Design and Applied Technology
(Secondary 4 - 6)

Learning Resource Materials

Technological Principles

Strand
II

Nature of Technology

Production Process

System and Control

Design and Applied Technology

(Secondary 4 – 6)

Compulsory Strand 2
Technological Principles

[Learning Resource Materials]

Resource Materials Series
In Support of the Design and Applied Technology Curriculum
(S4 – 6)

Technology Education Section
Curriculum Development Institute
Education Bureau
The Government of the HKSAR

Developed by
Institute of Professional Education
And Knowledge (PEAK)
Vocational Training Council

Technology Education Section
Curriculum Development Institute
Education Bureau
The Government of the Hong Kong Special Administrative Region
Room W101, 1/F, West Block, Kowloon Tong Education Service Centre,
19 Suffolk Road, Kowloon Tong, Hong Kong

Reprinted with minor amendments 2010

Project Advisor:

Mr. O Hin Ming, Brian	(Head, Department of Engineering, IVE/ Tsing Yi, VTC)

Authors:

Miss Chan Yat Ning, Vicky	(Teaching Associate, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Cheng Che Yung, Andrew	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Chu Kin Cheong	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Fung Ka Shuen	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Fung Siu Kei, Ringo	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Lau Hok Keung	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Dr. Lo Ka Wah, Joe	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Lee Tak Wai, Geddy	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Dr. Shiu Yiu Cheung, Greg	(Senior Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)
Mr. Wu Yat, Kevin	(Lecturer, Department of Engineering, IVE/ Tsing Yi, VTC)

Project Coordinators:

Mr. Li Yat Chuen	(Senior Training Consultant, PEAK/VTC)
Mr. Tsang Siu Wah	(Training Consultant, PEAK/VTC)

CONTENTS

INTRODUCTION

The world and her civilization have made noted advancement in the last 100 years; the reasons are mainly due to the flourishing of inventions and new technologies during the period. People make use of inventions to introduce new applications which need new technologies to make products better and finally spin off to renovation. Invention, technology and renovation form a spiral circle with one chasing another. In the 21st century, we have seen people living in a world in which they can achieve almost everything that they want to and get whatever they want to have.

Products are the results of invention, technology applications and innovations; almost all products serving people are powered by some form of energy. The world has limited natural energy resources and the issue is how human beings can harness energy appropriately so that the energy in the world can last longer and cause least problems to the environment.

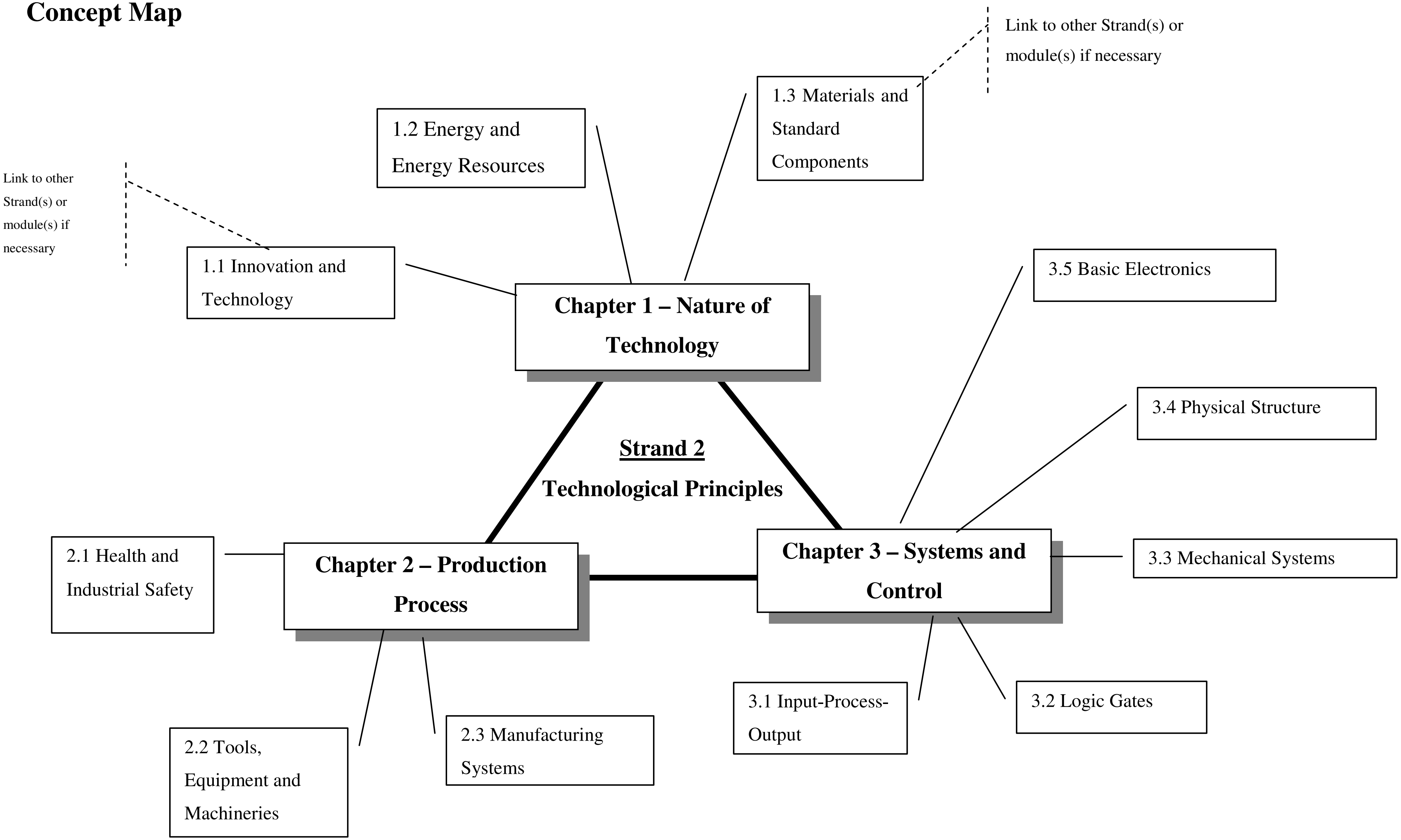
Materials exist in the form of natural resource or synthesized. People utilize different properties of materials for different applications such as high tensile alloy for aircrafts and tin for beverage cans. People are paying attention to the economical use of materials and the impact to the environment from material disposal.

Chapter one "Nature of technology" of this Learning Resource Materials highlights the importance of invention, innovation and technology and the differences among them. The use of energy and how energy can be efficiently exploited in real life applications are discussed. Students will be introduced to understand material properties and their applications in engineering work.

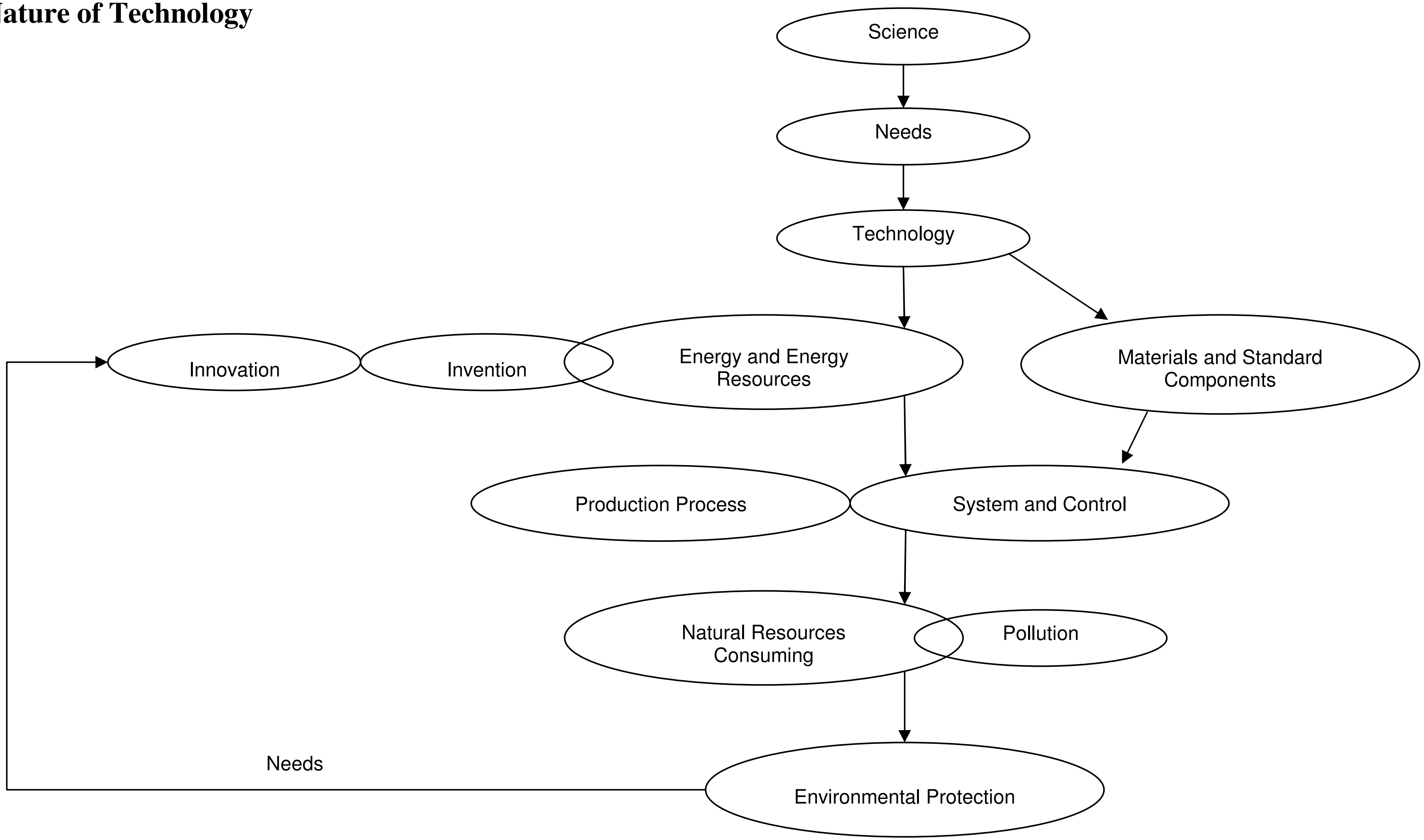
Manufacturing of products need to rely on tools, equipment and machinery. Their appropriate uses in manufacturing processes or during the repair and maintenance work have significant bearing on the safety and health of the operators. Chapter two "Production Process" will discuss the appropriate use of tools and their safety precaution in using them. Different manufacturing systems are discussed and how they help the manufacturing process in producing quality products at lower cost and shorter time.

The design and build of manufactured products require the application of engineering knowledge. Fundamental “Systems and Control” are presented in Chapter three with an aim to allow student to learn the fundamental engineering principles including input-process-output, logic gates, mechanical systems, physical structure and basic electronics.

Concept Map


Link to other Strand(s) or module(s) if necessary
1.3 Materials and Standard Components
1.2 Energy and Energy Resources
Link to other Strand(s) or module(s) if necessary
1.1 Innovation and Technology
Chapter 1 – Nature of Technology
3.5 Basic Electronics
3.4 Physical Structure
Strand 2
Technological Principles
2.1 Health and Industrial Safety
Chapter 2 – Production Process
Chapter 3 – Systems and Control
3.3 Mechanical Systems
3.1 Input-Process-Output
3.2 Logic Gates
2.2 Tools, Equipment and Machineries
2.3 Manufacturing Systems

Nature of Technology



An example for interpreting the nature of design, learning attitude and the relation between design, technology and business

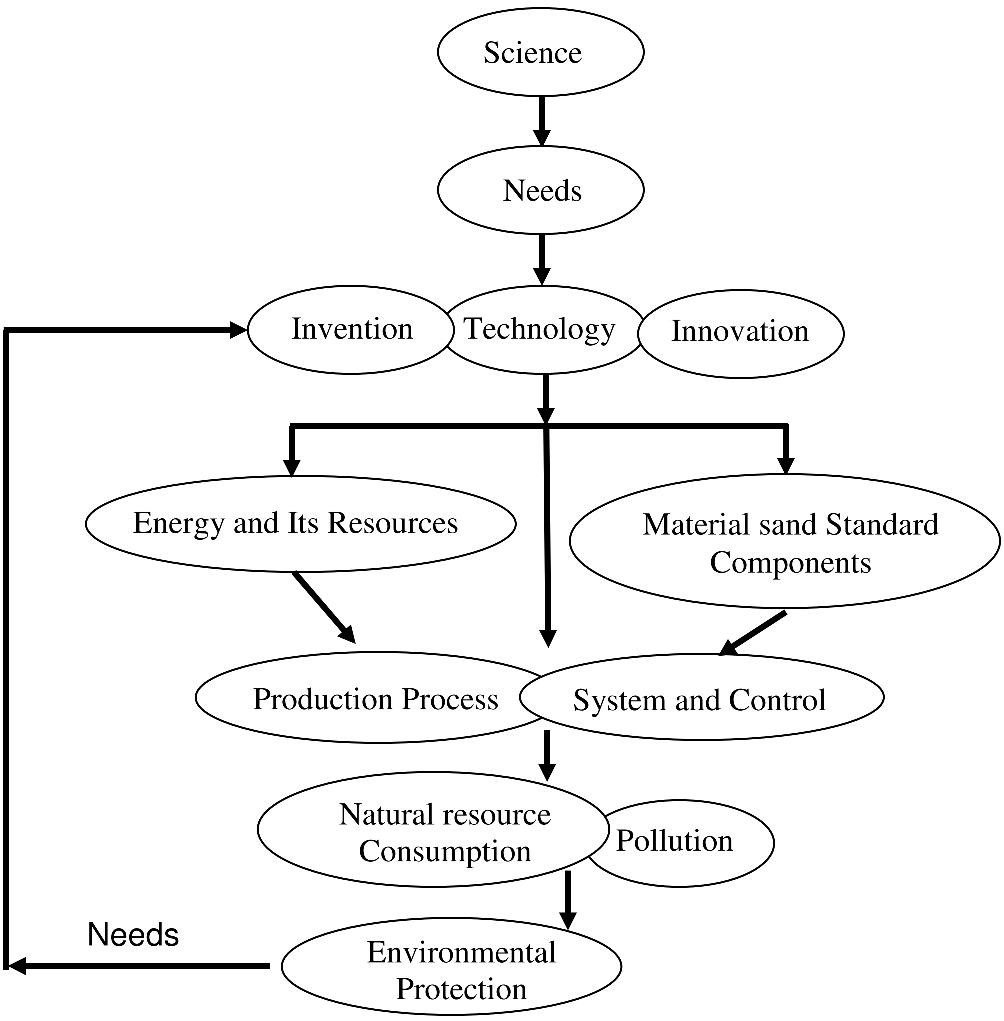
CHAPTER 1 – NATURE OF TECHNOLOGY

This chapter covers the following topics:

(a) Innovation and Technology
(b) Energy and Energy Resources
(c) Materials and Standard Components

These topics along with resource materials and activities facilitate the students' understanding of:

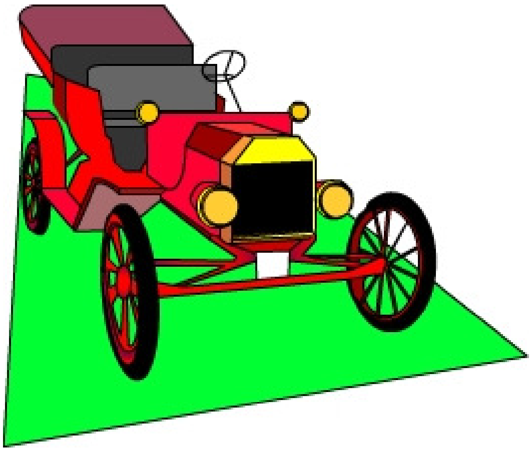
(a) The nature of technology;
(b) The systems of energy sources and naturals resources;
(c) Energy consumption in product operations and its impact on design; and
(d) The properties of commonly used materials.



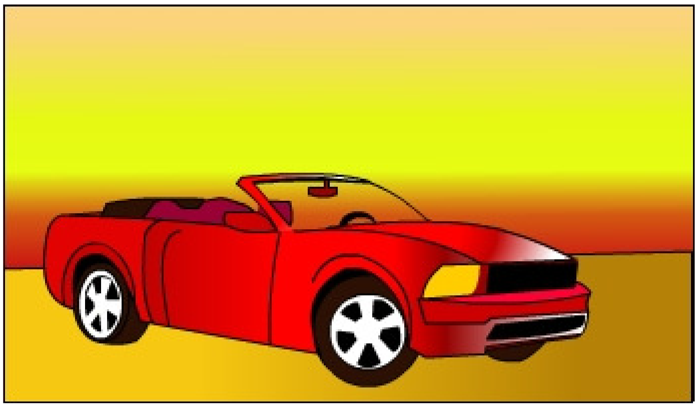
1.1 INNOVATION AND TECHNOLOGY

An invention is an object, process or technique that has a novelty value. It may be inspired by earlier developments, collaborations, ideas or else. The invention process requires the awareness of the potential of an existing concept or method being modified or transformed into an invention. Some inventions may result from drastic breakthrough in science and/ or technology that extend the boundaries of human knowledge.

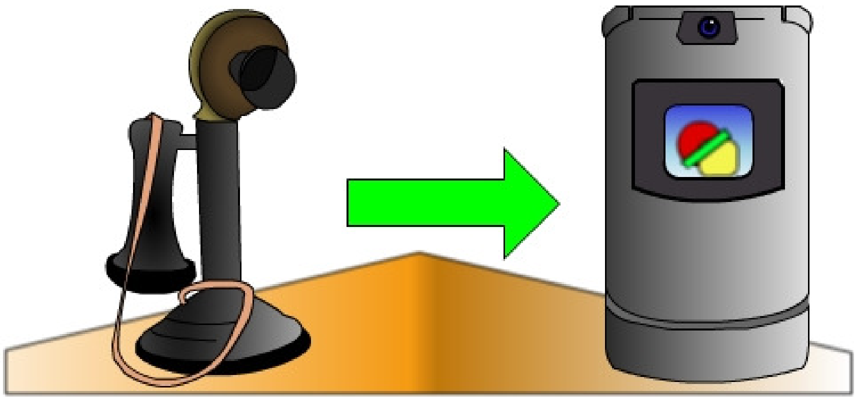
An invention is different from an innovation: An invention is theoretical, whilst an innovation is an application of an invention. Innovation may also be regarded as an improvement of a process or invention.



Invention of car



Innovation of car



Invention Innovation

Octopus System is an innovation in collaborating different ideas and technologies, such as the inventions of cards, Radio Frequency (RF) sensors, detectors and computing machines.

Technology is the achievement of science and engineering. Apart from the narrow interpretation of ‘technology’ that refers to, for example, machines, hardware or utensils, it covers broader concepts, such as systems, organization methods and techniques.

Technology can either be applied generally or specifically. Specific areas include ‘construction technology’, ‘medical technology’ and ‘state-of-the-art technology’. For example, studying wind power falls into science’s fields, while studying how wind power is used for production of electricity is a topic of technology and engineering.

Technology and its effects are ubiquitous. For instance, technology facilitates economic development, construction of high-rise buildings and magnificent bridges, and improvement of the living quality.

Unfortunately, many technological processes have adverse impact on the Earth through, for example, producing unwanted by-products or pollutants, and depleting natural resources.

Implementation of some technologies changes the values of a society or raises new ethical questions. The concept of efficiency for human productivity is an example. Originally, efficiency is applied only to machines.

Examples of the integration of technologies and engineering works:

Tsing Ma Bridge

The Hong Kong International Airport

STOP AND THINK
Give an example of an innovation which is originated from an invention.

1.2 ENERGY AND ENERGY RESOURCES

New inventions and innovative designs have kept coming up since the invention of electricity and micro-controllers. Products of cars, lighting, refrigerators, televisions, computers, air-conditioners, cookers, etc have improved people's living quality. Energy sources thus become critical for the reliance of all these products.

The most common energy source is electricity. Nowadays, owing to the limited energy resources and the higher cost of energy, many products are designed as energy efficient as possible. Such a design objective can be reached through since the very first stage of a design. For example, the suitability of materials and driving devices, feedback from sensing devices and control by micro-controllers all have to be considered.

The use of energy from gas for cooking

The transformation of heat energy by means of electricity

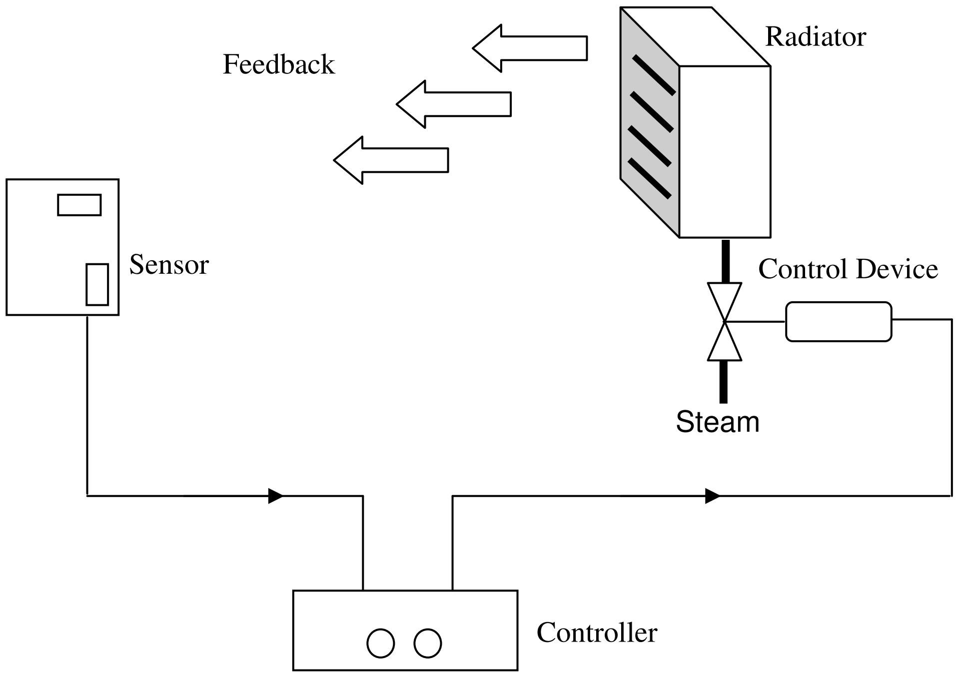
The transformation of electrical energy to light energy

1.2.1 Control Systems

A temperature cooling system is an example of a control system as shown below. In the control system, the radiator regulates the temperature of the steam. The main purpose of having a system under some kind of manual or automatic control is to guarantee that the system is regulated or monitored for the performance stipulated. The system contains several key components, including the sensor, the controller, the controlling device (with an actuator) and the controlled device. The functions of the components are clearly shown in the example below.

(a) The sensor is a temperature sensor. It provides feedback of the radiator temperature to the controller.
(b) The radiator is the controlled device. It cools down the steam temperature by means of evaporation and radiation.
(c) The steam valve is the controlling device. It regulates the amount of steam passing through. The opening or closing position of the valve is controlled by the controller using an actuator.

In this control system, the steam energy is in the form of heat. It is removed from the steam. The energy required for the control is the electricity required in the sensor, controller and actuator. This control system is adopting a similar working principle to many control systems used in air-conditioners.



1.2.2 An Energy Conversion Process

A bicycle is a human-powered vehicle. The basic components of a typical bicycle include a supporting frame, a pair of wheels, a pair of pedals, a saddle, and a handlebar.

Energy is provided for a bicycle by the person who rides on with power exerted on the pedals. Through the chain between the pedals and the rear wheel, the driving force pushes the bicycle forward. The energy conversion in moving a bicycle is the process in which the cyclist uses energy to overcome the friction on the road for the bicycle's moving along. In some cases, gears are installed for extra mechanical advantage, facilitating the cyclist's riding on an uphill road.

A multi-geared bicycle

Mountain bicycle

Handlebar of a multi-geared bicycle

Handlebar of a mountain bicycle

There are different designs of bicycles to suit different purposes. For example, racing bicycles are made with lightweight, shaped aluminium tubing and carbon fibre stays and forks. They have drop handlebars and thin tires and wheels. This design is mainly for efficiency and aerodynamics.

Mountain bicycles are designed for long distance and rough surface riding. Such a bicycle thus has two disc brakes, a full-suspension frame and oversized tires, in addition to a handlebar that is perpendicular to the axis of the bicycle.

1.2.3 <u>Energy Resources</u>

Fossil fuels (coal, oil), natural gas, nuclear, and renewable sources of energy are examples of common energy resources. Since the 19th century, the sources of energy used for industrial and domestic purposes worldwide are mainly the natural resources of coal, oil and natural gas as well as nuclear energy.

It is estimated that the world's coal, oil and natural gas will be used up in 165, 41 and 63 years respectively. Another concern is the by-products that are generated from energy consumption or during energy conversion. These by-products are polluting the environment at an alarming rate.

It means that human beings need to better utilize the existing, remaining natural resources on one hand. On the other hand, human beings need to plan for sustainable development. Many of the by-products are wastes or pollutants. Liquid, solid and gases wastes are released during energy conversion and result in acid rain, smog (particles) and gases (carbon dioxide, nitrogen dioxide and sulphur dioxide).

Emission from plants causing air pollution

Using renewable and clean sources of energy is a better solution to improve the environment. Solar, hydro, wind, tidal, biomass, and terrestrial heat are some of the common sources for generating power to satisfy our needs for their virtually unlimited and basically clean nature. The prevailing technology, unfortunately, still cannot handle two major problems of such renewable energy sources: One is price and the other one is mass production.

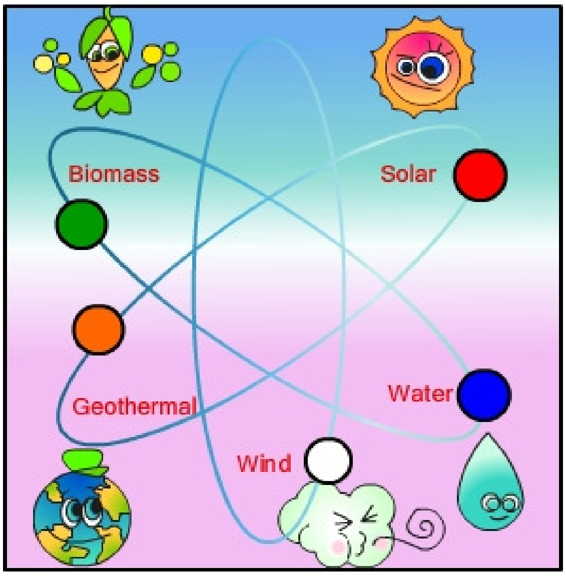
The cost for exploring renewable energy sources is much higher than that for fossil fuels. In addition, the volume obtained is much lower than that from fossil fuels.

Therefore, plans for sustainable development have to address

(a) Reduction of the level of waste emissions,

(b) Expansion of the use of renewable energy sources, and

(c) Promotion of energy saving and efficiency.



Clean energy for the generation of electrical energy

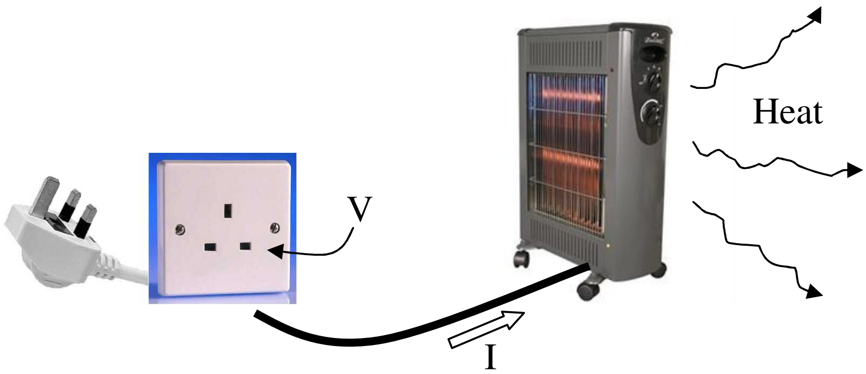
Energy equations

(1) Electrical energy: E = Voltage x Current x Time (unit Watt-hour)

For example, the energy input to a heater for heat energy transformation comes from three components, namely

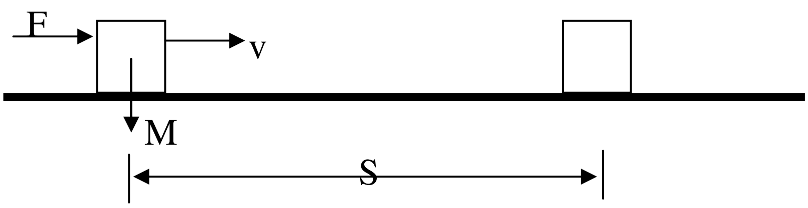
(a) Voltage from a 13-A socket,
(b) Current passing through the conductor, and
(c) Operating time of the heater.

The normal unit for electrical energy is kilowatt-hour, kWh.



(2) Mechanical energy

Kinetic energy = Force x Displacement
= Fs
= $1/2\ mv^2$



where $F = ma$ (Newton N)

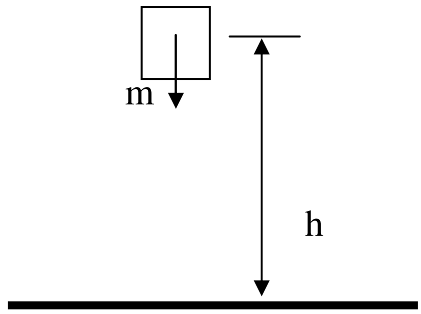
m = mass of the moving object (kg)

v = velocity of the moving object (m/s)

a = acceleration (m/s^2)

The energy unit is Joules, J.

Potential energy = mgh



where m = mass of the dropping object, kg

g = acceleration due to gravity, 9.81 m/s^2

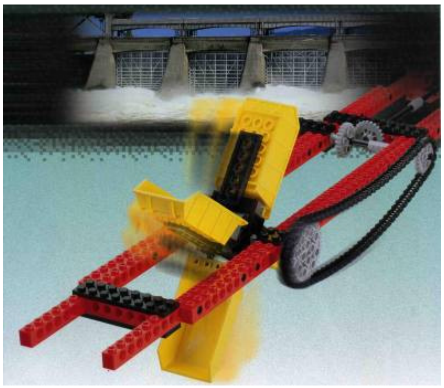
h = height

S T O P A N D T H I N K

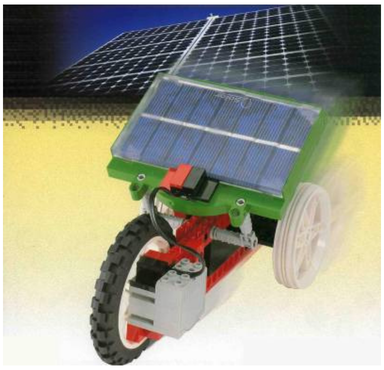
Study how energy is used in the following models

(a) Wind energy

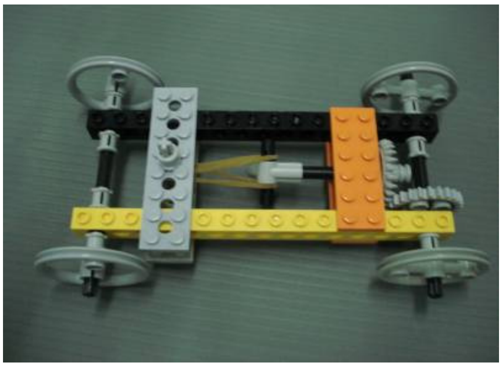
(b) Water energy



(c) Solar energy



(d) Mechanical energy (rubber band)



1.3 MATERIALS AND STANDARD COMPONENTS

All inventions, engineering applications and appliances require materials. Nanotechnology has brought numerous inventions, particularly cosmetics and chemical products, to the world. If there had been no materials, human beings would not have been able to build so many advanced and magnificent engineering constructions, such as Two ifc and Tsing Ma Bridge.

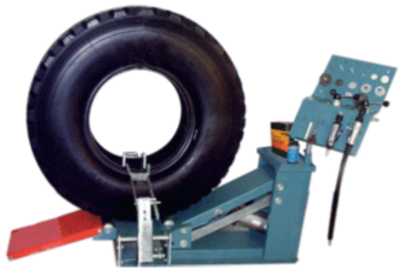
Generally speaking, there are three different categories of materials, namely

(a) Natural materials, such as aluminium, gold, lead, rubber and wood;
(b) Processed natural materials, such as cement, paper and alloy, and
(c) Synthetic materials, such as acrylic plastics, foam boards and glass.

Making best use of materials with their individual properties taken into consideration can help manufacture safe products that improve our living quality.


Copper


Alloy – steel


Rubber


Foam board


Acrylic plastics


Glass

1.3.1 Material Properties

Material properties can be categorized into physical and mechanical properties.

(a) Physical properties

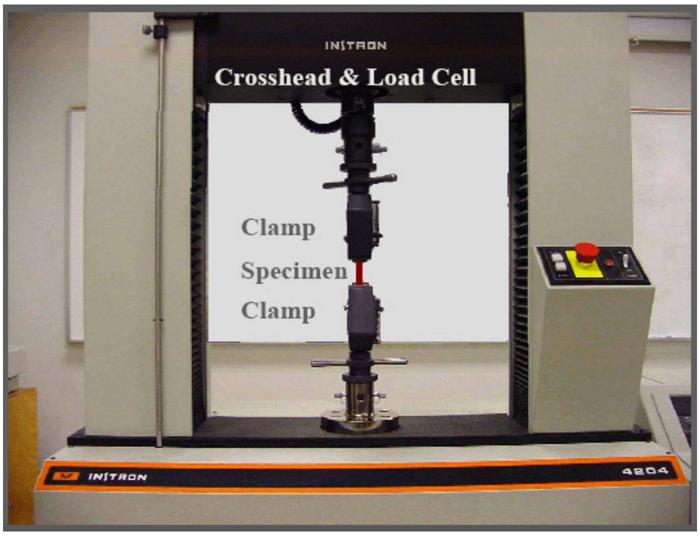
Physical properties of materials do not change under any external forces. For example, the melting point of ice, i.e. 0°C, remains unchanged regardless of what kind of heat energy is applied. Apart from melting point, other common physical properties of materials include

(i) Boiling point,
(ii) Coefficient of linear expansion,
(iii) Density,
(iv) Electrical conductivity,
(v) Latent heat of fusion,
(vi) Latent heat of vaporization,
(vii) Specific heat capacity, and
(viii) Thermal conductivity.

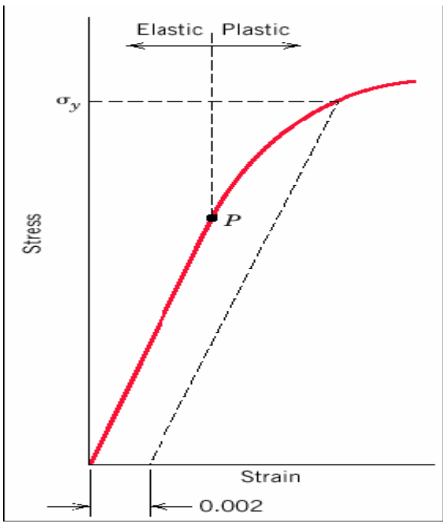
(b) Mechanical properties

Mechanical properties are the characteristics shown when forces are exerted on materials which are in solid state. Some common mechanical properties are

(i) Tensile and compressive strength,
(ii) Ductility,
(iii) Hardness,
(iv) Malleability,
(v) Stiffness, and
(vi) Toughness.



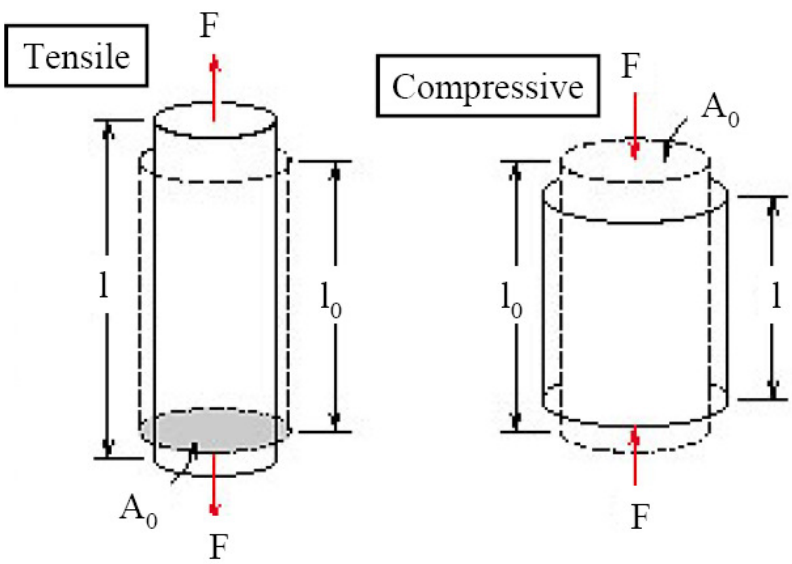
Tensile Testing



(i) Tensile and compressive strength

Tensile strength measures how a material is able to withstand deformation when stretched. For example, materials of good tensile strength can be used to make steel cables in cranes.

Compressive strength refers to the capacity of a material to keep its original form, resisting deformation, when compressed. Steel is used for making the outer cases of cars because of its high compressive strength. This characteristic enables a car to resist the compressive force that the car is encountered in a car clash.



(ii) Ductility

Ductility describes how a material is able to keep its strength without fracturing when stretched out. Copper and tin are materials of good ductility. The property enables them to be materials for wires, such as copper and tin wires.

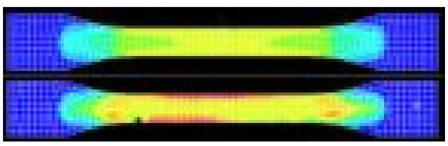
(iii) Hardness

Hardness refers to the ability that a material resists to be cut, penetrated and grinded. A material is usually brittle or easily fractured if it is hard.

(iv) Stress

Stress is the internal force per unit area in an object under external forces. A normal stress (σ) is perpendicular to the cut surface and defined as follows:

$$\sigma = \frac{P}{A} \quad \text{N/m}^2$$



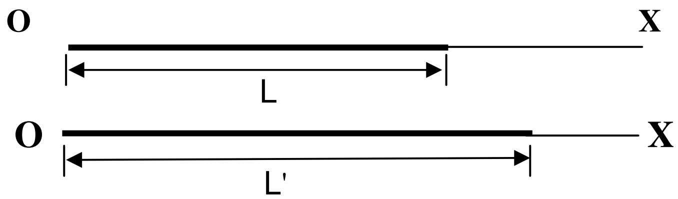
(v) Strain

Strain geometrically measures deformation. It refers to the relative displacement that particles apart within a material body, or measures how much a particularly displacement is different locally from a rigid-body one.

Normal strain measures how large the stress of compression or stretch along a material line is. Shear strain measures how large the stress of distortion on along the sliding face of a material. Strain is a measurement of no dimension in decimal fraction, percentage or ‘parts-per’ convention.

Assume that there is a rod with an initial length of L and stretched length of L'. Strain measure (ε) is the ratio of elongation to the original length. It is a dimensionless ratio.

$$\varepsilon = (L' - L)/L$$



(vi) Elastic Limit

An elastic limit refers to the maximum stress that allows all deformation strains to be fully recoverable. In many cases, this limit is considered the practical upper limit of stress that a component can resist and function as originally designed. Beyond the elastic limit, permanent strains will deform the material, making its function impaired.

A proportional limit is the maximum stress that stress is still linearly proportional to strain. In most cases, it equals the elastic limit.

1.3.2 <u>Maximize the use of materials</u>

Design specifications and requirements of the material properties need to be taken into consideration to maximize the use of materials when materials are selected for production of a product. For example,

(a) Suitability of material properties,
(b) Environmental friendliness of materials,
(c) Requirements on the surface finishing,
(d) Cost of materials against production budget,
(e) Manufacturability,
(f) Compatibility with the design as a whole, and
(g) Standard against tailor-made components.

1.3.3 Material used in beverage containers

Owing to its material properties as follows, tin is commonly used for beverage containers:

- Being recyclable;
- Being squashed for storage;
- Good ductility, allowing containers to be pulled without cracking;
- Low density, reducing the container weight; and
- Softness, enabling tin to be sealed easily and water proof

H I G H L I G H T

Material properties

Explain what properties the materials should carry for the purposes of the following items

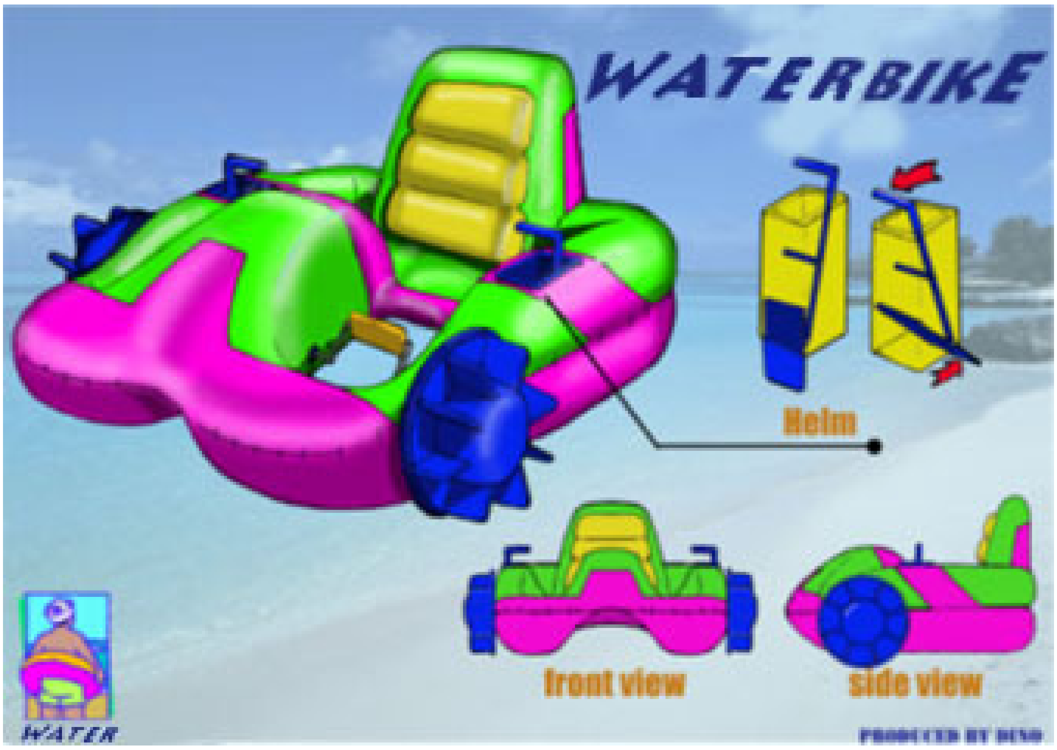
Service ladder

Mountaineering bike

D O T H E R I G H T T H I N G

Select suitable materials for the new product shown below by taking the following into consideration:

a) What materials can meet the purpose?
b) Where can these materials be found?
c) Will tailor-made or standard parts be required?



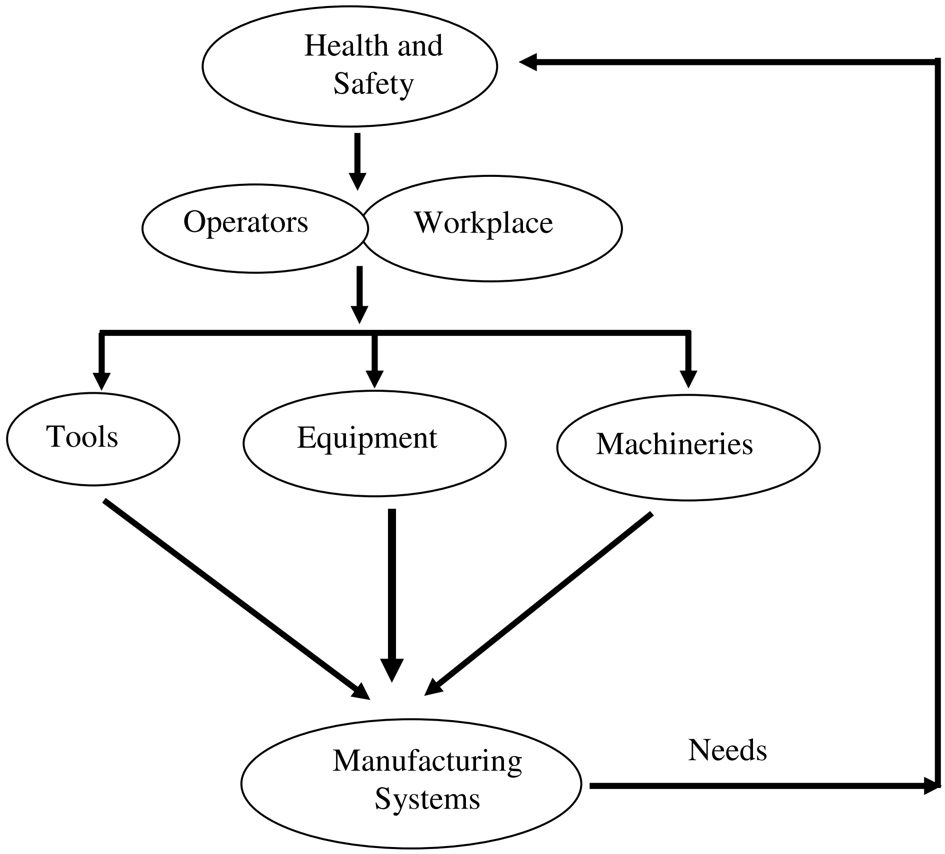
CHAPTER 2 – PRODUCTION PROCESS

This chapter covers topics on:

(a) Health and Industrial Safety;
(b) Tools, Equipment and Machineries; and
(c) Manufacturing Systems.

These topics along with resource materials and activities facilitate students to:

(a) Be aware of safety precautions in the workplace;
(b) Select and use appropriate tools and equipment;
(c) Execute appropriate fabrication processes; and
(d) Understand different manufacturing systems.



2.1 HEALTH AND INDUSTRIAL SAFETY

Everyone should work in and play a role to create a safe and healthy environment.

Each employer has the roles of:
(a) Providing and maintaining plans and work systems that do not harm safety or health;
(b) Providing staff with all necessary information, instructions, training and supervision for safety and health;
(c) Providing and maintaining safe access to emergency exits; and
(d) Using suitable equipment and following system or work practices provided by their employers.

Premises occupiers should also ensure the safety and health of all people working on the premises, no matter who is / are the direct employer(s).

2.1.1 <u>Safety Precautions in the Workplace</u>

(a) Accidents Prevention

To ensure
(i) The workplace is properly designed, constructed and maintained;
(ii) All dangerous parts are effectively guarded; and
(iii) All dangerous areas are fenced.

(b) Fire Prevention

To ensure
(i) Illuminated 'EXIT' signs are provided over all exits;
(ii) Clear directions to exits are provided;
(iii) All passages are in a safe condition and free of obstruction;

(iv) All exit doors are unlocked; and
(v) Suitable and adequate fire safety measures are provided.

Some common fire hazards have been listed below:
(i) Accumulation of inflammables, such as rubbish and paper;
(ii) Careless disposal of lighted cigarettes or matches;
(iii) Improper handling and over storage of dangerous substances;
(iv) Improper maintenance of fire service installations and equipment;
(v) Improper storage or overloading of electrical wiring, plugs and sockets;
(vi) Inadequate cleaning of work areas;
(vii) Keeping inflammables close to sources of heat;
(viii) Leaving unused electrical equipment switched on; and
(ix) Obstruction of heater, machinery or office equipment ventilation.

Having good housekeeping of and awareness to fire precautions can reduce the possibility of having fires. The checklist below can act as guidelines:
(i) Check regularly to ensure that electrical wiring, plugs and sockets are correctly fused and are not overloaded;
(ii) Clean regularly all work areas;
(iii) Do not keep useless inflammable materials, such as rubbish and wastepaper;
(iv) Keep inflammables away from source of heat;
(v) Keep machinery and office equipment regularly cleaned;
(vi) Keep necessary inflammables in right quantity and in appropriate locations;
(vii) Properly maintain fire services installations and equipment.
(viii) Turn off all unused electrical equipment;

(c) Safe, Healthy and Hygiene Working Environment

It is important to keep the workplace clean and ensure it is bright and ventilated enough for working. Adequate drainage, lavatory and washing facilities should also be provided.

(d) First Aid in the Workplace
First aid facilities should be available in the workplace. All first aid items should be maintained such that they are always ready and good for use. According to the instruction of Education Bureau, the school workshop should have a suitably equipped first aid box including the following items:

(i) Vinyl gloves,
(ii) Antiseptics,
(iii) Cotton wool,
(iv) Sterile adhesive dressings,
(v) Sterile dressing/ gauze etc.

Reference link:
http://www.edb.gov.hk/FileManager/EN/Content_4665/Safety%20in%20School%20Workshops%20booklet_Eng.pdf

(e) Good Housekeeping in the Workplace

Effective housekeeping gets rid of potential hazards, making jobs done safely and properly. It serves as a basis of accident and fire prevention. On the other hand, poor housekeeping hides hazards, frequently leading to accidents.

The benefits of good housekeeping practices include:
(i) Having better control of tools and materials;
(ii) Having fewer tripping and slipping accidents work areas;
(iii) Having more efficient equipment cleanup and maintenance;
(iv) Improving preventive maintenance and thus reducing property damage;
(v) Improving staff morale;
(vi) Moving materials more smoothly;
(vii) Providing better hygienic conditions for better health;
(viii) Reducing chance that workers are exposed to dangerous substances;
(ix) Reducing fire hazards; and
(x) Using space more effectively.

STOP AND THINK

a) Explain the importance of a safe and healthy working environment .
b) State what a worker should do before working, in order to ensure the safety at work.
c) State what a worker should do in case of accident.

2.2 TOOLS, EQUIPMENT AND MACHINERIES

Human beings make use of different tools, equipment and machineries to carry out jobs required for the physical strength or capability of attaining high precision that are beyond their limitations. Having said that work safety cannot be ignored. Therefore, workers have to handle tools and equipment in an appropriate manner so that the jobs can be completed safely without causing any health problems to anyone around.

2.2.1 Right Tools, Equipment and Machineries for Right Jobs

Most accidents are caused by having overlooked safety precautions when tools and equipment are used. For example, some people were hurt or struck by some tools that had been misplaced or misused. A prolonged use of the same tools or improper selection of tools can also result in muscular-skeletal diseases.

Users should always use appropriate tools, equipment and machineries in a suitable way. Some common safety measures are listed below:

Hazards in the Workplace	Safety Measures
Electrical current	(a) Ensure that metallic parts of tools, equipment and machineries are earthed; and (b) Ensure that electrical circuits are protected against earth leakage
Electrical wiring	Properly install wiring and avoid dangling or exposed electrical wires
Measuring instrument	Use measuring instruments to ensure the safety of the working environment
Nails or sharp pieces	(a) Wear safety shoes; and (b) Remove sharp pieces or unused nails from floor
Protective gears	Wear protective gears, such as helmet, gloves, shoes or safety vest/belts, when necessary
Space	Provide workers with sufficient working space
Tools, equipment and machineries	(a) Use proper tools, equipment and machineries for jobs; and (b) Ensure that they are safe for use
Work at height	Use ladders or work platforms for jobs at height

2.2.2 Metal Shaping

Sometimes, materials are shaped to required dimensions for designated purposes of work. This process is known as metal shaping. Examples of tools used for metal shaping are listed below:

Tool	Purpose
Drill	Make holes
File brush	Remove debris
Files and rasp	Smooth surface
Mallets or hammers	Shape work piece by force
Punch	Make holes
Saw	Cut materials
Scriber	Draw lines
Steel ruler and callipers	Measure length
Sniper	Cut thin metal sheet

A file or hand-file is a tool for shaping hard materials by abrasion. A typical file has
(a) A hardened steel bar covered with sharp, parallel ridges or teeth; and
(b) A narrow, pointed tag at one end for fitting a handle.

A rasp is a tool for woodwork. It is large and has raised, pointed teeth on its surface.

General Safety Precautions

(i) Management should set up a system to examine the conditions of tools, examining whether they are well-constructed without any defects. Tools that are worn out or damaged and cannot be fixed should be discarded immediately.
(ii) Hand tools, especially their cleanliness, should be checked every time before use.
(iii) Choice of hand tools should be careful. Suitable tools should be chosen for different jobs. The handle of a tool should fit the hand of the operator in order to avoid being slipped from the operator's hand.
(iv) Hand tools can only be used for purposes they are designed for. It is because the material strength of a tool is selected according to the nature of work to be used. If tools are misused, they may be fractured or even cause danger to the operators or other people.
(v) Hand tools should be kept in a proper toolbox or tool-belt.
(vi) Operators should check work pieces for any protruding metal parts that may damage hand tools every time before work.
(vii) Operators should use hand tools in appropriate posture and with suitable strength.
(viii) Operators should concentrate on their own jobs especially when using hand tools. Playing with hand tools should be strictly prohibited.
(ix) Operators should wear approved goggles for protection of eyes from flying metal or wooden pieces or filing.
(x) Tools with sharp edges should be handled carefully.
(xi) Metal piece should be fastened in vice and all tools should be placed in a suitable place after use.

Metal Files

Rasp

2.2.3 **Forging**

Forging refers to metal shaping by plastic deformation. Conventionally, forging is done under high temperatures for softening metals more easily and less fracture.

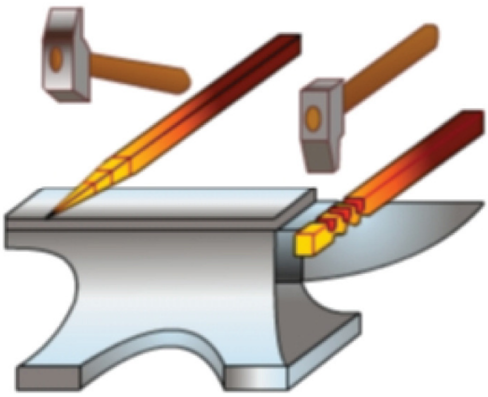
A typical smithy contains

(a) A forge, which is also known as 'hearth', for heating metals to a malleable temperature.

(b) An anvil for laying metal pieces on while hammering; and

(c) A slack tub for rapid cooling and hardening the forged metal pieces there.

Tools include tongs and hammers are for holding and striking hot metals respectively.



Forging different pieces of metals (1) denting and (2) point shaping

Furnace to heat up the metal

Furnaces release carbon monoxides, highly toxic fumes and gases leading to inhalation hazards as well as emitting infrared radiation that can damages eyes and skin during the process of hot forging. In addition, improper handling of hot objects can lead to thermal burns. Another problem with forging is the creation of noise, which is harmful to hearing. As a result, appropriate precautions are mandatory.

General Safety Precautions

(i) Equipping all furnaces with chimneys or canopy hoods;
(ii) Forging in separate rooms;
(iii) Keeping forging rooms cool;
(iv) Using exhaust fans;
(v) Wearing ear plugs or muffs during forging;
(vi) Wearing protective goggles; long-sleeved, cotton shirts; leather gloves; safety shoes and face shields.

2.2.4 Joining Materials

Joining metals can be done through many different ways. Among others, brazing, riveting, soft soldering and welding are common examples.

Welding joins metals by melting the pieces concerned and adding a filler material in between. A pool of molten material or 'weld puddle' is then formed. Upon cooling, a strong joint is formed.

Soldering and brazing work differently to welding. They join target pieces by melting a lower-melting-point material which becomes a bond in between the pieces. The pieces are not melted in such cases.

Welding

When only one side is available for accessing the joint, blind rivets may be used. A rivet is put in a hole which has been drilled on the metal concerned beforehand. The rivet is then set by pulling the mandrel head into the rivet body. The rivet body is expanded and flared. When the mandrel's head reaches the blind side, the pulling force is resisted. At a designated force, the mandrel snaps at its break point. A tight joint is formed by the rivet body and the mandrel is ejected.

This process is quick and simple. The setting force depends on the design of the rivet mandrel, at which the break point is predetermined.

Blind Rivets

Riveting Tool

After Riveting

A screw is a threaded fastener. It consists of a shaft and a head. The shaft is either cylindrical or conical. There is a helical ridge or thread, which in fact is an inclined plane, wrapping around the shaft.

For fastening the target object, a thread has to mate with a helix on the object. The object may already have a mating helix when manufactured, such as taps and dies. The helix may also be created only when the object is first driven in by a screw, such as a self-tapping screw.

The head of a screw is designed for a screwdriver or wrench to
(a) Allow the screwdriver or wrench to hold the screw firmly for driving;
(b) Avoid the screw passing through the object; and
(c) Hold the object tightly in compression.

General Safety Precautions

Among others, potential dangers of riveting are listed below:

(a) The noise created by riveting may hurt people's hearing and general health;

(b) Flying pieces of metal created by riveting may hurt eyes; and

(c) The heavy loads, uncomfortable postures and repetitive movements associated with riveting may result in traumas, back, arm and hand pains.

In order to minimize such risks, the following measures are recommended:

(a) Providing workers with ear and eye protective equipment;

(b) Teaching workers to use safe lifting and moving techniques; and

(c) Using correct postures.

Screwdrivers and electric screwdrivers are commonly used for driving screws. In order to minimize the risks of fire, electrical shock and personal injury, safety precautions should be observed.

Wise selection of screwdrivers among various shapes and sizes for different purposes is required.

(a) It is advisable to choose contoured handles which can fit the shank tightly;

(b) A slot screwdriver which has a blade tip width should be used. Its width should be the same as the width of slotted screw head;

(c) A correct size and type of screwdriver should be used for cross head screws;

(d) A vice or a clamp should be used to hold those small or easy-moving pieces;

(e) Safety glasses or an appropriate face shield should be worn to reduce hazards;

(f) The handle of a screwdriver should be kept clean to avoid injuries or slippage due to a greasy handle;

(g) Screwdrivers with insulated handles should be used when electric work is done on operating equipment.

(h) If a worker works near strong magnets, such as working in a laboratory, he should use non-magnetic tools;

(i) A screw-holding screwdriver with screw-holding clips or magnetic blades should be used for screwing in any awkward or hard-to-reach areas. Square-tipped screwdrivers that hold screws with recessed square holes may help in such situations;

(j) Screwdrivers should be kept in a rack or partitioned pouch for easy selection.

The following safety measures are applicable to electric screwdriver users:

(a) Electric screwdrivers should not be used in damp or wet environments, or in presence of flammable liquid or gases;

(b) Electric screwdrivers should be kept in dry and locked-up places when idle;

(c) Loose clothing or dangling jewelleries should not be worn;

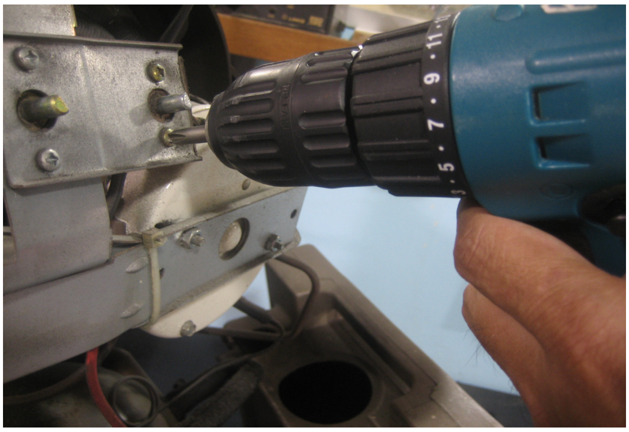
(d) Tool cables should be inspected regularly and, if damaged, repaired or replaced;

(e) Electric screwdrivers should be disconnected from power supply when changing accessories or not used.

Powered Hand Drill

Electric Drilling Method

Electric screwdrivers



Method of using an electric screwdriver

2.2.5 <u>Machining</u>

Machining refers to material shaping processes with power-driven machines, such as a lathe, milling machine and drill press. Machining is required for manufacturing almost all metal products and some plastic parts.

Cylindrical holes can be made in solid materials easily with power hand drills or drill presses. The technology of laser cutting, which uses a laser to cut materials, is common in industrial manufacturing. A laser cutting machine directs the output of a high power laser at the target material. The material will melt, burn or vaporize away, leaving an edge with a high quality surface finish. While the popularity of semiconductor lasers is increasing for their higher efficiency, CO_2 is still the most popular lasers for cutting materials.

Milling machine

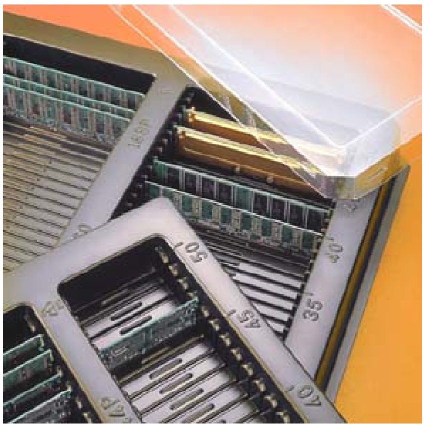
Lathe

Vacuum Forming Machine

Vacuum forming is a thermoforming process. In a vacuum forming process, a plastic sheet is heated up to a designated temperature, or 'forming temperature', and stretched on a single-surface mould. Vacuum is then applied between the mould surface and the sheet.

Vacuum forming is often used for forming plastic parts with shallow depth. For example, a piece of thin sheet can be shaped into rigid cavities for unit doses of medicines. On the other hand, permanent objects, such as turnpike signs and protective covers, can be formed by a thicker piece of sheet.

Thermoplastics are conventional materials for vacuum forming. Popular choices include High Impact Polystyrene Sheeting. It is moulded around a wooden mould and can form almost any shape.



Vacuum Forming Products

General Safety Precautions

The following safety measures should be taken to mitigate the risk of accidents with powered hand drills and drill presses:

(a) Wear face shields or safety glasses;
(b) Keep drill air vents clear for good ventilation;
(c) Keep drill bits sharp;
(d) Keep cords clear of the cutting area during use;
(e) Check cords for frays or damage every time before use;
(f) Power off before changing or adjusting bit or attachments;
(g) Tighten the chuck securely;
(h) Remove the chuck key before drilling;
(i) Hold work pieces firmly during drilling;
(j) Slow down the rate of feed when the surface is about to be broken through;
(k) Drill a small hole as a pilot before a larger.

The following safety measures should be taken to mitigate the risk of accidents with drill presses:

(a) Wear face shields or safety glasses;
(b) Ensure that there is an easy-reaching start/stop button of the drill press;
(c) Remove cutting with a vacuum cleaner, brush or rake;
(d) Remove burrs and chips from drilled holes;
(e) Clean out the holes frequently when making deep holes;
(f) Prevent work from spinning with a clamp or drill vice;
(g) Lubricate drill bits when drilling metals;
(h) Reduce the drilling pressure when the drill is about to break through the work piece, preventing the drill from pulling into the work and breaking;
(i) Keep drill bits clean and sharp to avoid breakage;
(j) Keep the floor around the drill press away from oil and grease;
(k) Keep the working surface away from scraps, tools and materials; and
(l) Keep guards in place and in good working order.

The following safety measures should be taken to mitigate the risk of accidents and mechanical damage with turning machines for their rotating parts, belts and pulleys, high voltage electricity, noise and compressed air:
(a) Do not operate when the machine door is open;
(b) Do not operate without proper training;
(c) Wear safety goggles;
(d) Do not exceed the rated chuck limit;
(e) Do not operate before the machine is properly installed; and
(f) Do not service the machine when power is connected.

The following safety measures should be taken to mitigate the risk of accidents with laser cutting:
(a) Wear approved protective goggles to protect eyes from burning by laser reflection;
(b) Do not cut highly reflective surfaces, especially mirrors, to avoid damages caused by laser reflection;
(c) Keep flammables away from cutting area to avoid burning due to laser spots;
(d) Ensure that ventilation is adequate to prevent from respiratory hazards caused by fumes and mists from laser cutting machine;
(e) Observe manufacturer's safety procedures to prevent from electric shock.

The following safety measures should be taken to mitigate the risk of accidents with vacuum forming machines:
(a) Ensure that all fixed and interlocked guards are ready;
(b) Do not use an operating machine when the interlocked guards are open;
(c) Return the heater to its rest or rear position when the interlocked guards are open;

2.2.6 <u>Finishing</u>

There are many types of metal finishing for making finished products attractive and appealing to customers. Among others, some examples are
(a) Electroplating,
(b) Paint spraying, and
(c) Powder coating.
.
Generally speaking, metal finishing is to deposit substances, such as paint or gold, on the surface of a substrate.
The major ingredients of paints are solvents, such as thinner and diluents, resins and pigments. In addition, there may be additives, such as hardeners, driers, thickeners, extenders and mollusc killers. Except water, most solvents used in paints are highly volatile organic compounds.

(a) Electroplating

It is a process that coats a conductive object with a thin layer of a material, such as metals, by electrical current through a solution. Generally speaking, electroplating is used to achieve two purposes, namely

(i) Depositing a layer of materials on a surface for particular purposes, such as abrasion and wear resistance and corrosion protection; and

(ii) Build up thickness on undersized parts.

(b) Paint Spraying

Paint spraying and coating are done through one of the following methods:

(i) Airless spraying – This method produces viscous high-solid heavy-duty coatings. Paint liquid is dispersed through a small orifice under high pressure by small piston pumps powered by compressed air. The extent of overspray and ricochet is about 20% because paint droplets decelerate soon after leaving the gun.

(ii) Compressed air spraying – It is one of the most common spraying methods. Paint liquid is atomized by low pressure compressed air in either

- Internal-mix nozzles, where liquid and compressed air are combined in the chamber inside; or
- External-mix nozzles, where liquid and compressed air are ejected through separate orifices to combine outside the nozzle.

The losses of the paint liquid with this method are over 50% in general because the paint droplets are unable to reach the object or are reflected from the surface.

Compressed Air Spraying Gun

(iii) Electrostatic – In such processes, an electrical charge is applied to liquid droplets or solid particles, making them to attach to an earthed conductive work piece. This method enables as much as 90% of the paint droplets to attach to the surface.

(c) Powder coating

It is a process to apply powder onto the work piece and the powder is cured under heat to allow it to flow and form a coat. Thermoplastic or a thermoset polymer can be used as the powder which is able to form a hard finish that is tougher than conventional paint. Powder coating is mainly used for coating of metals, such as automobile and motorcycle parts.

Fire and Health Hazards

Using inflammables in paint spraying increases the risk of fire and explosion. For example, when paint mists meet potential sources of ignition, such as static electricity, sparks and flames, fire or explosion can occur. Furthermore, some liquid sprayed may not deposit on the work piece but other surfaces, such as walls, floors or clothing. Such inflammable deposits will become sources of fire if ignited.

People exposed to the hazardous substances in paint spraying may suffer acute or chronic health effects:

(a) Long-term (chronic) health effects include:
   (i) Chronic obstructive airway disease;
   (ii) Chronic dermatitis;
   (iii) Damage to the reproductive system, haemopoietic system, kidneys and livers.
   (iv) Lung cancer; and
   (v) "Painter's syndrome", which results from long-term exposure to organic solvents and affects the brain.

(b) Short-term (acute) health effects include:
   (i) Burning of skin or eyes;
   (ii) Headache, dizziness, nausea and fatigue;
   (iii) Irritation to the noses, throats and lungs;
   (iv) Occupational asthma;
   (v) Occupational contact dermatitis; and
   (vi) Vomiting and diarrhoea.

General Safety Precautions

The following safety measures should be taken to mitigate the risk of accidents with paint spraying and coating:

(a) Elimination of substances or paints whose risk levels have been evaluated as moderate or higher.

(b) Substitution of less hazardous substances, paints or processes in either of the following two ways:

  (i) Replacing hazardous substances or procedures with less hazardous ones. For example, substituting flammable paints liquids by less flammable or water-based liquids, or substituting the spraying processes by rollers, brushes and dipping; or

  (ii) Replacing hazardous items of paints with the less hazardous ones;

(c) Separation of employees from hazards by physical barriers, distance or time:

(d) Enclosure of paint spraying and coating processes if the processes are fully automated;

(e) Execution of hazardous spraying and coating processes in designated spraying rooms constructed of fire resistant materials;

(f) Execution of hazardous spraying and coating processes in designated spraying rooms or areas which are well-ventilated;

(g) Use of electrically earthed airless paint spraying gun;

(h) Use of equipment constructed, designed, installed and maintained to prevent from ignition of the flammable atmosphere; and

(i) Use of personal protective equipment, such as respirators and protective clothing

D O T H E R I G H T T H I N G
a) Explain the risks of a metal container making process, which involves the use of hand tools, such as saws, hammers, electric drills, screwdrivers and paints. b) Suggest safety precautions that should be taken to minimize the risks.

2.3 MANUFACTURING SYSTEMS

There are many different manufacturing systems. The simplest form should be that skilled craftsmen and their apprentices make goods in their own homes as workshops for individual customers. In this way, most of the parts are unique, hand-fitted and made by a single person from the beginning to the end.

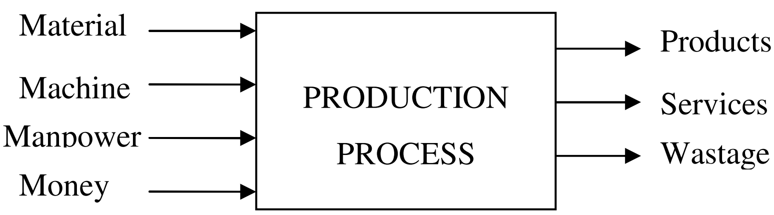
Simple and tailor-made product built by a single worker

Inventions of mechanical- and electric-powered machines, etc have revolutionized the manufacturing processes of most, if not all, industries. Workers are hired and centralized in factories to work under the supervision of employers. Since then, manufacturing has been developed from one-off to batch, mass production and continuous production.

Mass production of a sophisticated product by teams

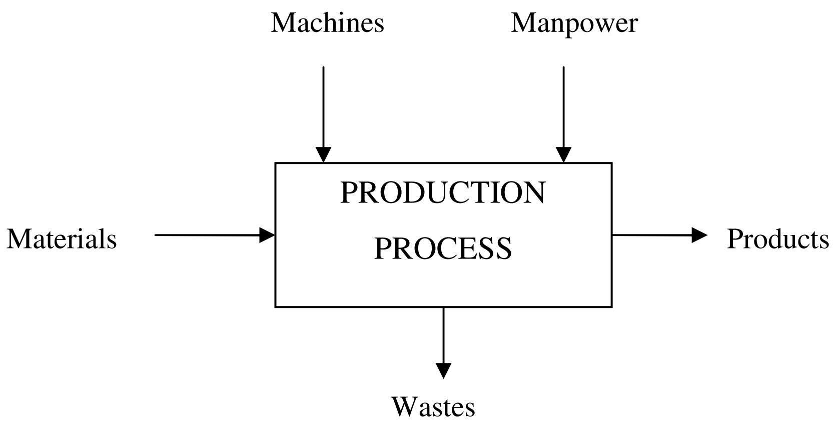
2.3.1 <u>Manufacturing Systems</u>

Manufacturing systems are often described by models. An example of which is shown below:



A Production Model

The four M's, i.e. Materials, Machines, Manpower and Money, are inputs to a production process. Goods, services and, hopefully, money are the outputs.
In addition to describing the production process in a manufacturing company, such a model is applicable to individual processes, such as a machining centre, a car wash, a plating bath, a bank's cash dispenser and a fast food outlet. The model is applicable to most other manufacturing processes with minimal adjustment as shown below:



A Model of a Single Production Process

2.3.2 Types of Production Process

Manufacturing systems can be classified by different types of production processes. A production process refers to how goods are produced to meet customer requirements and product specifications within particular constraints, such as cost. The effects of a process chosen on productivity, flexibility, cost and good quality are long-term. There are four basic types of production processes, namely

(i) One-off or jobbing production
(ii) Batch production
(iii) Mass production
(iv) Continuous production

(a) One-off or Jobbing Production

One-off or jobbing production is also known as Job-shop production. It usually produces customized products with reference to the designs supplied by customers. The production volume is low, and is usually one item only. General-purpose production equipment is used for a broad range of operations. Employees have broad skills.

Jobbing production is generally regarded as high variety but low volume production. For example,

(i) A furniture-making shop produces customized furniture;
(ii) A garment manufacturing shop produces tailor-made fashion; and
(iii) A machine shop produces specialized machinery according to customer's specification.

(b) Batch Production

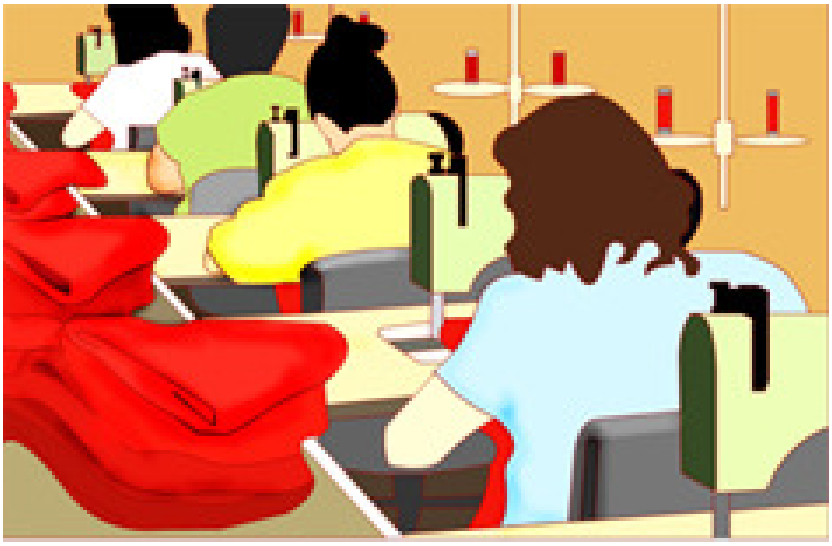
Batch production is also known as intermittent production. The manufacturing task is divided into a number of operations. Each operation is a self-contained, whole batch that is completed before moving on to the next operation. Similar to jobbing, equipment used is for general purpose and workers employed are highly skilled.

Most of operations in batch production involve fabrication, such as machining, rather than assembly. Subject to the processing requirements, a batch of a lot size, such as 50, is sent to the system such that jobs requiring machining work are sent to a machining shop. Since a batch may be routed to many different workshops before completed, frequent stopping, starting and waiting can be observed from the system. Thus, the manufacturing process of a particular product is not continuous but intermittent. Batch production is common in machine tool manufacturing, bakeries, garment making and furniture making.

(c) Mass Production

In mass production, large amounts of a standard product are produced for the mass market. Since the product demand is high and stable, it is cost justified for a producer to use dedicate equipment for production of particular products. Therefore, mass production is more capital intensive, equipment specialized and labour-skill limited.

In many cases, mass production makes use of flow lines or assembly lines. ‘Flow’ refers to the path that a product moves from one location to another in a process. ‘Assembly line’ refers to the production setting of mass production. In an assembly-line setting, products are made of several parts, which are combined together in the production process or flow. The operations concerned are mainly assembling. Typical mass-produced products include automobiles, televisions, personal computers, and most consumer products.



Line mass production

(d) Continuous Production

Continuous production is usually for production of a high volume of standardized products. Raw materials are fed into different production stages or operations and processed into one product or more. Very often, a continuous production system is highly automated and operating 24 hours per day. In addition to continuous processing, the output is continuous. Typical products of continuous production are refined sugar, refined oil, paints, chemicals, steel, paper and electricity.

2.3.3 The appropriate type of manufacturing system

A summary of various types of production processes has been tabulated below:

	Jobbing	**Batch**	**Mass**	**Continuous**
Demand	Infrequent	Fluctuating	Stable	Very stable
Volume	Very low	Low to medium	High	Very high
Variety	Infinite	Many	Few	Very few
Equipment	General purpose	General purpose	Special purpose	Highly automated
Worker Skills	Broad skills	Broad skills	Limited skills	Equipment Monitoring
Efficiency	Very low	Low	High	Very high
Labour Cost	Very high	High	Low	Very low
Capital Cost	Very low	Low	High	Very high
Product Cost	Very high	High	Low	Very low

Comparison of Types of Production Process

The above table tells that no single production process has absolute advantages over the others. It is more important that a right process be selected for a product. The selection primarily depends on two product characteristics, namely variety and demand volume.
Generally speaking, the higher variety of products, the more flexibility in the production process is required. Products with lower variety, i.e. more standardized, can benefit from mass production or continuous production for their efficiency. Low-volume production is more labour intensive for skilled labour cost, whereas high-volume production is more capital intensive for equipment investment. The following diagram provides a summary:

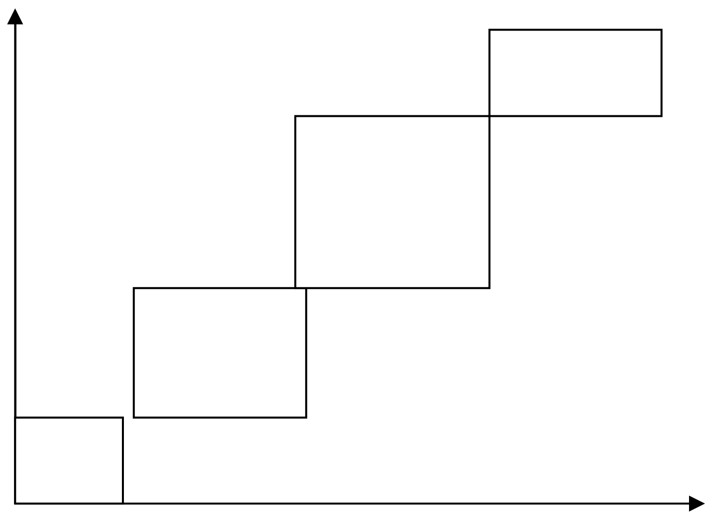


Figure 1: Matching Product Characteristics with Process Choice

A cost analysis can be used for selecting a production process. In such an analysis, the fixed and variable costs have to be determined. Fixed costs refer to the costs that do not change with production volume, such as capital invested. Variable costs refer to the costs that vary directly proportional to the production volume, such as labour cost and material cost. Production cost is the total of both.

Figure 2 shows the costs of a jobbing process. Figure 3 shows the production cost of each process type. It shows that jobbing production incurs the least cost for a low volume, followed by batch production at a medium volume and mass production at a high volume. It results from jobbing having the lowest fixed cost and highest variable cost. On the contrary, mass production has highest fixed cost and the lowest variable cost resulting in the least cost in total when the volume is large.

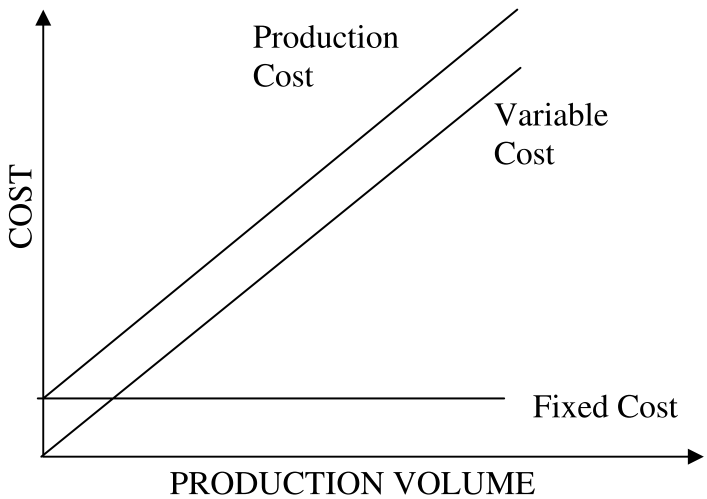


Figure 2: Costs of a Jobbing Process

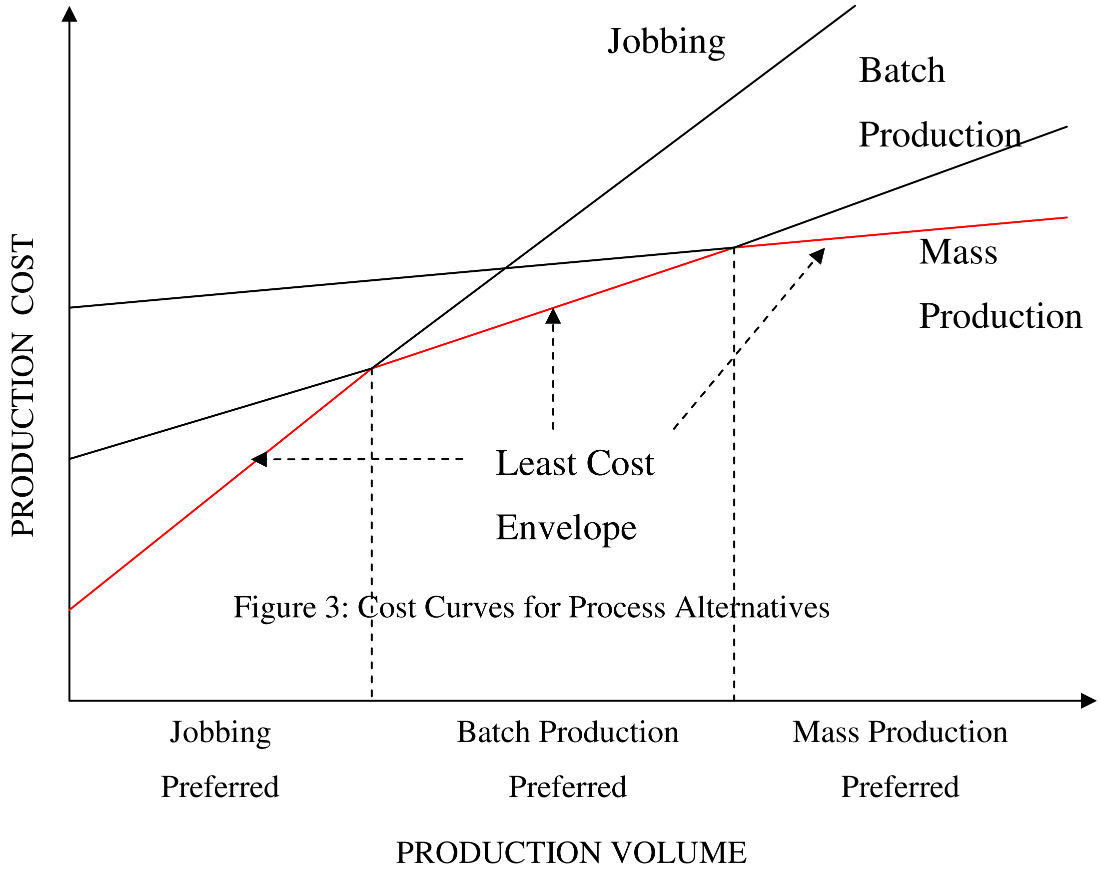
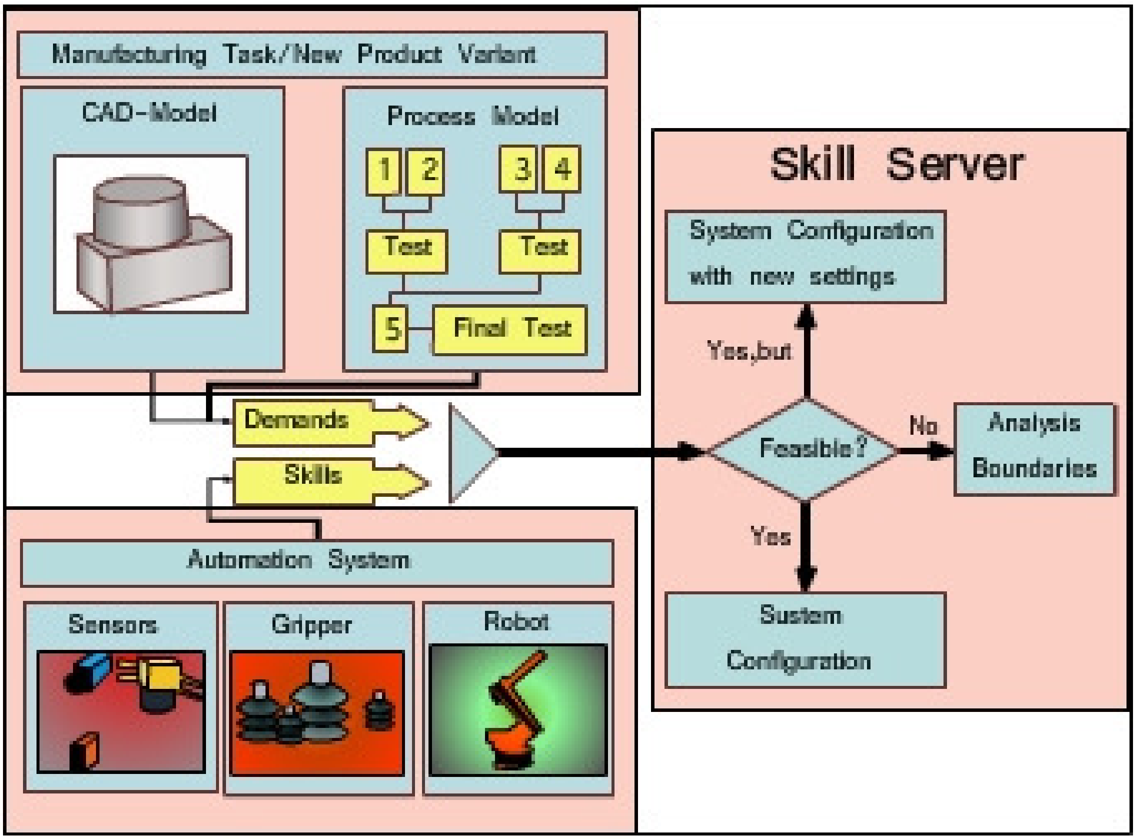


Figure 3: Cost Curves for Process Alternatives

There is an Intelligent Manufacturing Systems (IMS) program established globally by the industry for developing the next generation of manufacturing and processing technologies. The program provides a framework for:

(a) Global cooperative research,
(b) Formation of project consortium,
(c) People networking around the globe,
(d) Exchanging current and future manufacturing requirements, and
(e) Channel for disseminating related information.

The world community's quality of life hopefully can be enhanced as such.



Intelligent manufacturing system

S T O P A N D T H I N K

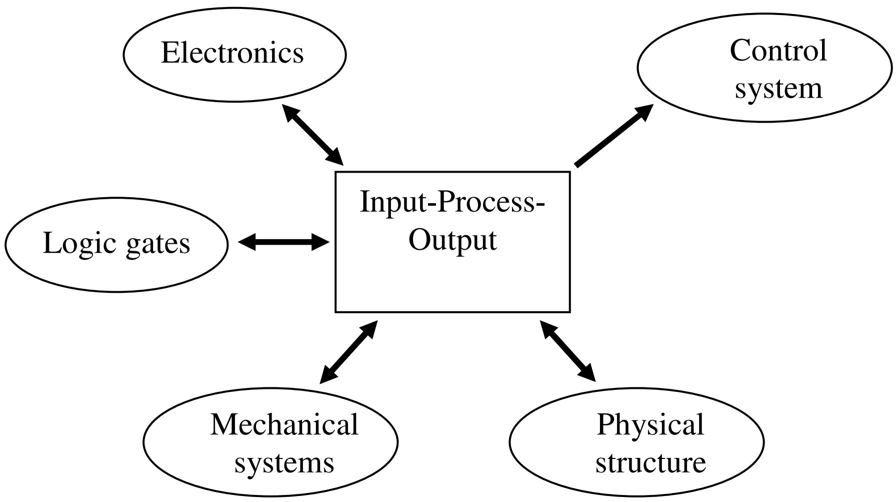
Name the most appropriate manufacturing system for the production of the following products:

a) Gifts at large chain stores, such as McDonalds and 7-Eleven;
b) Unique souvenirs to speakers of a conference;
c) Elite toys of a limited edition; and;
d) Elite toys of a limited edition; and;

CHAPTER 3 – SYSTEMS AND CONTROL

This chapter covers topics on:
(a) Input-Process-Output,
(b) Logic Gates,
(c) Mechanical Systems,
(d) Physical Structure, and
(e) Basic Electronics.

These topics along with resource materials and activities facilitate the students to:
(a) Understand various forms of system and control;
(b) Illustrate control systems with block diagrams;
(c) Interpret truth tables for simple logic gates;
(d) Apply knowledge and concepts of mechanics to design, fabrication and control of systems;
(e) Understand the nature of forces and stability of structures; and
(f) Understand the basic principles of electronic systems.



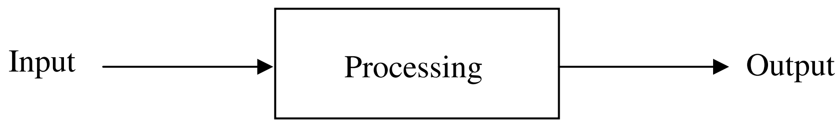
3.1 INPUT-PROCESS-OUTPUT

Most, if not all, engineering systems, even as common as a hair-dryer or a washing machine, need certain kinds of controls to ensure that the systems can meet the design specifications.

Control systems can be in different forms, such as

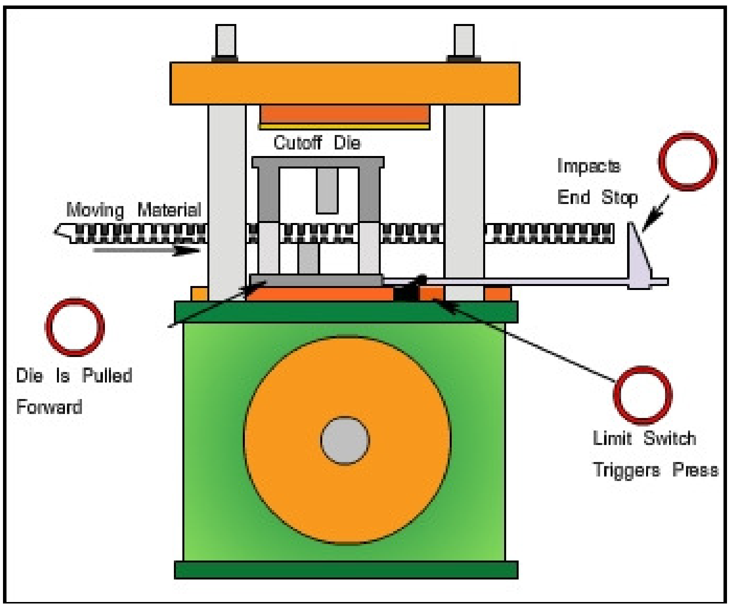
(a) A computer control system,
(b) An electronic control system,
(c) A mechanical control system, or
(d) A pneumatic control system.

Generally speaking, there are two types of control systems, namely open- and closed-loop.



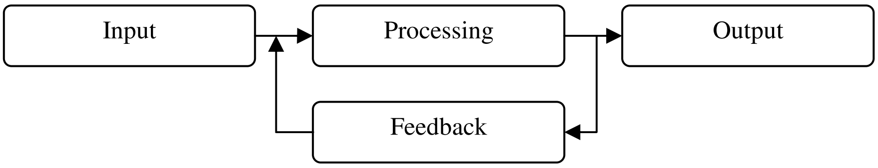
An Open-Loop Control System

An open-loop control system is as simple as the process that converts the input quantity to an output quantity. For example, a hair-dryer user manually switches to get hot-air or cool-air, and different air speeds. The control relies on the user, who turns off the hair-dryer when he considers appropriate.



A closed loop control system – metal cutting

A closed-loop control system is more complicated. It feeds back output signals to the input side for necessary input, and thus output, adjustment. The output quantity is compared with the input one for the maintenance of a pre-determined output level.



A Closed-Loop Control System

A detector must be present in a closed-loop control system for monitoring the output quantities and comparing them with the pre-determined values. For example, in a washing machine, many sensors or detectors are used to control water flow, water temperature, washing time, washing modes and actions of the washing drum, etc.

3.1.1 Sub-systems in a mass transit system

The railway system in Hong Kong is complicated. It is controlled by many different sub-systems, such as mechanical, electronic and pneumatic systems. Each sub-system is designated for a purpose.

MTR system in Hong Kong

3.1.2 Mechanical sub-system

The major component of the mechanical sub-system is the train. The system controls the train's movement, speed, opening/ closing of train doors. The system has to operate in a safety manner for commuters. It is subject to regular repair and maintenance, safety inspection and component testing.

Evaporative emissions refer to the seepage of fuel vapours from fuel tanks and carburettors. In order to keep them away from escape into the atmosphere, the fuel system is sealed. The vapours are thus retained and can be re-burned.

Tailpipe exhaust emissions are composed of carbon monoxide (CO), unburned hydrocarbons (HC) and oxides of nitrogen (NO_X). To minimize the formation of these pollutants, engines are designed to, for example, carefully control over fuel calibration and ignition timing. The emission control system is an integral part of the engine. It is equally true for vehicles with computerized engine controls and those subject to mandatory emission check.

3.1.3 Electronic sub-system

Electronic systems exist almost anywhere in the railway system. For example, they can be found in lifts and escalators, display boards, turnstiles and train display screens. Among their many purposes, the core one is to control. An electronic sub-system normally consists of electronic discrete components, sensors/transducers, integrated circuits, power drives and microprocessors.

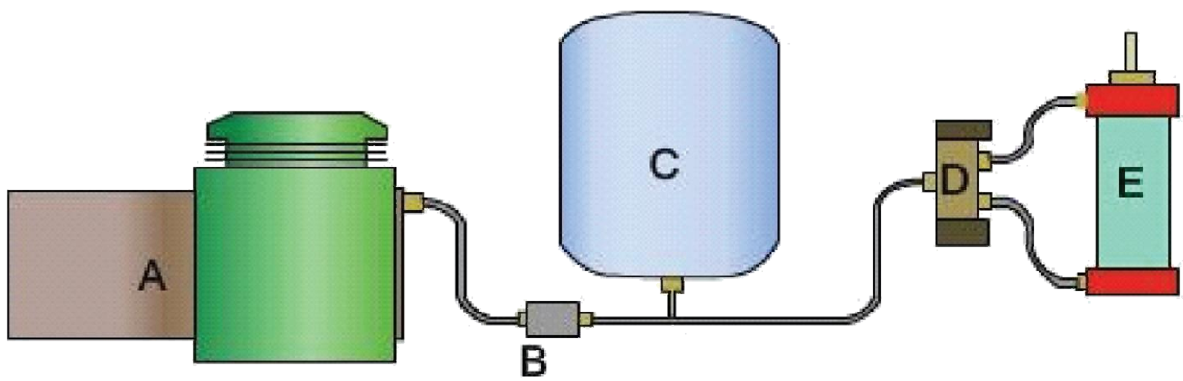
3.1.4 Pneumatic sub-system

A pneumatic system uses compressed air to convey and control energy.

(a) Firstly, air is pressurized in a cylinder to supply energy.
(b) Secondly, with the use of switches, signals are input to the system.
(c) Thirdly, air is transferred along sealed pipes to the pneumatic parts for processing.
(d) Finally, the pneumatic parts produce force to complete designated tasks.

A common use of a pneumatic system in a railway system is for door control, taking advantage of the system's offering of smooth control.

Elements of a basic pneumatic system



A – Compressor: a pump which compresses air, raising it to a higher pressure, and delivers it to the pneumatic system (sometimes, can also be used to generate a vacuum).
B – Check valve: one-way valve that allows pressurized air to enter the pneumatic system but prevents backflow (and loss of pressure) into the compressor when it is stopped.
C – Accumulator: stores compressed air, preventing surges in pressure and relieving the duty cycle of the compressor.
D – Directional valve: controls the flow of pressurized air from the source to the selected port. Some valves permit free exhaust from the port not selected. These valves can be actuated either manually or electrically.
E – Actuator: converts energy stored in the compressed air into mechanical motion. A linear piston is shown.

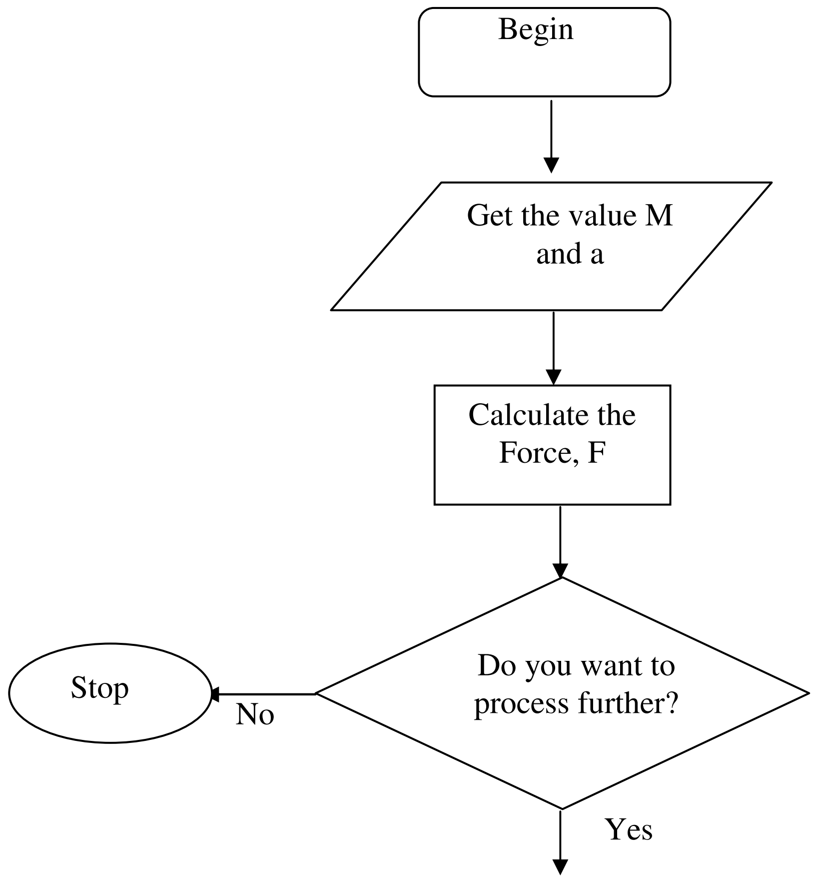
3.1.5 Algorithm Equations and Flowcharts or Tables

In many cases, discrete algorithms are used to approximate the continuous equations of motion, creating numerical integrators for mechanical system simulation. One example is to predict an object's movement during uphill and downhill, or on a smooth and rough surface. Motion related equations depend on different conditions, the mass of the object and external forces acting on it, etc. To solve an engineering problem, one can formulate such equations and create a flowchart.

Examples of motion related equations:

(a) $F = Ma$ where F is the force acting on object, M is the mass of object, a is the acceleration of object

(b) $f = \mu N$ where f is the frictional force, μ is the coefficient of friction, N is normal reaction



A typical Flowchart for the calculation of Force, F

S T O P A N D T H I N K
a) Name some control functions built in a cooker and a washing machine; b) Name the components used for such controls;

3.2 LOGIC GATES

Basic logic applications can be found easily in daily life. Generally speaking, digital logic can be classified into two categories, namely combinational logic and sequential logic.

For combinational logic, logical outputs depend on the logical function and the logical input states at a particular moment. For sequential logic, the outputs depend on their own previous states in addition to those common to combinational logic. Both categories of logic are used widely in computers and domestic appliances.

Either logic circuit relies on logic gates to process input signals for production of outputs. In this connection, the following explain how basic logic gates work.

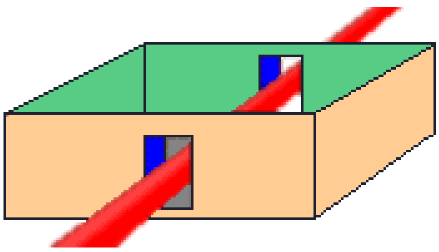
Each logical element or condition has a logic value of either '0' or '1'. Different logical signals or conditions are combined to form a logical result. Take the following logical statement as an example:

'If I move the switch on the wall up, the light will turn on.'

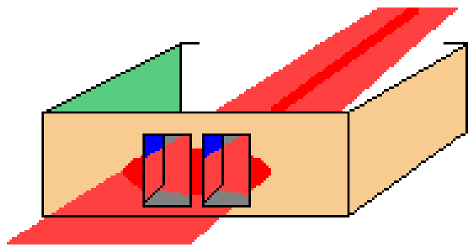
It means that the light will follow the location of the switch. In other words, when the switch is up, on, true or '1', the light will follow suit. On the contrary, if the switch is down, off, false or '0', the light will still follow.

Doors are used below to explain simple logic functions:

AND Logic Function



OR Logic Function



In the AND logic example above, in order to let 'light' get through the house, both the front AND the back doors must be open. However, in the OR logic example, either the left front OR the right front door, or both, must be open.

In order to make the output of an AND Logical Function to be TRUE, both input (1) AND input (2) must be TRUE. In an LED context,
(a) TRUE means that power is applied to the LED when the switch is closed; and
(b) FALSE means that power is NOT applied to the LED when the switch is open.

The following truth table explains the input-output relationship of an AND logic gate:

Truth Table

A & **B** are the Input switches
C is the Output LED

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

In order to make the output of an OR Logical Function to be TRUE, one of the following conditions must be satisfied:

(a) Input (1) is TRUE;

(b) Input (2) is TRUE; OR

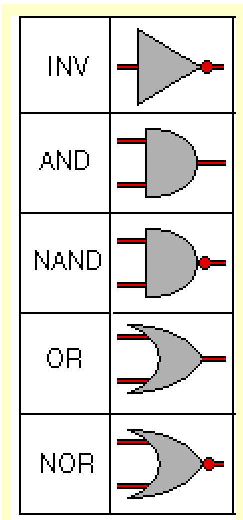
(c) Both are TRUE.

Truth Table

A & **B** are the Input switches
C is the Output LED

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

Other logical functions, such as NOT (or INV), NAND (or NOT AND), NOR (or NOT OR), can be explained similarly. The symbols of such functions are listed in the following table.

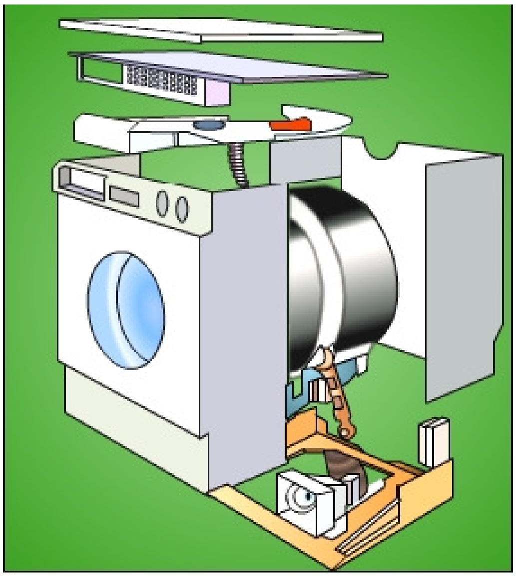


The following block diagram and input-output table show how an automatic washing machine makes use of logical functions. The logic circuit turns on the water heater when

(a) The door is close, or the corresponding logic value is ‘1’;

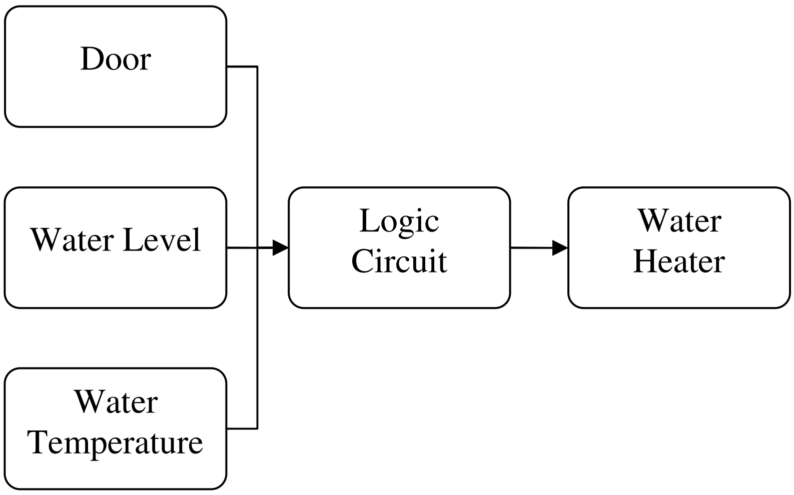
(b) The water level is high enough, or the corresponding logic value is ‘1’; and

(c) The water temperature is below a threshold, or the corresponding logic value is ‘0’.



door lock and position sensor
0 : open
1 : closed

Example of using combinational logic in an automatic washing machine



Inputs			Output
Door	**Water level**	**Water temperature**	**Water heater**
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	0

Digital logic is the foundation of computers, which play a very important role in systems and controls.

S T O P A N D T H I N K

a) Design a logic circuit with different logic gates to emulate the traffic light
b) Present the design in the form of a circuit diagram.

3.3 MECHANICAL SYSTEMS

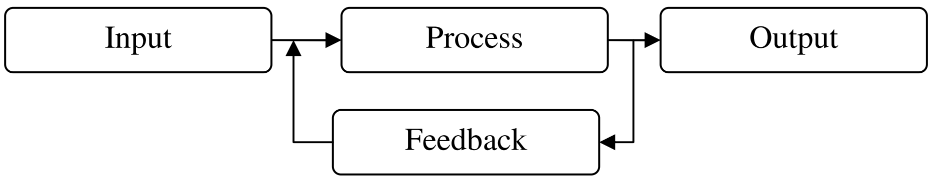
A mechanical system consists of some interacting elements. Its output is derived from the principles of mechanics.

There are three types of mechanical systems used in mechanical systems, namely
(a) Control,
(b) Transmission System, and
(c) Motion Conversion.

3.3.1 <u>Control</u>

A Control system can be divided into various stages including:
(a) Input
(b) Process
(c) Output
(d) Feedback

Example: Weather Station

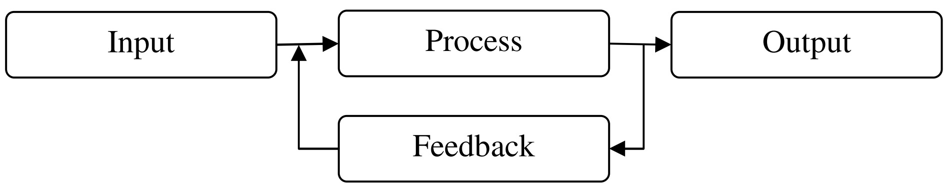


(a) INPUT - Sensor(s) for measuring temperature, rainfall, humidity, etc
(b) PROCESS - Computer(s) for analysis of the incoming data
(c) OUTPUT - Final printout(s) of temperature, such as display screen and printer
(d) FEEDBACK – Device(s) for monitoring data

The weather station system above has a feedback mechanism. Thus, it is a closed system. Open system have no feedback.

Example: Automatic Garden Sprinkler System
(Reference: http://technologystudent.com)

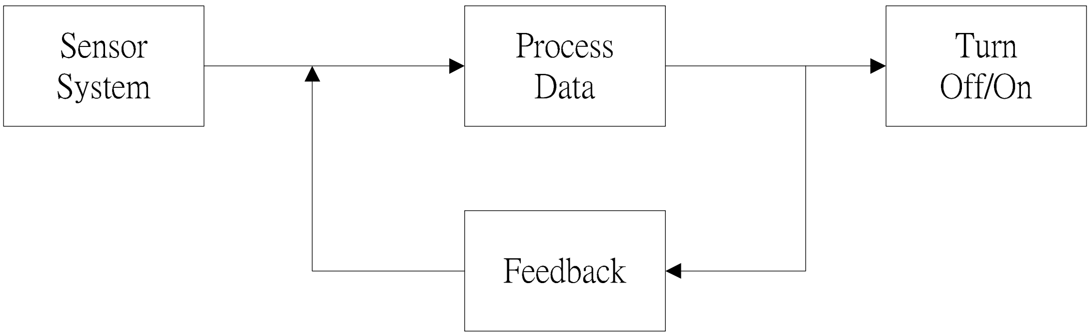
To design a system INPUT-PROCESS-OUTPUT with FEEDBACK



Consider the design criteria of the system:

(a) INPUT – How does the system sense the dryness of the soil?
(b) PROCESS – What devices can be used for controlling?
(c) OUTPUT – The system is expected to turn on the sprinkler when there is no sufficient water in the soil.
(d) FEEDBACK – The soil's moisture level should be checked continuously.

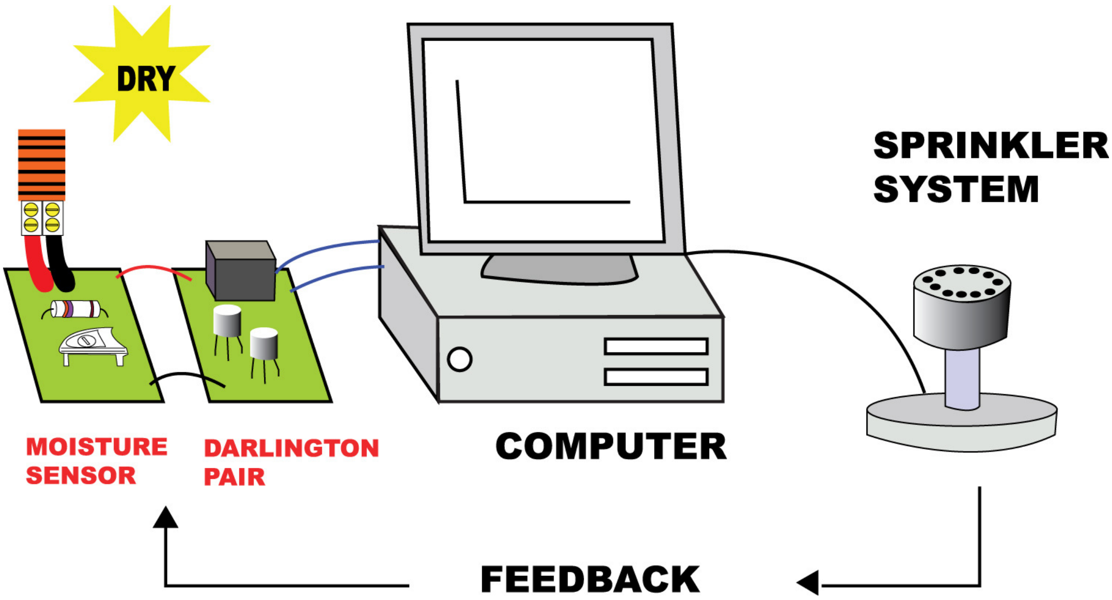
Suggestion Solution:



(a) INPUT
- Using a moisture sensor to measure the moisture level or when water is needed

(b) PROCESS
(i) Using a Darlington pair to amplify the signal from the sensors
(ii) Using a computer program to control the operations of the solenoid, and turn on the sprinkler

(c) OUTPUT
- Using a sprinkler system for watering



Input Device
Input devices can be divided into digital and analogue sensors.

Examples of input devices:

Measuring	Input device
Light	Light dependent resistors (LDR)
	Phototransistors
Temperature	Thermocouples
	Thermistors
Motion (Movement)	Potentiometers
Humidity	Electrodes
Sound	Microphones
Force (Strain/ Bending)	Strain gauges
Manual/ Mechanical	Switches

Processing Devices
Processing devices are to detect the signal from an input device, and return outcomes to the output devices.

Examples of processing devices:

PROCESSING DEVICE	EXAMPLE
Amplifiers	Amplifies input signals
Electronic switches	Switches at different levels
Timers	Switches after time delay
Gates(AND/ NAND/ OR/ NOR)	Combines inputs
Counters	Counts input pulses
Computer	Detects the signal from input device
Micro-processor	Detects the signal from input device

Output Devices

Output devices are responsible for presenting outcomes of the system.

Examples of output device examples:

OUTPUT DEVICES	EXAMPLE
Relays	Controls higher voltages/circuits
Lamps	Light
Buzzer/Bells	Sound
Speakers	Sound
Motors	Movement (rotary)
Stepper motors	Movement (precise rotary)
Solenoids	Movement (linear)
Indicators	Information

Examples of control types that are common in toys:

(a) Velocity control

(b) Position or point-to-point control
- ➢ To compute the motion trajectory based on the velocity profiles of a move

(c) Motion control
- ➢ To control the position or velocity of the system

(d) Electronic gearing
- ➢ To control the position of the slave axis linked to the position of the master axis
- ➢ Remark: The two axes have no linear relationship.

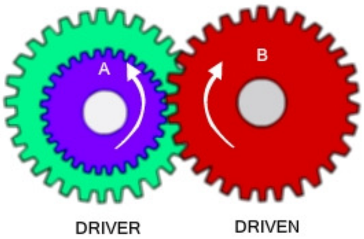
(e) Voltage Control
- ➢ To control the transmission voltage through
  1. Adjusting the transformer, and
  2. Switching capacitors and inductors on the distribution systems.

S T O P   A N D   T H I N K

Name the control devices needed for an automatic vertically opening/ closing roll door.

3.3.2 Transmission system

A Transmission system converts speed to power by a gear system for some specific applications.



COMPOUND GEARS **GEARS**

Compound gears are very common components of engines. In a gear train, the final gear is the final or correct rotational speed for speed control.
(Source: http://technologystudent.com/gears1/gears3.htm)

Example: Bicycle gearing
(Source: http://en.wikipedia.org/wiki/Bicycle_gearing)

Gearing on a bicycle refers to the choice of a suitable gear ratio to attain an optimum efficiency or riding comfort. For different purposes, such as the rider's cycling style, different types of gears and ranges of gears can be used. A multi-speed bicycle has the advantages of having gear selection for various circumstances. For example, a high gear may be more suitable for a rider when he is cycling downhill; a medium gear for a flat road; and a low gear for uphill.

A bicycle is in fact a machine transmitting power from the rider's legs to its rear wheel, through its pedals, crankset, chain and rear hub. A rider's legs generate power when panelling. The speed is limited by the narrow pedalling speed range. The bicycle optimizes the power or speed through gearing. For bicycles using derailleur gears, the gear ratio is the ratio of the number of teeth on the chaining of the crankset to that on the rear cog or sprocket. For a derailleur-equipped bicycle, the sprocket is a component of the cassette. On hub gears, the ratio is determined by the hub's internal planetary gears.

A lower gear, which has a larger mechanical advantage, requires a rider to panel at a faster cadence, but less force, to maintain a particular speed or power output at the rear wheel than a higher gear does. The choice of cadence and pedalling force differs from rider to rider. However, it should be noted that prolonged and excessive exertion of force in a high gear or at a low speed increases the chance of knee damage.

A bicycle with a hub gear.

Shimano XT rear derailleur on a mountain bike

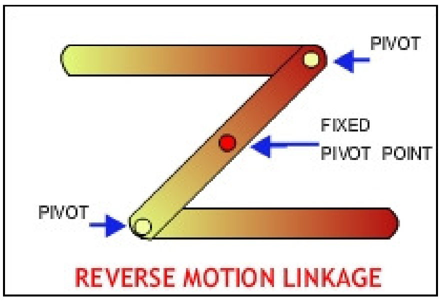
3.3.3 Motion Conversion

Motion conversion converts an object from one position to another position.

(a) Linkage

Linkages are common in mechanics. They can change the direction, speed and timing of moving parts. There are many linkages in the daily life. Some common examples are introduced below:

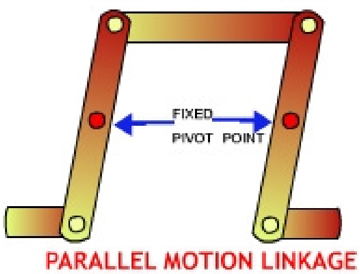
(a.1) Reverse Motion Linkage



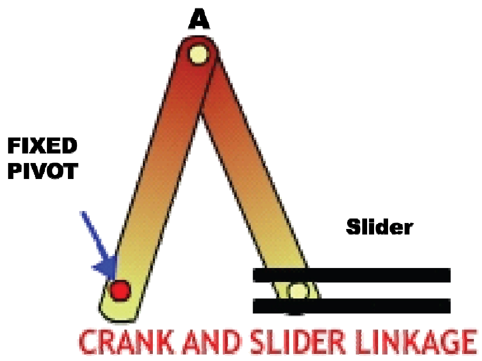
- Two rods are linked and move in an opposite direction. When the top rod moves to the right, the bottom rod moves to the left.

(a.2) Parallel Motion Linkage

- In the parallel motion linkage, the top rod leads the movement of two bottom rods. When the top rod moves right, it will lead two bottom rods move left (in parallel and opposite direction).
- Example: A Toolbox



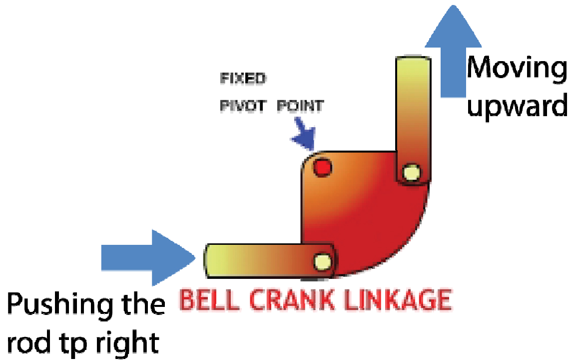
(a.3) Crank and Slider Linkage



- A rod moves back and forth in a slider (Linear motion) with rod which has a fixed pivot. It will produce a circular motion at point A.
- Example: A steam train, the cylinder of internal combustion engine

(a.4) Bell Crank Linkage

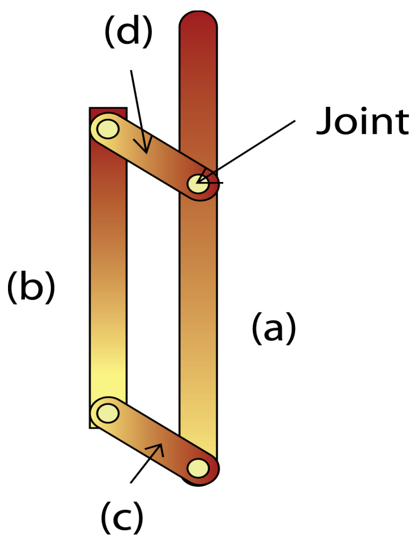
- Bell crank linkage coverts the direction of movement in different angles (1° to 180°). As shown in the figure, pushing the horizontal rod to right, it will lead the vertical rod moving upward.
- Example: A bicycle brake



(Source: http://technologystudent.com/cams/link1.htm)

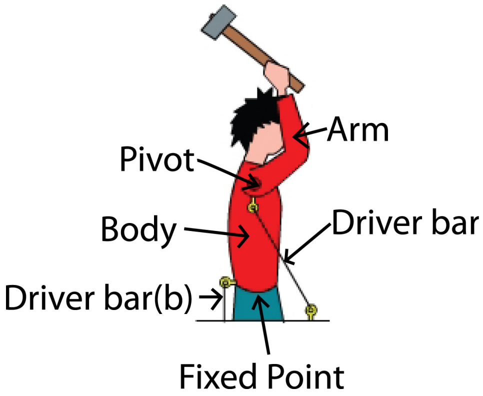
(a.5) Four Bar Linkages

The four bars in a four-bar linkage form a parallelogram. There are several types of such a linkage:



- It is a basic four bar linkage. The bars construct a parallelogram.
- Bar (c) and (d) are equal in length. They connect a moving bar (a) and fixed bar (b). The distance between the joints on the moving bar is equal to that between the joints on the fixed bar
- The movement of lower bar (c) mirrors the upper bar (d).
- The lower bar (c) is moved to control the semi-circular motion of bar (a).

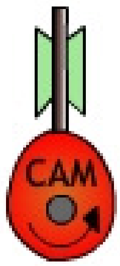
Example: Application of simple two linked linkages



- It converts a small linear movement of drive bar (a) into the rotational movement of body for the hammer motion. Pulling the rope of drive bar (a) leads the arm moving in curve motion.
- Pulling the rope of drive bar (b) will lead the body rotating within an angle of 90° .
- The hammer speed is faster than that of the drive bar (a).
- This example shows that a linkage can change the movement direction and motion speed.

(Source: http://www.flying-pig.co.uk/mechanisms/pages/linkage.html)

(b) Cam and follower



- A cam and follower system is used in many machines and toys extensively.
- There are two parts in such a mechanical system, namely cam profile and follower.
- A cam is an input rotating motion leading the linear motion of its follower.

The motion transmission of a cam and follower system is shown below:

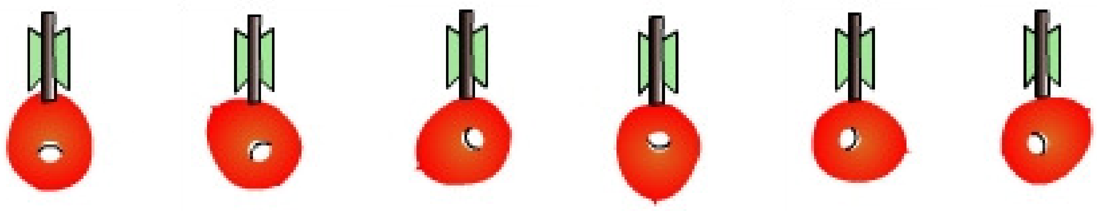


Diagram 1 Diagram 2 Diagram 3 Diagram 4 Diagram 5 Diagram 6

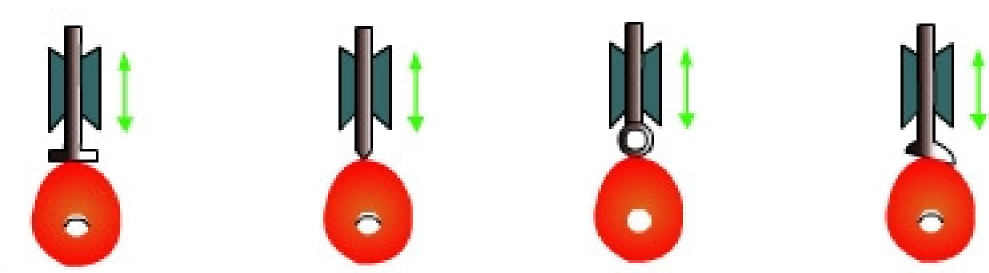
- As the rotating cam pushes the follower up, the follower will fall down slowly.
- When the follower is in the highest position at the beginning as shown in Diagram 1.
- The cam starts to rotate in an anti-clockwise direction.
- As the cam rotates, the follower moves down.
- Diagram 4 shows that the follower is in the lowest position.
- If the cam rotates continuously, the follower starts rising to its original position.

Terms of a cam and follower system:

- One Cycle – one rotation of cam

- Dwell – The follower does not rise or fall when the cam rotates.
- The Rise – The part of a cam leads the follower to go up.

The shape of the follower affects the motion. There are various types of followers:

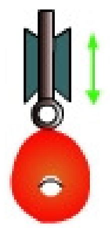


FLAT   POINT/KNIFE   ROLLER   OFFSET

Cam Profile – the shape of the cam affects how a follower moves. For example,

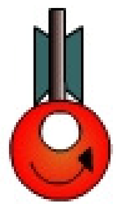
PEAR:

- It is used widely on the shafts of cars.
- The follower remains motionless for half a cycle.
- The follower rises and falls for another half of the cycle.



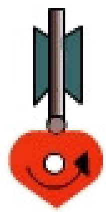
CIRCULAR:

- It is used widely in steam engines.
- The follower has a smooth motion.



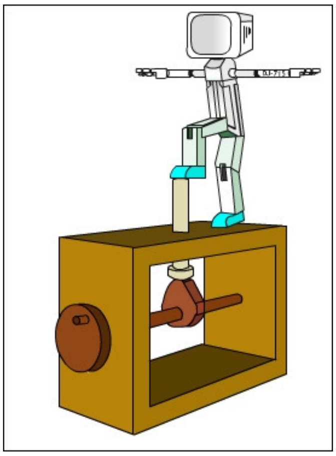
HEART:

The follower has a uniform velocity for moving up and down.



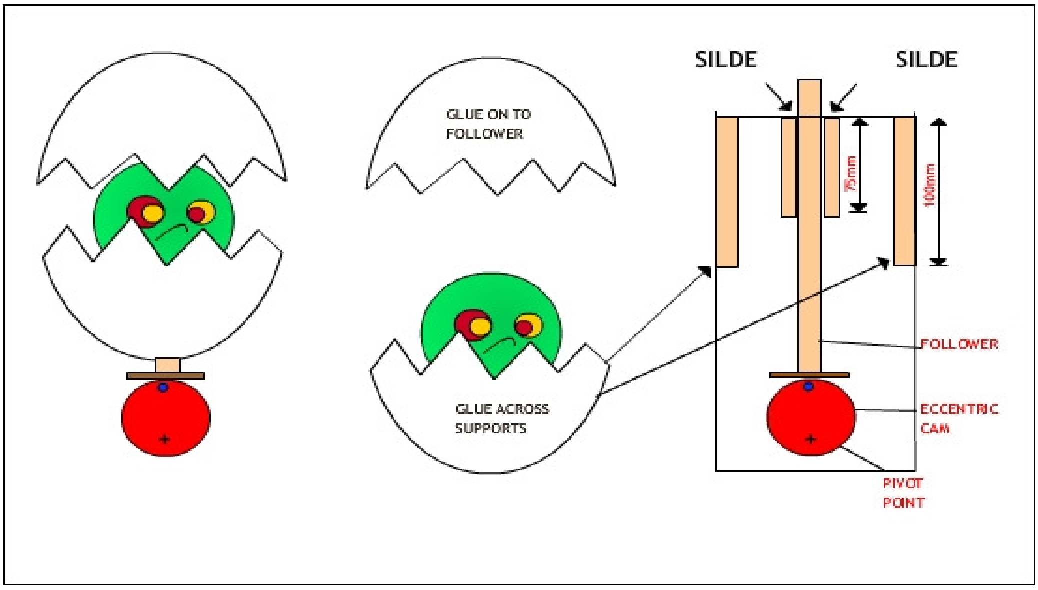
Example: Application of a cam and a follower in toys

The cam profile rotates when the handle is being turned. As a result, the toy moves up and down.



(Source: http://technologystudent.com/cams/cam1.htm)

Cam Toy Exercise:



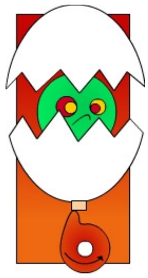
The mechanical toy design as shown above is based on CAM mechanism. It is a simple application of a cam and follower system.

The upper egg shell is connected with a follower. When the flat follower moves up, the upper egg shell follows to go up. The toy face is thus visible.

The cam profile can be changed as follows:

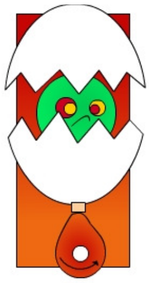
Drop cam:

The movement is different from a circular cam. Its motion is not as smooth as using a circular cam. The upper egg shell is moving up in relatively constant speed and then moving down suddenly.


DROP CAM

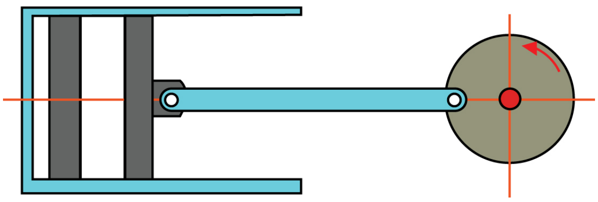
Pear cam:

The upper egg shell is moving up quickly and moving down quickly. However, the movement is only half a revolution.


PEAR SHAPED CAM

(source: http://technologystudent.com/cams/camt1.htm)

(c) Slider crank



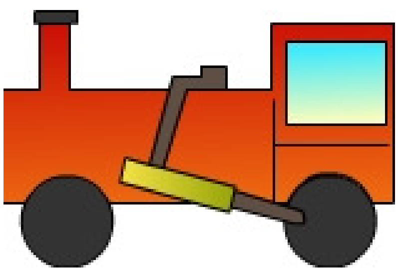
There are three major components in a slider crank mechanism, namely

- Crank – the rotating disc;
- Slider – it slides inside the tube; and
- Connecting rod – The rod that joins the crank and slider

Operations of a Crank Slider:

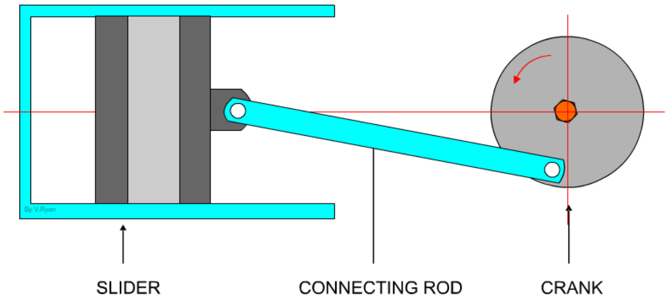
When the slider moves to the right, the connecting rod will push the wheel or crank for a 180° rotation. When the slider moves back into the tube, the connecting rod pulls the wheel or crank to complete the rotation.

Example 1: A steam train



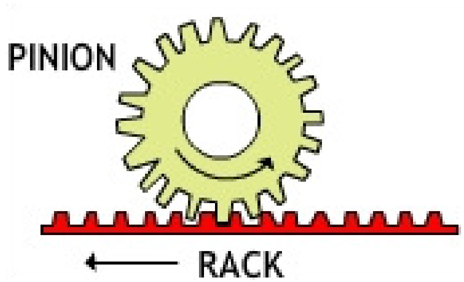
Steam pressure supplies Crank Slider system energy for moving the connecting rod and thus the wheel or crank.

Example 2: A cylinder of internal combustion engine



(Source: http://www.technologystudent.com/cams/crkslid1.htm)

(d) Rack and pinion

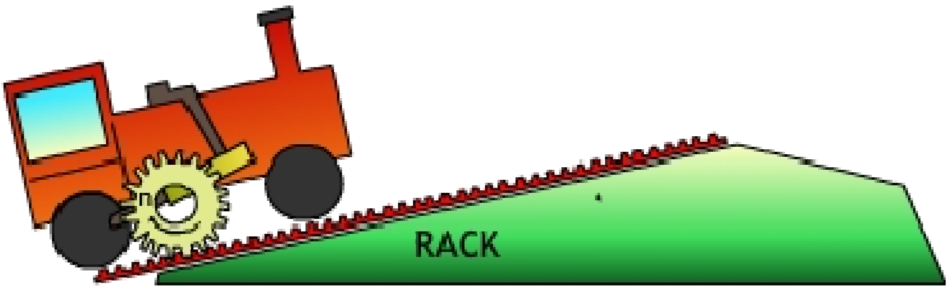


A rack and pinion system is composed of two gears, namely

- Pinion – it is a normal round gear; and
- Rack – it is a straight or flat gear.

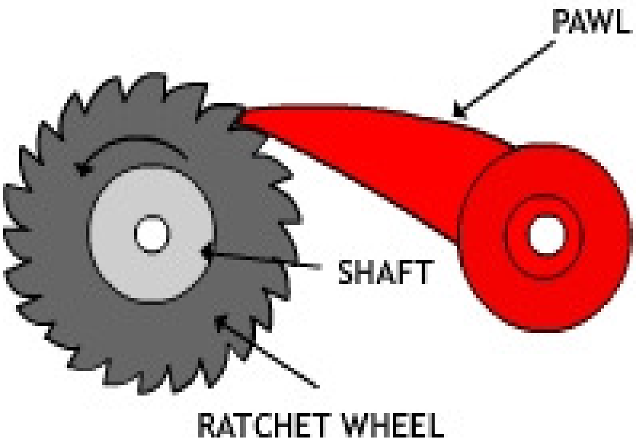
Operations of a Rack and Pinion – Rotary motion changes to linear motion:
Pinion rotates and moves the rack in a straight line.

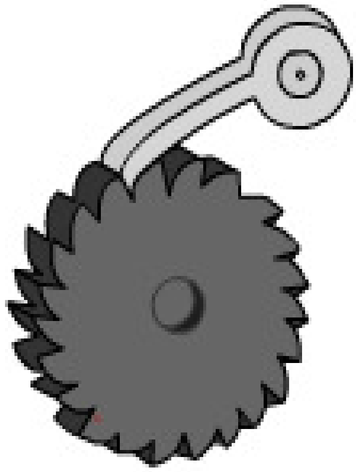
Example: Uphill trains



A Rack and Pinion system prevents a train from slipping backward when going uphill: There is a large gear wheel or pinion at the centre of the train. The pinion is designed to mesh with the extra track or rack on the rail.
(Source: http://technologystudent.com/gears1/gears4.htm)

(e) Ratchet and pawl



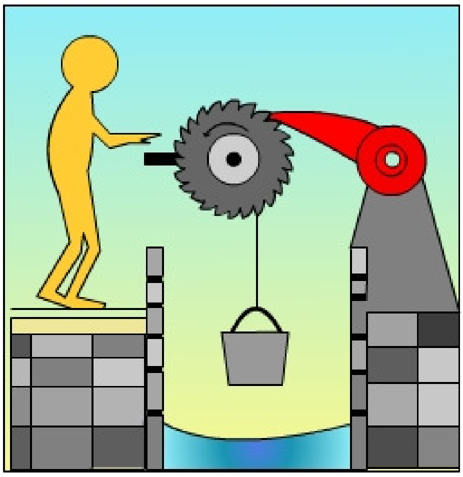


A Ratchet mechanism is composed of two major components, namely

- Ratchet – A wheel with teeth
- Pawl – An arm following the wheel to go up and down

Operation of ratchet mechanism:

- When the ratchet is rotating, the pawl falls into the gap or 'dip' between the teeth.
- The ratchet wheel can rotate in a single direction, either clockwise or anticlockwise.

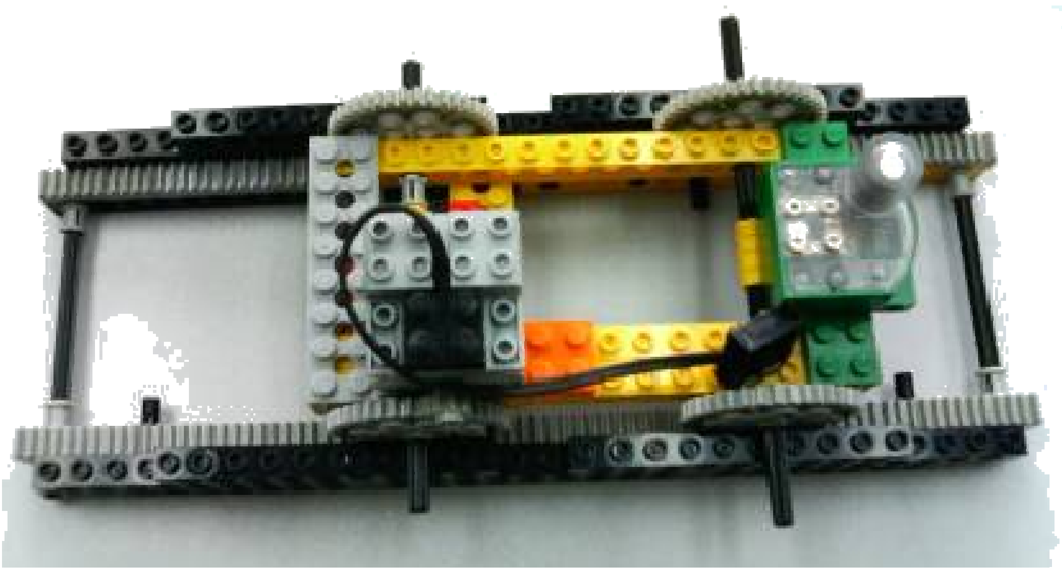


Example: A well

A ratchet mechanism can be applied to a well. The above picture shows that the person can rotate the handle only in an anticlockwise direction, leave his hands off when necessary. It is because there is a pawl locking the gap or 'dip' between teeth.
(Source: http://technologystudent.com/cams/ratch1.htm)

STOP AND THINK

Describe how a mechanism for the following movement of a train on a rack and pinion is design.



3.4 PHYSICAL STRUCTURE

A structure is the framework that keeps an object's shape and form against applied forces. In the context of physical structure, strength and stability are considered.

(a) Strength refers to the capacity of individual elements of a structural system against the load applied on the system.

(b) Stability is the capability of a structural system to transfer the loadings on it to the ground safely.

(Source: http://www.uoregon.edu/~struct/courseware/461/461_lectures/461_lectures_index.html)

3.4.1 Forces

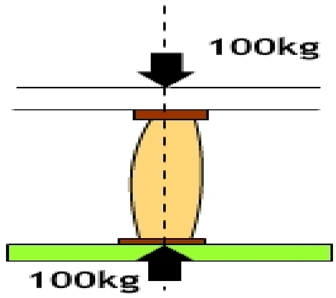
A force changes or tends to change the state of motion of an object. Force is a vector quantity and can be represented either mathematically or graphically.

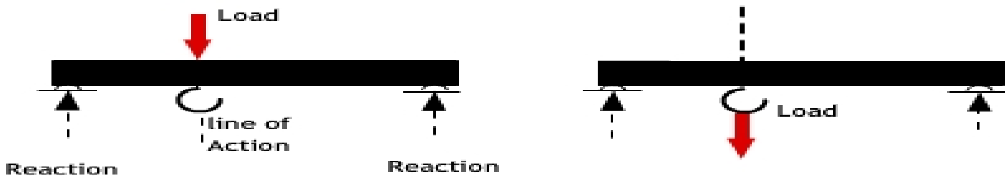
An exact description of a force requires three elements, namely:

(a) Magnitude,
  (i) It is usually expressed in Newton (N); and
  (ii) It is represented graphically by the scaled length of an arrow, which refers to the force;

(b) Direction,
  (i) It can be observed through the line of action of the vector of the force.

(c) Point of Application
  (i) It is the location of the force applied on an object.



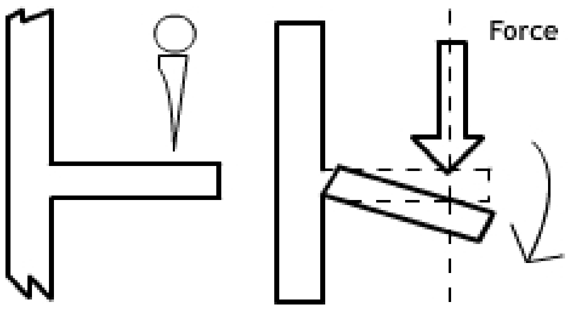


- Reaction – The force in the same magnitude but opposite direction to the action force
- Load – The point of an external force acted on an object
- Equilibrium – No net change in the static effect of an object

(Source: http://www.uoregon.edu/~struct/courseware/461/461_lectures/461_lecture4/461_lecture4.html)

3.4.2 Moments

A moment refers to the magnitude of force which is applied to a body at a distance from the axis of rotation.



Suppose that two people are pushing a door in opposite sides. If the forces are in the same magnitude, a state of equilibrium appears. However, if either one stops pushing suddenly, the door will swing away. The person who keeps pushing the door creates a moment on the door.

The magnitude of a moment is the force that applied at a point or axis. It is directly proportional to the distance of the force.

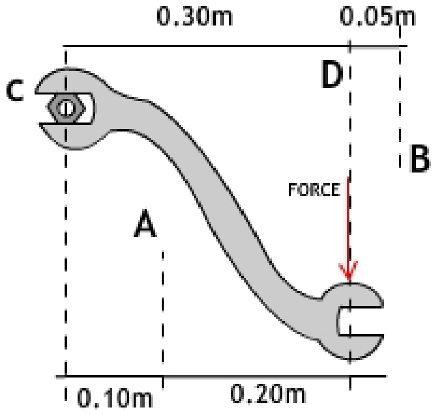
Centre of Moments is the actual location, or the reference point or axis, that the force causes rotation.

Moment

(a) It is the product of the force (F) and the moment arm (d).

Moment = Force x Distance
M = Fd

(b) It is expressed in unit of Newton-metres (Nm).
(c) It is in either clockwise or counter-clockwise direction.

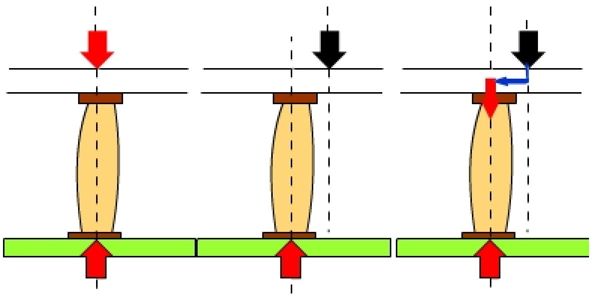


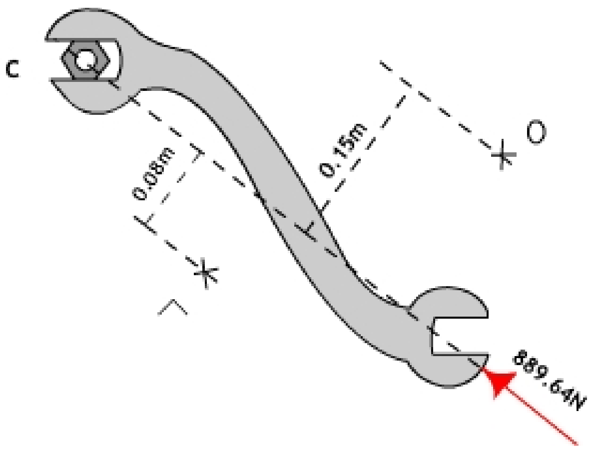
Example:
It is a wrench on a nut at point C. A force of 444.82N is applied at a distance 0.30m from the nut.

If the centre of moments is at point C, then
Moment arm = 0.30m
Moment = 444.82 x 0.30 = 133.45Nm

If the centre of moments is at point A, then
Moment arm = 0.20 m
Moment = 88.96Nm

Zero moment occurs when the force is applied at the point that is parallel to axis of the centre of moments. It is because the force cannot cause the rotation.





Example:

A force of 889.64N is applied on the wrench. Since the moment arm (d) is zero, the moment is zero. There is no tendency for the force to rotate the nut.

A moment can also refer to the result of forces diverting, or detouring, from a direct line drawn between a system's loading point and its supports. Generally speaking, the higher efficiency the structural systems have, the smaller amount of detours will be.

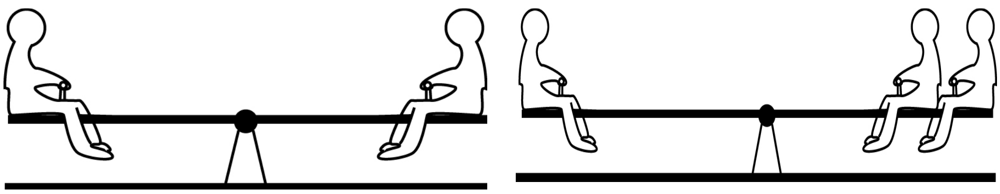
In some cases, calculating the moments of the components of a force around a certain point is easier than the moment of the force itself. For example, it is difficult to determinate the perpendicular distance of the force that of the force's components. The moment of several forces about a point can be easily obtained by adding up the individual moments about the same point.

(Source: http://www.uoregon.edu/~struct/courseware/461/461_lectures/461_lecture5/461_lecture5.html)

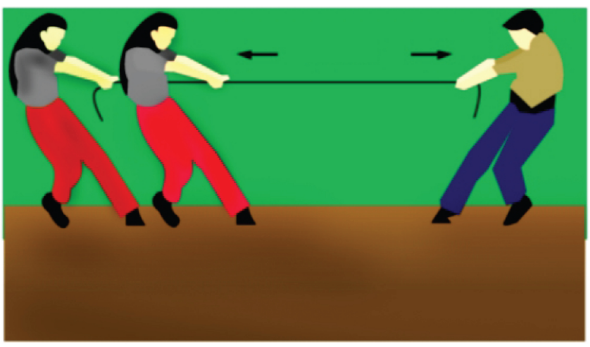
3.4.3 Equilibrium

Equilibrium refers to state that a system has no motion when acted by forces. In daily life, architectural structures are expected to remain static instead of moving dynamically, even when a loading is added.

A see-saw in a playground is an example of equilibrium in daily life.



A state of equilibrium can be obtained when the weights of people of two sides are identical and the people are sitting at exactly the same distance from the centre. Equilibrium will remain unchanged until something happen. For example, if one more person is added on the right side, or one of the original two people changes her/ his positions, the see-saw will swing. It will become rest again when a new state of equilibrium reaches.



In the example shown above, a state of equilibrium is struck when the net force is zero. In other words, the force pulling to right is equal to the force pulling to left.

The structure is in equilibrium when all forces or moments on the structure are balanced. This means that each force acting upon the structure is netted off by an equal and opposite counterpart.

Example: Bamboo beam

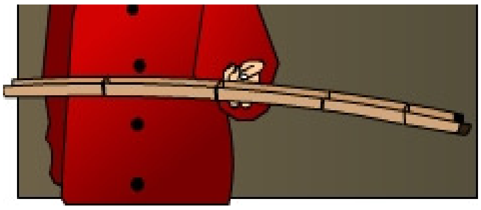


Figure A

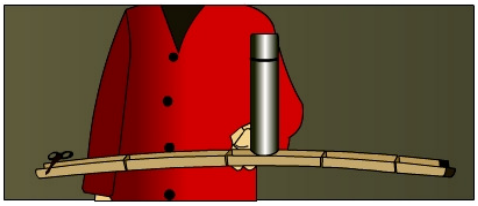


Figure B

The figures above show that the bamboo beam is held in a state of equilibrium:

(a) Figure A shows that the beam system maintains a state of equilibrium by itself.

(b) Figure B shows that a thermos and a pair of scissors have been placed on the beam. The weight of the pair of scissors is much less than the thermos. In order to achieve a state of equilibrium, the moment arm of the pair of scissors has to be longer than the moment arm of the thermos so that all moments and forces are balanced.

A state of equilibrium can be achieved with the following conditions satisfied:

Sum of All Vertical Forces (Fy) = 0

Sum of All Horizontal Forces (Fx) = 0

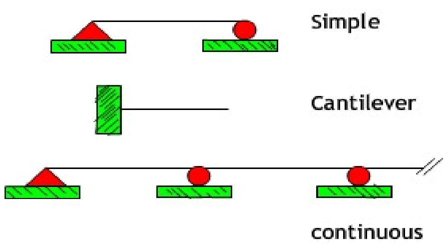
Sum of All Moments (Mz) = 0

(Source:http://www.uoregon.edu/~struct/courseware/461/461_lectures/461_lecture6/461_lecture6.html)

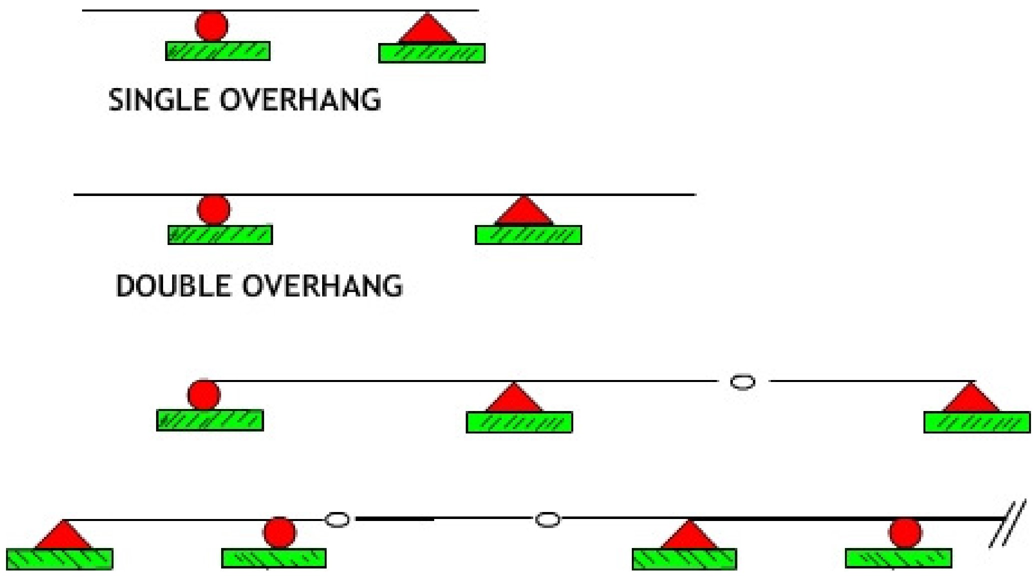
3.4.4 Beams

A beam is a structural member that carries loads. An internal stress is developed by the load on a beam for resisting applied loads. Bending stresses, shearing stresses and normal stresses are the three main internal stresses.

A. Types of beams:



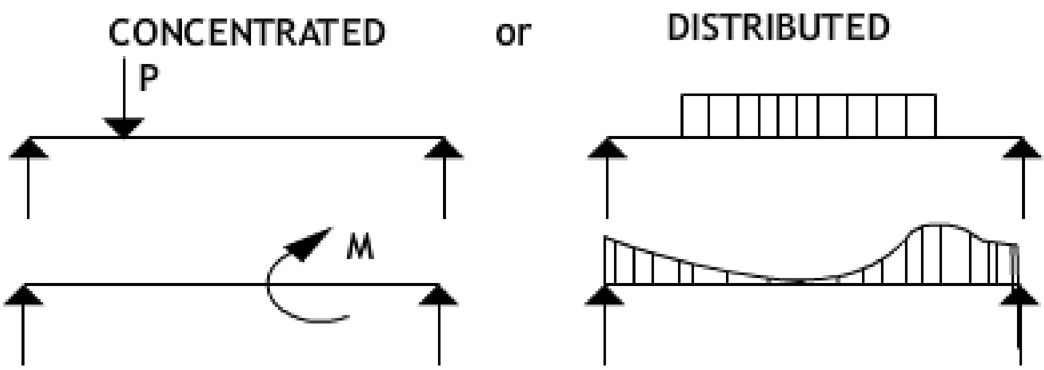
Complex system of beam types:



There are two beam loading conditions, namely

(a) Concentrated
  - (i) A force or moment is applied as a concentrated load.
  - (ii) The force or moment is applied at a single point along the axis of a beam.

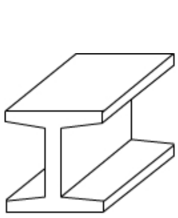
(b) Distributed
  - (i) A force or moment is applied as uniformly or non-uniformly distributed load.



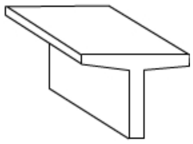
(Source: http://www.uoregon.edu/~struct/courseware/461/461_lectures/461_lecture31/461_lecture31.html)

B. Beams and Sections

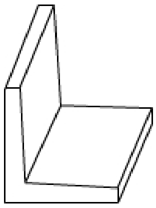
Beams are often used as the distance between two walls. The performance of beams relies on the materials they are made of and their shape. Steel girders are widely used for holding the roof up in buildings. There are different shapes or ‘sections’ of beams, such as:



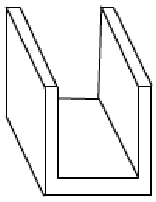
I - SECTION



T - SECTION

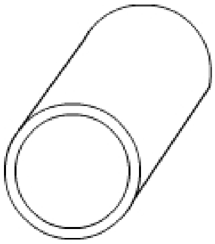


L- SECTION

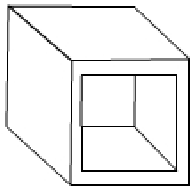


U- SECTION

Apart from their use in buildings, sections are used in bicycles with circular sections or 'tube' and metal tables with square sections. Sections allow bicycles and metal tables to be less expensive and lighter.



CIRCULAR SECTION



SQUARE SECTION

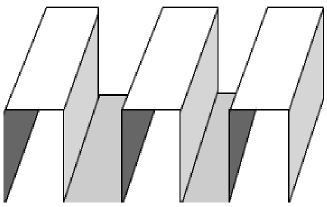
Reasons of using sections:

(a) Sections are lighter than solid materials;
(b) Sections are cheaper than solid materials;
(c) The structure of a section is very strong; and
(d) Bending and breaking the structure of a section is more difficult than solid materials.

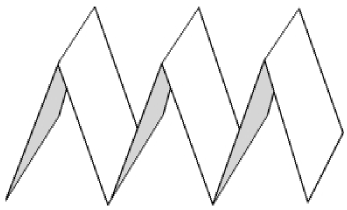
(Source: http://technologystudent.com/struct1/beam1.htm)

C. Frames

A frame is often used in daily life such as a stool. Frames' strong structures enable the construction of high buildings.

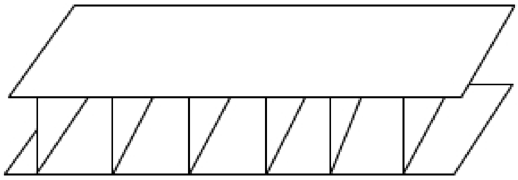


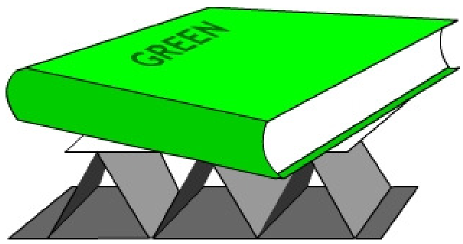
Square frames are strong against the pressure applied in a straight down direction. It is weak and easy to collapse if the pressure is in a side direction.



Triangular frames are very strong. This explains why many man-made structures, such as buildings, employ triangular frames, which are also known as Triangulation.

The above frames can be created with card or paper. Sticking a piece of card on the top and bottom of a frame can make the frame even stronger. An experiment can be conducted by putting books on the top of each frame to test the strength of each frame.



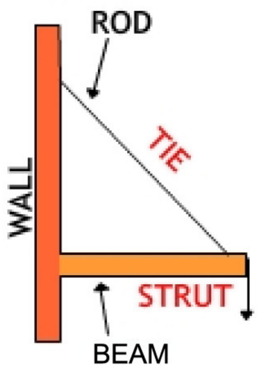


(Source: http://technologystudent.com/struct1/frame1.htm)

D. Struts and Ties

A tie refers to the structure on which a tensile force acts. A strut refers to the structure on which a compressive force acts.

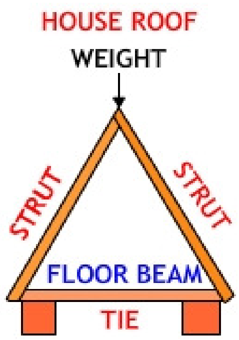
All structures have the forces to apply on struts and ties:



Wall

(a) The weight of the beam is the tensile force on the rod (Stretching); thus the rod acts as tie.

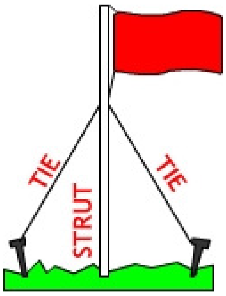
(b) The weight of the beam is the compressive force on the beam; thus the beam acts as strut.



Roof

(a) The floor beam acts as tie since a tensile force (stretching) is applied by the weight.

(b) The roof beams act as struts since a compressive force is applied by the weight.



Flagpole

(a) There is a tensile force on the wire; thus wires are the ties.

(b) The pole is the strut. Explain where the compressive force comes from.

(Source: http://technologystudent.com/struct1/strut1.htm)

S T O P A N D T H I N K

The picture shows the structure of an outdoor tent. Discuss the physical structure of the tent, such as the beam, support, force and equilibrium aspects .

See also the suggested activities in the Learning Resource Materials.

3.5 BASIC ELECTRONICS

3.5.1 Basic theory

(a) Current and Voltage

Current is the flow of electrons. When a current flows through, for example, a lamp, there is voltage difference across the lamp, making it on.

Voltage difference is similar to water pressure, while the analogy of current is water flow. The amount of water flow increases as the water pressure increases. Similarly, if the voltage difference is large, more current can flow though an electrical appliance. For the above example, a larger current results in a brighter lamp. However, an excessive current may generate excessive heat, melting the conducting wire and damaging electrical appliances.

The unit of current is Ampere (A). The unit of voltage is Volts (V).

(b) Resistance and Power

Resistance exists in all electrical appliances. Resistance is the force opposing the electric current. Mathematically, it is the ratio of voltage difference and the current through the electrical appliance, or Ohm's law. A large resistance consumes more power, which is subject to the amounts of the current and resistance, or $P = I^2R$ (where P = Power, I = Current and R = Resistance).

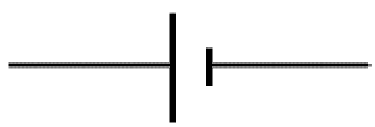
The unit of resistance is Ohms (Ω). The unit of power is Watt (W).

(c) Electromotive Force (EMF)

EMF refers to the power supplied to an electric circuit, such as a battery or the power supply. When a circuit is closed, EMF drives an electric current to flow through the circuit. On the contrary, if the circuit is opened, no electric current can flow, and the electrical appliances connected to the circuit cannot be switched on.

There are two types of EMF sources, namely AC and DC. If the EMF source voltage is changing, it is AC source. Otherwise it is DC.

The electric circuit symbol for a DC EMF source is:



Formula:

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

$$P = I^2 R \text{ or } P = \frac{V^2}{R}$$

(d) Series Circuit

The total resistance of a circuit connected with multiple electrical appliances in series is the sum of all resistances.

3.5.2 Electronic Elements

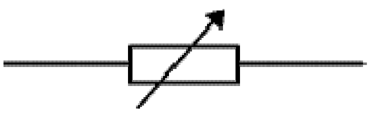
(a) Resistor

A resistor in an electric circuit is to control or limit the current flowing through, protecting the electronic devices in the circuit.

In a circuit diagram, the symbol of a resistor is:

A resistor whose resistance is adjustable is called a 'variable resistor'.

The symbol is

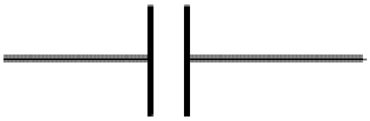


(b) Capacitor

A capacitor stores electric charges. Its major use is to shape the voltage waveform. In addition, it can store energy like a rechargeable battery.

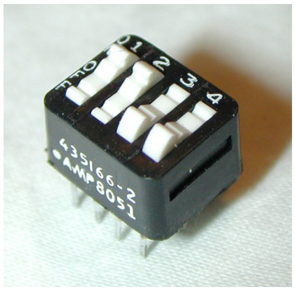
The above capacitor can be charged by solar cells or by motors. ‘The capacitor can be used for powering a motor. When the capacitor is fully charged, the operating voltage is normally 2.5V.’

The circuit symbol is



(c) Switch

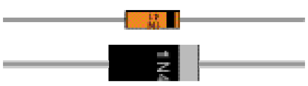
A switch is used for opening or closing a circuit, changing the current path or circuit.

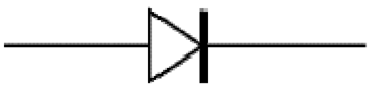


The circuit symbol is

(d) Diode

The function of a diode is to control an electric current to flow in one direction without reversal.



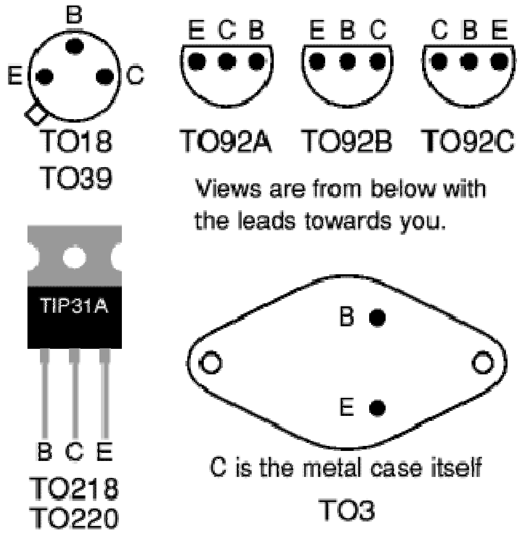


(e) Transistor

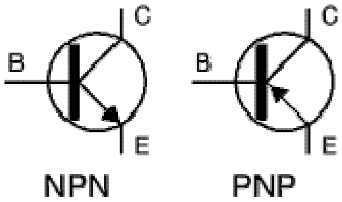
Transistors can be used to
(i) Amplify voltage signals, or
(ii) Function as a switch to provide larger currents for high power devices, such as motors.

A transistor has three terminals, namely Base, Collector and Emitter. A small signal appears at the base terminal can induce a large voltage signal at the collector. Therefore, a motor connected at the collector or emitter terminal can receive a large current for larger power with only a small current.

Some examples of high power transistors are shown below:



The electric circuit symbols are:



(f) LED

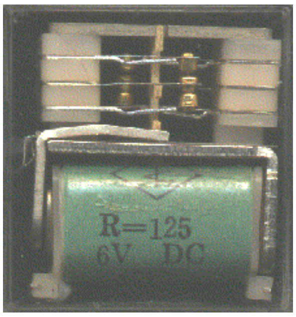
A current flowing though LED can emit different colour lights. High intensity LED's are available in the market.

(g) Buzzer

A buzzer is in fact a conventional speaker. A buzzer or speaker vibrates and produces sound with an electric current passed though. The frequency of electric voltages or currents affects the sounds produced.

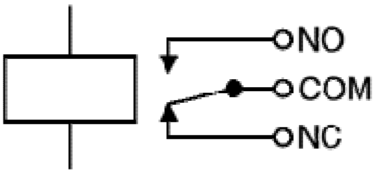
(h) Relay

A relay is a switch controlled by a small electric current, switching large currents to different portions of an electric circuit to control high-energy electrical appliances.



An electric current going through an electric wire coil as shown above can produce a magnetic force. The force generated will move the metal plate from a portion of an electric circuit to another portion. As a result, In this case, a large current or 220 V AC voltage can be directed to motors or electrical appliances.

An example of the relay symbol is shown below:



(i) Motor

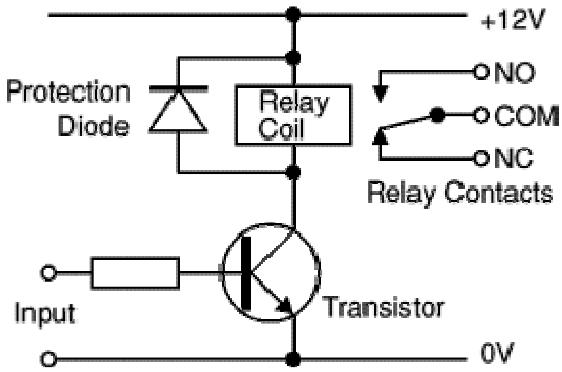
A motor rotates when a current flows through it. If the current's direction reverses, the motor's rotating direction reverses as well. Generally speaking, the speed or rotating angle of a motor cannot be controlled. A servo motor is an exception that its speed is controllable. Another exception is stepper motors. The total rotating angle and corresponding moving distance are controllable and measurable.

For a motor to function properly, sufficient power is a prerequisite. One way to ensure sufficient power is to make use of a power amplifying circuit. Another choice is connecting a separate Relay-controlled power supply to the motor.

The motor shown above has a gear attached, providing a large torque.

S T O P   A N D   T H I N K

Explain the operations of the following circuit.



3.5.3 Electronic System

Electronic products can be as complicated as medical instruments and computer notebooks; or as simple as electronic toys. However, no matter how complicated they are, they can be easily understood if they are decomposed into functional blocks.

(i) **Functional blocks**

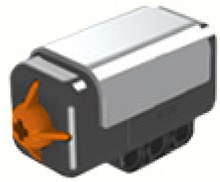
Similar to human bodies, some normal electronic products are equipped with function blocks of sensor for receiving information from environment, processors for processing inputs and producing outputs, and actuator for acting on output instruction, such as displaying the output information.

For a human body, the communication among such functional blocks is responsible by the neural system. For electronic products, it relies on sensors and actuators.

(ii) **Sensor Functional Block**

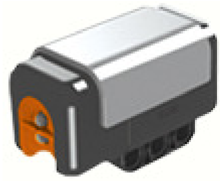
The sensor of an electronic product is the interface between the real world and the electronic system of the product. For example, a temperature sensor is responsible for converting different temperatures into corresponding electronic signals. When receiving an electronic signal, a processor converts the signal back into the corresponding temperature by referring to a predefined signal-temperature mapping table. Another example is light intensity sensor. Such sensors convert the different light intensities to corresponding electronic signals. For further illustration purposes, some sensor products are listed below.

(b.1) Touch sensor



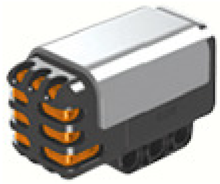
'The Touch Sensor gives your robot a sense of touch. The Touch Sensor detects when it is being pressed by something and when it is released again.'

(b.2) Light sensor



'The Light Sensor enables your robot to distinguish between light and dark. It can read the light intensity in a room and measure the light intensity of coloured surfaces.'

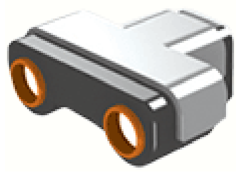
(b.3) Sound sensor



A sound sensor measures sound pressure. Sound pressure levels are complicated and very often the readings on the sensors are displayed in percent [%]. The lower the percent the quieter the sound is. For example,

- 4-5% is like a silent living room;
- 5-10% would be someone talking some distance away;
- 10-30% is normal conversation close to the sensor or music played at a normal level; and
- 30-100% are people shouting or music being played at a high volume.

(b.4) Ultrasonic sensor



'The Ultrasonic Sensor enables your robot to see and detect objects, avoid obstacles, sense and measure distance, and detect movement. The Ultrasonic Sensor uses the same scientific principle as bats: it measures distance by calculating the time it takes for a sound wave to hit an object and return.'

(iii) **Processor Functional Block**

The data captured by a sensor have to be processed by a microprocessor. A microprocessor is considered the 'brain' of an electronic system.

For example, the ambient temperature is 30°C. This temperature is first captured by a temperature sensor as input data and then sent to a microprocessor. The microprocessor subsequently compares the temperature captured with the predefined criterion that any temperature above 28°C is considered 'hot'. Upon meeting the criterion, the microprocessor instructs the actuator to turn the fan or the cooler on.

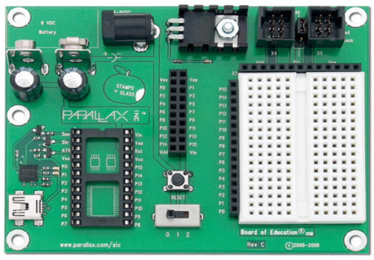
The example shows that a microprocessor should be programmable (do the comparison), and has a memory (keep the predefined 'hot' threshold of: 28°C). In addition, the processor functional block should have an input interface or port to accept data sent from the sensor to the microprocessor. An output port for delivering the microprocessor's instructions to an output device is also mandatory.

The above processor block has four input ports for attaching to sensor blocks, and three output ports for motor blocks.

Parallax has a BASIC Stamp II product. The product is a 24-pin Dual inline package (DIP) module.

In order to connect the peripheral modules to this processor, an extra circuit board is required. The circuit board below can be used for education purposes:

A circuit board is for paving the conducting path (copper wire) that joins individual electronic components. It is also known as 'PCB'. The white board shown in the above diagram is usually called 'breadboard' in Hong Kong. There is a pre-defined conducting path under the breadboard, minimizing the soldering or wiring effort.



There are four ports in Basic Stamp II. They can be configured to either input or output. Since each port can only support up to two motors or four LED displays, Basic Stamp II provides higher flexibility than Basic Stamp I.

Both types of blocks need development of computer programs. The program codes will be downloaded to the microprocessors.

(iv) **Output Functional Block**

Like human, output functional block can produce sound, movement and can express or display information.

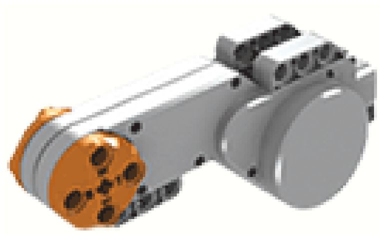
(v) **Information Display Functional Block**

This functional block is for display purposes. For the processor mentioned above, the LCD display has been incorporated in the processor unit NXT.

LED display is another popular alternative. For the Basic Stamp II mentioned above, one port can support four LED displays, making it feasible to construct an LED array for displaying the more complicated patterns, such as Chinese characters. For protecting an LED against overloading by electric currents, an appropriate resistor can be connected with LED in series.

(vi) **Motion Making Functional Block**

Motion Making Functional Block is also known as actuator. Motor is one of the popular types. Since the current coming from an output port is not strong enough to drive a motor, direct connection between these two devices is rare, if not never. As a result, a power driver module as a motor's current provider is necessary. Similarly, other high power output devices, such as speakers, require power driver modules.



For example, a servo motor module is built-in with a power driver module. This module is directly connected to a microprocessor.

(vii) **Sound Producing Functional Block**

A large speaker can produce sound with a power driver module in general, while a Buzzer or Piezo speaker can produce sound without the module.

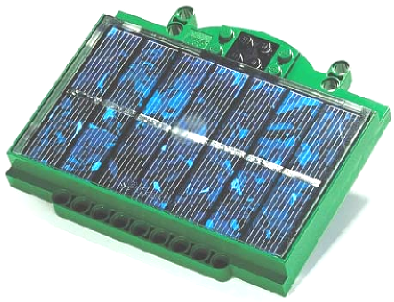
Buzzer can produce different sounds according to the voltage signal frequencies. Mixed frequencies can produce music tone as well.

(viii) **Energy Functional Block**

A wall socket in Hong Kong supplies 220V, Alternative Current (AC) electricity. Such high voltage is a risk in daily life. For electronic products using Direct Current (DC), the voltage is much lower.

Battery cells are one source of DC electricity. Power adapters are another. A power adapter is a special electronic product or functional block that converts electricity in AC to that in DC.

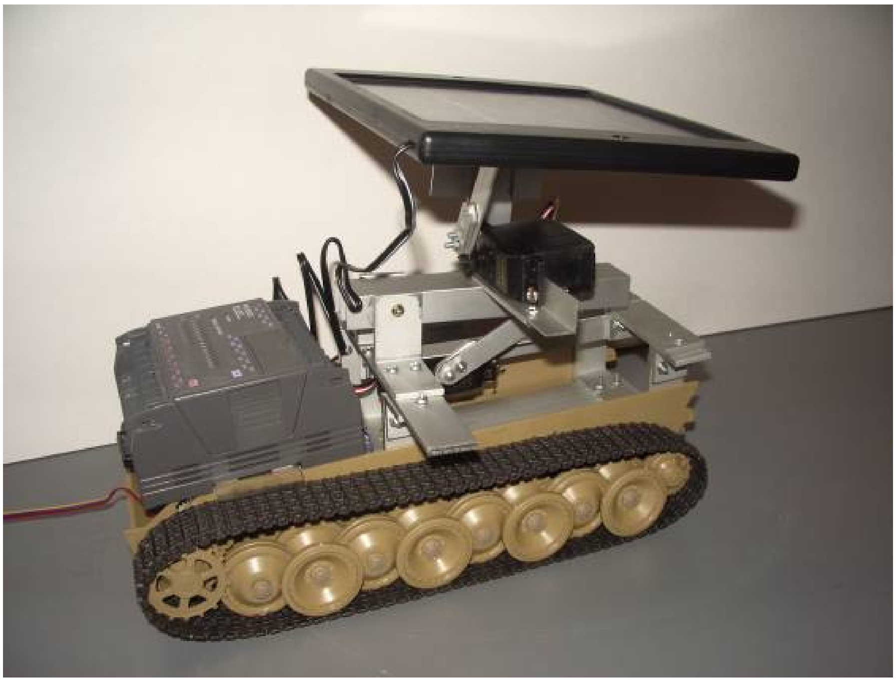
Solar cells, along with other alternative energy sources, can help as well. Solar cells convert sun light energy to electrical energy. The development in technology keeps lowering the price of Solar cells. For example, Solar cell products are sold as a kit tool.



The above Solar Cell can provide 3 Volts and 200 mA electricity enough driving the motor of the toolkit under the full sun light.

S T O P A N D T H I N K

Explain the functions of the following solar tank's components, namely solar panel, Programmable Logic Controller (PLC), mechanical supporting frame and the track.



THEME – BASED LEARNING

Theme 1 - Case Study of Octopus

Topic: Nature of Technology – Inventions and Innovative Applications for Living:

This theme is to show the beauty of technology application. Octopus is an integration of innovation and technology, energy and energy resources, and materials and standard components.

A. Background

Octopus is a contactless smart card system. Its cards store monetary value and require no power supply. Octopus enables electronic fund transfer for payment of transactions executed in most transportation systems and many retail outlets, such as supermarkets, fast-food restaurants, on-street parking meters, car parks, service stations and vending machines.

This system has been recognised internationally for its leading and innovative use of technologies.

Octopus card is a Radio Frequency Identification (RFID) application that can store rechargeable data. Whenever a transaction is done with Octopus, the system extracts data (monetary value) from the RFID in the card and, through an RFID scanner, reset the data, such as increasing or decreasing the monetary value. Octopus's RFID is a passive device, requiring no energy source for operations and having an unlimited life cycle.

B. Innovative Inventions

Apart from Octopus, there are many other applications for RFID. For example, it can be used for baby identification in hospitals, guest identification in hotels and stock checking.

Baby Identification in Hospitals

It is not news about baby kidnapping and accidental baby switching in hospitals. RFID is an easy solution to these two problems. In an RFID-implemented hospital, each baby has to wear a bracelet with an RFID tag embedded. At the same time, a parent or guardian of the baby has to wear a counterpart, matching RFID tag. Whenever the baby concerned passes through a designated station, her/ his RFID tag has to be scanned. The system will alert hospital staff if the scanner reveals that either of the following situations happens:

(a) Only one tag is detected; or

(b) Unmatched tags.

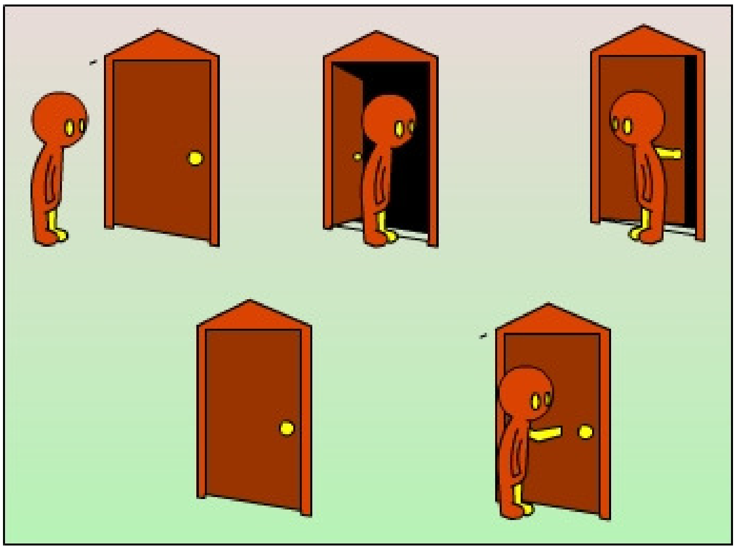
For better security control, in addition to an RFID tag, a baby bracelet has to be incorporated with a tempering prevention device that alerts hospital staff in case of unlawful breaking of the bracelet.

Guest Identification in Hotels

The usual problems with hotel keys are key loss, illegal key duplication, difficult identification for genuine guests, etc. RFID again is an easy solution to hotel management.

In an RFID-implemented hotel, each guest is given an RFID tagged ID card upon check-in. The RFID reader built at each room will verify, through the guest's RFID, the identity of each guest attempting to enter into the room. As a result, only the right guest can go into the right room, which will open the door and even switch on the power supply for a welcome. For security purposes, the RFID will be reset upon the departure of the guest using it.

Besides guest identification, RFID can help accounting, registration, etc in a hotel.



Stock Checking

RFID can facilitate stock checking. No matter whether it is a warehouse or a supermarket, the status and information of each RFID-tagged product item can be checked through an RFID scanner. Even more, product information retrieved can be transmitted to the mobiles and Personal Data Assistant (PDA)'s of customers.

C. Follow-up Activities

1. Explain why major entrepreneurs in Hong Kong's transport industry use Octopus for fee payment.
2. Suggest applications of RFID, in addition to the cases illustrated above. Briefly explain how.

RFID Tags

RFID Scanner or Reader

Theme 2 - Food preparation in a Restaurant Kitchen

Topic: Production Process

This theme is to demonstrate the use of appropriate tools, equipment and machineries at workplaces; the health and safety issues; and the manufacturing systems associated with product processing or fabricating.

A. Background

In many developed countries, restaurant kitchens or similar establishments are subject to public health laws. These kitchens are inspected regularly by the government. In case of not meeting hygienic requirements, they may be force-closed.

Canteen is often pioneer for new technology. For example, the use of 'energy saving stove' by Benjamin Thompson in large kitchens started thirty years before that in domestic counterparts. It is an early 19th century fully-closed iron stove with one fire for several pots.

Nowadays, in order to keep the kitchens clean and cost-justified, the walls and floors of most western restaurants kitchens are tiled and other surfaces, such as workbench, doors and drawer fronts, are made of stainless steel. For quick and easy heating, many professional kitchens are installed with gas stoves, instead of electrical ones. Also in professional kitchens are special cooking tools, such as large installed deep fryers, and steamers etc.

A modern kitchen with capacity of preparing fresh food for up to hundreds

While changing people's life style, the fast food and convenience food cultures change the operations of kitchens. With the almost single objective of food delivery, restaurants as such may simply re-heat prepared meals, or at most grilling a hamburger or steak. It is especially true for those kitchens with limited space, such as galleys in aircrafts, ships, trains and space shuttles. In a space shuttle, food is completely prepared, dehydrated and sealed in plastic pouches before launched. The galley is solely an area for rehydration and heating.

B. Follow-up Activities

1. Identify the risks of the following in a kitchen
(a) Use of improper cooking utensils,
(b) Human errors, and
(c) Environment situations.

2. Identity the most appropriate production processes for the kitchen of the following:
(a) A fine classy French restaurant,
(b) A large fast food canteen, and
(c) A delivery service pizza restaurant.

Theme 3 - Identify the Sub-Systems in a Track Guided Vehicle

Topic: Systems and Control

This theme is to highlight the need of integrating different sub-systems and controls for the production a vehicle moving along a coloured track. The sub-systems include the input-process-output, mechanical, physical structure, electronics and embedded controller.

A. Background

The following vehicle is designed for moving along a coloured track. The moving mechanism, electronics, light sensor and embedded controller sub-systems are covered in the movement.

(a) The moving mechanism sub-system is composed of two wheels and a driving motor.
(b) The electronics sub-system is the source of power for driving the motor.
(c) Light sensor sub-system (i.e. a control programme) provides the logic gates with signals about the coloured track.
(d) The embedded controller sub-system controls the vehicle to track the coloured track and correct the moving direction.

B. Follow-up Activities

Explain the functions of the following sub-systems:
1. Input-process-output process by the embedded controller;
2. Mechanical sub-system including wheels and the motor gear box;
3. Light sensors; and
4. Physical structure.

ASSESSMENT TASKS

Assessment Task 1 Case Studies

Case 1: Lighting along Hong Kong Victoria Harbour

Strategy and Activity

(a) Identify the types of lights used in the buildings;
(b) Estimate the energy used for the lights in an evening and state your assumptions; and
(c) Discuss the pros and cons of spending such money on the lights every evening

Case 2: Safety and Health of a Manufacturing System

Strategy and Activity

The following three workplace pictures show a manufacturing system for material processing, hand-operation and welding. Discuss the precaution measures of each of these systems for the safety and health of the workers.

Material Processing

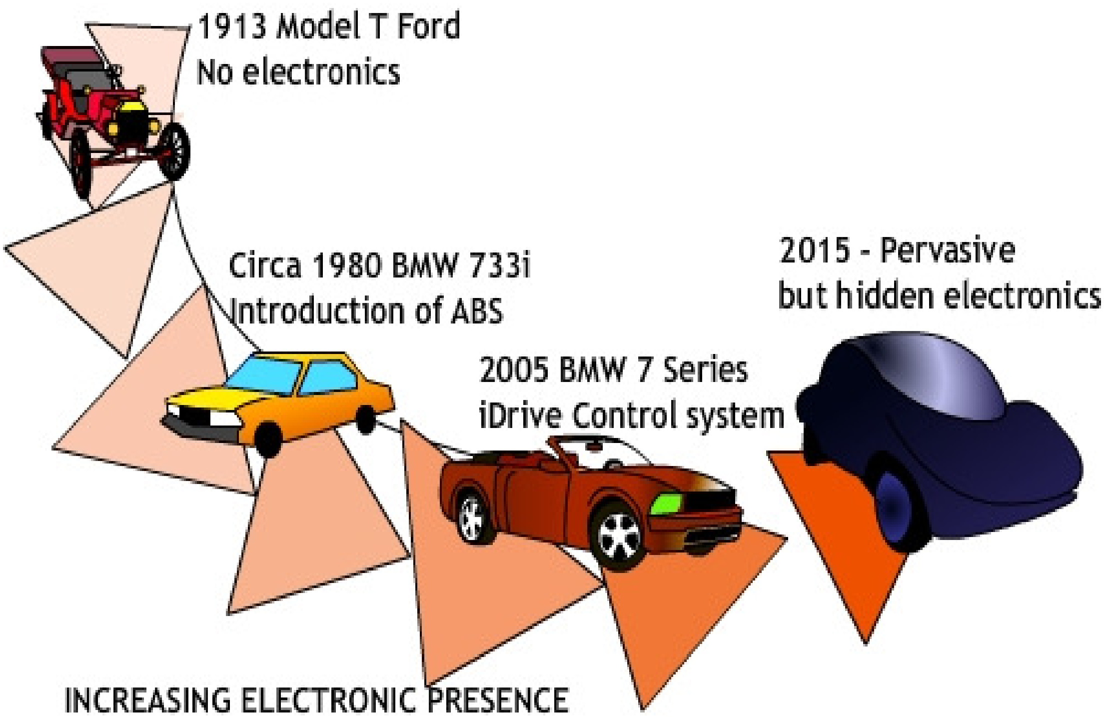
Hand-operated bending tool

Welding

Case 3: Evolution of System and Control in cars

Strategy and Activities

Explain what the changes of electronics, logic gates, mechanical system, physical structure and control have been made to the evolution of cars.



Assessment Task 2 Design Project

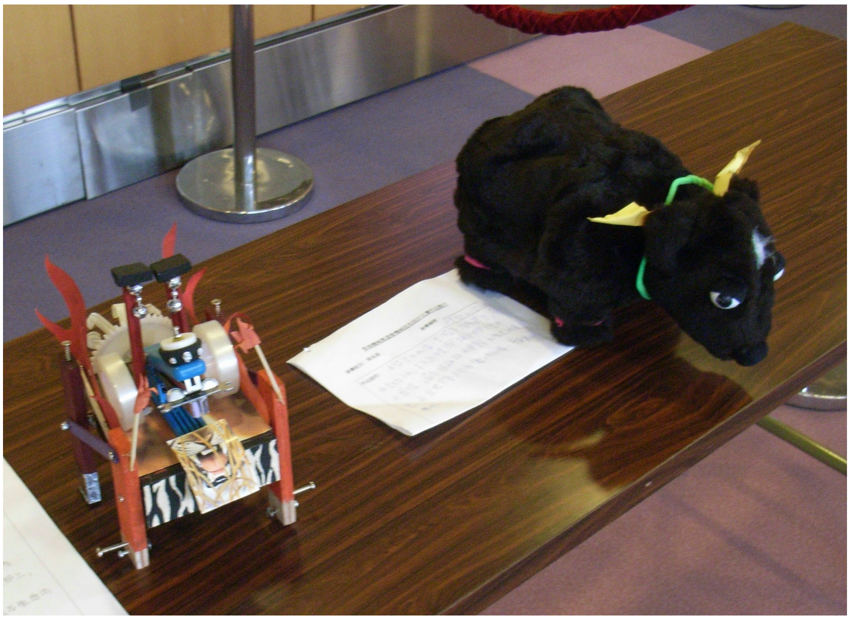
Project Title: A battery powered robot

Design Specification

(a) Materials
  (i) Two 3A batteries,
  (ii) DC motor,
  (iii) Gear box, and
  (iv) Wood, plastics or clothes for the body and frame

(b) Robot movement
  (i) The robot should be able to move on a flat surface with different motion features.

Two sample robots

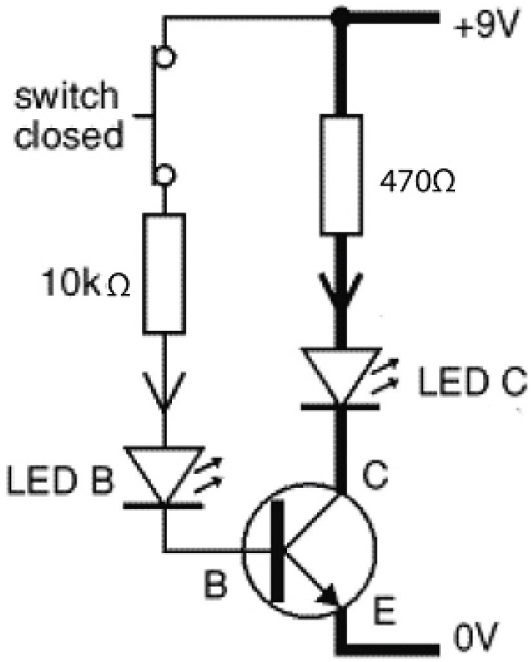


Assessment Task 3 Practical Task

Topic: LED

Part 1: Building an LED Light Board (60 minutes)
1. Refer to the circuit for the LED Light Board shown below;
2. Select the right components for building and testing the circuit;
3. Place the components on the provided breadboard; and
4. Solder the components

Part 2: Testing and commissioning of the circuit (30 minutes)
1. Set an right voltage of power supply;
2. Check the circuit to ensure that it will still be safe when the power is on;
3. Switch on the power; and
4. Observe the circuit's performance: It is expected that when a large current flows through the circuit, the LED emits bright light; otherwise, it emits dim light.



Assessment Task 4 Quizzes

QUIZ 1 – Innovation and Technology

Multiple Choice Questions

1. Which one of the following statements best describes ‘invention’?

A. Invention is science.
B. Invention and technology are related.
C. Invention realizes an existing concept or method.
D. Invention is the improvement of living quality.

2. Which one of the following statements best describes ‘innovation’?

A. Innovation realizes an invention.
B. Innovation is only applicable to engineering.
C. Innovation costs more but can pay off.
D. Innovation cannot be materialized without new technology.

3. Which one of the following statements best to describes ‘technology’?

A. Technology realizes engineering.
B. Technology cannot be materialized without new technology.
C. Technology provides all engineering problems with solutions.
D. Technology is the achievement of science and engineering.

4. Technology improves living quality on one hand, it creates problems to people on the other. It is because

A. People are too tired to keep themselves updated of the ever-updating new technology.
B. Applying technology to daily life is costly.
C. Technology comes along with by-products, such as pollution and wastes.
D. Technology is rarely practical.

5. Which of the following is not a technology that Two ifc adapts?

A. Technology for lift and escalator control
B. Technology for energy saving
C. Technology for central air-conditioning
D. Technology for regenerative energy

6. Octopus is an innovative application of the inventions of

A. Audio sensor, cards, detector and milling machines
B. Cards, detector, infrared sensor and laser machines
C. Cards, computing machines, detector and RF sensor
D. Cards, computing machines, detector and light sensor

7. Which of the following statements identifies innovation?

A. Innovation itself is change, and gives birth to change as well.
B. Innovation happens in a context.
C. Innovation adds value to an existing situation.
D. Innovation is an improvement of a process or invention.

8. Which of the following statement(s) is/are the effect(s) of invention and/ or innovation on modern life?

A. Computers bring convenience for humankind, changing people's daily life.
B. Invention and innovation change the communication modes among people, making people's paces faster and faster.
C. The world is evolving into a global village, i.e. globalization.
D. All of the above

9. Which of the following is widely considered an innovative payment system of the recent years?

A. Direct Debit Authorization and Instruction
B. Octopus card
C. Cheque
D. EPS

10. Which of the following statements is FALSE?

A. Technology enhances efficiency.
B. Technology enhances people's life quality.
C. Eco-technology is adopted to protect the earth against global warming.
D. None of the above

Long Questions

1. Describe how telecommunication evolves from table-top telephones to mobile phones.

2. Describe how technology changes telephones of the 1970's to the recent multi-function models.

3. Octopus shows people's reliance on technology for improvement of life. Name four Octopus's applications.

4. Name three areas that technology is the most commonly applied to in daily life.

5. Explain, with an example, how inventions and innovations can be integrated to enhance people's quality of life.

QUIZ 2 - Energy and Energy Resources

Multiple Choice Questions

1. Which of the following is NOT a source of renewable energy?

A. Wind
B. Tidal wave
C. Solar
D. Nuclear

2. Which of the following is NOT using mechanical energy?

A. Cycling
B. Riding on a swing
C. Light from a torch
D. Hydro-electric power

3. Which of the following is NOT an energy conversion process?

A. Fishing
B. Cycling
C. Ironing clothes
D. Driving

4. A 6-volt battery is used to keep a room lit for 15 minutes. The light requires a current of 0.3 A. What is the electrical energy drawn from the 6-volt battery?

A. 0.3 W - hr
B. 0.45 W - hr
C. 6 W - hr
D. 1.8 W - hr

5. A 60 g object is moving at a speed of 5 m/s. If there is no friction in the movement, how much the kinetic energy is associated with the movement?

A. 150 J
B. 0.15 J
C. 750 J
D. 0.75 J

6. A 10 kg object drops 20 m from a roof top to the ground vertically. What is the potential energy associated with the fall?

A. 200 J
B. 981 J
C. 1962 J
D. 500 J

7. Which one of the following is NOT a clean energy for generation of electricity?

A. Solar
B. Fossil fuel
C. Biomass
D. Geothermal

8. 8. Which of the following BEST describes the energy conversion for the flashlight?

A. The chemical energy stored in a battery is converted into mechanical energy.
B. The solar energy stored in a battery is converted into heat.
C. The potential energy stored in a battery is converted into light.
D. The chemical energy stored in a battery is converted into light and heat.

9. If a book is pushed along a bench for 2 metres with a force of 2 N, how much work has been done?

A. 1 J
B. 2 N
C. 4 J
D. 4 N

10. A light bulb of 40W gets through 40 Joules of energy per second. How much energy will it get through in one minute?

A. 2400 J
B. 240 J
C. 60 J
D. 40 J

Long Questions

1. Energy on one hand improves people's quality of life, its improper use and generation cause problems to human beings on the other. Elaborate the pros and cons of using energy.

2. Describe the control process for generation of electrical energy by wind power.

3. A 100 kg object is moving at a speed of 50 m/s. It is driven by energy stored in a battery. The battery is charged up from a power source of 220 V and 0.3 A. If all electrical-mechanical energy conversions are perfectly efficient, i.e. 100%, how long does the battery require for full charge-up from zero stored energy? [Given: 1 kWh = 3,600,000 J]
4. An object is falling vertically from a height of 100 m, having a loss in potential energy. If the same amount of energy is used to drive the object to move horizontally on a frictionless surface instead, what is the object's speed?

5. If the potential energy of a 100 kg object at a height of 200 m is converted to electrical energy, how much Watt-hour can be acquired? [Given: 1 kWh = 3,600,000 J]

QUIZ 3 - MATERIALS AND STANDARD COMPONENTS

Multiple Choice Questions

1. Which of the following is a natural material?

A. Aluminium
B. Plywood
C. Fibre
D. Glass

2. Which of the following is malleable?

A. Stone
B. Wood
C. Paper
D. Gold

3. What is the strain of a copper wire when is stretched from its initial length of 1.2 m to 1.3 m?

A. 0.077
B. 0.083
C. 1.083
D. 0.923

4. An object which weighs 10 N is put on the top of a rod, whose surface area is 0.2 m^2. What is the stress on the rod?

A. 500 N/m^2
B. 250 N/m^2
C. 50 N/m^2
D. 10 N/m^2

5. Which of the following is NOT the physical properties of solid state materials?

A. Boiling point
B. Density
C. Hardness
D. Thermal conductivity

6. Which of the following is a material mechanical property?
A. Latent heat of fusion
B. Density
C. Thermal conductivity
D. Ductility

7. A rod's stress is 2500 N/m^2. Its surface area is 0.15 m^2. What is the force added on the rod?

A. 56 N
B. 375 N
C. 16667 N
D. 6 x 10-5 N

8. 8. A force of 100 N is applied on a surface area. The stress is 250 N/m^2. How big is the surface area?

A. 0.4 m^2
B. 0.25 m^2
C. 4 m^2
D. 25 m^2

9. The strain of a wire stretched to 1.8 m is 0.225. How long is the wire originally?

A. 2.11 m
B. 2.21 m
C. 1.50 m
D. 1.47 m

10. The initial length of a wire is 2.0 m. What is its final length if the strain is 1.12?

A. 4.24 m
B. 3.40 m
C. 3.36 m
D. 0.94 m

Long Questions

1. A spring of 1 metre is stretched from its initial length to 2 metres. It returns to 1 metre after released. If stretched to 2.5 metres, the spring will return to 1.25 metres when released. Explain this phenomenon based on the stress-strain curve shown in Figure 1 below.

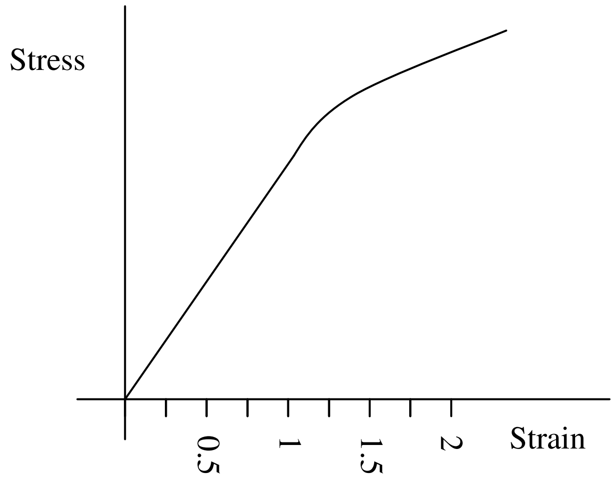


Figure 1

2. Explain why many beverage containers are made of tin.

3. Name three material properties.

4. Name some factors that designers or engineers have to take into consideration such that materials can be best utilized for manufacturing.

5. Describe a good industrial application each for
(a) Diamond, and
(b) Tin.

QUIZ 4 - Health and Industrial Safety

Multiple Choice Questions

1. To ensure a safety promotional programme is effective, which of the following should be included?

A. Publicity of safety legislation
B. Safety procedures
C. Safety instructions
D. All of the above

2. Which of the following is/are (a) common cause(s) of fire in workshop?

A. Defective electrical equipment and wiring
B. Improper storage of flammable liquid
C. Use of naked flame
D. All of the above

3. Safety training helps a worker to

A. Know more about her/ his personal profile.
B. Know more about the safety aspects of her/ his work.
C. Develop her/ his future career.
D. Improve her/ his communication skills.

4. Which of the following statements is FALSE?

A. Safety should be managed in the same way as other business activities in the company are.
B. To improve site safety, efforts of the government, employer and employees are required.
C. Most accidents can be prevented.
D. A company's inherent risks cause no impact on its safety policy.

5. Which of the following types of hand gloves shall be used for anti-abrasion?

A. Cotton
B. PVC
C. Steel
D. None of the above

6. The use of personal protective equipment in paint spraying processes

A. Should always be the first thing to consider in controlling hazards.
B. Should be the last resort of defence when the control measures to eliminate and control hazards are not implemented effectively.
C. Is the only means to eliminate and control hazards in work.
D. Is not a legal requirement.

7. Which of the following statements is FALSE?

A. O_2 is the most popular lasers for cutting materials.
B. Laser is a kind of light radiation. It can be visible and invisible.
C. A laser system produces a very small spot with a high power laser on the material be cut.
D. The fumes and mists created during laser cutting process adversely affect people's respiratory systems.

8. 8. Which of the following are important to personal protection for doing forging work?

(i) Ear protection
(ii) Foot protection
(iii) Breathing Apparatus
(iv) Pair of goggles

A. (i), (ii) and (iii)
B. (i), (ii) and (iv)
C. (ii), (iii) and (iv)
D. All of above

9. Which of the following working environments SHOULD NOT be provided by an employer to his employees?

A. A safe and healthy working environment
B. An environment with safe means of access to an egress window
C. Plant and work systems that do not endanger safety or health
D. An environment in a condition that is safe but inevitable to suffer risks to increase the work efficiency

10. Which of the following is NOT a common fire hazard?

A. Lack of proper maintenance of fire service installations and equipment
B. Flammable material left close to source of heat
C. Adequate cleaning of work area

D. Electrical equipment left switched on when not in use

Long Questions

1. Suggest three precautions that can mitigate the risk of fire in a workshop.

2. List three benefits that good housekeeping practices in the workplace can provide.

3. What should be stored in a first aid box?

4. Explain why extreme care should be taken when laser cutter is used to cut reflective materials.

5. Name four major safety precautions in the workplace.

QUIZ 5 - Tools, Equipment and Machineries

Multiple Choice Questions

1. How frequent should hand tools be inspected?

A. Every day
B. Every month
C. Every time before use
D. Every year

2. Which of the following measures cannot minimize the induced hazards in a forging process?

A. Do forging in separate room
B. Wear ear plugs/ear muffs
C. Equip all furnaces with chimneys/ canopy hoods
D. Keep room warm

3. Which of the following does NOT belong to a machining process?

A. Filing
B. Drilling
C. Milling
D. Turning

4. Which of the following materials is suitable for vacuum forming?

A. Steel
B. Wood
C. Thermoplastics
D. Thermosetting plastics

5. Which of the following methods is NOT common for paint spraying and coating?

A. Airless spraying
B. Compressed air spraying
C. Electrostatic plastics
D. Vacuum

6. Which one of the following is NOT a hazard in the workplace?

A. Work at height
B. Electrical wiring
C. Protection equipments
D. Sharp pieces

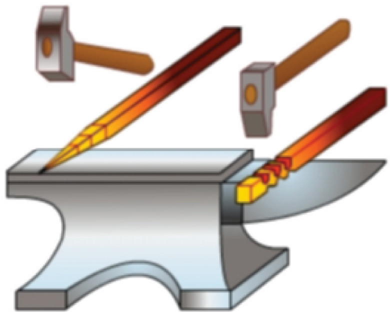
7. Which of the following is NOT a metal shaping tool?

A. Scriber
B. Cutter
C. Punch
D. Hammer

8. 8. Which of the following is a measurement tool?

A. Calliper
B. Punch
C. Mallet
D. File brush

9. Which of the following describes the metal shaping process as shown below?



A. Punching
B. Sawing
C. Bending
D. Forging

10. Which of the following is a metal joining method?

A. Punching
B. Welding
C. Laser cutting
D. Drilling

Long Questions

1. Name three hazards that may be induced during riveting.

2. List three general safety precautions for using an electric screwdriver.

3. Describes two general safety measures for using laser cutting.

4. Name any three methods of joining materials.

5. State three types of machines used for metal fabrication each with an example.

QUIZ 6 - Manufacturing Systems

Multiple Choice Questions

1. Which of the following is a list of the four M's in production process?

A. Materials, machines, computers, manpower.
B. Materials, machines, resources, manpower.
C. Materials, machines, manpower, money.
D. None of the above.

2. Which of the following is a list of the four basic types of production processes?

A. Goods, services, hybrids and continuous.
B. Manual, semi-automatic, automatic and service.
C. Intermittent, modular, continuous and technological.
D. Jobbing, batch, mass and continuous.

3. A job shop is an example of

A. One-off production.
B. Batch production.
C. Mass production.
D. Continuous production.

4. Which of the following products is/ are likely to be assembled on a flow line?

A. Automobiles.
B. Washing machines.
C. Television sets.
D. All of the above

5. Continuous production is common for production of

A. High-volume, high-variety products.
B. Low-volume, high-variety products.
C. High-volume, low-variety products.
D. None of the above

6. Which one of the following is NOT a type of production processes in manufacturing systems?

A. Quality production
B. Batch production
C. Jobbing production
D. Mass production

7. Which of the following production processes incurs the highest capital costs?

A. Jobbing
B. Batch
C. Mass
D. Continuous

8. 8. Which one of the following production processes needs special-purpose equipment?

A. Jobbing
B. Batch
C. Mass
D. Continuous

9. Which of the following production processes uses equipment instead of workers for monitoring?

A. Jobbing
B. Batch
C. Mass
D. Continuous

10. Which one of the following is the best production process for production which has stable demand and limits the workers' skill?

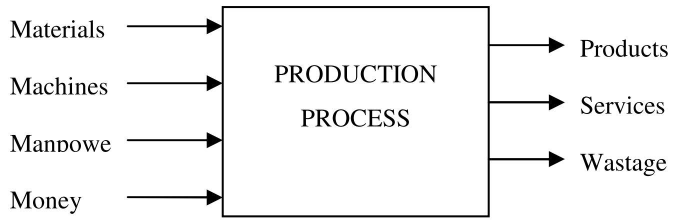
A. Jobbing
B. Batch
C. Mass
D. Continuous

Long Questions

1. Compare the four types of production processes on the basis of volume, variety, worker skills, efficiency and product cost.

2. Sketch a graph to show the Least Cost Envelope for jobbing, batch and mass production.

3. Use the following typical production cycle to describe that for biscuit production.



4. Explain why a continuous production process is suitable for "See's", a famous brand of chocolate.

5. Explain why a mass production process is suitable for a publisher which has received orders from 100 schools for ten titles of well recognized textbooks. The volume of each textbook is large.

QUIZ 7 - Input-process-output

Multiple Choice Questions

1. Which of the following is an open loop control system?

A. Keeping temperature constant inside a refrigerator
B. Self-control lighting system
C. Ringing a door bell
D. Riding a bicycle to follow a line

2. Which of the following is a closed loop control system?

A. Air-conditioning with temperature control system
B. Timer
C. Boiling water in a kettle
D. Water fall

3. Which of the following is functioned by a mechanical sub-system?

A. Rice cooker
B. Heater
C. Lighting
D. Exhaust Hood

4. Which of the following is NOT an advantage of an electronic sub-system?

A. Silent operation
B. Smaller in size
C. Smooth control
D. Data and signal compatible with other systems

5. Which of the following is not getting the TRUE output of a two input OR Logical Function?

A. Both inputs are TRUE.
B. Input (1) is TRUE
C. Both inputs are False
D. Input (2) is TRUE

6. Which of the following sensors can measure the noise made by low-flying aircrafts?
A. Position sensor
B. Humidity sensor
C. Sound sensor
D. Light sensor

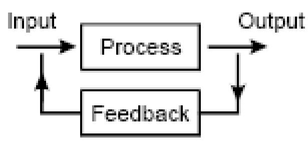
7. Which of the following is the correct sequence of instructions for making a cup of tea?

A. Pour in boiling water, drink tea, put teabag in cup, boil kettle
B. Boil kettle, put teabag in cup, pour in boiling water, drink tea
C. Put teabag in cup, boil kettle, drink tea, pour in boiling water
D. Drink tea, pour in boiling water, put teabag in cup, boil kettle

8. 8. Which of the following is an output device that produces tangible hardcopies?

A. Monitor
B. Printer
C. Scanner
D. Cathode Ray Tube (CRT)

9. Which of the following systems can be best described by the diagram below?



A. An electrical fan of two speeds, namely high and low
B. A security camera that films video on a continuous loop
C. A windmill with a fantail that turns the rotor into the wind
D. An outdoor light with a timer that turns on and off at preset times

10. An engineers who design a pneumatic system uses an actuator to:

A. Control the flow of fluid in a single direction.
B. Control the pressure of the fluid in the system.
C. Move fluid from one part of the system to another.
D. Convert fluid power into mechanical power.

Long Questions

1. Name, and describe the functions of, two sub-systems in a washing machine.

2. Describe what the mechanical sub-system of the MTR should do in order to drive a train to move at different speeds and stop at a correction position.

3. Design an algorithm, and draw a flowchart, to identify the heaviest boy among three.

4. Explain why a desktop fan is not a closed-loop control system.

5. Explain why a refrigerator has closed-loop control systems inside.

QUIZ 8 - Logic Gates

Short and Multiple Choice Questions

1. Complete the truth table of XOR.

A	B	A XOR B

2. Which of the following logic gates can produce outputs as the truth table shown below?

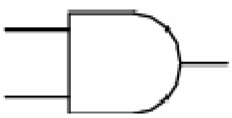
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

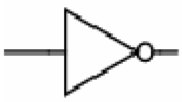
A. NOR
B. OR
C. AND
D. NOT

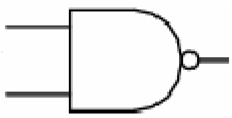
3. Which of the following gates has two inputs, and outputs high only when both inputs are low?

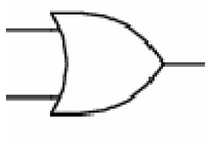
A. XOR
B. OR
C. AND
D. NOR

4. Which of the following symbols represents a NAND gate?


A


B


C


D

5. Which of the following is the output state of a 2-input OR gate if the inputs are 0 and 1?

A. 0
B. 1.5
C. 1
D. 2

6. Which of the following is the output state of a 2-input AND gate if the inputs are 0 and 1?

A. 0
B. 1.5
C. 1
D. 2

7. Which of the following is the input state of a NOT gate if the output is 0?

A. 0
B. 1.5
C. 1
D. 2

8. The states of a logic gate can only be either

A. 0 or 1.5.
B. 0 or 2.
C. 1 or 2.
D. 0 or 1.

9. The output of a logic gate can be one of two __________.

A. Gates
B. Inputs
C. States
D. Outcomes

10. An OR gate has

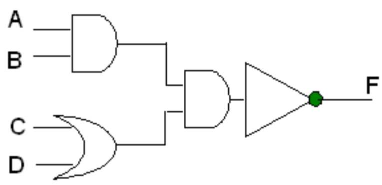
A. Two inputs and one output.
B. One input and one output.
C. One input and two outputs.
D. Two inputs and two outputs.

Long Questions

1. Draw a logic circuit with an AND gate, an OR gate or both gates to emulate a two-way control of a single lamp. The lamp is turned on and off according to the Switches A and B as follows:

Switch A	Switch B	Lamp
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON

2. What is F's value when
(a) A = 1, B = C = D = 0; and
(b) A = B = D = 1, C = 0?



3. A robot is programmed such that it will set off an alarm (through its sound chip) when smoke is detected (through its sensor). Draw the truth table and a logic circuit for the robot.

4. In addition to its smoke sensor, the robot in Question 3 has just been installed with a temperature sensor for fire protection. The robot sounds out a warning noise whenever it detects smoke or feels the temperature above a threshold. Draw the truth table and a logic circuit for the upgraded robot.

5. A dark room is installed with an alarm, a light sensor, a door touch switch and a temperature sensor. The room functions when the door is closed, and the temperature reaches its threshold or the light intensity reaches its threshold. Draw the truth table and a logic circuit to set off the alarm when the conditions are not met.

QUIZ 9 - Mechanical Systems

Multiple Choice Questions

1. Which of the following is NOT an input device of a control system?

A. Switch
B. Microphone
C. Computer
D. Phototransistor

2. Which of the following is NOT a type of Cams and Followers?

A. Flat
B. Slider
C. Roller
D. Offset

3. Which of the following lists contains major components of Slider Crank?

A. Crank, Slider and Connecting rod
B. Crank, Slider and Cam
C. Slider, Cam and Follower
D. Slider and Gear

4. Which of the following does NOT change a rotational motion into a linear motion?

A. Cams and Followers
B. Rank and pinion
C. Linkage
D. Slider crank

5. Which of the following best describe a light-dependent resistor?

A. Measuring light
B. Measuring temperature
C. Measuring sound
D. Measuring humidity

6. Which of the following is NOT a block diagram component of a closed loop control system?

A. Input
B. Output
C. Feedback
D. Sensor

7. What is the main difference between a closed loop system and an open-loop one?

A. There is a feedback mechanism for control in a closed-loop system.
B. There is no input in an open-loop system.
C. There is a feedback mechanism for control in an open-loop system.
D. There is no output in a closed-loop system.

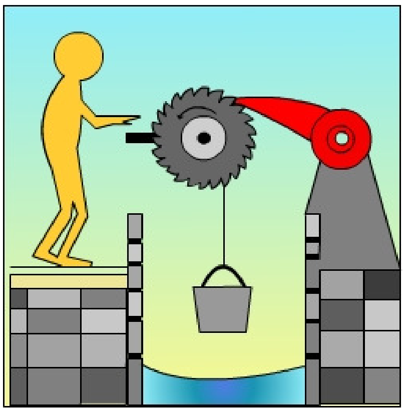
8. 8. Which of the following is NOT used in the processing system?

A. Micro-processor
B. Gates
C. Computer
D. Motor

9. Which of the following is NOT a function of a gear system?

A. Power transmission
B. Current transmission
C. Motion transmission
D. Speed transmission

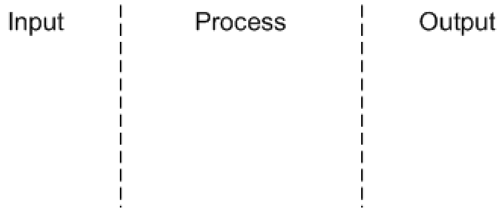
10. Which of the following mechanisms best describes the figure below?



A. Ratchet mechanism
B. Rack and Pinion
C. Linkage
D. Slider crank

Long Questions

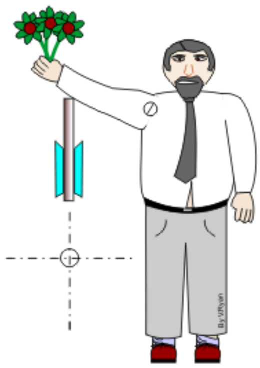
1. Give ONE example about the operation of production line in block diagram. [Hints: Draw a system diagram to represent the INPUT-PROCESS-OUTPUT process]



2. The diagram below shows a simple mechanism.

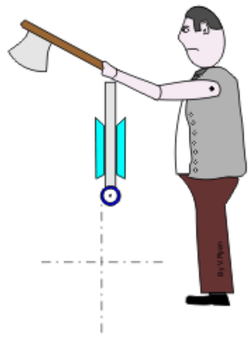
(a) What type of mechanism is this?
(b) Label the components for the following motion?
(Source: http://technologystudent.com/cams/mecq4.htm)

3. A local florist designs a model to be placed next to the checkout. The mechanism (shown below) is almost complete, except that a simple mechanism has to be added. The mechanism requires that the character's arm moves up and down smoothly.



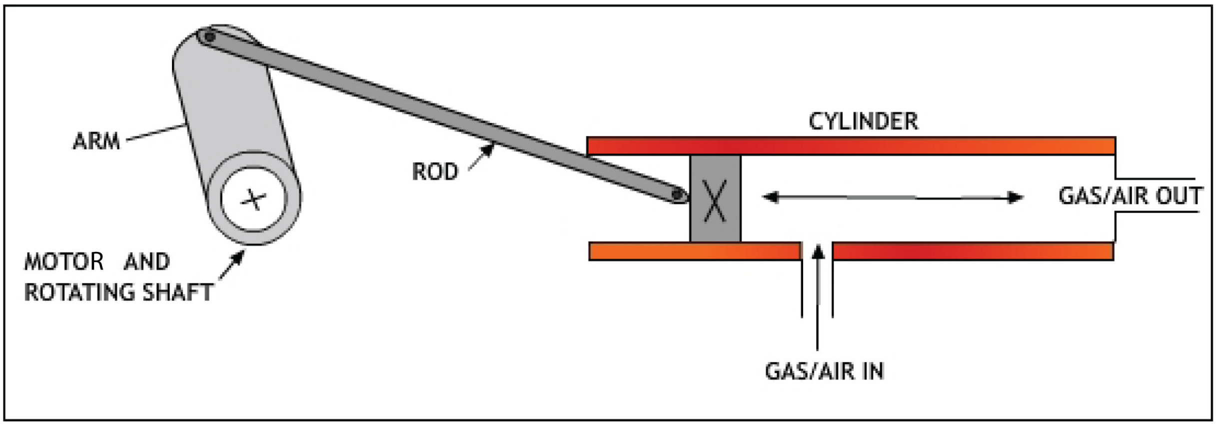
(a) Complete the drawing by adding the mechanism.
(b) Explain how it works.

4. A museum designs a model to be placed at the entrance. The mechanism is based on an executioner (shown below) and is almost complete. The mechanism requires that the character's arm move up slowly and drop down quickly.



(a) Complete the drawing by adding the mechanism.
(b) Explain how it works.

5. The diagram below shows a simple mechanism that moves Piston X back and forth inside a cylinder. It is part of an internal combustion engine.



Piston X moves back and forth. What type of motion is this?
(a) What type of mechanism systems of the internal combustion engine?
(b) How the design of internal combustion engine can be improved the motion efficiency?

QUIZ 10 - Physical Structure

Multiple Choice Questions

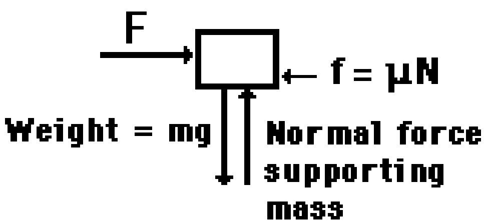
1. Which of the following is NOT a description of force?

A. Magnitude
B. Direction
C. Distance
D. Point of Application

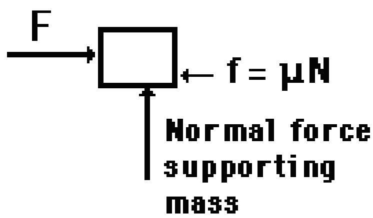
2. Which of the following is describing the conditions of equilibrium?

A. Sum of vertical forces = Sum of horizontal forces
B. Sum of vertical forces = 0
C. Sum of moments = Sum of forces
D. Sum of horizontal forces = Weight of load

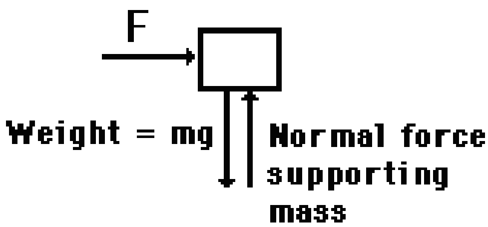
3. Which of the following is a correct diagram to describe an applied force that pushes an object with friction?



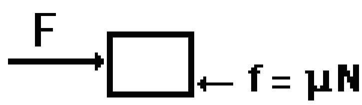
A.



B.



C.

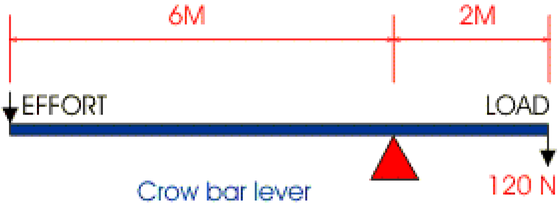


D.

4. Which of the following is NOT an advantage of a section structure?

A. Lower cost
B. Less material used
C. Stronger structure
D. Easy installation

5. A crow-bar is used to lever a load of 120 N. The load is 2 m from the fulcrum. The effort is 6 m from the fulcrum. What effort is required to move the load?



A. 60 N
B. 70 N
C. 50 N
D. 40 N

6. 6. Which of the following frames has strongest support for heavy load?

A. Triangular frame
B. Square frame
C. Circular frame
D. Rectangular frame

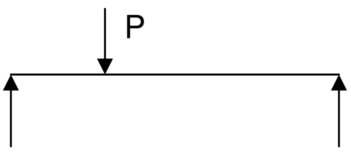
7. Which of the following best describes 'Strut'?

A. It is a tensile force.
B. It is the structure that has compressive force acting on.
C. It is the structure that has tensile force acting on.
D. It is a compressive force.

8. Which of the following best describes 'Tie'?

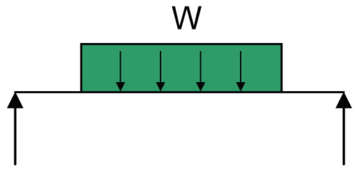
A. It is a tensile force.
B. It is the structure that has compressive force acting on.
C. It is the structure that has tensile force acting on.
D. It is a compressive force.

9. What does P denote in the figure below?



A. Concentrated force
B. Concentrated moment
C. Distributed force
D. Distributed Moment

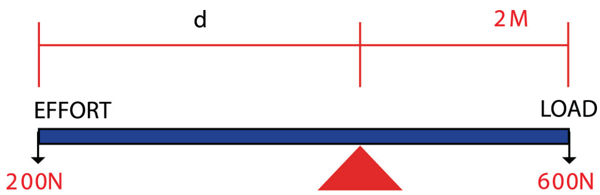
10. What does W denote in the figure below?



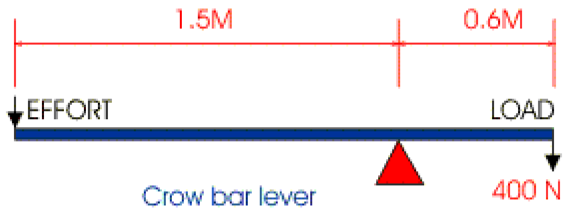
A. Concentrated force
B. Concentrated moment
C. Distributed force
D. Distributed moment

Long Questions

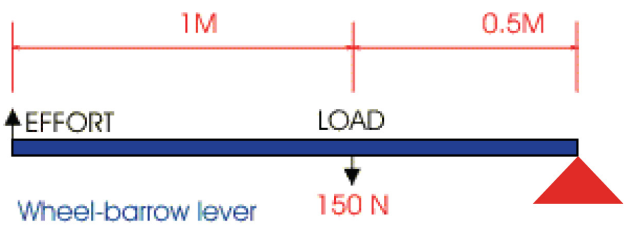
1. In the diagram below, what is the distance d required to balance the load with a force of 600 N?



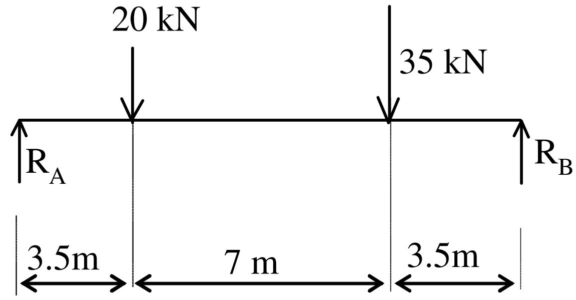
2. In the diagram below, a crow-bar is used to balance a load with a force of 400 N. What is the minimum effort required to keep the balance?



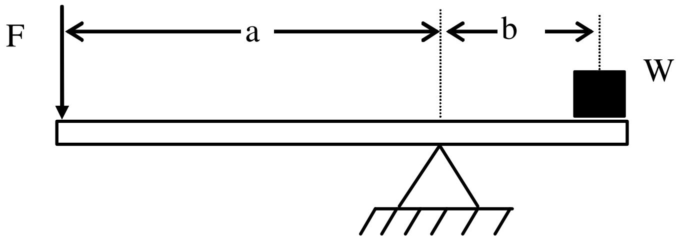
3. A wheel-barrow is used to lift a load with a force of 150 N. The wheel acts as the fulcrum. What is the minimum effort required to keep the balance?



4. What are the reactions at the supports (i.e. R_A and R_B) for the beam shown below?



5. Express F in terms of W, a and b.



QUIZ 11 - Basic Electronics

Multiple Choice Questions

1. A 30 Ohms resistor and a 60 Ohms resistor are connected in an electric circuit as shown in Figure 1.
   The voltages across the 30 ohms and 60 ohms resistors are ______ respectively.

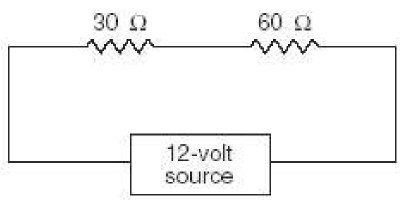


Figure 1

A. 3V; 6V
B. 3V; 8V
C. 4V; 6V
D. 4V; 8V

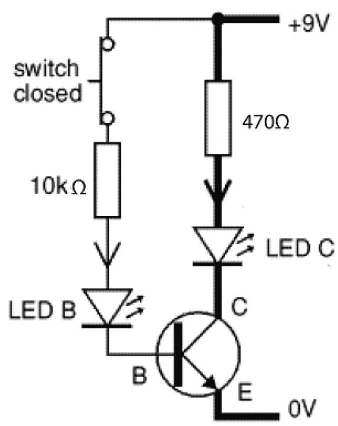
2. In Figure 1, the current flowing through the 30 Ohms and 60 Ohms resistors are ______ respectively.

A. 0.4A; 0.2A
B. 0.1A; 0.1A
C. 0.2A; 0.4A
D. 0.2A; 0.2A

3. In Figure 1, the power consumption by 30 Ohms and 60 Ohms resistors are ______ respectively.

A. 4.8 W; 2.4W
B. 1.6W; 3.2W
C. 3.2W; 1.6W
D. 0.5W; 1.1W

4. When a large current flows through an LED, the LED emits bright light. The LED emits dim light otherwise. Which of the following statement is most likely to be true?



A. LED B is bright and LED C is bright.
B. LED B is bright and LED C is dim.
C. LED B is dim and LED C is bright.
D. LED B is dim and LED C is dim.

5. A 1KΩ resistor and a 2KΩ resistor are connected in parallel with 12V DC power source as shown below:

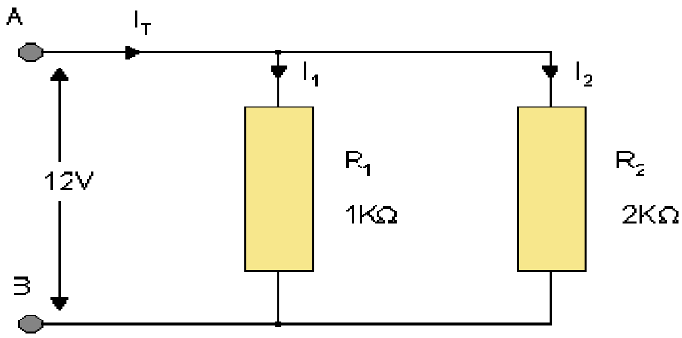


Figure 2

The current I_1 flowing through 1KΩ resistor is

A. 0.012 A.
B. 0.12 A.
C. 0.01 A.
D. 0.1 A.

6. With reference to Figure 2 in Question no. 5, the current I_2 flowing through 2KΩ resistor is

A. 0.012 A.
B. 0.12 A.
C. 0.006 A.
D. 0.06 A.

7. With reference to Figure 2 in Question no. 5, the current I_T drawn 12V DC power supply is

A. I_1 - I_2.
B. I_1 + I_2.
C. Not known
D. None of the above

8. What is the power output of a resistor if the voltage and the current across it are 12 V and 50 mA respectively?

A. 0.6 W
B. 0.7 W
C. 0.8 W
D. 0.9 W

9. Which of the following is the maximum safe current through a 1.8KΩ resistor rated at 0.5 W?

A. 0.16 A
B. 0.016 A
C. 0.7 A
D. 0.07 A

10. Which of the following consists of two plates that are separated by a dielectric and can store a charge?

A. Transistor
B. Diode
C. Resistor
D. Capacitor

Reference:http://www.kpsec.freeuk.com/trancirc.htm

Long Questions

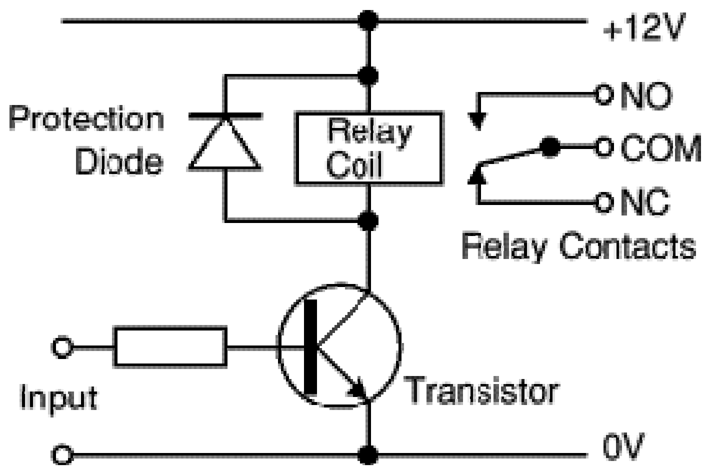
1. A solar tracker directs a solar photovoltaic panel towards the sun, enhancing the power produced by the solar panel. A controller responding the sun's direction instructs active solar trackers direct the trackers with motors and gears.

From a system perspective and based on concepts introduced in Basic Electronics, explain the controller's mechanism.

Reference:http://en.wikipedia.org/wiki/Solar_tracker

2. Explain why it may not be accurate to measure the travelling distance of a robot car by counting the number of turns of the wheel rotated.

3. Explain how the circuit as shown below can be used to control and drive a motor. State the assumptions made.



4. A 220 V electrical heater has a full output of 330 W. Compare the power loss in the heater under full and half-full power output.

5. In the control circuit of Question 3, the relay coil requires a 0.6 A magnetizing current from the 12 V DC supply for switching on. The transistor is turned on by a 6 mA base current. The voltage drops across the transistor is 0.4 V. Calculate:

(a) The current gain in the transistor; and

(b) The power loss in the transistor.

USEFUL WEBSITES

The list of useful reference resources are as follows:

Resources	URL
Occupational Safety & Health Council	http://www.oshc.org.hk
Chinese Technical Press	http://www.ctphk.com
Hong Kong Education City	http://www.hkedcity.net
Reference Books from Education Bureau (EDB)	http://www.edb.gov.hk/FileManager/EN/Content_3139/te_subject_reference_books_sep07.pdf
State of Equilibrium and force	http://technologystudent.com/forcmom/force2.htm
Transistor circuit	http://www.kpsec.freeuk.com/trancirc.htm
A free-body diagram involving equilibrium of forces	http://hyperphysics.phy-astr.gsu.edu/hbase/freeb.html
The Free Encyclopaedia : WIKIPEDIA	http://en.wikipedia.org
English-Chinese Dictionary	http://cdict.giga.net.tw
Wiki search on line	http://www.wiki.com
Electronics Club in UK	http://www.kpsec.freeuk.com

GLOSSARY OF TERMS

Term	Description
Actuator 致動器	A mechanical device that moves or controls a mechanism or system
Aerodynamic 空氣動力學	A branch of mechanics that deals with the motion of air and other gases, and with the effects of such motions on bodies in the medium
Alternate Current (AC)交流電	An electric current whose magnitude and direction vary cyclically, as opposed to direct current (DC)
Biomass 生物量	Organic matters, especially plant matters, that can be converted to fuel and are therefore regarded as a potential energy source
By-product 副產品	A secondary or incidental product, as in a process of manufacturing
Carbon Fibre 碳纖維	A strong, stiff, thin fibre of nearly pure carbon, made by subjecting various organic raw materials to high temperatures, combined with synthetic resins to produce a strong, lightweight material used in construction of aircraft and spacecraft.
Carbon Monoxide 一氧化碳	A colourless, odourless, poisonous gas, CO, that burns with a pale-blue flame, produced when carbon burns with insufficient air
Direct Current(DC) 直流電	Constant electric charge flowing in the same direction, as opposed to alternate current (AC)
Dynamic 動力學	Pertaining to force related to motion
Efficiency 效益	The state or quality of being efficient; competency in performance
Equilibrium 平衡	A state of rest or balance due to the equal action of opposing forces
Terrestrial Heat 地熱能	A nature and renewable energy from the lava of Earth that can be used on electricity generation
Gravity 地心吸力	The force of attraction by which terrestrial bodies tend to fall toward the centre of the earth
Industrial Revolution 工業革命	The complex of radical socioeconomic changes. It took place in England in the late 18th century, that are brought about when extensive mechanization of production systems results in a shift from home-based hand manufacturing to large-scale factory production
Light Emitting Diode (LED) 發光二極管	A semiconductor diode that emits incoherent narrow-spectrum light when electrically biased in the forward direction of the p-n junction
Logic Gate 邏輯門	Performs a logical operation on one or more logic inputs and produces a single logic output. The logic normally performed is Boolean logic and is most commonly found in digital circuits
Machinery 機械	An assemblage of machines of mechanical apparatuses
Mass Production 大量生產	Produces large volume of standard product for a mass market

Term	Description
Micro-controller 微控制器	A computer-on-a-chip. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC)
Mould 模子	A hollow form or matrix for giving a particular shape to something in a molten or plastic state
Muscular-skeletal Disease 肌肉骨骼疾病	Work related disease developed over time and are caused either by the work itself or by the employees' working environment. They can also be resulted from fractures sustained in an accident
Nanotechnology 納米技術	Refers broadly to a field of applied science and technology whose unifying theme is the control of matter on the molecular level in scales smaller than 1 micrometre, normally 1 to 100 nanometres, and the fabrication of devices within that size range
Natural Resources 自然資源	Resources (actual and potential) supplied by nature
Octopus 八達通	A contactless and non-powered stored value smart card for the electronic transfer of payments in online or offline systems in MTR or convenient stores
Pneumatic System 氣動系統	A system that uses compressed air to convey and control energy
Pollutant 污染物	Something that pollutes
Renewable Energy 再生能源	Any naturally occurring, theoretically inexhaustible source of energy, as biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel
Radio Frequency Identification (RFID) 無線射頻識別	An automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. An RFID tag is an object that can be applied to or incorporated into a product, animal, or person for the purpose of identification using radio waves.
Tidal 潮汐的	Of, pertaining to, characterized by, or subject to tides e.g. a tidal current
Vacuum Forming 真空成形	A process of thermoforming, whereby a sheet of plastic is heated to a forming temperature, stretched onto or into a single-surface mould, and held against the mould by applying vacuum between the mould surface and the sheet
Volatile Organic Compound 有機揮發性化合物	Organic chemical compounds that have high enough vapour pressures under normal conditions to significantly vaporize and enter the atmosphere

REFERENCES

A. Textbook

Education Department (2002). *Design & Technology [Alternative Syllabus] [S4-S5], Learning Material Trial Version.*

Royal College of Art (1998)**.** *D&T Routes Core Book: Design & Technology 14-16, Design & Technology 14-16*. Hodder & Stoughton

林志立，陳國和 (2005)。《初中設計與科技，第一、二、三冊》。中華科技出版社。

林志立，蔡志鴻 (1998)。《高級程度工程科學，第一、二冊》。中華科技出版社。

B. Reference Books

Lambert (2002). *GCSE Resistant Material Technology for Edexcel*, Heinemann,

杜秉祺、容顯懷、柯財權、黃志剛。《生活與科學》。牛津大學出版社(中國)有限公司。

朱經武 (2008)。《科學就在生活中》。 商務印書館(香港)有限公司。

邁克爾・G・澤伊 (2003)。《擒獲未來:21 世紀的科技與人類生活》。三聯書店。

《初中基本科技第一冊》。中華科技出版社。

呂仲文 (2004)。《機械創新設計》。機械工業出版社。

李洋。《現代電子設計與創新》。中國電力出版社。

王立權 (2007)。《機器人創新設計與制作》。清華大學出版社。

張義和 (2001)。《數位邏輯實習》。大中國。

ACKNOWLEDGEMENTS

The authors wish to thank the following persons/organizations for permission to use their photographs and images

- Semia Limited (Lego Education Toolkit)

and under the Wikimedia Commons Creative Commons AttributionShareAlike2.5 License (http://creativecommons.org/licenses/by/2.5/)

- Trinecke zelezarny (P.23 – Furnace)
- Tom Allen (P.34 – Single Worker)

The following photographs and images are from the Public Domain:

- P. 24 (Welding), P. 34 (Aircraft by teams)

Every effort has been made to trace the copyright for the photographs and images as needed. We apologize for any accidental infringement and shall be pleased to come to a suitable arrangement with the rightful owner if such accidental infringement occurs.

Technology Education Section
Curriculum Development Institute
Education Bureau
The Government of the HKSAR

Developed by
Institute of Professional Education
And Knowledge (PEAK)
Vocational Training Council