Ionizing Radiation in the Education of Medicine

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Abstract. Physics is a fundamental science that finds its applications in all areas of our lives. Its application in modern medicine is undeniable. In today's medical practice special attention is dedicated to the use of ionizing radiation. The wide range of modern science and technology offers enormous possibilities for creation and implementation of new equipment using adequate doses of ionizing radiation. For accurate medical diagnostics and effective treatment of patients, this type of equipment must provide the necessary information to the physicians. On the other hand, the physicians should possess enough knowledge in the relative field of medicine.

This paper contains information about the knowledge communicated to the students of the graduate program *Medical Physics* and *Biophysics* in the discipline *Medicine* in the first year of graduate study at the *Medical University "Prof. Dr. Paraskev Stoyanov" of Varna*. Firstly, we discuss the topics in the lectures of these two disciplines, concerning knowledge about ionizing radiation. Secondly, the respective laboratory exercises are described that illustrate the lectures in the graduate programs *Medical Physics* and *Biophysics*.

Keywords: ionizing radiation, education, medicine, medical physics, biophysics

1 Introduction

The most difficult task of the faculty of the Department *Physics and Biophysics* is to convince all students in the medical disciplines, that physics is not only a mandatory course but absolutely necessary for their professional training and, at a later stage, for their medical practice.

At the Medical University Varna, students are taught in four departments, a college and at an affiliated institute in the town of Sliven. A forthcoming opening of affiliated institutes in Shumen and Veliko Tarnovo is foreseen. The students of all departments study physics in various programs: Medical Physics, Biophysics, Medical equipment in the nurse practice and in obstetrics and gynecology practice, etc. The level of studied physics and the horarium of the lectures and exercises in various specialties are consistent with the respective discipline, namely "*Medicine*", "*Dental Medicine*", "*Pharmacy*", "*Nurse*", "*Obstetrics*", "*Medical optician*", "*Clinical laboratory*", "*Health Inspector*", "*Beautician*", etc. Physics is studied only by first-year students.

In the course of physics of all specialties, a special place is dedicated to the ionizing radiation and its use for diagnostic and treatment purposes in medicine and to the ways of prevention against harmful effects.

Most extensively about the benefits and harms of ionizing radiation are taught the students in discipline "*Medicine*". That's why here, we would like to present the information delivered in this course of physics. The students learn physics during two semesters in the first year of the graduate program. During the first semester the graduate program "*Medical physics*" and during the second semester the graduate program "*Biophysics*" is taught.

The two courses encompass lectures and laboratory exercises which provide knowledge and skills for use of ionizing radiation and prevention against its harmful effects.

2 Review

The course of lectures in physics for the discipline *Medicine* is selected carefully by taking into account that the provided knowledge is aimed at future physicians. The purpose of this selection is to provide knowledge in physics specifically related to medicine, namely medical physics. The lectures concerning the ionizing radiation in the discipline *Medical Physics* are three:

- X-rays;
- Radioactivity. Use of radioactive radiation in medicine;
- Dosimetry and radiation protection.

Each of these lectures presents separate topic about ionizing radiation.

Following topics are considered in the theme "X-rays":

- construction and operation of X-ray tubes;
- types of X-ray radiation;
- types of interaction of X-rays with matter;
- physical fundamentals of diagnostic radiology;
- specific features of the x-ray computed tomography.

In clarifying this topics the course answers questions specifically concerning the interest of the medical specialists: Why bones attenuate X-rays much more strongly than soft tissue; factors, which determine the linear attenuation coefficient for the X-rays; formation of images in the radiology; use of radiology in cases when the tissues do not provide images of enough contrast, difference between fluoroscopy and radiography, basics of X-ray therapy, etc. The clarification of these issues is a good basis for future physicians, especially if these specialists are majoring in radiography.

The next topic in the course is ***Radioactivity. Use of radioactive radiation in medicine***. It gives specific knowledge about:

- nature of radioactive decay and types of radioactive decay;
- concept of activity;
- half-life;
- fundamental law of radioactive decay;
- biological half-life;
- types of ionizing radiation;
- linear ionization and free path;
- radionuclide diagnostics;
- radiotherapy.

This topic provides basic knowledge for the work of the future physician in the field of nuclear medicine and therapy by means of ionizing rays. Here are discussed terms like radionuclide, radiopharmaceutical, radiotherapy interval, constant of the radioactive decay, half-life, biological half-life, effective period of halve-decrease, linear ionization and free path of the ionizing particle, etc. The reasonable introduction and clarification of these terms creates a stable base for the knowledge about the ionizing rays.

The third theme concerns the protective measures against harmful effects of using ionizing rays – ***Dosimetry and radiation protection***. This theme is of great significance for the future physicians and their practice. It includes knowledge about:

- Absorbed dose.
- Equivalent dose.
- Exposure.
- Dose rate and exposure.
- Equipment for radiation monitoring.
- Protection from ionizing radiations.

This topic provides basic knowledge about the subject of dosimetry, basic values and the respective units, used in dosimetry, construction and operation of the measuring devices for various parameters in dosimetry. This topic provides the concept of background radiation and its components, about radiation protection and about the need for separation of the population in groups for which the standards of radiation protection are different, as well as about the respective annual dose limits for each group.

The knowledge given in this topic is extremely important for all physicians and for those who will work on field using ionizing radiation for diagnostic or treatment purposes like radiology, nuclear medicine and radiotherapy as well as for all other people.

The course of lectures in the graduate program *Biophysics* in the second semester includes two topics related to ionizing radiation: ***Processes in cells with radiation impact* and *Mechanisms of radiation effects***. These two topics discuss the biophysical aspect of the processes which evolve in the human body exposed to ionizing radiation. The first topic examines the processes on cellular level. The second theme considers the processes running in the human body as a whole and concerning the entire human population. Discussed are also two hypotheses on the mechanism of radiation effects: the target hypothesis and the chain reaction hypothesis.

The lectures provide basic knowledge and the laboratory exercises are those that apply this knowledge in practice. Furthermore, laboratory exercises are a desirable and interesting way to consolidate the knowledge obtained in the lectures. Last but not least lab exercises develop different personal abilities in the students like: interest, creativity, communication, responsibility, teamwork skills. Part of the time for laboratory work is devoted to repetition and systematization of the knowledge needed for the respective laboratory exercise. The seek and implementation of various teaching methods in this part of the laboratory exercise increases the efficiency of the work of the students during work. It raises the interest not only to the appropriate laboratory exercise but also to the study of physics as a whole. Discussing the theory necessary for the appropriate exercise gives the students an idea of where and how relevant knowledge are applied in their future medical practice. Finding of application for the collected knowledge in physics in clinical practice is a key moment for maximum efficiency and interest in the training of medical students.

In the program of the discipline *Medicine* there are two laboratory exercises that illustrate the topics of ionizing radiation - each one addressed respectively to *Medical Physics* and *Biophysics*.

In the discipline *Medical Physics* the exercise illustrating the lectures about application of ionizing radiation in medicine is called **"Ionizing radiation. Determination of the total linear attenuation coefficient of γ-rays as they pass through matter"**.

In this exercise, students recall knowledge from lectures about following:

- Which rays are ionizing?
- What effect has ionizing radiation in inanimate and especially in living objects?
- Mechanisms of interaction of photon ionizing radiation passing through matter: photo effect, Compton effect and formation of electron-positron pairs;

- Total linear attenuation coefficient
- Flowchart and principle of operation of the Geiger - Müller counter

In the lab sheet of each student the essence of the exercise is explained and there is a report form, which must be filled in during the work.

Aim of the exercise :
Determination of the total attenuation coefficient μ for the γ-radiation.

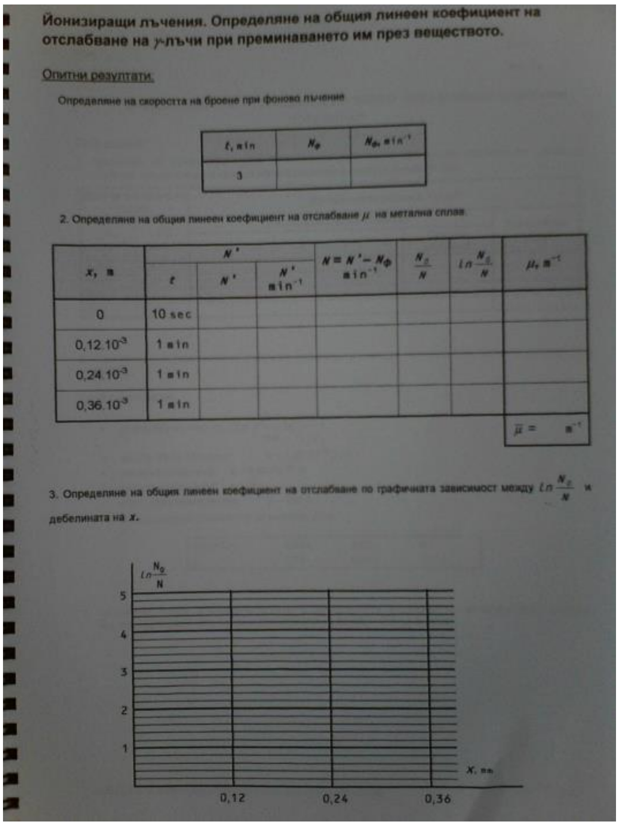
Necessary equipment and materials :
Lead container with a γ-source, plate holder with plates of the examined substance, dose meter-radiometer and stopwatch.

The exercise consists in measuring the ionizing radiation in the laboratory environment under different conditions:

- background radiation - when the source is enclosed in a lead container;

Figure 1. Necessary equipment and materials: lead container with γ-source, framework with lamellae of substance under investigation, dosimeter – radiometer and stopwatch.

Figure 2. Laboratory set-up of practice "Ionizing radiation. Determination of the total linear attenuation coefficient of γ-rays as they pass through matter".



Йонизиращи лъчения. Определяне на общия линеен коефициент на отслабване на γ-лъчи при преминаването им през веществото.

Опитни резултати.

Определяне на скоростта на броене при фоново лъчение

t, min	N_Φ	N_Φ, min^{-1}
3		

2. Определяне на общия линеен коефициент на отслабване μ на метална сплав

x, m	N'			$N = N' - N_\Phi$ min^{-1}	$\frac{N_0}{N}$	$\ln\frac{N_0}{N}$	μ, m^{-1}
	t	N'	N' min^{-1}				
0	10 sec						
0,12.10^{-3}	1 min						
0,24.10^{-3}	1 min						
0,36.10^{-3}	1 min						
							$\bar{\mu}$ = m^{-1}

3. Определяне на общия линеен коефициент на отслабване по графичната зависимост между $\ln\frac{N_0}{N}$ и дебелината на x.

Figure 3. Report of laboratory practice "Ionizing radiation. Determination of the total linear attenuation coefficient of γ-rays as they pass through matter".

- radiation without protection – direct measurement at the open lid of the container;
- with protection – successively three separation plates of the examined substance having the same dimensions are placed between the source and the radiometer.

On the basis of the obtained results and by means of the acquired knowledge from the lectures (the respective relations) the students determine the total linear attenuation coefficient of the examined substance (metal foil).

All data and calculations are filled in the report and the last assignment in it is to determine graphically the attenuation coefficient by using the relation between $\ln N_0/N$ and the thickness of the separation plate x.

Figure 4. The students.

For the discipline *Biophysics* the exercise is entitled "'**Radioactivity. Determining volume activity of β-radioactive aerosols**".

The theoretical knowledge required from students for this exercise is following:

- What is radioactivity?
- Main types of radioactive decay
  - α-decay;
  - β-decay (electron and the positron decay);
  - K-electron capture;
  - isomeric transition.
- Activity. Basic law of radioactive decay;
  - Radioactivity of atmospheric air (most of all, the presence of radon as risk factor for human health).

The work flow of the exercise is described in the lab sheets for the students: preparation, implementation and completion of work. Before each exercise the safety measures are explained and reminded.

Aim of the exercise :
Ddetermination of the volume efficiency of β-radioactive aerosols.

Figure 5. Necessary equipment and materials: aspirator device, framework with air filter.

Figure 6. Laboratory set-up of practice "Radioactivity. Determining volume activity of β-radioactive aerosols".

Necessary equipment and materials :
Aaspiration device, air filter frame, frame holder, dose meter-radiometer and a stopwatch. In this exercise, two practical tasks are to be performed:

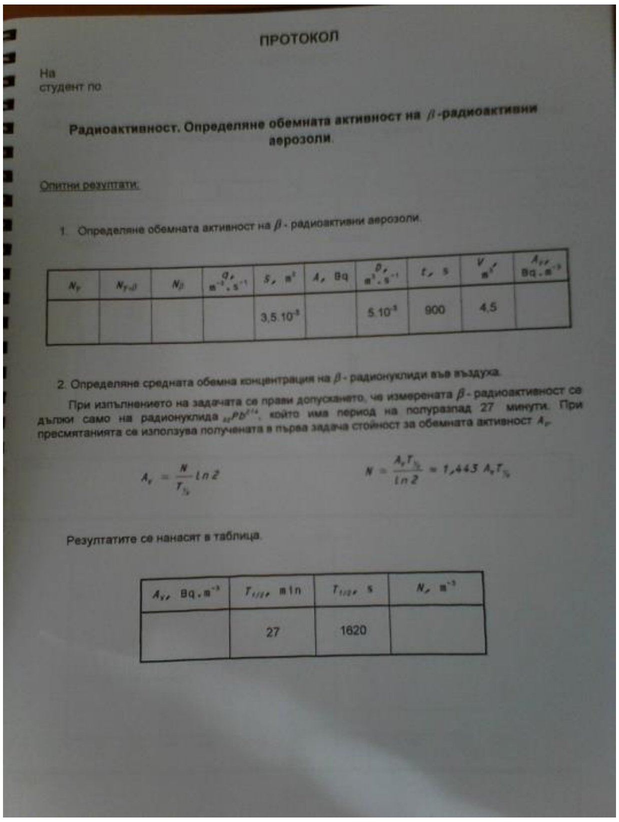
Figure 7. Necessary equipment and materials: mobile rack frame dosimeter – radiometer and stopwatch.

Figure 8. Reporting of γ-radiation.

Figure 9. Reporting of $\gamma + \beta$-radiation.

The first task coincides with the aim. For its implementation it is necessary to put a filter on the inlet of aspiration device (a standard vacuum cleaner) and to aspirate air from the laboratory room for a defined time (e. g. for 15 minutes). Then, by using the radiometer the γ-radiation and $\gamma+\beta$ radiation from the filter is measured. The dimensions of the filter are taken into account. The obtained data are filled in a table of the reporting form and on the basis of prior knowledge (the respective relations and constants) the volume activity is calculated.

The second task involves determination of the average volume concentrations of β-radioanuclides in the air. For this task, which is purely computational, the results obtained from previous task are used as well as the necessary information from lectures. To obtain more significant results in the laboratory room it is necessary to eliminate opening of windows and doors in order to accumulate larger amounts of radon. The best results are obtained on Monday during



ПРОТОКОЛ

На

студент по

Радиоактивност. Определяне обемната активност на β-радиоактивни аерозоли.

Опитни резултати:

1. Определяне обемната активност на β - радиоактивни аерозоли.

N_γ	$N_{\gamma+\beta}$	N_β	q, $m^{-2}.s^{-1}$	S, m^2	A, Bq	D, $m^3.s^{-1}$	t, s	V, m^3	A_V, $Bq.m^{-3}$
				$3,5.10^{-3}$		5.10^{-3}	900	4,5	

2. Определяне средната обемна концентрация на β - радионуклиди във въздуха.

При изпълнението на задачата се прави допускането, че измерената β - радиоактивност се дължи само на радионуклида $_{82}Pb^{214}$, който има период на полуразпад 27 минути. При пресмятанията се използува получената в първа задача стойност за обемната активност A_V.

$$A_V = \frac{N}{T_{1/2}} \ln 2 \qquad N = \frac{A_V T_{1/2}}{\ln 2} = 1,443\, A_V T_{1/2}$$

Резултатите се нанасят в таблица.

A_V, $Bq.m^{-3}$	$T_{1/2}$, min	$T_{1/2}$, s	N, m^{-3}
	27	1620	

Figure 10. Report of laboratory practice "Radioactivity. Determining volume activity of β-radioactive aerosols".

the first exercise, when in the weekend large amount of radon is accumulated. Sometimes when the weather is hot and opening the windows is necessary, the results are almost near the background levels. In both cases explanation from the students for the obtained results is required.

The practical part of both exercises is affordable and easy to implement. The experimental layouts are simplified to a minimum. The used equipment and materials are easy to find and do not require specialized skills or training for using them. The only exception is the use of radioactive source for the first exercise, having a very low activity, which is near to the radioactive background.

Figure 11. The students.

3 Conclusion

In conclusion, we can state that these exercises are the most desirable for performance by the students. This shows a great interest for the exercises and therefore for the use of ionizing radiation in medicine. Throughout the course, however, they are only two. Considering the current development of medical technology with the use of ionizing radiation for diagnostic and treatment purposes we believe that the number of the laboratory exercises in this area should be increased.

Currently, laboratory exercises are conducted only in educational laboratories of the department *Physics and Biophysics* at the university. We believe that some of the exercises could be exported to the clinics and the premises at the *University Hospital St. Marina*. This is a very difficult process because it has to be adapted to work with patients in these clinics. Conducting of laboratory work should not interfere with the direct operation of the clinic. Moreover, the large number of students (60–70 groups of 10–12 students each) requires spending of much time to conduct exercises. The last but very important factor is the radiation protection of students.

To be able to work directly in environment of ionizing radiation, they must have a completed course for work in environment with ionizing radiation and must hold an appropriate certificate. Such a course is impossible to be held for students who have not yet the necessary minimum of knowledge – these are first-year students. Students are not allowed to work directly with the available equipment in the clinics because they do not have the knowledge for that. It is necessary in advance to provide a specialist from clinic who will work with the specific medical equipment. All these factors and some others are real obstacles for conducting of exercises at the university hospital.

However, we are working closely with the medical staff (mostly medical physicists) to create new exercises and to adapt them to the respective conditions in the clinics, as well as for the successfully carrying them in conditions similar to those under which they will work as future nurses and specialists. We collect ideas and contributions from various scientific and business forums, from national and international seminars, conferences, congresses etc. concerning the topic of ionizing radiation. The national and international forums for training related to medical physics and biophysics, and especially in the field of administration and safety measures for work with ionizing radiation are also a useful source of ideas for new laboratory exercises.

We are ready to accept ideas for laboratory exercises from specialists in this field.

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