

The Electromagnetic Wave Application of X-Ray in Medical Treatment

Takele Teshome Somano

Department of Physics, Natural and Computational Science, Wolaita Sodo University (WSU), Sodo, Ethiopia

Email address:

Takele.teshom@wsu.edu.et

To cite this article:

Takele Teshome Somano. The Electromagnetic Wave Application of X-Ray in Medical Treatment. *American Journal of Physics and Applications*. Vol. 10, No. 4, 2022, pp. 62-68. doi: 10.11648/j.ajpa.20221004.12

Received: August 12, 2022; **Accepted:** September 21, 2022; **Published:** October 28, 2022

Abstract: The concept underlying the use of X-rays in scientific treatments is called radiation scattering, which incorporates the scattering of photons, neutrons, or both. When carried out in scientific procedures, X-rays interact with the virtual shells of atoms in solids with the useful resource of the usage of scattering, depending on the X-form rays and the radiation period. Soaking up and emitting electrons. Nuclei are incredibly heavy a very good manner to be detected with the useful resource of the usage of X-ray. Bragg that there have been conditions for a sharp pinnacle in scattered radiation intensity. Placing a patient's body thing with inside the front of an X-ray technician, who then lighting it with short bursts of radiation to make an image for scientific use X-ray the only versions amongst X-rays and ordinary moderate are their multiplied electricity and comparable wave. X-rays are applied in medicine for scientific analysis. Dentists use them to discover complications, cavities and impacted tooth. Soft body tissues are apparent to the waves. Bones and tooth block the rays and show up as white on the black background. We find out the use of x-ray as a treatment is referred to as radiation treatment and in big component used for the management (which incorporates palliation) of cancer. It requires higher radiation energies than for imaging a lone.

Keywords: X-Ray, Radiation, Electrons Absorption, Photon, Wave

1. Introduction

1.1. Backgrounds of the Project

A project's background is a formal document containing a common description of what is expected to be done within the project, what prerequisites for the project are and how to produce the expected amount of work. The document is to be created prior to the implementation process to make a foundation for further goal setting and implementation. Creating a clear and unambiguous background of a project is one of the most important actions to be taken at the very beginning to ensure success of the project at the end. The clearer the background is the more accurately and understandably the project will be spelled out. Below I give a definition of project background. Background is one of the key characteristics of a project to explain why initiate the project, what prerequisites are and what results are supposed to be obtained at the successful completion.

1.2. X-Rays

X-ray is a form of electromagnetic radiation, which has X-ray, has a wavelength in the range of 0.01 to 10 nanometers x-ray corresponding to frequencies in the range 30 pet hertz to exert (3×10^{16} Hz to 3×10^{19} Hz) and energies in the range 100 eV to 100 Kev. The wavelengths are shorter than those of ultraviolet rays longer than of gamma rays. In many languages X-radiation is called Pontgen radiation, after wilhelem pontgen, [1] who is usually credited as its discoverer, and who had named it X-radiation to signify an unknown type of radiation. [2] Spelling of x-ray(s) in the English language includes the variants X-ray(s). [3] X-rays with photon energies above 5-10 Kev (below 0.2-0.1 nm wavelength) are called hard X-rays, while those with lower energy are called soft X-rays. [4] Due to their penetrating ability hard X-rays are widely used to image the inside of objects.

Example: In medical radiography and airport security. As a result, the term x-ray is metonymically used to refer to a radiographic image produced using this method in addition to the method itself. Since the wavelength of hard x-rays are

similar to the size of atoms they are also useful for determining crystal structures by x-rays crystallography. By contrast soft x-rays easily absorbed in air and the attenuation length of 600 eV ($\sim 2\text{nm}$) x-rays in water is less than 1 micrometer. [5] The distinction between x-rays and gamma rays is not universal. One often sees the two types of radiation separated by their origin x-rays are emitted by electrons, while gamma rays are emitted by the atomic nucleus. [6-9] an alternative method for distinguishing between x-ray and gamma radiation is on the basis of wavelength with radiation shorter than some arbitrary wavelength such as 10^{-13} defined as gamma rays. [10] These definitions usually coincide since the electromagnetic radiation emitted by x-ray tubes, generally has a longer wavelength and lower photon energy than the radiation emitted by radioactive nuclei.

1.3. Objective of the Paper

1.3.1. General Objective

The general objective of the project work was to determine and understand application of X-ray in medical treatment.

1.3.2. Specific Objective

Specific objective of my project specified the general objectives.

- 1) To acquire basic knowledge on application of X-ray in medical treatment.
- 2) Briefly explanation of the source, property, uses and efficient of X-ray.
- 3) To determine the x-ray characteristics.

1.4. Significant of Project

This project work help the science of students to get the concept of x-ray properties and clear explanation for the question of what is the application of x-ray in medical treatment and what the function of it?

1.5. Scope of the Project Work

To deal the application of X-ray in medical treatment need further knowledge sufficient time and so on, so to do this project work deal with conserving the ability we focused on the application of x-ray in medical treatment.

1.6. Limitation of Project Work

During conduct of the project work there is much storage of materials such as:

- 1) Internet.
- 2) Stationary material.
- 3) Computer access.
- 4) Science text books or reference materials.
- 5) E-library.
- 6) Money and time.

2. Properties and Sources of X-Rays

2.1. Properties of X-Rays

X-ray with energies ranging from about 100eV to 10 MeV is

classified as electromagnetic waves, which are only different from radio waves light, and gamma rays in wavelength and energy. X-rays show wave nature with wavelength ranging from about 10 to 10^3 nm.

According to quantum theory, the electromagnetic frenetic wave can be treated as particles called photons or light quantum. Some of the essential characteristics of photon such as energy and momentum X-rays travel in a straight line and diverge from the point origin. X-rays have similar properties to light. When a high voltage with several tens of kV is applied between two electrodes, the high speed electrons with sufficient kinetic energy drawn out from the cathode, collide with the anode (metallic target). The electrons rapidly slow down and lose kinetic energy. Since the slowing down patterns (method of losing kinetic energy) vary with electrons, continuous x-rays with various wavelengths are generated. When an electron loses all its energy in a single collision, the generated x-ray has the maximum energy or the shortest wavelength. The value of the shortest wavelength limit can be estimated from the accelerating voltage (V) between electrodes [11] X-rays are absorbed by matter; the absorption depends on the atomic structure of the matter and the wavelength of the x-ray beam. They are invisible to eye, cannot be heard and smelt. They cannot be reflected, refracted or deflected by magnetic or electric field. They show properties of interference. Diffraction and refraction are similar to visible light. X-rays can penetrate liquids, solids and gases; the degree of penetration depends on quality, intensity and wavelength of x-ray beam. They do not require any medium for propagation. X-ray induces color changes of several substances or their solutions. X-rays are absorbed by matter; the absorption depends on an atomic structure of the matter and the wavelength of the x-ray beam. X-rays interact with materials they penetrate and cause ionization. X-rays have the property of attenuation, absorption and scattering they also show heating effect [35].

2.2. Sources of X-Rays

Since x-rays are emitted by electrons, they can be generated by an x-ray tube a vacuum tube that uses a high voltage to accelerate the electrons released by a hot cathode to a high velocity. The high velocity electrons collide with a metal target the anode, creating the X-rays. [12] In medical x-ray tubes the Rhenium (5%) and Tungsten (95%), but sometimes Molybdenum for specialized applications such as when softer X-rays are needed as in Mammography.

In crystallography, a copper target is most common with Cobalt often being used when fluorescence from Iron content in the sample might otherwise present a problem. The maximum energy of the produced x-ray photon is limited by the energy of the incident electron which is equal to the voltage on the tube times the electron charge, so on 80keV tube cannot create X-rays with energy greater than 80keV. When the electrons hit the target x-rays are created by two different atomic processes x-ray, fluorescence's. If the electron has enough energy it can knock an orbital electron out of the inner electron shell of a metal then fill up the vacancy

and x-ray photons are emitted.

This process produces an emission spectrum of x-rays at a few discrete frequencies sometimes referred to as the spectral lines. The spectral lines generated depend on the target (anode) element used and thus are called characteristics lines. Usually these are transitions from upper shells into K shell (called K-lines), L shell (called L-lines) and so on. Bremsstrahlung, this is radiation given off by the electrons as they are scattered by the strong electric field near the high-Z (proton number) nuclei. These X-rays have a continuous spectrum. The intensity of the incident electrons are the voltage on the x-ray tube. So the resulting output of a tube consists of a continuous bremsstrahlung spectrum falling off to zero at the tube voltage, plus several spikes at the characteristic lines. The voltage used in diagnostic x-ray photons range from roughly 20 to 150keV. [13] Both of these x-ray production processes are inefficient with a production efficiency of only about 1% and hence to produce a usable flux of x-rays, most of the electric power consumed by the tube is released as waste heat. The x-ray tube must be designed to dissipate this excess heat. Short nanosecond bursts of x-rays peaking at 15keV in energy may be reliably. X-ray produced by peeling pressure-sensitive adhesive tape from its backing a moderate vacuum. This is likely to be the result of recombination of electrical charges produced by turbo electric charging. The intensity of x-ray Chemiluminescence is sufficient for it to be used as a source for x-ray imaging. [14] Using sources considerably more advanced than sticky tag, at least one startup firm is exploiting turbo charging in the development of 8 highly portable ultra-miniaturized X-ray devices [15]. A specialized source of x-rays which is becoming widely used in research is synchrotron radiation, which is generated by particle accelerators. Its unique features are x-ray outputs many orders of magnitude greater than those of x-ray tubes, wide x-ray spectra, excellent collimation and linear polarization [16].

In modern society x-ray viewed as the means of social and economic problems and the quantitative methods of data base reports, this x-ray treatment is critical looking at the existing the project that is significant to the work that you are carrying out and decide which idea or information are important to the project and addition to:

1. Concepts find out solution of x-ray in medical treatment.
2. Theoretical and physical interaction of x-ray in medical treatment.
3. The source of information for this project is related document reference from library, many text books (grade 11, grade 12 and from college and university books, Internet explorer) the information from those materials are collected as it was use full to this project. The project involves collects information in some books and journal thus available in libraries. And concluded what we done in this project paper and detail study derivation of Bragg's law by using two successive parallel planes.

2.2.1. X-Ray Interact with Matter

X-rays interact with matter in three main ways, through

photo absorption, Compton scattering and Rayleigh scattering.

The strength of these interactions depend on the energy of the x-rays and the elemental composition of the material, but not much on chemical properties since the x-ray photon energy is much higher than chemical binding energies. At higher energies the Compton Effect dominates [26].

2.2.2. Photoelectric Absorption of X-Ray

In this process a photon disappears and an electron is ejected from an atom. The electron carries away all the energy of the absorbed photon minus the energy binding the electron to the atom [17]. A photo absorbed photon transfers all its energy to the electron with which it interacts, thus ionizing the atom to which the electron was bound and producing a photo electron that is likely to ionize more atoms in its path. An outer electron will fill the vacant electron position and the produced either a characteristic photon or an Auger electron. These effects can be used for elemental detection through x-ray spectroscopy or Auger electron spectroscopy. The probability of photo electron absorption per unit mass is approximately proportional to Z^3/E^3 , where Z is the atomic number and E is the energy of the incident photon [27-29].

2.2.3. Coherent Scattering (Rayleigh Scattering)

In this process by which photons are scattered by bound atomic electrons and in which the atoms neither ionized nor excited. The scattering from different parts of the atomic charge distribution is then coherent, that is there are interference effects. For an assemblage of atoms the scattering from different atoms may add up coherently or incoherently depend on the atomic arrangement. It is often assumed that the Rayleigh scattering is elastic. However the scattering from a free atom is never strictly elastic because of the recoil energy. In crystal lattice the recoil is negligible because it is absorbed by the crystal as a whole, however the incoherence with the lattice vibration (phonons) may give rise to elastic thermal diffuse scattering. This scattering is at least partially coherent. In general, the Rayleigh scattering from an assemblage of atoms may be coherent to incoherent and elastic or inelastic. [17].

2.2.4. Incoherent Scattering (Compton Scattering)

This process can be visualized as a collision between the photon and one particular electron. The photon loses some of its energy and its wavelength is accordingly modified, thus the scattering is inelastic. No interference takes place between radiations scattered by different electrons of the material system [17]. Compton scattering is the predominant interaction x-ray and soft tissue in medical imaging. The transferred energy can be directly obtained from the scattering angle from the conservation of energy and momentum. [28].

3. Medical Uses and Effect X-Rays

3.1. Medical Uses of X-Rays

X-rays have been used for medical imaging. The first medical use was less than a month after his paper on the

subject [18]. In 2010, 5 billion medical imaging studies were done worldwide [19]. Radiation exposure from medical imaging in 2006 made up from about 50% of total ionizing radiation exposure in the United States. [20].

3.1.1. Radiography of X-Rays

Radiography is an x-ray image obtained by placing a part of the patient in front of an x-ray detector and then illuminating it with a short x-ray pulse. Bones contain much calcium which due to its relatively high atomic number x-rays efficiently. This reduces the amount of x-ray reaching the detector in the shadow of the bones, making them clearly visible on the radiography. The lungs and trapped gas also show up clearly because of lower absorption compared to tissue, while difference between tissue types is harder to see. Radiography is useful in the detection of pathology of the skeletal system as well as for detecting some disease process in soft tissue. Some notable examples are the very common chest x-ray. This can be used to identify lung disease such as pneumonia, lung cancer or pulmonary edema and the abdominal x-ray. Which can detect bowel or intestinal obstruction, free air (from visceral perforations) and free fluid (in ascites)? x-rays may also be used to detect pathology such as gallstones (which are rarely radio pique) or kidney stones which are often (but not always) visible.

Traditional plain x-rays are less useful in the imaging of soft tissues such as the brain or muscle [19]. In medical diagnostic applications, the low energy (soft) x-rays are unwanted, since they are totally absorbed by the body, increasing the radiation dose without contributing to the image. Hence a thin metal sheet, often of aluminum called an x-ray filter, is usually placed over the window of the x-ray tube, absorbing the low energy part in the spectrum. This is called hardening the beam since it shifts the center of the cardiovascular system including the arteries and veins (angiography) an initial image is taken of the anatomical region of interest. A second image is taken of the same region after an iodinated contrast agent has been ejected into the blood vessels with in this area. These two images are then digitally subtracted, leaving an image of only the iodinated contrast outlining the blood vessels. The radiologist or surgeon then compares the image obtained to normal anatomical images to determine if there is any damage or blockage of the vessel. [20].

3.1.2. Computed Tomography of X-Ray

Computed tomography (CT scanning) is a medical imaging modality where tomography images or slices of specific areas of the body are obtained from a large series of two dimensional x-ray images taken in different directions. This cross sectional images can be combined into a three dimensional image of the inside of the body and used for diagnostic and therapeutic purpose in various medical declines. [21].

3.1.3. Fluoroscope of X-Ray

Fluoroscope is an imaging technique commonly used by physicians or radiation therapists to obtain real-time moving images of the internal structures of a patient through the use of

a fluoroscope. In its simplest form, a fluoroscope consists of an x-ray source and fluoroscope screen between which a patient is placed. However modern fluoroscopes couple the screens to an x-ray image intensifier and CCD video camera images to be recorded and played on a monitor. This method may use a contrast material. Example include cardiac catheterize (to examine for coronary artery) blockage) and barium swallow (to examine for esophageal disorders). [22].

3.1.4. Radiotherapy of X-Ray

The use of x-ray as a treatment is known as radiation therapy and largely used for the management (including palliation) of cancer. It requires higher radiation energies than for imaging alone. [23].

3.1.5. Other Uses of X-Ray

X-ray crystallography reduced by the diffraction through the closed spaced lattice of atoms in a crystal is recorded and then analyzed to reveal the nature of that lattice. A related technique, fiber diffraction, was used by Rosalind Franklin to discover the double helical structure of DNA. [24] X-ray microscopic electromagnetic radiation in the soft x-ray band to produce images of very small objects. X-ray fluorescence, a technique in which x-rays are generated within specimen and detected. The outgoing energy of the x-ray can be used to identify the composition of the sample. Paintings are often x-ray to reveal the under drawing Pentium or alterations in the course of painting, or later restorers. Many pigments such as lead white show well in x-ray photographs. X-ray spectroscopy has been used to analyze the reactions of pigments in paintings. For example, in analyzing color degradation in the painting of Van Gogh. [25] Airport security luggage scanners use x-rays for inspecting the interior of trucks x-ray art and feline art photography, artistic use of x-rays. For example, the works by Stanislawski x-ray hair removal. A method popular in the 1920s but now banned by the FDA. [26].

3.2. Effect of X-Ray

One of the riskiest of all diagnostic tools is the x-ray machine. Most people who visit a doctor will experience at least one exposure to these high frequency waves of ionizing radiation (x-rays). This is the facts that have been discovered so far about the adverse effects of x-rays. If children are exposed to x-ray while still in the mother's womb (in utero), their risk of all cancers increases by 40 percent, the tumors of the nervous system by 50 percent, and of leukemia's by 70 percent. Today there are thousands of people with damaged thyroid glands, many of them with cancer of the thyroid. [23] Multiple x-rays have been linked with multiple myelitis a form of bone marrow cancer scientists have told the American congress that x-radiation of the lower abdominal region puts a person at risk for developing genetic damage that can be passed unto the next generation. They also linked the typical diseases of aging such as diabetes, high blood pressure, coronary heart disease, strokes and cataracts with previous exposure to x-rays. X-rays ordered by doctor's account for

over 90 percent of total radiation exposure of the population (Cambridge university press, 1993). In Canada almost everyone gets an annual x-ray of one sort or another. Old x-ray equipment still used in many hospitals gives off 20 to 30 times as high a dose of radiation as is necessary for diagnostic purposes. [27] Unless it is for a real emergency situation, x-rays should be avoided as far as possible because their harmful side effects may pose a greater health risk than does the original problem. As a patient you have the right to refuse x-ray diagnosis. by discussing your specific health problem with your physician, you can find out whether exposure to x-rays is really necessary or not. Many physicians today share this concern with their patients and try to find other way to determine their exact condition. [26] X- ray is a type of high energy radiation and has some harmful effects, which include biological radiation effects. These radiation effects can be destructive to all living tissues and can cause DNA damage and mutations.

The DNA damage if occurs can further enter certain states such as senescence that is an irreversible state of dormancy, cell suicide also known as a apoptosis and unregulated cell division that form a cancerous tumor. [28] The x-ray has bad effects on pregnancy and childbirth. The birth defects can deform the body of the infant and could be fatal to his life. X-rays can harm the tissue in the bones which is called bone marrows. X-ray can cause badness that is the loss of hair on the head x-ray also cause cancer development. Thyroid cancer and invisible spectrum. X-rays have biological radiation effects, which are observed when ionizing radiation strikes living tissue and destroys the molecules of cellular matter. Birth defects are also known as congenital disorders are abnormalities of structure or function that exists at birth. Pregnancy and childbirth imply the gestation period of the human reproductive cycle. Bone marrow is a soft and pulpy tissue that fills the bone cavities, which occurs in two forms i.e. red and yellow hair loss is a badness or alopecia that is partial or complete loss of hair affecting the scalp. Thyroid cancer also known as endocrine gland occurs in all vertebrate animals. [27] To keep into the internal body parts of the patients. An x-ray check is necessary but it is difficult to avoid the possible side effects of the patient x-rays. There is always some side effect of the x-rays passing through the body. So long it does not become very important x-ray test should be avoided. Do not insist the doctor to prescribe an x-ray check from your side. [21] People often get an x-ray done without any medical advice but they do not know about the ill effects of the x-rays. In the x-ray, CT scan and in the mammography tests etc., ionizing radiation is used which is fatal, while in the MRI and pregnancy tests ionizing radiation is not used so, these tests are safe. Children and women must take special care while undergoing any x-ray check. Children are more sensitive to x-rays. Owing to their small physical size children are especially at risk because the x-rays many badly affect their small physical genitals. Often at the time of x-ray check of children, their parents are present.

At that time the mother and the father should wear x-ray prevention cloths and the mother, if pregnant should stay out

of x-ray or CT scan room. [29] Pregnant women should undergo x-ray examination only if there be an urgent need. She should also take proper x-ray security measures to define herself. X-ray test is particularly prohibited from the eight to fifteenth week pregnancy. Women who are in the age of pregnancy must take the x-ray test with in the first ten days of menstruation cycle. To conclude we may say that s proper estimation of profit and loss must do. For example an estimated profit during the CT scan of brain is several times more than the loss. But without the medical advice it is not justified to take x-ray, CT scan or mammography tests. X-Rays always have harmful effects on the human body. Most people know about the harmful consequences of nuclear explosions. The harmful effect could be broadly divided in to two categories. The first physical and the second is genetics. More radiation in the body may lead to leukemia (blood cancer) a fatal disease. On the other hand, the properties of x-rays may bring serious disorders in new born children or could lead to heart defects. Therefore x-ray, CT scan or mammography check should be done on the advice of doctor only. [23] Rays can harm the tissue in the bones which is called bone marrow. X-ray can cause boldness that is the loss hair on the head x-rays also cause cancer development thyroid cancer and invisible spectrum. X-rays have biological radiations effects. Which are observed when ionizing radiation strikes living tissue and destroys the molecules of cellular matter? Births defects are also known as congenital disorders are abnormalities of structure or function that exists at birth, pregnancy and childbirth imply the gestation period of the human reproductive cycle. Bone marrow is a soft and pulpy tissue that fills the bone cavities, which occur in two forms i.e. red and yellow. Hair loss is a baldness or alopecia that is partial or complete loss of hair affecting the scalp. Thyroid cancer also known as endocrine gland occurs in all vertebrate animals. [24].

4. Conclusion and Summary

4.1. Conclusions

Today we realize that x-rays are just like ordinary lighting fixtures besides that x-ray photons have greater strength and comparable wave period than seen mild rays, the shorter the wave period ($1.00 \times 10^{-6} \text{ cm} - 1.00^*$) the more potent the strength x-rays additionally referred to as roentgen rays. Today's x-ray machines are really composed of an x-ray tube incorporates an electron gun which fires electrons at a target, normally tungsten and one in every of atomic techniques promoted via way of means of the excessive strength electrons from an x-ray picture. The strength misplaced because the electron slows down, is emitted as x-rays. To shield the frame towards needless publicity to radiation, lead aprons, additionally referred to as gonad shields are draped over the frame. These shields are particularly used to shield the reproductive organs from x-ray radiation. If cells with inside the reproductive gadget are broken, the broken can be surpassed directly to the sufferer's children. This is likewise

why x-rays aren't given to pregnant women, because the human fetus is severely liable to radiation. To shield them from needless radiation, x-ray technician's step out of the room or in the back of the protecting display screen at the same time as the x-ray system is with inside the operations. In trendy with inside the clinical field, x-rays are beneficial for greater than diagnosis. X-ray radiation is used as a remedy for most cancers tumors with inside the fields of physics and chemistry, x-ray diffraction is used to have a look at the composition of crystalline substances. The styles made via way of means of x-rays diffracted via crystals can pick out the detail or compound.

4.2. Summaries

X-ray is a shape of electromagnetic radiation. It is with photon energies above Kev (bellow 0.2-0.1nm wavelength) is known as tough x-rays. The difference among x-rays and gamma rays isn't always universal. X-ray photons bring sufficient strength to ionize atoms and disrupt molecular bonds. X-rays have an awful lot shorter wavelength than seen light, which makes it feasible to probe systems an awful lot smaller than what may be visible the usage of an everyday microscope. Since x-rays are emitted through electrons, they may be generated through, an x-ray tube, a vacuum tube that makes use of an excessive voltage to boost up the electrons with depend in 3 major ways, via image absorption Compton scattering and Rayleigh scattering. Radiograph is beneficial with inside the detection of pathology of the skeletal gadget in addition to for detecting a few sickness methods in tender tissue. These are the records which have been located up to now approximately the unfavorable results of x-rays; until it's far for an actual emergency situation, x-rays have to be averted as a ways as feasible due to the fact their dangerous facet results can also additionally pose a more fitness chance than does the authentic problem. Children and ladies need to take unique care even as present process any x-ray check. Children are greater touchy to x-rays; pregnant ladies have to go through x-ray exam most effective if there be a pressing need. She has to additionally take right x-ray safety features to protect herself.

Acknowledgements

First of all I would like to thank Almighty to God. For given me the strength and wisdom to complete my project successfully.

Next I express my special thanks and gratitude to my Friend Yeshanewu F. (MSc) who advice and help me to do this project. I also like to thank deeply my family for their financial support and moral encouragement and also I would like to say thank you for all who gave me consult advice and encouragement on my education life.

References

[1] "X-ray". NASA retrieved November 7, 2012.

- [2] NOVAL line, Robert. Squire's fundamental of radiology Harvard University press. 5th edition 1997 ISBN 0.674-833339-2.
- [3] "X-ray". Oxford English dictionary (3rd edition) oxford university press September 2005.
- [4] David Atwood (1999) soft x-ray and extreme ultraviolet radiation Cambridge University.
- [5] "Physics.Nist.gov" physics.nist.gov Retrieved 2011-11-08.
- [6] Denny P. P: Heaton (1999) physics for DIAGNOSTIC radiology USA: CRC press. P 12 ISBO-7503-0591-6.
- [7] Feynman Richard; Robert Leighton, Matthew Sands (1993) The Feynman lectures on physics V 01.1 USA: Addison Wesley pp. 2-5 ISBN-201-02116-1.
- [8] L Annunziata Michael; Mohammad Abrade (2003) Handbook of radioactivity A analysis Academic press p. 58. ISBO-12-436603-1.
- [9] Grupen Claus; G. Cowan S. D. Edelman T. stroh (2005) Astroparticle physics springer p. 109. ISB N3-540-25312-2.
- [10] Charles Hodgeman Ed. (1961) CRC handbook of chemistry and physics 44th edition USA chemical Rubber co. p. 2850.
- [11] <http://www.springer.com/978-3-642-16634-1>
- [12] Whites Erick Roberick Caws on (2002). Essentials of dental radiography and radiology Elsevier Health Sciences pp. 15-20.
- [13] Dauer LT, Thornton RH, Hay JL, Balter R, Williamson MJ, St Germain J. Fears, feelings, and facts: interactively communicating benefits and risks of medical radiation with patients. *AJR Am J Roentgenol*. 2011; 196 (4): 756-761.
- [14] Bush burg Jerrold Anthony Seibert Edwin Leidholdt, John Boone (2002) the essential physics of medical imaging.
- [15] Camera C. G; Escobar J. V: Hird J. R Peterman S. J (2008) Correlation "between nanosecond x-ray flashes and stick slip friction in peeling tap" *Nature* 455, 1089-1092 do Retrieved 2 February 2013.
- [16] Mitroff sarah (9 september 2012) "tribogenics incredible shrinking x-ray machine" *wired Business*. Retrieved 2 February 2013.
- [17] L Gerward laboratory of applied physics 3 technical university of Denmark.
- [18] Roobottom (A Mitchell G. Morgan Hughes. G 2010) "radiation reduction strategies in cardiac computed tomography angiography" *chin Radio* 65 (11) 859-67.
- [19] Medical radiation exposure of the USA population greatly increased daily march 2, 2009.
- [20] Herman gabon J (2009) fundamentals of computerized tomography image reconstruction from projections (2nd edition).
- [21] Hall ES Berenner DS (2008) "cancer risks from diagnostic radiology" *Br J Radial* 81 (965): 362-78 dui 10-1259/birr10198454 PMID 18440940.
- [22] Berenner DS (2010) "should we be concerned about the rapid increase in CT usage?" *Environ health* 25 (1): 63-8 DOI 10.1515/reveh.2010-15.1.63 PMID 202459161.

- [23] Kasai nobutami masao kakido (2005) x-ray diffraction by macro molecules Tokyo kodansha pp. 291-2 ISBN 3-540-25317-3.
- [24] De santis m. cesari E nobli E, Straface G. cavaliere AF Caruso A (2007) "radiation effects on development" birth defects Res. C Embryo today 81 (3) 177-82 Doi, 10.1002/bdrc20099.pmid 17963274.
- [25] 11th reports on carcinogens Ntp.niehs.nih.gov. Retrieved 2010-11-08.
- [26] www.fda.gov/Radiation-Emittingproducts/...Rays/ucm142632.htm
- [27] <http://www.juniordentist.com/Properties-of-x-ray.html>
- [28] B. L. Henke E. m Gullikson and J. C. Davis x-ray interaction photo absorption scattering transmission and reflection at E=50-30000ev, Z=192 Atomic data and nuclear data tables v.
- [29] Jerrold T. Bush burg. J Anthony seibert, Edwin M, leidhold and John m. Boone (2002). The essential physics of medical imaging Lippincott Williams and wilkins p. 42 ISBN 978-0-683-30118-2.