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Medical Physics and General Physics for Healthcare Technology

Hamza Amin Hamza
Al_Mustaqbal University, Department of Medical Physics

Jaafar Muhammad jaber
Al Israa University College Department of Medical Device Engineering Technologies

Attea Awaid Attea
University of Thi-Qar / College of Science / Department of Physics

Imam Ali Salman
Department of Medical Device Engineering Technologies College of Electrical Engineering Middle Technical University

Meaad Hadi Ghareeb
University of karbala, College of science, Department of physics

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Annotation: The medical physics profession is characterized by a long history of formal education, a structured training program, and appropriate local accreditation of medical physicists. Although the many medical societies around the world have been persistently promoting the establishment of a more structured education and training program in medical physics, progress has been slow due to the heavy workload from clinical duties and the consequent shortage of locally available instructors in this complicated field. Advances in communications technologies have the potential to overcome many of these hurdles and help graduate and even undergraduate MP courses reach a wider audience. Medical physicists with good teaching knowledge and skills will be recruited as part-time online instructor collaborators. Courses can be conducted using live video/audio/graphics teleteaching with audience interaction. The implementation of online courses should serve as a springboard for further development of video/audio taped on-demand courses and/or e-Learning. Low-cost video/audio equipment for local recording and broadcasting as well as the necessary supporting facilities for the preparation of high-quality multimedia-learning material for on-demand courses are also discussed. The teaching of medical physics is very different from general physics. Medical physics is not just ‘physics’ applied to medicine and healthcare technology; medical physicists need a distinctly different training from that of a physicist. Courses on medical physics must therefore not only teach the principles of the techniques and applications of ionizing radiation, including radiation therapy, diagnostics, imaging, safety, biophysics, etc., but also teach topics on biomedical engineering and nonionizing radiation. The avowed biomedical engineering department of a university would not have a group of medical physics instructors. With progress in imaging, radiation dosimetry and protection, teletherapy, and treatment planning, modeling and computations of dose distributions and radioactive dose delivery may have to be taught by engineers rather than physicists.

1. Introduction to Medical Physics

Medical physics is the branch of applied physics pertaining to the provision of services, instruments, equipment and photographic techniques for the purposes of diagnosis and treatment of diseases, and is thus an evolving area of physics with significant practical implications for the health care industry. Development of new modalities for disease detection and treatment relies on new advancements in applied physics. Accordingly, these topics should be featured in a good general education physics curriculum that focuses on their scientific interrelation in the understanding of the health care technologies [1].

The medical physics profession is one that many, often after a long and arduous journey, have come to appreciate as rewarding and fulfilling. In formal terms, the profession lies at the nexus of physics, medicine and engineering in the health care arena. Medical physicists are adept in the physical sciences and their application to medicine through post-graduate education followed often by higher degrees in relevant disciplines. The training is complemented by the study of biology, pathophysiology, instrumentation, medical ethics/law and the practice of medicine, all of which underpins the relevance of physics and engineers to health care technology and local health service delivery.

2. Fundamentals of General Physics

Physics is the branch of science concerned with the nature and properties of matter and energy. Physics is the study of matter and energy and how they interact with one another. Physics underpins many other scientific disciplines including engineering, astronomy, and chemistry which rely on the principles of physics.

General Physics is one of the basic courses in the Engineering course of study and the prerequisite of some other specialized physics courses. The primary purpose of General Physics II is to develop a fundamental understanding of the major principles, techniques, and importance of thermodynamics, electricity and magnetism, light and optics, quantum physics and atomic structure, nuclear physics and radioactivity, and the other areas of modern physics.

General Physics II is a calculus-based course intended for students in the Health Science, Biology, Optometry, and Pre-Physician Assistant majors. The aim of the text is to relate the lessons in physics to some of the issues and challenges we all face every day as health science students, practitioners, and as general human beings. This text covers the second half of the introductory sequence in general physics and includes topics such as thermodynamics, electromagnetism and optics, electrical circuits and magnetism [2]. Each chapter is organized in a similar manner with key objectives, fascinating facts or ideas to ponder, a worked example, summary and concepts, relevant mathematical relationships, and lots of problems, some with justification of the answer.

Modern physics in some other courses is also the requirement of some engineering courses. The principles of modern physics are the necessary background of physical processes and devices used in computation, communication, electronic, and various medical applications of physics questions. Modern Physics II covers atomic structure, wave particle duality, the theory of the atom, the theory of radiation and photonics, and the theory of solid matter [3].

3. Radiation Physics in Medicine

Radiation Physics in Medicine Education has been provided in the discipline of Physics for Health Professionals even before the establishment of medical devices. Healthcare Technology does typically employ and benefit from techniques and apparatus of General Physics. Nevertheless, the authors firmly believe that the body of knowledge and practice of Medical Physics should focus on radiation physics in healthcare technology. Medical physicists should be dedicated, amongst others, to improve the commissioning, quality assurance and safety assurance of X-ray machines, interpretative imaging, nuclear medicine tomographs and radiation therapy machines. Medical physicists should provide these services to and consult on matters regarding X-ray machines, imaging systems, nuclear medicine systems and radiation therapy systems. In order to cater for this in education, Medical Physics covering radiation physics in Medicine should be provided to healthcare professionals.

A recent more serious, more desperate and more tragic pandemic that afflicted all parts of mankind on Earth is that of COVID-19. It brought on healthcare devastation. The Physicist role in the healthcare struggle against COVID-19 cannot be over-emphasized. Unfortunately, beyond a few notable exceptions, the dominant role of medical physics in particular has been grossly neglected, or worse ignored, in the struggle against COVID-19. Importantly, the use of medical physics in healthcare involves the use of medical devices in general and devices employing the interaction of two kinds of energy radiation with matter, i.e. ionizing radiation and non-ionizing radiation. Medical physics devices employing ionizing radiation deserve top priority and attention in the internal and external medicine of COVID-19. The glaring effectiveness of and huge demand for these devices necessitate the legal, professional and safe use of these devices in the battle against COVID-19. This necessitates the top priority appointment of qualified responsible medical physicists looking after COVID-19 medical devices in each and every healthcare facility. [4][5][6]

3.1. Types of Radiation

Radiations are of two types: Particulate and Electromagnetic. Particulate radiations are comprised of sub-atomic particles, electrons, protons, neutrons, and alpha particles which, when moving at high speed, possess the property of passing through matter. Derived from an external source, these radiations are of little danger since they are incapable of penetrating to the gonads and bone marrow, tissues in which the more sinister biological effects are manifest. These radiations are particularly dangerous when derived from a source which may be ingested with food and perhaps selectively concentrated in body tissues. Electro-magnetic radiations comprise a continuous spectrum extending from long electrical waves, through infra-red, visible and ultra-violet light down to soft and hard X-rays and gamma rays. Radiations of very short wavelength, namely X and gamma rays, have the property of high penetration in tissues. Particulate radiations, together with ultra-violet light, X and gamma rays are collectively known as ionising radiations because they possess the property of ejecting electrons from the outer shells of atoms in their paths. Man has always been subject to irradiation from cosmic rays and radioactive materials in the earth's crust and atmosphere, together with radioactive elements within his body in small amounts [7]. The medical physicist is a specialist in the application of physics to medicine. In addition to a physics degree, postgraduate training in medicine, anatomy, biology, radiation protection, and related subjects is required. This training generally is through a medical physics residency program, typically of three years duration. Medical physicists promote the safe and effective application of radiation and physics in the diagnosis and treatment of disease, and in the ethical conduct of research in medicine, biology, and physics [8]. Medical physicists work in hospitals, industry, and university, and are usually considered to be an essential part of the clinical staff of a hospital. The medical physicist is an essential member of the team which provides radiation therapy treatment, data collection and processing to promote safe and effective management for radiation dose in flank collapse computerised tomography studied by dental pioneer.

3.2. Radiation Detection and Measurement

Radiation detection and measurement are part of any radiation protection program. Radiation is naturally occurring and although radiation is widely used in many occupations, it is also the main working risk affecting the safety of health workers and patients. The most relevant reference levels for ionizing radiation include: in x-ray medical imaging: entrance surface dose (ESD), and dose area product (DAP), in radiotherapy: maximum dose at the isocenter for photons or maximum dose at surface for electrons, absorbed dose to a volume of tissue at 3D treatment planning and delivered dose, in radio-theranostics: quantity measured & measured activity, in SPECT: time of flight, in air kerma-area product (KAP) and in occupancy time for gamma cameras. This paper describes a personal realtime detector for health workers who handle patients undergoing a radioisotope procedure or who work near radiotherapy machines. A personal dosimeter is proposed. This is typically a badge-shaped detector of photon radiation: gamma and x-rays designed to be worn during radiation exposure [9]. It is placed on a belt to measure the skin dose of photon radiation during a given time period. The goal of the personal monitoring is to show the exposure, and if this is high, a report can be printed for a detailed analysis to acquire information with respect to the beneficial and harmful parts. The main advantages of the proposed personal radiation detectors are: it measures the skin dose of radiation, assessment of doses in real-time, no pre-calibration, high sensitivity, light weight, low cost, and a current measurement of doses displayed approximately in seconds.

4. Medical Imaging Techniques

In modern healthcare systems, the need for early detection of diseases, more efficient diagnosis, faster treatment, and follow-up prior to surgery and interventional procedures, all pose growing demands which can be best met by using a combination of diverse imaging techniques [10]. Such combination imaging and the use of hybrid imaging devices are thus on the rise. Modality-embedded functionally different imaging systems are in turn regularly improved, while completely new imaging modalities are being introduced to the clinical environment. In addition to conventional imaging devices, new imaging techniques based on emerging technologies are also being developed. This range of combinations, hybridizations and emerging techniques introduces increasing complexity into the field of medical imaging. Comprehensive overviews of healthcare technologies in medical imaging are rarely published.

The objective of the chapter is to offer an overview of medical imaging technologies and the corresponding imaging modalities used in the healthcare technology field that can be of help in furthering understanding the opportunities and challenges offered by the technologies. The rapidly evolving field of medical imaging has become very difficult to overview hence this chapter offers a more comprehensive overview than typically available. Accordingly, imagery technologies are grouped into three groups: X-ray-based techniques including radiography, CT, C-arm, digital subtraction angiography, projections, fluoroscopy, mammography, and single- and dual-energy techniques; magnetic resonance-based techniques including MRI, fMRI, and magnetic resonance spectroscopy; nuclear medicine techniques including gamma cameras, SPECT, and PET; ultrasound imaging; and various emerging and doted visualizing technologies such as electrical impedance tomography, optoacoustic, photoacoustic, terahertz imaging, laser-induced fluorescence imaging, optical imaging, nuclear-magnetic resonance imaging, and hyperspectral imaging. Each technique is discussed more thoroughly regarding the physics of imaging, developments, applications, equipment involved, and possible challenges. Historical notes are also provided how the technologies have evolved and began to be used in clinical routine.

4.1. X-ray Imaging

This study is focused on x-ray imaging techniques such as mammography, dental imaging, computed tomography, and fluoroscopy based on information gained through professional experiences of candidate medical physicists who also work as medical device engineers. Furthermore, x-ray tubes and pyroelectric generators used in conventional imaging and new-age imaging devices, respectively, are described in terms of their geometries and feature differences.

Most mammography devices operate in a two-dimensional method. They use an x-ray tube with a geometric shape that allows either parabolic collimation or fan-beam radiation. The tube is always pointed toward the image receptor while being away from the patient and the compression plate. Therefore, the x-ray beam is almost perpendicular to the image receptor and leads to high signal-to-noise ratio images. Additionally, in order to light up a bigger imaging area and also for safety, the kV filtration of Mo-Mo is used to absorb low-energy as well as long-wavelength photons [11]. Automatic exposure control is also used by moving a compensator into the beam so that it can absorb some of the x-ray photons before reaching the image receptor.

Dental radiography is an imaging technique that allows visualization of teeth and jaw bone by obtaining images of them. When a radiography device is used for dental imaging, a radiation source (x-ray tube), a radiation receptor (film or imaging plate), and an x-ray attenuator (the head of the patient) is placed nearby. There are two techniques generally used for dental radiography. In one of them, known as intraoral radiography, the imaging receptor is placed inside the mouth, while the x-ray tube is placed outside. The other one is extraoral radiography, in which the imaging receptor is also placed outside of the mouth. A single or multiple extraoral curves are used in this technique instead of a single intraoral spherical shape. Panoramic x-rays for wide-scope images, cephalometric x-rays, for side-view images of the head and neck are some of the extraoral techniques. Another imaging device is cone beam computed tomography (CBCT), which is commonly used in oral and maxillofacial imaging.

Composed of two generally orthogonal and almost flat surfaces, all image receptors such as imaging plates and films are planar and flat geometrically. However, treated on the patient surface, surface areas are of unrounded shapes. Hence, being flat and planar should not be a skeptic compatibility criterion for x-ray imaging methods regarding parts of patient surfaces. On the other hand, despite flatness, curved surfaces can also give rise to 2D imaging. Thus, on the flatness condition, curved geometries for reception bins might be considered disqualified for cone-beam-like views, while they are fully adequate for a troll-unique projection as in mammography.

4.2. Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) started life as Magnetic Resonance Spectroscopy in the 1970s/80s, and whilst other modalities such as ultrasound and computed tomography have equally fascinating histories, there are two important reasons it ultimately became the dominant modality for soft tissue imaging. First, the invention of the gradient coil allowed huge improvements in the speed of acquisition of two-dimensional (2D) projections which could be reconstructed into tomograms. Second is the intrigue surrounding the physics associated with the actual occurrence of the image and how good the image is or could be. This paper aims to address the latter. Emphasis is placed on the face of the actual occurrence of the image, that is, the imaging physics that attends the matter, the nucleus of the information of the image. In a discussion on MRI it is usual to start with a review of the anatomy of some bits and pieces of the MRI machine. Consideration of the various constituent elements of the machine is however an exercise in minutiae, an open door to oblivion which distracts from a proper appreciation of the nature of the imaging technique itself, that is, the physics behind MRI. On the other hand, ignoring the hardware would be like considering a dentist’s drill without an appreciation of its construction and operation, it would be impossible to appreciate the capability and an example of the advantages of the procedure. Accordingly, some sections are devoted to the hardware (exactly that, some sections), and exactly the disciplines of ‘medical physics’ and ‘general physics’ which are of prime importance to the healthcare technologist at an MR scanner will be highlighted.

The basic principle behind MRI is that certain nuclei, such as hydrogen-1, can be made to absorb and emit energy in a magnetic field at precise frequencies determined by the local magnetic field. Information related to the environment of the nuclei—the chemical shift—can be obtained by analysing the spectrum of the emitted energies. This information can be mapped back to three-dimensional images without requiring any knowledge of its source. With the application of magnetic resonance imaging (MRI), anatomical images of soft tissue contrast and resolution far superior to any currently available technique were put within the grasp of clinicians. As a consequence of half a century of research and engineering by physicists, echoed by efforts from chemists, the imagers quickly became capable of attaining clinically useful images. Essentially overnight, MRI progressed from an obscure research topic to the dominant imaging modality for soft tissues. In the intervening decades everyone with any interest in the field has become used to the term MRI. [12][13][14]

4.3. Ultrasound Imaging

Ultrasound is a vital modality employed in various major fields of healthcare technology for safe and accurate medical diagnoses. Today, healthcare technology has evolved considerably and, thus, is a prerequisite for better healthcare. Medical sonography is a method of imaging that employs sound energies to create images of organs and other anatomy within the human body. Medical doctors use ultrasound imaging to view different bodies' heart, vessels, kidneys, liver, and other internal organs [15]. Healthcare doctors also use ultrasound devices to show the fetus during pregnancy. The image features can be provided with high quality for both diagnosis and treatment of diseases. Nearly, all ultrasound scans are made via a sonar tool on the external side of patient’s body parts. However, some of this work also involves operating a sonar tool on the internal side. A specific tool called a transducer or probe is applied over part of your body, to transmit the sound energies that recirculate off of the internal tissues and receive the reflected energy.

Ultrasonic images are created by sending out an ultrasonic sound wave via the transducer. The sound produces small particles that wiggle in a front-and-back fashion. The wiggly motion signal contains the collected information of the transmitted sound waves. Their structures can be produced using a post-processing synthesizer. The produced image shows the structures of the body during the movement of internal organs and blood flow. The most common probes used in medical ultrasound are curved and flat (linear). Curved probes' frequencies range from 2 to 5 MHz. A transducer with a frequency range of 4.5–5 MHz is typically used in obstetrics and gynecology. Linear transducers are occasionally used at high frequencies of 7 MHz for cardiology and blood vessels. This generates parallel sound energies with respect to the scan surface to create rectangular type images. This is a simple and straightforward way of assessing the performance of imaging applications across nearly all the clinical frequencies. Nevertheless, at those frequencies accuracy of results is not only influenced by the probe characteristics, but also different kinds of time delays and imaging algorithms. The main objective of this study is to examine the performance and accuracy of the ultrasonic imaging device by performing measurements on tissue-simulating phantom.

4.4. Computed Tomography (CT)

A computerized tomography (CT) scanner produces tomographic images (slices) of an object using an algorithm to reconstruct the shape of the object from projection images of the object [16]. This process is analogous to a person drawing the outline of an object from an image of the object cast on a wall by a light source. This trick is executed with a camera and a barometer. X-ray tomography (or X-ray CT) exploits the light source to be an X-ray tube, as well as the material and geometry of the light sensor, to be a scintillator and photo-detector respectively, to render images that can be "seen through". Since the invention of CT, it has been an indispensable imaging modality in nuclear medicine, and similarly has numerous applications outside medical imaging.

Settling these issues with the conventional CT technique has resulted in many practical difficulties, that is, the X-ray detectors are sensitive to spills of light, cumbersome, complicated, and expensive for general use. Moreover, the radiation produced by X-ray tubes is not safe. So small, safe teaching tools for CT are highly desirable. In spite of many recent developments based on different physical principles, essential efforts on opto-geometrical methods of CT scanning have not appeared. 3D reconstruction from projection images taken only via visible light is realized, using a laser as a point light source, and back-projection images as a simple and inexpensive scanning system that closely resembles the clipped traditional CT scanner. [17][18][19]

5. Therapeutic Applications of Physics

This article discusses medical physics, including several video interviews with a medical physics clinic team within the local healthcare setting. A video is presented, as well as other video materials, for teaching purposes and as supporting materials [20].

Medical physics has become an essential theme in science for years to come. However, only a small number of full-fledged and sustained education and engagement programs in physics for health care technology have been proposed. The academic fields of medical physics and healthcare physics are rapidly growing globally, and the challenges include a large number of job openings and unfilled positions expected over the coming years. As practitioners and educators in medical physics and healthcare physics, there is a strong need to engage students with interests in physics or engineering and teaching them that physics can have a significant and positive impact on human health.

Over the last year, in support of this initiative, a series of activities involving a professional skills video interview and other supportive videos were put together for a group of students from a junior high school, an institution emphasizing equality in opportunities for students. Through a group of educational videos made in the local health care setting, it is demonstrated that, in addition to the conventional projects on general physics and widely computational physic video creation platforms, it is also valuable to create exciting video materials about the treatment of diseases by any branch of physics and how this technology is applied in the actual local environment for public interest in medical physics and healthcare physics.

5.1. Radiotherapy

Radiotherapy is a broad subject occurring in external beam and brachytherapy irradiations, with this present chapter concentrating on medical physics and general physics principles mainly in external beam radiotherapy. Not a comprehensive review that covers all areas of interest, this chapter brings some medical physics aspects of interests that are usually problems in clinical practice or very specific topics not often referred to in textbooks. External radio-therapy applies high-energy photons, charged particles like protons, heavier ions, and neutron beams to treat malignant tumors. These high-energy beams because of their specific interactions with biological and nonbiological matter, mainly ionization, are extensively used in modern health-care technology. A number of Physics review articles have been published on the subject of medical radiotherapy in recent years referring to general principles of external, systemic, brachy-therapy, and important branches in health-care medical physics including proton and heavy ion therapy [21].

In a linear accelerator transporting X-rays for tele-radiotherapy, there has been a need to obtain special made safety interlocks keys for use by the calibrated safety interlocks model ST300. A new design for making the safety keys for use in tele-therapy has been developed using local resources. A calibrated safety interlock model ST300 uses safety keys for controlling the operation of the equipment at radiotherapy centers. Despite being calibrated and very effective, special made interlocks keys are also needed for tele-radiotherapy containment rooms with Cobalt sources while it was possible to use mundane keys before. Thereafter, an aluminum hardware design for the keys with rotary and positioning issues have been developed, including the key blades attached with standard screws [22].

This chapter also deals with different medical physics aspects of proton therapy, but only some very specific items from general principles are dealt with. Although patient positions in the cyclotron from horizontal to vertical placement have been introduced lately, opening up a lot of new opportunities and requiring different shielding conditions could not be discussed. Many of the treatments are done with isotopes instead of other cyclotron-produced isotopes. Treatment planning systems here include not only considered depth dose calculations but also various collimator types, and accelerators besides widely used ones. Wide arrays of beam apertures are used, but additives besides graphite energy degraders are not commonly used.

5.2. Brachytherapy

Brachytherapy is a form of radiotherapy that means “short distance therapy” which involves the delivery of a high dose of radiation inside or very close to the cancer tissues. The history of brachytherapy dates back to about a centenary, when Pierre Curie postulated the use of radioactive sources for treatment purposes. With the acceptance of radioactive sources for therapeutic application, soft tissue masses were being treated with radon needles for the disease of lupus. By the late 1920’s technology existed to apply radioactive isotopes such as radium, cobalt-60 and strontium-90 to the treatment of cancer. Brachytherapy is extensively used alone or in conjunction with primary external beam radiation therapy (EBRT) for treating various cancers, including but not limited to, brain, prostate, cervix, head and neck, lung, skin, esophageal, biliary system. Brachytherapy can be classified into Radionuclide and Electronic brachytherapy. In radionuclide brachytherapy, a radioactive source such as iodine-125, palladium-103, iridium-192 is used to irradiate the target tissue. Presently after EBRT, Electronic Brachytherapy is gaining traction worldwide. In this form of brachytherapy the x-ray source is miniaturized, produces low power x-ray which in turn generates low energy x-rays in the range of 20-50 kVp. There are many advantages of electronic brachytherapy, including relatively less shielding lead is required, no radiation when the source is off, no radioactive waste, better imaging modalities with electronic sensors [23]. In many countries, the treatment of cancer, like other diseases, is governed by a considerable body of law. In addition, the treatment of cancer is subject to an array of inter- and multi-disciplinary laws and regulations applicable both inside the clinic and externally. Institutions providing solely External Beam Radiotherapy (EBRT) treatment using Multi-Leaf Collimator (MLC) based medical electron linear accelerators (LINACs) require only to adhere to a manageable volume of law. With the increasing popularity of delivering Radiation Therapy (RT) using confined sources, such as Stereotactic Body Radiotherapy, Brachytherapy (BT), etc., it has become necessary to understand how these techniques are regulated, and to fulfil obligations spread across new jurisdictions [24].

5.3. Particle Beam Therapy

The choice of particle beam for ionizing radiation therapy is determined by the beam range, which indicates the depth in tissue at which the peak dose occurs. For protons and light ions, both water equivalent depth dose and lateral dose distribution are practically the same as for photons of 250 keV and for 137Cs gamma rays, respectively. Neutrons have a different depth dose distribution for protons than for light and heavy ions significant for eye tumor proton therapy. Magnetic focusing to the point of visual conformity of treatment plan assures larger pristine beam (PW 50 = 30 Gy) with guard doses and more track structure in a region of critical high dose for biologic precision. The introduction of a range modulator or “special effects” attenuators is necessary when treating deep seated lesions with mono-energetic, high-energy high let beams of protons or heavy ions. Random delivery of therapeutic doses by intensely focused beams of hadrons synchronously moving with ion activity places great demands on technology [25]. Capillary focusing, multiple tree-type crystals, “magneto-optical lenses,” and various fast beam switchers or deflectors supplemented by aimable secondary beams are in basic development.

Other applications of hadron therapy include preclinical animal facilities, radioisotope production with high current beams, fast beam loss collimation and beam deflection on cargo. Medical considerations, dosimetry, RBE and other topics of hadron therapy are discussed in detail. Aside from extensive institutional profiles giving geographic location, research profile, hospital priorities, equipment and beam delivery technology at biomedical and research facilities past and planned, emphasis is on special experimental studies required including kinematics/transport of nonideal beams, detuning with respect to isochronicity, multilayer studies required for practical applications of PCT, random delivery of long term doses at great parallelism and tracking with primary or secondary beam optical depth of the order of a cm [26].

6. Physics of Biological Systems

Physics is fundamental to understanding biological systems from a macroscopic to molecular scale. Biological and physiochemical problems in human health are becoming more and more complex; thus, more detailed and sophisticated physical approaches are required. Graduate students in medical physics require education on biological systems over a variety of topics and scientific fields. Biological problems from a biophysics viewpoint covering lower to higher scales should be continued for class and departmental education. Experimental and theoretical researches for biological systems at the molecular and microscopic scale can be covered in research topics like single molecule spectroscopy, NMR, TEPC, and X-ray scattering. Evolution of a gigantic and complex biological system, the human body, composed of various organs that function together can be discussed from a medical and physiological viewpoint.

Functional magnetic resonance imaging using BOLD signals is a novel and promising brain imaging technique to non-invasively visualize the brain anatomy and vasculature, and to monitor human brain activity. This technique has opened up new horizons to investigate the workings of the human brain in health and disease in vivo, non-invasively, and in real-time. BOLD fMRI offers a window into the global human brain function, while spatial-frequency domain MRI detects the regional responses individually. Biomedical developments ranging from basic biology to clinical medicine including the physics and physiology of MRI, BOLD fMRI, dynamic contrast-enhanced MRI, and fMRI technologies based on principles other than that of BOLD fMRI would be discussed.

Many modern medical methods for diagnosing diseases and studying biological processes are based on physical principles. The health risk from medical exposure to ionizing radiation for diagnosis should be understood, particularly in regards to patients and the public. Public awareness of radiation risk is low, despite widespread usage. Informed consent will become a critical issue for radiation exposure in diagnosis. Future practical knowledge of radiation risk should be integrated into the medical education of upcoming doctors. Conference presentations are useful for updating scientific knowledge and theoretical topics; however, hands-on demonstrations of personal experiences or practical applications are more effective to impart knowledge. There is a danger of being misled by the media over general health hazards related to natural radiation sources. Generally, delivery of solid materials used in brachytherapy is by manual methods. Some of the methods and instruments of the above tasks are presented. [27][28][29]

6.1. Biomechanics

Biomechanics is the study of the mechanical properties of biological systems. Musculoskeletal biomechanics encompasses the biomechanics of the musculoskeletal system, including bones, joints, muscles, tendons, and ligaments. Biomechanics seeks to understand the cause of motion and the effect of forces on living systems.

The discipline of biomechanics has grown significantly in recent years. The application of mechanical engineering and material science principles to biological systems has given new insight into how biological systems work and has led to many advances in diagnosis and treatment of mechanical disorders in humans. Biomechanics is commonly a component of medical physics or bioengineering programs and is an area of biomedical research. There are several approaches to studying biomechanics, including experiments on systems and computer simulations of systems.

Biomechanics also encompasses the developing field of cellular biomechanics, which encompasses the mechanical properties and characteristics of cells. Cell shape, surface friction, and elasticity can all contribute to cellular behavior and tissue structure and hence function. Impaired cellular biomechanics can lead to diseases such as atherosclerosis and cancer. However, research into cellular biomechanics has lagged behind that of musculoskeletal biomechanics in large part due to the difficulty of conducting experiments at the cellular level. Cellular events happen at nanometre scales in space, at nanosecond timescales, and present the challenge of tracking a system, applying forces, or measuring deformations in small, fast-moving nanometre-sized structures. Nevertheless, greatly improved instrumentation has led to a resurgence of interest in this area of biomechanics.

Cellular trajectories can be measured with micro-particle image velocimetry, where a flow of micron-sized beads is illuminated by a laser through an objective lens onto a camera. In the raw images collected, the beads appear as bright points against a dark background and thus their positions can be precisely determined. The bead positions and conservation of mass can be used to predict the flow pattern, while individual bead trajectories can be used to analyze the motion of the cell as a whole. With cells stiffened or softened using pharmaceutical agents, a noisier, slower, more tortuous trajectory occurs in the softened case, indicating increased motility. [30][31][32]

6.2. Bioelectromagnetism

The literature concerning the bioelectric mechanisms and their contributions to the origin of life has recently achieved the complexity equal or greater than its biological counterpart. Extreme varieties of bioelectromagnetism are presented in the medium of physics. As examples, the quantum bioelectromagnetic mechanisms of the biomolecular computation, fundamentals of quantum computers, nanobiotechnology and genomics, nonsupervisory bioelectromagnetic guidance of embryogenesis and evolution, standards of humanity and death are treated. Rigorous geometrical treatment of the bioelectromagnetism and bioelectronics as the hybrid subject in mathematical physics, biophysics, and bioengineering is developed. There are two notions of geometrical bioelectromagnetism: microscopic, which deals with on and below the molecular scales and macroscopic, which deals with modeling the bioelectromagnetic phenomena in organisms and medicinal applications of the electromagnetic fields in the research and medicine [33].

The macroscopic bioelectromagnetism studies mostly the bioelectromagnetic phenomena on the length scales larger than those of the biostructures and aims at modeling the bioelectromagnetic phenomena in the tissues. On those scales the hydrodynamic treatment of the bioelectromagnetism is valid. The notion tissue is used synonymously with organ with regard to the scales considered. The physical similar to blood as an isotropic electrically conducting electroinjective viscous low Reynolds number Newtonian fluid enveloping the bioelectromagnetic field in the vascular system is considered. The limit of high and low frequencies, as well as the case of the oscillation frequency equal to the characteristic frequency of the binary in both magneto and electrohydrodynamic models are considered. [34][35]

7. Medical Equipment and Technology

Medical equipment, in its simplest definition, is any device that can be used for medical purposes. While medical equipment typically has components that are non-electrical in nature, medical devices can also be considered types of medical equipment. While some medical devices are instruments, apparatuses, or machines used to diagnose or treat individuals, the attention of this chapter is focused on the equipment involving electronic components that have emerged over the last several decades to provide better healthcare services. Such equipment is referred to as medical electronic equipment, some examples of which include: Imaging devices that provide spatial resolution of tissues. Patient monitoring equipment that measure physiological parameters and vitality of patients in real time. Therapeutic and surgical equipment that treat various maladies. Laboratory equipment that give insight into bodily processes and physiological conditions. Intensive care unit (ICU) devices that help ill patients with vital body functions when needed the most. Telemedicine and teleradiology systems that help earnest doctors along with their patients separated by daunting geographical distances.

The assortment of different medical equipment is huge. However, even with the phenomenal growth of almost every sector in recent times, medical equipment, a very critical sector, remains behind. There are some fundamental differences between medical equipment and equipment needed in other industries. With the advancement of technology, many new products in other sectors are being launched every day, but this does not apply here. Whatever new technology is made, it is broken down into smaller, complex parts, and ruthlessly, cost-cutting is done to make it cheaper but less effective. Because of this reason, the plasma or laser machines made only a decade ago are still as effective as their modern-day counterparts and hence cheaper for usage. But in terms of usability, operation, and service, they resemble entirely different products. It could be mentioned here that many doctors in government hospitals use equipment bought decades ago, when those years' models of equipment were prized in a few million dollars and rarely worked. All kept records in notebooks, made themselves to a big intellectual property and medical equipment hub. [36][37]

7.1. Design and Function of Medical Devices

Medical devices have been in widespread use in hospitals and laboratories for many years. Medical devices can be classified as instruments (devices that do not alter the anatomy or physiology), machines (complex devices that consist of several components and are powered by a source of energy), and equipment (normally simpler electronic/radiographic devices). All instruments and most machines are built from mechanical parts, while electronic devices include radiographic imaging devices, patient monitors, and generators.

The instrument: thermocouple thermometer. The thermocouple thermometer is a temperature measuring device based on the Seebeck effect. It consists of two dissimilar metals that are welded together to form two junctions. One junction is kept at a constant reference temperature while the other is in contact with the body to be measured. The thermal EMF generated at the measuring junction is inversely proportional to temperature. This tiny voltage is amplified and applied as an input to the on-board ADC. The resulting digital temperature in °C or °F can be displayed in a digital format on an LCD/LED. The display circuit may include bias and adjusting resistors to increase brightness or change the display format.

The machine: x-ray tube. An x-ray tube is a vacuum envelope housing an anode, a filament-cathode, and a high-voltage supply. The tube also comprises an aluminum-housing to keep it cool, a glass envelope to maintain vacuum and insulate high-voltage components, lead shields to minimize scatter-radiation, and one or more glass windows to permit transmission of the useful beam. The operation of an x-ray tube is based on the principle of conversion. High-speed electrons generated at the filament are decelerated at the anode target, producing secondary radiation in the x-ray range. A rotating-anode provides a large area of target by spinning the anode disc at a speed of 12000-120000 revolutions/minutes. The target also consists of a thin walled polyetherimide glass hollow filter shaped like a focused funnel to reduce undesired x-ray while permitting specific x-ray.

The equipment: Fluoroscope. A fluoroscope consists of a founded tube and an ionization chamber connected to a grid-pulse counter. The cathode of the tube is heated by direct current, causing the emission of electrons. The electrons hit a metal plate-coated with a fluorescent material producing light emission in the visible range. This tube is coupled to the eye, giving the view of the observed body. Instruments are built of metallic sheets and a silvering. The lead oxide glass slab consists of Pb0, which is an effective x-ray shutter. An ionization chamber pipe is transparent to visible rays. High-tension filters, beamsplitter, photographic camera, photo-sensor, and logging device constitute the rest of the equipment.

7.2. Quality Assurance in Medical Physics

Radiotherapy in healthcare technology involves the use of computerized devices that redirect high-energy radiation beams onto anatomical distributions. The aim is the destruct of pathological tissues, mainly oncopathological sites, either exclusively or associated with adjacent healthy tissues. Each radiation therapy plan is prior validated and verified by a physicist, who is in charge to guarantee the safety of the procedures. Monitoring devices or systems that analyze pre-dosed computed images are also in charge of these tasks. In addition to monitor systems, using dosimetric systems capable of reconstructing three-dimensional distributions of absorbed dose is advisable to audit the radiation sources and validate the radiation therapy treatment. That is done by the physicist team by means of periodic quality assurance tasks that accompany the radiation therapy processing. The scope of this work is to teach and promote the use of dosimetric systems to audit that complex ingredient of healthcare technology.

After several meetings with health authorities, the International Atomic Energy Agency and the International Organization for Medical Physics have created the Cancer Control Program. The aim is to provide universal access to radiation therapy of safe procedures supervised with the qualified methods. The first step has been to ensure the state of the art of radiation therapy services and develop a quality-based road map. One fundamental topic in this road map is the auditing of quality assurance procedures, such as the validation of treatment plans and daily procedures that conduct the radiation therapy treatment delivery. Auditing these complex tasks requires the use of knowledge tools and methods that mainly involve expertise, because the generation does not respect quality standards.

Fixed and controllable referential frameworks have been recently proposed for imaging service auditing. Those frameworks can be extensively developed for other health technology-related services, including radiation therapy devices, by using numerical devices developed either for knowledge management or by numerical representation. The development of the methodology and its framework for the complexities of a treatment plan verification will be explained and an analogous approach for user facilities characterization and monitoring will be shortly overviewed. As a desired goal towards medical physics, healthcare audit devices compatible with the auditing methodologies will be introduced. The outcome will be to establish a collaboration network with local teams and institutions to share knowledge and prepare materials and frameworks to develop local and geographical capacities autoproducing net known feasible devices. [38][39]

8. Safety and Regulations in Medical Physics

Medical physics is primarily a clinical specialty in the different branches of medicine that deliver diagnostic imaging and radiation therapy. Medical physicists play a major role in ensuring the safe and effective delivery of these procedures to patients by working closely with closely allied disciplines of engineering, technology and radiobiology. Medical physics is an applied branch of physics. At undergraduate level it combines upper-level physics and math with biology, anatomy and physiology. At the post-graduate level it incorporates higher-level physics and math with clinical training in hospitals. Workwise, medical physicists are involved in virtually all the procedures that use ionizing radiation for diagnostic or therapeutic purposes. The medical physics health technology is a health technology covering the application of physics in medicine. Given its major role in healthcare delivery, health technology assessment (HTA) of medical physics is of importance and benefit in quantifying, pricing, regulating, integrating, financing and promoting the industries of this health technology.

The focus of medical physics HTA is on medical physicist certification and training program accreditation, emphasizing the non-medical and regulatory profession of medical physics, the contribution of medical physicists to clinical quality assurance of the medical physics health technology, the consequences of non-accreditation, and related initiatives by international organizations. The steady growth in the number of clinical applications, regulations, and specializations requires a high degree of knowledge and professional competency on the part of medical physicists. This is true in regard to traditional applications such as x-ray machines and megavoltage radiation therapy machines, where many medical physics production facilities exist. Many medical physicists work in clinical positions where their professional duties directly influence the quality and safety of delivery of care to patients [40].

8.1. Radiation Safety Standards

Radiation safety is an important counterpart in all facilities utilizing ionizing radiation. Some facilities use ionizing radiations in different streams (e.g. imaging facilities, radiotherapy facilities, radioisotope handling facilities, etc.), while other facilities use non-ionizing methods or facilities (e.g. laboratories, hospitals, …etc.) where radiation safety regulations are not that stringent. Facilities using these non-ionizing methods fall short of the same safety standards applicable to radiation safety. This is despite the apprehension that there are equivalent ionizing hazards known to us, yet there is little or no now radioprotection against this very high hazard that will create alarming weather of cancer diseases as a byproduct of these activities [41]. Radiation safety standards have increased worldwide recently with the increase in the usage of this technology. Unfortunately, and as a consequence, the side effects of radiation on body cells have also increased. Implementing a nationwide radiation safety program is one of the most urging topics worldwide. The responsibility for working out the details of this program is shared by multiple disciplines within the health facility organization. It is a conjoint responsibility of medical physicists, radiologists, instrumentation specialists, and computer specialists to collaborate in preparing the technical, scientific, and logistical aspects of the program. In recent years, radiation safety is an extremely hot topic. The topic has dramatically increased with the recent tragedies of Chernobyl and Fukushima. There has also been a realization of increased hazards with chronic radiation exposure. There has been a growing awareness of the need for medical physicists in radiology departments and in other medical imaging facilities.

8.2. Ethical Considerations in Medical Physics

Different stakeholders (physicists, medical physicists, biology and radiotherapy experts, manufacturers, medical centers, and public) need to be deeply involved in the interdisciplinary field of physics in clinical and preclinical applications. Some recent medical physics research topics including physics applications for ion-beam cancer therapy, therapeutic molecular imaging physics, optical imaging physics, preclinical imaging of small animals, image-based patient-specific diagnosis and treatment planning, and establishment of a digital imaging standard, the International Standard for Digital Imaging and Communications in Medicine (DICOM). The presentations focused on physical issues for medical physics including the effects of medical physics in healthcare technology (HCT) and the development of new physical imaging modalities, enhanced expertise in physics and bioengineering developments, fulfilling clinical needs through a system engineering approach, and interdisciplinary collaboration [42]. The three most important points are given: (i) The direct role of physicists is to physic-based instrumentation as well as Quantitative Imaging (QI)-based physical dimension standard of image acquisitions and interpretations that are core elements for prevention, detection, diagnosis, and assessment of disease progression in HCT and (ii) recent breakthroughs and breakthroughs needed include novel physical imaging modalities, technologies, and standards for and Enhanced expertise in physics and bioengineering advancements, and the last is interdisciplinary collaborations that are critical for developing HCT and an international organization for clinical and preclinical and imaging complied with widely-used standards are the keys for rapid developments. The need and possible application of code developed half a century ago on planet earth for practical medical uses on board space stations in a new spatial environment were presented. Such ideas, mathematics, and methods needed to be described to specialists in medicine, medical physics, or biology. The five priorities, that is, dynamical covert design of a patient-wise heterogeneous and variable phantom, Real-CoVERT tests without the phantom, a hybrid model for multi-modal measurements detection, physical meaning and strategies for signal reconstruction and interpretation, and density/photon-based standardization of various algorithm codes needed to be obtained by specialists in medical, medical physics, or biology, and the questions fully discussed were given [8].

9. Emerging Technologies in Healthcare

The diagnosis, evaluation, and treatment of various diseases in medicine and medical sciences had been expedited with the help of medical imaging. Different medical imaging modalities, including X-ray, Computed Tomography, Magnetic Resonance Imaging, Nuclear Imaging, Ultrasound, Electrical Impedance Tomography, Emerging Technologies, Hybrid Imaging Technologies for in vivo imaging, Optical Imaging are widely used in today’s healthcare throughout the world, including Bangladesh. Recently, special care has been taken in making these devices with lowness and robustness with high diagnostic performance. X-ray devices, therefore, are in wide use in most clinics, upazila health complexes, and hospitals, comprising facilities for X-ray, CT scan, and fluoroscopy procedures. Less costly modalities such as Ultrasound, Doppler also have recently been in broad use in almost all segments of the healthcare system. MRI, a modality with superior diagnostic performance over others, is recently in use by some hospitals and clinics. The number of hospitals and clinics installed with these devices is gradually increasing, although these are mostly in a limited number. These medical imaging modalities comprise the technologies to visualize soft tissues and anatomical details, which are not possible with other modalities. Nuclear imaging modalities are very sensitive and specific diagnostic modalities mostly used in cancer detection and treatment monitoring. These modalities are also available in a limited number of setups in developed countries.

Imaging technologies, although they are generally noninvasive, are only sought for diagnostic purposes based on some previous treatment. In an increasing number of patients, it is observed that imaging is not to be done for past unsought accidents leading to trauma. Some emerging imaging technologies are discussed here along with their clinical applications, which include biomedical imaging modalities with lab on a chip technologies. Clinical Magnetic Field Imaging and Magnetic Resonance Imaging-supported implementation in evaluation of head injury, 3D Electroencephalogram acquisition, source localization, and computer-aided diagnosis in seizure detection/sorting using Graph Theory and Wavelet Transform, Wearable NMR-cap-supported drug delivery in treatment of Alzheimer's disease and MRI-based evaluation of progress of the disease evolution stage. Simple explanations of functioning principles of these devices are also given, as well as the modes of signal extraction and interpretation on which the diagnosis is based.

9.1. Artificial Intelligence in Medical Imaging

Artificial Intelligence (AI) is a methodology in the field of computer engineering that allows the creation of algorithms, which are mathematical equations that can process a large amount of data in order to provide an outcome such as information and/or actions to take. AI was born in 1955 and was originally defined as "the science and engineering of making intelligent machines." Until AI was formed, knowledge bases and algorithms had to be written down by man, but with AI it was possible to study the mechanisms of thought and to replicate them in machines in order to form intelligent machines. AI's origins are linked to the study of the human brain, then called neurophysiology, which studied the cells of the brain, neurons, with the aim of reproducing them with mathematical and electronic models capable of simulating the thought processes of a living being [43].

AI's mathematical and algorithmic part is composed of Artificial Neural Networks, the basic unit of this technology, which consist of a multitude of interconnected individual processing units that can be said to be equivalent to the neurons of the human brain. In 1985, in conjunction with computational power increase, a landmark publication took place leading to the neural network technology's renaissance: the Backpropagation Algorithm, able to efficiently train a multilayered neural network architecture. With this algorithm, Neural Nets took the name of Machine Learning (ML) and started to unlock their potential. ML is a means by which decision-making mechanisms progressively improve its performance in performing a task and/or predicting an outcome from a learning process. The task from which to obtain new information, a new model, or a new behaviour lies in the data. In order to decide the outcome of the task, a mechanism is needed that is able to extract from the data what is essential in order for the outcome to be provided, in accordance with the explanatory model used. Most recently, the term "Deep Learning" (DL) was coined to indicate a type of ML based on the use of multilayered neural networks that, ordered according to a hierarchy of processing layers, can automatically discern relevant features from the unlabeled data [44]. AI is used in a new sector of research called "Radiomics" together with clinical and pathology data in order to correlate which imaging patterns are associated with specific pathology subtypes studied by means of high throughput analysis of features and machine learning. AI appears to have the potential to revolutionize healthcare and is going to change the role of radiologists by improving performance in terms of diagnosis, mass customizing treatments, and using healthcare resources in a more effective way. This technology could boost how the interpretation of medical imaging will be performed in the near future with the aim of increasing performance, reproducibility, objectivity, and reliability.

9.2. Telemedicine and Remote Monitoring

Telemonitoring, a subdivision of telemedicine, has significant medical applications [45]. Telemonitoring employs audio, video, and telecommunications for remote monitoring of patient status. While often used by remote participants separated by large distances, the concept is well known by many regarding its instantiation in video conferencing and webcam chats. The word has also been used to describe every manner of purported medical data gathering from ruptured foetal/maternal heart rate pairs, simple heart rate monitor alarm, intricate home glucose meter/surgeons' computers, and digital blood pressure gauges to more exotic transports. Although brands differ, these devices connect to authorized systems that respond to the information that they upload, often interpreted by human experts or algorithms.

Historically, this was either to counter some finite set of conditions or to share the ongoing pursuit of remote expert interpretation or both. The former is often called alarm or home monitoring, with later expectations or applications referred to as telemonitoring. It might be easy to think of remote monitoring as a modern invention of the recently-hatched Internet or at least telecommunication satellite, but routine use began in 1961 when Yuri Gagarin's ECG and other signals were continuously telemetered from space to earth prior to the first human orbit around the earth.

Modern telemedicine applications are well-described; a progression of filtration, classification, contextualization, visualing, and forwarding is nominally followed. A linear or device assembly analogy, although flawed, lends insight. Data are substrates or transposed into formats, processed, and forwarded either up the chain for installation or use curves, interacting on the way with display options. Home monitoring of blood glucose or uncontrolled hypertension leads to more sophisticated telemonitoring. A system of computer "hubs", regular experiences, interpretation with alerts, and subsequent interaction to diagnose, prescribe, and counteract is expected of the presence of chronic disease. The same system is elaborate for heart failure (HF), extreme nighttime cough, and paroxysmal atrial fibrillation [1].

10. Future Trends in Medical Physics

In many countries, medical physics education and training have matured over decades. However, for other countries, recent advances in medical technology, combined with an increasing demand for health care, have brought about a sense of urgency. Health care in rapid development often goes hand-in-hand with a new assortment of medical equipment and systems. Over time, these have become increasingly specialized and complex, giving rise to the need for knowledgeable individuals who can understand how they work [1]. This need was regarded as unavoidable for countries with existing data, and necessary for others considering the introduction of such technology. A young physics professor in a new university was recruited by a hospital to join an effort to establish a medical physics service and, ultimately, a training program. It was expected that a three- to five-year commitment would be sufficient for the professor to impart enough knowledge that an independent service could be run by local staff. Incremental integration then became desirable. It was already known that finding training personnel could be difficult, as this option had only become practical in recent years. Medical physics education and scholarship already existed, but had to rely on adaptation and improvisation [46]. Typically, graduate programs or another post-baccalaureate option could be expected, where available. In addition, professional and international organizations were looking for ways to adapt peering programs to helmet-mounted displays, binoculars, and telecommuting. The main barriers to telecommuting were social and economic, but ancient cultures were not overlooked. Apart from the absence of regulations mandating training, compensation was also a concern. Due to widely different cost-of-living levels, participant loss benefitting from this program was a possibility. Then, in fledgling programs where participation was less formal, incentive and motivation were also issues. While the broad definitions might seem imprecise, it was hoped that the audience for this discussion would intuitively know what is being discussed. At best one or two cases were documented in the literature, especially dense and important contributions that might provide insight to those contemplating a similar endeavor. Unfortunately, the author had not been privy to their proceedings and so could not relate their experiences.

11. Case Studies in Medical Physics Applications

Medical physicists ensure the safe and effective use of ionizing and non-ionizing radiation for medical purposes. A brief history of the development of medical physics in Hong Kong is sketched. The education and training of medical physicists in Hong Kong is described. The needs and challenges are also discussed. Recommendations for continuous developments and improvement of medical physics in Hong Kong are summarized.

Healthcare Technologies (HT) encompass a wide variety of medical equipment, appliances, and technologies, for the purpose of diagnosing, treating, monitoring, and determining health status [1]. It is more commonly known in the health sector as Health-related Technologies (HRT). Healthcare technologies can be of medical and non-medical types. It can be classified into four broad categories: medical and clinical, equipments and appliances, electronics and IT, and facilities and environment related equipment. Beyond this classification, the medical and clinical concerned healthcare technologies include radiotherapy physics, diagnostic radiology physics, nuclear medicine physics, and imaging physics. On a project team level, the medical physics staff has to work together with diverse professionals in diverse discipline who have different background, training, knowledge, and approaches to problem resolving. Within the limits of its staffing and expertise, the medical physics team has to be conversant with the principles, characteristics, and radiation safety aspects of a wide range of medical and clinical healthcare technologies. With the rapid developments in such technologies, the knowledge and the expertise required became ways beyond the capability of a team, thus teamwork is a must.

12. Conclusion

New advances in technology are influencing the field of medical physics. The impact of these advances on teaching medical physics is discussed. General developments in teaching and tele-teaching technologies are reviewed. Actual tele-teaching experiences are described, with a detailed account of a special long-distance teaching server designed for medical physics. Future developments in the field of tele-teaching in medical physics are discussed. The use of modern technology in education is pervasive in many professional fields, and it is no less so in the field of medical physics. Consequently, advances in teaching medical physics by remote means are reviewed. Illustrative examples of general online and distance learning resources are given, along with a detailed description of a special set of resources, technologies, and techniques developed over the past five years for medical physics. The impact of these on advance learning in this rapidly growing field is discussed. The discussion also includes some systemic issues important for further improvement and effectiveness of such systems in regions of intensive growth of such training. Tele-teaching for medical physics involves real-time tutoring and presentation of educational materials through the Internet and related modern technologies. There is a strong need for a global educational initiative in medical physics and engineering in view of the rapidly growing needs for trained personnel. Tele-teaching aspects of developments in all health-related technologies are considered important in achieving this goal. In the past few years, intensive efforts have focused on real-time tele-teaching in medical physics, including systematic analyses, theoretical approaches, technical solutions, platform applications, and actual experiences with accessible servers. These considerations are reviewed, including a specific description of the latest developments, analysis, and experience with long-distance tele-teaching in medical physics. Tele-teaching in medical physics is examined in a wider context of modern development of education in related fields and potential connections with other disciplines. Current and future needs, trends, and challenges are discussed, and some new developments and promising directions of this effort in relation to recent educational technologies are suggested. As with many fields influenced by the fast development of new technologies, remote education is an ever-growing field in medical physics. The medical physics profession is in a unique position to benefit from this growing field because of the unique requirements for well-trained personnel, substantial efforts toward establishing a global training infrastructure, and the existing well-developed resources in this discipline.

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