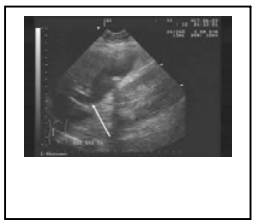
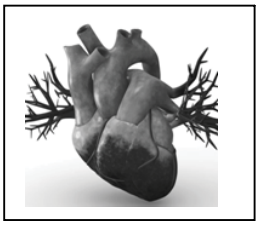
Chapter fourteen

PHYSICS TO SAVE LIFE



[Establishing a relationship between physics with biology, a new subject has been developed, which is called Bio-physics. We need a healthy, strong and disease free body to survive. To keep a sound health we need proper treatment. In medical science, proper diagnosis is an important issue. Different types of medical instruments are prepared based on different theories and principles of physics. These devices function by utilizing different principles and theories of physics. A few of such instruments will be discussed in this chapter.]

By the end of this chapter we will be able to-

1. Explain the basis of bio-physics.
2. Explain the contributions of Jagdish Chandra Bose in bio-physics.
3. Explain that human body runs following the rules of physics.
4. Explain the applications of ideas and theories of physics in the instruments for diagnosis of diseases in medical science.
5. Explain the hazards of using modern technology and devices and mechanism of prevention.
6. Conscious about the necessity of diagnosis of diseases for proper treatment and raise consciousness among others.
7. Appreciate the contributions of science and technology for diagnosis of diseases.

14.1 Basis of bio-physics

Bio-physics is such a branch of science which is developed on the basis of a number of branches of science. Theories and methods of physical science are employed in biophysics to study a system of biology. Biology is the science of studying living world. How plants and animals collect food, communicate, percept from the environment and reproduce are discussed in biology. On the other hand the mathematical rule which nature follows is the subject-matter of physics. For a long period, the scientists believed that the laws of living world and physical world are different. But with the progress of physical and biological science, a deep harmony is found between these two apparently different disciplines. At first physics and biology has evolved as two different subjects. The mutual relationship and coordination between these two subjects has increased a lot with the advancement of science. It was thought before that living world follows a different rule and the laws of physical science are applicable only for the inanimate objects. But now we know that the animal body can be compared to a machine from many aspects and it is possible to explain many behaviors of animal body with the help of physical laws. Actually, the laws of physics are universal. So, not only the physical world, but also the animal kingdom can be explained with the help of physics in many cases. This is the basis of bio-physics.

The challenge of bio-physics is to explain different complexities of life on the basis of simple laws of physics. Bio-physics is a powerful tool to reach at the depth of life by investigating different secrets of life and analyzing different events using mathematics and physics. Bio-physics is a bridge between biology and physics.

14.2 Contributions of Jagadish Chandra Bose

Acharya Sir Jagdish Chandra Bose was a physicist as well as a biologist. In our sub-continent he is the first internationally recognized scientist. Bose family hailed from the village Rarikhal of Bikrampur under district of Dhaka. He was born in Mymensingh on 30th November, 1958. His father Bhagawan Chandra Bose was a deputy magistrate in the district of Faridpur. Bose's education started at a vernacular school in Faridpur. Next he got admitted to Hare school and Saint Xavier's school and college in Kolkata and passed his student life. After completing B.A. he went to England for higher study in the year 1880. His student life in England was from 1880 to 1884. He completed the B.A. degree with honours in physics from University of Cambridge and a B. Sc. degree from University of London. In 1885, he started as a professor of physics in Presidency College. Though there were not adequate facilities of research in Presidency College, he carried out his research work. As there was scarcity of time in day, he had to conduct his research work in night many times. In the laboratory he researched a lot about, how radio signals can be transmitted to a distant place without the help of wire and succeeded. In 1895, for the first time in history he sent radio signal to a distant place without wire and demonstrated in public. He has mentionable contributions in micro-wave research. He was the first who was able to reduce the wavelength of generated

wave to millimeter level (about 5 mm). He was the first to use a semiconductor junction to detect radio signal. Instead of taking commercial benefit from this invention, he opened it for all, so that others can develop this research more.

Subsequently, Jagadish Chandra Bose made a number of important and pioneering discoveries in plant physiology. Among these, invention of crescograph to record the growth of plants, extremely slight movement and how plants respond to various stimuli are notable.

His major contribution in the field of bio-physics is the nature of conduction of the stimuli in plants. Earlier it was thought that, the nature of response of plants to different stimuli is chemical, but he became able to show that it is electric in nature.

In 1917 he established 'Bose Biggan Mandir' in Kolkata in order to research about plant physiology. His writings in Bengali language are compiled in a book named 'Abyakta'. 'Response in the Living and Non-Living' is a mentionable book of him. Jagadish Chandra Bose expired dated on 23rd November 1937.

14.3 Human body and machine

We use different types of devices to meet our various needs of everyday life such as- automobiles, refrigerator, television, steam engine, internal combustion engine etc. Many people designated human body as a machine. Though human body is not a machine at all, it behaves as a machine in many aspects. As like as a machine, it is also made up of many small parts or organs, absence or infirmity of one organ the activities of the whole body is disturbed. Each part of the body, like each part of a machine, does special jobs.

Each organ of human body is interconnected with other organs, each organ runs at its own individual speed, but all function in a specific way and there is a predetermined relationship to each other. In this sense, the human body is analogous to the most complicated man-made machines.

Heart, kidneys, lungs, liver etc. are such parts of human body. As for example- heart is actually an automatic pump, which is able to circulate blood throughout the whole body by its own electric signal without any external stimulation. On the contrary, kidney is a special filtration machine which eliminates the nitrogenated waste materials of the body. Due to the coordination of functions of such small machines the whole human body remains active.

Human body is like an organic machine. Energy is needed in a machine to do work. In different engines using fuels like petrol, diesel, CNG etc. we convert chemical energy into mechanical energy. Similarly, human body also transforms chemical energy into

mechanical and heat energy by food ingestion and respiration. Therefore, human body is like an organic machine in fact. But, in many aspects, human body is more amazing than the most complex machine made by humans. Human body can perform such functions which is not possible for any machine. For instance- human body develops from only one cell. With the passage of time, this single cell transforms into a complete human body, which is build with thousand billions of cells. But this doesn't happen in case of any machine. Sometimes functions of the whole body stops due to infirmity of only one part of the body. For example- when function of the heart stops, functions of all other parts of the body stops too, and functions of the brain also stops very quickly.

14.4 Instruments used for diagnosis of diseases

Once the doctors were used to identifying diseases by observing different external symptoms of the patients and prescribed medicine and diet accordingly. Modern instruments to identify diseases were not invented at that time. As a result, it was not possible to locate the exact positions of different organs. In addition, in which degree a particular organ of the patient is infected was not possible to know. Various types of instruments are invented utilizing different technologies of science to diagnose diseases. With the help of these instruments it became possible to determine diseases properly. It is impossible for a doctor to identify a disease without the right instrument, which is necessary to perform that particular test. The specific cause for a particular disease became known to us due to the invention of different devices. Once people used to believe different superstitions related to disease due to ignorance. In the modern society, the mortality rate is decreased by a large amount. The principal reason behind this is that physical instruments are being used for the purpose of diagnosis and treatment.

In this section, some of the instruments which are generally used for diagnosis of diseases are discussed.

X-ray

X-ray is a kind of electromagnetic radiation. The wavelength of X-ray is much lesser than that of the ordinary light. Its wavelength is about 10^{-10} m. X-ray was invented by Wilhelm Roentgen in 1895. Another name of Roentgen ray is X-ray. When the nature of Roentgen ray was not known, for being an unknown ray it was named X-ray. The power of X-ray to penetrate any material becomes more as its wavelength gets smaller. Ordinary light is visible and divided into different colours, but X-ray is invisible. If an opaque medium is placed in the path of ordinary light, it cannot penetrate the medium. On the other hand X-ray has high penetrating power. X-ray is produced in an X-ray tube. X-ray tube is a vacuum glass tube. There are two electrodes placed at the two ends of the glass tube. One of them is called cathode and the other is anode. There is a coil made of tungsten in cathode which is called filament. The cathode is heated by the current flowing through the filament. As a result, the electrons are freed and come out. If a high potential difference is applied between the electrodes, the electrons are accelerated with

very high speed and hit the target anode. Due to this, the motion of electrons suddenly stops and X-ray is produced. Here, the kinetic energy of electrons transforms into electromagnetic wave. This radiation of small wavelength is the X-ray. Therefore, if electrons with high speed strike a metal, then a type of radiation of unknown nature having high penetrating power and of very small wavelength is produced from the metal. This radiation is called is called X-ray. In figure 14.1 the essential parts of an X-ray tube are shown.

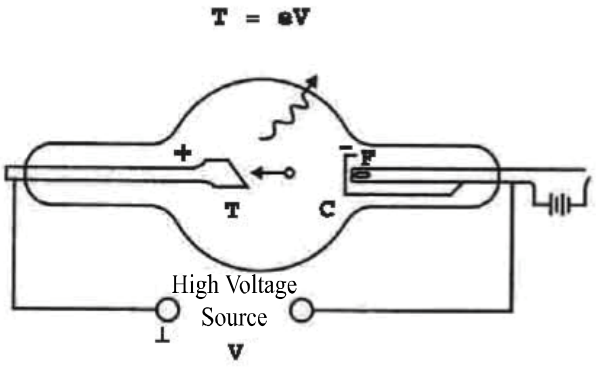


Figure: 14.1

Figure: 14.2

X-ray is used for various purposes. It has tremendous contributions to diagnose diseases in medical science.

1. Displaced bones, cracks in bone, bone fracture etc. can be identified very easily with the help of X-ray.
2. X-ray can be used to diagnose any type of disease in face, for example- to identify ulcer and decay at the root of tooth X-ray is used.
3. Intestinal obstruction can be identified by X-ray of abdomen.
4. The stones present in the gall bladder and kidneys can be identified by X-ray.
5. The diseases of lungs like pneumonia; lung cancer etc. can be traced by X-ray of chest.
6. X-ray is also used for treatment purpose. It can kill cancer cells. Cancer can be treated using radiotherapy.

   Necessary precautions should be taken so that unnecessary exposure of X-ray radiation cannot harm the patient. For this, the patient should be covered with apron made of lead as much as possible. X-ray of abdomen and pelvic region of pregnant women should not be done except in case of emergency. Apron made of lead must be used for other X-ray tests.

Ultra Sonography

Ultra sonography is a procedure that depends on the reflection of sound of high frequency. When sound wave of high frequency is reflected from an organ or muscle within the body, then an image analogous to that organ is formed in the monitor by the reflected waves.

The frequency of the ultrasound is 1-10 MHz which is used for diagnosis of diseases. In an ultra sonography machine, the high frequency ultrasonic waves are produced by electrically stimulating a crystal called a transducer. In an ultra sonography machine, the ultrasonic waves are transformed into a narrow beam. Next this beam is directed toward the organ whose image is to be recorded.

The beam is reflected, absorbed or transmitted by the organ toward which they are directed, depending on the nature of the surface they strike.

As the beam strikes an interface or boundary between tissues of varying density (e.g., muscle and blood) part of the sound waves are reflected back to the transducer as echoes. The echoes are then converted into electrical impulses that are displayed on a monitor presenting a 'picture' of the organ or muscle under examination.

Figure: 14.3 Ultrasonography

The most important use of ultra sonography is in the field of obstetrics and gynecology. With this, the fetal size, maturity and normal and abnormal position of fetus can be known. It is a fast, relatively safe, and reliable technique in the field of gynecology. Uterine tumors and other pelvic masses can be identified by ultra sonography.

Ultra sonogram is used in medical tests of different kinds, such as- gall bladder stone, defect in the heart and identification of tumors. When ultrasound is used for examination of the heart, then it is called echocardiography. Ultra sonography is a safer diagnosing method in comparison to X-ray. Yet, it is to be used for a very limited time. Besides, the transducer should always be kept in movement, so that it does not become static at any position.

CT scan

CT scan stands for Computed Tomography Scan. In medical science it is the process of creating image. Tomography is the process of generating a two-dimensional image of a slice or section through a 3-dimensional object. CT scanner is a large machine and uses X-rays. Where X-ray forms a two dimensional image of a three dimensional organ inside the body, there the image formed by CT scan machine is three dimensional.

The CT scan machine uses digital geometry processing to generate a three dimensional of the inside of an object. The three dimensional image is made after many 2-

dimensional X-ray images are taken around a single axis of rotation. This job is done using a computer. A CT scanner emits a series of narrow beams through the human body as it moves through an arc. While an X-ray machine sends just one X-ray beam through the body of the patient. As a result, the final picture formed by CT scan is far more distinct and detailed than an X-ray one. The X-ray detector used in a CT scanner can detect hundreds of different levels of density in patient's body. This data collected by the detector is transmitted to a computer. Computer builds up a three dimensional picture of the part of the body and displays it on the screen.

Three dimensional images of soft tissue, blood carrying veins or arteries, lungs, brain, etc. is obtained by CT scan. CT scan is used for detection of cancer in lever, lungs and pancreas. The image obtained by CT scan helps a physician to detect tumor, to determine the size and position of the tumor and how much the tumor infected the adjacent tumor. By the CT scan of head, any type of bleeding inside the brain, swelling of artery and existence of tumor can be detected. Whether there is a problem in the blood circulation is also known by the CT scan. Generally CT scan test is not done in case of pregnant women. If dye is used in CT scan test there is a possibility of allergic reaction.

Figure: 14.4 CT Scan

Magnetic Resonance Imaging (MRI)

MRI is the abbreviated form of the English term 'Magnetic Resonance Imaging'. In MRI machine extended image of an organ or place of the body is formed utilizing strong magnetic field and radio wave. MRI machine works depending on the physical and chemical principles of 'Nuclear Magnetic Resonance'. Using this principle, information about the nature of any molecule can be known. MRI is a painless and safe disease

diagnosis method. X-ray or any other kind of radiation is not used in this machine. The signals received from the part of the body which is scanned with MRI are transformed using computers and a very distinct image of that part of the body is formed. Each individual image acts as a slice of the organ of the body. Thus a number of images are formed, which exhibits all the characteristics of that part of the body.

Figure 14.5: MRI machine

The image obtained by MRI can be compared to each individual slice of bread. When one slice of the bread is picked up, then the interior part of the bread can be seen along with the slice. Similarly, each image found by MRI helps to view everything inside the body. The intensity of the wound is determined using MRI in case of twisting of ankles and back pain. MRI is an extremely valuable test to form an extended image of brain and spinal cord.

ECG

ECG is the abbreviated form of the word electrocardiogram. ECG is a diagnostic procedure that is routinely used to assess the electrical and muscular functions of the heart. We know that the heart produces tiny electrical impulses without any external stimulation. This electrical signal spread through the heart muscle to make the heart contract. We detect these impulses by the ECG machine. With the help of ECG we can measure the rate and rhythms of heartbeats. It gives indirect evidence of blood flow in the heart.

The electrodes placed on the different parts of the body detect the electrical impulses coming from different directions within the heart. To get a complete picture of the heart, twelve signals are identified using ten electrodes. An electrode lead is placed on each arm and leg i.e. total of four and rest six electrodes are placed across the chest wall [Figure 14.6]. The signals received from each electrode are recorded. The printed view of these recordings is the electro gram.

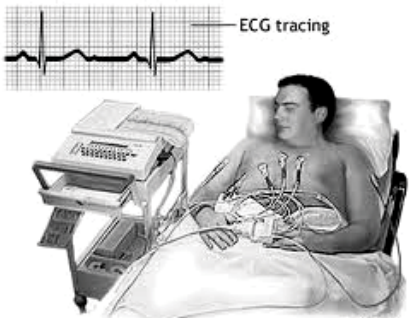


Figure 14.6: ECG procedure

For a healthy person, there are normal patterns of the electrical impulses from each electrode. If any type of abnormal condition is observed in the heart of a person, then the patterns from the electrodes will be different from that of a normal pattern.

Generally, ECG test is done to find the cause of external symptoms such as- palpitations, irregular and fast heart beat, chest pain etc. of some diseases. Sometimes it is done as a part of routine tests- for example, before you have an operation you can take the help of ECG.

The heart disorders that can be detected by ECG are:

1. Abnormal heart rhythms- for example, if the heart is very fast, very slow or irregular.
2. A heart attack- which happened recent or some time ago.
3. An enlarged heart- i.e. the size of the heart is increased.

Endoscopy

Generally endoscopy means looking inside something. But by endoscopy we mean looking interior of a hollow organ or cavity of the body for medical reasons using an endoscope machine. We examine the interior side of hollow organs of our body using endoscope machine.

Figure: 14.7 Endoscopy

In an endoscope machine, there are two tubes. Through one of them light is transferred to a definite organ of patient's body from outside. Due to the total internal reflection of light on the inner wall of the optical fiber, bright light enters the body cavity of patient.

This light illuminates the diseased or injured organ. The reflected part of light returns back through the second fiber optic tube in the same way. The reflected light enters the eyes of doctors through the eyepiece lens. As a result, the doctor can see what is happening inside the examined organ.

Endoscopy allows doctors to check for any type of irritation, ulcer, inflammation and abnormal tissue growth in the internal organ. Endoscopy is used to examine a number of different organs, including:

(A) the lungs, central partition of the chest; (B) the stomach, small intestine, large intestine or colon; (C) the female reproductive organ; (D) the abdomen and pelvis; (E) the inside of urinary bladder; (F) the nasal cavity and sinuses surrounding the nose; (G) the ears.

Radiotherapy

The word radiotherapy is the abbreviated form of the word 'Radiation therapy'. Different diseases like cancer, abnormal nature of thyroid gland, some diseases concerning blood are treated using it. Generally radiotherapy destroys cancer cells utilizing highly energized X-ray. It destroys the power of multiplication of the cells by damaging the DNA inside the tumor cell. Mainly, it is the application of ionizing (radioactive) radiation in the treatment of disease.

Radiotherapy is of two types:

1. External beam radiation or external radiotherapy

2. Internal radiotherapy

In case of external radiotherapy highly energized X-ray, cobalt radiation, electron or proton beams are applied from outside the body. The beam is applied directing to that site of the body where the tumor is located. As a result, the growth and power of multiplication of the cancer cells get destroyed. In this process a very few number of healthy cells also get affected. Yet, our aim is to destroy cancer cells as many as possible than the healthy cells. Most of the healthy cells that got damaged can repair themselves.

Figure 14.8: Radiotherapy machine

In case of internal radiotherapy, radiotherapy is applied from inside the body of a patient. In this process patient takes radioactive liquids as drinks or radioactive liquids are introduced to the body of patient through injection. Radioactive phosphorus in case

of blood cancer, radioactive strontium in bone cancer and radioactive iodine in thyroid cancer is used in the liquid. This process is called brachytherapy.

ETT

ETT is the short form of 'Exercise Tolerance Test'. It is a test of the stimulated heart. Electric activities or functions (rate or rhythm) of the heart during exercise are recorded by ETT. In fact, it is an ECG test of the patient while doing exercise. This test is very important for identifying the diseases related to coronary artery. During this test, extra stress of exercise is imposed on the heart.

Figure 14.9: ETT test

Partial blockage developed in the coronary arteries of heart is identified by this test. Generally, this type of abnormal condition in patient's body cannot be identified while taking rest.

During the test, the patient is instructed to ride a stationary bicycle or to walk continuously on a treadmill machine. The physician records the ECG of the patient during exercise. By adjusting the speed of rotation of the wheel and slope of the surface, the degree of stress is gradually increased. Physicians become able to identify the changes that occur in the patient's heart during exercise through ETT.

Angiography

Angiography is such an imaging test where X-ray is used to view the blood vessels of the body. This test is used to study whether the arteries or veins are narrow, blocked or enlarged in the body. The normal flow of blood is obstructed in the body when the blood vessels are blocked and they are narrow or not wide. During angiogram the physicians inject a liquid through a thin and flexible tube into the patient's body. The liquid is called 'dye' and the tube is called 'catheter'. The blood vessels become visible on an X-ray due to the use of dye. This dye is later eliminated from the body through kidneys and urine. Through a definite entry point the catheter is introduced into a definite artery or vein. The entry point may be in any blood vessel of the body. Sometimes, the 'dye' used is also termed as 'contrast'.

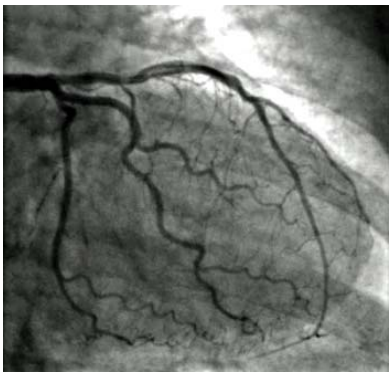


Figure: 14.10

The causes for which the physicians generally recommend an angiogram are as follows-

A. Blockages of the arteries outside the heart.
B. Enlargement of the arteries
C. For understanding the kidney artery conditions
D. Problems with veins

Sometimes the physicians can also treat a blockage in a blood vessel without any surgery during an angiogram. The mechanism or the procedure following which the blocked arteries are cleared during an angiogram is called angioplasty.

Isotopes and its uses

Isotopes are the variants of a definite element. Atoms of the same element having different mass number are called isotopes. That is, in isotopes of an element, the number of protons is same but the number of neutron is different. The number of protons in the nucleus of atom of an element identifies the element uniquely. But in principle, an element may have any number of neutrons. The total number of protons and neutrons present in the nucleus of an element is its mass number. For this reason, each isotope of an element has different mass number. Carbon can be considered as an example. Three isotopes of carbon ${}^{12}_{6}C$, ${}^{13}_{6}C$ and ${}^{14}_{6}C$ - the mass number of them are 12, 13, 14 respectively. The atomic number of carbon is 6, i.e. there are six protons in each carbon atom. As a result, the number of neutrons in the isotopes of carbon is 6, 7 and 8 respectively.

In the field of medical science, radioactive isotopes are widely used in nuclear medicine. Radioisotopes have two types of applications.

A. For diagnosis purpose
B. For treatment purpose

The presence of harmful cancer tumor anywhere in the body or in an organ can be identified by radioisotopes. The energetic gamma rays emitted from the isotope Co-60 is used for the treatment of cancer. The gamma rays emitted from Co-60 is used to sterilize surgical instruments. Iodine-131 (^{131}I) is used for the treatment of the abnormal growth

of the thyroid gland. Technetium-99m is the most widely used radioactive isotope for diagnostic studies in nuclear medicine. Technetium is used for brain, bone, liver and spleen imaging or scanning. Blood- Leucaemia caused by excess of white blood cell is treated with phosphate of radioactive phosphorus-32. In nuclear medicine, radioisotopes are introduced into the body of the patient through the veins to diagnose diseases. The radioactive materials are selected depending on the organ which will be examined. Besides these, radioisotopes are widely used in the field of agriculture, food preservation, controlling pests and industries.

Exercise

A. Multiple choice questions

Tick (√) the correct answer.

1. What is concerned to scientist Jagdish Chandra Bose?
   i. establishment of Bose Mandir
   ii. uses of radioactive element
   iiil invention of Cresco graph

Which of the following is correct?

(a) i (b) i and ii

(c) i and iii (d) i, ii and iii

1. The cause of distinct vision of a bone in a X-ray film is-

(a) Bone is non-penetrable by X-ray (b) muscles are non-penetrable by X-ray

(c) Wavelength is very large (d) high penetrating power

3. The technology to examine blockage in a fine blood vessel-

(a) angiogram (b) angioplasty

(c) ETT (d) ECG

4. How the rate of heart beat and rhythm is measured?

(a) Identifying electric signals (b) using X-ray

(c) by nuclear magnetic resonance (d) using sound wave

B. Creative questions

Binu's aunt is going to be mother. She goes to doctors regularly for check-up. In one month, the doctor advised her to have a test to know the exact position and size of the fetus. She made the test done using ultra sonography and the doctor has got a clear concept about the fetus through it.

(a) What is the elaborated form of MRI?
(b) Why the isotopes are the variants of a definite element?
(c) Discuss the role of ultra sonography to get a clear idea about the fetus.
(d) Is it possible to perform this test with the help of any other medical technology? State logic in favour of your answer.

C. General questions

1. Does physical and biological world follow totally different rules?
2. How biophysics was originated?
3. Why the laws of physics can be applied for the living world?
4. Describe the contributions of Jagdish Chandra Bose in physics.
5. What are his contributions in biophysics?
6. Explain- human body sometimes behaves as a machine.
7. Human body is an organic machine- give arguments in its favour.
8. How instruments invented by physics can be used for treatment purposes?
9. Name some instruments used for diagnosis of diseases.
10. What is X-ray? Write down its applications in diagnosis of diseases and their treatments.
11. How ultra sonography identifies diseases in the field of treatment?
12. Describe the images found by MRI.
13. Which diseases can be identified by ECG?
14. For what purposes endoscopy machine is used?
15. Why radiotherapy is used in the field of treatment?
16. ETT is a kind of ECG- describe.
17. In which cases angiogram is done?
18. What is isotope? For what purposes it is used in treatment?

2013

Academic Year

9-10 Physics

দারিদ্র্যমুক্ত বাংলাদেশ গড়তে হলে শিক্ষা গ্রহণ করতে হবে

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