AAPM REPORT No. 64
(Revision of AAPM Report No. 11)

A GUIDE TO THE TEACHING OF CLINICAL RADIOLOGICAL PHYSICS TO RESIDENTS IN DIAGNOSTIC AND THERAPEUTIC RADIOLOGY

Committee on the Training of Radiologists
American Association of Physicists in Medicine

November 1997 – Committee Approval
August 1998 – Education Council Approval

January 1999
Published for the
American Association of Physicists in Medicine
by Medical Physics Publishing

Further copies of this report ($10 prepaid) may be obtained from:

Medical Physics Publishing
4513 Vernon Blvd.
Madison, WI 53705-4964
1-800-442-5778

International Standard Book Number: 0-944838-09-X
International Standard Serial Number: 0271-7344

Published by Medical Physics Publishing
4513 Vernon Blvd., Madison, WI 53705-4964

Printed in the United States of America

Committee on the Training of Radiologists (1996 & 1997)
Cynthia H. McCollough, Chair

J. Ed Barnes
Phillip C. Berry
Michael J. Dennis
Alain L. Fymat
Rosemary Gallagher
Bruce J. Gerbi
Maynard D. High
Eric E. Klein
Patrick N. McDermott
Jerome A. Meli
Marleen M. Moore
Adel A. Mustafa
Edward Nickoloff
Arthur P. Olson
Arthur Pinkerton
Mark S. Rzeszotarski
Almon S. Shiu
Theodore Villafana
Robert D. Zwicker

Samuel C. Hill, Jeff Kotzan, James Willis - *Liaisons from* A^3CR^2
David S. Marsden - Consultant, Past Chair

1982 Ad Hoc Committee
John Glover, Chair

Joseph Arcarese
Gary Barnes
Ted Fields
Joel E. Gray
Lincoln Hubbard
Jonathan Law
Louis Levy
Edward Manny
David Marsden
James Vandergrift

A GUIDE TO THE TEACHING OF CLINICAL RADIOLOGICAL PHYSICS TO RESIDENTS IN DIAGNOSTIC AND THERAPEUTIC RADIOLOGY

TABLE OF CONTENTS

PREFACE

This publication is intended to be a guide for those who teach clinical radiological physics to residents in diagnostic and therapeutic radiology. When appropriate, differentiation is made between specialties. However, most of the material contained in this guide is relevant to both specialties; thus, the terms radiologist and radiation oncologist are generally interchangeable throughout this report. When a differentiation between specialties is appropriate, the differentiation is clearly noted, such as in Sections 8.1 and 8.2, which detail suggested content for a comprehensive radiological physics course for either diagnostic or therapeutic radiology residents. Any comments or suggestions concerning this guide should be directed to the Committee on the Training of Radiologists, American Association of Physicists in Medicine.

1.0 INTRODUCTION

Many changes have occurred in diagnostic and therapeutic radiology since the publication of the first edition of this report in 1982. Numerous technological advances have occurred and computers play an increasingly significant role in clinical practice, as does digital data networking and post-processing. The sophistication of these developments demands that residents receive appropriate technological training. A qualified medical physicist, in addition to teaching the basics of radiological physics, can provide much of this training and thereby play a vital role in equipping physicians to practice radiological medicine into the 21st century.

This updated report is designed to provide guidance to those concerned with providing quality clinical radiological physics instruction to radiology residents: medical (radiological) physicists, resident program directors, department chairs and faculty, and hospital administrators. To this end, this report discusses the rationale for offering a quality educational program in clinical radiological physics, necessary resources and instructor qualifications, appropriate course content and organization, suggested teaching techniques, and resource materials.

2.0. RATIONALE FOR THE TEACHING OF CLINICAL RADIOLOGICAL PHYSICS TO DIAGNOSTIC AND THERAPEUTIC RADIOLOGY RESIDENTS

A firm knowledge of clinical radiological physics is essential for today's radiology resident. Knowing and being able to summarize why this statement is true will equip the physicist, program director, and department chair to secure the resources necessary for a successful course. These resources (which include a course director and faculty, a place to hold the course, a budget for educational materials, and scheduled time for the residents to attend the course) will be discussed in greater detail in the following section. Beyond such practical considerations, students of any discipline learn and retain knowledge most successfully if they see a meaningful relationship between the subject matter and their daily life. Residents will be motivated to learn radiological physics only if they understand its relevance to clinical practice.

Why Learn (Teach) Radiological Physics?

1. Patient and Employee Safety:

   In radiological medicine, now as never before, the clinical procedures, exams, and treatments have becoming increasingly complicated, the equipment is technically sophisticated and expensive; and ethical, regulatory, and legal considerations demand vigilant concern for patient and employee safety. In the radiology or radiation oncology department, the radiologist or radiation oncologist has the final responsibility for patient care. Thus, it is imperative that the resident learn the capabilities and limitations of the tools used to practice radiological medicine, and the potential risks associated with their use.

2. Clinical Expertise:

The practice of radiological medicine depends to a significant degree on the understanding and application of various physical principles as they pertain to activities in which the radiologist or the radiation oncologist has the prime responsibility. This understanding of the principles involved in radiological medicine distinguishes a radiologist or radiation oncologist from other medical specialists.

3. Technical Communication Skills:

   The radiologist or radiation oncologist needs to be able to communicate meaningfully with a variety of technical personnel, particularly regarding equipment selection, technique parameters, and regulatory compliance. He or she may be responsible for hiring quality control and maintenance personnel, evaluating the performance of technical personnel, and assuring compliance with radiation safety guidelines and regulations. Because the radiologist or radiation oncologist relies upon medical physicists, technologists, service engineers, and vendor representatives for information and services, he or she must be able to ask appropriate questions and discern scientific data from marketing claims.

4. Equipment Decisions:

   Radiologists and radiation oncologists should, by their knowledge of radiological physics principles, have a clear understanding of the operation, capabilities and limitations of the diagnostic and therapeutic technologies used in their area of specialization. The radiologist or radiation oncologist must make important decisions concerning equipment specification and selection, facility design, patient and staff safety, and clinical efficacy in diagnostic or therapeutic procedures. In this era of cost-containment and managed care, it is essential that the radiologist or radiation oncologist make wise purchase decisions. This task is significantly aided by a thorough understanding of the physics principles which undergird radiologic technologies.

5. Radiation Specialist:

   In many cases, a radiologist or radiation oncologist may be asked to serve on, or chair, the Radiation Safety Committee. In all cases, the radiologist or radiation oncologist is considered to be an institutional resource on matters relating to radiation. Thus, it is imperative that the resident be well educated in radiological physics.

6. Certification and Licensure:

   Clinical radiological physics is a required portion of an accredited radiology or radiation oncology residency program. In the United States, residents are held accountable for this material via a mandatory written examination administered by the American Board of Radiology (ABR). Additionally, the Nuclear Regulatory Commission (NRC) may directly authorize a user to administer radioisotopes once certain training requirements have been met, in accordance with 10 CFR 35.934 and 10 CFR 35.940. Institutions that have a large broad scope radioisotope license with the NRC may be empowered by the NRC to grant the institution's radiation safety committee the authority to authorize radioisotope users. To accomplish this, the resident (or fellow or non-certified staff physician) must meet certain requirements that include 200 hours of classroom and laboratory training in radiation physics and instrumentation, radiation protection, and the mathematics pertaining to the use and measurement of radioactivity. A user can easily fulfill this goal, when classroom hours, lab hours, orientations, rotations, and reviews are summed. Once a resident completes his or her residency, board certification alone allows an institution to apply for the physician to be a user on a NRC materials license.

3.0 RESOURCES NEEDED FOR PHYSICS EDUCATION

The residency program director should consider carefully the allocation of space, time, equipment, and personnel needed to provide a quality clinical radiological physics educational program. Although it is not possible to make detailed statements applicable to all programs, some general recommendations can be made.

The didactic teaching of clinical radiological physics must be carried out at a time of day and under circumstances that are conducive to learning. Attendance at classes should be mandatory. Residents should not be "on call" during class. The instruction in clinical radiological physics should warrant the same consideration as all other aspects of the program. Quite clearly, the attending staff may have to "cover" so that the residents can obtain their physics training. To allow clinical radiological physics to be taught only when residents have "nothing more important to do" is to undermine the entire effort in terms of its importance and to severely limit the quality of the experience.

The 1995 survey by the American Association of Academic Chief Radiology Residents indicated that 95% of 54 responding programs in diagnostic radiology offer a physics lecture course which takes at least one year to complete. Total program hours ranged dramatically from 14 to 175 hours, with one-third of the programs offering at least 90 hours of didactic teaching. Similarly, the 1995 survey of physics instruction in radiation oncology indicated that the average program devotes about 61.4 classroom hours and 27 laboratory hours per year to physics instruction. The inclusion of orientation programs and physics rotations brought the total teaching effort to as much as 170 hours of physics education per year. As noted above, 200 hours of physics education (or board certification) are required by the NRC to use radioisotope materials. It is the recommendation of this committee that approximately 200 hours of physics education should be provided for each radiology specialty independently, whether it be diagnostic radiology, therapeutic radiology or nuclear medicine. Approximately half of these hours should be composed of didactic (classroom) instruction, with the remaining portion composed of laboratory exercises, demonstrations, self-study or physics rotations.

It must be appreciated that a significant part of the physicist's time may be occupied with teaching. It is commonly accepted that for every 1 hour of classroom time, 3 hours should be allowed for preparation. Thus, adequate time away from other duties must be provided for faculty involved in teaching residents.

There must be support for, and reinforcement of, the teaching of clinical radiological physics from the program director and the clinical staff. The program director should periodically reassess, with the physics instructor, the content and methodology of the clinical radiological physics program. In addition, it is quite helpful to have the program director and members of the clinical staff contribute to the radiological physics training program, if only in a modest way. Examples of helpful contributions from the clinical staff include the identification of artifacts, machine malfunctions, and limitations or benefits of equipment design noted during the performance of clinical examinations. Information of this type aids in the instruction and understanding of physics principles and helps to tie theory to clinical practice.

The residents who are taking the clinical radiological physics course should be evaluated and their status in the program should be made contingent on satisfactory performance, as is the case in their clinical areas. The expectations of the program director and the methods of evaluation (grading) should be clearly defined at the start of the program.

4.0 QUALIFICATIONS OF INSTRUCTORS

Careful consideration must be given to the choice of course director and faculty. In any discipline, the successful practice of a profession does not guarantee that an individual possesses strong teaching skills. Because it is common practice for physicists to teach at the college or university level, most physicists have experience in front of a classroom. However, additional skills must be fostered to successfully motivate and teach physicians who are often distracted by the clinical pressures of their residency. Because residents often do not appreciate the significance of radiological physics with regard to their clinical training and future radiological practice, this course may take a position of lower priority in their already busy training schedules. Thus, the person(s) selected to teach clinical radiological physics to radiology residents should be aware of the needs and limitations of this teaching environment, and be able to adapt without compromising the quality of the teaching process. Strong motivational, communication, and interpersonal skills are particularly valuable. In addition to considering the individual's teaching ability, the radiological physics teacher should be a Board Certified medical physicist or have an extensive background in clinical radiological physics, instrumentation, radiation biology, and radiation safety. Furthermore, the physics educator should have relevant clinical experience in the specialty to be taught, whether diagnostic or therapeutic radiology, or nuclear medicine.

There are presently no standards for this type of teacher training, and no specific education courses to prepare medical physicists to teach physicians. Local teachers' colleges, adult education programs, special symposia, and tutorials are available to foster general teaching skills, some with an emphasis on the medical environment. In many medical institutions, the medical physicist must also teach a variety of medical professionals, including nurses, technologists, medical students and other physicians and physicists. Thus, it may be desirable for the institution or department to encourage and support the acquisition of advanced teaching skills. For any teacher, the constructive criticism of one's students and peers, self-study, introspection, and several years of experience are the best means of improving one's skills.

5.0 COURSE ORGANIZATION AND CONTENT

The organization and content of a course in clinical radiological physics must meet several criteria:

1. It must catch and hold the sincere interest of the student.
2. It must impart relevant information in a clear and concise manner.
3. It must fit into the total residency program in an appropriate way.

It is important to stress that a residency is primarily a professional training period and not a continuation of academic studies; therefore, clinical radiological physics should be practical and pertinent to the practice of radiology or radiation oncology. The resident should be taught what is essential and relevant in order to satisfy the needs of the patient and health care team, considering issues such as medically-pertinent technical knowledge, the economics of health care, and the safety of all concerned.

Several definite recommendations can be given to help achieve the above criteria. The overall program of clinical radiological physics should be as intensive as possible and the majority of its content given early in the program. The director should emphasize the success of the program in terms of concepts learned rather than clock hours, although care must be given to meet specific training requirements [e.g., NRC or Mammography Quality Standards Act (MQSA)], when applicable.

5.1 Orientation Course

There should be a brief introductory course soon after the resident has entered the program. If such a course is effectively presented, a resident will have acquired a working knowledge of the technical aspects of a radiology department, be prepared to speak and listen intelligently to physicists, technologists, and radiologists, be watchful for physical principles at work, have established a rapport with the physics staff early in the training period, and be better prepared for the more intensive physics course that will follow. An introductory overview is recommended to avoid having the resident enter a course whose relevance might be unclear and whose goals may seem remote. The course should: (1) include at least some opening remarks by the program director to establish the significance of clinical radiological physics; (2) give an overview of the application of physics to the specialty; (3) demonstrate some useful skills on how to safely use radiation-producing devices; (4) provide, with the chief technologist or medical dosimetrist, hands-on demonstrations of patient positioning, selection of the suitable equipment for the intended procedure, equipment capabilities and limitations, formulation of therapy dose prescriptions, dose (monitor unit) calculations, and source loading (as appropriate for a given specialty); and (5) teach the fundamental aspects of radiation safety; including prenatal and employee radiation policies and limits, radiation risks, personnel monitoring, emergency procedures and incident reporting, handling of radioactive sources, and the use of survey meters. This course should consist of 20 - 40 hours of orientation and introductory material and occur within the first few weeks of the program.

5.2 Comprehensive Course

An ideal radiological physics teaching program would be tailored to each individual year's residents. This would mean teaching three to four years of different topics, simultaneously. This approach is impractical for a number of reasons, including the small numbers of residents in individual years, the difficulty of taking time for lectures away from the already full clinical schedule, and the ever increasing demand on the physicist’s time for other clinical responsibilities. Given that repeat exposure to unfamiliar material substantially increases retention and understanding, it is recommended that a single, comprehensive course be given to all residents and repeated on an annual basis. This allows multiple opportunities for a resident to hear lectures on any given topic and can allow those who must miss certain lectures to hear them during a subsequent year. It is further recommended that attendance at this course be required for first year residents, who are typically less essential for the clinical practice than are senior residents. A key advantage to providing a comprehensive physics course early in the resident’s training is that it allows the resident time and opportunity to assimilate physics principles into clinical practice. Additionally, the American Board of Radiology, beginning in 1998, will offer the written board examination in Physics as early as the second year of residency. Thus, the residents who pursue this option will require a didactic physics course sometime in their first year.

It is desirable to present basic physics principles in an early, well-defined segment of a comprehensive course or as its own separate course. This helps to identify those topics that serve as the physical basis for the more clinically related topics. It also facilitates offering a core physics course for multiple specialty programs (with appropriate specialized outside reading). The basic physics course (or course segment) should deal with fundamental aspects of radiation, matter and their interactions and the level should be appropriate to the intended audience. Thus, theory and mathematics should give way to plain-English explanations, simple illustrations, and relevant conclusions. The presentation should be qualitative except for those aspects in which the resident must develop competence in actual calculation, such as the mathematics of decay. Determining how many physics computations a diagnostic or therapeutic radiologist actually performs in practice will help put these matters into perspective. Such computational problems that serve a useful purpose should be practiced in both lecture and as homework. While there is a tendency to teach the basic physics topics in a traditional fashion, instructors must relate through clinical examples the need for this section of "non-applied" information.

The second stage of the comprehensive course should concentrate on clinical radiological physics topics with an emphasis on application to clinical practice. After fundamental principles are presented, theory can best be linked to practice by identifying a number of relevant clinical tasks and then working through the various elements required to solve the particular problem.

Several examples include:

1. Have the students configure various treatment plans using an anthropomorphic phantom and various photon and electron modalities and energies. Have the students compare the various options and identify the optimal plan for various patient scenarios. Finally, have the students perform the optimal treatment plan on the anthropomorphic phantom and measure the results.

2. Ask the students to predict their future nuclear medicine practices. Have them write up a mock NRC license application.

3. Present the students with the detailed specifications of several radiographic and fluoroscopic x-ray units. Have them choose among them and give detailed justification.

4. Have the students prepare a Request for Bid specification document for an interventional, CT or MRI suite. Be sure that they address service and room preparation needs.

The clinical radiological physics course should contain those elements of radiation protection that apply to the specialty. The course should prepare the radiologist to apply protection schemes for patients and staff, to appreciate the problems of effective facility design, to understand the concepts of keeping exposure of personnel “as low as reasonably achievable (ALARA),” and to understand the requirements of licensure, regulation, and accreditation. Thus, it is very important that the physicist educator clearly understands how physics fits into the role of radiologist or radiation oncologist and then develop the course in clinical radiological physics to meet those needs. Section 8 of this report addresses specific topic guidelines for a comprehensive, radiological physics course. Approximately 60 - 100 hours of classroom instruction are recommended for the comprehensive course.

5.3 Review Sessions for Certification Examination

Prior to the written physics examination, most residents appreciate additional time (20 hours or more) dedicated to polishing their physics problem-solving skills. Several resources (see section 7.6) are available which provide abundant sample physics questions. Many of these also provide answers or short explanations. These are excellent materials for self-study, self-assessment, and group question and answer practice sessions.

Informal review sessions are most effective when the students are responsible for arranging the meeting time and place and for setting the agenda. These sessions should provide the students with an opportunity to focus on the topics that they feel need further clarification; time should not be spent repeating material which has been previously presented unless a specific question arises which necessitates some didactic review. Students should come to these sessions prepared to ask questions, having already spent time attempting to solve sample questions so that they can bring forward those that posed some difficulty (answer keys in even the best of texts are occasionally wrong). If it is apparent that outside preparation has not been done, the teacher may wish to have students take turns solving problems for the group. Some mechanism by which to actively involve the students in the problem-solving process is necessary in order for the students to gain experience and confidence in dealing with this material. Written and oral examinations may provide this incentive.

A word of advice for the faculty: it may be helpful to establish topics for a given session ahead of time and have the appropriate physicist (perhaps a local expert on the topic) attend, if at all possible. This is particularly important for young faculty, or those who may not work routinely in all areas of radiological physics. Teachers must be willing to admit when they don't know an answer, but must also be sure to figure out the answer prior to the next session. Students will forgive the instructor for not being able to answer a question, but respect and rapport will be seriously damaged if the instructor attempts to bluff his or her way out of a difficult question.

5.4 Clinical Rotations in Medical Physics

For the motivated teacher and student, a Medical Physics rotation can provide an exceptional learning opportunity. These rotations can allow the resident to observe the daily activities of a medical physicist, and to better understand the role of medical physicists. As many of the duties of the medical physicist occur "behind-the-scenes," such a rotation may be the only opportunity for a resident to see many of the duties that a medical physicist performs to support the clinical practice. This insight can be particularly valuable for the resident who will later need to obtain or evaluate medical physics services for his or her facility. The "hands-on" experience obtained by working with the medical physicist will allow the resident to form realistic assessments of manpower and equipment commitments for patient-related physics services.

The demands on a resident's and physicist's time usually makes the scheduling of a rotation difficult. Because there exists such variety in the manner in which a medical physicist spends his or her work day, the resident must be able to spend significant amounts of time with the physicist at various portions of the day. One method of ensuring as broad an experience as possible is to have a list of specific activities that should be experienced or accomplished. While the official rotation may allow only one week of assignment to the physicist, additional hours should be mandatory until the list of required activities has been completed. Examples of activities which may be included on such a list include: attendance at a meeting of the Radiation Safety Committee, participation in quality assurance measurements for several types of equipment (mammographic unit, linac, CT or MRI scanner, etc.), observing a fetal dose calculation and subsequent patient or physician consultation, and shielding specification and inspection. The goal is not to teach the residents how to be a medical physicist, but to familiarize them with some of the activities for which the medical physicist has responsibility and to provide an opportunity to see the material taught in the classroom applied to the clinical setting.

5.5 Summary of Time Commitment

While every program should be tailored to meet the specific needs of an institution's residents and faculty, the recommended time commitments can be summarized as follows:

Orientation Course	20-40 hours
Comprehensive Course	60-100 hours
Laboratories and Demonstrations	20-40 hours
Review Sessions	20-40 hours
Clinical Rotations	20-40 hours
Self Study	80-100 hours

Using these guidelines, the 200 hours of physics education required by the NRC can be readily achieved. Approximately one-half of the physics educational hours should involve classroom instruction, while the remaining hours should include laboratory exercises, demonstrations, clinical rotations in Medical Physics, and self study.

6.0 TEACHING TECHNIQUES

Suggesting teaching techniques is an important aspect of this Guide. Although there is no substitute for a well-organized course, certain methods can make the course a more effective and enjoyable learning experience. Physicists new to the role of resident educator, as well as experienced teachers, should experiment with a variety of methods, seeking to use those which best engage and stimulate their students.

6.1 Audio-Visual Aids

Classroom time is an important part of a training program because it is a setting in which the instructor can help the student develop the appropriate concepts of clinical radiological physics. Concept formation is greatly enhanced by the use of visual presentations. Several different methods are available for presenting visual material.

1. Blackboard (Chalkboard) or Whiteboard:

It is essential to have a large writing surface available during lectures, even if prepared handouts, overheads, or slides are the primary lecture media. Often an impromptu question motivates the instructor to sketch a diagram or graph or to write down an essential fact or formula pertinent to the current discussion. Taking the time to write down or draw a concept often allows the student additional time to process the explanation, as well as visually reinforcing the concept. Caution should be used, however, in presenting the entire lecture on the board as this requires the student to be more occupied with transcribing the material than understanding it.

2. Handouts:

   Most medical schools make extensive use of handouts. Consequently, residents are quite attuned to this type of material. The physicist will find this invaluable in that only relevant material need be provided for the residents' reading. Handouts provide a mechanism for the physicists to accurately depict complex graphs, charts, and drawings which would otherwise require considerable time to explain and draw in the classroom. The student can make notes directly on the handouts and thereby devote their effort to learning the concepts instead of trying to take notes or sketch drawings accurately.

3. Overhead Projection:

   One of the most versatile modes for presenting visual material in the classroom is the overhead projector. In addition to projecting radiographic images, it can be used to present illustrations and text summaries. There are several ways of obtaining the transparencies for this mode of projection. Most copy machines and computer printers can produce transparencies from typed material. Special markers are available for drawing and writing directly on transparent sheets. These can be used to prepare illustrations before class time or add information during the presentation. Overhead projection offers a high degree of flexibility in comparison with 35-mm slides. With the overhead projector, it is easy to go back to previous illustrations for the purpose of review, relating concepts, or answering questions.

4. Video Projection:

   A new but particularly useful tool for classroom instruction is a device which allows computer screens to be projected using either an LCD flat-panel in combination with an overhead projector, or a direct video projection system. These devices are becoming quite common, and are typically available from the audio-visual department. Using such a device, physicists can prepare slide presentations on a portable computer that can then be easily displayed in the classroom. Software packages for slide preparation are readily available (examples include Powerpoint, Harvard Graphics, and Aldus Persuasion). An additional benefit of these software packages is the ability to print paper handouts of slides for distribution to the students.

5. 35-mm Slides:

Both radiographic images and printed illustrations can be copied onto 35-mm slides for classroom projection. As noted above, several commercial software packages are available for slide preparation using personal computers. A disadvantage of 35-mm slides is that the material must be arranged in the projector trays before the presentation. This makes it somewhat difficult to alter the order of presentation in the classroom or to refer to previously used illustrations. Additionally, students seem to be less inclined to interrupt a slide presentation with questions. In general, overhead projection techniques promote increased classroom interaction between student and teacher than do lectures which use 35-mm slides exclusively. Slides are a useful media, however, for portions of the lecture which seek to demonstrate physical principles using a number of clinical or phantom images.

6. Radiographic Images:

   It is very important that the concepts of image formation and image quality be illustrated by the use of actual clinical radiographic images. An instructor should create a set of teaching images using both actual patient cases and phantom or test objects. The American College of Radiology's Radiological Learning Laboratory includes a teaching file of radiographic films with a useful section on the Physical Principles of Radiographic Imaging (many of these images, and others, are included in the American Association of Physicists in Medicine's Visual Teaching Aids for Diagnostic Radiology slide teaching set). For classroom use, radiographic images can be projected onto a screen by the use of an overhead projector, captured via video camera for display on a television monitor, or photographed using 35-mm film for slide projection.

7. Electronic Teaching Environment:

   The utilization of the latest computer technology as an aid to teaching should be emphasized. Many departments now have several digital imaging modalities networked together, and images from these modalities should be used advantageously. In addition, the availability of teleradiology, teleconferencing, computer-based CD-ROM, World Wide Web, video players and recorders, and live or satellite TV communications should be employed whenever practical. Multimedia educational computer software is becoming more available from a variety of sources, including many radiological societies and publishers. A self-learning laboratory equipped with multimedia computers, video players, and 35-mm slide viewers should be available with 24-hour access.

6.2 Laboratories and Demonstrations

Laboratory experiments are useful in reinforcing basic concepts previously presented in lectures and in providing residents with important and desired hands-on experience. The important guidelines in conducting lab experiments are to have a definite, stated objective, to be brief and to the point, and to require only the absolute minimum data collection necessary to illustrate the objective. Laboratories should be part of the resident's training only when they can be used well, and when appropriate equipment can be made available at an appropriate time.

Demonstrations are also useful teaching aids. Examples are the operation of film changers and other special-procedure equipment; checks on radiation and light-field congruence and other quality assurance tests; and the calibration of a linac. Familiarity with acceptable performance limits and the sequence of steps used to correct malfunctioning equipment should be presented. The guidelines discussed above for laboratory experiments also apply to demonstrations.

6.3 Clinical Radiological Physics Participation

Nearly all of the activities of the clinical medical physicist should be of interest to the prospective diagnostic or therapeutic radiologist. The application of physics principles will emphasize and reinforce the didactic course. There are, of course, limitations. Boredom with some of the more tedious tasks may cause an unpleasant and unproductive experience. Also, it is not usually possible to organize the simultaneous participation of more than one or two residents.

The activities in which a resident could fruitfully participate include: calibration and safety checks of radiation producing and radiation detecting equipment; visiting a radioisotope pharmacy and observing dose assays and wipe tests; quality control; measurements of gamma, ultrasound, CT or MRI scanners and film processors; therapy treatment planning and dose computations; radiation safety surveys; and shielding design and evaluation. In addition, it would be useful to observe a Radiation Safety Committee meeting or an inspection by an accrediting or regulatory agency [e.g., Joint Commission for Accreditation of Healthcare Organizations (JCAHO) or NRC].

The degree of participation will vary with the institution, the task, and the interests of the resident and the physicist. One should not expect the resident to function as a coworker and should remember he or she is a student learning new skills. For some activities the resident can only be an observer; in that case, it is important to prevent boredom and to ensure that the significance of the activity not be misunderstood. There is a need to maintain a proper professional and teaching atmosphere; the use of a resident as a "go-for" is to be avoided.

The scheduling of a resident's time for participation in clinical radiological physics is often difficult due to the many demands on the resident's time. Some institutions utilize a formal rotation through physics. In other cases, a portion of another rotation, such as half a day per week while the person is assigned elsewhere, is utilized. Only in small institutions, and generally with mixed success, can residents be taught physics without a scheduled time allotment.

The personality of the clinical physicist who works with the residents during clinical participation is crucial to the success of this mode of teaching. An articulate, well-organized individual who likes to demonstrate and discuss is needed. Not only should the resident spend time with the physicist, but the physicist should be a participant in the clinical conferences at which physics can occasionally be the subject for discussion. The residents and physicists can participate in the department journal club by presenting published articles closely related to radiological physics. The "AAPM/RSNA Physics Tutorials for Residents" published in *Radiographics* provide excellent material for such presentations.

6.4 Guest Lecturers

The physics course will be off to an enviable start if the chief radiologist gives a lecture entitled "How I Use Physics in My Daily Practice" as the opening lecture in the clinical radiological physics course. Guest lecturers can add motivation, diversity of views, and specialized expertise, or even fill a gap in the instructor's schedule. However, because of differences in teaching styles, personal emphasis, and terminology, guest lecturers can create chaos unless their number is limited and they are carefully utilized. If the presentation is poor, the views presented are contrary, or the subject is inappropriate, even a single guest lecturer can have a devastating effect.

The course instructor and the guest lecturer should agree beforehand in detail on the contents of the lecture. The instructor should know the lecturing style and ability of the guest as much as possible. The instructor should sit in on the lecture, both to connect the lecture to the rest of the course and to evaluate the lecturer for possible future use. The guest lecturer should have specific expertise and interest in the subject, a good lecturing style, and a willingness to cooperate to achieve the goals of the course.

"In-house" guest lecturers may be radiologists or radiation oncologists, other physicists, radiopharmacists, radiobiologists, biomedical engineers, or technologists. Many commercial firms, professional organizations, and government agencies also have guest lecturers available. The costs of a guest lecturer are usually an honorarium and travel expenses. In general, in-house and commercial lecturers will require neither; this is also often true for government lecturers. In all but a few cases, the honorarium is more token than substance. The money to support the lecturers can come from the institution's budget or unbudgeted "professional" funds.

6.5 Self-Study

Under certain circumstances it may be more cost effective to handle the physics course by way of supervised self-study. While many resources are available (see sections 7.1 - 7.9), it is best to select material that requires the student to participate actively in obtaining the required knowledge. If this mechanism is used to teach a large portion of the clinical radiological physics curriculum, some mechanism of motivation and assessment should be used. Both written and oral examinations, as well as clinical rotations and problem-solving sessions, can help to supplement the resident’s self-study efforts.

6.6 Examinations

Objective evaluation of the resident's progress should be included in a radiological physics education program. Periodic examinations serve both as a teaching aid and motivational tool and can provide feedback regarding strengths and weaknesses to both the teacher and the student. In order for exams to have their maximum educational impact, they should be reviewed and returned promptly.

"Examinations" should be looked at in the broad sense: they can include surprise quizzes, end-of-course written tests, take-home problems, oral presentation of a project assigned during the clinical radiological physics rotation, or any other mechanism of evaluating the student's understanding of course content. A number of resources containing multiple choice-type questions are available to help assess the resident's progress, but the instructor should carefully review all questions and answers for errors. Multiple-choice questions should be used judiciously, as they primarily test the retention of specific information and do little to foster inductive reasoning or address complex (real life) situations.

The learning and teaching of clinical radiological physics constitutes a serious commitment of time and personnel resources. Thus, it is reasonable to expect the serious attention of the resident. While making the clinical radiological physics course relevant to the practice of radiological medicine is the best way to maintain the interest of the resident, relating a resident's status in the program to his or her performance in the course will provide additional motivation. Examination results should be reported to the program director. Just as poor performance in clinical rotations may jeopardize the successful completion of a residency program, a resident should not be allowed to continue in a program irrespective of his or her performance in physics.

7.0 RESOURCE MATERIAL

The Training of Radiologists Committee of the AAPM has compiled a list of resource material in the categories listed below. The AAPM does not claim that this list is complete; nor can it vouch for the quality or availability of the material. Each teacher should review as much of the material as possible to determine its quality and applicability to the teaching program and to gain insight into alternative methods of presenting the same material. Some texts may be too advanced for resident use but would be valuable reference material for educators. Comments for improvement of this list are encouraged and should be forwarded to the AAPM Training of Radiologists Committee. The most current electronic version of this list may be found on the AAPM website.

7.1 Books

General

Attix FH. **Introduction to Radiological Physics and Radiation Dosimetry**. New York, NY: John Wiley & Sons, 1986. 607 pp. ISBN 0-47101-146-0.

Cameron JR, et al. **Medical Physics: The Physics of the Body**. Madison, WI: Medical Physics Publishing, 1992. 343 pp. ISBN 0-944838-25-1.

Carson PL, Editor. **Radiation Science: Uses in Medical Imaging and Therapy.** Dubuque, IA: Kendall/Hunt, 1996. ISBN 0-78720-817-5.

Cember H. **Introduction to Health Physics.** New York, NY: McGraw-Hill, Health Professions Division, 1996. 733 pp. ISBN 0-07105-461-8.

Evans RD. **The Atomic Nucleus.** Malabar, FL: R. E. Krieger, 1982 (originally 1955). 972 pp. ISBN 0-89874-414-8.

Fullerton GD, Editor. **Biological Risks of Medical Irradiations**. AAPM Monograph No. 5. New York, NY: American Institute of Physics for AAPM, 1980. 335 pp. ISSN 0163-1802.

Hall EJ. **Radiobiology for the Radiologist,** 4th Edition. Philadelphia, PA: J.B. Lippincott, 1994. 478 pp. ISBN 0-39751-248-1.

Hendee WR, et al. **Radiologic Physics, Equipment, and Quality Control**. Chicago, IL: Year Book Medical Publishers, 1977. 289 pp. ISBN 0-81514-228-5.

Hobbie RK. **Intermediate Physics for Medicine and Biology,** 3rd Edition. New York, NY: Springer, 1997. 688 pp. ISBN 1-56396-458-9.

International Commission on Radiological Protection. Numerous publications related to Diagnostic and Therapeutic Radiology as well as Medical Health Physics. Contact ICRP for complete publication listing (see section 7.9).

Johns HE, Cunningham JR. **The Physics of Radiology,** 4th Edition. Springfield, IL: Charles C. Thomas, 1983. 796 pp. ISBN 0-39804-669-7.

Johns HE, Cunningham JR. **Solutions to Selected Problems from The Physics of Radiology,** 4th Edition. Springfield, IL: Charles C. Thomas, 1991. 139 pp. ISBN 0-39805-750-8.

Knoll, GF. **Radiation Detection and Measurement,** 2nd Edition. New York, NY: John Wiley & Sons, 1989. 754 pp. ISBN 0-47181-504-7.

Martin MC, Smathers JB, Editors. **Current Regulatory Issues in Medical Physics: Proceedings of an American College of Medical Physics Symposium.** Madison, WI: Medical Physics Publishing, 1992. 458 pp. ISBN 0-944838-29-4.

Mettler FA, Jr, et al. **Radiation Accidents.** Reston, VA: The American College of Radiology, 1989. 47 pp.

Mettler FA, Kelsey CA, Ricks RC, Editors. **Medical Management of Radiation Accidents.** Boca Raton, FL: CRC Press, 1989. 416 pp. ISBN 0-8493-4865-X.

National Academy of Sciences/National Research Council, Committee on the Biological Effects of Ionizing Radiations. **Health Effects of Exposure to Low Levels of Ionizing Radiations, BEIR V.** Washington, DC: National Academy Press, 1990. 421 pp. ISBN 0-30903-995-9 (pbk.); ISBN 0-30903-997-5 (cloth).

National Council on Radiation Protection and Measurements. Numerous publications related to Diagnostic and Therapeutic Radiology as well as Medical Health Physics. Contact NCRP for complete publication listing (see section 7.9).

Prasad KN. **Handbook of Radiobiology,** 2nd Edition. Boca Raton, FL: CRC Press, 1995. 344 pp. ISBN 0-84932-501-3.

Raabe OG, Editor. **Internal Radiation Dosimetry: Health Physics Society, 1994 Summer School.** Madison, WI: Medical Physics Publishing, 1994. 667 pp. ISBN 0-944838-47-2.

Rajan KNG. **Advanced Medical Radiation Dosimetry**. New Delhi: Prentice-Hall of India, 1992. 522 pp. ISBN 81-203-0706-2. Distributed by Medical Physics Publishing, Madison, WI.

Shapiro J. **Radiation Protection: A Guide for Scientists and Physicians,** 3rd Edition. Cambridge, MA: Harvard University Press, 1990. 494 pp. ISBN 0-67474-586-8.

Tubiana M, et al. **Introduction to Radiobiology**. London: Taylor & Francis, 1990. 371 pp. ISBN 0-85066-745-3, ISBN 0-85066-763-1 (pbk.).

Wahlstrom B. **Understanding Radiation.** Madison, WI: Medical Physics Publishing, 1995. 100 pp. ISBN 0-944838-62-6.

<u>Diagnostic</u>

American College of Radiology. **Mammography Quality Control Manual: Radiologist's Section, Radiologic Technologist's Section, Medical Physicist's Section,** Revised Edition. Reston, VA: American College of Radiology, 1994. 210 pp. ISBN 1-55903-136-0.

Axel L, et al. **Glossary of MR Terms, 3rd Edition.** Reston, VA: American College of Radiology, 1995. 54 pp.

Brown MA, Semelka RC. **MRI Basic Principles & Applications.** New York, NY: John Wiley & Sons, 1995. 149 pp. ISBN 0-47112-825-2.

Bushberg JT, et al. **The Essential Physics of Medical Imaging.** Baltimore, MD: Williams & Wilkins, 1994. 742 pp. ISBN 0-68301-140-5.

Bushong SC. **Radiographic Science for Technologists: Physics, Biology, and Protection,** 5th Edition. St. Louis, MO: Mosby-Year Book, 1993. 714 pp. ISBN 0-80166-455-1.

Chandra R. **Introductory Physics of Nuclear Medicine,** 4th Edition. Philadelphia, PA: Lea & Febiger, 1992. 221 pp. ISBN 0-81211-442-6.

Curry TS, III, et al. **Christensen's Physics of Diagnostic Radiology,** 4th Edition. Philadelphia, PA: Lea & Febiger, 1990. 522 pp. ISBN 0-81211-310-1.

Dendy PP, Heaton B. **Physics for Radiologists.** Oxford: Blackwell Scientific; Chicago, IL: Distributors, USA, Year Book Medical Publishers, 1987. 417 pp. ISBN 0-63201-351-6.

Early PJ, Sodee DB. **Principles and Practice of Nuclear Medicine,** 2nd Edition. St. Louis, MO: Mosby, 1995. ISBN 0-80162-577-7.

English RJ, Brown SE. **SPECT: Single-Photon Emission Computed Tomography: A Primer,** 2nd Edition. New York, NY: Society of Nuclear Medicine, 1990. 236 pp. ISBN 0-93200-434-2.

Fish PJ. **Physics and Instrumentation of Diagnostic Medical Ultrasound.** New York, NY: John Wiley & Sons, 1990. 250 pp. ISBN 0-47192-651-5.

Fishman EK, Jeffrey RB, Jr. **Spiral CT: Principles, Techniques, and Clinical Applications**. New York, NY: Lippincott-Raven Publishers, 1995. 227 pp. ISBN 0-78170-218-6.

Frey GD, Sprawls P. Editors. **The Expanding Role of Medical Physics in Diagnostic Imaging.** Secaucus, NJ: Springer-Verlag for AAPM, 1997. 592 pp. ISBN 1-888340-09-6.

Goldman LW, Fowlkes JB, Editors. **Medical CT and Ultrasound: Current Technology and Applications.** Madison, WI: Advanced Medical Publishing for AAPM, 1995. 640 pp. ISBN 1-88352-603-5.

Gray JE, et al. **Quality Control in Diagnostic Imaging.** Rockville, MD: Aspen Publishers, 1982. 249 pp. ISBN 0-83911-681-0.

Harbert JC, et al. **Nuclear Medicine: Diagnosis and Therapy.** New York, NY: Thieme Medical Publishers, 1996. 1256 pp. ISBN 0-86577-570-2.

Haus AG, Jaskulski SM. **The Basics of Film Processing in Medical Imaging.** Madison, WI: Medical Physics Publishing, 1997. 340 pp. ISBN 0-944838-78-2; ISBN 0-944838-79-0 (pbk).

Hasegawa B. **The Physics of Medical X-ray Imaging,** 2nd Edition. Madison, WI: Medical Physics Publishing, 1991. 327 pp. ISBN 0-94483-823-5. (out of print)

Hendrick WR, et al. **Ultrasound Physics and Instrumentation,** 3rd Edition. St. Louis, MO: Mosby, 1995. 382 pp. ISBN 0-81514-246-3.

Hendee WR, Ritenour ER. **Medical Imaging Physics,** 3rd Edition. St. Louis, MO: Mosby Year Book, 1992. 781 pp. ISBN 0-81514-241-2.

Henkin R, et al. **Nuclear Medicine**. St. Louis, MO: Mosby, 1996. 1724 pp. ISBN 0-80167-701-7.

Horowitz AL. **MRI Physics for Radiologists: A Visual Approach,** 3rd Edition. New York, NY: Springer-Verlag, 1995. 180 pp. ISBN 0-38794-372-2.

Kelsey CA. **Essentials of Radiology Physics.** Philadelphia, PA: Lippincott-Raven, 1997. 467 pp. ISBN 0-39755-094-4.

Kremkau FW. **Diagnostic Ultrasound: Principles and Instruments,** 5th Edition. Philadelphia, PA: W. B. Saunders Company, 1998. ISBN 0-72167-143-8.

Loevinger R, et al. **MIRD Primer for Absorbed Dose Calculations.** New York, NY: Society of Nuclear Medicine, 1991. 128 pp. ISBN 0-93200-438-5.

Madsen MT, Ponto JL. **Medical Physics Handbook of Nuclear Medicine.** Madison, WI: Medical Physics Publishing, 1992. 114 pp. ISBN 0-944838-14-6.

Recommended Specifications for New Mammography Equipment, American College of Radiology.

Seibert JA, et al., Editors. **Specification, Acceptance Testing and Quality Control of Diagnostic X-ray Imaging Equipment.** Woodbury, NY: American Institute of Physics for AAPM, 1994. 1129 pp. ISBN 1-56396-421-X.

Shellock FG, Kanal E. **Magnetic Resonance: Bioeffects, Safety, and Patient Management,** 2nd Edition. Philadelphia, PA: Lippincott-Raven, 1996. ISBN 0-39758-437-7.

Smith HJ, Ranallo FN. **A Non-Mathematical Approach to Basic MRI**. Madison, WI: Medical Physics Publishing, 1989. 203 pp. ISBN 0-944838-02-2.

Smith HJ, Zagzebski JA. **Basic Doppler Physics**. Madison, WI: Medical Physics Publishing, 1991. 121 pp. ISBN 0-944838-15-4.

Sorenson JA, Phelps ME. **Physics in Nuclear Medicine,** 2nd Edition. Orlando, FL: Grune & Stratton, 1987. 590 pp. ISBN 0-80891-804-4.

Smith RC, Lange RC. **Understanding Magnetic Resonance Imaging.** Boca Raton, FL: CRC Press, 1998. 240 pp. ISBN 0-8493-2658-3.

Sprawls P, Jr. **Physical Principles of Medical Imaging,** 2nd Edition. Madison, WI: Medical Physics Publishing, 1995. 656 pp. ISBN 0-944838-54-5.

Wagner LK, Archer BR. **Minimizing Risks from Fluoroscopic X-rays: Bioeffects, Instrumentation, and Examination (A Credentialing Program for Physicians).** Houston, TX: RM Partnership, 1996.

Wagner LK, et al. **Exposure of the Pregnant Patient to Diagnostic Radiations: A Guide to Medical Management,** 2nd Edition. Madison, WI: Medical Physics Publishing, 1997. 259 pp. ISBN 0-944838-72-3.

Wolbarst AB. **Physics of Radiology**. Norwalk, CT: Appleton & Lange, 1993. 461 pp. ISBN 0-83855-769-4.

Zeman RK, et al. **Helical/Spiral CT: A Practical Approach.** New York, NY: McGraw-Hill, 1995. 332 pp. ISBN 0-07072-653-1.

Therapeutic

Bentel GC. **Radiation Therapy Planning,** 2nd Edition. New York, NY: McGraw-Hill, 1996. 643 pp. ISBN 0-00705-115-1.

Bentel GC, et al. **Treatment Planning and Dose Calculation in Radiation Oncology,** 4th Edition. New York, NY: Pergamon Press, 1989. 345 pp. ISBN 0-08034-328-7.

Blackburn B. **Blackburn's Introduction to Clinical Radiation Therapy Physics.** Madison, WI: Medical Physics Publishing, 1993. 218 pp. ISBN 0-944838-06-5.

Coia LR, et al., Editors. **A Practical Guide to CT Simulation.** Madison, WI: Advanced Medical Publishing, 1995. 209 pp. ISBN 1-883526-04-3.

Constantinou C: **Protocol and Procedures for Quality Assurance of Linear Accelerators.** Brockton, MA: Brockton Hospital, Radiation Oncology Department, 1993. ISBN 0-96382-660-3.

Hendee WR, Ibbott GS. **Radiation Therapy Physics,** 2nd Edition. St. Louis, MO: Mosby, 1996. 576 pp. ISBN 0-80168-099-9.

Higginbotham J, Editor. **Applications of New Technology: External Dosimetry.** Madison, WI: Medical Physics Publishing, 1996. 456 pp. ISBN 0-944838-69-3 (pbk.).

Jani SK. **CT Simulation for Radiotherapy.** Madison, WI: Medical Physics Publishing, 1993. 172 pp. ISBN 0-944838-32-4.

Jani SK. **Handbook of Dosimetry Data for Radiotherapy.** Boca Raton, FL: CRC Press, 1993. 199 pp. ISBN 0-84933-263-X.

Karzmark CJ, Morton RJ. **A Primer on Theory and Operation of Linear Accelerators in Radiation Therapy**. Madison, WI: Medical Physics Publishing, 1989. 41 pp. ISBN 0-944838-07-3.

Karzmark CJ, Nunan CS, Tanabe E, Editors. **Medical Electron Accelerators.** New York, NY: McGraw-Hill, Inc., Health Professions Division, 1993. 316 pp. ISBN 0-07105-410-3.

Khan FM. **The Physics of Radiation Therapy,** 2nd Edition. Baltimore, MD: Williams & Wilkins, 1994. 542 pp. ISBN 0-68304-502-4.

Klevenhagen SC. **Physics and Dosimetry of Therapy Electron Beams.** Madison, WI: Medical Physics Publishing, 1993. 479 pp. ISBN 0-944838-36-7.

Metcalfe P, Kron T, Hoban P. **The Physics of Radiotherapy X-rays from Linear Accelerators.** Madison, WI: Medical Physics Publishing, 1997. 493 pp. ISBN 0-944838-75-8; ISBN 0-944838-76-6 (pbk.).

Nag S. **High Dose Rate Brachytherapy: A Textbook.** New York, NY: Futura Publishing, 1994. 462 pp. ISBN 0-87993-588-X.

Pierquin B, Marinello G, Editors. **A Practical Manual of Brachytherapy.** Madison, WI: Medical Physics Publishing, 1997. 300 pp. ISBN 0-944838-73-1.

Palta J, Mackie TR, Editors: **Teletherapy: Present and Future.** Proceedings of the 1996 Summer School. College Park, MD: American Association of Physicists in Medicine, 1996. 817 pp. ISBN 1-88834-003-7.

Purdy JA, Editor. **Advances in Radiation Oncology Physics: Dosimetry, Treatment Planning, and Brachytherapy.** AAPM Monograph #19. Woodbury, NY: American Institute of Physics for AAPM, 1992. 1099 pp. ISBN 1-56396-054-0.

Purdy JA, Emami B, Editors. **3-D Radiation Treatment Planning and Conformal Therapy.** Madison, WI: Medical Physics Publishing, 1995. 465 pp. ISBN 0-944838-51-0. (out of print).

Scharf W. **Biomedical Particle Accelerators.** New York, NY: American Institute of Physics, 1994. 731 pp. ISBN 1-56396-089-3.

Selman J. **The Basic Physics of Radiation Therapy,** 3rd Edition. Springfield, IL: C. C. Thomas, 1990. 749 pp. ISBN 0-39805-685-4.

Smith AR, Editor. **Radiation Therapy Physics**. Berlin: Springer-Verlag, 1995. 465 pp. ISBN 0-38755-430-0.

Stanton R, Stinson D. **Applied Physics for Radiation Oncology**. Madison, WI: Medical Physics Publishing, 1996. 375 pp. ISBN 0-944838-60-X (pbk.).

Starkschall G, Horton JL, Editors. **Quality Assurance in Radiotherapy Physics:** Proceedings of an American College of Medical Physics Symposium**.** Madison, WI: Medical Physics Publishing, 1991. 387 pp. ISBN 0-944838-21-9.

Washington CM, Leaver DT, Editors. **Principles and Practice of Radiation Therapy, Vol. 1: Introduction to Radiation Therapy.** St. Louis, MO: Mosby, 1996. 368 pp. ISBN 0-81519-136-7.

Webb S. **The Physics of Three-Dimensional Radiation Therapy: Conformal Radiotherapy, Radiosurgery, and Treatment Planning.** Bristol: Institute of Physics Publishing, 1993. 373 pp. ISBN 0-75030-254-2.

Williams JR, Thwaites DI, Editors. **Radiotherapy Physics in Practice.** Oxford: Oxford University Press, 1993. 280 pp. ISBN 0-19963-316-9; ISBN 0-19963-315-0 (pbk.).

Williamson JF, et al., Editors. **Brachytherapy Physics**. Madison, WI: Medical Physics Publishing for AAPM, 1995. 715 pp. ISBN 0-944838-50-2 (pbk.).

Wright AE. **Medical Physics Handbook of Radiation Therapy**. Madison, WI: Medical Physics Publishing, 1992. 74 pp. ISBN 0-944838-17-0.

7.2 Journals and Journal Articles

AAPM/RSNA Physics Tutorial for Residents. Bimonthly continuing education articles teaching radiological physics. *Radiographics*. Easton, PA: Radiological Society of North America. ISSN 0271-5333.

Committee on Training of Radiologists, American Association of Physicists in Medicine. **Radiologic Physics Instruction for Diagnostic Radiologists: A Survey of Residency Programs.** *AJR*, 157: 409-410, 1991.

Committee on Training of Radiologists, American Association of Physicists in Medicine. **Radiologic Physics Instruction for Diagnostic Radiologists: Results of an Opinion Survey.** *AJR*, 152:393-397, 1989.

Doppke, et al. **A Survey of Radiation Oncologists Regarding Their Radiation Physics Instruction.** *Int. J. Radiation Oncology Biol. Phys.*, 25:345-352, 1993.

Handbook of Dosimetry Data for Use in Radiotherapy. *British Journal of Radiology*, Supplement 25, 1996.

Harolds JA. **Residents: Be Aggressive in Your Own Education!** Acad Radiol 5:655-657, 1998.

Klein EE, et al. **1995 Survey of Physics Teaching Efforts in Radiation Oncology Residency Programs.** *Int. J. Radiation Oncology Biol. Phys.*, 38:441-446, 1997.

Jackson VP, et al. **Status of Mammography Education and Knowledge of Radiology Residents.** Radiology 201:773-776, 1996.

Mezrich R. **A Perspective on K-Space.** Radiology 195:297-315, 1995.

7.3 Laboratory Exercises and Demonstrations

VanTuinen, et al., Editors. **Nuclear Medicine Instrumentation Laboratory Exercises for Radiology Residency Training.** Woodbury, NY: American Institute of Physics for AAPM, 1984. 88 pp. & 81 page addendum. ISBN 0-88318-000-1.

Wu RK, et al., Editors. **Workbook on Dosimetry and Treatment Planning for Radiation Oncology Residents.** Woodbury, NY: American Institute of Physics for AAPM, 1991. 32 pp. ISBN 0-88318-916-X.

7.4 Syllabi and Study Guides

American College of Radiology and American Association of Physicists in Medicine. **The Physics of Diagnostic Radiology: Syllabus and Study Guide;** 4th Edition. Reston, VA: American College of Radiology, 1987. (Out of print, revision planned)

American College of Radiology and American Association of Physicists in Medicine. **The Physics of Therapeutic Radiology: Syllabus and Study Guide;** 4th Edition. Reston, VA: American College of Radiology, 1987. (Out of print, revision planned)

American College of Radiology. **Radiation Bioeffects and Management Test and Syllabus.** Reston, VA: American College of Radiology, 1986.

Balter S, Shope TB, Editors. **RSNA Scientific Assembly Syllabus: A Categorical Course in Physics: Physical and Technical Aspects of Angiography and Interventional Radiology.** Oak Brook, IL: Radiological Society of North America, 1995. 258 pp. ISSN 1997-0222.

Huda W, Stone RM. **Review of Radiologic Physics**. Baltimore, MD: Williams & Wilkins, 1995. 286 pp. ISBN 0-68304-230-0.

Kopans DB, Mendelson EB, Editors. **RSNA Scientific Assembly Syllabus: A Categorical Course in Breast Imaging.** Oak Brook, IL: Radiological Society of North America, 1995. 215 pp. ISSN 1996-0118.

Seeram E. **Computed Tomography: A Study Guide and Review.** Philadelphia, PA: Saunders, 1996. 266 pp. ISBN 0-7216-6103-3.

Starchman DE, Editor. **Radiation Biology Syllabus and Questions for Diagnostic Radiology Residents.** Oak Brook, IL: Radiological Society of North America, 1986. 40 pp.

7.5 Audio-Visual Material

Slide Sets:

American Association of Physicists in Medicine. **Visual Aids for Teaching Diagnostic Radiological Physics to Radiology Residents.** College Park, MD: American Association of Physicists in Medicine, 1997.

American Association of Physicists in Medicine and Radiological Society of North America. **AAPM/ RSNA Physics Tutorials for Residents,** various topics and authors, slide sets with annotation booklet or audio cassette, Oak Brook, IL: Radiological Society of North America (Learning Center).

Basic Nuclear Medicine Physics, 1997.
Basic X-ray Physics, 1996.
The Physics of Screen-Film Radiography, 1995.
Cross Sectional Imaging: Emission Tomography, 1994.
Cross Sectional Imaging: Magnetic Resonance, 1993.
Cross Sectional Imaging: Ultrasound, 1992.
Cross Sectional Imaging: Computed Tomography, 1991.
The Perception of Radiation Risk, 1990.
Teletherapy Treatment Planning, 1987.

Radiologic Physics. St. Louis, MO: Mosby, 1996. ISBN 0-81516-947-7.

Film Teaching Files:

American College of Radiology. **Diagnostic Radiological Health Sciences Learning Laboratory: The Physical Principles of Imaging.** Reston, VA: American College of Radiology.

Software/CD-ROM:

Daniels C, Editor. **Fundamentals of Diagnostic Radiology Interactive Multimedia.** Madison, WI: Medical Physics Publishing, 1996. 1 CD. 486 PC; Windows 3.1 or Windows 95.

Hobbie RK. **Mac Dose 2.2.** Madison, WI: Medical Physics Publishing, 1989.

Kanal E. **Kanal's MR Tutor.** Pittsburgh, PA: University of Pittsburgh.

Binet E, Trueblood J. **Radiology Resource and Review (R^3).** Reston, VA: American Roentgen Ray Society, 1996.

Radiologic Physics. St. Louis, MO: Mosby, 1996. ISBN 0-81519-007-7.

Shope TB. **Radiation-Induced Skin Injuries from Fluoroscopy.** Rockville, MD: Food and Drug Administration, 1996. http://www.fda.gov/cdrh/rsnaii.html

Wherli FW, et al. **MRI Teaching Modules.** Philadelphia, PA: MRI Learning Center, University of Pennsylvania Medical Center, 1995. 1 CD. Macintosh (PC version under development), (215-662-7951).

The following titles are available from Educational Software Concepts; Edwardsville, KS (800-748-7734).

Dowd SB. **Advanced Concepts in Radiation Exposure/Image Quality.**
Dowd SB. **Radiation Exposure/Image Quality.**
Forshier S. **Introduction to Radiation Biology: Theoretical Considerations.**
Forshier S. **Patient Protection During Diagnostic Radiography Procedures.**
Forshier S. **Personnel Protection During Diagnostic Radiography Procedures.**
Forshier S. **Radiation Biology: Theoretical Considerations and Clinical Applications.**
Shehan DR. **Basic Radiographic Physics.**
Shehan DR. **Integration of Radiographic Physics.**
Steves AM. **Introduction to Radiopharmacy.**
Steves AM. **Preparation of Technetium-99m Labeled Radiopharmaceuticals.**
Steves AM. **Quality Control of Molybdenum-99/Technetium-99m Generator Eluate.**
Steves AM. **Radionuclide Generators.**
Steves AM. **Quality Control of Technetium 99m Labeled Radiopharmaceuticals.**
Steves AM. **(Radiopharmaceutical) Unit Dose Calculation and Preparation.**

<u>Videotapes:</u>

American College of Radiology. **Mammography Quality Control Video.** Reston, VA: American College of Radiology.

Cameron JR. **How to Explain X-Ray Exposure to your Patients.** Madison, WI: Medical Physics Publishing, 1993.

Carson PL, Editor. **Radiation Science: Uses in Medical Imaging and Therapy.** Dubuque, IA: Kendall/Hunt, 1996. ISBN 0-78720-817-5.

7.6 Sample Questions

American College of Radiology. **ACR In-Training Exam.** Reston, VA: American College of Radiology.

Canadian College of Physicists in Medicine. **Medical Physics Questions for Membership Examination, 4th Edition.** Madison, WI: Medical Physics Publishing, 1994. (out of print)

Chapman JD, Editor. **Radiobiology Practice Examinations, 1995 - 1998 editions.** Madison, WI: Advanced Medical Publishing.

Elster AD. **Questions and Answers in Magnetic Resonance Imaging.** St. Louis, MO: Mosby, 1994. 278 pp. ISBN 0-80167-767-X.

Goldfarb CR, et al. **Nuclear Medicine Board Review: Questions and Answers for Self-Assessment.** New York, NY: Thieme, 1998. 142 pp. ISBN 0-86577-703-9.

Metcalfe P, Kron T, Hoban P. **The Q Book: Problems and Solutions.** Madison, WI: Medical Physics Publishing, 1998. 100 pp. ISBN 0-944838-86-3.

RAMPS: New York Chapter of AAPM. **Radiological Physics Examinations (RAPHEX), 1992 - 1994 editions.** Madison, WI: Medical Physics Publishing.

RAMPS: New York Chapter of AAPM. **Radiological Physics Examinations (RAPHEX), 1995 - 1998 editions.** Madison, WI: Advanced Medical Publishing.

Sprawls P. **RadReview: Diagnostic Radiological Physics Examination and Study Guide.** Madison, WI: Medical Physics Publishing, 1995. 82 pp. ISBN 0-944838-56-1.

7.7 Texts on How to Teach Adults

Gullette MM, Editor. **The Art and Craft of Teaching**. Cambridge, MA: Harvard University Press, 1984. 130 pp. ISBN 0-67404-680-3.

Whitman N. **Creative Medical Teaching.** Salt Lake City, UT: University of Utah School of Medicine, 1990. 232 pp. ISBN 0-94019-307-8.

7.8 Web Sites

Relevant educational material may be found in abundance on the Internet. The home pages of many of the societies involved in medical physics or radiology include pointers to a variety of educational sites. Some relevant addresses include:

Advanced Medical Publishers: http://www.advmedpub.com
American Association of Physicists in Medicine (AAPM): http://www.aapm.org

American Board of Radiology (ABR): http://theabr.org
American College of Medical Physics (ACMP): http://www.acmp.org
American College of Radiology (ACR): http://www.acr.org
American Institute of Physics (AIP): http://www.aip.org
American Institute of Ultrasound in Medicine (AIUM): http://www.wel.com/user/aium
American Nuclear Society (ANS): http://www.ans.org
American Roentgen Ray Society (ARRS): http://www.arrs.org
American Society of Radiologic Technologists (ASRT): http://www.asrt.org
American Society for Therapeutic Radiology and Oncology (ASTRO): http://www.astro.org
Canadian College of Physicists in Medicine (CCPM): http://www.ccpm.org
Conference of Radiation Control Program Directors (CRCPD): http://www.crcpd.org
DICOM Home Page: http://www.xray.hmc.psu.edu/dicom/dicom_home.html
Electronic Medical Physics World: http://www.medphysics.wisc.edu/~empw
Federal Register On-line (National Archives and Records Administration): http://www.nara.gov/nara
Food and Drug Administration (FDA): http://www.fda.gov
Health Physics Society (HPS): http://www2.hps.org
Inter-Commission Accreditation for Vascular and Echocardiac Laboratories (ICAVL-ICAEL): http://www.icavl-icael.org
Joint Commission for Accreditation of Healthcare Organizations: http://www.jcaho.org
Medical Physics Journal: http://www.medphys.org
Medical Physics Publishing: http://www.medicalphysics.org
National Electrical Manufacturer's Association (NEMA): http://www.nema.org
National Technical Information Service: http://www.ntis.gov
Radiological Society of North America (RSNA): http://www.rsna.org
Society for Computer Applications in Radiology (SCAR): http://www.scar.rad.washington.edu
Society of Photo-Optical Instrumentation Engineers (SPIE): http://www.spie.org
US Government Information (FedWorld): http://www.fedworld.gov
US Nuclear Regulatory Commission (NRC): http://www.nrc.gov

7.9 Addresses

AAPM monographs, reports, topical reviews, manuals and proceedings
Current listing available from
AAPM Headquarters
One Physics Ellipse
College Park, MD 20740-3846
(301) 209-3350
(301) 209-0862 (Fax)

ICRP publications
Current listing available from
Pergamon Press, Inc.

660 White Plains Road
Tarrytown, NY 10591-5153
(914) 524-9200
(914) 333-2444 (Fax)

JCAHO Accreditation Manual
Available from
One Renaissance Blvd.
Oakbrook Terrace, IL 60181
(630) 916-5600
(630)792-5005 (Fax)

NRC (Title 10) and FDA (Title 21) Regulations
Available from
Superintendent of Documents
P.O. Box 371954
Pittsburgh, PA 15250-7954
(202) 512-2233 (Fax)

NCRP reports, proceedings, commentaries and lectures
Current listing available from
NCRP Publications
7910 Woodmont Ave., Suite 800
Bethesda, MD 20814
(800) 229-2652
(301) 907-8768 (Fax)

8.0 TOPIC GUIDELINES

Guidelines for Basic Science (Physics) topics relevant for the ABR exams are available from the ABR office in the Booklet of Information for either Diagnostic Radiology or Radiation Oncology.

American Board of Radiology
5255 E. Williams Circle, Suite 6800
Tucson, Arizona 85711

(602) 790-2900
(602) 790-3200 FAX

The 1987 ACR Syllabus and Study Guide books are no longer available, although copies may be available from a physics colleague. A revision is underway. Other ACR publications may be obtained from the ACR office:

American College of Radiology
1891 Preston White Drive
Reston, Virginia 22091

(800) 227-5463 (Switchboard)
(800) 227-7762 (Publications Sales)

The ABR topic guidelines and ACR syllabus should not be construed as the only material that should be covered in a clinical radiological physics course. Neither organization provides guidance concerning the depth of knowledge required in each area—this is left to the discretion of the physicist-teacher.

8.1 SUGGESTED TOPICS FOR A COMPREHENSIVE, RADIOLOGICAL PHYSICS COURSE FOR DIAGNOSTIC RADIOLOGY RESIDENTS

Topic	Suggested Hours
Atomic and Nuclear Structure	1
Types of Radiation	1
Interactions of Radiation with Matter	4
Radiation Quantities and Units	1
X-ray Production	2
Image Quality	2
Radiographic Geometry and Image Formation	2
Film-screen Detectors	2
Mammography	2
Fluoroscopy and II-based Radiography	2
Computer Principles	2
Computed Radiography	2
Computed Tomography	6
Digital Image Processing	1
Magnetic Resonance Imaging	10
Ultrasound Imaging	5
Radioactivity and Decay	1
Radionuclide Production and Radiopharmaceuticals	2
Radiation Detector Systems	2
Gamma Spectroscopy	1
Statistics	2
Planar Gamma Imaging Systems	2
Nuclear Tomographic Imaging Systems (SPECT and PET)	2
Quality Assurance Testing	2
Radiobiology	3
Radiation Protection	2
Explaining Radiation to Patients	1
Regulatory and Accreditation Issues	1
TOTAL	66

8.2 SUGGESTED TOPICS FOR A COMPREHENSIVE, RADIOLOGICAL PHYSICS COURSE FOR THERAPEUTIC RADIOLOGY RESIDENTS

Topic	Suggested Hours*
Concepts of Radiation/Structure of Matter	1
Radioactive Decay	1
Production and Interactions of Ionizing Radiation	5
Measurements of Ionizing Radiation	1
Quality of X-ray Beams	1
Measurement and Calculation of Dose	1
Dose Distribution and Scatter Analysis	1
Monitor Dose Calculations	4
Isodoses/Planning	1
Hetereogeneities	1
Treatment Aids	1
ICRU Report 50	1
3-D Planning and Virtual Simulation	1
3D Plan Evaluation	3
Electron-Beam Dosimetry	4
Treatment Planning	
- Head and Neck	0.5
- Brain and Central Nervous System	0.5
- Breast	0.5
- Lung & Esophagus	0.5
- Pelvic Tumors	0.5
- Skin and Extremities	0.5
Magna Field Irradiation Techniques	1
Radiation Oncology Quality Assurance	3
Radiation Safety	3
Brachytherapy	
- Basic Principles	3
- Interstitial Implants	1
- Intracavitary Therapy	1
- Remote Afterloading Systems	1

<u>Topic</u>	**<u>Suggested Hours*</u>**
- Eye Plaques	1
- Radiopharmaceuticals	1
- Brachytherapy QA and Radiation Safety	1
Hyperthermia	2
Radiobiology	8
Imaging Modalities (x-ray, CT, US, MRI)	4
Statistics	<u>6</u>
TOTAL	66

Average (± standard deviation) number of hours taught for many of the above topics can be found in: Klein EE, et al. **1995 Survey of Physics Teaching Efforts in Radiation Oncology Residency Programs.** *Int. J. Radiation Oncology Biol. Phys.*, 38:441-446, 1997.

AAPM REPORT SERIES ($10.00 Each)

No. 4 "Basic Quality Control in Diagnostic Radiology," AAPM Task Force on Quality Assurance Protocol (1977)

No. 6 "Scintillation Camera Acceptance Testing & Performance Evaluation, " AAPM Nuclear Medicine Committee (1980)

No. 7 "Protocol for Neutron Beam Dosimetry," AAPM Task Group #18 (1980) (FREE)

No. 8 "Pulse Echo Ultrasound Imaging Systems: Performance Tests & Criteria," P. Carson & J. Zagzebski (1980)

No. 9 "Computer-Aided Scintillation Camera Acceptance Testing," AAPM Task Group of the Nuclear Medicine Committee (1982)

No. 10 "A Standard Format for Digital Image Exchange," Baxter et al. (1982)

No. 11 "A Guide to the Teaching of Clinical Radiological Physics to Residents in Radiology," AAPM Committee on the Training of Radiologists (1982)

No. 12 "Evaluation of Radiation Exposure Levels in Cine Cardiac Catherization Laboratories," AAPM Cine Task Force of the Diagnostic Radiology Committee (1984)

No. 13 "Physical Aspects of Quality Assurance in Radiation Therapy," AAPM Radiation Therapy Committee TG #24, with contribution by TG #22 (1984)

No. 15 "Performance Evaluation and Quality Assurance in Digital Subtraction Angiography," AAPM Digital Radiology/ Fluorography Task Group (1985)

No. 16 "Protocol for Heavy Charged-Particle Therapy Beam Dosimetry," AAPM TG #20 of the Radiation Therapy Committee (1986)

No. 17 "The Physical Aspects of Total and Half Body Photon Irradiation," AAPM TG #29 of the Radiation Therapy Committee (1986)

No. 18 "A Primer on Low-Level Ionizing Radiation and its Biological Effects," AAPM Biological Effects Committee (1986)

No. 19 "Neutron Measurements Around High Energy X-Ray Radiotherapy Machines," AAPM Radiation Therapy TG #27 (1987)

No. 20 "Site Planning for Magnetic Resonance Imaging Systems," AAPM NMR TG #2 (1987)

No. 21 "Specification of Brachytherapy Source Strength," AAPM Radiation Therapy TG #32 (1987)

No. 22 "Rotation Scintillation Camera Spect Acceptance Testing and Quality Control," Task Group of Nuclear Medicine Committee (1987)

No. 23 "Total Skin Electron Therapy: Technique and Dosimetry," AAPM Radiation Therapy TG #30 (1988)

No. 24 "Radiotherapy Portal Imaging Quality," AAPM Radiation Therapy TG #28 (1988)

No. 25 "Protocols for the Radiation Safety Surveys of Diagnostic Radiological Equipment," AAPM Diagnostic X-Ray Imaging Committee TG #1 (1988)

No. 26 "Performance Evaluation of Hyperthermia Equipment," AAPM Hyperthermia TG #1 (1989)

No. 27 "Hyperthermia Treatment Planning," AAPM Hyperthermia Committee TG #2 (1989)

No. 28 "Quality Assurance Methods and Phantoms for Magnetic Resonance Imaging," AAPM Nuclear Magnetic Resonance Committee TG #1 (1990)

No. 29 "Equipment Requirements and Quality Control for Mammography," AAPM Diagnostic X-Ray Imaging Committee TG #7 (1990)

No. 30 "E-Mail and Academic Computer Networks," AAPM Computer Committee TG #1 (1990)

No. 31 "Standardized Methods for Measuring Diagnostic X-Ray Exposures," AAPM Diagnostic X-Ray Imaging Committee TG #8 (1991)

No. 32 "Clinical Electron-Beam Dosimetry," AAPM Radiation Therapy Committee TG #25 (1991)

No. 33 "Staffing Levels and Responsibilities in Diagnostic Radiology," AAPM Diagnostic X-Ray Imaging Committee TG #5 (1991)

No. 34 "Acceptance Testing of Magnetic Resonance Imaging Systems," AAPM Nuclear Magnetic Resonance TG #6 (1992)

No. 35 "Recommendations on Performance Characteristics of Diagnostic Exposure Meters," AAPM Diagnostic X-Ray Imaging TG #6 (1992)

No. 36 "Essentials and Guidelines for Hospital Based Medical Physics Residency Training Programs," AAPM Presidential AD Hoc Committee (1992)

No. 37 "Auger Electron Dosimetry," AAPM Nuclear Medicine Committee TG #6 (1993)

No. 38 "The Role of the Physicist in Radiation Oncology," Professional Information and Clinical Relations Committee TG #1 (1993)

No. 39 "Specification and Acceptance Testing of Computed Tomography Scanners," Diagnostic X-Ray Imaging Committee TG #2 (1993)

No. 40 "Radiolabeled Antibody Tumor Dosimetry," AAPM Nuclear Medicine Committee TG #2 (1993)

No. 41 "Remote Afterloading Technology," Remote Afterloading Technology TG #41 (1993)

No. 42 "The Role of the Clinical Medical Physicist in Diagnostic Radiology," Professional Information and Clinical Relations Committee TG #2 (1993)

No. 43 "Quality Assessment and Improvement of Dose Response Models," $25, (1993). Published by Medical Physics Publishing. They can be contacted at (800) 442-5778 or fax (608) 265-2121.

No. 44 “Academic Program for Master of Science Degree in Medical Physics,” AAPM Education and Training of Medical Physicists Committee (1993)

No. 45 “Management of Radiation Oncology Patients with Implanted Cardiac Pacemakers,” AAPM Task Group #4 (1994)

No. 46 “Comprehensive QA for Radiation Oncology,” AAPM Radiation Therapy Committee TG #40 (1994)

No. 47 “AAPM Code of Practice for Radiotherapy Accelerators,” AAPM Radiation Therapy TG #45 (1994)

No. 48 “The Calibration and Use of Plane-Parallel Ionization Chambers for Dosimetry of Electron Beams,” AAPM Radiation Therapy Committee TG #39 (1994)

No. 49 “Dosimetry of Auger-Electron-Emitting Radionuclides,” AAPM Nuclear Medicine TG #6 (1995)

No. 50 “Fetal Dose from Radiotherapy with Photon Beams,”AAPM Radiation Therapy Committee TG #36 (1995)

No. 51 “Dosimetry of Interstitial Brachytherapy Sources,” AAPM Radiation Therapy Committee TG #43 (1995)

No. 52 “Quantitation of SPECT Performance,” AAPM Nuclear Medicine Committee TG #4 (1995)

No. 53 “Radiation Information for Hospital Personnel,” AAPM Radiation Safety Committee (1995)

No. 54 “Stereotactic Radiosurgery,” AAPM Radiation Therapy Committee TG #42 (1995)

No. 55 “Radiation Treatment Planning Dosimetry Verification,” AAPM Radiation Therapy Committee TG #23 (1995), $48, (Includes 2 disks, ASCII format). Mail, fax, or phone orders to: AAPM Headquarters, One Physics Ellipse, College Park, MD 20740-3846, Phone: (301) 209-3350, Fax: (301) 209-0862

No. 56 “Medical Accelerator Safety Considerations,” AAPM Radiation Therapy Committee TG #35, Reprinted from Medical Physics, Vol. 20, Issue 4 (July/August 1993)

No. 57 “Recommended Nomenclature for Physical Quantities in Medical Applications of Light,” AAPM General Medical Physics Committee TG #2 (1996)

No. 58 “Managing the Use of Fluoroscopy in Medical Institutions,” AAPM Radiation Protection Committee TG #6 (1998)

No. 59 “Code of Practice for Brachytherapy Physics,” AAPM Radiation Therapy Committee Task Group #56, Reprinted from *Medical Physics*, Vol. 24, Issue 10, October 1997 (1997)

No. 60 “Instrumentation Requirements of Diagnostic Radiological Physicists,” AAPM Diagnostic X-Ray Committee TG #4 (1998)

No. 61 “High Dose Brachytherapy Treatment Delivery,” AAPM Radiation Therapy Committee Task Group #59, Reprinted from *Medical Physics*, Vol. 25, Issue 4, April 1998 (1998)

No. 62 “Quality Assurance for Clinical Radiotherapy Treatment Planning,” AAPM Radiation Therapy Committee Task Group #53, Reprinted from *Medical Physics*, Vol. 25, Issue 10, October 1998 (1998)

No. 63 “Radiochromic Film Dosimetry,” Recommendations of AAPM Radiation Therapy Committee Task Group #55 (December 1998)

No. 64 “A Guide to the Teaching of Clinical Radiological Physics to Residents in Diagnostic and Therapeutic Radiology,” Revision of AAPM Report #11, AAPM Committee on the Training of Radiologists (1999)

****

Return to: Medical Physics Publishing
4513 Vernon Blvd.
Madison, WI 53705-4964
(800) 442-5778 phone
(608) 265-2121 FAX

Name: ______________________

Address:__________________
__
____
__
____
__

____ copies of___________ @________
____ copies of___________ @________
____ copies of___________ @________

Prepayment required
U.S. check or International Money Order
Amount enclosed_________