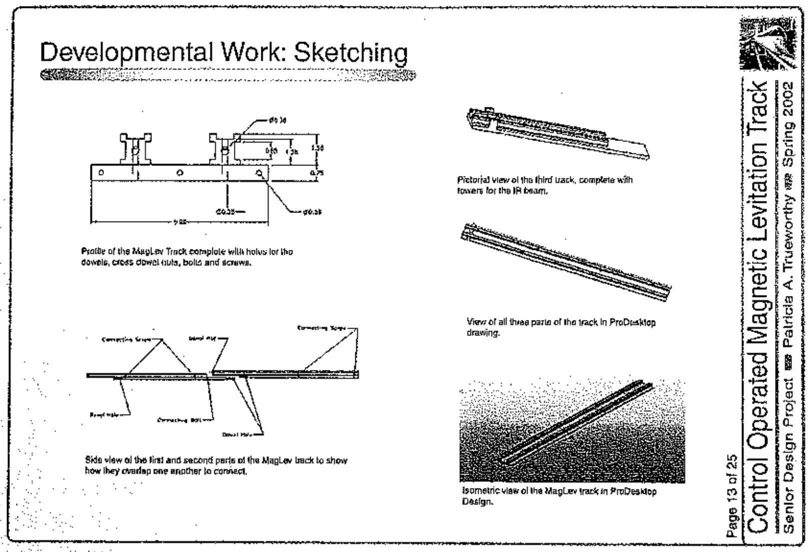

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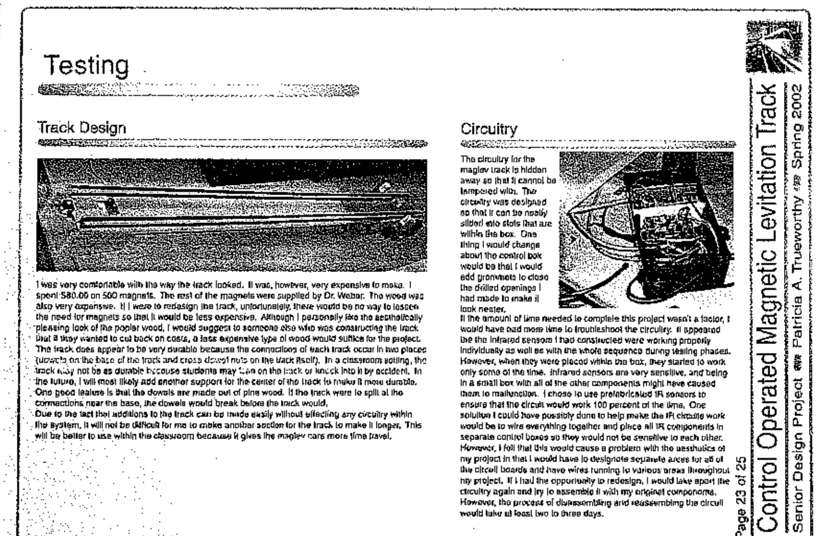

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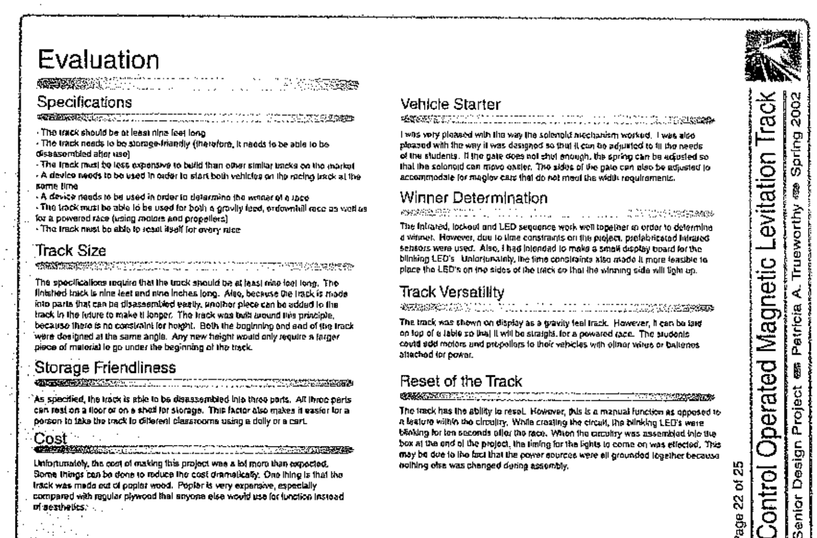

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COMMUNICATING THROUGH DRAWING

Drawing provides a language that allows individuals to describe the visible world and to **visualize**, refine, resolve, and communicate ideas. It is a skill that can be learned. Although some people have a natural talent for sketching and drawing, everyone can pick up the **techniques** and develop the basic skills.

You do not have to be an artist to draw and sketch. Although a few people find it very easy to learn, most of us must practice the techniques and "tricks" to be effective visual communicators. Quick, preliminary drawings are called sketches. Typically, they are used to capture the essence of an object or scene for later reference, or to roughly describe an idea that will need further development. Getting impressions and ideas down on paper as quickly and effectively as possible is a major goal of sketching.

Before we discuss the techniques of sketching, it is important that you become aware that most people must overcome barriers before they can learn to sketch and draw successfully. One barrier is the fear of not being able to sketch and draw, and looking foolish. Although it is rare that someone will admit they have this fear, just ask someone to sketch an idea or even a map. The first words out of that person's mouth are usually excuses about why their drawings will look awful. Overcoming this barrier takes some work, but the results can be very satisfying. After all, a picture has been said to be "worth a thousand words."

Whole-Brain Drawing

Nearly everyone has the manual dexterity to draw, but by adolescence, many people do not "remember" how to see. Drawing requires that we shift from thinking in a verbal and sequential way to a more intuitive approach. Scientists believe that **verbal thinking** happens on the left side of the brain, and **visual thinking** happens on the right side. Everyone uses this visual thinking quite naturally as a young child, but because most of our school experience by seventh or eighth grade has focused on reading and math, we forget how to see details and relationships that we need for drawing.

Exercises and activities can help people purposely activate the right side of the brain—the side that artists use when drawing, painting, and sculpting. One of the main strategies is to trick the overdeveloped left brain into inaction by challenging it to do things it's not good at. The ultimate goal is to be able to use your whole brain, with both halves working together, each doing what it does best.

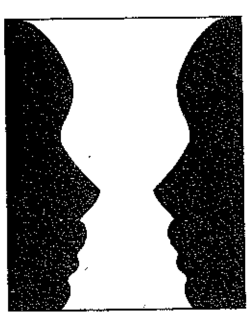

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Figure 5-8: *Faces and vase puzzle.*

Warm-Up Exercises

The following exercises can be done on plain white drawing paper or even copier/printer paper. Use a medium-dark pencil, like a 2B (that is, #2), or B or HB, very sharp.

Have you ever seen pictures that can be interpreted as two different things, depending on how you look at them? One example is the "faces and vase" puzzle (see Figure 5-8). At any given moment, you can see either the faces or the vase, but not both. Psychologists use this example to illustrate that the brain can flip back and forth between the two images, but it can only make sense of one set of information at a time.

Exercise 1: Drawing Mirror Images. Let's analyze the "faces and vase." Whether you're seeing two faces or a vase, all the same shapes and lines are present. Notice that the contour (outline) of the profile is also the outline of the vase. The object shape (positive shape) in one drawing becomes the shape of the background space (negative space) in the other.

It just so happens that drawing a puzzle like this can help us mobilize our **right brain.** Let us draw our own version of the "faces and vase."

right brain:
The right hemisphere of the cerebellum where it is believed simultaneous, holistic, spatial, and relational information processing are favored.

Step 1. Hold a piece of 8 ½ by 11 inch paper vertically. At the top of the paper, a few inches from the right edge, begin drawing a face of a witch in profile. This is not any specific witch, just a vision you have in your mind.

Step 2. Start at the forehead and use a continuous line to draw the profile large enough so that you end with the neck going off the bottom of the page, just below the chin (see Figure 5-9). Note: The entire profile must stay within the right half of the page. You can talk yourself through this drawing by saying, "First I draw the forehead, then the eyebrow ridge, then I go down the nose and tuck under; next I make the upper lip and some ugly teeth, then the lower lip and down around the chin, in to the neck and off the page." This should not be difficult to do. It is a very "**left brain**" activity, because you can name all the parts and use the symbols you have in your mind for "witch's chin, nose, forehead, lips," and so on.

Step 3. Now, think through the right-brain part. Along the left side of the paper, draw a mirror image of the face you just drew. It should look as though identical witches are staring at each other. This time you cannot just call on your mental symbols. You have to take an existing outline and flip it right to left (see Figure 5-10). It is no good talking to yourself the same way you did in the right profile drawing. Producing a mirror image is all about seeing relationships and visually measuring distances.

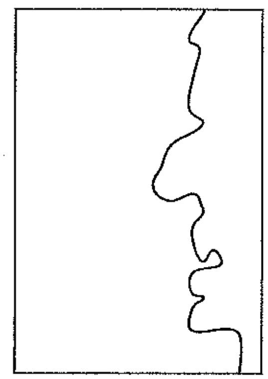

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Figure 5-9: Witch's profile.

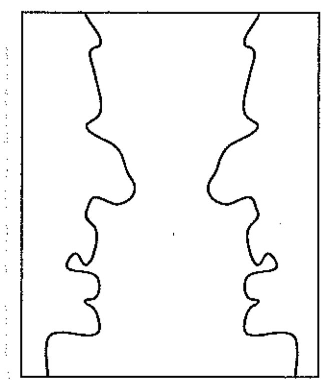

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Figure 5-10: Staring witches.

When you have finished, take a look at your picture. Which witch was easier to draw? Did they come out looking pretty much the same? Were you aware of having to use some different strategies to draw the second profile than you needed for the first? (No fair folding the paper and tracing. That is an example of your sneaky left brain trying to take over.)

By the way, take a look at the shape between the twin witches, it should look like a sort of vase or urn. (To use this drawing as an example of an optical puzzle—the standard faces and vases conundrum—you may want to modify some of the contours, which will, of course, change how your witches look.)

Exercise 2: Turn It Upside Down. The faces and vase exercise gives you a little glimpse of trying to call upon your right brain for some drawing help. If you found it easy, you are probably already in touch with your right brain. If you found it rather difficult, then you probably have a very well-developed left brain, and it wants to stay in charge.

left brain:
The left hemisphere of the cerebellum, where it is believed linear, verbal, analytical, and logical information processing are favored.

Step 1. Next we will look at a line drawing of a woman's face (see Figure 5-11). On a piece of paper the same size as the drawing, try copying the picture (see Figure 5-12). Give yourself about fifteen minutes to complete the drawing. In case you find this tedious, do not worry, that is not surprising. When you are finished, set the drawing aside.

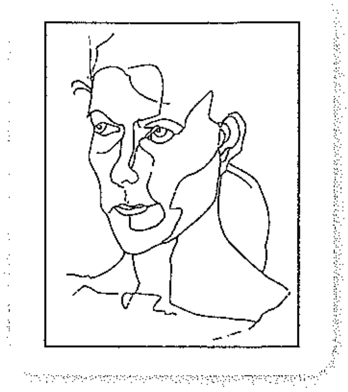

Figure 5-11: *Face right side up.*

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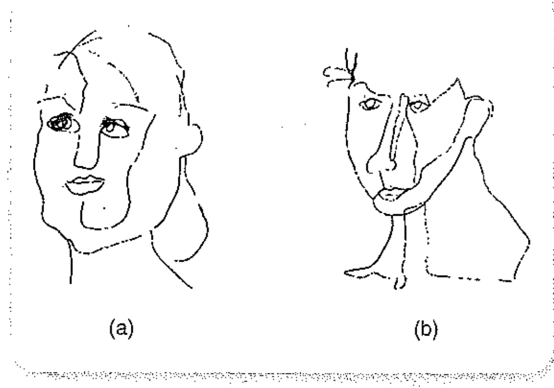

Figure 5-12: *Student drawings.*

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Step 2. Now turn the picture you were copying upside down (see Figure 5-13). Once again use a piece of paper the same size as the drawing, but now copy the upside-down drawing (see Figure 5-14). Your drawing will be upside-down too. Allow yourself about 15 minutes for this drawing. (You may want to set a timer or ask someone to let you know when the time is up, because the right brain is not very interested in time and is not likely to be keeping track.)

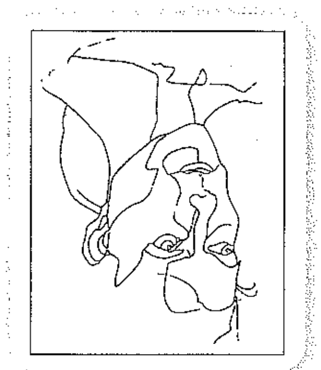

Figure 5-13: *Face upside down.*

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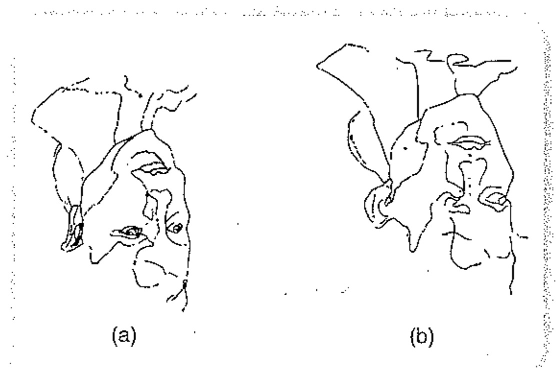

Figure 5-14: *Student drawings.*

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Once you get started on this activity, you will find that *what you are drawing* (eye, contour of the cheek, ear) becomes irrelevant. It is all a matter of lines and spaces and their relationships—higher, lower, distance apart. This is the kind of silent activity that the right brain really likes.

Step 3. When you have finished this drawing, turn it right side up. Now compare it to the copy you made from the right-side-up picture. Which one looks better? In most cases, the second drawing, done upside down, will be far more pleasing. It will look much less self-conscious, more relaxed. Just look at the kind of line used in each drawing. The upside-down drawing probably uses a much smoother line. The proportions may be off a bit, but seeing size relationships improves with practice, once you have let the right brain know that you welcome its help.

If you try a few more upside-down drawings, you will get used to seeing the world in terms of visual relationship. You will be able to call on that ability whenever you need it. In fact, you already use your right brain for many of your more accomplished activities—like playing a sport, dancing, riding a bike, or driving a car. Anywhere you have to judge distances and **spatial relationships** quickly and continuously, your right brain is quietly taking the lead. And if you are good at those activities, you probably find them exhilarating and relaxing at the same time. That is how artists feel when they are drawing. If we learn to draw using the right brain, we develop a very useful communication skill that is also relaxing and stimulating. It is a win-win situation.

Exercise 3: Blind Contour Drawing. If you are up to the challenge, try a third activity that takes you further into the world of the right brain. Some artists describe this kind of activity as a combination of seeing, feeling, and drawing. It is an exercise to help you learn to follow the shape of an object; it is **contour drawing**.

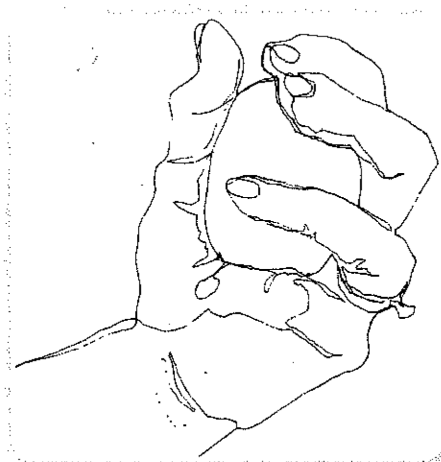


Figure 5-15: *Hand and egg (photo) and continuous line drawing.*

Step 1. If you are right-handed, place an 8 1/2 by 11 inch sheet of paper on a table to your right. Tape it in place so you don't have to worry about it moving around. Sit sideways at the table so that your right hand can draw on the paper, but face ahead or slightly to the left so that you are not easily able to see your paper. Hold a small object (a bottle, egg, spoon) in your left hand (see Figure 5-15). This is what you will be looking at as you draw. If you are left handed, you now get more brain exercise. Reverse the directions in Step 1 so that the paper is on your left and the object in your right hand.

Step 2. Position your pencil at a point toward the bottom of your paper. Focus your eyes at a point on your wrist just below your hand.

Step 3. With your eyes, travel along the contour (outline) of your hand, following the line as it goes around each finger, perhaps moving in a bit at a fold where the finger bends, back out around the outline of the finger, along the parts of the object you can see, and so on until you get to the other side of the wrist.

Step 4. With your pencil, follow the same path your eye is taking around the hand. Do this without looking at the paper. This is very difficult at first, because it is hard to judge distances without feedback from your eyes. Force yourself to try, and if you feel yourself going off the page, try to retrace your pencil line until you get back on the paper, and then continue. This will probably make you want to draw smaller, which is fine. You should finish the drawing at the same time you finish the visual journey around your hand.

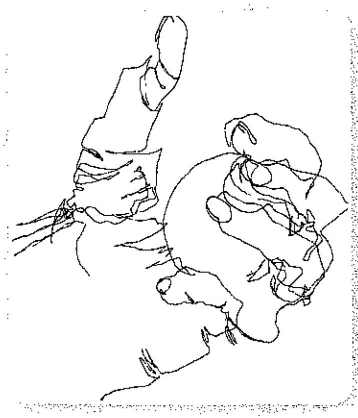
Step 5. Take a look. It is very unlikely that you will have produced a well-proportioned portrait of your hand, but you probably have a nicely flowing line around shapes that "feel" like the fingers and object you were drawing (see Figure 5-16).

Contour drawing is not something you do for immediate gratification. However, if you are willing to try a few more times, you will be surprised how much better you become at:

- Seeing details,
- Judging distances, and
- Controlling your drawing hand and the marks you make on your paper.

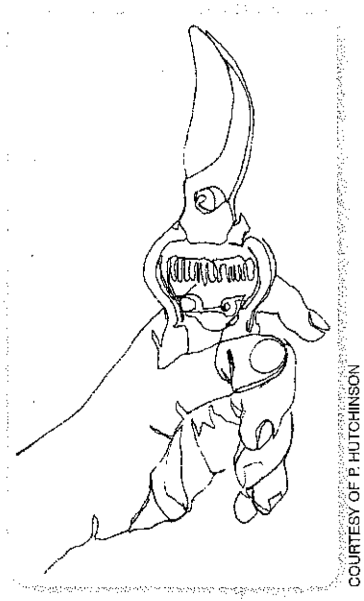
Try drawing your foot (barefoot, and then in a sneaker), a paper bag, and a sandwich on a plate. Another good way to practice is to copy outlines from maps. Try your state or the map of the United States or North America. (Maybe you will discover a talent for **cartography**!)

These first three exercises are primarily meant to get you in touch with your right brain. If you thought you would be drawing like Rembrandt at this point, your expectations were much too high. You should, however, be looking at things and noticing details you may have previously missed. You should also have seen that you *can* occasionally draw lines that are confident and flowing, if only your left brain is not trying to criticize (see Figure 5-17).



COURTESY OF P. HUTCHINSON

Figure 5-16: Student contour drawing.



COURTESY OF P. HUTCHINSON

Figure 5-17: Advanced student contour drawing.

Exercise 4: Positive and Negative Shapes. Most of the time, we think of the world as full of objects, surrounded by nothing—empty space. For purposes of drawing, the space that surrounds objects needs to be visible to us. It is a very useful tool for drawing objects effectively and in proportion. One way to make **negative shapes** more visible is to put a frame around the objects you want to draw, because now the shapes of space have an outer edge. Drawing negative shapes is a right brain activity, because they are often hard to describe in words.

Step 1. Fold a piece of light cardboard in half and cut a square or rectangle, about 8 by 8 inches or 6 by 8 inches out of the middle. Place this frame on the glass table of an overhead projector and project the square or rectangle of light onto a light-colored piece of paper taped to the wall. Position the projector so that the projected shape of the frame is contained on the paper. Trace around the frame shape on the paper.

Step 2. Open a pair of scissors and place them on the projector table, within the frame. Move them around until they overlap the edge a bit on at least two sides of the frame. (If they are big enough, they may run off all four sides, which is fine.)

Step 3. Look at the shadow image projected. You see the shape of the scissors, but surrounding it are a number of shapes of light, the negative shapes, or shapes of negative space. Now trace around the negative shapes, and then turn off your projector. Look at the shapes on your paper. Lightly number all the negative shapes and cut them out, and then discard the shape of the scissors. Now, on a sheet of contrasting colored paper, arrange the negative shapes and use a glue stick to glue them down. If you can re-create the way they were arranged on the original drawing, you will have produced the image of the scissors (the positive shape) in the background color (see Figure 5-18).

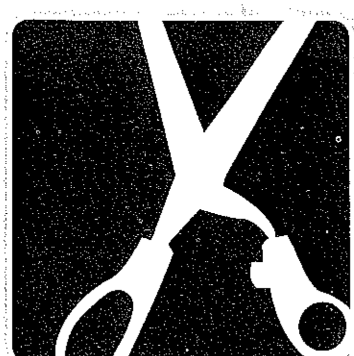


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Figure 5-18: Seeing and drawing negative shapes around the scissors.

Using negative shapes to create a positive image usually produces quite a striking pattern. If you were to alter any of the negative shapes, it would change the positive image. This exercise makes you aware of both kinds of shapes. To apply what you have learned to your own drawing, make yourself a small viewing window by cutting out a little frame with a 1 by 1 inch or 1 1/2 by 1 inch opening. Move this back and forth in front of your eye to frame things you want to draw—an object or a scene. The frame helps you eliminate a lot of the confusing information surrounding your subject. If you can quickly sketch the positive and negative shapes you see in the frame, you can capture your image very effectively.

After some practice, you will be aware of the negative shapes around things without having to use a frame. If you are drawing a subject and having trouble with the proportions, you can always switch to right brain mode and concentrate on the negative shapes. If one of them looks wrong, fixing it may make your positive shape look better too.

DRAWING BASICS

When you first set out to draw an object, you probably pick up a pencil or pen and begin to draw a line. And yet, nothing in the real world is surrounded by a line. An outline is a useful way to block out the space an object occupies, but to really see the world, you also need to be aware of **shading**, color, **texture**, types of shapes and forms, and how objects relate to other things around them in space.

These aspects of the physical world become the "visual tools" of drawing, and later the **elements of design**:

element of design:
A basic visual component or building block of designed objects (for example, line, shape and form, value, color, texture, or space).

- Line
- Shape and form
- Value (shading)
- Color
- Texture
- Space

The more time you spend looking and drawing, the more useful these elements will seem.

Line

A line defined mathematically has only direction and length, but no width. In sketching, of course, the width of a line is not only real but also important to the appearance of the sketch. To achieve a good line, an HB pencil is fine for most sketching, because it can be used to make faint lines or bold lines, according to how hard you press it against the paper (see Figure 5-19). It will become blunt quickly, so it is important to maintain a sharp point. Experiment with different qualities of line: straight, curved, sharp, fuzzy, uniformly thick, or varied.


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Figure 5-19: **Different kinds of lines.**

Shape/Form

Lines are used to enclose a space. The **shape** of an object is the **two-dimensional** space enclosed within the lines. Shapes can be natural or **organic** (things in nature, like clouds, leaves, and rocks), geometric (squares, triangles, circles, or combinations of these mathematically generated shapes), or some combination of the two. Shapes made with only straight lines are called **rectilinear shapes** (see Figure 5-20).

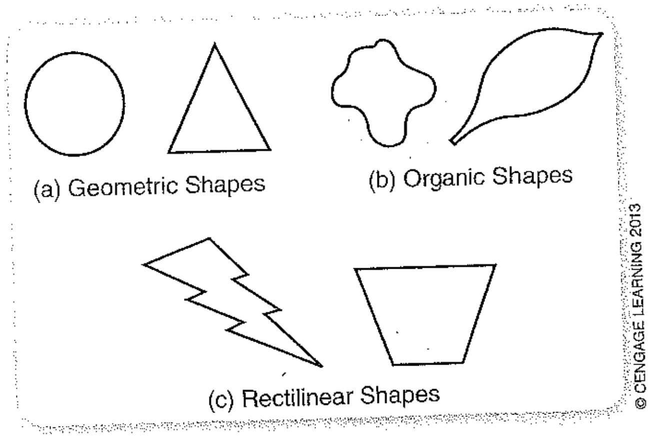

Figure 5-20: Types of shapes.

When a shape is given a third dimension, it becomes a **form**. In sketching, this can be done by using lines, shading, and/or color. The geometric forms of the cube, cylinder, cone, and sphere are developed from the square, circle, and triangle (see Figure 5-21). They are the basis for many of the manufactured objects seen every day (see Figure 5-22).

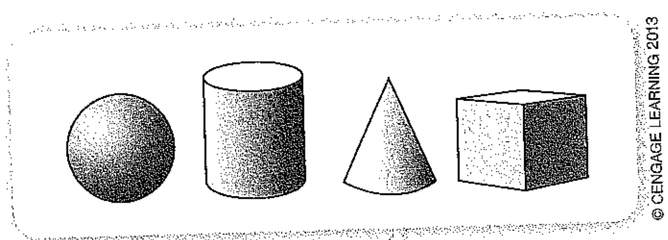

Figure 5-21: Basic forms: sphere, cylinder, cone, cube.

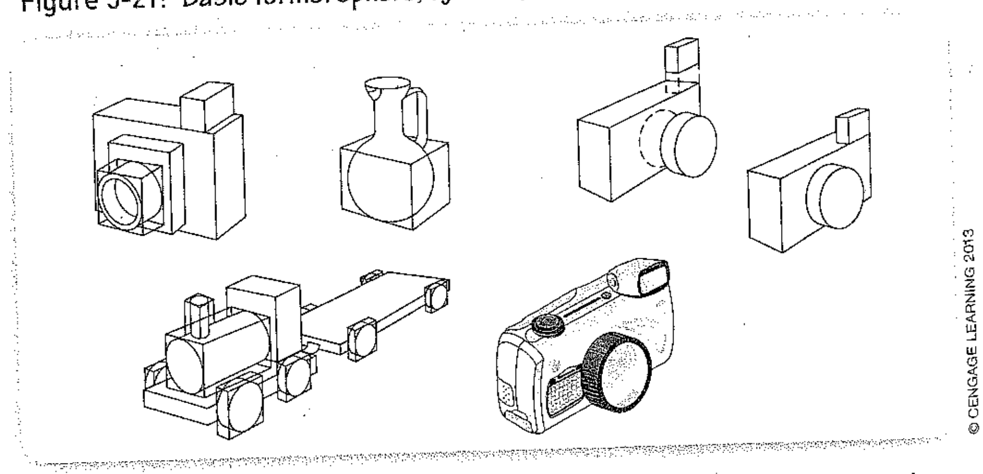

Figure 5-22: Each of these objects is made from a combination of geometric forms. Artists block in the shapes, then remove the overlaps and sketch lines, and finally add shading, color, and background to make the objects look real.

Many other geometric forms are also common, such as the tetrahedron and various **prismatic** shapes (see Figure 5-23). Look for more examples of these forms in the designed world.

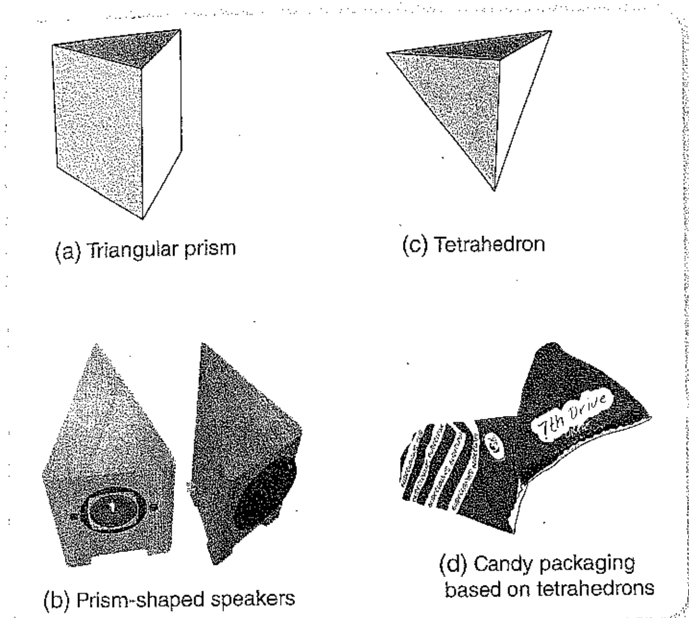

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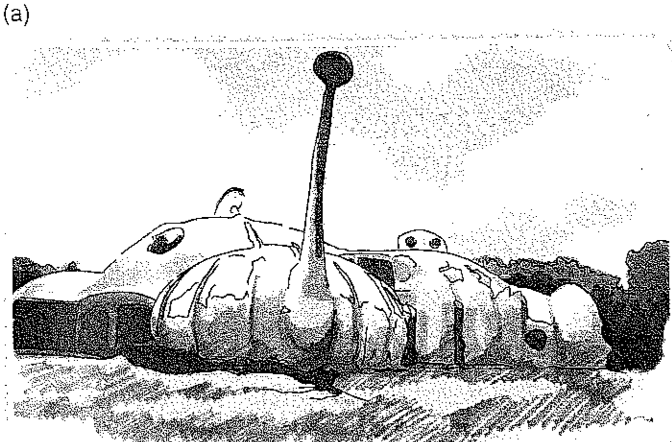
Figure 5-23: (a) Triangular prism. (b) Prism-shaped speakers. (c) Tetrahedron. (d) Candy packaging based on tetrahedrons.

In addition to geometric forms, natural forms are also used as a basis for creating products and structures, such as the buildings pictured in Figure 5-24.

(a)



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(b)

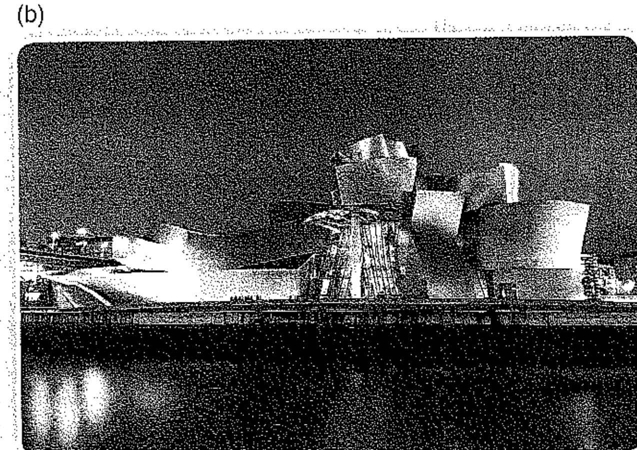

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Figure 5-24: (a) The Xanadu House in Florida represents a possible direction for housing in the future. Demolished now, it was made from a combination of organic forms. (b) The Guggenheim Museum in Bilbao, Spain, is made from crumpled and twisted geometric forms.

Your Turn
Value Scale

Step 1. Draw a vertical rectangle, 2 inches wide × 7 inches long. Mark off seven bars, 1 inch high and 2 inches wide. Leave the top bar the white of the page.

Step 2. Shade the bottom bar as black as you can with your pencil, making it as smooth as possible, so you cannot see your pencil strokes.

Step 3. Shade in the five bars between white and black in equal steps from very light to very dark gray. Try to make each bar just one shade, very even and smooth. A light pressure on the pencil will give you a light tone; a heavier pressure can give you a very dark tone. These principles apply to both regular and colored pencils. As you move the pencil back and forth, you can blend in the tone, going back over places you have missed. Getting a smooth, even tone takes practice and patience (see Figure 5-25). It is better to use a lighter pressure and go over an area several times than to use a heavier pressure and end up with a streaked, uneven effect. Caution: It is best to start at the top of the scale (lightest gray) and work your way down the scale. Be conservative—it is always easier to darken than to lighten.

Step 4. Step back and see if your eye can travel up and down the seven-step scale smoothly—no step should be greater than any other. Go back and adjust as needed, until you are satisfied.

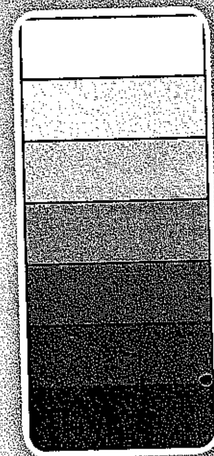
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Figure 5-25: Value scale.

Value

Although the curved line at the base of the cone and the three visible sides of the cube in Figure 5-21 are the first clues that these are **three-dimensional** forms, it is the shading that makes the forms convincingly realistic.

The shading is the result of light falling on the surfaces of the objects. The greater the range of shades, or **values**, on your drawing, the more three-dimensional the forms will look. When you draw, think of the white of the paper as the lightest value available to you. The blackest black your pencil can make is your darkest value. Between these are many shades of gray. Shading successfully requires two things: controlling your pencil and seeing the widest possible range of values.

Light Source and Shading. When we look at an object, we see a range of tone, according to how much light strikes a particular surface. Because light most often comes from one main source, such as the sun or a lamp in the room, the surfaces of an object toward the light source reflect the most light. Surfaces at an angle to, or away from, the light source do not reflect as much light, so they appear darker. Even when there are several sources of light, one usually dominates the object we are viewing because of the intensity of that light or its proximity to the object we are looking at.

The cube in Figure 5-26a is drawn by outlining the edges where two surfaces meet. This cube looks rather dull and lifeless. In Figure 5-26b, however, the

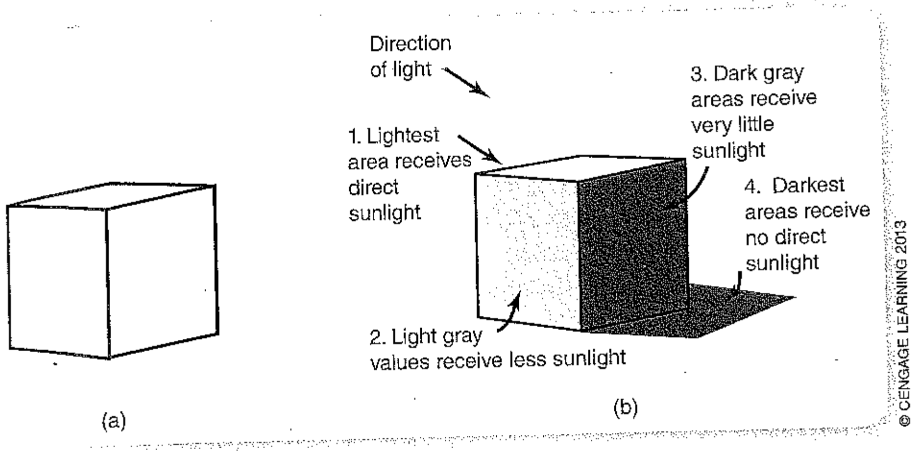


Figure 5-26: **The cube shown in part (a) receives depth and greater realism from addition of shading in part (b).**

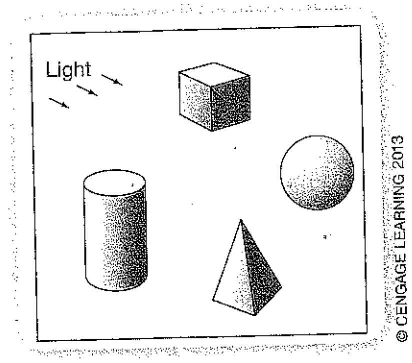


Figure 5-27: **The direction of the light coming from the source and the distance from the source to the object affect how light or dark a surface will appear.**

same cube has been shaded with pencil to represent the amount of light reflecting on the three surfaces we can see. A cast shadow has also been added to define the surface the cube is sitting on. This second cube has depth and appears more realistic. This is because it more closely resembles the way in which we see actual objects.

For sketching purposes, it is handy to think of the light source as coming over your left shoulder (see Figure 5-27). This will help you visualize which surfaces are lighter and which are darker.

Shade your forms along their long axis, holding the pencil at a low angle so that most of the length of the pencil lead contacts the paper (see Figure 5-28). This will give you a granular type of shading. If you choose, the tone can be made smoother by smudging with a tissue along the same axis.

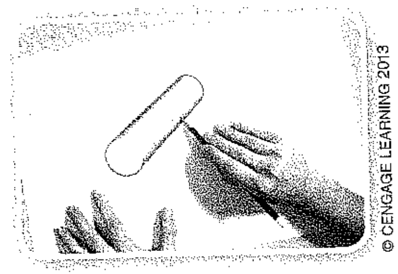


Figure 5-28: **Using a pencil to get a blended shade on a cylinder.**

Highlights. Highlights and reflections are visible when light strikes bright and shiny objects. In drawing, the highlights and reflections are often exaggerated to give the object more impact or a look of realism. A shiny, flat, horizontal surface has vertical highlights (see Figure 5-29a). These are easy to add by using pencil shading, markers, or other techniques. Curved or rounded shapes, such as spheres or cylinders, tend to distort the light hitting them (see Figure 5-29b). A cylinder tends to stretch the highlight along its length, and even the inside of the cylinder, being curved, reflects light. A sphere will reflect light in a circular pattern. Often people use a window on a sphere as a highlight. Notice that the square window bulges in all directions as the sphere's surface turns the window into a kind of circle (see Figure 5-29c).

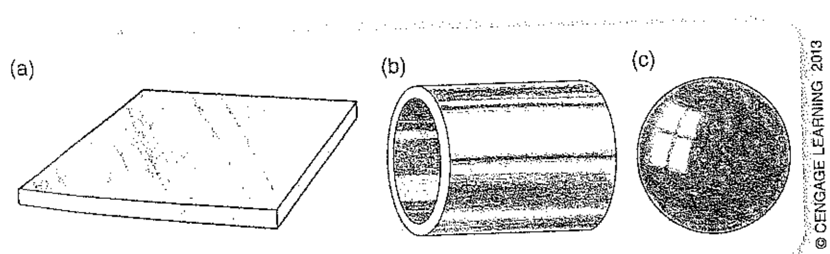


Figure 5-29: **(a) Flat, reflective surface; (b) highlights on a shiny cylinder; and (c) a spot reflection on a sphere.**

Color

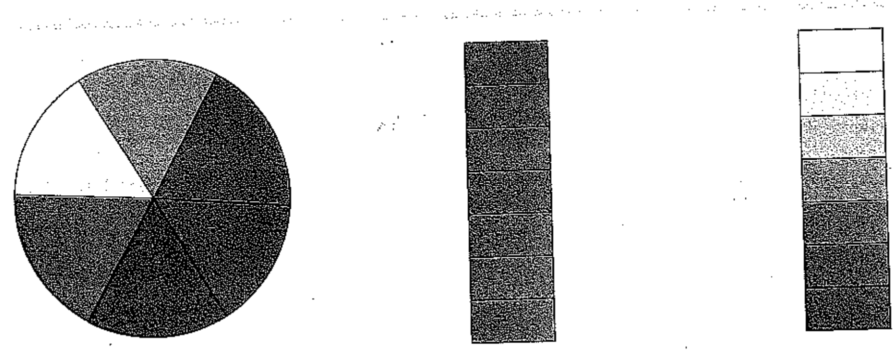
Color is an important part of life and affects us on a number of levels. It has found its way into our everyday language to help us express our emotions. "Feeling blue," "green with envy," and "seeing red" are only a few of many examples of how color has become part of our language. Color has profound physical and psychological effects on our moods and feelings of well-being. Certain "cool" colors are used in hot environments and "warm" colors in cold environments to help people cope with the temperature extremes. Calming colors are used in hospitals, schools, and even in prisons, to help minimize agitation and disruption. Color is a part of tradition, religion, and all aspects of our everyday lives.

We see color because of the wavelength of the light that reflects from an object to our eyes. **Photoreceptors** in the retina of our eyes, called **rods** and **cones**, are sensitive to the value and intensity of colors. Generally speaking, the rods distinguish the level of lightness and darkness of colors, while the cones perceive their brightness or dullness. Where the level of light is dim, as at twilight, we see little color. When light is bright, colors also appear intense.

Hue, Chroma, and Value. **Hue** refers to a specific color's name—for example, red or mauve or viridian. Hue refers to the actual wavelength of the light on the spectrum. Reds have the longest **wavelength** (lowest frequency 700 nm). The other end of the spectrum contains the blue hues, which have short wavelengths (highest frequency 400 nm) as shown in Figure 5-30a.

Value sometimes refers to the lightness and darkness of a hue. A light value of a hue is called a **tint**, while a dark value is referred to as a shade. Value describes the amount of light the color actually reflects. The value of a color can be altered by adding either white or black to the hue. Tints and shades are shown in Figure 5-30b.

Brightness or intensity of a hue is referred to as **chroma**. A pure hue or color is the most intense, but the color may be neutralized, or dulled, by mixing it with a color on the opposite side of the color wheel, as shown in Figure 5-30c.



(a) Hues shown on the color wheel are at their brightest intensity.

(b) Intensity bright colors become duller by adding the complement.

(c) This scale shows value—the tint and shades of a color.

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Figure 5-30: *(a) Hues shown on the color wheel are at their brightest intensity. (b) Intensity bright colors become duller by adding the complement. (c) This scale shows value—the tint and shades of a color.*

Primary Colors. When painters, printers, and video engineers talk about **primary colors**, they are discussing the basic colors from which all other colors are made. But because each of these individuals works with color media and light differently, the primary colors they refer to are different. Color theory is presented in more detail in Chapter 18 (Graphics and Presentation). Color can be added to drawings using pencils and paints that are made with pigmented clays, resins, and other substances that absorb light (see Figure 5-31).

Secondary and Tertiary Colors. When two primary colors are mixed, a **secondary color** results. Mixing red and blue yields violet; red and yellow, orange; and yellow and blue, green. When a primary color and a secondary color are mixed, the result is called a **tertiary color** (a third color). All the possibilities so far add up to twelve colors, and these are often illustrated in what is called a **color wheel**.

The color wheel (see Figure 5-32) is a handy tool for choosing colors. The color wheel contains the three primary colors, the three secondary colors, and the six tertiary colors.

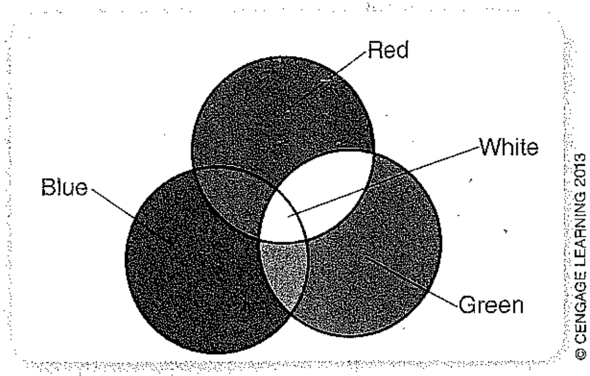


Figure 5-31: *Mixing colors by adding pigments together subtracts light, making each new color darker.*

Most artists use several different hues of the primaries if they want to mix a full range of secondary and tertiary colors. It is difficult to mix both purple and orange from the same red, so artists often have a "warm" red with which to mix oranges and a "cool" red with which to mix purples. *Warm* means that the red leans toward yellow, while *cool* suggests that the red already has a purple (or bluish) cast. Crimson, scarlet, and carmine are all names for different hues of red (see Figure 5-33).

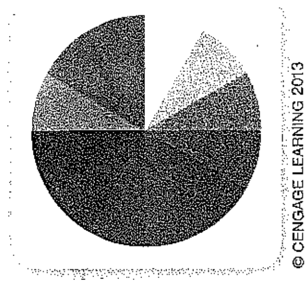


Figure 5-32: *Color wheel.*

Colors close to one another on the color wheel, such as blue, blue-green, and green, are called **analogous colors** (see Figure 5-34). They are related because they share components. Interior and fashion designers often use analogous colors to create harmonious color schemes.

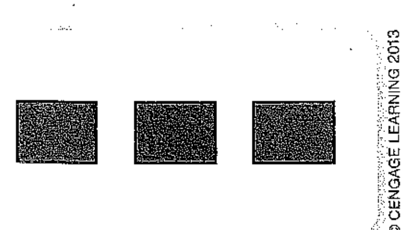


Figure 5-33: *Pure, warm, and cool reds.*

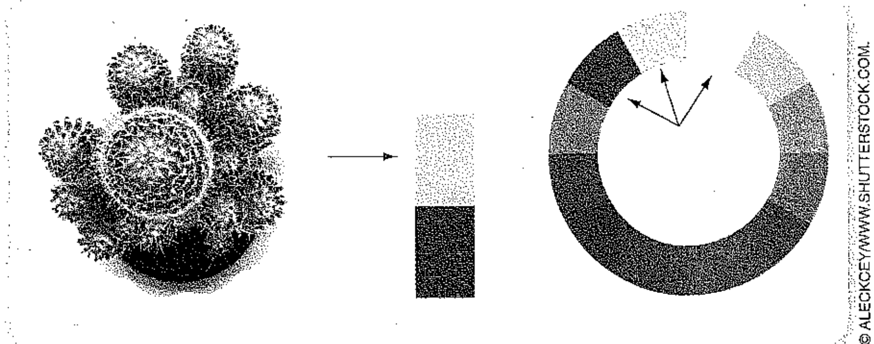


Figure 5-34: *Analogous color scheme in nature.*

Colors from opposite sides of the wheel are **complementary colors**; because they contrast with each other, they can be used to create emphasis in a color scheme. It is important to understand how this contrast works if you want to create visual effects in your design work. For instance, the use of green shapes on a red background causes a surface to vibrate, visually. This may work well for the wallpaper of a nightclub, but because red and green are close to the same value, green letters on a red package will be hard to read from a distance. Contrast of value is more important than contrast of color for distance vision, so if you use dark green letters against a white background, you will be able to read it from some distance. If you mix a bit of red into the white, creating just a slight pinkish tinge, the green will appear brighter by contrast to the complementary color. Even the subtle use of color can be very important as you illustrate your design ideas (see Figure 5-35).

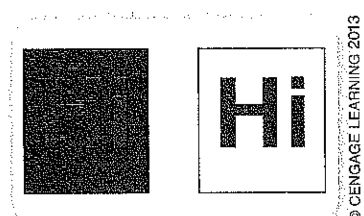


Figure 5-35: *Green lettering against a red background and a slightly reddish-white background.*

Color Science and Technology

Renaissance artists theorized about color from the fifteenth century onward. Isaac Newton attempted to describe the nature of color from a scientific standpoint in his 1704 treatise, *Opticks*. Our understanding of color continues to expand, thanks to computer artists, optical scientists, and industrial chemists.

From an optical perspective, we know that our eyes are sensitive to light that lies in a very small region of the electromagnetic spectrum labeled "visible light." This visible light corresponds to a wavelength range of 400 to 700 nanometers (nm) and a color range of violet through red. The human eye is not capable of "seeing" radiation with wavelengths outside the visible spectrum. The visible colors from shortest to longest wavelength are violet, blue, green, yellow, orange, and red. Ultraviolet radiation has a shorter wavelength than the visible violet light. Infrared radiation has a longer wavelength than visible red light. The white light is a mixture of the colors of the visible spectrum. Black is a total absence of light.

Our ability to see in color is a marvelous adaptive and survival tool. Technology can help us to extend our physical ability. Thanks to infrared film and goggles, for example, we can see images beyond the visible spectrum.

Texture

The texture of a material is an important feature. In products, it is useful for both functional and aesthetic purposes. It can provide a nonslip "grip" on the handle of a tool, a floor surface, or a skateboard. It can also add an interesting visual element to a product. Texture can be the result of the nature of the material itself, or it can be a result of a production process, such as molding (see Figure 5-36).

Figure 5-36: Many objects use molded lines and other features to achieve texture. Some textures are functional, others purely decorative.

Sketching the texture of a material is not difficult. Architects use a number of graphic standards that represent materials like concrete, earth, and foam insulation (see Figure 5-37). These and other techniques can add a great deal of impact to a drawing and can give viewers a better idea of what the object you are sketching actually looks like.

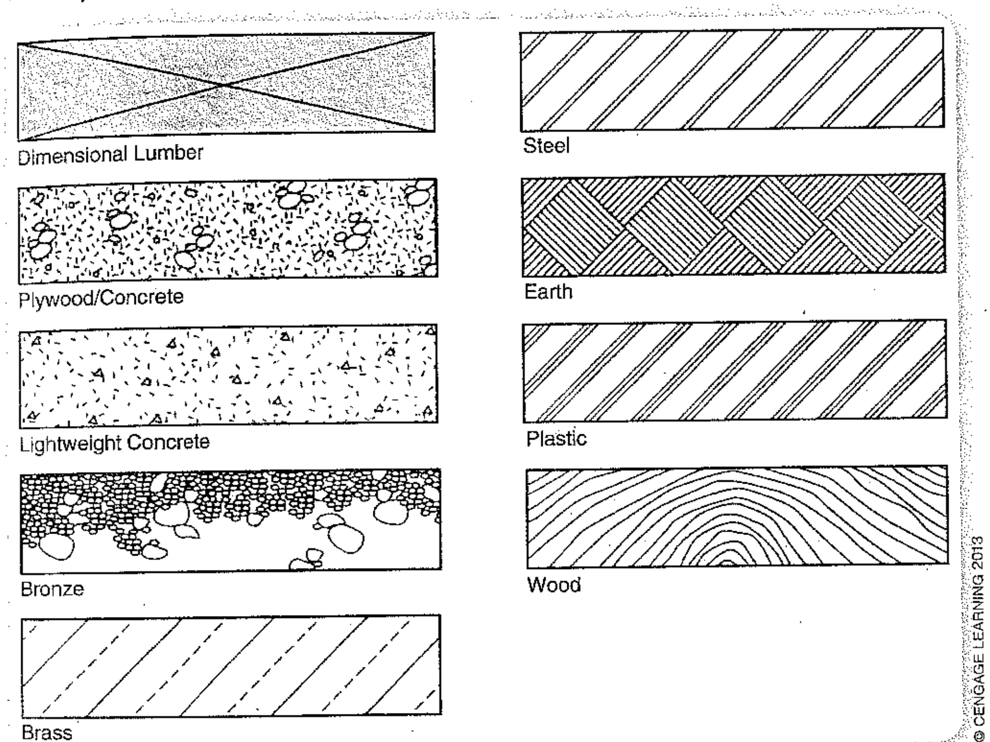


Figure 5-37: *Graphic standards for some materials.*

One of the easiest materials to sketch is wood. With a little practice, you can even sketch different kinds of wood, such as pine, mahogany, and oak. The different grain characteristics of these woods make it easy. Other textures are also easy to achieve (see Figure 5-38).

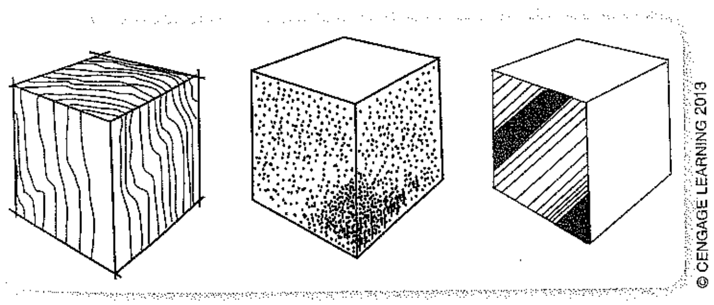
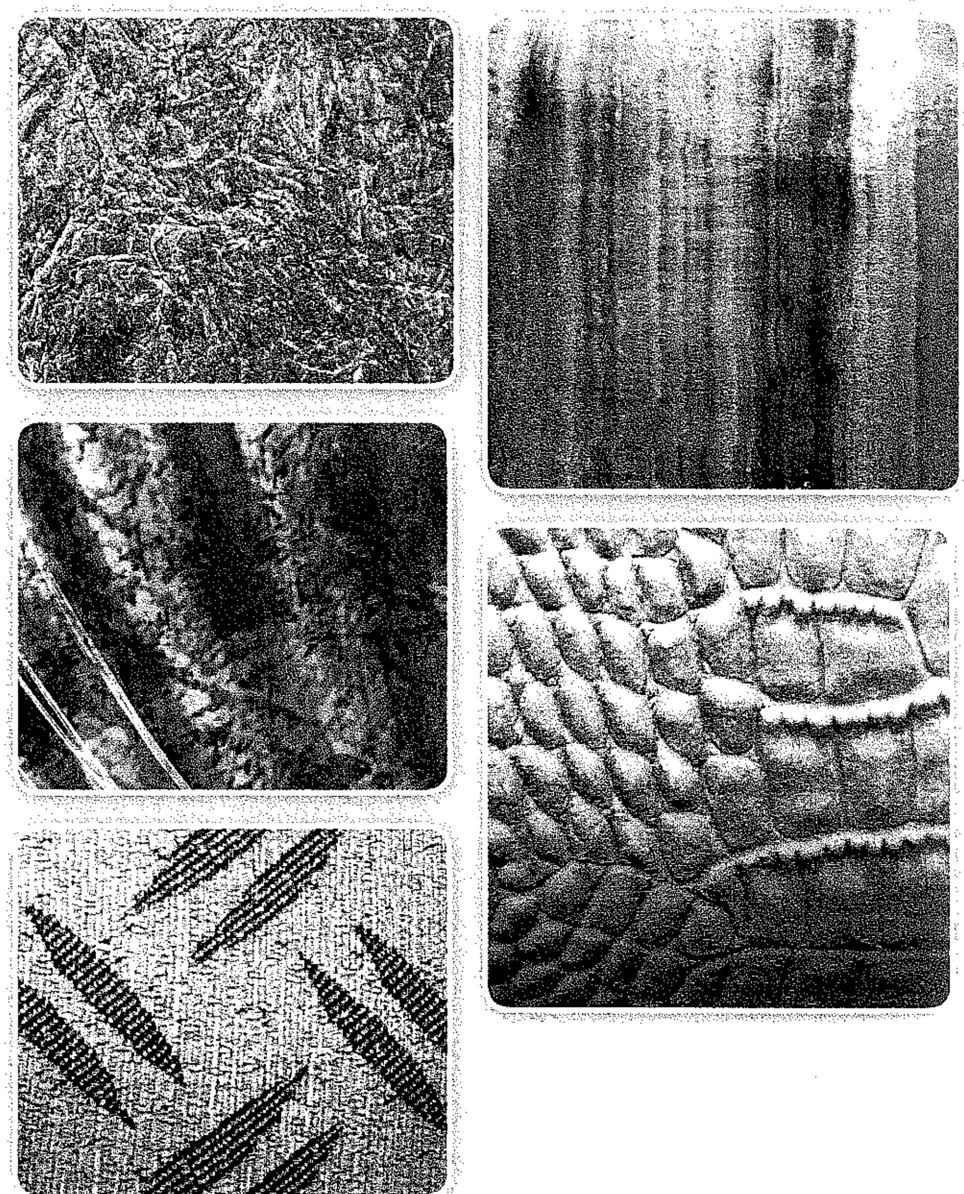


Figure 5-38: *Simple sketching techniques to achieve the appearance of texture.*

Artists have a number of tricks for simulating texture (see Figure 5-39). One is to make rubbings over an actual texture, such as sandpaper or embossed metal. Some media, such as pastels (artists' chalks) or colored pencils are particulate and can be used on rough-surfaced paper to create interesting textures. Shapes can then be cut from this paper and attached to a surface to simulate fabric, concrete, or stone. These simulated textures, as well as real textures, can be placed on a scanner and printed, and then incorporated into a drawing.

Figure 5-39: Examples of simulated textures.



COURTESY OF P. HUTCHINSON.

Space

All of the objects we see exist in space. We may isolate them to work out the details, but when we explore a scene visually, or when we try to show someone how a product we have designed will look in use, we need to understand how to show space. At least five spatial cues help make sense of a scene:

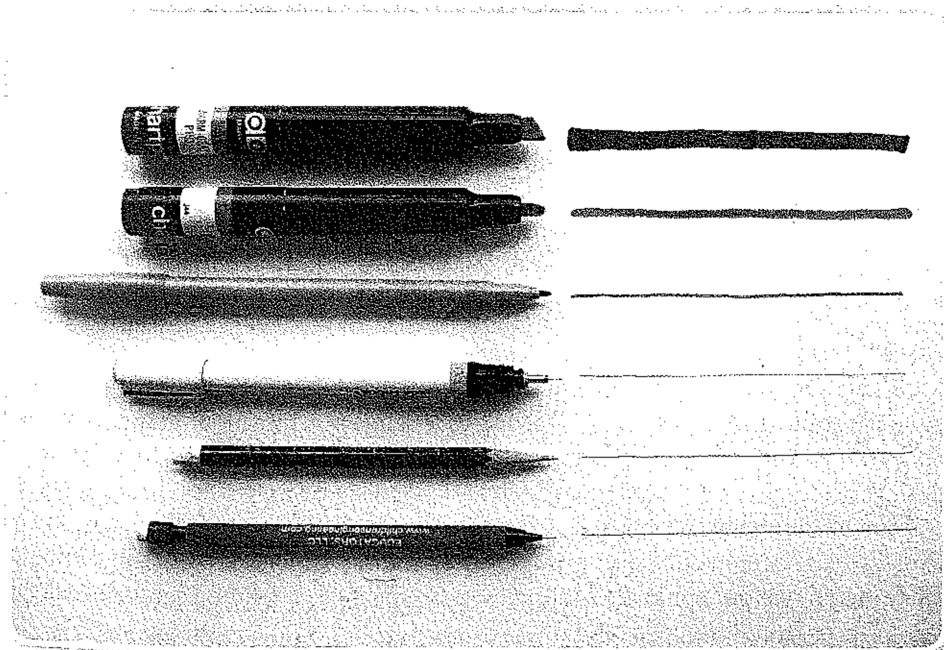
- High and low position,
- Large and small relationships,
- Overlapping,
- Lines converging as they move away from us, and
- Atmospheric haze that makes close things sharper than faraway things.

These cues allow us to navigate in the world without bumping into things. They also help us make effective drawings.

SKETCHING AND DRAWING TECHNIQUES

When someone needs to represent an object in space, one of the following perspective drawings techniques can be used. **Perspective drawing** techniques are used to represent three-dimensional objects in a two-dimensional space. All perspective drawing techniques use a **vanishing point** to define where lines of an object converge in the distance. **Isometric drawings** represent a three-dimensional object in two-dimensions but do not use a vanishing point. For that reason, this drawing technique does not show objects as we actually see them but the technique can be used to show objects quickly. In addition to these perspective techniques, objects can be represented using **technical drawing** techniques where the object is represented with a high level of precision and accuracy and containing all the information needed to produce the object. Technical drawing will be explained in greater detail in Chapter 8.

Many tools are available for freehand sketching and drawing. Pencils, pens, and markers are among the handiest and most versatile for freehand sketching. When more precision is desired, straight edges or rules, t-squares and triangles can be used with a drawing board or drawing machine. Grid papers are also available or drawing software can be used. Recommended sketching pencils range from soft (6B) to medium (2B) to hard (2H). Markers come in very fine to very broad points: Some are water-based, others are spirit-based (see Figure 5-40). The texture of the paper you use affects the control you achieve in your drawing. If you need to capture some small details or make notes, use a smoother paper. On a very hard paper surface, softer pencils will smear.



COURTESY OF P. HUTCHINSON.

Figure 5-40: **Different drawing implements provide different line qualities.**

Perspective Drawing

In the world of three-dimensional space, we take into account that things seem smaller the farther away they are. A car in the distance appears very small; as it moves closer, it appears much bigger, even though it is the same car. We often do not take notice of this phenomenon, because we take it for granted.

COURTESY OF P. HUTCHINSON.

Figure 5-41: Follow the roof, windows, ends of column, and fence posts to find the vanishing point.

The same principle applies to a long building (see Figure 5-41). Standing near one end, we see the full height of the near wall. The other end of the building, in the distance, seems smaller, and the roof connects the two by slanting down from the near wall to the far wall. At the same time, the ground at the bottom of the near wall almost seems to rise to meet the bottom of the far wall.

A photo of the building, taken from where we are standing, shows what is happening. If we draw a line along the roofline and one along the ground line, we find that they meet. This point of convergence is called the **vanishing point**. Lines drawn along the top and bottom edges of the windows converge at the same point.

linear perspective: In drawing, an approximate representation, on a flat surface, of an image as it is perceived by the eye. Typically, objects are drawn smaller as their distance from the observer increases, and items are somewhat distorted when viewed at an angle.

Linear Perspective. During the Renaissance, scientists/artists/engineers developed rules that would explain the perspective that their right brains understood quite naturally, and the system of **linear perspective** was invented. Using terms like *horizon line*, *vanishing point*, *key edge*, and *front face*, masters could teach apprentices how to lay out pictures of complicated scenes. The system of linear perspective can be cumbersome, but it is a good way to represent space realistically. In the 1800s, when Nicephore Niepce produced the first permanent photographic images, the camera's "vision" confirmed the rules of perspective developed centuries earlier.

one-point perspective: A method of realistic drawing in which the part of an object closest to the viewer is a planar face, and all the lines describing sides perpendicular to that face can be extended back to converge at one point, the vanishing point.

Point Perspective. Drawings that use only one vanishing point are called **one-point perspective** drawings. The vanishing point is located on a **horizon line**, which is a horizontal line representing your eye level. Placement of the horizon line is important for how the object will appear in the drawing. Figure 5-42 illustrates how the placement of the horizon line affects the appearance of the object.

In one-point perspective, the vanishing point is used to depict one or two faces of an object as well as the **front face**. The front of the object is drawn "head-on." The vanishing point should not be placed too far to the side of the object or the object will look distorted.

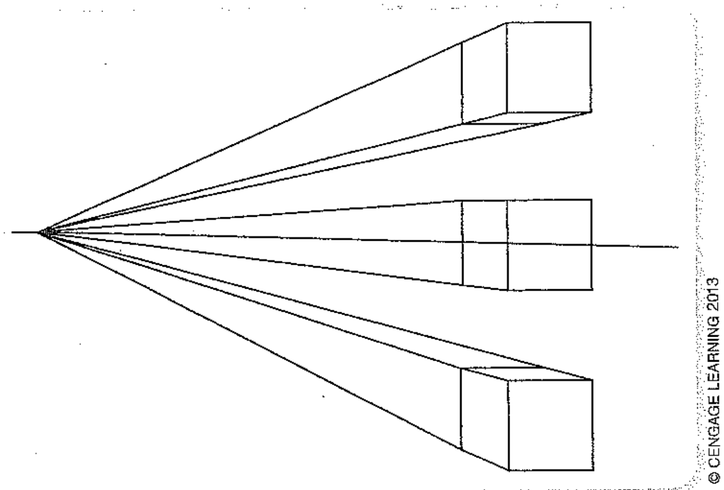


Figure 5-42: The placement of the horizon line affects the view of an object.

Exercise 5: Cube in One-Point Perspective

Step 1. Use a ruler to make sure your lines are straight. You can also draw on graph paper to keep corners square. Draw a square, a line, and a point in the positions shown in Figure 5-43. The square is the front face, the closest side of the cube you will draw. The line, called the horizon line, stands for your eye level. The vanishing point is the point where parallel lines converge. It tells you where you are standing, because it is projected back from your eyes onto the horizon line.

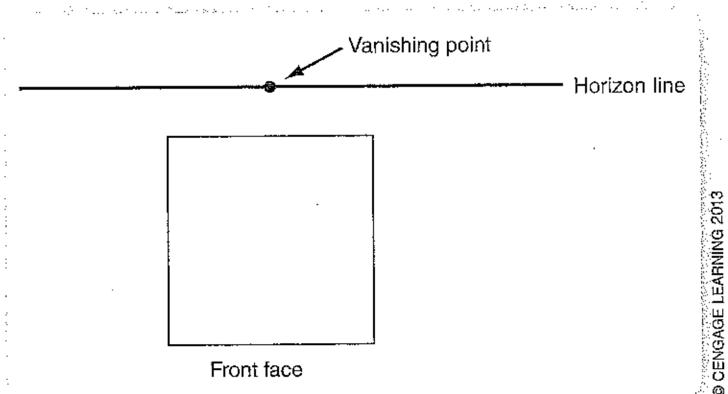


Figure 5-43: Step One

Step 2. Draw a dashed line from each corner of the front face to the vanishing point. These are imaginary lines. Next, draw a dashed line parallel to the top edge of the square about one-third of the way back to the horizon line. Place the dashed line between the diagonals going back to the vanishing point. Note that it is shorter than the top edge of the square. This makes it appear to be at some distance back from the square. If you draw a dashed line parallel to the sides of the square dropping down from the points where the horizontal line meets the diagonals, you create the top corners of the back face of the cube. Where those lines meet the diagonals going back to the vanishing point from the bottom of the front face, draw a dashed line parallel to the bottom of the front square. For the time being, all the lines other than the edges of the front square and the horizon line should be dashed. What you have drawn here is a transparent cube (see Figure 5-44).

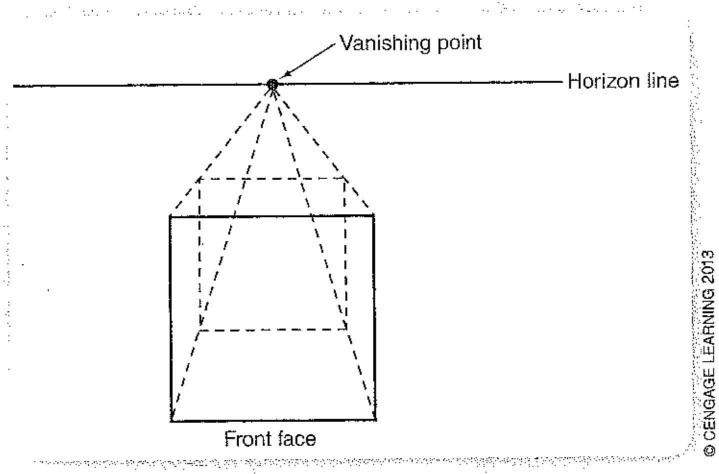


Figure 5-44: Step Two

Step 3. The position of the horizon line and vanishing point tell us that you are directly in front of the cube and slightly above it. What you see of the cube is the front and top faces. Outline those in solid black lines (see Figure 5-45). This way you are showing what is seen and what is not seen but is understood.

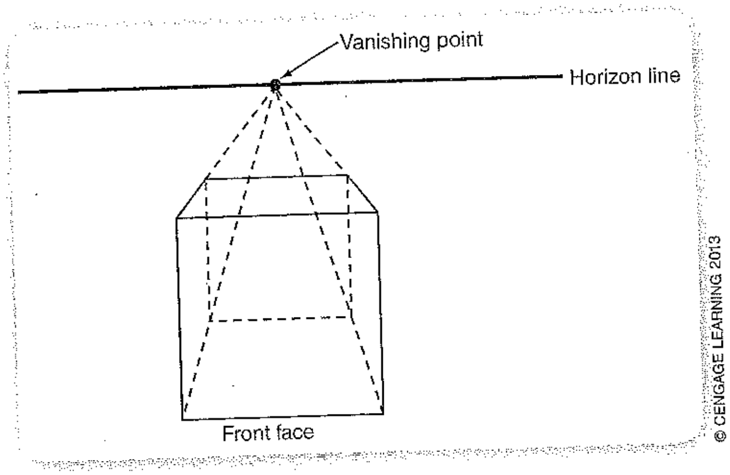


Figure 5-45: Step Three

Interior Views. One-point perspective is also useful for drawing the interior of a room (or an entire outdoor scene). When depicting a scene from a standing position, the horizon line is placed just slightly above the center, and the vanishing point is usually centered on this line (see Figures 5-46 and 5-47).

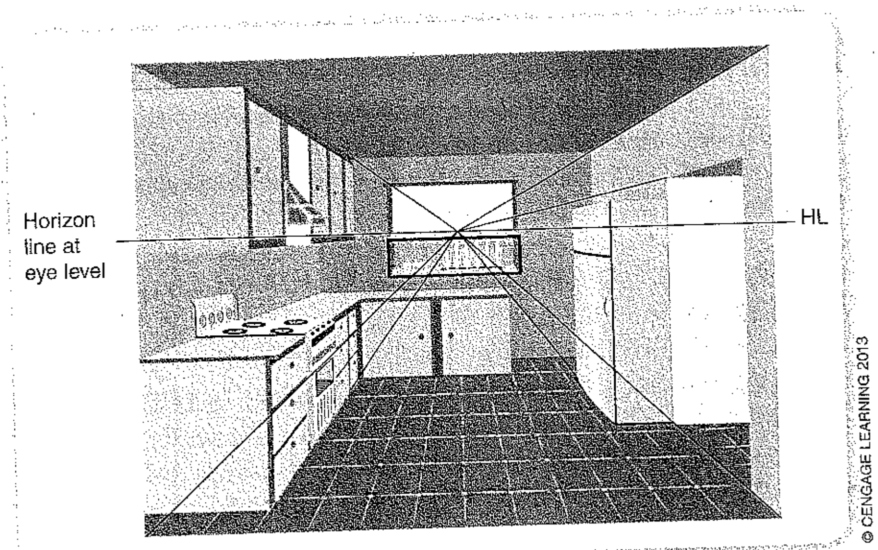
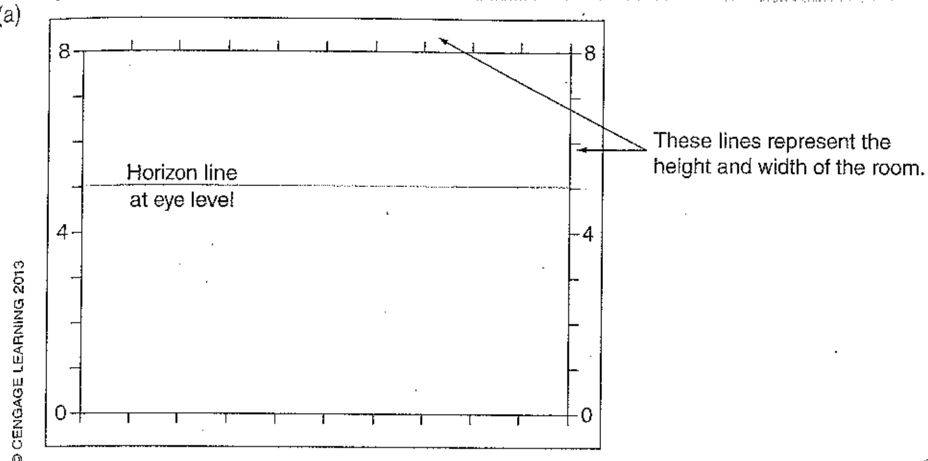


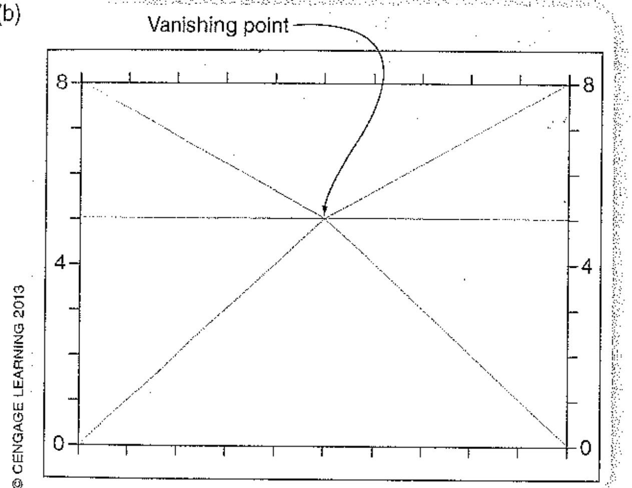
Figure 5-46: One-point perspective of a kitchen interior.

(a)



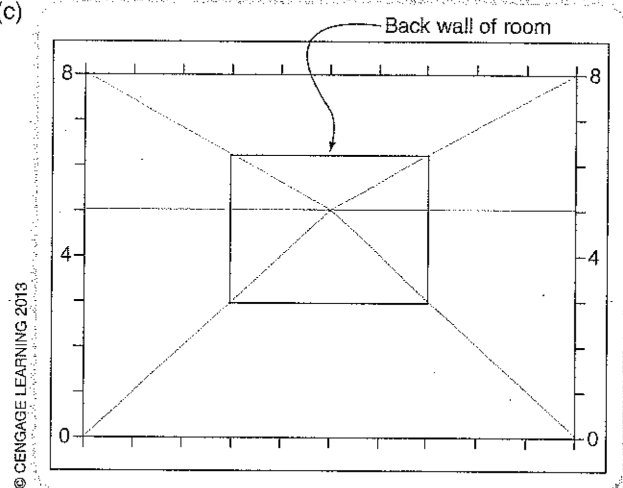
(a) Always start a one-point perspective with a front face. In this case, the front face is the page itself. Next draw a horizon line slightly above the center. If the drawing is of an interior of a room, locate the horizon line at standing eye level. In the sketch (a), the walls have been scaled in feet to determine an 8-foot ceiling at an eye level of 5 feet 6 inches.

(b)

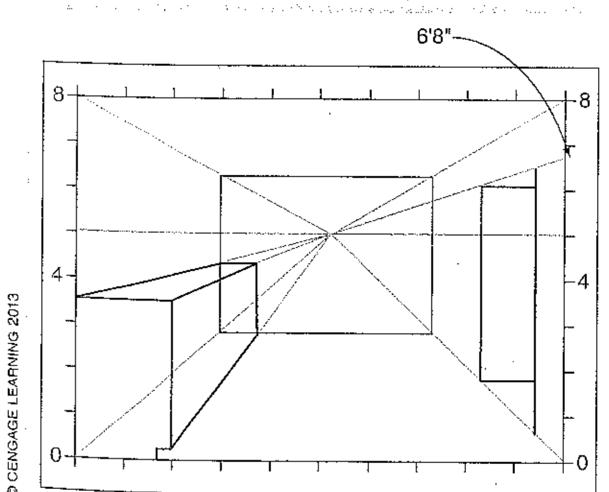


(b) Locate a vanishing point on the horizon line in about the middle of the drawing. Connect the near corners of the room to the vanishing point. A room can also be drawn with the vanishing point off-center. As long as the vanishing point is within the walls of the room, the one-point perspective will work.

(c)



(c) A smaller rectangle with the same proportions as the original outline of the room is drawn to represent the back wall of the room. Its corners are points on the converging diagonal lines. You will need to estimate the length of the room and use this to determine the size of the box.



(d) Draw cabinets, doors, windows, and other features of the room using the vanishing point. Each of these objects is a small one-point perspective drawing. Start with a front face—whatever side of the object is facing you is the front face. In this drawing, the cabinet height and depth are scaled on the outline and connected to the vanishing point. These lines represent horizontal lines in the room.

Figure 5-47: Interior of a room in one-point perspective.

Figure 5-48 shows an outdoor scene viewed from a one-point perspective. If you follow the lines of the sides of the buildings back into space, they will converge in a single point.

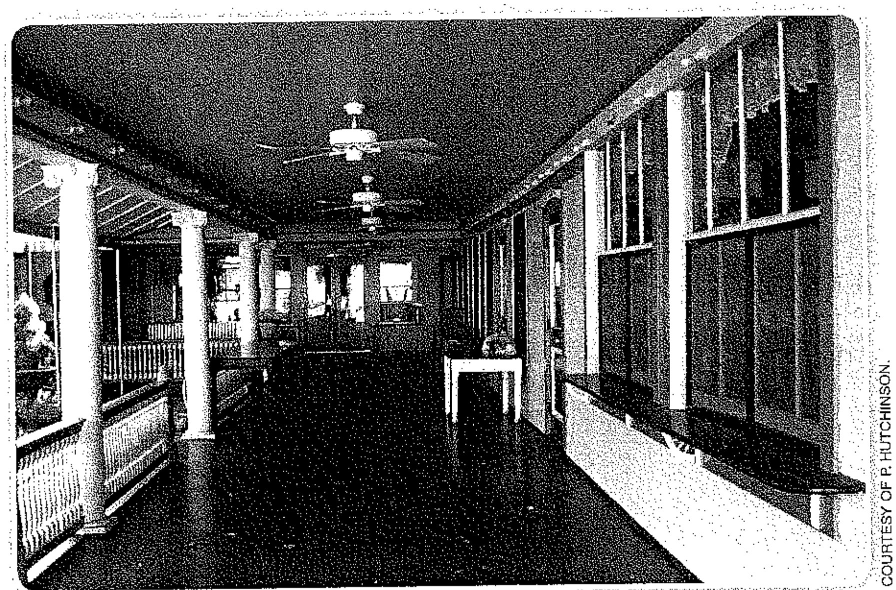


Figure 5-48: *Outdoor one-point perspective.*

two-point perspective:
Two-point perspective is a realistic way of drawing objects in three dimensions using a horizon line, a key edge, and two vanishing points.

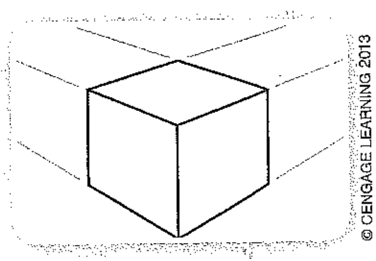


Figure 5-49: *A box in two-point perspective.*

Two-Point Perspective. Two-point perspective is similar to one-point perspective, but is used for the more common situation in which you are not right in front of the object you want to draw. In a two-point perspective, you are at an angle to the object; so the closest part of the object will be an edge rather than a face. This closest edge is called the key edge. When viewing an object at an angle, it is necessary to provide two vanishing points. These determine the outlines of the two or three sides you see (see Figure 5-49).

Placement of the horizon line depends on the eye level you are trying to represent in your drawing. If you wish to present a "bird's-eye view," the horizon line should be high on the page, well above the space in which you will draw your object (see Figure 5-50). To view the underside of the object being drawn, place the horizon line low on the page, below your drawing space.

The placement of the two vanishing points will have an effect on the appearance of the object you are drawing. In many cases, the vanishing points will need to be off the paper on which you are drawing to give the object a realistic appearance. Placement of the vanishing points too close together distorts the appearance of the object. Figure 5-51 illustrates how placement of vanishing points can give you different effects. A good rule to follow is that the bottom angle of the box you are drawing should be no less than 90 degrees unless you are trying to achieve a very dramatic effect.

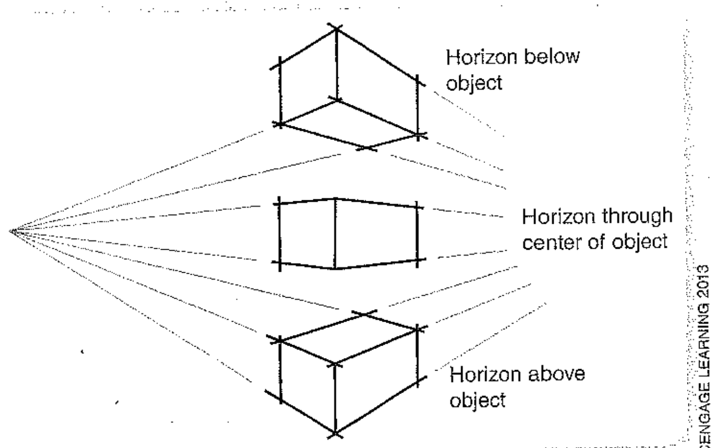


Figure 5-50: *The horizon line is your eye level. A low horizon line means that you are below the object and can see the bottom. A high horizon line gives you a bird's-eye view.*

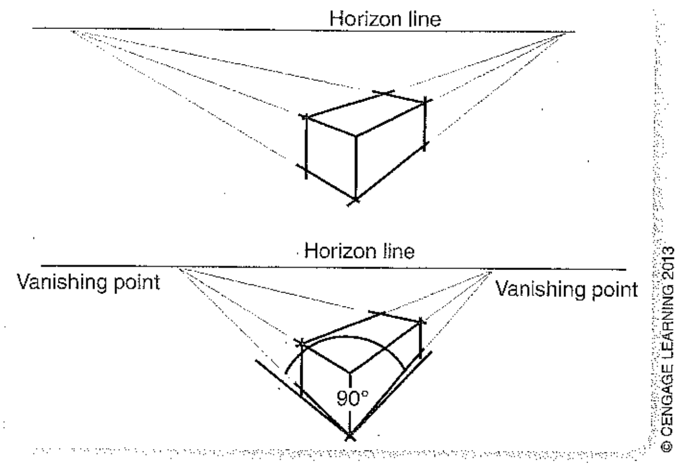


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Figure 5-51: *Close and far-apart vanishing points.*

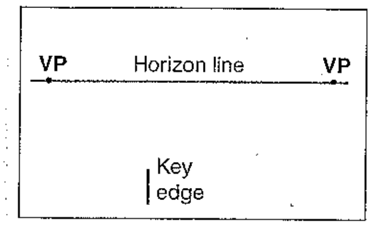

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Figure 5-52: *Draw a horizon line about one-quarter way down the page. Place a vanishing point near each end of the line. Draw a short vertical line, the key edge, at the bottom of the page, as shown, just left of center.*

Exercise 6: Horizon Line and Vanishing Points

Step 1. To draw a box in two-point perspective, start with a vertical line (the key edge) rather than a square face; add a horizon line and two vanishing points (see Figure 5-52). The key edge is the closest corner of the box you want to draw. The horizon line is once again your eye level, and the vanishing points are situated on the horizon line to the left and right of the key edge. If you place them fairly close together, you will get a result that is quite dramatic (in fact, sometimes uncomfortably distorted) and suggests that you are close to the box. If you place them quite far apart, you will get a much more comfortable view, as if you are at some distance from the box.

Step 2. Draw a light line from the top and bottom of the key edge to each vanishing point (see Figure 5-53).

Step 3. Now, draw the vertical lines that represent the far edges of the two side walls on either side of the key edge (see Figure 5-54). Outline each side of the box. The side that is closer to a vanishing point will be shorter than the other side.

Step 4. Draw a light line back to the opposite vanishing point from the back corners of the two visible sides (see Figure 5-55). This will outline the top of the box. Because you are above the box, you can see three faces—two sides plus the top.

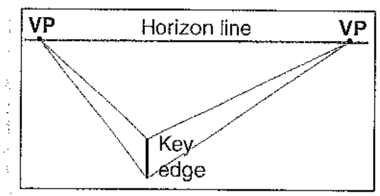

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Figure 5-53: *Connect the ends of the key edge to both vanishing points.*

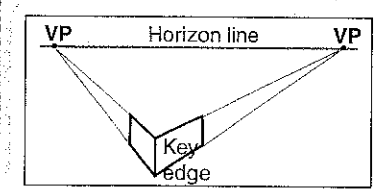

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Figure 5-54: *Sketch in the far edges of the two visible sides of the cube.*

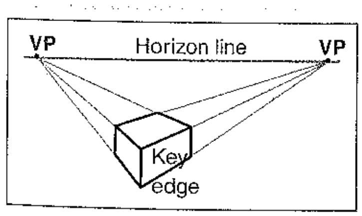

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Figure 5-55: *Lightly connect the far corners of the cube to the opposite vanishing points. Darken the outlines of the cube.*

The building exterior (see Figure 5-56) and the room interior (see Figure 5-57) are both viewed from a two-point perspective. Following the edges of the walls, ceiling, roofs, door, and window frames on either side of the key edges back to two points where they converge allows you to appreciate the two-point perspective view. A line drawn through the two points is the horizon line (your eye level).


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Figure 5-56: *Exterior two-point perspective.*

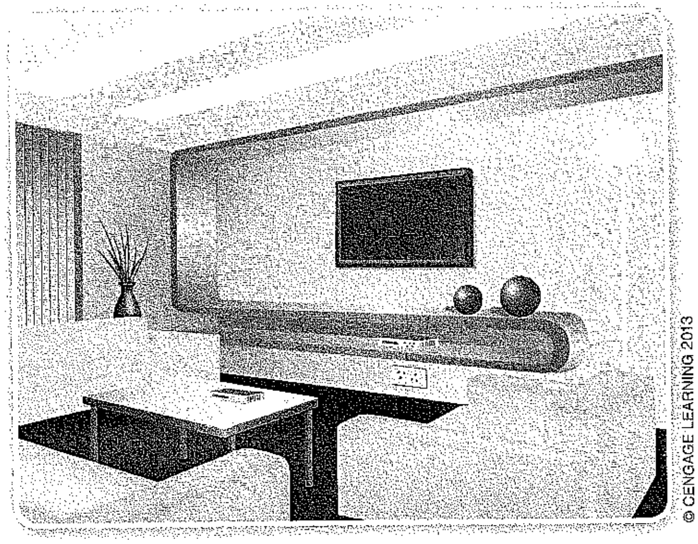


Figure 5-57: Interior two-point perspective.

Linear perspective has many rules and is time-consuming to learn and use. It is a left-brain drawing technique, making it ideal for translation into computer code. Many of the drawing programs available for architects, industrial designers, and engineers can generate perspective drawings very rapidly, allowing clients to see realistic views. Typically, changes are then made on isometric or trimetric views and translated into perspectives by the software.

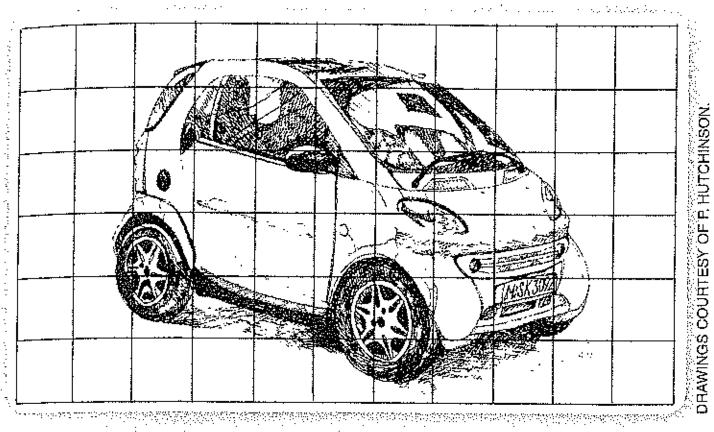
Perspective and Mathematics

Perspective as a realistic way to describe what we see has its roots in the Renaissance. Before this time, medieval artists typically sized objects and characters according to their importance, not relative distances.

Around 1300, the artist Giotto di Bondone used an algebraic method to determine the placement of distant lines in his paintings. His method was generally accepted until the twentieth century. In the early 1400s, Filippo Brunelleschi demonstrated the geometrical method of perspective by painting the outlines of various Florentine buildings onto a mirror. Extending the building's outlines beyond the edges of the mirror, he noticed that all of the lines converged on the horizon line.

Soon, nearly all of the artists in Florence applied geometrical perspective to their paintings. All horizontal lines converged to a vanishing point, and the rate at which the lines receded into the distance was graphically determined. Not only was perspective a way of showing depth, it was also a new method of composing a painting into a single, unified scene.

Today, CAD software and some computer games (especially games using 3-D polygons) use linear algebra (in particular matrix multiplication) to create a sense of perspective. The scene is a set of points, and these points are projected to a plane (computer screen) in front of the viewpoint (the viewer's eye). The mathematical problem of perspective is simply finding the coordinates on the plane that correspond to the points in the scene. By the theories of linear algebra, a matrix multiplication directly computes the desired coordinates, thus bypassing any descriptive geometry theorems used in perspective drawing.



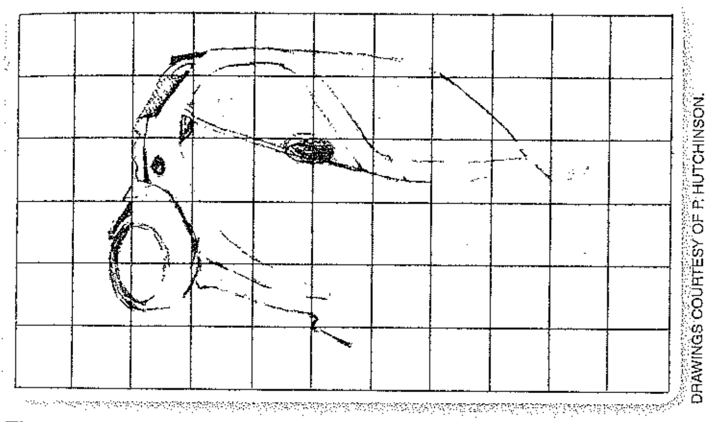


Figure 5-58: *Using a grid to copy a drawing.*

Understanding Perspective Visually. The right brain of the artist seems to be able to bypass the verbal rules of perspective, capturing spatial relations at a glance without plotting all the points necessary in a CAD program. That is because the right brain is holistic and looks at the overall visual relationships rather than trying to explain to itself what is happening to forms as they extend into the distance.

Two very simple visual aids that artists have used for centuries are the **transparent grid** (see Figure 5-58) and the paper frame (see Figure 5-59). Placing a grid over a scene allows the scene to be broken down into smaller parts. The grid helps organize what we see, so that we can concentrate on one manageable dose of information at a time.

A paper or cardboard framing viewer held between the eye and the subject helps filter out surrounding information that competes for our attention.

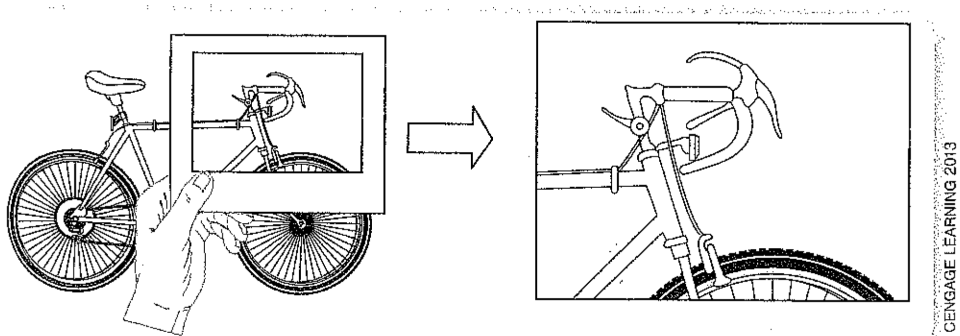


Figure 5-59: *Using a framing viewer to eliminate confusion and narrow focus.*

Exercise 7: Using a Grid to Capture the Whole Scene

Step 1. On a piece of clear acetate, make a two-inch grid using a fine-tipped permanent marker. Draw a grid the same size on drawing paper. Make a space (where you can draw) right in front of a window through which you can see buildings (some closer than others) or a street scene. Place your drawing paper in a comfortable place. You may want to prop your pad or drawing board on a book so that it's at an angle, because you will want to be able to avoid moving your head too much on this drawing. Now, tape the transparent grid to the window and look through it at the scene you want to draw (see Figure 5-60).

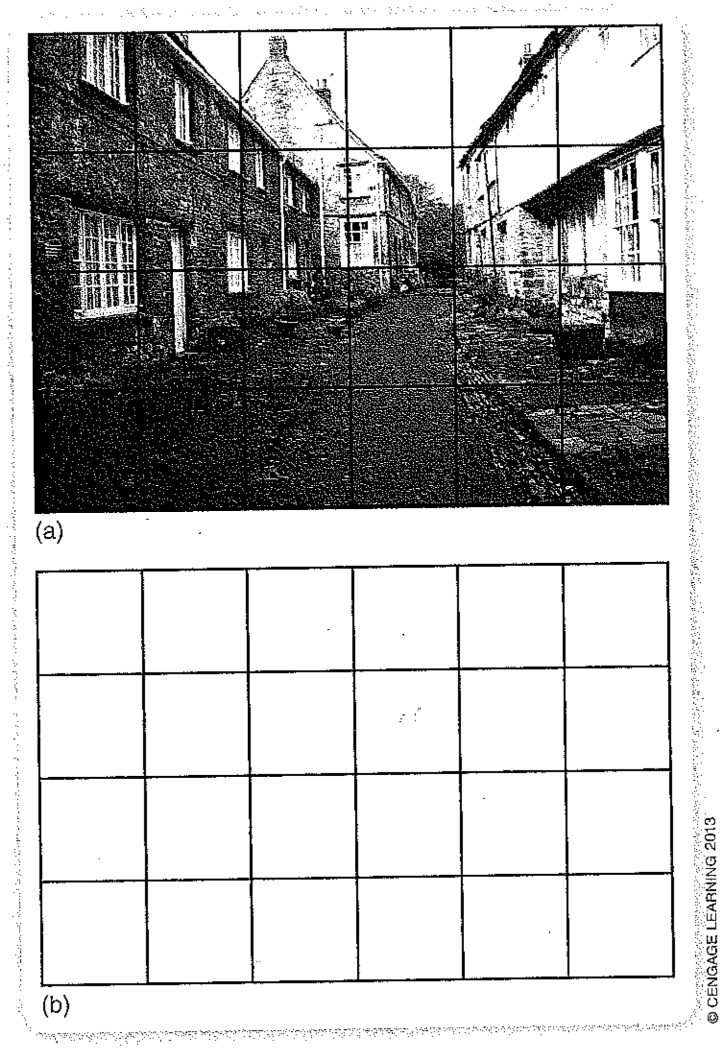


Figure 5-60: Reproduce the scene viewed through the transparent grid in the squares of the gridded paper.

Step 2. Draw what you see through the grid, square by square. In other words, transfer the lines and shapes you are seeing in the top left square of your window grid to the top left square of the paper grid, and so on. (Notice that when you broke the scene into small pieces with the grid, you moved from left to right brain mode, because you could not really name the things you were drawing.)

Point of Interest
Sketching as investigation

The best way to prepare to draw your ideas—things that exist only in your mind—is to practice drawing the world around you.

Although most of us use our sight effectively to avoid tripping over furniture and running into doors, we seldom look at details unless something catches our eye. A closer look at everyday objects often reveals features we have missed. These features may be proportion, material, a design element such as line or texture, or the way in which one part fastens to another. Art students spend hours drawing things in classes and then often keep a notebook with them to practice sketching the things they see outside of class.

Isometric Drawing. Using isometric grid paper, you can sketch all the objects we have previously drawn, but without the horizon line and vanishing points. In isometric view, objects are seen at an angle, so that the greatest number of sides (three) can be seen at once. All parallel lines are drawn in parallel—so no vanishing points are needed. Diagonal lines representing horizontal edges are drawn 30 degrees from a horizontal base line. Measuring on these drawings is simple, because lengths do not diminish in the distance.

Isometric drawings do not show objects the way we actually see them, but designers use this technique to explain an idea quickly. As with perspective drawing, all of the basic shapes can be drawn in isometric view, and more complex forms can be made from these forms.

Isometric construction can be used for quick sketching and comes in handy, particularly for visual brainstorming, which is typically done from ideas and not physical objects in front of you. Using Exercise 8, practice visual brainstorming. Because isometric drawing is a drafting convention and a standard feature of mechanical design software, much more attention will be given to this approach in Chapter 10.

Skills for the Future

Some futurists project that virtually all of the logical and sequential abilities of the left brain will eventually be taken over by the computer. In his 2005 book, *A Whole New Mind,* author Daniel Pink notes that many of these qualities make up more than half of the work done in fields like **engineering**, law, medicine, and accounting. The right brain abilities—visualizing, empathizing, thinking holistically—are less likely to be replicated by computers, and these will be the skills most valuable for future professionals and entrepreneurs. So, honing these skills now could give you an advantage in tomorrow's job market.

Exercise 8: Isometric Drawing

Step 1. Draw the front vertical edge of the cube (see Figure 5-61).

Step 2. The sides of the box are drawn at 30 degrees to the horizontal to the required length (see Figure 5-62).

Note: All lengths are drawn as actual lengths in standard isometric.

Step 3. Draw in the back verticals (see Figure 5-63).

Step 4. Draw in the top view with all lines drawn 30 degrees to the horizontal (see Figure 5-64).

Step 5. Now try drawing the remote in isometric view (shown in Figure 5-65).

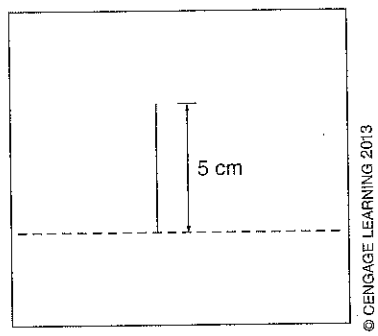


Figure 5-61: Step 1.

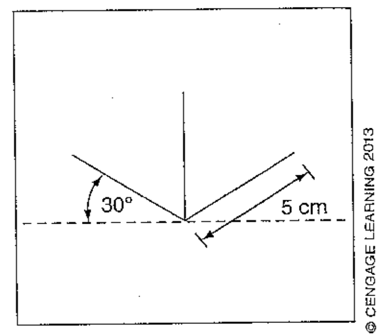


Figure 5-62: Step 2.

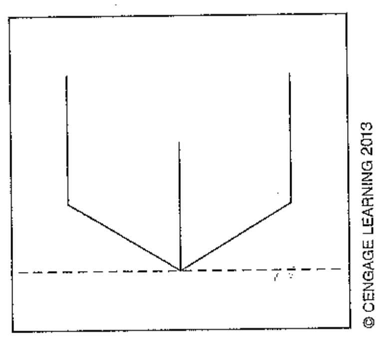


Figure 5-63: Step 3.

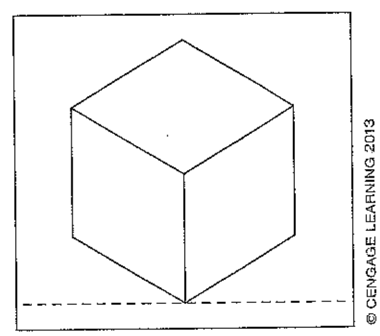


Figure 5-64: Step 4.

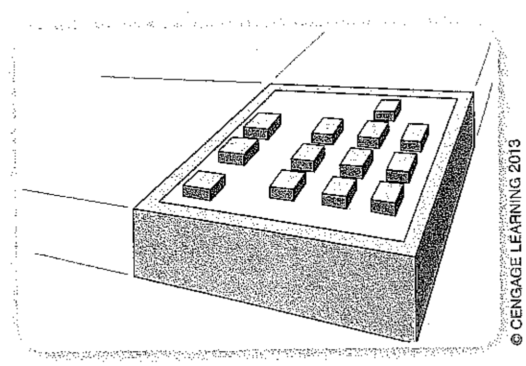
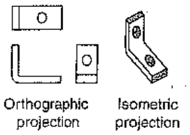


Figure 5-65: Two-point perspective remote.

Types of Drawings

- **Orthographic projections** show three different sides of an object as though seen head-on (see Figure 5-66).
- **Cutaways** use a jagged edge to show what is under a part of the facade of an object (see Figure 5-67).
- **Exploded drawings** show how the parts of an object fit together (see Figure 5-68).
- **Sectional views** show an internal slice of the object, much like a CAT scan image (see Figure 5-69).

Because they help isolate an aspect of the subject you are working with, it is helpful to use these approaches from time to time in your sketching.



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(a)

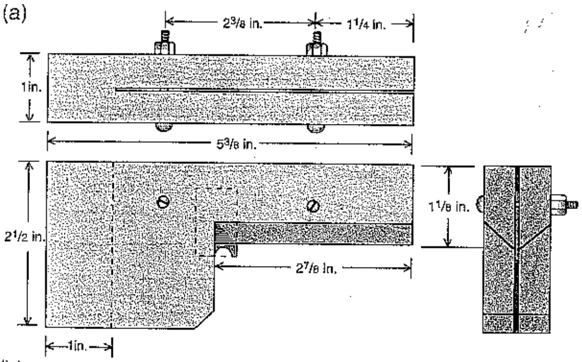

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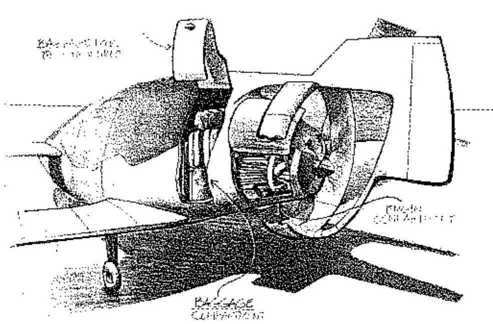
Figure 5-66: *Orthographic projections.*

(a)



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(b)

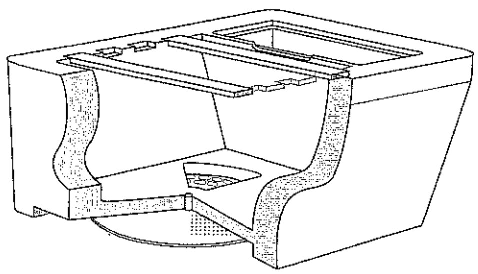

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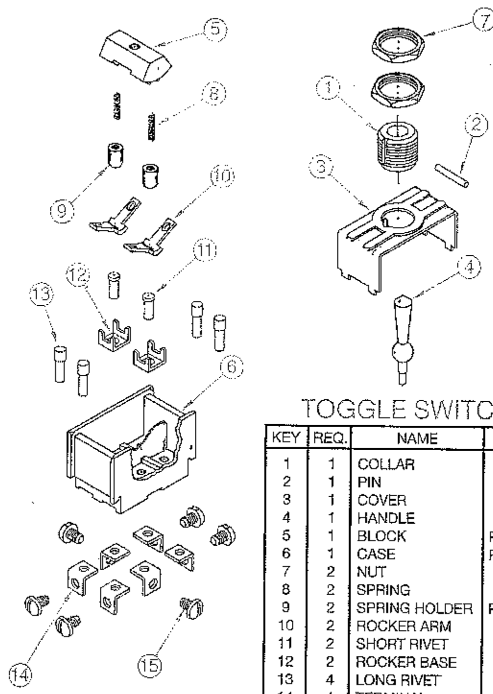
Figure 5-67: *Cutaway drawings.*



TOGGLE SWITCH

KEY	REQ.	NAME	MAT.
1	1	COLLAR	STL
2	1	PIN	STL
3	1	COVER	STL
4	1	HANDLE	STL
5	1	BLOCK	PLSTC
6	1	CASE	PLSTC
7	2	NUT	STL
8	2	SPRING	STL
9	2	SPRING HOLDER	PLSTC
10	2	ROCKER ARM	BRZ
11	2	SHORT RIVET	BRS
12	2	ROCKER BASE	COP
13	4	LONG RIVET	BRS
14	4	TERMINAL	BRZ
15	4	SCREW	BRS

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Figure 5-68: *Exploded drawing.*

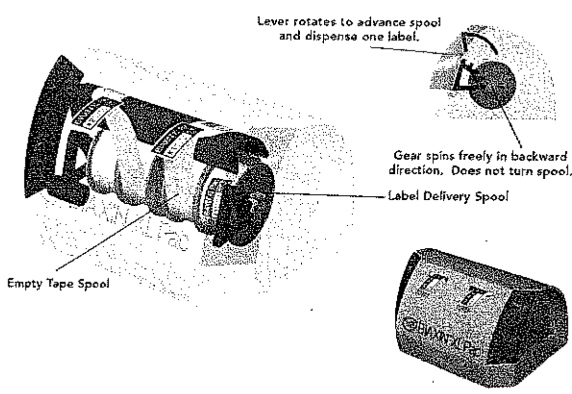

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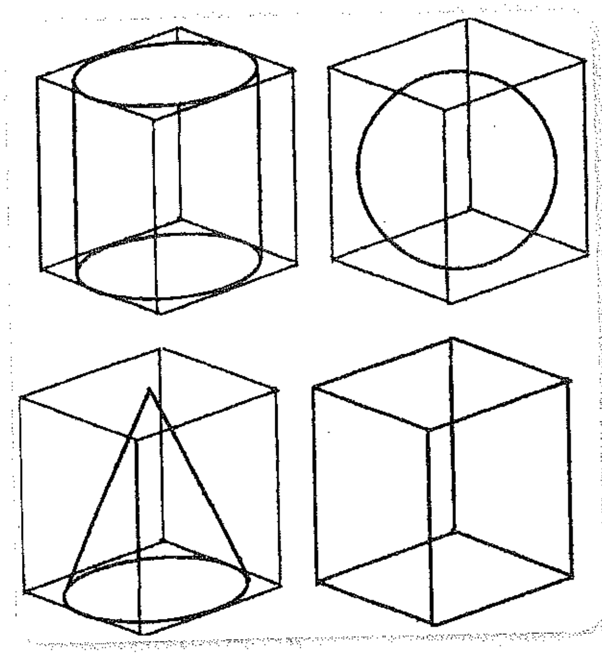
Figure 5-69: *Sectional drawing.*

OTHER DRAWING CONVENTIONS

Besides perspective and technical drawing techniques, many other drawing conventions are used by designers to record or convey ideas.



DRAWINGS COURTESY OF P. HUTCHINSON.

Figure 5-70: Basic forms drawn in relation to crates in isometric view.

Crating

Crating is the process of visualizing the object you want to draw inside a box or a crate. First draw a cube in one- or two-point perspective. The cube can be used to help you develop the other basic shapes: the cylinder, cone, and sphere (see Figure 5-70). Diagonal lines are used to find the center of the crate side. In the cylinder, the center of each end is connected and becomes the center axis of the cylinder. The tip of the cone is at the center of the top plane of the crate, and the circumference of the cone bottom touches the center of each side of the bottom of the crate. The sphere touches one point at the center of each side of the crate. More complex objects can be constructed from a basic form or combination of forms, as in Figure 5-71.

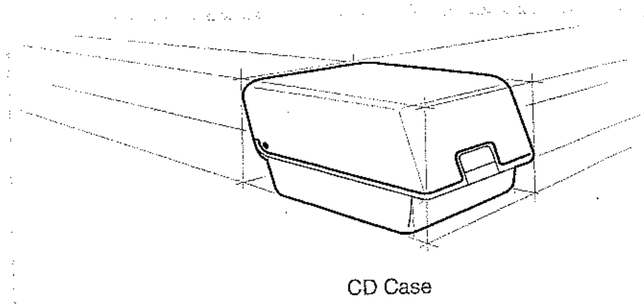


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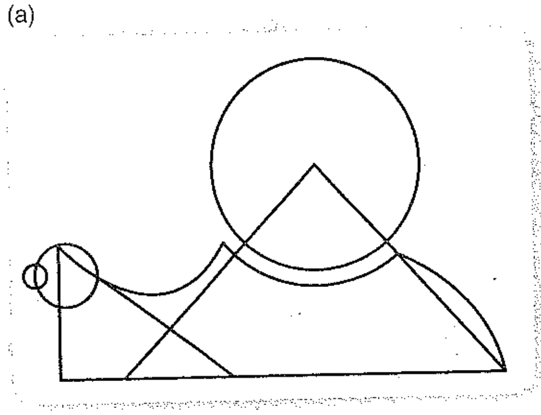
Figure 5-71: A box or crate is used to help sketch an object.

Natural (or organic) shapes are more difficult to think of as drawn in perspective, because they do not have straight edges. Imagine this novelty tape dispenser as a combination of basic shapes. Then think of (visualize) it within a snug box or crate. Following the edges of the box back to a vanishing point makes the perspective more obvious (see Figure 5-72).

(a)



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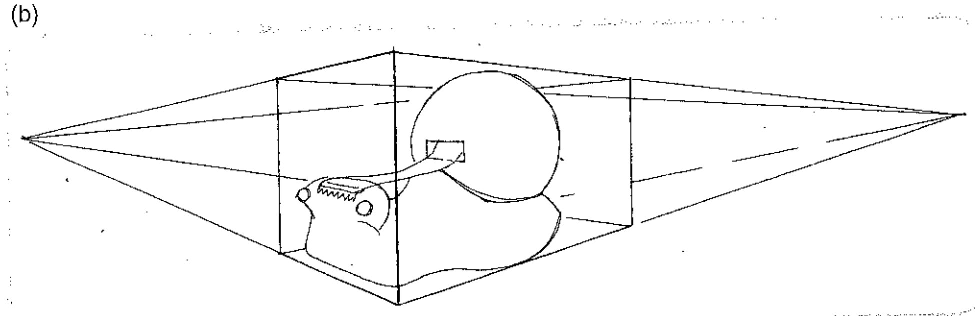


DRAWING COURTESY OF P. HUTCHINSON

Figure 5-72: A novelty tape dispenser (a) drawn as basic shapes, and (b) shown in two-point perspective.

Sighting for Proportion

Drawing the parts of a person or object in correct proportion can be difficult at first. **Sighting** helps to determine relative points in a drawing. Artists know they need tools to take the **visual measurements** they need, and they find those tools all around them.

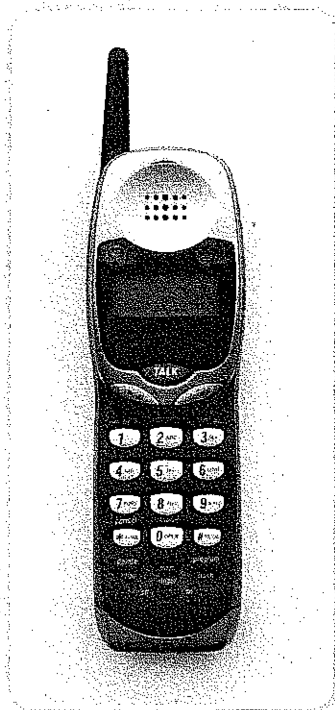
Try drawing a cordless phone like the one in Figure 5-73. Look at the relative sizes of the different features. The light-colored upper oblong shape is about the same length as the darker, lower keypad area. The screen is about three buttons wide. The whole length of the phone is about five antenna lengths. Close up, you can actually measure these relationships and then use the details as units of measurement. By checking the sizes of the components against one another, you can keep your drawing in proportion.

The same approach can be applied to a building seen from some distance. Doors and windows can be used as the units of measurement, and distances can be measured using your pencil. This only works, however, if you keep your measuring unit a constant distance from your eyes. You may even have to close one eye and squint at your subject.

Hold your pencil, blunt end up, at arm's length in front of you and place the end of the pencil touching the top of the door frame. Use your thumb to mark the bottom of the door on the pencil (see Figure 5-74). You have created a unit of measure to help you find the proportions of your building. The facade of the building may be 1 1/2 door lengths high and 2 door lengths wide, and so on.

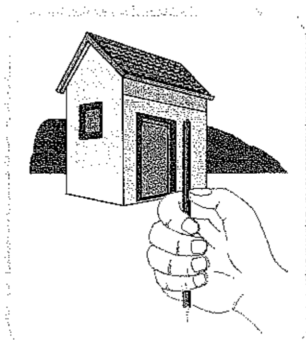
When drawing people, artists often talk about a figure being seven heads high, with arms that are three heads long. They are using what mathematicians call **nonstandard units** of measure, which will help you find proportions consistently on your drawing subject.

The drawing techniques that follow can be used throughout your portfolio, as needed. There is no one right place for a given technique—it must simply fit the purpose for which it is being used. Quick sketches, for example, should be done freehand, without rulers and straightedges; linear perspective is not necessary in visual brainstorming.



COURTESY OF P. HUTCHINSON.

Figure 5-73: *The keys and screen on this cordless phone can be used as units of measurement when measuring visually to draw the object.*



COURTESY OF PROF. MATT JOHNSON, KEAN UNIVERSITY

Figure 5-74: *Sighting using a pencil as a measuring tool.*

Outlining

Outlining in a drawing can help express spatial qualities of a form (see Figure 5-75). The use of dark lines surrounding an object can make it stand out from its background. Outlining the closest planes of an object can make the form look more three-dimensional. Using both shading and outlining on a sketch can be confusing, because shading describes how light falls on a form in space, and outlining tends to reduce the drawing back to a flat symbol or cartoon.

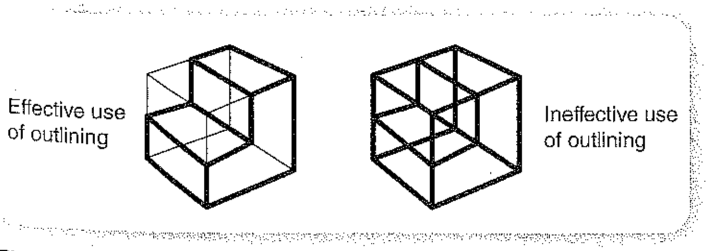


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Figure 5-75: *Outlining to help express special quality.*

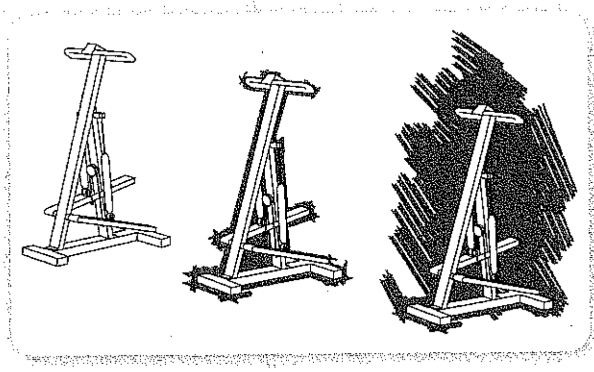
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Figure 5-76: *Compare the three drawings. Which makes the object easiest to see and understand?*

Adding a Background

A contrasting background always helps isolate and focus attention on an object. Use bold, rapid strokes with a black or dark-colored marker to add a backdrop. It is not enough to just outline the object, because the outline will then compete with the object itself. Extend out from the outline so that the dark shape becomes a background. The outer edge of the background should not draw attention to itself or, once again, it will compete with the object you want to "spotlight" (see Figure 5-76).

Colored Pencil Techniques

The use of colored pencils is a relatively easy way to make sketches and drawings more interesting, effective, and informative. They may be used to make a colored background and to outline, highlight, or shade. Colored pencils lend themselves to shading and soft **transitions**, and they are good for representing **matte surfaces** (finely textured but nonreflective).

Begin with a sharp point, and hold the pencil as you would for shading. The idea is to create a smooth blend of color by going over an area a number of times in several directions (see Figure 5-77). Light pressure must be used to obtain an even color application.

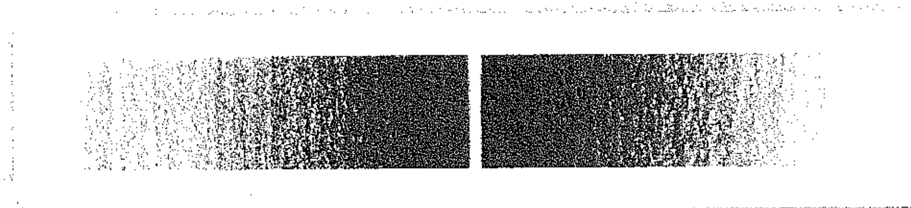
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Figure 5-77: *Using a colored pencil to make a smooth transition in tone.*

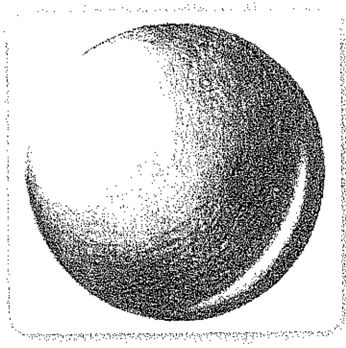
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Figure 5-78: *Shading a sphere with colored pencil to give a 3-D appearance.*

Colored pencils are ideal for shading to give an object a 3-D appearance (see Figure 5-78). Notice how the color on the sphere is dark and sharp at the edges and softer as it moves toward the internal highlights. Carefully blend the color to get a crisp, neat drawing.

Color Marker Techniques

Color marker rendering is an effective and dramatic technique that looks more difficult than it actually is. Although it takes some practice, there are "tricks" that you can use to make your drawings look as professional as Figures 5-79 and 5-80. Simple techniques are described in Figure 5-81.

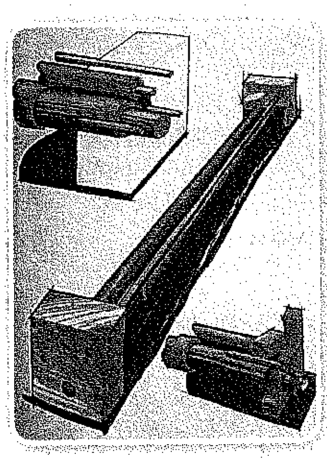
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Figure 5-79: *Shading with markers.*

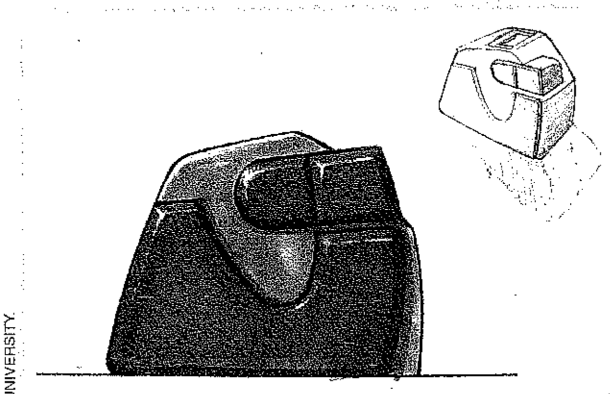
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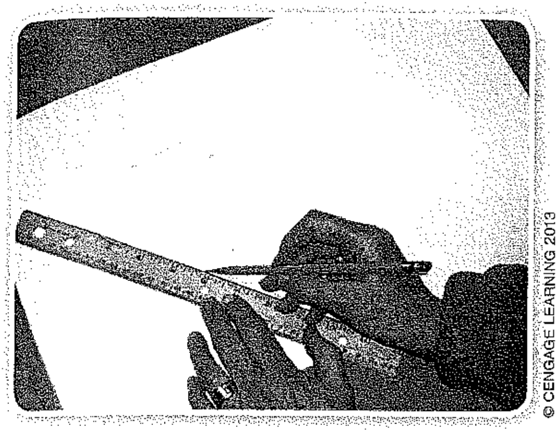
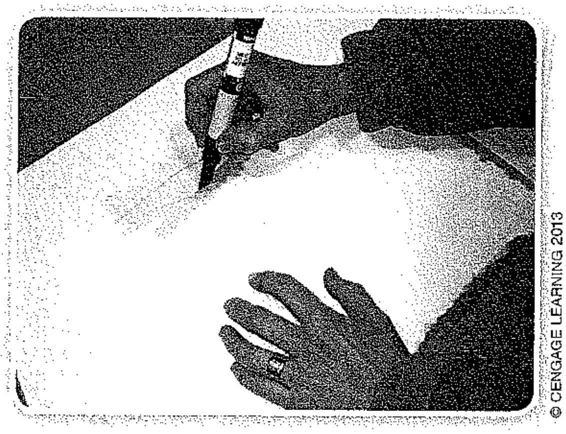
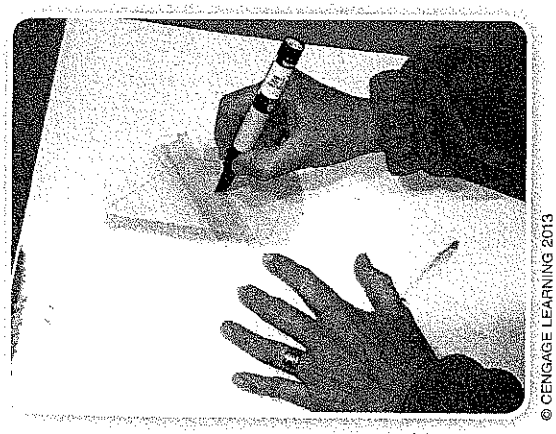
Figure 5-80: *Concept drawing using markers.*



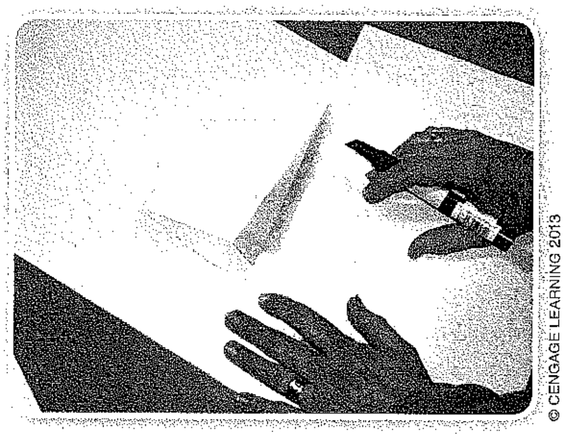
(a) Sketch a cube in perspective or isometric. Use light pencil lines. Put two additional pieces of paper under your original drawing to prevent "bleeding" through to the work surface underneath.



(b) Use two pieces of paper as a mask. Place the mask over your sketch so that only the top surface of the cube is visible. Use a medium-value marker, and work from one side of the cube's top surface to the other. Begin each stroke on the mask, and use bold, rapid, vertical strokes that end past the object lines of the cube. You are working out from the "V." Don't go back over areas you have missed.

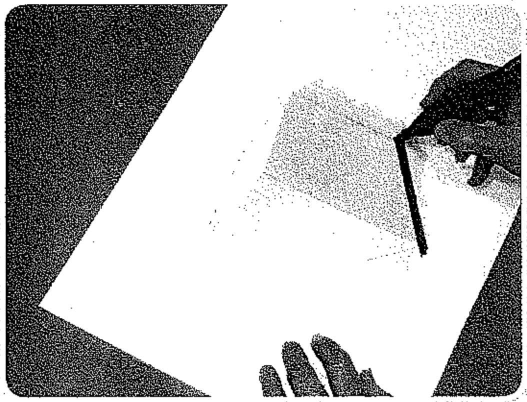


(c) Rotate the page to give yourself a comfortable position in which to use the marker. Adjust the mask to leave a thin space between the colored top surface and the left surface you will render. This space will be the corner of the cube between these surfaces. Work out from the "V," and use the same technique, but wait about a minute and give this surface a second coat of marker. This will make this side darker than the top surface.



(d) Again, rotate the page, and reposition the mask to expose only the right side. Be sure to position the mask pieces so that a thin, uncolored space is left between cube surfaces. Again, work out from the "V." Give this side three coats of marker, waiting a minute or so between coats. These three coats will make this surface the darkest side.

Figure 5-81: Using color markers to add appeal to drawings.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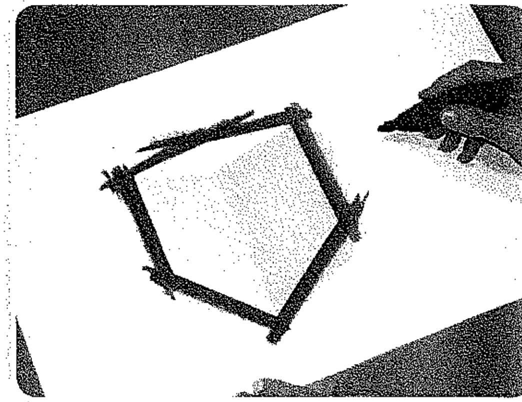
(e) To complete the rendered cube, use a black wide-tipped marker and smooth, bold strokes along the six outside object lines. This technique will make the object stand out from the page and clean up the outside edges.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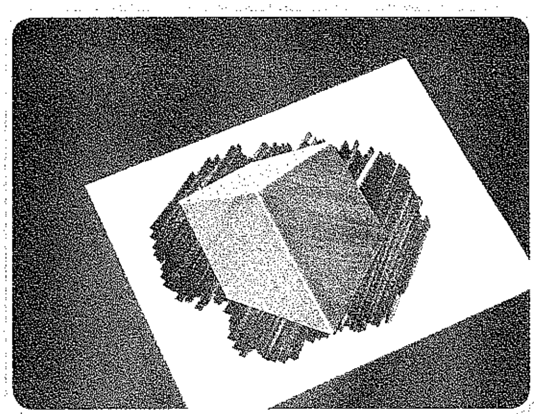
(f) Overlapping the marker strokes gives the object a sharp, designer-rendered appearance. You can use this technique to outline pencil-drawn objects, too.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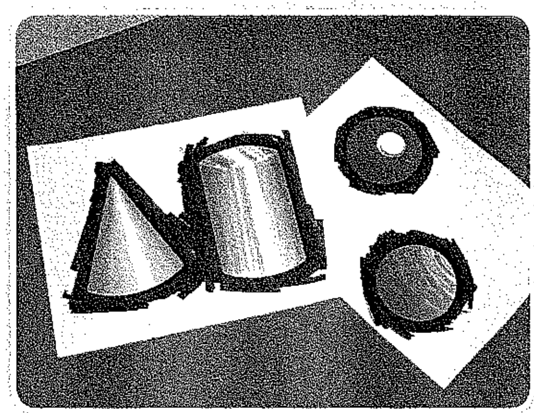
(g) Another excellent technique for marker rendering is to cut out the cube and use stick glue to paste it on another sheet of paper. A background can be applied first with another contrasting color marker.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(h) A cylinder, cone, and sphere are shown rendered here. Notice how the marker lines are drawn along the axis of the cylinder and how the value goes from dark along the upper edge to light, to dark along the bottom edge. A cutout placed on the end surface to mask that area is shown. The marker lines on the cones begin at the top and radiate out as they reach the bottom.

Figure 5-81: (Continued)

The two main purposes for hand drawing are (1) to help you describe what you can see, and then (2) to use that experience to describe ideas that exist only in your mind. The concepts and techniques that have been discussed in this chapter should provide you with some tools for drawing effectively. The problem identification, initial research, and idea-generating steps of the design process use these skills heavily. As a designer's ideas gel, the questions to be answered become more technical, and technical drawing and modeling approaches are used. Technical development, testing, and evaluation using CAD/CAM and engineering simulation software, as well as graphing, spreadsheets, and other computer programs are explained in other chapters.

All of these tools contribute to the documentation of the design process, and you will want to use as many of them as are available when creating your own design portfolio.

modeling:
Creating a visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original. Modeling is often used to test ideas, make changes to a design, and to learn more about what would happen to a similar, real object.

USING DRAWINGS IN THE DESIGN PROCESS

The drawing techniques we have discussed so far are designed to help you draw what you see. This is particularly useful for studying the world around you and understanding how things work, their components, and how they fit together. This kind of drawing serves the information-gathering aspect of the design process and allows you to create visions of what a developed solution might look like in use.

Preliminary Sketches

Freehand drawing allows you to develop and present your ideas. The first ideas you put down on paper are usually in the form of **preliminary sketches** (see Figure 5-82). These are done quickly so that you do not lose your train of thought or flow of ideas. This process should not be encumbered with straightedges, rulers, compasses, or other drawing instruments. These instruments only slow down the process that, by its very nature, is free and creative.

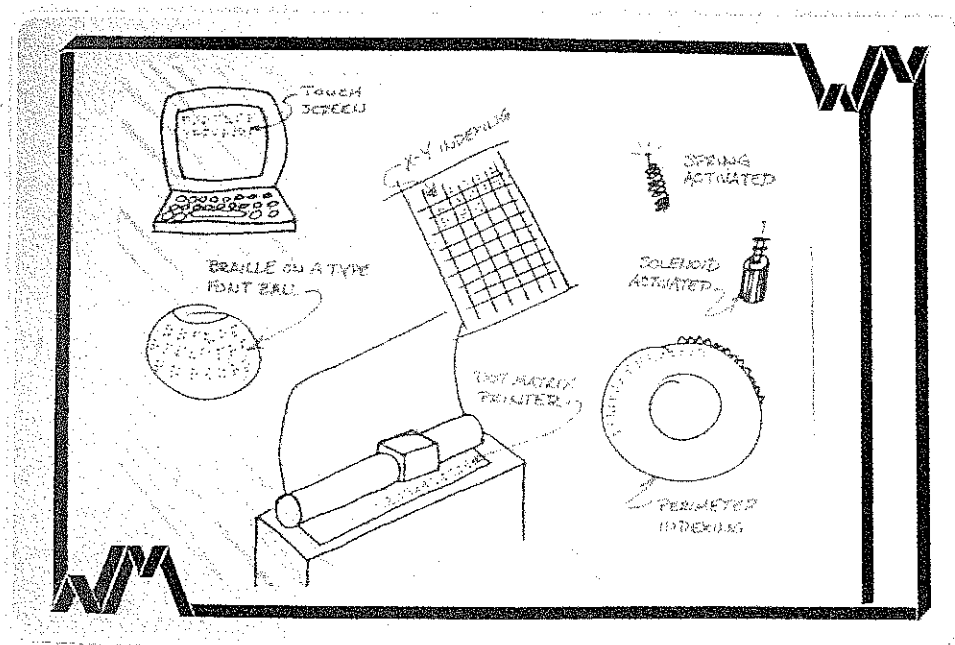

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Figure 5-82: *Preliminary sketches of computer Braille reader ideas.*

visual brainstorming:
A method of ideation in which drawing (in contrast to verbalizing) is used to generate large numbers of ideas. First, an existing object is drawn, then variations on that object are drawn, and then variations on one of those ideas are drawn, and so forth.

At the beginning of the design process, it is helpful to be able to pull ideas out of our minds and put them on paper as quickly as possible. Then we can develop and communicate those ideas. There are ways to simplify that process by using symbols and techniques that communicate without all the details, much as a stick figure can symbolize a person and a sketch map can provide directions to a destination.

Visual brainstorming, like verbal brainstorming, is a method for stimulating and expressing the most possible ideas in the least possible time. Try this in the Your Turn exercise. Begin by drawing an object that you would like to improve upon, for example, a skateboard (see Figure 5-83).

Your Turn
Visual Brainstorming

Step 1: Sketch the skateboard in Figure 5-83 as it now exists.

Step 2: Do five variations on this sketch. If a photocopier is available, you can make five photocopies of the original sketch and then draw over the parts where you would make simple modifications.

Step 3: Choose the variation that seems the most interesting and make five variations on that version.

Step 4: Choose the best of these and develop the idea in more detail.

This kind of activity should be done as spontaneously as possible, so you do not get bogged down in details.

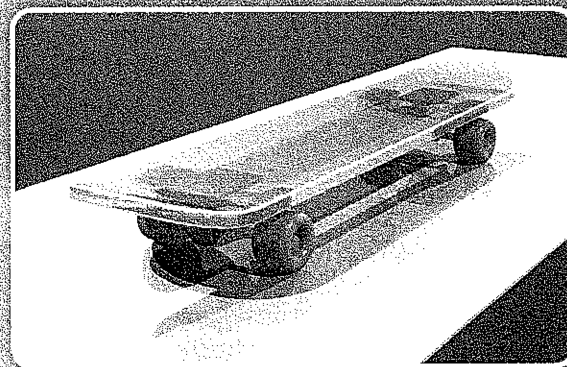
COURTESY OF CHRIS WAYMAN, STAFFORDSHIRE UNIVERSITY

Figure 5-83: *Visual brainstorming led to the design of this skateboard innovation.*

Annotated Sketches

The addition of notes about materials, fasteners, and other features (**annotations**) to a drawing is called an **annotated sketch** (see Figure 5-84). These remarks are reminders to yourself about what you were thinking at the time you developed the idea. Ideas are often lost if they are not recorded immediately.

Developmental Sketches and Drawings

The next step in designing is the further development of the ideas in the preliminary sketches. These **developmental sketches** contain more detail as the ideas are refined (see Figure 5-85). At the completion of the developmental

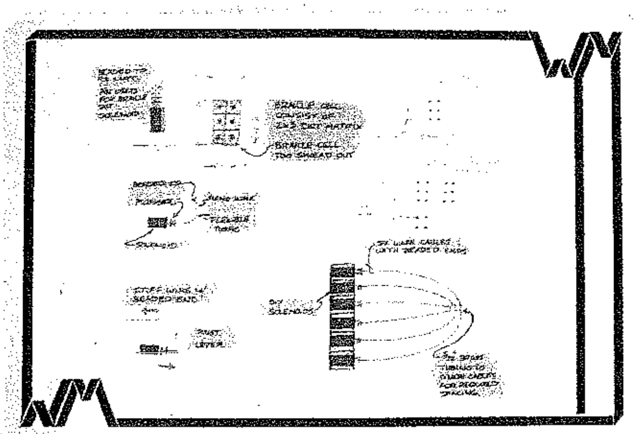
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Figure 5-84: *Annotated sketch of computer Braille reader components.*

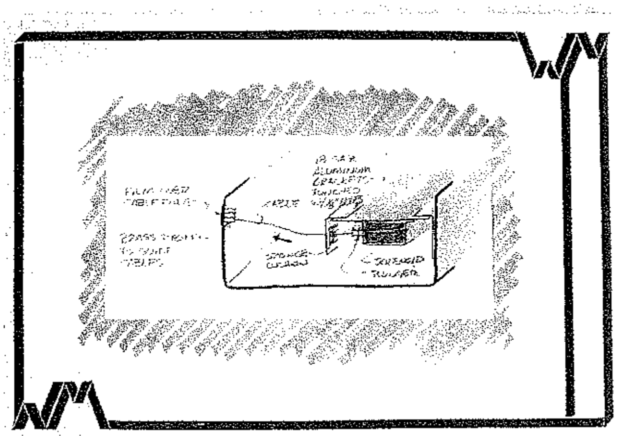
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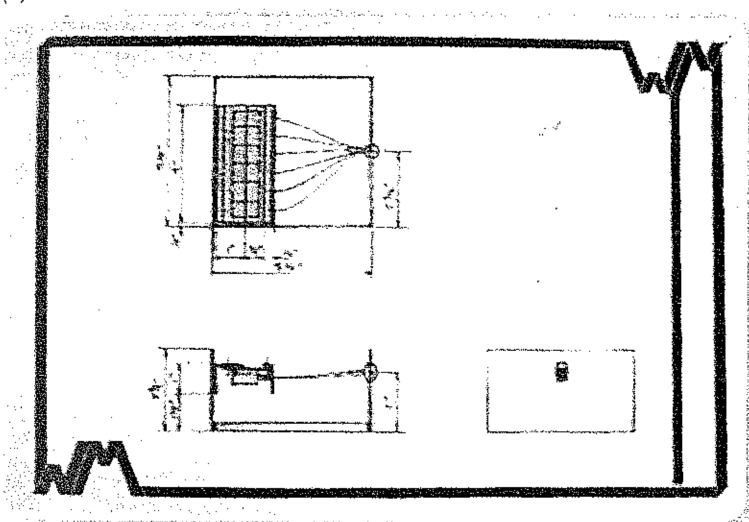
Figure 5-85: *A developmental drawing showing the solenoid control in the final Braille reader system.*

sketches, the solutions should be workable, with features such as mechanical linkage or electronic circuitry worked out. Annotations are often a part of developmental sketches. Developmental sketches are done both freehand and using CAD programs. Software approaches to product development will be detailed in Chapter 8.

Production Drawings

In the final stage, production drawings are developed that contain the information needed to actually make thesolution (see Figure 5-86). These are often drawn to scale, so that size, proportion, and location of features such as holes can be finalized. Working drawings will be discussed in a later chapter.

(a)



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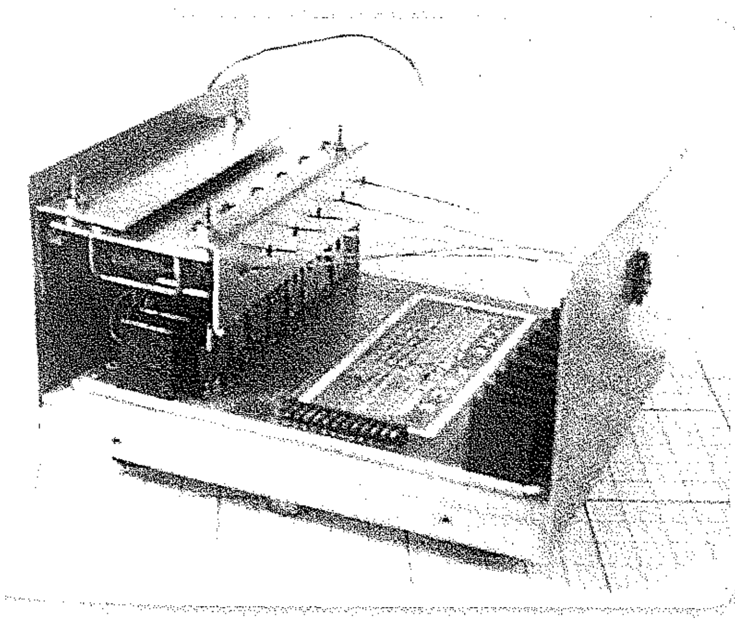

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Figure 5-86: A production/working drawing showing (a) final placement of components and (b) the model of the Braille reader system.

Point of Interest

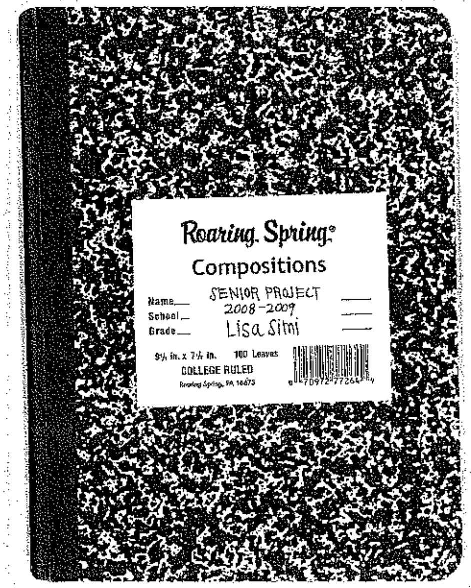
How to document your design process

Design Step	Documentation Technique
Defining the Problem	Description of a technological situation explaining the problem. Write, draw, annotate. Use computer-generated text or neat hand lettering.
Brainstorming	Include a collection of the ideas considered including ideas from different members of the design team.
Researching and Generating Ideas	Notes, sketches, letters, interview tapes, bibliography, and photos. Use photocopies of catalog pages and other reference materials. Include diagrams that explain mechanical or electronic principles to be applied.
Identifying Criteria and Constraints	Actual brief with specifications, conditions, and requirements. Use computer-generated text or neat hand lettering.
Exploring Possibilities	Notes, preliminary sketches, and development sketches with annotations, 2-D models. Use pencil, color pencil, marker, technical pen, and other mediums. This should be a well-documented section.
Selecting an Approach	Notes, matrix comparing requirements to solutions, checklists, and so on. Presentation drawings using color pencil, marker, or other color medium.
Developing a Proposal	Photos of evolutionary models: wood, plastic, cardboard/paper, foam core, metal, ceramic, found objects; computer simulations, kits, clay, VHS, DVD, and so on. Working drawings, such as orthographic projection. Color rendering of final appearance of solution.
Modeling or Prototyping	Photos of various stages of completion; descriptions of necessary adjustments and changes, and so on.
Testing and Evaluating	Data checklists, graphs, charts, photos, slides, VHS, and DVD. Evaluation (solution evaluation description of test results and self-criticism: "press type" and self-evaluation), computer-generated text, neat hand lettering, and so forth. In addition, a title page is always appropriate, and, if the portfolio is lengthy, a table of contents may help the organization. The portfolio sections correspond with the design steps outlined in earlier chapters.
Refining the Design	Include a list of problems to be addressed in the redesign of the project and show evidence that the problems were resolved.
Creating or Making	Show evidence that the production process will result in a product that meets all design specifications or show how the production process has been modified if necessary.

7 DEVELOPING AN ENGINEER'S NOTEBOOK AND DESIGN PORTFOLIO

As noted earlier in this chapter, an engineer's notebook is typically bound with numbered pages (see Figure 5-87). The purpose of the engineer's notebook is to keep a written record of all the important work completed on a project or a range of projects. Notebook entries could include calculations, graphs, ideas, concerns, and results of testing or research. An engineer's notebook is where patentable ideas are described in full detail. In this format, a patent idea in a notebook is most often signed by a witness that has read and understood the idea. All notebook entries should be dated. More about developing an engineer's notebook will be presented in Chapter 6, Reverse Engineering.

Design portfolios are used to show the design process to clients, and therefore the content and format are less important than the aesthetic presentation. For students learning about design, the portfolio may be used to show the design process and solutions to a teacher or a review board. Both the design portfolio and the engineer's notebook will contain critical information from the design process. Following is a list of sections and appropriate documentation strategies.



COURTESY OF LISA SIMI.

Figure 5-87: Bound Engineering Notebook.

PORTFOLIO

Because design portfolios serve a less formal purpose as compared to the engineer's notebook, no special formatting, binding techniques, or content are required. A design portfolio should contain a number of sections, depending on the complexity of the project. Simple design problems will have fewer sections, often combining several from the previous "Point of Interest" list. Major projects will use all or most of the sections, or will combine the sections into another logical format.

Title Page, Page Numbering, and Table of Contents

Your portfolio should have an attractive title page that clearly identifies the portfolio's purpose and author. Each page of the portfolio should be numbered. A design portfolio should have a table of contents listing the design steps and where to find them. This will need to be the last step in organizing your portfolio. Portfolios will be most attractive if they follow sound graphic design principles. More information about graphic design principles can be found in Chapter 18 (Graphics and Presentation).

Page Orientation

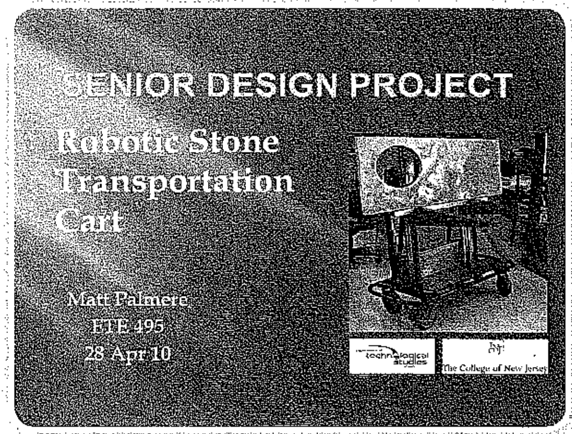
A horizontal or **landscape** orientation of the paper is well suited for portfolio work (see Figure 5-88). Choose a paper size that is large enough to allow for a border and a title block and still give you plenty of room to draw. A standard 11 by 17 inch page is large enough without being too cumbersome to carry around, but other sizes are acceptable. You may also need to develop or purchase a cover or case to keep pages from tearing and to protect your work from wind, rain, and other hazards.

Logo

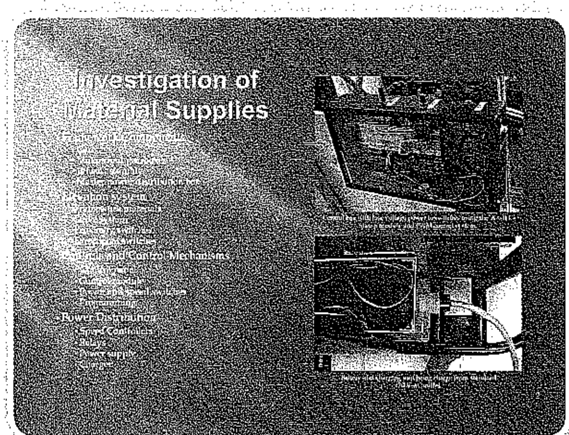
A company that wishes to be easily recognized develops a symbol for use on its products, correspondence, and advertising called a **logo**. You may develop your own logo for your design work and incorporate it into both your portfolio and your final design solutions. In the portfolio, the logo may appear on each page.

Binding

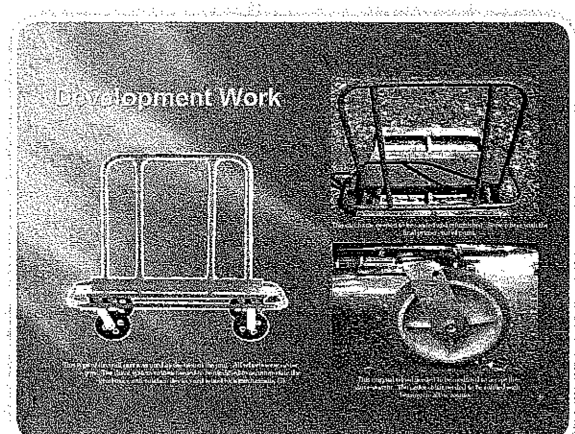
Pages may be bound on either the left side or the top, using plastic bindings, a modified three-ring binder, or one of a variety of other methods.



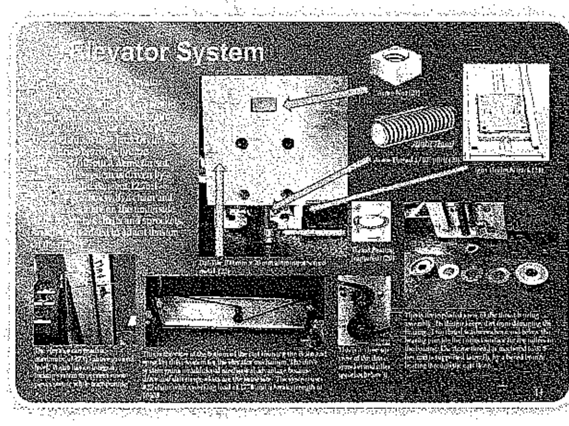
COURTESY OF MATTHEW PALMERE.



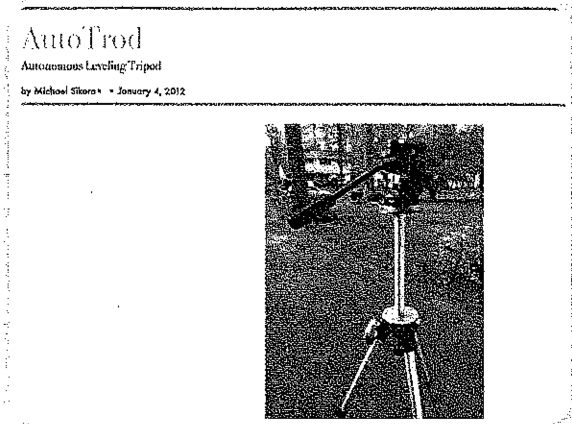
COURTESY OF MATTHEW PALMERE.



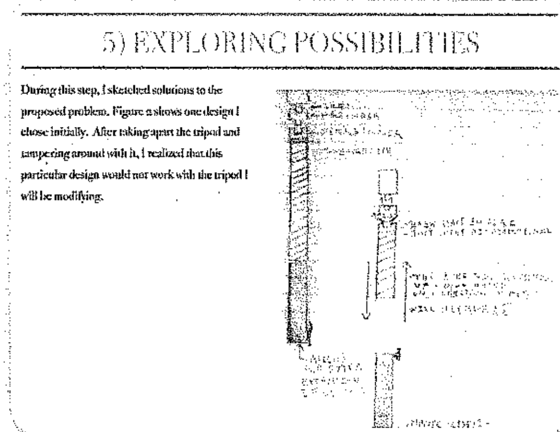
COURTESY OF MATTHEW PALMERE.



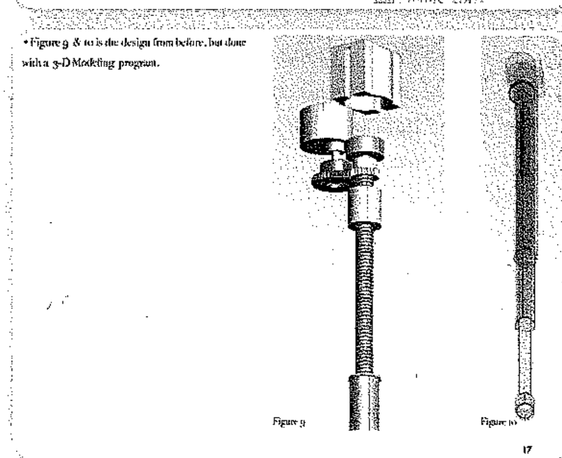
COURTESY OF MATTHEW PALMERE.



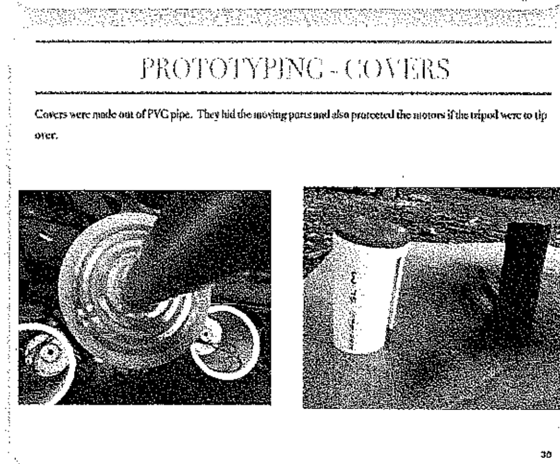
COURTESY OF MICHAEL J. SIKORA IV.



COURTESY OF MICHAEL J. SIKORA IV.



COURTESY OF MICHAEL J. SIKORA IV.



COURTESY OF MICHAEL J. SIKORA IV.

Figure 5-88: *Selected pages from senior design portfolios.*

Page Content

It is important to strike a balance between putting too little and too much on a page. A typical page in a portfolio might have a number of drawings (see Figure 5-89). There is no reason, however, that all of these drawings must originally have been drawn on the same piece of paper. You can redraw from original sketches onto one page or cut out a number of different drawings and glue them on a portfolio page. These techniques will allow you to present ideas in an interesting and concise format.

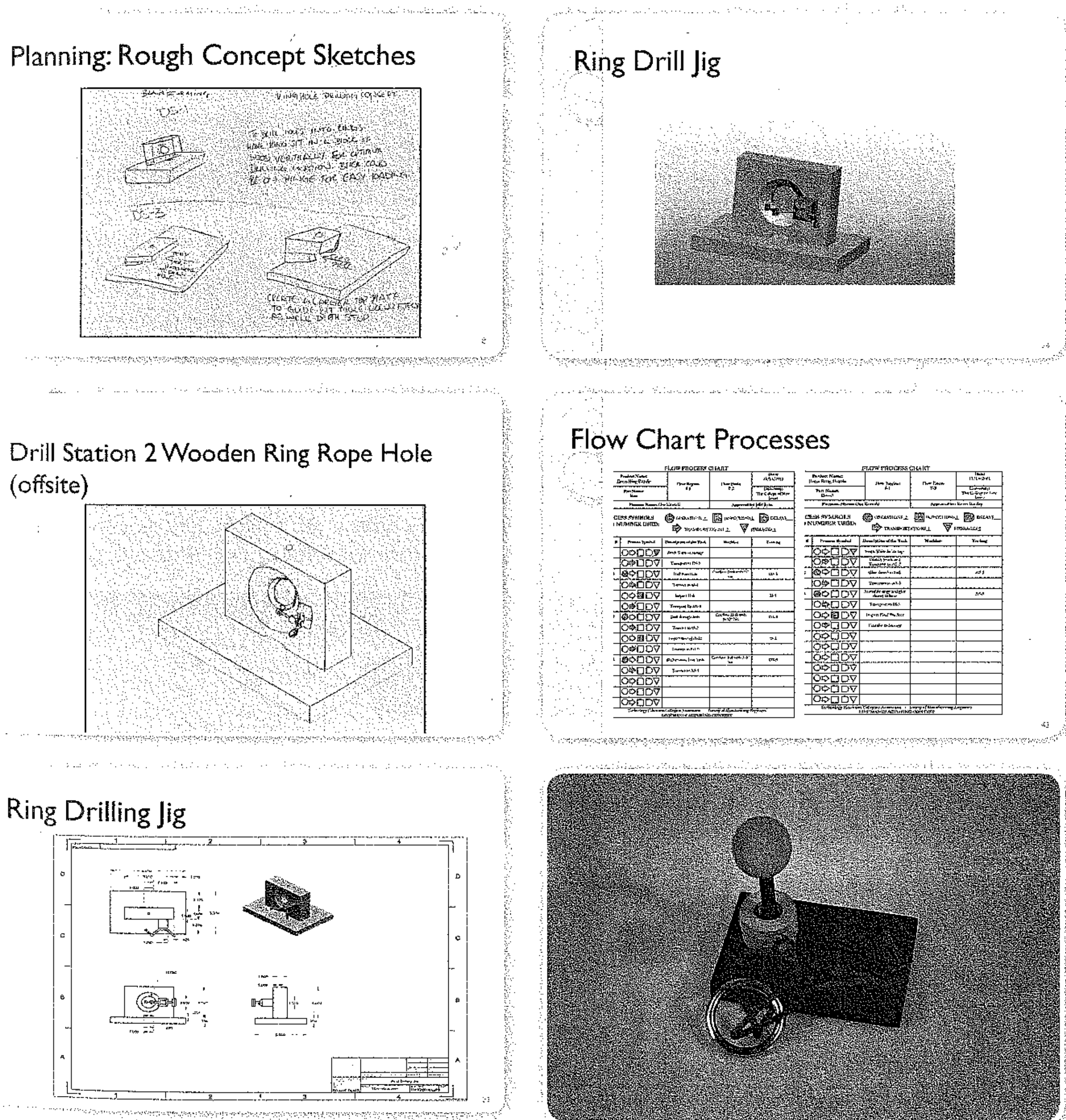


Figure 5-89: *Pages of a design portfolio showing examples of drawing techniques used during the design process. a) sketching, b) perspective, c) orthographic, d) rendering, e) charting, f) final product.*

COURTESY OF JULIE RYAN, CLOE KAWECKI, KEVIN BRADLEY, TANNER WILSON, JOE CARSON, AND DALTON FOWLER, TCNJ TEAM MEMBERS, TECA EASTERN REGIONAL MANUFACTURING DESIGN CHALLENGE

Portfolio Page Layout

Organizing the appearance of the page is an important part of portfolio presentation. Figure 5-90 illustrates a number of strategies you can use to make a page look interesting.

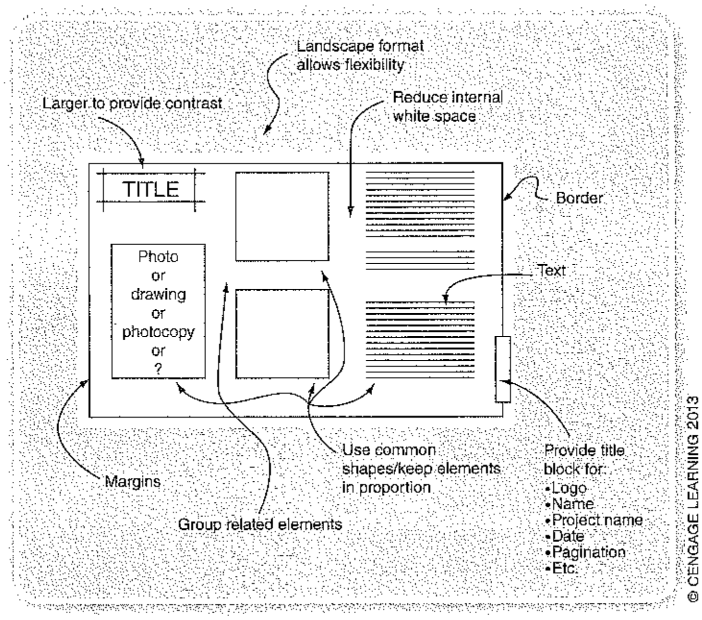
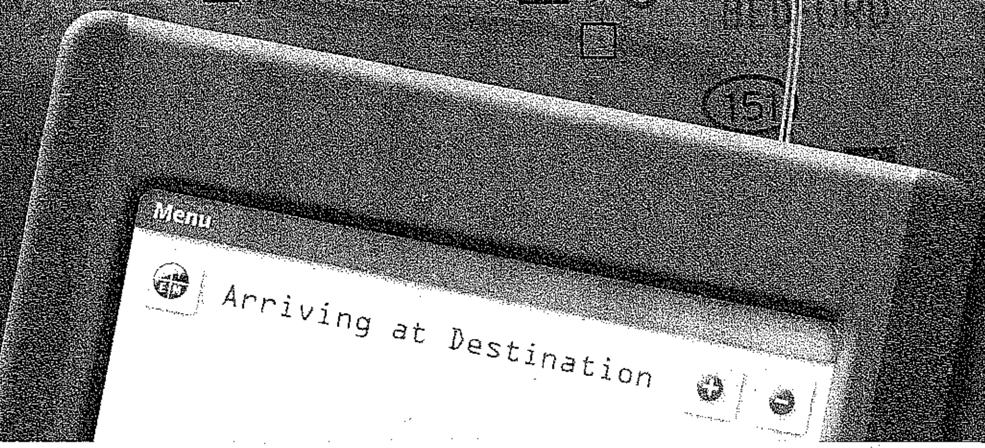


Figure 5-90: A well-organized page is easy to read and understand. It follows rules of alignment.



SUMMARY

Drawing is integral to designing and investigating. Ideas, which are the seeds of the scientific hypotheses and technological innovations that define our modern world, cannot grow unless they are exposed to the "light of day." Investigating the wings of birds through sketches allowed the Wright brothers to formulate their theories of flight. Each of Leonardo da Vinci's inventions was developed through a series of drawings. Modern innovators like James Dyson and Jonathan Ive develop their inventions through drawings.

Today, the computer has provided a powerful graphic tool. CAD and solid modeling programs tempt us to sidestep the discipline of drawing. But software cannot replace the human element in designing. When we gain confidence with freehand sketching, we acquire a valuable tool for examining and communicating our thoughts. That confidence comes from learning to use our whole brain to interpret what we see. Like writing, keyboarding, texting, or using a computer mouse, sketching is also a matter of motor skill. All of these develop through practice.

Awareness of the elements of drawing: line, form, shape, value, color, texture, and space, as well as techniques like linear perspective, shading, color mixing, gridding, crating, and exploded and cutaway drawings make us more fluent scientists, designers, and inventors. We can use these abilities as students to document our work; as professionals communicating with collaborators and clients; and as homeowners, family members, and citizens in the technological world.

BRING IT HOME

OBSERVATION/ANALYSIS/SYNTHESIS

1. Using an HB pencil, create a one-point perspective sketch of one of the following: VHS cassette tape, audio cassette tape, "Walkman"-type personal stereo, iPod, BlackBerry personal organizer.
2. Using colored pencils, make a cube stand out by shading around it.
3. Using colored pencils, give a cube a 3-D appearance by shading with three values of one color.
4. Using a scale and calipers, sketch a full-size or half-scale orthographic projection drawing with a front, top, and side view of one of the following: iron, hair dryer, electric drill, personal stereo, cordless telephone.
5. Research and reproduce a number of symbols used for a special-purpose map, such as a geological survey or aeronautic sectional.
6. Use visual brainstorming techniques to explore five improvements on the design of a tent for camping. Choose your favorite of these and develop five variations on that solution.
7. Scan and print or photocopy five copies of your best tent design and show five different color schemes that might appeal to five different groups of users (for example, families, teens, retirees, Girl Scouts, or military).
8. Design and produce a master portfolio page, including an original logo, company name, and a block for project name, date, and other necessary information.
9. Use the techniques in this chapter to fully document a design problem.