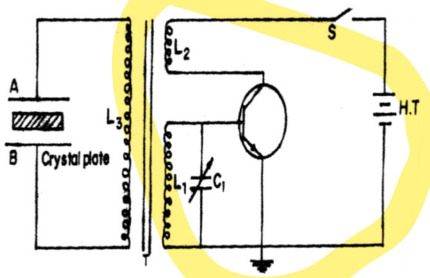
1. Explain the production of ultrasonic waves using piezoelectricity and magnetostriction with relevant diagrams.

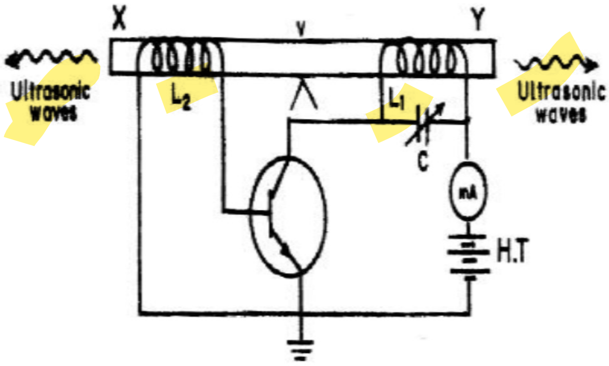
Piezoelectricity: - Ultrasonic waves are produced by a piezoelectric oscillator through the piezoelectric effect. If mechanical pressure is applied to one pair of opposite faces of certain crystals like quartz, equal and opposite electrical charges appear across its other faces. This is called as piezo-electric effect. Conversely, when an alternating voltage is applied to a piezoelectric material, it vibrates, producing ultrasonic waves. This is inverse piezoelectric effect or electrostriction. The frequency of these waves depends on the frequency of the applied voltage.



The quartz crystal is placed between two metal plates A and B. The plates are connected to the primary (L_3) of a transformer which is inductively coupled to the electronics oscillator. The electronic oscillator circuit is a base tuned oscillator circuit. The coils L_1 and L_2 of oscillator circuit are taken from the secondary of a transformer T. The collector coil L_2 is inductively coupled to base coil L_1. The coil L_1 and variable capacitor C_1 form the tank circuit of the oscillator.

When the battery is turned on, the oscillator produces high frequency alternating voltages with a frequency $f = \frac{1}{2\pi\sqrt{L_1C_1}}$. Due to the transformer action, an oscillatory e.m.f. is induced in the coil L_3. This high frequency alternating voltages are fed on the plates A and B. Inverse piezo-electric effect takes place and the crystal contracts and expands alternatively. The crystal is set into mechanical vibrations. The frequency of the vibration is given by $n = \frac{1}{2l}\sqrt{\frac{Y}{\rho}}$. Where l is length of the crystal, Y is Young's modulus of the crystal and ρ is density of the crystal.

Magnetostriction: When a magnetic field is applied parallel to the length of a ferromagnetic rod made of ferromagnetic materials such as iron or nickel, a small elongation or contraction occurs. This change in length (increase or decrease) produced in the rod depends upon, the strength of the magnetic field and the nature of the ferromagnetic materials. But, it does not depend of the direction of the field.



XY is a rod of ferromagnetic materials like iron or nickel. The rod is clamped in the middle. The alternating magnetic field is generated by electronic oscillator. The coil L_1 wound on the right hand portion of the rod along with a variable capacitor C. This forms the resonant circuit of the collector tuned oscillator. The frequency of oscillator is controlled by the variable capacitor. The coil L_2 wound on the left hand portion of the rod is connected to the base circuit. The coil L_2 acts as feed –back loop.

2. Explain the use of ultrasonic waves in bio imaging with an example.

Ultrasonic waves are used in bio-imaging to create real-time images of internal body structures by using sound waves to detect echoes from different tissues. In an ultrasound scanner, the transducer sends out a beam of sound waves into the body. The sound waves are reflected back to the transducer by boundaries between tissues in the path of the beam. When these echoes hit the transducer, they generate electrical signals that are sent to the ultrasound scanner. Using the speed of sound and the time of each echo's return, the scanner calculates the distance from the transducer to the tissue boundary. These distances are then used to generate two-dimensional images of tissues and organs.

During an ultrasound exam, the technician will apply a gel to the skin. This keeps air pockets from forming between the transducer and the skin, which can block ultrasound waves from passing into the body.

Medical ultrasound is divided into two categories: diagnostic and therapeutic. Diagnostic ultrasound is a non-invasive diagnostic technique used to image inside the body. Ultrasound probes, produce sound waves that have frequencies above 20KHz. But most transducers in current use operate at MHz range. Most diagnostic ultrasound probes are placed on the skin. But, for better image quality, probes may be placed inside the body via the gastrointestinal tract or blood vessels. In addition, ultrasound is sometimes used during surgery by placing a sterile probe into the area being operated on.

Diagnostic ultrasound can be further sub-divided into anatomical and functional ultrasound. Anatomical ultrasound produces images of internal organs or other structures. Functional ultrasound combines information such as the movement and velocity of tissue or blood, softness or hardness of tissue, and other physical characteristics, with anatomical images to create information maps. These maps help doctors visualize changes/differences in function within a structure or organ.

Therapeutic ultrasound does not produce images. Its purpose is to interact with tissues in the body such that they are either modified or destroyed. Among the modifications possible are: moving or pushing tissue, heating tissue, dissolving blood clots, or delivering drugs to specific locations in the body. The advantage of using ultrasound therapies is that, in most cases, they are non-invasive. No incisions or cuts need to be made to the skin, leaving no wounds or scars.

Another functional form of ultrasound is elastography, a method for measuring and displaying the relative stiffness of tissues, which can be used to differentiate tumors from healthy tissue.

Ultrasound is also used for imaging interventions in the body. For example, ultrasound-guided needle biopsy helps physicians see the position of a needle while it is being guided to a selected target, such as a mass or a tumour in the breast. It can also be used for minimally invasive surgery to guide the surgeon with real-time images of the inside of the body.

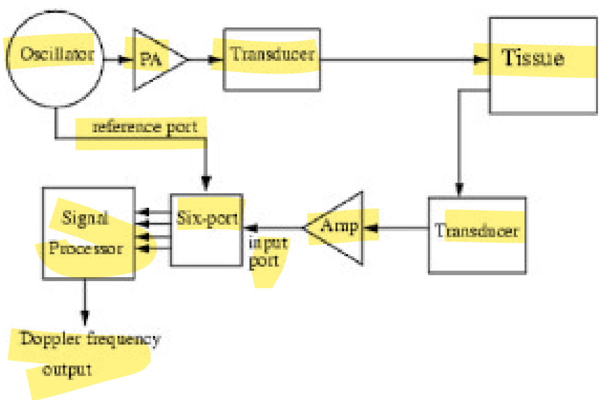
Example: - Echocardiogram uses ultrasound to visualize the heart's chambers, valves, and blood flow. An echocardiogram uses this process to create a moving image of the heart, showing the structure of the heart walls, the movement of the valves, and the speed and direction of blood flow. This method is safe because it doesn't use ionizing radiation and can be used to diagnose or monitor conditions like a developing foetus during pregnancy.

3. What is Doppler Effect? Explain its application in medicine with a block diagram.

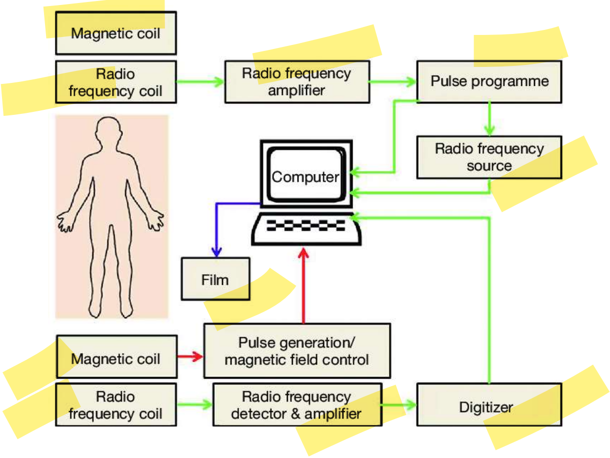
The Doppler Effect is the change in frequency or wavelength of a wave in relation to an observer who is moving relative to the wave source. When the source and observer are moving closer together, the frequency appears to increase and when they are moving further apart, the frequency appears to decrease.

In medicine, the Doppler Effect is most commonly utilized to measure blood flow through arteries and veins. High-frequency sound waves fed into the body bounce off moving objects, such as red blood cells. The frequency of the reflected waves changes based on the speed and direction of the blood flow which is the Doppler shift. Blood flowing against the sound waves creates a higher frequency shift. Blood flowing away from the sound waves creates a lower frequency shift. The ultrasound machine measures these frequency shifts, processes the data, and displays it visually or audibly. This allows medical professionals to assess blood velocity, detect blockages, narrowing or other vascular issues.

Transducer is a device containing piezoelectric crystals that converts electrical energy into sound waves and vice versa. The transducer driven by an oscillator sends waves into the body and captures the echoes. Receiver & Amplifier captures the returning echoes and amplifies the weak signals for processing. In the Signal Processor unit the Doppler shift is calculated by comparing the reference frequency with the received frequency. Display presents the processed information visually, often using color-coding or spectral waveforms to show velocity.



4. Explain MRI system components with schematic diagrams.



Magnetic Resonance Imaging (MRI) is a non-invasive imaging technology that produces three dimensional detailed anatomical images. It is used for disease detection, diagnosis, and treatment.

In MRI, magnetic field produced by a strong magnet forces protons in the body to align in the direction of that field. A radiofrequency current is passed through the patient, disturbing the alignment of protons. When the radiofrequency field is turned off, the protons realign with the magnetic field and the MRI sensors detect the energy released as the protons realign with the magnetic field. The time taken for the protons to realign with the magnetic field and the amount of energy released, depends on the environment and the chemical nature of the molecules.

The magnet is created by coils with an electric current running through it that then creates a magnetic field (say Z-axis). This electromagnet is responsible for the main permanent magnetic field. The constant electric current generates a lot of heat and liquid helium is used to cool down the system. The electromagnets can create a magnetic field strength of 7T.

Gradient coils are orientated in the x, y and z axes used to alter the gradient of the magnetic field. The coils are switched on and off rapidly, in 1ms or less.

RF (radiofrequency) coils are tuned to a particular frequency. They produce a magnetic field at right angles (XY plane) to the main magnetic field and also receive the MR signals being produced. To maximise the signal the coils have to be placed as close to the part being imaged as possible.

Types of RF coils are,

1. Standard body coil (transmit and receive): permanent part of the scanner. Used to image large parts of the body.
2. Head coil (transmit and receive): incorporated into a helmet and used for head scans.
3. Surface (or local) coils (receive only): these are small coils applied as close to the area being imaged as possible e.g. arm, leg, orbits, lumbar spine coils etc.
4. Phased array coils: multiple receiver coils that receive the signals individually but are then combined to improve the signal-to-noise ratio.
5. Transmit phased array coils -- to generate a controlled, shaped radiofrequency (RF) magnetic field allowing for precise field homogeneity and faster, more efficient imaging.

5. Explain the procedure and applications of nuclear cardiac stress test.

A nuclear cardiac stress test uses a radioactive tracer and a gamma camera to image blood flow to your heart at rest and during stress (exercise or medication), revealing blocked arteries, heart damage, or poor pumping function, helping diagnose coronary artery disease, guide treatment, and assess heart attack risk by showing "cold spots" where blood flow is low.

The patient will fast, avoid caffeine/tobacco, and wear comfortable clothes; electrodes (ECG) and a blood pressure cuff are placed on the patient. The test is conducted in two phases:

1. **Resting Phase:** First, the test is conducted while the patient is at rest. A radiotracer which is a safe, radioactive substance absorbed by healthy heart muscle; poor flow areas don't absorb it well, is injected into the patient’s bloodstream. A gamma camera takes initial pictures while the patient rests. Images of heart are taken to assess baseline heart function and blood flow at rest.
2. **Stress Phase:** In the second phase, patient is either asked to exercise on a treadmill or receive a medication to dilate blood vessels or increase heart rate as if the patient is physically active if exercise isn't possible. The radiotracer is injected again, and second set images are taken of heart to assess blood flow during exercise or stress.

A cardiologist compares rest and stress images to find areas with poor blood flow (cold spots which are the areas on the scan with little to no tracer, indicating reduced blood flow or damaged tissue.).

Applications:

1. Detects blockages in coronary arteries that limit blood flow during high demand.
2. Identifies areas of the heart muscle damaged by a past heart attack.
3. Evaluates how well treatments (like bypass surgery or stents) are working.
4. Predicts future heart problems or risk of heart attack.
5. Shows how well the heart muscle pumps.

explain the principle and procedure of external bean radiotherapy and internal radiotherapy

External Beam Radiotherapy (EBRT)
Principle: EBRT uses high-energy radiation beams (X-rays, gamma rays, or electrons) generated outside the body to destroy cancer cells by damaging their DNA while minimizing harm to surrounding healthy tissue.
Procedure: The patient is positioned carefully, and the tumor location is identified using imaging. A linear accelerator directs focused radiation beams at the tumor from different angles over several treatment sessions.

Internal Radiotherapy (Brachytherapy)
Principle: A radioactive source is placed inside or near the tumor, delivering a high radiation dose directly to cancer cells with minimal exposure to nearby tissues.
Procedure: Radioactive implants, seeds, or capsules are inserted temporarily or permanently into the affected area under medical guidance. The radiation acts locally to destroy cancer cells.

Both methods aim to control or eliminate tumors effectively.