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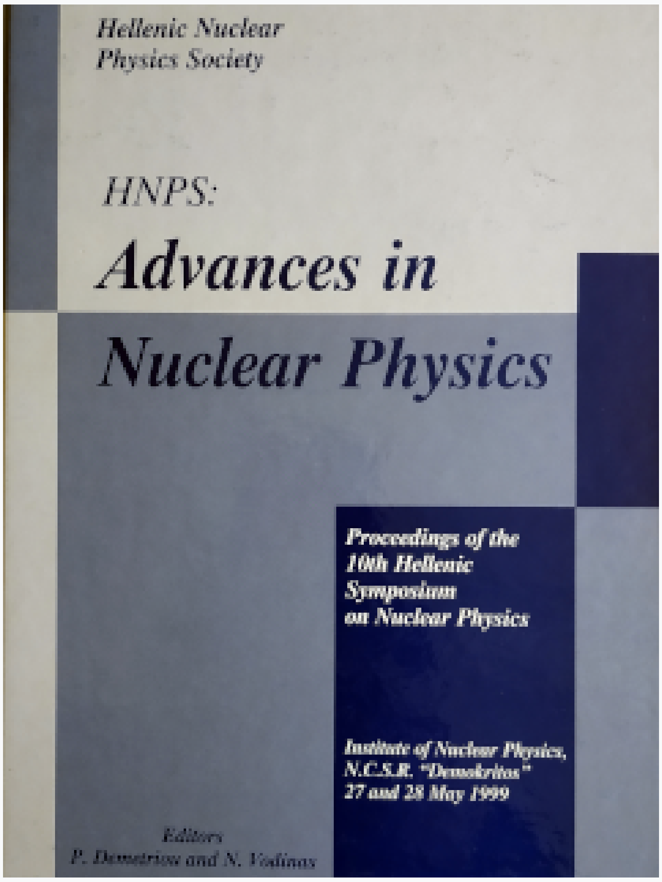

Developing HTML-based courses concerning training in Atomic and Nuclear Physics applied in modern Medical Technology

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Abstract

HTML-based Educational Means have been developed, in the field of Physics applied in Medicine. The first section consists of educational needs deriving out of the material conditions, and the most common implementations of medical equipment used for in vivo Diagnostic and Treatment Procedures. The second section concerns educational needs which stem out of the theoretical and practical aspects of the in vitro Analytical and Measurement Methods. The courseware allows for distance education and by way of editing tools, self-evaluation tests, and active links, can be adapted to the individual needs of the user, facilitating the understanding of the scientific subject- matter under consideration.

1 Introduction

1.1 Hypertext and Multimedia Courseware

Hypertext and Multimedia courseware are gaining importance in University education. Transforming conventional lectures or textbook material into an electronic format, offers limited benefits thus, the structure and the content of a course should be changed in order to take advantage of the technology.

HTML-based teaching tools interact both with teachers and students and they may influence our understanding of the scientific subject matter under consideration. Presently, it seems likely, that distant courses will not develop into a total substitute for in-person education.

An appropriate combination of traditional and on-line educational activities will rather follow. On-line instructional material accessed by the students, may also partially release the teaching staff. That could offer them more time to concentrate on more substantive tasks improving their interaction with the individual student [28],[29],[30],[31],[32].

1.2 Educational Means concerning Atomic and Nuclear Physics in Medicine

The modern Hospital is not a uniform structure. It consists of various functional units which contribute to the achievement of common goals, which are set for the entire structure but maintain a relative autonomy and perform unique roles. Each Hospital Unit, on the one hand, adopts similar methodological approaches [23],[24],[26],[27] to decision making but, on the other, it informs these approaches with the corresponding concrete content peculiar to its scope.

In order to support training in decision making during the procedure of the use of contemporary Biomedical Equipment, HTML-based Educational Means have been developed, in the field of Atomic and Nuclear Physics applied in Medicine.

The first section consists of educational needs deriving out of the material conditions, and the most common implementations of medical equipment used for in vivo Diagnostic and Treatment Procedures. The second section concerns educational needs which stem out of the theoretical and practical aspects of the in vitro Analytical and Measurement Methods. A part of the material presented in the following paragraphs can be found on: http://www.bmtl.bme.teiath.gr.

2 In vivo Diagnostic and Treatment Procedures

The main type of decision making in medical imaging concerns the discrimination of forms and the ascription of specific characteristics on to them and the degree of personal involvement of an expert in the final evaluation is still very strong because of the great variation of the forms of biological structures. Medical Imaging Techniques and Equipment [3],[16] include:

- Classical Radiography Systems.
- Classical Fluoroscopy and Angiography Systems.
- Digital X-ray Equipment.
- Single Photon Emission Computerised Tomography (SPECT).
- Positron Emission Tomography (PET).
- Magnetic Resonance Imaging (MRI).

The structure of a modern hospital encompasses radiotherapy facilities, which usually include:

- Therapy Accelerators.
- Radioisotope Tele- and Brachy-Therapy Systems.
- Supporting Equipment.

2.1 From Conrad Roentgen to Digital Radiology

The discovery of X-rays in 1895 gave birth to modern Biomedical Technology. After more than a century of fruitful applications in Science and Technology, X-rays still play a dominant role in Medicine.

Radiography Systems for General Use include general Radiography Equipment (Bucky-Systems) for :

- Skeletal examination.
- Chest examination.
- Head examination.

Further, mobile Radiographic Equipment, as well as, specialised Radiography Systems are used, such as:

- Mammography Systems.
- Simple Dental X-ray Equipment.
- Panoramic Dental X-ray Units.

Systems equipped with Image Intensifier, comprise of remote controlled, mainly over-table, Fluoroscopy Systems, mobile C-arm Operating Theatre X-ray Equipment and conventional, mainly under-table, Angiography Systems.

Digital Radiology, beyond Computer assisted Tomography (CT-scanner), and Digital Subtraction Angiography, is gradually intruding all X-ray Imaging activities, starting mainly from Digital Fluoroscopy Systems, and including remote controlled systems, Operating Room C-arms etc.

For the management of X-ray Diagnostic Equipment and the corresponding decision making procedures, points of importance include workflow planning to optimise existing architectural design, selection of appropriate systems, fitting to the Hospital needs, selection and sharing of X-ray equipment power supply (generator), conditions of X-ray equipment maintenance contract, archiving and digital image handling, Radiation Protection, and Quality Assurance in everyday Operation.

2.2 Nuclear Medicine

A complete Nuclear Medicine service includes:

- Radio-pharmaceutical Preparation.
- Examination ((-Camera, SPECT) and treatment areas.
- Patient areas.
- Physics area.

If PET [7] is performed a Cyclotron must be available. Compact Cyclotrons are the cost effective, easy to operate, shelf-shielded radioisotope delivery systems. Commercially available modern machines, produce substantial quantities of the major positron emitting isotopes and compounds, in a variety of chemical forms under full automation.

2.3 Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging has various attractive attributes, such as:

- The use of non-ionising radiation.
- Excellent soft tissue contrast.
- Visualisation of any desired plane, without special patient positioning.
- No bone artefacts.
- Non invasive character of the examination.
- Potential for flow measurements and for dynamic studies.

2.4 Superconductivity - SQUID

The presentation of Super Conducting Quantum Interference Devices, includes:

- The Josephson effect.
- Biomagnetic Fields.
- MCG.
- MEG.
- Technical Realisation.

2.5 *The nature of decision-making in Medical Imaging*

Decisions are forms of reasoning which lead to specific actions. That is, specific reasons are stated which contain data, theories, hypotheses, personal opinions, descriptions of states of affairs, past experiences etc. The action to be performed is inferred on the basis of these reasons. In other words, a decision entails the reasons, the method of inference and the action itself.

The nature of decision making [19]in Medical Imaging be examined presently in order to determine the special characteristics of its components, i.e. the reasons, the method of inference and the ensuing actions. These reasons fall within two categories:

- The first consists of reasons which refer to biological functions, financial and administrative indicators and technical procedures. These reasons contain parameters which are expressed in objective and quantifiable terms. Reasoning schemata which consist solely of such reasons can be adequately expressed by deterministic or probabilistic models, as for example the definition of the radiological parameters, according to patient anatomy, the selection of an appropriate imaging technique, according to the history and the physical examination findings.
- The second category consists of reasons which refer to the aspects which are unique to the problem in question, that is they express the specific parameters which allow for the instantiation of the specific problem. Reasoning schemata entailing reasons of the second category only are a theoretical possibility but they are never encountered in such a pure form. Rather, reasons of the second category are used in conjunction to those of the first in order to chart the course of treatment for the given patient. Such reasoning in its pure form, constitutes the casuistic approach.

The case of a real patient, however, exemplifies a form of reasoning which exhibits both types of reasons, i.e. the deterministically or probabilistically expressed parameters and the individuating indicators, such as the determination of a specific tumor to be irradiated, the decision of the application of open field or endoscopic surgery, according to the radiological findings etc.

2.6 *Radiotherapy*

Radiotherapy facilities exhibit unique to themselves decision making situations since the particular care they provide hinges on both the medical-social and the physical-technical aspects of the case in question. The subject matter presented includes:

- ^{60}Co Teletherapy.

- Electron Accelerators.
- Neutron Therapy.
- Intra Operative Radiation Treatment.
- ^{60}Co, ^{92}Ir, and ^{137}Cs Brachytherapy.
- ^{131}I Therapy.

A very important point in this part, concerns the Simulation and Localisation systems in Radiotherapy, and their functional relation to and mutual interaction with the Treatment Planning systems. Some special techniques, beyond usual Tele- and Brachy-Therapy [8],[9],[10], such as Irregular and Large Field Irradiation [6], Stereotactic Irradiation, Radiosurgery, and Intra-Operative Radiation Treatment, combined to the appropriate equipment and the necessary radiation protection procedures, are also outlined.

Biological Treatment Planning in Radiotherapy considering spatial and temporal dose distribution, forms another topic of interest. Systems that provide the means for the estimation of important biophysical parameters such as the Extrapolated Response Dose (ERD), the Tumor Response Probability (TCP), the Normal Tissue Complication Probability (NTCP) etc. are also examined. Most of them are based on probabilistic algorithms, including the concept of memory dose, and established on experimental data for normal tissue tolerance dose levels to therapeutic irradiation., obtained mainly through cell-series irradiation.

Programs for the patient Irradiation Management performed, including record keeping, fractionation, overlapping of past and present schemata etc. and enabling retrospective data analysis and prospective outcome judgement [21], are also referred to.

Charged particles [15] are gaining importance in external Radiotherapy of deep located tumors, because of:

- The limited angular and lateral scattering.
- The growth of energy deposition with increasing penetration depth.

The Radiological Safety Aspects [17],[18],[22] are strongly influencing the site planning. The accelerator room should usually be in the deepest basement, buried, taking into account the natural features of the ground and of the lay-out. Patients or bulky items should be brought into the vault through a radiation protection door [14].

Determination in final architectural lay-out of the location, is influenced by the shape and the dimensions of mazes, shafts and penetrations so that safety and functionality are optimised and by the definition of accessibility policy.

The electron and photon interactions with matter, leading also to a photo-neutron component and the estimation of the associated radiation parameters which are necessary, in order to calculate the appropriate shielding of walls, roof and ceiling, that determines the civil engineering parameters, are also presented.

3 In vitro Analytical and Measurement Methods

The function of the in vitro Diagnostic Laboratories is on the one hand, to produce data which will be incorporated in the decision making procedures of other Departments and, on the other, to chart courses of action on the basis of the information they extract out of the specimens. In vitro Analytical Techniques and Equipment include:

- Spectrophotometry, Atomic Emission and Absorption Techniques.
- Magnetic Resonance Spectroscopy.
- Radio Immuno Assays.
- Radiation Protection Instrumentation.
- Environmental Monitoring Equipment.

3.1 Spectrophotometry, Atomic Emission and Absorption Techniques and Magnetic Resonance Spectroscopy

Qualitative and quantitative tests in body fluids, tissues and products and drug-monitoring provide the ground for medical reasoning. Further, laboratory lay-out and infra-structure, analytical instrumentation and the corresponding managerial practice, determine the quality of the data that form the core of the inference. The most important equipment presented [1],[2],[11],[13],[20], [25] include:

- VIS/UV/IR Spectrophotometers.
- Spectro-Fluorimeters and Immuno-Fluorescence.
- Atomic Emission and Absorption Techniques.
- Flame-Photometers.
- Flame Ionisation Detectors.
- Atomic Absorption Spectrophotometers.
- Mass Spectrometers.
- Nuclear Magnetic Resonance (NMR) Spectroscopy.
- Electron Paramagnetic Resonance (EPR) Spectroscopy.

3.2 Radio Immuno Assays

The Radio Immuno Assay technique, for which Rosalyn Yalow was awarded the Nobel Prize, had and still has wide application in medicine: "It can measure such minute amounts of hormones and enzymes in the body that the Nobel Prize committee compared it to detecting a half cube of sugar dissolved in a 3600 square mile lake one foot deep"[33].

3.3 Radiation Protection and Environmental Monitoring Instrumentation

During a Radiological Facility operation, in several points around it, qualitative and quantitative measurements, should be performed, in order to assure the appropriate function of the entire installation. Concerning real-time monitoring, the major controls and the corresponding equipment are illustrated:

- Beam presence detected by fixed ionisation chambers or equivalent detectors, connected to the Operation Console.
- Electron dose rate or the equivalent beam current measured by twin built-in ionisation chambers and Marcus chambers.
- X-ray Dose Rate in Radiotherapy, measured by several types of external ionisation chambers.
- Neutron component monitoring [4],[5],[12] outside the shielding, in control room, door etc. detected by BF3 or LiJ(Eu) detectors, associated with the Bonner Spectrometer.

Professionally exposed personnel should be equipped with portable survey meters, and should be regularly monitored, through:

- Personal badge dose-meters.
- Thermoluminescence (TLD) albedo dose-meters.
- Ionisation chamber based pocket and pencil dose-meters.

Beyond personnel dosimetry, other systematic measurements of integral dose over some time period that might be necessary, as well as, activation measurements of parts of the equipment, the shielding and other materials and the associated equipment are examined. Finally, Radiation Protection related Beam Diagnostics and the corresponding beam quality parameters, such as presence of the beam, beam current, alignment, and energy calibration are likewise mentioned.

The components of an environmental monitoring program, and more specifically, ambient (stray) radiation and background dose-rate measurements, aerosols and water radioactivity measurements, and noxious gases measurements in the accelerator room that should be carried out frequently, are further summarised in this section:

- Ambient radiation dose - rate measurements.
- Aerosols (air, vapour and dust) measurements.
- Water measurements.
- Soil, grass and vegetation samples measurements.
- Measurements of Noxious gases in Accelerator Rooms.

4 Conclusions

The present means are adapted to the needs of students or to those of trainees already engaged in professional work, such as, physicians, nurses, engineers, physicists etc. The courseware allows for on-site and distance education and by way of editing tools, self-evaluation tests, and active links, can be adapted to the individual needs of the user, facilitating the understanding of the scientific subject-matter under consideration.

The new educational technologies are likely to force us, to re-examine our educational policies. University education is not just about mastering knowledge, but rather developing the students' personality and their special abilities, in a given social context. The cautious application of the emerging information technologies in Education may contribute towards this goal.

References

[1] C.S. Anderson, S. Cockayane, Clinical Chemistry: Concepts and Applications (Saunders, Philadelphia, 1993).

[2] J.J. Carr, Biomedical Equipment: Use, Maintenance and Management, (Prentice Hall, New Jersey, 1992).

[3] T.S. Curry, J.E. Dowdey, R.C. Murry, Christensen's Physics of Diagnostic Radiology, (Lea and Febiger, Philadelphia 1990).

[4] D. Fehrentz, B. Spyropoulos, Neutronen Dosimetrie an einem 42 MeV Betatron, Medizinische Physik 1981, s.693-696.

[5] D. Fehrentz, G.M. Hassib, B. Spyropoulos, Neutronenverschmutzung in Roentgenstrahlenbuendel von Electronenbeschleunigern, Strahlen-therapie 159 (1983) 703.

[6] D. Fehrentz, F. Hensley, D. Oetzel, B. Spyropoulos, P. Vodolan, Verfeinerte Bestimmung der Dosisleistung bei Irregulaeren Photonenfelder, Strahlenentherapie 12 (1992) 703.

[7] R. Frackowiak, L. Araujo, PET Scanning: A Diagnostic Technology Comes of Age, Siemens Review 57/4 (1990) 2.

[8] C. Frank, P. Fritz, B. Spyropoulos, S. Trinh, M. Flentje: Verstaerkung des Kontakteffektes nach LDR - Bestrahlung versus HDR - Bestrahlung in V 79 Sphaeroiden, Jahrestagung der Oesterreichischen Gesellschaft fuer Radioonkologie, Feldkirch, 11 - 12.10.1991.

[9] P. Fritz, B. Spyropoulos, C. Frank, M. Flentje: Strahlenbiologische Aspekte bei der gepulsten Brachytherapie, Deutsche Brachytherapie Konferenz, Koeln, Juni 1992.

[10] P. Fritz, K.J. Weber, C. Frank, B. Spyropoulos, M. Flentje: In vitro investigations concerning pulsed brachytherapy, "Brachytherapy 1992".

[11] L. Hallmann, Klinische Chemie und Mikroskopie, (Georg Thieme Verlag, Stuttgart, 1980).

[12] G.M. Hassib, B. Spyropoulos, Neutron leakage characteristics in high energy medical accelerators, Radiation Protection Dosimetry Vol.3 No1/2 (1982) 67.

[13] R.S. Khandpur, Handbook of Biomedical Instrumentation, (Tata McGraw-Hill, New Delhi, 1989).

[14] S. Koutroumbas, B. Spyropoulos, B. Proimos: New shielding materials for the treatment suites of radiotherapy devices, Intern. Conf. Med. Phys. Biol. Eng., Helsinki, 1985.

[15] G. Kraft, Radiobiological and physical basis for radiotherapy with protons and heavier ions, Strahlentherap. Onkol. 166 (1990) 10.

[16] E. Krestel, Imaging Systems for Medical Diagnostics, Siemens A.G, Berlin 1990, pp. 592-601.

[17] B. Spyropoulos, Radiological Safety aspects of the Design and the Operation of the 185 MeV Athens RTM Facility, 1st Mediterranean Congress on Radiation Protection, Athens, 5-7 April 1994.

[18] B. Spyropoulos, Radiological Protection Policy Aspects concerning the preliminary design and operation modus of the Athens Racetrack Microtron Facility, Proceedings of the Particle Accelerator Conference, Dallas, Texas, 1-5 May 1995, TAA15.

[19] B. Spyropoulos, B. Papagounos, A theoretical approach to Artificial Intelligence Systems in Medicine, Artificial Intelligence in Medicine 7 (1995) 455.

[20] B. Spyropoulos, C. Dervos, I. Siafaka et al, Methods and measurements for the quantitative determination of the extend of chemical, electrical and electromagnetic radiation hazard sources in the operating room, Proceedings of

the International Conference on Clinical Engineering, Merano October 1995, p. 149.

[21] B. Spyropoulos, E. Yannakoudakis, J. Anagnostopoulos et al, A low-cost modular information system enabling management of Biomedical Technology, Hospital Departments, Clinical Information and Medical Decision Support, Proceedings of the International Conference on Clinical Engineering, Merano October 1995, p. 241.

[22] B. Spyropoulos, Radiological Protection Policy Aspects concerning the Design and Operation Modus of Medium Energy (< 1 GeV) or High Current (> 25 MeV, 1 kA) Electron Accelerators Facilities, Advances in Nuclear Physics, Proceedings of the 7th Nuclear Medicine Conference, Makedonian Publications, Athens, May 1996.

[23] B. Spyropoulos, P. Parvantonis, A Universal System for the Diagnostic Evaluation of Biomedical Signals, 1996 AMIA Annual Fall Symposium, October 26-30, 1996, Washington DC, p. 824.

[24] B. Spyropoulos, P. Parvantonis, A. Mikronis et al. A Universal Bio-Signal and Pattern Acquisition, Processing and Decision Supporting System, IEEE, Engineering in Medicine and Biology Society, 18th Ann. Intern. Conference, October 31-November 3, 1996, Amsterdam, p. 132, 7.1.2.-1.

[25] B. Spyropoulos, C. Dervos, I. Siafaka, A method for the Monitoring of the Air-Pollution in the Operating Room caused by Anesthesia Agents, IEEE, Engineering in Medicine and Biology Society, 18th Ann. Intern. Conference, October 31-November 3, 1996, Amsterdam, p. 36, 1.1.1.-1.

[26] B. Spyropoulos, G. Papagounos, Decision making in a modern Hospital: Some theoretical and practical aspects, IEEE, Engineering in Medicine and Biology Society, 19th Ann. Intern. Conference, Chicago, IL, October 30-November 2 1997.

[27] B. Spyropoulos, G. Papagounos, Ethical aspects of the employment of Expert Systems in Medicine, Proceedings of the 4th International Conference on Ethical Issues of Information Technology, p. 701-711, Rotterdam, 25-27 March 1998.

[28] B. Spyropoulos, R. Lymperopoulou, Developing HTML-based Educational Means for Biomedical Technology and Medical Physics post-graduate Courses: Rationale and Status Report, Proceedings of the 1st European Symposium in Biomedical Technology and Medical Physics, Patras, Greece, 28-29 August 1998.

[29] B. Spyropoulos, G. Papagounos, HTML-based Educational Means supporting training in Decision Making in the professional and scientific context of the modern Hospital: Status Report, 4th International Congress on New Technology in Surgery: "Surgery Meets High-Tech in the Information Age", Munich, 9-12 December 1998.

[30] B. Spyropoulos, On-line Educational Means supporting the tutoring of the Physical Principles applied in modern Biomedical Equipment Technology, UB20.04, 1999 Centennial Meeting of the American Physical Society, Atlanta, 20-26 March 1999.

[31] B. Spyropoulos, I. Marneris, On-line Educational Means on Radiological Protection and Accelerator General Safety Policy in Radiotherapy and Industrial Sterilisation Facilities, APAC-001, Nr. 3775, 1999 Particle Accelerator Conference New York City, March 29th - April 2nd, 1999.

[32] A.H. Sullivan, A Guide to Radiation and Radioactivity Levels near High Energy Particle Accelerators, (Nuclear Technology Publishing, Ashford, Kent, 1992) p. 71.

[33] R. Yalow, The Boston Globe, Monday, January 5, 1981.