Relevant Knowledge

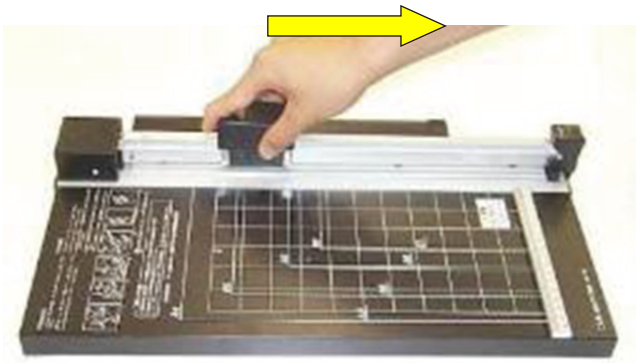
I. Simple Properties of Structures and Movements

Classification of Motion

There are four common types of mechanical motion.

1. Linear Motion

Linear motion occurs when an object moves in a straight line.



A paper cutter

2. Rotary Motion

Rotary motion occurs when an object rotates about a centre in a circle.

A fan

3. Oscillating Motion

Oscillating motion occurs when an object moves backwards and forwards repeatedly about a centre in an arc.

A swing

4. Reciprocating Motion

Reciprocating motion occurs when an object moves backwards and forwards in a straight line repeatedly.

A jigsaw

Four kinds of mechanical motions
http://resources.hkedcity.net/resource_detail.php?rid=995567402

Relevant Knowledge

II. Different Structural Design for Various Needs

1. Different Structures can Enhance Functionality to Suit Different Needs

Structures can be categorised into two classes: naturally occurring and man-made.

(a) Naturally-occurring Structures

Naturally-occurring structures exist in animals, plants and other things in nature, for example, human skeleton, honeycombs, trees and natural caves.

Human skeleton

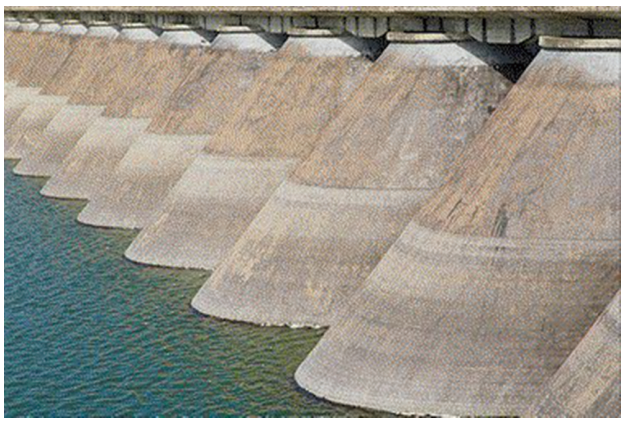
Honeycomb

(b) Man-made Structures

For different needs at different times, humans build and/or assemble a lot of man-made structures, such as bridges, buildings, furniture, ships and towers, for enhancing functionality and fulfilling various needs. There are three major kinds of man-made structures.

(i) Mass Structures

Mass structures are very strong and can withstand loads by means of their own weights. A typical example of this kind of structure is water dams.



A water dam

(ii) Shell Structures

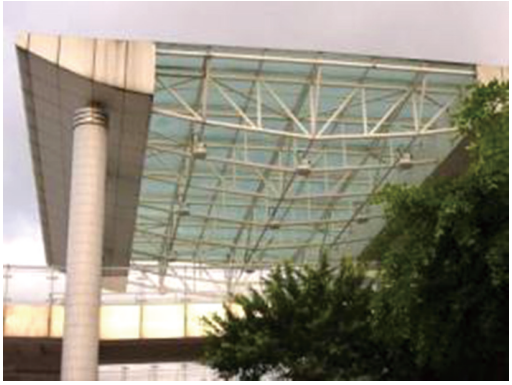
Shell structures withstand loads through their 'skin-like' structures. They are the common construction methods for sheet materials. Balloons and domes of buildings are examples of shell structures.

A brick kiln

(iii) Framed Structures

Framed structures, also known as skeletal structures, are formed by joining bars together at their ends to form a framework. If all the rods of a structure lie in the same plane, it is called a plane frame; if they are put together in a three-dimensional manner, it is called a *space frame.*

A plane frame – roof truss



A space frame – Central Pier

Space frames are usually covered with sheet materials. For example, a greenhouse consists of a metal frame and covering materials such as glass.

A greenhouse

2. Different Mechanisms can Enhance Functionality to Suit Different Needs

We can always find a wide range of mechanisms applied on various designs, which help enhance the functionality of the designs to fulfil different needs.

The following figure shows the mechanisms that can be found on a bicycle for enhancing its functionality.

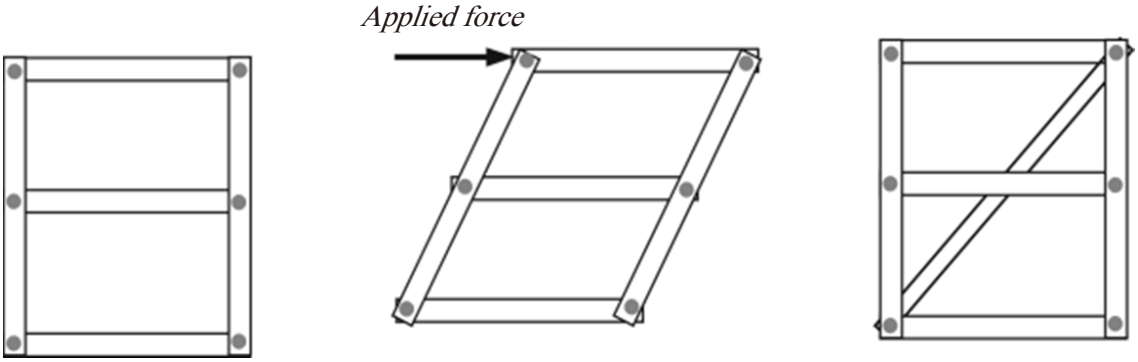
In fact, we can find that each part of the structure of a bicycle is performing the function of enhancing the functionality of the design to meet different needs.

Students should finish this analysis in the exercise section.

3. Application of Appropriate Designs with Considerations of the State of Equilibrium and Weak Points of Structures

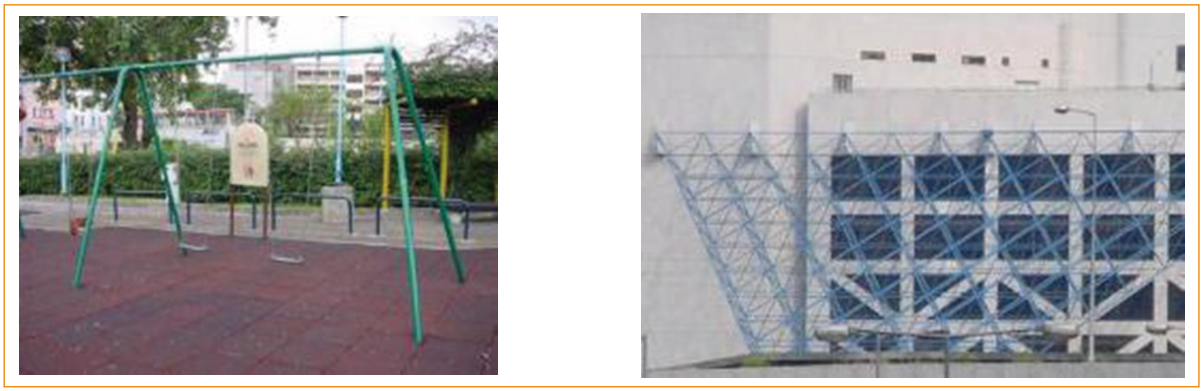
(a) Equilibrium and Stability

Structures joined by rods may not be in equilibrium and stable. For example, the rods in the following figures are all joined by bolts and nuts. The shape of the frame structure is not stable and may alter due to external forces. If a diagonal rod is added to the structure, its stability will become higher.



(a) An unstable frame structure *(b) Easy to be distorted by external forces* *(c) A more stable structure*

If a structure can stand on its own without falling or does not permanently deform due to forces acted upon it, it is a stable structure in equilibrium. Among various kinds of structures, triangular ones possess high stability and can stay in an equilibrium state. As a result, they are widely applied in machinery and architectural structures. In designing structures, the use of triangular structures can raise their stability.

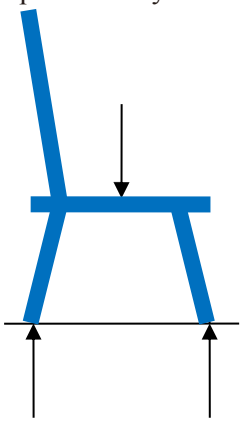


Examples of triangular structures

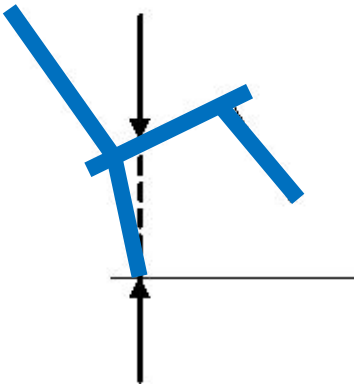
Another way to enhance equilibrium and stability is to join rods into 3-dimensional shapes. For example, the basket of a shopping trolley used in supermarkets is made up of rods perpendicular to each other. As each rod is bent into a U-shape and fixed on the metal frame of the basket, it does not deform easily. This kind of trolleys is strong, lightweight, easy to clean and can be stacked conveniently.

(b) Weak Points

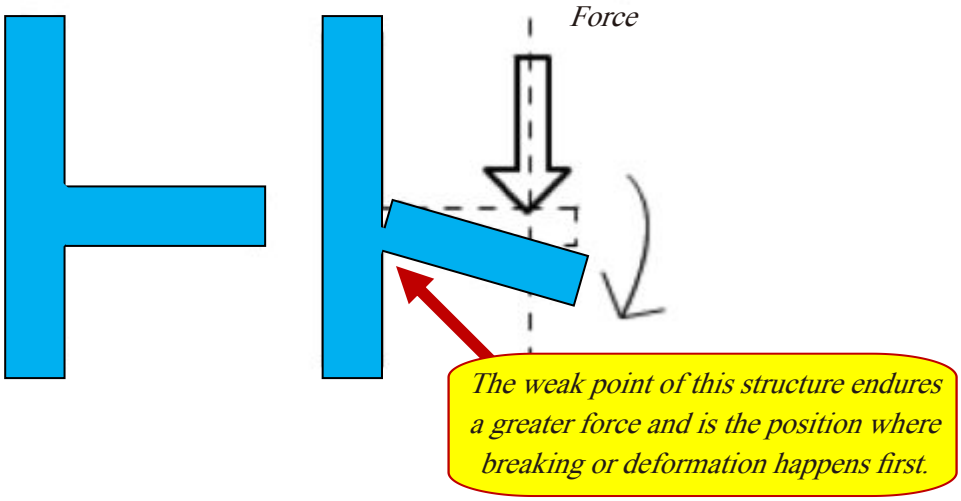
When a force is applied on a structure which is stably standing on its own and in equilibrium, yet it may still fall or deform permanently if it has a poor design or is being misused. The position at which breaking or deforming happens first is where the weak point of the structure appears.



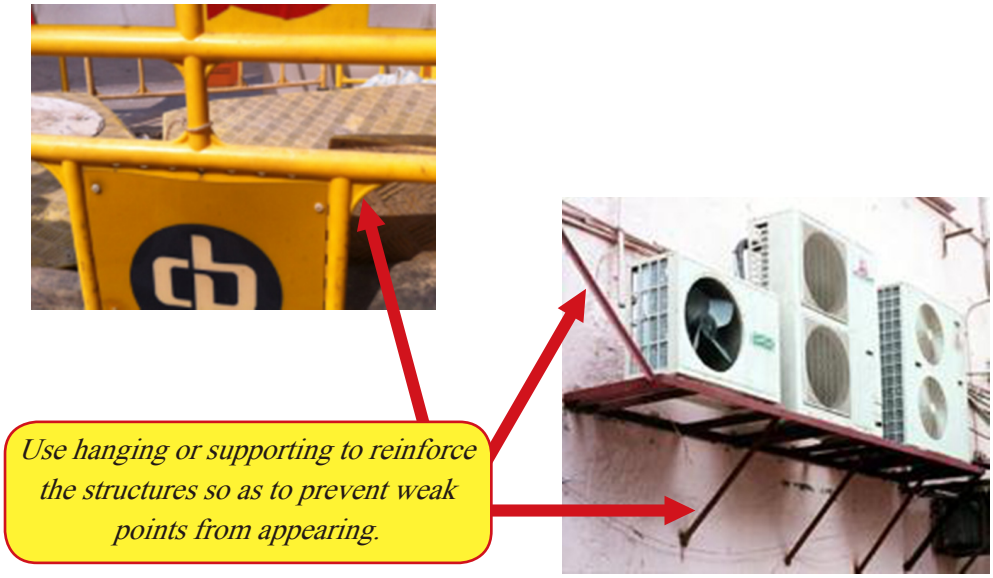
When used normally, the force applied on a chair is distributed evenly.



When a chair is misused, the force applied concentrates on part of the support structure.



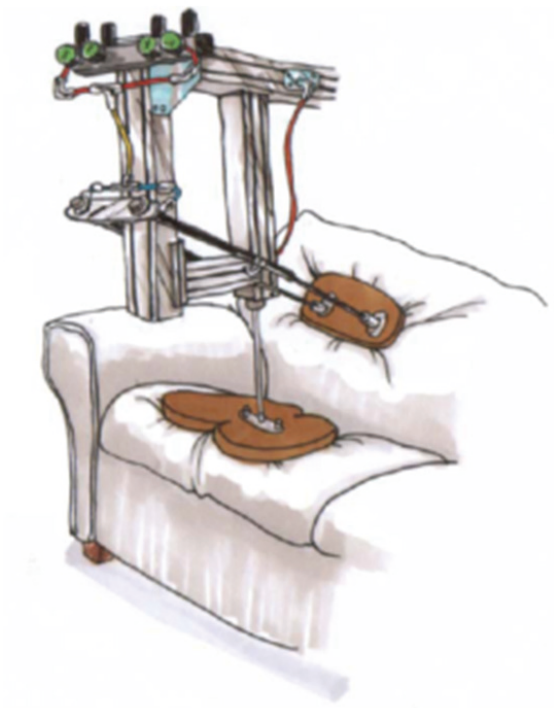
Structures being reinforced are easily found around us. They are made to be so to prevent weak points from appearing.



Some designs, such as bamboo scaffolding, rely on the **experience** of workers passed on from their predecessors.

However, most of the modern designs rely on **repeated testing and improvement.** Many products will be used for a long period and may be banged on each other very often, so their weak points must be identified and reinforced. For example, hair dryers and irons usually have strong casings such that slight impact will not cause damage to the products.

If a furniture producer wants to guarantee the sofas it produces can be used for a certain period of time, it has to simulate the action of an adult with an average weight ramming into the sofas for thousands or even tens of thousands of times, in order to find the weak points and make improvement.



II Use of Mechanisms for Transmission and Control of Movements

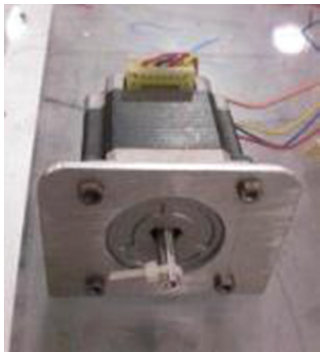
Various parts of machinery may require different driving devices, which can be electric, hydraulic and pneumatic. Consideration of a mixture of factors has to be given when selecting driving systems. Not only that the driving systems have to meet the requirements on precision, speed and acceleration control, production costs, complexity of controllers and other factors also have to be taken into account. Mechanical driving systems may not adopt a single driving means, but rather a combination of different driving methods so as to enhance their cost-performance. Commonly-used driving devices include mechanical, electric, hydraulic and pneumatic driving devices.

1. Mechanical driving device

A screw jack

2. Electric driving device

A small D.C. motor



A stepper motor

3. Hydraulic driving de

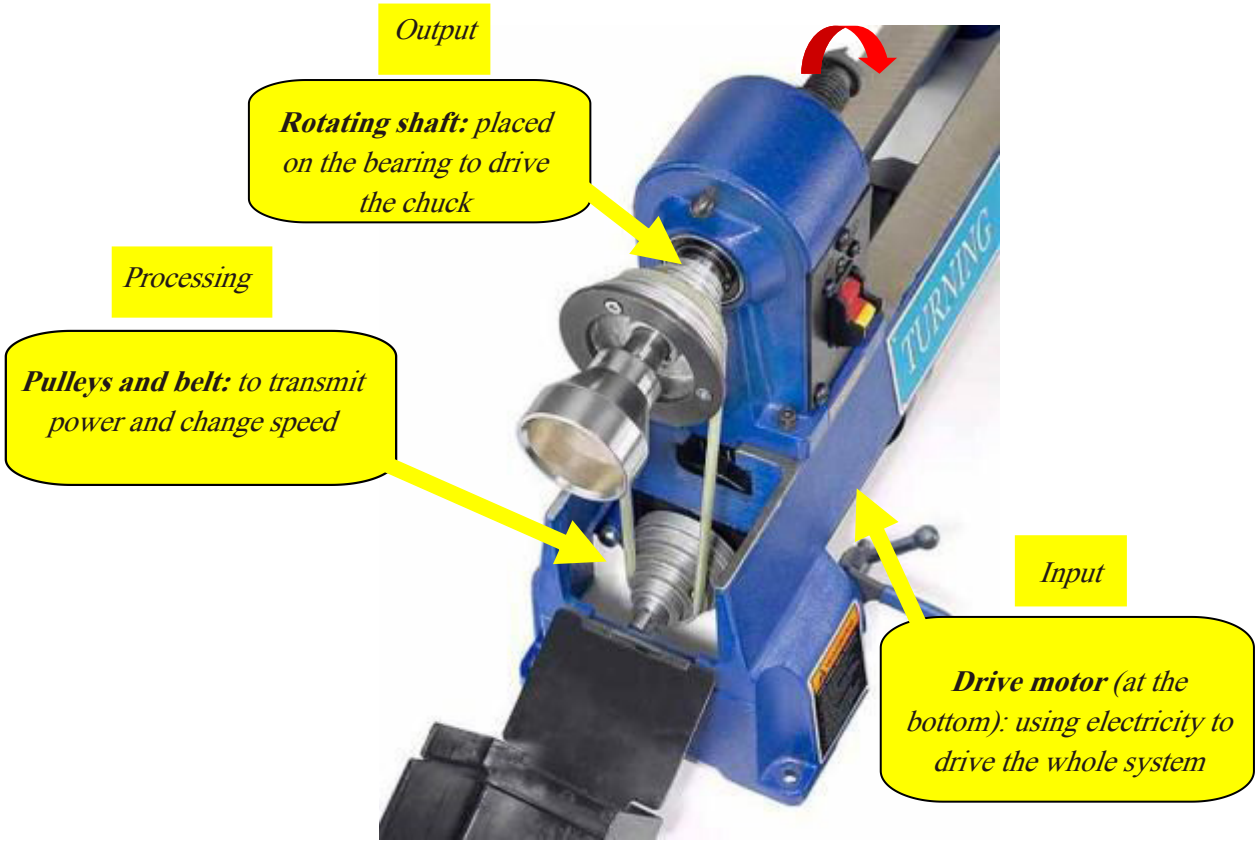
A hydraulic forklift

4. Pneumatic driving device

A silent pump

Mechanisms for Transmission and Control of Movements

To transmit and control movements, in addition to power sources and driving devices, other mechanical parts, such as rotating shafts, belts and pulleys, are also needed.

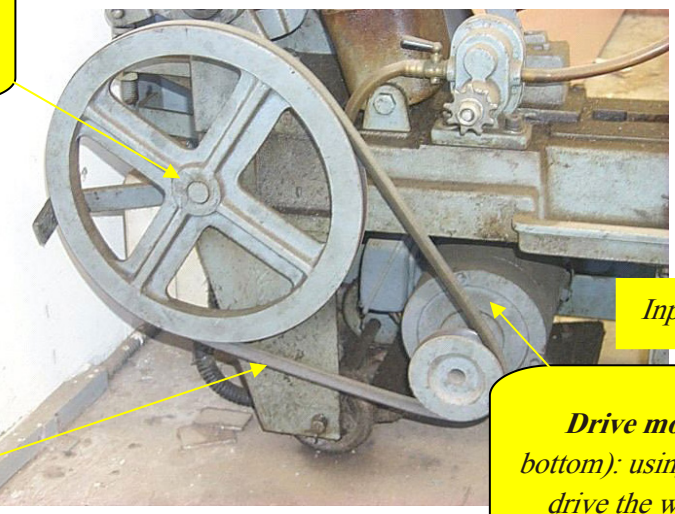


The driving and transmission control system of a small lathe

Relevant Knowledge

Output

Rotating shaft: *placed on the bearing to drive the saw blade*



Processing

Pulleys and belt: *to transmit power and change speed*

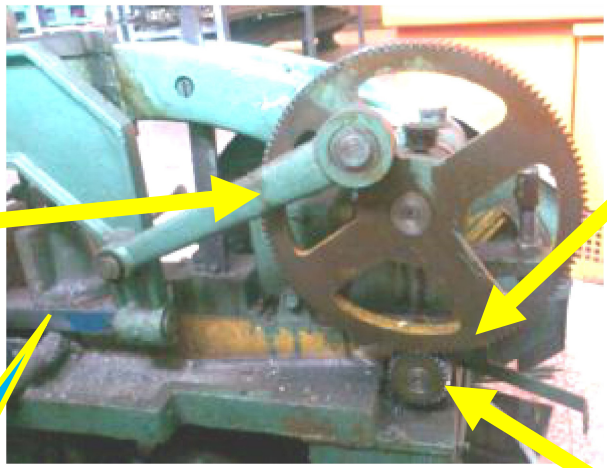
Input

Drive motor *(at the bottom): using electricity to drive the whole system*

The front side of a sawing machine (with the guard removed)

Output

Crank: *Transforming rotary movement into linear movement so as to move the saw blade back and forth。*



Processing

Gear train: *to transmit power and change speed*

Saw blade

The back side of a sawing machine (with the guard removed)

Input

Rotating shaft: *transmit power through motor, pulleys and belt*

The driving and transmission control systems of sawing machines

Relevant Knowledge

III Change in lifestyles

1. Impacts of Technology on Our Living

The development of technology has induced a tremendous change in the way we live in various aspects, ranging from medicine, food, education, entertainment, domestic life to trade. For instance, the development of medical technology helps doctors get hold of the situation of patients more readily. An example of which is X-ray technology, which can penetrate through the body of a patient, displaying an image of the internal structure of a body such as a fractured bone. Besides, medical technology such as artificial hearts, antibiotics, genetic engineering and so on greatly improves the effectiveness of medical treatments. The use of equipment such as endoscopes in minimally-invasive surgery reduces the trauma and pains brought by surgery. The average lifespan of human has also increased thanks to medical technology advancement.

An X-ray image

Packaged foods

Development of food technology allows human to preserve food for a longer period without rotting. Canned foods, frozen foods, paper-wrapped foods and bottled drinks are some examples. In addition, farmers apply a wide range of technological innovations, namely herbicides, pesticides, chemical fertilisers, genetic modification, etc., to increase crop yields.

In the area of education, the learning materials of students have extended from traditional textbooks to educational television, teaching tapes, multimedia discs, the Internet, electronic books and the likes. In fact, many schools have already set up a number of multimedia computers for students to acquire knowledge of different subjects and search information on the Internet through the use of information technology.

Various kinds of entertainment have also been brought by the advancement of technology. Examples are hi-fi systems, music CDs, colour television, recorders, game consoles and computer games. Nowadays, many film producers will add special effects to films which are difficult to produce in the real world with the use of computer animations, such as three-dimensional effects, bringing broad visual stimulations to audience. High-definition standard is widely adopted today as well. The development of technology also provides entertainments with portable music and films.

After the application of technology, household equipment has become more convenient and time-saving. Taking laundry as an example, in the 1950s or 1960s, most people were still using wooden washboards for washing clothes, which was both time-consuming and tiring. When semi-automatic and fully-automatic washing machines were invented, laundry became a lot easier. Nowadays, some washing machines are even equipped with microcomputers to control the washing process and laundry can be done with just a push of a button. Apart from this, the advent of microwave ovens has altered the cooking habits of humans. A microwave oven will not generate heat but it can heat up foods containing water. Other examples of household equipment with technology applied include air conditioners, light bulbs, dishwashers and refrigerators.

A microwave oven

Using an Octopus card

Technological development has also changed the way people trade. In the early days, people traded only through the exchange of money and goods. With the development of technology, American businessmen issued the first credit card in 1950, with other businessmen followed suit soon after. Since then, banks began to install automated teller machines (ATMs) and issue ATM cards. Technology has also made toll collection systems electronic. For example, stored-value tickets have been used by Hong Kong Mass Transit Railway. The Octopus card is an improved product of the electronic toll collection systems. The Octopus card not only can be used for paying the fares for most kinds of transport, but can also be used to store value and pay for the purchases in many retail shops. Coins may no longer be needed in the wallets or pant pockets. May be in the future, chips can even be implanted in human bodies such that bringing a card becomes redundant!

2. The Advent and Development of Telephones

In communications, in the early years, it took a long time for a letter to reach the addressee. With the arrival of telephones, voices could reach a far place in no time. However, even though telephones were invented, due to limited network, most people could not access them freely and the fees to use them were considerably high. As the demand grew, technology continued to develop and production skills advanced, mobile phones emerged. Coupled with the invention of optical fibre, the speed of network rollout has been accelerated. People living in remote areas can now enjoy the convenience of real time communication.

The emergence of smartphones by Apple Inc. is the outcome of the development of tools, equipment, resources and human intelligence. The success of the third and fourth generations of smartphones, together with the market- and profit-oriented driving forces, has encouraged network providers, retail shops, application developers and other accessory producers to focus on developing and producing relevant services or products. Other brands of mobile phone manufacturers such as Samsung and Sony also engage in the production of smartphones and compete for market share, leading to a significant increase and enhancement of the functions of smartphones.

In the past, we need to spend time to visit relatives and friends living somewhere far away. Now we can use social networking applications on smartphones to keep in touch with them instead of visiting them in person.

However, such development does not happen naturally in every corner of the world. The cost of it is very substantial and not everyone can afford it. Apart from this, for certain political and cultural reasons, some governments forbid relevant devices to get into their countries.

These inventions are not restricted to voice communication but also provide instant text and image communication. Moreover, they allow users to search and acquire information they need immediately, as well as to take pictures, take videos, play games, etc. The amount of functions is growing day by day. However, does such development bring only benefits to humans? The problems brought by it will be discussed in the exercise section.

An early fixed-line telephone

A mobile phone

Smartphones

Besides, the influence of technology is twofold. For example, in the era of fixed-line telephones, there appeared the switchboard operators. This occupation phased out at the appearance of other products. When pagers first appeared, due to their technology, price and other factors, many people owned and carried one with them. A large number of page operators thus appeared, which was later eliminated gradually as mobile phones emerged. Formerly, most employees work at the locations and times specified by employers but as communication devices advanced, more and more people can work at home and deliver the outcomes of their work to the employers electronically. People's work, nature of work, work locations and working times are all undergoing changes with the development of technology. The interpersonal relationships among people and among family members, as well as society, are constantly changing too because of the development of communications technology and working pattern.

3. Influence of Market on Technology

A smartphone costing thousands of dollars, plus hundreds of dollar monthly subscription fee, is not cheap at all. What has made it so popular? It is the combined results of market and technology.

As mentioned in the previous section, the first and second generations of smartphones did not catch much attention of the public and their market was not big. As the developer added more innovative technological elements to the third generation smartphones, they became appealing to people. It cooperated with other technology companies in the way that the developer took care of the designs and made requests only, leaving the technology companies to manufacture the parts for it. The fourth generation smartphones hit the market and were well received.

Businessmen who were originally unoptimistic about smartphones spotted their market value and considered their profits even higher than traditional mobile phones. Thus they delved into figuring out newer and better technology, intent to get a share of the market and earn huge profits from it.

Development of hardware (some have been achieved while the others are still under testing):

i. screen with higher resolution;
ii. clearer screen with higher fidelity (3D, 4K, etc.);
iii. shape and ergonomic design (slip-proof, curved screen and body, etc.);
iv. core with faster computing speed;
v. larger memory;
vi. longer battery life;
vii. lighter;
viii. waterproof, shockproof, etc.

Development of software:

i. more user-friendly;
ii. more stable;
iii. taking up less space;
iv. faster response;
v. faster and more accurate input methods (voice-control, handwriting and intelligent input, etc.);
vi. eye-tracking and eye input methods;
vii. clearer output sound;
viii. output of smell is being tested.

Other features such as fingerprint recognition, eye recognition, faster and more stable data connection and paperless transactions are the interactions between software and hardware technology. Some technology is being developed which is not known to the public yet. Businessmen spot the market opportunity in it and thus invest in its related research and development. As a result, the market, in turn, exerts its influence on the rapid development in communications technology.

The market changes rapidly and unpredictably. The US company, Motorola and Canadian company, Blackberry used to produce the leading products in the mobile phone industry. Yet, failing to discover the changing market, they both could not escape from being eliminated.

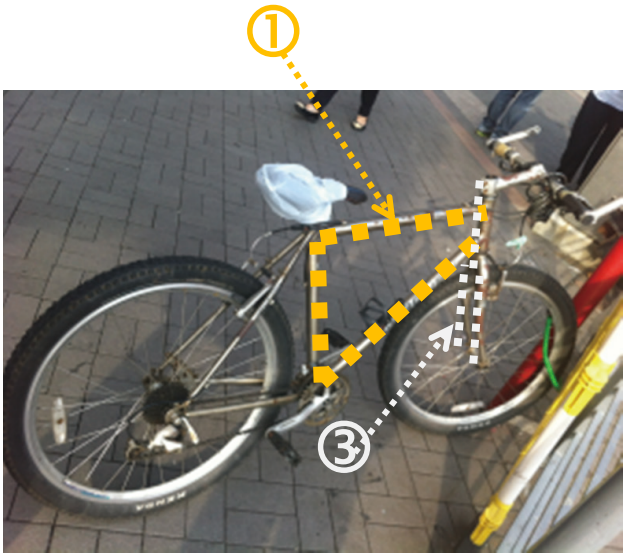
4. Interactive information

	Website	Content
1.	http://tds.ic.polyu.edu.hk/ds/db/08_pd1/index.htm	Basic product design
2.	http://tds.ic.polyu.edu.hk/ds/pd/06_production/index.htm (design and production)	Introduction of the designs for mass production and small-scaled production

Relevant Knowledge

Lesson Activity:

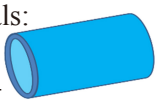
Activity 1 Observe a bicycle, in a group of two, study how its different structures can enhance functionality to suit different needs. Describe your observations by both writings and drawings.



1. The body with a triangular frame: _____

_____

2. The frame made of tubular materials:



_____

3. Y-shaped supports used for both front and rear wheels:

_____

4. What alterations have been made on the structures of the mountain bike shown in the right figure to further enhance its functionality? What will have to be sacrificed?

_____

_____

_____

_____

_____

Activity 2 Weak points exist in most objects. Designers have added reinforcing structures to solve this problem.

Point out the reinforcing structures that have been added to the following two pieces of design. What unfavourable results may occur if they are further reinforced?

Activity 3 As have been pointed out in previous sections, on one hand, smartphones bring us a lot of convenience and change the way we live, but on the other hand, they also cause problems. Two in a group, point out the problems raised and suggest solutions to them.

1. Adverse effect on health:_____

_____

2. Adverse effect on interpersonal relationships: _____

_____

3. Adverse effect on energy use: _____

_____

4. Adverse effect on economy, politics and culture: _____

_____

5. ( ) : _____

_____

6. ( ) : _____

_____

Activity 4 Use words and diagrams to illustrate the functions that you think will be provided in the next generation of personal communication tools. What changes in behavioural patterns and occupations do you think that will happen in society?

_____

_____

_____

_____

_____

Project Activity
– Structure Model of Dynamics

Project Activity Guidelines

1. Objectives

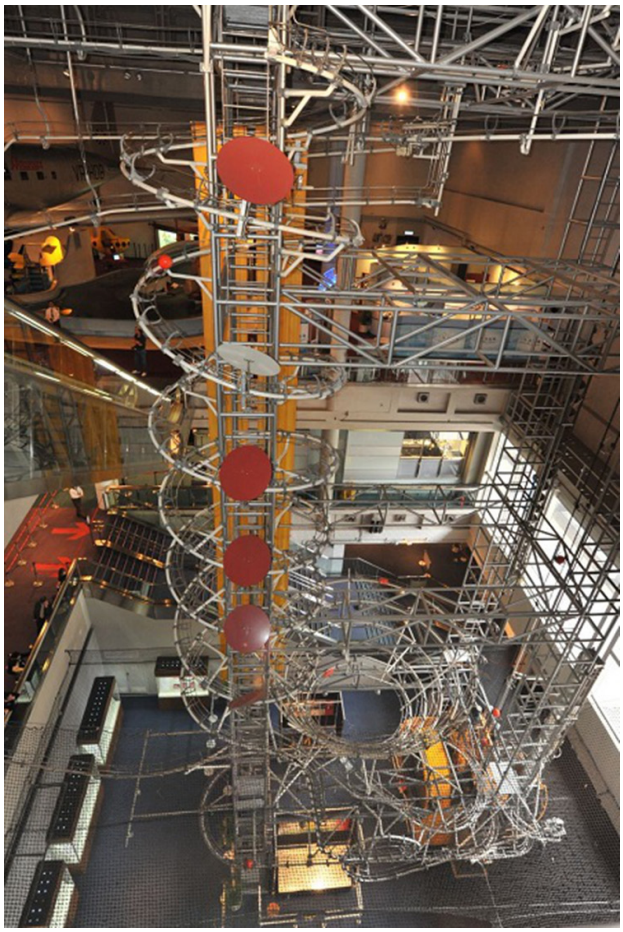
With the knowledge and use of basic marking tools and cutting hand tools, and basic understanding of mechanisms, students will design and make a structure model of dynamics.

2. On completion of the design project, students should be able to

1. understand and apply the main design process;
2. understand and apply simple structures and mechanisms; and
3. use mechanisms to change the forms or output of motion.

3. Situation

Johnson and Collins visited the Hong Kong Science Museum and were fascinated by its largest exhibit, the Energy Machine. After the balls were lifted to the top of the Energy Machine, they saw the balls drive different mechanical parts move, made different motions and created different sounds. They then decided to create a small model each as a gift to children in underdeveloped countries, hoping these children might learn simple mechanical principles through these models and then apply the principles in other areas. Besides, with the consideration that these places do not have sufficient resources, they would choose some simple materials in order to encourage the children to create their own toy stuff with simple materials.



4. Design Brief

Design and make a model of dynamics which must use mechanical components as the moving parts. An example action is to use a rotating or moving action to drive two or more output actions.

5. Recommended Time

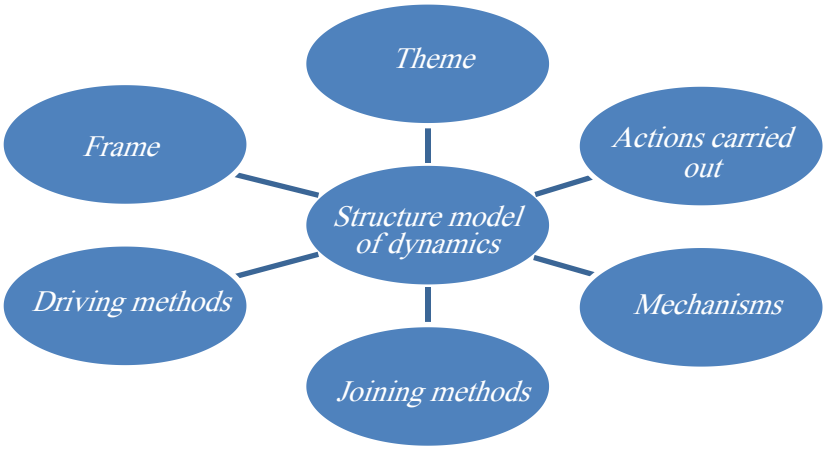
12 teaching periods × 40 minutes (total 480 minutes)

6. Required Materials

Wood, joining materials and hand tools

7. Activity Content

a. Considerations



The following issues should be considered when designing and making the structure model of dynamics.

(i) What is the theme of the structure model of dynamics?

(ii) What actions can it perform?

(iii) What mechanisms should be used to carry out the actions?

(iv) What is the structure of the base?

(v) How to connect different parts?

(vi) What are the driving methods?

(vii) When all parts are connected, will they impede each other?

(viii) What surface finishing methods should be used?

b. Production procedures

(i) Choose a theme.

(ii) Design the appearance.

(iii) Design the actions to be performed.

(iv) Design the connecting and driving methods.

(v) Choose an appropriate material for each part.

(vi) Make each moving part.

(vii) Test each moving part for its movement condition and test the overall movement condition when they are connected.

(viii) Apply an appealing appearance.

(ix) Test the movement condition after fixing the appealing appearance.

c. Design folio

1. Record each idea with a sketch and choose one of the better designs.
2. When finished making the model, examine the basic requirements of the design with experiments. For example, examine whether the structure design, degree of fun, mobility, ease of use, aesthetic level, safety, etc. meet the requirements of the design project.
3. After selecting the final design, specify the dimensions of each part in detail and draw the production drawing to scale.

References:

1. Design specifications:

i. Wood, plastic sheets and cardboards, accompanied by adhesives, paper, bamboo sticks, wire and other materials, are recommended for use in this design project.

ii. The volume should not exceed 150 mm (length) × 100 mm (width) × 150 mm (height).

iii. The design has to be suitable for use by children under 10 years of age.

iv. It is even better if the design is educational.

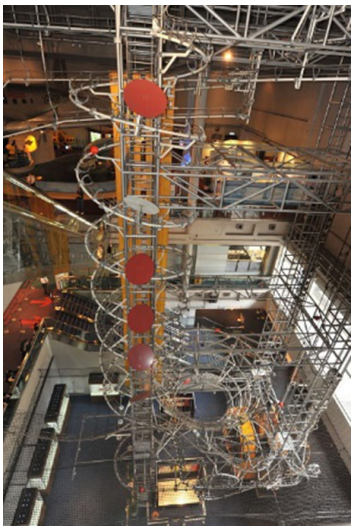
v. The parts can be joined by adhesives or screws but the use of joints is not necessary.

vi. Other standards include:

(a) the finishing for wood surfaces of the design can be done by methods such as painting and waxing;

(b) the appearance of the design must be appealing and attractive.

2. Information collection



a. The Energy Machine of the Hong Kong Science Museum
http://hk.science.museum/en_US/web/scm/pe/energy.html

b. An advertisement of a brand of drinks, starring a range of world-class athletes, shows a series of mechanical motions
http://www.youtube.com/watch?v=M0jmSsQ5ptw

c. Using a series of mechanical motions to squeeze toothpaste
http://www.youtube.com/watch?v=XlTNYU6khGc

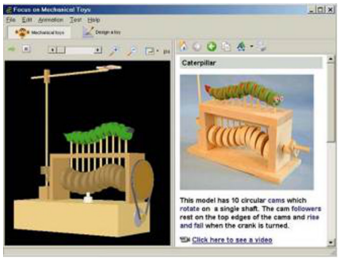
d. A wooden marble machine
http://www.youtube.com/watch?v=MNipg3AVCG4

e. http://www.youtube.com/watch?v=7C155oQfhoU

f. A rubber band machine gun which can shoot 600 of it in a row
http://tv.qooza.hk/watch.php?v=1720&fbc=1344b3

g. A wooden rubber band handgun
http://www.youtube.com/watch?v=iN2VJNxvoLk

h. Downloadable moving toy simulation trial software
http://www.focuseducational.com/product/design-technology-mechanical-toys/22



i. http://www.mechanical-toys.com/mainpage.html

j. http://www.walterruffler.de/Designs.html Paper automata

k. http://www.technologystudent.com/joints/mecty1.htm

3. Mechanical Components

These moving mechanical toys consist of a combination of different mechanical components, which include levers, linkages, cranks, cams, gears, pulleys and racks. Students can try to make one of their own.

a. Lever

A lever is a tough and straight rod that moves around a fixed point. This fixed point is called the fulcrum/pivot. The position at which forces are applied is called the effort and the position of the load is called the load. The main function of a lever is to change the magnitude, velocity and direction of the force applied through altering the positions of and distances between the effort, load and fulcrum/pivot.

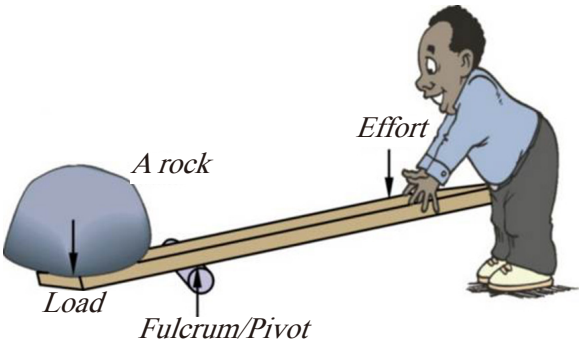
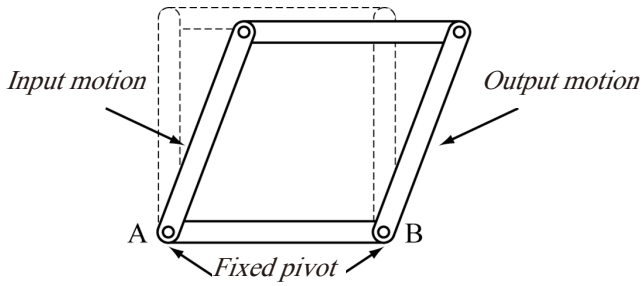


Figure 2.1

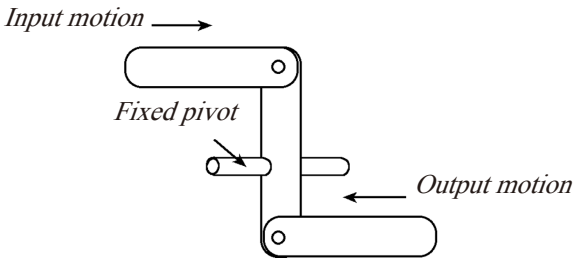
b. Linkage

A linkage mechanism is a mechanism consists of a set of linkages connected using hinged joints or sliding joints. It, on the one hand, transmits motions, and on the other hand, changes the direction of the motions and the power. The following are some common examples of linkage mechanisms.

(i) Parallel-motion linkage

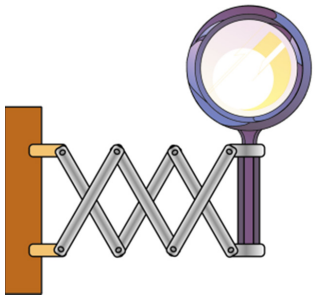


(ii) Reverse-motion linkage



(iii) Right-angled-motion linkage
The input motion is output with a change of 90º. Example: a retractable mirror.

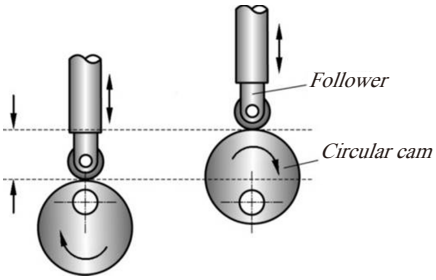
(iv) Rotary motion linkage
Linear motion is changed to rotary motion.



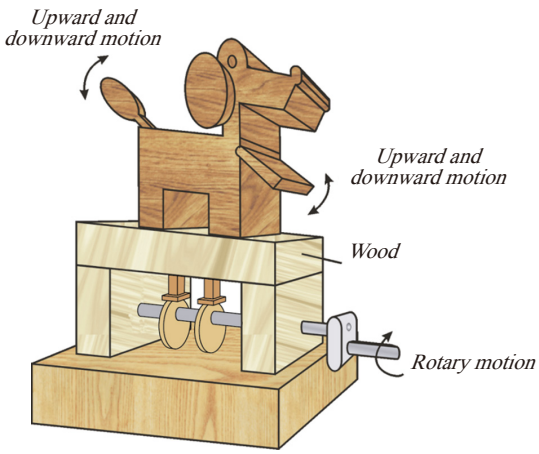
A retractable mirror: reverse-motion and right-angled-motion linkages

c. Cam and follower

A cam is a flat block with a specially-designed shape. Its main function is to transform the input rotary motion into the reciprocating motion of the follower through its eccentric rotation.



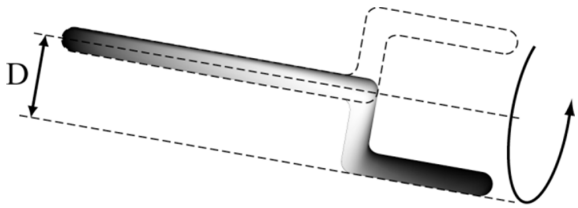
Principle of cam motion



Real example of application of cam motion: rocking horse

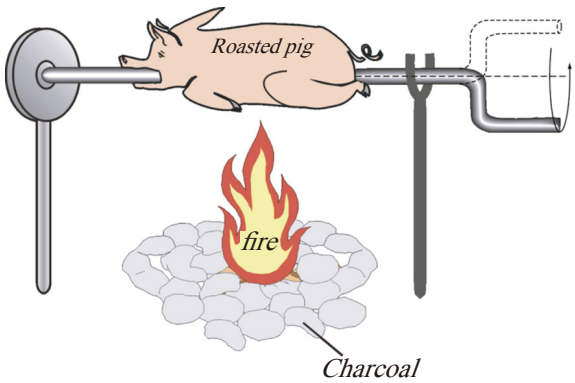
d. Crank mechanism

A crank is a mechanism that transfers torque to the rotating shaft. When providing an input force, the farther it is away from the axis, the greater is the output torque.



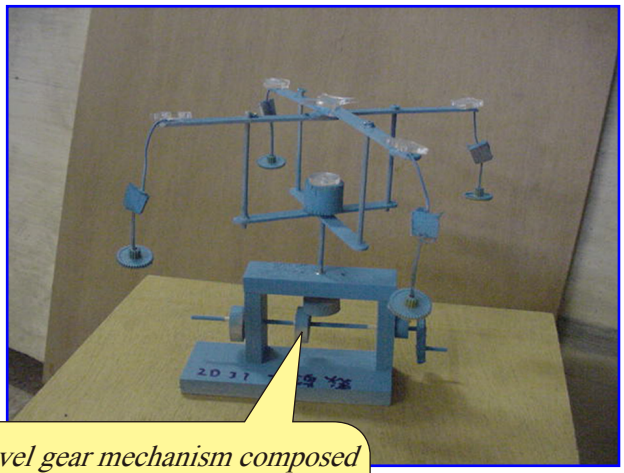
The larger is the distance D, the greater is the output torque.

A crank



The rack for roasting pigs is an example of cranks

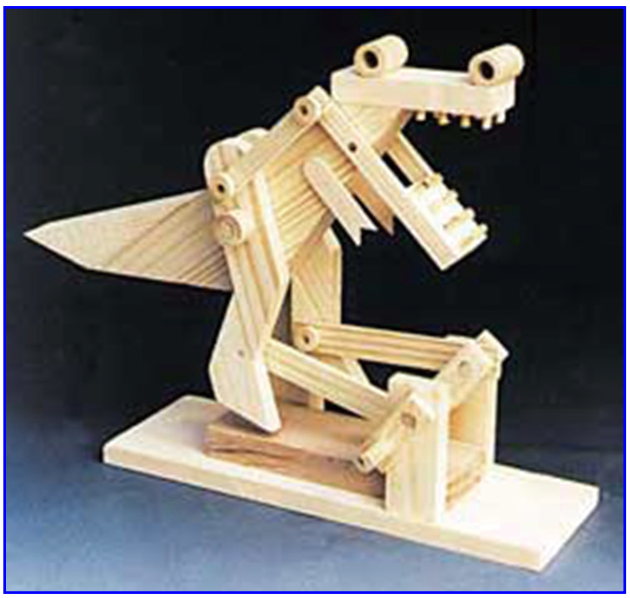
Other examples:



Bevel gear mechanism composed of two circular wood pieces

The bases of the above dynamic decorations were made of 20 mm × 10 mm White wood strips

The following figures show two mechanical linkage toys that can be bought from retail shops or the Internet.



Design Process Record Form

Situation

Johnson and Collins visited the Hong Kong Science Museum and were fascinated by its largest exhibit, the Energy Machine. They then decided to create a small model each as a gift to children in underdeveloped countries, hoping these children might learn simple mechanical principles through these models and then apply the principles in other areas. Besides, with the consideration that these places do not have sufficient resources, they would choose some simple materials in order to encourage the children to create their own toy stuff with simple materials. Would you like to play a part in making structure models of dynamics to give to those children?

Design Brief

(i) The major materials used are _____

(ii) The mechanical components such as levers and linkages are required to drive the moving parts of the design.

Design Specifications

(a) Materials:

Name of material	Dimensions	Quantity	Remarks
Major material	_mm × _mm × __mm (length × width × height)		
Round sticks	Diameter _____mm Length_____mm		
Other materials			

(b) The volume does not exceed

_____mm × _____ mm ×_____mm。

(c) Purposes of the design

(i)Suitable for use by children under 10 years of age

(ii)An educational design is even better

(d) Joining methods:

(i) _____

(ii) _____

(iii) _____

(e) The design project is finished within_____periods (from_____ (date)_____(month) to _____(date)____(month)).

(f) Other standards:

(i) the appearance of the design is appealing and attractive;

(ii) finishing process has been applied to the surfaces of the design; and

(iii) others: ： _____

Information Collection

(a) Finished products sold on the market:

(Can be searched from newspapers, magazines and the Internet.)

The Design

(a) The initial ideas (sketch of the design)

(b) The final idea after modification

(Related dimensions must be labelled on the production drawing.)