Medical physics graduate program based in the Department of Physics*

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ABSTRACT. The localization of the educational programs for medical physicists in hospitals and medical centers is primarily due to the historical reluctance of physics departments to provide training for professionally-oriented students such as medical physicists. Our Medical Physics Graduate Program represents a cooperative effort of the Departments of Physics, Radiation Oncology, and Radiology, as well as the Office of Radiation Safety. The goal of this two-year master's degree program is to prepare students for clinical positions in diagnostic radiological physics, nuclear medicine physics, therapeutic radiological physics, and medical health physics. A further aim is to prepare candidates for board certifications by the American Board of Radiology, the American Board of Medical Physics, the American Board of Health Physics, and the American Board of Science in Nuclear Medicine. Our Medical Physics Graduate Program is noteworthy for its emphasis on clinical training. In this respect it differs significantly from most graduate programs in physics where primary emphasis is directed towards classroom training and research experience. The tremendous success of the first twelve graduates from our program in securing multiple offers of high-paying clinical positions in medical physics reflects the favorable demand-supply ratio for medical physicists who have received appropriate clinical training.

RESUMEN. La ubicación de programas educacionales sobre física médica en hospitales y centros médicos se debe primordialmente a una renuencia histórica de los departamentos de física académicos de proveer entrenamiento a estudiantes cuya orientación profesional es médica. Nuestro programa de física médica para graduados representa un esfuerzo cooperativo entre departamentos de física, radiación oncológica y radiología, así como también la participación de la Oficina de Seguridad Radiológica. El objetivo principal de este programa de dos años para obtener el diploma de maestría es el de preparar a estudiantes para ocupar puestos clínicos en áreas relacionadas con diagnosis y física radiológica, física nuclear médica, física radiológica terapéutica, salud y física médica. Una extensión del objetivo principal es la de preparar candidatos para obtener certificados de la Junta de Radiología Americana, la Junta Americana de Física Médica, la Junta Americana de Física de Salud y la Junta Americana de Ciencia en Medicina Nuclear. El programa enfatiza un entrenamiento clínico adecuado y, en este sentido, difiere considerablemente de otros programas para graduados en física en los cuales el énfasis se orienta hacia la enseñanza y experiencia en investigación científica. El gran éxito logrado por los doce primeros graduados de este programa, en cuanto a ofertas de trabajo bien remunerado en el campo de la física médica, refleja una razón favorable entre la demanda-oferta de físicos médicos que reciben un entrenamiento clínico apropiado.

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1. INTRODUCTION

Medical physicists are scientists who are applying their physics educational background to medicine. Although they collaborate with physicians in almost all fields of medicine [1] most of them have found employment in the departments, or divisions, of radiation oncology, diagnostic radiology, nuclear medicine, and radiation safety. These departments, and clinical institutions in general, are less likely to institute academic degree programs than the departments of physics. On the other hand, the physics departments have two major difficulties in establishing and maintaining viable educational programs in medical physics. First, a traditional department of physics does not have the sophisticated and very expensive clinical radiological equipment required for the training of medical physicists. Second, due to the salary levels for medical physicists [2], some physics departments may have difficulty recruiting and retaining a board-certified medical physicist on their faculty. To help medical physics students identify the practical importance of each topic in radiological physics, the instructor must be intimately familiar not only with physics but also with all aspects of clinical radiological procedures. The physics professor who satisfied both of these requirements is a rarity, to say the least. Although an attempt was reported to institute a medical physics program in a department of physics [3], all five educational programs for medical physicists, accredited by the American Association of Physicists in Medicine (AAPM), are based in the departments of radiation oncology, radiology, radiological sciences, or medical physics [4].

The minimum academic requirements for membership in the AAPM include an M.A. or M.S. degree in physical science plus two years of experience in medical physics or a Ph.D. or D.Sc. degree in physical science plus one year of experience in medical physics [5]. The American Board of Radiology (ABR) requires a master's or doctoral degree in medical physics or physics as the minimum educational requirements for admission to the examination for a certificate in radiological physics or its subfields [6]. The American Board of Medical Physics (ABMP) requires eleven years of experience in clinical medical physics and an acceptable score in the GRE physics exam for candidates who wish to take the three-part certification examination and who have only a B.S. degree [7]. These rules make it difficult, if not impossible, for an individual with only an undergraduate degree to enter the profession of medical physics.

It is the position of the AAPM that a person with a graduate degree in physics and no additional training in physics applied to medicine is *not* a clinical medical physicist and should not be permitted to work in a clinical situation unsupervised by an experienced clinical medical physicist [8]. Academic programs leading to a research-oriented Ph.D. degree in medical physics are available at some universities. However, it should be recognized that the academic training of this nature cannot take the place of in-service clinical training, which ideally should be organized in accordance with the AAPM-sponsored training guidelines [9]. Although more than half of the AAPM members hold doctoral degrees, a Ph.D. degree is not required for entrance in the profession of medical physics. A master's degree in medical physics is the basic degree for a clinical medical physicist. The graduate program described in this paper is a master's degree program in medical physics. It represents a unique cooperative effort of the Departments of Physics, Radiation Oncology, and Radiology, as well as the Office of Radiation Safety. The location of this program and a traditional master's degree program in "pure" physics in the same Department of Physics has provided the opportunity for comparison of these two programs in terms of the curriculum, number and qualifications of students, and placement of graduates.

2. GOALS OF THE MEDICAL PHYSICS GRADUATE PROGRAM

In its policy statement, the AAPM has divided the education of a clinical medical physicist into three stages [10]. *The first stage* includes at least a bachelor's degree in physics or equivalent. *The second stage* introduces medical physics into the curriculum at the level of a master's or doctoral degree program. If the graduate degree is in physics, it should be supplemented by a formal postgraduate training program in medical physics. *The third stage* involves in-service training under the supervision of a senior level clinical medical physicist. The length of the in-service training period should be two years or longer of full-time employment.

Our Medical Physics Graduate Program is inviting applications from candidates who have completed *the first stage* of education of a medical physicist, *i.e.*, who have obtained a strong educational background in physics or a related field. The program is providing *the second stage* of medical physics education and clinical training preparing the graduates for *the third stage* of in-service clinical training. Some of the goals of the Medical Physics Graduate Program can be stated in terms of the curriculum described in Sect. 4. Other goals, stated more generally, include:

i) The overall objective of the Medical Physics Graduate Program is to prepare graduates to enter clinical residency programs in medical radiological physics or to assume responsibilities of a junior medical physicist in diagnostic radiological physics, nuclear medicine physics, therapeutic radiological physics, and medical health physics. This clinical involvement should be under the supervision of an experienced, senior level clinical medical physicist, fulfilling the third stage of in-service medical physics training.

ii) A further aim is to prepare candidates for board examinations by the American Board of Radiology, the American Board of Medical Physics, the American Board of Health Physics, and the American Board of Science in Nuclear Medicine. The speciality board certification is an indicator of having met the minimum requirements and experience contained in the above three stages of education and training of a medical physicist.

iii) Graduates from the Medical Physics Graduate Program should be able to teach radiological physics to radiology residents [11], radiologic technologists [12], medical students [13], medical physics students [14], and graduate students in related disciplines. They can assist also in clinical training in radiological physics for all of these categories of students.

iv) An optional goal is to prepare graduate students for a scientific career which may include doing research in medical physics. Students who select this option obtain specific knowledge in areas related to their research, write and defend an optional master's thesis, and are encouraged to present and publish the results of their research.

3. ADMISSION PROCESS

Announcements of our Medical Physics Graduate Program in the Information Exchange section of *Physics Today* have been the main source for inviting hundreds of inquires about this new program. About half of the potential applicants already hold M.S. and Ph.D. degree in physics, or are in the final stage of completing the requirements for such degree.

Applicants to our Medical Physics Graduate Program are expected to have a strong foundation in physics or engineering. They should have mastered calculus through multivariable calculus and vector analysis, ordinary and partial differential equations, linear algebra, complex variables, calculus-based mathematical statistics, calculus-based general physics, modern physics, as well as intermediate-level courses in mechanics, thermodynamics, electricity and magnetism, optics, quantum mechanics, and associated mathematical methods [15]. A successful applicant is expected to be experienced in electronics and computer programming in at least one higher-level computer language. Although a course in human anatomy and physiology is very desirable, it is not a required prerequisite for admission to our Medical Physics Graduate Program, because a candidate is expected to be primarily a physicist. Some applicants hold graduate degrees in physics or related fields and some have background in nuclear physics. Provision for remedial education in quantum mechanics, nuclear and radiation physics is provided for students who have not taken intermediate-level courses in these fields.

Since the clinical training is performed in small groups with two to four students in a section, the capacity of our program is limited to only eight students in a two-year master's degree program. We are trying to admit four students every fall semester. Out of the students admitted for the last two years, six have done graduate work in physics at other U.S. universities. One of them received a Ph.D. degree in low-temperature physics, four obtained M.S. degrees, and one took a year of graduate theoretical physics courses at a major U.S. university before enrollment to our Medical Physics Graduate Program. All of these students, and many others whom we could not admit, decided to switch to medical physics because of better employment prospects.

Although the medical physics graduate students spend a large portion of their time on the medical campus, they are registered and have their office in the Department of Physics. Until now there have been sixteen students in our Medical Physics Graduate Program. Four of them were women, and seven were international students [16]. None of the international students admitted for the last two years came from a foreign country. All of them transferred from other U.S. universities. Most of our medical physics graduate students have been supported by graduate assistantships from the Department of Physics. The most common responsibilities of our graduate assistants include teaching undergraduate general physics laboratories, grading homeworks, proctoring the computer lab, tutoring students in the general physics courses, and participation in the medical physics research projects which may lead to a master's thesis. The availability of a substantial number of teaching assistantships is the main advantage of having this program based in the Department of Physics, because the clinical departments usually do not have this kind of support available for graduate students.

4. Medical physics curriculum

Students in our Medical Physics Graduate Program must satisfy the medical terminology requirement, the computer language requirement, pass the comprehensive examination in the Department of Physics, take nine semester hours of electives, and obtain a minimum final grade of B in each of the required courses listed in Table I.

A. Required courses

The curriculum of our Medical Physics Graduate Program is oriented to the needs of the practicing clinical medical physicist. The required courses include Biological Effects of Radiation, Nuclear and Radiation Physics, Health Physics I and II, Nuclear Medicine Physics, Therapeutic Radiological Physics, Diagnostic Radiological Physics, Clinical Rotation in Diagnostic Radiological Physics and Clinical Rotation in Therapeutic Radiological Physics. The catalog description of each course is included in Table I. The core required courses cover four major areas of medical radiological physics: diagnostic radiological physics, nuclear medicine physics, therapeutic radiological physics, and medical health physics. There is a remarkable symmetry in the core course structure between a typical physics graduate program and a graduate program in medical physics. In Table II these four main areas of radiological physics are compared with four areas of theoretical physics: classical mechanics, classical electrodynamics, quantum mechanics, and statistical physics. While diagnostic radiological physics, therapeutic radiological physics, and health physics are presented in our Medical Physics Graduate Program with two semester-long courses each, the physical aspects of nuclear medicine are, at this time, covered in a single four-credit-hour course. Just as there is a great deal of uniformity in the selection of the four areas of theoretical physics, not only in the United State but around the world, the four main areas of radiological physics are equally well defined [17]:

i) *Diagnostic radiological physics* is the branch of medical physics that deals with the diagnostic application of roentgen rays, gamma rays from sealed sources, ultrasonic radiation, or radiofrequency radiation and the use of equipment associated with the production and use of that radiation.

ii) *Medical health physics* is the branch of medical physics that deals with the safe use of roentgen rays, gamma rays, electron or other charged particle beams, neutrons, radionuclides, and radiation from sealed radionuclide sources for both diagnostic and therapeutic purposes in humans and the use of equipment required to perform appropriate radiation tests and measurements.

iii) *Medical nuclear physics* is the branch of medical physics that deals with the therapeutic and diagnostic application of radionuclides, except those used in sealed sources

TABLE I. Required courses in the Medical Physics Graduate Program. Departmental abbreviations: BIOL = Biology, PHYS = Physics, RONC = Radiation Oncology.

RONC 5570 or BIOL 5370. Biological Effects of Radiation (2)
A survey of the biological effects resulting from the interactions of energy and matter for scientifically and technically oriented students.

PHYS 5450. Nuclear and Radiation Physics (3)
An introductory course in nuclear physics including a review of such topics as the constituents of the nucleus, nuclear forces, radioactivity, alpha and beta decay, and gamma rays. A study of the interaction of the various types of radiation and their detection and biological and ecological consequences of radiation usage.

PHYS 5710,5711. Health Physics I(3,0)
Two classroom and three laboratory hours per week.
Detailed coverage of specific health physics topics. Hazards associated with radioactivity and electromagnetic spectrum will be reviewed with special emphasis on ionizing radiation. Topics will include nuclear power, medical radiation protection, and low-level radioactive waste disposal. Field trips will be required.

PHYS 5720,5721. Health Physics II(3,0)
Two classroom and three laboratory hours per week.
Detailed coverage of specific health physics topics. Hazards associated with radioactivity and electromagnetic spectrum will be reviewed with special emphasis on nonionizing radiation. Topics will include radiofrequency, microwave, and laser safety. Field trips will be required.

PHYS 6710,6711. Nuclear Medicine Physics (4,0)
Three classroom and three laboratory hours per week.
Physical aspects of the diagnostic and therapeutic applications of radionuclides and the equipment associated with their use. Radioactive sources for diagnosis and therapy, internal radiation dosimetry, radiation measuring and imaging equipment, calibration of nuclear medicine equipment and devices, counting statistics, quality assurance, and radiation protection including survey techniques and installation design.

PHYS 6718 or RONC 6718. Therapeutic Radiological Physics (3)
A detailed study of the application, in therapeutic practice, of electromagnetic radiations, high-energy particle beams, hyperthermia, and ultrasound. Emphasis is on the conceptual, instrumental, and methodological aspects of therapeutic radiology. Comprehensive working knowledge is provided to function professionally in a clinical setting.

PHYS 6720, 6721. Diagnostic Radiological Physics (4,0)
Three classroom and three laboratory hours per week.
Physical aspects of analog and digital radiography, fluoroscopy, mammography, conventional and computerized tomography, medical ultrasound, and magnetic resonance imaging. Diagnostic generating equipment and sources, recording media and their applications, information transfer theory, sensitometry, dosimetry, calibration of diagnostic equipment, quality assurance, and radiation protection including survey techniques and installation design.

TABLE I. Required courses in the Medical Physics Graduate Program (continued).

PHYS 6991. Clinical Rotation in Diagnostic Radiological Physics (3)
A course in which the student is assigned to various clinical departments where medical physics procedures are regularly used. These assignments will be at the ECU School of Medicine and other participating medical institutions. The students will initially observe and later perform a number of medical physics procedures under the supervision of a senior medical physicist. The procedures will provide hands-on training in the diagnostic techniques utilizing, as appropriate, either ionizing or nonionizing radiation.

PHYS 6992 or RONC 6992. Clinical Rotation in Therapeutic Radiological Physics (3)
A course in which the student is assigned to various clinical departments where medical physics procedures are regularly used. These assignments will be at the ECU School of Medicine and other participating medical institutions. The students will initially observe and later perform a number of medical physics procedures under the supervision of a senior medical physicist. The procedures will provide hands-on training in the therapeutic technique utilizing, as appropriate, either ionizing or nonionizing radiation.

for therapeutic purposes, and the use of equipment associated with the production and use of radionuclides.

iv) *Therapeutic radiological physics* is the branch of medical physics that deals with the therapeutic application of roentgen rays, gamma rays, electron and other charged particle beams, neutrons, or radiations from radionuclide sources and the use of equipment associated with the production and use of that radiation.

While numerous textbooks are available for teaching the core theoretical physics courses, it is difficult to select an appropriate text for the core radiological physics courses. Most radiological physics textbooks have been written as a compromise between instructing graduate students in physics and resident physicians in radiology, whose physics training is often limited to two semesters of general physics without calculus [18,19]. Some other texts are too theoretical for the needs of a clinical medical physicist and require signal processing background which many physicists do not have [20,21]. Faced with this situation, some instructors of medical radiological physics decided not to use a required textbook. Instead, they hand out copies of papers and lecture notes to their students. Some of these compilations are being transformed into textbooks [22]. The diagnostic radiological physics includes medical imaging modalities which are based on very different physical principles. Even if one ignores the more exotic medical imaging modalities, it is difficult to find a text which presents the physical principles of X-ray imaging, magnetic resonance imaging, and medical ultrasound at a level appropriate for graduate students in medical physics. The book used in our program as the textbook for the course in Diagnostic Radiological Physics was compiled by fifteen members of the Joint Department of Physics of the Institute of Cancer Research and Royal Marsden Hospital in London, UK [23]. Although the chapters in this book have been written by different authors, the consistency is good and there is no unnecessary repetition throughout the book. Another text was written by thirty-three Siemens scientists [24]. This book is available in German original and in English translation. Both of these books were written by multiple authors, indicating

TABLE II. Comparison of the Medical Physics Graduate Program and the master's degree program in "pure" physics.

	Medical Physics	"Pure" Physics
Area of concentration	Radiological Physics	Theoretical Physics
Core courses	Diagnostic Radiological Physics Nuclear Medicine Physics Therapeutic Radiological Physics Medical Health Physics	Classical Mechanics Classical Electrodynamics Quantum Mechanics Statistical Physics
Total credit hours	37 semester hours	30 semester hours
Clinical training	Required and most essential	None
Thesis	Optional	Required
Additional requirements	Medical terminology requirement Computer language requirement Comprehensive examination	Computer language requirement Comprehensive examination
Maximum number of students in a section	2–4	Limited only by the size of the classroom
Board certifications	American Board of Radiology American Board of Medical Physics American Board of Health Physics American Board of Science in Nuclear Medicine	None

that the field of diagnostic radiological physics or medical imaging has become so wide that it is very difficult for a single person to produce a graduate text on this subject. Neither of these two books evolved on the American continent. We have experienced difficulty in obtaining the textbook for Diagnostic Radiological Physics by the beginning of the semester [25]. While solving homework problems and returning graded problems to students with copies of instructor's solutions is as important for learning radiological physics as for any other area of physics, there are very few textbooks with problem sets at the end of each chapter [26,27]. Another difference between radiological physics and many other areas of physics is that radiological physics texts get outdated much faster due to the very rapid development of new technologies, some of which are based on completely new physical principles. While *The Atomic Nucleus* by Evans, published in 1955, can still be used quite satisfactorily as a text for an introductory nuclear physics course [28], a knowledgeable medical physicist will notice that the radiological physics books published only a couple of years ago contain information which has been outdated.

As shown in Table III, the courses are offered every second year, allowing admission of students every fall semester. Students entering the program in the Fall 1993, 1995, 1997 etc. will study in their first year diagnostic radiological physics and health physics and in the second year therapeutic radiological physics, nuclear medicine physics, and

TABLE III. Medical physics schedule. Courses are offered every second year.

Fall semester 1993, 1995, 1997,...		
	PHYS 5710, 5711	Health Physics I (3,0)
	PHYS 6720, 6721	Diagnostic Radiological Physics (4,0)
Spring semester 1994, 1996, 1998,...		
	PHYS 5450	Nuclear and Radiation Physics (3)
	PHYS 5720, 5721	Health Physics II (3,0)
	PHYS 6991	Clinical Rotation in Diagnostic Radiological Physics (3)
Fall semester 1994, 1996, 1998,...		
	RONC 5370 or BIOL 5370	Biological Effects of Radiation (2)
	PHYS 6710, 6711	Nuclear Medicine Physics (4,0)
	RONC 6718 or PHYS 6718	Therapeutic Radiological Physics (3)
Spring semester 1995, 1997, 1999,...		
	RONC 6992 or PHYS 6992	Clinical Rotation in Therapeutic Radiological Physics (3)

radiobiology. Students entering in the Fall 1994, 1996, 1998 etc. will start their program with the latter courses.

B. Clinical training

Since direct hands-on experience with clinical equipment is an essential part of learning radiological physics, every medical physics program must provide clinical experience at the intermediate and advanced levels. Such instruction is more difficult, more time-consuming for students and instructors, and more costly than instruction in the didactic courses. Due to the lack of clinical equipment, a physics department cannot offer clinical training. Arrangements must be made with a hospital to provide access to the clinical facilities and the equipment in the departments, or divisions, of diagnostic radiology, nuclear medicine, radiation oncology, and radiation safety. Available instruments and equipment should include reasonably recent models in current use by medical physicists [29]. The limited number of educational programs for medical physicists and the small number of students these programs can admit make the demand-supply ratio favorable for the graduates from those medical physics programs which provide clinical training [30].

C. Elective courses

Many elective courses are available to the medical physics students, the most popular being Modern Electronics, Instrument Computer Interfacing, and Advanced Techniques in Experimental Physics. Nine credit hours of electives provide varying degrees of preparation for different kinds of careers. While those clearly directed to doctoral programs may choose to take even more advanced course work and research, it is recognized increasingly that practical experience is more beneficial for securing highly-paid clinical positions. An important aspect of our program is that it encourages a broad view of the discipline rather than a specialized concentration. Master's degrees are given in medical physics rather than any subspecialty such as diagnostic imaging physics or radiation oncology physics.

D. Medical terminology requirement

Although our students are primarily physicists, they must know enough human anatomy, physiology, pathology, diagnostic radiology, nuclear medicine, radiation oncology, and radiobiology to be able to understand and participate in clinical discussions. The essentials of some of these areas have been condensed in the medical terminology requirement which can be satisfied either by receiving a minimum final grade of B in a human anatomy and physiology course or by passing an exam based on the book *The Language of Medicine*, by Chabner [31].

E. Computer language requirement

Satisfactory knowledge of a computer language may be demonstrated by satisfactory completion of a programming or instrument computer interfacing course, evidence of use of a computer language in research or course projects, or by satisfactory performance on an exam in which the student is asked to convert an algorithm to a program in an acceptable computer language. This requirement is identical for the medical physics students and for the "pure" physics graduate students.

F. Comprehensive examination

This exam must be taken during the first week of the student's second semester. It consists of 12 questions covering the following major areas of undergraduate physics: general physics, mechanics and thermodynamics, electromagnetism and optics, and modern physics. The comprehensive exam is the same for the medical physics students and for students in the traditional physics graduate program.

G. Thesis option

Since basic research is usually not a primary occupation for master's level medical physicists, a formal thesis is not required for graduation from the program. A student who selects the thesis option should choose an area of interest and identify a specific research project. The thesis research counts as six credit hours of electives. Two theses have been defended, "Film dosimetry of high energy electron beams using video framegrabbing techniques", and "Detectability of pulmonary nodules in linearly and logarithmically amplified digital images of the chest". The former thesis was awarded as the best student paper by the Southeastern Chapter of the AAPM [32].

5. PLACEMENT OF GRADUATES

By the time of the writing of this paper, twelve students have graduated from our Medical

Physics Graduate Program. Their success in obtaining employment in clinical medical physics has exceeded even our most optimistic expectations. All twelve of our graduates have been offered medical physics positions before their graduation from our program or immediately after it. One of our graduates received six job offers and several others obtained multiple offers. Starting salaries offered to the graduates from our program range from $38,000 to $56,000. In several cases, more than one student from our program was interviewed for the same position, and at least one hospital interviewed our graduates only, signifying that the competition for the clinical medical physics positions is limited. All twelve of our graduates have accepted positions which will enable them to work under the supervision of an experienced medical physicist, fulfilling *the third stage* of medical physics in-service training. Such experience counts toward the eligibility for board certification by the American Board of Radiology and the American Board of Medical Physics. Since the latter board allows candidates without professional experience to take Part I exam in general medical physics, four of our students have taken and passed this exam. The types of jobs offered to our graduates follow closely the distribution by the type of position advertised through the AAPM Placement Service [33]. One of our master's degree graduates accepted the position of an assistant professor of radiation oncology at a major medical school. Although some of our graduates were offered clinical residency positions, none of these offers was accepted, since the stipends offered to residents are lower than the salaries for the junior medical physics positions secured by all of our graduates.

6. DISCUSSION

The localization of medical physics graduate programs in hospitals and medical centers is primarily due to the historical reluctance of physics departments to provide educational programs for professionally-oriented students such as medical physicists. Such reluctance has undergone some remission in recent years and some physics departments are thinking of starting programs similar to ours [34,35]. However, the migration of medical physics graduate programs to university campuses is not accomplished without problems. Most physics departments have neither the faculty nor the clinical equipment for training of medical physicists. For example, graduate students in medical physics, as in almost all medical disciplines, need on-the-job training and experience, and should spend considerable time in a hospital environment. Such environment is not available on university campuses. As another example, faculty members of most physics departments have neither the experience nor the expertise required to design adequate training programs in medical physics. Due to the above mentioned difficulties, and because of the other unusual requirements associated with medical physics training, a collaborative education effort between the departments of physics, radiation oncology, and radiology is particularly appealing. This approach to medical physics training combines the medical staff of the hospitals, together with the teaching staff and laboratory facilities of the educational institutions, into a collaborative effort to train medical specialists such as medical physicists.

The coexistence of the Medical Physics Graduate Program, described in this paper, and a traditional master's degree program in "pure" physics in the same department has provided a unique opportunity to compare these two programs. It can be seen from Table II that the Medical Physics Graduate Program is more demanding than the other program. The medical physics students have to take 37 semester hours of courses, compared to only 30 semester hours for the physics students. The required courses in the Medical Physics Graduate Program amount to 28 semester hours, compared to only 24 semester hours in the other program. The additional requirements, beyond the required and elective courses, represent a significant difference between these two programs. While the traditional physics students have to satisfy only the computer language requirement and pass the comprehensive examination, the medical physics students have to satisfy also the medical terminology requirement. This is a challenging task for a person with physics background, regardless which of the options, described in Sect. 4D, is selected.

The formal education of most "pure" physicists has ended with the completion of their graduate studies. A medical physicist faces, after graduation with a master's or doctoral degree, the very important *third stage* of medical physics in-service training. By the completion of this stage, the medical physicist has to take a series of board examinations by the American Board of Radiology, the American Board of Medical Physics, the American Board of Health Physics, and/or the American Board of Science in Nuclear Medicine. The board certificate indicates that its holder has completed certain requirements of study and training which the board considers to be at or above the minimum level constituting an adequate foundation in the field, and has passed certain examinations designed to evaluate the competence in the field of radiological physics. The certificate is not a license to calibrate radiation emitting machines or to practice radiological physics in any of its aspects, nor is it a recognition of special achievements in the field of radiological physics [36].

The size of our Medical Physics Program has been determined by the number of students for whom we can provide quality clinical training, and it has exceeded the number of available graduate assistantships. When the applicants realize that they have a good prospect to obtain a position with a respectable salary after graduation from our two-year master's degree program in medical physics, they are willing to come and study enthusiastically even if we cannot offer any financial support to some of them. On the contrary, the upper limit to the size of the traditional physics program has been set by the number of available assitantships. Unfortunately, some of the students who have been attracted to the physics departments with assistantships have difficulty finding employment after graduation. On the other hand, the graduates from our Medical Physics Graduate Program have been extremely successful in obtaining medical physics positions, which not only pay attractive staring salaries, but also provide clinical experience, indispensable for career advancement of a medical physicist. One should not conclude from this that there are more jobs available for medical physicists than for "pure" physicists. Medical physics is a relatively small and highly specialized profession. The demand for medical physicists, and specially for those qualified to practice clinical radiation oncology physics, appears to be so much higher than for the "pure" physicists, only because there are only so few places in the United States where one can study medical physics and each of these programs can provide clinical training for very few students. If the purpose of a university is to provide scientists with the profile which this society needs, our Medical Physics Graduate Program has certainly met this goal.

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