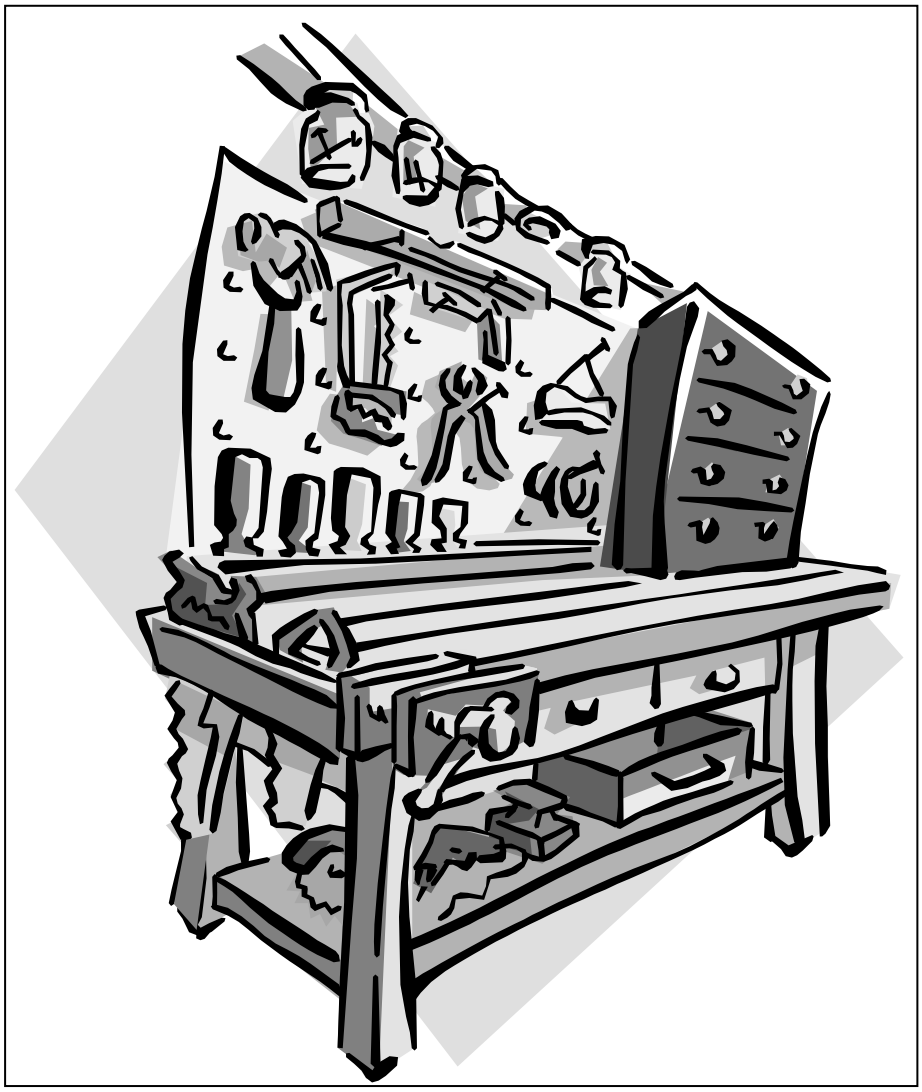
TECHNOLOGY

GRADE 9



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Contents

LEARNING OUTCOMES EXPLAINED

<u>Learning Outcome 1</u>: Technological Processes And Skills

The learner will be able to apply technological processes and skills ethically and responsibly using appropriate information and communication technology.

Investigates

- Identifies and explains a problem, need or opportunity from a given real-life context, and investigates the context, the nature of the need, the environmental situation, and the people concerned.
- Analyses existing products relevant to an identified problem, need or opportunity based on:
    - safety;
    - suitability of materials;
    - fitness for purpose;
    - cost;
    - manufacturing method.
- Develops and performs practical testing procedures to determine or compare the suitability or fitness for purpose of relevant properties of materials, electrical or mechanical systems, structures, processes or finished products.
- Uses a variety of available technologies and methods to:
    - locate (e.g. use library referencing system, database searches, indexes);
    - collect (e.g. questionnaires, data collection forms, requests for information, information, searches, literature surveys);
    - compare;
    - sort;
    - verify;
    - evaluate (e.g. cross-checking different sources or resources);
    - store information (e.g. filing systems, indexes).

Designs

- Writes or communicates a short and clear statement or a design brief for the development of a product or system related to a context, problem, need or opportunity that has been identified by self.
- Lists product and design specifications and constraints for a solution to an identified problem, need or opportunity based on all of the design key words listed below:
    - people: age, target market, human rights, access;
    - purpose: function, what the product will do;
    - appearance and aesthetics: form, colour, shape, feel;
    - environment: where product will be used or made, impact on the environment in the long and short term;
    - safety: for users and manufacturers;
    - cost: cost of materials, wastage, cost of manufacture, maximum selling price;
    - ergonomics;
    - quality;
    - production: mass production, batch production, one-off production.
- Generates a range of possible solutions that are significantly different from each other, and that show clear links to the design brief and the specifications and constraints.
- Chooses possible solutions based on well-reasoned argument related to the specifications and personal opinions, and develops a chosen idea using graphics.

Makes

- Develops plans for making that include all of the following:
    - resource lists (e.g. materials lists, tools, people, costs);
    - formal drawings showing dimensions or quantities (e.g. orthographic, oblique or isometric views, sequence drawings, exploded views);
    - manufacturing sequence (e.g. flow diagrams, flow charts).
- Chooses and uses appropriate tools and materials to make designed products with precision and control by measuring, marking, cutting or separating, shaping or forming, joining or combining, and finishing a range of materials accurately and efficiently.
- Uses measuring and checking procedures while making to monitor quality and changes, and adapts designs in response to practical difficulties encountered when making the products.
- Demonstrates knowledge and understanding of safe working practices and efficient use of materials and tools.

Evaluates

Evaluates the product or system based on self-generated objective criteria linked directly to the design brief, specifications and constraints using self-designed procedures (e.g. surveys, questionnaires, testing procedures) for self-testing, and suggests sensible improvements or modifications that would clearly result in a more effective or higher-quality end product.

Evaluates the efficiency of the plan of action followed, objectively demonstrates insight into the consequences of key decisions, and suggests sensible improvements.

Communicates

Present ideas (in a project portfolio) using two-dimensional or three-dimensional sketches, circuit diagrams or systems diagrams that include most of the following features:

- use of South African conventional drawing standards (e.g. scale, outlines, dimension lines, first and third angle projection);
- notes that clarify design reasoning and key choices;
- impressive enhancements of significant sketches (e.g. colour, texture, shade, thick and thin lines, shadow).

Chooses and uses appropriate technologies to combine and organise graphics and text effectively to produce project portfolio, poster presentations, case study reports, and so on, that have a formal organised structure appropriate for the target audience

Learning Outcome 2: Technological Knowledge and understanding

The learner will be able to understand and apply relevant technological knowledge ethically and responsible.

Structures

Demonstrates knowledge and understanding of structures:

- properties of materials that affect their performance in structures (e.g. mass, hardness, stiffness, flexibility, corrosion resistance, strength in tension, compression, shearing);
- analysis of the effects of different loads (even/uneven, static/dynamic).

Processing

Technological knowledge and understanding of how materials can be processed (e.g. galvanised, frozen, dried, painted, varnished, electroplated) to change or improve properties (life-span, and how recyclable materials can be re-manufactured.

Systems and Control

Demonstrates knowledge and understanding of interacting mechanical systems and sub-systems by practical analysis and represents them using systems diagrams:

- gear systems
- belt drive or pulley systems with more than one stage;
- mechanical control mechanisms (e.g. ratchet and pawl, cleats);
- pneumatic or hydraulic systems that use restrictors;
- one-way valves;
- systems where mechanical, electrical, or pneumatic or hydraulic systems are combined.

Demonstrates knowledge and understanding of how simple electronic circuits and devices are used to make an output respond to an input signal (e.g. resistors, light-emitting diodes, transistors, push or magnetic switches, thermistors, light-dependent resistors).

Learning Outcome 3: Technological Knowledge and understanding

The learner will be able to demonstrate and understanding of the interrelationships between science, technology, society and the environment.

Indigenous Technology and Culture

Explores, compares and explains how different cultures in different parts of the world have effectively adapted technological solutions for optimum usefulness.

Impact of Technology

Recognises and identifies the impact of technological developments on the quality of people's lives and on the technological in which they live, and suggests strategies for reducing any undesirable effects.

Bias in Technology

Produces evidence that details opinions, backed up by factual evidence, about bias (e.g. gender, age, access) in making technological decisions, and suggests strategies for redress.

STRUCTURES

At the end of this chapter you will do the following Capability Task:

CAPABILITY TASK

You are going to design and make a roof structure. It may be a shell or a frame structure. The structure will be made from ice cream sticks. The height, width and length may not exceed 30 cm. The structure must be able to carry a load of 1 kg. You may use glue or screws to join the sticks.

You will also hand in a portfolio containing:

Investigation:

Give a description of the problem in the form of a Design brief

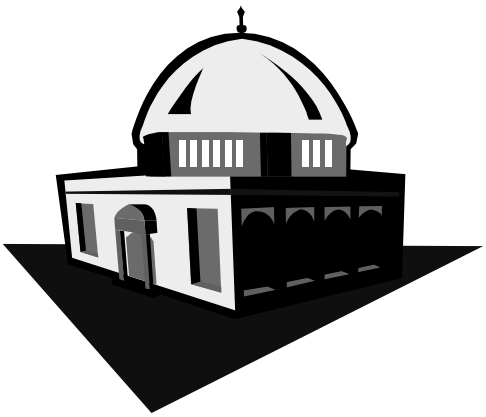
Designing:

Specifications & constraints
Possible solutions, ideas (at least 3 - each one A4 size with labels and explanations)
Informed decision & final drawing

- An A4 isometric drawing
- An orthographic projection
- Detailed description and 3-D drawing with labels

Making:

Materials and tools needed
Flow diagram to show the steps in making the roof



Evaluating:

Weaknesses and strengths
Improvements and modifications

Resource Tasks

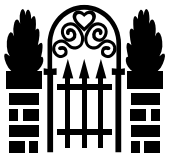
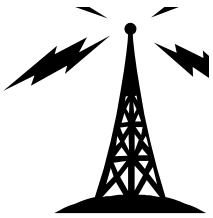
Case Studies

Research

TYPES

Structures are all around us, some are natural like eggshells, spider-webs, caves and trees and others are man-made like bridges, towers, houses, shopping bags and cups. Structures are further divided into two other groups namely frame and shell structures:

Frame Structures
A frame structure is a structure made up of many rigid parts joined together to form a 'framework'.
These different parts are called embers.

Shell Structures
A shell structure is more enclosing than a frame structure - it surrounds and encloses something.



Solid/mass Structures
Solid structures rely heavily on solid construction such as masonry to support loads and to transfer these loads safely to the ground.
Advantages of solid structures are that they are held in place by their own weight, losing small parts often has little effect on the overall strength of the structure
- Mountains, caves and coral reefs are natural mass structures
- Sand castles, dams and brick walls are manufactured mass structures

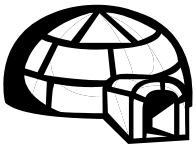

FUNCTIONS

Supporting a load
A structure must be able to support its own weight and the load it has to carry. A load can be a person, an object or a force. A moving load is known as a dynamic load. A stationary load is known as a static load.


Spanning a gap
The most common structure fulfilling this function is a bridge. Bridges fulfills another function - supporting a load - they have to carry their own weight and the weight of whatever travels over them.


Enclosing people, animals or objects
All containers fulfill this function, as well as most buildings. Natural objects include shells, caves, hollow tree trunks etc.





PROPERTIES

Stability - the capacity of an object to maintain or return to its original position; the state of being balanced in a fixed position.

Strength - the capacity to withstand forces that tend to break an object or change its shape; it is an object's ability to hold its shape without collapsing.

Rigidity - the ability not to buckle or distort.

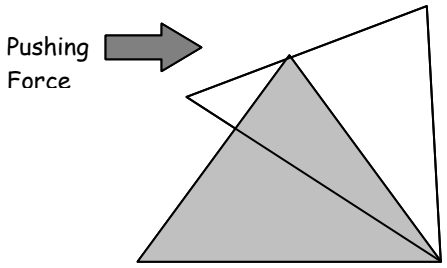
The strength and rigidity of a structure depend on its ability to **resist force**.

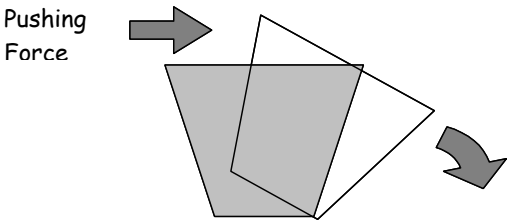
Stability

Why are some structures more stable than others?
We say that a structure has high stability if, when it is loaded, it tends to return to, or remain in, the same position. The degree of stability depends on the relationship between the base, the height and the weight of the structure.
The weight of an object is due to the force of gravity pulling down vertically on the mas of the object. The invisible position of the mass through which the force of gravity pulls is called the centre of gravity. If the position of the centre of gravity is low and lies well inside a large base area, the object is said to be very stable. If the centre of gravity lies to one side of the base area, the object is much less stable. If the centre of gravity is outside the base area, the object is very unstable and may require further support. A tall object tends to be unstable because its centre of gravity is in a very high position. Because of this, it can be more easily moved outside the base area by the application of external loads. A structure is said to be stable when it will not topple over easily when acted upon by a force. Stability is an important concept not only for civil and structural engineering but for life in general. There are many structures around the home that depend on the principles of stability. Consider what would happen in the home if simple household products were designed without considering stability. You would have cupboards falling over, chairs would be unstable, pans and pots in the kitchen would be constantly tipping over. You would have a pretty rough time! This section of the structures classroom will describe the basic principles of structures and show how engineers take account of stability.

The concept of stability

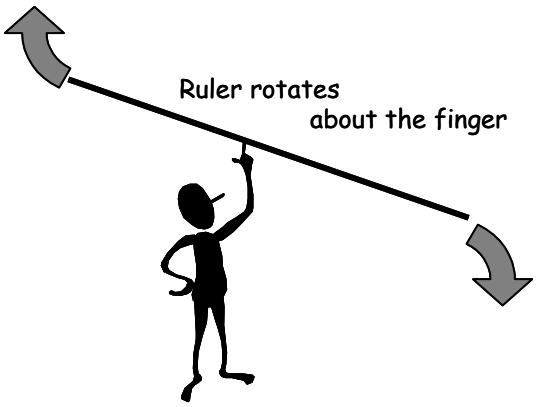
If a force is applied to the triangle it will tip up as shown. When the force is released, the triangle falls back down to its original position. The behaviour of this structure is said to be stable.





When the process is repeated on this structure it will tilt over then topple. The behaviour of this structure is said to be unstable.

To fully understand stability you must first have an understanding of the principles of centre of gravity.

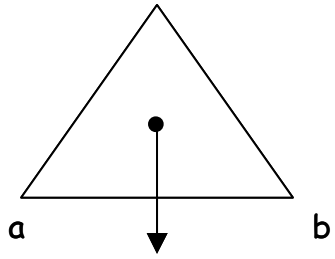


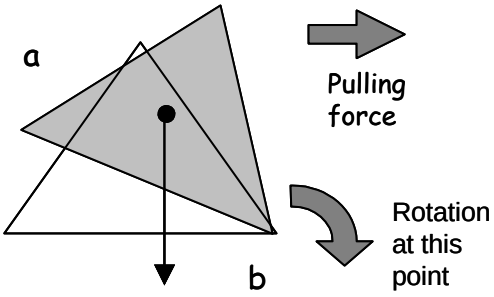
Centre of gravity

Balance a ruler on your finger as shown below with more of the ruler on one side of your finger than the other.
You will observe that it topples off your finger. This is because there is more material to the left of your finger than to the right.

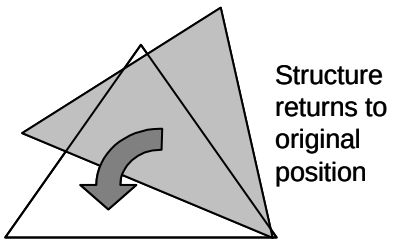
Gravity has an effect on the material at each side of your finger, and since there is not an equal amount on either side the ruler is unbalanced and thus topples over. The pull of gravity acting on the ruler is what gives it its weight and causes the ruler to tilt.
In order to balance the ruler on your finger, you must position it so that the point at which the pull of gravity acting to the right and left of your finger is equal. When you position the ruler on your finger so that it is perfectly balanced, then you have found the centre of gravity. You can apply this principle to any shaped object. Once the object is perfectly balanced you have found the centre of gravity.

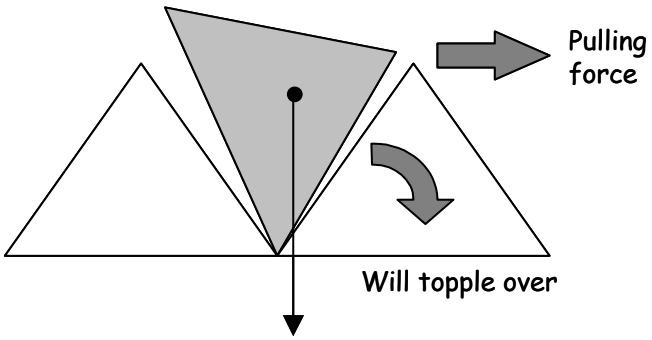
The stability of a structure is related to the position of the centre of gravity for that structure. As indicated in the diagram below, as the structure is tilted, its centre of gravity rises. It is rotated about point b, caused by the pulling force.

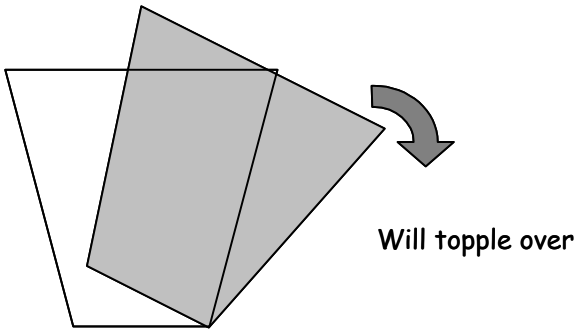




If the structure is stable, on release of the pulling force the structure will return to its original
position.



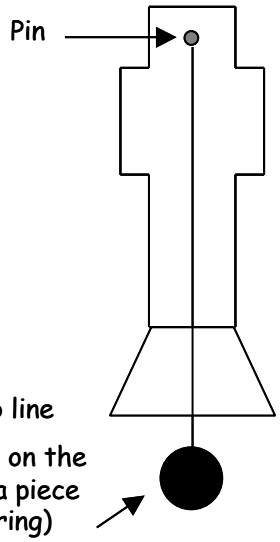


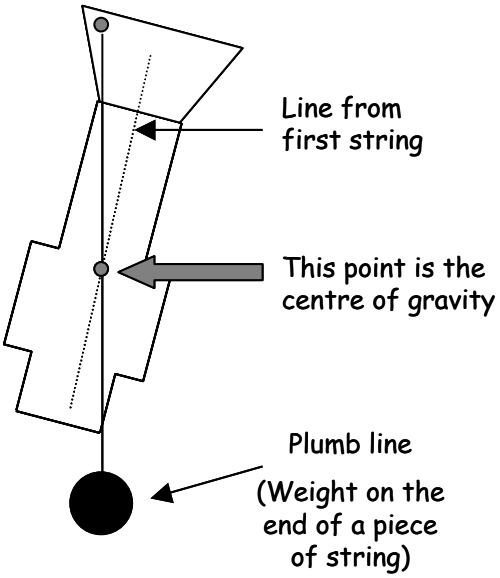


However, it must be noted that this will only be the case if the centre of gravity remains inside the base of the structure. When the structure is tilted to such a degree that its centre of gravity is outside its base, then the structure will become unstable as gravity acts on it and causes it to topple over.
If an unstable object is rotated as shown, when the pulling force is removed the structure will continue to rotate and will eventually topple over.

Accurately determining the centre of gravity.

The method that was previously explained for finding the centre of gravity of an object is by trial and error, and therefore is only a approximation. For a more accurate approach try this exercise. Use a piece of thick card and cut out an irregular shape as shown opposite. Hang the string and a plumb line from a pin as shown. Mark the position of the plumb line with a pencil.

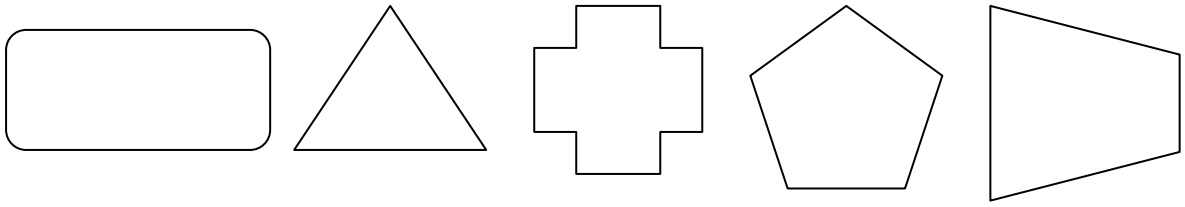




Repeat the process again, but this time place the pin at a different location, and mark the position of the plumb line string. Where the two pencil lines cross is the centre of gravity of the shape.

This method of determining the centre of gravity of an object is very accurate, and will work with any irregular shaped object.

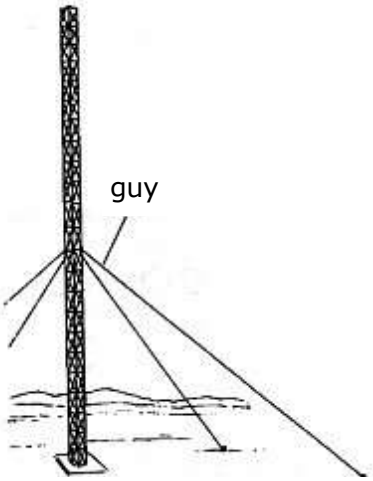
Can you determine the centre of gravity of these objects.



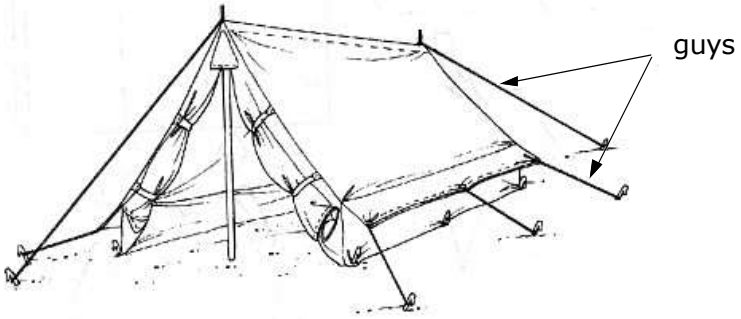
Some rules for stability:

- A low centre of gravity.
- A wide base is generally more stable than a structure with narrow base.
- The weight at the top of the structure should by less that the weight at the bottom.

It is not always possible to design structures that comply with these rules, and therefore sometimes special measures should be taken to make a structure stable. The tower crane is a long slender structure with a very thin base, and a very wide top. It has a large load to carry at the top at one end of the arm as indicated in the previous picture. A counter weight is placed on the opposite side of the crane arm to that of the. This system works by balancing the load with that of the counter weight.

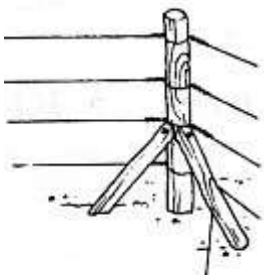


Structures like high towers and tents can also be made stable by anchoring it to the ground with guys. **Guys** are ropes, cables or chains (flexible members) that hold a structure firmly in place by pulling on it.

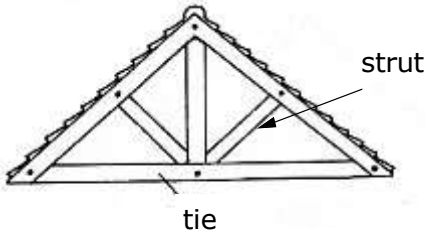


STRUTS and TIES

All structures have forces acting on them. Ties, guys and struts are structural members used to make structures stable. The part of the structure that has a tensile force acting on it is called a **TIE** and the part that has a compressive force acting on it is called a **STRUT**.



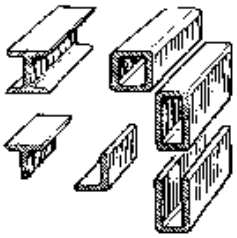
A **tie** (usually inflexible) holds other members in place by pulling on them. Many frame structures have members called **struts** (always inflexible). Struts hold members in position by pushing against them. Struts are made of materials like wood or steel that do not bend.

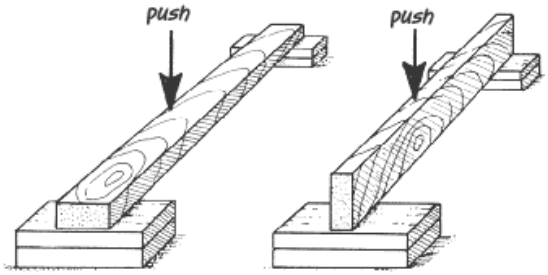


Other structural members

Columns are vertical structural members.

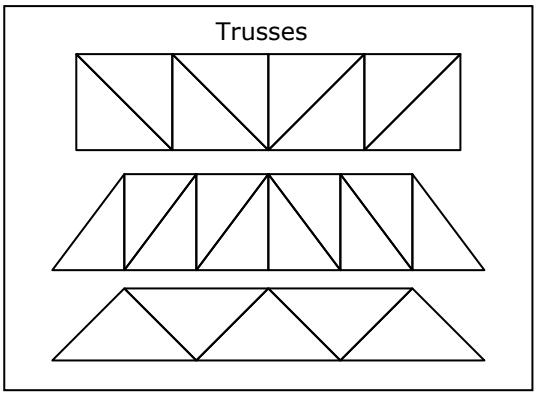
Beams are horizontal structural members. Beams often spread a load across two or more columns. How well the beam works depends the material it is made from and its shape. If you lay a beam flat and push down at the center, t gives easily. If the beam is on its side and you push down at the center, the beam is much more rigid.
Beams used in larger structures take many different forms, some are simply solid, some are hollow, and others have special cross-sections to provide strength and rigidity.

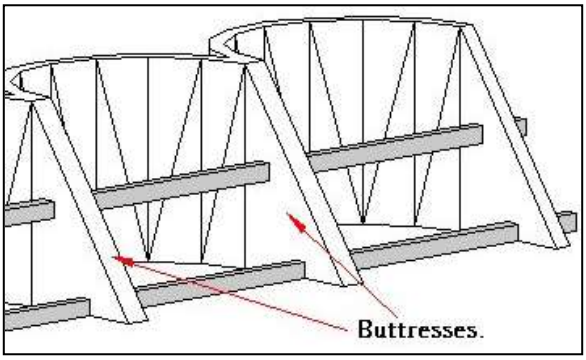




A **cantilever** is a structural member which sticks out like an arm form the main structure. A cantilever is a beam which is supported at one end only.

A **truss** is a structure made up of triangles.



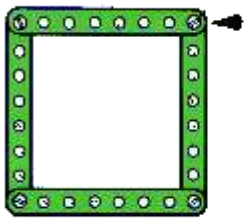


A **buttress** is a structure built against or projecting from a wall which serves to support or reinforce the wall.

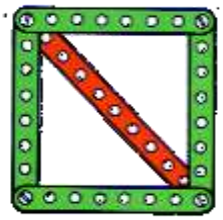
THE DESIGN OF FRAME STRUCTURES

If you look at some pictures of familiar frame structures like cranes, electricity pylons or roof supports you may notice that triangulation is used to make them rigid.

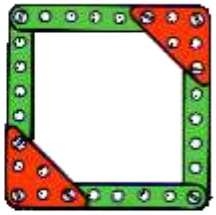
Making Structures Rigid



When forces are applied to a simple four-sided structure it can be forced out of shape quite easily. A structure which behaves in this way is said to be non-rigid.



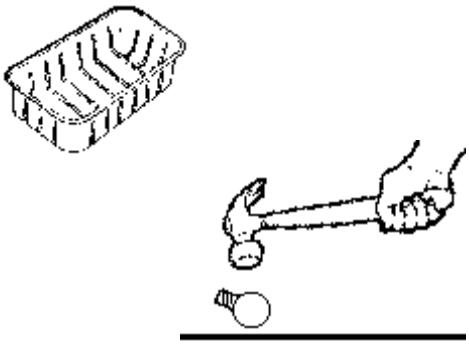
By adding an extra bar or member (usually a strut) corners A and B are prevented from moving apart. The structure then cannot be be forced out of shape, and is said to be rigid. Notice that the additional member has formed two triangles in the structure.



An alternative to triangulation is to use a gusset plate. A gusset is simply a piece of material used to brace and join the members in a structure. A triangular gusset plate has been used here but they can be made in a variety of shapes.

Framed structures achieve most of their strength and rigidity from the way they are assembled. Most frameworks are built using a combination of struts and ties to make triangles. Triangles make very strong and rigid structures. Using triangles in this way is called **triangulation**.

Most shell structures achieve their strength and rigidity from the way they are shaped. Shell structures very rarely have large flat surfaces they tend to be designed and made with ribs to act as stiffeners. Egg and light bulbs containers are good examples. Both eggs and light bulbs can withstand considerable static forces if they are applied carefully.



Forces

Forces can be either **static** (stationary) or **dynamic** (moving).

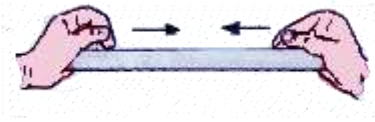
Static forces are usually forces caused by the weight of the structure and anything which is permanently attached to it.

Dynamic forces are caused by things such as wind, waves, people, and vehicles. Dynamic forces are usually much greater than static forces and are very difficult to predict. These are the most common reason for structural failures.

An **external force** is a force placed on the structure from outside, by the wind perhaps or perhaps by someone sitting or standing on it.
Internal forces are the forces which the structure must provide within itself to resist the external forces placed upon it. If the external forces are greater than the internal forces, a structure will collapse.

Forces acting on and within Structures
External forces or loads cause internal stresses to be set up in a structure. Not all forces or loads act in the same way. Forces can bend, pull, press, or twist. Each of these types of force are given special names.

Tension : Is a force which tries to pull something apart. A structural member in tension is called a tie. A tie resists tensile stress.



Compression : Is a force which tries to squash something together. A structural member in compression is called a strut. A strut resists compressive stress.

Bending : Bending is a word you will have met before. A structure which is subjected to bending is being stretched and squashed at the same time.

Shear : A shear force is created where two opposite forces try to cut tear or rip something in two.

Torsion : Is the name given to a turning or a twisting force.

Bridges

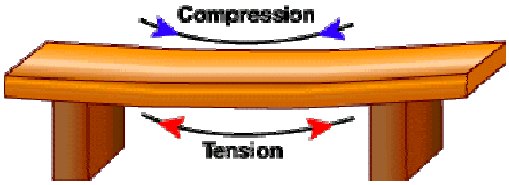
There are four major types of bridges:

- The **beam bridge**
- The **arch bridge**
- The **suspension bridge**
- The **cable-stayed bridge**

The biggest difference between the three is the distances they can cross in a single **span**. A span is the distance between two bridge supports, whether they are columns, towers or the wall of a canyon. A modern beam bridge, for instance, is likely to span a distance of up to 60 m, while a modern arch can safely span up to 240 to 300 m. A suspension bridge, the pinnacle of bridge technology, is capable of spanning up to 2,100 m.
What allows an arch bridge to span greater distances than a beam bridge, or a suspension bridge to span a distance seven times that of an arch bridge? The answer lies in how each bridge type deals with two important forces called **compression** and **tension**:

- **Compression** is a force that acts to compress or shorten the thing it is acting on.
- **Tension** is a force that acts to expand or lengthen the thing it is acting on.

The Beam Bridge



Consists of a horizontal beam supported at each end by piers. The weight of the beam pushes straight down on the piers. The farther apart its piers, the weaker the beam becomes. This is why beam bridges rarely span more than 250 feet.

Compression

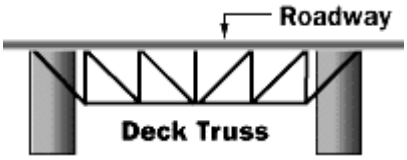
The force of compression manifests itself on the top side of the beam bridge's deck (or roadway). This causes the upper portion of the deck to shorten.

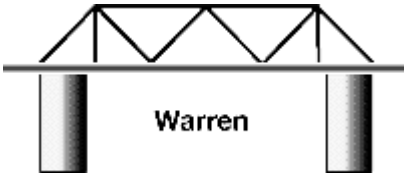
Tension

The result of the compression on the upper portion of the deck causes tension in the lower portion of the deck. This tension causes the lower portion of the beam to lengthen.

Truss Strength

A single beam spanning any distance experiences compression and tension. The very top of the beam experiences the most compression, and the very bottom of the beam experiences the most tension. The middle of the beam experiences very little compression or tension.
If the beam were designed so that there was more material on the top and bottom, and less in the middle, it would be better able to handle the forces of compression and tension. (For this reason, I-beams are more rigid than simple rectangular beams.)
A truss system takes this concept one step further. Think of one side of a truss bridge as a single beam. The center of the beam is made up of the diagonal members of the truss, while the top and bottom of the truss represent the top and bottom of the beam. Looking at a truss in this way, we can see that the top and bottom of the beam contain more material than its center (corrugated cardboard is very stiff for this reason).
In addition to the above-mentioned effect of a truss system, there is another reason why a truss is more rigid than a single beam: A truss has the ability to dissipate a load through the truss work. The design of a truss, which is usually a variant of a triangle, creates both a very rigid structure and one that transfers the load from a single point to a considerably wider area.





The Arch Bridge

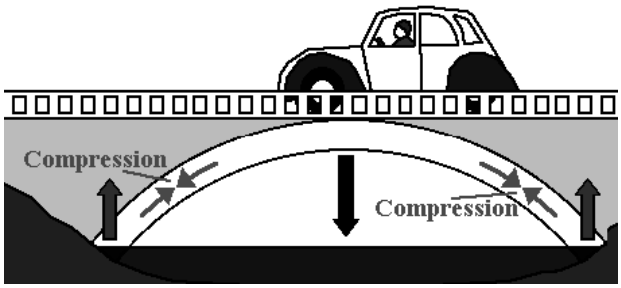
An arch bridge is a semicircular structure with abutments on each end. The design of the arch, the semicircle, naturally diverts the weight from the bridge deck to the abutments.

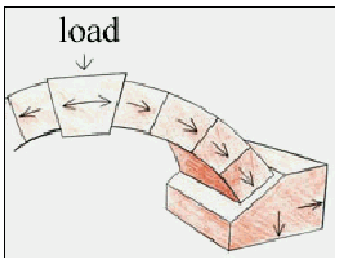
Compression

Arch bridges are always under compression. The force of compression is pushed outward along the curve of the arch toward the abutments. The arch is squeezed together, and this squeezing force is carried outward along the curve to the supports at each end. The supports, called abutments, push back on the arch and prevent the ends of the arch from spreading apart.

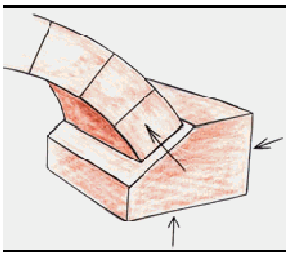
Tension

The natural curve of the arch and its ability to dissipate the force outward greatly reduces the effects of tension on the underside of the arch.

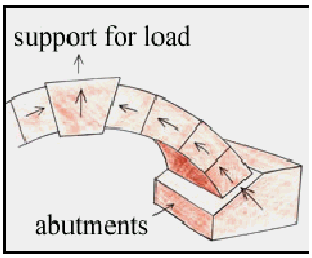




The load at the top of the key stone makes each stone on the arch of the bridge press on the one next to it. This happens until the push is applied to the end supports or *abutments,* which are enbedded in the ground.



The ground around the abutments is squeezed and pushes back on the abutments.



For every action there is an equal and opposite reaction. The ground which pushes back on the *abutments* creates a *resistance* which is passed from stone to stone, until it is eventually pushing on the key stone which is supporting the load.

The Suspension Bridge

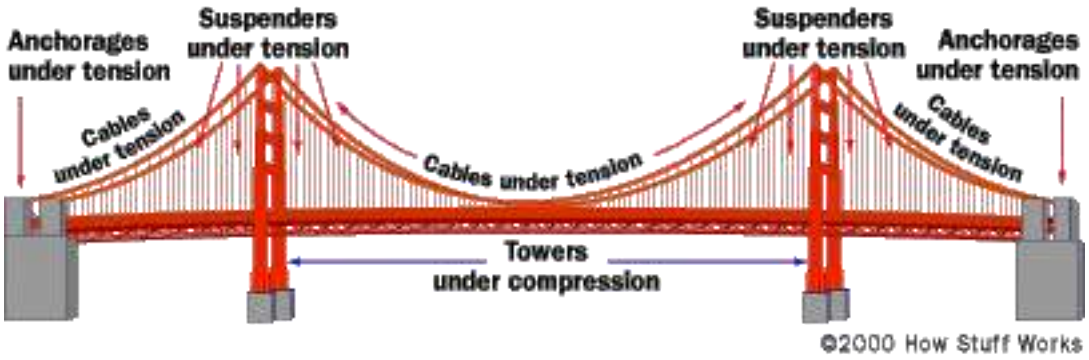
In all suspension bridges, the roadway hangs from massive steel cables, which are draped over two towers and secured into solid concrete blocks, called anchorages, on both ends of the bridge.

Compression

The cars push down on the roadway, but because it is a suspended roadway, the cables transfer the compression to the towers, which dissipate the compression directly into the earth where the anchorages are firmly entrenched.

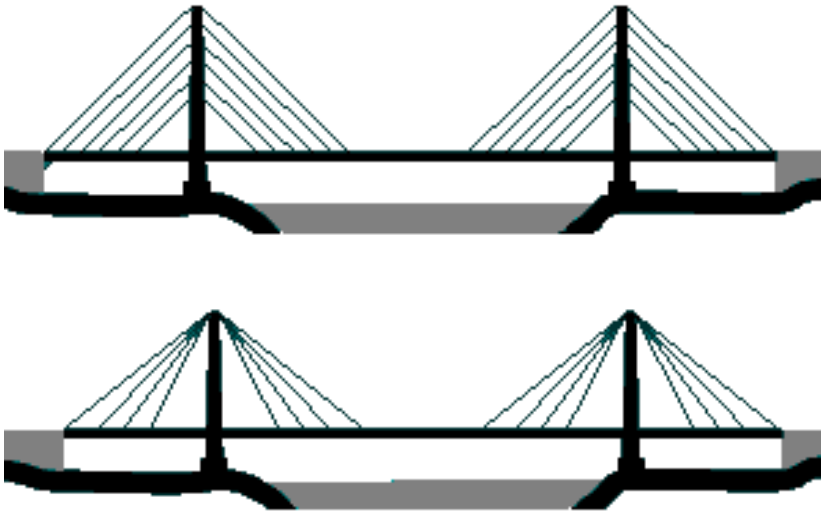
Tension

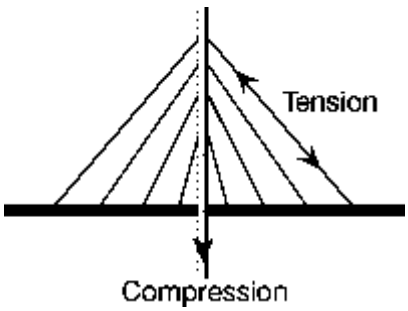
The supporting cables, running between the two anchorages, are the recipients of the tension forces. The cables are literally stretched from the weight of the bridge and its traffic as they run from anchorage to anchorage. The anchorages are also under tension, but since they, like the towers, are held firmly to the earth, the tension they experience is dissipated.

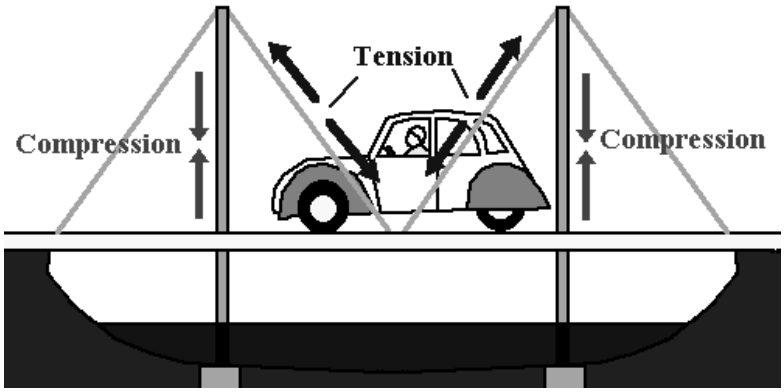


The cable-stayed bridge

The cable-stayed bridge, supports the roadway with massive steel cables, and therefore is in tension. The cables run directly from the roadway up to a tower and transfer compression to the tower, which alone bear the load.
The cables can be attached to the roadway in a variety of ways. In a radial pattern, cables extend from several points on the road to a single point at the top of the tower. In a parallel pattern, cables are attached at different heights along the tower, running parallel to one other. Cable-stayed bridges are becoming the most popular bridges for medium-length spans 150 to 900m.

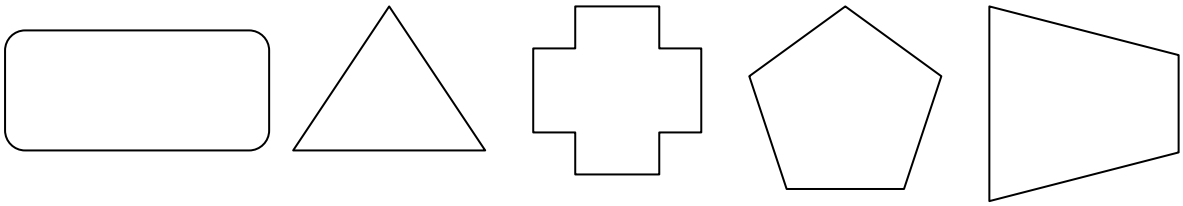






RESOURCE TASK 1

Can you determine the centre of gravity of these objects.

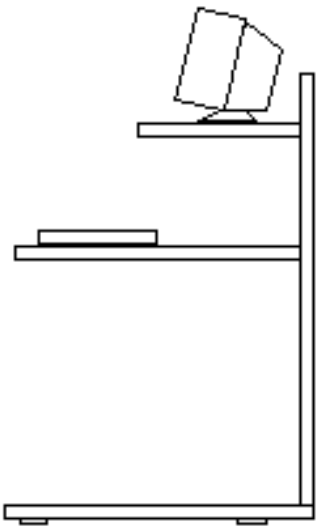


RESOURCE TASK 2

Study the diagram of a computer desk. Each member of the structure is under some type of force.
The top shelf has to carry the weight of the screen.
The middle shelf can be used as a desk if the keyboard is pushed back.

What do you think should be done to **strengthen** the desk.

Redraw the entire structure and add structural members to strengthen it. Label your drawing by naming the **forces** and **members**.



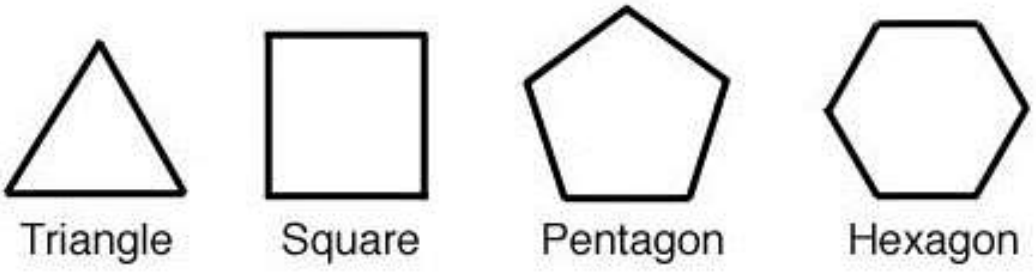
RESOURCE TASK 3

Complete the table for the different types of forces

Name of Force	Definition	Effect on Objects	Example
Gravity			
Compression			
Tension			
Friction			
Torsion			

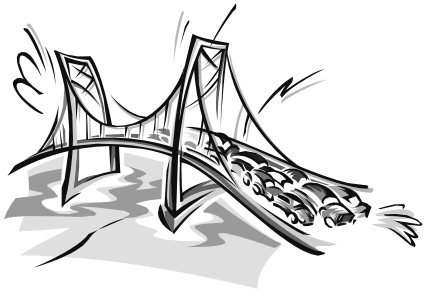
RESOURCE TASK 4

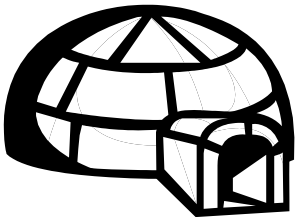
Add members to each of the shapes to make them rigid.

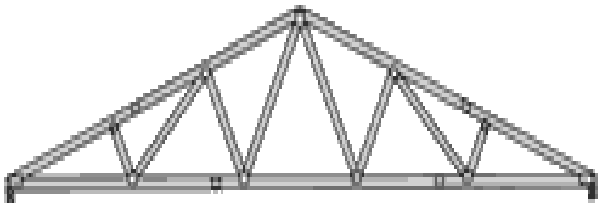


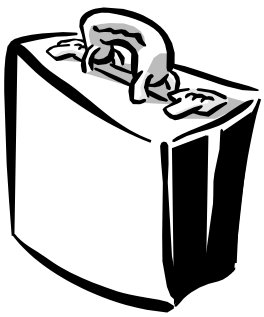
RESOURCE TASK 5

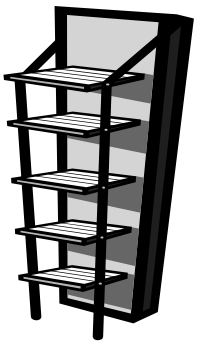
Name the **type** of structures and identify the **purpose** of each.





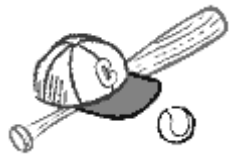




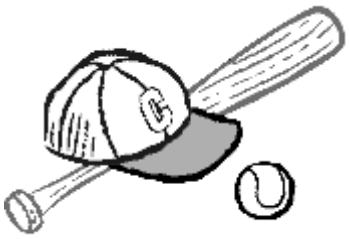


CASE STUDY 1

Welcome to Char County, the hottest dang region in the state. The sizzling sun has caused lots of problems in this county, and the residents are looking to you for help.
They need three new domes for three very different reasons. Use your engineering skills to match the perfect dome to the right location in Char County.

		
Location One: Baseball Stadium	**Location Two: Greenhouse**	**Location Three: Capitol Building**

Location 1: Baseball Stadium

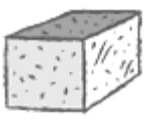
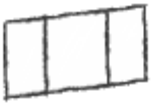
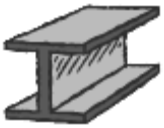
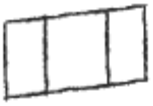


Problem: It's too hot to play baseball outside in the summer
Task: Build a dome over a ballpark
Purpose: To create an enclosed, air-conditioned space for ball players and spectators
Size: Really big (must cover nine acres)
Budget: $250 million

Special Notes: "Do you have any idea how hard it is to play baseball in the summer? The air is so hot and sticky, I feel like I'm pitching in peanut butter! Our fans can't stand the heat either. And the bugs? They're huge! Without an air-conditioned dome, our team is doomed!"
-- Pitcher, Char County Flames

You decide to build a state-of-the-art dome for the Char County Flames. What kind of roof will you build? Do you want the roof to open like a convertible? Or will you build a **rigid** roof, one that stays permanently closed?

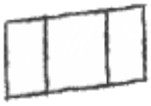
 Rigid roof	 Roof that opens
Rigid Roof You've decided to build a dome with a rigid roof. Not a bad choice! The first domed stadium in the United States had a rigid roof. You've built a **steel** frame for your roof, and now you must cover it with a **strong** material. Here are your choices:	**Retractable Roof** You've decided to build a dome with a roof that opens and closes, also called a retractable dome. Great choice! Retractable domes are great for ballparks because they can be opened on nice days and closed on rainy or hot days. Choose a material to complete your retractable dome roof:

 Concrete	 glass	 plastic	 steel	 glass	 plastic

Location 2: Greenhouse

Problem: Plants are wilting in the heat
Task: Build a big greenhouse
Purpose: To teach kids about plants from around the world
Size: Medium (must cover 1/2 acre)
Budget: $10 million

Special Notes: "Kids are tired of looking at our giant cactus -- but it's the only plant that will grow in this scorching heat. We want kids to learn about all kinds of plants. With a dome, we can control the climate and grow all kinds of plants. Remember, greenhouse domes must be low to the ground -- they're not tall and skinny like the domes on Capitol buildings!"
-- President, Char County Botanical Garden
You think it's a great idea to build a dome over the Char County Botanical Garden. Now it's time to design the greenhouse. Will you build a ribbed dome, made from a series of arches? Or will you try a geodesic dome, made from a series of triangles?

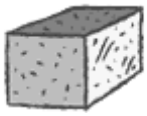
<table>
<tr><td> 
Ribbed dome</td><td colspan="3"> 
Geodesic dome</td></tr>
<tr><td>Ribbed Dome
You've decided to build a ribbed dome. Your steel arches are in place. Now it's time to insert the panels of your greenhouse. Which material will you choose?</td><td colspan="3">Geodesic Dome
You've decided to build a geodesic dome. The weight of the dome is distributed evenly throughout the series of triangles in the structure. Geodesic domes are lightweight, and they enclose the most amount of space with the least amount of material. Since they have less area to lose heat from, they're also very energy-efficient. Your frame made of aluminum triangles is in place. Now it's time to insert the panels of your greenhouse. Which material will you choose?</td></tr>
<tr><td> 
wood</td><td> 
glass</td><td> 
plastic</td></tr>
</table>

Location 3: Capitol Building

Problem: A fire destroyed the dome on the Capitol Building
Task: Build a bigger, better dome
Purpose: To make Char County proud of its government
Size: Extra tall (280 feet high)
Budget: $15 million

Special Notes: "Whose bright idea was it to build our dome with wood? Some careless person dropped a match last week. Now our historic building is nothing but a crumbled, charred mess. I want you to build me a solid, fireproof dome that can support itself. I want the dome to be so tall and elegant that people from every corner of Char County can see it!"
-- Governor, Char County

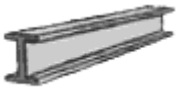
Now you must decide between two materials. You can build the new dome with concrete, which is a very cheap, but very heavy, material. Or you can build it with **steel**, which is very strong, but more expensive than concrete.



Concrete

Concrete Dome
Remember: concrete is very heavy. About halfway down the curve of the dome, the weight of the structure is pushing the sides outward, creating a stress called tension. Cracks are beginning to show. How will you prevent your massive structure from collapsing?

	Build buttresses to support the dome		Carve holes in the dome to make it lighter



Steel

Steel Dome
The best thing about building with steel is that you can cast pieces in almost any size and shape, then assemble them like a giant jigsaw puzzle. There's only one problem. If you build a very tall, solid steel dome, the heavy weight of the structure will push the walls outward, creating a force called tension. This may cause the dome to crack and collapse! How will you get around this problem?

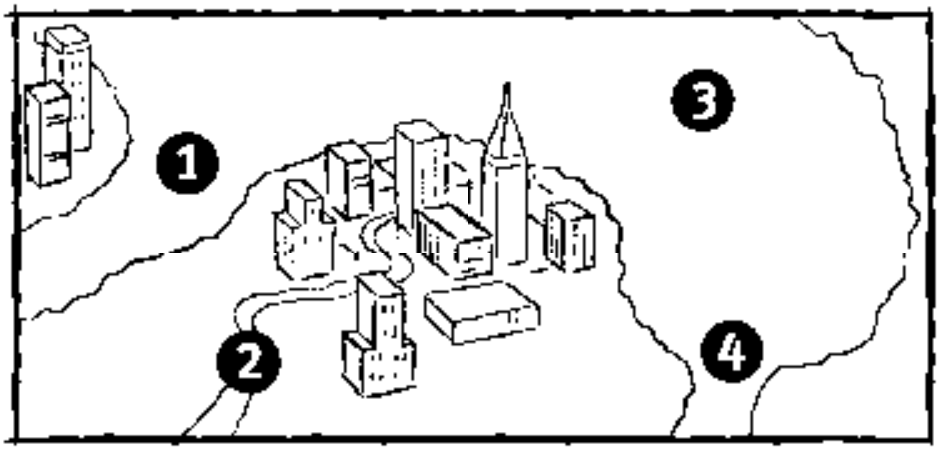
	Build reinforced concrete rings around the dome to keep the walls from spreading		Fool the governor with a double-dome design

CASE STUDY 2

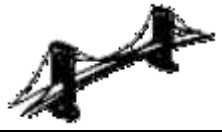
Welcome to Craggy Rock!

You got here just in time. This growing community needs four new bridges, and they're very picky about what they want!
Test your engineering skills and try to match the right bridge to the right location.
Click on one of these four regions to get started. By the way, you may use each bridge type only once -- that's a direct order from the mayor of Craggy Rock. Good luck!

Location 1: Multi-lane bridge for commuters and tourists
Location 2: Footbridge across a stream
Location 3: Highway bridge across a busy shipping port
Location 4: Railroad bridge in a national park



Location 1: Build a multi-lane bridge for commuters and tourists **Span**: 600m **Crossing**: River **Connects**: City and major highway	
Special Notes: "I want a one-of-a-kind bridge that will span our beautiful river and welcome visitors from all over the world to our thriving city. Make sure the new bridge leaves enough room for sailboats on the river. Please don't build a bridge that looks like the Golden Gate Bridge in San Francisco or the Brooklyn Bridge in New York." -- Mayor of Craggy Rock	
Give reasons why you should or should not build the following bridges:	

Location 2:

Build a bridge for rollerbladers and bikers
Span: 30m
Crossing: Stream
Connects: Two bike paths

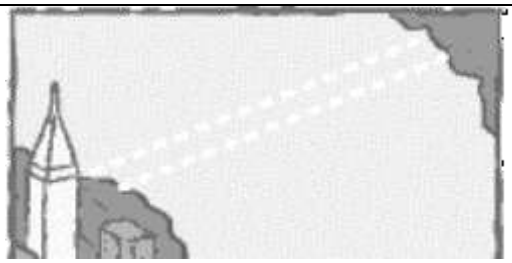
Special Notes:
"We're tired of getting bumped off the road by angry drivers! We want a simple bridge -- one that will connect the bike paths in East and West Craggy Rock over the city stream. We don't have much money, so we're not asking for much. We just want to get to work every day without risking our lives!"
-- Craggy Rock Bike-n-Blade Coalition

Give reasons why you should or should not build the following bridges:




Location 3:

Build a highway bridge across a busy shipping port
Span: 1500m
Crossing: Ocean bay
Connects: Island and mainland



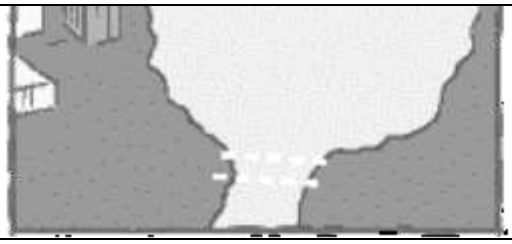
Special Notes:
"Our records indicate that more than 500 ships pass through Craggy Rock Harbor each day. Please build a bridge that does not block the flow of water traffic. We do not want angry sailors or congestion of any kind in our harbor. Thank you."
-- The United States Coast Guard

Give reasons why you should or should not build the following bridges:



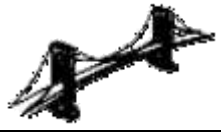

Location 4:

Build a railroad bridge in a national park
Span: 150m
Crossing: Deep river gorge
Connects: Two rocky bluffs



Special Notes:
"We do not want the new bridge to detract from the natural beauty of Craggy Rock National Park. Please build a simple and elegant bridge -- one that does not have towers or piers."
-- The National Park Service

Give reasons why you should or should not build the following bridges:

Processing and materials

By the end of this chapter you will do the following Capability Task:

CAPABILITY TASK

You are going to design and make a pencil case. The pencil case will be made from fabric. You may not use a sewing machine, it has to be handsewn. Any fasteners may be used. Decorations, size, shape and additional pockets etc. is up to you. Remember you have to give informed reasons for what you do and what you use.

You will also hand in a portfolio which will contain the following:

Investigation:

Give a description of the problem in the form of a Design brief

Designing:

Specifications & constraints
Possible solutions, ideas (at least 3 - each one A4 size with labels and explanations)
Informed decision & final drawing

- The pattern drawn on scale, on grid paper
- The different views drawn A4 size and coloured to look exactly like the final product

Making:

Materials and tools needed
Flow diagram to show the steps in making the pencil case

Evaluating:

Weaknesses and strengths
Improvements and modifications

Resource Tasks

Case Studies

Research

MATERIALS

When selecting materials you have to keep the following in mind:
- The properties required
- The construction or manufacturing processes involved
- The costs of materials and manufacturing
- The availability of materials
- Environmental factors

PROPERTIES

(A) How materials react to forces and strength

a) Resistant properties

Tensile strength: ability of a material to withstand pulling or tension forces
Compressive strength: ability of materials to withstand pushing or compressive forces
Torsional strength: ability of material to withstand being twisted or placed under torsion
Stiffness: how little distortion or deflection occurs when a material is placed under pressure
Hardness: Ability to withstand being scratched cut or dented
Brittleness: When material fractures with little or no deformation
Toughness: Resistance to impact

b) Non-resistant properties

Ductility: Allows a material to be elongated or stretched without breaking
Elasticity: When a material can be stretched out of shape, but it will go back to its old shape when you remove the force.
Flexibility: If a material bends easily and does not crack.
Plasticity: When a material changes shape when you press or squash it, it will not go back to its old shape when you remove the force.

(B) How materials react to water

Absorbent: Materials that suck up water easily.
Waterproof: Materials that seems to push water away, it just runs of the material

(C) How materials react to heat

Absorbtion and reflection: The colour or nature of the surface of a material can absorb or reflect heat better
Thermal properties: *Conductivity*—how well heat travels or is conducted through a material
Insulation—when materials do not allow heat to pass through them
Expansion—expanding when heated and contracting when cooled down

(D) How materials react to electricity

Electrical properties: - low resistance (conductor): allow electricity to pass through
- high resistance (insulator): doesn't allow electricity to pass through

PROCESSING

Definition: To process a material is to change it from one form to another

Three stages:
- Input
- Process
- Output

Inputs include:

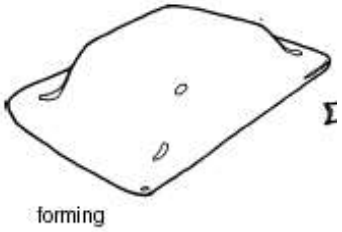
- Design specifications
- Materials Equipment to make the product
- People and their skills
- Premises
- The energy needed to make the product

Processes used will depend on what the product is going to be.
For example:
- measuring and weighing
- Cutting and joining or assembling
- Combining or separating
- Moulding or shaping
- Finishing processes
- packaging

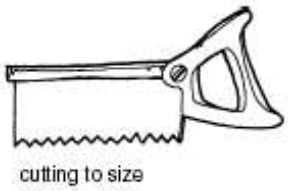
Outputs

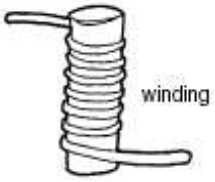
- Final products
- Waste products that are thrown away, re-

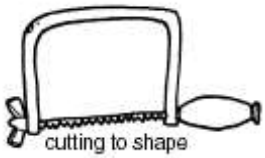
CUTTING AND SHAPING

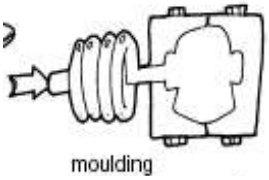

forming


extruding


cutting to size

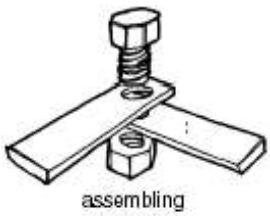

winding


cutting to shape

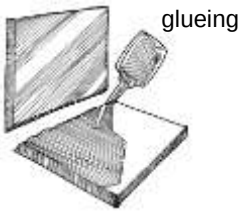

moulding

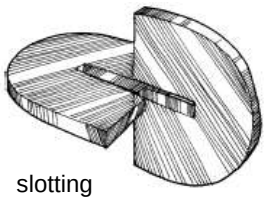
ASSEMBLING

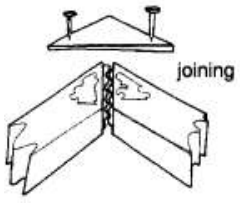
This may involve the following techniques:
• slotting together (suitable for sheet plastic or plywood);
• glueing together (suitable for paper, card, plastic or plywood);
• soldering together (suitable for wire and metals).


assembling


soldering


glueing


slotting


joining

TEXTILES

Fabric property:	Explanation of property:	Ways of testing fabric property:
Abrasion resistance	Scales on fiber make fabric resistant to abrasion. Example: wool.	Count the number of scrapes with sandpaper before signs of abrasion appear.
Absorbency	The molecular and chemical structure of the fibers and the space between the fibers allow the retention of water.	-Count number of drops or spoonfuls of water that the fabric or fiber can hold.-Weigh the fabric or fiber before and after soaking in water for a designated length of time.
Cling of fibers	Fibers with crimps in their shape allow them to grab onto another surface like felt to a felt board. (Fabrics that have the same property may cling to another surface.)	Test whether a fabric will cling to a felt board. Attach paperclips to the fabric (for weight) to see how much cling the fabric has before it slides off the board.
Dyeability	Fibers that link together will hold color from dyes better.	Apply food coloring and rinse, rate by intensity of color remaining in fibers/fabric. If possible, compare with other samples.
Elasticity (ability of fibers to return to original shape after stretching)	Elastic fibers have molecules with strong connections and a natural crimp that allows lengthening.	Stretch fabric to a predetermined length; measure before and after stretching.
Electrical Conduction	Static electricity is produced when the fabric is rubbed against a surface. Static build-up is due to poor conductivity.	Rub the sample against your hair, then test your hair for tangling. Static causes hair strands to be attracted to each other.
Soiling	Fibers are crimped, promoting collection of dirt.	-Rub a measured amount of soil on the fabric sample and then rinse.-Compare to a clean sample of fabric and rate the amount of soil remaining.
Pilling (balling up of fibers on surface)	The balling up of fibers on the surface of a fabric is caused by weak or loosely woven fibers. Stronger fibers will have little or no pilling.	Count rubs on a carpet, then count the number of balls created.
Strength (resistance to tearing)	The length and twist of fibers determine the resistance to tearing.	Bend a paperclip into an "S" shape, and hang washers on one end with the fabric on the other. Hold the edge of the fabric and continue adding washers until fabric tears.
Density	Tightly woven fibers make a denser fabric than loosely woven fibers.	Shine a penlight through fabric, noting how far the beam travels in a dark room, if at all.

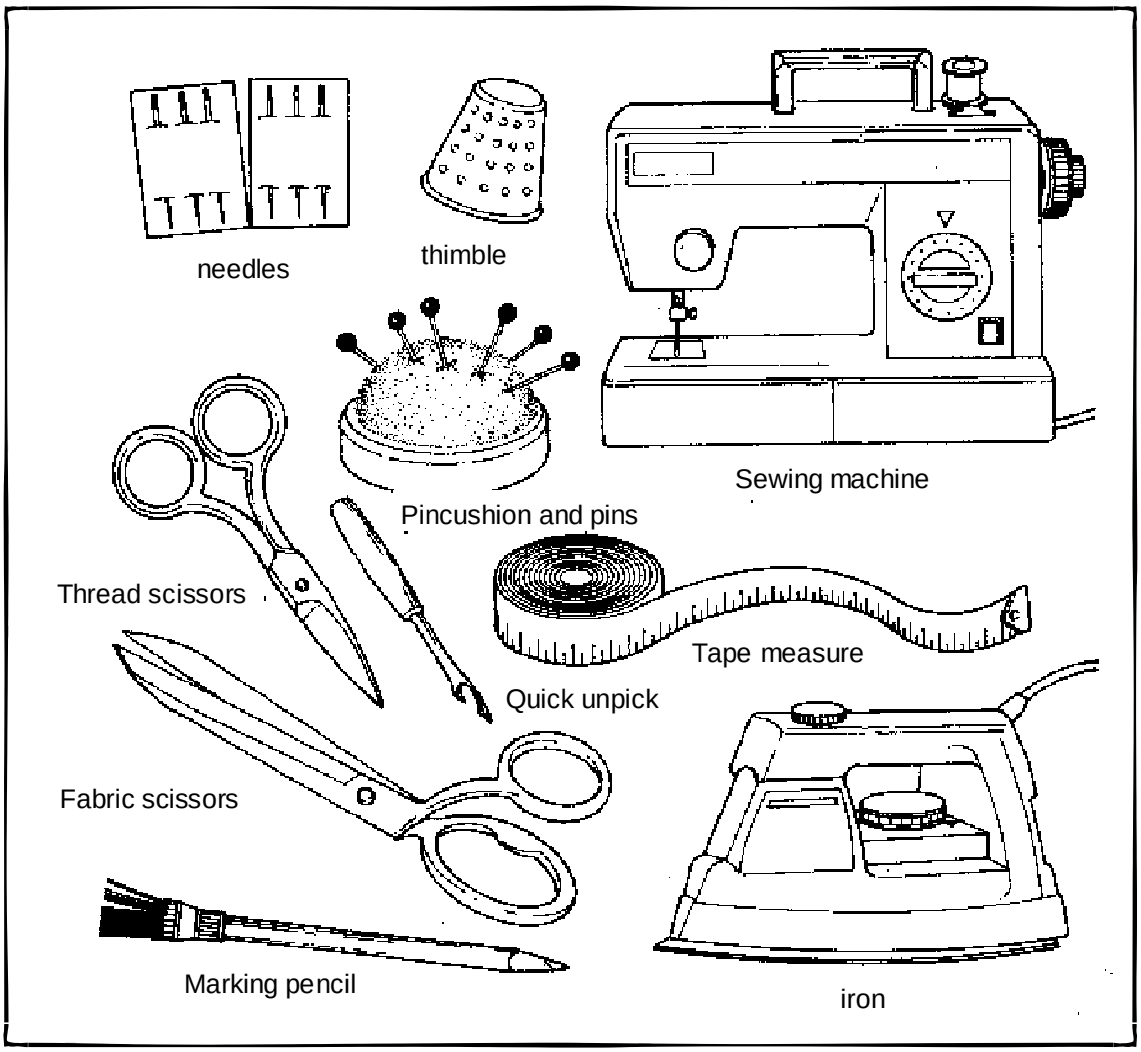
Fibre	Natural / Manufactured	Characteristics	Uses	Comments
COTTON	Natural Fiber - cellulosic	• Comfortable • Soft hand • Absorbent • Good color retention, prints well • Machine-washable, dry-cleanable • Good strength • Drapes well • Easy to handle and sew •	Apparel - Wide range of wearing apparel: blouses, shirts, dresses, childrenswear, activewear, separates, swimwear, suits, jackets, skirts, pants, sweaters, hosiery, neckwear. Home Fashions - curtains, draperies, bedspreads, comforters, throws, sheets, towels, table cloths, table mats, napkins	
HEMP	Natural Fiber	• Three times stronger than cotton • Good abrasion resistance/very durable • Anti-microbial and UV resistance • Naturally resistant to mold, mildew, rot • Readily takes dyes • Softens with each washing, without fiber degradation • Breathable • Washable or dry cleanable • Wrinkles easily/poor resiliency • Poor drapeability • Not as soft as other fibers	Apparel - dresses, suits, separates, skirts, jackets, pants, blouses, shirts, childrenswear. Home Fashions - curtains, draperies, upholstery, bedspreads, table linens, sheets, dish towels.	The highest quality hemp comes from the "true" hemp plant called Cannabis Sativa. Sisal hemp and Manila hemp (also known as Abaca) are lower quality hemp fibers. Hemp can have a rather harsh hand. Therefore, it is best utilized in blends with other fibers (i.e. cotton, silk, wool, polyester).
WOOL	Natural Fiber - made from the fleece of sheep	• ComfortableLuxurious, soft hand VersatileLightweight Good insulatorWashable Wrinkle-resistantAbsorbent Easy to dye	Apparel - sweaters, dresses, coats, suits, jackets, pants, skirts, childrenswear, loungewear, blouses, shirts, hosiery, scarves. Home Fashions - carpets, draperies, upholstery, blankets.	
NYLON	Manufactured Fiber	• Lightweight • Exceptional strength • Good drapeability • Abrasion resistant • Easy to wash • Resists shrinkage and wrinkling • Fast drying, low moisture absorbency • Resistant to damage from oil and many chemicals • Static and pilling can be a problem • Poor resistance to continuous sunlight	Apparel - swimwear, activewear, intimate apparel, foundation garments, hosiery, blouses, dresses, sportswear, pants, jackets, skirts, raincoats, ski and snow apparel, windbreakers, childrenswear. Home Fashions - carpets, rugs, curtains, upholstery, draperies, bedspreads Other - Luggage, back packets, life vests, umbrellas, sleeping bags.	Nylon is one of the strongest fiber. For this reason it´s used in garments that take a great deal of hard wear, like panty hose and swimwear. The most popular fiber blend used in swimwear today is nylon and spandex. Although nylon is a very strong fiber, it has poor resistance to prolonged exposure to the sun.

Fibre	Natural / Manufactured	Characteristics	Uses	Comments
POLYESTER	Manufactured Fiber	• Strong • Crisp, soft hand • Resistant to stretching and shrinkage • Washable or dry-cleanable • Quick drying • Resilient, wrinkle resistant, • Abrasion resistant • Resistant to most chemicals • Low absorbency • Static and pilling problems	Apparel - essentially every form of clothing, dresses, blouses, jackets, separates, sportswear, suits, shirts, pants, rainwear, lingerie, childrenswear Home Fashions - curtains, draperies, floor coverings, fiber fill, upholstery, bedding.	Of all the manufactured fibers, polyester is the most used. Polyester is the best wash-and-wear fiber. In addition, when polyester is blended with other dry-clean only fibers, like wool, acetate, or rayon, the durability of the blended fabric improves and, in some cases, the fabrics can even be made washable.
RAYON	Manufactured Fiber - cellulosic-based from wood pulp	• Soft and comfortable • Drapes well • Highly absorbent • Dyes and prints well • No static, no pilling problems • Fabric can shrink appreciably if washing dry-clean-only rayon • Washable or dry cleanable.	Apparel - Blouses, dresses, jackets, lingerie, linings, millinery, slacks, sportshirts, sportswear, suits, ties, work clothes Home Fashions - bedspreads, blankets, curtains, draperies, sheets, slip covers, table cloths, upholstery.	Rayon is also called viscose. Anytime a rayon garment, labeled "dry clean only," is washed, a risk is taken. In order to get the maximum life out of your washable rayon garment, it's best to hand wash and drip/hang dry.

Care labels

Wash	 cold wash  luke warm wash  hand wash
Bleach	 bleach  do not bleach
Tumble dry	 tumble dry  do not tumble dry
Iron	 hot iron  warm iron  cool iron  do not iron
Dry clean	 dry clean  do not dry clean

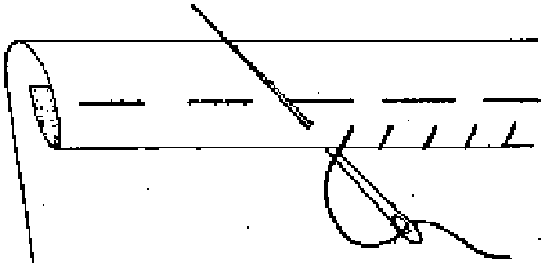
Sewing equipment



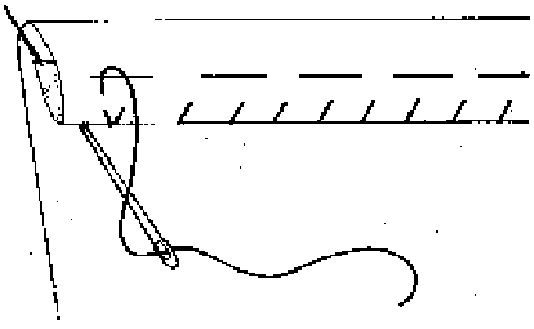
HOW TO: Hand sew a hem:

Follow steps (a) and (b) for sewing a hem by machine. Then follow steps (c) and (d) below.

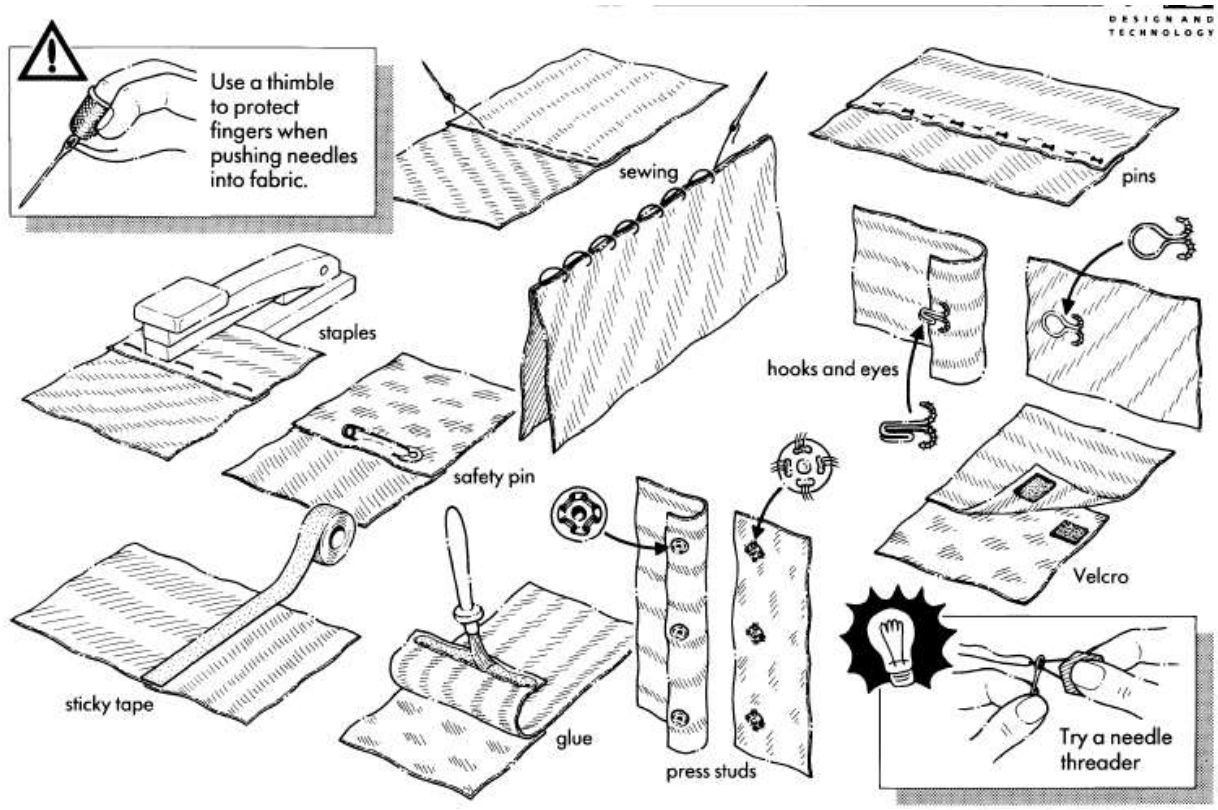
Using a single thread about 30 cm long, begin with a small double stitch to secure the start of the hem. Pick just a few threads of the fabric, just below the fold of the hem.Pull the needle through the fabric at a slant and catch a small amount of the fold.



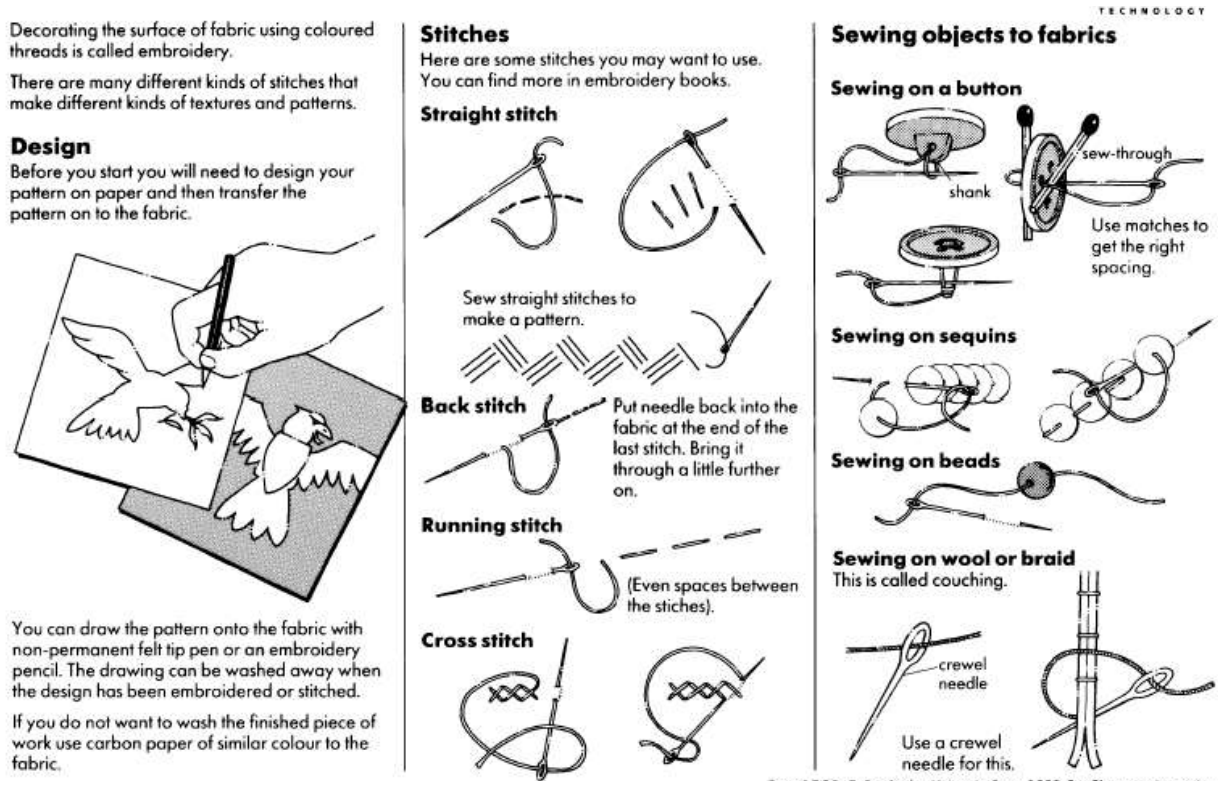
Continue working like this along the fold of the hem, sewing evenly spaced stitches. Finish off with a double stitch in the other direction to form a 'v'.



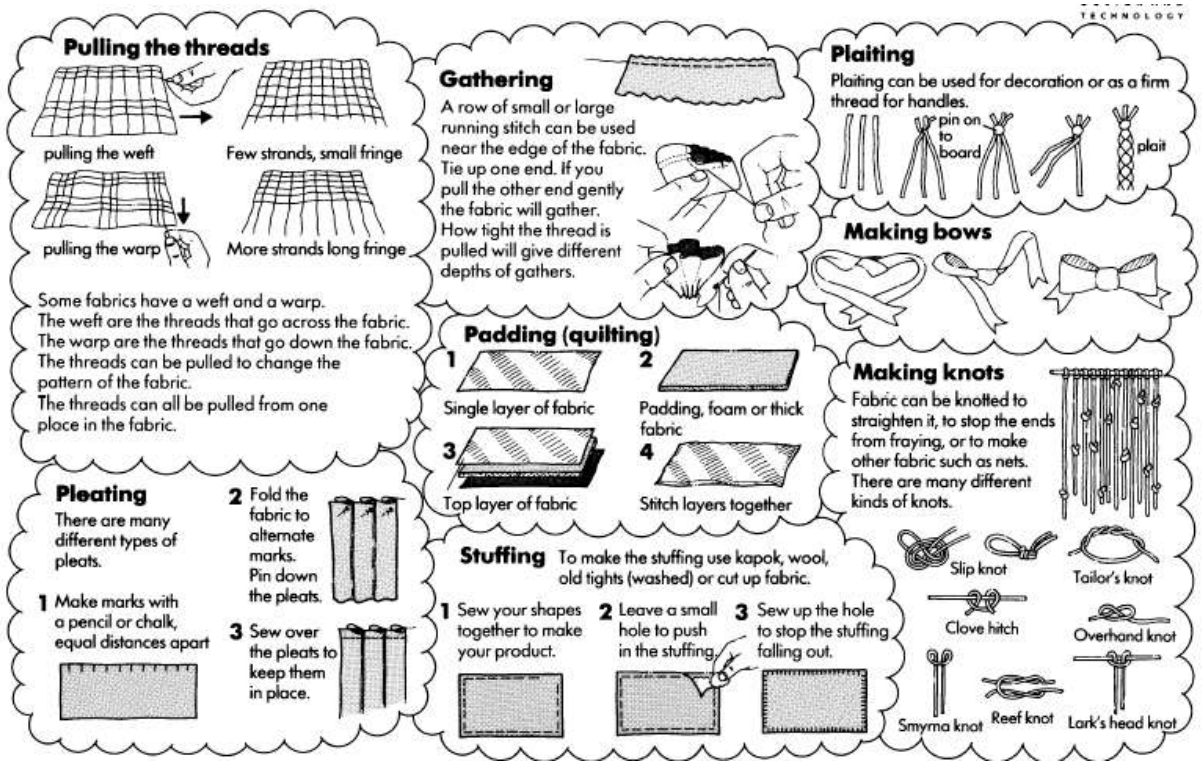
Joining



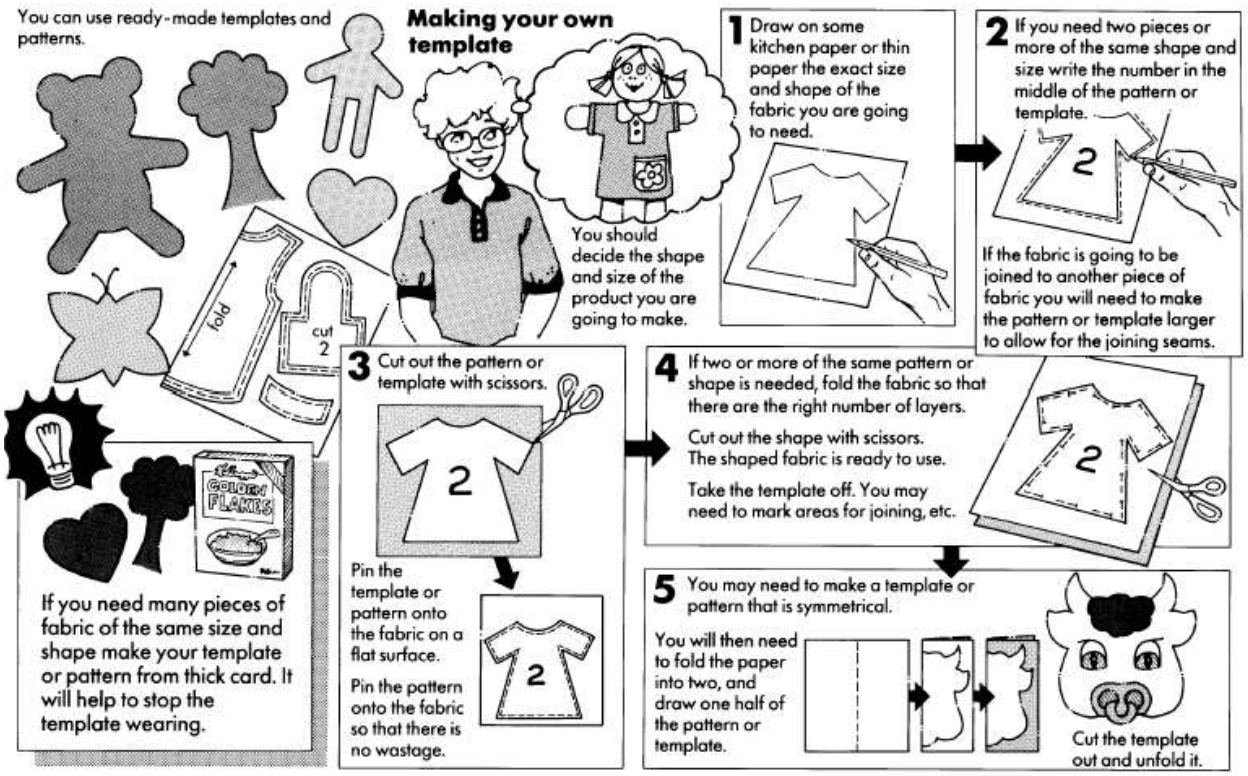
Sewing



Working with fabrics

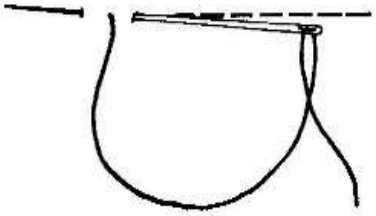


Making and using templates and patterns

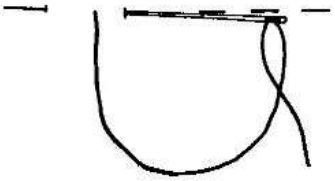


Hand Sewing Stitches

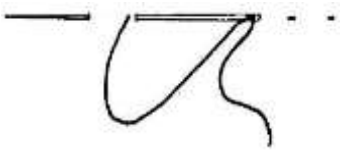
Backstitch - strong, versatile stitch used for seams, topstitching, handpicked zippers



Even Backstitch



Half-Backstitch

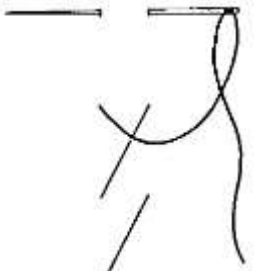


Pickstitch

Prickstitch

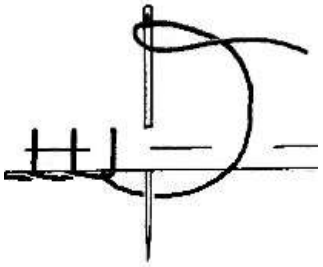
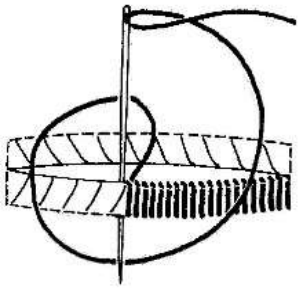
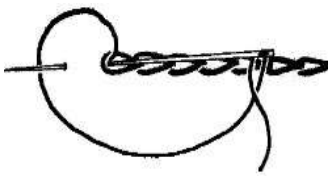
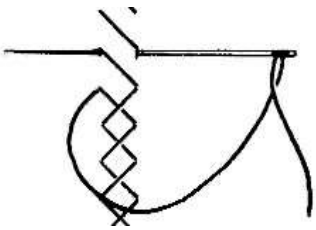
Basting - used to temporarily hold together two or more fabrics

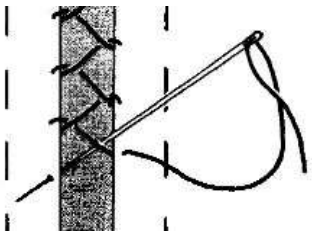
Even Basting



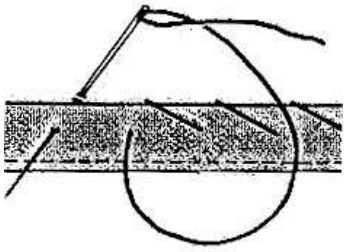
Diagonal Basting

Uneven Basting

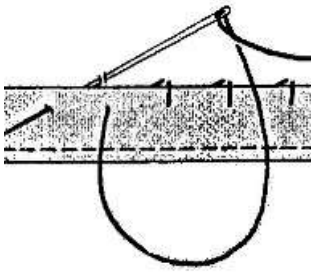
Blanket Stitch - decorative edging	**Buttonhole Stitch**
	
Chainstitch - decorative stitch worked right to left	**Cross Stitch** - decorative stitch worked top to bottom and back up to top
	
Fagoting Stitch - decorative stitch	**Featherstitch** - decorative stitch



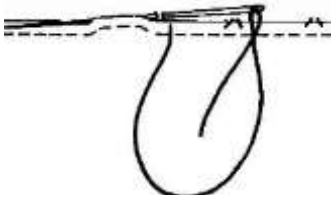
Hemming Stitches



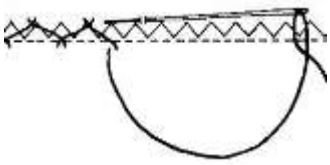
Slant Hemming Stitch



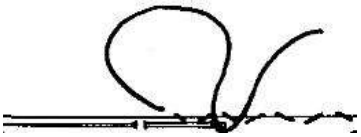
Vertical Hemming Stitch



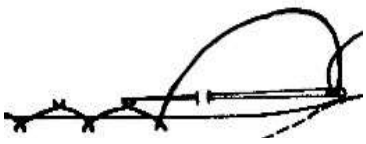
Uneven Slipstitch



Catchstitch

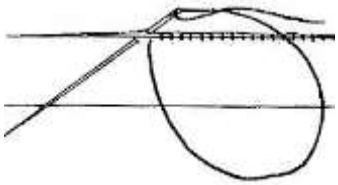


Blind-Hem Stitch



Blind Catchstitch

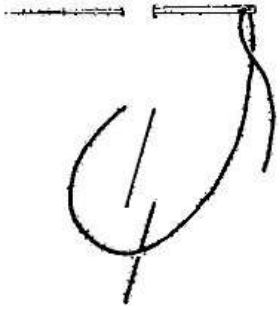
Overcast Stitch

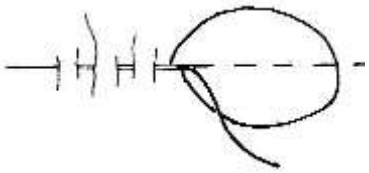


Overhand Stitch

Padding Stitches - used in tailoring to hold interfacing to outer fabric

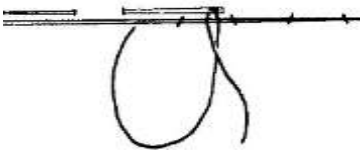
Running Stitches - short, even stitches used for seaming, tucking, mending, and gathering



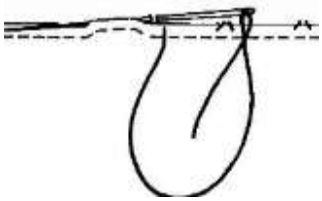


Running Stitch

Slipstitch - nearly invisible stitch

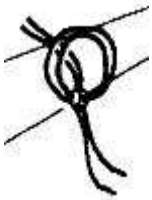


Even Slipstitch

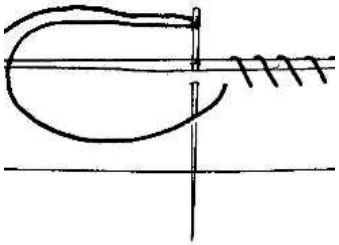


Uneven Slipstitch

Tailor Tacks - used to transfer pattern marking to fabric



Whipstitch - overhand stitch used to join two finished edges



Inserting a Zip

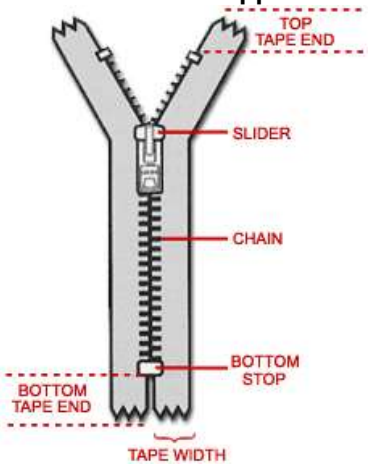
How to measure a zip:
The tape should be laid from the BOTTOM STOP to the top of the slider with the zip in closed position. If using a concealed zip, allow an extra 2.5 cm on top.

Quick Fixes:

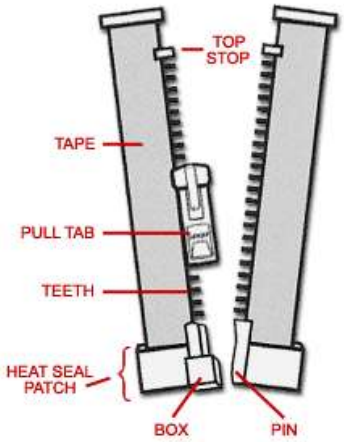
- Lightweight or loosely woven fabrics will be easier to handle if a strip of light iron-on interfacing, 1" wide, is pressed to the wrong side of each edge.
- On very fine fabrics like chiffon, use a strip of the fabric instead.
- Avoid stretching the fabric at all stages.
- Clip threads leaving a marker on each side of the zip and garment, using contrast threads, and then match these up to keep the zip in place when sewing the seam.

Types of zippers

Closed end zipper



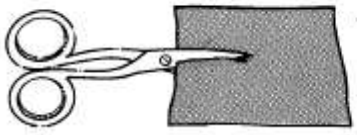
Open end zipper



Threads should be no more than 40 cm long.

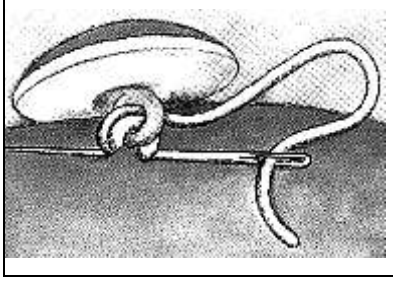
Tie a knot at the end of the thread so that it will not come through the fabric once you start to sew.

Scissors must be sharp.



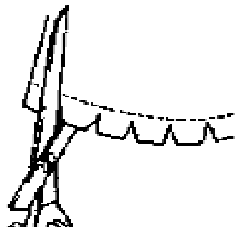
Do not use the scissors you use for fabric to cut paper. It will blunt them.

Buttons

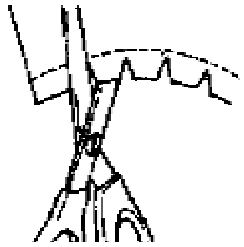
	**4 hole buttons.** Make a knot on the outside of the cloth at the spot where you are going to sew on the button. Pass the thread two or three times through each hole. Finish by making a knot and reinforcing with a back stitch on the inside. Vary the stitches for decorative effect.
	**2 or 4 hole buttons with stalk** Hold a match firmly on the button and sew it to the fabric as you would normally; when you pull out the match you will have the length of the stalk.
	The length of the stalk can also me made by turning the button towards the seamstress and pinching the cloth from the right.
	Wrap the thread around the stalk until it is completely covered, fasten the thread by pulling it through the inside of the stalk and then cut.
	**Reinforced button** A small opposing button of different material is used and fastened to the inside of the garment; sew the two buttons at the same time following the same procedure for buttons with stalk.
	**Button with metal ring** We especially recommend the use of a thick thread for this kind of button as the metal causes deterioration of the thread. Sew the button on through the ring while pinching the cloth; stop the thread by proceeding as stated above.

HOW TO:

Make a curved seam lie flat:

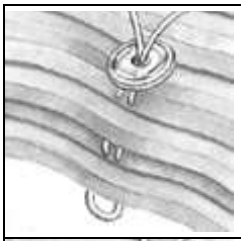
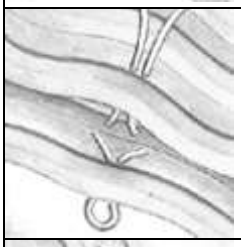
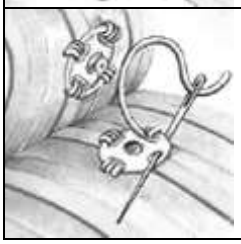


Some seams are stretched because they curve outwards. To make these seams lie flat, cut snips into the seam allowance fabric. Be very careful not to cut through the seam stitching.

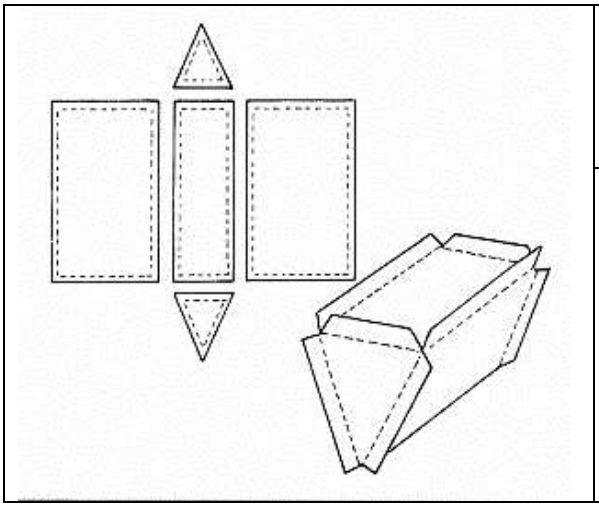


Some seams are squashed and bulky because they curve inwards. Cut wedges of fabric out of the seam allowance to get rid of the extra fabric and make the seam lie flat.

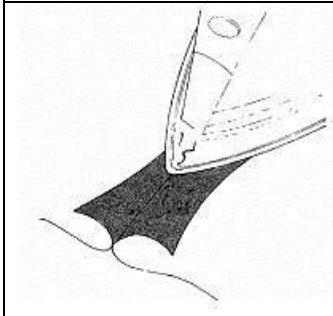
Press Studs

	**Fig. 1** In order to determine the exact position of the button thread the central hole of the automatic button; you will have to make a stitch by sewing both sides of the cloth simultaneously and pulling the thread out of the hole itself, leaving a little slack; then cut.
	**Fig. 2** Open the two opposite sides of the cloth, cut the thread in the centre; this will give you the correct position at which you will apply the two parts of the press studs.
	**Fig. 3** Sew the male at the upper side and on the inside by passing the needle 3 or 4 times through the holes without letting the stitches go through the right side; make a knot and a small back stitch. Cut the thread. Place the female underneath and sew in the same way as you sewed on the male.

Working with a pattern



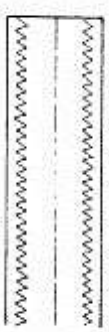
Measure around for seam allowances. Depending on the type of fabric, you might have to allow a bit extra for hems. When you work with lots of corners in your design, you could cut them off to make the final product neater.



After stitching a seam use an iron to press the seam open.

Neaten the raw edges of the seam. You can use any of the following methods:

Edge-stitching: Fold under 5 mm of the seam and pin or tack it in place. Then stitch close to the folded edge using straight stitches.



Zigzagged edges: If the seam is frayed, cut off the frayed threads or fold under 5 mm from the edge of the seam. Zigzag close to the edge of the seam using medium stitches, but don't go over the edge. Trim off any frayed threads which remain.

Pinking shears: If the fabric is thick and does not fray easily, you can trim the edges with pinking shears to neaten them. Sew a single line of straight stitching 5 mm from the edge of the seam. Then trim the edge with the pinking shears.

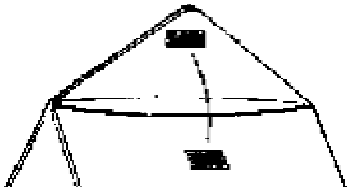
Fastening chooser chart

	Ease of use	*Ease of fitting*	*Variety of types*	*Strength*	*Ease of care*	*Cost*
Buttons 	●●	●●●● holes ●	●●●●	●●	●●	▲▲
Toggles 	●●●	●●●	●	●●	●●	▲▲
Zips 	●●●	●	●●	●●●●	●●	▲▲▲
Velcro 	●●●●	●●●●	●	●●●●	●●●	▲▲
Hooks/eyes 	●	●●	●●	●	●●●	▲
Eyelets and laces 	●●	●●●	●●	●●●●	●●	▲▲
Press studs 	●●●	●●●	●●	●	●●●	▲
Clips/buckles 	●●	●●●	●●	●●●	●●●	▲▲▲

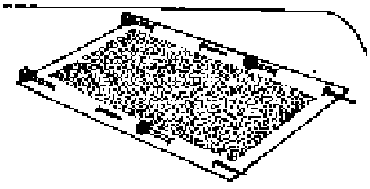
HOW TO: Sew on fasteners:

Velcro

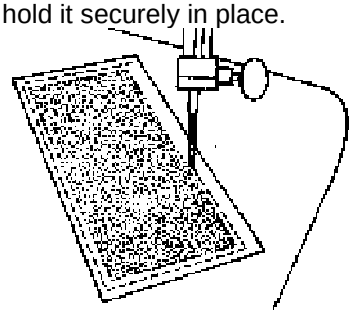
Velcro is a stiff nylon tape with two different right sides which when pressed together, stay fixed like that until pulled apart. Velcro is usually used where it will not show.



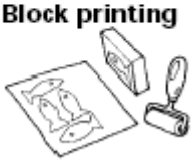
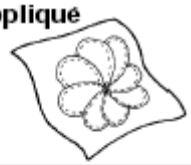
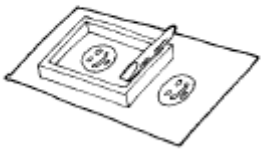
Cut a piece of velcro to the size you need. Both sides must be the same length. Pin the rough, bristly side on th the bottom part of the opening. Pin the soft, fluffy side on to the top part of the opening.



Machine stitch close to the edge around each strip of velcro to hold it securely in place.

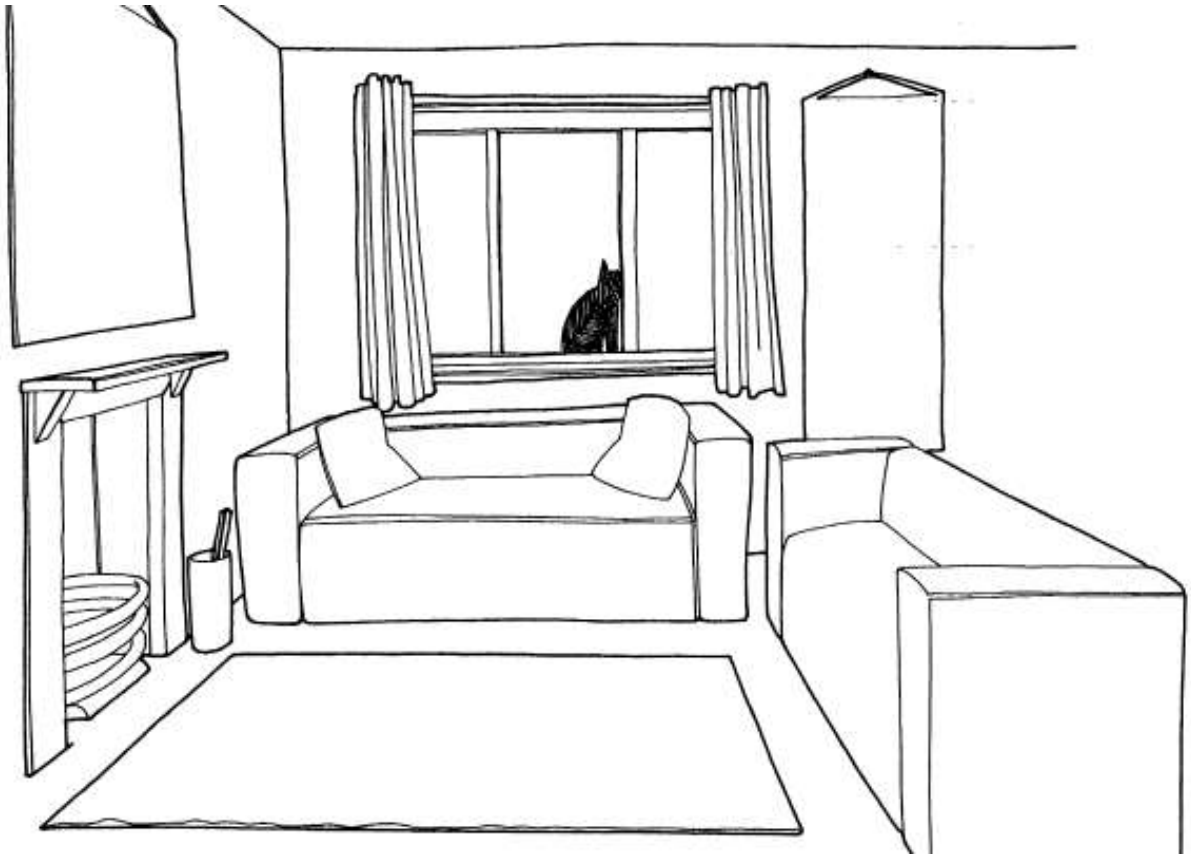


Fabric Decoration Chooser Chart

Technique	*One-off or repetitive*	*Time needed*	*Simple or complex*	*When to do it*
Tie dyeing 	one-off	quick (check for dyeing and drying)	very simple	before cutting, when in parts, or on the finished item
Batik 	one-off	varies depending on the detail of motif and number of colours to be dyed	varies, needs practice	before cutting or onto cut parts
Fabric marker pen 	one-off	quick for simple motifs, slower for more fiddly ones	simple	onto cut parts or finished items
Transfer painting 	one-off	quick for simple motifs	simple, lettering must be reversed simple	onto cut parts or finished items
Block printing 	repetitive	slow - block must be prepared first, but printing is quick	simple	before cutting
Applique 	one-off	slow - for careful cutting, positioning and stiching	complex, needs practice	onto cut parts
Embroidery 	one-off	varies depending on the detail	simple with practice	the finished item
CAM Embroidery 	one-off and repetitive	varies depending on the detail	simple with practice	the finished item
Screen printing 	one-off	slow - screen must be prepared first, but printing is quick	varies - depends on complexity of screen	before cutting, when in parts, or on the finished item

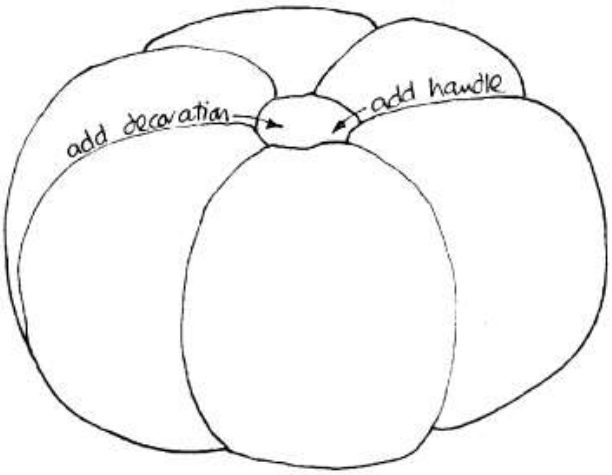
RESOURCE TASK 1

Suggest fabrics for this room and give reasons for choosing it.



RESOURCE TASK 2

Draw the pattern (on graph paper and on scale) that will be used to make this cushion, add measurements and indicate seams. (The cushion will be ± 50 cm high and 75 cm wide)



RESOURCE TASK 3

Use a piece of fabric 10 cm x 10 cm and demonstrate 6 different stitches on it. Use a contrasting thread so that it is easy to distinguish.

CASE STUDY 1

Pencil cases	Fabric	Soil easily	Fastener	Stitching	Appearance	Rigid	Extras	Size	Shape	Colour

CASE STUDY 2

Fabric sample	Fibre types	Origin	Characteristics	Uses

Property	Explanation	Test results	Burn test	Care	Care symbols

SYSTEMS AND CONTROL

Systems and Control

Demonstrates knowledge and understanding of interacting mechanical systems and sub-systems by practical analysis and represents them using systems diagrams:

- gear systems
- belt drive or pulley systems with more than one stage;
- mechanical control mechanisms (e.g. ratchet and pawl, cleats);
- pneumatic or hydraulic systems that use restrictors;
- one-way valves;
- systems where mechanical, electrical, or pneumatic or hydraulic systems are combined.

Most manufactured products can be thought of as ***systems***.

*A system is a group of **components** connected so that they work together to perform a task.*

The component parts may be ordered steps in a procedure or organizational structure but we need only concern ourselves with physical components each of which has its own contribution to make to the overall operation of a system.
All systems consist of at least three clearly identifiable sections. The ***input*** stage is where energy or information is fed into the system. The ***process*** stage is where energy or information is processed or converted. The ***output*** stage causes something to happen. The flow of information or energy from input through the process stage to the output is often called a ***signal.***

The ***energy source*** for the system will determine which type of component is required at each stage. If the energy source is compressed air the components will need to be pneumatic components and these will combine to produce a pneumatic system. If the energy source is electricity the components will need to be electrical or electronic and these will combine to produce an electronic or electrical system. The energy input into a system can be:

Movement - *(mechanical systems),*

Oil/water under pressure - *(hydraulic systems),*

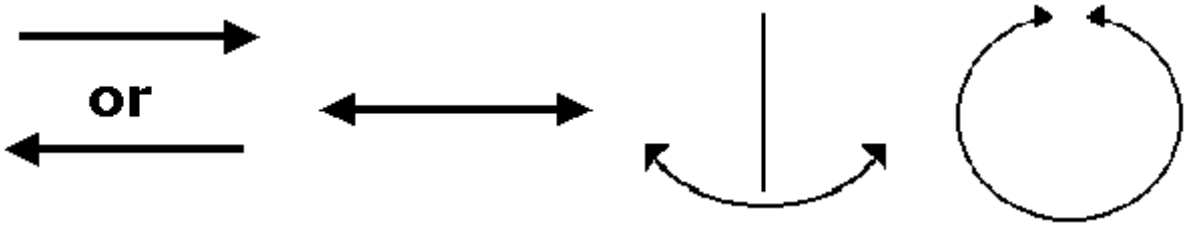
Air under pressure - *(pneumatic systems),*

Electricity - *(electrical or electronic systems).*

MECHANICAL SYSTEMS

MOVEMENT

There are four basic kinds of motion, or movements:



Linear motion movement in a straight line and in one direction

Reciprocating motion movement backwards and forwards in a straight line

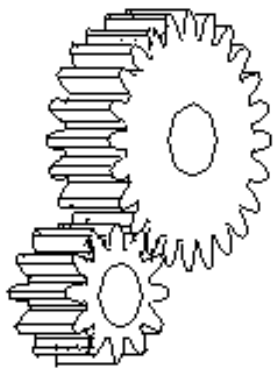
Oscillating motion a swinging back and forth

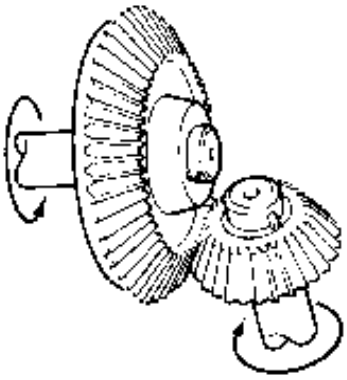
Rotary motion a circular motion.

GEARS

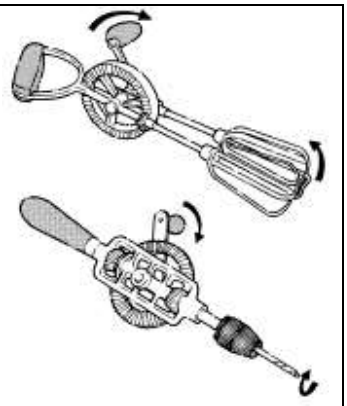
Gears are wheels with teeth. Gears can be used to slow things down or speed things up, change direction and/or control several things at once. Gears are wheels whose perimeter is made up of evenly sized and spaced teeth. The teeth of one gear mesh with those of an adjoining one and transmit rotary motion between the two gear . The driven gear always rotates in an opposite direction to the driving gear. If both gear have the same number of teeth, they will rotate at the same speed, however if they have different numbers of teeth then the gear with fewer teeth will rotate more quickly. A gear system is a combination of two or more gears working together. Two gears connected together turn in opposite directions; the gear upon which the effort force is being applied is the DRIVER gear and the other gear is the FOLLOWER (driven gear). By placing a gear (IDLER) between the driver and the follower gear, you can make the driver and follower gear turn in the same direction. The smaller driver gear connected to a larger follower gear, results in slower speed, but greater force in the follower gear (gearing down). A larger driver gear, connected to a smaller follower gear results in faster speed, but less force in the follower gear (gearing up). There are different types of gears: spur gear, bevel gear, worm gear, rack and pinion.

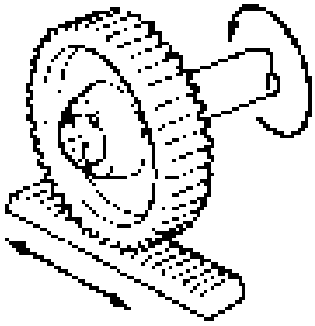
Types of gears

	**Spur gears** Multiple gears can be connected together to form a gear train. If there are an odd number of gears, the output rotation will be the same direction as the input. If there is an even number, the output will rotate in the opposite direction to the input. In a simple type of gear train, the number of teeth on the intermediate gears does not affect the overall velocity ratio, which is governed purely by the number of teeth on the first and last cog.	



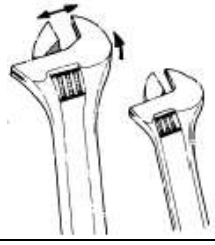
Bevel gears
Bevel gears are used to change rotational movement through an angle of 90°. Bevel gears will provide some mechanical advantage or increase in velocity ratio.

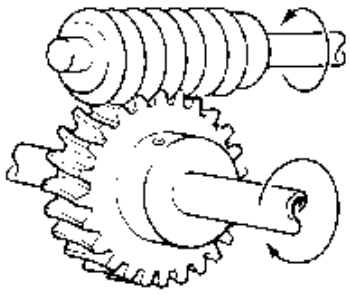




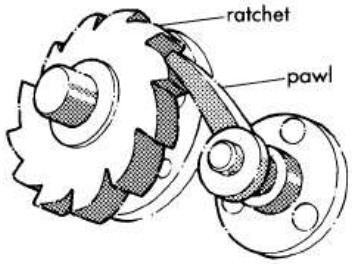
Rack-and-spur gears
The rack-and-spur gear is used to convert between rotary and linear motion. Often the spur rotates in a fixed position and the rack is free to move. Alternatively, the rack may be fixed and the spur rotates moving up and down the rack. This latter arrangement on two-handled cork-pullers.

Rack-and-worm gears
The rack-and-worm gear changes rotational movement into linear movement. In a shifting spanner, the rack-and-worm system is used to adjust the position of the jaw of the spanner—to make the gap wider or narrower. The worm is turned to adjust the position of the spanner. So for each revolution of the worm, the rack advances the distance between two consecutive teeth on the rack.





Worm-and-spur gears
A worm-and-spur gear is often used when a large speed reduction is required and not much power is needed. Unlike ordinary gears, the motion is not reversible, a worm can drive a gear to reduce speed but a gear cannot drive a worm to increase it. The velocity ratio of two adjacent cogs can be calculated by dividing the number of teeth on the driven gear by the number of teeth on the driving gear. The velocity ratio of a worm-and-spur gears is easily calculated because the worm has only one tooth. The worm gear is always the drive gear. For example, if the wheel gear has 60 teeth and the worm gear has 1 tooth, then the velocity ratio is 1/60 = 1:60



Pawl and ratchet
A ratchet mechanism is based on a wheel that has teeth cut out of it and a pawl that follows as the wheel turns. Studying the diagram you will see that as the ratchet wheel turns and the pawl falls into the 'dip' between the teeth. Ratchets can also be used to drive a motion in one direction and allow free-wheeling in the reverse direction.

Mechanical Control systems

Cam-cleat

Rachet and pawl

One-way valves

Calculating mechanical advantage

Gearing up and down

When the driver gear is small and the driven gear is big, the big gear rotates slower—this is called gearing down because the output is slower than the input.
If the driver gear is big and the driven gear is small, the smaller gear rotates faster—this is called gearing up because the output is faster than the input.

Understanding the mechanical advantage in gears

In Maths we have learnt that the circumference of a circle is proportional to the diameter of the circle. Another fact is that the teeth on any set of gear wheels, that mesh together, are all exactly the same size. If we put these two facts together, we can say that the number of teeth on any individual gear wheel (in a set of meshing gear wheels) is proportional to its diameter.

Formula:

$$\text{Mechanical Advantage} = \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}} \quad \textbf{OR} \quad \frac{\text{diameter of driven gear}}{\text{diameter of driver gear}}$$

Activities:

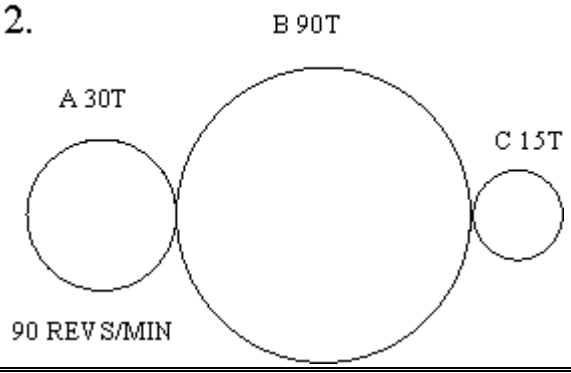
Use either formula to calculate the missing values.

	Gear pair 1	**Gear pair 2**	**Gear pair 3**
Diameter of driver gear (mm)	250		22
Diameter of driven gear (mm)		180	88
Teeth on driver gear	25		11
Teeth on driven gear		60	
Mechanical advantage	3	5	

The gears in the table below can all mesh. Determine the missing values.

	Gear 1	**Gear 2**	**Gear 3**	**Gear 4**	**Gear 5**
Diameter of gear wheel (mm)	250	125		500	62,5
Teeth on gear wheel	40		60		

2.



Gear A revolves at 90revs/min. What is the output and direction at Gear C.

GEAR A	GEAR B	GEAR C
30 TEETH	90 TEETH	15 TEETH

First work out the speed at Gear B.

$$\frac{90\ B}{30\ A} = 3$$

$$\frac{90\ REVS}{3} = 30 REVS\ AT\ B$$

(Remember B is larger than A therefore, B outputs less revs/min and is slower).

Next, take B and C. C is smaller, therefore, revs/minute will increase and rotation will be faster.

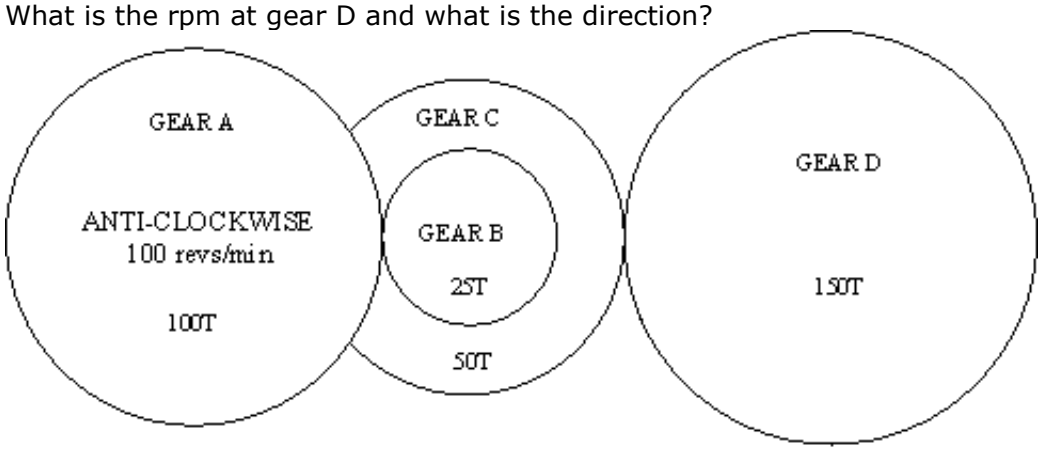
$$\frac{90\ B}{15\ C} = 6$$

$$30\ REVS \times 6 = 180\ REVS\ AT\ C$$

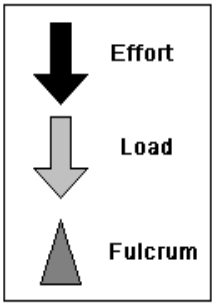
What direction does C revolve ?
A is clockwise, B consequently is anti-clockwise and C is therefore clockwise.

Try the following question:

What is the rpm at gear D and what is the direction?

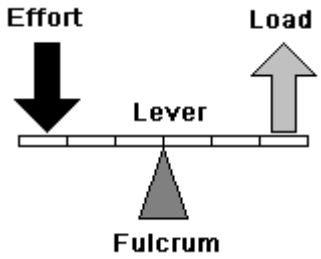


LEVERS



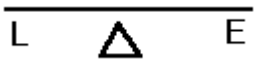
A lever helps you do more work with the strength you already have. A lever is a simple machine. All tools are combinations of the simple machines. Simple machines are things like: a wheel, a screw, an incline, a pulley or a lever. All levers have 3 parts, or 3 things we can find on them. The fulcrum, the load, the effort and of course the lever, itself.

Here's the key to these different kinds of levers:

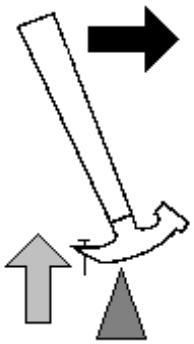


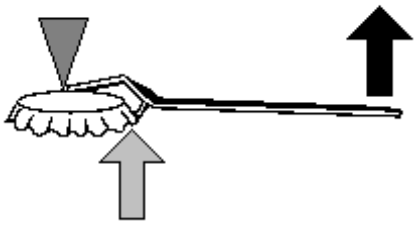
The fulcrum (FULL-krum) is the place a lever rocks back and forth. You could call it a pivot. When it's right in the middle of the lever, the amount of effort you push down equals exactly the amount of load you can lift with the other end.

First Class Lever



Pound a nail almost all the way into some wood. Use your fingers to pull it out. Now try pulling it out with the hammer. It's a lot easier. The claw on a hammer is a lever. We call this kind of lever a first-class lever. It does not mean it's a better lever - just that it's the first kind of lever.



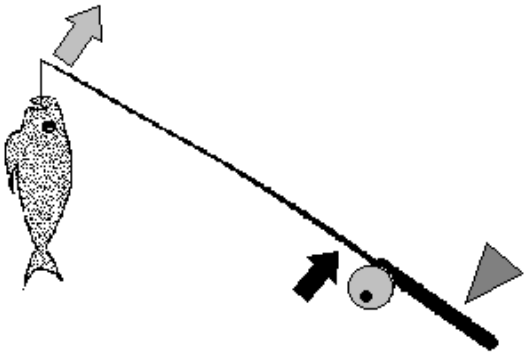


Second Class Lever

Use your first finger and thumb to pop off a metal cap from a soda bottle. Don't twist it off, pry it off. Now try a bottle opener. Much easier, right? A bottle opener is a second-class lever, which means the fulcrum is at the end of the lever and the load is in the middle.

Third Class Lever

A third-class lever has its fulcrum at one end and the load at the other end, with the work you do in the middle. It's how a fishing pole works. You lift just a short distance at the handle, but the end of the pole pops up several feet - hopefully with dinner on the line.

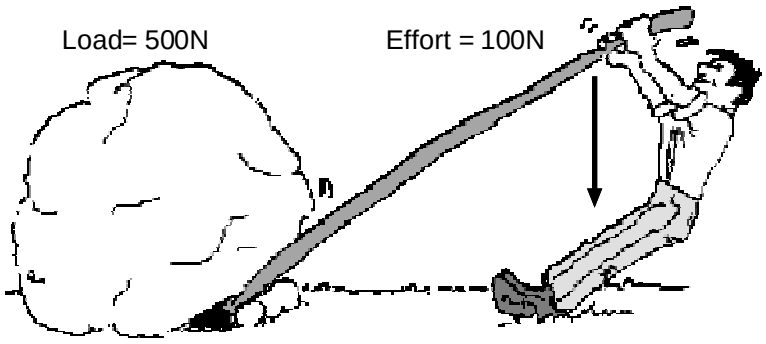


Mechanical Advantage (MA)

$$MA = \frac{\text{Load}}{\text{Effort}}$$

$$MA = \frac{500\ N}{100\ N}$$

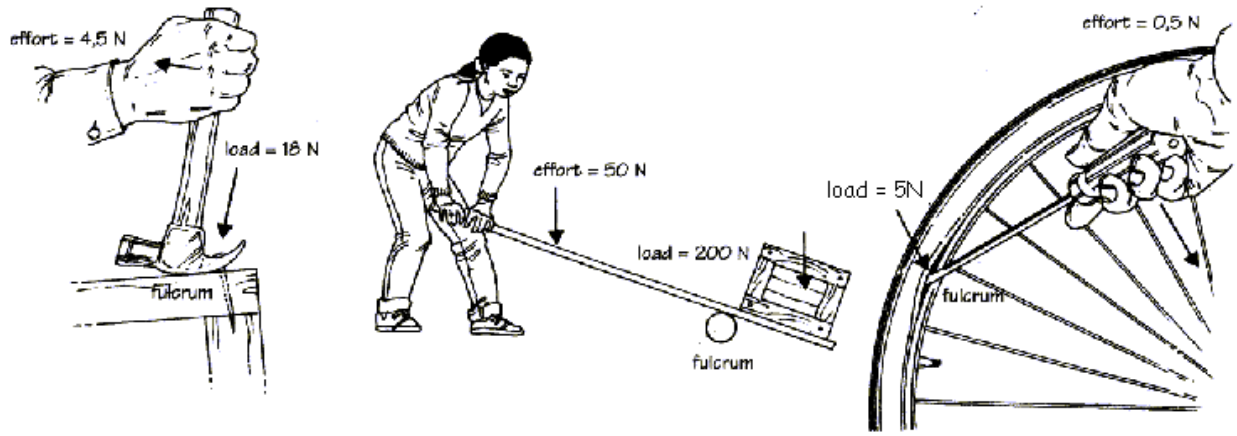
$$= 5$$



The greater the mechanical advantage, the more help the lever gives you.

Activity

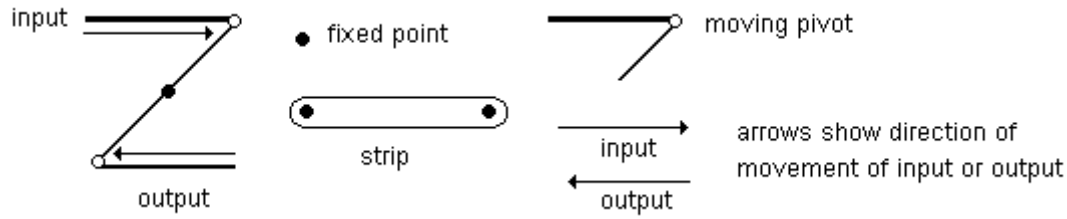
Determine the mechanical advantage of each lever below.



Linking levers

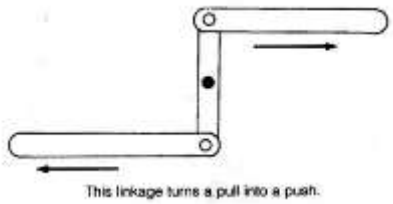
Sometimes a number of different levers are connected together to do certain jobs. A mechanism that is made by connecting levers is called a linkage. A linkage is a system of levers that is used to transmit motion (e.g., nail clippers, back-hoe, and pedal garbage can). The levers in a linkage are connected at fixed pivots or moving pivots. (Remember, a pivot is another word for fulcrum.) A fixed pivot is one which turns around one point. A moving pivot is one which can move away from its original position.
Linkages are often used to change the direction of force or movement: a push can be changed to a pull, or a pushing movement can be changed to a turning movement. Linkages can also change the distance of movement.

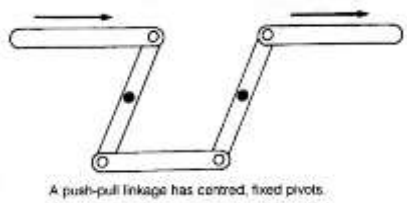
How to draw linkages



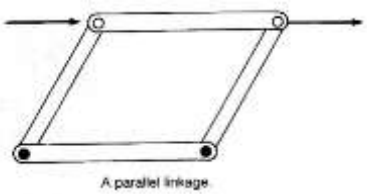
Different kinds of linkages

Reversing linkages, reverse the direction of a force or movement. A **push-pull linkage** is used to get an output movement which is in the same direction as the input movement. This type of linkage connects two rods with two fixed pivots. The linkage makes sure that both levers move at the same time in the same direction.

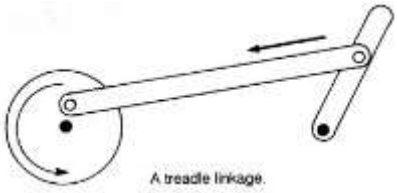

This linkage turns a pull into a push.


A push-pull linkage has centred, fixed pivots.

Linkages can also be used to make objects move together in a line at a fixed distance apart, or to make objects stay parallel to each other.

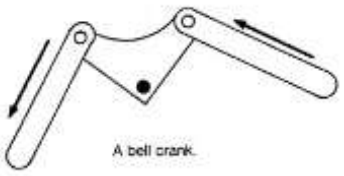

A parallel linkage.

Parallel linkages are used in things such as a tool box. Parallel linkages can also be used to copy or repeat movement, for example folding security doors.

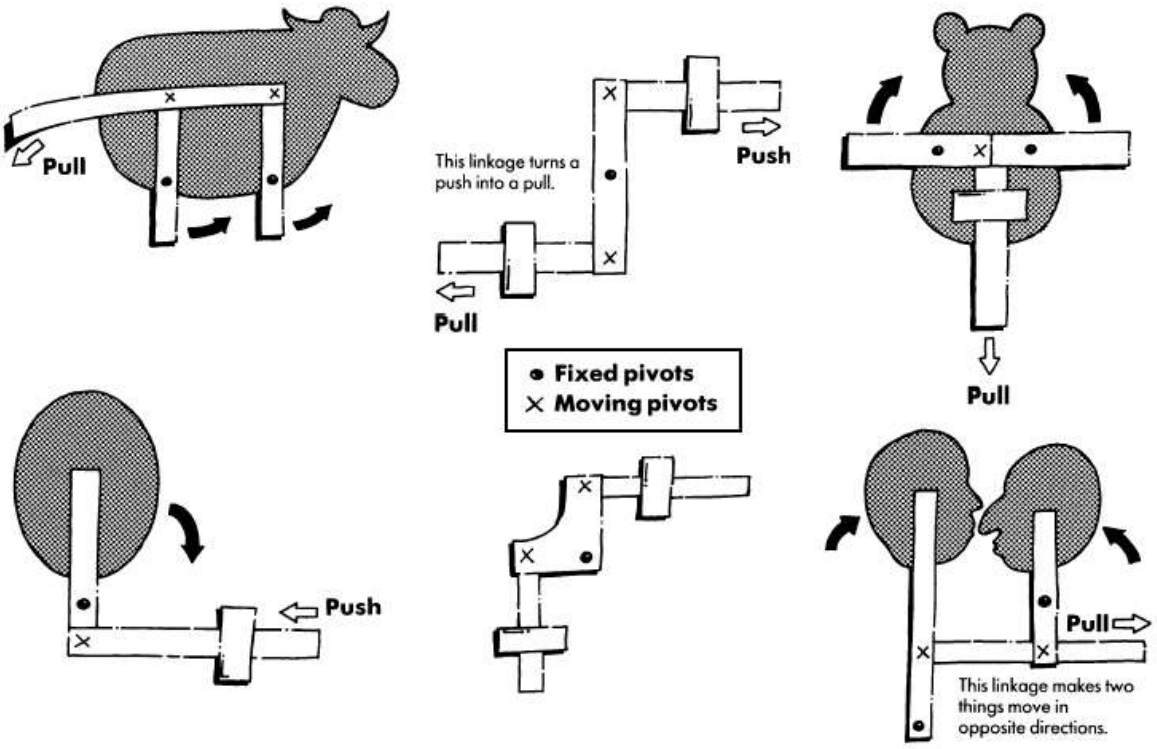


Some linkages changes rotary movement into a to-and-fro movement. Treadle linkages can also change a to-and-fro movement into a rotary movement. Rotary describes something that turns in a circle around a centre point.

Another linkage which rotates around a fixed pivot is a bell crank. A bell crank changes the direction of movement through 90°.

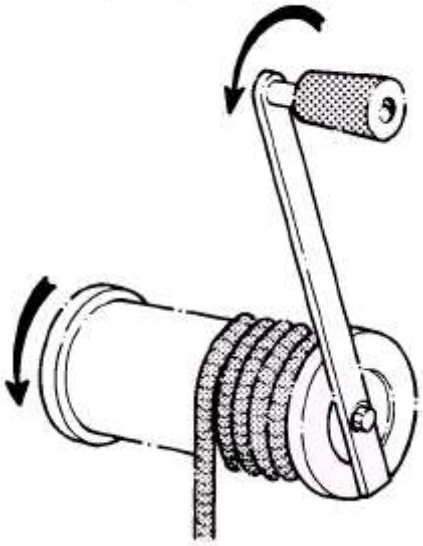


Examples of how linkages can be used to create movement in toys

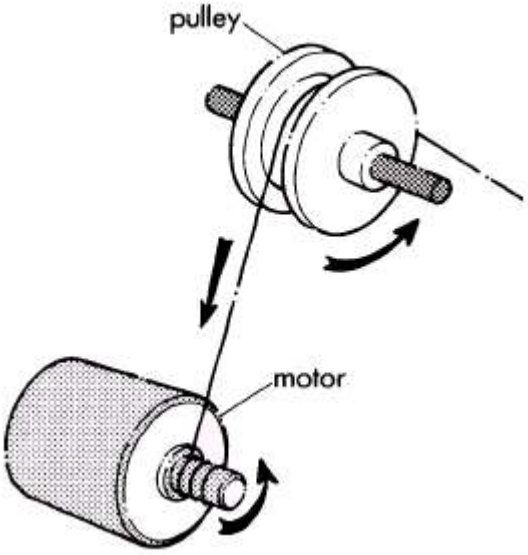


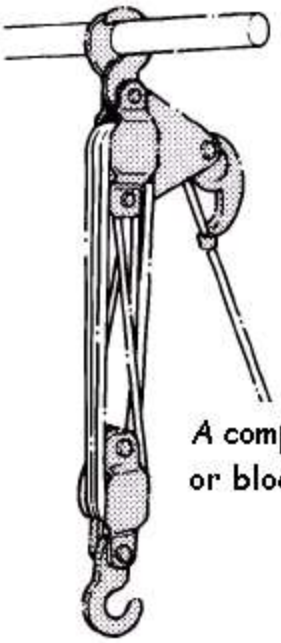
PULLEYS

A pulley with a crank

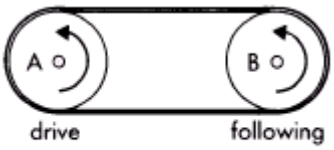


A pulley driven by a motor

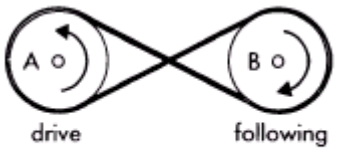




A compound pulley or block and tackle



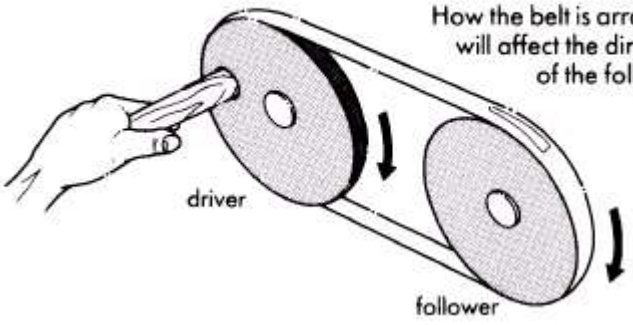
The pulleys rotate in the same direction.

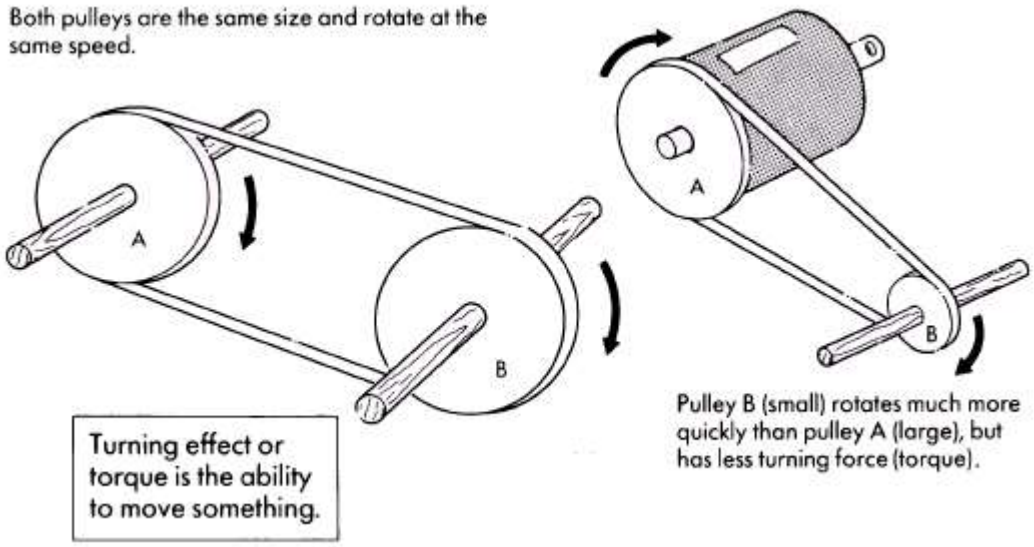


The pulleys rotate in opposite directions.

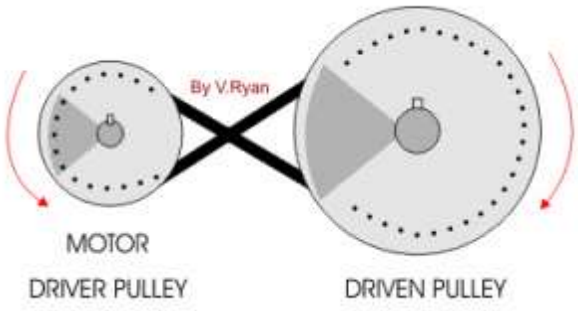
Belt arrangements

How the belt is arranged will affect the direction of the follower.





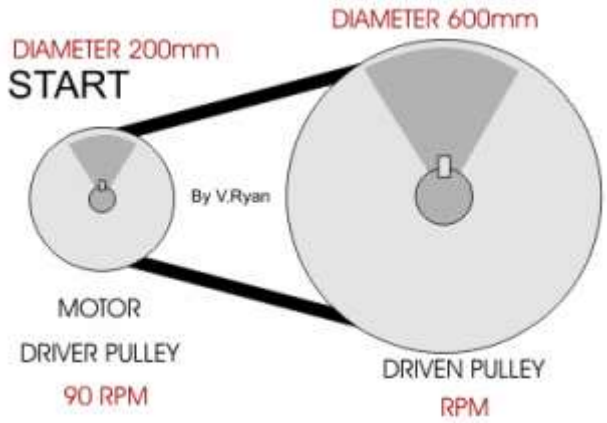
REVERSING ROTATION



Sometimes it is necessary to reverse the rotation of the driven pulley wheel in relation to the driver pulley.

This is achieved by twisting the belt as shown in the diagram to the left. Care must be taken when this is done as the belt can rub where it crosses and this may increase friction or damage it.

VELOCITY RATIO



The diagram opposite shows a small driver pulley pulling round a larger driven pulley. The rpm (revolutions per minute) of the larger driven pulley wheel will be less than the smaller driver pulley wheel. The same principle regarding speed of rotation regarding gears applies to pulley systems as well.

The diameter of the driver pulley wheel is 200mm and the driven pulley wheel is 600mm. This means for every single revolution of the larger driven pulley wheel, the smaller driver pulley wheel rotates three times. This is due to **velocity ratio**. The ratio can be worked out mathematically in different ways. The two most likely methods are shown below

METHOD ONE:

$$\frac{\text{DISTANCE MOVED BY DRIVER PULLEY}}{\text{DISTANCE MOVED BY DRIVEN PULLEY}} = \frac{600}{200} = \frac{600}{200} = 3 \quad \text{OR} \quad 1:3$$

DRIVEN : DRIVER

METHOD TWO:

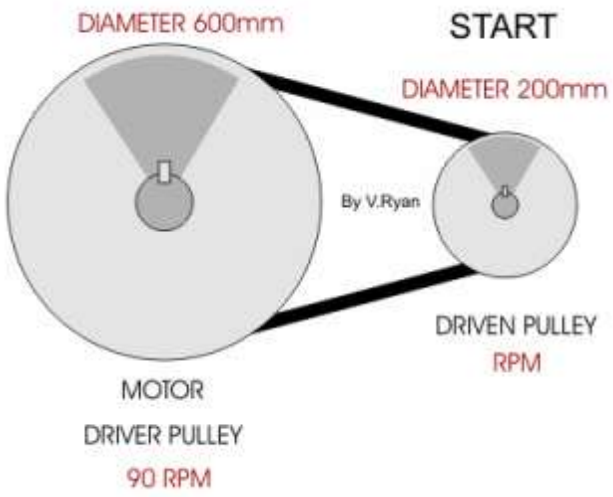
$$\text{VELOCITY RATIO} = \frac{\text{DISTANCE MOVED BY DRIVER PULLEY}}{\text{DISTANCE MOVED BY DRIVEN PULLEY}}$$

$$= \frac{\text{DRIVER PULLEY MOVES 2 REVOLUTIONS}}{\text{DRIVEN PULLEY MOVES 1 REVOLUTIONS}} = \frac{3}{1} \quad \text{OR} \quad 1:3$$

DRIVEN : DRIVER

This means that the larger pulley wheel (the driven pulley wheel) revolves a third of the rpm compared to the smaller driver pulley wheel. In effect the driven pulley wheel is slower and revolves a third as many times as the driver. This means that, if the rpm of the driver pulley wheel is divided by 3, the output rpm of the driven pulley wheel will be found.

$$\text{VELOCITY / SPEED OF ROTATION OF DRIVEN PULLEY WHEEL} = \frac{\text{RPM OF DRIVER PULLEY}}{3} = \frac{90 \text{ rpm}}{3} = 30 \text{ rpm at Driven pulley wheel}$$



In this example the driver pulley wheel is the largest of the two. Because it is the largest it will automatically be the slowest and output less rpm's than the smaller driven pulley wheel.
The diameter of the driver pulley wheel is 600mm and the driven pulley wheel is 200mm. This means for every single revolution of the larger driver pulley wheel, the smaller driven pulley wheel rotates three times. This due to velocity ratio. The ratio can be worked out mathematically in different ways. The two most likely methods are shown below. Please note, the driven pulley wheel is placed on top of the equation, as it is the larger number.

METHOD ONE:

$$\frac{\text{DISTANCE MOVED BY DRIVEN PULLEY}}{\text{DISTANCE MOVED BY DRIVER PULLEY}} = \frac{600}{200} = \frac{600}{200} = 3 \quad \text{OR} \quad 1:3$$

DRIVER : DRIVEN

METHOD TWO:

$$\text{VELOCITY RATIO} = \frac{\text{DISTANCE MOVED BY DRIVEN PULLEY}}{\text{DISTANCE MOVED BY DRIVER PULLEY}}$$

$$= \frac{\text{DRIVEN PULLEY MOVES 3 REVOLUTIONS}}{\text{DRIVER PULLEY MOVES 1 REVOLUTIONS}} = \frac{3}{1} \quad \text{OR} \quad 1:3$$

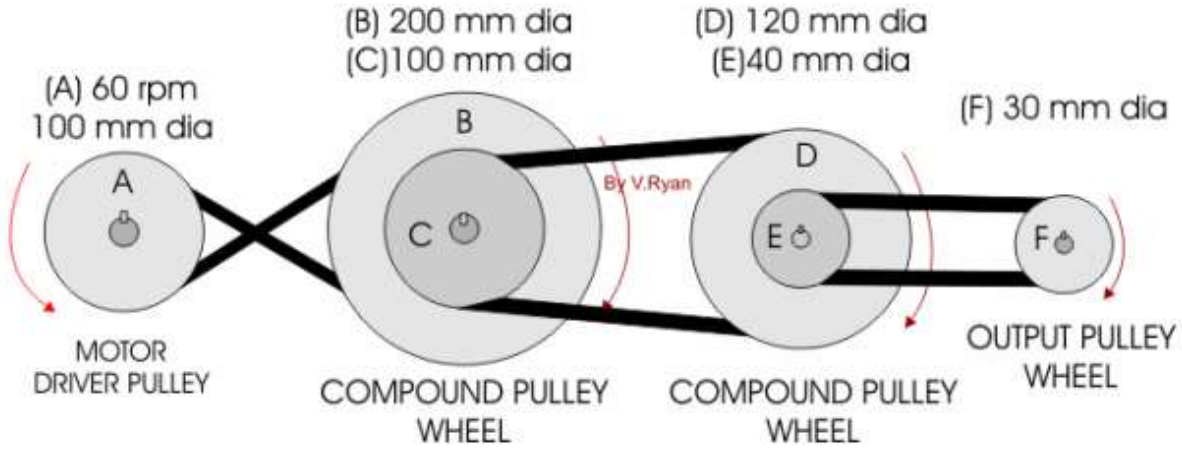
DRIVER : DRIVEN

This means that the larger pulley wheel (the driver pulley wheel) revolves a third of the rpm compared to the smaller driven pulley wheel. In effect the driver pulley wheel is slower and revolves a third as many times as the driven. This means that, if the rpm of the driver pulley wheel is MULTIPLIED by 3, the output rpm of the driven pulley wheel will be found.

$$\text{VELOCITY / SPEED OF ROTATION OF DRIVEN PULLEY WHEEL} = \text{RPM OF DRIVER PULLEY X 3} = 90 \text{ rpm X 3}$$

$$= 270 \text{ rpm at Driven pulley wheel}$$

PULLEY QUESTION

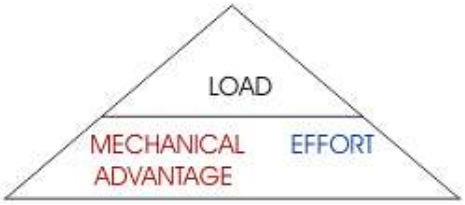


1. A system of four pulley wheels are set up as shown in the diagram above. The driver pulley rotates in an anti-clockwise direction. In what direction does the output pulley wheel revolve ?
2. If pulley 'A' (driver) rotates at 60 rpm what is the output rpm at 'F'.

To answer the question split the pulleys into pairs and work out the velocity ration of each pair. Treat the pairs of pulleys as separate questions. Use the diameters when dividing and place the largest number on the top of the division.

EASY FORMULAS

MECHANICAL ADVANTAGE

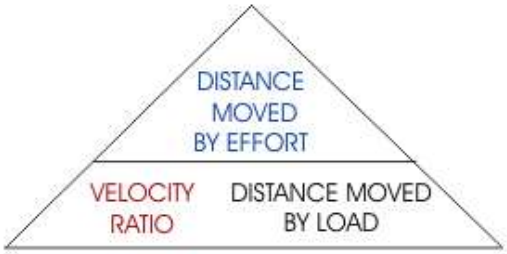


$$\text{MECHANICAL ADVANTAGE} = \frac{\text{LOAD}}{\text{EFFORT}}$$

$$\text{LOAD} = \text{MECHANICAL ADVANTAGE} \times \text{EFFORT}$$

$$\text{EFFORT} = \frac{\text{LOAD}}{\text{MECHANICAL ADVANTAGE}}$$

VELOCITY RATIO

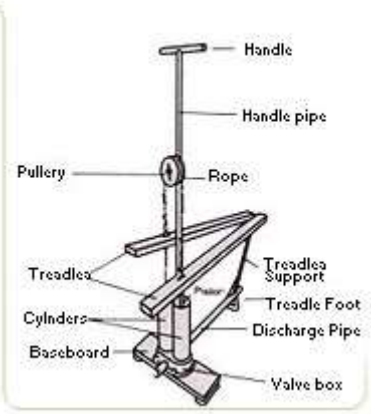


$$\text{DISTANCE MOVED BY LOAD} = \frac{\text{DISTANCE MOVED BY EFFORT}}{\text{VELOCITY RATIO}}$$

$$\text{VELOCITY RATIO} = \frac{\text{DISTANCE MOVED BY EFFORT}}{\text{DISTANCE MOVED BY LOAD}}$$

$$\text{DISTANCE MOVED BY EFFORT} = \text{DISTANCE MOVED BY LOAD} \times \text{VELOCITY RATIO}$$

Treadle pump



http://www.aovinternational.com/treadle-pump.html

also see: http://www.skipumps.com/treadle.htm
http://www.skipumps.com/malawipump.htm

foot-operated suction pump
Fully Hot Dip Galvanized Steel Body, piston cups/seals of nitrile rubber, treadles and baseboard of good quality painted wood.
High capacity pumping with 2 cylinders for continuous flow of water from ground level to depths upto 7 meters.
Capable of pumping from 5000 litres of water per hour.

The device, a treadle pump, is foot-operated, and ideal for farmers who cannot afford to run a diesel pump.

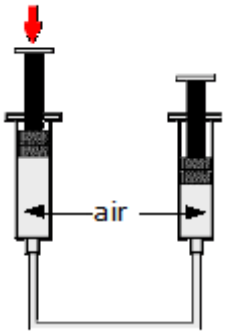
It gives them access to groundwater for irrigation, and the prospect of higher yields.

HYDRAULICS AND PNEUMATICS

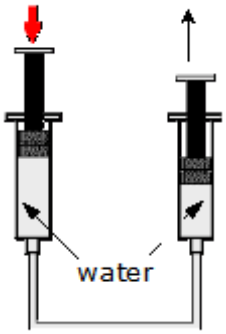
Hydraulics and pneumatic systems basically work in the same way. The only difference is that hydraulic systems use an incompressible liquid to operate, while pneumatic systems use compressed or 'squashed' air to operate.

How do these two systems really work?

In a **pneumatic system** the second syringe will stay in place to a certain extent when the first syringe is pushed down because air is compressible.



In a **hydraulic system** the second syringe will move upwards, when the first syringe is pushed down, even though it is held down because liquid can not be compressed.

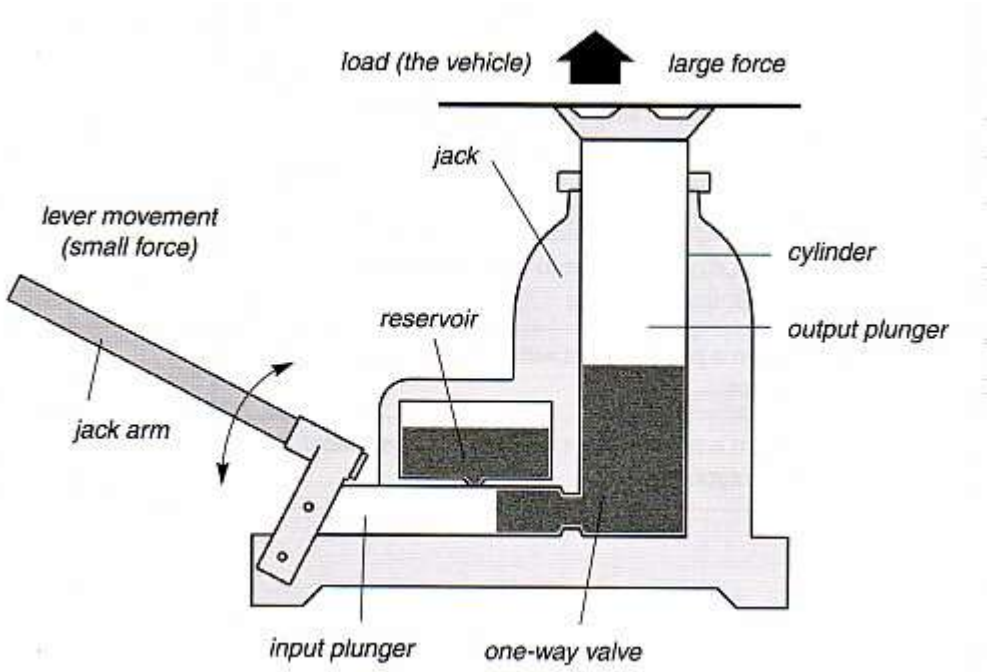


Hydraulic systems

Open and closed hydraulic systems

Hydraulics is about the flow of liquids in pipes and channels, and the pressure the liquids exerts. In an open hydraulic system, a fluid flows from one point to another if there is a difference in pressure. In a closed hydraulic system the fluid does not leave the container it is in. The pressure of the fluid in the container does the work.

Hydraulic jack

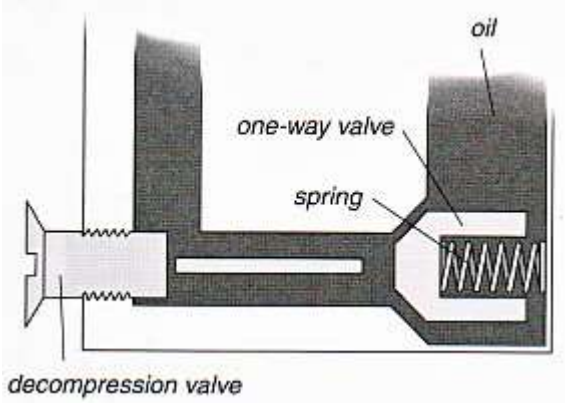


A hydraulic **jack** has to be pumped to raise a car. As the handle moves up and down, the input piston pumps oil from the reservoir through a one-way valve into the main cylinder. Each movement of the handle pumps only a small amount of oil and raises the car only a small distance at a time. To lower the vehicle the one-way valve is released, and the vehicle's weight forces the oil back into the reservoir.

Valves

Valves are used in many appliances. A valve is a component that allows things to pass through selectively.

A one-way valve is used in the hydraulic jack. This means that oil can be forced in one direction by the valve, but the design of the valve prevents the oil from flowing back through it. The oil can only flow back if the valve is opened. Such a decompression valve allows the pressure to lessen controlled by hand.

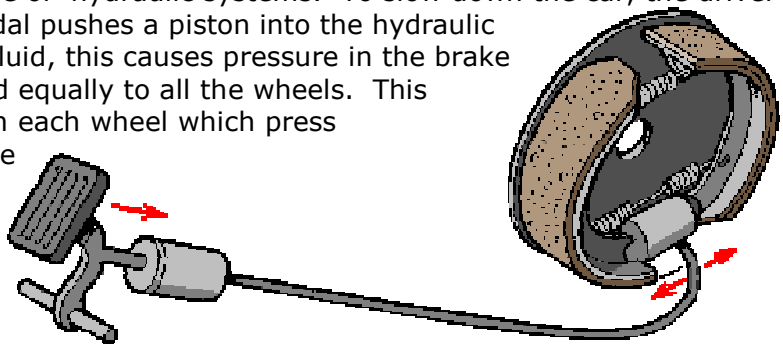


decompression valve

In the illustration the one-way valve can be pushed to the right when the oil from the cylinder on the left is forced into the cylinder on the right. When oil is not pumped through from the left, the spring forces the valve back to the left and thus prevents any oil from flowing back into the cylinder on the left.

To allow the oil to flow into the cylinder on the left again, the decompression valve is turned. When the screw valve is turned, it pushes the one-way valve to the right and then the oil flows back.

Brakes on many vehicles make use of hydraulic systems. To slow down the car, the driver steps on the brake pedal. This pedal pushes a piston into the hydraulic system, which is filled with brake fluid, this causes pressure in the brake fluid. The force is then transmitted equally to all the wheels. This exerts a force on the brake pads in each wheel which press against the rotating disc inside the car's wheels. The wheel slows down and the car eventually stops.

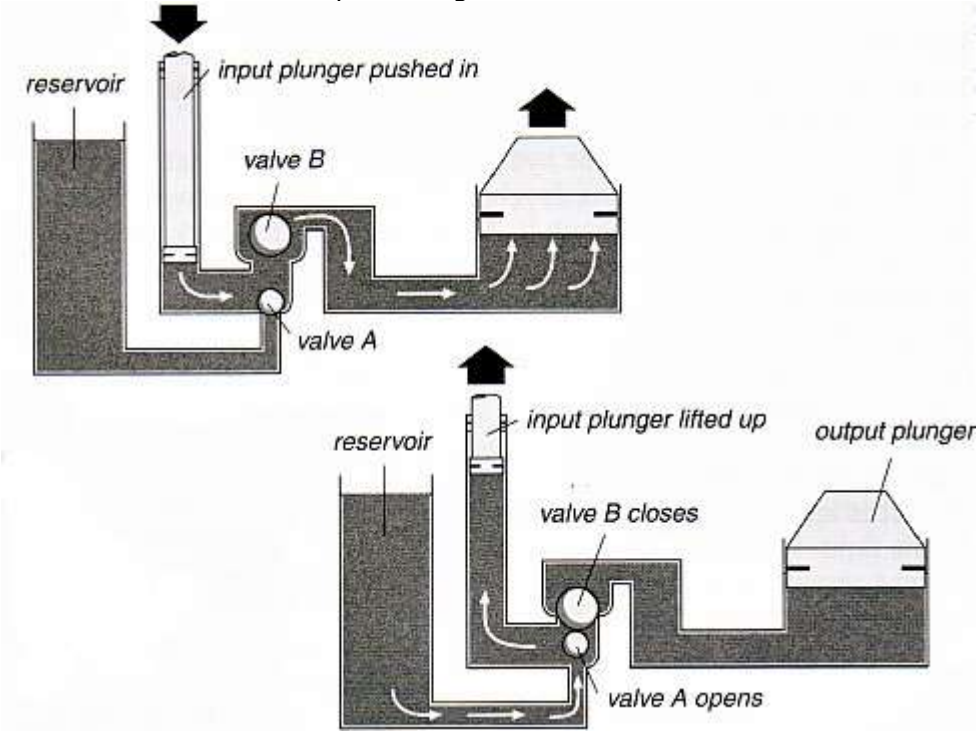


Principles of hydraulics

Hydraulics is based on the principle that a force is transmitted through a liquid. This means that if a liquid, such as water or oil, is in a cylinder or tube, a force applied to the liquid at one end will be passed through the liquid. The force will then be exerted by the liquid at the other end. This happens because a liquid cannot be compressed.
If the area of the disc of the output piston or pistons is the same size as the area of the input piston, then the output force is equal to the input force. But if the area of the output pistons is larger (say three times larger) than the input piston, then the output force is also larger (in this case three times larger). If the area of the output piston is half of the area of the input piston, then the output force is half of the input force.

Use of a reservoir to make a plunger move further

A reservoir is a storage tank for fluids. It can be as small as the brake fluid reservoir of a car or as large as a storage dam for a city.
To move heavy objects it is necessary to transform a small input force into a big output force. However, this means that only a small output distance is achieved. How can we design a hydraulic system so that we can obtain greater output distances?
Many hydraulic systems use a reservoir for the oil. The oil which the output plunger must press out is kept in a separate part or reservoir, and only released when necessary. The reservoir and two one-way valves enable a number of input strokes of the pump to cause a series of output distances, which have to be added up. This is illustrated in the following two illustrations. When the small plunger (input) is pushed in, valve A is pushed closed and valve B is pushed open. Liquid flows into the big cylinder and lifts up the output plunger. When the small plunger stops at the end of its downward stroke, valve B closes as a result of the liquid being forced back.



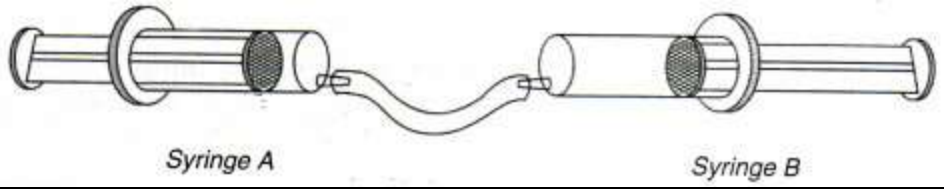
Practical test

You need
Two plastic syringes of the same size (without needles);
a piece of plastic tube that fits tightly over the end of each syringe; water.

You do
1. Connect the two syringes with the plastic tube as shown in the illustration.
2. Fill the system with water by holding it under water. Make sure there is no air in the system! Press one plunger down while the other plunger is completely out. As soon as the plunger is pressed in, press the other plunger in.
3. Remove from the water. Slowly apply force to the one plunger by pressing it in.

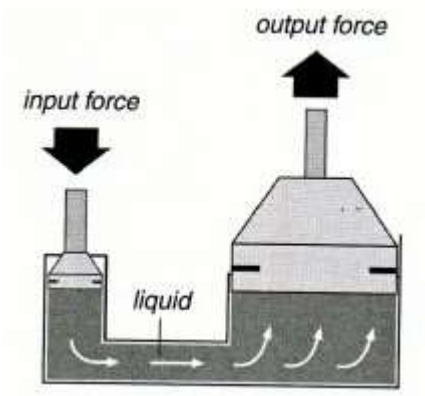
The syringe to which the force is applied is called the input syringe while the other syringe is called the output syringe.

- What happened?
- What distance in mm was the input syringe pressed?
- What distance in millimeters did the output syringe move?
- Do you think the force with which the input syringe was pressed was the same size as the force that the output syringe experienced?



Syringes of different sizes

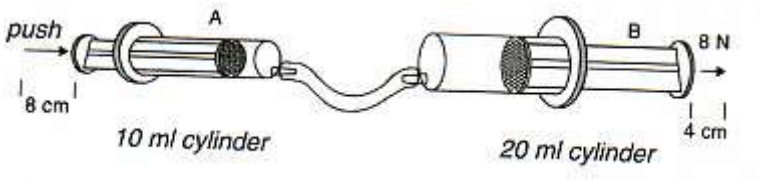
You saw that the force applied to one plunger is transferred by the liquid to push out the other plunger. Hydraulics is based on the principle that a force is transferred by a liquid. This means that if a liquid such as water or oil is in a cylinder or tube, a force applied to the liquid at one end moves through the liquid. The force will be then applied by the liquid at the other end. This happens because the liquid cannot be compressed. The figure illustrates this principle. A force applied to the liquid, is transferred by the liquid. All hydraulic systems work according to this principle.



Further test

You will now repeat the previous practical test, but with a small syringe at A and a bigger syringe at B. Use a 10 ml syringe and a 20 ml syringe.

1. Again determine the length that syringe A is pressed in.
2. Also determine the length syringe B moved.
3. What is the ratio between the distance the output syringe and the input syringe moved?



Conclusion
When a small cylinder has half the volume of water of the bigger cylinder, the bigger cylinder will move only half of the distance of the smaller syringe, but the force will be twice as much.

Two output syringes vs. one input syringe

What will be the effect if two output syringes of the same size were connected to one input syringe of the same size, as in the figure?
With what can the two output syringes be replaced in order to obtain the same effect as in 1?

Do the following experiment to see whether you were right.

1. Connect a 20 ml cylinder to two 10 ml cylinders, as in the illustration.
2. Determine the distance each cylinder moved.
3. The 20 ml cylinder moved _____mm and the 10 ml cylinder moved _____mm.
4. The ratio between the two distances is _____.

Conclusion
There is a connection between the distance the input cylinder moved and the distance the output cylinder moved.

What can be concluded from previous activities?

Did you know?

It is not only the size of the syringe that is important; it is the surface of the plunger disc that determines the output force in relation to the input force.

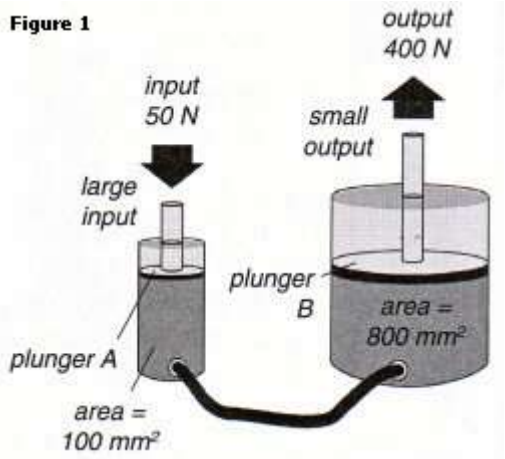
The unit in which force is measured is Newton (N). A force of 10 N is necessary to lift a mass of 1 kg.

If the surface of the disc of the output plunger or plungers is the same as the surface of the input plunger the output force is equal to the input force.
If more than one output plunger is used, the total joint surface of the output plunger is important. When the surface of the output plunger is greater than that of the input plunger, (say three times greater), the output force is also greater (in this case, three times greater). If the disc surface of the output force is half the disc surface of the input plunger, the output force is also half of the input force.
The output force can therefore be raised or lowered by using cylinders of various sizes (in other words, cylinders of which the surface of the plungers differ). Forces can be amplified by using cylinders of which the surfaces differ.
What would the effect be if a small hole in the tube were to cause the liquid to leak out of the system?

Compare forces in a hydraulic system

The simple hydraulic system in the following illustration is filled with oil. When force is applied to plunger A, the force is transferred through the oil. Oil is forced down the connecting pipe from cylinder A to cylinder B. The surface of plunger B is eight times greater than the surface of plunger A. Therefore the force of plunger B is also eight times greater than the force applied to plunger A.

Figure 1



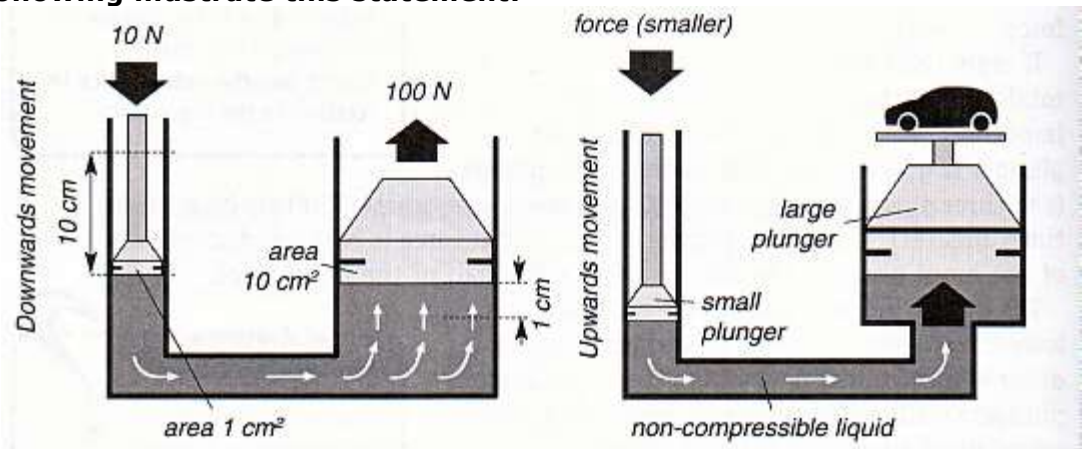
If the input force at plunger A is 50 N, the output force at plunger B is 50 x 8 = 400 N. The force in a hydraulic system is increased or diminished in the same proportion as the surfaces of the plungers or cylinders.

Questions:

Relationships in hydraulic systems

1. What is the relationship between the distances moved by the output and input plungers in this system?
2. If the force of 50 N presses plunger A down 200 cm, how far is plunger B pressed up?

The following illustrate this statement:



Mechanical advantage of a hydraulic system

The mechanical advantage of the system in Figure 1 can be calculated using the following formula:

$$MA = \frac{load}{effort} = \frac{400N}{50N} = 8$$

Of course, you do not get anything for nothing! As the output force is greater than the input force, the output distance moved by the piston is less than the input distance. If the mechanical advantage gained is eight, then piston A must move eight times further than the output distance moved by piston B. This is illustrated in Figure 8 and Figure 9.

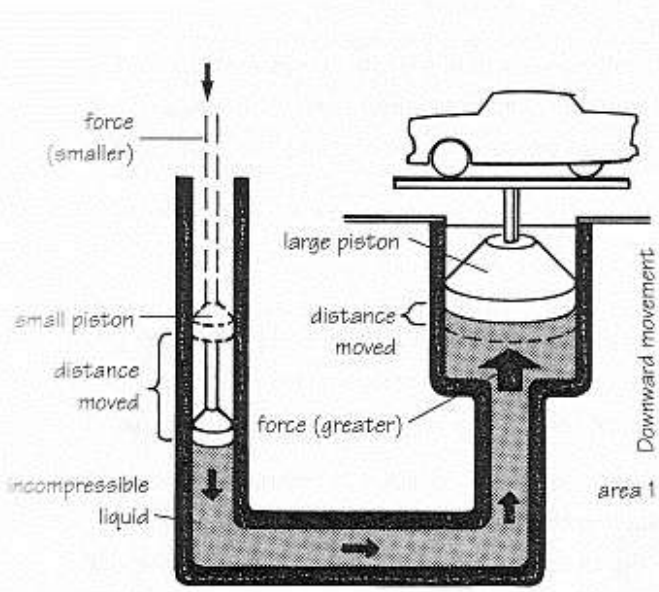


FIGURE 8
Small input force becomes large output force, but a large input distance is needed for a small output distance.

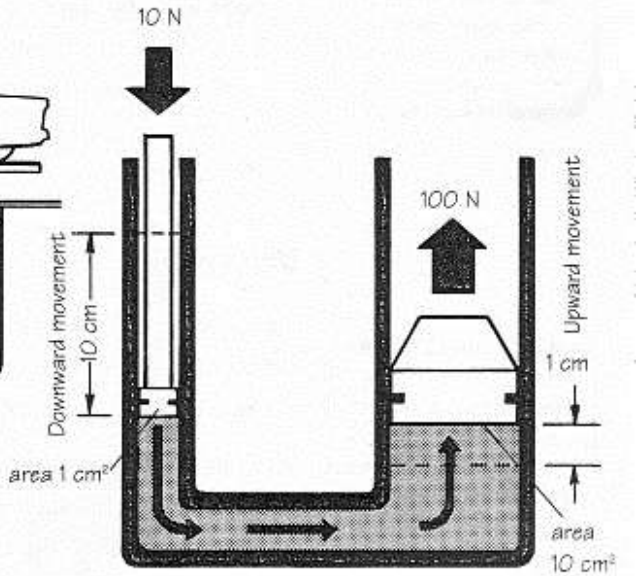


FIGURE 9
A 10 N input force is converted to a 100 N output force, but the input distance of 10 cm only results in an output distance of 1 cm.

Calculating input and output forces and distances

1. A hydraulic lift system has an input piston with an area of 0,5 ml and an output piston with an area of 2 m^2. What force is needed to lift a load of 1 000 N?

2. What distance must the input piston move in the same system to lift the load 100 cm?

3. a. Calculate the output force of a hydraulic system if the input force is 10 N, and the area of the input cylinder is 15 cm^2, while the area of the output cylinder is 45 cm^2.
   b. What is the mechanical advantage of this system?

4. In a particular hydraulic system, the output force is 400N if the input force is 100N. If the output piston moves 20 mm, how far must the input piston be pushed down?

5. You have an appliance that can exert a maximum force of 2 N. You must build a lift mechanism that can lift a load of 6 N for a puppet show. All you have are identical syringes, tubes and connectors. Design a hydraulic system that can solve the problem. Draw a diagram with captions to demonstrate your design. Use captions to indicate how you are going to mount the syringes.

Pneumatic systems

Any machine that uses compressed air to do work is a pneumatic system. Compressed air is air that has been forced into a small space. You compress air every time you pump up a bicycle tyre or blow up a balloon. In industry, air is compressed by machines called compressors.

Uses

Bus doors are opened and closed using a pneumatic system. The piston in the system moves in and out in a straight line, but is connected to a lever system that makes the door swing open and closed. The hissing sound you hear when the doors open and close is the movement of compressed air. **Car hoists** that lift cars in workshops are also operated by pneumatic systems. **Pneumatic wheel spanners** and **jackhammers** are also examples of pneumatic systems.

Components of a pneumatic system:

- A supply of compressed air, usually from a compressor
- Air lines containing the compressed air
- Cylinders with pistons for producing force and movement
- Valves that control the flow of compressed air

Tip:

100 g = 1 Newton

Calculating pressure in a pneumatic system

You can calculate the pressure of a pneumatic system by dividing the maximum weight lifted (in Newton) by the area lifted (in m²). Therefore N / m² = pressure (Pascal (Pa))

$$\textbf{Pressure (Pa)} = \frac{\text{Force (N)}}{\text{Area (m}^2\text{)}}$$

$$\textbf{Area (m}^2\textbf{)} = \frac{\text{Force (N)}}{\text{Pressure (pa)}}$$

$$\textbf{Force (N)} = \text{Pressure (Pa)} \times \text{Area (m}^2\text{)}$$

Using the formula on the previous page, calculating the pressure in a system with a lifting area of 100cm² that can lift a mass of 500 g, would be done like this:

500 g = 5 N (Remember: 100 g = 1 N)

Force = 5 N
Area = 0,01 m²

$$\text{Pressure (Pa)} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Pressure} = \frac{5\ \text{N}}{0{,}01\ \text{m}^2}$$

Pressure = 500 Pa

Activity

1. If the pressure in a pneumatic system is 200 Pa, what size should the lifting area be to lift a weight of 600 g?

2. If a pneumatic system has a lifting area of 300 cm² and can lift a mass of 2000 g, what pressure would have to be exerted?

3. If the base of a lifting machine is 5 m² and the pressure exerted by the system is 200 Pa, calculate the weight the machine could lift.

4. a) If piston A has a surface area of 0,01 m^2 and is pushed down with a force of 100 N, what would the pressure on the be?
   b) If the second piston in the above pneumatic system (piston B) has a surface area of 0,6 m^2, what force will piston B experience?

5. If piston A has an area of 0,03 m^2, and is pushed down with a force of 300 N to place pressure on the system, what would the force on piston B then be, if the surface area of piston B is 0,8 m^2?

ELECTRICITY

Direct Current (DC) Electricity
The movement of electrons through a conductor from a negatively charged area to one that has positive charges is called Direct Current (DC) electricity, because the electricity is traveling directly through the wire from (-) to (+).

Creating DC
Batteries use chemical energy to create the electrical potential.

The electrical circuit
Since DC electricity is the flow of electrons from the negative (-) terminal of a battery or generator, through a conducting material such as a metal wire, to the positive (+) terminal, the electricity goes in a complete circuit from the source and back again. This combination of a source of power and wire—along with light bulbs, motors and such in between—is called an electrical circuit.

Voltage, current and resistance
The electricity moving through a wire or other
conductor consists of its voltage (V), current (I)
and resistance (R). The voltage or potential energy of a source of electricity is measured in Volts. The current or amount of electrons flowing through the wire is measured in Amperes or Amps. The resistance or electrical friction is measured in Ohms.

Electrical voltage
A potential or pressure builds up at one end of the wire, due to an excess of negatively charged electrons. The pressure causes the electrons to move through the wire to the area of positive charge. This potential energy is called Voltage, and its unit of measurement is the Volt.

Electrical current
The number of electrons is called the current and its unit of measurement is the Ampere or Amp.

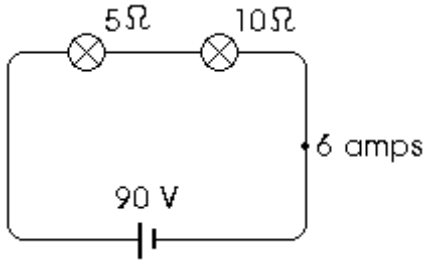
Resistance
An Ohm is the unit of measurement of the electrical resistance. A conductor like a piece of metal has its atoms so arranged that electrons can readily pass around the atoms with little friction or resistance.
In a nonconductor or poor conductor, the atoms are so arranged as to greatly resist or impede the travel of the electrons. This resistance is similar to the friction of the hose against the water moving through it.

Ohm's Law
The relationship between the the voltage (V), current (I) and resistance (R) is:
V = I x R.
This is known as Ohm's Law. From this law, if you know two of the electrical values, you can determine the third.
For example, if a car battery has a potential of 12 volts and it goes through a bulb of 6 ohms, how much current is flowing though the circuit? Since V=I x R, and V = 12 volts and R = 6 ohms, then I = 12/6 = 2 amps.

Resistance can cause heat and light
Electrical resistance is essentially friction within the wire. Just as friction can get something hot, so can the electrical resistance result in the wire getting warm or even hot enough to glow. The amount of heat is proportional to the diameter of the wire, its material and thus resistance, and the current. The thinner the wire, the more electrical resistance. This is because it is more difficult for the electrons to pass through the wire. It is like there is more "friction" in the wire. That is why a thin wire is used in an electric light bulb: it has more resistance and thus gets hotter faster.

Series circuit

In an electrical circuit, several electrical devices such as light bulbs can be placed in a line or in series in the circuit between the positive and negative poles of the battery. This is called a series circuit. One problem with such an arrangement is if one light bulb burns out, then it acts like a switch and turns off the whole circuit.



Applying Ohm's Law to a series circuit

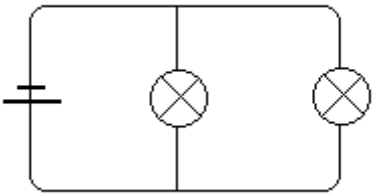
An extension of Ohm's Law is that the total resistance of a series circuit is the sum of the resistances. Thus, in this circuit, the total resistance is:

5 ohms + 10 ohms = 15 ohms of resistance.

Let us check to see if Ohm's Law is correct. Since the voltage V = 90 volts, the current I = 6 amps, R = 15 ohms, and 90 = 6 x 15.

Parallel circuit

A better arrangement to solve this problem is to place the bulbs in a parallel circuit, such that if any bulbs go out, the circuit is still intact.



Not only is a parallel circuit useful for Christmas lights, the electrical wiring in homes is in parallel. In this way lights and appliances can be turned on and off at will. Otherwise if you turned one light off -- or one burned out -- all the other lights in the house would go off too. If either light bulb would go out, the other would still shine. You could add other bulbs or even appliances such as electric motors in parallel to this circuit, and they would remain independent of each other.

You could also replace a bulb with a series circuit of bulbs or add bulbs or devices in series between parallel items. There are many combinations possible.

What would happen if you added a light bulb in series between bulb r1 and r2 and then that bulb burned out?

The three most basic units in electricity are voltage (**V**), current (**I**) and resistance (**r**). Voltage is measured in **volts**, current is measured in **amps** and resistance is measured in **ohms**. There is a basic equation in electrical engineering that states how the three terms relate. It says that the current is equal to the voltage divided by the resistance.

I = V ÷ r

Increasing the voltage will make more current flow. Decreasing the resistance in an electrical system, increases the current flow.

Electrical power is measured in **watts**. In an electrical system power (**P**) is equal to the voltage multiplied by the current.

P = V x I

In an electrical system, increasing either the current or the voltage will result in higher power. Let's say you have a system with a 6-volt light bulb hooked up to a 6-volt battery. The power output of the light bulb is 100 watts. Using the equation above, we can calculate how much current in amps would be required to get 100 watts out of this 6-volt bulb.

You know that **P** = 100 W, and **V** = 6 V. So you can rearrange the equation to solve for **I** and substitute in the numbers.

I = P ÷ V
= 100 W ÷ 6 V
= 16.66 amps

What would happen if you use a 12-volt battery and a 12-volt light bulb to get 100 watts of power?

100 W ÷ 12 V = 8.33 amps

So this system produces the same power, but with half the current. There is an advantage that comes from using less current to make the same amount of power. The resistance in electrical wires consumes power, and the power consumed increases as the current going through the wires increases. You can see how this happens by doing a little rearranging of the two equations. What you need is an equation for power in terms of resistance and current. Let's rearrange the first equation:

I = V ÷ R can be restated as V = I x R

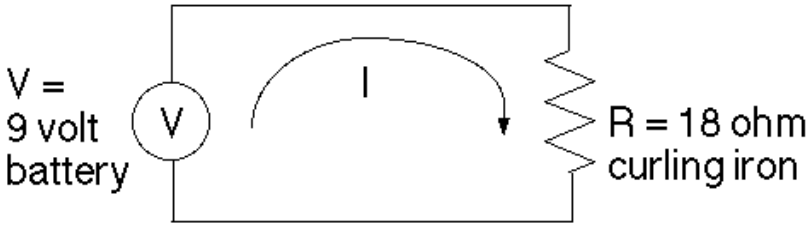
Now you can substitute the equation for V into the other equation:

P = V x I substituting for V we get P = I x R x I, or P = I^2R

What this equation tells you is that the power consumed by the wires increases if the resistance of the wires increases (for instance, if the wires get smaller or are made of a less conductive material). But it increases dramatically if the current going through the wires increases. So using a higher voltage to reduce the current can make electrical systems more efficient.

Example Problem:

A nine volt battery supplies power to a cordless curling iron with a resistance of 18 ohms. How much current is flowing through the curling iron?



Solution:

$$V = I \times R$$

Since V(Voltage) and R(Resistance) are known, solve for I(Current) by dividing both sides of the equation by R.

$$\frac{V}{R} = \frac{I \times R}{R}$$

The R's on the right hand side of the equation cancel.

$$\frac{V}{R} = \frac{I \times \cancel{R}}{\cancel{R}}$$

I is then left in terms of V and R.

$$I = \frac{V}{R}$$

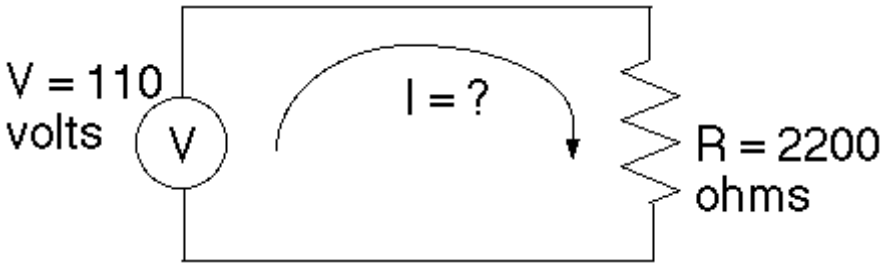
Substitute in the values for V(Voltage) and R(Resistance).

$$I = \frac{9}{18}$$

Solution for I(Current).

$$I = 0.5 \text{ Amps}$$

Problem 1
A 110 volt wall outlet supplies power to a strobe light with a resistance of 2200 ohms. How much current is flowing through the strobe light?



Problem 2
A CD player with a resistance of 40 ohms has a current of 0.1 amps flowing through it. Sketch the circuit diagram and calculate how many volts supply the CD player?

Resistors

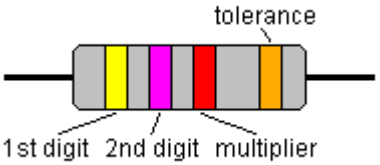
Components used to control the size of the current that flows in an electronic or electric circuit are called resistors. The size of the current that flows depends on several factors, including a property of the component called its resistance. The greater the resistance, the smaller the current. These components will restrict the flow of electricity. The unit of resistance is the OHM; it has the Greek letter omega (Ω) to represent it. They are cheap and easy to use.

Fixed-value resistors are described in terms of their resistance (measured in ohms), their tolerance and their power rating (measured in watts). As a larger current passes through a resistor, the resistor heats up: the power rating describes the maximum power that may be dissipated in the form of heat before the resistor is damaged. A fixed-value resistor has a series of coloured bands around its body, which signifies the resistor's value and tolerance.

Resistor Colour Code

The resistor colour code is a way of showing the value of a resistor. Instead of writing the resistance on its body, which would often be too small to read, a colour code is used. Ten different colours represent the numbers 0 to 9. The first two coloured bands on the body are the first two digits of the resistance, and the third band is the 'multiplier'. Multiplier just means the number of zeroes to add after the first two digits. Red represents the number 2, so a resistor with red, red, red bands has a resistance of 2 followed by 2 followed by 2 zeroes, which is 2 200 ohms or 2.2 kilohms.

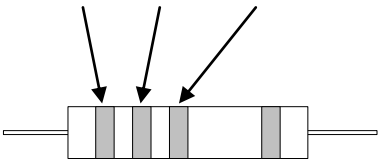
The final band is the tolerance (the accuracy).



Here is the complete list of colours:

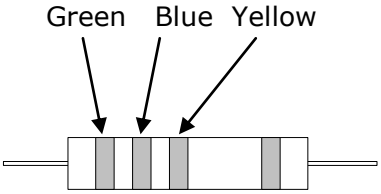
1st colour band 1st digit		2nd colour band 2nd digit		3rd colour band Number of Zeros		4th colour band Tolerance	
Black	0	Black	0	Black	No zeros	Gold	5%
Brown	1	Brown	1	Brown	One zero		
Red	2	Red	2	Red	Two zeros	Silver	10%
Orange	3	Orange	3	Orange	Three zeros		
Yellow	4	Yellow	4	Yellow	Four zeros		
Green	5	Green	5	Green	Five zeros		
Blue	6	Blue	6	Blue	Six zeros		
Violet	7	Violet	7	Violet	Seven zeros		
Grey	8	Grey	8	Grey	Eight zeros		
White	9	White	9	White	Nine zeros		

Example 1: Blue Grey Brown



1st Colour band	Blue = 6
2nd Colour band	Grey = 8
3rd Colour band	Brown = 1 zero
Answer = 680 Ω	

Example 2:



1st Colour band	Green = 5
2nd Colour band	Blue = 6
3rd Colour band	Yellow = 4 zeros

Answer = 560,000 Ohms or 560K Ω

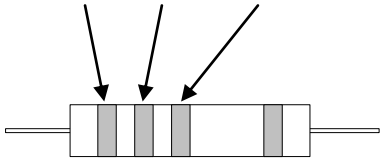
K = 1000 so 10K means 10,000 and 2K7 means 2,700

Now try these, find the value of these colours:-

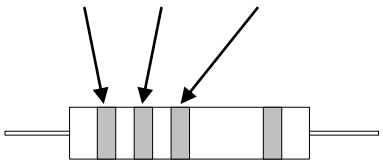
a) Brown, Black, Brown	=	(2)
b) Red, Red, Brown	=	(2)
c) Yellow, Violet, Yellow	=	(2)
d) Orange, Orange, Red	=	(2)
e) Brown, Black, Red	=	(2)
f) Green, Blue, Yellow	=	(2)

Write in the three colours for each of these resistor values:-

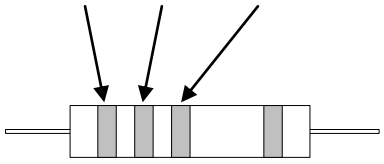
g) 270Ω



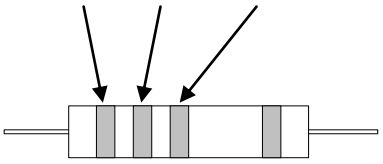
h) 1K8Ω



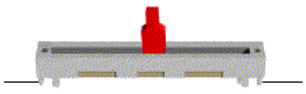
i) 820Ω



j) 120KΩ



Variable resistors are ones whose resistance can be varied between an upper and lower limit. They may be adjusted by rotary or linear controls.



Fuses

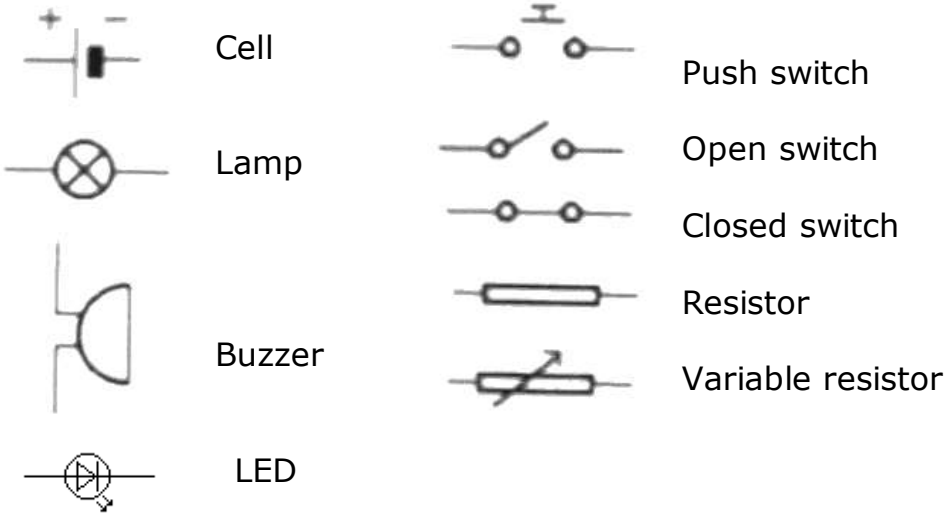
Safety devices used to protect an electrical circuit from the effect of excessive current. Its essential component is usually a strip of metal that will melt at a given temperature. A fuse

is so designed that the strip of metal can easily be placed in the electric circuit. If the current in the circuit exceeds a predetermined value, the fusible metal will melt and thus break, or open, the circuit.

Light-Emitting Diode (LED)

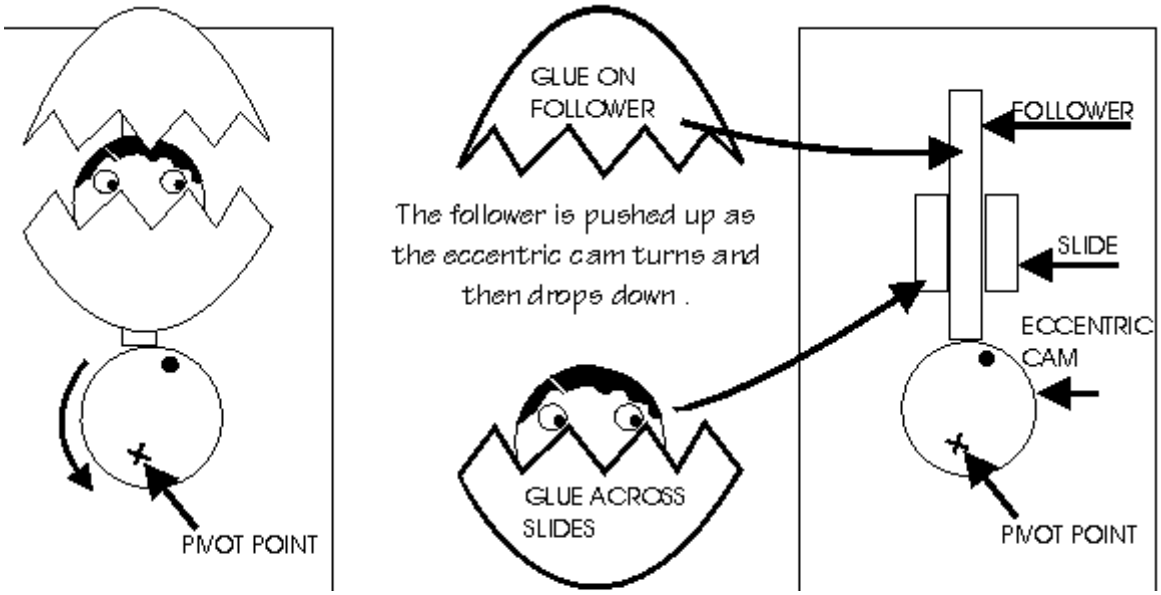
Devices that gives out light when a small current (typically 10 milliamps) flows through it. LEDs are used extensively as electronic indicators. They are available in a range of sizes and shapes, and give out light of a variety of colours. The most common types are cylindrical and glow red, green, or yellow. The current flowing through an LED must be strictly limited to avoid damaging the device.

Electrical Symbols



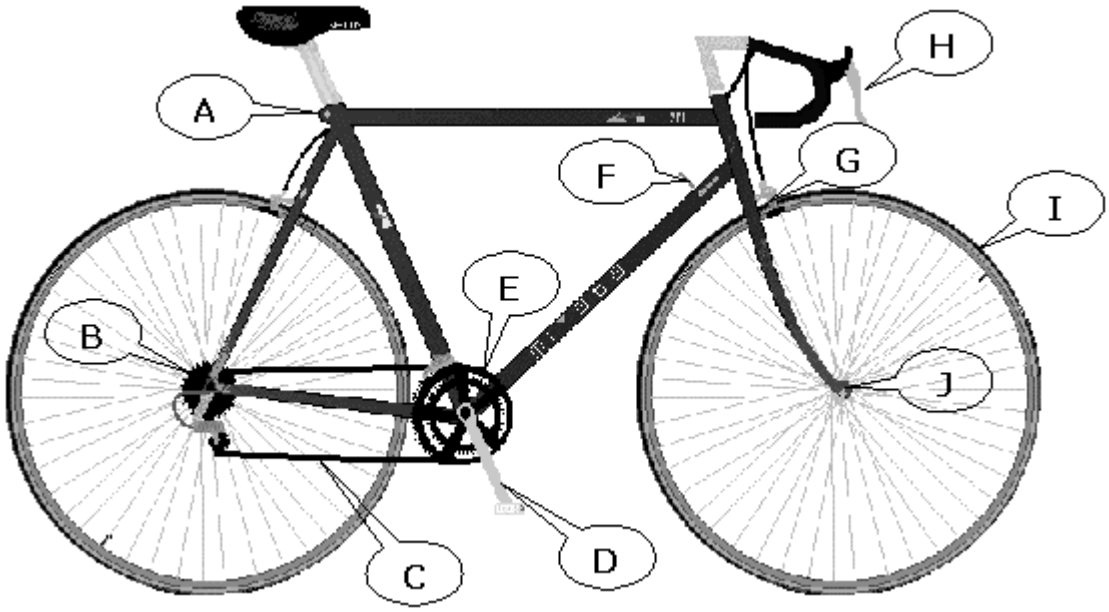
RESOURCE TASK 1

Below is an example of a cam toy based on a 'cracked' egg. As the handle on the eccentric cam is turned the top part of the egg rises and a face with large eyes is seen. The principle is very simple and the basic design is shown below.



RESOURCE TASK 2

Name the different mechanisms found on a bicycle.



A _____ **D** _____ **G** _____

B _____ **E** _____ **H** _____

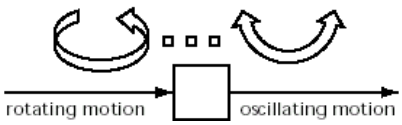
C _____ **F** _____ **I** _____

J _____

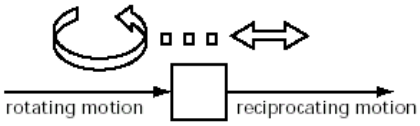
RESOURCE TASK 3

What mechanisms will you use to change the type of motion or direction of motion? Give examples of each.

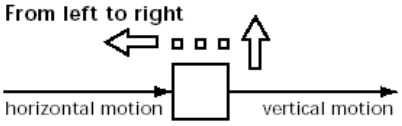
From rotating to oscillating



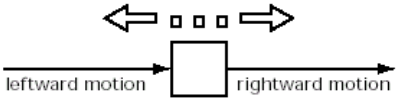
From rotating to reciprocating



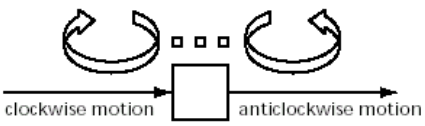
From left to right



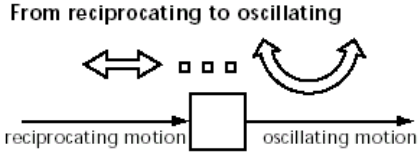
From left to right



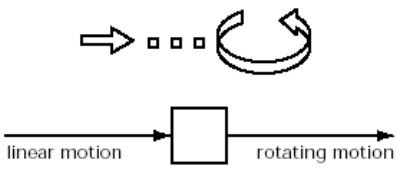
From clockwise to anticlockwise



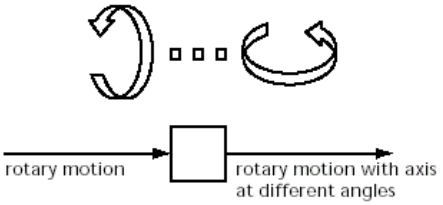
From reciprocating to oscillating



From linear to rotating



To change the axis of rotation



RESOURCE TASK 4

Test your knowledge and complete the table

Column A		Column B
1 lever arm		A. a lever in which the load is between the fulcrum and the effort.
2 force		B. a gain in effort or distance, or a change of direction.
3 effort		C. a wheel that has teeth along its edge.
5 advantage		D. a bar or beam free to pivot around a fulcrum.
6 friction		E. a pulley attached to the load that is being lifted.
7 gear		F. metric unit, used to measure force.
8 compound pulleys		G. a lever in which the effort is between the fulcrum and the load.
9 newton (N)		H. the tendency of a stationary object to remain at rest and a (block and tackle) moving object to keep moving.
10 load		I. the resistance or weight that is moved using a lever.
11 class 2 lever		J. a lever in which the effort is between the fulcrum and the load.
12 movable pulley		K. a force that slows down an object or causes it to stop moving.
13 inertia		L. the point at which a lever arm rotates.
14 class 3 lever		M. an instrument to measure certain forces.
15 fulcrum		N. the force applied to the resistance.
16 spring scale		O. to push or pull on matter.

Solve the problems below. Draw an illustration of your solution and explain why you think it will work.

1: A large man is stuck down in a well. A sixth grader finds him. He is not seriously injured. How should the kid get him out?

2: You need to get a 150 lb. crate on a porch with steps on one side. The porch is 5 ft. high. Which simple machine will allow you to do this the easiest and quickest?

3: You have a go-cart with a very strong engine. You are entering it into a race, but it is too slow. You aren't allowed to have gears, so how can you make it go faster?

4: You need to turn a huge piece of wood into smaller pieces for your camp fire.

5: You're going up a steep hill on your bike. Should you shift into the lowest gear or the highest gear? Explain your answer with words and illustrations.

6: You need to carry loads of bricks into your backyard. Which simple machine will you use and why? BE SPECIFIC!

7: You need a hole in the middle of a piece of wood. Which simple machine will you use and why?

8: Explain why friction is both good and bad. Give lots of examples.

CASE STUDY 1

You own a toy store and just got a large shipment of ice skates to sell. You want to make a display in your store window that shows two dolls, dressed up like ice skaters, spinning in place. You have one electric motor that will turn one doll but you'll have to use gears to make the second doll turn. Figure 2 shows how this works.
You build it and it works fine except that one doll spins clockwise and one spins counterclockwise. You want them to both spin the same direction. What can you do? There's just one more thing. You want one doll to spin slower and one faster. Any ideas? Draw a diagram of your design in your exercise book.

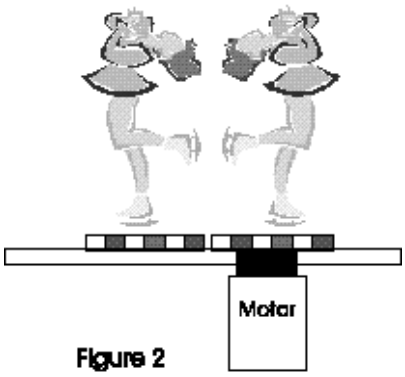
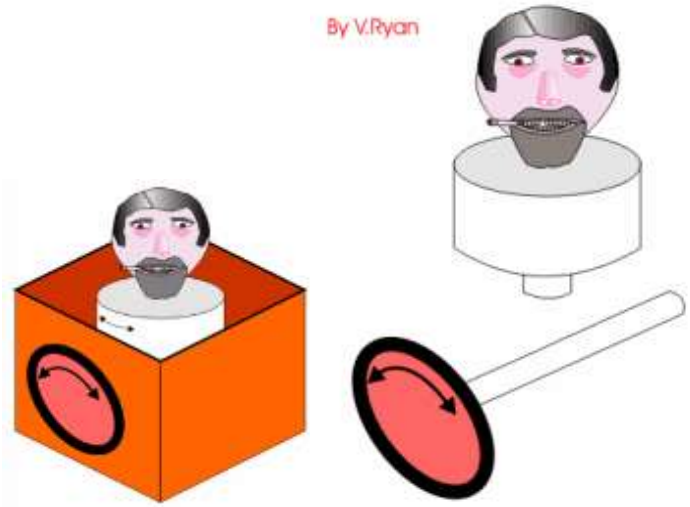
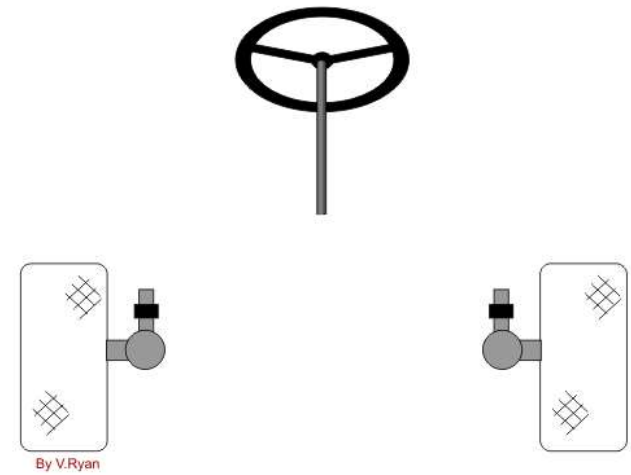


Figure 2



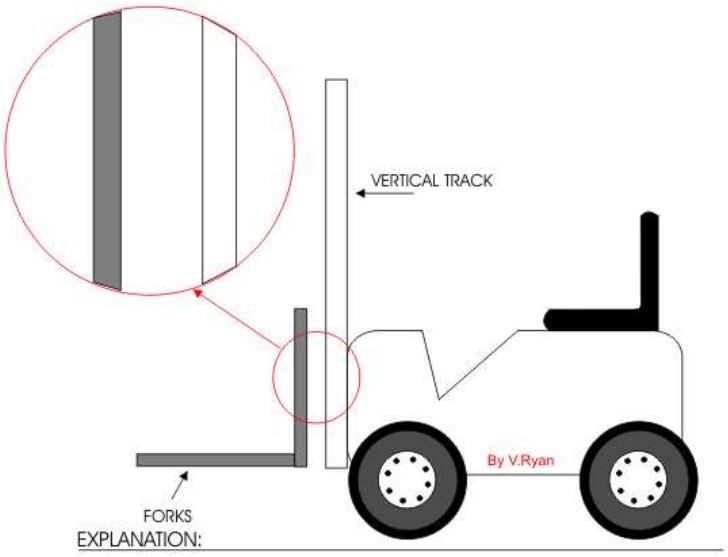
A shop owner has approached your design company to make a mechanical toy based on a head turning. The owner would like your company to manufacture a shop display that is eye catching for passers-by.
The picture to the left shows the intended idea. As the round handle turns the head also rotates.

Using the incomplete diagram on the right, sketch a mechanism that would convert the rotary motion of the handle into rotary motion of the head.



The diagram on the left shows a vehicle and its steering system. The most important part of the mechanisms is missing. This allows the steering wheel to turn the wheels left and right so that it can be steered.

In the space available, add a drawing of the mechanism that allows direct turning of the wheels.

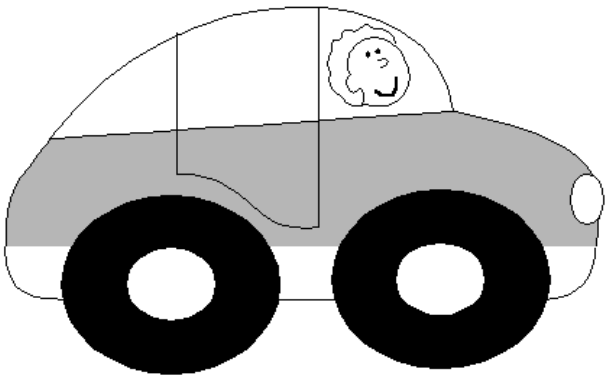


The diagram below shows a fork lift truck. It is used to lift pallets, complete with their heavy loads. The forks on the front of the truck move up and down the vertical track. In the magnified area, draw the missing mechanism that allows movement of the forks.

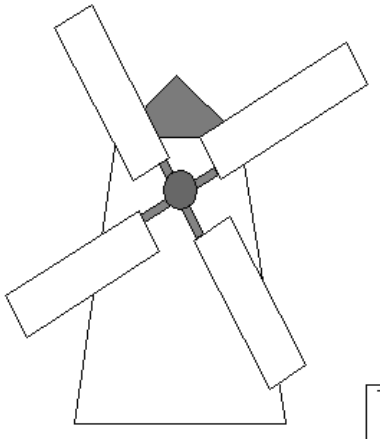
In the circular area, add an enlarged drawing of the mechanism that allows the up / down motion of the forks

CASE STUDY 2

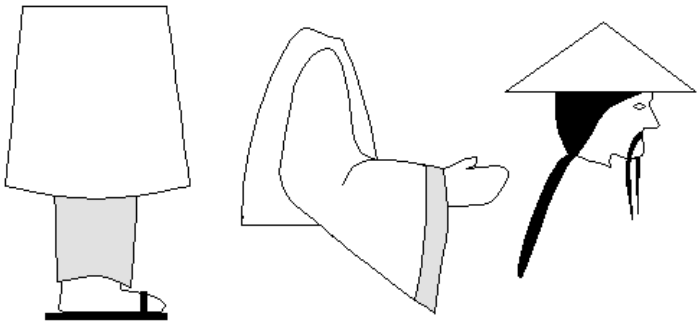
What mechanisms will you use to create motion in each of the following images. Make a 3-D drawing to illustrate your idea and give a detailed description of how it will work.



Make the head of the driver bob up and down



Make the fans of the windmill turn



Make the Chinese man bow

Make the witch fly horizontally

PORTFOLIO GUIDELINES

DESIGN BRIEF
I have to make a . . . . It must be made of . . . . . The . . . . . will be used by . . . . . .
It must show my understanding of . . . . . .

SPECIFICATIONS (e.g. size, material and shape)
The product should be suitable for …….(people: age, target market, human rights, access)
It has to be able to ……..(purpose: function)
It must look ……..(appearance & aesthetics: colour, shape, form, feel)
It must be suitable for a …… (ergonomics)
It has to be made of ……..(materials)
The physical measurements should be …….(size)
There should be no damage to nature (environment: where used, impact on environment: in making and in long and short run)
It has to be safe for …… (safety: users and manufacturers)
It has to take the following budget into account …….(cost: of materials, wastage, manufacture, maximum selling price)
It has to be made with care and precision …….. (quality)

CONSTRAINTS (boundaries within which the work must be done)
It has to be completed in ……time
I may not exceed ……budget
……..many people will work on it
It has to be made of …….
I must use ……..tools

INFORMED DECISION
I chose……because……..but I could have used……..
I looked at……...to see if it was suitable
I compared…..and…….and found that….
I tried…….and……..and decided to use…….
……..was better than…….. because……

EVALUATION
Weaknesses and Strengths
The best part of my…….. is……
This part of my…….didn't work because…….
The materials I used were/ were not……
My ……..works because……
My ……doesn't work (as well as I thought) because……..
My…….solved the problem effectively because……
My ……..wasn't effective because……..

Improvements and modifications
An alternative material could have been……
Another solution would be…….
Next time I could try……..
Instead of doing……I could have……
I could have improved……..
It would have been better if……..
The tools I used were……/I should have used a different……..

FLOWCHARTS
Flowcharts are used to show the correct sequence of events of a particular operation. Flowlines must be added in between the boxes and these lines should have arrows on them to show the direction of flow of instructions.

TERMINOLOGY

A short circuit
happens when an electrical circuit travels from the power source through a wire and back to the power source without meeting an electrical component.
Abutment
a structure used to support either end of a bridge
Adjacent
lying near or adjoining; (angles) sharing a vertex and one common arm
Advantage
a benefit or gain
Angle
The union of two rays that have a common endpoint. The rays are called the sides of the angle and the common endpoint is called the vertex of the angle. Note: the plural form of vertex is vertices
Angle girders
are beams angled to form two sides of a triangle. When used in pairs, the triangle shape adds strength. Angle girders are folded in the middle, lengthwise, and then placed one inside the other. Angle girders can be used in multiples.
Application
apply your results (conclusion) to your everyday life
Arch
A shape that is roughly semi-circular; capable of supporting a great deal of weight. The force of the load on an arch is carried along the sides of the arch to its supports, thus spreading out the effect of the load.
Area
A measure of the surface enclosed by a figure
Asymmetrical
one half of something is not exactly the same as the other half
Atom
is the smallest component of matter. Atoms are made up of protons, neutrons, and electrons.
Attraction
occurs where oppositely charged materials come together.
Average
a single number that represents a set of numbers; see mean, median, and mode
Axle
a rod or shaft on which a wheel rotates
Balanced
is equilibrium: a condition in which all the forces acting in a system completely neutralize one another
Battery
is a unit made up of two or more cells that is used to store electricity.
Beam
lengths of material (e.g., wood, concrete or steel) that support or strengthen a structure
A large long piece of wood or other material used as a support in withstanding a force
Belt drive
a pulley system in which one pulley drives another by a belt
Benchmark
something taken or used as a pint of reference or for a comparison
Bevel gear
gears with sloping sides that mesh together at different angles and therefore can transmit energy around corners
Block and tackle
a pulley system which combines a fixed pulley with at least one other movable pulley that can move a load; provides mechanical advantage

Box beam
is shaped like a box, hollow inside. It follows from the U beam.
Bridge
A structure built over a river, road, etc so that people, cars, trains, etc can get across
Butt joint
Two pieces of material joined end to end also a form of support joint used to strengthen a structure
Cam
a mechanism that changes rotary motion into linear motion
Cam and cam follower
A mechanism that changes rotary (circular) motion into linear motion (motion in a straight line)
Cargo
goods carried on a ship, airplane or other vehicle
Cell
is a unit that produces electricity from a chemical source.
Centre of gravity
the point at which all of the mass of a body seems to be centered
Chain drive
a pulley system in which one wheel drives another by means of a chain
Charge
A property of an atomic particle (electron), which interacts with a material to give rise to electricity. Usually described in two forms; as a positive and a negative charge.
Circuit
A path through which electricity flows. A circuit may be closed (complete) or open (broken).
Circumference
A measure of the distance around a circle
Compression
a force that squeezes an object or compacts it. a pushing force.
Conclusion
discuss results of your experiment, relate to your hypothesis, support with your data
Concrete materials
Objects that students handle and use in constructing their own understanding of mathematical concepts and skillls and in illustrating that understanding
Conductor
is a material, like metal, that allows electricity to flow easily through it.
Congruent
Having the same size and shape
Coordinates
the numbers in an ordered pair that locate a point on a grid by indicating the distance and direction of the point from the y-axis and the x-axis
Corrugated beams
use the principles of angled girders and flat beams. Sometimes corrugated beams are made as a double sandwich.
Crane
a machine for lifting and lowering heavy loads
Crown gear
a toothed wheel that changes the direction of force through a right angle (teeth are at a right angle to the face of the wheel)
Cube
A regular solid having six congruent square faces
Current
The rate of flow of electrical charges through a conductor. The unit of current is an ampere (A).
Current electricity
is electrical power caused by the flow of electrons.
Cylinder
A three dimensional figure having two congruent, parallel and circular bases

Deck
the roadway of a bridge
Degree
A unit for measuring angles
Design process
The stages of development of a product or process, including identifying a problem, developing a plan to solve the problem, building a structure or mechanism to solve the problem, testing the structure or mechanism, and communicating results and reflections on the process and the product
Device
an object that is designed for a specific purpose
Direct current
is electricity that flows in only one direction.
Direction
the course or position of an object or point in relation to another object or point
Effort
the force (energy) supplied to a machine to produce work
Elastic force
the force developed in matter that has been deformed that causes it to return to its original shape
Electric circuit
is the path taken by electricity traveling from a power source, through connections or output devices and back to the power source.
Electric force
a force produced by electricity
Electricity
is a form of energy caused by the movement of electrons from one atom to another.
Electromagnet
is a magnet that is created by electricity passing through a coiled wire
Electronics
is the use of electrical devices to control the way electricity flows around circuits.
Electrons
are particles of an atom that hold a negative charge.
Electrostatic charge
is the static electricity in an object.
Energy
The measure of a system's ability to do work. (work results when there is motion against resistance or force). The unit of energy is a joule (J).
Energy transformation
Changing form one form of energy to another. An example could be changing from potential energy to kinetic energy in a waterfall, or electrical to heat
Estimate
to judge or calculate approximately the amount or value or size of something
Estimations strategies
Mental mathematics strategies used to obtain an approximate answer. Students estimate when an exact answer is not required and estimate to check the reasonableness of their mathematics work.
Filament
is a piece of metal (usually tungsten) that glows when heated inside a light bulb.
Fixed pulley
a pulley that remains in one place attached to a permanent structure such as a wall
Flat beam
is a flat structure that can be supported at either end. If too great a load is placed on a beam, it will bend, or even break.
Flexibility
the ability to bend and move without distortion or damage
Flexible
bends easily; when something bends easily under force, it is flexible

Follower
A gear, wheel, or other machine part that is given motion by another part
Force
push or pull applied in a direction measured in Newtons
Formula
A set of ideas, words, symbols, figures, characters, or principles used to state a general rule. For example: the formula for the area of a rectangle is A = l x w.
Frame
Structure which serves as an underlying support
Frame/framework
the basic parts of a structure when put together
Friction
The resistance to motion from surfaces that touch; resistance of a body in motion to the air, water, other surfaces, etc.
Friction force
a force that opposes the motion, of one object sliding over the surface of another object
Function
the use of an object or system
Gear
a wheel with teeth around the rim; used to transmit force to another gear with matching teeth
Gear ratio
the relation between the number of teeth on the input gear divided by the number of teeth on the output gear (number of input teeth ÷ number of output teeth)
Gear system
a group of gears that work together to perform a job
Gear train
A group of two or more gears
Gearing down
using a small fast gear to drive a larger slower gear to slow down the output
Gearing up
using a large slow gear to drive a smaller faster gear to speed up the output
Generator
is a mechanism that turns heat or movement into electrical energy.
Gravitational force
a force of attraction between any 2 pieces of matter
Gravity
The natural force that causes objects to move or tend to move toward the centre of the earth; gravity causes objects to have weight
Gusset
a plate used to strengthen corners, including truss joints, and to prevent twisting of attached pieces
Hexagon –
A six sided polygon
Hinge
That on which something turns; a joint on which a door, gate, cover, lid, etc., swings back and forth
I beam
is shaped like its name. Its shape gives it strength. It can support a greater load than a solid flat beam.
Incline
A slope or slant
Induction
happens when a negatively charged item approaches a neutrally charged item, the electrons (-) on the neutral surface are repelled and move away. This causes a positive charge on the surface which attracts the negative charge of the other item.
Input
anything that is put into a system including people, materials and energy

Insulator
is a material that does not allow electricity to pass through it.
Insulator
A property of material that provides a large amount of resistance to the flow of electricity.
Kilogram
a unit of mass
L beams
are shaped like an L, with varying height sizes.
Laminated flat beams
give extra strength when two or more flat beams are glued together.
Led
is an abbreviation of Light Emitting Diode, an electronic device that lights up when electricity is passed through it. LEDs are usually red.
Lever
By applying a pushing or pulling force on one part of the lever, the lever about the fulcrum to produce action at another point. There are three classes of levers. Levers are classified by the placement of the fulcrum, load and effort
Lift
Upward force on a forward moving object that results when the air flow around the top of the object is faster than the air flow beneath it
Linear
motion that follows a straight-line path
Linkage
system of connected parts to allow movement
Load
the weight of an object that is moved by a machine; the resistance to movement that a machine has to overcome; critical load the weight the bridge supports, an amount of material or the result of a force
Machine
a mechanism or device that helps a person do work
Magnetic force
a force produced by a magnet
Magnitude
greatness or importance
Mass
The amount of matter in an object; mass is usually measured in grams or kilograms
Materials
complete list of all tools, objects and substances, description and amounts
Matter
is anything that has mass and occupies space.
Mean
the sum of a set of numbers divided by the number of numbers in the set
Mechanical advantage
the advantage in effort that is gained by using a mechanical device which multiplies the force applied to it and produces a larger force than does the work; the formula: M.A. = force produced ÷ force applied
Mechanical energy
The energy of an object in motion (kinetic).
Mechanical system
two or more interrelated parts joined for a common purpose
Mechanism
the moving parts of a structure that do work
Median
the middle number when an odd number of data are arranged in numerical order, or the mean of the two middle numbers when an even number of data are arranged in numerical order
Mesh
when the teeth of gears, etc. fit together so the system works

Method
"command" steps on how to do the scientific inquiry (or experiment) in proper order
Mitre
box instrument used to hold wood steady while it is being cut at different angels
Model
a smaller or larger version of a structure, but made to the same proportions
Motion
Change of position or place
Movable pulley system
a pulley that moves with the load; consists of a pulley suspended from a rope with each section of the rope on either side of the pulley; each section of the rope supports half of the load
Muscular force
the force exerted by the muscles
Net
A pattern that can be folded to make a three dimensional figure
Neutron
is a part of the atom with no charge (found in the centre or nucleus of the atom).
Newton
the unit used to measure force (equivalent to the force required to accelerate a 1 kg mass at a rate of 1 metre per second per second)
Non-renewable resource
Referring to a resource that once depleted is not replaceable for a long period of time. An example is crude oil.
Observations
a fact based on your 5 senses, you may record what you observed through written form, diagrams/pictures, photographs/video, data tables, data graphing
Octagon –
An eight sided polygon
Oscillating
to and fro in an arc, between two points. Vibrating. traces part of a circle, around a point
Output
the actual result obtained from a system
Parallel circuit
is a circuit where there is more than one path both to and from the power source, where electrical components can be placed.
Pawl
a hinged or pivoted device that locks a ratchet in place
Pentagon –
A five sided polygon
Perimeter
A measure of the distance around a plane figure
Pin joint
a simple method of connecting parts of a structure model
Pinion
a gear wheel that meshes with a sliding toothed rack to change circular motion to back-and-forth motion (corkscrew)
Pivot
A shaft, pin, or point on which something turns
Plane
any flat surface
Plumb line (also line of thrust)
(plumbum is the Latin word for lead) if you hang a plumb line from any point, it swings for a while and then comes to rest. Its point shows the direction to the center of gravity of the earth. The plumb line determines whether the "structure" is vertical (straight up and down)
Point
a fixed place from which position and distance are reckoned
Polygon
A closed two dimensional shape formed by three or more line segments

Potential energy
The energy stored in an object as a consequence of its position or state.
Pressure
A pressing force acting upon a surface (pressure = force ÷ area)
Prism
A polyhedron with at least two congruent and parallel faces (bases). A prism is named by the shape of its bases, for example, rectangular based prism.
Protons
are a part of the atom with a positive charge (found in the nucleus of the atom).
Pulley
A wheel with a grooved rim in which a rope, belt, or piece of string can be run and so change the direction of a pull and lift weights; it is a simple machine. Pulleys are used on cranes to lift objects, sailboats to adjust the sails, and elevators to lift the cab.
Pyramid –
A three dimensional figure with a polygonal base and triangular lateral faces
Qualitative data
information gathered in comparative observations in which no measurement takes place
Qualitative properties
description involving no measuring
Quantitative data
data gained through measurement and/or mathematical calculations that consist of numbers and/or units of measurements
Quantitative properties
are measured; includes properties such as length, width, height, mass, volume, capacity, etc.
Rack
a sliding rod with teeth that meshes with a pinion to change circular motion to back-and-forth motion (corkscrew)
Ramp
A ramp using an inclined plane to move an object from a lower position to a higher position uses less force than lifting the object directly. Ramps can be found on the back of moving trucks so furniture can be easily lifted from the ground and into the truck.
Ratchet
a mechanism consisting of a pawl that engages the sloping teeth of a wheel or bar, permitting motion in one direction only
Ratio
a comparison of two or more quantities with the same unit
Ray
Part of a line extending infinitely in one direction only
Reciprocating
motion back and forth in a straight line, in one dimension. motion up and down, in a straight line, in one dimension. related to linear, but moves in two directions. alternating and usually continuous
Rectangle
A quadrilateral with four right angles
Rectangular prism
A polyhedron with at least two congruent, parallel and rectangular faces (bases)
Renewable resource
is a resource that can never be used up or that is regenerated within a reasonable time period.
Repel
is a force that pushes one object away from another.
Repulsion
occurs where similarly charged materials pull apart.
Resistance
Any force tending to hinder motion
Resistor
is a substance which works to slow down or stop the flow of motion. It is used in electronics to reduce the voltage of the electrical current.

Right angle
An angle whose measure is 90°
Rotational or rotary
in a circle. along a curved path
Rounded number
an approximation of an exact number
Scale
the ratio of the distance between two points on a map, model, or diagram to the actual distance between the two locations
Scientific inquiry/question
What are materials, method and independent and dependent variables?
Screw
A screw Is an inclined plane that is wrapped around a cylinder. It is used to fastern two or more objects together.
Series circuit
is an electrical circuit where the current flows from the power source to an electrical component and then to another, etc. and then back to the power source.
Shear
two forces (compression and tension) that act on an object in opposite directions along the same line or plane. can be a cutting action or a shearing off motion as in an avalanche
Sheering force
the type of force that causes sheet metal or paper to be separated by the cutting action of shears or scissors
Similar figures –
Geometric figures that have the same shape but not always the same size
Skeleton
A three dimensional figure showing only the edges and vertices of the figure
Span
the part of a roadway that goes from one pier to another
Spar
supporting pole
Sprocket
an arrangement of tooth-like projections arranged on a wheel rim to engage the links of a chain in a pulley or drive system (bicycle sprocket)
Spur gear
two gears that mesh on the same plane and turn in opposite directions to control speed and force
Square
A quadrilateral with four right angles and four equal sides
Stability
The capacity of an object to maintain or return to its original position; the state of being balanced in a fixed position
Static
is not moving; staying in the same place.
Static electricity
Stationary charges that build up on the surface of objects and do not flow continuously as in a closed circuit.
Stiffness
the ability of a structure to withstand being bent, twisted, stretched or changed in shape
Straight angle
An angle whose measure is 180°
Strength
measured by the amount of force a structure takes before failure or material before it breaks
Stress
A force created inside a material or an object (that tends to deform it) by other outside forces acting on it

Structure
an arrangement of parts to form an entire object; a supporting framework such as a bridge or building that is built to sustain a load
Strut
A part of a structure whose function is to resist compression; a member in a framework designed to relieve pressure or weight and prevent the framework from collapsing
Surface area –
The sum of the areas of the faces of a three dimensional object
Switch
is a device that controls the flow of electricity through a circuit by completing or breaking the circuit.
Symmetrical
the condition whereby half of something is the mirror image of the other
System
a group of objects that work together to do a job
Tally
a mark made to keep count of a number of objects or events. Tally marks are often grouped together in fives to help in counting
Tally chart
A chart that uses tally marks to count data and record frequencies
Taxi
(airplane) move along the ground under the machines own power before take-off
Tension
a force that pulls on an object, stretching or straining; (the weight of a suspension bridge causes tension in the cables that hold it up)
Terminal
is a device attached to the end of an electrical device or power source like a battery to allow for easy connection.
Three dimensional figure
A figure having length, width and height
Tie
A part of a structure that resists tension; beams or rods (including wire, rope, or string) that prevent parts of a structure from separating
Torsion
a force that causes an object to twist along its axis. can include compression and tension
Toughness
the amount of energy a material can absorb before breaking
Triangle
A polygon with three sides
Triangulation
a means of strengthening a structure using the triangle for strength and rigidity, such as trusses
Truss (1)
a structure using triangular shapes to give strength to a bridge
Truss (2)
a timber support in the roof of a house
Tubes
also can be used together to provide strength, without a lot of mass.
U beam
is also shaped like its name. It can be inverted, and can have a variety of side heights. U beams can be used in multiples.
Vice
instrument with two jaws between which objects may be gripped
Volt
is a unit that tells how much energy each electron carries.
Voltage
is a measure of how much energy each electron is given by the power source. The potential energy difference between two points on a conductor carrying a current. The unit of voltage is a volt (V).

Wedge
A piece of wood, metal, or other material, tapering to a thin edge used in splitting, separating, etc. A wedge is used to separate objects by forcing them apart. Wedges are used by an axe to split wood and a knife to cut your dinner into bite-sized pieces.
Weight
The pull of gravity on an object; unlike mass, weight changes with location. It is a force, measured in newtons (n). and has to do with the attraction of a mass to the earth through the force of gravity
Wheel
A round frame turning on a pin or shaft in the centre
Wheel and axle
A wheel and axle is a lever that rotates around a fixed point, with the centre being the fulcrum. A wheel and axle can be found on bicycles, steering wheels and water wheels.
Winch
A machine for lifting or pulling; turned with a crank or engine
Work
the result of a load moving because of a push or pull; work is a product of force multiplied by the distance the load moves (W= f x d)
Worm gear
screw that meshes with a gear; the screw can turn the gear but the gear cannot turn the screw