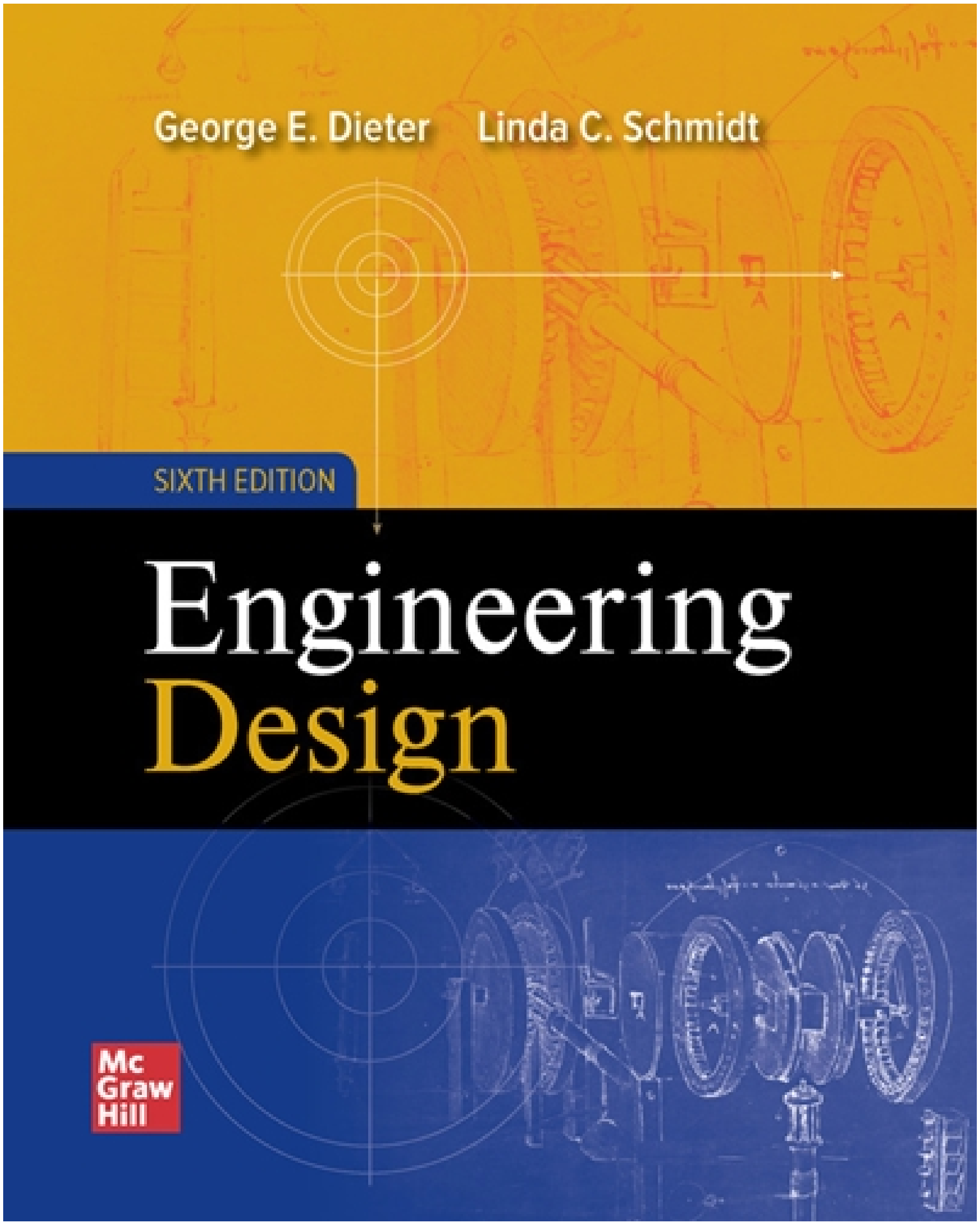
Solutions for Engineering Design 6th Edition by Dieter



Solutions

Solutions Manual to Accompany
Engineering Design Sixth Edition
George E. Dieter and Linda C. Schmidt

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CHAPTER 1

ENGINEERING DESIGN

1.1. A major manufacturer of snowmobiles needs to find new products to keep the workforce employed year-round. Starting with what you know or can find out about snowmobiles, make reasonable assumptions about the capabilities of the company. Then develop a needs analysis that leads to some suggestions for new products that the company could make and sell. Give the strengths and weaknesses of your suggestions.

A company making snowmobiles should have the capability to design and build equipment that stands up in an aggressive service environment. Working in the snowmobile business should have resulted in expertise in small gasoline engines. The company probably sells to a network of distributors, so there is no experience in selling directly to the customer.

Snowmobiles are part of the growing business market segment of recreational vehicles. An obvious business opportunity that would extend the sales year around is to develop water sport equipment like jet skis. The market is crowded with suppliers, but an innovative design with an attractive entry price, or novel technology or features, could find acceptance. Another market possibility is off-road vehicles like a small dune buggy or three-wheel motorcycles. The same conditions for a new product would apply as for jet skis.

A related, but separate possibility for a new product would be specialized vehicles for business and industry. Some examples are: a safe vehicle for bicycle messengers in crowded city streets, a small logging vehicle, small construction machinery, and a parts-picking vehicle for large warehouses.

1.2. Take a problem from one of your engineering science classes, and add and subtract those things that would frame it more as an engineering design problem.

This is an individualized exercise for each student. In general, to make it a design problem the student would remove specific data, like forces, material properties, and add constraints like safety, reliability, and conformance to standards.

1.3. There is a need in underdeveloped countries for building materials. One approach is to make building blocks (4 by 6 by 12 in.) from highly compacted soil. Your assignment is to design a block-making machine with the capacity for producing 600 blocks per day at a capital cost of less than $300. Develop a needs analysis, a definitive problem statement, and a plan for the information that will be needed to complete the design.

<u>Needs Analysis</u>

Must be capable of being constructed with local materials and labor. Total cost to be less than $300 (U.S.). Should be easily transportable to different locations. Must be powered with human labor since you cannot count on availability of electricity. Hydraulic components may be invalid solutions because of cost and/or maintenance (sand in seals, etc.).

<u>Musts</u>

1. Cost less than $300
2. Weight less than 130 lb.
3. Human powered.
4. Made from local materials (mostly wood, plain carbon steel)
5. Easily manufactured in local garage shop
6. Produce $4 \times 6 \times 12$ in. blocks

<u>Wants</u>

1. Able to make tiles $2 \times 6 \times 12$ in
2. Easily maintained
3. Easy and safe operation
4. Adaptable to a variety of soil mixes.

7. Produce 600 blocks per day
8. Compressive strength at least 300 psi dry

Problem Statement
The objective of this project is the design and construction of a prototype model of a block making machine. The blocks are to be made of soil with a minimum of cement added, and are $4 \times 6 \times 12$ inches. The machine must be human powered, weigh less than 130 lb., cost less than $300 to build, and be capable of producing 600 blocks per day with a 5 person crew. Blocks must have a compressive strength of 150 psi as formed and 300 psi when cured. The machine should be easily constructed of local materials with local labor (assume a third world tropical location). The machine also should be adaptable to a variety of soil cement mixtures, and to making tiles $2 \times 6 \times 12$ in. A crew of five persons should be capable of operating the machine to produce 600 blocks per day.

Information Needed

1. Determination of the processing conditions for making blocks.
   What pressures must be generated? Curing temperature and time? Effect of different soil mixtures on pressure.
2. Mechanisms for generating pressure.
3. Human Factors Engineering
   Magnitude of force that can be produced by a human
   Human fatigue
4. Materials handling
5. Available construction materials and their properties.

1.4. The steel wheel for a freight car has three basic functions: (1) to act as a brake drum, (2) to support the weight of the car and its cargo, and (3) to guide the freight car on the rails. Freight car wheels are produced by either casting or rotary forging. They are subjected to complex conditions of dynamic thermal and mechanical stresses. Safety is of great importance because derailment can cause loss of life and property. Develop a broad systems approach to the design of an improved cast-steel car wheel.

This topic is covered in detail in a paper by M.R. Hanley, et.al, *Trans. ASME, Journal of Engr. Material*, vol. 102, Jan. 1980, pp. 26–31.

1.5. The need for material conservation and reduced cost has increased the desirability of corrosion-resistant coatings on steel. Develop several design concepts for producing 12-in.-wide low-carbon-steel sheet that is coated on one side with a thin layer, e.g., 0.001 in., of nickel.

Some possible concepts are:
- Vapor deposition, in a vacuum on a continuous (as opposed to batch) basis.
- Ion implantation.
- Slurry coating with nickel powder; sinter and hot roll to form a bond with the base steel metal.
- Electroless nickel plating plus cold rolling.

1.6. The support of thin steel strip on a cushion of air introduces exciting prospects for the processing and handling of coated steel strip. Develop a feasibility analysis for the concept.

This topic is treated in detail in a paper by W.G. Jaffrey and G.M. Boxal, *Journal. Iron and Steel Institute*, May 1963, pp. 401–408.

1.7. Consider the design of aluminum bicycle frames. A prototype model failed in fatigue after 1600 km of riding, whereas most steel frames can be ridden for over 60,000 km. Describe a design program that will solve this problem.

This design problem is discussed in a paper by R. Davis and M.L. Hull, *Trans. ASME*, *Journal. of Mechanical Design*, vol. 103, Oct. 1981, pp. 901–907. The need that an aluminum bicycle frame fulfils is decreased weight. While the section modulus will have to be greater for aluminum than steel because of its lower elastic modulus, 10×10^6 vs. 30×10^6 psi, preliminary finite element analysis shows about a 20% weight reduction. A simple FEA using beam elements can establish the critically stressed joints. A more precise FEA can map out the stresses at these joints, and from this the stress concentration factors can be determined. The selection of the particular aluminum alloy will be based on cost and fatigue properties. To give the problem a more current flavor, have the students find papers on the use of fiber-reinforced composites in bicycle construction. This will introduce the issue of material cost and difficulty in manufacturing the structural members.

1.8. You are a design engineer working for a natural gas transmission company. You are assigned to a design team that is charged with preparing the proposal to the state Public Utility Commission to build a plant to receive liquefied natural gas from ocean-going tankers and unload it into your company's gas transmission system. What technical issues and societal issues will your team have to deal with?

(a) Societal impacts: supply of coal miners; accident rate of coal miners; long-term impact of respiratory diseases in miners; damage to environment from surface mining, especially in mountainous country; adequacy of railroads to transport coal; traffic interference, noise, dirt, accidents from coal transport; adequacy of engineering design talent to design plants since much of this expertise is now retired. A major deterrent to massive substitution of coal produced gasoline, in addition to the cost of plant construction, is the need to control greenhouse gases (CO_2) created in coal processing. These costs are very substantial. It should be noted that the country of South Africa provided all of it gasoline from coal using the Sasol process for many years, but this was before the world-wide concern about global warming.

(b). In the past there was a big difference between the way society views the impacts of energy generated from nuclear materials and coal. Nuclear is more difficult to consider on a rational unemotional basis due to fear of nuclear weapons and nuclear radiation leaks. Look how long it is taking to establish a national repository for spent fuel rods in the Nevada desert. On the other hand, some people remember when their homes were heated by coal. There is a romanticism associated with the coal miner. People are generally more comfortable with energy from coal than from nuclear sources. This is changing with the great concern about global warming from greenhouse gases, to which CO_2 resulting from coal combustion is a major contributor. Nuclear energy does not contribute to global warming. The safe disposal of nuclear waste remains the main concern of many people, as is the possibility of terrorist acquisition of nuclear material and using it to make a "dirty" bomb. Alternative energy sources like wind, solar power, and biofuels will grow, but at this time they do not appear capable of reaching the magnitude needed for electric power generation by the nation. Thus, the path remains clear for resumption in building nuclear power plants. The greatest obstacle from this happening is the growing cost of construction of a nuclear generation plant, although the 2011 nuclear accident in Japan due to earthquake and tsunami has produced a cloud over further international growth of nuclear generation of electricity.

1.9. You are a design engineer working for a natural gas transmission company. You are assigned to a design team that is charged with preparing the proposal to the state Public Utility Commission to build a plant to receive liquefied natural gas from ocean-going tankers and unload it into your company's gas transmission system. What technical issues and societal issues will your team have to deal with?

It is interesting how quickly things change in the energy field. When answers to the 4th edition were being prepared in 2008 it was correct to state that increased use of natural gas (NG) for generation of electricity had increased the price of NG such that it was economical to ship NG to the United States or Europe from Algeria, the Middle East, and the Caribbean. Now, in 2012 the situation is reversed. Application of directional drilling methods and the use of high-pressure fluids (fracking) to increase the permeability of the shale formations holding the gas, have uncovered massive amounts of NG in shale deposits in the Appalachia states, Texas, and North Dakota. This is more gas than can be utilized in the United States, so the local price of NG is severely depressed below the current price in Europe and Asia. Therefore, plants built to receive NG from overseas are being refitted to ship NG from U.S. sources overseas.

Natural gas is liquefied with refrigeration techniques to -260 F, which reduces its volume by a factor of 600. In the liquefaction process impurities such as water, hydrogen sulfide, and CO_2 are removed to leave nearly 100 percent methane. The liquefied natural gas (LNG) is transported in special doubled-hulled tankers with insulated tanks to maintain the LNG at proper temperature.

At the tanker terminal the LNG is transferred to double-walled storage tanks with insulation between the walls. The pressure must be regulated to minimize vaporization, for both economic and environmental reasons. The next step in the process is to pump the LNG to the vaporizer units, where it is heated under controlled conditions and introduced into the gas transmission pipeline.

<u>Technical Issues</u>

a. Design of the transfer piping system
b. Design of the storage vessels
c. Design of the vaporizer unit
d. As discussed below, safety is a paramount issue, but so is cost. A LNG transfer terminal can easily cost \$5B. There needs to be careful balance between these issues, with safety given top consideration.

<u>Societal Issues</u>
Safety is a major concern in working with LNG. Although LNG is not flammable or explosive, when exposed to 5 to 15 volume percent air it becomes highly flammable. If LNG hits water it vaporizes violently and rapidly, forming a gas cloud that can travel for several miles before dispersing to a safe level. If the gas cloud is ignited the flame can travel through the cloud back to the source of the vapor. Thus, the area covered by the fire can be extensive. A leak of LNG or a spill, if ignited, is called a pool fire. This is more localized than a cloud fire, but of longer duration. If LNG is accidently released from a pressurized containment the leak usually takes the form of a spray of liquid droplets and vapor. This is called a torch fire and delivers greater radiant heating than a pool fire. If the LNG is confined when ignited, it can result in a violent explosion.

When the transportation of LNG was first developed in the 1960s there were several major explosions and fires. Public concern arose over this new technology and as a result the U.S. government developed safety standards (49-CFR-193) and the National Fire Protection Association issued consensus standards (NFPA-59A) which have been continually updated. Since most LNG transfer terminals have been sighted in narrow harbours or waterways, there has been concern that a ship collision or grounding might cause a LNG release. More recently there is been concern that a terrorist attack could cause a fire or explosion. Accordingly, the U.S. Coast Guard has issued regulations dealing with the site selection and design of LNG terminals (33-CFR Part 127). Thus, the design of the LNG plant will be highly constrained by codes, regulations, and standards.

One final societal concern deals with the emission of methane, which is a potent greenhouse gas. Clearly, the design must give high priority to preventing venting or escape of methane to the environment. We started this discussion with the statement that natural gas is a preferred fossil fuel from the standpoint of global warming. However, there are some who claim that after all of the energy consuming processes of refrigeration and transportation are taken into account the net benefit of using LNG may not be beneficial to the environment.

1.10. You are a senior design engineer at the design center of a major U.S. manufacturer of power tools. Over the past 5 years your company has outsourced component manufacturing and assembly to plants in Mexico and China. Although your company still has a few plants operating in the United States, most production is overseas. Think about how your job as the leader of a product development team has changed since your company made this change, and suggest how it will evolve in the future.

Outsourcing manufacturing to a foreign country usually is done to take advantage of lower manufacturing wages. A secondary objective can be to increase sales in the country of manufacture.

Most product development depends on fine-tuning the design once it gets into production to improve upon design features that make assembly difficult and some parts more expensive to manufacture than expected. Occasionally, customer usage uncovers functional issues that need correction. These follow-on design activities often involve the modification of tools and fixtures used in production, or even the design of a modified part. Often these design tasks are performed by a small design staff that is in residence at the manufacturing location. There are also issues with maintaining quality standards with a workforce where language and culture are much different from the home country.

Therefore, moving the manufacturing plant offshore greatly increases the communication task of leader of the product development team. Early on he/she must visit the new plant and gain the confidence of the plant manager and the top engineer. It is also important to bring that engineer back to the home office to be trained in company values and procedures. Much communication will be done via the Internet, so effective communication protocols must be established.

1.11 The oil spill from BP well Deepwater Horizon is one of the world's greatest environmental disasters. Nearly 5 million barrels of crude oil spewed into the Gulf of Mexico for 3 months. As a team, do research on the following issues: (a) the technology of drilling for oil in water deeper than 1000 feet; (b) the causes of the well blowout; (c) the short-term damage to the U.S. economy; (d) the long-term effects on the United States; and (e) the impact on the owner of the well, BP Global.

The oil spill from the blow-out of British Petroleum (BP) well Deepwater Horizon is one of the world's greatest environmental disasters. Nearly 5 million barrels of crude oil spewed into the Gulf of Mexico for more than three months. Information for the specific questions, (a) through (d) can be found in the following places.

(a) The technology for drilling in water deeper than 10,000 ft. see HowStuffWorks: How Offshore Drilling Works. For general information on oil well drilling see Wikipedia: Oil well drilling.
(b) For information on the Deepwater Horizon accident see Wikipedia: Deepwater Horizon
(c) Sort-term impact: Damage largely affected people living in the Gulf Coast (Louisiana, Alabama, Mississippi, and the Florida panhandle). Immediate jobs lost in the fisheries

industry, fishing for shellfish and processing for sale nationwide. Since the accident happened May through August, which is the height of the tourist season for Gulf Coast beach resorts people lost jobs in hotels, restaurants, gift shops, and entertainment facilities. Most of these businesses depend on the summer months for most of their annual revenues. The Federal moratorium on deep sea drilling in the gulf affected people who work on drilling platforms or supply and service the platforms. All told, 50,000 to 100,000 highly paid jobs.

(d) Long-term impact on the United States: There is a major impact to the U.S. oil supply. The deep waters in the Gulf of Mexico are the largest largely undeveloped but proven source of crude oil in the U.S. Although drilling has been re-established it is with increased federal regulations that significantly increase costs, which drives out the smaller capitalized independent oil companies. The cost to rent a deep-water drilling platform is many hundred thousand dollars per day. With the moratorium in place for many months, these platforms could not afford to wait around unproductive, so many were moved to oil fields in Africa and South America. All these issues make it more difficult for the U.S. to become self-sufficient in oil production

CHAPTER 2

PRODUCT-DEVELOPMENT PROCESS

2.1. Consider the following products: (a) a power screwdriver for use in the home; (b) a desktop inkjet printer; (c) an electric car. Working in a team, make your team estimate of the following factors needed for the development project to launch each of the products: (i) annual units sold, (ii) sales price, (iii) development time, years, (iv) size of development team, (v) development cost.

The following are some reasonable estimates.

	Power screwdriver	Desktop inkjet printer	Electric car
Annual units sold	100,000	4,000,000	300,000
Sales price	$30	$150	$35,000
Development time	1 year	1.5 years	4.5 years
Peak size of team	3	100	800
Development cost	$250,000	$8 million	$500 million

2.2. List three products that are made from a single component.

A toothpick, paperclip, a wooden baseball bat, a crowbar, a water glass, a tent peg are some examples of a product consisting of a single component.

2.3. Discuss the spectrum of engineering job functions shown in Figure 2.7 with regard to such factors as (a) need for advanced education, (b) intellectual challenge and satisfaction, (c) financial reward, (d) opportunity for career advancement, and (e) people versus "thing" orientation.

Answers will vary.

In general terms, the need for advanced education decreases from research to technical sales in the spectrum of engineering functions. Many would say that research, development and design provide more intellectual satisfaction, but high job satisfaction can be found in any of the engineering functions depending on the individual and their circumstances. While R&D provides a high initial salary, the long-term financial rewards may be higher in production, sales, or management unless the researcher proves to be highly innovative.

Opportunity for career advancement depends greatly on the individual situation. Strong professional recognition can be provided by a lifetime in R&D. Career advancement within the corporation usually requires a broad exposure to most of the functions listed in Fig. 2.7. In general, the people-orientation increases in going from research to management.

2.4. Strong performance in your engineering discipline ordinarily is one necessary condition for becoming a successful engineering manager. What other conditions are there?

- Show strong organizational skills: abilities to work with people, meet deadlines, coordinate work, and administer paperwork.
- Show leadership: capacity for organizing and directing people.
- Strong communication skills: ability to write clearly and sell your ideas.

- Attitude: willing to spend time on administrative details for the good of the group; willing to delegate to and trust others; commitment to organizational goals.

2.5. Discuss the pros and cons of continuing your education for an MS in an engineering discipline or an MBA on your projected career progression.

The combination of an engineering degree plus an MBA provides the tools for broad corporate management. This will likely result in a career path that leaves technical work for marketing, finance, etc. An MS in engineering is needed for higher level design work and is the minimum educational requirement for a career in R&D.

2.6. Discuss in some detail the relative roles of the project manager and the functional manager in the matrix type of organization.

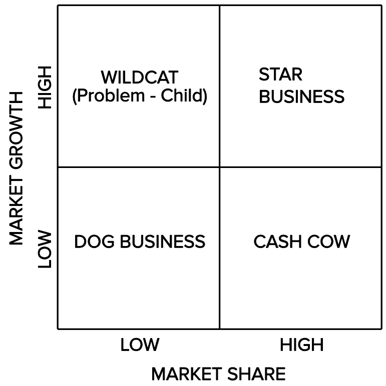
Project Mgr.	Functional Mgr.
Takes lead in scoping project.	Participates in development of project plans.
Takes responsibility for developing project needs for cost, schedule, and performance.	Participates in development of project resource needs for one specific specialty area.
Leads project team.	Makes detailed estimate of specialty area workloads.
Integrates and communicates project information.	Assigns personnel to project.
Tracks and assesses progress against plan.	Maintains technical excellence of specialty area.
Resolves conflicts.	Recruits, trains, and manages people in specialty area.
Communicates.	Communicates.

2.7. List the factors that are important in developing a new technologically oriented product.

If the following questions can be answered affirmatively then the success of a new product would be likely.
a. Is there an assured market for the product
b. Does the product satisfy a well-documented societal need?
c. Can the product be readily differentiated from its competition?
d. Is the product free from governmental regulation?
e. Do you have a proprietary position with the product?
f. Do you have the technical expertise to design, produce, and service the product?
g. Do you have sufficient financial controls in place to sell the product at a profit?

2.8. In Section 2.6.2 we briefly presented the four basic strategies suggested by the Boston Consulting Group for growing a business. This is often called the BCG growth-share matrix. Plot the matrix on coordinates of market growth potential versus market share, and discuss how a company uses this model to grow its overall business.

The word description of business portfolio strategy the Boston Consulting Group, discussed briefly in Sec.2.6.2 is shown pictorially here.



This is shown chiefly because the words cash cow, star, and dog businesses are commonly used in the business literature. However, these strategies should not be taken too literally. In a mature technology area it may not make sense to just milk the cash cow and kill the dog because mature technology businesses tend to result in very large sales volume. Therefore, it may make sense to do enough R&D to keep the cow healthy so that it can continue to provide the cash to start additional promising new tech businesses. Moreover, a moderate shift in a large market may turn a dog business into a cash cow.

2.9. List the key steps in the technology transfer (diffusion) process. What are some of the factors that make technology transfer difficult? What are the forms in which information can be transferred? Use your experience to provide answers.

Answers will vary.

Steps in technology transfer:

a. Information must be prepared in a form suitable for transmittal.
b. An appropriate audience to receive the information must be identified.
c. Information must be transmitted to individuals who can act on it most quickly. These people must be able to understand the new information and have a position in the organization to allow them to act on it.

Factors which make technology transfer a difficult process are:

a. The quantity of scientific/technical information available.
b. The need for feedback between user and originator.
c. The need for multiplicity of communication channels.
d. The need to provide for security of proprietary information. This is often difficult to achieve when outsourcing design and/or manufacturing functions.

Information can be transmitted in the following forms:

a. Technical reports and papers
b. Newsletters
c. Data sheets
d. Workshops and seminars
e. Internet
f. Employees changing jobs
g. Telephone “hot-line”.
h. Service representatives, technical salespeople, extension agents.

2.10. John Jones is an absolute whiz in computer modeling and finite-element analysis. These skills are badly needed on your product development team. However, Jones is also the absolute loner who prefers to work from 4 P.M. to midnight, and when asked to serve on a product-development team he turns the offer down. If ordered to work on a team he

generally fails to turn up for team meetings. As team leader, what would you do to capture and effectively utilize John Jones's strong expertise?

John Jones is essential for the success of the team, so by both Jones and the team must compromise. Much work of the team is done outside of team meetings, so that Jones' unusual working hours will not be a hindrance to team progress provided some arrangement can be made for communicating with him.

It is important for Jones to be at team meetings where the group expertise is used in making critical decisions. Here is where compromise is required. For example, it might be decided that every third meeting will be held from 4 to 6 pm, accommodating Jones' schedule and requiring flexibility from the rest of the team. The team leader, and sponsor if needed, must obtain a firm pledge from Jones that he will faithfully honor this schedule. With realization of the accommodations the team members are making to utilize his special expertise, it is even possible that he will agree to come in early so that team meetings can be held in the early afternoon.

2.11. An important issue in most product development projects is making sure that the project schedule can take advantage of the "window of opportunity." Use Figure 2.6b to help explain what is meant by this concept.

For any product development project there is a window of opportunity, or market window, in which customers are receptive to the product and no obvious competition exists. An experienced product development manager always lives in fear of the window being closed by the competition. Yet in the absence of any known competition it is often difficult to instil the needed urgency in the development team. When the market window closes the team must play "fast follower" and lose the advantages of being first to market.

Another type of window of opportunity is found in the development of large technical systems, such as a military airplane. For strategic reasons the system must be developed over multiple years, and performance improvement achieved with new technology, has a high priority. As suggested by Fig.2.6b, there is a gap between what is currently achievable in some critical technology, and R&D currently underway. This gives promise of improving performance. But the program can only keep the technology window open for a limited number of months. If the new technology is not proven capable in the time window the program must go with the next best alternative. The new, better technology might not get its chance until the next aircraft of its type is developed 20 years in the future. To better manage this problem many agencies or industries have developed technology roadmaps that attempt to give a timeline for the advancement of a critical technology.

2.12. The development of the steel shipping container that can be transferred from a ship to a truck or train has had a huge impact on world economies. Explain how such a simple engineering development could have such far-reaching consequences.

Prior to the adoption of the shipping container, consumer and industrial goods were shipped in crates, boxes, and barrels in the hold of a cargo ship (the break-bulk system). This freight was loaded and later hauled out of the bowels of the ship with cargo nets and winches and the hard labor of large gangs of stevedores. The process was very labor and time consuming. It often took 3 to 5 days to unload a cargo ship.

The introduction of steel shipping containers in early 1960s resulted in major improvements in port handling effectiveness, significantly lowering shipping costs. This eventually made it cost effective to make products in China and ship them to the U.S. consumer.

Malcom McLean is responsible for the concept and implementation of a complete containerized freight transportation system consisting of:

- standardized steel containers, 20 or 40 ft. long × 10 high × 8 wide.

- specialized container ships that carry stacked containers on deck as well as below in the cargo hold.
- special designed cranes portside to load containers directly on flatbed railcars or tractor-trailer trucks.
- computerized system for quickly identifying containers and their contents

In addition to the technology of the new shipping system, several social and political innovations were necessary before containerized shipping became widely accepted. These were:

- Protracted negotiations with the longshoremen unions before they agreed to accept the early retirement buyout plan that reduced their ranks to the current smaller workforce.
- Major changes in the U.S. Interstate Commerce Commission regulations
- International standardization for container dimensions, capacities, and corner fittings for attachment to the crane.
- Development of special dockside cranes along with specialized computer software for deciding where to locate each container for optimum retrieval.

Today, 90 percent of all non-bulk cargo worldwide moves in containers.

References: Marc Levinson, *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, Princeton University Press, 2006
Wikipedia: see Containerization

2.13. Explain the physics behind the charge-coupled device (CCD) discussed in Section 2.6.1, and explain why this was the invention that made digital photography practical.

A charge-coupled device (CCD) is an electrical device that is used to create images, store information, or transfer an electrical charge as part of a larger electronic system. The CCD is the heart of the digital camera, where it takes an optical input and converts it into an electronic signal which is then processed to produce an image. The CCD is also used in fax machines, photocopiers, bar-code readers and video cameras.

A CCD chip consist of an array of square or rectangular silicon picture elements (pixels) that are created on the surface of the chip by a semiconductor micro fabrication process in a two-dimensional pattern, When the photons in the light beam hit a pixel an electron is released from the valence bonds of the silicon. This produces a free electron and a “hole” in the silicon valance shell where the electron was originally located. An electron has a negative charge and a hole has a positive charge. The number of electrons liberated is proportional to the number of photons striking the pixel.

In an ordinary photographic process, the image is produced by the chemical process that occurs when the photons of light strike the coated film. If the CCD pixel array is subjected to light for a specified exposure time the number of electrons released in each pixel must be captured so they can be counted and converted digitally to an image. This is done with a series of tiny electrodes, called gates, which are buried in each pixel during its fabrication. The array of electrodes produces a positive potential to hold the electrons in place, in their “electron-bins” within each pixel, until the exposure is completed. Then the number of electrons in each pixel is read out by controlling the potential, pixel by pixel, so the electrons in each bin travel together and can be counted.

The original charge-coupled devices were pure silicon, but currently CCD sensors are being made from Complementary Metal Oxide Semiconductors (CMOS). Integrated circuits made by the CMOS process represent the bulk of current IC production, so there is a large cost advantage to making CCDs by CMOS. This has resulted in large scale use of charge-coupled devices. There is, however, a tradeoff with image quality from CMOS CCDs, so they are not used in applications where extreme sensitivity is required.

2.14. What other technological developments besides the steel shipping container were required to produce the global marketplace that we have today? Explain how each contributed to the global marketplace.

This requires independent research by students. Answers will vary.

Other technological developments, beside the shipping container, that have made the global marketplace a possibility are:

- Air freight – to deliver critically needed parts overnight compared with the three-week ship travel time from China
- Internet communication – for rapid communication with overseas suppliers, and for transmission of CAD drawings and other product development documents
- Electronic funds transfer – rapid settling of accounts is crucial for international trade.
- Radio–frequency identification (RFID) tags that make it possible to quickly identify what is inside each container.
- Global positioning sensing (GPS) that makes it possible to track location of each container.

2.15. The demand for most edible fish exceeds the supply. While fish can be raised in ponds on land or in ocean enclosures close to shore, there are limitations of scale. The next step is mariculture—fish farming in the open sea. Develop a new product business development plan for such a venture.

Answers will vary.

<u>Business Plan</u>
According to the National Marine Fisheries Service, 40 percent of the important species of fish are being taken from the sea at a rate faster than they can be replaced. Estimates by the U.S. Department of Agriculture are that the current fish harvest of 97 million metric tons per year will be far below the projected demand of 175 million metric tons in 2025. Aquaculture enterprises, in which fish are raised in enclosures close to shore or in ponds on land, cannot achieve the economy of scale needed to address this problem.

The solution is fish farming in the open sea- mariculture- combining technology learned from deep sea drilling and aquaculture. Huge concrete and steel cages will radiate from a central column anchored to the floor of the Gulf of Mexico. The cages can be raised and lowered by buoyant tanks and rotated around a core support structure to aid in cleaning the cages. Pelletized food will be transmitted to the cages by pipes.

Initially, high value species like red snapper, striped bass, and mahi mahi will be raised. Depending on the species, one 10,000 sq. ft. unit can produce 3 to 5 million pounds per year of fish. It will take 20 pounds of feed@$0.35 per lb.to grow 10 pounds of fish, that will yield 3 pounds of fillets selling for $6 to $8 per lb. wholesale. Once the bugs are worked out of the technology, the return on investment could approach 100 percent.

Source: W.G. Flanagan, *Forbes*, Oct. 23, 1995, pp. 328–329.

2.16. Conventional thinking in product development has been that innovation starts in advanced developed countries like the United States and Japan. Products marketed in countries where the average income is much lower often are older models of U.S. products or used but still serviceable equipment. Several U.S. multinational companies have established R&D labs in India and China. Originally this was to take advantage of the large number of well-educated engineers who could be employed at salaries much lower than the going U.S. rate, but soon it was found that these engineers were adept at developing products for sale to the mass markets in these local countries. Typically, these are products with somewhat reduced functionality, but they still are useful quality products. Now these

U.S. companies are beginning to market these products in the United States as a low-cost product line that is attractive to a new low-end market segment. Search the business literature for examples of this new approach to *trickle-up* product innovation. Discuss advantages of this new approach to product development and discuss possible risks.

Answers will vary.

Some examples of trickle-up products:

- GE portable electrocardiograph machine that sells for $2500.
- Tata Nano automobile that sells for around $3500 in India
- Acer Notebook sells for $250

Advantages of the Trickle-Up Approach to Product Development

- The obvious advantage is that it introduces a new product line for sale in the U.S. to a market segment that has not been reachable because of the price of the product.
- Another advantage is that it is a big morale booster to in-country engineers to see the product they developed now being bought in the U.S.

Possible Risks

- The major risk is that the lower price product might cannibalize sales of higher priced products with higher profit margins.
- The second risk is that a low price product line might carry a stigma of shoddy workmanship and jeopardize the brand name of the product. Quality must be maintained over all else. Will the customers really be satisfied with a smaller range of functions in the product?
- How the new product is advertised and marketed will be critical to the protection of the brand.

CHAPTER 3

TEAM BEHAVIOR AND TOOLS

3.1. For your first meeting as a team, do some team-building activities to help you get acquainted. (a) Ask a series of questions, with each person giving an answer in turn. Start with the first question and go completely around the team, then the next, etc. Typical questions might be: (1) What is your name? (2) What is your major and class? (3) Where did you grow up or go to school? (4) What do you like best about school? (5) What do you like least about school? (6) What is your hobby? (7) What special skills do you feel you bring to the team? (8) What do you want to get out of the course? (9) What do you want to do upon graduation? Do a brainstorming exercise to come up with a team name and a team logo.

Generally, teams composed of engineering students are not very interested in as icebreakers. One reason is that by the time they get to be juniors or seniors they are used to forming and working in teams. However, in the initial team meeting they should take the time to introduce themselves in some detail and to exchange complete contact information. If the situation calls for more of a warm-up or icebreaker, there are many websites that sell materials for team warm-up sessions. One useful site with free information is: http://www.teampedia.net/wiki/index.php?title

3.2. Brainstorm about uses for old newspapers.

Some starter ideas: wrap fish; line the parrot's cage; print a book; insulate a house, make more paper (recycling); fly swatter; rain hat; logs for fireplace; confetti; bookmark; protect floor.

Some "further out" ideas: ground cover for star gazing; emergency lipstick blotter; place on seat at ball games; practice origami; wrap dishes when moving; make a Halloween mask; rollup and use as a back scratcher.

3.3. Teams often find it helpful to create a team charter between the team sponsor and the team. What topics should be covered in the team charter?

The following is a typical format for a Team Charter. In an industrial setting the draft of the Team Charter is developed between the sponsor and the team leader, with the help of the facilitator. The draft of the charter is presented to the team at an early meeting. The modified charter is reviewed by the sponsor, and if acceptable, transmitted back to the team. In the college situation the instructor usually is the sponsor. Often there is not a designated team leader, so the team develops the Charter in conjunction with the instructor.

<u>Project Title:</u> A brief 3–4 word title for the project

<u>Problem Statement:</u> A one or two sentence description of the stimulus for creating the team. The problem statement should not focus on a particular solution and should attempt to describe the problem from the customer's perspective.

<u>Need to Address the Problem:</u> Cite survey data. operational data, cost statistics, anecdotal evidence, etc. that justify the need to organize this team.

<u>Project Scope:</u> List open-ended questions which frame the dilemmas faced by the current process owners and service providers in attempting to deal with the problem. Describe the boundaries of the problem. List the issues that are outside of the bounds of this project.

<u>Final Report Expected By:</u>

Interim Milestones Required of the Team: List any preliminary products required of the team prior to its completion.

Resource Issues: Describe any resources set aside to assist the team in its work. Describe any limits on resources that should affect team recommendations.

Project Sponsor:

Team Leader:

Team Membership:

Team Facilitator:

Others Influenced by the Problem: List interested individuals, offices, projects, committees, who might act as a resource to the team. Also list individuals who will be kept informed of the team's progress and recommendations.

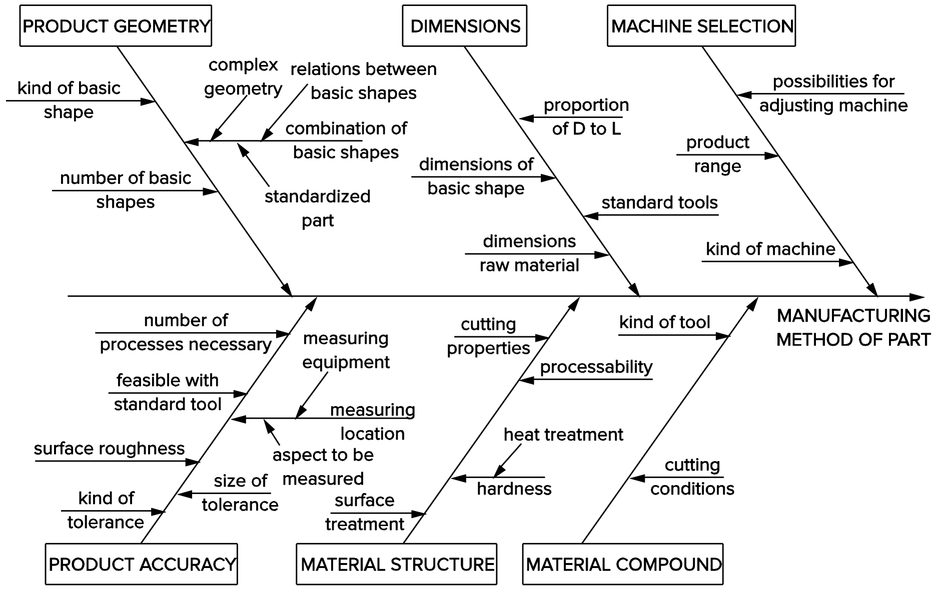
Implementation Plan: This is to remind the team and the sponsor that an implementation plan is required, in addition to recommendations for solving the problem. The sponsor should indicate the degree of specificity expected in this implementation plan.

Students often have difficulty differentiating between the Team Charter and the Team Guidelines. The Team Charter is an agreement between the team and team sponsor (usually the instructor or some other faculty advisor). It serves chiefly to make sure that the team and sponsor agree with the problem definition and scope, and the required deadlines and project deliverables. It also forces the team to think about its organization. The Team Guidelines describe the details of the process by which the team will work to be successful. Of importance is an honest description of what the team agrees to do about a team member who misses team meetings or who does not follow through on assignment made at team meetings. In the case of a "problem member" of a team, a signed Team Guideline is a good first step toward arriving at a resolution.

3.4. To learn to use the TQM tools described in Section 3.6, spend about 4 hours total of team time to arrive at a solution for some problem that is familiar to the students and that they feel needs improvement. Look at some aspect of an administrative process in the department or campus. Be alert to how you can use the TQM tools in your design project.

Typical problems that attract student interest are:
- Improving the curriculum
- Making study aids more available to students
- Increasing the hands-on aspects of the curriculum

The TQM tools that are most often involved in technical design decisions are:
- Brainstorming for problem definition and concept generation.
- Affinity diagram for bringing clarity to a multidimensional problem and breaking it down into more manageable chunks.
- Cause and effect diagram for laying out the factors involved in a problem. See diagram below for factors in selecting a manufacturing process to make a part.
- How-how diagram for stimulating and organizing solutions to design issues



3.5. The *nominal group technique* is a variation on using brainstorming and the affinity diagram to generate and organize ideas for the definition of a problem. Do research about NGT, and use it as an alternative to the methods discussed in this chapter.

The nominal group technique (NGT) is a method for group idea generation and ranking the ideas for consensus. Often it starts with silent brainstorming (brainwriting) to generate the ideas. The use of the term "nominal" in this method comes from the fact that it often starts out with a nominal, i.e., silent and independent idea generation, group activity, and independent evaluation by each team member.

Next the ideas or topics are written on a blackboard. If the number of choices generated by brainstorming is large, it may be useful to employ some list reduction method. Start with the entire list of ideas displayed so that everyone can see them. For each item ask the question, "Should this item continue to be considered?" A simple majority vote keeps the item on the list; otherwise it is marked with brackets. At the end of voting, any item marked with brackets can be put back on the list by a single team member. Next, each idea is compared with all others, in a pairwise fashion, to decide whether they are different ideas. If all team members feel they are essentially the same, then the ideas are combined with a new wording.

The last step of the NGT involves decision making, with the members of the team acting independently and anonymously. If the number of choices is relatively small, then each person can rank order the choices. For example, if there are five choices, A, B, C, D, E, each person would associate a value of 1 to 5 to each choice, where 5 is best. The values for all members of the team would be combined, and the choice with the highest score would be the team's first choice. When the number of choices is large, e.g., 20, it becomes difficult to rank order so many items. Here, the "one-half plus one" approach is often used. The team is asked to pick the top 11 items (20/2) +1 in rank order. Again, the ranking of each team member is combined to arrive at the overall team decision.

A variation on decision making by ranking is rating by multivoting. Each team member receives a number of votes, usually about one-third of the total number of choices. You can distribute these votes among as many or as few choices as you wish. Often the voting is done by giving each team member the appropriate number of colored sticky dots, and the voting is done by going to the chart of options and pasting them beside your choice(s). Multivoting usually proceeds in stages. In the first round those choices with only a few votes are eliminated. The number of votes per member is adjusted, and a second round of voting is held. The process is repeated until a clear favorite emerges.

The advantage of the NGT is that team members with differing styles of providing input are treated equally because the process imposes the same format requirement on each member. Strong personalities do not unduly influence the outcome. The volume of the loudmouth is turned down while the soft-spoken voice is more clearly heard. While the method reduces the pressure to perform, because of the lack of group interaction during idea generation, it has a lower chance of generating truly unique ideas. Also, note that NGT combines idea generation and evaluation into a single session. Thus, it often is used in instances where time is very short and a solution with consensus must be found quickly.

3.6. There are certain short statements (killer phrases) that unthinking persons often say during brainstorming sessions that destroy the free flow of ideas. The team should make a list of 10 or 12 killer phrases as a reminder of what not to do when brainstorming.

The following are common words and phrases that when used in a brainstorming session often inhibit the free flow of ideas.

It won't work.   Really!   That's an old idea.   That's crazy   Too expensive!
We did that before and it didn't work.   You don't understand the problem.
It's against policy (the rules).   We don't have time for that!   Yes, but . . . .
How could you be so stupid to think ….   Here we go again.   It's not our responsibility.

3.7. After about 2 weeks of team meetings, invite a disinterested and knowledgeable person to attend a team meeting as an observer. Ask this person to give a critique of what he or she found. Then invite this person back in 2 weeks to see if you have improved your meeting performance.

Suggested issues to consider when evaluating team performance:

- Does the team understand what they are to accomplish at the meeting? Do they follow an agenda?
- Is there effective leadership?
- Is there a feeling of collegiality and easy give and take between members?
- Do all team members appear to contribute?
- Does the team reach decisions efficiently? Do these appear to be mainly consensus decisions?
- Does the meeting end with well-defined tasks for each member to complete before the next meeting (action items)?

3.8. Develop a rating system for the effectiveness of team meetings.

Assigned student observers should be invited to team meetings to assess the effectiveness of the planned work of the meeting. Inevitably, team member behavior is a big factor in team effectiveness. A process for evaluating team member behavior and a policy for implementing it are needed

One useful team member evaluation form is shown below. In order to be effective we find that this survey should be administered three times during the semester: (1) after an early project deadline; (2) at the midpoint of the class, and (3) at the end of the project. In the initial evaluation, emphasize that the peer evaluation is aimed at identifying areas for growth of the team members. Generally, students will initially give each other strong positive ratings, often giving each member an identical high rating. Emphasize that giving realistic ratings is expected in professional practice. As the use of the peer evaluation instrument continues students gain better understanding of their team and what is expected in peer evaluation. Students will be more responsive and candid when the survey is administered online rather than during a class period.

An important way to give credibility to peer evaluation is by insisting that students who receive low peer ratings in the first evaluation request feedback and develop a plan for improvement. As a first step, ask the student to meet with their team to discuss the perceived weakness and develop a plan for improvement. If this is not possible, then the instructor should discuss the problem with the student.

Peer Evaluation

Your Name: ____________ **Instructor Name:** ______________

Team Name: ____________ **Section Number:** ______________

Almost Never / About Half / Almost Always

1 2 3 4 5

Circle one rating score in each box to indicate your perception of each member's performance (including you own) with respect to the specified behaviour. Justify ratings that are significantly different specified behaviour from the team's norm.

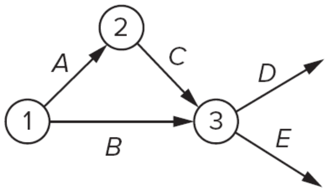
TEAM MEMBER BEHAVIOR	**YOUR NAME**	**FULL NAMES OF OTHER TEAM MEMBERS**				
Regularly attends group meetings	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Comes prepared for meetings	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Asks for assistance as needed	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Delivers work that meets group standards	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Completes work in time for collaboration	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Identifies resources for team progress	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Responds to group communication	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Is respectful of others in meetings	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Provides constructive feedback	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Completes a mutually agreed upon amount of work	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Sum of Ratings:						
Rank your team members wrt Intellectual Contribution						
Rank your team members wrt Work Effort						

3.9. Keep a record of how you spend your time over the next week. Break it down by 30-minute intervals. What does this tell you about your time management skills?

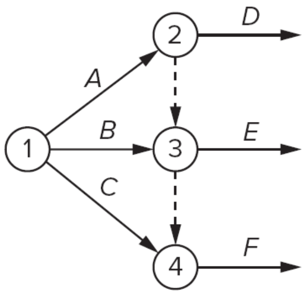
Include the following categories: class time; personal time (eating, sleeping, personal hygiene), commuting time; fitness time (exercise); study time, class project time, working time; extracurricular activities time; socializing.

3.10. The following restrictions exist in a scheduling network. Determine whether the network is correct, and if it is not, draw the correct network.

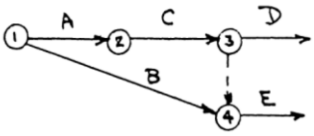
(*a*) A precedes C
B precedes E
C precedes D and E



(*b*) A precedes D and E
B precedes E and F
C precedes F



(a) The scheduling network is incorrect as shown in the text, because B precedes both D and E, while according to the problem it should only precede E. The correct network is obtained by introducing the dummy activity connecting events 3 and 4. Note that a dummy activity has zero duration.



(b) The network in 4.10(b) is incorrect because as drawn A precedes D, E, and F while the problem states that A precedes only D and E. The correct network is