CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE
LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

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July 31, 2007

Mr. Thomas Essig
Chief, Materials Safety and Inspection Branch (MS T8F3)
U. S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD
U.S.A. 20852

Dear Mr. Essig

The Canadian College of Physicists in Medicine is applying to the U. S. Nuclear Regulatory Commission to evaluate our application to have the Canadian College of Physicists in Medicine (CCPM) Membership certification for Radiation Oncology Physics evaluated for posting of Specialty Board(s) Certification Recognized by NRC under 10 CFR Part 35.

As the President of the CCPM, this letter is to inform you that Mr. Michael Evans is the Board designee acting on behalf of the CCPM with respect to this application to the U.S. NRC. Mr. Evans is currently a Board Member of the Canadian College of Physicists in Medicine (CCPM) and within the Board Mr. Evans holds the position of Chief Examiner. Please be assured that the CCPM is committed to communicating with the NRC in an accurate and responsible manner, and that every effort will be made to ensure that information provided to the U. S. Nuclear Regulatory Commission will be complete and true.

Should you require any further information please do not hesitate to contact either me or Mr. Evans.

Yours sincerely

Dick Drost, Ph. D., FCCPM
President, CCPM

cc, M. Evans, D. Wilkins

Canadian College of Physicists in Medicine application to the U.S. Nuclear Regulatory Commission for Specialty Board(s) Certification Recognized by NRC under 10 CFR Part 35

Submitted on behalf of the CCPM

July 31, 2007 by

Michael Evans, M. Sc., FCCPM

Medical Physicist and Class II Radiation Safety Officer,
McGill University Health Centre;
Assistant Professor, Faculty of Medicine, McGill University;
Chief Examiner, Canadian College of Physicists in Medicine.

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Canadian College of Physicists in Medicine application to U.S. Nuclear Regulatory Commission for Specialty Board(s) Certification Recognized by NRC under 10 CFR Part 35

The Canadian College of Physicists in Medicine (CCPM) is the certifying organization for Medical Physicists in Canada. Established in 1979, the mission of the CCPM is to serve the public by identifying, through certification, individuals who have acquired, demonstrated, and maintained a requisite standard of knowledge, skill and understanding essential to the clinical practice of medical physics.

Medical physicists who satisfy certain educational and experience criteria are certified by examination to the level of Member or Fellow. Membership certifies medical physics competence in the delivery of patient care and requires maintenance through recertification, while Fellowship attests to excellence in the provision of clinical service, education and/or research. Recognition and certification by the CCPM provides the necessary mechanism for medical institutions to ensure that a high standard of medical physics services are available for patient care. As of July 2007 there are 213 medical physicists certified in Radiation Oncology Physics as Members by the CCPM. The CCPM directory from October 2006 lists 40 members as working in the U.S.A.

On behalf of the Canadian College of Physicists in Medicine I am applying to the U. S. Nuclear Regulatory Commission to evaluate our application to have the Canadian College of Physicists in Medicine (CCPM) Membership certification for Radiation Oncology Physics evaluated for posting of Specialty Board(s) Certification Recognized by NRC under 10 CFR Part 35.

Certification in Canada as a Member of the CCPM is often regarded as analogous to certification in the United States by the American Board of Radiology (ABR), and many CCPM certified Members are also certified by the ABR. The American Association of Physicists in Medicine (AAPM) considers CCPM certification as an indicator of competency to practice medical physics. Since many physicists with CCPM Membership certification work in the United States, the Board of the CCPM has been asked to proceed with this application to the U.S. Nuclear Regulatory Commission on their behalf.

I am currently a Board Member of the Canadian College of Physicists in Medicine (CCPM) and within the Board I hold the position of Chief Examiner. Accompanying this application is a letter signed by Dr. Dick Drost, the current President of the CCPM, indicating that I am the Board designee acting on behalf of the CCPM with respect to this application (**Appendix 1**). In this application I acknowledge, on behalf of the CCPM, that the CCPM is committed to communicating with the NRC in an accurate and responsible manner, and that every effort will be made to ensure that information provided to the U. S. Nuclear Regulatory Commission will be complete and true.

Much of the information provided in this application is available on our website; the URL for this being (http://medphys.ca/article.asp?id=209). It may be more convenient to begin at the homepage located at (http://medphys.ca). On this website may be found the most current version of the CCPM Constitution and Bylaws (http://medphys.ca/CCPM/bylaws.pdf). As a reference I am also appending a hardcopy of these bylaws (**Appendix 2**), and will be referring to them in this application

CFR 35.51 Specialty Board Application:

In particular this application is requesting recognition under section **CFR 35.51** entitled ***"Training for an authorized medical physicist"***. The CCPM currently has four membership sub-specialty categories, namely; Radiation Oncology Physics, Diagnostic Radiological Physics, Nuclear Medicine Physics and Magnetic Resonance Imaging. This application is requesting recognition under **CFR 35.51** for the **Radiation Oncology Physics sub-specialty only**.

CCPM Membership Certificates (Radiation Oncology Physics):

Certificates issued by the CCPM clearly indicate the sub-specialty, and a sample of a CCPM Radiation Oncology Physics certificate is appended (**Appendix 3**).

CFR 35.51 Specialty Board Criteria 1:

CFR 35.51 (a) ... a specialty board shall require all candidates for certification to : (1) Hold a master's or doctor's degree in physics, medical physics, other physical science, engineering, or applied mathematics from an accredited college or university;

This criteria is satisfied by CCPM bylaw Article III (section 1) (a) whereby "Only those who hold graduate degrees in Medical Physics, Physics, Science with Physics as a major option, or another field deemed acceptable by the Board of the College are eligible to become Members of the College." There is a clause regarding the approval of a B.Sc. under exceptional circumstances, although in my memory as a CCPM Member (since 1986) I do not believe this has ever occurred.

CFR 35.51 Specialty Board Criteria 2:

CFR 35.51 (a) ... a specialty board shall require all candidates for certification to : (2) Have 2 years of full-time practical training and/or supervised experience in medical physics – (i) Under the supervision of a medical physicist who is certified in medical physics by a specialty board recognized by the Commission or an Agreement State;

This criteria is satisfied by CCPM bylaw Appendix II : Minimum Experience Requirements (1.) Membership. In this paragraph the two-year criteria is described. In addition the requirement for the supervision of the candidate is described in CCPM bylaw Appendix III: Examinations (1.) Membership. Two of the referees are required to be physicists and one must be a physician. In this paragraph we state that at least one, but preferably both of the physicist referees must be certified by the CCPM, and that the referees must be familiar with the candidates work, and have worked with the candidates. I believe that these criteria satisfy the spirit of the training requirements set out in CFR 35.51 (a)(2)(i).

As additional evidence of the recognition of the CCPM Membership process, I am including a letter from the New York State Education Department dated May 4, 2005 (**Appendix 4**), stating that the CCPM Membership exam has been determined to be acceptable for individuals applying for Medical Physics licensure in the State of New York.

Further documentation the USNRC might find useful in assessing the recognition of the CCPM Membership process may be found in various American Association of Physicists in Medicine (AAPM) publications. In particular, the 1993 AAPM Report No. 38 "The role of a physicist in radiation oncology" (**Appendix 5**) on page 7 states "...only those persons certified by the ABR in Therapeutic Radiological Physics, or ... The Canadian College of Physicists in Medicine ... can be assumed competent to function independently in a clinical situation". The most current AAPM website from July 2007 (http://www.aapm.org/medical_physicist/fields.asp) discusses the definition of a Qualified Medical Physicist (**Appendix 6**), and reiterates the competency statement with respect to the Canadian College of Physicists in Medicine.

CFR 35.51 Specialty Board Criteria 3:

CFR 35.51 (a) ... a specialty board shall require all candidates for certification to : (3) Pass an examination, administered by diplomats of the specialty board, that assess knowledge and competence in clinical radiation therapy, radiation safety, calibration, quality assurance, and treatment planning for external beam therapy, brachytherapy, and stereotactic radiosurgery;

The CCPM Membership exam is structured to be a two stage process. Candidates must first pass a written component, and, if successful, must then pass an oral exam. Once successful they are considered Members of the CCPM, and may designate themselves so with the initials MCCPM. CFR 35.51 (a)(3) is satisfied by the description in CCPM Appendix III : Examinations (1.) Membership.

The written exam is administered in one day, and is comprised of four sections. Sections I and II are administered in the morning over a 2.5 hour period, and Sections III and IV are administered in the afternoon over a 2.5 hour period. The total length of the exam is thus 5 hours.

The exam is given in locations across Canada on the same day (for example this year, 2007, the written exam was given on Saturday, March 10, in Vancouver, Edmonton, Calgary, Winnipeg, Toronto, Ottawa, Montreal, Moncton and Sydney). The exam is invigilated by a CCPM member chosen by the Chief Examiner.

The Section formats are described in detail in the CCPM bylaws Appendix III : Examinations (1.) Membership (Written Examination).

Section I consists of short answer questions (written) covering general medical physics. Sample questions are available on the website (http://medphys.ca/ccpm/exams/Sample_Part_I.pdf) and are included in this application in **Appendix 7**.

Section II consists of short answer (written) and multiple choice questions designed to test the applicant's knowledge of radiation safety. The Section II syllabus is available on the website (http://medphys.ca/ccpm/exams/radiation_safety_syllabus-2007.pdf) and is included in this application in **Appendix 8**.

Sections III and IV of the CCPM Membership written exam contain questions specific to the Radiation Oncology Physics sub-specialty. Section III contains 83 questions and Section IV contains 40 questions. During the 2.5 hour afternoon exam, the candidates are given 10 questions to answer (5 questions from Section III and 5 questions from section IV). The question bank for Sections III and IV is available for candidates on the website (http://medphys.ca/ccpm/exams/RadOncOct07.pdf) and is also included in this application as **Appendix 9**. The candidate is expected to prepare in advance by using these questions as a study guide, and be prepared to answer the 10 questions chosen for the examination.

Passing criteria are described in the CCPM bylaw, Appendix III : Examinations (1.) Membership (Written Examination). In summary, each section must be passed with a minimum mark of 50%, and the overall mark for the four sections combined must be 65% or higher.

Upon successful passing of the written component of the CCPM Membership exam, the candidate is then eligible to sit for the oral component of the CCPM Membership exam. This year, 2007, the Radiation Oncology Physics oral exams were held at McGill University in Montreal. The CCPM bylaws describing the oral exam are given in bylaw Appendix III : Examinations (1.) Membership (Oral Examination). The oral exam is delivered in a 1.5 hour session and consists of three 30 minute sessions. The candidate is examined by two examiners in each session, so that during the entire 1.5 hour exam the candidate will be examined by six examiners. All examiners are physicists who are currently CCPM certified Members. In total 15 questions (5 per session) are asked. The topics covered by the three oral sessions are (i) Equipment and Calibration, (ii) Clinical Applications and (iii) Special Techniques and Radiation Safety. In order to pass the oral examination, candidates must pass each session with three correct answers, and the candidate must obtain a total of ten correct answers out of a possible fifteen questions asked.

More information concerning the written and oral exams may be obtained by reading the CCPM policies and procedures document available on the website (http://medphys.ca/CCPM/CCPMPoliciesAndProcedures.pdf). The specific policies and procedures related to the written and oral components of the CCPM Membership exam are included in this application as **Appendix 10**.

By examining the information related to the written and oral components of the CCPM Membership exam included in:
Appendix 2 (CCPM Bylaws),
Appendix 4 (Letter from New York State Education Deptartment),
Appendix 5 (AAPM Report 38, 1993),
Appendix 6 (AAPM Webpage July 2007 – Qualified Medical Physicist),
Appendix 7 (Sample questions for Section I),
Appendix 8 (Syllabus for Section II – radiation safety),
Appendix 9 (Section III and IV question bank) and
Appendix 10 (CCPM policies and Procedures)
the CCPM is confident that the NRC may be able to verify that the criteria described by *CFR 35.51 (a)(1), (2)* and *(3)* are satisfied.

CCPM Membership (Radiation Oncology Physics) effective date:

The increased emphasis on radiation safety in Section II became effective with the 2003 exam. The change in CCPM Membership exam format, to both introduce the oral exam, and include a component with a specific section on radiation safety in the oral exam, became effective in 2004. Therefore it would seem reasonable to indicate that the Membership certification program that the CCPM requests NRC recognition under section CFR 35.51 entitled "*Training for an authorized medical physicist*" becomes effective from 2004.

CCPM Membership (Radiation Oncology Physics) validation period:

The CCPM Membership is valid for a period of five years, after which Members must re-certify. The rules for re-certification are described in CCPM bylaw Appendix IV: Requirements for Re-certification, and are included in this application in **Appendix 2**.

In summary, this document presents supporting evidence by the Canadian College of Physicists in Medicine to the U. S. Nuclear Regulatory Commission to have the **CCPM Membership certification for Radiation Oncology Physics** evaluated for posting of **Specialty Board(s) Certification Recognized by NRC under 10 CFR Part 35**.

I hope that the NRC will react favorably to our application.

Respectfully submitted July 31, 2007 by:
Michael Evans, M. Sc., FCCPM;
Medical Physicist & Class II Radiation Safety Officer, McGill University Health Centre;
Assistant Professor, Faculty of Medicine, McGill University;
Chief Examiner, Canadian College of Physicists in Medicine.

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APPENDIX 1

Supporting letter from
Dr. Dick Drost
President
Canadian College of Physicists in Medicine

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

July 31, 2007

Mr. Thomas Essig
Chief, Materials Safety and Inspection Branch (MS T8F3)
U. S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD
U.S.A. 20852

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Should you require any further information please do not hesitate to contact either me or Mr. Evans.

Yours sincerely

Dick Drost, Ph. D., FCCPM
President, CCPM

cc, M. Evans, D. Wilkins

APPENDIX 2

Bylaws of the
Canadian College of Physicists in Medicine

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

CONSTITUTION AND BYLAWS

June 2005: Revision X

CONTENTS

ARTICLE I: NAME

The name of this organization shall be "The Canadian College of Physicists in Medicine" (hereinafter denoted by "the College" or by "CCPM").

Head Office
The head office of the College shall be in the City of Edmonton, in the Province of Alberta. The address shall be considered permanent until such time as it is changed by the Board and approved at an AGM of the College.

ARTICLE II: OBJECTIVE

The objective of the College shall be to protect the public by:

(1a) Identifying competent persons who are responsible for applications of the physical sciences in the medical field.

(1b) Identifying individuals demonstrating excellence in the practice of medical physics.

(2) Promoting knowledge and disseminating information relating to developments of the physical sciences in the medical field.

ARTICLE III: MEMBERSHIP CATEGORIES AND CONDITIONS FOR ADMISSION

There are two categories of admission to the College: Member and Fellow. Members are certified by written and oral examination to be competent in physics as applied to medicine. Fellows are certified to have demonstrated excellence in the practice of medical physics.

Members will be recognized to have competence in up to two of the following sub-specialties of medical physics:

1) Radiation Oncology Physics
2) Diagnostic Radiological Physics
3) Nuclear Medicine Physics
4) Magnetic Resonance Imaging

Members will also be recognized to have competence in Radiation Safety. Those certified in any ionizing radiation sub-specialty are recognized to have competence in ionizing radiation safety, while Members certified in Magnetic Resonance Imaging are recognized to have competence in magnetic and electromagnetic field safety.

From time to time, the Board will review the sub-specialties and add to or delete from them as may seem desirable. Members desiring recognition in more than one sub-specialty must fulfill the requirements in each field.

Only medical physicists with patient related experience are eligible for certification by the College. Further clarification on this point is provided in Appendix I.

(1) Eligibility for Membership

(a) Only those who hold graduate degrees in Medical Physics, Physics, Science with Physics as a major option, or another field deemed acceptable by the Board of the College are eligible to become Members of the College. Under exceptional circumstances the Board may approve an application from a person with only a B.Sc. in one of the above fields.

(b) Only those with experience in the medical field for the time period outlined in Appendix II are eligible to become Members of the College.

(c) Applicants must also satisfy the Board that they meet the standards deemed desirable in a Member and must pass written and oral examinations.

(2) Eligibility for Fellowship

(a) Those who have successfully fulfilled the requirements for Membership are eligible to become Fellows of the College, or medical physicists working in Canada and certified as competent by an appropriate organisation in another country may be eligible for Fellowship at the discretion of the Board.

(b) Only those with experience in the medical field for the time periods outlined in Appendix II are eligible to become Fellows of the College.

(c) Applicants must also satisfy the Board that they meet the standards desirable in a Fellow and must pass an oral examination.

(3) Re-certification
Retention of competency certification (Membership) in the Canadian College of Physicists in Medicine shall require re-certification every five years. This requirement exists independently for each sub-specialty certification. Details of this process are given in Appendix IV.

Details of the application and examination process are outlined in Appendix III.

ARTICLE IV: OFFICERS AND GOVERNING BODIES

The governing body of the College shall be known as "the Board" and shall consist of eight Fellows or Members of the College. Each member of the Board will serve for a four-year term, and may be re-nominated for one additional term. He/she is then ineligible for re-election to the Board for four years. Election of new Board members shall be made by secret ballot at the Annual General Meeting of the College. Postal votes will also be accepted. The new Board, with the exception of the Secretary-Treasurer, shall take office at the conclusion of the Annual General Meeting. The Secretary-Treasurer will take office on the first day of the next financial year. A president who retires after his last year on the Board will stay on the Board as an ex-officio member for one year after his term.

Duties of the Board
The Board shall act in accordance with the objectives of the College and is responsible for promulgating the rules as provided for in these Bylaws.

Annually the Board shall, among themselves, elect Fellows to serve as the following executive officers:

1) President
2) Vice President
3) Registrar
4) Secretary-Treasurer
5) Chief Examiner
6) Deputy Chief Examiner

The Board shall appoint an Examining Committee charged with responsibility for maintaining and updating the question bank, setting and marking written examinations and conducting oral examinations. Only Fellows may serve on this committee and turnover should be gradual to maintain uniformity of style and standards.

The Board shall appoint a Nominating Committee each year to solicit nominations for vacancies on the Board. The Nominating Committee shall consist of the immediate Past-President of the College and two other Fellows or Members, at least one of whom shall not be a member of the Board

The Board shall appoint other committees of Members and Fellows as necessary. There should be at least one board member on these committees.

The Board shall authorize any two individuals, Members or Fellows, to sign, draw, make, endorse, execute and issue cheques on behalf of the College. The financial year of the College shall end on December 31.

Additional duties of the Board shall include:

(a) The setting of fees as described in Article VI of these Bylaws.

(b) The assessment of individual applications for Membership or Fellowship. This will be handled by a Credentials Committee chaired by the Registrar.

(c) The approval of individuals as examiners as may be requested from time to time by the Chairman of the Examination Committee.

(d) The appointment of an auditor to audit the accounts of the College.

Duties of the President
The President shall preside at all annual general meetings and Board meetings of the College and shall call to the attention of the College any matter which affects its interest. He/she shall take action in accordance with the recommendations approved at these meetings. All matters of major policy shall have prior approval of a majority of the Board.

Duties of the Vice President
The Vice President shall preside at any meeting of the College from which the President is absent. The Vice President should be prepared to serve as President if requested by the Board.

Duties of the Registrar
The duties of the Registrar shall include:

(a) Producing an annual registry of Members and Fellows.

(b) Preparing and distributing information pertaining to the application process for Membership and Fellowship.

(c) Processing applications for Membership and Fellowship.

(d) Chairmanship of the Credentials Committee.

(e) Collaborating with the Secretary of COMP to provide CCPM data for the common COMP/CCPM database.

Duties of the Secretary-Treasurer
The duties of the Secretary-Treasurer shall include:

(a) Collaborating with the Secretary of COMP to provide CCPM data for the common COMP/CCPM database.

(b) Recording and distributing the minutes of AGM and Board meetings.

(c) General supervision of the financial affairs of the College.

(d) Maintaining the constitution and bylaws of the College.

Duties of the Chief Examiner
The Chief Examiner is the chairperson of the Examination Committee and is responsible for:

(a) Maintaining and updating the question bank

(b) Setting and marking written examinations

(c) Conducting oral examinations.

Duties of the Deputy Chief Examiner
The Deputy Chief Examiner shall assist the Chief Examiner in the examination process.

ARTICLE V: MEETINGS

The College shall hold at least one annual general meeting (AGM) a year. This will usually be held in conjunction with the annual meeting of the Canadian Organization of Medical Physicists. Robert's rules of order shall be followed. The quorum is 15% of the total number of Members and Fellows.

The Board shall meet at least once each year. The quorum is four members including at least one executive officer.

ARTICLE VI: FEES

Examination and recertification fees shall be determined by the Board and approved at an AGM of the College. The annual registration fee shall be set by the Board and approved by an AGM of the College and shall be collected by the Canadian Organization of Medical Physicists (COMP).

Indemnities to Board Members:

(1) Every director and officer of the College and his or her heirs, administrators, executors and other legal personal representatives shall be indemnified and saved harmless by the College from and on account of:

   a) any and all liabilities and costs, charges and expenses that he or she sustains or incurs on account of or in respect of any action, suit or proceeding against such person pursuant to anything done or permitted to be done by such director or officer in respect of the execution of the duties of his or her office; and

   b) any and all other costs, charges and expenses that he or she sustains or incurs in respect of the affairs of the College, except those costs, charges or expenses resulting from willful neglect or default, and except travel expenses not previously sanctioned by the President of the Board.

(2) Any act done by a director or officer of the College is not invalid by reason only of any defect that is thereafter discovered in his or her election, appointment or qualifications.

ARTICLE VII: REVOCATION OF MEMBERSHIP OR FELLOWSHIP

Membership or Fellowship may be revoked by the Board under any one of the following conditions:

(a) When the individual falls more than two years in arrears in payment of the CCPM/COMP annual registration fee.

(b) When sufficient evidence has come to light that the individual is judged to be professionally incompetent or ethically unacceptable as deemed by the statement "COMP/CCPM Code of Ethics" published by the Canadian Organization of Medical Physicists and the Canadian College of Physicists in Medicine.

Membership of an individual may be revoked by the Board if the individual fails to obtain re-certification in his/her declared subspecialty.

ARTICLE VIII: ENACTMENT, REPEAL AND AMENDMENT OF BYLAWS

(1) Enactment, repeal or amendment of bylaws shall be voted on at an Annual General Meeting of the College.

(2) Proposals for additions, corrections or amendments to the bylaws should be forwarded to the Secretary/Treasurer by means of a resolution passed by the Board, or by a petition signed by at least five Members or Fellows in good standing. The proposals must be received by the Secretary/Treasurer at least four months before an Annual General Meeting at which it is desired that they be considered.

(3) The Secretary/Treasure shall submit any such proposals to all Members and Fellows in writing by mail, at least two months before the Annual General Meeting at which they are to be considered, and shall place discussion of these proposals on the agenda of the meeting.

(4) At least two-thirds of the votes cast shall be in favour of the proposed additions, corrections or amendments before they shall be adopted. Postal votes will be accepted.

(5) Amendments to the Appendices of these Bylaws can be made by the Board without following paragraphs (1) to (4) of this article. The modified appendices must be endorsed at the next AGM in order to remain in effect.

ARTICLE IX: DISSOLUTION

If, in the opinion of the Board, the College is no longer serving a useful purpose, the following procedure may be adopted:

(a) The Board shall mail to all Members and Fellows a notice that dissolution is proposed on a certain date unless a majority of the Members and Fellows wish the College to continue.

(b) On the date specified, the Registrar shall tally the votes and unless a majority favours continuation, the Registrar shall notify the Executive of COMP that the College is dissolved and shall turn over all records and Monies to the Executive of the Canadian Organization of Medical Physicists.

APPENDIX I: CERTIFICATION

Certification by the CCPM is the mechanism whereby medical institutions can be assured that the medical physics needs of patients are being provided by competent Medical Physicists. This is analogous to the need of medical institutions to ensure that the credentials of physicians are commensurate with the medical needs of patients being treated. Thus medical physicists require certification if their work is patient-related, as in the work of medical physicists in radiotherapy or imaging in medical institutions. This also applies to those physicists who provide these services as consultants to medical institutions.

Who requires "certification"

1. All (eligible) Medical Physicists who are directly employed by medical institutions for the provision of medical physics services.
2. All (eligible) Medical Physicists who provide medical physics consultation services to medical institutions. These relate primarily to the medical physics aspects of: design, development, acquisition, commissioning and ongoing quality control of equipment in use for patient care.

APPENDIX II: MINIMUM EXPERIENCE REQUIREMENTS

1. Membership

A Membership applicant must satisfy the Credentials Committee of the College that they have completed patient-related experience in physics as applied to medicine for two years full time equivalent after a postgraduate degree; the two years to be completed by March 31st of the year the examination will take place. The experience claimed must be relevant to the specialty under consideration and have been obtained within the last five years. The term "patient related" refers to activities such as occur in the design, development, purchase, commissioning, calibration and use of medical equipment for the diagnosis and treatment of patients. The experience required by B.Sc. level applicants will be set on an individual basis by the Board.

2. Fellowship

A Fellowship applicant must satisfy the Credentials Committee of the College that they have demonstrated excellence in clinical service, education and/or research related to medical physics. A minimum of seven years full time equivalent experience in medical physics is required.

APPENDIX III: EXAMINATIONS

1. Membership

Applicants for Membership are required to submit a completed application form to the Registrar and secure three satisfactory letters of reference. Two referees must be medical physicists and preferably both, but at least one, of these physicists must be Fellows of the College or physicists certified by the American Board of Radiology or the American Board of Medical Physics. The third referee must be a physician. All referees must be familiar with the candidate's work and have worked with the candidate within the last five years.

The sub-specialty must be indicated on the Membership application form.

Applications must be approved by the Credentials Committee of the College to allow the candidate to sit the written examination.

Certification for membership consists of written and oral examinations. A candidate must pass the written examination to be eligible for the oral part and only becomes certified after passing the oral examination.

Written Examination

The written examination will be given in two sittings on the same day. (No aids other than calculators are allowed.) Sections I and II are given in the first sitting, followed by a lunch break and Sections III and IV in the second sitting.

Section I consists of short answer questions (no choice) covering general medical physics and also clinical anatomy and biological science relevant to clinical medical physics practice. Applicants from all sub-specialties write the same examination. (1.5 hours)

Section II consists of short answer questions (no choice) to test the applicant's knowledge of radiation protection. Applicants from the three ionising radiation sub-specialties write the same examination, a different examination is supplied for the Magnetic Resonance Imaging specialty. (1 hour)

Section III and IV (2.5 hours total) This portion of the examination is based on a question bank specific to the applicant's sub-specialty available to the applicant by the first of October prior to the examination.

The question bank will be posted on the CCPM web site together with more specific information regarding the upcoming examination. The questions for Sections III and IV will be chosen at random from the bank.

Section III contains questions specific to the sub-specialty.

Section IV contains questions which cover more general areas of the sub-specialty.

Each section of the examination counts for one-quarter of the final mark. A mark of less than 65% overall or a mark of less than 50% on any section constitutes a failure and the candidate is required to rewrite the entire examination.

Candidates for a second specialty certification are not required to write Section I and only required to write Section II if one of the specialties concerned is Magnetic Resonance Imaging. In this case, Section II must be taken for both ionizing and non-ionizing radiation safety. The regulations above regarding Sections III and IV will still apply. Each section counts for one-third of the final mark. Candidates are required to take an oral examination for each specialty.

The question bank can change gradually from year to year to reflect developments in the sub-specialties listed. New sub-specialties will be added as necessary to reflect the broad and changing scope of medical physics.

Candidates who are unsuccessful in the written examination on three sittings must re-apply for permission to write. The candidate may not write the examination again until 3 years have elapsed since the last attempt.

Oral Examination
Candidates for the oral part of the Membership examination must have passed the written part. A candidate who passes the written part of the Membership examination, but fails the oral part, would not be eligible for election to the College. However, the candidate would not have to resit the written examination before re-attempting the oral examination.

The oral examination is administered by an examining committee and is designed to test the applicant's practical experience and competence in their sub-specialty. The examining committee will prepare and approve a set of questions with answers prior to the examination. All candidates in a session are asked the same questions. Emphasis is placed on clinical judgment and communication skills.

Candidates remaining unsuccessful in the oral *examination three years after passing the written* examination become ineligible for further attempts. They must wait until three years have elapsed at which point they may re-apply for permission to re-sit the entire examination process, both written and oral.

2 Fellowship
Applicants for Fellowship are required to submit a completed application form to the Registrar and secure three satisfactory letters of reference. Two referees must be medical physicists and preferably both, but at least one, of these physicists must be Fellows of the College. The third referee must be a physician. All referees must be familiar with the candidate's work and have worked with the candidate within the last five years. Candidates for Fellowship must demonstrate a wide-ranging knowledge of medical physics and advanced knowledge in one of the sub-specialties listed in Article III.

Fellowship applicants must pass an oral examination administered by an examining committee (five to seven examiners, including the chairman) which examines all candidates for Fellowship in a given year. The duration of the oral exam is one to two hours and the candidate begins with a 15 minute presentation describing some of his/her own work in the field of medical physics, followed by general questioning. All examiners must participate in the questioning and all must vote unless they have a conflict of interest, e.g., they work in the same department. In this case the examiner is excused and leaves the room for that candidate's exam. Two negative votes constitute failure.

APPENDIX IV: REQUIREMENTS FOR RE-CERTIFICATION

1. Membership in the Canadian College of Physicists in Medicine shall require re-certification every five years starting from the time of election. For members holding certification in two specialties, this re-certification is required independently for each specialty certification.
   i) Documentation as specified below must be submitted to the Registrar in the first six months of the fifth year following election to the College in order to be considered for re-certification. The College will issue an appropriate reminder.
   ii) Members of greater than 5 year standing at implementation of this policy will be required to recertify at the next 5 times *n*th anniversary of their election.
   iii) A specialty chosen from Radiation Oncology, Nuclear Medicine, Diagnostic Imaging or Magnetic Resonance must be declared during the re-certification process.
2. All requests for re-certification will be made to the Registrar of the CCPM. The Chairperson of the Examination Committee will make recommendations to the Board for re-certification or deletion from the register. The Board will have final authority.
3. Re-certification requires that the applicant either satisfies all conditions, i), ii) and iii) below or, at the Board's discretion, the applicant is required to pass an oral examination designed to evaluate current knowledge of Medical Physics in the declared specialty in which re-certification is required.
   i) The applicant must have been employed as a Medical Physicist for five years with at least 60% full time equivalent. Applicants certified in two specialties must have been engaged in the relevant specialty at least 40% full time equivalent during the preceding five years.
   ii) A letter of reference from a CCPM, ABMP or ABR certified physicist confirming active, ethical and competent participation in Medical Physics activities in the declared specialty area over the past five years.

(Where the applicant is the sole certified Physicist in an institution, the physician with the highest administrative responsibility for that sub-specialty, e.g., Head of Radiation Oncology, Head of Nuclear Medicine, etc., could write the letter of reference.)

   iii) Fifty (50) credits by any combination of the following professional activities within the past five years. Applicants holding dual certification may only claim specific credits once, and may only claim credits appropriate to the certification being reassessed.

a) Clinically Relevant Service

A 5 credits for each major technique or procedure developed and fully written up for departmental use with the applicant as a named developer/author. (The written reports may be requested for review by the CCPM re-certification panel.)

B 5 credits per year for being a Medical Physicist with supervisory responsibilities over other medical physicists and/or demonstrated local leadership in clinical or scientific issues such as chairing interdisciplinary or centre-wide committees on topics such as quality assurance, equipment selection, etc.

b) Teaching/Education

A 1 credit for three hours of in-service didactic teaching or seminars (include such things as teaching radiation therapists, in-service sessions on topics such as radiation protection of staff or the general public, presentation of new treatment or imaging techniques, grand rounds, departmental seminars, etc.).

B 1 credit for each three hours of formal didactic teaching of medical residents (in radiation oncology, radiology or nuclear medicine), medical physics graduate students, radiation therapists, diagnostic or nuclear medicine technologists, dosimetrists or treatment planners.

C 1 credit for each half day attendance at a regional, national or international meeting at which medical physics is an important component.

D 1 credit for each half day of attendance at a relevant continuing education activity such as summer school, symposium, manufacturer's training course, computer or management training.

E 3 credits for each talk or poster presented at a regional, national or international meeting, summer school, or symposium.

c) Academic/Research

A 3 credits for each non peer-reviewed article published.

B 5 credits for each publication in a peer-reviewed journal or text book chapter.

C 10 credits for acting as author, editor or co-editor of a scientific book.

d) Professional Activities

A 5 credits per year for being an officer of a major Medical Physics organization such as the CCPM, COMP or the AAPM.

NOTES

(1) Members who have been temporarily absent from the field at some time during the previous five year period may calculate credits based on any five years of the preceding seven years in order to meet the requirements for re-certification.

(2) Unusual circumstances (e.g., enrolment in a post secondary institution for further graduate level education) will be considered on an individual basis by the Board).

(3) Any Member who loses his/her certification status may get reinstated through either the normal initial certification process or through the oral examination as defined in 3 above. The actual procedure used will be at the discretion of the Board.

APPENDIX 3

Sample Certificate for the Membership (Radiation Oncology Physics) sub-specialty of the Canadian College of Physicists in Medicine

THE CANADIAN
COLLEGE
OF PHYSICISTS
IN MEDICINE

LE COLLÈGE
CANADIEN
DES PHYSICIENS
EN MÉDECINE

elects

élit

Radiation Oncology Physics

to membership
in recognition of
proven competence in physics
as applied to medicine.

comme "membre"
en hommage à sa
compétence avéré en physique
appliquée à la médecine.

President

Vice President

Registrar

APPENDIX 4

Letter from the New York State Education Department

THE STATE EDUCATION DEPARTMENT / THE UNIVERSITY OF THE STATE OF NEW YORK / ALBANY, NY 12234

State Board for Medicine
89 Washington Avenue, West Wing, 2nd Floor
Albany, NY 12234
Tel: (518) 474-3817 EXT. 560 FAX: (518) 486-4846
E-mail: MEDBD@MAIL.NYSED.GOV

May 4, 2005

Brenda G. Clark, PhD, FCCPM
President
Canadian College of Physicists in Medicine
600 West 10th Avenue
Vancouver, BC V5Z 4E6

Dear Dr. Clark:

I am writing in follow-up to the State Education Department's review of the medical physics examinations administered by the Canadian College of Physicists in Medicine.

As you may know, Article 166 of the New York State Education Law and Subpart 79-8.4 of the Regulations of the Commissioner of Education require that individuals applying for licensure in medical physics after August 25, 2004 must pass an examination acceptable to the Education Department. I am pleased to inform you that the membership specialty examinations in radiation oncology, diagnostic imaging, and nuclear medicine, which are developed and administered by the Canadian College of Physicists in Medicine, have been determined to be acceptable within the provisions of Subpart 79-8.4 of the Regulations of the Commissioner of Education.

I hope that this information is helpful and if you have any questions, please feel free to contact me.

Sincerely yours,

Thomas J. Monahan
Executive Secretary

cc: State Committee for Medical Physics
Laura Lynch
Robert Bentley

APPENDIX 5

American Association of Physicists in Medicine (AAPM)
Report No. 38
"The role of a physicist in radiation oncology"

AAPM REPORT No. 38

THE ROLE OF A PHYSICIST IN RADIATION ONCOLOGY

Published for the
American Association of Physics in Medicine
by the American Institute of Physics

AAPM REPORT NO. 38

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE

STATEMENT ON
THE ROLE OF A PHYSICIST IN RADIATION ONCOLOGY

The report of Task Group 1 of the Professional Information and Clinical Relations Committee:

Members: Lloyd Asp
Morris Bank
Theodore Fields
William Hendee
Douglas Jones
Cohn Orton
Vincent Sampiere
George Starkschall
K. David Steidley
Bruce Thomadsen (Chair)

Consultants: Christedoulis Constantinou
Howard Couvillon
Robert Dunoskovic
James A. Deye
Richard Geise
Subramania Jayaraman
Patricia Johnson
Alan Kepka
Isaac Rosen
Susan Selden
Richard Steeves
Thomas White

This statement follows that entitled "The Roles, Responsibilities, and Status of the Clinical Medical Physicist," issued by the AAPM in 1985, to concentrate on the role and relationships of the clinical medical physicist practicing in radiation oncology.

Further copies of this report may be obtained from:
American Association of Physicists in Medicine
335 East 45th Street
New York, NY 10017

International Standard Book Number: 1-56396-229-2
International Standard Serial Number: 0271-7344

Published by the American Institute of Physics, Inc.
335 East 45th Street, New York, NY 10017

Printed in the United States of America

CERTIFYING ORGANIZATIONS

THE AMERICAN BOARD OF RADIOLOGY (ABR) certifies physicists in the specialties of:

Therapeutic Radiological Physics
Radiological Physics
Roentgen Ray Physics

Certification by the ABR includes examination in clinical aspects of medical physics, medical radiological equipment and instrumentation, and radiation safety.

THE AMERICAN BOARD OF MEDICAL PHYSICS (ABMP) certifies physicists in:

Radiation Oncology Physics
Hyperthermia Physics
Medical Radiation Protection [for radiation safety]

Certification by the ABMP includes examination in clinical aspects of medical physics, appropriate equipment, instrumentation, and radiation safety.

THE CANADIAN COLLEGE OF MEDICAL PHYSICS (CCMP) certifies physicists in radiological physics. Fellowship or membership implies equivalent testing to ABR certification in radiological physics (all subspecialties).

THE AMERICAN BOARD OF HEALTH PHYSICS (ABHP) certifies physicists in:

Comprehensive Health Physics [for radiation safety]

Following the policy outlined in the AAPM statement, only those persons certified by the ABR in Therapeutic Radiological Physics or Radiological Physics, The Canadian College of Medical Physics, or by the ABMP in Radiation Oncology Physics, can be assumed competent to function independently in a clinical situation. Certification by the ABHP or by the ABMP in Medical Radiation Protection indicates competence only in radiation safety aspects of radiation oncology, and not in the practice of radiation oncology physics. Participation in a post-graduate training program and practical experience alone do not imply competency.

APPENDIX 6

American Association of Physicists in Medicine (AAPM)
Webpage from July 2007
"Definition of a Qualified Medical Physicist"

Definition of a Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields of medical physics.

I. **Therapeutic Radiological Physics**

This particular field pertains to:

- the therapeutic applications of x-rays, gamma rays, electron and charged particle beams, neutrons and radiations from sealed radionuclide sources
- the equipment associated with their production, use, measurement and evaluation
- the quality of images resulting from their production and use
- medical health physics associated with this subfield

II. **Diagnostic Radiological Physics**

This particular field pertains to:

- the diagnostic applications of x rays, gamma rays from sealed sources, ultrasonic radiation, radio frequency radiation and magnetic fields
- the equipment associated with their production, use, measurement and evaluation
- the quality of images resulting from their production and use
- medical health physics associated with this subfield

III. **Medical Nuclear Physics**

This particular field pertains to:

- 1. the therapeutic and diagnostic applications of radionuclides (except those used in sealed sources for therapeutic purposes)
- the equipment associated with their production, use, measurement and evaluation
- the quality of images resulting form their production and use
- medical health physics associated with this subfield

IV. **Medical Health Physics**

This particular field pertains to:

- the safe use of x rays, gamma rays, electron and other charged particle beams of neutrons or radionuclides and of radiation from sealed radionuclide sources for both diagnostic and therapeutic purposes, except with regard to the application of radiation to patients for diagnostic or therapeutic purposes
- the instrumentation required to perform appropriate radiation surveys

It is expected that an individual will not hold himself/herself out to be qualified in a subfield for which he/she has not established competency. An individual will be considered competent to practice one or more of the subfields of Medical Physics if that individual is certified in that subfield by any one of the following:

- The American Board of Radiology
- The American Board of Medical Physics
- The American Board of Health Physics
- The American Board of Science in Nuclear Medicine
- The Canadian College of Physics in Medicine

The American Association of Physicists in Medicine regards board certification in the appropriate medical subfield as the appropriate qualification for the designation of Qualified Medical Physicist.

In addition to the above qualifications, a Qualified Medical Physicist shall meet and uphold the "**Guidelines for Ethical Practice for Medical Physicists**" as published by the American Association of Physicists in Medicine, and satisfy state licensure where applicable.

APPENDIX 7

Canadian College of Physicists in Medicine
Membership Exam
Sample questions for Section I:
General Medical Physics

CCPM MEMBERSHIP EXAMINATION
PART I

Answer all questions.

The allocation of marks is indicated beside each question. Part I has of a total of 100 marks.

[40%] 1. Sketch the following devices and label at least four (4) major components in each diagram. Discuss briefly and concisely the physical principle of the devices, indicating the important functions of the components you have labelled.

(a) Single Photon Emission Computed Tomography (SPECT) scanner
(b) A Helical/Spiral CT scanner
(c) Magnetic Resonance Imaging (MRI) scanner
(d) A real-time Ultrasound imaging scanner with Doppler capabilities
(e) A 3-dimensional conformal radiotherapy delivery system

[18%] 2. Explain each of the following terms in point form.

(a) Linear Energy Transfer (LET)
(b) Buildup factor
(c) Tissue-air ratio
(d) Stopping power
(e) Dose equivalent
(f) Sensitivity and Specificity of a diagnostic test
(g) Relative Biological Effectiveness (RBE)
(h) SAR in MRI
(i) Bragg peak

[18%] 3. Compare and contrast the similarities and/or differences of the following in point form.

(a) Portal imaging and diagnostic x-ray imaging
(b) Compton and coherent scattering
(c) Physical and Biological half-life
(d) Linear attenuation coefficient and Hounsfield unit
(e) Critical organ dose and effective dose equivalent (H_E)
(f) Characteristic radiation and bremsstrahlung
(g) Molybdenum and rhodium filter
(h) Exposure and air-kerma
(i) Primary and secondary barrier

[24%] 4. For each of the following:

(i) give a short description or definition
(ii) explain its relevance
(iii) give some typical numerical values and indicate the conditions for these values if applicable

(a) Spatial resolution in line pairs per mm of a mammography system
(b) Maximum permissible dose for a radiation worker
(c) Compton peak in the energy spectrum of a γ-emitting radioisotope ^{99m}Tc
(d) Gyromagnetic ratio of hydrogen nucleus
(e) Gradient magnetic field in magnetic resonance imaging
(f) Kilovoltage of a CT head scan
(g) Glandular dose in mammography
(h) Oxygen enhancement factor

APPENDIX 8

Canadian College of Physicists in Medicine
Membership Exam
Syllabus Section II:
Radiation Safety

Syllabus for Radiation Safety section of CCMP Membership Exam

Topics

1. Objectives and principles of radiation protection
2. ALARA
3. Dosimetric quantities and units
4. Natural and human-made sources of radiation exposure
5. Biological Effects of Ionizing Radiation
6. Instrumentation
7. Counting statistics
8. Basic External Dosimetry
9. Basic Internal Dosimetry
10. Familiarity with Canadian and international Agencies
11. CNSC regulations (see www.nuclearsafety.gc.ca)
12. Organization and administration of Radiation Safety Programs (licensing, relationships to hospital administration/occupational health & safety)
13. Monitoring and interpretation
14. Transportation and waste
15. Emergencies & incident preparation/planning and response

References

Note: This list is not to be considered comprehensive

1. ICRP 60
2. Nuclear Safety and Control Act
   - Sections 1, 24-27, and 44
3. General Nuclear Safety and Control Regulations
   - Sections 12, 16-17
4. Class II Nuclear Facilities and Prescribed Equipment Regulations
   - Sections 3-7, 10, 15, 17-21
5. Nuclear Substances and Radiation Devices Regulations
   - Sections 4, 11, 16-21, 23, 30-31 and 36
6. Radiation Protection Regulations
   - Sections 5- 7, 11-17 and 20-21
7. NCRP 49, 51, 147, 151 (facility design, diagnostic and therapy)
8. Herman Cember, *Introduction to Health Physics*
9. James Martin, *Physics for Radiation Protection: A Handbook*
10. NCRP 93
11. Philip R. Bevington, Data Reduction and Error Analysis for Physical Sciences
12. Jacob Van Dyk, *The Modern Technology of Radiation Oncology. A Compendium for Medical Physicists and Radiation Oncologists.*
13. Knoll, *Radiation Detection and Measurement*

APPENDIX 9

Canadian College of Physicists in Medicine
Membership Exam
Prepared question bank for Sections III and IV:
Radiation Oncology Physics sub-specialty

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÉGE CANADIEN DES PHYSICIENS EN MÉDECINE

MEDICAL PHYSICS QUESTIONS FOR MEMBERSHIP EXAMINATION

Edition 7.0

Canadian College of Physicists in Medicine

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÉGE CANADIEN DES PHYSICIENS EN MÉDECINE

Medical Physics Questions For Membership Examination (Edition 7.0)

Questions de Physique Médicale pour L'Examen d'Admission (Édition 7.0)

Available from the:

Canadian College of Physicists in Medicine

Disponible de:

Le Collége Canadien des Physiciens en Médecine

Wayne A. Beckham, Ph.D., FCCPM
CCPM Registrar / Greffier du CCPM
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Electronic version: ISBN: 0-9684873-3-5

FOREWORD TO THE SEVENTH EDITION

The Canadian College of Physicists in Medicine (CCPM) certifies competency in medical physics through its Membership examination process. The Membership exam consists of both a written and an oral component, and certification for competency in medical physics is given in four sub-specialties: namely Radiation Oncology Physics, Diagnostic Radiological Physics, Nuclear Medicine Physics and Magnetic Resonance Imaging Physics.

During the 2005 CCPM annual general meeting in Hamilton, Ontario, the membership requested a revision of the examination booklet with particular emphasis on the questions in Parts III and IV of the Radiation Oncology Physics subspecialty. This new edition (Edition 7) of the examination booklet reflects these revisions. In particular the Part III and IV question banks of Radiation Oncology Physics have been reviewed and updated. In addition, Parts III and IV have been reformatted to contain 83 questions (Part III) and 40 questions (Part IV) respectively. The content and breadth of the new format is similar to the original question set written by Ervin Podgorsak and in use since 1985, however the new format will allow for a more diverse set of questions to be chosen for the written examination.

The written component of the Membership exam consists of four Parts, and the exam is administered during a single day. Parts I and II are given first in a 2.5 hour sitting followed by a lunch break. Parts III and IV are given after the lunch break in a 2.5 hour sitting so that the total writing time during the examination day is 5 hours.

Part I consists of short answer questions (no choice) covering general medical physics as well as clinical anatomy and biological science relevant to clinical medical physics practice. Applicants from all sub-specialties write the same Part I examination and the time allowed for Part I is 1.5 hours.

Part II consists of short answer questions (no choice) to test the applicant's knowledge of radiation safety and protection. Applicants from the three ionising radiation sub-specialties write the same Part II examination, whereas a different Part II examination is supplied for the Magnetic Resonance Imaging specialty. The time allowed for Part II is 1 hour.

Parts III and IV are based on the question bank specific to the applicant's sub-specialty and available to the applicant by the first of October prior to the examination. The question bank will be posted on the CCPM web site, and this examination booklet covers the question bank used for Parts III and IV. Part III contains questions specific to the sub-specialty, and Part IV contains questions that cover more general areas of the sub-specialty.

For the Diagnostic Radiological Physics, Nuclear Medicine Physics and Magnetic Resonance Imaging Physics sub specialties, the Part III question bank contains 20 questions and the Part IV question bank contains 10 questions. For the Membership exam, one question from Part III and one question from Part IV are chosen at random. The total time allowed to complete both the Part III and Part IV questions is 2.5 hours.

For the Radiation Oncology Physics sub-specialty the Part III question bank contains 83 questions and the Part IV question bank contains 40 questions. For the Membership exam, five questions from Part III and five questions from Part IV are chosen at random. Each question is equally weighted and therefore counts for 20% of the appropriate Part mark. Where the question contains two or more parts, these parts are also equally weighted unless otherwise indicated. The total time allowed to complete both the Part III and Part IV questions is 2.5 hours.

While this seventh edition represents a major reorganization and updating of Parts III and IV of the Radiation Oncology sub-specialties, it in fact only builds upon the work of my predecessors. In particular I would like to acknowledge the work of the previous Chief Examiners, namely Marget Young, Ervin Podgorsak, Mike Bronskill, Jake Van Dyk, Terry Peters, Gino Fallone, Ting-Yim Lee and Katharina Sixel. Other individuals who assisted with previous versions are also credited in the appropriate edition foreword. The updating and reformatting of the Radiation Oncology subspecialty was accomplished with the help of many people, and for their efforts I would like to thank Brenda Clark, John Schreiner, Tom Farrell, Boyd McCurdy, Ian Kay, Ervin Podgorsak, Robert Corns, and in particular Katharina Sixel.

Michael D.C. Evans, M. Sc., FCCPM
Chief Examiner, CCPM
McGill University Health Centre
Montreal, Québec.

September 2006

FORWARD TO EDITION 6.2

A new edition number, Edition 6.2, is posted on the COMP/CCPM website as of October 1, 2003. There are no changes to the question bank. However, the Registrar is now Dr. Wayne Beckham, instigating an update to this document. Furthermore, the edition number has been unified amongst all subspecialties. Regarding exam format, details are posted in a separate document on the website. Please refer to it for specific instructions and information. This examination booklet covers the question bank used for Sections III and IV of the written Membership exam.

Katharina E. Sixel, PhD, FCCPM
Chief Examiner, CCPM
Toronto-Sunnybrook Regional Cancer Centre
Toronto, Ontario

FORWARD TO EDITION 6.1

Edition 6.1 represents a minor revision from the previously published sixth edition. One ambiguity in question III.7 has been corrected, and question III.19 has been substantially altered (Radiation Oncology section). The College Board decided that these changes did not warrant a new edition number. However, to allow for incremental improvements to the exam questions, we have instigated the release of minor version changes. Please refer to the full Forward to the Sixth Edition below for a more complete description of the written exam.

Katharina E. Sixel, PhD, FCCPM
Chief Examiner, CCPM
Toronto-Sunnybrook Regional Cancer Centre
Toronto, Ontario

FOREWORD TO THE SIXTH EDITION

This sixth edition is the result of a review to update questions related to the Radiation Oncology Specialty in Medical Physics. Some new questions were also added in this area to keep abreast of new developments.

The Canadian College of Physicists in Medicine certifies competency in Medical Physics through its Membership examination. Certification for competency in Medical Physics is given in four sub-specialties: Therapeutic Radiological (Radiation Oncology) Physics, Diagnostic Radiological Physics, Nuclear Medicine Physics, and Magnetic Resonance Imaging Physics.

The Membership examination consists of four Parts- Parts I and II are given first in a 2.5 hour sitting followed by a lunch break. Parts III and IV are given immediately after the lunch break in a second 2.5 hour sitting. Part I consists of short questions covering general medical physics that must be answered by all applicants. Parts II, III and IV are specific to each sub-specialty and consists of questions that must be answered by applicants in the appropriate sub-specialty.

Part II examines the practical aspects for each sub-specialty. Parts III and IV are based on the present question bank for each sub-specialty. Part III of the question bank contains 20 questions that test the in-depth knowledge of the candidate for each sub-specialty. Part IV of the question bank contains 10 questions that cover areas, not necessarily directly related to the sub-specialty, but for which the candidate is expected to possess expertise.

For each sub-specialty, Part III of the Membership examination consists of one question selected randomly from the corresponding Part III of this question bank, and Part IV of the Membership examination consists of one question selected randomly from the corresponding Part IV of this question bank.

1 would. like to extend my appreciation to the Fellows/Members who assisted in the preparation of this edition. In particular, 1 would like to thank Drs. Katharina Sixel, Brenda Clark and John Schreiner who extensively reviewed and edited the questions in the Radiation Oncology Speciality. Special thanks also to Drs. George Mawko and Michael Kolios for making the document available on the Worldwide Web.

Ting-Yim Lee, PhD, FCCPM.
Chief Examiner, CCPM
Lawson Health Research Institute and
Robarts Research Institute
London, Ontario

FOREWORD TO THE FIFTH EDITION

This fifth edition is the result of a review to update certain questions related to general nuclear medicine and to radiation biology and radiation protection as related to medical physics. Some new questions were also added in these areas to keep abreast of new developments.

The Canadian College of Physicists in Medicine certifies competency in Medical Physics through its Membership examination. Certification for competency in Medical Physics is given in four sub-specialties: Therapeutic Radiological (Radiation Oncology) Physics, Diagnostic Radiological Physics, Nuclear Medicine Physics, and Magnetic Resonance Imaging Physics.

The Membership examination consists of four Parts- Parts I and II are given first in a 2.5 hour sitting followed by a lunch break. Parts III and IV are given immediately after the lunch break in a second 2.5 hour sitting. Part I consists of short questions covering general medical physics that must be answered by all applicants. Parts II, III and IV are specific to each sub-specialty and consists of questions that must be answered by applicants in the appropriate sub-specialty.

Part II examines the practical aspects for each sub-specialty. Parts III and IV are based on the present question bank for each sub-specialty. Part III of the question bank contains 20 questions that test the in-depth knowledge of the candidate for each sub-specialty. Part IV of the question bank contains 10 questions that cover areas, not necessarily directly related to the sub-specialty, but for which the candidate is expected to possess expertise.

For each sub-specialty, Part III of the Membership examination consists of one question selected randomly from the corresponding Part III of this question bank, and Part IV of the Membership examination consists of one question selected randomly from the corresponding Part IV of this question bank.

1 would. like to extend my appreciation to the Fellows/Members who assisted in the preparation of this edition. In particular, 1 would like to thank Dr. Anna Celler and Dr. Piotr Slomka who offered suggestions and made upgrades to questions in general nuclear medicine, and Dr. Shirley Lehnert (a radiobiologist at McGill University) and Dr. Peter Raaphorst for reviewing and upgrading questions in radiation biology related to medical physics.

B. Gino Fallone, PhD, FCCPM, ABMP
Chief Examiner, CCPM
McGill University, Montreal, July 1998.

FOREWORD TO FOURTH EDITION

This new edition of the question booklet bas been produced to reflect the new format of the membership exam, which now examines candidates of Medical Physics in four distinct specialties, Radiation Oncology, Diagnostic Radiology, Nuclear Medicine and Magnetic Resonance.

The new format consists of four parts; Part I is a series of short answer questions common to all specialties, examining the candidate's general knowledge of Medical Physics; Part II is specialty specific, examining practical aspects of the discipline; Part III examines the candidate's in-depth knowledge of the specialty, while Part IV examines areas, not necessarily directly related to the specialty but in which the candidate is expected to possess some expertise.

This booklet contains the question bank for parts III and IV of each specialty, with 20 questions in part M and 10 in part IV. For the exam, one question will be selected from each question bank

I would like to thank my many colleagues within the CCPM who assisted in the preparation of this new edition, and in particular Drs. E. Podgorsak, W. Huda, R. Sloboda and B. Rutt. I am also indebted to Dr. D. Nishimura of Stanford University for allowing us to use questions from his course notes "Introduction to Magnetic Resonance Imaging".

T. M. Peters, PhD, FCCPM
Chief Examiner, CCPM
Montreal, December 1994

FOREWORD TO THIRD EDITION

The purpose of this third edition is to update some of the questions which were deemed outmoded or inappropriate, and to add two new sections on Magnetic Resonance (imaging and spectroscopy), and Imaging Techniques. The previous Physics of Imaging section becomes Miscellaneous Imaging Modalities while all of the theoretical questions have been moved to the new Imaging Techniques section.

This booklet now contains 110 questions related to various branches of Physics in Medicine. The questions are placed in eleven groups (from A to K) of ten questions each, and one question will be randomly chosen out of each group of ten to form the examination for Membership in the Canadian College of Physicists in Medicine (CCPM). The examination will thus consist of eleven questions out of the 110, and the candidate will be expected to answer three of the eleven questions. The candidate should therefore study three groups of ten questions and be prepared at the examination to spend about one hour answering one of the questions selected from, each of the three groups.

The question bank will continue to be periodically reviewed with the intent of improving the coverage of Medical Physics and to keep abreast of new developments.

I would like to thank Ervin Podgorsak for the work he put into the compilation of the first two editions of this book, and all of the CCPM Fellows who helped both of us with suggestions and advice during the preparation of this and the earlier revisions.

Terry M. Peters, PhD, FCCPM
Montreal, Quebec
January 1990

FOREWORD TO SECOND EDITION

During the 1985 general assembly of Fellows and Members of CCPM it was agreed that the format for the 1986 and 1987 written examinations will be essentially the same as that for the 1984 and 1985 examinations. A committee was assembled, however, to review the question booklet and suggest improvements and modifications. This booklet is the result of the review.

I would like to thank the following Fellows or Members who agreed to review individual sections of the booklet: Dr. Andrew Rainbow (Section A), Cupido Daniels (Section B), Dr. Ron Sloboda (Section C), Dr. Geoffrey Dean (Section D), Dr. Conrado Pla (Section E), Karen Breitman (Section F), Chris Thompson (Section G), Dr. Montague Cohen (Section H) and Dr. Ellen El-Khatib (Section I). I would also like to thank Ms. Lisette Fortin for the typing and preparation of the revised booklet.

McGill University
Montréal, Québec
November 1985

Ervin B. Podgorsak, PhD, FCCPM
Chairman
CCPM Examination Committee

FOREWORD TO THE FIRST EDITION

This booklet contains 90 questions related to various branches of Physics in Medicine. The questions am placed in nine groups (from A to 1) of ten questions, and one question will be randomly chosen out of each group of ten to form. the examination for Membership in the Canadian College of Physicists in Medicine (CCPM). The examination will thus consist of nine questions out of the 90, and the candidate will be expected to answer three of the nine questions. The candidate should therefore study three groups of ten questions and be prepared at the examination to spend about one hour answering each of the three questions. Information about the exact examination rules and examination dates is available from the Registrar of CCPM.

In the future the question bank will be periodically reviewed with the intent to improve the coverage of Medical Physics and to keep abreast with new developments. No changes, however, will be made for the 1984 and 1985 examinations.

I would like to thank the Fellows of CCPM and the considerable number of interested non-fellows who helped me with suggestions and advice during the preparation of the questions. In particular, I would like to thank Drs. Trevor Cradduck, and Frank Prato for preparing the second half of section C as well as section D, Dr. Michael Bronskill for preparing section G, and Drs. René Béique and Douglas Cormack for help with section H. 1 would also like to thank Ms. Francine Lecours for the typing and preparation of the booklet.

McGill University
Montréal, Québec
January 1984

Ervin B. Podgorsak, PhD, FCCPM
Chairman
CCPM Examination Committee

Suggested texts for preparation of the examination.

It must NOT be assumed that questions will be based solely from these texts.

A: Radiation Oncology

1. The physics of radiation therapy: F. M. Kahn; Williams and Williams, Baltimore.
2. Introduction to radiological physics and radiation dosimetry: P.H. Attix; Wiley, New York.
3. The physics of radiology (Fourth Edition.): H.E. Johns and J.R. Cunningham; Charles C. Thomas, Springfield Ill.
4. Modern technology of radiation oncology: J. Van Dyk (Editor); Medical Physics Publishing, Madison Wisconsin.
5. Radiation physics for medical physicists: E.B. Podgorsak; Springer, New York.
6. Radiation oncology physics: a handbook for teachers and students: E.B. Podgorsak (Editor); IAEA, Vienna.
7. Radiobiology for the radiobiologist: E.J. Hall; Lippincott Williams & Wilkins, New York.
8. ICRP publication 60: 1990 recommendations of the international commission on radiological protection: The International Commission on Radiological Protection; New York.
9. NCRP report 147: Structural shielding design for medical x-ray imaging facilities: National Council on Radiation Protection and Measurements; Bethesda MD.
10. NCRP report 151: Structural shielding design and evaluation for megavoltage X- and gamma-ray radiotherapy facilities: National Council on Radiation Protection and Measurements; Bethesda MD.

B: Diagnostic Radiology

1. The physics of radiology (4th Ed.): H.E. Johns and J R. Cunningham. Charles C. Thomas, Springfield Ill.
2. The physics of medical imaging: S. Webb; Adam Hilger, Bristol.
3. The physics of medical x-ray imaging (2' Ed.): B. Hasegawa; Medical Physics Publishing, Madison, WI.
4. Christensens's physics of diagnostic radiology: T.S. Curry, J.E. Dowdey and R.C. Murry (4th ed.), Lippincott Williams & Wilkins, New York; 1990.
5. Physics of radiology: A. Wolbarst, Medical Physics Publishing, Madison, WI; 2000.

C: Nuclear Medicine

1. Physics in nuclear medicine: S.R. Cherry, J.A. Sorenson and M.E. Phelps; W.B. Saunders, Philadelphia.

2. Nuclear medicine physics: L.E. Williams (Ed); CRC Press, Boca Raton.

3. The physics of radiology (4th Ed.): H.E. Johns and J.R. Cunningham; Charles C. Thomas, Springfield Ill.

4 Introductory physics of nuclear medicine, R. Chandra; Lea & Febiger, Philadelphia.

5. Radiation detection and measurement, G. F. Knoll; John Wiley and Sons, Third Edition, 2000.

6. Basic science of nuclear medicine, R.P. Parker, P.H.S. Smith, D.M. Taylor; Churchill Livingston, New York.

D: Magnetic Resonance

1. The physics of MRI: 1992 AAPM Summer School Proceedings; P Sprawls and M Bronskill (Eds), AAPM Monograph # 21, American Institute of Physics, Woodbury, NY.

2. Nuclear magnetic resonance imaging in medicine and biology: P.G. Morris; Oxford University Press, Oxford.

3. Magnetic resonance imaging: physical principles and sequence design, E.M. Haacke, R.W. Brown, M.R. Thompson, and R. Venkatesan, A. John Wiley & Sons, 1999.

4. In vivo NMR Spectroscopy: principles and techniques, R. A. de Graaf, John Wiley and Sons, 1998.

5. Questions and answers in magnetic resonance imaging, Second Edition, A.D. Elster and J. H. Burdette, Mosby, 2001.

6. Handbook of MRI pulse dequences, M. A. Bernstein, K. F. King, and X. J. Zhou, Elsevier Academic Press, 2004.

TABLE OF CONTENTS

Section A: Radiation Oncology Specialty

You will be required to answer **FIVE** questions from Part III and **FIVE** questions from Part IV (total of **TEN** questions). The **TEN** questions for the Membership exam are chosen at random. Total time for Parts III and IV is 2.5 hours.

Each question is equally weighted and therefore counts for 20% of the appropriate Part mark. Where the question contains two or more parts, these parts are also equally weighted unless otherwise noted.

Part III: Basic Medical Physics

1. a. Define attenuation and absorption coefficients for photon beams and describe the difference between the two coefficients.
   b. Prepare a table showing the relationship between the linear, mass, atomic and electronic attenuation coefficients and show suitable units of these coefficients.

2. a. Define the mass energy transfer and mass energy absorption coefficient.
   b. Describe the relationship of these two coefficients with the mass attenuation coefficient.
   c. Express kerma and absorbed dose in terms of the mass energy transfer coefficient and mass energy absorption coefficient, respectively.

3. a. List the main photon-matter interactions contributing to the mass attenuation coefficient of an x-ray photon.
   b. Sketch the mass attenuation coefficient for water and lead on a log-log graph in the energy range from 10 keV to 100 MeV indicating the regions where a certain type of interaction predominates.
   c. On a graph exhibiting atomic number Z vs log photon energy sketch two curves, one giving equal probability for photo-electric effect and Compton effect and the other equal probability for Compton effect and pair production.

4. a. Sketch and describe the photon-matter interation that dominates for most materials at a photon energy of 50 keV.
   b. On a graph exhibiting F-factor vs log photon energy sketch three curves, giving F-factor for bone, water and soft tissue in the energy range 10keV to 1 MeV.

5. a. Sketch and describe the photon-matter interaction that dominates for most materials at a photon energy of 1 MeV.
   b. Plot a graph showing the maximum and the average kinetic energy of a Compton recoil electron as a function of photon energy hν in the energy range from 10 keV to 100 MeV.

6. a. Sketch and describe the photon-matter interaction that has a threshold at a photon energy of 1.02 MeV.
   b. Using $E^2 - p^2c^2$ = invariant, calculate the thresholds for pair production and triplet production.

7. a. On a log-log graph sketch, for air, the mass attenuation coefficient μ/ρ, mass energy transfer coefficient μ_{tr}/ρ, and mass energy absorption coefficient μ_{ab}/ρ in the photon energy range from 10 keV to 100 MeV.
   b. Express air kerma in terms of μ_{tr}/ρ.

8. Briefly define or explain:
   (a) fluorescent yield
   (b) Auger effect
   (c) internal conversion
   (d) Coster-Kronig electrons
   (e) Rayleigh scattering
   (f) photoelectrons
   (g) triplet production
   (h) annihilation photon
   (i) characteristic radiation
   (j) Klein-Nishina coefficients.

9. Consider the three most important modes of photon interactions with a medium:
   a. For each, state the dependence of the appropriate attenuation coefficient upon the photon energy hν and atomic number Z of the medium.
   b. For each, briefly describe the processes contributing to the transfer of energy from the photon to the medium that follow the interactions.

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10. a. Sketch and briefly describe the Compton interaction.
    b. State the relativistic equations which represent the conservation of energy and momentum and are used in the derivation of the Compton relationship:

    $$\lambda' - \lambda = \lambda_c(1 - \cos\theta).$$

    c. Derive the Compton equation for the energy of the recoil electron.

11. a. Using the Compton relationship $\lambda' - \lambda = \lambda_c(1 - \cos\theta)$, derive expressions for the energy $h\nu'$ of the scattered photon and the kinetic energy KE of the recoil electron.
    b. Show that the energy of the backscattered photon is equal to 255 keV for a high energy photon.

12. At a photon energy $h\nu$ of 4 MeV in lead, the atomic attenuation coefficients for photo-electric effect ${}_a\tau$, Compton effect ${}_a\sigma$, and pair production ${}_a\kappa$ are 0.567×10^{-24} cm^2/atom, 7.878×10^{-24} cm^2/atom, and 5.782×10^{-24} cm^2/atom, respectively. Calculate the mass attenuation coefficient μ/ρ, the mass energy transfer coefficient μ_{tr}/ρ, and the mass energy absorption coefficient μ_{ab}/ρ (bremsstrahlung fraction g is 0.130). Clearly explain the steps involved in the calculation.

13. A photon of energy $h\nu$ interacts with lead:
    a. Give the general relationship between $h\nu$ and the maximum kinetic energy E_{max} of the free electron produced through photo-electric effect, Compton effect and pair production.
    b. Assuming $h\nu = 2$ MeV, calculate E_{max} for the three effects.

14. The Klein-Nishina formula relating the Compton differential cross-section $d\sigma_c/d\Omega$ with the photon scattering angle θ is given by:

    $$\frac{d\sigma_c}{d\Omega} = \frac{r_e^2}{2} \times \frac{1+\cos^2\theta}{\left[1+\alpha(1-\cos\theta)\right]^2} \times \left\{1 + \frac{\alpha^2(1-\cos\theta)^2}{\left[1+\cos^2\theta\right]\times\left[1+\alpha(1-\cos\theta)\right]}\right\}$$

    where $\mathbf{r}_e = 2.818$ fm is the classical electron radius and $\alpha = h\nu/m_ec^2$ with $m_ec^2 = 0.511$ MeV.
    a. Show that for $\alpha = 0$ and any θ, and for $\theta = 0$ and any α, $d\sigma_c/d\Omega$ transforms into the classical scattering coefficient per electron $d\sigma_o/d\Omega$.
    b. Integrate $d\sigma_o/d\Omega$ over $d\Omega$ to get $\sigma_0 = 66.5 \times 10^{-30}$ m^2 and plot $d\sigma_c/d\Omega$ vs θ for photon energies 0, 1 MeV and 10 MeV.

15. a. Sketch the Compton differential cross-section $d\sigma_c/dE$ as a function of the electron kinetic energy E for photon energies $h\nu$ of 0.5 MeV and 1 MeV.
    b. Discuss the effect of electron binding on Compton scattering for low photon energies.

16. a. Define the stopping powers attributed to collision and radiation losses.
    b. Describe the difference between the stopping power and linear energy transfer (LET).

17. a. Use principles of classical mechanics to derive an expression for the mass collision stopping power S_{coll} for a heavy charged particle interacting with orbital electrons in a medium.
    b. Describe the role of the mean excitation energy of the atom, I, in the Heitler's quantum mechanical derivation of S_{col}.

18. a. Describe the energy and atomic number dependence of the mass collision stopping power S_{coll} for electrons in the energy range from 10 keV to 100 MeV.
    b. Sketch S_{coll} for electrons in water and lead in this energy range.
    c. Sketch the radiative stopping power S_{rad} for electrons in the same energy range.

19. a. Sketch the variation of the mass collision stopping power S_{coll} as a function of energy in the range from 10 keV to 100 MeV.
    b. Use this sketch to describe the optimum design of a bremsstrahlung target for a high energy linac.
    c. Describe how a multi-element target can be used to provide a photon beam of a more desirable spectrum.

20. Briefly define or explain:
    (a) guard electrodes
    (b) air-wall material
    (c) collection efficiency
    (d) stem effect
    (e) build-up cap
    (f) W for air
    (g) leakage current
    (h) chamber calibration factor
    (i) ion pair
    (j) initial and general recombination.

21. a. Draw schematically and briefly describe the standard free air ion chamber and clearly state its components and limitations.
    b. Draw schematically a parallel-plate (pancake) and a thimble ion chamber, label their main components and show a simple electronic circuit associated with them.

22. Draw a saturation curve for a typical parallel-plate ion chamber irradiated with a continuous photon beam and briefly describe the behavior of the saturation curve as a function of radiation intensity, electrode separation, and photon energy.

23. Briefly describe the use of ferrous sulphate dosimetry and calorimetry as the two alternatives to a standard ionization chamber in absolute dosimetry.

24. With a simple diagram illustrate the two steps involved in energy transfer from a photon to the medium. With the aid of this diagram, clearly define the following:
    (a) kerma
    (b) absorbed dose
    (c) exposure
    (d) electronic equilibrium
    (e) bremsstrahlung
    (f) conversion electrons
    (g) effective atomic number
    (h) delta rays.

25. a. Write kerma and absorbed dose in terms of the photon energy fluence and mass attenuation coefficients both for a homogeneous photon beam with energy $h\nu$ and for a heterogeneous photon spectrum with maximum energy $h\nu_{max}$.
    b. Briefly describe the Bragg-Gray cavity theory and clearly define the parameters involved.

26. Describe the method to determine dose in a medium using a cavity ionization chamber with a wall material different from the material of medium. Clearly define the steps involved and identify any approximations used in the determination of dose from ionization chamber measurements.

Part III: Basic Medical Physics

27. a. List and briefly define the factors involved in determining dose in a medium using an exposure calibrated ionization chamber.
    b. Define the "dose in free space" and give an example of a situation for which this parameter is useful in radiation therapy.

28. a. Using labeled diagrams, compare an x-ray tube used for therapy with an x-ray tube used for diagnosis, clearly indicating the key differences.
    b. Explain how these differences translate into differences in quality control protocols for orthovoltage therapy units and conventional treatment simulators.

29. a. Describe the shutter error associated with the timer on Cobalt and x-ray machines.
    b. Explain how this error is measured.
    c. How it is applied in practice when setting treament times on a Coblat machine vs a linear accelerator.
    d. Explain the relevance, if any, of this error for IMRT.

30. a. Estimate the power delivered to the target of an x-ray tube operated at 100 kVp, 50 mA, 3-phase 12-pulse rectified.
    b. Compare this to the power delivered to the target of a 20 MV linac operated at 50 pps with an electron current pulse width of 7 μs and a height of 50 mA.

31. a. Describe the role and typical properties of targets used in linacs.
    b. Discuss how target design affects the quality (% depth dose) of the x-ray beam for a given incident electron energy.
    c. Describe the methods used to produce a clinical electron beam from the pencil beam which exits these accelerators.

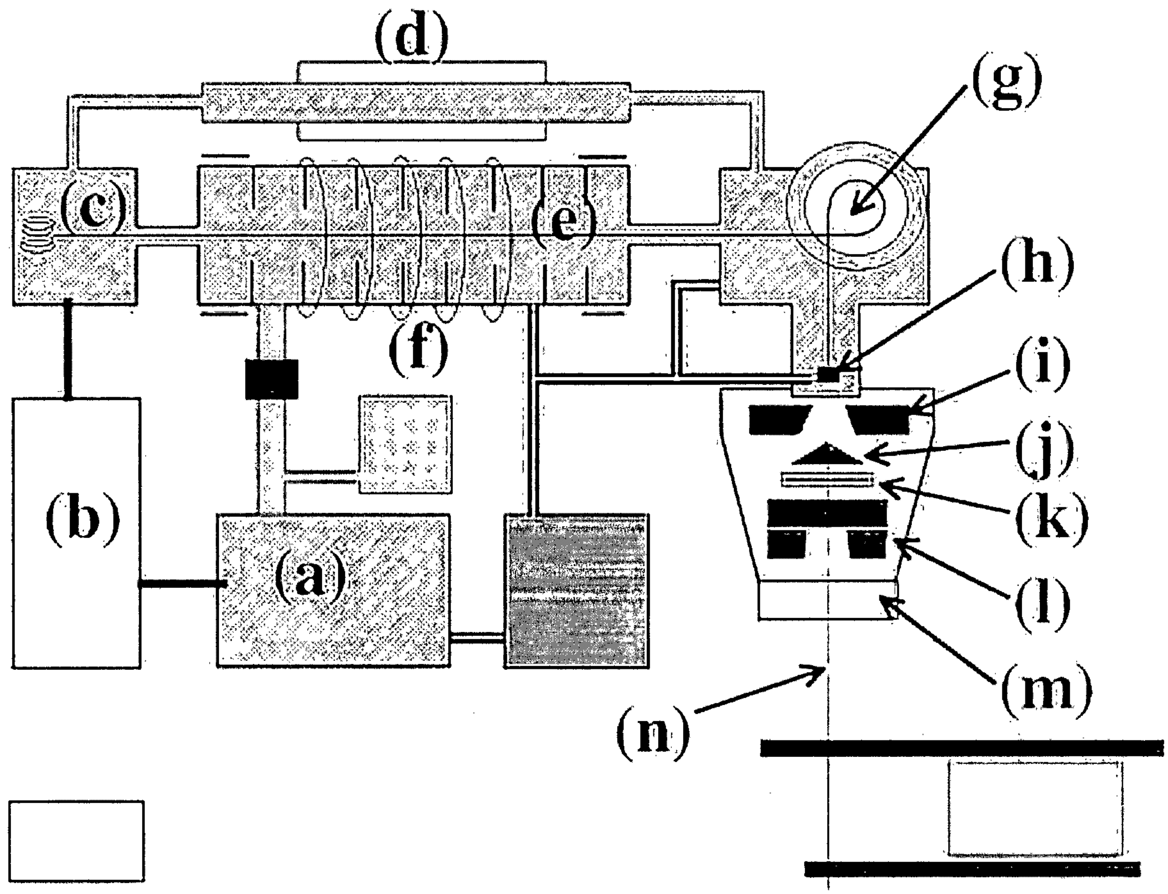
32. a. Describe the role and typical properties of flattening filters used in linacs.
    b. Discuss how flattening filter design affects the the quality (% depth dose) of the x-ray beam for a given incident electron energy.
    c. What is the impact of filter design on dose rate?

33. Draw a schematic diagram, indicating major subsystems, of a medical linear electron accelerator used for photon production showing the functional relationship between the components.

34. Give a range of values and units for the following parameters of a typical linear accelerator:
    (a) peak beam current
    (b) average beam current
    (c) modulator pulse width
    (d) peak modulator current
    (e) radiofrequency of operation
    (f) beam current pulse width
    (g) electron gun voltage
    (h) length of accelerating waveguide
    (i) target material and thickness in a 6 MV linac
    (j) electron kinetic energy in the waveguide.

35. Consider the schematic diagram of a linear accelerator below. Match the label blanks of the major components to the following list.

i) bending magnet	viii) microwave power source
ii) electron gun	ix) multi-leaf collimator
iii) flattening filter	x) primary collimator
iv) focussing coil	xi) pulsed modulator
v) ionization chamber	xii) target
vi) isocenter	xiii) vacuum pump
vii) jaws	xiv) waveguide.



36. a. Explain why the output (cGy/MU), both in air and in phantom, of a linear accelerator changes with field size.
    b. Sketch a graph of relative output in air (eg REF, ROF or S_c) vs. field size for typical 6 MV and 18 MV photon beams.
    c. Sketch a graph of relative output in phantom (eg. RADF, RDF, or $S_{c,p}$) vs. field size for typical 6 MV and 18 MV photon beams.
    d. What is the effect of increasing photon energy on the relationship between these factors and field size?
    e. What is the challenge when measuring relative output in air for a high energy beam?

37. a. List the key functional specifications for a conventional multileaf collimator system.
    b. The three major linear accelerator manufacturers all use different MLC designs. Using appropriate diagrams and a table, contrast these design variations.

38. You are asked to oversee design and installation of a facility for a 18 MV linear accelerator to be used in the photon (18 MV) and electron mode (6 MeV to 21 MeV).
    a. Discuss which regulatory agency(ies) and which regulation(s) must be considered and adhered to.
    b. List room design considerations for standard radiotherapy prodecures.
    c. List additional design considerations that might be imposed by special techniques such as intraoperative radiotherapy, total body electron irradiations, and total body photon irradiations.

39. Acceptance testing of a linear accelerator with multileaf collimation and electronic portal imaging can be classed into several broad catagories. List five of these catagories. Within each catagory, give an example of a measurement or test, as well as an acceptable tolerance specification.

40. What are the beam parameters required by a radiation therapy treatment planning system for photons which uses a model based dose calculation algorithm? How are they measured and how are they used in dose distribution and monitor unit calculations?

41. Calculate the maximum activity that can be produced in 10 g of ^{59}Co when it is irradiated in a neutron fluence rate Φ of 10^{13}cm^{-2}s^{-1}. The atomic weight of cobalt is 58.94, and the activation cross section σ is 37 barns/atom. First calculate the time t_{max} in which the maximum activity of ^{60}Co will be achieved.
Do not assume in your derivation that $\lambda(^{60}\text{Co}) >> \sigma\Phi \approx 0$.

42. Describe in detail a protocol for clinical reference dosimetry of a medical linear accelerator using a cobalt-60 calibrated ionization chamber. Give the equation used and fully define each parameter. How is beam quality specified? Include a description of the measurement geometry and conditions, as well as the medium in which the measurement must be made.

43. Define the following functions used in manual Radiation Oncology dose calculations, sketch the relevant geometry, and clearly state what beam parameters the functions are influenced by:
    (a) percentage depth dose PDD
    (b) tissue-air ratio TAR
    (c) tissue-maximum ratio TMR
    (d) tissue-phantom ratio TPR
    (e) scatter-air ratio (SAR)
    (f) off axis ratio (OAR)
    (g) peak-scatter factor PSF
    (h) relative dose factor (RDF)
    (i) zero area percentage depth dose
    (j) wedge factor (WF).

44. Sketch the following percentage depth doses (PDD) in water:
    a. PDD as a function of depth, field size 10x10 cm^2 for 100 kVp x rays at 10 cm SSD, cobalt-60 at 80 cm SSD, and 10 MV x rays at 100 cm SSD.
    b. PDD as a function of depth, field size 10x10 cm^2 for cobalt-60 at SSD 80 cm and at SSD 120 cm:
    c. PDD as a function of effective beam energy, field size 10x10 cm^2, depth of 5 cm, for the following beam energies: cobalt-60 at 80 cm SSS, 250 kVp x rays at 10 cm SSD, and 4 MV, 6 MV , 10 MV and 25 MV x rays all at 100 cm SSD.

45. a Sketch off axis ratios (i.e., beam profiles) as a function of distance from central axis for a typical 6 MV beam at a depth of 1.5 cm, 10 cm and 20 cm. The graphs should be normalized to dose on central axis for each curve.
    b. When a beam of megavoltage photons irradiates a phantom surface, there is a dose delivered to the superficial layers both within the beam and peripheral to it. Describe the factors affecting the magnitude of this dose. How is this dose measured?

46. Derive the following relationships, make sketches and clearly identify the steps involved in the derivations:
    a. between PDD and TAR
    b. between TAR and TMR
    c. between PDD and TMR.

47. Describe the following three methods for tissue heterogeneity corrections in dose calculations with photon beams: a simple hand calculation approach, a correction based dose calculation algorithm approach, and a dose kernal superposition algorithm approach. Give the advantages and disadvantages of each.

48. Monte Carlo (MC) dose calculation engines are available for treatment planning systems.
    a. Discuss the advantages of the MC dose engine over other methods.
    b. Briefly explain how a particle history is calculated from a collection of pseudo-random numbers.
    c. Briefly explain how a dose distribution is obtained from a collection of particle histories.

49. The Klein-Nishina formula relating the Compton differential cross-section $d\sigma_c/d\Omega$ with the photon scattering angle θ is given by:

$$\frac{d\sigma_c}{d\Omega} = \frac{r_e^2}{2} \times \frac{1+\cos^2\theta}{[1+\alpha(1-\cos\theta)]^2} \times \left\{1 + \frac{\alpha^2(1-\cos\theta)^2}{[1+\cos^2\theta] \times [1+\alpha(1-\cos\theta)]}\right\}$$

where $\mathbf{r_e}$ = 2.818 fm is the classical electron radius and $\alpha = h\nu/m_ec^2$ with m_ec^2 = 0.511 MeV.
    a. Describe how this equation could be used by a Monte-Carlo simulation program to model a Compton interaction in a medium.
    b. Describe how the program would decide the trajectory and energy of an electron produced in the interaction.

50. Dose distributions calculated using a Monte Carlo (MC) dose engine are subject to statistical noise.
    a. Explain why statistical noise is present in a MC dose distribution.
    b. Write expressions showing how the relative noise depends upon:
        i The number of particle histories
        ii. The dose-grid voxel size
        iii. The dose as a percentage of prescription dose
        iv. The MC simulation time.

    c. Sketch a typical cumulative dose volume histogram (DVH) for a planning target volume prescribed to 70 Gy with minimum dose and maximum dose of 67 and 72 Gy respectively. On the same graph sketch the DVH that would be obtained using a MC dose engine with relative statistical noise of 10%.

51. Briefly define or explain:
    (a) kinetic energy of electrons
    (b) electron fluence
    (c) R_{50} of an electron beam
    (d) practical range of electrons
    (e) secondary electrons
    (f) stopping power ratio
    (g) Cerenkov radiation
    (h) Fricke dosimetry
    (i) G-value
    (j) calorimetry.

52. Describe three techniques which may be used to determine the kinetic energy of an electron beam impinging onto a phantom. Define energies for which these methods are applicable.

53. a. Sketch percentage depth doses and isodose distributions for a typical 10 x 10 cm^2 electron beam, SSD 100 cm, with initial kinetic energies of 6, 15, and 25 MeV.
    b. Briefly describe both missing tissue and heterogeneity corrections for electron beams.

54. a. Sketch percentage depth doses for a 15 MeV electron beam for field sizes 3x3 cm^2, 10x10 cm^2 and 30x30 cm^2. Provide an explanation for the differences and/or similarities of these three curves.
    b. Briefly describe the corrections that must be considered when electron fields are shaped to substantially reduce their size.

55. Describe the protocol for absorbed dose measurement in an electron beam with a dose calibrated ionization chamber. Clearly define the parameters used. Include a description of the measurement geometry and appropriate phantom material. Describe the method to specify beam quality.

56. Describe the basic physics behind the Thermoluminescent Dosimetry (TLD) process, and show schematically a typical apparatus for TLD measurements . Clearly label the components.

57. Briefly define or explain:
    (a) pre- and post-irradiation annealing
    (b) glow curve (thermogram)
    (c) recombination centre
    (d) storage trap
    (e) activation energy
    (f) supralinearity
    (g) infrared emission of the planchet
    (h) Randall-Wilkins model
    (i) phosphorescence
    (j) fluorescence.

58. a. Name at least three substances which are currently used as thermoluminescent dosimeters and state an advantage for each one.
    b. Describe the use of thermoluminescent dosimetry for patient dose monitoring in external beam therapy.
    c. Describe calibration and handling techniques.
    d. Include a description of the relevance of the measured values when attempting to validate doses calculated on a treatment plan.

59. Name four relative dosimetry techniques other than Thermoluminescent Dosimetry. Briefly describe their main characteristics and applications, as well as advantages and disadvantages.

60. There are various approaches used in interstitial and intracavitary brachytherapy. Describe 4 different brachytherapy dose delivery methods, including the mechanism of dose delivery and radioisotope used. Give a clinical application for each. Explain the advantages offered by afterloading and remote afterloading techniques.

61. Describe four brachytherapy sources; two commonly used in remote afterloading systems and two used for manual loading techniques. Include physical construction, and radiation parameters such as half-life, typical activity, energy, and air kerma rate constant. Comment on the clinical use of each source.

62. Describe the practical issues of brachytherapy source calibration. Explain how an absorbed dose distribution for a typical brachytherapy source is determined.

63. What are the advantages and disadvantages of high dose rate gynaecological brachytherapy? How can doses delivered at high dose rate be compared with doses delivered at low dose rate? What is a typical dose fractionation scheme for cervix cancer treated with high dose rate brachytherapy?

64. With respect to permanent seed implantation for the treatment of early stage prostate cancer:
    a. Briefly outline the steps required for patient treatment from initial assessment through post implant treatment evaluation.
    b. Give a description of the radioactive seeds conventionally used in the treatment including the appropriate properties required for treatment planning.
    c. Describe the steps and tools required for the recommended quality assurance of the radioactive seeds prior to implantation.

65. With respect to permanent seed implantation for the treatment of early stage prostate cancer, describe the commonly used dose calculation formalism giving definitions and explanations for all quantities.

66. a. Specify the radiation properties (isotope, activity, half-life, energy and air kerma rate constant) of the radioactive seeds used in HDR brachytherapy for prostate cancer.
    b. Describe how the treatment is delivered.
    c. Describe four differences in the radiation protection concerns for HDR prostate treatment versus permanent seed implantation.
    d. Describe the differences in eligibility and selection for patients undergoing HDR brachytherapy versus permanent seed implant.

67. Describe in detail a standard radiation treatment of the breast or chest- wall, including the regional lymph nodes. Include considerations of protecting organs at risk, achieving dose homogeniety in 3 dimensions, and problems associated with beam junctioning. Also state the typical total dose and fractionation schemes used.

68. Consider the planning, treatment and verification of 3D conformal prostate irradiation.
    a. Use ICRU 50 terminology to describe the appropriate tumour and target volumes.
    b. Describe a typical treatment technique.
    c. Describe methods for the verification of patient set-up .
    d. List two organs at risk and for each list tolerance doses and associated toxicity.
    e. Give a typical total dose and fractionation used in dose escalation protocols.

69. Describe the rationale for total body irradiation (TBI) prior to bone marrow transplantation for leukemia, the dose regimen usually given, the medical problems encountered during or after TBI, as well as the theoretical advantages or disadvantages of delivering the dose in a single fraction as compared to multiple fractions.

70. Briefly describe four different techniques used for the production of large photon fields for total body irradiation (TBI) prior to bone marrow transplantation for leukemia.

71. Describe the dosimetric measurements that must be performed before a therapy unit can be used for total body photon irradiation (TBI) prior to bone marrow transplantation for leukemia.

72. Describe in detail the required changes to, and measurements on, a standard linear accelerator before it can be used to deliver total skin electron irradiation (TSEI). Describe at least two treatment techniques currently employed for TSEI. State typical doses and fractionations used.

73. a. List 3 clinical disease sites or indications for which stereotactic radiosurgery is a treatment of choice. What is the typical dose and fractionation scheme for each?
    b. Describe the equipment and measurements required for the commissioning and clinical implementation of a linear accelerator based stereotactic radiosurgery program.

74. Briefly describe the basis of tomotherapy and explain how intensity modulation is achieved throughout the target volume. Sketch and describe the main components of a helical tomotherapy unit. Describe two issues in beam dosimetry which may be more challenging with a tomotherapy unit compared to conventional linac dosimetry.

75. Low energy photons and other directly or indirectly ionizing particles, such as protons and neutrons have been used for cancer therapy. Briefly define, or explain:
    (a) Bragg Peak
    (b) collision stopping power
    (c) multiple Coulomb scattering
    (d) photosensitizer
    (e) neutron RBE
    (f) boron-10 capture reaction
    (g) switchyard in a proton therapy facility
    (h) epithermal neutrons.

76. a. State the rationale for the use of neutrons for cancer therapy.
    b. Sketch a typical neutron depth dose curve specifying the energy. Describe the range of energies that are appropriate for neutron therapy.
    c. Describe an effective approach to generating clinically viable high energy neutron beams.

77. a. State the rationale for the use of protons for cancer therapy.
    b. Sketch the relative dose versus depth curve for a 120 MeV proton beam. Show how multiple modulated beams can be combined to produce a more clinically useful depth dose distribution.
    c. Describe the range of energies that are appropriate for proton therapy.
    d. Describe two methods for producing clinically useful large laterally uniform fields from the narrow proton beams produced in proton accelerator.

78. a. Describe the mechanism of photodynamic therapy and discuss the role of oxygen.
    b. Describe the range of wavelengths suitable for photodynamic therapy giving reference to the absorption characteristics of typical photosensitizers and tissue penetration. (Use graphs as appropriate.)
    c. Describe the two main classes of light sources for photodynamic therapy. Give two examples of each class specifying wavelengths and power.
    d. Describe two approaches to delivering the light from the source to the target and include the limitations each imposes on possible treatment sites.

79. Hyperthermia, cryosurgery, and radioimmunotherapy with monoclonal antibodies may be described as alternative treatments for cancer. In each case, describe the basis for the therapy, a method of treatment delivery, specify a site treated by the technique and describe a possible problem in utilization.

80. Define or explain (use sketches where applicable)
    a. CT Simulator
    b. Cone beam CT
    c. Image Intensifier (II)
    d. Film - screen combination
    e. Filtered back-projection .

81. Define or explain (use sketches where applicable)
    a. CT number vs electron density
    b. Imaging with megavoltage photon beams
    c. Digitally reconstructed radiographs (DRR)
    d. Beam's-eye view
    e. 3-D dosimetry with Fricke-gel dosimeters and MRI.

82. Describe three different types of on-line digital portal imaging systems. Discuss the advantages and disadvantages of each of these systems.

83. Compare the use of CT and MRI in radiotherapy treatment planning with reference to resolution, contrast, spatial and geometric uniformity of the images and their ability to:
    a. give information for tissue inhomogeniety corrections
    b. delineate tumour volumes and critical organs (describe tumour extent)
    c. locate bony landmarks.

Part IV: Radiation Protection and Radiation Biology

1. Briefly define or explain:
   - (a) stopping power
   - (b) half-value layer (HVL)
   - (c)tenth value layer
   - (d) air kerma
   - (e) absorbed dose
   - (f) equivalent dose (H_T)
   - (g) effective dose (E)
   - (h) radiation weighting factor (w_R)
   - (i) tissue weighting factor (w_T).

2. Describe the concept of linear energy transfer (LET) and its use as a measure of radiation quality. How does LET vary with the type and energy of charged particles and with depth in a medium in which charged particles are slowed down.

3. Outline how the linear quadratic radiobiological model describes and explains the variation of relative biological effectiveness and/or shape of dose-response curve as a function of radiation type and energy.

4. Define the oxygen enhancement ration (OER) and explain how the presence of oxygen modifies radiation response. What is a typical value of OER for a dose of 200 cGy from x rays? Sketch OER as a function of LET.

5. a. Briefly describe the evidence upon which the ICRP values of radiation weighting factors (w_R) are based.
   b. What is the equivalent dose (H_T) of an absorbed dose of 10 mGy for a beam of 10 MeV neutrons?

6. Briefly define or explain:
   - (a) photo-peak
   - (b) dynode
   - (c) W for air
   - (d) glow curve
   - (e) Compton edge
   - (f) electronic avalanche
   - (g) space charge
   - (h) quenching
   - (i) coincidence loss
   - (j) paralyzable and non-paralyzable system.

7. Ionization chambers, proportional counters and Geiger-Meller counters are all gas filled radiation detectors.
   a. Sketch a graph illustrating the operation of a gas filled detector plotting pulse amplitude against applied voltage. Indicate the regions on this graph which define the different detector types.
   b. Discuss the relative merits of these detectors in the the field of radiation protection, and give an example of when they would be used.

8. Describe:
   a. an ionization chamber and its associated circuitry when used with an electrometer
   b. the calculation of absorbed dose in air from a measurement of ionization in air with an ionization chamber.

9. Describe:
   a. a proportional counter
   b. the energy discrimination ability of a proportional counter
   c. how to calibrate a proportional counter to give readings in radiation quantities that are pertinent to radiation protection.

10. Describe:
    a. Geiger-Mueller (G-M) counter
    b. how to distinguish between beta and gamma radiation with a G-M counter, and
    c. how to determine source strength of a beta emitter with a G-M counter.

11. a. Briefly define or explain:
       i) standard deviation and standard error
       ii) precision and accuracy of measurement
       iii) relative and absolute uncertainty.
    b. Describe the effect of background radiation on the precision of radiation measurements.

12. a. Briefly define or explain
       i) thermal neutrons
       ii) elastic collision
       iii) recoil proton.
    b. Describe the measurement of neturons in the presence of x- or gamma rays.
    c. Describe the methods, equipment and problems associated with measurements of equivalent dose from neutrons.

13. Between the age of 40 and 50 a woman had the following examinations using ionizing radiation:
    a. thyroid uptake scan using 50 microcuries of I-131 with an uptake of 25%
    b. four mammograms (2 projections each breast)
    c. ten lung radiologic examinations (PA at 150 kVp).

    Estimate the mortality risk from cancer resulting from each of these examinations. In each case clearly state your assumptions with respect to the examination.

14. Give the annual effective dose limits for stochastic effects recommended by the ICRP in its report No. 60 for both occupational and public exposures. Explain how effective dose is determined when the whole body is irradiated non-uniformly. Give four examples of tissue weighting factors and describe how these factors are used.

15. The Canadian Nuclear Safety Commission specifies effective dose limits for three catagories of people:
    a. Nuclear energy worker
    b. Pregnant nuclear energy worker
    c. A person who is not a nuclear energy worker.

    State and justify the effective dose limits for the three groups and compare them to the effective dose from natural background. Include the time periods for which the limits apply. Comment on how emergencies may affect dose limits.

16. Based on ICRP Report 60, the Canadian Nuclear Safety Commission specifies equivalent dose limits as well as effective dose limits. List the organs or tissues for which an equivalent dose limit exists, give the magnitude of the equivalent dose limit in mSv, and the time period for which this limit applies, for
    a. Nuclear energy workers
    b. Any other person.

17. Briefly define or explain :
    (a) detriment in a population
    (b) stochastic effects
    (c) deterministic effect
    (d) linear energy transfer (LET)
    (e) relative biological effectiveness (RBE)
    (f) oxygen enhancement ratio (OER)
    (g) stem cells
    (h) body burden
    (i) therapeutic ratio
    (j) free radicals.

18. A fetus is exposed to a dose of 50 mSv during the 10th week of pregnancy. Describe the possible effect(s) of this exposure and estimate the risk factors associated with each effect.

19. Briefly define or explain :
    (a) primary barrier
    (b) leakage radiation
    (c) scatter
    (d) secondary barrier
    (e) use factor U
    (f) workload W
    (g) occupancy factor T
    (h) beam stopper
    (i) tenth-value layer (TVL)
    (j) ALARA principle.

20. Sketch a floor plan for a typical radiation oncology bunker, housing an isocentrically mounted 6MV linear accelerator.
    a. Define and give typical values for W, T and U, as well as thicknesses for primary and secondary barriers.
    b. Explain how the barrier thicknesses are calculated in practice and where the necessary information on transmission parameters may be obtained.
    c. Explain how and why the ALARA principle was taken into account when the room was designed.

21. Describe briefly why it is difficult to obtain accurate information on the biological effects on humans of low doses (e.g., 10 mGy) of low-LET ionizing radiations, especially if the dose is accumulated over a long period of time.

22. a. A study indicates that in 243 women who received multiple fluoroscopies with an average dose to the breast of 12.1 Gy there were 23 additional cases of cancer of the breast. Using this data and the methodology established by ICRP 60, estimate the risk of developing cancer as the result of a mammogram which gives an average dose of 2 mGy, assuming:
       i) a linear dose-response relationship and
       ii) a linear-quadratic dose-response relationship in which the linear and quadratic contributions are equal at 3.5 Gy.
    b. Evaluate the dose and dose rate effectiveness factor (DDREF) for the data and model presented in part a). State the accepted range of values for the DDREF and comment on how this model complies.

23. Give approximate values for and describe the genetically significant dose in North America due to the following:
    a. natural background (cosmic rays, external gamma rays and internal radiation)
    b. nuclear power reactors
    c. fallout from bomb tests
    d. occupational exposure
    e. diagnostic radiology and nuclear medicine
    f. background radiation due to radon (lung cancer incidence).

24. Define the following:
    (a) early effects
    (b) late effects
    (c) linear quadratic model
    (d) hyperfractionation
    (e) T_{pot}
    (f) α parameter of the LQ model
    (g) β parameter of the LQ model
    (h) SLDR
    (i) accelerated repopulation.

25. a. Describe the usefulness and limitations of the linear-quadratic model in comparing different dose-time-fractionation schemes used in radiotherapy.
    b. Using the linear-quadratic model, with d = dose per fraction, and n = number of fractions, derive the equation for biological effective dose:

$$\frac{E}{\alpha} = dn\left(1 + \frac{d}{\alpha/\beta}\right)$$

26. a. In terms of the linear-quadratic model, describe the range of the α/β ratio for early and late responding tissues and give two examples each of early and late responding tissues.
    b. With respect to the linear-quadratic model, define and compare the concept of dose in Gy, and $Gy_{\alpha/\beta}$.
    c. Compare a conventional therapy regimen of 30 fractions of 2 Gy at one fraction per day, 5 days per week with that of a hyperfractionation schedule of 70 fractions of 1.1 Gy given at 2 fractions per day 6 hours apart, 5 days per week. Assume $\alpha/\beta = 3$ for late effects, and $\alpha\ /\beta = 10$ for early or tumour effects. Express the results in Gy_3 and Gy_{10}, and compare the two regimens in terms of impact on tumour response at normal tissue late response.

27. A cancer center has decided to close for a summer break of 10 working days. The radiation oncologist has concerns that this may effect radiotherapy outcome.
    a. Give the equation using the linear quadratic model which may be used to assess the effects of this closure, including a term for tumour stem cell proliferation.
    b. Assume Hodgkins lymphoma has a T_{pot} of 5 days and glioma a T_{pot} of 30 days. Calculate the effective dose reduction factor for each of these tumours in terms of Gy_{10}.
    c. Describe whether closure of the clinic is advisable for either of these tumours.

28. Briefly define or explain the following concepts of tumour radiobiology:
    (a) radiobiological hypoxia
    (b) labeling index
    (c) dose modifying factor
    (d) spheroid model
    (e) hyperfractionation
    (f) hypofractionation
    (g) anoxic radiosensitizer
    (h) bioreductive drugs
    (i) partial tolerance
    (j) LD_{50}.

29. Sketch a model of a tumor at various stages of its growth, showing capillaries and areas of hypoxia and necrosis. What is the concentration of oxygen below which cells are generally considered to be radiobiologically hypoxic? What is the diffusion distance of oxygen in tissue?

30. Describe the "4 R's" in radiobiology and explain when they are important.

Part IV: Radiation Protection and Radiation Biology

31. Cataracts may be classified as delayed somatic effects of radiation.
    a. Describe how cataracts develop in the lens of the eye as a result of exposure to ionizing radiation.
    b. Describe the time/dose relationship for cataract production by x- or gamma-rays.
    c. Describe the threshold for cataract formation and the effect of total dose on the latent period for cataract induction.
    d. Compare the incidence of cataract following neutron irradiation with that seen following x or gamma irradiation.

32. What changes produced in the cell by ionizing radiation might be involved in the transformation of a normal cell to a cancer cell. Is radiation considered to be a strong or a weak carcinogen? What is the effect on induction of cancer from ionizing radiation in the occupational dose range?

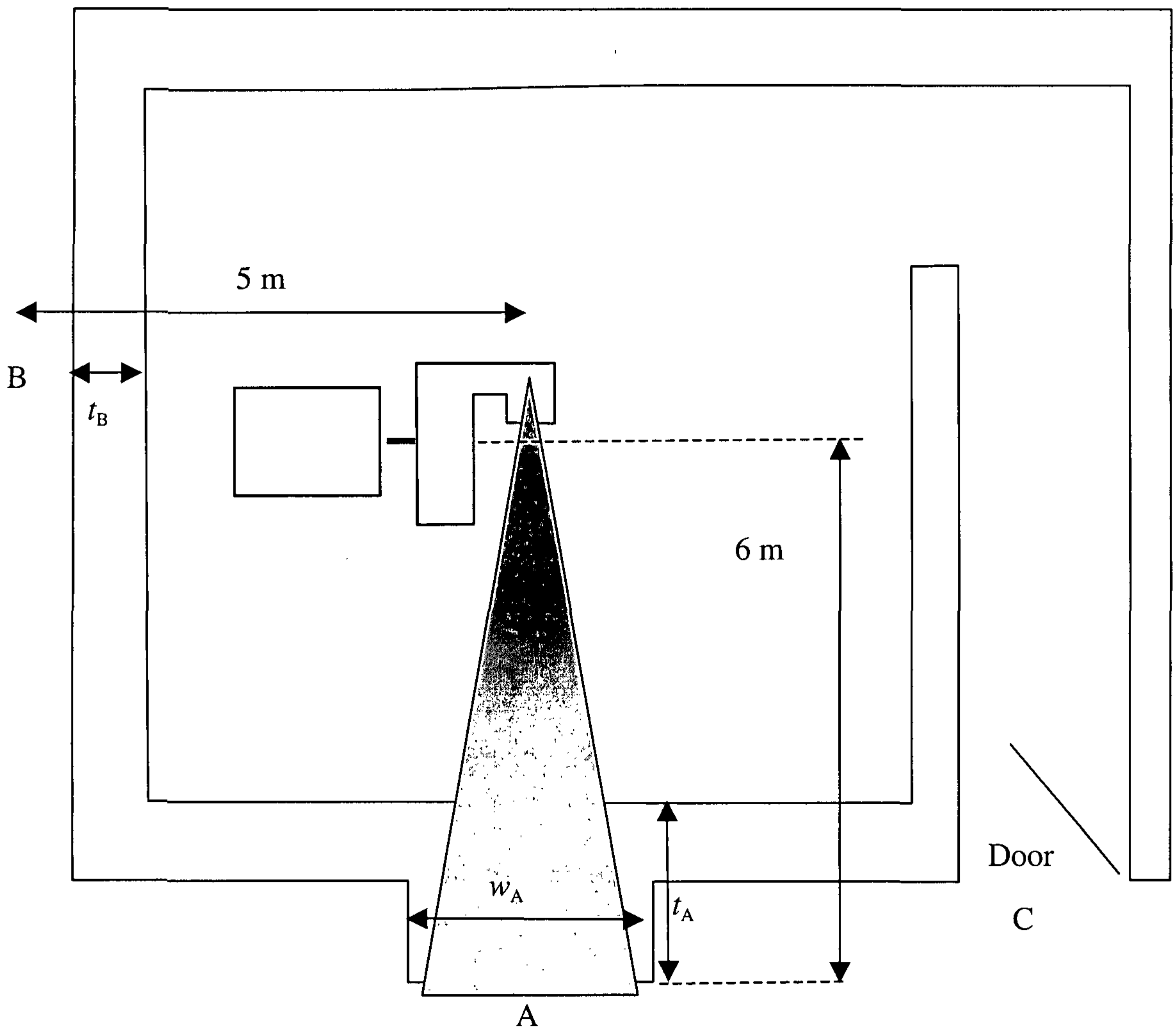
33. Describe the genetic effects of radiation in humans and explain the use of the concept of the doubling dose as the unit of measurement of the radiation effect. Also list the sources of genetically significant radiation and the average dose equivalent they contribute to the general population. What is the genetic effect of ionizing radiation in the occupational dose range?

34. Briefly describe the effect of ionising radiation on the embryo and the fetus. Describe the acute effects of whole-body irradiation and give the radiation dose that would produce such effects.

35. On a semilog plot, draw a typical example of a cell survival curve, clearly define its parameters and describe its shape. Compare and describe typical cell survival curves for aerated cells vs hypoxic cells irradiated with:
    a. x rays
    b. 4 MeV neutrons
    c. 10 MeV protons
    d. negative pions.

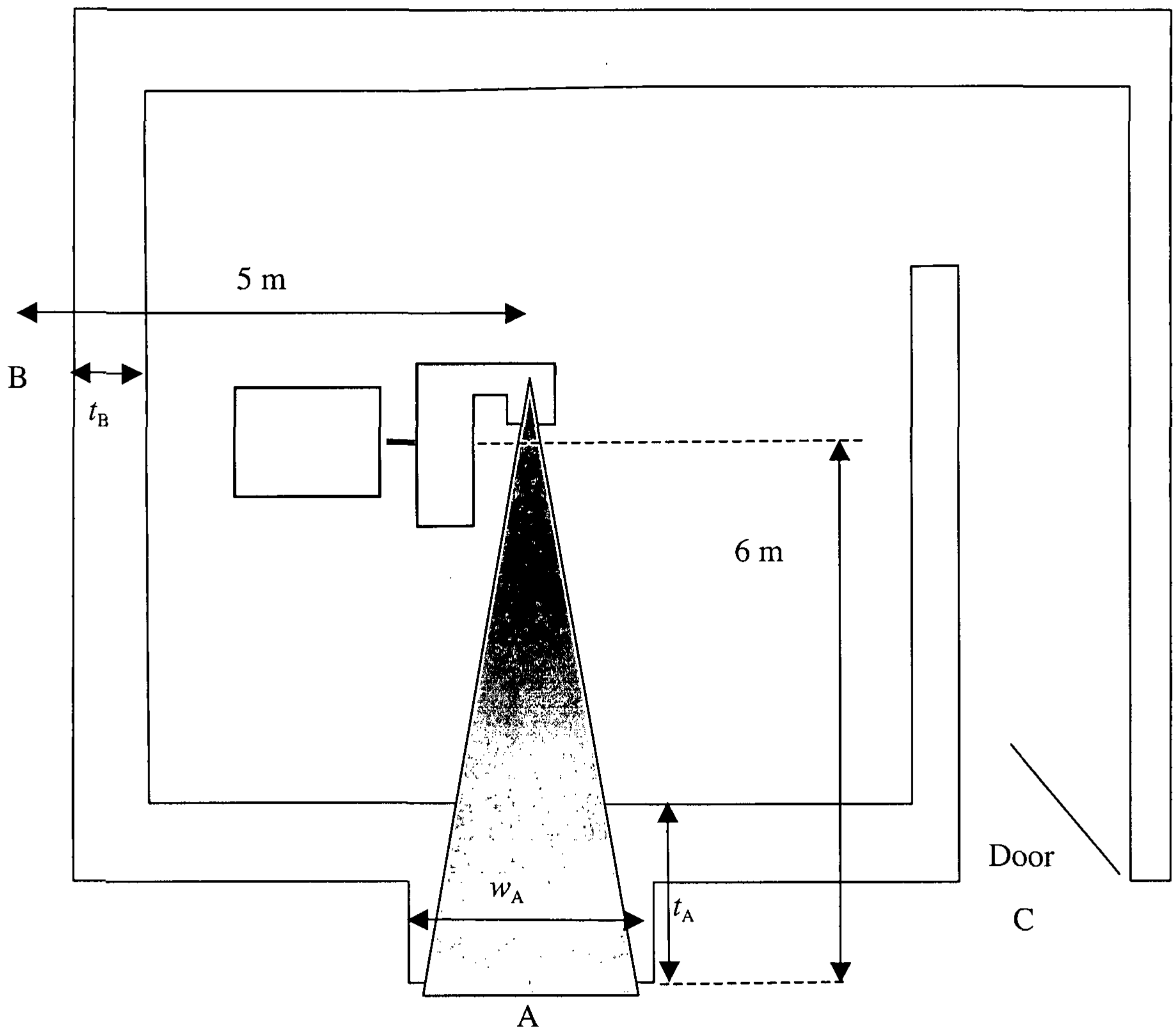
36. Radiation damage to different organs and tissue may be manifest as a functional deficit characteristic of the system irradiated. Describe the underlying processes which lead to the following radiation-induced changes:
    a. immunosuppression
    b. sterility in males
    c. paralysis of the lower limbs following irradiation of the spinal cord.

37. A patient is given a chest radiograph in the PA position.
    a. Give a typical value for the minimum skin exposure required to produce a high-quality radiograph.
    b. Estimate the scattered radiation exposure received by a technologist standing at various points 2 m from the patient.
    c. If 200 films are taken per day, calculate the shielding that is necessary for the room. Clearly state any assumptions you have made.

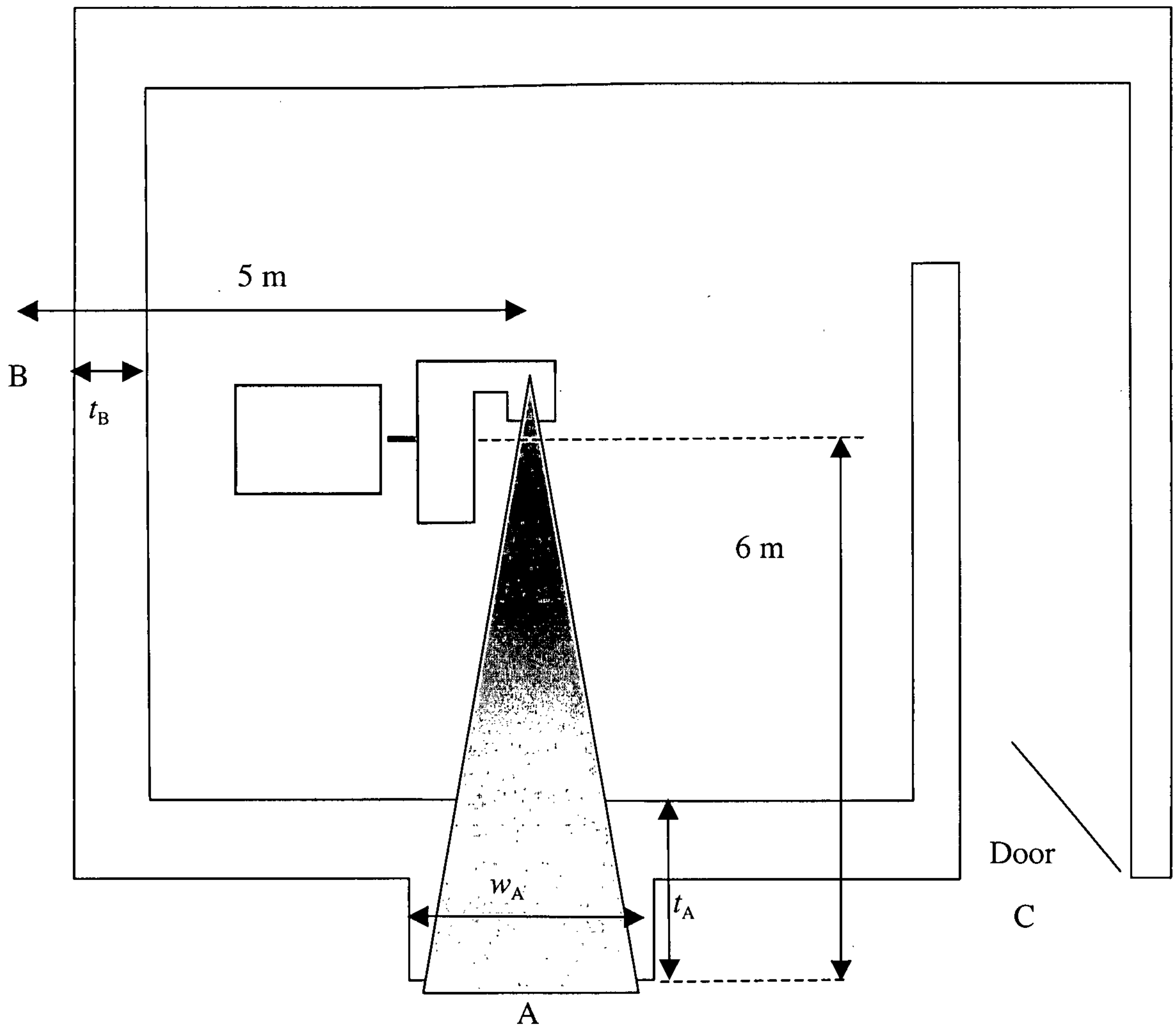


38. An 18 MV linac (SAD 100 cm, maximum field size at isocentre of 40 x 40 cm^2) is to be installed in a stand-alone facility on the ground floor as shown in the sketch of the floor plan (not to scale). The gantry is rotated to 90 degrees and there are no rooms above the linac. The operator console is at location A, office space is at location B and all other adjacent areas are unoccupied. Assume that 30 patients are treated per day. Using the methodology suggested by NCRP 151, and clearly stating all assumptions:

   a. calculate the primary barrier thickness (t_A) at Point A for regular concrete, high density concrete and lead
   b. calculate the width of the primary barrier (w_A) at point A for regular concrete
   c. calculate the thickness of the secondary barrier (t_B) at point B for regular concrete.



39. An 18 MV linac (SAD 100 cm, maximum field size at isocentre of 40 x 40 cm^2) is to be installed in a stand-alone facility on the ground floor as shown in the sketch (not to scale). There are no rooms above the linac. The operator console is at location A, office space is at location B, the treatment room door is shown and all other adjacent areas are unoccupied. Assume that 30 patients are treated per day. Using the methodology suggested by NCRP 151, and clearly stating all assumptions:
    a. discuss the design criteria for a treatment room door and clearly indicate the materials and material thicknesses used
    b. clearly describe and identify the location of all safety accessories both inside and outside the room
    c. discuss the area radiation safety survey, and list the equipment to be used. Indicate typical measured values you might expect to measure at points A, B and C (both for door open and door closed), and indicate the nature and location of any warning signs.



40. A dual energy linac (6 and 18 MV, SAD 100 cm, maximum field size at isocentre of 40 x 40 cm^2) is to be installed in a stand-alone facility on the ground floor as shown in the sketch (not to scale). There are no rooms above the linac. The operator console is at location A, office space is at location B and all other adjacent areas are unoccupied. Assume that 20 patients are treated per day using 6 MV IMRT, and 10 patients are treated per day using conventional 18 MV techniques. Using the methodology suggested by NCRP 151, and clearly stating all assumptions:
    a. calculate the primary barrier thickness (t_A) at Point A for regular concrete,
    b. calculate the thickness of the secondary barrier (t_B) at point B for regular concrete.

APPENDIX 10

**Canadian College of Physicists in Medicine
Policies and Procedures Manual
pertaining to Membership Exam
(written and oral components)**

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

Policy and Procedure Manual

July 2002

Revised April 2006

CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

LE COLLÈGE CANADIEN DES PHYSICIENS EN MÉDECINE

Contents

Section A: Code of Ethics

Adopted at the COMP Annual General Meeting, Charlottetown, PEI, 12 July 1997

Code of Ethics

This Code of Ethics is intended to aid members of the Canadian Organization of Medical Physicists (COMP) and the Canadian College of Physicists in Medicine (CCPM) in maintaining ethical conduct in their profession. It is intended as a guideline by which members may determine the appropriateness of their conduct in relationships with patients, employers, co-workers, colleagues, members of other professions, governments, and the public.

1. Medical Physicists must be committed to using their education, experience, skills, and talents for the benefit of society.

2. Medical Physicists shall always actively promote and safeguard the well-being and interests of the patient, public, and co-workers.

3. Medical Physicists shall accept responsibility for their own work and also that carried out under their supervision or direction. A Medical Physicist shall take all reasonable steps to ensure that those working under their guidance are competent to carry out the tasks assigned to them, and that they accept responsibility for their work.

4. All relations with patients, employers, employees, co-workers, colleagues, and members of other professions shall be conducted with integrity, fairness, and appropriate confidentiality.

5. The Medical Physicist shall strive to avoid conflict of interest and to declare to those affected or potentially affected any situation that could lead to conflict of interest.

6. Medical Physicists engaged in private practice or consulting shall compete with others primarily on the basis of professional credentials, knowledge, expertise, and caliber of service rendered.

7. Medical Physicists must realize their own limitations, refuse assignments for which they are not qualified, and seek consultation when appropriate.

8. Within their practice Medical Physicists shall continually strive to improve and keep current their professional knowledge and skills, and apply these where appropriate.

9. Medical Physicists shall strive to advise authorities, governments, and agencies on public policies affecting the safety, quality, and economics of all applications of physics in medicine.

10. In the preparation of publications, reports, and statements, Medical Physicists shall ensure that information is accurate, and that conclusions and recommendations are based on sound research and knowledge. Resource materials shall be appropriately referenced when applicable.

Section E: Membership

E.01: Standards for Membership

Policy No.: E1, Rev 0 | Created: 22-Nov-2001 | Approved: 13-Jul-2002

Policy: *Candidates for Membership shall demonstrate competence in their designated sub-specialty and in general radiation safety principles, in accordance with the College by-laws.*

Procedure:

.01 The candidate shall demonstrate familiarity with clinical medical physics practice.

- .01.1 Competency is characterised by: familiarity with general concepts of clinical medical physics, clinical anatomy and relevant biological science.
- .01.2 Inadequate response is characterised by: inaccuracy; lack of knowledge; lack of focus.

.02 The candidate shall demonstrate critical knowledge within the designated sub-specialty with competent answers to previously unpublished questions.

- .02.1 Competency is characterised by: clarity; focus; knowledge of current medical physics practice.
- .02.2 Inadequate response is characterised by: inaccuracy; lack of knowledge; lack of clarity; lack of detail on common practice.

.03 The candidate shall demonstrate detailed knowledge within the designated sub-specialty by providing well developed answers to previously published questions.

- .03.1 Competent answers are well constructed and characterised by: clarity; detail; completeness; appropriate use of illustrations, mathematical equations, references and examples.
- .03.2 Inadequate response is characterised by: lack of clarity; lack of detailed knowledge; lack of focus.

.04 The candidate shall demonstrate thorough knowledge of radiation safety.

- .04.1 Competency is characterised by: thorough knowledge of the biological effects of ionising radiation; detailed knowledge of Canadian radiation regulations and the principles and practices of radiation protection.
- .04.2 Inadequate response is characterised by: inaccuracy; lack of clarity; lack of understanding of the basic physical processes of radiation interaction with tissue; lack of understanding of the implications of inappropriate radiation safety practice.

.05 The candidate shall demonstrate judgment skills commensurate with clinical practice.

- .05.1 Competency is characterised by: the ability to formulate appropriate decisions or courses of action based on evidence and sound clinical practice; the ability to access appropriate reference material; the ability to deal appropriately with errors and mistakes.

.05.2 Inadequate response is characterised by: inability to formulate strategy; a willingness to make statements or deliver advice outside the individuals knowledge base; inability to determine extent of own knowledge; lack of awareness of appropriate reference material.

.06 The candidate shall demonstrate communication skills commensurate with clinical practice.

.06.1 Competency is characterised by: clarity; focus; appropriate interpersonal behaviour; appropriate attention to detail.

.06.2 Inadequate response is characterised by: lack of clarity; lack of focus; inappropriate interpersonal behaviour.

Section E: Membership

E.02: Eligibility

Policy No.: E2, Rev 0 Created: 28-Dec-1997 Approved: 13-Jul-2002

Policy: *Candidates for the Membership Examination shall meet certain minimum criteria*

Procedure:

.01 Applicants for the Membership examination shall possess a Masters or Doctoral degree in Medical Physics or a related subject from a recognized university. Notwithstanding, other applicants may be considered in exceptional circumstances at the discretion of the College Board.

.02 Applicants for the Membership examination shall possess a minimum of two years full time equivalent patient related experience in physics as applied to medicine following the qualifying degree. This experience must be completed by March 31st of the year the examination is to be taken.

.03 The two years of clinical experience may include a residency but cannot include work or studies undertaken towards the award of a Masters or Doctoral degree.

.04 The term "patient related" refers to activities such as the design, development, purchase, commissioning, calibration and use of medical equipment for the diagnosis and treatment of patients.

.05 Three satisfactory letters of reference shall be provided, in accordance with the College by-laws.

.06 The applicant shall abide by the College Code of Ethics.

Section E: Membership

E.03: Application Process

Policy No.: E3, Rev 0 Created: 30-Dec-1997 Approved: 13-Jul-2002

Policy: *Prospective candidates for the Membership Examination shall submit an application form and the names of three referees by the deadline specified on the application form.*

Procedure:

.01 The Registrar shall publish the examination schedule and application procedure through a notice in the Newsletter at least three months prior to the examination date.

.02 The applicant shall solicit references as required by the application procedure.

.03 The applicant shall append an up-to-date curriculum vitae and documentary evidence of university degrees in the form of transcripts or copies of diplomas.

.04 The applicant shall give one copy each of the completed application form, assessment form and curriculum vitae to each referee and request a response directly to the Registrar within three weeks after the application deadline.

.05 The application form, curriculum vitae and a cheque or money order for the appropriate fee, payable to the CCPM, shall be sent to the Registrar at the address on the application form to arrive on or before the deadline.

.06 Applications and supporting documents failing to meet the required deadlines shall not be processed.

.07 The Registrar shall collate the documentation for each candidate and forward these to the members of the Credentials Committee at least one month before the examination date.

.08 On receipt of the report of the Credentials Committee the Registrar shall notify all applicants of their status at least two weeks prior to the examination date.

.09 If the application is not approved or is withdrawn at least one week prior to the written examination, the application fee shall be refunded (less a $50.00 administrative fee). The fee associated with the oral examination will be refunded if the applicant does not pass the written examination.

.10 The Board reserves the right to reject applications without explanation.

.11 Applicants denied permission to sit the examination may appeal to the Board within two weeks of their notification of the decision.

Section E: Membership

E.04: Credentials Committee

Policy No.: E4, Rev 0 Created: 30-Dec-1997 Approved: 13-Jul-2002

Policy: *All applications for membership shall be assessed by a committee of three Fellows of the College, chaired by the Registrar.*

Procedure:

.01 Prior to the deadline for receipt of applications, as Chair, the Registrar shall form a Credentials Committee consisting of the Registrar and two other Fellows of the College. Apart from the Registrar, the identities of the other two members shall be kept confidential.

.02 No later than one month prior to the examination date, the Registrar shall forward, by courier, curricula vitae, application forms and referees' reports on all applicants to the members of the Credentials Committee.

.03 The Credentials Committee shall review the submitted material and determine whether or not each applicant meets the eligibility criteria specified in the Policy on Eligibility.

.04 The Registrar shall notify all applicants of their eligibility to sit the Membership Examination based on the outcome of the review of their credentials.

The Credential Committee may seek advice from the Board on questionable applications.

.05 Applicants who dispute the decision of the Credentials Committee may appeal to the Board of the College. Such appeals shall be dealt with at the next Board meeting or at such other time as the Board may determine.

Section E: Membership

E.05: Examination Committee

Policy No.: E5, Rev 0 Created: 01-Jan-1998 Approved: 13-Jul-2002

Policy: *The Examination Committee shall consist of Fellows or Members of sufficient knowledge to competently mark examination papers.*

Procedure:

.01 The Examination Committee shall be chaired by the Chief Examiner.

.02 The Chief Examiner, in consultation with the Board, shall select for the Examination Committee a sufficient number of Fellows or Members to cover all subspecialties for which there are candidates.

.03 It shall be confirmed that the selected members of the Examination Committee are available and willing to mark examination papers within two weeks of receipt.

.04 Back-up examiners, who shall not be members of the Committee shall be identified to be called upon to provide a second, independent assessment of marginal papers.

.05 The Examination Committee may be called upon to assist the Chief Examiner in updating and revising the examination booklet.

Section E: Membership

E.06: Examination Booklet

Policy No.: E6, Rev 0 Created: 01-Jan-1998 Approved: 13-Jul-2002

Policy: *50% of the marks for the written examinations shall be based on knowledge of the answers to questions available to the candidates in advance, in the form of an examination booklet.*

Procedure:

.01 The Chief Examiner is responsible for maintaining the examination booklet.

.02 Sections III and IV of the examination shall be based on questions from the examination booklet.

.03 The examination booklet contains four sections each covering one the sub-specialties Therapeutic Radiological Physics; Diagnostic Radiological Physics; Nuclear Medicine Physics and Magnetic Resonance Imaging.

.04 Each of the four sections contains twenty questions specific to the sub-specialty and ten questions which cover more general areas of the sub-specialty.

.05 The examination booklet to be used shall be available from the Canadian Medical Physics web-site by 1st October of the year prior to the examination.

Section E: Membership

E.07: Written Examination Design

Policy No.: E7, Rev 1 | Created: 01-Jan-1998 | Approved: 13-Jul-2002

Policy: *The Examination Committee shall set the Written Membership Examination.*

Procedure:

.01 Section I of the written exam shall consist of short answer questions (with limited or no choice) covering general medical physics and also radiation protection, clinical anatomy and biological science relevant to clinical medical physics practice.

.02 The Chief Examiner shall set Section I of the written examination.

.03 Section II of the written exam shall consist of short answer questions (with limited or no choice) to test the applicant's practical experience and competence in Radiation Protection.

.04 A member of the Examination Committee competent in Radiation Protection shall set Section II of the written examination.

.05 Section III shall contain one question chosen at random, by the Chief Examiner, from the twenty questions in the bank specific to the subspecialty.

.06 Section IV shall contain one question chosen at random, by the Chief Examiner, from the remaining ten questions which cover more general areas of the subspecialty.

.07 The examination so designed shall be approved by the Examination Committee.

.08 The Chief Examiner shall add the questions in Sections I and II to a question bank.

Section E: Membership

E.08: Written Examination Process

Policy No.: E8, Rev 1 | Created: 01-Jan-1998 | Approved: 13-Jul-2002

Policy: *The Chief Examiner and a local Invigilator shall ensure that the written examination is conducted according to established procedures.*

Procedure:

.01 The Chief Examiner shall identify a Fellow or Member at the home institution of the candidate to serve as Invigilator.

.02 In the event that a Fellow or Member is unavailable at the time of the examination or that the home institution of the candidate is unsuitable or unavailable as an examination site the Chief Examiner shall make other arrangements as appropriate.

.03 The Chief Examiner shall allocate to each candidate a confidential Identification Number.

.04 Appropriate examination papers together with sufficient blank answer books shall be sent to each Invigilator by courier, one week prior to the examination.

.05 The Invigilator shall distribute the each appropriate examination paper to the candidates at the start of each section of the examination.

.06 1.5 hours shall be allowed for Part I of the written examination, to be followed without a break by 1 hour allowed for Part II.

.07 After 2.5hr. (Parts I and II) all candidates at each centre shall take a break of 45 - 90min.

.08 A further continuous 2.5 hr. shall be allowed for Parts III and IV of the written examination.

.09 The Invigilator shall sign the front cover of each answer booklet to confirm that the examination was conducted in accordance with established procedures.

.10 Upon completion of the written examination the Invigilator shall photocopy all answer booklets and retain these in case the originals are lost.

.11 On the first working day following the written examination the Invigilator shall courier all original answer booklets to the Chief Examiner.

.12 Costs incurred by the Invigilator such as photocopying and courier charges are reimbursable on application using the standard Expense Report Form to the Treasurer.

Section E: Membership

E.09: Instructions to Candidates for the Written Examination

Policy No.: E9, Rev 1 Created: 02-Jan-1998 Approved: 13-Jul-2002

Policy: *All candidates shall abide by the rules of the written examination.*

Procedure:

.01 The examination shall last 5 hours comprised of two 2.5 hr sessions with a 45 - 60 minute lunch break. (The actual length of the lunch break shall be agreed upon by the candidate and the invigilator before the examination starts).

.02 Candidates may use only the supplied answer booklets, a non-programmed calculator and normal writing and drawing instruments.

.03 Candidates shall use a black pen and/or a dark pencil to facilitate photocopying.

.04 Candidates shall identify all booklets with their own examination code number only and not their name or any other identifying information.

.05 Each of the four sections of the exam shall be answered in a separate examination booklet. If additional booklets are required for any one part the booklet shall be inserted within the other and each booklet is to be clearly labeled e.g. PartI:1/2, PartI:2/2.

.06 No pages are to be torn out of the booklets.

.07 All questions, and all answer booklets, whether used or not, shall be returned to the Invigilator at the conclusion of the exam.

.08 Candidates may answer the written examination in French, after prior arrangements have been made with the Chief Examiner.

Section E: Membership

E.10: Marking

Policy No.: E10, Rev 0 | Created: 04-Jan-1998 | Approved: 13-Jul-2002

Policy: *Examiners shall mark the written examination against an answer key and within a specified time.*

Procedure:

.01 The Chief Examiner shall distribute completed answer booklets to the examiners by courier or by hand no later than one week following the examination.

.02 Marked answer booklets shall be returned to the Chief Examiner by courier or by hand no later than 10 days after receipt.

.03 A pass shall be awarded to candidates who achieve an average mark of 65% overall and with a mark of no less than 50% for any section.

.04 Candidates who score 60-70% overall or 45-55% on any section shall have either the whole exam or the relevant section remarked.

.05 The Chief Examiner shall forward unmarked copies of the relevant answer booklets for marginal candidates (paragraph .04 of this policy) to a member of the Board for an independent assessment.

.06 The Board member shall return the marked exam within one week of receipt.

.07 For exams that are remarked the average of the two marks shall be taken as the final mark.

.08 The Chief Examiner shall compile a list of all candidates stating whether or not they have met the standards of the examination (see the Policy on Examination Standards) with one of the notations Pass or Fail.

Section E: Membership

E.11: Notification of Written and Oral Examination Results

Policy No.: E11, Rev 1 Created: 05-Jan-1998 Approved: 13-Jul-2002

Policy: *Candidates shall be notified of the results of the written and oral examinations within a specified time.*

Procedure:

.01 The Chief Examiner shall notify candidates of the result of the written examination by e-mail, telephone or regular mail within six weeks of the written examination.

.02 The Chief Examiner shall notify candidates of the results of the oral examination by email, telephone or regular mail within one week of the oral examination.

.03 Framed Certificates shall be mailed to successful candidates after election to the College.

Section E: Membership

E.12: Written Examination Appeal

Policy No.: E12, Rev 1 Created: 05-Jan-1998 Approved: 13-Jul-2002

Policy: *Candidates may contest the results of the written examination by written appeal to the Board.*

Procedure:

.01 A candidate contesting the results of the written examination may appeal to the Board of the College in writing to the Chief Examiner.

.02 The candidate shall state in writing the basis of the appeal.

.03 The appeal shall be lodged within 4 weeks of the examination result being communicated to the candidate.

.04 An appeal may be refused by the Board if there is no reasonable expectation that a remark will change the candidate's final status.

.05 The Chief Examiner shall discuss the rationale for refusing an appeal with the candidate.

.06 When an appeal is granted, the candidate's examination papers shall be sent to a Member with competence in the sub-specialty of the candidate.

.07 The Member shall mark and return the written examination paper within one week of receipt.

.08 The final mark awarded to the candidate shall be the arithmetic average of all marks given.

.09 The Chief Examiner shall notify the candidate of the result of the appeal within one month of receipt of the appeal.

Section E: Membership

E.13: Oral Examination

Policy No.: E13, Rev 0 Created: 26-Nov-2004 Approved: 04-Jul-2005

Policy: *Candidates must pass an Oral Examination for Membership Certification*

Procedure:

.01 All candidates who pass the Written Membership Examination are eligible for the Oral Examination.

.02 Candidates must pass the Oral Examination to become eligible for election to the College.

.03 The Oral Examination shall be held between the time that candidates are notified of their Written Examination results and the Annual General Meeting of the College.

.04 By application to the Chief Examiner and under exceptional circumstances, the candidate may defer sitting the oral examination until a subsequent year (but no longer than three years can elapse before sitting).

.05 If the candidate is ineligible to sit the oral examination due to a failure of the written part, or if a deferral is granted, a $50 processing fee will be withheld and the remainder of the oral examination fee refunded. Candidates who defer the oral examination will be required to re-submit the full oral examination fee on subsequent application to sit the examination.

.06 The Oral Examination is specific to each subspecialty.

.07 The Oral Examination shall be 1.5 hours in duration.

.08 The Oral Examination shall consist of sections covering equipment and instrumentation, clinical applications, and specialty knowledge and techniques. The same questions will be asked of all candidates within a subspecialty.

.09 A separate examination committee shall be convened for each subspecialty.

.10 The size of the examination committee will depend upon the number of candidates per subspecialty. At minimum, candidates will be tested by 3 examiners in a continuous session. Where candidate numbers warrant, parallel sessions will be conducted. At minimum, 2 examiners will be assigned per session, each covering one of the examination sections. Candidates shall rotate amongst sessions such that each candidate is evaluated by the same examiners.

.11 Candidates may choose to answer the oral examination questions in French, if prior notification has been given to the Chief Examiner. In this case, a separate, bilingual examination committee may be convened, as required.

.12 Candidates must answer the majority of questions correctly in each section. The Examiners per section will generate a single final mark sheet per candidate. Questions will be marked pass/fail. Examiners must reach consensus on their grades.

.13 Marks for each section shall be collated and reviewed by the examination committee after all candidates have been examined. In addition to passing each section, candidates must answer 2/3 of all questions correctly.

.14 Results of the Oral Examination are not subject to appeal by the candidate.

.15 Examiners shall be reimbursed travel expenses, if any, incurred by participating in the Oral Examination.