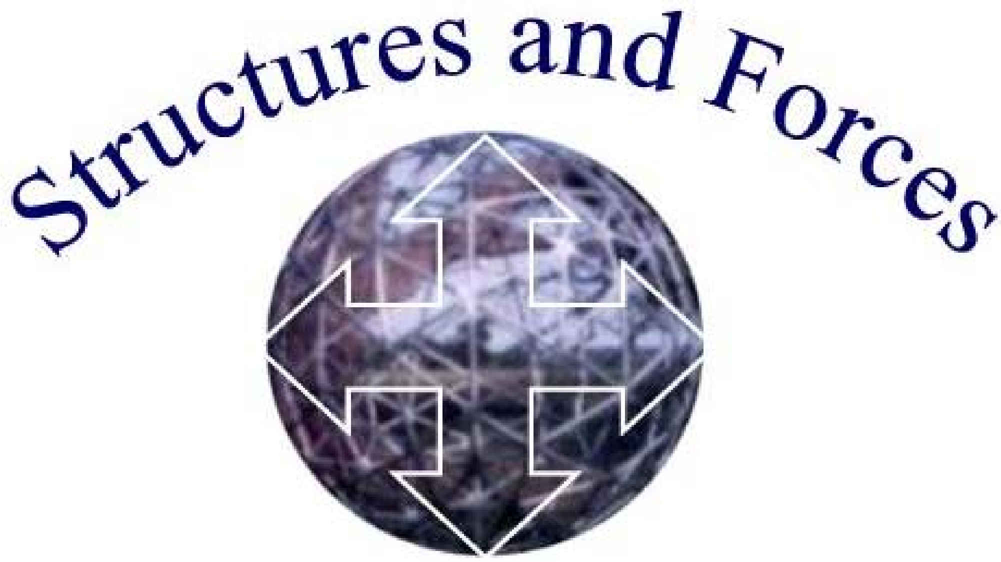
Science Focus 7 - Unit 4



Teaching Notes

Edquest Resources 2001

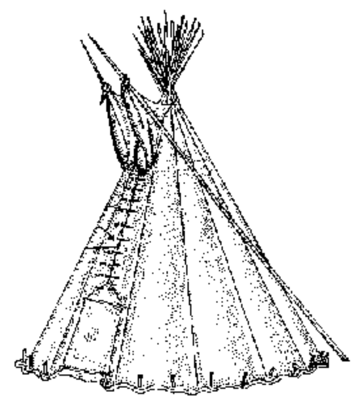
Topic 1 – Types of Structures (pgs. 270-280)

Structures are things that have a definite size and shape, which serve a definite purpose or **function**. To perform its function, every part of the structure must resist **forces** (stresses such as pushes or pulls) that could damage its shape or size.

Classifying Structures

Natural
- not made by people
- occur naturally in the environment

Manufactured
- built by people
- many are modelled after natural structures



Structures can also be classified by their **Design**

Mass Structures can be made by, piling up or forming similar materials into a particular shape or design.
- Mountains, coral reefs are **natural mass structures**
- Sand castles, dams and brick walls are **manufactured mass structures**)

Advantages: held in place by its own weight, losing small parts often has little effect on the overall strength of the structure

A Layered Look
- mass structures are not always solid, but are layered and have hollowed out areas for specific functions.
- a power dam and the Great pyramids of Egypt are a good examples

Sandbag Wall Structure to prevent Flooding
http://www.gov.mb.ca/gs/memo/dyke.html

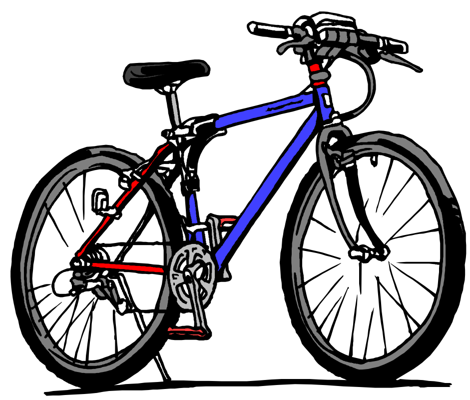
(4 Key Elements) – to avoid failure
- must be heavy enough to stay in place
- must not be too heavy to compact the earth unevenly below it
- must be thick enough so it cannot be pushed out of place
- must be anchored firmly

Frame Structures

Have a skeleton of strong materials, which is then filled and covered with other materials, supporting the overall structure. Most of the inside part of the structure is empty space.
- **Load-Bearing Walls**: these are the walls that support the **load** of the the building.
- **Partition Walls**: these are the walls that divide up the space inside the building.
- because they are relatively easy to design and build, and inexpensive to manufacture, the frame structure is the most common construction choice.

A Bicycle frame **supports the load** it carries on the seat.

Identify:
Rigid Joint
Mobile Joint
Brace
Rigid Shape
Type of Material
Support



All frames, whether simple or complex must overcome similar problems. To solve these problems joints, type of material, bracing, anchoring and design all must be considered in the overall structural frame construction.

Find Out Activity p. 275

Golf Ball Bridge (Investigation 4-A … pgs. 276-277)

Shell Structures

Structures, which keep their shape and support loads, even without a frame, or solid mass material inside, are called **shell structures**. These structures use a thin, carefully shaped, outer layer of material, to provide their strength and rigidity. The shape of a shell structure spreads forces throughout the whole structure, which means every part of the structure supports only a small part of the load, giving it its strength.

Examples include: igloos, egg cartons, turtle shell, food or pop cans, or, even bubbles in foam and cream puffs.

Flexible structures, like parachutes, balloons and different types of clothing are a different type of shell.

Shell structures have **two very useful features**:

- they are completely empty, so they make great containers
- their thin outside layer means they use very little material

Problems in building shell structures include:

- A tiny weakness or imperfection on the covering can cause the whole structure to fail.
- When the shell is formed from hot or moist materials, uneven cooling can cause some parts to weaken other parts by pushing or pulling on nearby sections.
- Flat materials are difficult to form into the rounded shell shape.
- Assembly of flexible materials is very precise, so that seams are strong where the pieces are joined.

Mix and Match

Some structures are combinations of different types of structures:

- **Football helmets** are shell structures – to protect the head, with a frame structure attached in front - to protect the face.
- **Hydro-electric dams** are mass structures, with frame structures inside to house the generators
- **Airplanes** are frame structures, with a 'skin' that acts like a shell – giving it the added strength to resist stresses and making it lightweight and flexible.
- **Domed buildings** combine shell and frame construction
- **Warehouses** are often built with columns to support the roof (frame) and concrete blocks, (mass structures) which stay in place because of their weight.

Can you think of other structures that are combinations?

Topic 1 Review p. 281

Topic 2 - Describing Structures (pgs. 282-296)

Function – What is the structure supposed to do? What was it designed for?

Most structures have several functions, which may include:

- **supporting (its own weight)**
- **containing (substances)**
- **transporting**
- **sheltering**
- **lifting**
- **fastening**
- **separating**
- **communicating**
- **breaking**
- **holding**

Precise, measurable standards normally are indicated in the specifications the structure must comply with in order to perform its function/s.

Aesthetics – is the study of beauty in nature.

- The best designs usually 'look good' – '**aesthetically pleasing**'
- The aesthetics are usually accomplished by the shape, texture, color, type of material, symmetry and simplicity of the repeated pattern used in the design.

Safety – all structures are designed and built within an acceptable margin of safety (but usually, structures are designed with a built-in **large margin of safety**).

Cost – adding extra strength to a structure costs money, as well as using more highly skilled workers and better materials does.

- Designers plan their structures to withstand conditions they hypothesize will occur. Good design is a **compromise** between a reasonable margin of safety and reasonable cost.

- Usually, **totally unexpected events** will cause even the best (well-designed) structures to fail (example: the World Trade Centre Towers).

Materials – the properties or characteristics of different materials must match the purpose of the structure.

Composite Materials

There are different kinds of strength

- **tension** (pulling) …. steel rods
- **compression** (pushing) …. concrete

To enable the structure to withstand both types of forces acting on it, a composite material is used – **reinforced concrete** (concrete poured over steel rebar (rods).

Layered Materials

Layers of different materials (Tetra Pak) are pressed and glued together, combining the properties of the different materials. The layers are often called **laminations**.

Woven or Knit Materials

Spinning or twisting, looping or knotting fibres together gives material added strength. A **loom** is used to weave two or more pieces of yarn together in a criss-cross pattern to make cloth. Pressing, gluing, melting and dissolving are also ways to combine materials to gain strength.

Choosing Materials

When choosing materials involves weighing advantages and disadvantages of the different materials (higher quality, stronger materials are usually more expensive)

Factors to consider:

Cost
- will inexpensive material you use allow the structure to perform its function over a reasonable time?

Appearance
- is the appeal of the structure ‘pleasing’ over time?

Environmental Impact
- does the structure harm the environment?

Energy Efficiency
- does the structure conserve energy?

Which Tissue would you buy? How do Advertisers promote and sell the least effective Tissue to the consumer?

Tough Tissue Test (p. 289)

Joints – how do you fasten the structure together?

Mobile Joints are joints that allow movement
Rigid Joints do not allow movement

- **Fasteners** (nails, staples, bolts, screws, rivets and dowels). Unfortunately, the holes made in the structure, by the fastener, actually weaken the structure. One fastener allows movement when the parts are pushed or pulled, whereas, more than one will make a more rigid joint – but, will also weaken it more.
- **Interlocking shapes** (like Lego) fit together because of their shape. Dovetail joints in drawers, dental fillings and folded seams are some examples.
- **Ties,** like thread, string and rope, fasten things together.
- **Adhesives**, or sticky substances can also hold things together. ***Thermosetting glues*** (hot glue) and ***solvent-based glue*** (drying glue) strengthen the joint because of the bonds between the particles (like epoxy resins). Even the strongest adhesives can fail under extreme conditions and if the joint is stronger than the material it is joining, the material next to the joint can fail. Adhesives can also be a health hazard (like ***Super Glue*** – which dries very quickly when you use it – possibly bonding your skin if you touch it, or they can release harmful chemical vapours as they harden.
- **Melting** – Pieces of metal or plastic can be melted together (welding, soldering – brazing or using chemicals)

Post-It Notes – *An accidental glue (that turned into a huge success story). It did not meet the specifications, because it couldn't hold things together very well.* (p. 292)

Traditional Structures (Project – Making a Model)
Create a replica scale model of a **Famous Bridge Structure** or choose from one of the **Seven Wonders of the World**. Directions for the accompanying research report – Use the questions on p. 295. Add interest in the project by having them create their model as an 'Edible Model'. (They can eat it after they have presented it.)

Topic 2 Review p. 296

WRAP-UP p. 297

>>>> A good review of Topics 1 – 2 in this Unit <<<<

Topic 3 – Mass and Forces (pgs. 298 – 304)

Mass

The mass of an object is the measure of the amount of matter in it.
The mass is the number of particles the substance has
A small cylinder of metal was used, as a standard, by which, to compare different substances. This standard (in the metric system) is called the **primary standard** of mass, and the amount of material in it is called one **kilogram** (kg). Smaller masses are measured in **grams** (g).
'Kilo' means one thousand (1000) and is equal to 1000 grams. Very small masses are measured in **milligrams** (mg). 1000 **mg**. equal 1 **g**.
A **balance** is used to measure the amount of mass in a particular substance. Standard scientific balances include the triple beam balance and the equal arm balance.

Mass stays the same no matter where you are in the universe.

Forces and Weight

Force is a push or pull on an object. The standard unit of force is called a **newton (N).** (1 newton of force will stretch a thin rubber band, or will be what it takes to lift up a D-cell battery). A **force meter** (**spring scale**) is used to measue the amount of force – the pull of gravity – on a mass. To describe a force accurately, you need to determine its direction and size.

Weight

Weight is a force and should properly be measured in newtons. Sir Isaac Newton (*Did You Know* – p. 300) described the force that pulls objects together as the force of **gravity**. The **gravitational forces** between two objects depends on the masses of the objects and the distance between them. This gravitational force is called **weight**. Because gravitational force depends on the distance between two objects, an object's weight changes depending on where it is. (the farther away from the earth, the less the weight.

REMEMBER: Mass is the amount of matter an object is made of and weight is the force with which gravity pulls on an object.

Picturing Forces

A **force diagram** is a simple picture that uses arros to show the strength and direction of one or more forces (a longer arrow represents a larger force and a wider arrow represents a stronger force)

Topic 3 Review p. 304

Topic 4 – Forces, Loads and Stresses (pgs. 305 – 314)

External forces on structures are stresses that act on a structure from outside the structure. These forces produce **internal forces**, or stresses, within the materials from which the structure is made. These internal stresses can change the shape or size of a structure and is called **deformation**. This deformation can lead to repair of the damage to the structure, or failure of the structure.

External Forces

A **dead load** is a permanent force, acting on a structure. This includes the weight of the structure itself.

A **live load** is a changing, or non-permanent force acting on a structure. This includes the force of the wind and the weight of things that are in or on a structure. Impact forces (things that collide with the structure) are another type of live load.

Internal Forces

Tension forces stretch a material by pulling its ends apart
Tensile strength measures the largest tension force the material can withstand before failing.

Compression forces crush a material by squeezing it together. **Compressive strength** measures the largest compression force the material can withstand before it loses its shape or fails.

Shear forces bend or tear a material by pressing different parts in opposite directions at the same time. **Shear strength** measures the largest shear force the material can withstand before it rips apart.

Torsion forces twist a material by turning the ends in opposite directions. Torsion strength measures the largest torsion force the material can withstand and still spring back into its original shape.

A **bending force** is a combination of tension and compression
Shear and **torsion forces** are also a combination of tension and compression

Resisting Stress – The Inside View
Strength of materials can be traced to the forces between the tiniest particles of the materials. (See. Figure 4.39 p. 314)

Topic 4 Review Page 314

Topic 5 – How Structures Fail (pgs. 315 – 319)

Forces acting on structures can cause them to fail to perform their function.
Failure can occur if the force is too strong for the structure's design or if the force is acting on a vulnerable part of the structure.

A **lever** is a device that can change the amount of force needed to move an object. When a force is applied to the effort arm, a large force, which can move the structure, is created. This can be intentional - like when a crowbar is used to move a heavy rock, or it can be unintentional – like when a gust of wind knocks down a flagpole.

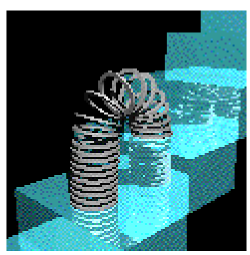
(Crowbar)  (Flagpole) 

Material Failure

Shear – minor weaknesses in a material can cause failure because the particles move farther apart and are less attracted to each other. This can be caused by compression.

Bend or Buckle – compression can also cause a material to bend and buckle – like a pop can that is stepped on. To prevent this reinforcements – **stringers** and **ribs** - are used to strengthen the structure (fig. 4.46)

Torsion – Twisting can cause material failure. When sections of the structure slide past each other the structure can crack or break in two. When the twisting action makes the structure unusable (even though it is not broken) it has failed because it has lost its shape.


(Slinky)

Making Use of Stress


(Crash Test Dummies)

Knowing that materials fail when external forces are applied can be useful.

Buckle – **Car bumpers** are designed to buckle in a collision – as the metal fails, it absorbs some of the energy of the impact, which protects the occupants of the vehicle. **Blades of grass** on a sports field buckle as players land, which absorbs some of the impact forces on the players body.

Shear – **Shear pins** are used in outboard motors to prevent failure of the motor (when the propeller gets tangled in weeds, a shear pin breaks and the propeller becomes disengaged with the motor and gears. The **clutch and automatic transmission** in a vehicle take into account shear forces, which enable parts to slip past each other and produce a smooth ride.

Twist – **Spinning wheels** twist cotton or wool fibres so they lock together – making them strong enough to make cloth. Controlled twisting can also be useful in **hair braids**, **ropes** and **telecommunication cables**.

Metal Fatigue

Metal breaks down over time and extended use. (They get bent and twisted over and over). The particles in the metal move further apart and have less attraction to each other. When a crack develops it weakens the metal – **metal fatigue** – and can eventually fail even if a small force is applied.

Topic 5 Review p. 319

Wrap-Up (Topics 4 and 5) p. 320

Topic 6 - Designing with Forces (pgs. 321-328)

Engineers use their knowledge of forces to create designs that will most likely prevent the structures from failing. Three **key methods** to help structures withstand forces are:

- distribute the load (in this way no one part of the structure carries most of the load)
- direct the forces along angled components (so that forces hold pieces together instead of pulling them apart)
- shape the parts to withstand the specific type of force acting on them

Structural Problems

1 – Frame structures experience load forces which can push or pull them out of shape (Illustration p. 321)
2 – A Horizontal beam structure that is supported only at both ends will bend in the middle (Illustration p. 322)
3 – Solid beams are often too heavy and use too much material (Illustration p. 323)

Flying Buttresses – are columns on the outsides of a structure that connect to the building near the top and are used to support the outer walls in much the same way that two sides of an arch support each other. (Web site with examples)
http://library.thinkquest.org/10098/cathedrals.htm

Strengthening Structures

All materials have their limitations. Materials can be strengthened or weakened as they are made. (Concrete – if the correct recipe is followed, the concrete can be very strong (**compressive** strength), but if the proportions are incorrect, the resulting concrete can crumble and fail, however it does not have very good **shear** or **torsion** strength. Shear forces can be fatal in metal if the shear strength is not analyzed when the metal is manufactured. The cooling process can eliminate almost all defects if it is done properly.


(Backyard Swings ***Figure 4.57***)

Using Frictional Forces

- The **force of friction resists movement between two surfaces that rub together**. A brick wall is held together and kept evenly spaced with mortar, which helps to create large friction forces between each brick.

- Friction is also important in frame structures. The friction between the nail and the wood keeps the nail in place and the joints solid. Different types of nails provide differing amounts of friction. Squeaks in floors are caused by fasteners that have loosened.

- - Friction between the ground and the bottom of a structure is an important design consideration. Friction holds the structure in place when external forces (wind) are acting on it. Too little, or too much friction can cause problems (moving chairs across the floor).

Topic 6 Review (p. 328)

Topic 7 - Stable Structures (pgs. 329 – 340)

The collapse of a structure can occur when the external forces cause the structure to become unbalanced. To design stable structures, engineers need to know what features of a leaning object determine whether it will tip over or stay balanced.

Center of Gravity

Engineers need to locate the center of gravity of a structure in order to stabilize the structure. The **center of gravity** is the specific point where all of the mass of the structure is evenly distributed around. The force of gravity acts on all parts of the structure and if all parts are evenly distributed around the center of gravity, then the structure will be stable.

Unbalanced Structures

By locating the structure's center of gravity, an engineer can tell if the structure is stable or unbalanced. (Figures 4.64A and 4.64B)

Firm Foundation

The **foundation** upon which the structure is built must be stable, especially if it is moist, otherwise the compressive forces may cause the structure to tip and become unstable. If engineers and builders do not take into account the soil type and formations, the structures built may experience cracks in their foundations and walls.
Foundations can be constructed on solid **bedrock,** or, **pilings** (large metal, concrete or wood cylinders) can be used, if the layers of soil above the bedrock are loose enough. Some lightweight structures do not have to rest on the bedrock or, have to have a foundation that goes down very deep, because the ground doesn't freeze.
A road base is made up of layers (Figure 4.68B)
The load of the structure can be spread out over a large area (footings help to do this – figure 4.68C)

Rapid Rotation

Speed helps to increase stability.
Gyroscopes

Spin stabilization, the principle with which the gyroscope works, is especially useful for objects that do not rest on a solid foundation.

Topic 7 Review p. 340

WRAP-UP p. 341

>>>> A good review of Topics 6 – 7 in this Unit <<<<

Unit Review

Pages 346 - 349