

UNIT LEARNING PACKS

# FOCUS IN ACTION

## **Grade 7 Science Focus**

Unit D - Structures and Forces

## '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\\_8u1.html](http://www.scienceman.com/scienceinaction/pgs/hot_8u1.html))

### ***Unit 4 – Structures and Forces***



- **Topic 1 Notes & Quiz**
- **Topic 2 Notes & Quiz**
- **Topic 3 Notes & Quiz**
- **Topic 4 Notes & Quiz**
- **Topic 5 Notes & Quiz**
- **Topic 6 Notes & Quiz**
- **Topic 7 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](mailto: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>

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

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

### Classifying Structures

#### Natural

- not made by people
- occur naturally in the environment



#### Manufactured

- built by people
- many are modelled after natural structures



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

**Mass Structures** can be made by, piling up or forming similar materials into a particular shape or design.

- Mountains, coral reefs are **natural mass structures**
- Sand castles, dams and brick walls are **manufactured mass structures**

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

#### A Layered Look

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

#### Sandbag Wall Structure to prevent Flooding

<http://www.gov.mb.ca/gs/memo/dyke.html>

*(4 Key Elements) – to avoid failure*

- must be heavy enough to stay in place
- must not be too heavy to compact the earth unevenly below it
- must be thick enough so it cannot be pushed out of place
- must be anchored firmly



#### Frame Structures

Have a skeleton of strong materials, which is then filled and covered with other materials, supporting the overall structure. Most of the inside part of the structure is empty space.

- **Load-Bearing Walls:** these are the walls that support the **load** of the building.
- **Partition Walls:** these are the walls that divide up the space inside the building.
- because they are relatively easy to design and build, and inexpensive to manufacture, the frame structure is the most common construction choice.

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

**Identify:**

Rigid Joint  
Mobile Joint  
Brace  
Rigid Shape  
Type of Material  
Support



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

**Find Out Activity** p. 275

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

### Shell Structures

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

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

**Flexible structures**, like parachutes, balloons and different types of clothing are a different type of shell. Shell structures have **two very useful features**:

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

Problems in building shell structures include:

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

### Mix and Match

Some structures are combinations of different types of structures:

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

Can you think of other structures that are combinations?

**Topic 1 Review** p. 281

## Structures and Forces Quiz

### Topic 1 – Types of Structures

1. All of the following structures can be classified as manufactured, EXCEPT
  - A. jigsaw puzzle
  - B. a spoon
  - C. a feather
  - D. a fishing net
  
2. A mass structure can be made by piling materials into a particular shape or design. The following are examples of natural mass structures ...
  - A. dams and mountains
  - B. brick walls and coral reefs
  - C. ice sculptures and sand castles
  - D. mountains and coral reefs
  
3. 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
  
4. 'Running bond' is a pattern used for strength in ...
  - A. dams
  - B. brick walls
  - C. beaver dams
  - D. omelets
  
5. Frame structures have a skeleton-like appearance and are made of very strong materials so they can support the ...
  - A. partition walls
  - B. retaining walls
  - C. load bearing walls
  - D. roof and covering materials
  
6. 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

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

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

Most structures have several functions, which may include:

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

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

**Aesthetics** – is the study of beauty in nature.

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

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

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

- Designers plan their structures to withstand conditions they hypothesize will occur. Good design is a **compromise** between a reasonable margin of safety and reasonable cost.
- Usually, **totally unexpected events** will cause even the best (well-designed) structures to fail (example: the World Trade Centre Towers).

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

### Composite Materials

There are different kinds of strength

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

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

### Layered Materials

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

### Woven or Knit Materials

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

### Choosing Materials

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

#### Factors to consider:

- **Cost** - will inexpensive material you use allow the structure to perform its function over a reasonable time?
- **Appearance** - is the appeal of the structure 'pleasing' over time?
- **Environmental Impact** - does the structure harm the environment?
- **Energy Efficiency**- does the structure conserve energy?

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

#### Tough Tissue Test (p. 289)

**Joints** – how do you fasten the structure together?

**Mobile Joints** are joints that allow movement

**Rigid Joints** do not allow movement

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

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

#### Traditional Structures (Project – Making a Model)

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

#### Topic 2 Review p. 296

#### WRAP-UP p. 297

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

## Structures and Forces Quiz

### Topic 2 – Describing Forces

1. Containing, sheltering, transporting, lifting ... are all words to describe a structure's ...
  - A. **design**
  - B. **stability**
  - C. **function**
  - D. **aesthetics**
2. 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**
3. 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**
4. The following is an example of a composite material
  - A. **a cardboard box**
  - B. **tent**
  - C. **drywall**
  - D. **reinforced concrete**
5. 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**
6. Mobile joints are used to secure materials together in a structure. All of the following joints are examples of mobile joints (allowing movement in a structure) EXCEPT ...
  - A. **a trailer hitch**
  - B. **photocopier lid**
  - C. **ball and socket joint (shoulder)**
  - D. **Lego**
7. 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**

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

#### Mass

The mass of an object is the measure of the amount of matter in it.

The mass is the number of particles the substance has

A small cylinder of metal was used, as a standard, by which, to compare different substances.

This standard (in the metric system) is called the **primary standard** of mass, and the amount of material in it is called one **kilogram** (kg). Smaller masses are measured in **grams** (g).

'Kilo' means one thousand (1000) and is equal to 1000 grams. Very small masses are measured in **milligrams** (mg). 1000 **mg**. equal 1 **g**.

A **balance** is used to measure the amount of mass in a particular substance. Standard scientific balances include the triple beam balance and the equal arm balance.

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

#### Forces and Weight

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

#### Weight

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

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

#### Picturing Forces

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

## Structures and Forces Quiz

### Topic 3 – The Mass and Forces

- The mass of an egg-sized lump of lead and the mass of an elephant ...
  - are very different
  - are about the same
  - are measured in Newtons
  - would change if they were measured in different places
- Weight is a force that is measured by the gravitational pull on the object. It is usually measured in ...
  - Newtons
  - kilograms
  - grams
  - pounds
- A student compared his mass and weight in two different places (Vancouver and Banff). Which statement is correct?
  - His mass and weight were unchanged.
  - His mass and weight were both the same.
  - His mass was the same, but his weight was different
  - His mass was different, but his weight was the same.
- 'Crush It' was an investigation activity that tested the strength of a shell structure. The responding variable in this activity was ...
  - How much weight the shell could hold before it failed.
  - How much mass the shell could hold before it failed.
  - How long the shell performed its function.
  - How many different textbooks were used as weights.
- Which force diagram shows what happens with very active Weepic, after it has cleared the wall?
  - 
  - 
  - 
  - 

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

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

### External Forces

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

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

### Internal Forces

**Tension forces** stretch a material by pulling its ends apart

**Tensile strength** measures the largest tension force the material can withstand before failing.

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

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

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

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

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

### Resisting Stress – The Inside View

Strength of materials can be traced to the forces between the tiniest particles of the materials. (See. Figure 4.39 p. 314)

## Structures and Forces Quiz

### Topic 4 – Forces, Loads and Stresses

1. The change in the shape or size of a structure can be due to internal forces which are produced by external forces acting on the structure and are called ...
  - A. structural instability
  - B. dead loads
  - C. live loads
  - D. deformation
2. Bend or twist a certain material, by pressing on different parts, in different directions, at the same time. The force you are creating is called ...
  - A. tension force
  - B. compression force
  - C. shear force
  - D. torsion force
3. A hurricane or tornado is an example of a force that can cause extreme damage to a structure when it acts on the structure, even for a short time. The environmental event is classified as a ...
  - A. live load
  - B. dead load
  - C. deformation
  - D. torsion event
4. Cross-country skis are designed to bend when a force is applied. Bending allows the middle of the ski to contact more snow, giving the skier a better grip when pushing off. Compression is the force that is applied to the ...
  - A. binding
  - B. edges
  - C. camber
  - D. ski boot
5. The strength of a certain material has been described by scientists as the forces between the tiniest particles of the material. Because the particles have yet to be seen, scientist can only make ...
  - A. inferences
  - B. observation
  - C. analysis
  - D. conclusions

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

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

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



### Material Failure

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

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

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



(Slinky)



### Making Use of Stress (Crash Test Dummies)

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

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

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

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

### Metal Fatigue

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

Topic 5 Review p. 319  
Wrap-Up (Topics 4 and 5) p. 320

## Structures and Forces Quiz

### Topic 5 – How Structures Fail

1. 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



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. 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 need more reinforcement.

4. 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

5. 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

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

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

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

### Structural Problems

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

**Flying Buttresses** – are columns on the outsides of a structure that connect to the building near the top and are used to support the outer walls in much the same way that two sides of an arch support each other.

(Web site with examples) <http://library.thinkquest.org/10098/cathedrals.htm>

### Strengthening Structures

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



(Backyard Swings **Figure 4.57**)

### Using Frictional Forces

- The **force of friction resists movement between two surfaces that rub together**. A brick wall is held together and kept evenly spaced with mortar, which helps to create large friction forces between each brick.
- Friction is also important in frame structures. The friction between the nail and the wood keeps the nail in place and the joints solid. Different types of nails provide differing amounts of friction. Squeaks in floors are caused by fasteners that have loosened.
- Friction between the ground and the bottom of a structure is an important design consideration. Friction holds the structure in place when external forces (wind) are acting on it. Too little, or too much friction can cause problems (moving chairs across the floor).

Topic 6 Review ( p. 328 )

## Structures and Forces Quiz

### Topic 6 – Designing With Forces

1. 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
2. Construction of a roof truss utilizes an important principle. Certain shapes will determine greater strength. Because roofs need to be very strong, roof trusses are shaped in ...
  - A. rectangles
  - B. squares
  - C. triangles
  - D. parallelograms
3. A frame structure can support a very heavy roof because of the principles of design. The vertical supporting posts in the structure visibly demonstrate this principle. The principle followed is ...
  - 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
4. 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
5. 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
6. Put your hands on your desk and put all your weight on them - then try to move them forward? This demonstration can be used to identify that your hand (much like a structure) resists movement forward because of ...
  - A. static forces
  - B. kinetic forces
  - C. external forces
  - D. frictional forces

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

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

**Center of Gravity**

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

**Unbalanced Structures**

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

**Firm Foundation**

The **foundation** upon which the structure is built must be stable, especially if it is moist, otherwise the compressive forces may cause the structure to tip and become unstable. If engineers and builders do not take into account the soil type and formations, the structures built may experience cracks in their foundations and walls.

Foundations can be constructed on solid **bedrock**, or, **pilings** (large metal, concrete or wood cylinders) can be used, if the layers of soil above the bedrock are loose enough. Some lightweight structures do not have to rest on the bedrock or, have to have a foundation that goes down very deep, because the ground doesn't freeze.

A road base is made up of layers (Figure 4.68B)

The load of the structure can be spread out over a large area (footings help to do this – figure 4.68C)

**Rapid Rotation**

Speed helps to increase stability.

**Gyroscopes**

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

Topic 7 Review p. 340

**WRAP-UP p. 341**

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

**Unit Review**  
**Pages 346 - 349**

## Structures and Forces Quiz

### Topic 7 – Stable Structures

1. 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. reinforced concrete
- B. mass
- C. central location
- D. lack of glass materials used

2. The Leaning Tower of Pisa 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

3. Observe each of the situations below and identify which structure will likely not fail.



A.



B.



C.



D.

4. 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 make 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

5. Sometimes if a new invention comes along, it is based on a scientific principle. Again that is the case with 'Ginger', or 'It' as it was called. The one person motorized vehicle that was recently unveiled uses the principle - *to gain stability of a forward moving object, you need to increase its speed*. This new invention utilizes this principle with one of its components, a ...

- A. gymnosperm
- B. gyroscope
- C. spinacre
- D. rotator disk

## Structures and Forces Review

**Focusing Questions:**

How do structures stand up under a load?

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What forces act on structures,

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What materials and design characteristics contribute to their strength and stability?

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**Guiding Questions and Activities to Help you Study Key Concepts**

**Topic 1 - Classification of Structures according to their origin (natural or manufactured) and according to how they are built (mass, frame, shell) - Similarities, in form or function, of manufactured structures to natural structures.**

Describe the differences between **natural** and **manufactured structures**.

Natural Structures	Manufactured Structures

Can you detail examples of **manufactured structures** that have their design based on a **natural structure**?

Manufactured Structures	Design based on ...

What modifications need to be made to certain types of frame structures to **stabilize** them? Give detailed examples, if you can. (p. 275)

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**Topic 2 - Factors considered by structural designers include: shape, function, appearance, safety, esthetics, cost, materials, and joints**

What are some of the **common functions** of structures?

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What does '**aesthetically appealing**' mean?

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What is a '**margin of safety**'?

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What **factors** make building a structure more expensive?

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How do **material properties** determine their use?

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What are the common **different types of materials**?

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When choosing material for a structure, what considerations do **designers** need to get information about before making a decision?

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What are the two different types of **joints**?

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Describe the various types of **fasteners** - giving examples of each type.

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### Topic 3 - Measurement of Mass (How and units) - Measurement of Weight (How and units)

Describe the difference between **mass** and **weight**.

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What **instruments** are use to measure mass and weight?

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What **units** are mass and weight calculated in and how were these units developed?

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Draw force diagrams that show a **balanced force** and an **unbalanced force**.

Balanced Force	Unbalanced Force

**Topic 4 - External forces including live loads (changing or non-permanent) and dead loads (the weight of the structure itself) - Internal forces of tension, compression, shearing, buckling and bending**

What is **deformation**?

Describe the differences between **external** and **internal** forces, giving examples of each.

Internal Force	Examples
External Force	Examples

Draw force diagrams that illustrate the different **internal forces** that can act on a structure.

Internal Force -	Internal Force -
Internal Force -	Internal Force -

Describe tensile strength, compressive strength, shear strength and torsion strength.

Type	Description of Structural Strength
Tensile	
Compressive	
Shear	
Torsion	

Identify the forces acting on different **parts of a bicycle** and the types of strengths of each of the main parts.

Bicycle part	Type of force acting on it	Type of Strength

How do **materials** get their strength?

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**Topic 5 - Deformation in structures - Properties of Materials to withstand internal forces. - Failure of materials under pressure from forces by snapping, buckling, bending, stretching, shearing and twisting**

Describe how a **lever** can generate a large force.

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Describe the types of forces, which cause shear failure, buckling failure and torsion failure.

**Shear** \_\_\_\_\_

**Buckling** \_\_\_\_\_

**Torsion** \_\_\_\_\_

How can knowledge about **failure of materials** and structures be useful?

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What is **metal fatigue**?

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### **Topic 6 - Choices in design and materials to strengthen a structure against specific kinds of forces - Frictional Forces**

What are the **three key methods** used by designers to help structures withstand forces and prevent failure?

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What is **corrugation**?

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What are **flying buttresses**?

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How can the way a material is made, **lower the cost** of making that material, but still be strong?

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How can you strengthen a **load-bearing** horizontal beam that is supported only at the ends?

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How can frictional forces be used to **stabilize** a structure?

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### Topic 7 - Structural stability (ability not to tip over)

How can you locate the **center of gravity**?

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What is a '**thrust line**'?

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What are the key strategies used in making a **firm foundation**?

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What scientific principle does a **gyroscope** demonstrate and what **practical applications** can you describe that show a gyroscope in action?

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**Practical Applications:** \_\_\_\_\_

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## Structures and Forces UNIT TEST

1. All of the following structures can be classified as manufactured, EXCEPT
  - A **jigsaw puzzle**
  - B **a spoon**
  - C **a feather**
  - D **a fishing net**
2. The following are examples of **natural** mass structures ...
  - A **dams and mountains**
  - B **brick walls and coral reefs**
  - C **ice sculptures and sand castles**
  - D **mountains and coral reefs**
3. 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**
4. 'Running bond' is a pattern used for strength in ...
  - A **dams**
  - B **brick walls**
  - C **beaver dams**
  - D **omelets**
5. Frame structures have a skeleton-like appearance and are made of very strong materials so they can support the ...
  - A **partition walls**
  - B **retaining walls**
  - C **load bearing walls**
  - D **roof and covering materials**
6. 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**
7. Containing, sheltering, transporting, lifting ... are all words to describe a structure's
  - A **design**
  - B **stability**
  - C **function**
  - D **aesthetics**

8. 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**
9. One important criteria of 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**
10. The following is an example of a composite material
- A **a cardboard box**
  - B **tent**
  - C **drywall**
  - D **reinforced concrete**
11. 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**
12. Mobile joints are used to secure materials together in a structure. All of the following joints are examples of mobile joints (allowing movement in a structure) EXCEPT ...
- A **a trailer hitch**
  - B **photocopier lid**
  - C **ball and socket joint (shoulder)**
  - D **lego**
13. 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**

14. The mass of an egg-sized lump of lead and the mass of an elephant ...
- A are very different
  - B are about the same
  - C are measured in Newtons
  - D would change if they were measured in different places
15. 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
16. 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.
17. **'Crush It'** was an investigation activity that tested the strength of a shell structure. The responding variable in this activity was ...
- A How much weight the shell could hold before it failed.
  - B How much mass the shell could hold before it failed.
  - C How long the shell performed its function.
  - D How many different textbooks were used as weights.
18. Which force diagram shows what happens with very active Weepic, after it has cleared the wall?



19. The change in the shape or size of a structure can be due to internal forces which are produced by external forces acting on the structure and are called ...
- A structural instability
  - B dead loads
  - C live loads
  - D deformation
20. Twisting a certain material, by pressing on different parts, in different directions, at the same time. The force you are creating is called ...
- A tension force
  - B compression force
  - C shear force
  - D torsion force

21. A hurricane or tornado is an example of a force that can cause extreme damage to a structure when it acts on the structure, even for a short time. The environmental event is classified as a ...
- A **live load**
  - B **dead load**
  - C **deformation**
  - D **torsion event**
22. Cross-country skis are designed to bend when a force is applied. Bending allows the middle of the ski to contact more snow, giving the skier a better grip when pushing off. The forces that are applied to the 'camber' (middle part of the ski) are ...
- A **compression and torsion**
  - B **tension and compression**
  - C **torsion and shear**
  - D **shear and tension**
23. The strength of a certain material has been described by scientists as the forces between the tiniest particles of the material. Because the particles have yet to be seen, scientist can only make ...
- A **inferences**
  - B **observation**
  - C **analysis**
  - D **conclusions**
24. 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**
25. 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**
26. Crash test dummies are used by auto safety designers and inspectors to identify impact points when material fails in a collision. 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 need more reinforcement.**

27. 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**
28. 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**
29. 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**
30. Construction of a roof truss utilizes an important principle. Certain shapes will determine greater strength. Because roofs need to be very strong, roof trusses are shaped in ...
- A **rectangles**
  - B **squares**
  - C **triangles**
  - D **parallelograms**
31. A frame structure can support a very heavy roof because of one of the principles of design. The vertical supporting posts in the structure visibly demonstrate this principle. The principle followed is ...
- 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**
32. 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 vehicles 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**
33. 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**

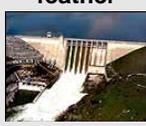
34. Remember when you put your hands on your desk and put all your weight on them - then tried to move them forward? This demonstration was used to identify that your hand (much like a structure) resists movement forward because of ...
- A static forces
  - B kinetic forces
  - C external forces
  - D frictional forces
35. 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 World Trade Center Tower's collapse is example of a structure failing because it encountered a force beyond what it was designed to withstand. 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 reinforced concrete
  - B mass
  - C central location
  - D lack of glass materials used
36. 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
37. 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
38. Sometimes if a new invention comes along, it is based on a scientific principle. Again that is the case with the 'Segway. The one person motorized vehicle, that was recently unveiled, uses the principle - **to gain stability of a forward moving object, you need to increase its speed**. This new invention utilizes this principle with one of its components, a ...
- A gymnosperm
  - B gyroscope
  - C spinnaker
  - D rotator disk

Complete the **Numerical Response** Questions that follow

## Structures and Forces Numerical Response Questions

This is a Sample Numerical Response ...

Classify each structure

1	 feather	2	 bicycle
3	 dam	4	 mountain

_ 4 _	_ 1 _	_ 3 _	_ 2 _
Natural Mass	Frame	Manufactured Mass	Frame

4	1	3	2
.	.	.	.
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

NR1 - Match the description with the type of material it represents.

- 1 made from more than one type of material
- 2 putting layers of materials together to make them stronger
- 3 interlocking to make the material stronger
- 4 melting and dissolving substances together

\_\_\_\_\_      \_\_\_\_\_      \_\_\_\_\_      \_\_\_\_\_  
 yarn      drywall      aluminum foil      reinforced concrete

.	.	.	.
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

NR3 - Gravitational Force on the Earth is equal to approx. 10 Newtons for each kilogram of mass. How much force does 125 grams have?

Show how you figured it out!

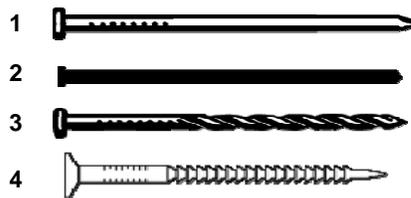
.	.	.	.
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

NR4 - Internal Forces – are forces, which can be exerted on a structure from within. Match the type of internal force with its description.

- 1 tension
  - 2 compression
  - 3 shear
  - 4 torsion
- \_\_\_\_\_ squeezing together  
 \_\_\_\_\_ twisting and turning  
 \_\_\_\_\_ tearing or ripping  
 \_\_\_\_\_ pulling apart

.	.	.	.
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

NR5 - Different nails are used for different purposes. Put the following nail types in order of their fastening ability. Most friction to least friction



\_\_\_\_\_      \_\_\_\_\_      \_\_\_\_\_      \_\_\_\_\_  
 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

## Structures and Forces Topic Quiz - Answer Keys

Science Focus 7 Topics	Questions						
	1.	2.	3.	4.	5.	6.	7.
<b>Topic 1 – Types of Structures</b>	<b>C</b>	<b>D</b>	<b>A</b>	<b>B</b>	<b>D</b>	<b>A</b>	
<b>Topic 2 – Describing Forces</b>	<b>C</b>	<b>D</b>	<b>B</b>	<b>D</b>	<b>A</b>	<b>D</b>	<b>A</b>
<b>Topic 3 – Mass and Forces</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>A</b>	<b>A</b>		
<b>Topic 4 – Forces, Loads and Stresses</b>	<b>D</b>	<b>C</b>	<b>A</b>	<b>C</b>	<b>A</b>		
<b>Topic 5 – How Structures Fail</b>	<b>C</b>	<b>C</b>	<b>A</b>	<b>D</b>	<b>C</b>		
<b>Topic 6 – Designing With Forces</b>	<b>D</b>	<b>C</b>	<b>A</b>	<b>C</b>	<b>B</b>	<b>D</b>	
<b>Topic 7 – Stable Structures</b>	<b>B</b>	<b>D</b>	<b>A</b>	<b>D</b>	<b>B</b>		

## Structures and Forces Unit Test – Answer Key

1	<b>C</b>	12	<b>D</b>	23	<b>A</b>	34	<b>D</b>	NR4	<b>2431</b>
2	<b>D</b>	13	<b>A</b>	24	<b>C</b>	35	<b>B</b>		
3	<b>A</b>	14	<b>A</b>	25	<b>C</b>	36	<b>D</b>	NR5	<b>4312</b>
4	<b>B</b>	15	<b>A</b>	26	<b>A</b>	37	<b>D</b>		
5	<b>D</b>	16	<b>C</b>	27	<b>D</b>	38	<b>B</b>		
6	<b>A</b>	17	<b>B</b>	28	<b>C</b>	NR1	<b>3241</b>		
7	<b>C</b>	18	<b>A</b>	29	<b>D</b>				
8	<b>D</b>	19	<b>D</b>	30	<b>C</b>	NR2	<b>3124</b>		
9	<b>B</b>	20	<b>D</b>	31	<b>A</b>				
10	<b>D</b>	21	<b>A</b>	32	<b>C</b>	NR3	<b>1.25</b>		
11	<b>A</b>	22	<b>B</b>	33	<b>B</b>				