Electricity and Electromagnetism

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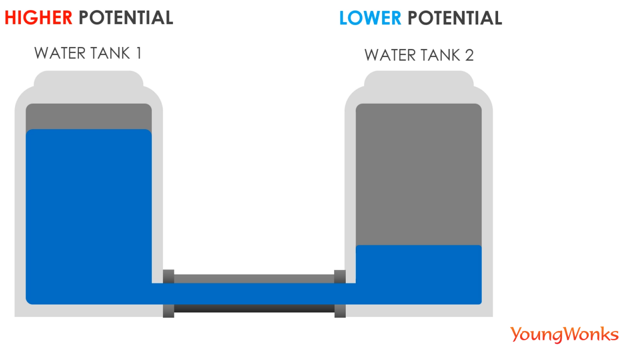


Figure 1.1: potential difference

1. Electricity

There are two types of electricity:

- static electricity
- current electricity

Voltage

- Voltage is the potential difference between two points which is the change in potential energy per charge. For example, every battery has two terminals, and its voltage is the potential difference between them.
$$V = \frac{\Delta E}{\Delta q}$$
- The SI unit is J/C or Volts (V).
- Voltage is not the same as energy. Voltage is the energy per unit charge. Thus a motorcycle battery and a car battery can both have the same voltage , yet one stores much more energy than the other.

Current

Electric current measures the rate of flow of charges in a conductor.

$$I = \frac{\Delta Q}{\Delta t}$$

Thus the SI unit of current is C/s or Ampere (A).

Resistance

The opposition to the flow of electric current in an electric circuit is known as resistance. The SI unit of electrical resistance is called Ohm.

Ohm's Law

Ohm's law gives the relation between the relation between voltage and current.

Ohm's Law

"The current in a conductor is linearly proportional to the difference of potential between any two points and inversely proportional to the resistance, provided physical conditions such as temperature, pressure, etc. remain the same.

Diagnostic Methods

EEG

Supplementary Information

Q. How is voltage (potential difference) created across the cell membrane of a neuron in its resting state?

- The thin cell membrane separates electrically neutral fluids having differing concentrations of ions, the most important varieties being Na+, K+, and Cl-.
- Free ions will diffuse from a region of high concentration to one of low concentration (diffusion). But the cell membrane is semipermeable.
- In its resting state, the cell membrane is permeable to K+ and Cl-, and impermeable to Na+.
- The Coulomb force prevents the ions from diffusing across in their entirety.

Basics

An EEG is a recorded measurement of the voltages appearing at the scalp surface due to the electrical activity of the brain.

Principle Working and Uses

Refer to text.

ECG

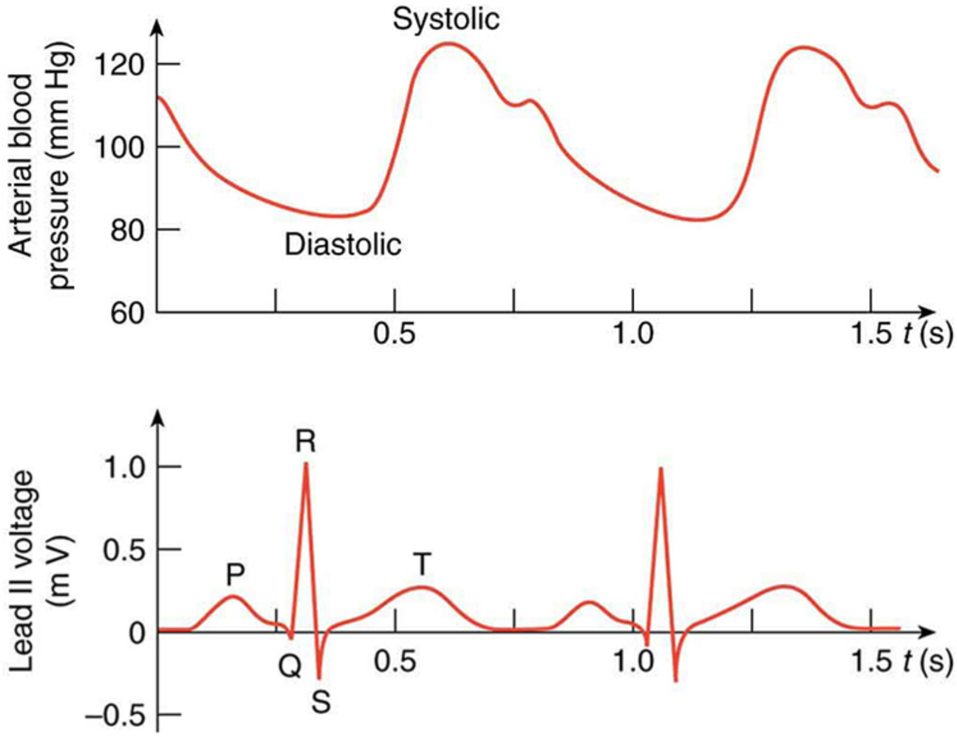
Principle

- An electrocardiogram (ECG) is a record of the voltages created by the wave of depolarization and subsequent repolarization in the heart.
- Just as nerve impulses are transmitted by depolarization and repolarization of adjacent membrane, the depolarization that causes muscle contraction can also stimulate adjacent muscle cells to depolarize (fire) and contract.
- Depolarization of the heart muscle causes it to contract. After contraction it is repolarized to ready it for the next beat.
- Thus, a depolarization wave can be sent across the heart, coordinating its rhythmic contractions and enabling it to perform its vital function of propelling blood through the circulatory system
- The ECG measures components of depolarization and repolarization of the heart muscle and can yield significant information on the functioning and malfunctioning of the heart.

The voltage between the right arm and the left leg is called the lead II potential and is the most often graphed. We shall examine the lead II potential as an indicator of heart-muscle function and see that it is coordinated with arterial blood pressure as well.

Wave pattern

Refer to text.



Application or Uses

- Taken together, the 12 leads of a state-of-the-art ECG can yield a wealth of information about the heart.
- For example, regions of damaged heart tissue, called infarcts, reflect electrical waves and are apparent in one or more lead potentials.
- Subtle changes due to slight or gradual damage to the heart are most readily detected by comparing a recent ECG to an older one. This is particularly the case since individual heart shape, size, and orientation can cause variations in ECGs from one individual to another.

Artificial Pacemaker

Principle

- The heart rate is normally controlled by electrical signals generated by the sino-atrial (SA) node, which is on the wall of the right atrium chamber.
- This causes the muscles to contract and pump blood.
- Sometimes the heart rhythm is abnormal and the heartbeat is too high or too low.
- An aritificial pacemaker is an application of the RC timing circuit used to control heart rate.
- The artificial pacemaker is inserted near the heart to provide electrical signals to the heart when needed with the appropriate time constant.
- Pacemakers have sensors that detect body motion and breathing to increase the heart rate during exercise to meet the body's increased needs for blood and oxygen.

Uses

- Used to maintain normal heart beats in cases of heart block or arrhythmia.
- Electronic cardiac pacemaker may be temporary or permanent. Temporary pacemakers are helpful to persons who have a transient blockage of conduction pathway after a myocardial infraction or cardiac surgery.
- In cases of irreversible cardiac damage and complete conductive pathway blockage a permanent pacemaker may be used.

Procedural Details

Refer to text. pg 173.

Defibrillation

- Defibrillator is an electric device used to deliver an electrical current (shock) of preset voltage to the heart through paddles placed on the chest wall (closed chest procedure).

- This current cause the entire myocardium to depolarize completely at the moment of shock, thus producing transient asystole and allowing the heart's intrinsic pacemaker to regain control.

- The amount of energy required to produce this effect is determined largely by the client's transthoracic impedance, or resistance to current flow.

- Because of this factor, the amount of energy that reaches the heart is less than the amount that the defibrillator is charged to deliver.

- The procedure is associated with potential hazards, particularly myocardial damage.

- The higher the amount of energy or frequency of the shock, the greater the risk of injury.

- Advances in the equipments now allow measurement of transthoracic impedance. Once impedance is determined, the defibrillator automatically selects the amount of current. It is expected this mode of defibrillation will reduce the risk of complications.

Automated External Defibrillator

- An automated external defibrillator or AED is a portable electronic device that automatically diagnoses the potentially life threatening cardiac arrhythmias of ventricular fibrillation and ventricular tachycardia in a patient, and is able to treat them through defibrillation, the application of electrical therapy which stops the arrhythmia, allowing the heart to re-establish an effective rhythm.

- AEDs are designed to be simple to use for the layman, and the use of AEDs is taught in many first aid, first responder and basic life support (BLS) level CPR classes. CPR is recommended in many cases before use of an AED.

Figure 1.2: Automated external defibrillators are found in many public places. These portable units provide verbal instructions for use in the important first few minutes for a person suffering a cardiac attack.

ECT

Refer to text.

2. X-rays

Basics

- X-rays are part of the electromagnetic spectrum.
- They are highly energetic radiation with a frequency beyond that of the UV spectrum.
- The first nobel prize in physics was awarded for the discovery of X-rays.

Uses of X-rays

- Dental and medical x rays that have become an essential part of medical diagnostics.
- X rays are also used to inspect our luggage at airports,
- They are also used for early detection of cracks in crucial aircraft components.

CT Scan

Principle

- A standard x ray gives only a two-dimensional view of the object.

Figure 2.1: On the left, a patient being positioned into a CT scanner. On the right, the 3D image of a skull produced by CT.

- Dense bones might hide images of soft tissue or organs.
- If you took another x ray from the side of the person (the first one being from the front), you would gain additional information.
- While shadow images are sufficient in many applications, far more sophisticated images can be produced with modern technology.

Process

- X rays are passed through a narrow section (called a slice) of the patient's body (or body part) over a range of directions.
- An array of many detectors on the other side of the patient registers the x rays.
- The system is then rotated around the patient and another image is taken, and so on.
- The x-ray tube and detector array are mechanically attached and so rotate together.
- Complex computer image processing of the relative absorption of the x rays along different directions produces a highly-detailed image.
- Different slices are taken as the patient moves through the scanner on a table.
- Multiple images of different slices can also be computer analyzed to produce three-dimensional information, sometimes enhancing specific types of tissue,

Uses

Refer. to https://www.radiologyinfo.org/en/info.cfm?pg=bodyct

3. MRI

Basics

- Magnetic resonance imaging (MRI) is one of the most useful and rapidly growing medical imaging tools.
- It non-invasively produces two-dimensional and three-dimensional images of the body that provide important medical information
- It has none of the hazards like those associated with x-rays.
- MRI is based on an effect called nuclear magnetic resonance (NMR)

Mechanism of Operation

Refer to text.

Uses

- The location and density of protons give a variety of medically useful information, such as organ function, the condition of tissue (as in the brain), and the shape of structures, such as vertebral disks and knee-joint surfaces.
- MRI can also be used to follow the movement of certain ions across membranes, yielding information on active transport, osmosis, dialysis, and other phenomena.
- With excellent spatial resolution, MRI can provide information about tumors, strokes, shoulder injuries, infections, etc.

Disadavantages

- While MRI images are superior to x rays for certain types of tissue and have none of the hazards of x rays, they do not completely supplant x-ray images.
- MRI is less effective than x rays for detecting breaks in bone, for example, and in imaging breast tissue, so the two diagnostic tools complement each other.
- MRI images are also expensive compared to simple x-ray images and tend to be used most often where they supply information not readily obtained from x rays.
- Another disadvantage of MRI is that the patient is totally enclosed with detectors close to the body for about 30 minutes or more, leading to claustrophobia.

- It is also difficult for the obese patient to be in the magnet tunnel.