AVIATION TECHNOLOGY
FORM 1
COURSE BOOK

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TOPIC 1

OCCUPATIONAL AND CAREER INFORMATION

Specific objectives

At the end of this topic, the learner should have acquired information on:

a) Range of occupational opportunities in the aviation field.
b) Entry qualifications for occupations in the aviation field.
c) Entry requirements for further training in the aviation field.

Sub-Topics

a) Flight Crew careers.
b) Engineering careers.
c) Cabin crew careers.
d) Air traffic controllers.
e) Ground handling personnel.

Introduction

DEFINITION OF AVIATION TECHNOLOGY

-It refers to the study of designing, manufacturing, maintaining and flying of an aircraft.

Roles of aviation to the Kenyan economy

- Transportation of passengers, mails and freight.
- Security purposes e.g. internal security forces and the military.
- Research by different organizations e.g. meteorological department, wildlife services.
- Aerial photography-mapping and surveying.
- Evacuation and medical services .i.e. In flooded areas
- Creation of employment opportunities e.g. Pilot, Flight dispatchers etc.
- Agricultural activities e.g. spraying.

Flight crew careers.

i) Pilot/captain/Pilot in command(PIC)
ii) Co-pilot/first officer.
iii) Flight engineer.
iv) Navigator.

Pilot

He/she seats at the port (left) side of the cockpit. Their roles include:

- Final decision maker during flight.
- In charge of take-off and landing.
- Carries out emergency drill in emergency situations.
- In charge of communication with the control tower.
- Ensures that necessary checks are done before take-off, during and after landing.


First officer

He acts as the co-pilot and seats at the right side (star board) of the flight deck. Their roles include:

- Assists the pilot(deputizes)
- Carries out the check list i.e takeoff check list, climb check list, cruise check list, approach checklist and landing checklist.
- Takes over command in case the pilot is incapacitated.
- Carries the petty cash.
- Monitors the working of navigational computers, communication radios and engine instruments.

Qualifications for piloting

Physical and health qualifications:

- One must be in an excellent state of health i.e. not asthmatic, high blood pressure etc.
- Must have good hearing and eye sight as mostly radio communication and instrument viewing is mandatory.
- Should have a minimum age of 17 years

Academic qualifications:

- Must have very good performance in Mathematics, Physics, English and Geography with at least C+ and above.
- Should have an aggregate grade of C+ and above.

Pilot license categories

1. **Student Pilot License (SPL)**

This is the license given to a student pilot.

2. **Private Pilot License (PPL)**

This the most basic license. Student must successfully complete a minimum of 45 flying hours in addition to ground school. This license does not permit one to fly for commercial purposes.

3**. Commercial Pilot License (CPL)**

To acquire this category of license, the pilot must have a PPL and a flight experience of not less than 200 flight hours. Must also have instrument rating. With this license, the pilot can fly for pay.

4 **Airline Transport Pilot License (ATPL)**

This is the highest level of license that a pilot can have. The pilot should already have a CPL before obtaining the ATPL. A pilot must have a flight experience of not less than 1500 hours including 200 hours as pilot in command (PIC)

Flight engineer

The flight engineer is carried on long range flights to supervise the working of the engines, instruments, electricals and mechanical systems and ensuring they function properly. Other roles may include:

- Advices the pilot in case of flight emergencies.
- He enters/fills the technical logbook e.g. oil uplifts, aircraft defects, position of the aircraft c.o.g, accumulated flight hours, flight number etc.
- Starts the engines before take-off.
- Responsible for supervising the aircraft's speed and altitude.

Qualifications for a flight engineer:

- Be at least 18 years of age.
- Possess a valid Class 1 Medical Certificate.
- At least 3 years of practical experience in aircraft maintenance and at least 5 hours of flight training in the duties of a flight engineer.

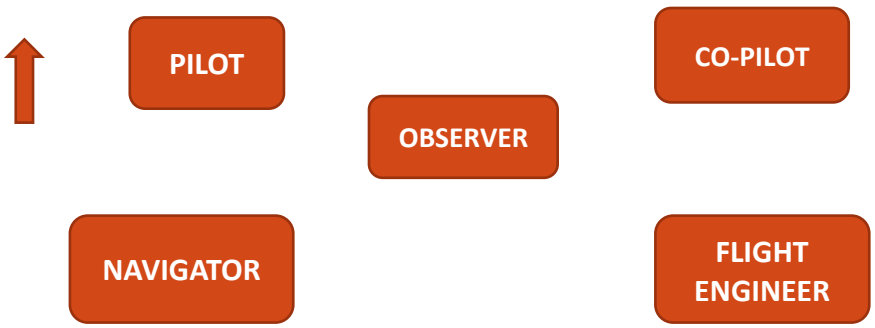
- Possess a degree in aeronautical engineering from a college or engineering school acceptable by KCAA.

Navigator

He/she is a member of the flight crew and seats behind the captain in the flight deck. Their roles include:

- Monitors aircraft position at all times.
- Advices the captain on estimated time to destination and route.
- In charge of maintaining aeronautical charts and publications, navigational equipment, and communications.
- Assists in flight planning

Flight Deck/Cockpit sitting arrangement



Aircraft engineering careers.

Aircraft engineering can be categorized into two main groups namely:

a. Aeronautical engineering.
b. Maintenance engineering

a) **Aeronautical engineering/aerospace engineering.**

It involves designing and testing of aircraft, and aircraft systems.

b) Aircraft maintenance engineering.

This requires a wide variety of skilled engineers who ensure the aircraft is airworthy through timely scheduled and unscheduled checks, servicing and system overhaul. It can be categorized into three:

i. Airframe maintenance engineer.
ii. Power plant maintenance engineer.
iii. Avionics engineer.

i. **Airframe maintenance engineer**.

They are responsible for the maintenance of the aircraft body and the fuselage. They should have at least a diploma level training in aeronautical engineering and a license from KCAA.

ii. **Power plant maintenance engineer.**

They are responsible for day to day maintenance of the aircraft engines and overhaul of engine components. They should have at least a diploma level training in aeronautical engineering and a license from KCAA.

iii. **Avionics engineer.**

Responsible for the maintenance of electrical and electronic systems, and instruments of the aircraft. They should have at least a diploma level training in aeronautical engineering and a license from KCAA.

Cabin crew careers

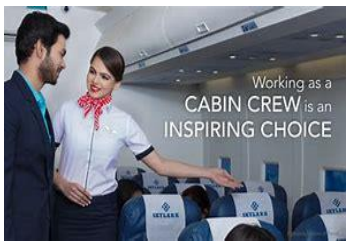
These careers involve taking care of passengers and ensuring their comfortability while the aircraft is in flight. The personnel in these careers include:

i) Hostesses and stewards.
ii) Purser.

i) **Hostesses and stewards**.

These are ladies and gentlemen who work in the passenger aircraft cabin and play the following roles:

- Serve food and drinks to passengers during flight.
- Brief passengers on flight safety and actions to take in case of an emergency.
- Assist in giving first aid in case of unfortunate incidents during flight.
- They take care of the passenger's needs and ensure they are comfortable throughout the flight.
- They report any serious concerns in the cabin to the pilot for necessary action.



ii) **Purser**

He/she is the chief cabin crew member and has the following responsibilities:

- He/she ensures that the services provided to the passengers is of the highest standard.
- He/she keeps the aircraft's flight accounts records.
- In charge of entertainment and ensures that the passengers are comfortable in the aircraft during flight.
- He/she orders for supplies before flight.
- He/she is in charge of all operations and logistics in the cabin during flight.
- He/she gives instructions to the cabin attendants before and during flight.

Air traffic control

These are personnel located at the control tower of every airport with a need to control the flow of aircraft. They can be put into two categories:

a) **Air traffic controllers.**

b) **Ground controllers**.

a) Air traffic controller.

- Air traffic controller gives instructions to the pilot on when to land and take-off. In case the aircraft needing to take off or land are many, he/she puts them on a waiting list.
- Ensures that aircraft in the controlled airspace are safely separated i.e. a vertical separation of 1000 feet is the standard.
- Ensures that the airport beacon transmitter and radar equipment are functioning properly.
- Responsible for collecting landing and take-off fees in the airport.
- Keep in constant communication with the pilot to update him on weather and direction/position of the aircraft.
- Advices the pilot on the action to be taken during an emergency in flight.

b) **Ground Controllers.**

These are airport personnel who are located at the airport control tower.

They are mostly concerned with aircraft that is on the ground especially at the ramp and on the taxiways, after landing or before take-off. These personnel have the following responsibilities:

- Guide the aircraft from the runway to the terminal gate.
- They ensure the aircraft remain on their taxiways and away from active runways to avoid ground collisions.
- They ensure the airports stay operational by keeping the aircraft moving within the airport to avoid delay.
- They clear the runway off any vehicles and personnel during take-off and landing
- They inform the pilot about the weather and are also responsible for adjusting runway lights incase visibility is poor.
- They call fire department or medical services in case of a fire emergency.
- They give permission for engine startup, pushback procedures, refueling and other ramp activities.
- They allocate terminal gates to the arriving aircrafts.

Ground handling

These are personnel concerned with the aircraft once it enters the terminal area either for passengers to disembark, off-loading of goods, refueling, etc.

The personnel include:

a) Marshallers.
b) Flight dispatchers.
c) Security officers.

a) **MARSHALLER.**

- This personnel is responsible for directing the pilot using standard hand signals during ground operations like engine start up prior to take-off, taxiing, parking etc. He has to dress up in easily identifiable clothing for him to be spotted easily. At night they use flash lights.

b) **FLIGHT DISPATCHER**.

A flight dispatcher is positioned in the operations department of an airline and has the following responsibilities:

- Helps in scheduling flights.
- Ensures all civil aviation regulations are adhered to.
- Prepares flight plans.
- Supplies meteorological reports.
- Briefs the flight crew members before the flight commences.
- Provides flight and fuel information.

c) SECURITY OFFICERS.

These are Kenya Airports Authority employees who are assigned the roles of ensuring overall security of aircraft, passengers and other personnel. They carry out passenger, baggage and cargo screening to ensure that no illegal drugs and firearms enter or leave through the customs.

In case of any irregularities or non-compliance, they call the police.

AVIATION ORGANIZATIONS

Each country is responsible for regulating aviation operations for any aircraft within its airspace. Nevertheless, there are some regulations that govern international flights to ensure equitable treatment for all civil airline operators.

Aviation organizations hence can be categorized as either:

a) Local;

i) Kenya Airports Authority (KAA)

ii) Kenya Civil Aviation Authority (KCAA)

b) International;

i) International Civil Aviation Organization (ICAO)

Ii) International Air Transport Association (IATA)

I) Kenya Airports Authority (KAA)

This organization has the following responsibilities;

- It is responsible for the construction of civil airports and their maintenance.
- They approve construction and establishment of private airstrips.
- Provide security within the airport.
- They provide rescue and firefighting equipment at the airport.
- They charge airlines for the usage of the airport facilities.
- They maintain runways, taxiways and aprons.

ii) **Kenya Civil Aviation Authority (KCAA)**

KCAA is responsible for;

- Approval of aviation organizations based on their liquidity.
- Licensing of aviation personnel e.g pilots, maintenance engineers, air traffic controllers etc.
- Licensing of aircraft based on their airworthiness conditions.
- In charge of aircraft accident and incidents investigations.
- Calibrate airport beacons.

INTERNATIONAL ORGANIZATIONS

i) **International Civil Aviation Organization (ICAO)**

This organization plays the following roles;

- Ensures safe and orderly growth of international civil aviation world over.
- Negotiates for freedoms of air e.g freedom to overfly a foreign state, freedom to land in a foreign state on emergency situations etc.
- Promote safety of flight in the international airspace.
- Encourage the art of aircraft design and operation for peaceful purposes.

- Adopted the phonetic alphabets for use in civil aviation. These alphabets are as follows:

A- Alpha	**B**-Bravo	**C**-Charlie	**D**-Delta	E-Echo	**F**-Foxtrot
G-Golf	**H**-Hotel	**I**- India	**J**- Juliet	**K**-Kilo	**L**-Lima
M-Mike	**N**-Novembre	**O**- Oscar	**P**-Papa	**Q**- Quebec	**R**-Romeo
S-Sierra	**T**-Tango	**U**-Uniform	**V**-Victor	**W**-Whiskey	**X**- X-Ray
Y- Yankee	**Z**- Zulu				

ii) **International Air Transport Association (IATA)**

- Meet the needs of people world by ensuring a safe, regular, efficient and economical air transport.
- Regulating air transport charges to prevent unnecessary competitions among airlines.
- Training, examining and issuing certificates after qualification to cabin crew members and other aviation related hospitality personnel.

TOPIC 2

WORKSHOP SAFETY

Specific objectives.

At the end of this topic, the learner should be able to:

- State safety rules to be observed in an aviation workshop.
- Demonstrate correct safety practices while in the workshop.
- Apply correct first aid procedures.

Sub-topics

a. GENERAL WORKSHOP SAFETY RULES.
b. PERSONAL SAFETY.
c. TOOLS AND MACHINE SAFETY.
d. FIRST AID STANDARD PROCEDURES.

A) General Workshop Safety.

Definition of terms:

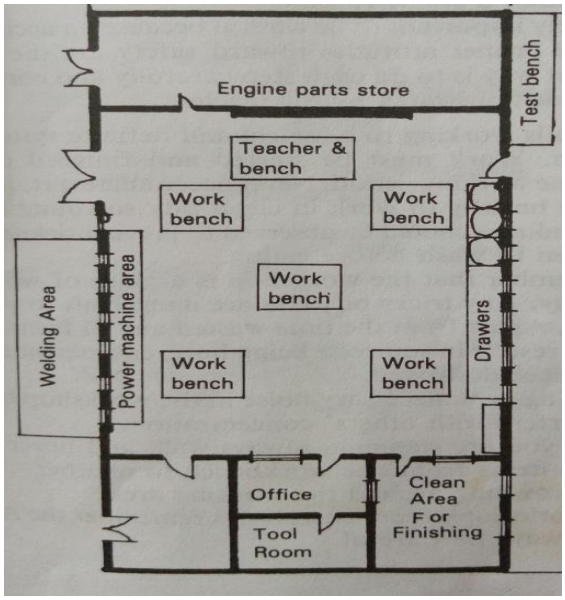
Safety-this is the state of being safe and free from danger**.**

Safety precautions-these are rules set for workshop and general working places that would if adhered to, prevent injury and damage to property**.**

Accident- An unfortunate incident which can lead to loss of life or injury to personnel, and damage to property.

Rules- Standard practices which are set to govern the code of conduct of personnel while at the workshop.

WORKSHOP LAYOUT.



GENERAL WORKSHOP SAFETY RULES.

- Do not enter or leave the workshop without permission.
- Always obtain permission before using any machine or tool.
- Always ensure to wear protective clothing when carrying out any workshop procedure e.g. welding and cutting.
- Always ensure all equipment are serviceable before use.
- Always use the correct machine for the correct job.
- If in doubt do not proceed, ask.
- Never carry any workshop tool in your pockets.
- Always ensure to use a three pin plug on the sockets.
- Ensure to wipe any oil spillage to prevent accidents through.
- Always concentrate on whatever you are doing while at the workshop.
- Do not eat, drink or even carry food in the workshop.

B) Personal safety.

This entails personal care one should observe in order to ensure their own safety and the safety of others they are working with. There are three enemies to personal safety:

a. **Haste**- this is one does things in the workshop hurriedly for the sake of finishing. In hurrying, many things may be compromised leading to accidents.
b. **Habit**- when we become used to doing one thing commonly, we tend to be overconfident hence may make us do things with little care.
c. **Ignorance-** a situation where someone tries to perform a task without the necessary skills. This can lead to accidents.
   Personal safety can be viewed in two broad perspectives:
   a) Behavioural.
   b) Dressing code.

a) **Behavioural.**

Safety is largely dependent upon knowledge and common sense. It solely depends on the attitude of mind rather than a set of rules. The proper attitudes towards safety bare the best insurance. The following are some of the suggestions and behavioural steps that if carefully and correctly followed, they can minimize accidents in the workshop:

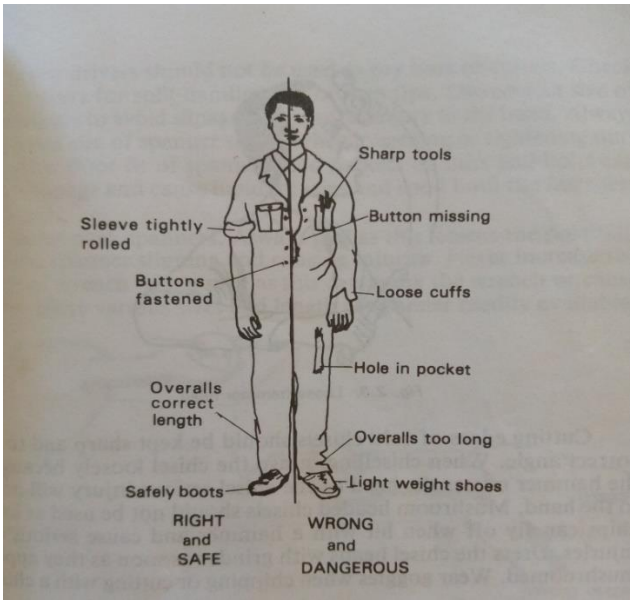
- Personal cleanliness should always be observed to prevent sickness, care must be taken to wash before eating.
- Always remember that the workshop is a place of work, not for horse play. Any tricks or jokes are dangerous to you and your colleagues.
- Avoid shouting or unnecessary noise in the workshop this will interfere with the concentration of others.
- Look where you are stepping, always walk along the isle and never run.
- Never throw items from work bench to another.
- Avoid overcrowding around the working area.
- Always be a good workshop keeper and always remember the ABC of safety- Always Be Careful.

b) **Dressing code**

Every person accessing the workshop:

- Keep your hair short and tidy, long hair could be pulled by a moving part of machines.
- Always ensure to remove all jewelry such as ring, chains and watches.
- Always wear special protective clothing when working in welding, forging and foundry areas.
- Ensure to always roll up your sleeves, tuck in your shirt, remove your tie and wear an overall which completely covers all loose ends of clothing.
- Always ensure to wear goggles or a face shield whenever there are sparks or very bright light experienced during welding procedures.

PROPER DRESSING CODE.



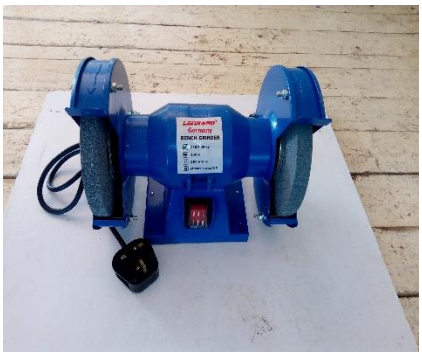
c) Tools and Machine Safety.

Aviation workshop tools and machines are designed, installed and operated to ensure maximum safety. In order to maintain a high standard of safety, tools and machines should be properly handled, operated and cared for. The following are general rules in regard to specific workshop tools and machines:

Drilling Machine

- Always ensure that the machine is firmly mounted to the bench or on the ground to prevent it from falling or sliding during operation.
- Before you start the drilling exercise, ensure the work piece is firmly clamped on the machine table.
- Always make sure the electrical connection is correct with no naked wires and a three pin plug is used.
- Select the right speed for the material being drilled; soft materials are drilled at high speeds while hard materials are drilled at slow speeds.
- Always use a coolant while drilling hard material like steels.
- Make sure you use the correct drill bit size.
- Dress appropriately to protect yourself against hot work pieces, metal chips etc.

Grinding machine.



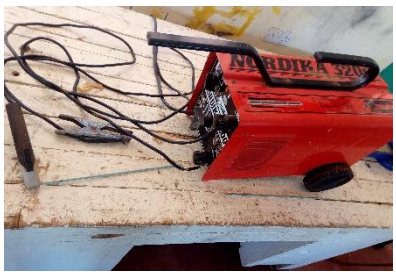
- Always ensure the machine guards are on before you commence the grinding operation.
- Ensure the work piece is firmly held as you progress with grinding.
- Do not grind from the side of the wheel.
- Always operate from the side, not in front of the grinding wheel in case it comes off accidentally.
- Make sure you are appropriately dressed; goggles and gloves to protect your eyes

Air compressor machine

- Always ensure the air compressor is grounded or earthed to prevent excess buildup of charges when it is running.
- Ensure always that the electrical connection for the compressor motor is intact and no loose or naked wires.
- Always ensure to drain the water that has accumulated in the tank before starting the compressor.
- Ensure valves are not leaking.
- Ensure the tank pressure gauge and the delivery pipe pressure gauge are functioning properly.
- Ensure the room is properly ventilated before starting the machine.

Welding machine.

- Ensure you select the correct voltage for the job.
- Always ensure the welding machine is on dry ground to minimize the risk of electrocution.
- Ensure there is no loose electrical connection, or naked wires.
- Always ensure heavy safety boots are worn during welding.
- Always use dark eye shield/goggles to protect your eyes from the flare



General safety rules in regards to hand tools

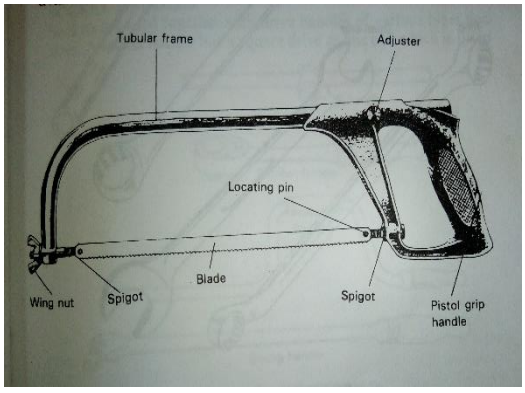
In order to minimize accident and injuries tools should be correctly used and well maintained. The following are some of the general safety rules in regard to specific hand tools:

Hammer

- Always check for split or broken handles and loose, worn out or chipped heads.
- Head should be firmly secured to the handle. Loose heads can come out of their handles when hitting the work piece and serious injuries.
- Keep your hands/fingers off the work piece when striking.
- Ensure that your workmates are distant enough from the striking range of the hammer blows to avoid injuries'

Hacksaw

- Always ensure that the hacksaw blade is properly tightened before using it.
- Always apply pressure on the forward stroke and ease the pressure on the back stroke. This is because the cutting stroke is the forward stroke.
- Ensure to use the full length of the blade during the cutting stroke.
- Ensure the hacksaw blade is placed correctly in the frame by ensuring the teeth face away from you.
- Ensure the work piece is firmly held before the cutting procedure



Screw driver

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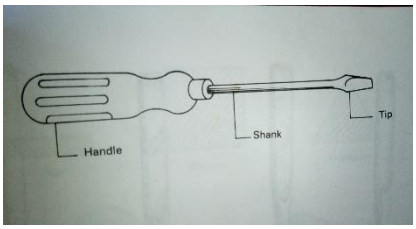
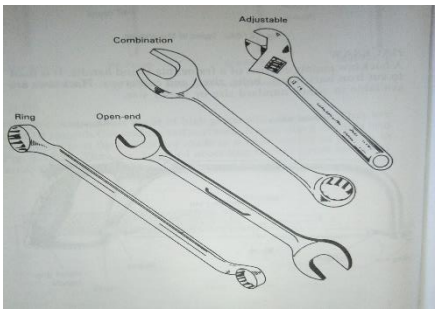


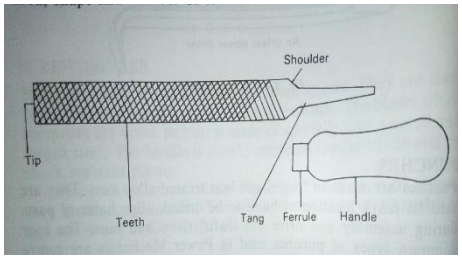
- The tip of the blade chosen should fit in the slot of the screw head to be turned.
- The tip of the screw driver should be reconditioned by grinding when worn out.
- The screw driver should not be used as a chisel as this will spoil the handle.
- When using the screw driver, the hands should be behind the tip to avoid injury.

Spanners



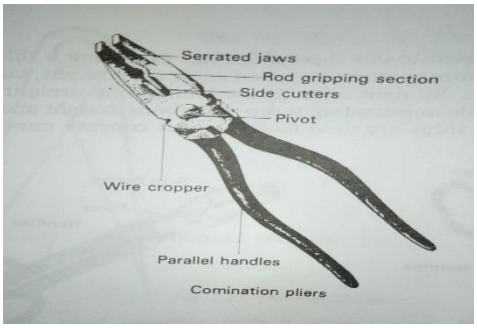
- Always use the correct size of spanner socket when loosening or tightening nuts and bolts.
- Never push spanners, always pull as this lessens the possibility of the spanner slipping and causing injuries.
- Never increase the length of wrench or spanner with a pipe as this can break the wrench and cause injuries.

Files



- Never use a file without a handle because the tang can easily pierce the hand.
- Never use a file as a pry bar because it could break easily and cause injuries.
- Always ensure to use the whole length of file during the filing exercise.
- Ensure the work piece is firmly held before the filing exercise commences.
- Ensure the file is cleaned after use and stored in a dry place to prevent rusting.

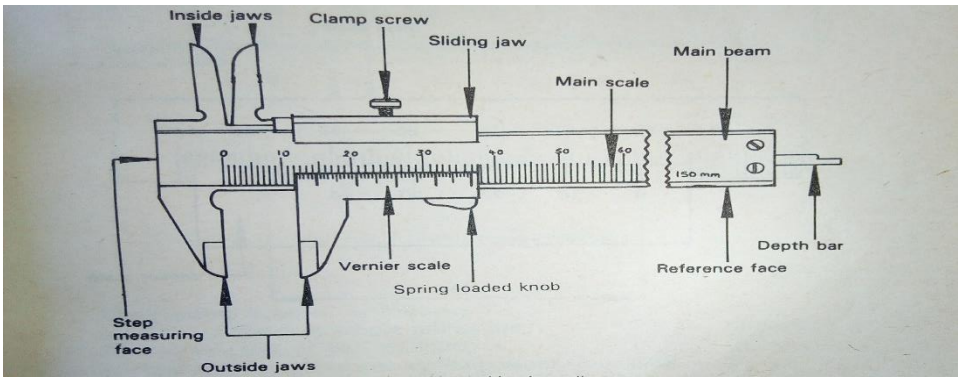
Pliers



- Ensure the joint of the pliers are well lubricated.
- Do not use pliers for tightening or loosening bolts or nuts.
- Ensure the handles are insulated especially while handling hot objects.

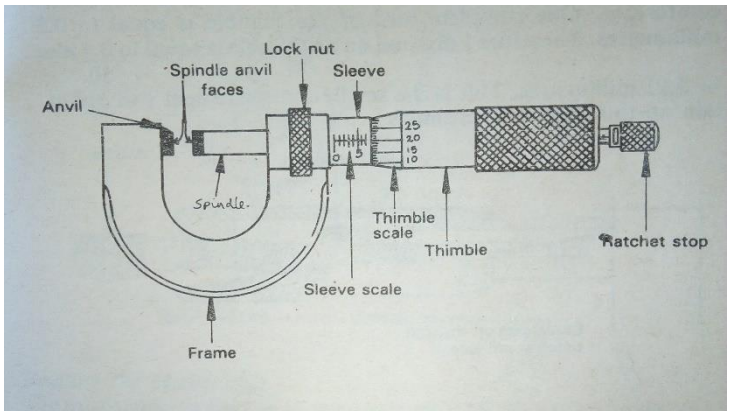
Vernier caliper

- The calipers should not be dropped because the measuring jaws will be indented and accuracy may be lost.
- Always clean and close the jaws into their position and place the calipers in its case after use.
- If the calipers are not to be used for a long time, they should be oiled to prevent rusting.
- It is necessary to ensure that all the screws are in position at all times.



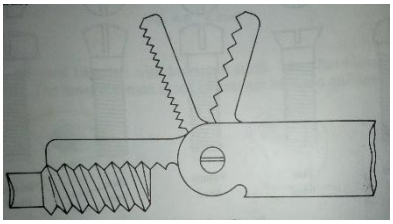
Micrometer screw gauge

- Micrometers should not be dropped, because they can easily loose the alignment of the screw thread.
- Always clean the anvil and spindle faces and oil the screw thread especially when it is not used for some time.
- The correct pressures should be maintain to ensure the anvil and spindle faces are not damaged in the course of taking measurements.
- They should be stored in their cases after use.



Thread-pitch gauge

- Ensure the adjusting knob is properly tightened to secure the blades in the frame
- Apply a thin film of oil between the blades to prevent corrosion.
- Never drop the thread gauge to minimize damage to the blade teeth.
- Always place the tool in its case after use for storage.



ASSORTED AVIATION WORKSHOP TOOLS.

CUTTING TOOLS

MEASURING AND CHECKING TOOLS

THREAD CUTTING TOOLS

SET OF SOCKET SPANNER

BALL PEIN HAMMERS

STUDENT'S ACTIVITY

ACTIVITY I

Students to identify safety devices incorporated in workshop machines.

ACTIVITY 2

With the guidance of the teacher, the students to learn how to operate the various machines in the workshop.

ACTIVITY 3

Students to identify the various tools they have at the workshop and make labeled sketches of the same.

ACTIVITY 4

Students to learn on how to use the various workshop tools provided and observe all the safety precautions when using them.

FIRST AID

It can be defined as the first and immediate help given to any person suffering from either a minor or serious illness or injury.

First aid objectives

- To save or preserve life.
- To ease pain.
- To reduce bleeding.
- To prevent infections.
- To promote recovery.

The ABC of first aid.

A-This stands for airway. You should ensure that there is no blockage to the victim's airway.

B-This stands for breathing. You should ensure that the casualty is breathing.

C-This stands for circulation. Check whether the casualty has a pulse.

Basic first aid procedures

A) Burns and scalds

Burns and scalds can be caused by dry heat from actual fire, electric current, friction, acids and alkalis. The general procedure for treating burns are:

- ❑ Place the part under running water and do not prick any formed blisters.
- ❑ Remove any constrictions like rings, bangles, belts and boots before the part starts to swell.
- ❑ Cover the wound with a clean nylon dressing.
- ❑ Immobilize a badly burnt part.
- ❑ Take the victim to hospital if the case is serious.

B) Cuts

These are breaks in the continuity of the body tissues which allow blood to escape. The breaks may allow germs entry into the body causing infections. It is for this reason that cuts should be treated promptly. Cuts with slight bleeding are treated differently from those with severe bleeding.

Treatment of slight bleeding cuts is as follows:

- ❑ Apply pressure on the bleeding point over a sterile dressing.
- ❑ Clean with running water.
- ❑ Clean with antiseptic to kill any possible germs.
- ❑ Dry the skin with cotton swabs.
- ❑ Bandage with a pad if necessary or an adhesive dressing.

Treatment of severe bleeding cuts is as follows:

- ❑ Apply direct pressure with fingers on the bleeding area over a clean dressing and hold it as long as necessary. If the cut is large, press the sides together firmly but gently.
- ❑ Lay the victim down in a suitable and comfortable position.
- ❑ Remove any foreign bodies which are visible and can be removed easily.
- ❑ Apply sterile dressing to the wound and press firmly.
- ❑ Cover the wound with a pad of soft material.
- ❑ Retain the pad and dressing in position with a firm bandage.
- ❑ Immobilize the injured part.
- ❑ Take the victim to the hospital as soon as possible.

Nb: it is possible to have cuts with foreign bodies which are not easily removable. One should not struggle to remove them. The procedures stipulated above should be followed with the foreign body still in the cut.

C) unconsciousness/hypoxia.

This can be caused by many factors; one is by failure of enough oxygen supply to the brain, the other one is by electrocution. All these can cause restricted breathing and blood circulation.

The following is a step by step procedure for handling an unconscious victim.

If the victim is not breathing:

1. Make sure that the air passage is clear by supporting the back of the neck and press the top of the head so that it tilts backward. Remove any foreign matter which might be in the mouth.
2. Press the chin upward for the victim to start breathing.
3. If the victim does not start to breath, begin mouth to mouth artificial respiration as follows:

i. Take a deep breath.

ii. Close the victim's nostrils with the fingers.

iii. Bring your mouth close to the victim's mouth, seal it with your lips and then blow into his mouth until the chest rises.

iv. Repeat this until the victim starts breathing naturally.

D) Eye injury.

i) Chemical

- Hold the eyelids apart and flush the eyeball with lukewarm water for atleast 15-30 minutes. Be careful not to let runoff water flow into the other eye.
- Place a gauze pad or clean cloth over both eyes and secure it with a bandage.
- Get to an eye specialist or emergency room immediately.

ii) Cut, scratch or embedded object

- Place a gauze pad or cloth over both eyes and secure it with a bandage.
- Do not try to remove the embedded object.
- Get to an eye specialist or emergency room immediately.

TOPIC 3

THEORY OF FLIGHT 1

Specific Objectives.

At the end of the topic, the learner should be able to:

a. State briefly the historical development of aviation.
b. Identify the various types of aircraft
c. Identify major parts of an aircraft.
d. Explain basic science concepts
e. Explain the concepts of flight
f. Construct simple aircraft MODEL

SUB-TOPICS

a. Introduction
b. Historical highlights.
c. Aircraft Classification
d. Nationality and registration marks.
e. Parts of an Aircraft.
f. Basic science concepts.
g. Bernoulli's Principle and the aerofoil.
h. Construction of a simple aircraft

INTRODUCTION

The history of aviation extends for more than two thousand years. From the earliest forms of aviation such as kites and gliders, attempts at tower jumping to supersonic and hypersonic flight by powered, heavier than air jets.

Flying has always fascinated man. We also have the Greek mythology where father and son built wings to escape from prison.

On 21st November 1783 John Francois de Roise and Marquis de Arlandes took off in a Montgolfier balloon over Paris in France. They flew over the city for 23 minutes landing 10 kilometers away.

HISTORICAL HIGHLIGHTS.

13th Century

Rodger Bacon, an English philosopher wrote on the possibility of man flying a machine sitting in the middle turning a mechanism to gain motion by artificial wings.

15th Century

Leonardo da Vinci wrote notes and made sketches on flying machines.

19th September 1783

The Montgolfier brothers flew a hot air balloon over Paris city.

1783

Louis Sebastian designed a parachute**.**

1804

Sir George Cayle wrote the first clear outline of aeronautical principles. He designed a machine powered by a steam engine and operating a propeller. He did not fly it but was able to demonstrate how a curved surface generates lift. He is known as the father of aviation. He used a glider that actually flew over a valley and over villages.

1884

Charles Reynolds and Luther Weber flew the first controllable airship.

1893

Lawrence Hargraves invented a rotating engine and also a box kite.

1903

The Wright Brothers took all the credit for the first heavier than air aircraft.

1907

Paul Cornu, an aircraft mechanic was the first man to fly a helicopter.

1914

The first airline flight was made in Tampa U.S.A

1930

Amy Johnson was the first woman to fly an aircraft from U.K to Australia.

1937

The "nerdeilberg" an airship exploded in America in 6th May.

1941
The first practical helicopter by Igor Sirkosky, solved the torque problem.

1967

Apollo rocket exploded during a test flight.

1964

Neil Armstrong was the first man to walk on the moon.

1975

The Concorde aircraft (supersonic jetliner) began passenger flight in France.

1981

Creation of the first space shuttle.

1986

The Challenger space shuttle exploded killing all the astronauts on board.

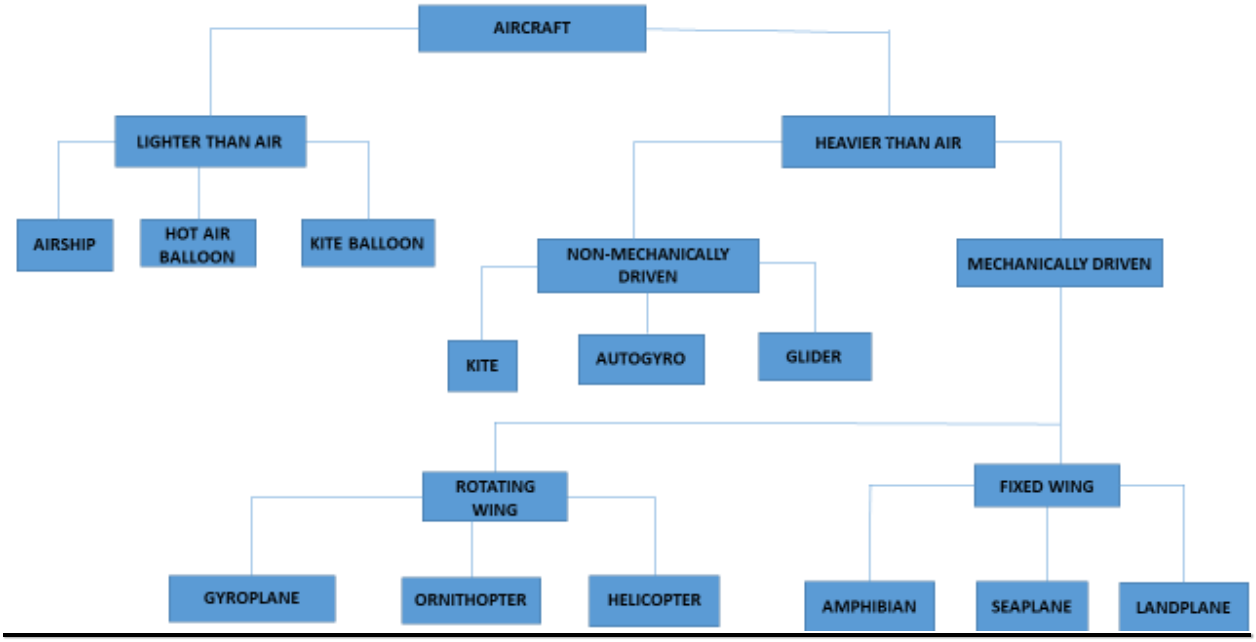
1992

The first human powered was launched.

2003

The Concorde suspended all the commercial flights after an accident over Paris that killed all the passengers and the crew.

AIRCRAFT CLASSIFICATION



Lighter than air aircraft.

These aircraft are also referred to as aerostats. Lighter than air aircraft get lift principally from buoyancy instead of generating lift through the use of aerofoil. Examples of such aircraft include:

i. Hot air balloons.
ii. Airship.

i) Hot air balloon.

A balloon works on the principle that lift force is greater than the weight force. The air inside the balloon is heated by a propane burner making it lighter than the air outside the balloon. To gain height, the air is heated more and to loose height, less gas is burnt. For landing, a valve at the top of the balloon is opened to release the hot gases out slowly.

ii) Airship

It is a balloon which has a power source and is mechanically driven to propel it through the air. An engine and the ability to steer distinguishes an airship from hot air balloons.

Heavier than air aircraft.

These are that generate lift by allowing air to flow over the aerofoil shaped wings. This flow creates a pressure difference between the upper and lower surfaces of the wings and this pressure difference is the lifting force.

Heavier than air aircraft can be categorized as:

a. **Mechanically driven.**
b. **Non- mechanically driven.**

a. Mechanically driven

These are aircraft that have an engine as a source of power to propel the forward. They are further classified to as:

- Rotary wing.
- Fixed wing

Rotary wing.

These are aircraft that have aerofoil shaped blades mounted at the top of the airframe that when they are rotated, they generate both lift and thrust.

These aircraft include:

1) Helicopter.
2) Gyroplane

1) **Helicopter**.

This is a heavier than air aircraft with a power source that drives an overhead rotor shaft to generate both lift and thrust.

2) Gyroplane.

It is a plane with two rotors; one rotor is a propeller used to generate thrust while the other automatic rotor which responds to the rotation by wind to generate lift.

Fixed wings

These are aircraft that have aerofoil shaped wings that generate lift by relative flow of air over them. They include:

1) Amphibians.

2) Sea planes.

3) Land planes.

1) Amphibians.

They are powered aircraft that can land on both water and on land. They have floats for landing on water and wheels to use on land.

2) Sea planes

These are aircraft that land on water only. They use float that are filled up with compressed nitrogen to allow them to float on water.

3) Landplanes.

This category constitutes the largest number of planes. They can only land on designated areas called runways that are tarmacked.

NATIONALITY AND REGISTRATION MARKS

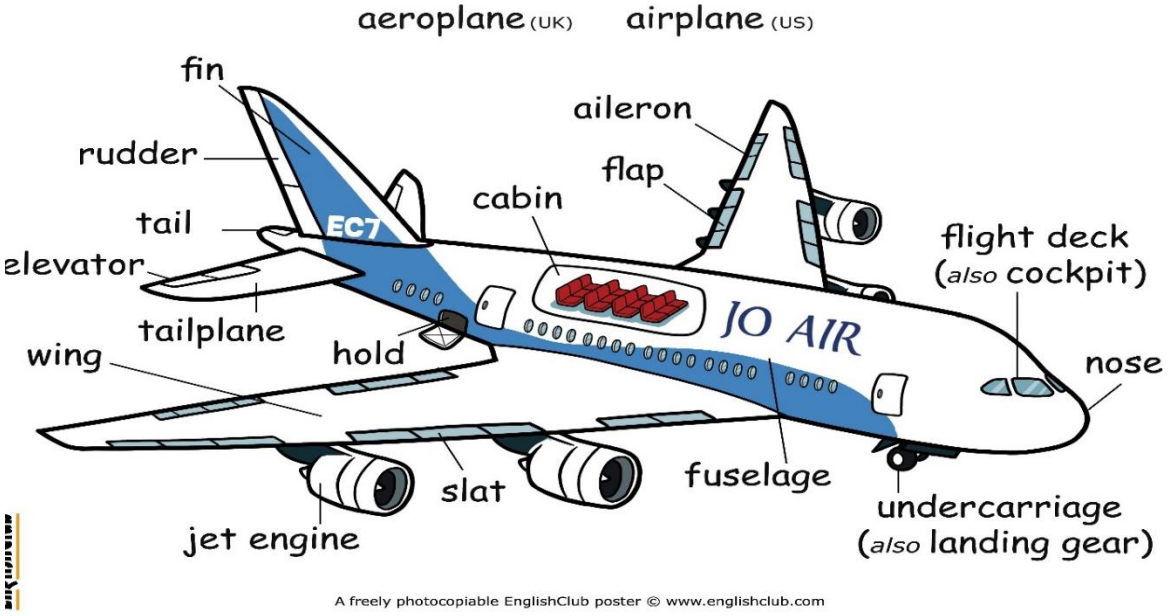
- The nationality mark of an aircraft is a group of two capital letters in roman characters and the registration is a group of these capital letters in roman characters.
- The registration letter are assigned by the Director of Kenya Civil Aviation Authority (KCAA).
- Aircraft nationality marks are assigned by ICAO. The nationality marks given to Kenya by ICAO is **5Y.**
- The nationality marks are painted at strategic areas of the aircraft, ensuring clear visibility from a distance.
- The colour of the marks should contrast that of the background and there should be no obstruction.
- The nationality and registration marks are separated with a hyphen.

<u>Position of aircraft nationality and registration markings</u>.

Aircraft nationality and registration markings are usually placed on the following areas:

- On the sides of the vertical stabilizer [equidistant, from leading edge and the trailing edge].
- On the side of the fuselage between the trailing edges of the wing and the leading edge of the horizontal stabilizer.
- Below the left wing or may extend the whole length of the wing [span]
- On helicopters, the markings can be placed on both sides of the tail boom and sometimes on the engine nacelles.
- On airships the markings are placed on both sides of the hull.
- On hot air balloons, the markings are placed on two sides diametrically opposite.

PARTS OF AN AIRCRAFT



An aircraft consists of five major parts namely:

i. Fuselage
ii. Undercarriage [landing gear]
iii. Main planes [wings]
iv. Power plants [engines]
v. Empennage [tail section]

Fuselage

This is the central part of the aircraft and has the following functions:

- It provides attachment for other aircraft parts e.g Wings, Undercarriage etc.
- In single engine aircrafts, it holds the power plant.
- It has a cabin which provides the space for carrying cargo and passengers.
- It protects the passengers from the harsh atmospheric conditions experienced during flight.
- It has a cockpit which holds all the flight operation controls, and housing the flight crew.
- It provides a passage for the aircraft control cables and wiring.

Undercarriages

These are structures that are located beneath the fuselage structure, and can also be referred to as landing gears. Their functions include the following:

- To support the aircraft during ground operations like taxing, parking and towing.

- ❖ It has a wheel assembly which allow ground movement of the aircraft before take-off and after landing.
- ❖ It has brakes which assist in slowing the aircraft after touch down.
- ❖ It acts as a shock absorber during landing.
- ❖ It has a steering mechanism to enable the aircraft maneuver while on the ground.
- ❖ It provides enough ground clearance for the engines and propellers.

Main planes

They are also known as wings, and are usually in a pair. One is attached to the right side of the fuselage, while the other is attached to the left side of the fuselage. The functions of the main plane include the following:

- ❖ To generate the lift force required to support the aircraft in flight.
- ❖ To provide the space for storing fuel.
- ❖ To provide the attachment for the engines in multi engine aircrafts.
- ❖ To provide the stowage area [wheel well] for undercarriages.
- ❖ To hold weapons especially in military aircrafts.
- ❖ To provide hinge surface for flight control surfaces like Flaps, Ailerons, and Spoilers etc.

Power plant

It is also known as engines, and can be wing mounted or fuselage mounted. The function of the engine include:

- ❖ To generate thrust force required to move an aircraft forward during flight.
- ❖ To generate electricity for cabin lighting and powering of aircraft systems through engine driven generators.
- ❖ To provide bleed air to be used for cabin pressurization and air conditioning, de-icing and anti-icing, and also for running gyroscopic instruments.
- ❖ To provide a means of slowing the aircraft after touchdown through thrust reversers.
- ❖ It provides a means of turning an aircraft on the ground through power differential.

Empennage

This is the tail section of the aircraft and consists of fixed surfaces like the Fin, Tail plane and the Tail cone, and movable surfaces like the rudder and elevators.

The empennage has the following functions:

- ❖ It has a fin/vertical stabilizer which assist in stabilizing the aircraft vertically.
- ❖ It has a tail plane/horizontal stabilizer to assist in stabilizing the aircraft horizontally.
- ❖ It has a tail cone which encloses the rear end of the fuselage, thus streamlining it.
- ❖ It houses the auxiliary power unit (APU) in large airplanes.
- ❖ It anchors the power plant in some aircraft models

BASIC SCIENCE CONCEPTS

Science Concepts refers to a methodology of using tools for recognizing, representing and manipulating various knowledge domains. The following are the basic science concepts that are applicable in Theory of Flight:

Mass

- Mass (M) is the quantity of matter in an object.
- The mass of an object is not dependent on gravity and is therefore different but relates to the weight of an object.
- The thrust produced by an aircraft propeller or jet engine is dependent on the mass flow of air through the engine.
- The SI Unit of mass is Kilogram (Kg)/ Pounds (Lb.).
- Other units for mass are:- grams(g)
  - milligrams(mg)
  - Tonnes(t)
- **Mass = Density ×Volume**

Weight

- The weight of an object is the force with which the object is attracted to the Centre of the earth.
- It is a product of the mass of the object and acceleration due to gravity (g).
- The SI Unit for weight is Newton (N). 1 Newton is the force required to give a body of 1 Kilogram an acceleration of 1m/s.
- Other units for weight are Kilo newton(KN)
- **Weight=Mass×Gravitational Acceleration**.

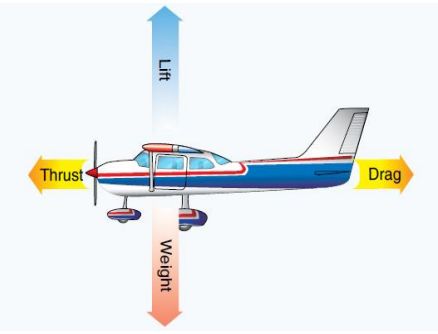
Force

- This is a pull or a push of an object.
- The SI unit of force is Newton **(N).**

  Force = Pressure × Area

There are four principle forces that act on an aircraft during flight, these are:-

a. **Weight** - It is a force that acts downwards from the center of gravity and tends to pull the aircraft towards the center of the earth.
b. **Lift** - It is a force that acts upwards from the wing center of pressure and tends to oppose or overcome weight.
c. **Drag** - It is the force that acts backwards from the center of gravity and resists the aircraft movement through the air.
d. **Thrust** - It is a force that acts forward from the engine and propels the aircraft forward.



Energy

- Energy is the ability of a system to do work.
- It can also be defined as the capacity of a physical system to do work.
- The SI unit of energy is **Joules (J).**
- Energy can be classified into two forms:-

i) **Potential Energy (P.E)**

ii) Kinetic Energy (K.E)

Potential energy: It is a form of energy possessed by a body because of its configuration or its position. For example;

a) An object raised at height-(position)

b) A tightly wound spring-(condition)

c) A gas stored in a cylinder-(condition)

Kinetic energy: It is a form of energy possessed by a body due its motion. For example

a) When a hammer is raised to hit a nail.

b) When water is released to rotate the turbines to produce hydroelectric power.

c) When wind drives turbines to drive electricity.

d) When a bullet is shot by a gun.

Kinetic energy= (1/2) ×Mv^2

LAWS OF CONSERVATION OF ENERGY

- It states that energy can neither be created nor destroyed, but can be transformed from one form to another.
- This means that the total amount of energy in the universe is constant.

a. Various forms of energy include:-Heat Energy.
- Chemical Energy.
- Nuclear Energy.
- Solar Energy.
- Mechanical Energy. etc.

Momentum

- Momentum refers to the quantity of motion that an object has.
- It can also be define as the product of mass and velocity of an object.
- The SI Unit for momentum is **Kg.m/s**
- **Momentum = Mass × Velocity**

Angular momentum is the tendency of a rotating body to continue spinning about an axis

Pressure

- This is the force acting perpendicularly per unit area.
- The SI Unit for pressure is **N/m^2**

  Pressure = Force÷Area

- Other units for pressure are:- a) Atmosphere (Atm.)
  b) Millibars (mb)
  c) Inches of Mercury (in Hg)
  d) Pounds per Square Inch (Psi)
  e) Millimeters of Mercury (mm Hg)

Density

- It refers to the mass per unit volume of an object.
- The SI Unit for density is **Kg/m^3** or **g/cm^3**

  Density = Mass÷Volume

Speed

- This is the rate of change of distance with time.
- Speed can also be defined as how fast or slow an object moves.
- Speed is a vector quantity.
- The SI Unit for speed is **Km/h**

Speed = Distance÷Time

Velocity

- This is the rate of change of displacement with time.
- Velocity is a vector quantity. i.e. It has both direction and magnitude.
- The SI Unit for velocity is **m/s**

Velocity = Displacement÷Time

Acceleration

- This is the rate of change of velocity with time. It is a scalar quantity.
- The SI Unit for acceleration is **m/s^2**

Acceleration = Change in Velocity÷Time

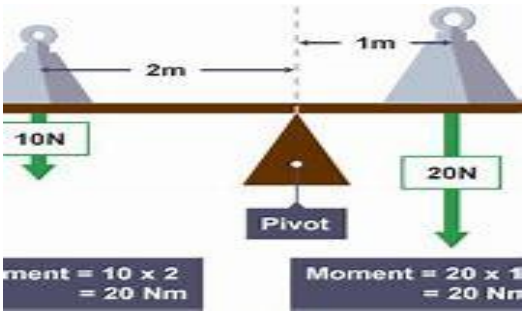
Centre of gravity

- This is a point in an object from where all its mass tends to act from.
- It is the point about which all gravitational moments adds up to zero.
- In an aircraft, it is assumed to be the point where the three principle axes meet.

Moments

- This is the turning effect of a force.
- It can also be defined as a tendency of a body to rotate.
- This is the product of force and perpendicular distance, separating the point of application of the force and the fulcrum/pivot.
- The SI unit of moments is **Nm.**

Moment= Force × Perpendicular distance



- Aircraft primary controls are placed at the furthest distance from the center of gravity to give them a long moment arm so that just a small force is able to control them.

FORCE AND MOTION

Effects of force

- ✓ Can make a stationary object move.
- ✓ Can change the shape of an object.
- ✓ Can change the direction of an object.
- ✓ Can stop a body in motion.

- The concept of force and motion is well explained in Newton's Laws of Motion as follows:

Newton's -First law of Motion

- It states that body in the state or in uniform linear motion will continue in that state unless acted upon by external forces.

This law is also referred to as **the law of inertia**.

Inertia: - The tendency of a body to remain in a state of rest or uniform motion in a straight line for example

If a car in motion stops instantly, the passengers tend to jerk forward as their masses resist stoppage.

Newton's -Second law of motion

- This law states that the acceleration of a body is directly proportional to the force causing it and inversely proportional to its mass that is, a large mass requires a huge force to accelerate it or to stop it.

  Acceleration= Force÷Mass

Newton's -Third law of motion

- This law states that for every action there is an equal and opposite reaction force. For example, for an aircraft to move forward, a propeller or a jet engine pushes large mass of air backwards and in turn a reactive force is generated which pushes the aircraft forward.

BERNOULLI'S PRINCIPLE AND THE AEROFOIL

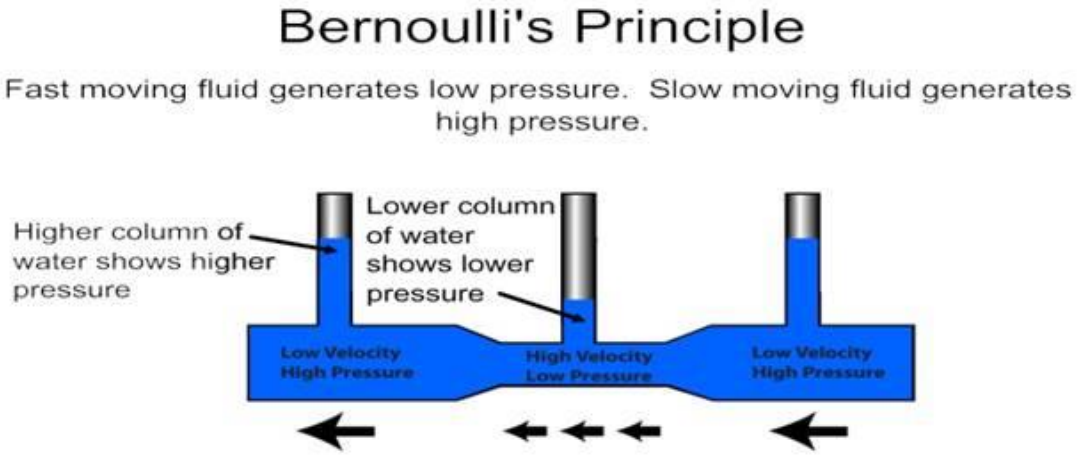
Bernoulli's Principle

Daniel Bernoulli, a Swiss scientist of 18th Century, discovered that if a fluid is flowing through a pipe with a restriction (narrow point) when it approaches this point, its velocity increases while its pressure decreases.

Bernoulli's Principle states that**; In a steady, non-viscous and incompressible fluid in motion, the total energy of a fluid particle is constant at all points on its path.**

Study of fluid flow in a closed tube

- Suppose a stream of water is flowing through a venturi tube as shown below:

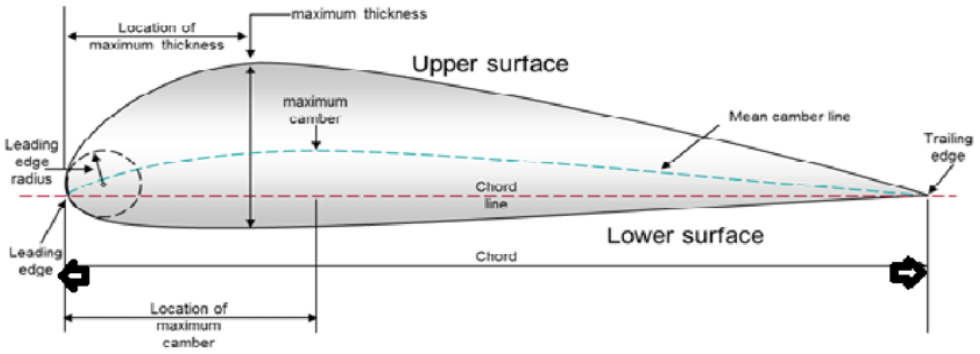


- The fluid flow at the tube inlet has a certain velocity and static pressure. Since the fluid flow is enclosed within the tube the mass flow along the tube remains constant.
- As the fluid flow approaches the constriction at the center of the tube, the velocity increases as the pressure decreases.
- Towards the venture tube outlet the velocity of the fluid decreases and static pressure increases. The total energy of the air stream remains constant.

The Aerofoil

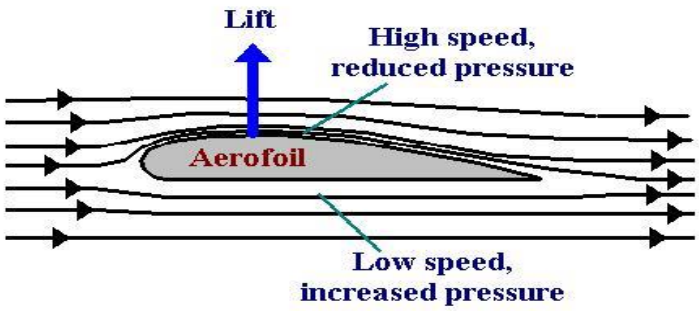
Aircraft wings and helicopter rotors are examples of aerofoil. When an aerofoil is moved through the air, it generates both lift and drag.

Parts of an aerofoil



LIFT GENERATION

- As the airflow approaches the leading edge of the wing, it separates into two flows
- The first airflow flows above the upper surface of the wing. While the second flows below the lower surface of the wing which is flat or has a very small curvature.
- Due to the upper surface camber, the air molecules travelling above the wing has a longer distance to cover as compared to the one travelling below yet both flows must meet at the trailing edge at the same time.
- This makes the airflow above, which has a longer distance to cover to move faster than the airflow below the aerofoil.
- According to Bernoulli's principle, the higher velocity above the aerofoil creates a region of low pressure while the slow airflow below the aerofoil creates a region of high pressure.
- This pressure difference creates a differential force called **lift.**



Topic 4
METEOROLOGY 1

SPECIFIC OBJECTIVES.

- **At the end of the topic, the learner should be able to:**

a) Differentiate between International Standard Atmosphere (ISA) and Prevailing conditions.
b) Describe the characteristics of atmospheric layers.
c) Identify, read and interpret weather instruments**.**

SUB-TOPICS

- ❖ Introduction
- ❖ Atmospheric elements.
- ❖ Properties of the atmosphere.
- ❖ Atmospheric layers.
- ❖ International standard atmosphere (ISA) & prevailing conditions.
- ❖ Weather instruments

INTRODUCTION

- Meteorology refers to a branch of science concerned with the processes and facts of the atmosphere, including weather and climate.
- To enable safe and comfortable flights we must understand the behaviour of the atmosphere.
- The earth is wrapped by a protective blanket known as the atmosphere hence, Atmosphere is the gaseous envelope that surrounds the earth and rest upon it.
- The basic unit of each gas is a molecule, when three atoms of a molecule combine they form the ozone.
- The highest concentration of ozone is found in a 25km thick layer, 16-40km from the earth surface.
- The ozone layer absorbs harmful ultra-violet rays, thereby protecting the earth against its dangerous effects.

ATMOSPHERIC ELEMENTS

Parameters of air (pressure, density, temperature) vary considerably both in weight and geographic condition around the world.

In the lowest 65-80 km of the atmosphere, the relative proportion of each gas in the air mixture is almost constant.

Composition of the atmosphere

a)Nitrogen - 78%

b) Oxygen - 21%

c) Carbon (IV) oxide - 0.03%

d) Inert gases - 0.97%

In the atmosphere, we also have impurities due to the presence of dust, smoke and waste industrial gases.

PROPERTIES OF THE ATMOSPHERE

Temperature

Atmospheric Temperature Lapse rate

Temperature lapse rate can be defined as the changes in temperature with change in altitude.

There are three types of temperature lapse rate;

a) *Positive Lapse Rate* – This is where temperature decreases with increase in height/altitude.

a) *Neutral Lapse Rate* – This is where temperature remains constant with increase in height. The atmospheric layer with this type of lapse rate is referred to as **Isothermal Layer**.

c) *Negative Lapse Rate* – This is where the temperature increases with increase in height. The atmospheric layer with this type of lapse rate is referred to as **Inversion Layer**

Density

- Density is mass per unit volume of a substance hence, air density is the mass of air per a given volume.
- Density decreases with an increase in altitude within the atmosphere.
- Air density at sea level is assumed to be 1.225 kg/M^2.

Pressure

- Pressure is the mass per unit area.
- A column on air exerts pressure on the earth's surface which decreases as the altitude increases.
- Pressure at sea level is assumed to be 1013.25mb or 101.3KN/M^2, 760mmHg, 29.92inHg.

Wind

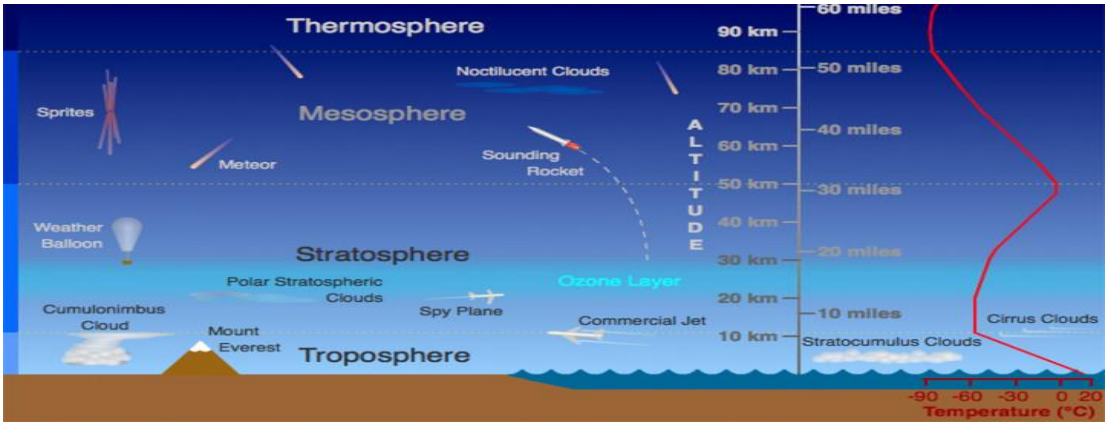
- Troposphere contains winds called jet streams.
- The strongest winds are encountered at the height of about 30,000 and above of winds moving from west to east at a speed of 150-350 miles per hour (mph).

ATMOSPHERIC LAYERS

- The atmosphere is divided into four main layers namely:-

a) Troposphere – Ranges from 0 to 11Km, where we find the tropopause.
b) Stratosphere – Ranges from 11Km to 48Km, where we find the stratopause.
c) Mesosphere – Ranges from 48Km to 80Km, where we find the mesopause.
d) Thermosphere – Ranges from 80Km and above

A TYPICAL MODEL SHOWING THE ATMOSPHERIC LAYERS



1. Troposphere

- This is the lowest layer of the atmosphere and closest to the earth‘s surface with an altitude of 11Km (36,000ft) from the sea level.
- It is a layer with positive lapse rate where temperature decreases with increase in altitude at a rate of 6.5˚C per Km or 1.98˚C per 1000ft.
- It is a layer with most weather elements for example, cloud formation and precipitation.
- It contains 78% of all gases, dust and water vapour.
- There is a decrease in pressure with rise in altitude.
- There is a decrease in air density with rise in altitude.
- Wind velocity increases with increase in altitude.
- It is the only layer that supports life.
- It is separated from Stratosphere by a layer of discontinuity called tropopause.

2. Stratosphere

- The altitude extends from 11km to 48km (56,000 ft-157,000ft).
- This is the second layer of the atmosphere extending above the tropopause
- It has an isothermal layer where temperature remains constant at -57°c from 11-15 km, and an inversion layer above this point, where the temperature increases up to 48 km.
- It contains the strongest winds called jet steams which are tubes of high speed winds moving from east to west. Airplanes take advantage of this wind to gain extra speed.
- Clouds are usually rear in this layer.
- This layer contains the ozone layer which keeps most of the infra- red radiation from the sun from reaching the earth’s surface, thus making the temperatures to rise in this layer.

Stratosphere is divided in to two layers:

a) Lower stratosphere

b) Upper stratosphere

a) *Lower Stratosphere*

- It extends from 36,000 feet to 82,000 feet (11-25km).
- The temperature in this region is almost constant at -57°c.

b) *Upper Stratosphere*

- It extends from 82,000 feet TO 157,000 feet (25-48 km).
- Temperature increases from -57°c to -2.5°c.
- At the end, there is a boundary layer called the stratopause.

3) Mesosphere

- It extends from 157,000 ft. to 262,000 ft.(48-80 km)
- This is the third layer of the atmosphere extending above the earth.
- The temperature falls rapidly hence it is the coldest temperature zone with an average temperature of -92°C
- At the top of mesosphere is the upper boundary layer called mesopause.
- It experiences very high velocities with a speed of about 300 km/h.

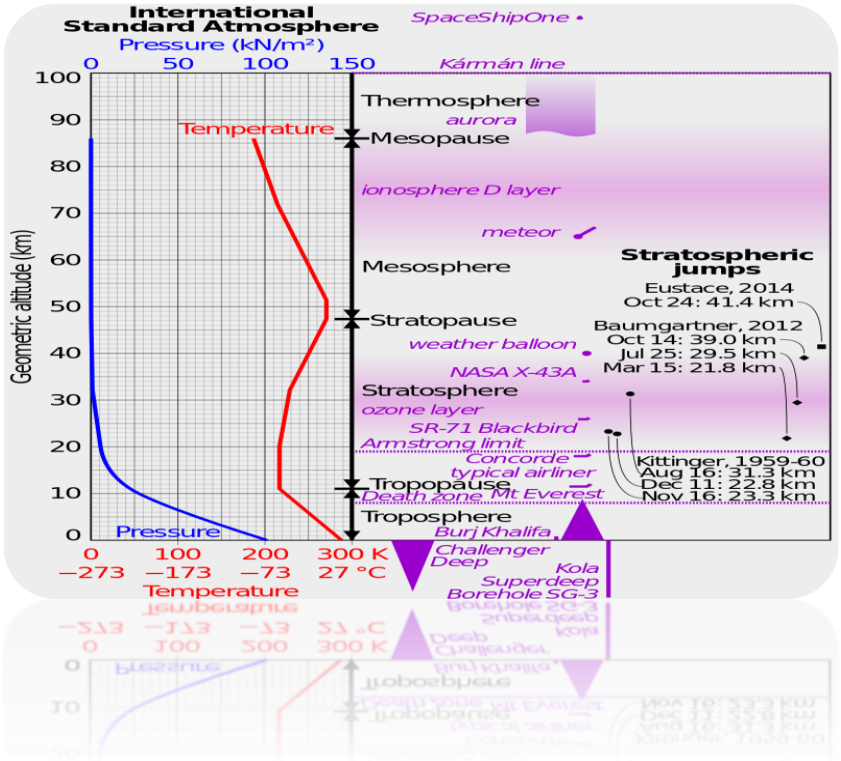
4) Thermosphere

- It extends from 262,000-1,312,355 ft. (80-400km).
- It's the 4^{th} layer extending from the mesosphere.
- There is no distinct temperature boundary to the top of this layer.
- The temperature increases rapidly due to the absorption of the solar energy.
- This zone is sometimes taken to include the ionosphere and exosphere.
- The ionosphere has the ability to reflect radio waves.

INTERNATIONAL STANDARD ATMOSPHERE (I.S.A) & PREVAILING CONDITIONS

- Prevailing Conditions refers to the atmospheric conditions that comprise of the existing state of the atmosphere in terms of temperature, wind and clouds.
- International Standard Atmosphere (ISA) is an atmospheric model of how the pressure, temperature, density &viscosity of the earth´s atmosphere changes over a wide range of altitude.
- It has been established to provide a common reference for temperature and pressure and consist of tables of various altitude.
- The international Standard Organization (ISO) published the ISA as an international standard.
- **<u>At sea level</u>**, the International standard atmosphere(ISA) gives values as follows:-
    - **Temperature**=15 °C /288k
    - **Pressure**=1013.25mb/760mmHg/29.92inHg/14.7psi/101.3kNm^{-2}
    - **Air Density**=1.225kgm^{-3}
    - **Speed of sound**=340ms^{-2}
    - **Acceleration due to Gravity**=9.81ms^{-2}
- I.S.A model divides the atmosphere in to linear temperature distribution.

INTERNATIONAL STANDARD ATMOSPHERIC MODEL SHOWING TEMPERATURE AND PRESSURE VARIATION WITH INCREASE IN ALTITUDE



WEATHER INSTRUMENTS

Windsock

- A windsock is an instrument used to measure the strength and direction of wind
- It is commonly found in airports. It is used to aid the air traffic controllers in selecting the runway depending on the wind direction.

Windvane

- It's used for measuring wind direction.
- The pointer faces the wind while the tail faces the direction the wind is blowing to.
- It consist of a horizontally rotating arm with a pointer pivoted on the vertical shaft

Rain gauge

- The measurement of rainfall is done by a rain gauge when it rains, water from direct raindrops collects into the jar through the funnel.

Anemometer

- The speed of wind is measured using an anemometer in kmh or in nautical miles. When the wind blows, the cups rotate.
- The stronger the wind, the faster the rotation.

Thermometer

This is an instrument used to measure air temperature

EFFECTS OF WEATHER TO AN AIRCRAFT IN FLIGHT

1. **Turbulence**

– This is caused by non-uniform wind flow. It leads to bumpy, rough and uncomfortable flight.

Factors leading to Turbulence

- Convectional vertical currents.
- Friction – The interaction of air with another surface i.e. with the ground or an obstruction and can cause mechanical turbulence.
- Wind Shear – Change in wind direction and speed over a short period.
- Aircraft cause wake turbulence behind their wings. This is particularly dangerous to other aircrafts during take-off and landing.

Precautions taken to avoid effects of turbulence on aircraft

- Aircraft must be properly separated.
- Aircraft must not fly above the other aircraft path, since vortices sink downwards.
- Avoid flying over areas of uneven terrains.
- Check weather forecast before planning a flight.

Keep heading and altitude change to minimum

2. **Fog**

- This reduces visibility.
- Very low visibility may lead to postponing of landings, taking off and other airport operations.
- Aircrafts may also be directed to other airports.

3. **Rain**

Rain affects the aircraft's braking action during landing as the runway becomes slippery. This may limit take-off and landing weight

4. **Temperatures**

- The temperature is important in view of engine performance. High temperatures can lead to reduction in air density, which has a direct negative effect on engine performance. This can also lead to reduction of take-off weight.

5. **Crosswinds**

- Crosswinds usually hit the aircraft from the sides during landing and taking off. This gives the aircraft unnecessary rolling which may be hazardous. The direction of wind is used in selecting runways.

6. Thunderstorm Hazards

- Flight through thunderstorms result to such hazards like hail, icing, lightning strikes and severe air turbulence.
- Since most low flying aircraft may not be equipped with weather radar, pilots must rely and have reliable and current weather data from the meteorological department.
- High wind speeds and severe down bursts are associated with thunder clouds.
- When a thunderstorm occurs near an airport, various operations like landing and takeoff and even refueling are suspended.

EFFECTS OF HIGH ALTITUDE FLIGHTS ON AIRCRAFT

- Low temperatures at very high altitudes can cause aircraft icing which can lead to:-

a) Increase in drag hence loss of lift when it accumulates on the aircraft surface.
b) Decrease in propeller efficiency.
c) Blockage of the pitot heads and static vents hence introducing errors in pitot-static Instruments.
d) May affect radio antenna bringing the possibility of communication failure.
e) Carburation icing hence reduce engine efficiency.

ADVANTAGES OF HIGH ALTITUDE FLIGHT

HUMAN:-

a) Reduced noise levels.
b) Comfort i.e. less air bumps/ turbulence.

AIRCRAFT:-

a) Economical in fuel consumption-less drag is experienced.
b) Less buffeting/vibrations.
c) Reduced incidents of lightning strikes.
d) Low atmospheric pollution

EFFECTS OF HIGH ALTITUDE FLIGHT ON HUMAN BEINGS

- Freezing
- Reduced humidity causes sore throat and cracking of skin.
- Anoxia which is caused by absence of oxygen supply to an organ or a tissue.
- Hypoxia which is caused by lack of sufficient oxygen in the brain, leading to blurred vision, impaired judgement and thinking, etc.
- Decompression sickness and vapour locks in the blood streams causing chest pains and sickness in breathing.
- The aircraft must be made from heavy structures to withstand high pressure differential hence more expensive.

TOPIC 5

AIRPORT OPERATIONS 1

Specific Objectives.

At the end of the topic, the learner should be able to:

a) State entry and departure rules and regulations at Kenyan aerodromes and airports.
b) Classify airports in Kenya.
c) Categorize the Kenyan airspace
d) Identify hazards encountered in Kenyan airspace.
e) Discuss the limitations in performance of personnel in the Aviation Industry.

Sub-topics

a) Introduction
b) Definition of terms as used in Airport Operations.
c) Entry and departure Rules and Regulations at Kenyan Aerodromes and Airport.
d) Airport Layout.
e) Airport facilities.
f) Classification of Airports in Kenya.
g) Classification of Airspace.
h) Hazards in the Kenyan Airspace.
i) Limitations in performance of personnel in the Aviation Industry.

Introduction

Airport operations refers to activities carried out at the airport to ensure that everything including aircraft ground handling, cargo handling, passenger handling, etc. runs as smoothly as possible. To achieve this, some important facilities are required at the airport. These facilities plays an important role in the full functionally of an airport.

This topic will therefore guide the learner in understanding the different airport facilities as well as their function, and the role they play to an aircraft either on the ground or in flight.

Definition of terms as used in Airport Operations 1

- ***Airport*** – It is a tract of land where aircraft can take-off and land and is usually equipped with hard surfaced runways and taxiways, hangars, control tower, aircraft maintenance and refueling facilities, accommodation for passengers and cargo.
- ***Aerodrome*** – It is an area of land or water (including buildings, installations and equipment) intended to be used either fully or partially for the arrival, departure and surface movement of aircraft.
- ***Airstrip*** – It is a kind of an airport with minimum facilities that could include only a runway and fueling equipment. It does not have many buildings, for example hangar, no control tower, no passenger and cargo handling facilities ***.etc.***
- ***Airside*** – It refers to movement area of an airport, adjacent terrain and buildings including tower, hanger, apron, passenger and cargo facilities. Access to such area is controlled.

- ***Landside***- It refers to an area of an airport and buildings which a non – travelling public is free to access.
- ***Apron/Ramp***- It is a defined area on land aerodrome that is meant to be used by aircraft for the purpose of parking of aircraft, embarking or disembarking of passengers, repair or maintenance of aircraft and loading and off- loading of mail and cargo.
- ***Operator***- It includes a person in an airline, organization, or enterprise that is involved in or offering to involve itself in aircraft operation or providing services on aircraft or passengers in a given aircraft.

- ***Screening-*** It refers to the security clearance procedures conducted either on person, cargo, mail and other goods and articles at the aerodrome.

  Screening involves activities like:

  a) Checking using security equipment and devices to determine their identity and purpose for being at an aerodrome.

  b) Checking mail, cargo, stores on baggage and other concealed weapons, explosives, incendiary devices.
- ***Vehicle-*** It refers to the following:
  - ✓ Motor Vehicle
  - ✓ Tractor
  - ✓ Ground Power unit
  - ✓ Push-back truck
  - ✓ Conveyor belt truck
  - ✓ Air Starter Unit

<u>Entry and Departure Rules and Regulations at Kenyan Aerodromes and Airports</u>

- **Screening of passengers and other person and luggage**.

  a) Any passenger who refuses to offer him or herself and luggage for screening will not be allowed to go beyond screening point.

  b) No passenger shall present themselves for screening or proceed to aircraft in possession of firearm, ammunition, explosive, incendiary material, or an article or material which is dangerous for safety of aircraft and prohibited by operator.

  c) The director may find it necessary for passengers to be screened and their cabin hold luggage be inspected in disembarkation, if any passenger who willingly or willfully refuses to submit themselves and their cabin hold luggage to be inspected will be denied clearance from aerodrome.

  d) The director may require a person entering waving bay or any other restricted area in aerodrome to be screened and anything in their possession to be inspected.

- **Denying Access to Aircraft**

The Director may refuse any person who is deemed to be a potential threat to aircraft safety, access to an aerodrome, or access to aircraft.

- **Search and Seizure**

The Director or any other person authorized by Director may at any time within an aerodrome stop, detain and search any person, vehicle or containers entering into or found in or leaving after suspected of having left an aerodrome.

- **Control of entry into and exit from restricted areas**.

No person shall except with permission from Director in writing;

i. Enter or be part of an aerodrome other than that part of members of public that are permitted.
ii. Enter or leave a restricted area otherwise by an entrance or exit for that purpose.
iii. Pass over or through a fence, barrier, wall, post, climb into or over a building.
iv. Enter or leave airside without clearance from an approved security checkpoint.
v. Drive or cause a vehicle to be driven into airside within aerodrome.
vi. Drive in or walk in and access the aerodrome unless he or she has an official duty at that time, authorized by the director.

- **Driving and Behaviour on airside**

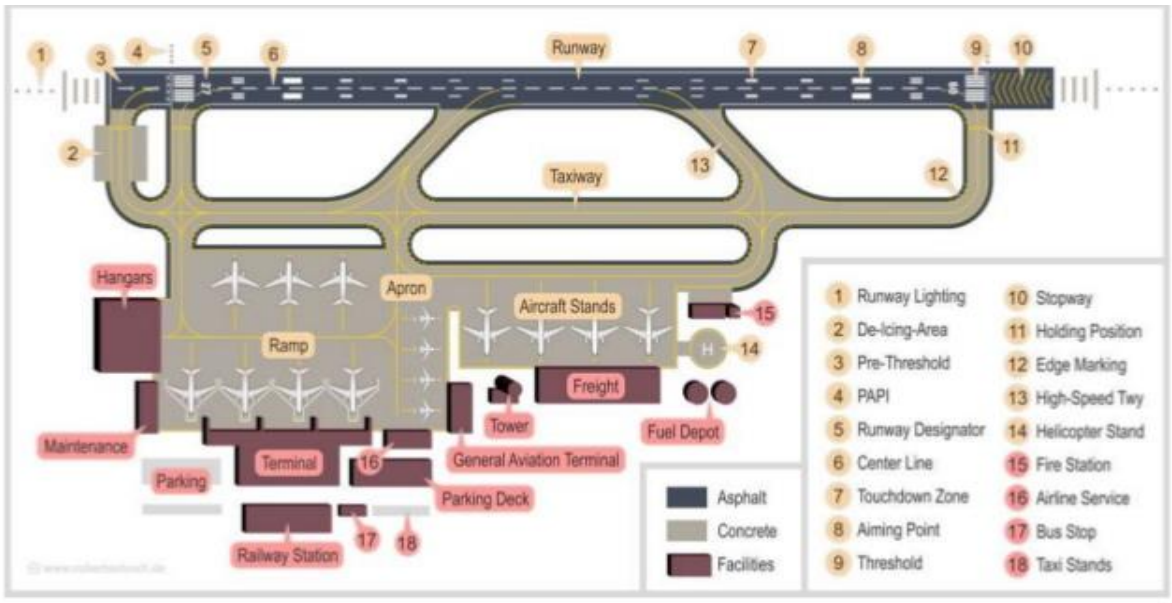
No person shall within the aerodrome:

i) Drive a vehicle on apron on speed excess of 25km/h unless necessitated by emergency.

ii) Drive a vehicle on airside in a manner likely to damage an aircraft or property or injury to persons.

iii) Place or leave any vehicle on the apron, run-way, taxiway without due consideration for safety of aircraft and other vehicles.

A typical layout of a modern Airport



Airport Facilities

1. Control Tower

The control tower is usually the tallest building above all other buildings within the airport. It is located where there is minimum obstruction from any part of the airport. Within the control tower, there are trained personnel who provide information to the pilots and other ground personnel. The trained personnel providing information are known as Air Traffic Controller and the Ground Controller. The Controllers get the advantage of being able to see aircraft approaching the airport, landing, taking off, taxiing, being towed and being parked from the tower.

From the tower, controllers have full view of other activities on the airport surfaces that may have a bearing in the surface operation of the aircraft in the airport. In the control tower there are equipment used by the controller to communicate with pilots and also with other personnel such as airport drivers and fire department when necessary.

Equipment involved in the air traffic controlling includes:

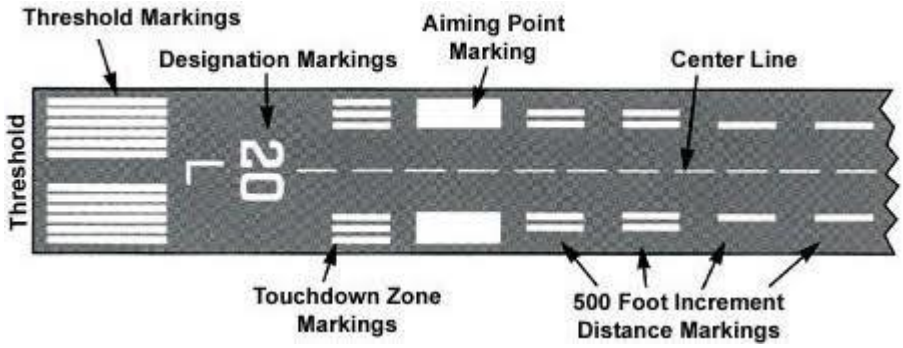
- ✓ Radio

- ✓ Telephone
- ✓ Radar Equipment(It is able to locate aircraft flying away or towards the airport vicinity)

2. <u>Runway</u>

- A runway is a rectangular piece of land of defined dimension used for take-off and landing. A keen look of runway will reveal a number of things among them:
  - ❖ Runway Number
  - ❖ Runway Lights
  - ❖ Aerodrome Markings

❖ **Runway Number**



Runways are designated with certain numbers i.e. 20. This number is based on Magnetic Heading on runway in question. Example is runway 09, landing or taking off on this runway is in direction 090 degrees. In a 20 numbered runway, landing or taking off on this runway is in direction of 200 degrees from the North.

Sometimes in some airports, we have runways which are parallel to one another. In this case a letter R below the runway number shows that this particular number is to the right of the two.

If there are three runways in parallel, the three letters R and L should be included below the runway number.

❖ **Aerodrome Signs and Markings**

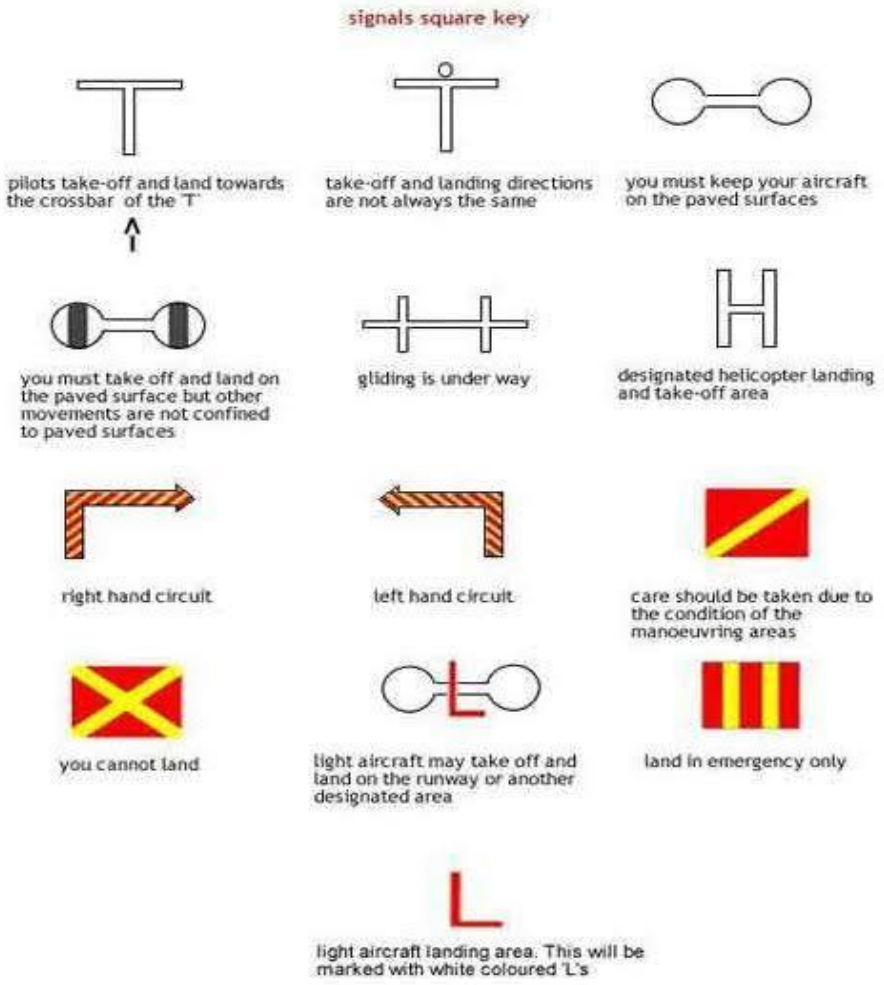
<u>Signs</u>

Aerodrome signs are usually located along the edges of taxiways and runways. The signs could be informative, precautionary or could be giving directive information to the taxiing pilot. The signs have different background colour to conform to the message being displayed on it. This could be yellow on black background, black on a yellow background and/or white on a red background

Type of Sign	Action or Purpose	Type of Sign	Action or Purpose
	**Taxiway/Runway Hold Position:** Hold short of runway on taxiway		**Runway Safety Area/Obstacle Free Zone Boundary:** Exit boundary of runway protected areas
	**Runway/Runway Hold Position:** Hold short of intersecting runway		**ILS Critical Area Boundary:** Exit boundary of ILS critical area
	**Runway Approach Hold Position:** Hold short of aircraft on approach		**Taxiway Direction:** Defines direction & designation of intersecting taxiway(s)
	**ILS Critical Area Hold Position:** Hold short of ILS approach critical area		**Runway Exit:** Defines direction & designation of exit taxiway from runway
	**No Entry:** Identifies paved areas where aircraft entry is prohibited		**Outbound Destination:** Defines directions to takeoff runways
	**Taxiway Location:** Identifies taxiway on which aircraft is located		**Inbound Destination:** Defines directions for arriving aircraft
	**Runway Location:** Identifies runway on which aircraft is located		**Taxiway Ending Marker:** Indicates taxiway does not continue
	**Runway Distance Remaining:** Provides remaining runway length in 1,000 feet increments		**Direction Sign Array:** Identifies location in conjunction with multiple intersecting taxiways

Markings

These are marking made on the surface of certain section of the airport (Signal Square). These markings should be clearly visible and the pilot should take the necessary action he or she takes note of them.



- ***Runway Lighting***

Light come in different colours, locations and ways of installation. The colours include:

- White
- Amber
- Blue
- Green
- Red

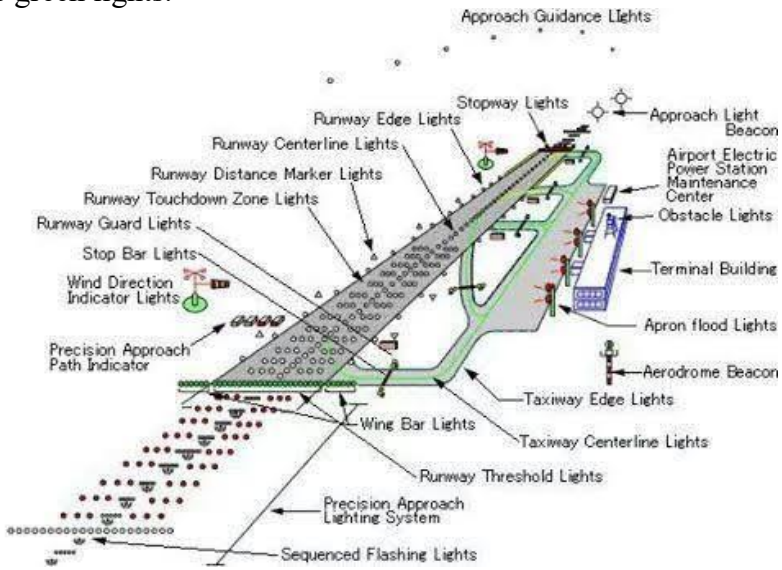
These colours have different significance. For example,

-Those in the Visual Approach Slope Indicator (VASI) or the Precision Approach Path Indicator (PAPI) lights will assist the pilot to know if he or she is in correct angle or slope path for safe landing.

-White and amber lights found at the edge of runway help pilot to know the extremities.

-Runway lights assist in improving visibility by illuminating especially at night.

-Green lights at the threshold of the runway assist the pilot in telling exactly where the runway begins. This will enable the pilot to know at what point of the runway to touch down the aircraft in relation to the green lights.



3. Taxiway

-This is a path on the airport that is used for aircraft movement and connects runways, ramps, hangars, terminals and other facilities.

-After an aircraft has landed, it will need to move to an area where it can be parked. The path used is the *Taxiway*, while the movement of aircraft with the engines as the source of power is called *Taxiing*.

- Conversely, when the aircraft is leaving the apron/ramp (parking area) to the runway, it will use the taxiways as directed by the air traffic controllers.

- When the pilot is taxing an aircraft, the air traffic controller will ascertain standard lights to give instructions to the pilot on what action to take

This lights include:

i) Flashing green lights- cleared to taxi

ii) Steady green light- cleared to take-off

iii) Flashing red light- taxi cleared landing area in use

iv) Red light- runway in use

v) Flashing white light- go back to starting point

vi) Blinking runway lights- vehicle and persons to vacate runway immediately.

The air traffic controller can also communicate with pilot when aircraft is still airborne using standard lights:

i) Steady Green light- Cleared to land
ii) Steady Red light or Red flare- Do not land, continue to circuit
iii) Flashing Green lights- Recall signal, return for landing.
iv) Alternating Red and Green light- Danger or be on alert. It warns the pilot of danger of pollution, soft field, ice or obstruction.
v) Flashing Red light-Airport is unsafe or do not land.
vi) Red Pyrotechnical light- It involves firing a red light flare either during day or night. It means do not land for the time being.

4. <u>Hangar</u>

- It is a shelter or building used for housing, parking or repairing aircraft.
- The hangar can be made of steel metal or concrete. Steel is more preferable since it is more flexible during expansion to accommodate bigger aircraft.
- Maintenance work on the aircraft can still go on outside the hangar, but because of weather conditions that may prove unbearable, for example rain, strong wind, fog and hot sun, maintenance work can still go on inside the hangar.
- A hangar has a number of sections having facilities to enable work to be conducted. For example

i) ***Offices***: - a) Chief engineer's office b) Chief pilot office

c) Directors office d) Technical records office

ii) ***Washroom***

iii) ***Common room***

iv) ***Store or shops:*** - a) Tools and equipment shop b) Fire Equipment shop

c) Electrical shop d) Engine shop e) Propeller shop

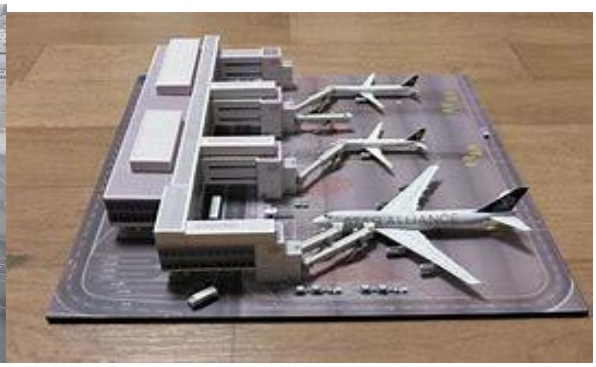
5. <u>Technical Stores</u>

- This is a designated place for keeping aircraft spare parts.
- When keeping the aircraft spare parts in a technical store, a system should also be put in place to ensure this parts are classified depending on whether they are repairable, serviceable or unserviceable. Etc. Technical stores are classified into two;

a) ***Quarantine Stores*** – This is a store where all newly received materials or parts are kept until they are inspected to confirm that they conform to the required standards.

b) ***Bonded Stores*** – This is a store where only the inspected and verified spare parts to be used in the aircraft are kept.

6. Airport Terminal



- It is a building in an airport where passengers transfer from ground transportation to the facilities that assist them to board and disembark from the aircraft.
- Within the terminal building passengers are checked for;

  - Travelling tickets/documents
  - Transfer of luggage
  - Go through security screening

7. Airport Beacon

- It is an equipment within the airport used to aid the pilots in locating the aerodrome from the air. It displays flashes of white and or coloured light.
- The airport beacon can also be used as an aeronautical beacon located at the center of airport and can be located at night.

8. Apron/Ramp

- It is defined as part of an airport with a hardened surface which is used for the parking of the aircraft.
- Within the apron, aircraft are embarked and disembarked with passengers, loaded or off-loaded with cargo or mails.
- Also in the apron, light maintenance are carried out on the aircraft i.e. – Change of tyre.
  - Top up of fluids.

- At the apron also, aircraft servicing is also carried out, such as;
  - Refueling.
  - Cleaning of the aircraft (Both internally and externally).
  - Catering Services.
  - Exhauster Services.
  - Checking the tyre pressure.
  - Go-round inspection to ascertain for dents and scratches

9. <u>Meteorological Department</u>

- It carries out the study of weather and relay this meteorological information to the control tower to be communicated to the pilot before flight and / or in flight.
- Some of the information include;
  - Wind direction
  - Wind speed and Strength
  - Temperature
  - Pressure
  - Visibility
  - Height of clouds

Kenyan Airports and Airstrips

Airport / Airstrip	Location
Jomo Kenyatta International Airport(JKIA)	Nairobi
Moi International Airport	Mombasa
Kisumu International Airport	Kisumu
Eldoret International Airport	Eldoret
Malindi Airport	Malindi
Wilson Airport	Nairobi
Lokichoggio Airstrip	Lokichoggio
Isiolo Airport	Isiolo
Ukunda Airstrip	Mombasa
Kakamega Airstrip	Kakamega
Eldoret Airstrip	Eldoret
Kitale Airstrip	Kitale
Bungoma Airstrip	Bungoma
Nanyuki Airport	Nanyuki

Airport Categories in Kenya

- According to Kenya Civil Aviation Authority(KCAA) regulations, Airports and Aerodromes in a country shall be categorized as follows:-

  a. Category A – Comprising airports and aerodromes available for use by both international and domestic air traffic.
  b. Category B – Comprising airports and aerodromes available for use only by domestic air traffic.
  c. Category C – Comprising airports and aerodromes available for use only by domestic air traffic of maximum certificated take-off mass not exceeding 30,000Kg.
  d. Category D – Comprising airports and aerodromes available for use only by domestic helicopter operations.
  e. Category E- Compromising airports and aerodromes available for use only by domestic air traffic of maximum certificated take-off mass not exceeding 5,700 Kg.

Classification of Airports In Kenya

- Airports in Kenya can be classified according to:

i) Function of the airport

ii) Size of the airport

iii) Ownership of the airport

iv) Civil/ Military airport

v) International and domestic flights/ local

vi) Fire fighting capacity

Terms Relating to Airport Classification

Critical Aircraft- Is defined as aircraft with the highest requirements that can use the airport. Based on the critical aircraft characteristics every airport is assigned a code number and a code letter to give the specific characteristics.

Code Number- It refers to the aircraft reference field length including:- stop-way and clearway

Code Letter- This refers to the critical aircraft wing span and distance that is between the external extremities of the wheel of its main landing gear

Airspace

- It refers to the portion of atmosphere above a particular land area especially that of a state.
- It may also refer to a designated sector of a space such as that in the vicinity of an airport.

Terms related to Airspace

1. ***Airway –*** It refers to an air corridor or designated route along which aircrafts fly from airports. Such routes are equipped with navigational aid or beacons.
2. ***Advisory Space-*** Airspace of defined dimensions within which air traffic advisory services is available.
3. ***Advisory route-*** Designated route along which air traffic advisory service is available.

4. ***Air traffic service airspace-*** These are airspaces of defined dimensions, alphabetically designated within which specific types of flights may operate and for which air traffic services and rules of operation are specified. It is classified as class A-G

5. ***Altitude-*** Distance of a level, point or object measured from mean sea level.

6. ***Area of Navigation (AR NAV) -*** Method of navigation which permits aircraft operation on any desired flight path within the coverage of a station referenced navigation aid.

7. ***Area navigation route-*** It's a route established for use of aircraft capable of employing area navigation.

8. ***Controlled airspace-*** Airspace of defined dimension within which air traffic control service is provided in accordance with the airspace classification,

9. ***Control area-*** Controlled airspace extending upwards from the surface of earth to a specified upper.

10. ***Danger Area-*** It is an airspace of defined dimension within which activities dangerous to the flight of aircraft may exist at specified times.

11. ***Flight Information Service-*** It is a service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flight.

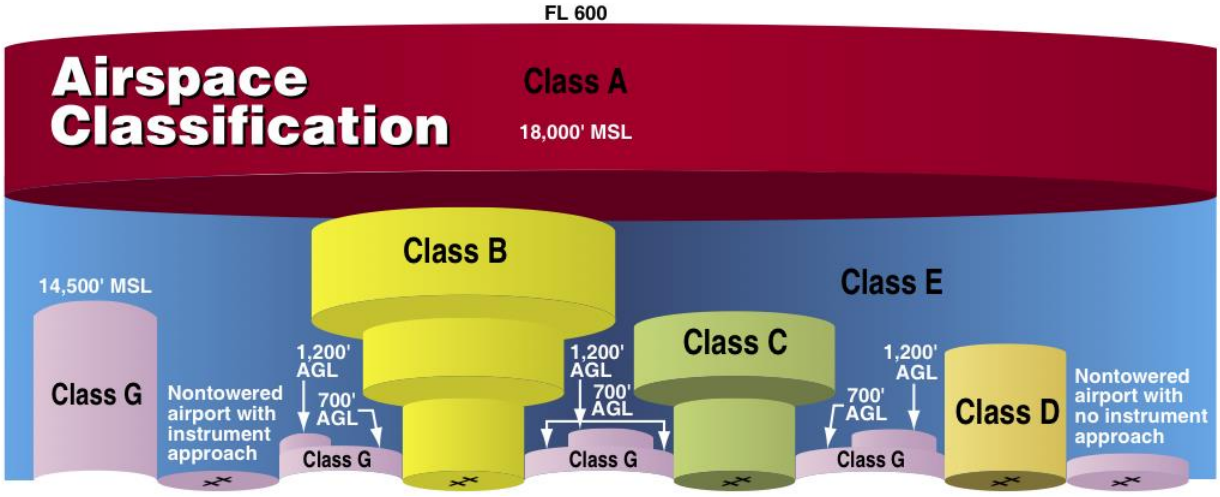
12. ***Flight Level-*** This is a surface of constant atmospheric pressure which is related to a specific pressure datum 1013.2 mb and is separated from other such surface by specified pressure intervals.

13. ***Flight Information Region (FIR) -***Is an airspace of defined dimension within which flight service and alerting service are provided.

14. ***Prohibited Area-*** Is an airspace of defined dimensions above land areas or territorial waters of a state within which the flight of aircraft is prohibited.

15. ***Restricted Area-*** This is an airspace of defined dimensions above the land area or territorial waters of a state within which the flight of an aircraft is restricted in accordance with certain specified condition.

Classification of Airspace



Air traffic services airspace shall be classified and designated according with the following:

- **Class A**

  This is an airspace above 13000ft in which only instrument flight rule flights are permitted. All flights are provided with Air Traffic Control Service.

  NB:

Instrument Flight Rules (IFR) - These are rules and regulations established by FAA to govern flight of aircraft exclusively using instruments and radio navigation aids such as the beacons or as directed under radar control by air traffic control.

Visual Flight Rules (VFR) – These are rules and regulations that govern an aircraft flight solely by reference to outside visual observations and

appropriate maps.

- **Class B**

This is an airspace from the surface to 10000 ft. surrounding the nation busiest airports. An ATC clearance is required for all aircraft to operate in the area. IFR and VFR are permitted in this airspace.

- **Class C**

This is an airspace surrounding the busiest airports in which VFR and IFR are permitted. It ranges from the surface to 4000ft above the airport elevation and an aircraft need a special permission from the ATC prior to entering this airspace and thereafter maintain the communication while within the airspace.

- **Class D**

This is an airspace ranging from the surface to 25000ft above the airport elevation surrounding airports with ATC services. IFR and VFR are permitted within this airspaces and a consistent communication should be maintained once the aircraft is within this airspace.

- **Class E**

This is an airspace that is neither A, B, C or D. It extends from the surface upwards or a designated altitude to the overlying controlled airspace. Instrument procedures is required in this airspace.

- **Class F**

This is uncontrolled airspace. The pilot gets advice from the nearest air traffic controller but all the weight of decision making is on the pilots shoulder.

- **Class G**

This is uncontrolled airspace and it extends from the surface to the base of the overlying class E air space. The ATC cannot control the air traffic in this airspace, therefore pilots relies mostly on VFR minimums which apply to Class G airspace.

NB:

It should be noted that the basis of classification of these airspaces is not the same worldwide or internationally. A state (Kenya included) is at liberty to select those airspace classes appropriate to their needs.

Hazards in the Kenyan Airspace

- **Hazard** –This is a condition that can lead to injury, illness or death of people, damage to equipment, property or to the environment.

  - It can also mean, anything that can cause an accident.

They include:-

- ✓ ***Free Balloons***
  Balloons used in parties, don't receive permissions from authority to be released into the air thus endangering the aircraft flying. Such balloons can tamper with the visibility of the pilot or can be sucked into the engine causing engine failure.

- ✓ ***Structure***
  Example of these Structures include; Sky scrapers (very tall buildings) and signal transmitters. If these equipment are extended very high into the atmosphere without a way of making theme visible during the day or night then the flying aircraft, may hit them.

- ✓ **Pyrotechnics(fireworks)**
  There are always certain ceremonies or celebrations where there is lighting of fireworks especially at night. This can be hazardous in the airspace since fireworks travel some distance high into the atmosphere, and this can tamper with visibility and can cause danger to the aircraft.

- ✓ **Moored Balloons**
  Moored balloons are always secured at some point on the ground and the strings can allow the balloon to soar or float into the air to some considerable height. Without notifying the pilot, he or she can happen to fly into the balloon and this can cause an accident.
- ✓ **Rockets and weapon firing**
  This includes the launched rockets and projectors that can strike the aircraft and cause an accident.

- ✓ **Efflux from volcanoes and industries**
  Efflux refers to something that flows out. For example exhaust fumes or dust due to volcanic eruptions. This efflux can tamper with pilot's visibility or can even cause engine failure.

- ✓ **Model aircraft and unmanned aerial vehicle (Drones)**
  Powered model aircraft when flown can sometime be a hazard in the airspace, specifically if it is flown without any special permission from a given air traffic controller for that activity to take place. Model aircraft and unmanned aerial vehicles can therefore lead to an aircraft accident if it crosses or flies on the aircraft path.

- ✓ **Kites, Parasails and Gyro gliders**
  Parasails are special parachutes with wing-like extensions.
  Gyro gliders are unpowered rotary wing aircraft.
  Kites are unpowered fixed wing aircraft. If used in the airspace without the knowledge of the pilot can cause an accident.

- ✓ **Bird strikes**
  Sometimes flock of birds cross the aircraft flight path. The birds can hit the aircraft wind shield or can also be ingested into the aircraft engine, leading to engine failure.

LIMITATIONS IN PERFORMANCE OF PERSONNEL IN THE AVIATION INDUSTRY

- ***Remuneration*** – Aviation personnel who are well paid will be more motivated and perform well in their duties, as compared to individuals who are poorly paid.
- ***General health*** – A person needs to be physically and mentally fit in order to perform optimally at work place. Conditions in the body that will affect ones alertness, ability to make correct decisions and reaction capabilities, can be greatly detrimental to performance.
- ***Environmental Factors*** – They include weather conditions such as; Temperature, Wind, Sunshine, Humidity and Precipitation. These are natural conditions and keep varying between extremes, e.g. Temperatures may be low or very high depending on seasons. At extremes, the body of human beings may not withstand, it may affect the biological system of the body and eventually affects the way an individual can perform.
- ***Workload*** – The size cut-out by individual may determine their performance level. Too much work with little rest can lead to exhaustion and fatigue, which can increase chances of making errors in their work thus affecting their performance.

- ***Level of qualification and training*** – Training is meant to equip an individual with knowledge, skills and experience necessary to apply in a real working environment. A poorly trained personnel is usually less qualified to handle some tasks given to them, thus affecting how they perform.

- ***Man and machine Factor*** – When a new machine or technology is introduced in the aviation workshop, the personnel may encounter challenges when using it. This will affect their performance level as the personnel may take some time to learn and familiarize with the technology.

- ***Poor working conditions*** – This may include lack of sufficient tools, bad company policies, abusive employers etc. If such conditions are not improved in the aviation working environment, they might greatly affect the performance of the employees.

- ***Attitude*** – This refers to someone's opinion or feelings about something, especially as shown by their behaviour. An aviation personnel with a negative attitude towards their work, organization and even their workmates, may end up performing very poorly in their duties. Good attitude is always an ingredient towards a better performance in the Aviation working environment.

TOPIC 6

AIRCRAFT MATERIALS.

Specific Objectives

By the end of the topic, the learner should be able to:

a) Identify types of wood and wood products.
b) Differentiate between hard wood and soft wood.
c) Identify type of non-metallic materials.
d) Differentiate between ferrous and non-ferrous metals.
e) Describe the chemical, physical and mechanical properties that make the materials suitable for use in aircraft construction.

Introduction

The word materials is derived from matter meaning the substance of which the physical universe is made. Thus, material is an element of a substance.

The natural sources of materials are distributed throughout the world and may be obtained from underground, on the surface, drenched from under the ocean or produced in factories such as alloys, glass, plastics and composites.

Aircraft parts are manufactured or fabricated from different materials which may include; ***Metals, Alloys, Wood, Plastics and Composites.***

WOOD AND WOOD PRODUCTS.

Wood in a hard fibrous tissue found in stems and roots of trees and other woody plants.

Not many aircraft are still made of wood these days though we still have a few companies manufacturing aircraft parts using wood.

Aircraft wood structures combine many of the properties associated with metal and composite structures such as:

- High strength to weight ratio.
- Low cost of purchase as compared to metals structures.
- Easy to machine/ work with.
- It can last long if treated properly.
- Wood is easily/ locally available.
- Wood structures absorbs vibrations easily.

Wooden structures require a minimum of special equipment for proper maintenance and repair.

Some of the aircraft wooden structures include:

- Wing spars.
- Ribs.
- Control surfaces.
- Propeller blades.
- Cabin floors.

Wood species can be broadly classified into two. They include:

a) Soft woods.
b) Hard woods.

The distinction between hard woods and soft woods is not based on the hardness of the wood but rather on the cellular structure of the wood.

Soft woods.

Soft woods are from trees which have needle like or scale like leaves [compound leaves] and are classified as evergreen or conifers.
The wood of these trees is composed primarily of fibrous cells and have a smooth even appearance when cut in cross-section.

The following are some of the properties of soft woods:

i. They are evergreen i.e. they do not shed leaves annually like hardwood trees.
ii. They have a fast growth rate as compared to hardwood.
iii. They have compound leaves i.e. a leave with many leaflets.
iv. They produce seeds without pods referred to as conifers.

Soft woods are less expensive as compared to hardwoods.

Examples of trees that produce softwoods include: Spruce, Douglas, Fir, White Cedar, Hemlock, Pine, and Larch. etc

Hard woods

Hard woods come from trees which have broad leaves and are classified as deciduous because they lose their leaves annually.
The wood of these trees is composed of a mixture of large cells, causing pores in the wood distributed among the smaller fibrous cells. These pores are usually visible when the wood is cut smoothly. Hardwoods are generally heavier than softwoods and are used where their strength advantage makes the extra weight acceptable over the softwoods

The following are some of the properties of hardwoods:

i. They shed their leaves annually i.e. they are deciduous.
ii. They are produced from trees with broad leaves.
iii. They have a slow growth rate as compared to softwoods.
iv. They have a high density; due to their slow growth rate, they/ tend to be more compact hence the high density.
v. The produce seeds with pods.

Examples of trees that produce hardwoods include: mahogany, white ash, birch, teak, aspen, elm etc.

Manufactured boards.

Manufactured boards are manmade boards built up or composed of wood products e.g. plywood, laminated board and chipboard. These boards have a number of advantages over the unprocessed wood which include:

a. Too much waste when converting solid timber.
b. The need for wider and stronger boards.
c. A remedy for timber defects such as splitting, knots, warping and bowing.

Veneer

This is a thin sheet obtained from logs by any of the following methods; rotary peeling, slicing.

The veneer is used for decorative work, paneling and manufacture of plywood and boards.

Types of processed wood products

a) Plywood

This is a board produced by bonding [gluing] veneers together at 45˚or 90˚ to each other. The arrangement of the veneers is in alternating directions in order to distribute the longitudinal wood strength.

There are two types of plywood i.e. three ply [made of three veneers] and multi ply.

The three ply has the face, core [inner ply] and back. The face and back veneers are placed at right angles to the core veneer. The veneers might be of the same thickness or the core might be thicker than the outer plies.

The multiply has more than three veneers. For balance in construction, the layers are bonded in odd numbers. This also makes the grains of the face and back veneers to run in the same direction.

b) Laminated boards/wood

This is a board which has a core made of a number of narrow strips/veneers of solid timber glued together parallel to one another to give the desired width. Cross-banding sheets of plain veneer are placed or fixed on both sides of the strips to hold them together before applying the face veneer. This board is not as strong as the ply boards but allows use of normal solid wood joints.

c) Solid wood

This is a complete piece of wood. Wing spars are usually made from this type of wood.

Advantages of wood as an aircraft material.

1. Wood has high strength to weight ratio.
2. It is easy to work with, i.e. easier to machine and shape than metals.
3. Can last long if well protected against weather elements and insect attacks.
4. It a poor conductor of both heat and electricity and therefore can be used as an insulator.
5. Wood is readily available and cheap.

Disadvantages of wood.

1. Wood is easily affected by insects like weevils and termites.
2. Wood is prone to defects like knots, warping and bowing which may affect its strength and use.
3. When exposed to weather elements especially moisture, it is susceptible to rotting.
4. It is limited to areas of low strength i.e. it is not as strong as metals.
5. It is labour intensive from time of harvesting through the processing period to the finished product.

METALS.

Metal structures constitute a major percentage of the components required in aircraft construction. There are many types of metals in use and they fall into three major groups;

a. Ferrous.

b. Non-ferrous.

c. Alloys.

Ferrous metals are the ones that contain iron as their main constituents e.g. Steel and its alloys, Cast iron, Wrought iron.

Non-ferrous metals contain no iron in their formulation e.g. copper, lead, Aluminium, Silver, Titanium, Gold. Etc.

Alloys are a mixture of two or more metals e.g. brass, bronze, nickel. Etc.

Properties of Metals

Metal properties can be categorized into three, namely:

a) Mechanical properties

b) Physical properties

c) Chemical properties

- **MECHANICAL PROPERTIES**

These are properties that a material exhibits upon the application of force. Examples of mechanical properties include:

i) **Ductility:** This is the ability of a material to be drawn into wires, rods and extrusions.

ii) **Hardness:** this is the ability of a metal to resist cutting, penetration or abrasion.

iii) **Malleability:** ability of a metal to be bent, or shaped into different forms by hammering without breaking.

iv) **Brittleness**: This is the tendency of a material to break/ snap/shatter without bending when exposed to stress i.e. cast iron.

v) **Conductivity**: This is the ability of a material to transfer heat or electricity from one point to another that is gold, silver.

vi) **Thermal Expansion**: The property of a metal to expand when heated and contract when cooled.

vii) **Elasticity**: This is the tendency of a material to return to its normal shape after being stretched or bending i.e. Flexibility of spring steel used for construction of the landing gears. A metal elastic limit is a point beyond which a metal does not return to its original shape.

viii) **Toughness:** Ability of a material to resist breaking or tearing when it is bent or stretched or twisted.

ix) **Fusibility (weldability):** This is the ability of a metal to become liquid when is heated and joined with another metal.

x) **Strength**: This is the ability of a material to withstand an applied load without failure.

xi) **Plasticity:** This is the ability of a material to undergo permanent deformation when load is applied i.e. Plasticine.

- **PHYSICAL PROPERTIES**

This refers to metal properties that can be measured or determined. Examples of physical properties include:

i) **Colour**: Hue of an object as perceived by humans that is red, blue among others.

ii) **Density**: This refers to the mass per unit volume of a substance used to compare the weight of metals.

iii) **Texture**: This refers to the smoothness or roughness of a material surface.

iv) **Length**: This refers to the longest dimension of an object.

v) **Melting point**: This refers to the temperature at which a material changes to a liquid.

vi) **Permeability**: This is the ability of a material to support a magnetic field.

vii) **Volume**: This refers to the space that is occupied by a material.

- **CHEMICAL PROPERTIES**

These are properties of metals that can be seen during a chemical reaction with another substance. Examples of chemical properties include;

i) **Flammability:** Ability of a metal to burn or ignite.

ii) **Oxidation:** ability of a metal to react with oxygen to form an oxide.

iii) **Chemical stability:** ability of a metal to resist oxidation.

iv) **Half-life:** the amount of time it will take for half of the original metal to decay.

v) **Toxicity:** ability of a substance to damage an organism.

Ferrous Metals.

Iron and its Production

Iron is the basic material for all ferrous metals. It is produced from iron ore whose major constituents are oxides and carbons.

The ore is usually mixed up with impurities and it is refined through a process called smelting done in a blast furnace.

The production of iron requires four principal materials; iron ore, fuel [coke], a fluxing agent [limestone] and air.

The lump may require crushing to reduce the lump size. The crude iron produced by smelting the ore is called **pig iron**. Pig iron is not directly suitable for engineering purposes hence must be further refined.

Cast iron.

The pig iron produced from the blast furnace has a high composition of carbon, which requires it to be further refined in a different furnace to produce cast iron. Cast iron is placed into two categories;

a) *White cast iron*

This is produced when the cast iron is cooled quickly so that carbon has no time to separate from the iron. This makes the metal hard and brittle. When the metal is cut, it shows a silvery appearance.

b) *Grey cast iron*.

It is produced when the cast iron is cooled very slowly in the mould. This allows carbon to separate from the iron resulting in in a metal that is soft and easy to machine. When cut, it shows a dark grey colour especially where carbon is.

Cast irons have the following general characteristics:

i. Easily machined.
ii. Brittle and easily broken.
iii. Takes well any compression loads but does not take tensile loads.
iv. It is good for casting

In aircraft manufacturing, cast irons are used for making casted parts like crankcases for piston engines,

Wrought iron

Wrought iron is a highly purified pig iron which has very low carbon content in it. When wrought iron is heated to the melting point, it does not liquefy but rather become pasty hence very easy to forge.

It has the following properties:

- It has high tensile strength.
- Malleable and tough.
- It is not good at machining.

- It does not work harden.
- It is easily forged.

Uses

Making iron sheets, bars, rods, pipes, ornamental work, railway couplings, bolts, nails, chain hooks, pipes, marine and architectural constructions.

STEEL

Steel is basically an alloy of iron and carbon. Apart from the carbon other elements are added to steel in small quantities to the metal certain qualities. The various types of steels in existence are classified as;

a) Low Carbon Steel

b) Medium Carbon Steel

c) High Carbon Steel

d) High Speed Steels.

Low Carbon Steels (L.C.S)

The low carbon steels have a carbon content between 0.1% and 0.5% and are commonly known as MILD STEELS .These are also divided in to simply mild steels and dead mild steels. The mild steels are those which have a carbon content of between 0.1% and 0.5%; while dead mild steels has less than 0.1% to 0.15%.

Properties

Mild Steel

- ✓ High tensile strength
- ✓ Easily machined
- ✓ Soft and ductile
- ✓ Cannot be hardened by heating and quenching

Dead Mild

- ✓ High ductility
- ✓ Easily machined but tears off, giving a poor finish
- ✓ Cannot be hardened by heating and quenching.

Uses

Mild Steel

Used in making gears, shafts, bolts and nuts, forgings, bridges etc.

Dead Mild Steel

Used in automobile bodies, buildings, pipes, chains, rivets, screws, nails etc.

Medium Carbon Steel (M.C.S)

The medium carbon steels have a higher carbon content and are stronger than mild steel.

The carbon content of these steels varies from 0.3% to 0.6%.These steels are difficult to bend, weld and cut than mild steels.

Properties

a) Harder, tougher and less ductile than mild steels.
b) Forges easily under heat.
c) Machines to good finish.
d) Hardened by heating and quenching.

Uses

The applications of M.C.S are wide and only a few are mentioned below:

Connecting rods, crankshaft pins, axles, drop forgings, boilers, rails, screw drivers, reamers and sledges.

High Carbon Steel (H.C.S)

High carbon steel contains between 0.6% to 1.5% carbon. It has a wide range of applications in the manufacture of cutting tools, because of its easy response to heat treatment.

Properties

- ✓ Harder, less ductile and slightly less tough than mild steel.
- ✓ Hot forges well.
- ✓ Machines easily.
- ✓ Hardened by heat treatment.

Uses

The uses of H.C.S are very wide and only a few can be mentioned here:

Drop forging, taps, screw drivers, blacksmith hammers, table knives, set screws, centre punch, rivet sets, rock crashers, threading dies, planning tools etc.

High Speed Steel (H.S.S)

High Carbon steel when hardened, is good for producing tools, but progressively softens as the speed of cutting and temperature increase.

These effects softens the tools and render them useless. If materials e.g tungsten, chromium and vanadium are added in small quantities the resulting steel is HIGH SPEED STEEL.

The basic high speed steel has a composition of about 18% tungsten, 4% chromium and 1% vanadium. This metal is fairly expensive because of its constituents and method of production. Another grade of H.S.S is produced by adding cobalt in small percentage to ordinary H.S.S.

This metal hardens well, is tough and resistant to wear.
PROPERTIES

- ✓ Hard and tough.
- ✓ Resistance to wear.
- ✓ Cuts at high speed when tool nose is at dull red heat, without deterioration.

Uses

- It is used mostly for producing tools e.g lathe tools, milling cutters, drills, reamers, cotters etc.
- When elements such as nickel, chromium manganese, molybdenum, tungsten and vanadium are added to steel, they introduce special properties as in the case of H.S.S
- The steel alloy produced by the addition of these elements is tougher, harder and stronger than ordinary steel. Each one of this alloy is examined briefly:

- **NICKEL STEEL**

Nickel steel is resistant to rust and withstands vibrations, shock and wear.

It is used mostly for engine crank shafts, connecting rods, steel rails, automobile and car axles.

- **MANGANESE STEEL**

Manganese is a hard, brittle, greyish white metal .when added to steel it adds strength and toughness to it. Manganese steel remains hard even when heated and cooled slowly. It withstands wear, hammering, straining and shocks. It is used mostly in the production of jaws for rock crashers, chains, gears safes etc.

- **MOLYBDENUM STEEL**

Molybdenum is a silvery white metal which, when added to steel, gives a strength and hardness and cause it to withstand heat and blows.

It is used mostly in the production of high grade machinery, very fine wire of diameter 0.1mm and roller bearings.

- **TUNGSTEN STEEL**

Tungsten is a rare, heavy white metal with a melting point higher than any other .when added to steel, it gives hardness, makes a finer grain and causes it to withstand heat. It is used as an alloying element in tool steel and high speed steels. It is also used in producing cemented-

tungsten carbide, also known as tungsten carbide, which is the hardest metal ever produced by man.Tungsten carbide cutting tools retains their hardness at red heat temperature as high as 900°c without any significant softening. The metal is expensive; hence only a small piece is silver soldered on the tip of a cutting tool. Such tools are known as carbide tools and cuts two to four times faster than H.S.S tools.

- **VANADIUM STEEL**

Vanadium is a silvery grey metal. It is brittle and resistance to corrosion when added to steel, it gives it lightness, toughness, strength and refines its grain. Vanadium steel withstands great shocks; hence it's used in producing springs for automobile axles and gears.

When chromium is added to vanadium steel, the result is chromium vanadium steel which is hard and has a greater tensile strength. It can be bent double while cold and is easy to cut. It is used for automobile parts such as springs, gears, steering knuckles, frames axles and connecting rods.

- **STAINLESS STEEL**

Stainless steel (chromium steel) is an alloy of high carbon steel and chrome.

Chromium steel is a bluish white metal. The chrome content makes it resistant to corrosion. The higher the percentage of chrome, the better the quality.

Properties

- ✓ It is hard and tough.
- ✓ Resistance to corrosion.
- ✓ Resistant to shocks.

Uses

It is used in the production of engine firewall and exhaust components, ball and roller bearings, pots, kitchen sinks, pans, cutlery, dental tools. Sometimes it is brightly polished and used as a mirror.

HEAT TREATMENT OF CARBON STEEL

Heat treatment is the process of heating carbon steels to certain temperature and cooling to give a desired property. This involves heating and cooling a metal according to a time temperature cycle which includes the following:

a) Heating the metal to a desired temperature.
b) Holding the metal at the above mentioned temperature for a period of time. This is referred to as soaking.
c) Cooling the metal at certain rate.

Heat treatment processes include:

a) Hardening
b) Tempering
c) Annealing
d) Normalizing
e) Case hardening

- **HARDENING**

This is the process of treating medium and high carbon steels to withstand abrasion, resist scratching and indentation. It is done by heating the steel slowly to a proper hardening temperature, then cooling rapidly. This rapid cooling is done by quenching in water, brine or oil. The maximum hardness obtained depends on the following:

a) The carbon content on the steel.
b) The speed of heating
c) The temperature at which the steel is quenched(hardening temperature)
d) The speed of cooling.

Tools such as files, drills and taps are examples of steels that have been hardened.

- **TEMPERING**

This is the process of reducing exclusive hardness and brittleness to increase toughness. It is done by reheating slowly the hardened steel to a temperature between 200°c and 300°c. The metal is held at this temperature for a period of time .this allows time for a necessary changes within a grain structure. After the soaking, the metal is allowed to cool in still air.

- **ANNEALING**

This process is carried out on steels in order to:

1) Soften the metal so that it can be easily machined.
2) Relieve the metal of internal stress caused by working the steel.
   It is normally carried out on steels which have been cold worked.
   To relieve the steel of this condition, it is heated in a furnace to above critical temperature, soaked and then cooled very slowly in the furnace.
   This makes the metal very soft and easy to work with.

- **NORMALISING**

  This method relieves the internal stresses caused by forging, welding, machining etc.
  When normalized, steel becomes soft and easy to machine.

Normalizing is quite similar to annealing, the difference being that in annealing a higher degree of softness is attained than in normalizing.

In normalizing, the material is cooled in still air at room temperature.

- **CASE HARDENING**

This is a process through which the skin/outer layer of the steel material is hardened. It is mostly applied to low carbon steels [mild steels]. In this process, the core of the material is left soft while the surface is made very hard. This can be achieved through two processes namely;

a) Carburizing.

b) Nitriding.

In **carburizing**, the material is heated in a carbon rich environment such that it absorbs enough carbon on its surface to harden it completely. This can be achieved through three methods;

i) ***Pack hardening***- material packed in a crucible full of charcoal and placed on a heat source for a duration of time up to 40 hours to allow it to absorb enough carbon to harden the skin.

ii) ***Liquid hardening***- the material is dipped in a carbon rich liquid e.g. barium cyanide and heated in order to absorb enough carbon on its skin in order to harden.

iii) ***Gas carburizing***- the material is packed in a carbon rich gas e.g. carbon II oxide [carbon monoxide] and allowed to absorb and harden.

Nitriding involves heating the material in anhydrous ammonia gas. Ammonia gas is absorb by the outer layer of material and has same effects on steel as carbon.

Non-Ferrous Metals.

These are metals that do not contain iron in them. They include; Aluminium, copper, lead, titanium, gold, tin, zinc etc. Almost all metals find use in the manufacture of aircraft from structural components to decorations.

I) Aluminium.

Aluminium is the most important material when it comes to aircraft manufacture. It is extracted from an ore called bauxite and is silvery white in colour. Aluminium lacks sufficient strength in its pure form. However its strength increases when it is alloyed with other metals. It has a melting temperature of 660˚C.

It has the following characteristics:

- It is soft and very malleable.
- It is very ductile.
- Light in weight and very strong

- Highly corrosion resistant. It form a layer of Aluminium oxide on the surface that protects it from any further reaction with environmental oxygen.
- It has a relatively good electrical conductivity.
- It readily alloys with other metal to form very strong materials.
- Its alloys are heat-treatable.

Uses.

- Used in the construction of the following aircraft parts:
- The skin of the aircraft.
- Piston head.
- Cylinder heads.
- Wheel hub.
- Rivets
- Stringers.
- Bulkheads.

Alloys of Aluminium

An **alloy** is a mixture of two or more metals, and is done to improve the properties of a metal.

Aluminium can be alloyed with copper, magnesium, zinc etc. Aluminium alloys are used extensively in the manufacture of aircraft and its components.

i) Duralumin

This is an alloy of 90% aluminium and 10% copper.

Al clad

Duralumin has a tendency to corrode, this may be prevented by hot rolling 5% thickness of pure aluminium on either side of the duralumin sheet. This is because pure aluminium is more corrosion resistant than it alloys. Therefore Al clad is an aluminium alloy coated with pure aluminium to improve its ability to resist corrosion. Al clad is usually used in aircraft skin.

Observe the following precautions as you handle Al clad Aluminium alloys:

- ✓ It should never be scratched as this removes the protective layer hence exposing the core to corrosion.

- ✓ The sheets should never be stack on top of each other to prevent them from scratching.
- ✓ They are always supplied with a polythene paper lapping and should never be removed unless the material is being used.
- ✓ Scratched materials should never be used in aircraft construction and repair.

Types of aluminium alloys

Aluminium alloys fall into two main groups;

i) **Cast Aluminium Alloys:** these are aluminium alloys that are produced and supplied after casting in a mould, and then machined to required specification. No further working is required except machining. Unfortunately, cast aluminium alloys are very brittle and also their mechanical properties are catastrophically reduced.

Examples of cast aluminium alloy include; **Piston head**, **piston connecting rod**, **engine cylinder head**, **wheel hub** etc.

ii) Wrought Aluminium Alloys: these are aluminium alloys which are produced through rolling, drawing or forging. These alloys are the most commonly used.

Examples of wrought aluminium alloys include; **Tubes, wires**, **sheets, bars** and **extrusions**.

In aircraft construction, wrought aluminium alloy is used in making; **Stringers**, **bulkheads**, **skins**, **longerons**, **ribs** and **rivets**.

II) Copper

Copper in its pure state is not strong enough for engineering application. Because of this, it is mostly alloyed with other metals to make it strong. Copper is reddish in colour and has a melting point of 1032˚C. It has the following properties:

- It is corrosion resistant- it forms a protective layer of copper oxide which prevents any further attack by corrosion elements.
- It can welded, brazed, soldered and tinned.
- It is good thermal and electrical conductor.
- It is very ductile which enables it to be drawn out and worked even when cold.

- It easily alloys with other metals to form superior alloys.

Uses

- Making of terminals and cables in electrical accessories.

Alloys of copper.

i) Brass

This is an alloy of copper and zinc. Brass has better mechanical properties over pure copper.

- ❑ It is easily machined.
- ❑ It is a good electrical and thermal conductor.
- ❑ It is ductile and strong.
- ❑ Corrosion resistant.
- ❑ Casts well

It is rarely used in aircraft but can be used sometimes for **fuel lines** and **oil line fittings**

ii) Bronze.

This is an alloy of copper and tin. It has the following properties:

- ❑ High resistance to corrosion by air, salty water, and chemicals.
- ❑ Strong and ductile.
- ❑ Resistant to shock and fatigue.

Bronze is mostly used in **tube fittings.**

iii) Monel

This is an alloy of copper and nickel.

III) Titanium

Titanium and its alloys are light weight metals with very high strength. Pure titanium is about 50% lighter than stainless steel yet approximately equal in strength to iron. It has a melting point of around 1660°c. Titanium has the following alloys: alpha alloys, alpha-beta alloys and beta alloys.

It has the following properties:

- Very high strength to weight ratio.
- Excellent corrosion resistant characteristics especially to corrosive effects of salt water.
- Excellent forming characteristics.
- Its alloys are heat-treatable.
- Has high heat resistance.
- Low coefficient of expansion.

Uses

a) Manufacture gas turbine engine parts like compressor blades and discs.
b) Fuselage structural members like longerons.

IV) Magnesium.

It is a silvery white metal with a very low density; much less dense than aluminium. It is not strong enough by itself for structural building and hence is usually alloyed.

When burnt, it gives an intense white light. It is highly malleable.

Uses

- Making of aircraft wheels/rims.
- Aircraft skin especially for area that do not experience high temperatures.

V) Lead

It is a bluish grey metal but turns to dull metallic lustre when exposed to atmosphere, the surface becoming dull grey. It is the heaviest of all common metals. It melts at a temperature of 330°c.

It has the following properties:

- Resistant to corrosion.

- Soft and malleable but not ductile.
- Low tensile strength.
- Low melting point.

Uses

Used in manufacture of aircraft batteries i.e. lead acid batteries.

VI) Tin

It is a white silvery metal obtained from an ore called tinstone. Tin can be identified by a unique crinkling sound it produces when bent called tin cry. It melts at a temperature of 232°c. It has the following properties:

- Produces a unique sound called tin cry when bent.
- Highly resistant to oxidation.
- Readily forms alloys. Copper +tin = bronze, tin + lead = solder.
- Good conductor of both heat and electricity.
- It is very malleable.

Uses

i) Production of solder used in joining metals.

ii) Used in the production of bronze alloy.

iii) Used in coating of other metals to inhibit corrosion.

VII) Zinc.

It is a bluish white metal mined from an ore called zinc blende. It has a melting point of 420°C. It is a brittle metal in its pure form but becomes more malleable and ductile with increase in temperature. It has the following properties:

- Relatively malleable and ductile.
- Work hardens as it is hammered.
- Readily forms alloys with other metals; copper + zinc = brass.
- Becomes brittle with temperatures above 200°C.
- Resistant to corrosion.
- Casts well.

Uses

i) Used in the production of brass.

ii) Used in the galvanization of steel and iron.

iii) Electrodes in dry cells.

PLASTICS.

Plastics are used for windshields, windows, landing light covers and interior furnishing of aircraft. They are preferred because of their low cost and ease of maintenance.

Advantages of plastics.

i. They have excellent electrical insulation characteristics.
ii. They come in multiple colours which is homogeneous.
iii. Plastics are light and strong.
iv. They are resistant to chemical attacks.
v. Easily formed into various shapes.
vi. Non-toxic.
vii. They are more resistant to breakage than glass.
viii. They can be transparent thus used in aircraft windshield and cabin windows.

Disadvantages of plastics.

i. They are subject to heat deformation.
ii. Poor mechanical strength.
iii. More susceptible to scratches than glass.
iv. Some types of plastics are attacked by solvents.
v. Difficult to dispose after use.

vi. They form static charges that attract dust and dirt particles.

Plastics can be classified into two main categories:

a. **Thermoplastics**
b. **Thermosetting plastics.**

Thermosetting plastics.

These are plastics that require application of heat to set up properly [harden]. Once hardened, any further increase of heat leads to deformation or structural weakening.

Thermosetting materials include many bonding materials called resins. Examples of thermosetting plastics include: epoxy, melamine, silicone, polyurethane and phenolic [Bakelite].

Thermoplastics.

This is a category of plastics that soften with heat application and harden once the heat is removed. When softened, these materials can be shaped as required and retain their structural strength when cooled. They are also referred to as clear plastics. Thermoplastics are classified as:

- Acrylics.
- Cellulose acetates.

Acrylics verses Acetates.

	Acrylics	**Acetates**
a)	When viewed from the edge, they appear clear or colour of tint if tinted.	They appear yellow when viewed edge on.
b)	It burns with a clear flame and gives off a pleasant fruit like smell.	It burns with a heavy black smoke and a strong pungent smell.
c)	If acrylic material is rubbed with a cloth moistened in acetone, it turns white.	Acetone softens acetate but does not affect its clarity.

d)	Zinc chloride has no effect on acrylic.	Zinc chloride turns acetate milky.

Cleaning of aircraft plastics surfaces.

- The best way to clean plastic surfaces is by flowing fresh water across the surface then using your hand to gently remove any particles adhering to the surface. A mild soap and water can be used in the process.
- Use of clothes when cleaning plastics should be done with care to prevent trapping particles in the cloth which damage the surface as clothe is moved around.
- Plastics should not be rubbed with a dry cloth since this is likely to scratch the surface and can cause the buildup of static charges.
- Machines should not be used when polishing as their high speed of operation may heat the plastic and cause distortion.
- Solvents such as thinners, benzene, and acetone should never be used on plastics because they can penetrate the surface and cause crazing.

Crazing is the formation of a network of fine cracks in the surface of the material which destroys clarity of vision and structural strength.

COMPOSITE MATERIALS.

- Composite structures are those aircraft structural and non-structural components that are assembled from metals and fibers and are joined by use of adhesives.
- Composite structures have found uses in all segments of aircraft design from fuselages, propellers and helicopter blades, and flight control surfaces.
- Composite materials have the following **advantages**:

a. High strength to weight ratio compared to sheet metals and steel structures.
b. They have low sensitivity to sonic vibrations i.e. they absorb them well.

c. They have reduced assembly costs because of reduction in number of fasteners required.
d. They have a very smooth surface reducing aircraft drag.
e. They are highly resistant to corrosion.
f. They have a high design flexibility thus can be made into various shapes.
g. They have high impact and tensile strength.

Composite materials have the following **disadvantages**:

a. More expensive to repair than metals.
b. They do not break easily i.e. they do not disintegrate and hence dangerous to the environment.
c. When burnt they release toxic fumes and micro-particles in the air both of which are health hazards.

Composite materials include; **fiberglass, Kevlar, carbon fibers, boron** etc.

Composites safety.

When working with any composite materials, proper safety precautions must be observed to prevent long term personal injury and damage by fire.

Many composites are made of very fine fibers which may be brittle and rigid enough to penetrate unprotected skin. Once in the skin, they are very difficult to remove and may cause toxic reactions and infections.

For these reasons, the following safety precautions should be well observed while handling them:

1. When sanding composites, wear appropriate respiratory filter to prevent breathing the dust.
2. Eye protection in the form of goggles or face shield should be worn to keep dust from eyes.
3. Long sleeve shirts and laboratory type coats should be worn to protect the hands.
4. After a day's work, take a shower to flush particles from the skin and hair.
5. You should work in well-ventilated areas and always have the appropriate type of fire extinguisher at hand.

TOPIC 7

AIRCRAFT RELATED DRAWING 1.

Introduction.

Technical drawing is a universal graphic language used in the technical world. The language is used by designers, manufacturers and users of industrial goods.

When an aircraft is conceived in the minds of engineers and designers, it is nothing but an idea until put on paper. After a drawing is made, others can add their expertise and ideas. When an aircraft is designed, detailed drawings of every single part are made. Once the drawings are made, they are sent to the reproduction department. Here, copies are printed by a process called blueprinting, where the black lines are printed as blue lines on paper. Every aircraft drawing is numbered so that a careful record is maintained. This way, if any changes are required, the information is passed onto affected personnel who incorporate the changes into the parts as they are built.

Why learn technical drawing?

1. Technical drawing is a universal language. Many people can understand drawing and other forms of graphics more easily and quickly than they can understand words.
2. Technical drawing are the means by which those working in industries such as mechanical engineering, building, architecture or electrical engineering communicate their ideas of the shape, form and dimensions of the articles being made.
3. Technical drawing encourages tidy and accurate methods of presenting those ideas in the form of drawing.
4. A knowledge of technical drawing allows you to think in three-dimensions – height, width and depth of objects being drawn.
5. Technical drawing is a basis for vocational training. A good knowledge will help if you wish to be employed in industries such as engineering and building.
6. Technical drawing is important as a design tool for communicating ideas between people working on any project in companies, industries, in the media etc.

Technical Drawing Instruments

The following minimum set of instruments are required in order to construct good quality technical drawing:

- **Drawing board** – most often made from wood, often from 12mm thick plywood. Sizes vary, but for school and college work one measuring 650mm by 470mm is suitable for working with A2 size (or smaller) papers. The surfaces of all drawing boards should be cleaned at regular intervals by wiping with paper or cloth to ensure the surfaces are flat smooth and clean.
- **Drawing paper** – drawing papers to be used for technical drawing in schools and colleges vary in size. The most commonly used are A2, A3 and A4 sheets. The drawing

papers can be fixed to the drawing board with pieces of sticky tape – masking tape is the best as well as being the cheapest.

- **Tee square** – usually made from hardwood. It is used to make horizontal and vertical lines on the drawing sheet. The blade length should be long enough for the board. Tee squares must be kept clean, wiped regularly with paper or cloth and occasionally plane the drawing edge to keep it straight.
- **Set squares –** two are necessary, unless you have an adjustable square. A 60, 30 and a 45, 45 are needed.
- **Protractor –** for constructing angles which are not set square angles. A plastic protractor, measuring up to 180 degrees is suitable.
- **Compasses and dividers –** a good quality pair of compasses which can draw circles up to 150mm radius is an essential item of equipment. Although not absolutely essential, a pair of dividers can prove to be of use at times, e.g. when measuring from another drawing to determine an unknown dimension.
- **Erasers –** essential for correcting mistakes. Vinyl erasers are preferable to rubber erasers.
- **Pencils –** can be purchased in nine grades of hardness – from H to 9H – and six grades of blackness – from B to 6B. There are also two other grades – F and HB. Two pencils are advisable – a 2H or 3H for drawing with instruments and an HB for freehand drawing such as lettering.

Drawing sheet layouts

Two typical drawing sheet layout are used in school or college when working on A2, A3 or A4. This include the upright position, which is known as 'portrait', and the horizontal position, known as 'landscape'. In a drawing sheet layout, note the following:

- **Border** or **Margin lines**: these surrounds the drawing. For an A4 size sheet, these should be set in 10 mm; for an A3 sheet, 15 mm and for A2, 20 mm. The idea of a margin is so that the outer edges of the drawing area are protected if the sheet edges become damaged – at least the drawing area may not be affected.
- **Title block area:** in the portrait layout a double rectangle title block is used, while in the landscape layout, a single rectangular title block is used. In the title block, the details are shown and include the following:
    - ✓ Your name.
    - ✓ Your class, form or Adm. No.
    - ✓ The title of the article being drawn.
    - ✓ Name of school, college or organization.
    - ✓ The scale of the drawing.
    - ✓ The date of drawing.

- **Height of lettering:** in title blocks, features such as names, article titles, etc. are usually printed in capital letters. Their height will vary according to the size of the drawing sheet in use. Suggested heights are 6 mm for A4 sheets, 8 mm for A3 sheets and 10 mm for A2 sheets.

Types of Drawing lines and Symbols

Types of Lines

1. **Thin continuous line**

- Used for construction purposes.

2. **Thick, black continuous line**

- Used for visible outlines and border lines.

3. **Center line**

- Used to show the center of cylindrical objects and circles in drawings.

4. **Dashed line**

- Used to show hidden details in articles drawn.

5. **Phantom line**

- Used to show the movement or travel of an object or a part in alternate positions.

6. **Cutting plane line**

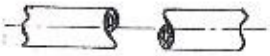
- Used to show the point of bisection on a component in order to provide a view of its interior features.

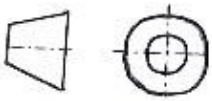
Drawing symbols for Mechanical and Electrical Drawing

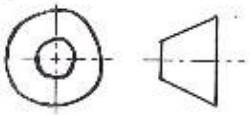
1. Long break line 

2. Short break line 

3. Solid rod/ shaft 

4. Hollow tube 

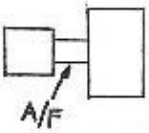
5. First angle projection 

6. Third angle projection 

7. Counter bore 

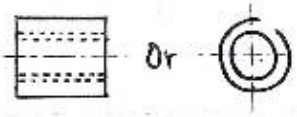
8. Countersunk 

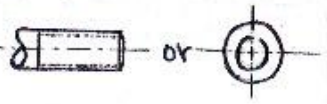
9. Machined surface 

10. Across flat 

11. Depth 

12. Spring 

13. Internal threads 

14. External threads 

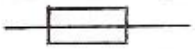
15. Ohmmeter 

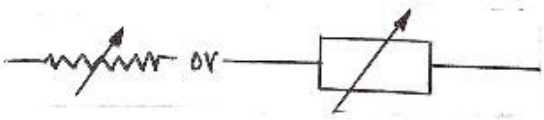
16. Voltmeter 

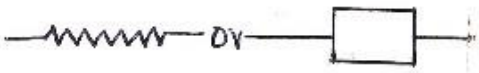
17. Transformer 

18. Motor 

19. Generator 

20. Fuse 

21. Fixed resistor 

22. Variable resistor 

23. Transistor 

24. Battery 

25. Cell 

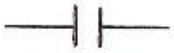
26. Earthing 

27. Diode 

28. Switch 

29. Ammeter 

30. Bulb 

31. Capacitor 

32. Galvanometer 

BASIC PLANE GEOMETRY

For a student to be expert in technical drawing, he or she must have a good knowledge of basic geometry. There are two forms of geometry that a student need to understand:

- **Plane geometry** – this deals with the geometry of flat surfaces (planes). Plane geometry is two dimensional (2-D) because it only deals in height and width.

- **Solid geometry** – this deals with the geometry of three dimensions (3-D) – solids in three planes – height, width and depth.

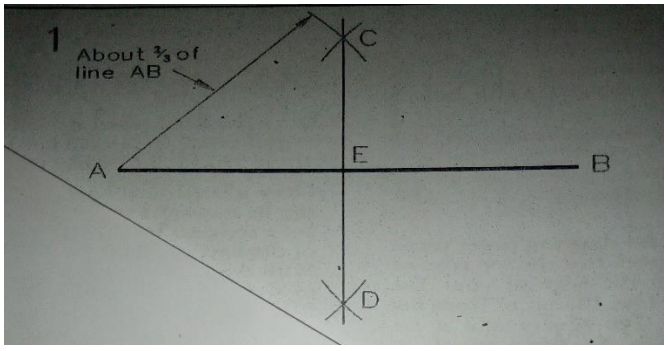
Drawing lines

Clip or tape a piece of A4 drawing paper on to your drawing board. Check that the top edge of the paper lines up with the edge of your Tee square. Draw a border line 10 mm in from the paper edges with the Tee square and a set square. Where the words 'A4 paper' appear in the figure below, draw in your name

Bisecting lines

A line is bisected when it is divided exactly into two equal parts. To bisect a line follow the example shown in Drawing 1 in the figure below.

1. Draw a horizontal line 105 mm long. Its length can be measured with your ruler.
2. Set a compass to about two-thirds of the length of the line.
3. With the compass centred at A draw two pairs of arcs, above the line, and below the line.
4. Without altering the compass draw another pair of arcs crossing the first pair with the compass centred at B.
5. C and D are the intersections of the arcs.
6. Draw a line from C to D with either the edge of a set square or with a ruler. When you have completed the bisection note: E is the centre of AB. E is the bisection point of the line. AE=EB



Practice exercises

1. With a set square, draw a vertical line 80 mm long and bisect it using the same method as the line of Drawing 1 was bisected.
2. With a 45, 45 set square draw a sloping line 95 mm long. Bisect the line you have just drawn.
3. With a 60, 30 set square, draw a sloping line 115 mm long and bisect it.

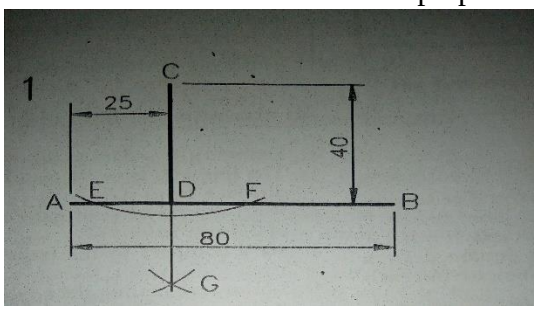
Perpendicular to lines

Two lines are perpendicular to each other if they are at a right angle (90 degrees) with each other.

To draw a line perpendicular to a line from a point on the line

Drawing 1

1. Draw the line AB 80mm long. Mark the point C 40mm above the line and 25mm from the left hand end.
2. Set a compass, centred at C, to a suitable size so as to draw an arc which cuts the line AB at E and F.
3. Re-set the compass and with the compass centred at E then at F draw the crossing arcs G.
4. Draw a line CG. The line CD is perpendicular to AB.



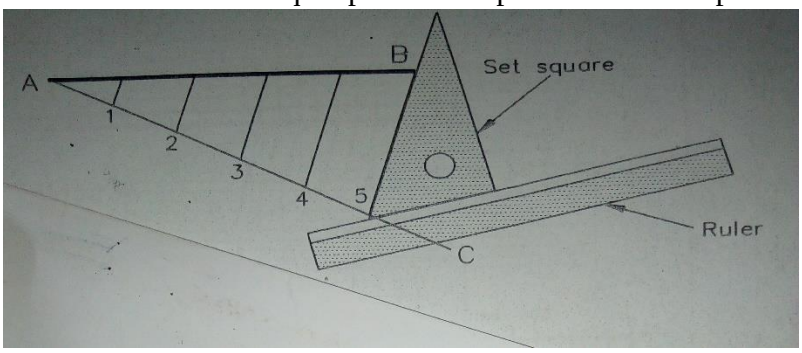
Dividing a Line into parts

The method shown can be used either for dividing a line into parts of equal lengths or into lines which are proportional in length to each other.

Dividing a line into parts of equal length

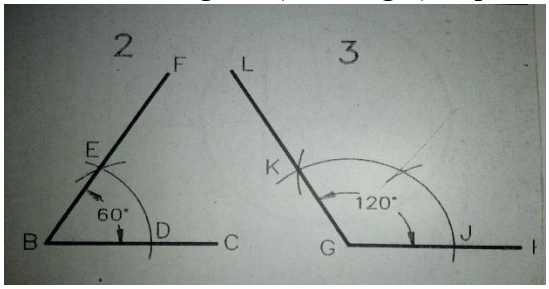
1. Drawing 1 - Draw line AB 93mm long with a Tee square.
2. Draw line AC from A at any angle to AB. The angle should be similar to that shown in Figure 2.5
3. Set a compass to about 20mm and with it, step off five equal spaces along line AC – giving the points 1 to 5.
4. Set up a ruler with a set square along its edge, so that one edge of the set square is along the line B5.
5. Hold the ruler firmly on to the paper, slide the set square along the ruler until its edge is at point 4 on line AC. Draw a line to touch the line AB. This line is parallel to line B5

6. Draw other parallels in the same way through points 1, 2 and 3 on AC.
7. AB is divided into 5 equal parts at the points where the parallel lines touch AB.



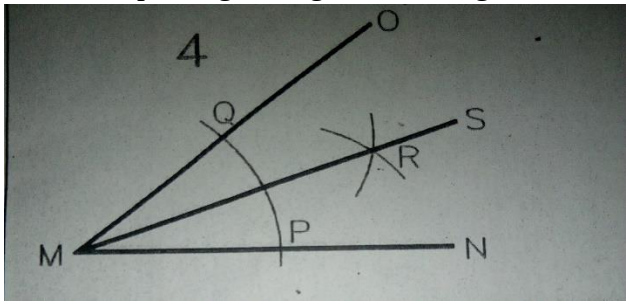
Constructing angles of 60 and 120 degrees

1. Drawing 2- Figure 2.10. Draw a line BC 50mm long.
2. Set a compass to about 30mm and with centre B draw an arc crossing BC at D.
3. Without altering the compass and centred at D draw an arc crossing the first arc at E.
4. Draw BF through the intersection of the two arcs.
5. The angle CBF is 60 degrees.
6. HGL of 120 degrees (Drawing 3) step off the radius twice along the arc from J.



To Bi-sect an angle

1. Drawing 4- Figure 2.10. Draw any angle. Draw any arc PQ. Set compass to a sensible size and with the compass centred first at M then at Q draw crossing arcs at R.
2. Draw MS passing through R. The angles NMS and SMO are equal.



TRIANGLES

Triangles have three sides and three angles. The sum (adding together) of the three angles always gives 180 degrees.

Types of triangle

There are four types of triangle as shown below:

1. **Equilateral** - all sides are of equal length. All angles are of equal size=60 degrees.
2. **Isosceles** -Two angles are of equal size. Two sides are of equal length
3. **Right angle**- One angle is a right angle =90 degrees
4. **Scalene**- All sides are of different lengths. All angles are of different sizes.
   All angles are of different sizes
   Two main types of scalene triangle:
   Acute -All angles are acute=less than 90 degrees
   Obtuse- One of the three angles is obtuse=between 90 and 180 degrees.

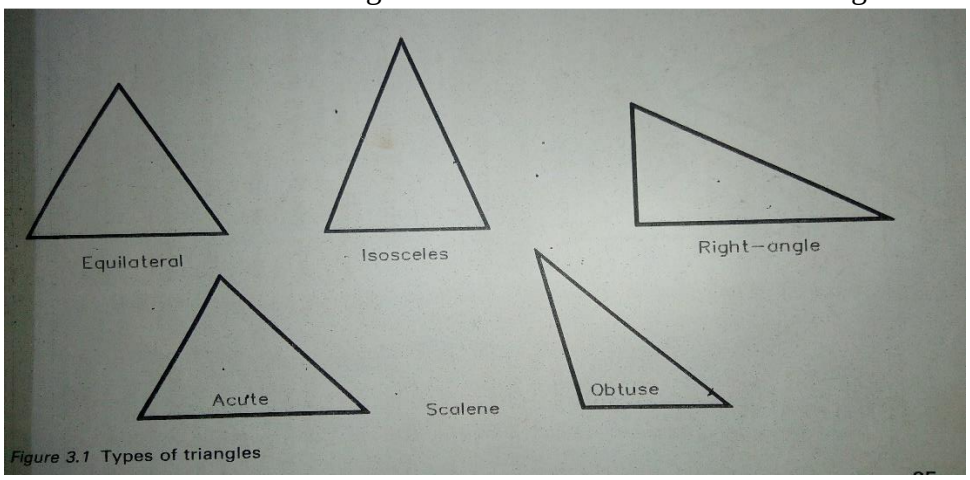


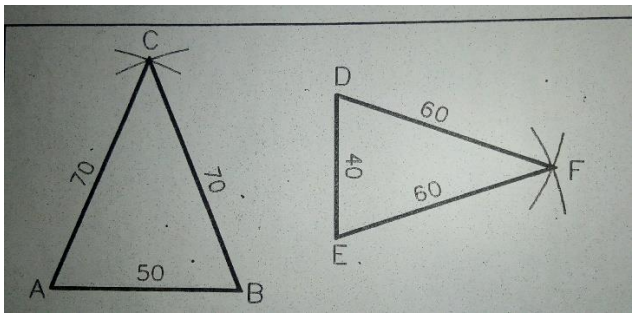
Figure 3.1 Types of triangles

To construct triangle ABC

1. Draw the base AB, 50mm long. Set a compass to 70mm.
2. With the compass centred first at A, then at B strike intersecting arcs to give C.
3. Join AC and BC to complete the triangle.

To construct triangle DEF

1. Draw DE. Set a compass to 60mm.
2. With the compass centred first at D, then at E strike intersecting arcs to obtain F.
3. Join DF and EF to complete the triangle.



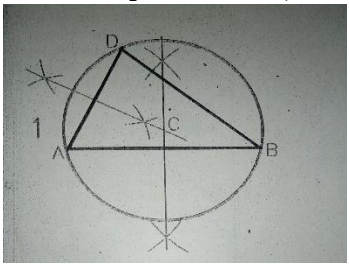
Nb/ Triangles ABC and DEF are isosceles triangles.

Triangles and Circles

A circle circumscribing a triangle

Drawing 1-Figure 3.7

1. Constructing the triangle ABD in which:
   AB=70mm; BD=65mm; AD=45mm.
2. Bisect AB and AD. The bisection lines cross at C.
3. C is the centre of a circle circumscribing ABD.
4. Set a compass to CA (or CB, or CD) and draw the circumscribing circle centred at C.



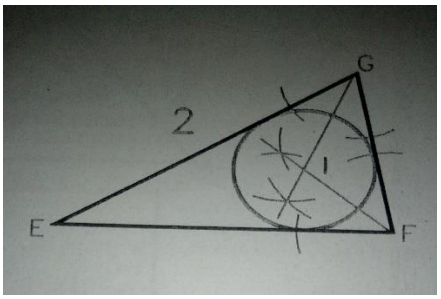
Nb/ A circle circumscribes a triangle if its circumference touches the vertices of the triangle.

When finding the centre C of a circle circumscribing a triangle, the most accurate results will be achieved if the sides of the triangle nearest to a right angle are bisected.

A circle inscribing a triangle

Drawing 2-Figure3.7

1. Construct the triangle EFG in which:
   EF=90mm; FG=50mm; EG=95mm.
2. Bisect the angles EFG and FGE to give I.
3. I is the centre of the circle inscribing triangle EFG.
4. Set a compass to a radius of the perpendicular distance I to any side of the triangle and with centre I draw the inscribing circle.



Nb/ A circle inscribes a triangle if its circumference touches (is tangential to) each side of the triangle.

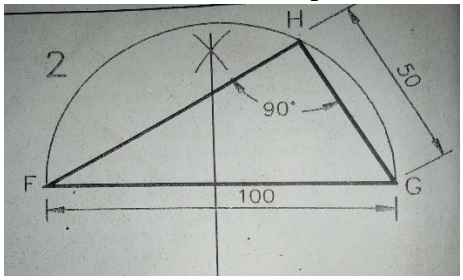
As with the construction of the circumscribing circle, the most accurate results are obtained if the bisections are made of the two angles of the triangle which are most near to being right-angles

Right–angle triangles

Constructing the triangle

Drawing 2

1. Draw the base FG 100mm long.
2. Bisect the base FG.
3. At the bisection point of FG, draw a semi-circle of radius equal to half FG.
4. With a compass set to 50mm, and centred at G strike an arc across the semi-circle to give H.
5. Join GH and FH to complete the triangle.



Practice exercise

Drawing 3

1. Construct triangle HJK in which:
   HJ = 70mm; JK=65mm; HK=115mm.
2. Bisect the sides HJ and JK and draw the circumscribed circle to HJK.

Drawing 4

1. Construct the triangle LMN in which:
   LM= 70mm; MN= LN=80mm.
2. Bisect the angles MLN and LMN and draw the inscribed circle to LMN.

TYPES OF QUADRILATERAL

Quadrilaterals are polygons which have four sides and four angles. Quadrilaterals may be irregular or regular. A polygon is regular if all its sides are of equal length and all its angles are of equal size.

Polygons with more than four sides

In irregular polygons sides are of different lengths and angles are of differing sizes. In regular polygons all sides are of equal length and all angles of equal size.

Regular Pentagon – has 5 sides and 5 angles;

All its sides are of equal length

All its angles are of equal size, each being 108 degrees.

Regular Hexagon- has 6 sides and 6 angles

All its sides are of equal length

All its angles are of equal size; each being 120 degrees.

Regular hexagons are frequently used in technical drawings.

Regular Heptagon- has 7 sides and 7 angles

All its sides are of equal length

All its angles are of equal size.

Regular Octagon- has 8 sides and 8 angles

All its sides are of equal length

All its angles are of equal size, each being 135 degrees.

Regular Nonagon- has 9 sides and 9 angles

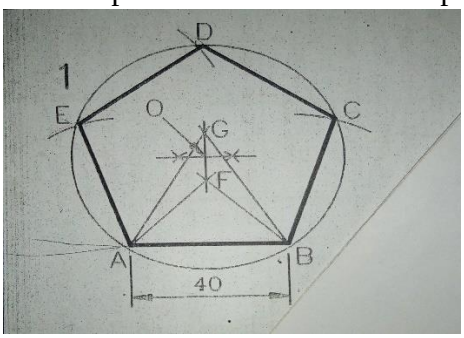
All its sides are of equal length

All its angles are of equal size.

To construct a regular Pentagon

1. Drawing 1 – Figure 3.13. Draw the base 40mm long.
2. At A and at B, draw lines at 45 degrees and at 60 degrees to intersect at F and G.
3. Bisect FG to obtain O. O is the centre of a circle which will circumscribe the completed pentagon.
4. With a compass set to OA (or OB) and centred at O draw a circle.
5. Set a compass to the side length of 40mm from A and then from B, strike arcs across the circle to give the points E and C.

6. Without altering the compass setting, strike an arc from E across the circle to give D.
7. Join the points so obtained to complete the regular pentagon.

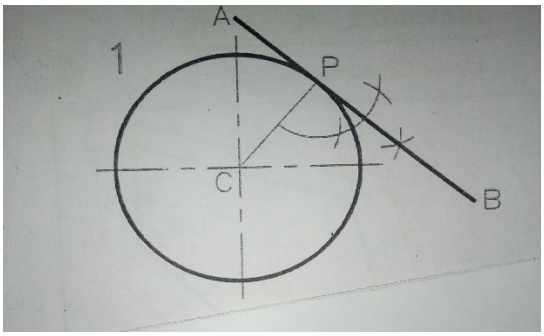


Line Tangent to circles

Line tangential to a circle at a point on its circumference

1. **Drawing 1**- Draw circle, centre C of radius 30mm. Mark any point P on its circumference.
2. Draw the radius CP.
3. At P construct a right angle to CP.
4. The line AB, at right angles to CP, is tangential to the circle.

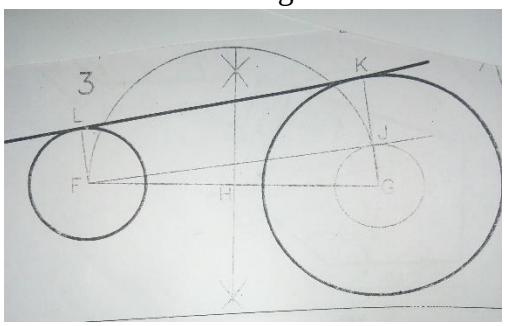
NB/ If a line touching a circle at a point, forms a right angle with a radius of the circle at the point, then the line is tangential to the circle.



External line tangent between two circles of unequal diameter.

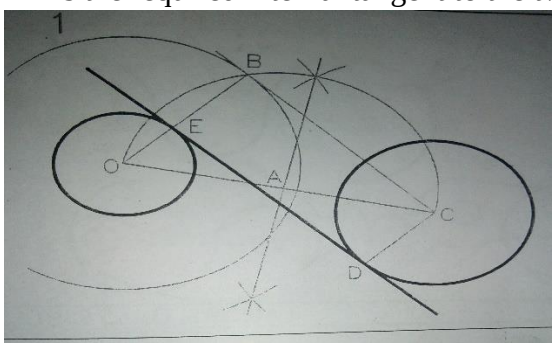
1. **Drawing 3**-.Draw two circles with their centre 100mm apart. Circle centre F of radius 20mm, circle centre G of radius 40mm.
2. With centre G draw a circle of radius = radius of circle G – radius of circle F. GJ=GK-FL.
3. Join FG, bisect FG and draw the semi-circle on FG to cross the circle just drawn at J.
4. Draw the tangent FJ(right angle in a semicircle)
5. Join GJ and extend to K.
6. Draw FL parallel to GK.
7. Join LK. LK is tangential to both circles.

NB/ The angle OTD must be a right angle. It is the angle in a semicircle. Therefore the line DTE must be tangential to the circle O.



Internal tangent to two circles

1. **Drawing 1-** Draw two circles. Circle centre O of 40 mm diameter, circle centre C of 60mm diameter. OC is 90 mm.
2. Join OC and bisect to give its mid-point A.
3. Draw a semi-circle with centre A on OC.
4. With centre O draw a circle of radius of the radius of circle O plus the radius of circle C. Thus OE+ CD= OB. B is the point where the circle intersects the semi-circle on A.
5. Join CB- the tangent from C to the circle OB (right angle in a semi-circle).
6. Join OB. Draw CD parallel to OB to cut the circle centre C at D.
7. ED is the required internal tangent to the two circles.



Types of Aircraft Related Drawings.

As an aviation technology student, there are several types of drawing and graphic representations you must become familiar with. Each type of drawing is designed to transmit a certain piece of information.

There are many types of technical drawings that include:

a) Detail drawings.
b) Assembly drawings.
c) Installation drawings.
d) Sectional drawings.

e) Exploded view drawings.
f) Block diagrams.
g) Logic flow charts.
h) Electrical wiring diagrams.
i) Pictorial diagrams.
j) Schematic diagrams.
k) Orthographic projection.
l) Isometric drawing.
m) Oblique drawing.
n) Perspective drawing.

a) Detail drawing.

This type of drawing supplies all the information required to construct a part, including all dimensions, materials and type of finish.

b) Assembly drawing.

This type of drawing depicts the relationship between two or more parts. This drawing reference individual parts by their part number and specify the type and number of fasteners needed to join them. After individual parts are fabricated, they are assembled into various sub-assemblies with the aid of an assembly drawing.

c) Installation drawings.

This type of drawing shows the general arrangement or position of parts with respect to an aircraft and provides the information needed to install them. Like the assembly drawing, an installation drawing lists the fasteners needed as well as any instructions required for the installation.

d) Sectional drawings.

This type of drawing is used when it is necessary to show the internal construction or shape of a part. To do this, the object is cut by a cutting plane line and a section is removed to illustrate this.

e) Exploded-view drawing.

In this type of drawing, all parts in an assembly are expanded outward from their relative positions, to show every part of the assembly. Each part is identified by both its physical appearance and its reference number which is used on the parts list.

f) Block diagrams.

This type of drawing consists of individual blocks that represent several components such as printed circuit board or some other type of replaceable module. Since most of the maintenance

needed on complex systems consist of identifying a malfunctioning sub-assembly and replacing it, block diagram greatly enhance this process.

g) Logic flow chart.

It represents the mechanical, electrical, or electronic action of a system without expressing construction or engineering information. By using the information in a flow chart, troubleshooting time is reduced to a minimum.

h) Electrical wiring diagrams.

Electrical wiring diagrams are included in most aircraft in most aircraft service manuals and specify things like the size of wire and types of terminals to be used for a particular application. Wiring diagrams identify each component within a system by its part number and its serial number. Because of this, wiring diagrams are extremely valuable for troubleshooting.

i) Pictorial.

In a pictorial diagram, pictures of components are used instead of the conventional are used instead of symbols used in schematic diagrams. Pictorial diagrams help a person to visualize the operation of specific systems.

j) Schematic Diagrams.

They are used to illustrate principle of operation and therefore does not show parts as they actually appear or function. Schematic diagrams indicate the location of components with respect to each other and in the fluid systems, it also shows the direction of flow.

Methods of Illustration

The method of illustrating a part refer to its orientation with the respect to how it is viewed on a flat plane. The orthographic projection, isometric, oblique, auxiliary and perspective are all methods of illustration.

Orthographic projection.

Most drawings used in the construction of a detailed part are drawn using the orthographic projection method of illustration. In orthographic projection, there are six possible views from which an object can be drawn; the front, rear, top, bottom, left side and right side. Each view is drawn as if you put an object in a transparent box and viewed it from one of the box faces.

Isometric drawing.

It is a projection of a three dimensional object on a flat plane. With this type of drawing, an object is rotated so that three sides are visible and touching the drawing plane. When doing this, you must ensure that the edges all form the same angle (30°) to the drawing plane.

Oblique drawing

An oblique drawing is an isometric drawing with one objects face parallel to the drawing plane. In other words, two axes are perpendicular to each other, with the front of the object identical to the front view of an orthographic drawing. The depth axes of the oblique drawing is typically any convenient angle and most often 45°. There are two special types of oblique drawings. They are; the **cabinet** drawing and the **cavalier**. In cabinet drawing, the oblique side is at 45^0 angle to the front side and is a half the scale. This allows for an accurate and undistorted front view. The remainder of the drawing is present only to illustrate depth. In cavalier drawing, the same scale is used for the front view as the oblique sidelines. However, the oblique sides are still set at a 45^0 angle to the front view. This creates a distorted picture of an object's true proportion, and are primarily used when detailing is required on the oblique side.