UNIT LEARNING PACKS

FOCUS IN ACTION

Grade 7 Science in Action

Unit D - Structures and Forces

EDQUEST
MIDDLE SCHOOL SCIENCE RESOURCES

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'Focus in Action' UNIT LEARNING PACKS

These booklets are designed to provide Grade 7 students with all the resources needed to review or reinforce concepts, covered in the Alberta Science Curriculum, and included in the Grade 7 Science Final Exam in June. There are circumstances in which **an entire unit** may be missed and covering the concepts from that unit (for the final exam) can be difficult. This can happen for a number of reasons:

- Students – new to the school – register throughout the year (from other provinces, school jurisdictions or countries)
- Students may be ill or have surgery and often can miss one or more units
- Students have extended holidays throughout the year
- Transfers from another school, who have completed the units in a different order

For additional support, students are directed to the **Edquest Middle School Science Website** or, Scienceman Resource (www.scienceman.com/scienceinaction/pgs/hot_7u4.html)

Unit 4 – Structures and Forces

- **Section 1 Notes & Quiz**
- **Section 2 Notes & Quiz**
- **Section 3 Notes & Quiz**
- **Section 4 Notes & Quiz**
- **Unit Summary**
- **Review Booklet** (Covered in class, prior to the Final Achievement Exam)
- **Unit Test**
- **Answer Key for Section Quizzes and Unit Test**

Additional support will be provided, in the form of practice Achievement Test Questions, during the course review in June. Multiple Choice Questions and Numerical Response Questions will be reviewed, as these are the types that will make up the Science 7 Final Exam

Handouts and other activities, to reinforce the concepts covered in this Unit, will be made available based on need. If you require further information or resources, email Edquest directly: edquest@gmail.com.

Finding Solutions to Problems, instead of Making Excuses

Student Instructions for use of this Learning Pack

The purpose of this Learning Unit Pack is to provide you with the resources that will help you cover the material from the curriculum that will be tested on the Final Exam in June.
Follow these steps to successfully complete this Unit Learning Pack:

Step 1 – Read the **Topic Notes**

Step 2 – Use a **highlighter** to identify the key words or phrases in the Topic Notes and reread the material again paying close attention to those words that you highlighted. If necessary, modify your highlights to make sure you understand the material in the notes.

Step 3 – Complete the **Topic Quiz**

Step 4 – Correct the Topic Quiz by **checking the answers** in the back of this Learning Pack.

Step 5 – Using your **textbook** and the **completed quiz**, find the page where the question and correct answer can be found and write it next to the question number in your Learning Pack.

Step 6 – **Repeat Steps 1-5** for each of the other Topics in this Unit.

Step 7 – Look over the **Unit Outline** to review the **Key Concepts** once you have completed all of the Topics.

Step 8 – Complete the **Unit Review**, using your **Learning Pack** and **Textbook**.

Step 9 – **Highlight** those sections of the Review that you had difficulty with and review those sections with your teacher prior to taking the Unit Test.

Step 10 – Take the **Unit Test** and correct it using the answer key provided in the back of the Learning Pack.

Step 11 – You should now be ready to answer any questions on the **Final Exam** related to this Unit.

Anything you still do not understand should be discussed with your teacher. Congratulations on your **Independent Study**, and Good Luck on the Final Exam. I hope you have made good use of this resource. Please provide feedback to your teacher, so that this resource can be improved.

Additional support is available in the form of practice Achievement Test Questions. **Multiple Choice Questions** and **Numerical Response Questions** will be made available on request, as these are the types that will make up the **Science 7 Achievement Exam**.

Handouts and other activities, to reinforce the concepts covered in this Unit may be acquired by visiting the Edquest Middle School Science Resource Website

http://www.edquest.ca

1.0 Structures are found in natural and human-made environments

1.1 Classifying Structural Forms

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

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

Structures can also be classified by their Design

Solid 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
- solid structures are not always completely 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)

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.

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.

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.

1.2 The Function of Structures

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.

Multiple Functions

Most structures have several functions, which may include:

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

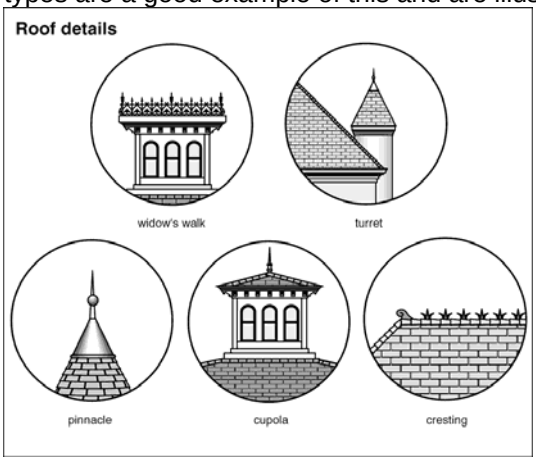
Precise, measurable standards normally are indicated in the specifications the structure must comply with in order to perform its function/s.

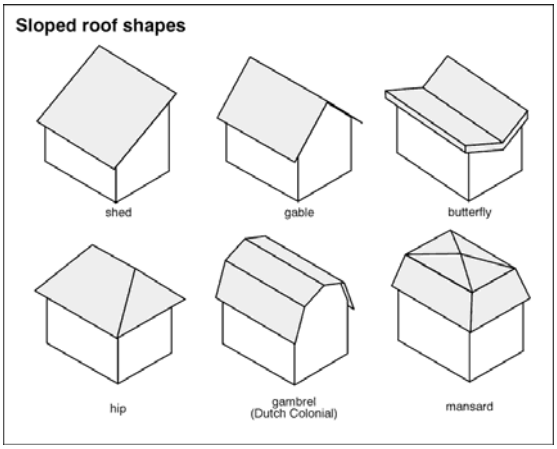
Function and Effective Design

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

Common Function, Different Design

Some structures may appear very different from each other, but share a common function. Roof types are a good example of this and are illustrated on p. 272.





Other Characteristics of Structures

Besides form and function, structures can be interpreted and classified by the materials and components they are made of. Natural and man-made structures share some common features.
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. Norman Breakey designed the pain roller to make painting a large wall less time consuming and more economical.
· 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).

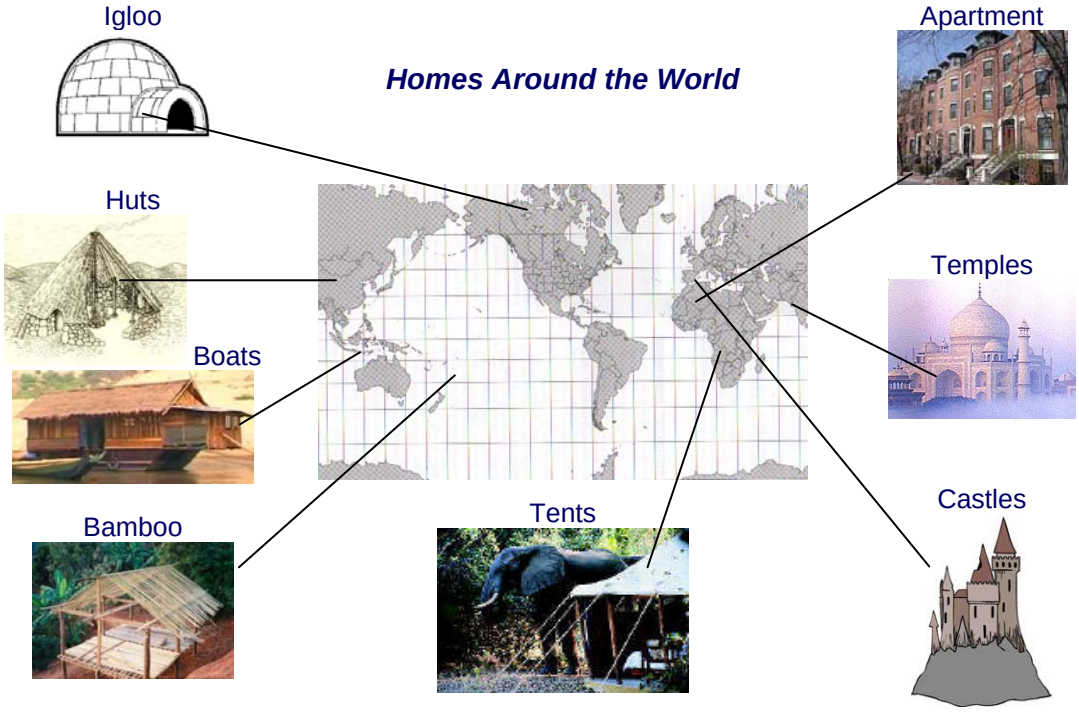
Aesthetics

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.

1.3 Human-Built Structures around the World

The Human Home

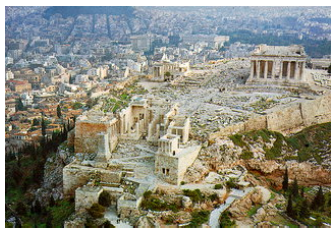
Homes from many different cultures reflect the adaptations these cultures have made to provide a suitable shelter. The varied structures result from climate, culture, tradition, technology and economics. Availability of materials, portability and traditional practices are considerations for different cultures when they build their homes.



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.

Current or Classical – Advantages and Disadvantages of Different Designs.


Stonehenge


Acropolis


Great Wall of China

Can you think of some other **Famous Structures**?

Section 1 – Natural and Human-made Structures Quiz

1.1 Classifying Structural Forms

1. A student who was studying for a rest remembered the different models the teacher used in class to identify the different kinds of structures. When the teacher made a tent-like position with the hands, the student remembered it represented a …
   - **A. mass**
   - **B. shell**
   - **C. frame**
   - **D. solid**

2. Piling materials into a particular shape, or design makes a solid structure. The following are examples of natural solid structures ...
   - **A. dams and mountains**
   - **B. brick walls and coral reefs**
   - **C. ice sculptures and sand castles**
   - **D. mountains and coral reefs**

3. A frame structure like your skeleton is made of very strong materials so they can support the ...
   - **A. ligaments**
   - **B. cartilage**
   - **C. joints**
   - **D. organs**

4. Egg cartons, food cans, bottles and pipes are examples of ...
   - **A. manufactured shell structures**
   - **B. natural shell structures**
   - **C. manufactured frame structures**
   - **D. natural frame structures**

5. Spider webs are examples of structures that can hold up to 4000 times the weight of the spider that made it. The spider web is a …
   - **A. solid frame structure**
   - **B. solid shell structure**
   - **C. natural shell structure**
   - **D. natural frame structure**

6. All of the following structures can be classified as manufactured, EXCEPT a …
   - **A. jigsaw puzzle**
   - **B. spoon**
   - **C. feather**
   - **D. fishing net**

7. How a structure is put together, how it is shaped and the types of materials that are used to build it are all part of the structure's ...
   - **A. design**
   - **B. function**
   - **C. classification**
   - **D. stability**

1.2 The Function of Structures

1. Containing, sheltering, transporting, lifting ... are all words to describe a structure's …
   - **A. design**
   - **B. stability**
   - **C. function**
   - **D. aesthetics**

2. 
Inukshuit is a unique symbol of Inuit culture, always pointing the way home. To anyone who encounters these manufactured structures (which come in many different forms and shapes) the greeting they convey is one of joy and happiness. Their purpose is to …
   - **A. show danger**
   - **B. guide travelers**
   - **C. reward hunters**
   - **D. identify hazards**

3. 
The 5 glass-pyramids of the ***Muttart Conservatory*** in Edmonton house different types of plant cultures, including; tropical, arid and temperate. It is more than just a garden though, because it hosts many of Edmonton's premier floral shows, educational programs for school children, horticultural courses for adults and continues as a very popular site for weddings, banquets and business functions.

Because these structures are used for a variety of reasons, they have multiple
   - **A. designs**
   - **B. functions**
   - **C. shapes**
   - **D. forms**

4. Roof types are designed for cover and also to serve a useful purpose in the environment in which they can be found. A very steep roof design in a mountainous area is designed to prevent …
   - **A. heavy rains**
   - **B. snow build-up**
   - **C. climbing animals**
   - **D. wind damage**

5. Canadian inventor, Norman Blreakey, made a revolutionary invention in 1940. The paint roller served a very important function, which was to paint a large area …
   - **A. faster and easier**
   - **B. with less skill required**
   - **C. with better quality paint**
   - **D. in a more expensive way**

6. Michael Kelly, a Prairie rancher invented barbed wire to keep his livestock from wandering off. His idea came from a natural structure, a …
   - **A. cactus**
   - **B. tumbleweed**
   - **C. prickly pear**
   - **D. thorny bush**

7. When choosing the most suitable materials to build a structure, architects, engineers and designers should consider all of the following before making their final choice ...

A. cost, appearance, environmental impact, energy efficiency
B. cost, color, life expectancy, impact strength
C. environmental appearance, type of symmetry, type of joints needed, cost effectiveness
D. flexibility, impact strength, energy efficiency, color

8. Some structures share the same function, although their appearance may be quite different. Each of the following roofs is used to provide a covering for a building.


1

2

3

4

Which roof type – called a gambrel roof - is commonly seen on a farm?

A. 1
B. 2
C. 3
D. 4

9. Each manufactured structure can be paired with a natural structure it is based on.

1 flippers 
2 egg carton 
3 umbrella 
4 honeycomb 
5 mushroom 
6 webbed feet 

Only one of the pairings below is correct.
Which one is it?

A. 6 - 1
B. 3 - 6
C. 6 - 5
D. 2 - 6

10. One important criteria of good design - that is usually not written down in the specifications - is that the structure ...

A. has a margin of safety
B. is esthetically pleasing
C. is cost effective
D. has a solid foundation

1.3 Human-Built Structures Around The World

1. ***Stonehenge*** is an ancient monument, located in England. It was built more than …

A. 30 years ago
B. 300 years ago
C. 3000 years ago
D. 30,000 years ago

2. Sun-baked ***'Adobe'*** brick houses are usually found in countries where the climate is …

A. Wet and cool
B. Hot and dry
C. Temperate
D. Damp and cold

3. The ***Taj Mahal*** in India is a …

A. tomb
B. temple
C. mosque
D. castle

4. ***Sod houses*** were common on the prairies and were used by …

A. engineers
B. settlers
C. businessmen
D. contractors

5. ***Current or Classical?*** The sailing vessel illustrated here was used as a pirate ship. It's big advantage was that it could …

A. hide easily
B. sail fast
C. sail with no wind
D. not be sunk

6. Both of these structures are houses for people in very specific environments. One advantage of structures such as these is that they …


Igloo


tent

A. are portable
B. protect from the cold nights
C. keep out animals
D. are fireproof

7. When a structure is built to withstand loads - more than it normally would carry - the structure is built with a larger ...

A. foundation
B. symmetrical base
C. set of pilings
D. margin of safety

2.0 External and Internal Forces act on structures

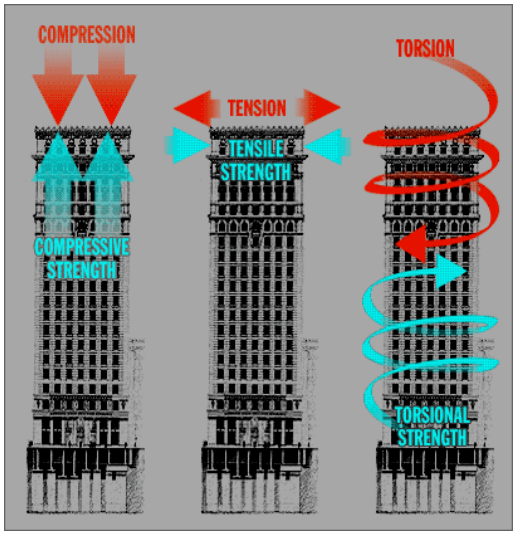
2.1 Measuring Forces

A **force** is a push or pull that tends to cause an object to change its movement or shape.

Magnitude, Direction, and Location

The actual effect of a force on a structure depends on:

- the *magnitude*, or size, of the force (the bigger the force's magnitude, the stronger it is and the more effect it will have on a structure)
- the *direction* of the force
- the *location* where the force is applied



When drawing forces, the force is represented by an arrow. The different sized arrows tell us a little about the magnitude, direction and location of the forces in a diagram.

The Newton

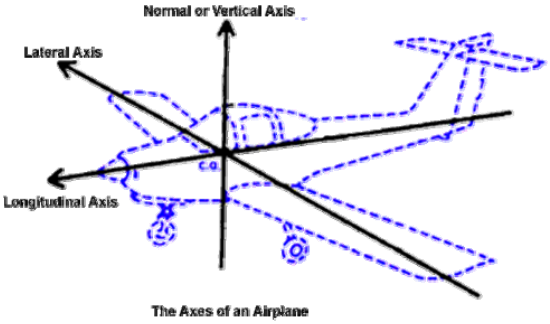
The standard unit for measuring force is called a **Newton** (N). One Newton is the amount of force needed to hold up a mass of 100g.

2.2 External Forces Acting on Structures

External forces on structures are stresses that act on a structure from outside the structure. Gravity is one such force, acting on all things all the time. *Impact forces* (things that collide with the structure) are another type of live load. External 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.

Centre of Gravity

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.



The Axes of an Airplane

Engineers need to locate the center of gravity of a structure in order to stabilize the structure. By locating the structure's center of gravity, an engineer can tell if the structure is stable or unbalanced.
Try this Virtual Lab

To increase the stability of a structure you can increase the width of the base compared to its height and move the base closer to the ground.

Symmetry

Symmetry is a balanced arrangement of mass occurring on opposite sides of a line or plane, or around a center or axis. The force of gravity on either side of the center point of this line is the same.

Load

The load is an external force on a structure.

Static and Dynamic Loads

- A ***static (dead) load*** is a permanent force, acting on a structure. This includes the weight of the structure itself and the non-moving parts it supports.
- A ***dynamic*** (*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.

Supporting the Load

Different kinds of structures are designed to withstand different loads and forces. Different bridges are built for different purposes.

Type of Bridge	
 Beam Bridge	- most common bridge used - flat beam supported at each end
 Truss Bridge	- lightweight, but strong bridge made of trusses (triangle-shaped frames) along its sides
 Suspension Bridge	- hangs between two ends (towers) that hold it up. - smaller cables attach the roadway to the hanging cables
 Arch Bridge	- is designed to withstand heavy loads. - Roman aqueducts are good examples of this type of bridge

Measuring A Structure's Load Performance

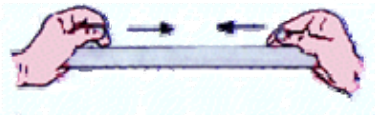
How effectively a structure holds up its load is determined by performance requirements. Load performance is maximum weight. Other performance considerations include safety, cost, and effectiveness in meeting the purpose for which it was designed.

Comparing Performance

The performance of one structure can also be compared to that of another. This performance comparison is made by comparing *the load per unit of its own mass* for each structure.

2.3 Internal Forces Within Structures

Compression, Tension, and Shear



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.

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

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.

Complementary Forces

A *bending force* is a combination of tension and compression

Shear and torsion forces are also a combination of tension and compression

2.4 Designing Structures to Resist Forces and Maintain Stability

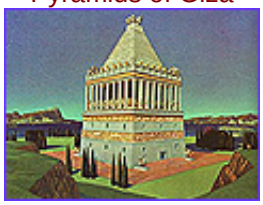
The Seven Wonders of the Ancient World

Pyramids of Giza

Hanging Gardens

Maussoleum

Statue of Zeus



Temple of Artemis

Colossus of Rhodes

Pharos of Alexandria

Additional Wonders of the Wodern World

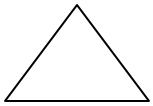
Chunnel Tunnel

Golden Gate Bridge

Panama Canal

Strong Structural Shapes

Rectangle



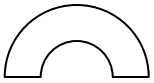
Triangle

Square

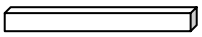
The ***triangle*** is a very strong and rigid shape that will not bend easily. A triangular prism is much stronger than a rectangular prism, a pentagonal prism, or any other multi-sided three-dimensional shape.

Structural Components

Arches — An arch is a common shape found in structures such as bridges. The arch can support a large load because the force of the load is carried down the arch to the foundation – spreading out the load.

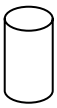


Beams — A simple beam is a flat structure that is supported on both ends . There are different types of beams, including : ibeams, ubeams, tbeams and girders, or box beams



Truss — A truss is a framework of beams joined together, usually in the form of interlocking triangles. A cantilever is a beam that is supported only at one end. When weight is placed on the beam, the beam bends in an N-shape to resist the load.

Columns — A column is a solid structure that can stand by itself and is used to support beams.



Structural Stress, Fatigue, or Failure

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 (that part of the structure that will likely fail the most often).

A structure needs *strength* and *stiffness* to avoid 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
- 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.

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

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.

 (Crash Test Dummies)

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 (Definition - The phenomenon leading to fracture under repeated or fluctuating stress.

Fatigue fractures start out at the beginning as minute cracks and grow under the action of fluctuating stress.)

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 when a small force is applied.

Building for Structural Stability

Building a stable structure that will perform its function in the environment in which it will be is a challenge to designers. A careful analysis of all the forces that will be acting on the structure must be made. 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**

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. 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).

Section 2 – External and Internal Forces Act on Structures

2.1 Measuring Forces

1. A force is a push or a pull that tends to cause an object to change its …
   - **A. height or length**
   - **B. movement or shape**
   - **C. colour or texture**
   - **D. direction or strength**

2. The actual effect of a force depends on three things: the magnitude, or size of the force; the direction of the force; and …
   - **A. how the force is applied**
   - **B. where the force is applied**
   - **C. why the force is applied**
   - **D. how long the force is applied**

3. In structural drawings, arrows represent forces. A force that is being applied to a heavy box to lift it off the ground would be shown by the following arrow …

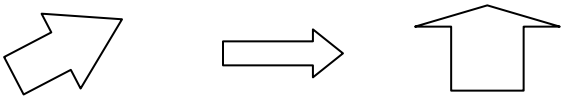
   A. 

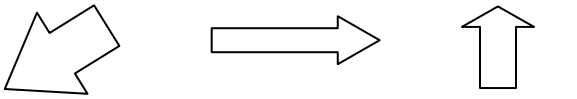
   B. 

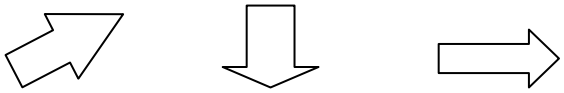
   C. 

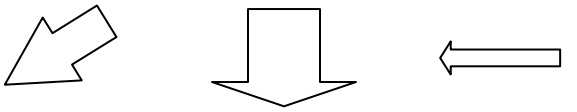
   D. 

4. A large force is applied to a freezer to move it up a ramp to the second floor, where a smaller force is used to push it to the window, and a very large force is needed to lift it up, to put it off balance, so it falls out the window and is demolished on the sidewalk below.

   A. 

   B. 

   C. 

   D. 

5. The standard unit of measuring force is named after a famous English scientist, who the first one to describe the *'law of gravitation'*, getting the idea for the law as he sat under an apple tree. This unit of measuring force is similar to the amount of force needed to hold an apple in your hand and is called a …
   - **A. joule**
   - **B. kilogram**
   - **C. Newton**
   - **D. gram**

2.2 External Forces Acting on Structures

1. An external force is a force applied to a structure by …
   - **A. its own mass**
   - **B. something else**
   - **C. an internal force**
   - **D. Newtons**

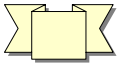
2. Identify which structure would have the greatest stability, because of its centre of gravity.
   - **A. High centre of gravity and a narrow base**
   - **B. High centre of gravity and a wide base**
   - **C. Low centre of gravity and a narrow base**
   - **D. Low centre of gravity and a wide base**

3. The Leaning Tower of Pisa is an example of a mass structure. The Tower was built with a lean originally and it had been getting worse, because of the foundation on which it was built. The structure has not fallen over yet, because its center of gravity still keeps it relatively stable. Once it started to lean more, engineers knew that the center of gravity shifted. The reason that the Tower is moving is because ...
   - **A. it is very windy in Pisa**
   - **B. Pisa has many earthquakes**
   - **C. the thrust line is inside the foundation**
   - **D. the thrust line is outside the foundation**

4. A student compared his mass and weight in two different places (Vancouver and Banff). Which statement is correct?
   - **A. His mass and weight were unchanged.**
   - **B. His mass and weight were both the same.**
   - **C. His mass was the same, but his weight was different**
   - **D. His mass was different, but his weight was the same.**

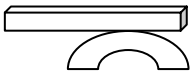
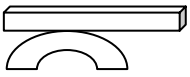
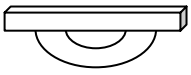
5. Weight is a force that is measured by the gravitational pull on the object. It is usually measured in ...
   - **A. Newtons**
   - **B. kilograms**
   - **C. grams**
   - **D. pounds**

6. *Symmetry* is a balanced arrangement of mass that occurs on opposite sides of a line or plane, or around a centre or axis. The force of gravity acting on each side is the same. Which of the following illustrations is symmetrical?

A.  **B.**  **C.**  **D.** 

7. Which of the following structures would have the greatest stability?

A.

A.  **B.**  **C.**  **D.** 

8. An external force on a structure is called a …
   - **A. force**
   - **B. load**
   - **C. mass**
   - **D. weight**

9  This bridge cannot perform its function any longer because it has collapsed. One of the probable causes of the failure of this structure was the actual weight of the bridge, which could not be supported by its suspension cables. This type of load is called …

A. gravitational
B. supporting
C. static
D. dynamic

10.  A dynamic load on this train bridge is the …

A. tracks
B. train
C. cement pillars
D. wood beams

11.  The dynamic load that makes this device work is …

A. wind
B. tsunami
C. earthquake
D. landslide

12. Designers generally use three key methods to help structures withstand forces. They include all of the methods below, EXCEPT for ...

A. distribute the load evenly
B. direct the forces along angled components
C. shape the parts for the forces they are likely to face
D. place lighter materials above heavier materials

13. When engineers build bridges, they take two conditions into account: what the bridge is crossing and what kinds of loads it will support, to decide which type of bridge will best suit the situation. Which type of bridge would engineers suggest to withstand very heavy loads?

A. Beam Bridge
B. Truss Bridge
C. Arch Bridge
D. Suspension Bridge

14. How well a structure will hold up under a load is important for cost, efficiency and …

A. aesthetics
B. appearance
C. safety
D. materials

15. Performance requirements are the guiding principles that engineers use to design structures. Maximum weight that the structure can support is expressed as …

A. weight capacity
B. load performance
C. static load mass
D. dynamic load mass

2.3 Internal Forces Within Structures

1. Internal forces are classified by the direction in which they act within an object. A force that acts to push parts of the object in contact with each other in opposite directions is this kind of internal force …
   A. bend
   B. buckle
   C. shear
   D. twist

2. When a solid material is compressed, small microscopic cracks in the material can enlarge or break apart. This can cause one section of the material to break away from the other part. This action is called ...
   A. bend
   B. buckle
   C. shear
   D. twist

3. Structures fail for a number of reasons. Engineers, study failed structures so they can design stronger, more durable structures. A flagpole that has been blown over in a strong wind happens because of the increased force that is applied to the ...
   A. entire structure
   B. entire base
   C. opposite side of the flagpole's base
   D. same side of the flagpole's base

4. Metal fatigue happens because metal is ...
   A. too old to be used any more
   B. not made properly
   C. bent or twisted over and over again
   D. exposed to extreme conditions

5. Complementary forces happen when different kinds of forces act on a structure at the same time. An example of a complementary force is …
   A. bend
   B. buckle
   C. shear
   D. twist

6. When you put your hands on your desk and put all your weight on them - then try to move them forward your hand (much like a structure) resists movement forward because of ...
   A. static forces
   B. kinetic forces
   C. external forces
   D. frictional forces

2.4 Designing Structures

1. The 7 wonders of the Ancient World took may years to complete, but they lasted a very long time. Why do you think that the Statue of Zeus at Olympia lasted so long?
   - **A. It was sheltered in a valley.**
   - **B. It was protected by the Greek Gods.**
   - **C. It was made of gold and ivory, which resists corrosion.**
   - **D. It was made of reinforced concrete and sealed with epoxy.**

2. The strongest structural shape is a …
   - **A. square**
   - **B. circle**
   - **C. triangle**
   - **D. rectangle**

3. When a structure has a single horizontal load-bearing beam, supported by two columns - one at each end, the beam will likely bend in the middle (A box and girder bridge spanning a river is a good example). This bending exerts pressure outward on the vertical supporting beams. To strengthen this bridge, so that heavy vehicle can cross it, you should ...
   - **A. reinforce the columns at both ends with braces**
   - **B. place additional columns in the middle**
   - **C. use a double cantilever design**
   - **D. utilize flying buttresses**

4. An arch, which is a common shape in bridges, can support large loads. This is possible because the force of the load is carried down through the arch to the foundation, from this point in the arch …
   - **A. loadstone**
   - **B. keystone**
   - **C. column**
   - **D. cantilever**

5. Beams are common components in a wide range of structures. The advantage of I beams is that they have a lot of strength but have less of this compared to simple beams …
   - **A. shape**
   - **B. mass**
   - **C. tension**
   - **D. girder**

6. Structural stability requires that a variety of materials should to be utilized to avoid deformation and structural failure. In a hang-glider the way that helps to reduce internal forces, such as tension, compression and shear, on the component parts is to …
   - **A. distribute the load evenly**
   - **B. direct the forces along angled components**
   - **C. shape the parts for the forces they are likely to face**
   - **D. place lighter materials above heavier materials**

7. Auto safety designers and inspectors to identify impact points when material fails in a collision use crash test dummies. When the car is rammed into a solid wall, the front end buckles. This happens to better protect the Crash test dummies (us) in a real accident. The metal deforms because of the energy it absorbs in the impact. Designers ...
   - **A. do this on purpose to ensure the material buckles.**
   - **B. identify the weaknesses and try to fix them.**
   - **C. determine what materials buckle the least.**
   - **D. identify where the front end needs more reinforcement.**

3.0 Structural strength and stability depend on the properties of different materials and how they are joined

3.1 Materials and Their Properties

Classifying Material Properties

Materials - the properties or characteristics of different materials must match the purpose of the structure. Properties Include: Brittleness, Ductility, Hardness, Plasticity,, Resistance to heat, Resistance to water, Compression, Tensile strength.

Kinds of Materials:

- 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 involves weighing advantages and disadvantages of the different materials
Factors to consider:

- Aesthetics
- 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?
- Consumer demand and availability
- Disposal of waste

Testing Deformation and Flexibility of Materials in Structures

Deformation is a change in the shape ina structure or any structural component, because the material is unable to resist the load acting on it. When too much deformation occurs within a structure, the structure will fail.

Flexibility is the ability of a material to be bent under force without breaking. How much an object can change shape without breaking under a given load is a measure of its flexibility.

3.2 Joining Structural Components

The place at which structural components in a structure are joined together is called a **joint.** Ties, like thread, string and rope, fasten things together.

Joints that Rely on Friction

Friction is the force that results when the surface of one object moves against the surface of another object. The strength of the force of friction also depends on the roughness or smoothness of the surfaces in contact with each other.

- 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.
- Mass - The friction between the base of the block and the surface underneath is enough to keep the block from moving

Joints that Rely on Bonding

- Adhesives, or sticky substances can also hold things together. Thermosetting glues (hot glue) and solvent-based glues (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.

Fixed or Movable? Which Joint For Which Structure?

Rigid, or Fixed Joints do not allow movement and usually result from bonding type joints. Mobile, or Flexible Joints are joints that allow movement.

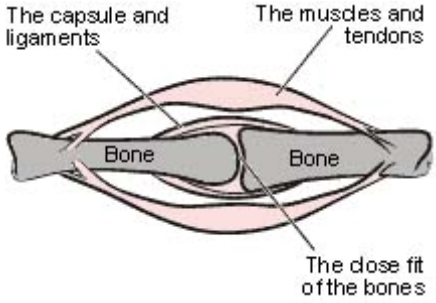
Designing Joints To Last

If a structure is to last a reasonable time, it must be designed to withstand the forces acting on it over time. Extremes in weather, repeated movement, and other exceptional forces can affect the life expectancy of a structure.

3.3 Properties of Materials in Plant and Animal Structures

Materials in Animal Structure

Bones, Ligaments, and Cartilage
Bones are hard and rigid, forming a structural frame. The bones are connected with ligaments, which are strong, flexible connective tissue. Cartilage, found at the end of some bones, reduces friction and provides a smooth surface for movement.

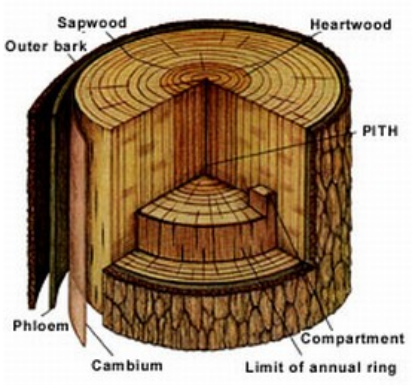


Muscles and Tendons
The muscles allow the skeletal frame to move. The fibrous muscle tissue is connected to bones like tendons, contracting and relaxing, allowing the bones to be pushed and pulled.

Joints
The joints in the body are specialized for various functions. Ball and socket joints in the shoulders and hips permit movement in many directions. Elbow and knees are hinge joints and allow movement forward and back. Joints that do not allow any movement, like the skull, ensure that the organ it covers will be protected

Skin, The Human Shell
The skin, a tough, flexible material, provides the structural shelter for all other parts of the human body. It waterproofs and protects it from harmful bacteria. It also helps to keep the body temperature constant, allowing it to perspire and shiver.

Materials in a Tree's Structure



The outer bark is the tree's protection from the outside world. It insulates against cold and heat and wards off insect enemies. The inner bark, or "phloem", is pipeline through which food is passed to the rest of the tree. The cambium cell layer is the growing part of the trunk. It produces new bark each year and new wood in response to hormones that pass down through the phloem with food from the leaves. Sapwood is the tree's pipeline for water moving up to the leaves. Sapwood is new wood. Heartwood is the central, supporting pillar of the tree. Although dead, it will not decay or lose strength.

Section 3 – Structural Strength and Stability

3.1 Materials and Their Properties

1. The materials in structures can be evaluated according to many properties. The property that describes how easily a material can be shaped is called …
   - **A. ductility**
   - **B. plasticity**
   - **C. brittleness**
   - **D. tensile strength**

2. The following is an example of a composite material
   - **A. tent**
   - **B. drywall**
   - **C. a cardboard box**
   - **D. reinforced concrete**

3.  This palm tree is demonstrating this property …
   - **A. brittleness**
   - **B. ductility**
   - **C. plasticity**
   - **D. flexibility**

4. A change of shape in a structure or a structural component, because the material is unable to resist the load acting on it is called …
   - **A. deformation**
   - **B. resistance**
   - **C. ductility**
   - **D. brittleness**

5. Windows on the top floor of a house are tinted to allow in the light, but keep out ultraviolet radiation. Solar panels used on the roof make the home more energy efficient because they produce …
   - **A. light**
   - **B. electricity**
   - **C. movement**
   - **D. availability**

3.2 Joining Structural Components

1. The place at which structural parts are fastened together is called the …
   - **A. bridge**
   - **B. joint**
   - **C. corner**
   - **D. connection**

2. The force that resists another object when the surfaces of each are in contact is called …
   - **A. fusion**
   - **B. force**
   - **C. friction**
   - **D. fissure**

3. One way landscape architects join stones to make retaining walls and split-rail fences is to use this method …
   - **A. rivets**
   - **B. welds**
   - **C. cement**
   - **D. mass**

4. Adhesives are used to bind materials together. A type of adhesive that hardens when it cools is ...
   - **A. thermosetting glue**
   - **B. therapeutic glue**
   - **C. solvent-based glue**
   - **D. solvent-enriched glue**

5. Moveable joints are used to secure materials together in a structure. All of the following joints are examples of moveable joints (allowing movement in a structure) EXCEPT ...
   - **A. a trailer hitch**
   - **B. photocopier lid**
   - **C. ball and socket joint (shoulder)**
   - **D. Lego**

6.  This unique and imaginative structure built in 1967, can be seen in St. Paul, Alberta. It is the first of its kind in the world. The purpose of this structure is for …
   - **A. town assemblies**
   - **B. political rallies**
   - **C. UFO landings**
   - **D. displaying artifacts**

7. Joints are made to withstand forces acting on them for long periods of time. Wear and tear parts of moveable joints are caused by friction. Friction also generates …
   - **A. deformation**
   - **B. fatigue**
   - **C. stability**
   - **D. heat**

3.3 Properties of Materials

1. The properties that help bones in your body perform their function are …
   A. ductility and brittleness
   B. hardness and flexibility
   C. rigidity and hardness
   D. plasticity and brittleness

2. There are 656 muscles in your body. These muscles allow your skeletal frame to move. The contraction and relaxing of these muscles is possible because they are made of …
   A. semi-solid fibrous tissue
   B. solid fibrous tendon
   C. solid fibrous cartilage
   D. semi-fibrous ligament

3. The layer of material in a tree truck that supports the rest of the structure, but does not function to conduct water and materials is the …
   A. woody layer
   B. heartwood
   C. sapwood
   D. vascular cambium

4. Science fiction often gives us exciting ideas about materials that can withstand almost any force. In reality, the perfect material has not been discovered yet. One material (if it could be made the thickness of a pencil - could stop a 747 jet). It is currently being synthetically developed and will have widespread use because of its strength. The material is known as ...
   A. Kelvar®
   B. spider silk
   C. industrial bamboo
   D. rice grain

5. The designers of spinning wheels work to ensure that the fibers, that are twisted together, are done so tightly that they lock together. If the fibers are twisted too much they tangle and shorten, unless you keep pulling them apart. This can be useful if you are wanting to make ...
   A. stronger fabrics
   B. lighter fabrics
   C. more durable fabrics
   D. stretchy fabrics

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

4.1 Building Safe Structures in All Environments

Margin of Safety

Safety is important to designers and so they design based on a margin of safety. This refers to the limits within which a structure is expected to perform its function safely.
Certain ranges of performance provide the designers with upper and lower limits (thresholds) within which the structure will perform best. The margin of safety will always exceed the upper limit because failure of the structure may cause harm to human life.

Testing for Structural Safety

(Crash Test Dummies)

One way to ensure that the structure you have designed is safe, is to test it to extremes. Hockey helmets are tested in this way to ensure they provide the protection they are designed for.

Cars are driven into brick walls to see what happens and how it happens, so that designs can be improved upon. Testing occurs at each and every stage of development and involves real and simulated situations.

Monitoring Structural Safety

Another way to evaluate the safety of a structure is to look at the frequency and conditions under which a structure fails. This information, gathered first hand or through surveys – from people who have used the structure - when analyzed, will help designers redesign the structural components to improve the performance of the structure.

Accounting For Environmental Factors

Climate Conditions

Climate related factors include: precipitation (rain, snow, ice), wind, heat, cold, humidity, and dryness. In the far north, building on permafrost, which is frozen in the winter and becomes spongy in the summer is proving to be a challenge.

Terrain Conditions

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 constructed on solid bedrock are best. 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. Unstable soil and steep terrain make building stable structures almost impossible. Some structures have to be built in certain places where the conditions are not ideal. It is the designers job to find a way to make it work. (Lighthouses are necessary – they are constantly being bombarded by wind and waves, but have survived fairly well, thanks to the designers who made it work.)

Earthquake Risk

Earthquake proof building are being more closely monitored and improved upon. The forces of an earthquake are unpredictable and so the margin of safety in the design has to be extremely high and that has been a challenge.
Here's an activity for you to make an Earthquake Proof Building
http://school.discovery.com/lessonplans/programs/earthquakeproof/

4.2 Strengthening Materials to Improve Function and Safety

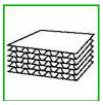
Science strives to provide solutions to practical problems. Structures are designed to meet human needs. Over time these needs may change and structures need to be modified or redesigned. Whatever the reason for this, it is the role of designers to utilize all available information to improve upon the structures we use.

Altering Materials For Strength

One way many structures can be improved is to combine materials and components into new arrangements, taking advantage of the best characteristics of each.

Corrugation

Corrugation is the process of forming a material into wave-like ridges or folds. Cardboard and metal are good examples.



Lamination

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

Strengthening Component Arrangements

Making use of trusses and arches, or adding small supports for reinforcement can make structural components stronger.

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.

Changing Methods of Fastening

Fasteners are usually the weakest part of a structure. Besides being an inconvenience when they fail, if the fastener was a vital component in the structure and it failed, it would be a safety concern. Changing the type of material used as a fastener, or even changing the type of fastener may hold structural parts together more effectively.

New Materials

Science and technology are creating new materials all the time. They are making it possible to build structures that are lighter, stronger and more stable. Composite materials and new technologically developed synthetic materials have made it possible for new designs and innovations in many areas.

4.3 Evaluating Designs from an Overall Perspective

When evaluating whether a structure is doing what it was designed to do, and doing it as well as it can, there are certain **factors to consider:**

Cost	Benefits	Safety	Impact on the Environment
- how much will it cost to build, operate and maintain the structure - can we afford to build it?	- is the appeal of the structure 'pleasing' over time? - who will enjoy the benefits of this structure?	**- is there a safety hazard?** **- who and what could be affected by these risks?**	- does the structure harm the environment? - does the structure conserve energy?

A Case Study In Improving Designs

'The Sherpa' – The first Rocky Mountain Bike, produced in 1982.
Read How Rocky Mountain Bicycles Makes Bikes on p. 335
Then answer the questions on p. 334.

Section 4 – Structures are designed, evaluated, and improved to meet human needs

4.1 Building Safe Structures in All Environments

1. Although each structure is designed for a very specific function the one thing that they all have in common is …
   A. cost
   B. safety
   C. durability
   D. appearance

2. Building components are designed to withstand more force than will normally occur or act on the structure. Unfortunately some structures fail in extreme situations because the forces acting on the structure have exceeded the structure's …
   A. building code
   B. stability parameters
   C. margin of safety
   D. deformation threshold

3. Various tests on a structure's design are made before it is approved for use by the consumer. Consumer Product Tests ensure that a product is safe to use. The first step in the testing process is to test the product's …
   A. components
   B. performance
   C. durability
   D. design

4. During the Ice Storm in Quebec in 1998, ice crystals formed on many structures. Some of these structures failed because the formation of ice crystals on the structure added to the structure's …
   A. flexibility
   B. overall mass
   C. safety margin
   D. tensile strength

5. The most recent mudslides in North Vancouver (January, 2005) caused extreme damage and some loss of life. This occurred because of the …
   A. unstable soil and steep terrain where these people lived
   B. heavy rainfall this area received in a short period of time
   C. poor construction practices and lack of appropriate safety margins
   D. minor earthquake that occurred at the same time as the sudden rainfall

6. Stability in a structure is dependant on a number of factors. One of these factors is whether or not a structure could fail if an extreme force was applied to the structure that was not in the original design specifications. The Empire State building is a steel frame building that survived the crash of a USAF Bomber hitting it between the 78th and the 79th floors. The design component that likely enabled the Empire State building to withstand this incredible force was its ...
   A. mass
   B. reinforced concrete
   C. central location
   D. lack of glass materials used

7. There are environmental and man-made conditions, which make the soil, loosen and become compact, which makes the soil relatively unstable. Three strategies are use to ensure a structure is built on a firm foundation. The three strategies include all of the following, EXCEPT ...
   A. find something solid
   B. make a soil layer
   C. spread the load
   D. utilize pressure and density

4.2 Strengthening Materials to Improve Function and Safety

1. Improving designs by using different materials or incorporating new technologies can help to make a structure perform its function more effectively. One way to solve a structural problem is to combine materials and components in new …

A. technologies
B. arrangements
C. adhesives
D. functions

2. At birth a baby has 350 bones. As the baby grows, the total number of bones in the body is reduced to 206. Nature's way of strengthening the body is to use the 144 'missing' bones to reinforce the frame by this method …

A. adhesive
B. gluing
C. fusion
D. fastening

3. The process of forming a material into wave-like ridges or folds is called corrugation. Common examples can be found in materials such as …

A. cardboard boxes
B. drywall sheets
C. aluminum foil
D. Reinforced concrete

4. A stronger material, made by gluing layers of the same material together, is done through a process known as …

A. corrugation
B. reinforcement
C. lamination
D. papier-mâché

5. Technological advancements have led to new composite materials being developed. One such material is used in such diverse products as tires, fibre optic cables, and sporting goods. This composite material is known as …

A. Spider silk
B. Kelvar®
C. Fibreglass
D. Titanium

4.3 Evaluating Designs from an Overall Perspective

1. Any design can be evaluated from many different perspectives. The most common perspectives designers and engineers use include …
   A. cost, benefits, safety, impact on the environment
   B. materials, benefits, safety, waste production
   C. cost, benefits, materials, aesthetics
   D. impact on the consumer, aesthetics, safety, waste reduction

2. Rocky Mountain bicycles modified a road bike and made this in 1982. The 'Sherpa' was the first one of these produced.
   A. racing bike
   B. all-terrain bike
   C. motocross bike
   D. mountain bike

3. Hollow triangle tubes are used as the traditional shapes for a bicycle. This is because they provide the best …
   A. flexibility
   B. ductility
   C. strength
   D. plasticity

4. All departments within the bicycle company, such as marketing can have access to the bicycle specifications because the company uses this for all its bike designing and manufacturing …
   A. engineering sketches
   B. computer-aided systems
   C. digital communication
   D. audio-visual technologies

5. A radio that operates by turning a crank in the back provides enough power to last about 30 minutes. The radio operates on mechanical energy, with no need for batteries or electricity. It could become very popular because one of its best advantages is its …
   A. portability
   B. design
   C. cost
   D. flexibility

REVIEW … Key Concepts

Unit 4 – Structures and Forces

1.0 Natural and man-made (Manufactured)

- Structural forms can be **shells**, **frames** or **solids**
- Each structure performs a specific function and can vary in its design
- Climate, culture, tradition, technology and economics influence the design of a structure

2.0 External and Internal Forces act on structures

- Effect of a force on a structure depends on **magnitude**, **direction** and **location** of the force
- **External** force is applied on the outside of a structure
- **Stability** is affected by the changes in the mass distribution and the design of its foundation
- A structure's ability to withstand a load depends on its overall strength and stability
- Performance standards are included in the overall structural design
- **Internal** forces include **compression**, **tension** and **shear**.
- Material shape and properties determine resistance to internal forces acting on them
- Structures undergo **structural stress**, **fatigue** and **failure**

3.0 Strength and Stability

- Natural and synthetic materials are classified by a range of properties
- Strength and flexibility of materials can be tested – **deformation**
- **Joints** – fixed or movable – friction, bonding or flexibility
- **Stability**, **strength** and **function** rely on the proper use of materials

4.0 Designing, Evaluating and Improving to Meet Human Needs

- Environmental factors can affect the stability and safety of a structure
- **Corrugation** and **Lamination** can strengthen materials
- Structural evaluation criteria: **costs, benefits, safety and potential environmental impact**

1.0 Natural and man-made (Manufactured)

❖ Structural forms can be **shells**, **frames** or **solids**

Describe the characteristics of each of the structural forms.

Shell

_____

_____

_____

_____

Frame

_____

_____

_____

_____

Solid

_____

_____

Mass _____

What kind of structure is the Calgary **Pengrowth Saddledome**?

_____

_____

❖ Each structure performs a specific function and can vary in its design

This is ***INUKSHUIT*** – What is its function?

_____

These glass pyramids have several functions.
Describe the functions of the **Muttart Conservatory** in Edmonton

_____

_____

_____

Describe how an everyday task such as ***'painting a wall'*** can become a technological problem solution that was transformed into a *new technique to paint the same wall* in less time.

_____

_____

_____

Identify a specific **function** each of the following structures was designed to meet.

Stonehenge _____

Chunnel Tunnel _____

Crash Test Dummy _____

'Firth of Forth' Bridge _____

Bedouin Tent _____

Ancient Seismograph _____

What **natural structure** is each of the following structures modeling?

_____

_____

_____

What is meant by **esthetics**? Give 2 examples of how aesthetics has been used to get approval for designing a particular structure in a specific environment.

_____

_____

_____

_____

_____

_____

❖ Climate, culture, tradition, technology and economics influence the design of a structure

Describe or illustrate a **specific traditional structure**, built somewhere in the world, whose design was influenced by …

Illustration	*Influence*	*Name of Traditional Structure – Where it is located*
	Cultural	_____ _____
	Climate	_____ _____
	Tradition	_____ _____
	Technology	_____ _____
	Economics	_____ _____

2.0 External and Internal Forces act on structures

❖ Effect of a force on a structure

The ***actual effect of a force on a structure*** depends on what three things?

_____

_____

_____

For each of the pictures below, use **force arrows** to show the forces at work on the structure.

This first one is done for you

Helicopter taking off

The Leaning Tower of Piza

Taking a wrist shot

Windsurfing on a big wave

How are forces **measured**?

_____

_____

_____

What role do **mass** and **distance** play in the ***Law of Gravitation*** – developed by Sir Isaac Newton?

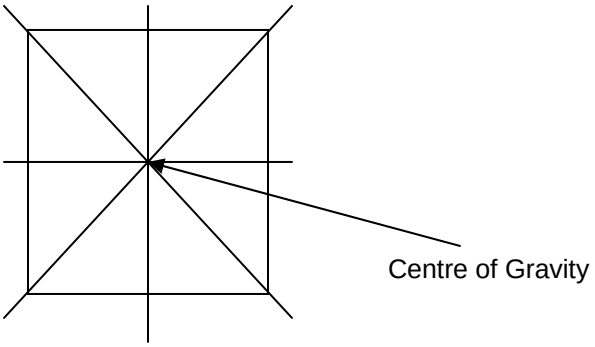
_____

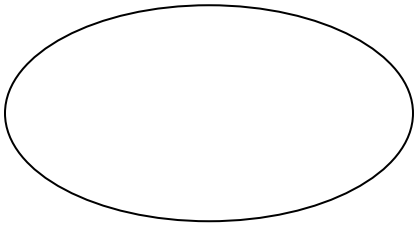
_____

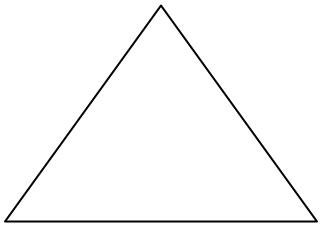
_____

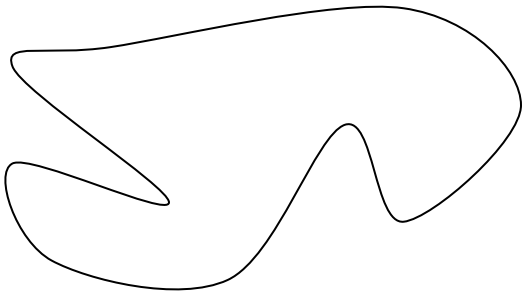
❖ **External** force is applied on the outside of a structure

Gravity acts on every structure. It is the downward force (pull) of the Earth on mass. The greater the mass, the greater the gravitational pull. This gravitational pull acts on the **center of gravity** within the structure. When a structure is supported in its center of gravity, it will be stable and stay balanced. Find the center of gravity for the following structures:









Describe what symmetry is. _____

_____

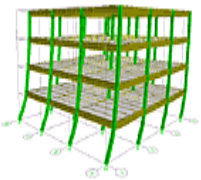
_____

❖ **Stability**

What two things must occur for a structure to be stable …

_____

_____



❖ A structure's ability to withstand a **load** depends on its overall strength and stability

Explain the difference between a **static load** and a **dynamic load**.

_____

_____

_____

Identify the loads present in the following situation

Train crossing a bridge

Static Loads	Live loads

What are the two conditions that engineers use to decide which type of bridge should ne built in a particular situation?

_____

_____

_____

For each type of bridge, sketch a simple diagram showing where the forces are applied in the bridge.

Type of Bridge

Beam Bridge

Truss Bridge

Suspension Bridge

Arch Bridge

- Performance standards are included in the overall structural design

What are **performance requirements**?

_____

_____

_____

How would you **compare** the performance of one structure compared to another?

_____

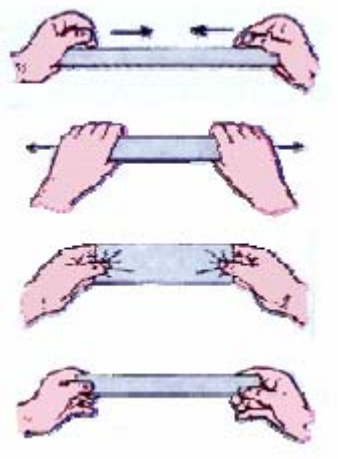
_____

_____

❖ **Internal** forces

Identify the type of **internal force** illustrated and the action it makes.

compression



squeezing / pushing together

_____ _____

_____ _____

_____ _____

Describe and illustrate **complimentary forces**

_____

_____

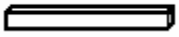
❖ Material shape and properties determine resistance to internal forces acting on them

How does the shape of a structure affect its overall strength? Illustrate the strongest shape.

_____

_____

Describe a specific structural characteristic for each of the following structural components.

_____ _____ _____ _____

_____ _____ _____ _____

❖ Structures undergo **structural stress**, **fatigue** and **failure**

To avoid failure, a structure needs _____ and _____

When a combination of internal and external forces is too much for a structure, stress, fatigue and failure can occur. Describe and illustrate if you can each of the different forms of structural failure.

Buckling _____

_____

Shearing _____

_____

Separation _____

_____

Deformation _____

_____

What forces are acting on this hang glider?

External Forces		Internal Forces
		

3.0 Strength and Stability

❖ Natural and synthetic materials are classified by a range of properties

What are the properties that help to identify what materials should be used when a structure is constructed?

_____ _____ _____ _____

_____ _____ _____ _____

What other considerations are taken into account?

_____ _____

_____ _____

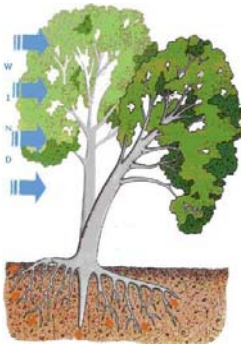
_____ _____

❖ Strength and flexibility of materials can be tested – **deformation**

What is **deformation**?

_____

_____



When the wind acts on the tree, what **complimentary internal forces** demonstrate the **flexibility** of the tree?

_____ _____

❖ **Joints** – fixed or movable – friction, bonding or flexibility

Describe the various types of joints that rely on:

Friction	**Bonding**
_____	_____
_____	_____
_____	_____
_____	_____

Explain the difference between **fixed** and **movable** joints.

_____

_____

_____

❖ **Stability**, **strength** and **function** rely on the proper use of materials

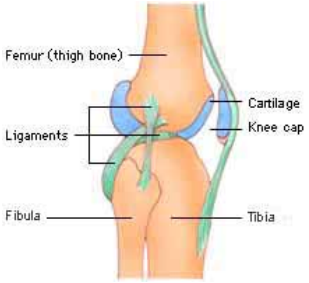
When a structure is stable, its materials strong, but its joints weak or not suited to long time use, what will happen?

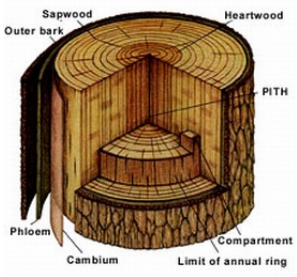
_____

_____

_____

Describe the **function** of the unique materials
that make up the **human frame structure** and a **tree**.





Bones _____

_____

Ligaments _____

_____

Cartilage _____

_____

Muscles _____

_____

Tendons _____

_____

Joints _____

_____

Bones _____

_____

Bark _____

_____

Woody layer _____

_____

Heartwood _____

_____

Sapwood _____

_____

Vascular cambium _____

_____

4.0 Designing, Evaluating and Improving to Meet Human Needs

❖ Environmental factors can affect the stability and safety of a structure

What is meant by **margin of safety**?

_____

_____

_____

How is safety maintained?

_____

_____

_____

What factors in the environment can affect the margin of safety and how are they taken into account when designing a structure?

_____

_____

_____

_____

_____

_____

❖ **Corrugation** and **Lamination** can strengthen materials

Describe the processes of corrugation and lamination

corrugation _____

_____

lamination _____

_____

In what other ways can materials be strengthened?

_____

_____

❖ Structural evaluation criteria: **costs, benefits, safety and potential environmental impact**

Waste disposal is a growing problem for many towns and cities. Design a community waste disposal structure that would revolutionize the collection and disposal of household waste. Answer the questions about your design and then illustrate it.

Cost - How much will the structure cost to build, operate and maintain?

_____

Is it affordable?

_____

Benefits - What are the benefits of having this structure?

_____

Who will enjoy those benefits?

_____

Safety - Is there a safety hazard?

_____

Who and what could be affected by the risks of this structure?

_____

Environmental Impact - What could be done to prevent harm to the environment?

_____

How will the structure operate?

_____

This is what the
Community Waste Disposal Structure
would look like

(If you need an extra page to do this, attach it after this page.)

Structures and Forces Unit Test

Section 1 – Natural and Human-made Structures

1. A student who was studying for a rest remembered the different models the teacher used in class to identify the different kinds of structures. When the teacher made a tent-like position with the hands, the student remembered it represented a …
   - **A. mass**
   - **B. shell**
   - **C. frame**
   - **D. solid**

2. A frame structure like your skeleton is made of very strong materials so they can support the ...
   - **A. ligaments**
   - **B. cartilage**
   - **C. joints**
   - **D. organs**

3. Spider webs are examples of structures that can hold up to 4000 times the weight of the spider that made it. The spider web is a …
   - **A. solid frame structure**
   - **B. solid shell structure**
   - **C. natural shell structure**
   - **D. natural frame structure**

4. All of the following structures can be classified as manufactured, EXCEPT a …
   - **A. jigsaw puzzle**
   - **B. spoon**
   - **C. feather**
   - **D. fishing net**

5.  *Inukshuit* is a unique symbol of Inuit culture, always pointing the way home. To anyone who encounters these manufactured structures (which come in many different forms and shapes) the greeting they convey is one of joy and happiness. Their purpose is to …
   - **A. show danger**
   - **B. guide travelers**
   - **C. reward hunters**
   - **D. identify hazards**

6.  The 5 glass-pyramids of the ***Muttart Conservatory*** in Edmonton house different types of plant cultures, including; tropical, arid and temperate. It is more than just a garden though, because it hosts many of Edmonton's premier floral shows, educational programs for school children, horticultural courses for adults and continues as a very popular site for weddings, banquets and business activities.

   Because these structures are used for a variety of reasons, they have multiple
   - **A. designs**
   - **B. functions**
   - **C. shapes**
   - **D. forms**

7. Roof types are designed for cover and also to serve a useful purpose in the environment in which they can be found. A very steep roof design in a mountainous area is designed to prevent …

A. heavy rains
B. snow build-up
C. climbing animals
D. wind damage

8. Michael Kelly, a Prairie rancher invented barbed wire to keep his livestock from wandering off. His idea came from a natural structure, a …

A. cactus
B. tumbleweed
C. prickly pear
D. thorny bush

9. When choosing the most suitable materials to build a structure, architects, engineers and designers should consider all of the following before making their final choice ...

A. cost, appearance, environmental impact, energy efficiency
B. cost, color, life expectancy, impact strength
C. environmental appearance, type of symmetry, type of joints needed, cost effectiveness
D. flexibility, impact strength, energy efficiency, color

10. Each manufactured structure can be paired with a natural structure it is based on.

1 flippers 

2 egg carton 

3 umbrella 

4 honeycomb 

5 mushroom 

6 webbed feet 

Only one of the pairings below is correct.
Which one is it?

A. 6 - 1
B. 3 - 6
C. 6 - 5
D. 2 - 6

11. One important criteria of good design - that is usually not written down in the specifications - is that the structure ...

A. has a margin of safety
B. is esthetically pleasing
C. is cost effective
D. has a solid foundation

12. Sun-baked ***'Adobe'*** brick houses are usually found in countries where the climate is …

A. Wet and cool
B. Hot and dry
C. Temperate
D. Damp and cold

13. ***Sod houses*** were common on the prairies and were used by … 

A. engineers
B. settlers
C. businessmen
D. contractors

14. Both of these structures are houses for people in very specific environments. One advantage of structures such as these is that they …

 Igloo  tent

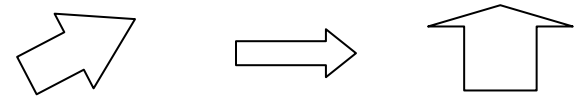
A. are portable
B. protect from the cold nights
C. keep out animals
D. are fireproof

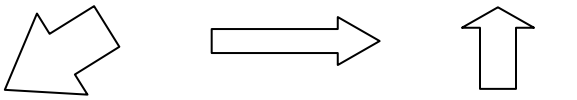
Section 2 – External and Internal Forces Act on Structures

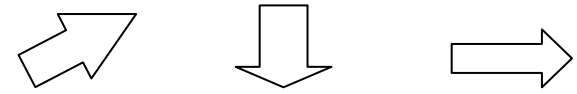
15. The actual effect of a force depends on three things: the magnitude, or size of the force; the direction of the force; and …

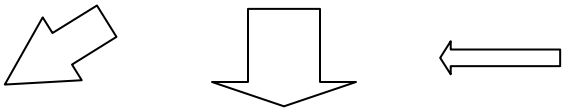
A. how the force is applied
B. where the force is applied
C. why the force is applied
D. how long the force is applied

16. A large force is applied to a freezer to move it up a ramp to the second floor, where a smaller force is used to push it to the window, and a very large force is needed to lift it up, to put it off balance, so it falls out the window and is demolished on the sidewalk below.

A. 

B. 

C. 

D. 

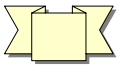
17. The standard unit of measuring force is named after a famous English scientist, who was the first to describe the *'law of gravitation'*, getting the idea for the law as he sat under an apple tree. This unit of measuring force is similar to the amount of force needed to hold an apple in your hand and is called a …

A. joule
B. kilogram
C. Newton
D. gram

18. Identify which structure would have the greatest stability, because of its centre of gravity.
   A. High centre of gravity and a narrow base
   B. High centre of gravity and a wide base
   C. Low centre of gravity and a narrow base
   D. Low centre of gravity and a wide base

19. Weight is a force that is measured by the gravitational pull on the object. It is usually measured in ...
   A. Newtons
   B. kilograms
   C. grams
   D. pounds

20. *Symmetry* is a balanced arrangement of mass that occurs on opposite sides of a line or plane, or around a centre or axis. The force of gravity acting on each side is the same. Which of the following illustrations is symmetrical?

A.  **B.**  **C.**  **D.** 

21.  A dynamic load on this train bridge is the …
   A. tracks
   B. train
   C. cement pillars
   D. wood beams

22. Designers generally use three key methods to help structures withstand forces. They include all of the methods below, EXCEPT for ...
   A. distribute the load evenly
   B. direct the forces along angled components
   C. shape the parts for the forces they are likely to face
   D. place lighter materials above heavier materials

23. When engineers build bridges, they take two conditions into account: what the bridge is crossing and what kinds of loads it will support, to decide which type of bridge will best suit the situation. Which type of bridge would engineers suggest to withstand very heavy loads?
   A. Beam Bridge
   B. Truss Bridge
   C. Arch Bridge
   D. Suspension Bridge

24. Performance requirements are the guiding principles that engineers use to design structures. Maximum weight that the structure can support is expressed as …
   A. weight capacity
   B. load performance
   C. static load mass
   D. dynamic load mass

25. Complementary forces happen when different kinds of forces act on a structure at the same time. An example of a complementary force is …
   A. bend
   B. buckle
   C. shear
   D. twist

26. When you put your hands on your desk and put all your weight on them - then try to move them forward your hand (much like a structure) resists movement forward because of ...
   A. static forces
   B. kinetic forces
   C. external forces
   D. frictional forces

27. The 7 wonders of the Ancient World took may years to complete, but they lasted a very long time. Why do you think that the Statue of Zeus at Olympia lasted so long?
   A. It was sheltered in a valley.
   B. It was protected by the Greek Gods.
   C. It was made of gold and ivory, which resist corrosion.
   D. It was made of reinforced concrete and sealed with epoxy.

28. The strongest structural shape is a …
   A. square
   B. circle
   C. triangle
   D. rectangle

29. An arch, which is a common shape in bridges, can support large loads. This is possible because the force of the load is carried down through the arch to the foundation, from this point in the arch …
   A. loadstone
   B. keystone
   C. column
   D. cantilever

30. Structural stability requires that a variety of materials should to be utilized to avoid deformation and structural failure. In a hang-glider the way that helps to reduce internal forces, such as tension, compression and shear, on the component parts is to …
   A. distribute the load evenly
   B. direct the forces along angled components
   C. shape the parts for the forces they are likely to face
   D. place lighter materials above heavier materials

Section 3 – Structural Strength and Stability

31. The materials in structures can be evaluated according to many properties. The property that describes how easily a material can be shaped is called …
   A. ductility
   B. plasticity
   C. brittleness
   D. tensile strength

32.  This palm tree is demonstrating this property …
   A. brittleness
   B. ductility
   C. plasticity
   D. flexibility

33. A change of shape in a structure or a structural component, because the material is unable to resist the load acting on it is called …
A. deformation
B. resistance
C. ductility
D. brittleness

34. The force that resists another object when the surfaces of each are in contact is called …
A. fusion
B. force
C. friction
D. fissure

35. One way landscape architects join stones to make retaining walls and split-rail fences is to use this method …
A. rivets
B. welds
C. cement
D. mass

36. Adhesives are used to bind materials together. A type of adhesive that hardens when it cools is ...
A. thermosetting glue
B. therapeutic glue
C. solvent-based glue
D. solvent-enriched glue

37. Moveable joints are used to secure materials together in a structure. All of the following joints are examples of moveable joints (allowing movement in a structure) EXCEPT ...
A. a trailer hitch
B. photocopier lid
C. ball and socket joint (shoulder)
D. Lego

38. Joints are made to withstand forces acting on them for long periods of time. Wear and tear parts of moveable joints are caused by friction. Friction also generates …
A. deformation
B. fatigue
C. stability
D. heat

39. There are 656 muscles in your body. These muscles allow your skeletal frame to move. The contraction and relaxing of these muscles is possible because they are made of …
A. semi-solid fibrous tissue
B. solid fibrous tendon
C. solid fibrous cartilage
D. semi-fibrous ligament

40. The layer of material in a tree truck that supports the rest of the structure, but does not function to conduct water and materials is the …
A. woody layer
B. heartwood
C. sapwood
D. vascular cambium

Section 4 – Structures are designed, evaluated, and improved to meet human needs

41. Various tests on a structure's design are made before it is approved for use by the consumer. Consumer Product Tests ensure that a product is safe to use. The first step in the testing process is to test the product's …
   A. components
   B. performance
   C. durability
   D. design

42. During the Ice Storm in Quebec in 1998, ice crystals formed on many structures. Some of these structures failed because the formation of ice crystals on the structure added to the structure's …
   A. flexibility
   B. overall mass
   C. safety margin
   D. tensile strength

43. The most recent mudslides in North Vancouver (January, 2005) caused extreme damage and some loss of life. This occurred because of the …
   A. unstable soil and steep terrain where these people lived
   B. heavy rainfall this area received in a short period of time
   C. poor construction practices and lack of appropriate safety margins
   D. minor earthquake that occurred at the same time as the sudden rainfall

44. A firm foundation is necessary to support a structure. Solid ground is not always firm and stable. There are environmental and man-made conditions, which make the soil, loosen and become compact, which makes the soil relatively unstable. Three strategies are use to ensure a structure is built on a firm foundation. The three strategies include all of the following, EXCEPT ...
   A. find something solid
   B. make a soil layer
   C. spread the load
   D. utilize pressure and density

45. Improving designs by using different materials or incorporating new technologies can help to make a structure perform its function more effectively. One way to solve a structural problem is to combine materials and components in new …
   A. technologies
   B. arrangements
   C. adhesives
   D. functions

46. At birth a baby has 350 bones. As the baby grows, the total number of bones in the body is reduced to 206. Nature's way of strengthening the body is to use the 144 'missing' bones to reinforce the frame by this method …
   A. adhesive
   B. gluing
   C. fusion
   D. fastening

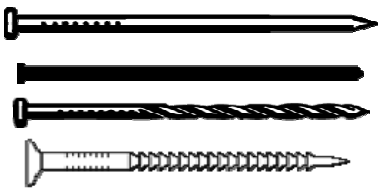
47. Technological advancements have led to new composite materials being developed. One such material is used in such diverse products as tires, fibre optic cables, and sporting goods. This composite material is known as …
   A. Spider silk
   B. Kelvar®
   C. Fibreglass
   D. Titanium

48. Hollow triangle tubes are used as the traditional shapes for a bicycle. This is because they provide the best …

A. flexibility
B. ductility
C. strength
D. plasticity

NR1 - Different nails are used for different purposes. Put the following nail types in order of their **fastening ability**. Most friction to least fiction

1
2
3
4



_____ _____ _____ _____

most friction → → → least friction

	.	.	
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

NR2 - Match the type of **rigid joint** with the example that illustrates it.

1 fastener
2 tie
3 interlocking shape
4 adhesive

___ **rivets**
___ **clothing hem**
___ **shoe lace**
___ **epoxy resin**

	.	.	
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

Structures and Forces Section Quiz – Answer Keys

Section 1 Quiz

(1.1, 1.2, 1.3)

	1.1	1.2	1.3
1.	C	C	C
2.	D	B	B
3.	D	B	A
4.	A	B	B
5.	D	A	B
6.	C	D	B
7.	A	A	D
8.		A	
9.		A	
10.		B	

Section 2 Quiz

(2.1, 2.2, 2.3, 2.4)

	2.1	2.2				2.3	2.4
1.	B	1.	B	9.	C	C	C
2.	B	2.	D	10.	B	C	C
3.	A	3.	D	11.	C	C	B
4.	A	4.	C	12.	D	C	B
5.	C	5.	A	13.	C	A	B
6.		6.	B	14.	C	D	A
7.		7.	C	15.	B		A
8.		8.	B				

Section 3 Quiz

(3.1, 3.2, 3.3)

	3.1	3.2	3.3
1.	B	B	C
2.	D	C	A
3.	D	D	B
4.	A	A	B
5.	B	D	D
6.		C	
7.		D	

Section 4 Quiz

(4.1, 4.2, 4.3)

	4.1	4.2	4.3
1.	B	B	A
2.	C	C	D
3.	A	A	C
4.	B	C	B
5.	A	B	D
6.	A		
7.	D		

Structures and Forces Unit Test – Answer Key

1	C	13	B	25	A	37	D
2	D	14	B	26	D	38	D
3	D	15	B	27	C	39	A
4	C	16	A	28	C	40	B
5	B	17	C	29	B	41	A
6	B	18	D	30	A	42	B
7	B	19	A	31	B	43	A
8	D	20	B	32	D	44	D
9	A	21	B	33	A	45	B
10	A	22	D	34	C	46	C
11	B	23	C	35	D	47	B
12	B	24	B	36	A	48	C
Numerical Response		NR1	4312	NR2	3124		