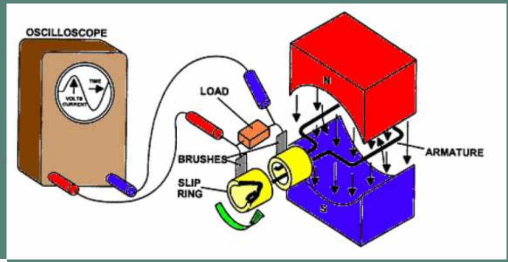
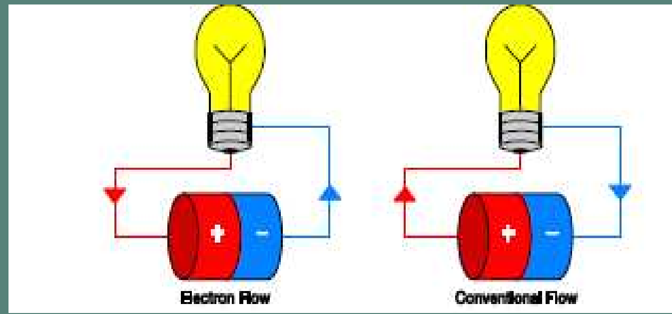
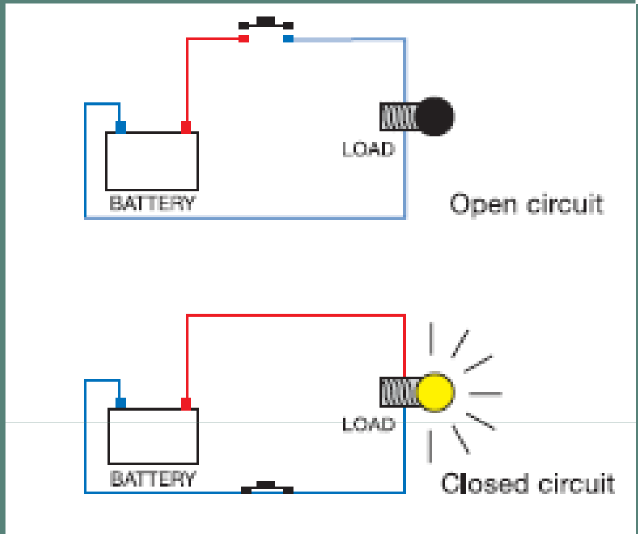
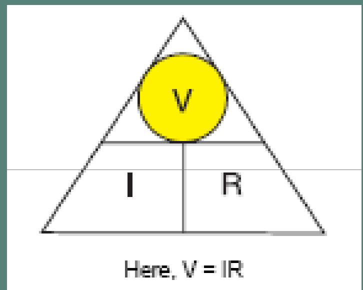
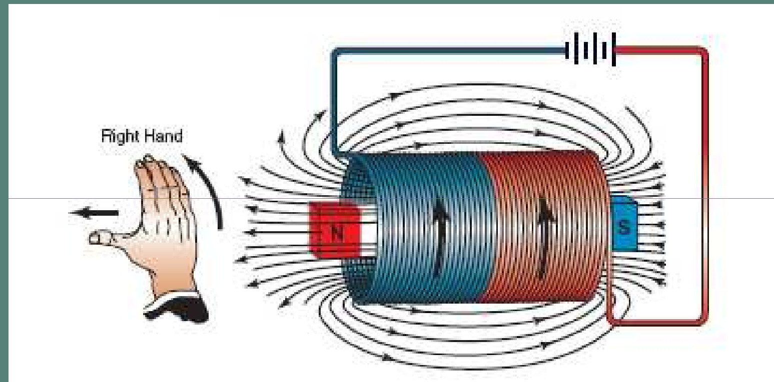
ELECTRICS

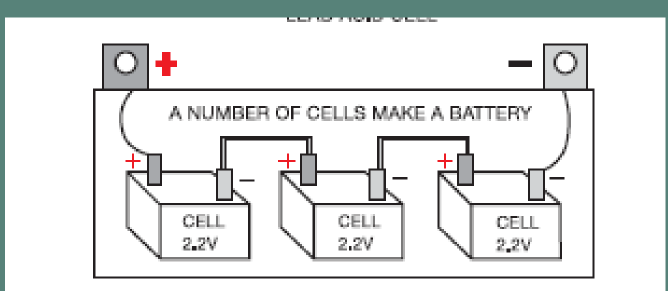

OSCILLOSCOPE
LOAD
BRUSHES
SLIP RING
ARMATURE

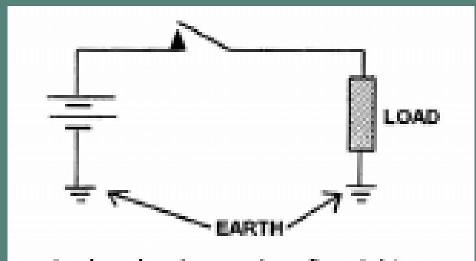

Electron Flow
Conventional Flow

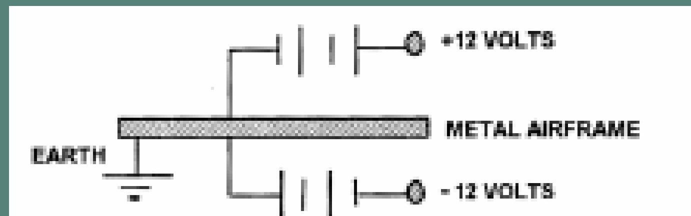

BATTERY
LOAD
Open circuit
BATTERY
LOAD
Closed circuit


V
I
R
Here, V = IR


Right Hand
N
S


A NUMBER OF CELLS MAKE A BATTERY
CELL 2.2V
CELL 2.2V
CELL 2.2V


LOAD
EARTH


+12 VOLTS
METAL AIRFRAME
EARTH
- 12 VOLTS

CURRENT (I); [A] ampers

- Electric current **(I)** is the flow of electrons in a conductor, but there must be a means to measure this flow.
- Therefore, 1 Coulomb passing a given point in 1 second equals 1 ampere, often abbreviated to as amp. [A]
- Amperes = Coulombs **/** Seconds, A= C/s
- Current in a circuit is measured by connecting an **ammeter in line, or in series, with the load**

$$\text{Amperes} = \frac{\text{Coulombs}}{\text{Seconds}}$$

VOLTAGE, ELECTROMOTIVE FORCE (EMF), [volt] [V]

- **VOLTAGE (V)** The **volt is the basic unit of electrical pressure.**
- **ELECTROMOTIVE FORCE (EMF)** is the force or pressure that sets electrons in motion, **EMF is measured as** voltage [v].
- EMF or voltage is necessary to create electric current. Power source have two poles: plus pole and minus pole.
- Voltage V = Work W / Charge Q

RESISTANCE (R) [ohms]

- The unit is the Ohm. **1 [Ohm]** exists when it restricts the current flow to **1 [amp]** when a pressure of **1 [volt]** is applied.
- Resistance opposes current flow and in doing so dissipates the voltage across it, which is why it is said that voltage is dropped across a load.
- Metals such as silver and copper have virtually no resistance and are used to conduct electricity.
- Rubber has a very high resistance and is a non-conductor used for insulation between conductive materials.
- Cables and wires are comprised of both materials: the metal conductor permits the flow of current along a given path, and the insulation covering it stops the voltage from forcing current out into other paths causing short circuits.

RESISTANCE (R) [ohms]

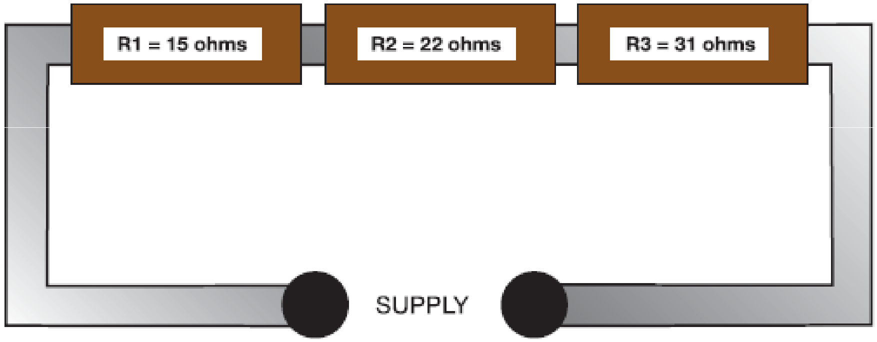
- The resistance of a material at a constant temperature is affected by its:

$$R = \frac{\rho \times L}{A}$$

- Specific Resistance **(ρ)**, the resistance offered by a cube of material at 0°C; Length **(L);** Cross Sectional area **(A).**
- The resistance of most materials increases with increasing temperature, and these materials have a **Positive Temperature Coefficient (PTC).**
- A few materials (semi-conductors), exhibit a decreasing resistance with increasing temperature, and these have a Negative Temperature Coefficient (NTC).

CONNECTING RESISTANCES IN SERIES IN A DC CIRCUIT

- When resistors are connected in series, the same current flows through each of them, and the total opposition to current flow is equal to the sum of the individual resistances.



- Total Resistance (RT) = R1 + R2 + R3

$$= 15 + 22 + 31 = 68\ \Omega$$

CONNECTING RESISTANCES IN parallel IN A DC CIRCUIT

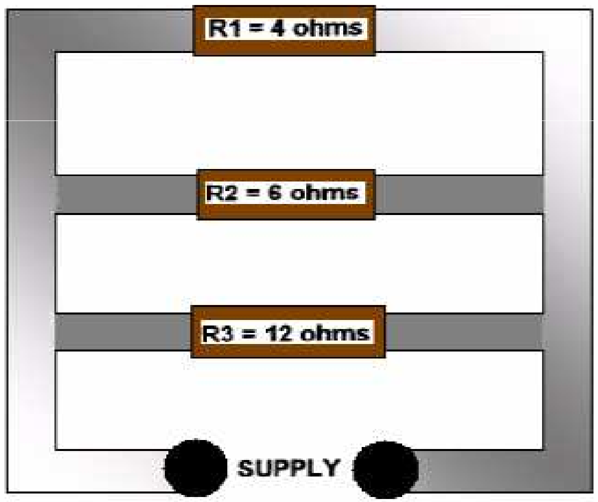
- If the resistances connect in parallel with each other, the current flows along two or more paths.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12} = \frac{6}{12}$$

$$R_T = \frac{12}{6} = 2 \text{ ohms}$$

- Parallel connection

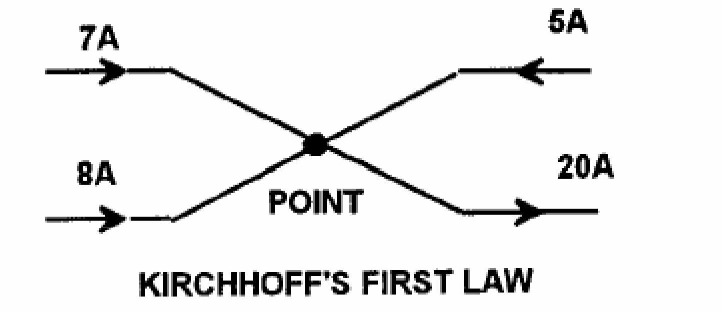


OHM'S LAW

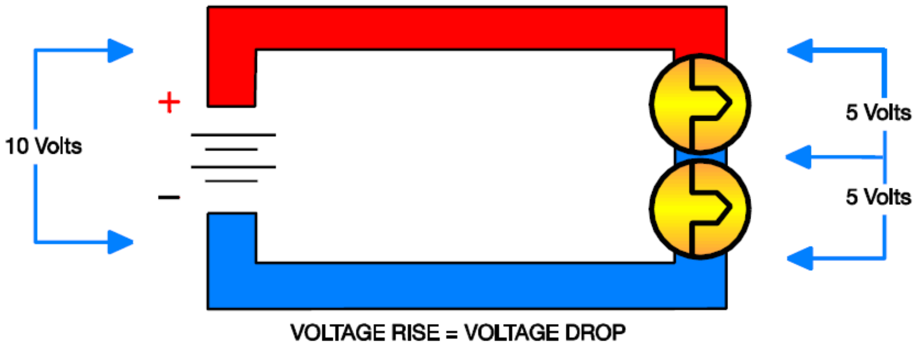
- Ohm's law states that the current I flowing in a circuit is directly proportional to the applied voltage V, and inversely proportional to the resistance R through which the current flows.
- Ohm's law by formulae:
  - $V = RI$;
  - $R = V/I$;
  - $I = V/R$;

KIRCHHOFF'S LAWS

- The first law states that the sum of the currents entering a junction must equal the sum of the currents leaving the junction.



- The second law states that in a closed circuit, the sum of the voltage drop always equals the supply voltage.



Power P [Watt] and Work [joule]

- Power P is measured in Watts and is calculated using the following formula:

$$P = VI$$

$$1[Watt] = 1[Volt] x 1[Amper]$$

- Work W is measured in joule [J] and is calculated using the following formula:

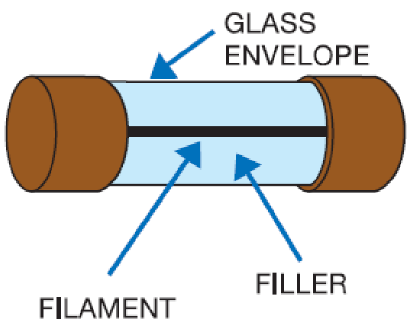
$$W = Pt$$

$$1[joule] = 1[watt] x 1[second]$$

NB! Non confondere i simboli di Work W con unità di misura [W] watt

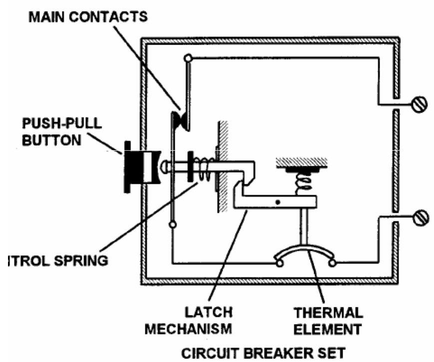
PROTECTION DEVICES

- **Fuse** This protection device opens or breaks the electrical circuit when excessive current flows. A fuse is designed to form a weak link in an electrical circuit **to protect** the majority of the cable between the supply and the load against overheating and burnout.



PROTECTION DEVICES

- **Circuit breaker** This device has the same function as a fuse but can be used to restore a circuit when it is reset. Modern designs are known as **trip free and cannot be** held in against a fault condition.



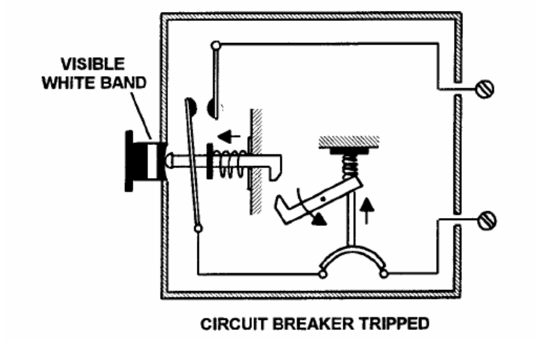
- **If a circuit breaker trips:**

➢ Switch the circuit off.

➢ Allow a period of approximately 20-30 seconds to allow the bi-metallic element to cool.

➢ Reset the circuit breaker.

➢ Switch the circuit on.

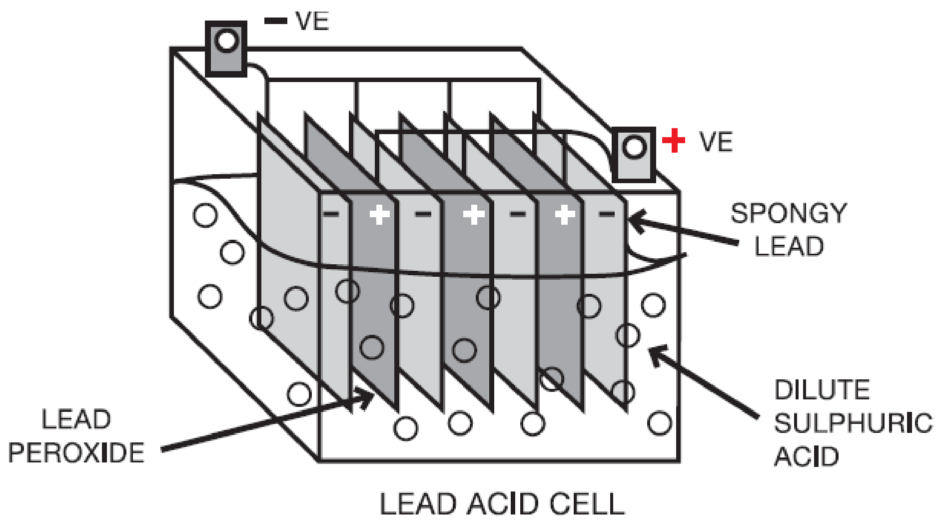


PROTECTION DEVICES

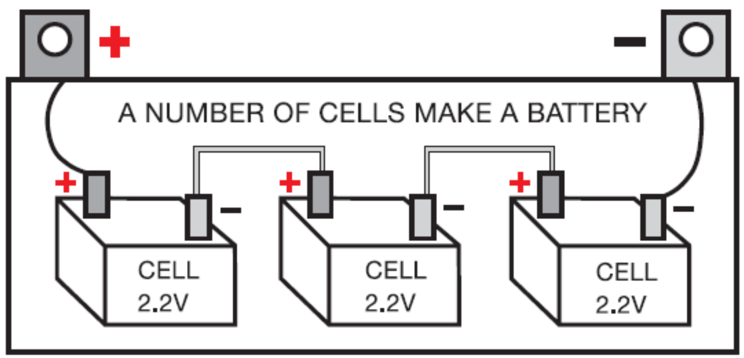
- **Time switches** are used to perform timing functions. They can be operated by a clockwork mechanism, electric motors or electronically.
- **Thermal switches. Such switches are employed where temperature** must be measured or sensed. Most switches in common use are either electronic or are based upon the bending properties of a bi-metallic strip
- Bi-metallic switches are also thermal switches, but specifically use the principle of a bi-metallic strip.
- **Proximity switches**. They are either magnetically or electronically operated when a steel or ferrous metal is brought into close proximity to the sensing element.

BATTERIES

- **LEAD ACID BATTERY** Each cell of a lead acid battery consists of positive plates of lead peroxide and Negative plates of spongy lead, as shown below.

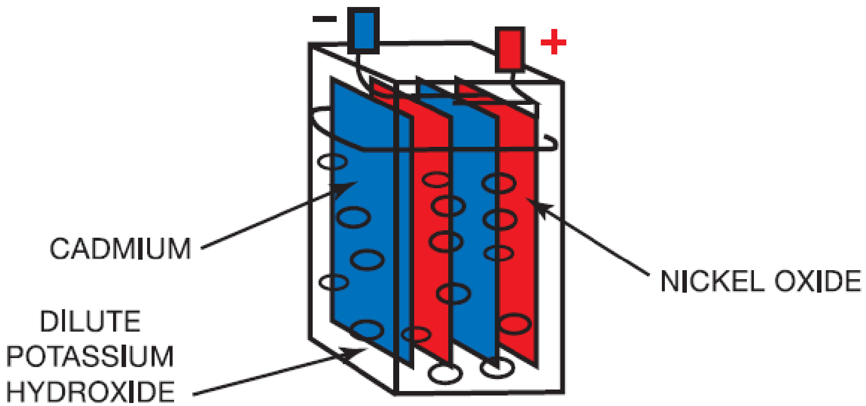


- Each cell is 2.2 V fully charged and 1.8 V fully discharged. Aircraft batteries ofthis type consist of either six cells (12 V) or twelve cells (24 V).



BATTERIES

- **ALKALINE BATTERY (NICKEL-CADMIUM)** Each cell of a nickel-cadmium battery in a fully charged condition consists of positive plates of Nickel Oxide and negative plates of pure Cadmium.
- Each cell is **1.2 V (fully charged) and 1.1 V (fully discharged).** Batteries of this type for use on an aircraft consist of either twenty cells (24 V) or twenty-two cells (26 V).



ALKALINE CELL

BATTERIES

- **BATTERY CAPACITY** The capacity of a battery is measured in **Ampere-Hours (AH), and is a measure of the total** amount of energy that it contains.
- **(ex.: 40 AH)**: This signifies that the battery is designed to last 10 hours when discharged at a 4-Ampere rate,
- or **1** hour when discharged at a **40**- Ampere rate.

BATTERIES

- **Actual Capacity** is the capacity of the battery as determined by a Capacity Test.

$$\frac{\text{Actual Capacity}}{\text{Rated Capacity}} \times 100 = \frac{38}{40} \times 100 = 95\%$$

- **NB!** For continued use in aircraft, this value must be **80%,** or more.

BATTERIES

BATTERY CONDITION CHECK An aircraft battery is a vital piece of equipment. Check the following for serviceability prior to flight:

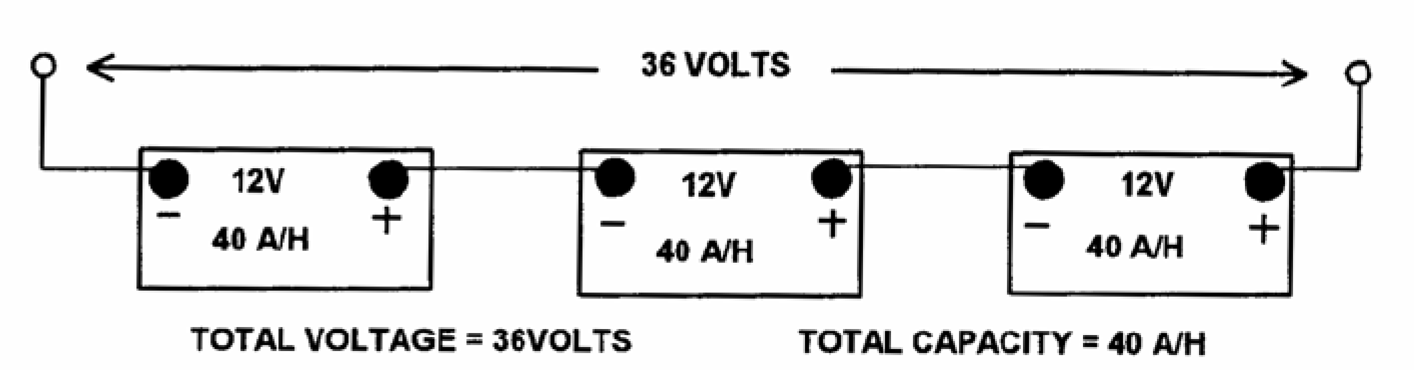
- Examine the battery **OFF load and note its voltage reading.**
- Select a specified load and note the new voltage reading.
- Compare both ON and OFF load readings, and ensure that the difference between the readings is within a set tolerance.

EMERGENCY USE

- In an emergency, the aircraft batteries must be capable of maintaining a supply for a minimum period of time. Main batteries must last at least **30 minutes** after total failure of the electrical generating system.
- Emergency Lighting Batteries must last for at least 10 minutes.

CONNECTION OF BATTERIES

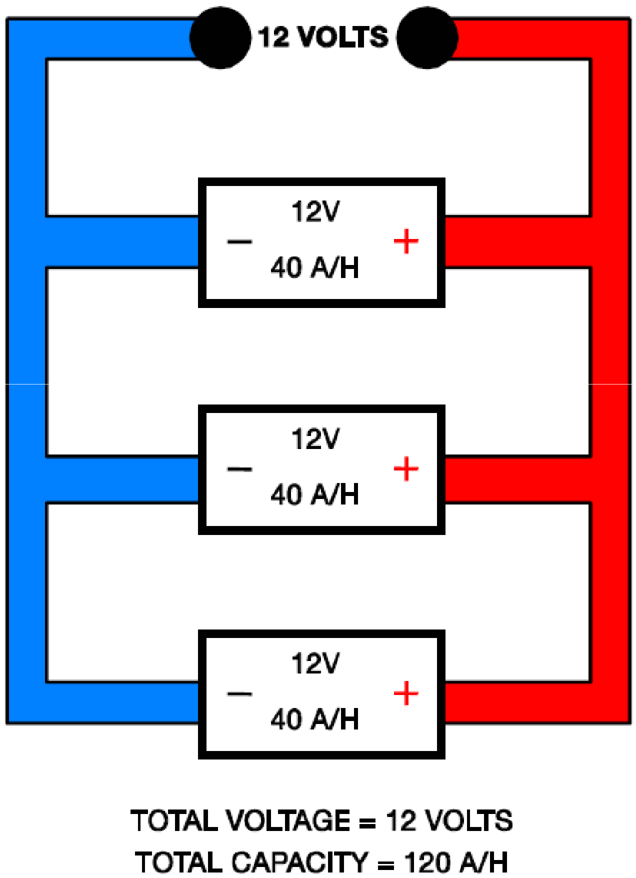
- **SERIES CONNECTION** If three identical batteries are connected in series, their voltages are added together, but their capacity remains the same as that of an individual battery, as shown below.



CONNECTION OF BATTERIES

PARALLEL CONNECTION

If identical batteries are connected in parallel, their capacities are added together, but the voltage remains the same as that of an individual battery.



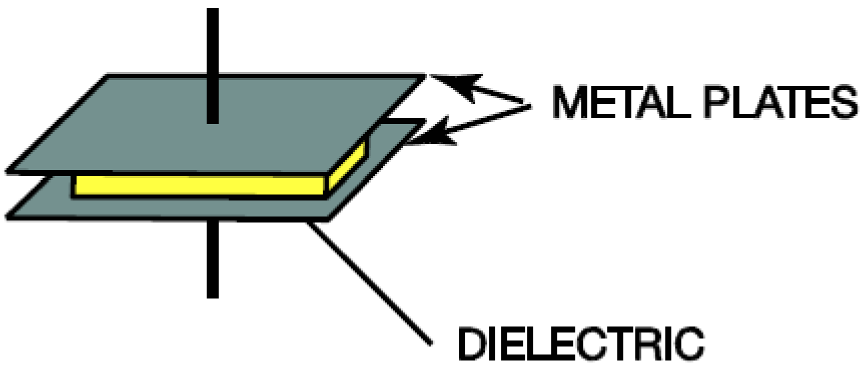
CAPACITANCE

- Capacitors in their simplest form consist of two metal plates separated by a non-conducting material called a dielectric. … rated in terms of microFarads (μF), nanoFarads (nF), and picoFarads (pF)

$$\text{Capacitance (C)} = \frac{Q}{V}$$

Where V = voltage across plates and Q = charge in Coulombs

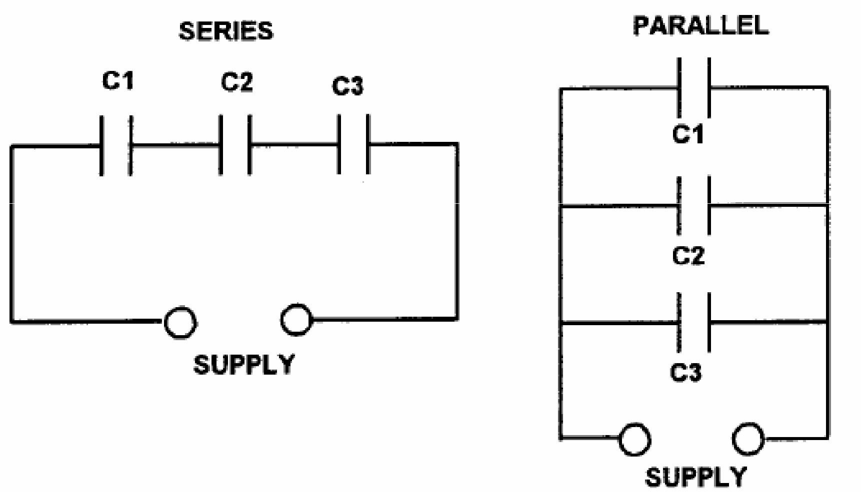
- A capacitor is often considered an energy storage device.



CAPACITORS IN SERIES AND PARALLEL

- **Capacitors in Parallel** increase the effective area of the plates, and thus increase the overall total capacitance.

  CT = C1 + C2+ C3...



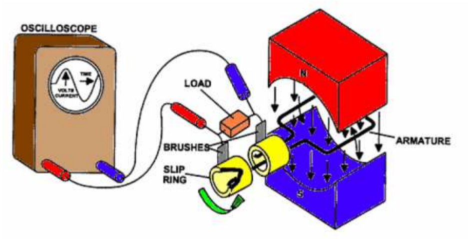
- **Capacitors in Series** increase the overall thickness of the dielectric, decreasing the total capacitance.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

ALTERNATING CURRENT

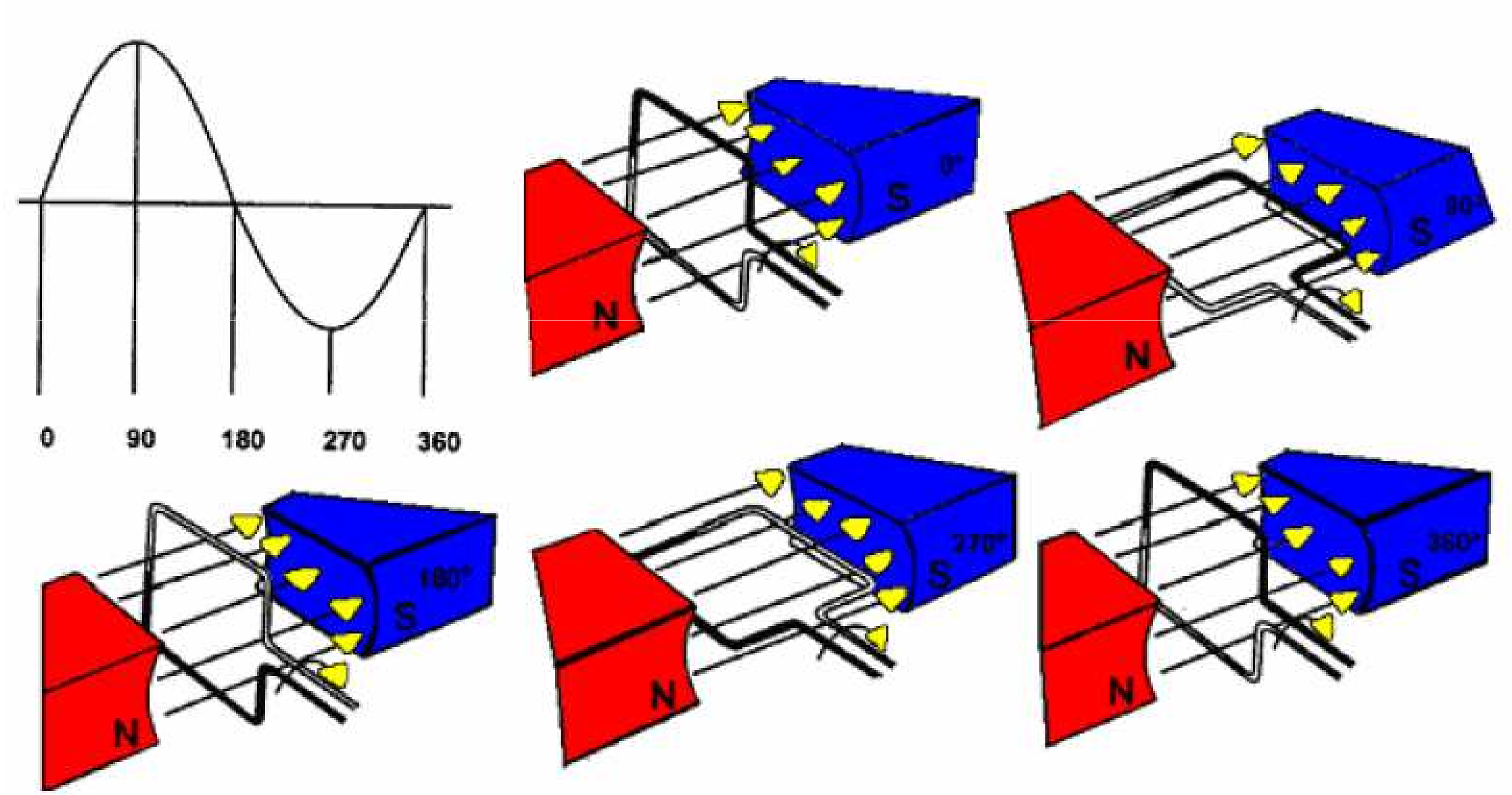
- **ADVANTAGES OF AC OVER DC**
- AC can be simply and efficiently changed from one voltage to another using a **transformer.**
- AC generators are simpler and lighter in construction than DC generators for the equivalent power output.
- AC can be easily and efficiently changed into DC using **rectifiers.**
- The magnitude or frequency of AC voltages can be easily modified to carry or transmitinformation as **AC signals.**
- The frequency at which electro-magnetic radio waves can be made to propagate outwardfrom a suitable aerial begins at 3000 Hz or 3 kHz, known as a radio frequency (RF).
- It is relatively easy to increase an AC supply frequency to the RF level.

GENERATING AC



- An AC generator converts mechanical energy into electrical energy by using the electromagnetic induction properties of a coil rotating in a magnetic field.
- The magnitude of the voltage produced is dependent on the following factors:
- **The strength of the magnetic field**
- **The speed at which the conductor cuts the magnetic field**
- **The length of the conductor within the magnetic field**
- **The angle at which the conductor cuts the magnetic field**

GENERATING AC



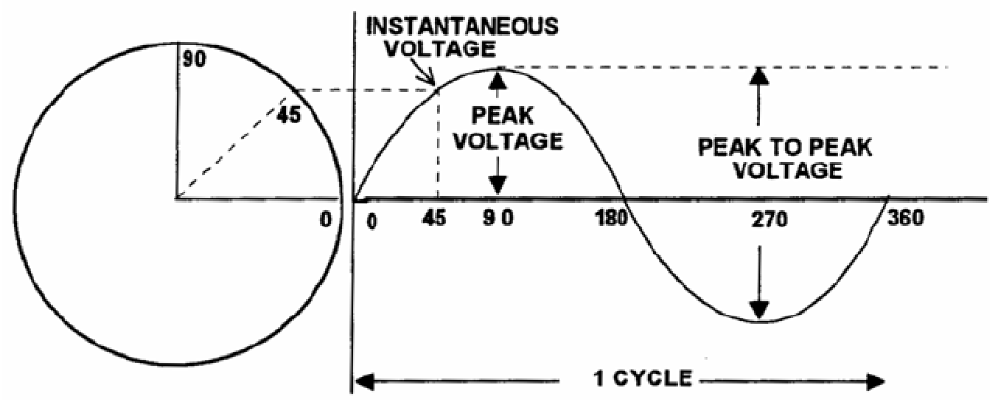
AC TERMINOLOGY

- **Root Mean Squared Value RMS (Effective Value)**

The RMS value is 0.707 of the peak value:

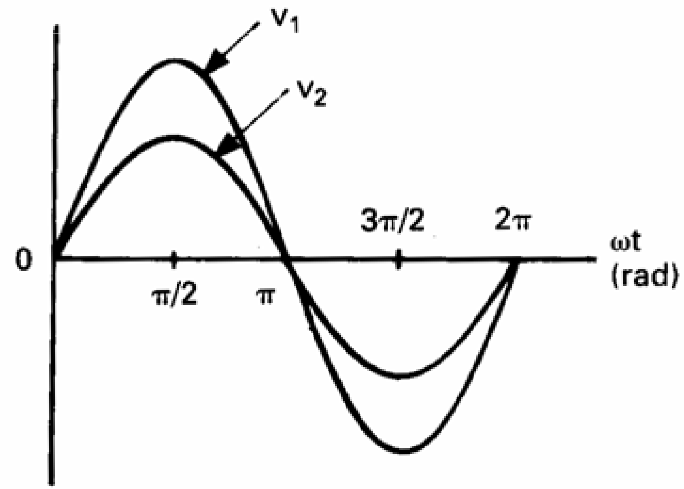
325 V domestic peak voltage x 0.707 = 230 V

- **Frequency** The number of complete cycles in one second [hertz]; **Periodic Time** is the time taken to complete one complete cycle and is the reciprocal of frequency:
- The standard AC electrical supply in modern aircraft is 200 volts 400 Hz.



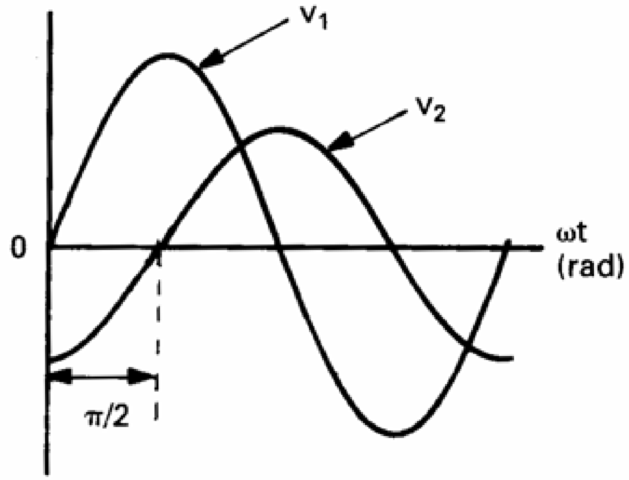
PHASE AND PHASE ANGLE

- Consider two AC voltages having the same frequency but with different magnitudes. They reach their maximum and minimum peak values at the same time. Both waveforms are **in phase with each other.**



PHASE AND PHASE ANGLE

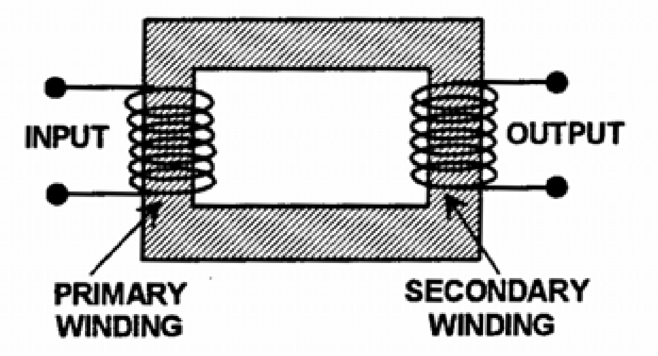
- If the waveforms are displaced from each other and cross the zero axis at different points, they are **out of phase, as** shown below. By convention, the angular difference between the two waveforms where they cross the horizontal axis and go positive is the **phase displacement or phase angle. In the above example, V1 leads V2 by 90°** or, alternatively, V2 lags V1 by 90°.



TRANSFORMERS

- It consists of two windings, the **primary** winding and the **secondary** winding. The windings are not electrically connectedtogether but are wound on the same laminated soft iron core. The magnitude of the EMF is proportional to the ratio of the number of turns between the primary and secondary windings.

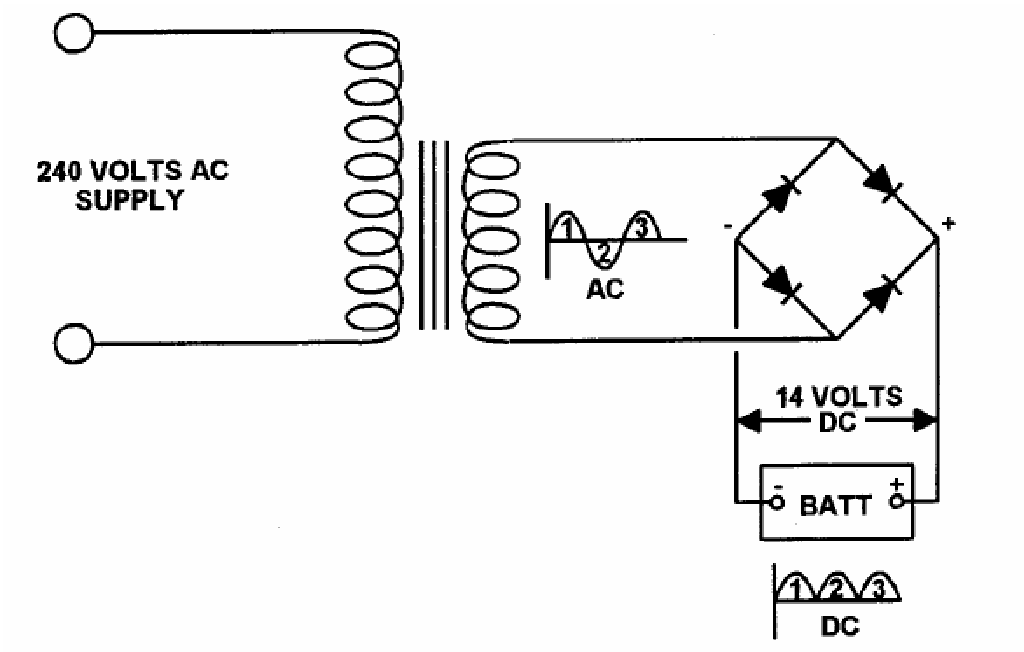
$$\text{Turns Ratio} = \frac{N_P}{N_S} = \frac{V_P}{V_S}$$



Where:-
Vp = Primary voltage
Vs = Secondary voltage
Np = Primary turns
Ns = Secondary turns

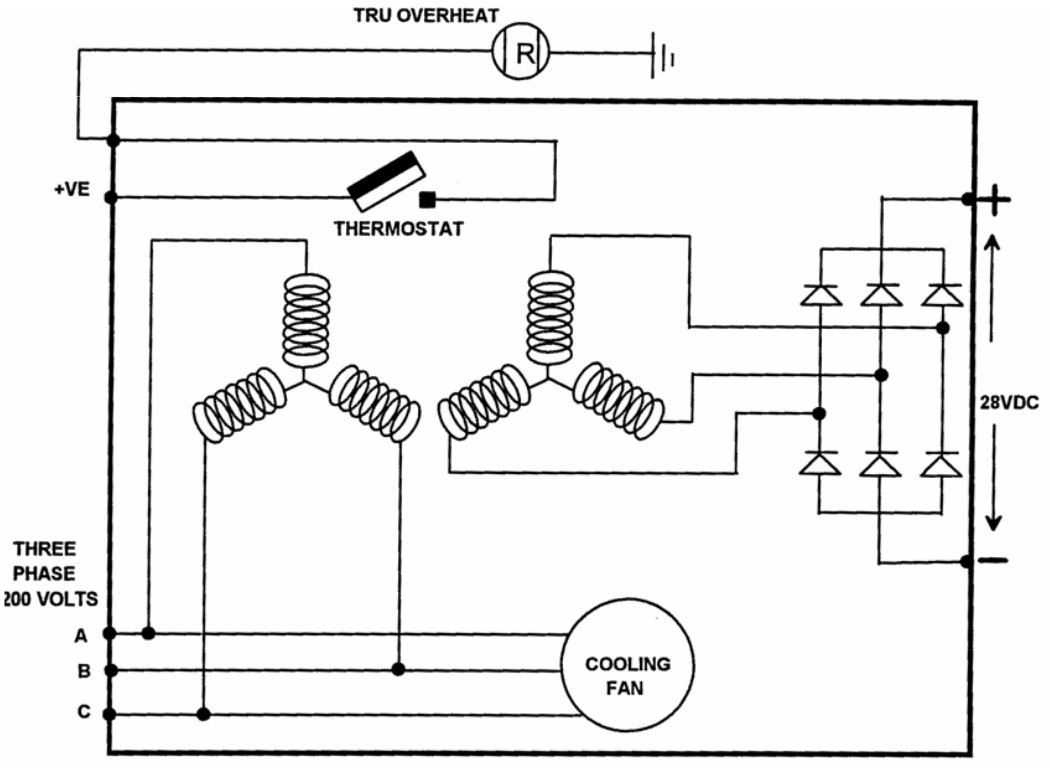
TRANSFORMER RECTIFIER UNITS

- A **transformer rectifier unit (TRU) is used to convert AC into relatively smooth DC An example** of a simple TRU circuit is that which is used in a car battery charger, as shown below.



TRANSFORMER RECTIFIER UNITS

- Most large aircraft AC generator systems have dedicated TRUs, which operate on the same principle, although they are slightly more sophisticated. A typical unit is illustrated below.

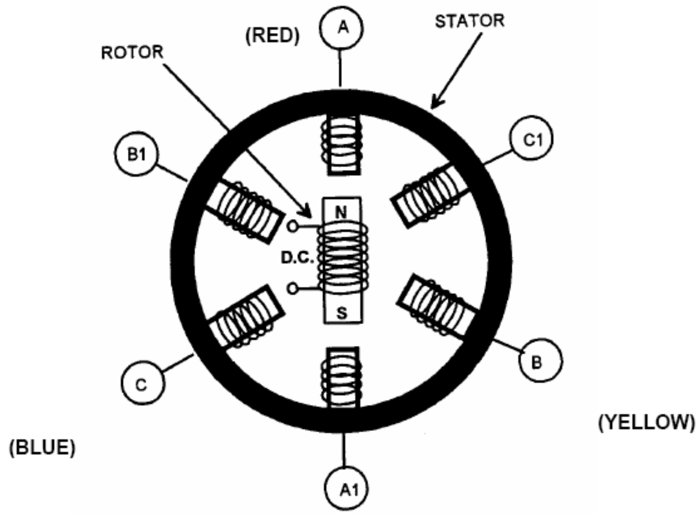


TRU

- The TRU that is fitted to an aircraft is supplied with 200 V 400 Hz three-phase AC, which is stepped-down through a three-phase star-star wound transformer and changed to 28 VDC by a six-rectifier bridge assembly. The output from the TRU is then fed to the aircraft's DC busbars.
- **Overheat** When operating, most TRUs are cooled by air from a thermostatically controlledcooling fan. If the TRU overheats (150°-200°) due to fan or other failure, a warning light illuminates on the flight deck. The TRU should then be switched off, either manually or automatically.
- **Reverse Current.** When the TRUs are operating in parallel with some other power source, the failure of a rectifier in a TRU can cause a reverse current to flow into it and may even cause a fire. Reverse current protection in the failed TRU is designed to sense the fault current when it reaches approximately 1 amp, and disconnect the TRU automatically from the DC bus bars.

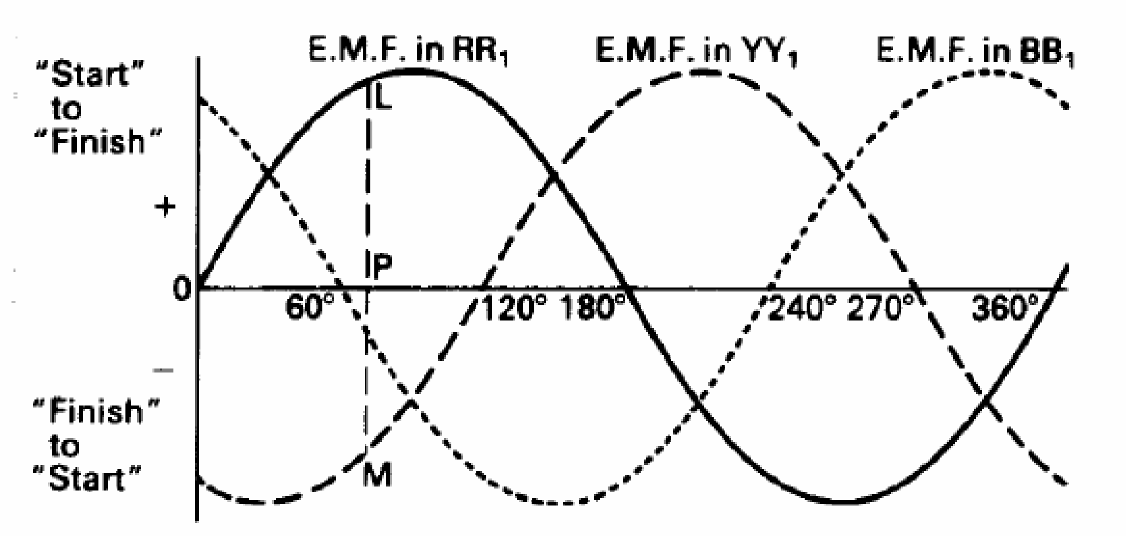
AC POWER GENERATION

- **SIMPLE THREE PHASE GENERATOR** A three-phase generator consists of two main parts, as shown below: The rotor carries the electromagnetic field that is driven by the aircraft engine, whilst the stator carries three sets (pairs) of coils (phase windings). These windings are fixed to one another at angles of 120°, and the phases are **AA1, BB1, and CC1 or coloured Red (RR1), Yellow (YY1), and Blue (BB1) respectively, where the A or Red phase is classified as the reference phase.**



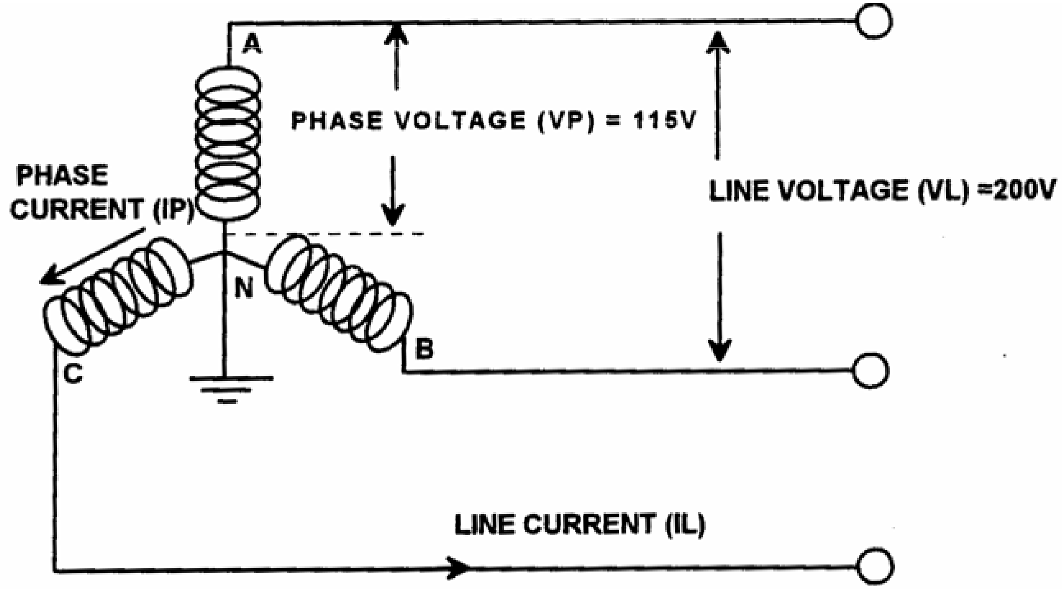
AC POWER GENERATION

- As the rotor rotates, it induces an EMF in each set of windings in turn and produces a sine wave output from each, as shown in the diagram:



STAR CONNECTION

- In the star configuration, one end of each phase winding is connected to a common point called the **Neutral (N) or Star Point, whilst the other end of each phase winding is connected to output** terminals distributing AC power of different phases.



ADVANTAGES OF THREE-PHASE

Three-phase AC generators are preferable for the following reasons:

- Less conductor weight is required for the transmission of a given power.
- They can produce a rotating magnetic field, which can be used to operate efficient three-phase AC motors.
- Three-phase AC gives smoother rectification than single phase AC

VOLTAGE AND FREQUENCY OF AC GENERATORS

Adjusting the field excitation of an AC generator using a voltage regulator controls its voltage output.

- The output frequency of an AC generator is alternatively dependent on the rotational speed of the rotor and the number of magnetic field poles:

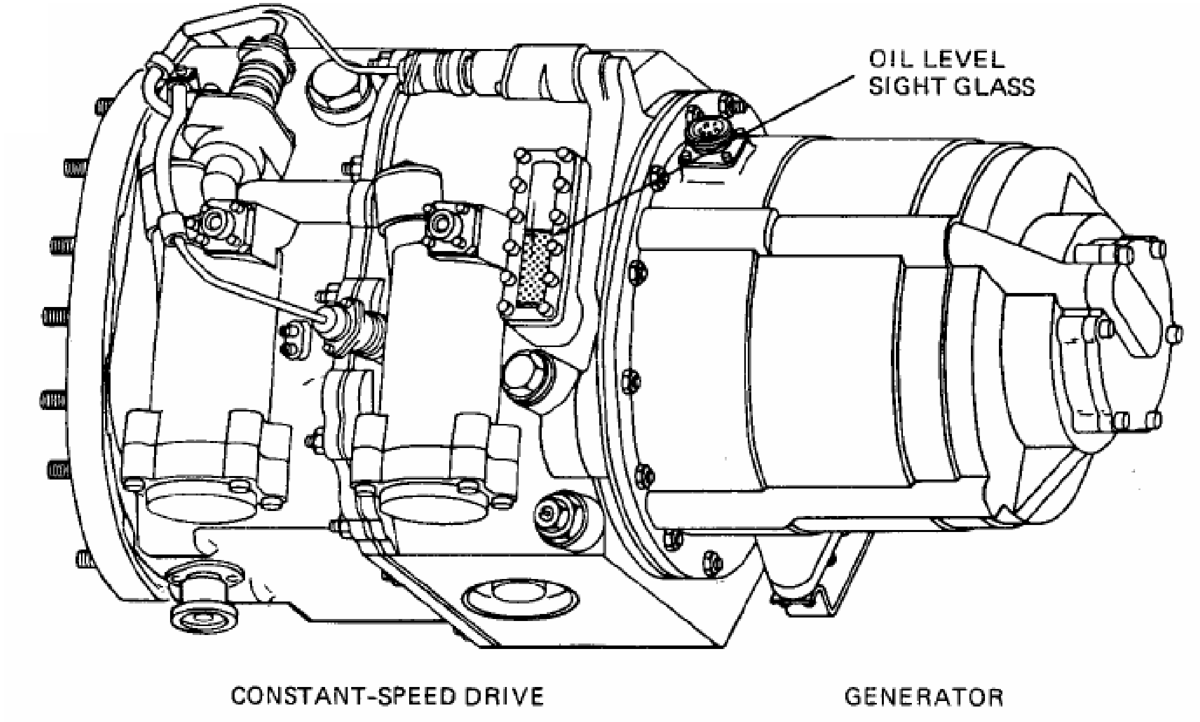
$$60 f = PN$$

where:

- f = frequency [Hz]
- N = Rotational Speed (rpm)
- P = Number of pole pairs on the rotor

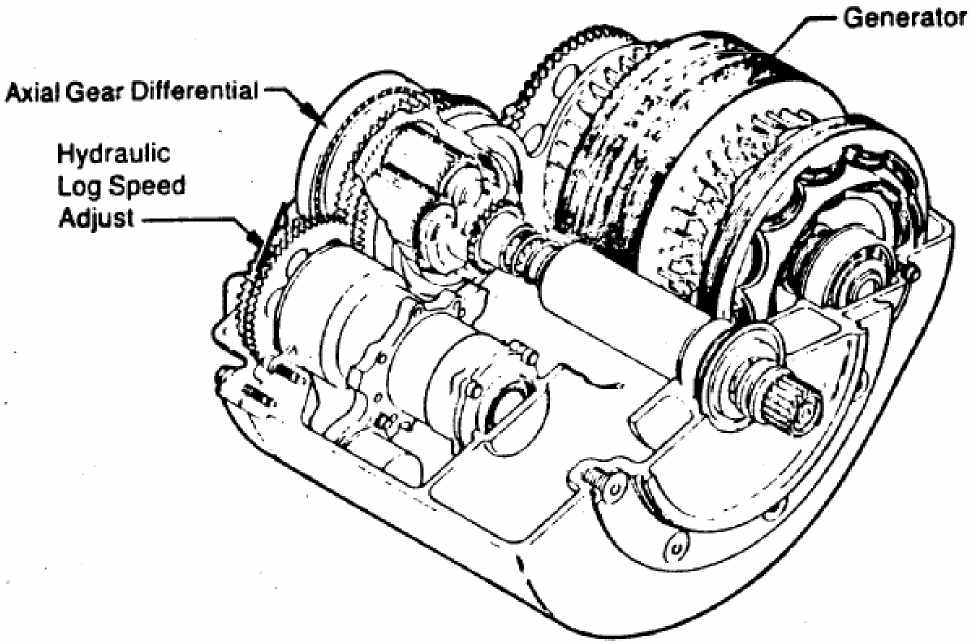
CONSTANT SPEED DRIVE UNIT (CSDU)

- The **CSDU is a mainly mechanical device, which is positioned** between the aircraft engine and the brushless AC generator. The CSDU is designed to keep the generator running at a constant speed, which is usually 8000rpm.



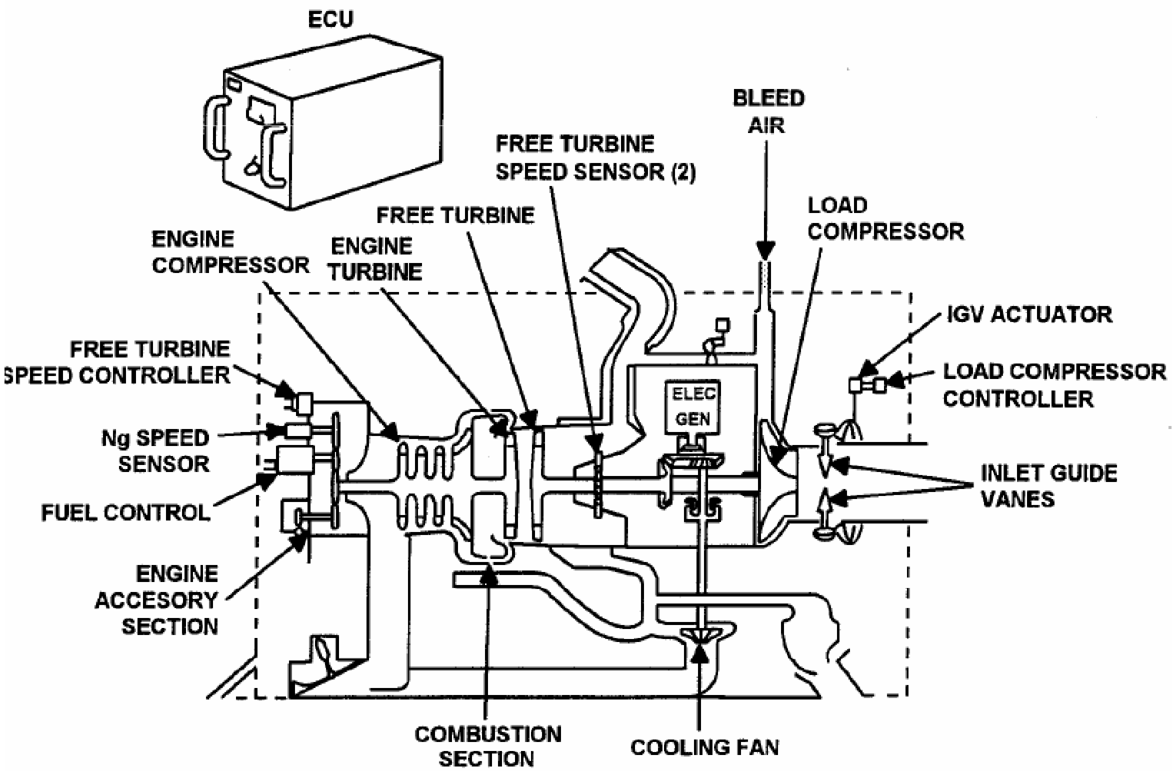
INTEGRATED DRIVE GENERATOR

- On modern aircraft, the CSDU and generator are normally combined as one unit, which is known as an **Integrated Drive Generator (IDG), as shown below, and the generator is alternatively oilcooled.**



AUXILIARY POWER UNIT

- The **auxiliary power unit (APU) is a compact unit which is usually fitted in the** tail section of an aircraft and provides electrical power (200 V, 3 Phase, 400 Hz) on the ground.



EMERGENCY RAM AIR TURBINE

- In the case of total main electrical AC failure, a **Ram Air Turbine (RAT), as shown in the** following diagram, can be extended automatically or manually into the airstream.