Careers and Profiles

Designing for the Environment

Jenny Tse is an architect in Alberta. It's important that Jenny understands the natural forces in the environment. Buildings in Canada have to last through the heat of summer, the cold of winter, wind, snow, rain, and even earthquakes!

"In Hong Kong, the weather is always warm and there is not much space for building. It was a fun and interesting adjustment to adapt myself to cold climate design," Jenny says. "For example, in the Arctic region, buildings are put on stilts. This stops the building's heat from escaping into the ground, which will melt the permafrost and cause the building to collapse."

How does Jenny plan a house? First, she starts drawing designs. These drawings show her ideas about the shape of the house and the arrangement of the rooms. If Jenny's clients like her design, she makes working drawings of the house. These are very detailed drawings that tell the builder how to construct the house. When construction starts, Jenny has to check the construction site often to make sure the builder is following her design and instructions. Then, finally, she hands the new house over to its new owners.

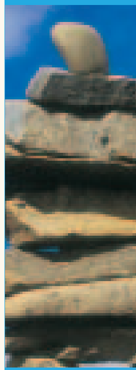
Figure 3.18 Jenny Tse was trained in Hong Kong and moved to Canada in 1969.

Figure 3.19 Jenny was a design architect of this building, Mineral Springs Hospital in Banff, Alberta.

Figure 3.20 Edmonton Buddhist Research Institute, Edmonton, Alberta, is another one of Jenny's designs.

Jenny's job changes all the time and gives her lots of challenges. Still, she says she loves it. "Students who want to be architects should be creative and love to work with people," says Jenny. "An architect's life is exciting, and you will learn a lot, too!"

1. Why must architects have a good understanding of the natural environment for which they are designing structures?
2. If you were an architect, which part of planning and overseeing the building of a house do you think would be most challenging? Why?



Assess Your Learning

1. As part of a community parks restoration project, students in a grade 7 class have volunteered to design and build a bridge across a 5-m-wide stream. They can use only non-living, natural materials found in the forest and a hand saw.
   a) Based on your knowledge of structural components, what suggestions would you make to the students for designing and constructing the bridge?
   b) What problems do you foresee happening as the bridge is used over time and under a variety of weather conditions?
2. Look at the typical brick wall shown in Figure 3.21. Why are the bricks in the wall not stacked directly on top of each other?

Figure 3.21 Question 2

3. Explain how each of the following methods can help improve the joining between two components:
   - sanding the surface of a smooth material to make it rougher
   - adding more weight (load) to an object sitting on a base
4. A weight lifter puts a powder on his hands before picking up a pair of heavy weights. Why?
5. Make a concept map that puts together what you have learned about designing a strong and stable structure. Compare your map with that of other students until you have included as many concepts and terms as possible. Put a question mark beside any concepts that you need to review or would like to learn more about.

Focus On SCIENCE AND TECHNOLOGY

Technological problems often have many solutions, involving different designs, materials, and processes.

Reflect on what you learned about materials in this section.

1. What were some of the properties of materials you read about?
2. Why is it important to evaluate the appropriateness of methods of joining for individual structures?
3. How could you apply what you have learned about materials and methods of joining to solve a technological problem such as how to build an emergency winter shelter?

4.0 Structures are designed, evaluated, and improved in order to meet human needs.

Key Concepts

In this section, you will learn about the following key concepts:

- margin of safety
- structural stability

Learning Outcomes

When you have completed this section, you will be able to:

- describe methods to increase the strength of materials and improve designs
- identify environmental factors that can affect the stability and safety of a structure
- analyze a technological design or process according to costs, benefits, safety, and impact on the environment

If you could travel back in time to talk with the cyclist in the black-and-white photograph above, what do you imagine he would say about his new bike? Would you expect him to feel that the bike was strong, efficient, and safe to ride? Would he feel his needs were being met by technology? What might he say about how the design of this bike was an improvement over earlier models?

Now imagine having the same conversation with the cyclist in the colour photograph. Do you think she, too, would feel that her bicycle was strong, efficient, and safe to ride? What improvements in her "state-of-the-art" bike might she identify compared to the bike of her counterpart in the black-and-white photograph?

Few structures remain unchanged in design once they are created. In this final section of the unit, you will learn about the processes used to develop, evaluate, and improve human-made structures so that they do the job we want them to in a safe, reliable, and cost-efficient way.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Building Safe Structures in All Environments

All structures are created to satisfy human needs. These needs may vary widely, but the one common to all structures is safety. Since so many environmental factors can affect the stability of a structure, designing for safety is a constant challenge.

Figure 4.1 Although all structures are created to satisfy a human need, none would be completely successful if their designer did not take environmental factors into account.

Margin of Safety

Safety is important to all designers. However, since it is impossible to make anything perfectly safe, designers work with a **margin of safety**. This refers to the limits within which a structure's safety performance is felt to be acceptable.

Think of speed limits on roads and highways. Cars and trucks are designed and built to move safely within these limits. While vehicles are intended to be driven at these speeds, designers still need to make cars and trucks that are safe to drive at slightly higher speeds. The margin of safety in this case might be 30 km/h or 40 km/h faster than the common speed limit.

Tire pressures are determined with a margin of safety also. The manufacturer will have assessed aspects such as size of tire, vehicle load and increased temperature due to use, weather or speed. If someone over-inflates the tires of a vehicle in order for it to carry a heavier than normal load, the margin of safety has been decreased. If a tire hits a pothole, there is a greater chance it will have a blow-out.

Building components are designed in the same way. For example, the steel beams in a bridge must be able to withstand three or four times their maximum intended load.

Figure 4.2 Road signs show drivers the safety limits that have been calculated by highway engineers.

Testing for Structural Safety

One way of finding out how safe a structure is before it is in full operation or available on the market is to test how well it can withstand the forces acting on it. Many such tests are extreme.

New hockey helmets are hammered against a steel anvil at almost 15 km/h, or test cars are driven into brick walls at 25 km/h. Helmets must be strong enough to protect a player's head against all types of collisions. Car bumpers must protect the front of cars against damage during impact. Testing occurs at all stages of a product's development, from choosing its components and testing them, to testing the design (e.g., by computer modelling) and testing the final product before approval for consumer use. In the activity where you will build a model of a drawbridge, you will test a component as well as the final product. You will also determine a margin of safety.

*info***BIT**

Brought Down by Ice

Six days of freezing rain damaged this hydro tower in Quebec. What forces caused it to collapse? Would a coating of ice be a static or a dynamic load? Suggest ways that a tower like this could be protected from this load.

A downed hydro tower and power line, damaged by the 1998 ice storm in Quebec and Ontario.

Monitoring Structural Safety

Another method of evaluating the safety of a structure is to look at how frequently that type of structure fails and why. This can be done through a process called monitoring, in which experts keep track of how well the structure performs. Information can also be gathered through surveys that ask the users of particular structures what their opinions of the structures are.

Accounting for Environmental Factors

Climatic Conditions

In many parts of the world, buildings, bridges, vehicles, and other outdoor structures must regularly withstand the forces of heavy snow, rain, and wind. Other climate-related factors are intense heat, intense cold, very high humidity, and extreme dryness.

Building on permafrost is a particular challenge in frigid regions around the world, such as Canada's North. Permafrost is a permanently frozen layer in the ground. Although frozen solid in the winter, the upper portions of permafrost melt in the summer, making the ground spongy. Without solid foundations, structures built on these areas undergo structural stress that usually leads to failure. Technology is helping to solve these problems.

Terrain Conditions

Unstable soils and steep terrain make building stable structures difficult. In areas where soils are soft or shifting, special construction techniques must be used. This problem wasn't taken into account when the Empress Hotel in Victoria, B.C., was built in 1905 on landfill over what used to be mudflats. A few decades ago, engineers found that the hotel had sunk about 75 cm over the years. The large stone building has since been "shored up" beneath with concrete supports and pilings.

Areas that are low lying often suffer flooding or pounding from storm waters. While it is debatable whether people should live in those areas at all, some structures, such as lighthouses, must be there. Building them to withstand the forces of water and wind is always a challenge.

On steep mountainsides, hill slopes, and cliffs, mass movement of snow, rock, and mud is a common hazard. Avalanche and rockfall tunnels are often built over highways where this danger exists. They must be able to support massive loads.

Figure 4.3 In Malibu, California, heavy winter rains during 1983 caused landslides on steep, unstable slopes. As a result, several homes suffered serious structural damage.

Earthquake Risk

When an earthquake shakes and heaves the ground, some structures fail and may even topple to the ground, while others remain standing. The stable structures protect people and property. Not all areas are subject to the risk of severe earthquakes, but in those that are, the structures must be designed and built to resist the external and internal forces acting on them.

Figure 4.4 A powerful earthquake struck western Turkey on August 18, 1999, killing more than 2000 people. Many victims were trapped in collapsed buildings such as the ones shown here.

Check and Reflect

1. Explain what is meant by "margin of safety."
2. List five environmental factors that structural designers and builders might have to take into account, depending on where they locate their structures.

Experiment ON YOUR OWN

BUILD A WORKING MODEL OF A DRAWBRIDGE

Before You Start ...

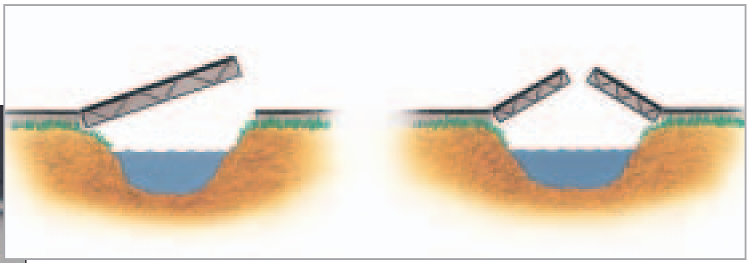
You are now familiar with the different types of structural forces, the characteristics of structural stability, and the nature of structural stress, fatigue, and failure. You've also learned a little about how designers test for structural safety. Here's an opportunity for you to use your knowledge to design, construct, and test a bridge that has moving parts.

The Question

How can a structure with movable parts be built so that it is functional, but strong and safe?

Design and Conduct Your Experiment

1. Working by yourself or with a partner, plan how you could design a model drawbridge that has either one or two movable sections.
2. Discuss what materials and equipment you will need to build and test your model. For example:
   a) What kind of building materials will you use?
   b) Set criteria for one of the building materials. Test the material to see that it meets your criteria and has a 25% margin of safety.
   c) How will you lift and lower the movable sections?
   d) How will you test the structure's strength and stability?
3. Draw up a plan. Include in it a detailed sketch of your design, a list of the materials you propose to use, and a brief description of how you will test the completed structure. Show this plan to your teacher before you proceed.



4. Build your model and test it. Modify the structure, if necessary, to correct practical problems or improve overall strength or stability. Be prepared to demonstrate to your class how the drawbridge works.
5. Present your experimental design and findings to the class. State what limits you would recommend for live load and what your margin of safety is. Describe how well your model meets those criteria.

Figure 4.5 Step 4

4.2 Strengthening Materials to Improve Function and Safety

As you've seen throughout this unit, a goal of science and technology is to provide solutions to practical problems.

A structure such as a bicycle is designed and built to meet a human need. Gradually, through use and formal and informal processes, it is evaluated and tested. From the results of these tests, new designs and materials may be applied. Sometimes, it is trial and error in technological problem-solving that brings about the changes. Other times, it is advances in scientific knowledge that lead to change, as when methods to increase the strength of materials are discovered or new materials are developed.

Altering Materials for Strength

One way that many structural problems can be solved is to combine materials and components in new arrangements. This lets you take advantage of the best characteristics of each.

*info*BIT

Body Fusion
At birth, a baby's skeleton contains 350 bones. As the baby grows through childhood and into an adult, many of the bones fuse together, until the total number of bones is 206. This fusing is nature's way of strengthening and reinforcing the frame of a human for adulthood.

Give it a **TRY** ACTIVITY

Designing a Better Backpack

No structural design, not even that of a backpack, stays the same over time. Humans are always working to adapt and improve designs to meet people's needs better. Here's your chance to do that yourself. The approach you use in this activity to evaluate and improve the backpack is the same basic process you would use to analyze and improve any technological design.

- Prepare a short questionnaire and survey a sample of students. Your survey should find out what the students use backpacks for, under what conditions they use them, and how long, on average, they find a backpack lasts. You should also ask whether your respondents have ever experienced backpack failures and, if so, what parts of their backpacks failed.
- When you have your survey results, work with a small group to brainstorm how the components, materials, and fasteners in backpacks could be improved and strengthened. How could backpacks be made so that they provide more efficient service for a longer time?
- Summarize your ideas and present them to the class. With all the groups, debate the advantages and disadvantages of the various suggestions.

Corrugation

Imagine you wanted to design a way of packing two layers of small glasses in a box. All you have on hand as packing material is some heavy paper. The divider between the two layers must be strong enough to resist bending under the load of the top layer of glasses. It must also be smooth enough to keep the glasses upright. You've learned that triangles and arches are strong shapes. If you folded a flat piece of paper into a series of triangles or arches, that would make a strong support. The only problem is, the folded surface would cause the top glasses to fall over.

What's the solution? If you combined the folded piece of paper with two smooth ones, the result would be a sandwich with a strong interior and a smooth exterior—perfect for making a sturdy, yet lightweight, divider (Figure 4.6).

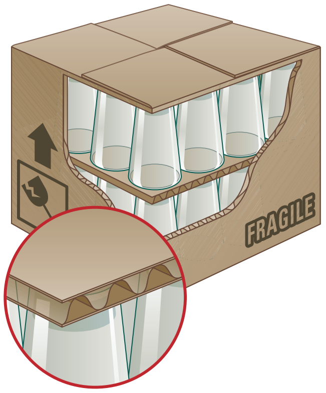


Figure 4.6 Corrugation provided the solution to this packing problem.

Corrugation is the process of forming a material into wave-like ridges or folds. Corrugated cardboard and corrugated metal are common examples.

Lamination

Gluing layers of a material together to create a strong bond is called **lamination**. Laminated materials are stronger than a single piece of the same material of the same thickness. Some laminated beams, for example, are made of short pieces of wood. Overlapping, interlocking, and gluing the members into single beams makes them better than solid beams for supporting heavy loads.

Have you ever looked carefully at plywood? Did you see the five or seven layers? It is laminated. Kitchen counter tops have a waterproof layer laminated onto wood. Another example of a laminated product is automobile safety glass. It consists of two pieces of glass with a layer of plastic in the middle. If the glass is hit by a flying object, the outside layer of glass may break but the plastic layer is elastic and it will hold the broken pieces of glass together.

Strengthening Component Arrangements

If stronger materials to build stronger components are not available or affordable, using different arrangements of components is often a good solution. Making greater use of trusses and arches, for example, can provide the strength that is missing. Even adding small supports for reinforcement (see Figure 4.7) can make structural components stronger.

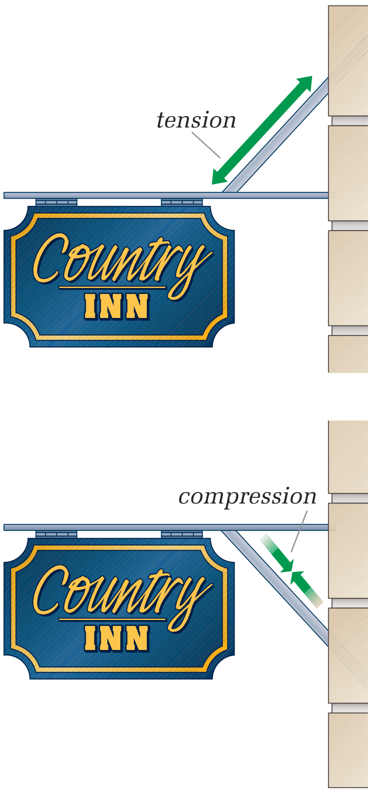


Figure 4.7 The component that provides support for the sign in (A) is called a "tie." It works by resisting tension in the structure. The component that provides support for the sign in (B) is called a "strut." It works by resisting compression in the structure.

Problem Solving Activity

Building Strong

Recognize a Need

One of the most popular annual events in your school is "The Year's Greatest Designers" competition. The theme this year is "New Idea, Old Materials." You and some friends decide to enter the competition.

The Problem

Your challenge is to design, build, and test a chair using recycled materials.

Criteria for Success

The chair must be made of recycled, "non-traditional chair" materials and be able to withstand an agreed-upon amount of stress. You may use up to four different kinds of material and as many methods of joining or fastening as you want.

Brainstorm Ideas

TOOLBOX

1 Working in a group of two or three, brainstorm ideas for a chair design, the materials you could use, and the method you will use to test your chair. Evaluate all the ideas discussed and reach a decision amongst yourselves about which idea your group will use. (Refer to Toolbox 3.)

Build a Prototype

2 Assemble your materials and any tools or equipment you will need to build your chair prototype.

3 Build your chair, testing all components as well as the final chair. Modify the design if necessary as you go.

4 Troubleshoot problems as they are identified. For example, are there some weaknesses in the original design? If so, how could you resolve them?

Test and Evaluate

5 With your group, present your completed chair to the class. Answer questions about the design. Be prepared to support your design decisions.

6 After all groups have displayed their chairs and given a presentation, the teacher will test how well each chair functions (i.e., how much weight it can support, how stable it is, and determine if the size is appropriate).

7 For all the chairs, the class will vote to select the one that is best in each of four categories: Most Original Use of Materials, Strongest and Most Stable, Most Aesthetically Pleasing, and Overall Best Chair.

Communicate

8 As a class, review the multiple solutions that were found for the practical problem posed by this activity. Why was there not just one solution?

9 Describe what you feel were the biggest challenges in meeting the criteria set for the problem. How did these limitations affect the process you went through in developing your design and then building a prototype?

Materials & Equipment

Materials will vary, but may include the following items. Check your choices with your teacher before starting to build.

- cans
- cardboard boxes
- cardboard tubing
- plastic containers
- rope
- plastic cord
- glue
- adhesive tape
- staples
- paint
- papier-mâché

Equipment will vary, but may include the following items. Check your choices with your teacher before starting to build.

- scissors
- scalpel or small sharp knife
- tape measure

Caution!

- Wear goggles when using a knife.
- Wear gloves when using paint.

*re*SEARCH

Titanium

Titanium is a durable but light metal. It is a material of choice in the automobile and aircraft industries. You may also know of titanium's use in sports equipment such as tennis rackets, bicycles, and golf clubs. Another important property of this metal is that it is non-toxic. This makes it a good material for producing artificial body parts. Research more about the use of titanium to build a wide variety of structures.

Changing Methods of Fastening

The purpose of most backpacks is to carry a load and keep the contents inside protected from weather. Some backpacks maintain their strength and usefulness better than others, but most often the parts that fail are the fasteners: the seams, zippers, and buckles that hold the various materials and components together.

Failed fastenings in structures such as backpacks are usually just an inconvenience rather than a safety concern. Think what would happen if the welds joining the steel plates of a ship's hull failed, or if the cables supporting a gondola snapped. Clearly, the consequences of poor fastenings in these cases could be disastrous.

Changing methods of fastening to strengthen even a simple structure can mean switching to screws from nails, or using cement rather than relying on mass to hold structural parts together.

New Materials

Science and technology are creating new materials all the time. Many of these are providing solutions to challenges of building stronger, lighter, and more stable structures.

Composites of carbon fibres, for example, have properties that are superior to steel and other metals. Their light weight allows them to be used in aircraft structures. Technological advancements have led to other composites such as Kevlar to be used in such diverse products as tires, fibre optic cables, and sporting goods. E-glass fibre (fibreglass) is widely used for energy efficient windows.

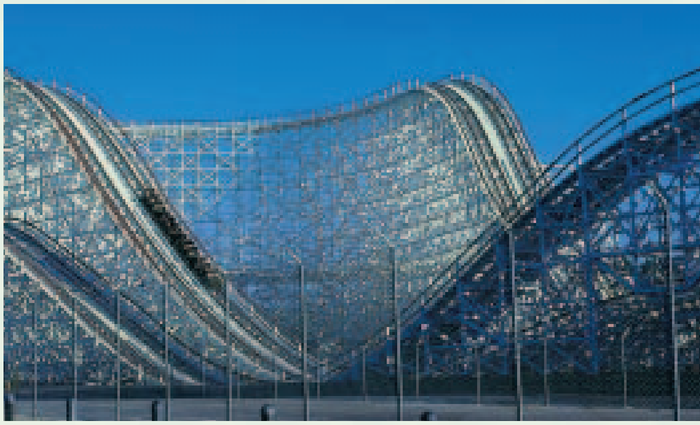
New plastics are being developed. How many objects can you see around you that are made of some type of plastic?

Check and Reflect

1. Define corrugation and lamination, and describe how they add strength to a material.
2. Explain why a builder might choose to reinforce the arrangement of components as a means of strengthening a structure rather than just buying stronger material.
3. True or false? A new material made from combining other materials can never be as strong as the originals. Explain your answer.

Careers and Profiles

Roller-Coaster Designer

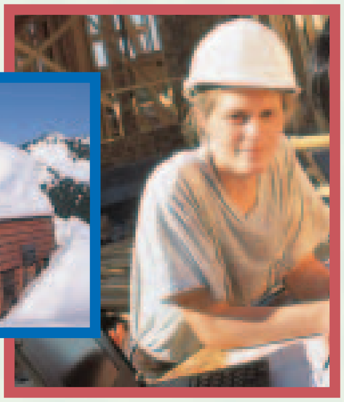


Roller-coaster designers use computer programs to design coasters. These programs help them change factors like the height and steepness of the coaster to get the fastest and safest ride possible.

Once the design is ready, a small-scale model of the coaster is built, probably around one-eighth of the actual size. The designers test this model to make sure it is safe and works well. Next, a full-sized model is built and tested. Finally, the roller coaster is completed. It is set up in an amusement park and ready to go!

What forces do you think are acting on the roller coaster shown at the right?

Building Inspector



People buying a new home often hire a building inspector to examine it. The inspector will check that the structure, heating, plumbing, and electricity in the dwelling are all safe and working well.

Building inspectors need to understand how structures work. They also need to understand how forces such as wind and gravity act on a building. In Canada, for example, roofs have to be strong enough to hold up the weight of snow that builds up during the winter.

Building inspectors make sure buildings are safe for people to live and work in. When a building is under construction, a city building officer will come to check that the builders are following proper safety rules.

- The structure and foundation of the building have to be strong enough to hold up the weight it will be carrying.
- Tall buildings have to be stiff enough to resist the force of strong winds.
- Buildings in earthquake zones have to be sturdy enough to withstand the shaking and movement of the ground.

1. What roles do a roller-coaster designer and a building inspector play in ensuring that amusement park rides and houses meet human needs within a margin of safety?
2. For each of these two careers, list three important skills a person would need to have to be successful.
3. Which aspects of these two careers do you think would be most interesting?

4.3 Evaluating Designs from an Overall Perspective

*info***BIT**

Holiday Lights—Safely

In 1917, a large fire in New York City was found to have been started by open candles placed on a Christmas tree. At the time, the Sadacca family had a novelty business selling imitation birds that lit up. Albert Sadacca, then 15, suggested that his family begin making electric lights for Christmas trees. The lights were not popular, however, until after Albert thought of painting the bulbs different colours.

Any structure, whether it is a backpack or a hydro-electric dam, must meet a range of human needs. "Will it do the job I want it to?" is not the only question that must be answered if you want to evaluate the "whole story" about how effective a structure is. Figure 4.8 lists several other important questions that must be answered.

Cost	Benefits	Safety	Impact on the Environment
• How much will the structure cost to build, operate, and maintain? • Can we afford to build it?	• What are the benefits of having this structure? • Who will enjoy those benefits?	• Is there a safety hazard? • Who and what could be affected by these risks?	• What steps might be taken to prevent environmental harm? • How will waste materials related to the structure be disposed of?

Figure 4.8 Any design should be evaluated from many perspectives.

A Case Study in Improving Designs

In 1978, two men in a Vancouver bike store modified a Nishiki road bike by adding wide tires, straight handlebars, and thumb shifters. This was the first "mountain bike" for the future founders of Rocky Mountain Bicycles. In 1982, the "Sherpa," their first Rocky Mountain bike, was produced.

Read about how Rocky Mountain Bicycles makes its bikes, and then answer the following questions in your notebook.

1. Give an example of a design change the company made based on what customers liked. How did the company get this information?
2. Why are triangles used in the frame of a bicycle?
3. What efforts does this company make to help create a sustainable environment? Why is this important?
4. A designer sometimes has to choose between the material with the best properties and a more economical material. Why? Give an example of how Rocky Mountain Bicycles does this. What would you predict might happen if a new, recycled plastic material, light but as strong as steel, were developed?
5. Why does this company invite trade magazines to test and evaluate its bicycles?

*math***Link**

The frame of a popular bicycle costs $139 to assemble in the factory. A proposed design change would save the manufacturer $4.50 per frame. If 2500 bicycles are built per month, how much money would the manufacturer save over 1 year by making this design change?

How Rocky Mountain Bicycles Makes Bikes

Figure 4.9 Before you make a new bicycle, you have to know what kind of bike people want. By doing market research, the company determines which bicycles are popular and which features, such as straight or curved handlebars, are favoured by customers.

Figure 4.10 At Rocky Mountain Bicycles, the most important criteria for materials are strength, weight, and cost. Some of the materials that have the best strength-to-weight ratios are expensive and limited to only high-end (meaning high cost) bikes. Aluminum, which costs less, also has excellent strength-to-weight properties and is used to make mid- to high-end frames. Steel is generally used for mid- to low-end frames because of its low cost.

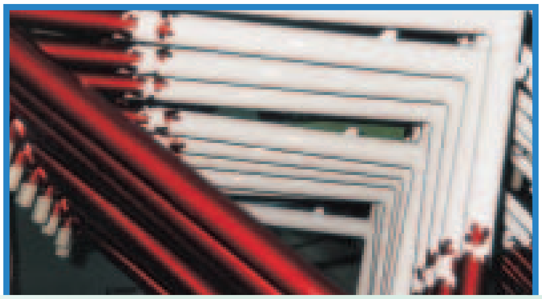


Figure 4.11 The traditional shape for a bicycle is essentially two triangles. Hollow tubes tend to be used because they provide the best strength and stiffness against forces for a given weight.

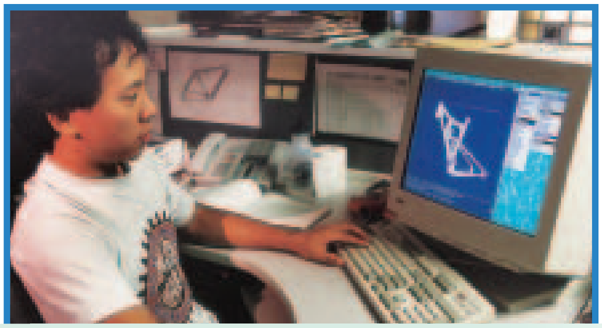


Figure 4.12 Rocky Mountain Bicycles uses computer-aided systems for all of its bike designing and manufacturing. This allows other departments in the company, such as marketing, to approve the design before an actual bike is built.

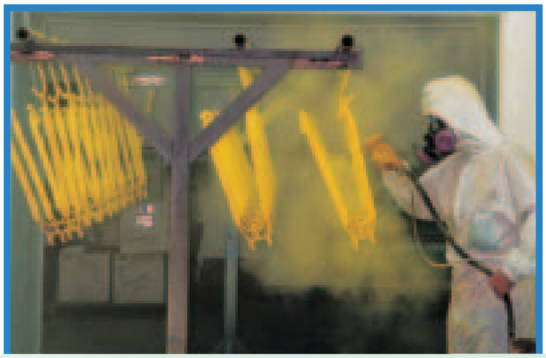


Figure 4.13 New techniques in painting use non-toxic chemicals that produce little waste. Extra material and rejected frames are cut up and recycled. Even the cardboard used for packaging is made from recycled material.

Figure 4.14 Rocky Mountain Bicycles uses a combination of trade shows, advertising in bike magazines, promotions, Web sites, and sponsorships to promote its products. It also encourages trade magazines to test and evaluate its product. However, word of mouth is the best advertisement.

Give it a TRY ACTIVITY

STRUCTURAL REPORT CARD

You've had a chance to learn about the technological process that goes into designing, building, and improving the product at Rocky Mountain Bicycles. You've also considered a number of criteria that are important in an overall evaluation of a structure. Now it's your turn.

Choose another structure of interest to you and evaluate the technological design and development process that has gone into creating it. Use the following criteria to guide your evaluation:

- cost of building the structure
- benefits provided by the structure
- safety of the structure
- impact of the structure on the environment

reSEARCH

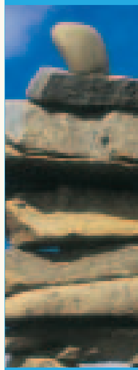
Wind Me Up

The radio shown here doesn't use batteries. Neither does it have a plug for electricity. Instead, a few turns of a crank in the back provide enough power for about 30 min of operation. Find out more about this type of radio and how it works.

Why would a structure such as this wind-up radio be popular? What human needs is it serving?

CHECK AND REFLECT

1. When a bicycle gets old and falls apart, who is responsible for disposing of the bicycle in an environmentally friendly way—the store that sells the bicycle or the buyer?
2. Make a flowchart to show the major steps in designing, making, and selling a new kind of bicycle. For each step, indicate which of the following factors should be considered and explain why: cost, benefits, safety, and impact on the environment.



Assess Your Learning

1. Do you agree or disagree with the statement "It is impossible to make everything perfectly safe"? Explain your reasoning.
2. Identify three environmental factors that can affect the strength and stability of structures in the area where you live. What structural designs help resist those environmental forces?
3. Waste is produced by many technological processes, as well as by the everyday operation of large facilities such as schools and hospitals. Study your own class's waste disposal habits as follows:
   - Make a three-column chart like the one shown in Figure 4.15.

Type of waste	Ideal way to dispose of it	What actually happens

Figure 4.15 Question 3

   - In the first column, list each type of waste item you see in your classroom.
   - In the middle column, state the ideal way to dispose of each type of waste: recycle, reuse, or dispose.
   - Investigate your school's recycling and waste-handling procedures. In the right-hand column, record what you find out actually happens to each type of waste.
   - Make suggestions about how your school could improve its methods of disposing of waste.

Focus On SCIENCE AND TECHNOLOGY

All technologies must be assessed to determine whether they are appropriate for the context in which they are to be used.

Reflect on what you learned in this section about designing, evaluating, and improving structures.

1. What environmental factors can affect the stability of structures?
2. How can materials be strengthened to improve safety and service?
3. Besides function, what considerations about a structure should be evaluated?
4. How could you apply what you have learned about designing safe and effective structures to planning a walking aid (walker) for elderly people who cannot walk on their own?

Preserve or Replace?

The Issue

Today, there are thousands of abandoned structures in North America, including homes, stores, and railroad stations. Some people think derelict structures are eyesores that should be torn down and replaced. Other people think older buildings are objects of beauty and heritage that should be preserved. What do you think? Read the two views below for and against preserving old buildings.

View 1: Old Buildings Should Be Preserved	View 2: Old Buildings Should Be Demolished and Replaced
Many old buildings have historical value. They are an important part of an area's heritage.	**Old buildings are unsightly.** This can reduce property values in the neighbourhood.
Many old buildings are beautiful and have architectural value. Demolishing them diminishes the character of an area.	**Old buildings that sit abandoned for a long time are a safety hazard.** They become in danger of collapsing.
Demolishing old buildings to replace them with new ones is a waste of materials and resources. It reflects the bad habits of a consumer society. Many structures can still be modified for new uses.	**Many old buildings don't meet modern building codes or the needs of modern tenants.** They fail to meet standards for electrical wiring, plumbing, and structural stability. Few meet fire code regulations.
	Renovating is often more expensive than demolishing and rebuilding from scratch. Any renovation job, no matter how carefully done, will destroy some of the building's original character.

A

B

The abandoned home shown in (A) was built in the 1890s. The same building has been carefully renovated into a two-family residence (B).

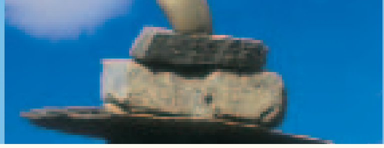
Go Further

Now it's your turn. Look into the following resources for information to help you form an opinion.

- Look on the Web: Check out the Web sites of heritage protection societies and associations.
- Ask the Experts: Talk to experts about the issue. Builders, architects, building inspectors, historians, and specialists in heritage restoration can provide you with important facts and background information.
- Check Newspapers and Magazines: Follow current stories about the issue in local, national, and international newspapers and magazines.

In Your Opinion

Think of an abandoned structure in your area. What would you do with this structure: preserve and renovate it or demolish and replace it? Summarize your opinion on the issue in a letter to the local newspaper, clearly explaining the reasons for your choice.



Unit Summary: Structures and Forces

Key Concepts	Section Summaries
1.0 • structural forms • function and design of structures	**1.0 Structures are found in natural and human-made environments.** • Structural forms can be classified as solids, frames, or shells. Each offers structural stability under different forces. Examples of the three forms are found in both the natural and the human-built environment. • For any structure to be effective, it must serve the function for which it was designed. Structures that have a common function may vary widely in design. Many structures serve multiple functions. • Climate, culture, tradition, technology, and economics all influence the design of human-built structures and reflect the great variation that exists across time and around the world.
2.0 • material strength and flexibility • forces on and within structures • direction of forces • structural stability • modes of failure • performance requirements	**2.0 External and internal forces act on structures.** • The effect of a force on a structure depends on the magnitude, direction, and location of the force. These aspects can be identified and measured. • An external force is one that is applied to an object from the outside. Stability can be affected by changes in the distribution of mass within the structure, and by changes in the design of its foundation. A structure's ability to withstand a load depends on its overall strength and stability. Performance requirements ensure that structures are performing to certain standards. • Three main types of internal forces at work within structures are compression, tension, and shear. The shape and properties of materials and structural components determine how well they can resist internal forces. When structures cannot withstand the forces acting on them, they undergo structural stress, fatigue, and failure.
3.0 • deformation • joints • material strength and flexibility • structural stability	**3.0 Structural strength and stability depend on the properties of different materials and how they are joined together.** • Structural material, including both natural and synthetic types, can be classified according to a range of properties. • The strength and flexibility of materials in a structure can be tested. One way is to measure the amount of deformation that occurs when a material is under a load. • The appropriateness of a type of joint in a structure depends on how and where it will be used in the structure. • Each of the many different materials found in the structure of a plant or animal plays a special role in maintaining the strength, stability, and functioning of that structure.
4.0 • margin of safety • structural stability	**4.0 Structures are designed, evaluated, and improved in order to meet human needs.** • Environmental factors can affect the stability and safety of a structure. • Materials and components can be strengthened in several ways to increase structural safety. Corrugation and lamination are two examples. • All structural designs and processes can be evaluated on the basis of identified criteria such as costs, benefits, safety, and potential environmental impact.

PROJECT

SURVIVE!!

Getting Started

In this climate, most people have experienced what it feels like to be outside in a winter storm. The wind seems to reach everywhere and makes it hard to keep warm. As the snow builds, it becomes more difficult to move around. If you can get indoors, you know you will be fine. But what if you're not near a warm place? What kind of shelter could you use in an emergency?

In this unit, you have learned how to design structures to withstand forces of various types. You have also learned about considering human factors as you turn ideas into designs. How could you use this information to design and build a temporary shelter to protect yourself until help arrived or the storm was over?

Your Goal

Your goal is to design a shelter that can be set up quickly by two people and that will help them survive a sudden winter storm.

What You Need to Know

Your shelter is to be presented to the class as a drawing and as a model. The model will be tested for its ability to meet the criteria below:

- The shelter must be portable, both when it is set up and when it is packed.
- You must be able to carry the shelter yourself or in a vehicle such as a car.
  - If the shelter is to be carried by a person, it must be small enough to fit inside a backpack (or be tied to the outside of a backpack). It must have a mass of less than 4.5 kg.
  - If the shelter is to be carried in a vehicle, it must be shorter than 0.5 m in any direction. Mass can vary.
- The shelter must be easy for two people to set up quickly in a wind.
- The shelter must be safe to use and must protect two people against wind chill and snow for at least two hours.
- You must dispose of waste materials from its construction properly.

Steps to Success

1 Work with your group to design a plan for solving this technological challenge. For example, think about how you will choose a design and materials, whether you need to build a prototype, how you will test your shelter, and how you will make modifications. (See Toolbox 3 if you need help with this.)

2 When you have a plan, show it to your teacher for approval. Make sure you have a diagram illustrating what your shelter will look like.

3 Proceed with the plan.

> **Caution!**
> - Use equipment with care.
> - Do not test your shelter unless your teacher is present.

4 Make changes to the plan as necessary. Document reasons for your change.

5 Be prepared to demonstrate your model to the class.

How Did It Go?

6 In a short report, answer the following questions:

- Describe how well your shelter met the criteria of the project. How do you know?
- What part of this challenge did you find most difficult? Why? How did you overcome or deal with this problem?
- What part of this challenge did you find most successful? Why?
- Compare your final product with your original idea. Explain any changes you made.
- Describe the skills you needed to learn in order to design and build your shelter. How did you identify those skills? Where did you go to learn them?
- How would you change your shelter so that a person could safely use a candle inside for warmth and light?

UNIT REVIEW: STRUCTURES AND FORCES

Unit Vocabulary

1. Create a concept map of the following terms. Remember to use a couple of words or a short sentence between the terms to show how you connected these terms.

   centre of gravity
   complementary forces
   dynamic and static load
   solid, frame, and shell structures
   structural stability
   structural strength
   structural fatigue
   structure
   materials

Check Your Knowledge

1.0

2. Define the term *structure*.
3. What is the difference between solid, frame, and shell structures?
4. Give an example of a combination structure in the human-built environment and in the natural environment. For each, say what structural forms are combined.
5. Why do structures that serve the same function often have such different designs?

2.0

6. Explain how the direction in which a force is applied can determine the effect that force has.
7. Give an example of a dynamic and a static load. How are these two examples the same and how are they different?
8. What four different types of bridges can be used to support a load? Use a labelled diagram to illustrate the similarities and differences between them.
9. Describe, using a diagram, three different types of internal forces.
10. Name six common structural components (or combination of components) and sketch them in your notebook.
11. What is the difference between structural stress and structural failure?

3.0

12. True or false? A material that is very rigid is always better in a structure than a material that is very flexible. Explain.
13. How can the deformation of a material under a load be measured?
14. What role does friction play in some methods of joining?
15. How would you evaluate whether a particular joint should be made using nails or glue?

4.0

16. How might heavy snow affect the strength and stability of a structure? Use the terms *force* and *structural fatigue* in your answer.
17. What is corrugation and how is it used in structures?
18. What criteria other than strength and stability might you use to evaluate a structure?

Connect Your Understanding

19. An archaeologist finds the remains of three types of structures in an area, all built during the same period of time by the same ancient people. The shell-like structures were made of light materials such as animal hide. The frame-like structures seem to have been permanent, but evidence indicates they were only used in warm weather. The solid structures were formed from piles of stone. Inside each pile were dried grains and other foods. What would you infer was the most likely function of each type of structure for these people? How did the designs of these structures suit their function?
20. A container is needed to hold 50 CDs. It should provide easy access to all discs and be able to withstand being dropped. What shape would you use? Why?
21. If you were to design a picnic table, would you pay more attention to the function or the aesthetics? Explain.
22. Look at the truck below and answer the following questions.
    a) What external forces are acting on the structure of the truck?
    b) Which types of internal forces are acting on the truck?

Question 22

23. From your knowledge and experiences in this unit, what do you think is the best type of structure to hold up a large mass? What evidence can you provide to support your opinion?
24. In what way does your body respond to a compressive force being applied to it? For example, what happens when you jump down from a bench?
25. A broken beam in a frame structure was found to crack along the lower surface first. How could you redesign the beam to account for this problem?
26. Do all methods of joining or fastening need to be strong? Think of two cases where the strongest means of fastening would not be a suitable choice.

27. a) You've been asked to design a hand-pulled wagon for a child. How would you decide what materials and methods of joining to use?

b) What changes to your selections in (a) would you make if you had to design a second wagon for an adult? Why?

28. Suggest improvements to the following structures that might make them useful to more people. Try to make the least change possible.

a) A narrow revolving gate is used to control the number of people entering the fairground at once. It works well for an average-sized person who is not carrying any objects.

b) Two of the three shelves in a set of kitchen cupboards are too high for any member of the family to reach without climbing on a stool.

Practise Your Skills

29. You have been asked to judge a competition in which students were challenged to design the strongest and most stable structure possible using Popsicle sticks and tape. In your role as judge, you will be discussing each structure with the students who designed it. To help you remember and explain the many factors involved in the design of structures, make yourself a concept map using the terms listed below:

- arch
- beam
- centre of gravity
- external forces
- internal forces
- load
- mass
- shape
- structural component
- weight

30. You have been asked to design a short footbridge across a muddy section of the schoolyard. Develop the plans needed to build this structure. You should have a diagram of the structure, a list of materials, and a brief description of how to assemble the bridge.

31. What structural shapes and materials would you use to build an observation tower in a bird sanctuary?

32. You have the choice of building a bicycle storage shed with either concrete blocks or wood. Create a chart that demonstrates the benefits and costs of using each type of material. Once you have completed your chart, select a material and describe why you chose it using the information you collected.

Self Assessment

33. Think about the three questions first posed in the introduction to this unit:

A How do structures stand up under a load?

B What forces act on structures?

C What materials and design characteristics contribute to a structure's strength and stability?

Go back through your notes and write A, B, or C beside main ideas to show how each aspect of your learning in this unit can help you answer those questions.

34. Think back on everything you did during this unit. Use your thoughts to answer the following questions:

- The most surprising part of this unit for me was:
- During my study of structures, the toughest part I found was:
- I solved this by:
- I would like to learn more about:
- My advice to someone starting this unit would be:
- What I liked most about structures was:

35. What types of careers could you pursue that are related to structures? Which one seems the most interesting to you? Why is this?

Focus On SCIENCE AND TECHNOLOGY

In this unit, you have investigated science and technology related to structures and forces. Consider the following questions.

36. Reread the three questions on page 263 about the nature of structures and forces. Use a creative way to demonstrate your answer to one of the questions.

37. What aspects about structures and forces did you investigate that demonstrated how technology could be used to develop solutions to practical structural problems?

38. Describe the process involved in designing a structure to perform a specific task. Was this a straightforward, step-by-step process, or did it require modifications as you developed and evaluated the design?

39. Describe the situation where an understanding of the local conditions was important for a technology to be used appropriately.