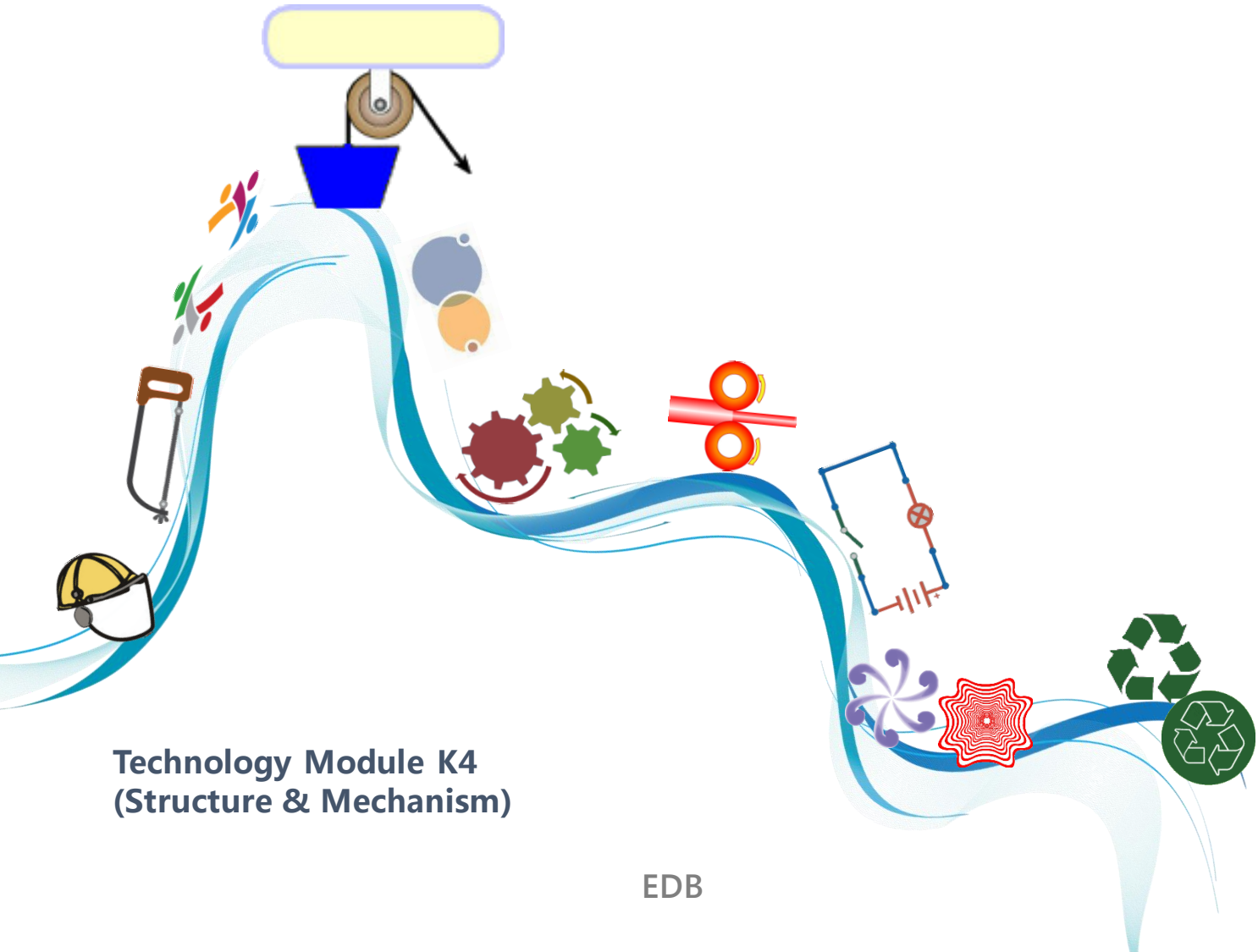
Enriched Technology Education KLA Curriculum

S1 Teaching Material

5

Structure & Mechanism



Technology Module K4
(Structure & Mechanism)

EDB

Preface

To support the implementation of the Enriched Technology Education Key Learning Area Curriculum (Enriched Curriculum) at junior secondary level, the Technology Education Section of Curriculum Development Institute, Education Bureau, has developed a set of learning and teaching resource materials covering technological subjects learning element modules for teachers' reference and use.

The purpose of providing this set of teaching resource materials is to enable teachers to adopt the related technological subjects learning element modules under the Enriched Curriculum for students to acquire thorough understanding and mastery of the three key aspects in Technology Education Key Learning Area, viz. the technological understanding, technological capability and technological awareness, using a flexible approach with reference to the suggested learning progress.

The content of this learning and teaching resources was compiled with project approach. It gives students a purposeful and meaningful learning context through a series of diversified activities such as design projects, case studies, technological exploration and simulation experiments, and thus arouses their interest in technology and devotion in learning, as well as nurtures their ability in problem-solving, realisation, innovation and spirit of entrepreneurship.

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Relevant Knowledge

I. Structure

1. Introduction to structure

A structure is created by combining many lightweight parts, which can be used to withstand a greater load. The parts that make up the structure are called members. Many buildings and machinery are all structures, such as: cable towers, buildings, bridges and cranes.

(a) The cable tower

(b) The crane

2. Forces on structure

When the structure is to withstand load, the nature of forces being applied to the members can be classified into compression, tension, bending, twist and shear, etc.

(a) Compression

Compression leads to the shortening of distance between members along the axis where the force is applied. For example, the pillar is being compressed and deformed.

Figure 1 (a) Compressive force

(b) Rubber being compressed

(b) Tension

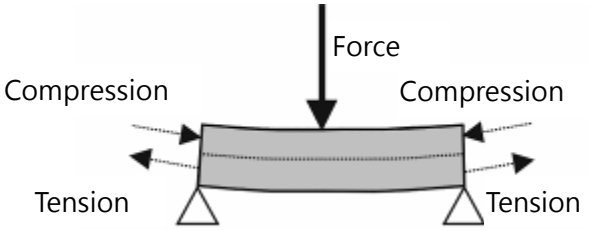
Tension leads to prolonged distance between members along the axis where the forces are applied. For example, the forces exerted by the hangers/stringers of suspension bridges and the iron chains of the swings.

Figure 2 (a) Tensile force

(b) Rubber being elongated

(c) Bending

Member of structure would become bended when the force is applied at the lateral face perpendicularly. It is compressed at the side of the exerting force whereas there is tension on the other side. For example, the bookcase shelf is bended under pressure.



(a) Bending force

(b) The bookcase shelf is bended by the weight of the books

(d) Twist

Twist is the effect produced by two equal forces in strength but opposite in direction, the function lines of two forces do not overlap. For example, the steering shaft turning the car steering wheel; manually unscrewing the cap of the bottle and so on.

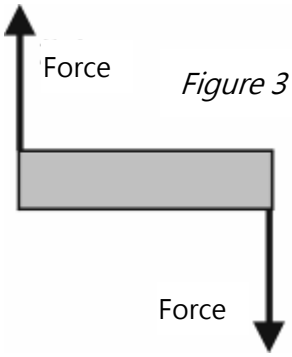
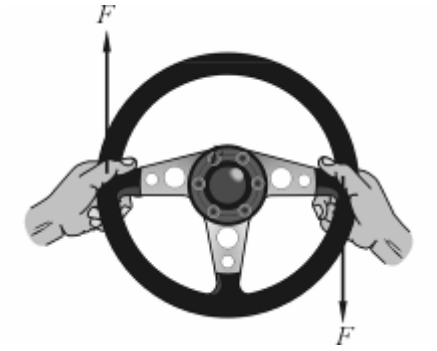


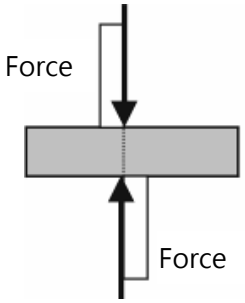
Figure 3 (a) Twisting forces



(b) The car steeling wheel being turned by force

(e) Shear

Shear is the result produced by a pair of forces equal in strength but opposite in directions being applied to the perpendicular axis of the member. For example, cutting papers by the scissors, riveting the steel plate, etc.



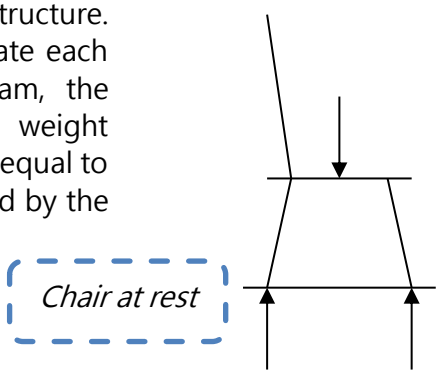
(a) Shearing force

(b) Cutting papers with the scissors

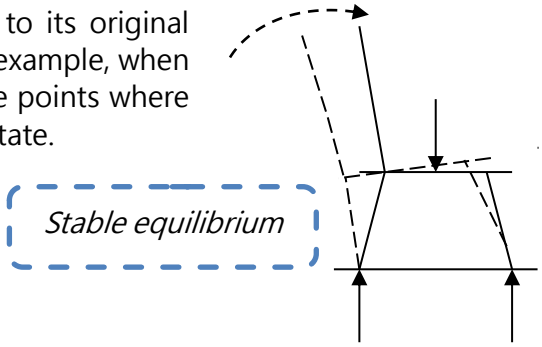
3. Equilibrium of structure

Relevant Knowledge

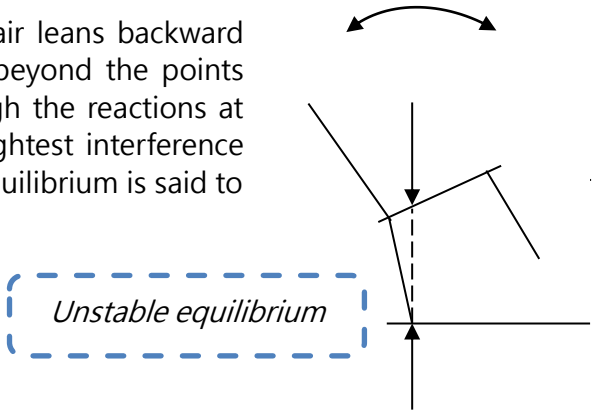
A structure in equilibrium is referred to as a stationary structure. This means that the forces applied to the structure eliminate each other without generating resultant force. In the diagram, the combined force exerted downward by the chair's own weight together with the weight of the person sitting on it must be equal to the balanced forces generated by the upward forces exerted by the floor, which is the reaction force.



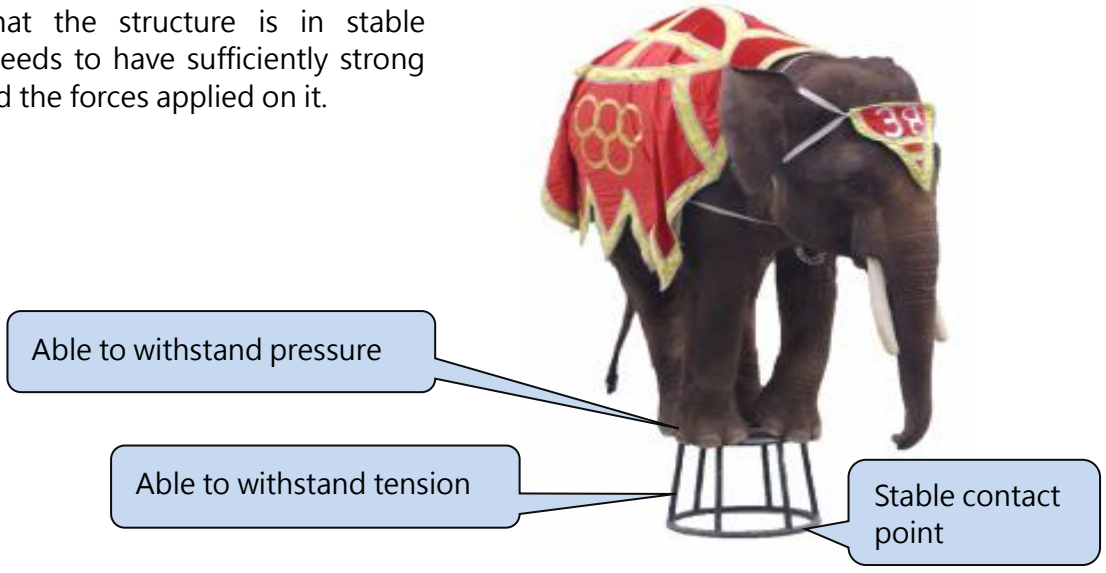
The equilibrium of a structure is stable if it returns to its original position after being interfered. Taking the chair as an example, when the weight acts within the area whose corners are the points where the legs touch the floor, this is the stable equilibrium state.



However, consider the person sitting on the chair leans backward until the weight is acting in the vertical plane beyond the points where the back legs touch on the floor. Although the reactions at these points can still balance the weight, the slightest interference can cause the chair to topple. In such case, the equilibrium is said to be unstable.



Besides ensuring that the structure is in stable equilibrium, it also needs to have sufficiently strong elements to withstand the forces applied on it.



Relevant Knowledge

4. Material and the shape of its cross section

(a) Properties of material

Appropriate materials must be chosen in the design and production of structures. Wrong choice of materials can result in structural damages by external forces easily or can cause permanent deformation. For example, cables can withstand greater tension but not any pressure. On the other hand, concrete can withstand extremely large compression force but it can easily be pulled off by tension.

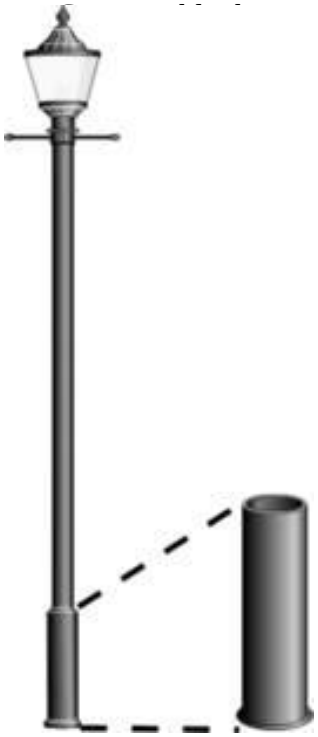
Hangers of the Tsing Ma Bridge

Concrete blocks

As the different parts of a structure may be subject to different loads, they may need to be constructed by different materials.

(b) Tubes

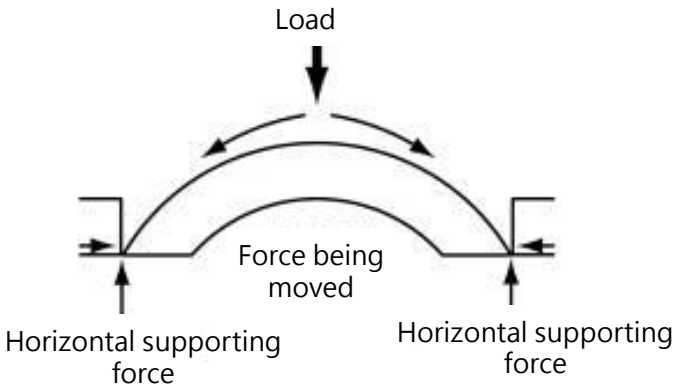
Comparing with solid cylinders manufactured with the same material, hollow tubes have a larger diameter, and thus requiring a greater radial load to bend it. Long cylindrical structures such as street lamppost, school flagpoles are mostly manufactured with tubes.



(c) Different types of structure

(i) Arch

Arch is a structure purely subject to compressive loads; the downward force of the load is transferred through the members to the left and right sides. Arch does not need any member for joining, as long as the members are placed in the proper positions, a robust structure will be formed. Commonly used materials include stone, brick, concrete, etc. Arch is commonly seen in the foundation part of ancient Chinese stone bridges and also in ancient buildings in Europe.

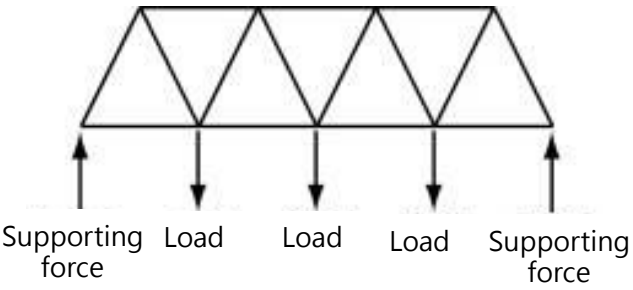


(a) Arch structure

(c) Practical example of arch structure

(ii) Framed Structure

Framed structure is formed by linking individual rod or bar shape objects. The advantage of framed structure is simple and lightweight, which is generally used to carry load. Its main components are rods and their joints. There are many examples of framed structure as lots of buildings and machinery are assembled by it. For example: cable towers, buildings, bridges and cranes, etc.



(a) Framed structure

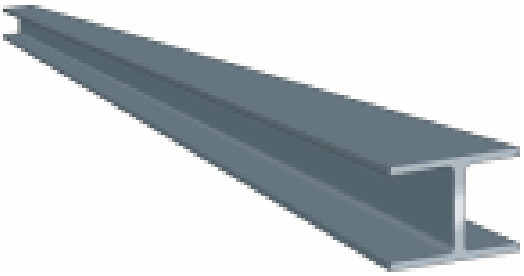
(b) Practical examples of framed structure

(d) Beams of different cross-sections

Commonly seen footbridges and cargo frames all belong to beams. Beams can withstand the pressure from top to bottom and the cross-sections shown below are the most common:

(i) I-beam

I-beam piles or crash barriers can evenly withstand the pressure.

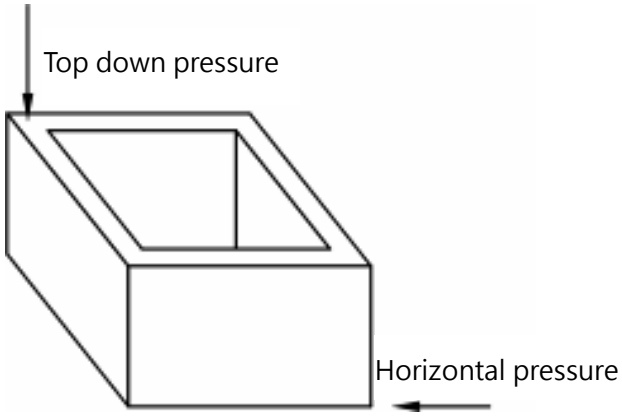


(a) Piles used in construction

(b) Crash barriers at the roadside

(ii) Box

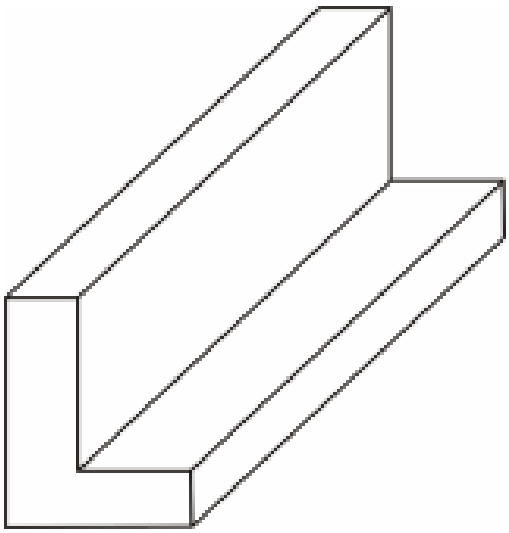
Box construction material can withstand greater twisting forces



The containers on a container truck is an example of square box structure

(iii) L-section beam

L-section beam is mainly used as the frame for holding air-conditioners or shelves on the wall for goods.



(a) L-section beam

(b) Frame for air conditioners

(e) Corrugated surfaces

The load that materials with flat surface can withstand is not as strong as the load intensity of the same materials with corrugated surface. Common examples are:

(a) Groove-shaped case of the container

b) Wave-shaped windscreen plastic sheet

(c) Corrugated cartons

Therefore, using the designs of different-cross sections can make the overall structure more compact and lighter, which can better withstand the load and not easily damaged or deformed.

Relevant Knowledge

II. Mechanism

1. Understand mechanisms with black box approach

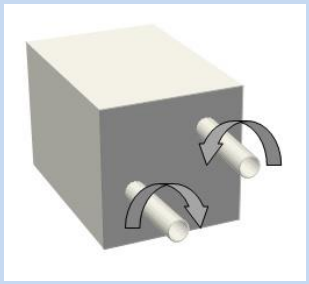
To enhance the effectiveness of machinery, compound machinery is composed by a number of mechanical components, and the designers will regard them as a black box.

(a) Robots

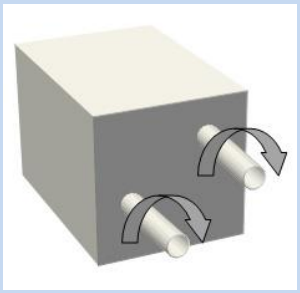
(b) Walking robots

Below are commonly seen black boxes for mechanical movements

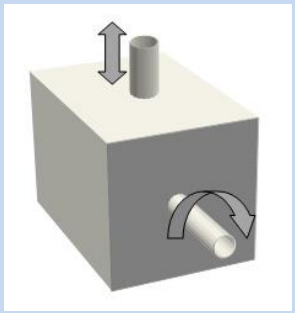
(a) Rotary motion ➡
Rotary motion
(opposite direction)



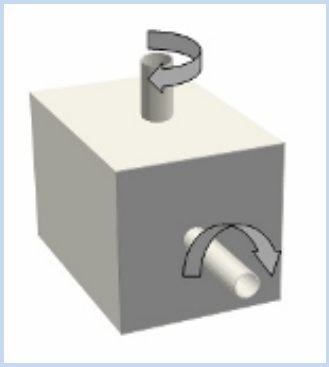
(b) Rotary motion ➡
Rotary motion
(same direction)



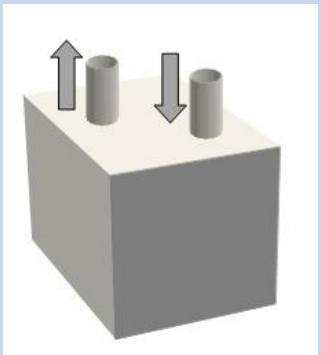
(c) Rotary motion ➡
Reciprocating motion



(d) Rotary motion ➡
Rotary motion (90 °)



(e) Reciprocating motion



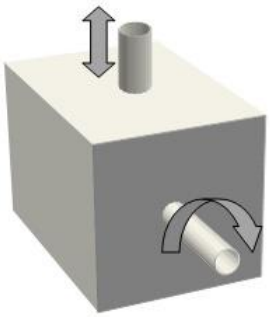
Relevant Knowledge

2. Properties of mechanical movements

The power of human body is limited, we need machinery to increase the strength, increase speed or apply forces conveniently.

(a) Increase the strength

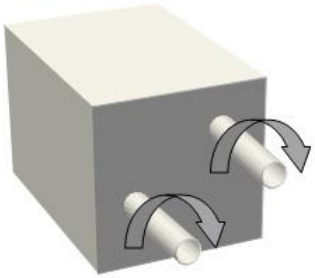
For example a car jack can be used to increase the user's strength; we can use less force to lift a very heavy car.



Mechanics to increase the strength (car jack)

(b) Increase the speed

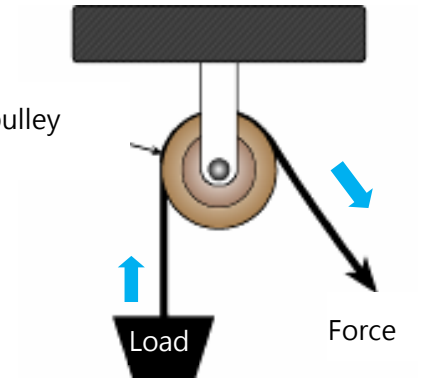
For example a bicycle can increase our speed and make us move faster than running.

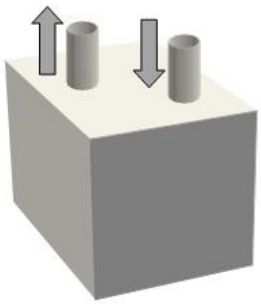


Machine to increase the speed (bicycle)

(c) Apply forces conveniently

Although some mechanisms cannot save effort or increase speed, it can change the direction of force to facilitate our application of force, such as fixed pulley is a common example.





Relevant Knowledge

3. Application of Mechanism

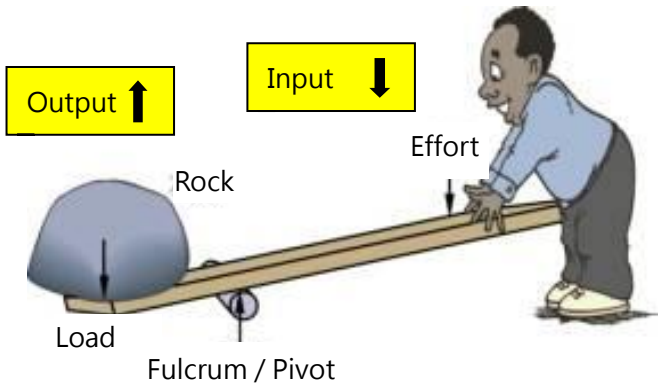
All machines are formed by a combination of different parts and these parts are called the mechanical components. Machine comprising of two or more simple machines is called compound machinery; they can drive and control movements.

(a) Simple mechanism

The earliest and simplest mechanical components used by human probably be the lever. It is a hard and straight bar which can rotate at a fixed point; this fixed point is called the fulcrum / pivot. The location where the force is applied is called the effort, and the position of the loading is called the load. The function of the lever is to change the magnitude, speed and direction of power by changing the position and distance between effort, load and fulcrum.

It contains the three major parts of a typical system:

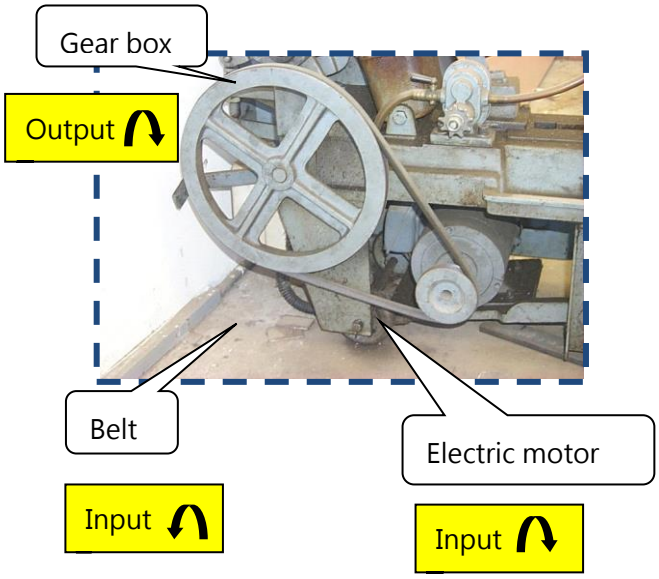
Input - Push down movement by human force
Process - Lever changes the magnitude and direction of the force
Output - The rock is being raised.



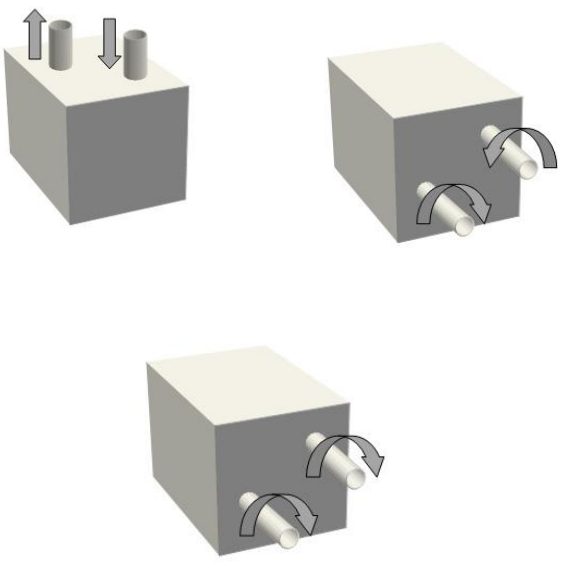
(b) Compound mechanism

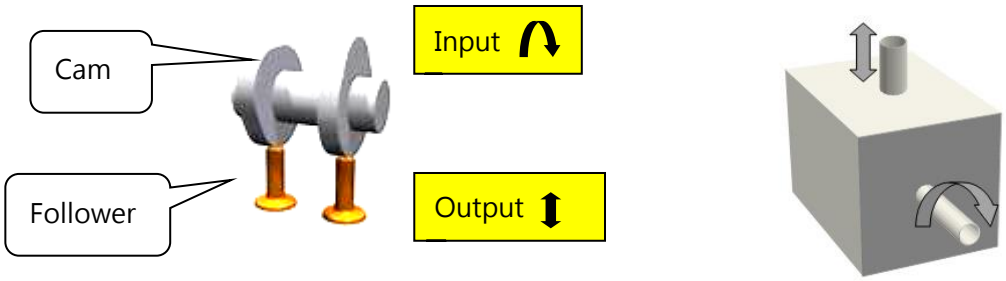
In compound machinery, lever, cam, belt, gear, linkage, crank, etc. are mixed and used to change the various input movements to output movements of all kinds.

Input - Movement of human force or machine
Process - Cam, belt, gear, linkage, crank, etc. change the magnitude and direction of forces
Output - Compound machine being driven



(a) The belt and gear box of the machine tool





(b) Cam shaft of the car engine

(c) The pedals, crank, chain and sprocket of a bicycle

III. Glossary of terms

結構	Structure	盒式	Box
壓縮	Compression	摺曲	Corrugated
拉張	Tension	黑盒	Black box
屈曲	Bending	機械結構	Mechanism
扭轉	Twist	齒輪	Gear
剪切	Shear	帶	Belt
平衡	Balance	鏈	Chain
拱架	Arch	凸輪	Cam
支架	Frame	連桿	Linkage
切面	Cross section	曲柄	Crank
機器	Machine	機械	Machinery

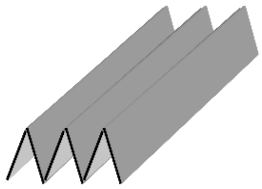
IV. Relevant Information

	Websites	Brief contents
1	http://lizarum.com/assignments/physical_computing/2008/mechanisms/cams.html	Simple mechanism - cam
2	http://www.petervaldivia.com/technology/mechanisms/gears.php	Simple mechanism - gear
3	http://www.lizarum.com/assignments/physical_computing/2010/FPMechanisms/index.html	What's inside the machine black box?
4	http://wsdt.office-on-the.net/resources/DTonCD1/school/cranks.html	Simple mechanism - crank
5	http://www3.ul.ie/~kirwanp/examplesofsystemsinuse.htm	Simple mechanism - cam

Lesson Activities

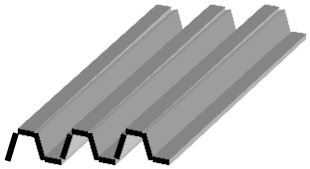
(1) Divide students of the class into groups of eight, each person takes an A4 paper

(2) Two of them follow method (a), two follow method (b), two follow method (c), and the remaining two method (d) to fold the A4 paper

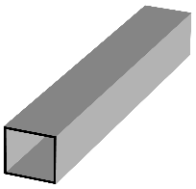


(a)

(b)



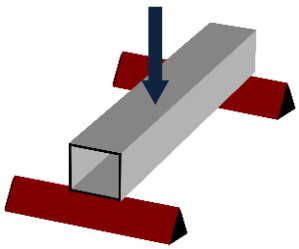
(c)



(d)

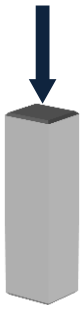
(3) Use items such as the erasers and pens of students in the group as support and conduct loading test to compare the various corrugated methods and the loading strength that can withstand when used as beams and poles:

Apply force



(i) Testing method for a beam

Apply force



(ii) Testing method of a pole

(4) Result records (☆☆☆☆ is the highest force，☆the lowest)

	(a)	(b)	(c)	(d)
Withstanding loading strength when used as beams				
Withstanding loading strength when used as poles				

Lesson Exercises

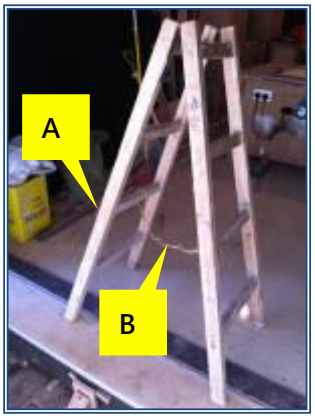
1. Please give an example for each of the five properties of force structure (compression, tension, bending, twist and shear).

2. List commonly used materials for the five types of load, and give some relevant examples.

Nature of the force	Examples	Commonly used materials
Compression		
Tension		
Bending		
Twist		
Shear		

Table 1

3. Siu Ming was led by teachers to visit a bridge being built. Siu Ming found that there were a lot of steel rods within the concrete but he did not understand the purposes of these rods. Please explain the reasons for using the steel rods?



4. The right diagram is a common folding ladder used by decoration workers. Please point out that when the worker steps on the ladder:

   (i) What type of force is being exerted on the leg labeled as A?

   (ii) What type of force is being exerted on the rope labeled as B?

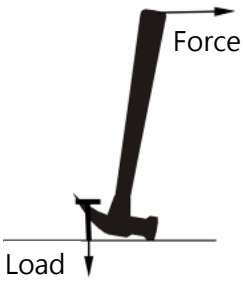
   (iii) What kind of accident may be caused if there is no rope used as labeled as B?

5. (i) Based on the consideration of the structure's strength, why tube is used to manufacture the school flagpole?

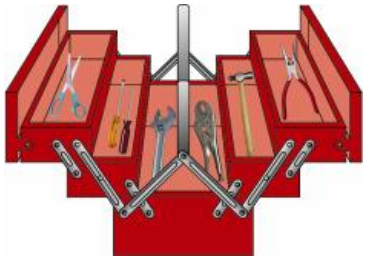
   (ii) List two examples that increase the structure's strength by changing the cross-section.

6. Explain the properties of arch structure. (With annotated sketches)

7. For the two machineries below, please point out their input-process-output

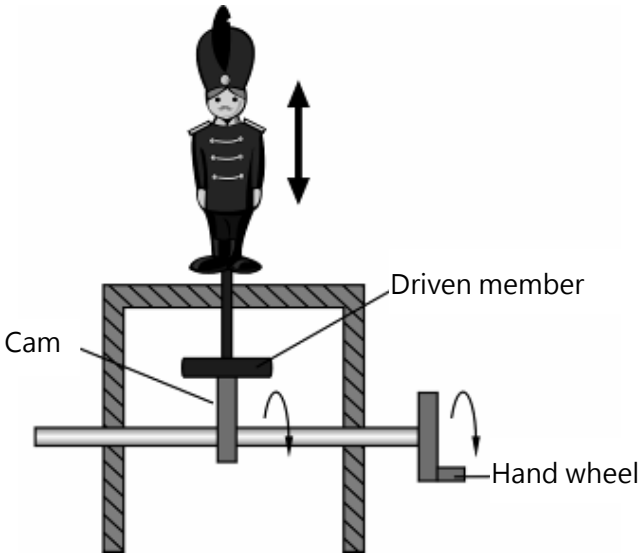


(a) Nail pulling hammer



(b) Tool box

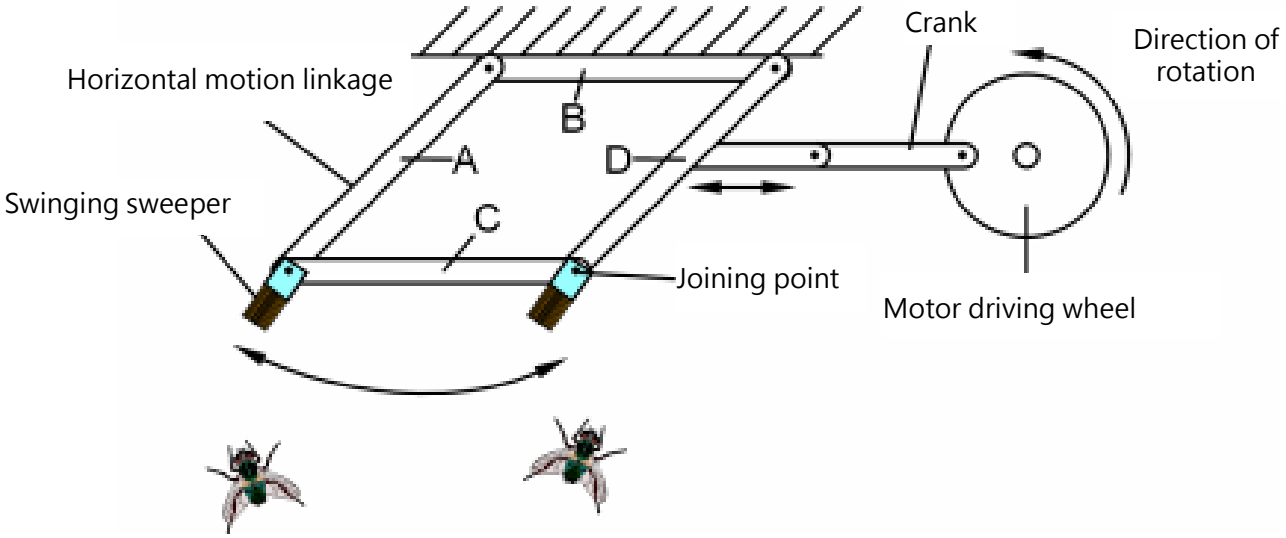
8. The diagram below is a movable toy, briefly explain how it can be moved.



9. In a tourist district kiosk, the shop owner installs the following device in the show window in order to expel insects causing nuisance to the food placed there.

(a) Briefly describe the operation of this device.

(b) Suggest some methods to change the swing magnitude of the swinging sweeper.



Project Activity - Structure

The watchtower

Guidelines for project activity

1. Objectives

Students get a basic understanding about design process and safety usage of hand tools. Use appropriate communication skills to express the design ideas and use appropriate hand tools to make the artefact.

2. At completion of the project activity students should be able to master

1. use of communication skills to express the design ideas;
2. use of hand tools to make the artefact.

3. Situation

It is happy and refreshing for going up the hill or high areas and look over a long distance. In the old days towers were usually built for defensive purposes against thieves and enemies.

4. Requirements of the project activity

(a) Task brief

Students have to make a watchtower which can hold a soda can (~335ml)

(b) Grouping

Four persons in each group Name of the group: _____

Names of team members:

(1) : _____ ( ) (2) : _____ ( )

(3) : _____ ( ) (4) : _____ ( )

5. Recommended time

(3 lessons + 1 lesson for competition) x 40 minutes (total 160 minutes)

6. Required materials

(i) Two pieces of newspaper (Two other pieces of newspaper for testing)

(ii) One roll of 12mm width adhesive tape

7. Activity contents

(i) Group members discuss, test and modify:

(i) Different methods to increase the strength of the paper

(ii) Methods to build a higher watchtower with less material

(iii) Methods to carry the required weight with less material

(ii) Consideration factors

The following questions should be considered in designing and making the watchtower:

(i) Only two pieces of newspaper and one roll of adhesive tape can be used
(ii) How to increase the strength of the newspaper
(iii) How to fully utilize the adhesive tape
(iv) The weight of the soda can
(v) Soda can's effect on the tower's centre of gravity
(vi) Time is limited

(iii) Making procedures

(i) Test the effects of reinforced newspaper
(ii) Design the appearance of the watchtower
(iii) Design how to place the soda can
(iv) Making
(v) Testing
(vi) Modify the design, re-work, test again
(vii) Competition

(iv) Competition:

Students put the soda can on a high platform and then leave the can and the tower, timing for 10 seconds without collapsing.

The teacher will measure from the table top to the lowest point of the soda can. The group that can carry the can to the highest level will win. In case of same results then the one using lighter materials will win.

(v) Recording and reflections:

Our design of the watchtower:

Sketch or affix photos

Our results:

The total weight of our watchtower: _____ g

Our watchtower raises the soda can by: ____mm

Efficiency of our watchtower: _____ mm/g

(Height raised ÷ Weight of the watchtower)

The best result in the class is to raise the soda can by: _____mm

Our modified version of the watchtower:

If we can make the watchtower again, it will be .....

Sketch or affix photos

Use not less than 30 words to briefly introduce your aspects of design which require modifications:

_____

_____

_____