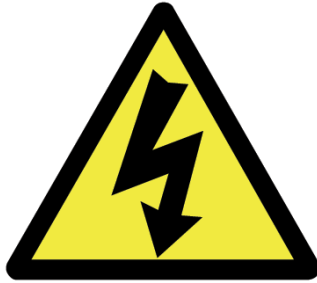


# Electricity



1

# Electricity

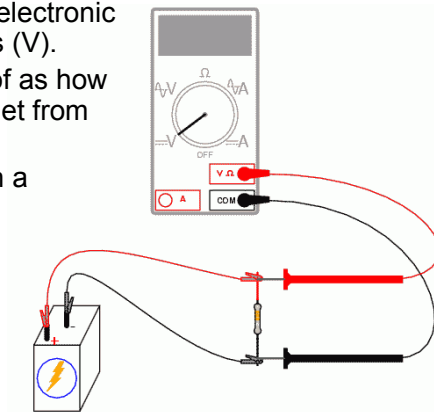
- Electricity is a general term that encompasses a variety of phenomena resulting from the presence and flow of electric charge.



2

# Voltage (V)

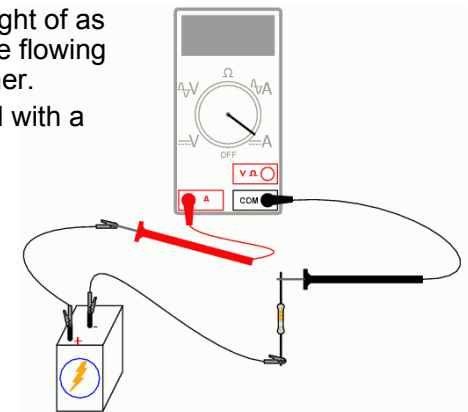
- Voltage is the difference of electrical potential between two points of an electrical or electronic circuit, expressed in volts (V).
- Voltage can be thought of as how badly electrons want to get from one point to another.
- Voltage is measured with a voltmeter.



3

# Amperage (I)

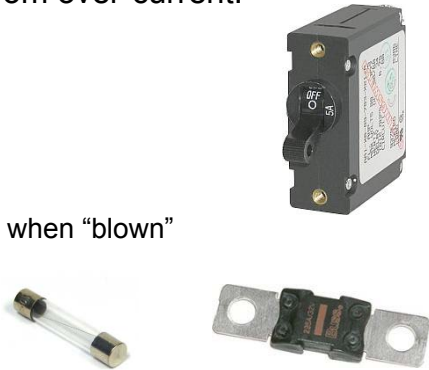
- Amperage is the flow of electric charge, expressed in amps (I).
- Amperage can be thought of as how many electrons are flowing from one point to another.
- Amperage is measured with an ammeter.



4

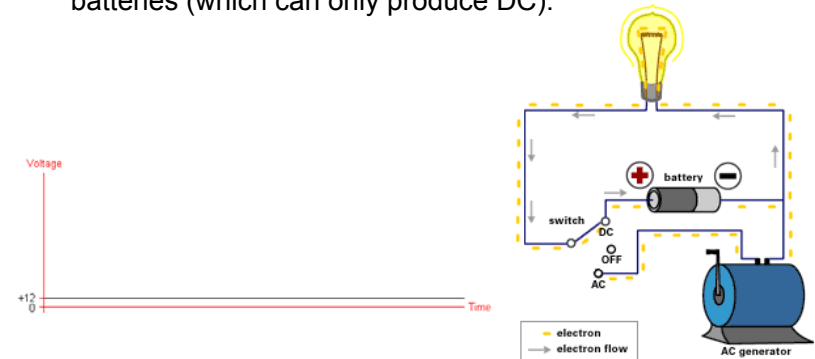
# Circuit Protection

- Circuit breakers and fuses are used to protect electrical circuits from over-current.
- Circuit breakers:
  - Easily resettable,
  - More costly,
  - Slower acting.
- Fuses:
  - Must be discarded when “blown”
  - Cheap
  - Fast acting



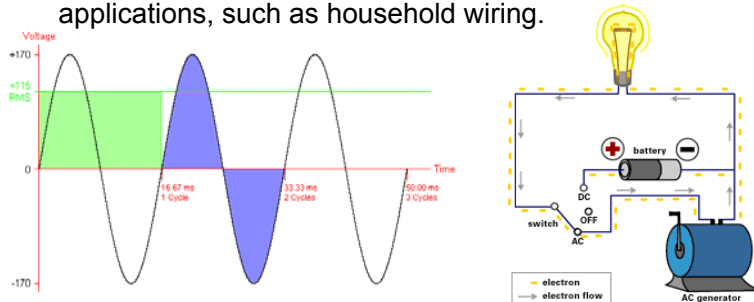
# Direct Current (DC)

- Direct current is the unidirectional flow of electric charge.
- Direct current is commonly found in low-voltage applications, especially where these are powered by batteries (which can only produce DC).



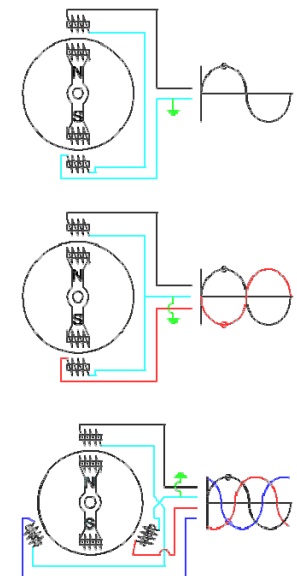
# Alternating Current (AC)

- Alternating current is an electric current whose direction reverses cyclically.
- The usual waveform of an AC power circuit is a sine wave, however in certain applications different waveforms are used, such as square waves.
- Alternating current is commonly found in higher-voltage applications, such as household wiring.



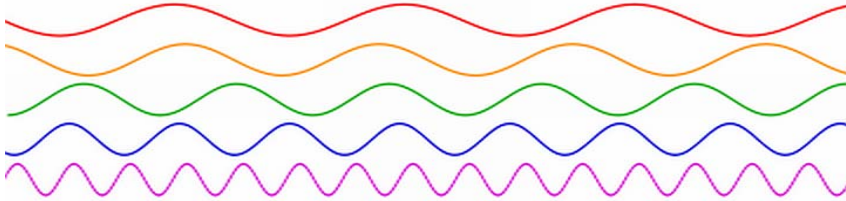
# Phases

- More than one AC waveform can be produced by a single alternator.
- Single phase AC has one phase.
- Split phase AC has two opposite phases (180° apart).
- Three phase AC has three phases 120° apart.



## Frequency (Hz)

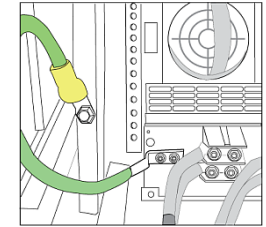
- The frequency is the speed at which alternating current changes direction.
- Only alternating current has frequency
- Frequency is measured in Hertz (Hz).
- In most parts of the Americas the AC frequency is typically 60 Hz, and in most other parts of the world it is typically 50 Hz.
- In a 60 Hz AC circuit, the electric current reverses direction 120 times per second (60 times each direction).



9

## Ground (Earth)

- Ground is the reference point in an electrical circuit from which other absolute voltages are measured.
- The ground in a steel ship's electrical system is usually the hull.
- In a DC system the negative side is usually connected to ground.
- In an AC system a wire that is connected to ground is called the "neutral".
- The ground connection on electrical equipment provides a safe path for any "leaked" electricity to dissipate



10

## Power (W)

- Electric power is the rate at which electrical energy is transferred by an electric circuit, measured in Watts (W).
- Power = Voltage x Amperage or  $W = V \cdot I$



11

## Resistance ( $\Omega$ )

- Electrical resistance is the degree to which an object opposes an electric current through it, measured in Ohms ( $\Omega$ ).
- The resistance of an object determines the amount of current flow (amperage) through the object for a given potential difference (voltage) across the object.
- Resistance = Voltage / Amperage or  $\Omega = V/I$
- Electrical resistors in a circuit dissipate power in the form of heat.
- Power dissipated = Voltage<sup>2</sup> / Resistance or  $W = V^2/\Omega$



12

## Conductors

- An electrical conductor is a material that allows the flow of electric current.
- Most metals are good conductors, especially copper and aluminium.
- Wire conductivity is often expressed in ohms per meter, with smaller figures indicating higher conductivity (less resistance).



13

## Insulators

- An electrical insulator is a material that resists the flow of electric current.
- Most plastics and ceramics are good insulators.
- An insulator is also known as a dielectric.
- Dielectric strength is the maximum voltage that an insulator can withstand without breaking down. It is often measured in volts per meter, with higher figures indicating better insulation (more resistance).



14

## Wires

- A wire is a length of conductor surrounded by an insulator.
- The larger (or better quality) the conductor, the greater the amperage that can safely pass through the wire.
- The thicker (or better quality) the insulation, the greater the voltage that can safely pass through the wire.
- Cables are made up of multiple wires.



15

## Diodes

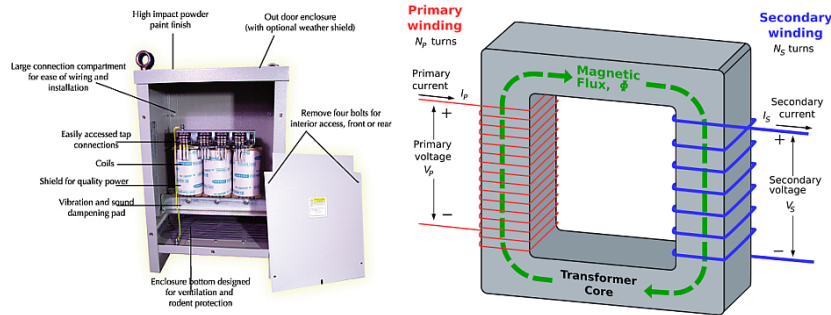
- Diodes are electronic devices that permit electric current to flow in one direction only.
- A diode can be thought of as an electronic version of a check valve.
- A Light Emitting Diode (LED) is a diode that emits light when sufficient current flows through it. Like regular diodes, LEDs allow electric current to flow in one direction only.



16

# Transformers

- Transformers are used to convert alternating current from one voltage to another.
- Isolation transformers are used to electrically isolate a ship's electrical system from the shore.
- Some transformers are encapsulated in epoxy to protect them from physical damage or corrosion.



17

# Converters

- Converters are used to convert direct current from one voltage to another.
- Most modern converters are electronic devices.
- Some converters are encapsulated in epoxy to protect them from physical damage or corrosion.

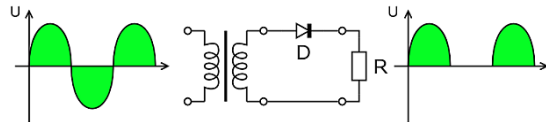


18

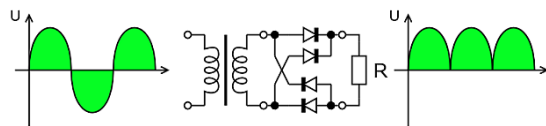
# Rectifiers



- A rectifier is an electrical device that converts alternating current to direct current.
- Rectifiers are made up of diodes
- In half wave rectification either the positive or negative half of the AC wave is passed.



- In full wave rectification both the positive and negative halves of the AC wave are passed.



19

# Battery Chargers & Power Supplies

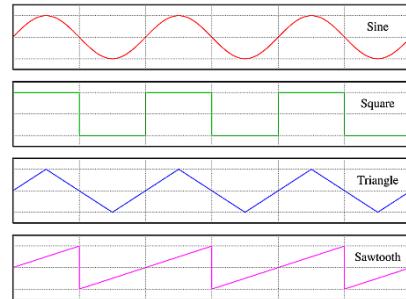
- Although rectifiers are still used for some applications, many modern devices require "cleaner" power than a rectifier is able to provide.
- Battery Chargers and Power Supplies convert AC into "true" DC.
- Most Battery Chargers and Power Supplies are computerized which allows high efficiencies, stable output power, and custom battery charging profiles.



20

## Inverters

- An inverter is an electrical device that converts direct current to alternating current.
- Most modern inverters are electronic devices.
- Better inverters output sine waves while cheaper inverters output square, triangular, or saw-tooth shaped waves.



21

## Transfer Switches

- Only one AC power source can be connected to a circuit at one time, unless specialized equipment is used and both AC power sources are identical and synchronized (same voltage, frequency, and phase).
- Transfer switches are used to select the desired AC input source.



22

## Multi-Function Equipment

- Often things such as inverters, battery chargers, and transfer switches are combined into one piece of equipment.
- This is done in order to simplify wiring, save space, and automate operation.



23

## Electricity Production

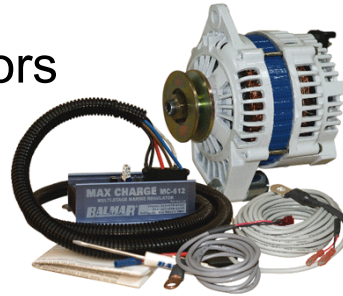
- Although most electricity is produced from rotary motion, there are several other technologies such as PV (solar panels) and thermocouples.
- Changing rotary motion into electricity can be accomplished with either:
  1. Dynamos – (sometimes also called Generators) produce DC power
  2. Alternators – produce AC power
- Alternators are used almost exclusively now as they are much simpler and reliable than Dynamos.
- In order to avoid confusion the term “Generating Set” or “GenSet” will be used to identify an Engine and Alternator package, although you will probably still hear some people call them “Generators”.

24





## Alternators

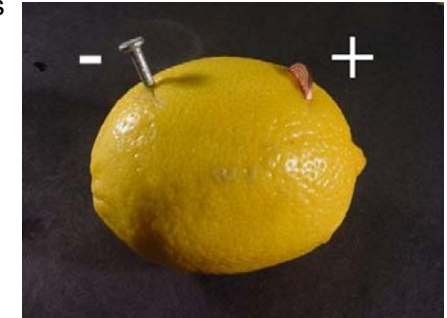


- Alternators can be either brushed or brushless.
- Brushed alternators use little pieces of carbon/graphite to pass electricity across a spinning gap - this often creates little sparks (which can cause radio interference). Brushed alternators are cheaper to produce, but the brushes do wear out over time and require replacement.
- Brushless alternators, as their name implies, have no brushes. They are more expensive to produce, but are more reliable and don't produce sparks.
- All alternators use a regulator to regulate the output voltage. This can either be internal or external.
- Alternators in DC systems (such as those found in cars) have internal rectifiers to convert the AC output to DC.

25

## Batteries

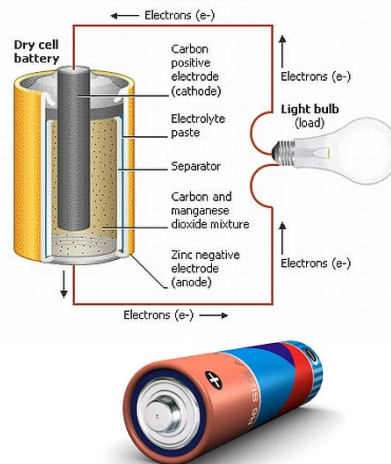
- A battery is a device that converts chemical energy directly to electrical energy.
- A battery consists of one or more voltaic cells. Each voltaic cell consists of two half-cells connected in series by a conductive electrolyte.
- Depending on type, cells typically have a nominal voltage potential anywhere from 1.2V to 3.0V.



26

## Dry Cell Batteries

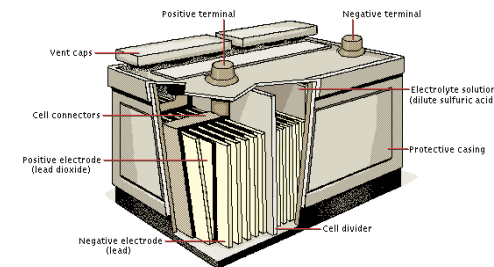
- A dry cell battery has a pasty low-moisture electrolyte.
- While a dry cell's electrolyte must contain some moisture to function, it has the advantage of containing no sloshing liquid that might leak or drip out when inverted or handled roughly, making it highly suitable for small portable electric devices.



27

## Wet Cell Batteries

- A wet cell battery has a liquid electrolyte.
- Wet cells are heavier and more fragile than dry cells, but the reduction-oxidation reaction is reversible allowing them to be easily recharged.
- Wet cell batteries are the most cost effective way of storing large quantities of electricity.



28

## Battery Measurements

- Physical size
  - Can be standard package size (ie: AA or 4D) or actual measurements (ie: 24" x 16" x 9")
- Voltage
  - Nominal battery voltage (ie: 1.5V or 6V)
- Amp-Hour Capacity
  - Battery capacity (ie: 1800mAh or 200Ah)
- Reserve Minutes Capacity
  - Time to discharge battery with a 25A load (ie: 55mins or 130mins)
- Cold Cranking Amps
  - Minimum amperage the battery will deliver at  $-18^{\circ}\text{C}$

29

## Lead Acid Wet Cells

- Lead acid wet cells contain plates of lead metal (Pb) and lead dioxide ( $\text{PbO}_2$ ), in an electrolyte of sulphuric acid ( $\text{H}_2\text{SO}_4$ ).
- Each lead acid cell has a nominal voltage of  $\sim 2$  VDC. A battery may be made up of multiple cells (a 12 VDC battery is made up of six cells).
- Because of the liquid electrolyte in most lead-acid batteries, overcharging with excessive charging voltages will generate oxygen and hydrogen gas (by the electrolysis of water), forming an explosive mix.

30

## Lead Acid Wet Cells

- Different applications require different battery construction:
  1. Starting batteries have a large number of thin plates designed for maximum surface area and therefore maximum current output, but can easily be damaged by deep discharges. Repeated discharges below 75% will result in capacity loss and ultimately in premature failure.
  2. Deep Cycle batteries have thicker plates that can deliver less peak current, but can withstand the mechanical stresses of frequent deep discharging. A good deep cycle battery can be regularly discharged down to 25%.
  3. All-Purpose batteries are a compromise between starting batteries and deep cycle batteries, and should be avoided whenever possible.

31

## Lead Acid Wet Cells

- There are three variations of the lead acid wet battery:
  1. Flooded (liquid) electrolyte batteries.
  2. Gelled electrolyte batteries.
  3. Absorbed Glass Mat batteries.



32



## Flooded (liquid) Electrolyte Batteries

- The electrolyte is a liquid solution of acid and water.
- Distilled water may be added to these batteries to replenish the electrolyte as necessary.
- Flooded cells can be charged at a maximum of C/4 (Capacity/4) rate (ie: 400Ah bank can be charged at 100A).

33

## Gelled Electrolyte Batteries

- The sulphuric acid is mixed with a silica fume, which makes the resulting mass gel-like and immobile .
- The battery is sealed. Any electrolyte lost during overcharging cannot be replaced.
- Gel cells can be charged at a maximum of C/20 (Capacity/20) rate (ie: 400Ah bank can be charged at 20A).

34

## Absorbed Glass Mat Batteries

- The sulphuric acid is absorbed into a mat of fine glass fibers .
- The battery is sealed. Any electrolyte lost during overcharging cannot be replaced.
- AGM cells can be charged at a maximum of C/1 (Capacity/1) rate (ie: 400Ah bank can be charged at 400A).

35

## Battery Safety

- All batteries are dangerous, but large lead acid batteries are particularly so.
- Always allow a lead acid battery to “sit” after charging before working on or near it, in order to let the hydrogen and oxygen dissipate.
- Keep all battery terminal connections clean and tight to maximize conductivity and prevent local heating or arcing.
- When working with or on batteries:
  - Wear protective clothing, gloves, and goggles
  - Use insulated tools to avoid shorting terminals
  - Make sure there is an eye-wash station and baking soda close at hand
  - Have a 2<sup>nd</sup> person working with you



36