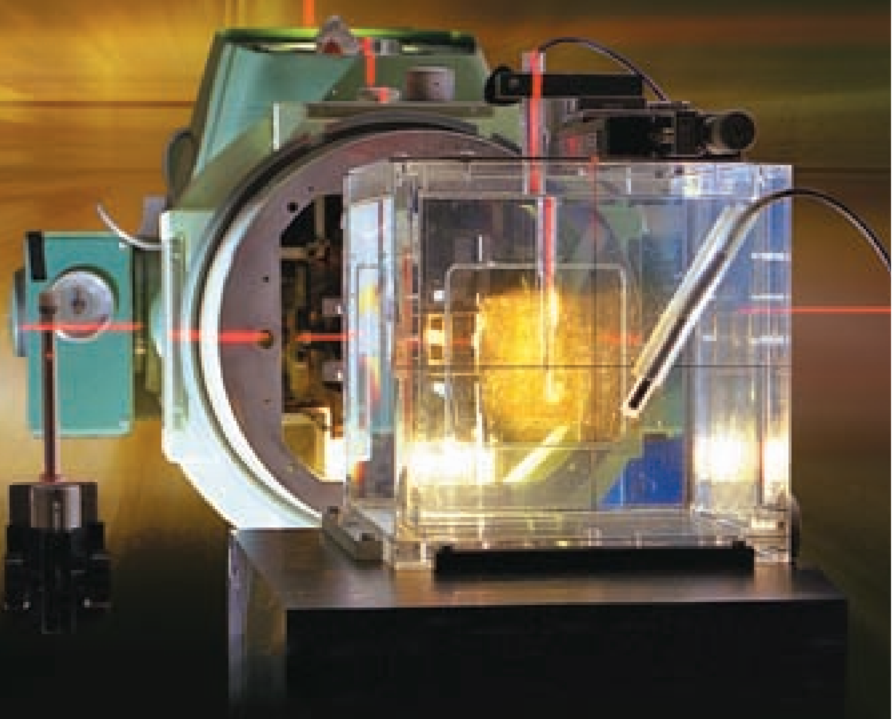
Radiation Oncology Physics:
A Handbook for Teachers and Students

E.B. Podgorsak
Technical Editor



Sponsored by the IAEA and endorsed by the COMP/CCPM, EFOMP, ESTRO, IOMP, PAHO and WHO

Cover photograph courtesy of E. Izewski

RADIATION ONCOLOGY PHYSICS:
A HANDBOOK FOR TEACHERS AND STUDENTS

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BANGLADESH
BELARUS
BELGIUM
BENIN
BOLIVIA
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BULGARIA
BURKINA FASO
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHILE
CHINA
COLOMBIA
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LATVIA
LEBANON
LIBERIA
LIBYAN ARAB JAMAHIRIYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MOROCCO
MYANMAR
NAMIBIA
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
PAKISTAN
PANAMA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
SAUDI ARABIA
SENEGAL
SERBIA AND MONTENEGRO
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA
VIETNAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

RADIATION ONCOLOGY PHYSICS: A HANDBOOK FOR TEACHERS AND STUDENTS

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2005

COPYRIGHT NOTICE

Sales and Promotion Unit, Publishing Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
http://www.iaea.org/books

Printed by the IAEA in Austria
July 2005
STI/PUB/1196

IAEA Library Cataloguing in Publication Data

Radiation oncology physics : a handbook for teachers and students / editor
E. B. Podgorsak ; sponsored by IAEA
… [et al.]. — Vienna : International Atomic Energy Agency, 2005.
p.; 24 cm.
STI/PUB/1196
ISBN 92–0–107304–6
Includes bibliographical references.

1. Radiation dosimetry — Handbooks, manuals, etc. 2. Dosimeters — Handbooks, manuals, etc. 3. Radiation — Measurement — Handbooks, manuals, etc. 4. Radiation — Dosage — Handbooks, manuals, etc. 5. Radiotherapy — Handbooks, manuals, etc. 6. Photon beams. 7. Electron beams. 8. Radioisotope scanning. I. Podgorsak, E. B., ed. II. International Atomic Energy Agency.

IAEAL 05–00402

FOREWORD

In the late 1990s the IAEA initiated for its Member States a systematic and comprehensive plan to support the development of teaching programmes in medical radiation physics. Multiple projects were initiated at various levels that, together with the well known short term training courses and specialization fellowships funded by the IAEA Technical Cooperation programme, aimed at supporting countries to develop their own university based master of science programmes in medical radiation physics.

One of the early activities of the IAEA in this period was the development of a syllabus in radiotherapy physics, which had the goal of harmonizing the various levels of training that the IAEA provided. This was carried out during 1997–1998, and the result of this work was released as a report used for designing IAEA training courses. In 1999–2000 a more detailed teachers' guide was developed, in which the various topics in the syllabus were expanded to form a detailed 'bullet list' containing the basic guidelines of the material to be included in each topic so that lectures to students could be prepared accordingly. During the period 2001–2002 E.B. Podgorsak (Canada) was appointed editor of the project and redesigned the contents so that the book became a comprehensive handbook for teachers and students, with coverage deeper than a simple teachers' guide. The initial list of topics was expanded considerably by engaging an enhanced list of international contributors. The handbook was published as working material in 2003 and placed on the Internet in order to seek comments, corrections and feedback.

This handbook aims at providing the basis for the education of medical physicists initiating their university studies in the field. It includes the recent advances in radiotherapy techniques; however, it is not designed to replace the large number of textbooks available on radiotherapy physics, which will still be necessary to deepen knowledge in the specific topics reviewed here. It is expected that this handbook will successfully fill a gap in the teaching material for medical radiation physics, providing in a single manageable volume the largest possible coverage available today. Its wide dissemination by the IAEA will contribute to the harmonization of education in the field and will be of value to newcomers as well as to those preparing for their certification as medical physicists, radiation oncologists, medical dosimetrists and radiotherapy technologists.

Endorsement of this handbook has been granted by the following international organizations and professional bodies: the International Organization for Medical Physics (IOMP), the European Society for Therapeutic Radiology and Oncology (ESTRO), the European Federation of Organisations for Medical Physics (EFOMP), the World Health Organization

(WHO), the Pan American Health Organization (PAHO), the Canadian Organization of Medical Physicists (COMP) and the Canadian College of Physicists in Medicine (CCPM).

The following international experts are gratefully acknowledged for making major contributions to the development of an early version of the syllabus: B. Nilsson (Sweden), B. Planskoy (United Kingdom) and J.C. Rosenwald (France). The following made major contributions to this handbook: R. Alfonso (Cuba), G. Rajan (India), W. Strydom (South Africa) and N. Suntharalingam (United States of America). The IAEA scientific officers responsible for the project were (in chronological order) P. Andreo, J. Izewska and K.R. Shortt.

EDITORIAL NOTE

PREFACE

Radiotherapy, also referred to as radiation therapy, radiation oncology or therapeutic radiology, is one of the three principal modalities used in the treatment of malignant disease (cancer), the other two being surgery and chemotherapy. In contrast to other medical specialties that rely mainly on the clinical knowledge and experience of medical specialists, radiotherapy, with its use of ionizing radiation in the treatment of cancer, relies heavily on modern technology and the collaborative efforts of several professionals whose coordinated team approach greatly influences the outcome of the treatment.

The radiotherapy team consists of radiation oncologists, medical physicists, dosimetrists and radiation therapy technologists: all professionals characterized by widely differing educational backgrounds and one common link — the need to understand the basic elements of radiation physics, and the interaction of ionizing radiation with human tissue in particular. This specialized area of physics is referred to as radiation oncology physics, and proficiency in this branch of physics is an absolute necessity for anyone who aspires to achieve excellence in any of the four professions constituting the radiotherapy team. Current advances in radiation oncology are driven mainly by technological development of equipment for radiotherapy procedures and imaging; however, as in the past, these advances rely heavily on the underlying physics.

This book is dedicated to students and teachers involved in programmes that train professionals for work in radiation oncology. It provides a compilation of facts on the physics as applied to radiation oncology and as such will be useful to graduate students and residents in medical physics programmes, to residents in radiation oncology, and to students in dosimetry and radiotherapy technology programmes. The level of understanding of the material covered will, of course, be different for the various student groups; however, the basic language and knowledge for all student groups will be the same. The text will also be of use to candidates preparing for professional certification examinations, whether in radiation oncology, medical physics, dosimetry or radiotherapy technology.

The intent of the text is to serve as a factual supplement to the various textbooks on medical physics and to provide basic radiation oncology physics knowledge in the form of a syllabus covering all modern aspects of radiation oncology physics. While the text is mainly aimed at radiation oncology professionals, certain parts of it may also be of interest in other branches of medicine that use ionizing radiation not for the treatment of disease but for the diagnosis of disease (diagnostic radiology and nuclear medicine). The contents may also be useful for physicists who are involved in studies of radiation hazards and radiation protection (health physics).

This book represents a collaborative effort by professionals from many different countries who share a common goal of disseminating their radiation oncology physics knowledge and experience to a broad international audience of teachers and students. Special thanks are due to J. Denton-MacLennan for critically reading and editing the text and improving its syntax.

E.B. Podgorsak

CONTRIBUTORS

Andreo, P.	University of Stockholm, Karolinska Institute, Sweden
Evans, M.D.C.	McGill University Health Centre, Canada
Hendry, J.H.	International Atomic Energy Agency
Horton, J.L.	University of Texas MD Anderson Cancer Center, United States of America
Izewska, J.	International Atomic Energy Agency
Mijnheer, B.J.	Netherlands Cancer Institute, Netherlands
Mills, J.A.	Walsgrave Hospital, United Kingdom
Olivares, M.	McGill University Health Centre, Canada
Ortiz López, P.	International Atomic Energy Agency
Parker, W.	McGill University Health Centre, Canada
Patrocinio, H.	McGill University Health Centre, Canada
Podgorsak, E.B.	McGill University Health Centre, Canada
Podgorsak, M.B.	Roswell Park Cancer Institute, United States of America
Rajan, G.	Bhabha Atomic Research Centre, India
Seuntjens, J.P.	McGill University Health Centre, Canada
Shortt, K.R.	International Atomic Energy Agency
Strydom, W.	Medical University of Southern Africa, South Africa
Suntharalingam, N.	Thomas Jefferson University Hospital, United States of America
Thwaites, D.I.	University of Edinburgh, United Kingdom
Tolli, H.	International Atomic Energy Agency

CONTENTS