INTERNATIONAL ORGANIZATIONS

The following international organizations' mission statements fully or partially address radiation protection and the use of ionizing radiation in medicine:

European Federation of Organisations for Medical Physics (EFOMP)
Dijon, France www.efomp.org

European Society for Therapeutic Radiology and Oncology (ESTRO)
Brussels, Belgium www.estro.be

International Atomic Energy Agency (IAEA)
Vienna www.iaea.org

International Commission on Radiation Units and Measurements (ICRU)
Bethesda, Maryland, USA www.icru.org

International Commission on Radiological Protection (ICRP)
Stockholm, Sweden www.icrp.org

International Electrotechnical Commission (IEC)
Geneva, Switzerland www.iec.ch

International Federation for Medical and Biological Engineering (IFMBE)
www.ifmbe.org

International Organization for Standardization (ISO)
Geneva, Switzerland www.iso.org

International Organization for Medical Physics (IOMP)
www.iomp.org

International Radiation Protection Association (IRPA)
Fontenay-aux-Roses, France www.irpa.net

International Society of Radiology (ISR)
Bethesda, Maryland, USA www.isradiology.org

International Union for Physical and Engineering Sciences in Medicine (IUPESM)
www.iupesm.org

Pan American Health Organization (PAHO)
Washington, DC www.paho.org

Radiological Society of North America (RSNA)
Oak Brook, Illinois, USA www.rsna.org

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
Vienna www.unscear.org

World Health Organization (WHO)
Geneva www.who.int

ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
ABC	Active Breathing Coordinator
ACR	American College of Radiology
ADCL	accredited dosimetry calibration laboratory
ALARA	as low as reasonably achievable
AP	anterioposterior
ART	adaptive radiotherapy
a-Si	amorphous silicon
BAT	B-Mode Acquisition and Targeting
BEV	beam's eye view
BGO	bismuth germanate
BIPM	Bureau international des poids et mesures
BMT	bone marrow transplantation
BNCT	boron neutron capture therapy
BSF	backscatter factor
BSS	International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources
CBCT	cone beam computed tomography
CCPM	Canadian College of Physicists in Medicine
CET	coefficient of equivalent thickness
CF	collimator factor
CHART	continuous hyperfractionated accelerated radiotherapy
CL	confidence level
CNT	carbon nanotube
COIN	Clinical Oncology Information Network
COMP	Canadian Organization of Medical Physicists
CPE	charged particle equilibrium
CPU	central processing unit
CSDA	continuous slowing down approximation
CT	computed tomography
CTV	clinical target volume
DCR	digitally composited radiograph
DICOM	digital imaging and communications in medicine
DIN	Deutsches Institut für Normung
DMLC	dynamic multileaf collimator

DMF	dose modifying factor
DRR	digitally reconstructed radiograph
DSA	digital subtraction angiography
DVH	dose–volume histogram
EBF	electron backscatter factor
EFOMP	European Federation of Organisations for Medical Physics
EM	electromagnetic
EPD	electronic personal dosimeter
EPID	electronic portal imaging device
ESTRO	European Society for Therapeutic Radiology and Oncology
FDG	fluorodeoxyglucose
FWHM	full width at half maximum
GM	Geiger–Müller
GTV	gross tumour volume
HDR	high dose rate
HVL	half-value layer
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IFMBE	International Federation for Medical and Biological Engineering
IGRT	image guided radiotherapy
IL	isodose line
IMAT	intensity modulated arc therapy
IMRT	intensity modulated radiotherapy
IOMP	International Organization for Medical Physics
IORT	intraoperative radiotherapy
IPEM	Institute of Physics and Engineering in Medicine
IPEMB	Institution of Physics and Engineering in Medicine and Biology
ISO	International Organization for Standardization
ITP	inverse treatment planning
ITV	internal target volume

IUPESM	International Union for Physical and Engineering Sciences in Medicine
LD	lethal dose
LDR	low dose rate
LET	linear energy transfer
linac	linear accelerator
LPO	left posterior oblique
MDR	medium dose rate
MLC	multileaf collimator
MOSFET	metal oxide semiconductor field effect transistor
MPR	multiplanar reconstruction
MR	magnetic resonance
MRI	magnetic resonance imaging
MU	monitor unit
MVCT	megavoltage computed tomography
NACP	Nordic Association of Clinical Physics
NAP	nominal accelerating potential
NCRP	National Council on Radiation Protection and Measurements
NCS	Nederlandse Commissie voor Stralingsdosimetrie
NEMA	National Electrical Manufacturers Association
NTCP	normal tissue complication probability
OAR	off-axis ratio
OER	oxygen enhancement ratio
OD	optical density
ODI	optical distance indicator
OSL	optically stimulated luminescence
PAHO	Pan American Health Organization
PDD	percentage depth dose
PDD(10)	percentage depth dose at 10 cm depth in water for a 10×10 cm^2 field
PDR	pulsed dose rate
PET	positron emission tomography
PMT	photomultiplier tube
PSDL	primary standards dosimetry laboratory
PSF	peak scatter factor

PTV	planning target volume
RAM	random access memory
RBE	relative biological effectiveness
RDF	relative dose factor
REF	relative exposure factor
REV	room's eye view
RF	radiofrequency
RFA	radiation field analyser
RGS	respiratory gating system
RPL	radiophotoluminescence
RPO	right posterior oblique
SAD	source to axis distance
SAR	scatter–air ratio
SD	standard deviation
SEBI	stereotactic external beam irradiation
SF	scatter factor
SI	Système international d'unités
SPECT	single photon emission computed tomography
SMLC	segmented multileaf collimator
SSD	source to surface distance
SSDL	secondary standards dosimetry laboratory
STP	standard temperature and pressure
STT	segmented treatment tables
TAR	tissue–air ratio
TBI	total body irradiation
TCP	tumour control probability
TCPE	transient charged particle equilibrium
TECDOC	technical document
TG	task group
TLD	thermoluminescent dosimeter
TMR	tissue–maximum ratio
TPR	tissue–phantom ratio
$TPR_{20,10}$	ratio of tissue–phantom ratio at depths of 20 cm and 10 cm in water
TPS	treatment planning system
TRS	Technical Reports Series
TSEI	total skin electron irradiation
TVL	tenth-value layer

UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UPS	uninterruptible power supply
WF	wedge factor
WHO	World Health Organization

BLANK

SYMBOLS

Roman symbols

a	radius of atom; specific activity; scattering coefficient
a_0	Bohr radius of hydrogen atom
a_{eq}	side of equivalent square
A	ampere (SI unit of current)
Å	ångström (unit of distance: 1 Å = 10^{-10} m)
A	area; field size; atomic mass number
A_Q	field size at point Q in a phantom
$\mathcal{A}$	activity
b	impact parameter
B	buildup factor; barrier transmission factor; magnetic field
B_{leak}	leakage barrier transmission factor
B_{pri}	primary barrier transmission factor
B_{scat}	scatter barrier transmission factor
Bq	becquerel (SI unit of activity)
c	speed of light
C	coulomb (SI unit of charge)
C	capacitance; cema (converted energy per unit mass)
ºC	degree Celsius (unit of Celsius temperature)
Ci	curie (unit of activity: 1 Ci = 3.7×10^{10} Bq)
C_{pl}	material dependent scaling factor: plastic to water
C_E	dose to water correction factor for megavoltage electron beams (old concept)
C_λ	dose to water correction factor for megavoltage photon beams (old concept)
C/Z	shell correction in collision stopping power
d	distance; depth; cavity size parameter
d_i	isocentre depth
d_{pri}	distance from radiation source to point of interest
d_{80}	depth of the 80% percentage depth dose in water for photon beams
D	dose
$\dot{D}$	dose rate
D_{air}	absorbed dose to air
D_{cav}	dose to cavity
D_{gas}	dose to gas

D_{med}	dose to medium
D_T	organ dose
D_w	dose to water
D_{wall}	dose to wall
D'_{med}	dose to small mass of medium in air
$D_{\alpha\text{–n}}$	distance of closest approach between the α particle and the nucleus
e	electron
e	charge of electron ($1\ e = 1.602 \times 10^{-19}$ C)
E	total energy; effective dose
E_B	binding energy
$E_B(K)$	binding energy of the K shell electron
$\bar{E}_d$	average energy of electrons incident on an interface
E_K	kinetic energy
$\bar{E}_K$	average kinetic energy
E_K^{thr}	threshold kinetic energy
E_n	energy level of orbital electron with principal quantum number n
E_R	binding energy of electron in ground state of hydrogen (Rydberg energy)
E_0	rest energy
$\bar{E}_{ab}$	mean (average) absorbed energy
$\bar{E}_{tr}$	mean (average) transferred energy
$\bar{E}_0$	mean (average) electron energy on phantom surface
$\bar{E}_z$	mean (average) electron energy at depth z in water
f	source to surface distance; collection efficiency
f_g	collection efficiency in general recombination
fm	femtometre (unit of distance: $1\ \text{fm} = 10^{-15}$ m)
f_{med}	roentgen to centigray conversion factor for medium
F	force
$F(r,\theta)$	anisotropy function
$g(r)$	radial dose function
$\bar{g}$	radiative fraction
G	gravitational constant
$G(r,\theta)$	geometry function
Gy	gray (SI unit of dose)
h	hour (unit of time)
h	Planck's constant; thickness of missing or excessive tissue
$\hbar$	reduced Planck's constant

H	equivalent dose
H^*	ambient dose equivalent
H'	directional dose equivalent
H_p	personal dose equivalent
I	current; intensity; mean excitation potential; measured ionization
I_{sat}	saturation current
I_{50}	50% value on the percentage depth ionization curve for electron beams
J	joule (SI unit of energy)
kg	kilogram (SI unit of mass)
k	correction factor; parameter in the isodose shift method
k_{att}	correction factor for photon attenuation and scatter in the chamber wall
k_{cell}	correction factor for central electrode
k_h	humidity correction factor
k_m	correction factor for non-air equivalence of the chamber wall
k_{pol}	polarity correction factor
$k(r_{med})$	correction factor accounting for photon beam attenuation in the buildup cap
k_q	ionization chamber correction factor
k_{sat}	saturation correction factor
$k_{T,P}$	temperature and pressure correction factor
K	kelvin (SI unit of thermodynamic temperature)
K	kerma
K_{col}	collision kerma
K_{rad}	radiative kerma
$(K_{air})_{air}$	air kerma in air
$(K_{air})_w$	air kerma in water
$(K_w)_{air}$	water kerma in air
$(K_w)_w$	water kerma in water
l	length
L	angular momentum; restricted linear collision stopping power
m	metre (SI unit of length)
m	mass
m_{air}	mass of air
m_e	electron mass

m_0	rest mass
m_p	proton mass
m_n	neutron mass
m_T	mass of organ or tissue
m_α	α particle mass
M	ionization chamber reading; atomic mass in atomic mass units u
$M(d)$	(Meisberger) polynomial of third or fourth degree
M_Q	ionization chamber reading at beam quality Q
MU	monitor unit (unit of quantity $\mathcal{MU}$)
$\mathcal{MU}$	monitor unit (quantity with unit MU)
n	neutron
n	principal quantum number
n_i	initial principal quantum number
n_f	final principal quantum number
N	newton (SI unit of force)
N	number of radioactive nuclei; ionization chamber calibration coefficient
N_A	Avogadro's number
N_a	number of atoms per mass
$N_{D,air}$	cavity air calibration coefficient
$N_{D,w}$	dose in water calibration coefficient
N_e	number of electrons per volume
N_K	air kerma in air calibration coefficient
$N_{K,co}$	air kerma in air calibration coefficient obtained in a ^{60}Co beam
N_X	exposure calibration coefficient
p	proton
p	perturbation correction factor; momentum
p_{cav}	cavity perturbation factor
p_{cel}	central electrode perturbation factor
p_{dis}	replacement correction factor
p_{fl}	electron fluence correction factor
p_q	overall perturbation correction factor for an ionization chamber
p_{wall}	chamber wall perturbation factor
P	pressure; power; design effective dose rate in a radiotherapy installation
Pa	pascal (SI unit of pressure)
P_{eff}	effective point of measurement
P_0	standard air pressure (101.325 kPa or 760 torr)

P_K	fraction of all photoeffect events for $h\nu > E_B(K)$ occurring in the K shell
Q	point of interest in phantom
Q	charge; beam quality
Q_{sat}	saturation charge
r	radius; distance
r_n	radius of electron orbit with principal quantum number n
r_0	nuclear radius constant
r_e	classical electron radius
r_{eq}	equivalent radius
R	roentgen (unit of exposure)
R	resistance; particle range in medium
R_P	practical range
R_∞	Rydberg constant
R_{90}	depth in water of the 90% percentage depth dose of an electron beam
R_{80}	depth in water of the 80% percentage depth dose of an electron beam
R_{50}	depth in water of the 50% percentage depth dose of an electron beam
s	second (unit of time)
s	restricted mass collision stopping power; screening constant
$s_{w,air}$	ratio of restricted mass collision stopping powers water to air
S	linear stopping power; scatter function; cell surviving fraction
S_c	collimator scatter factor
S_K	air kerma strength
S_P	phantom scatter factor
$S_{c,p}$	total scatter factor
Sv	sievert (unit of equivalent dose and unit of effective dose)
(S/ρ)	mass stopping power
$(S/\rho)_{col}$	mass collision stopping power
$(S/\rho)_{rad}$	mass radiative stopping power
$(S/\rho)_{tot}$	total mass stopping power
(S_Δ/ρ)	restricted mass stopping power
t	time; thickness
t_{max}	time of maximum radioactive daughter activity
$t_{1/2}$	half-life
T	tesla (SI unit of magnetic flux density)
T	temperature; linear scattering power; occupancy factor
(T/ρ)	mass angular scattering power

T_0	standard air temperature (273.2K or 0ºC)
u	atomic mass unit
U	unit of air kerma strength given as: 1 U = 1 cGy·cm^2·h^{-1}
u_A	standard uncertainty of type A
u_B	standard uncertainty of type B
u_C	combined standard uncertainty of a quantity
U	use factor; expanded uncertainty
υ	velocity
V	volt (unit of voltage)
V	voltage; potential; volume
V_{eff}	effective volume
w	weighting factor
w_R	radiation weighting factor
w_T	tissue weighting factor
W	watt (SI unit of power); transmitted particle in weak interactions
W	workload
(W/e)	average energy required to produce an ion pair
(W_{air}/e)	average energy required to produce an ion pair in air
X	attenuator thickness; exposure
$x_{1/2}$	half-value layer
$x_{1/10}$	tenth-value layer
$\bar{x}$	mean value of all measurements x_i
y	year (unit of time)
Y	radiation (bremsstrahlung) yield
z	depth in a phantom
z_{max}	depth of dose maximum
z_{ref}	reference depth
z_α	atomic number of the α particle
Z	atomic number
Z_{eff}	effective atomic number
Z^0	transmitted particle in weak interaction

Greek symbols

α	alpha particle; fine structure constant; initial slope of cell survival curve; fractional contribution to ionization by the chamber wall; electron arc angle
β	beta particle; particle velocity normalized to the speed of light in a vacuum; quadratic component of the cell survival curve; characteristic angle in electron arc therapy; effective electron fluence correction factor; proportionality constant between the dose and kerma in air
γ	gamma ray
Γ	specific gamma ray constant
Γ_X	exposure rate constant
Γ_{AKR}	specific air kerma rate constant
δ	delta ray
Δ	cut-off energy
ε	permittivity; photon energy normalized to the rest energy of the electron
ε_0	permittivity of vacuum
θ	scattering angle
θ_{max}	angle of maximum photon emission intensity
κ	linear pair production attenuation coefficient; homogeneity coefficient
λ	decay constant
λ_C	Compton wavelength of the electron
Λ	dose rate constant
μ	permeability; linear attenuation coefficient
${}_a\mu$	atomic attenuation coefficient
${}_e\mu$	electronic attenuation coefficient
μ_0	permeability of vacuum
μ_{ab}	linear energy absorption coefficient
μ_{en}	linear energy absorption coefficient
μ_{tr}	linear energy transfer coefficient
ν	photon frequency
ρ	density
σ	cross-section
σ_C	linear Compton attenuation coefficient
σ_R	linear Rayleigh attenuation coefficient
τ	average (mean) life of radioactive nucleus; linear photoelectric attenuation coefficient; fractional contribution to ionization by the chamber sleeve; kinetic energy normalized to rest energy

τ_s	shutter correction time
υ	velocity
ϕ	fluence
ψ	energy fluence
ω	angular frequency; fluorescent yield
ω_K	K shell fluorescent yield
Ω	solid angle

BIBLIOGRAPHY

AIRD, E.G., WILLIAMS, J.R., REMBOWSKA, A., "Brachytherapy", Radiotherapy Physics (WILLIAMS, J.R., THWAITES, D.I., Eds), Oxford Univ. Press, Oxford (2000).

AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE (New York)

A protocol for the determination of absorbed dose from high-energy photon and electron beams, Task Group 21, Radiation Therapy Committee, Med. Phys. **10** (1983) 741–771.

Radiation Treatment Planning Dosimetry Verification, AAPM Task Group 23 Report, American Institute of Physics, New York (1995).

Physical Aspects of Quality Assurance in Radiation Therapy, AAPM Task Group 24 Report, AAPM (1984).

Physical Aspects of Total and Half Body Irradiation, AAPM Task Group 29 Report, AAPM (1986).

Total Skin Electron Therapy: Techniques and Dosimetry, AAPM Task Group 30 Report, AAPM (1987).

Medical accelerator safety considerations, Report of AAPM Radiation Therapy Committee Task Group No. 35, Med. Phys. **20** (1993) 1261–1275.

Comprehensive QA for Radiation Oncology: Report of AAPM Radiation Therapy Committee Task Group 40, Med. Phys. **21** (1994) 581–618.

Stereotactic Radiosurgery, AAPM Task Group 42 Report, AAPM (1995).

Dosimetry of interstitial brachytherapy sources: Recommendations of the AAPM Radiation Therapy Committee Task Group No. 43, Med. Phys. **22** (1995) 209–239.

AAPM's TG-51 protocol for clinical reference dosimetry of high energy photon and electron beams, Task Group 51, Med. Phys. **26** (1999) 1847–1870.

American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning, Med. Phys. **25** (1998) 1773–1829.

Clinical use of electron portal imaging: Report of AAPM Radiation Therapy Committee Task Group 58, Med. Phys. **28** (2001) 712–737.

AAPM protocol for 40–300 kV x-ray beam dosimetry in radiotherapy and radiobiology, Task Group 61 Report, Med. Phys. **28** (2001) 868–892.

Quality assurance for computed-tomography simulators and the computed-tomography-simulation process: Report of the AAPM Radiation Therapy Committee Task Group No. 66, Med. Phys. **30** (2003) 2762–2790.

ATTIX, F.H., Introduction to Radiological Physics and Radiation Dosimetry, Wiley, New York (1986).

ATTIX, F.H., ROESCH, W.C., TOCHILIN, E., Radiation Dosimetry, Academic Press, New York (1968).

BENTEL, G.C., Radiation Therapy Planning, McGraw-Hill, New York (1996).

BENTEL, G.C., NELSON, C.E., NOELL, K.T., Treatment Planning and Dose Calculation in Radiation Oncology, Pergamon Press, Oxford and New York (1989).

BRAHME, A., et al., Accuracy requirements and quality assurance of external beam therapy with photons and electrons, Acta Oncol. Suppl. 1 **27** (1988).

BRITISH INSTITUTE OF RADIOLOGY, Central Axis Depth Dose Data for Use in Radiotherapy, Br. J. Radiol. Suppl. 17 (1983).

— Central Axis Depth Dose Data for Use in Radiotherapy, Br. J. Radiol. Suppl. 25 (1996).

CAMERON, J.R., SUNTHARALINGAM, N., KENNEY, G.K., Thermoluminescent Dosimetry, University of Wisconsin Press, Madison, WI (1968).

CHAO, K.S., PEREZ, C.A., BRADY, L.W., Radiation Oncology Management Decisions, Lippincott-Raven, New York (1999).

CLARK, M.J., et al., Dose quantities for protection against external radiations: Guidance on the 1990 recommendations of ICRP, Doc. NRPB **4** 3 (1993).

CLARKSON, J., A note on depth doses in fields of irregular shape, Br. J. Radiol. **14** (1941) 265.

CLINICAL ONCOLOGY INFORMATION NETWORK, ROYAL COLLEGE OF RADIOLOGISTS, Guidelines for external beam radiotherapy, Clin. Oncol. **11** (1999) S135–S172.

COIA, L., SCHULTHEISS, T.E., HANKS, G.E., A Practical Guide to CT-simulation, Advanced Medical Publishing, Madison, WI (1995).

CUNNINGHAM, J.R., Keynote address: Development of computer algorithms for radiation treatment planning, Int. J. Radiol. Oncol. Biol. Phys. **16** (1989) 1367–1376.

DOBBS, H., THWAITES, D.I., "Quality assurance and its conceptual framework", Physics Aspects of Quality Control in Radiotherapy (MAYLES, H.M., et al., Eds), Rep. 81, Institute of Physics and Engineering in Medicine, York, United Kingdom (1999) Ch. 1.

DUTREIX, A., When and how can we improve precision in radiotherapy? Radiother. Oncol. **2** (1984) 275–292.

ESSERS, M., MIJNHEER, B.J., In-vivo dosimetry during external photon beam radiotherapy, Int. J. Radiat. Oncol. Biol. Phys. **43** (1999) 245–259.

EUROPEAN SOCIETY FOR THERAPEUTIC RADIOLOGY AND ONCOLOGY, Quality assurance in radiotherapy, Radiother. Oncol. **35** (1995) 61–73.

— Practical Guidelines for the Implementation of a Quality System in Radiotherapy, Physics for Clinical Radiotherapy Booklet No. 4, ESTRO, Brussels (1998).

EVANS, R.D., The Atomic Nucleus, McGraw-Hill, New York (1955).

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

GILDENBERG, P.L., TASKER, R.R. (Eds), Textbook of Stereotactic and Functional Neurosurgery, McGraw-Hill, New York (1998).

GLASGOW, G.P., "Brachytherapy", Modern Technology in Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists (VAN DYK, J., Ed.), Medical Physics Publishing, Madison, WI (1999) 695–752.

GREENE, D., WILLIAMS, P.C., Linear Accelerators for Radiation Therapy, Institute of Physics Publishing, Bristol (1997).

GREENING, J.R., Fundamentals of Radiation Dosimetry, Adam Hilger, Bristol (1981).

HALE, J., The Fundamentals of Radiological Science, Thomas, Springfield, IL (1974).

HALL, E.J., Radiobiology for the Radiologist, Lippincott, Philadelphia, PA (2000).

HARTMANN, G., et al., Quality Assurance Program on Stereotactic Radiosurgery, Springer-Verlag, Berlin (1995).

HENDEE, W.R., IBBOTT, G.S., Radiation Therapy Physics, Mosby, St. Louis, MI (1996).

HORTON, J., Handbook of Radiation Therapy Physics, Prentice Hall, New York (1987).

INSTITUTE OF PHYSICAL SCIENCES IN MEDICINE, Code of practice for high-energy photon therapy dosimetry based on the NPL absorbed dose calibration service, Phys. Med. Biol. **35** (1990) 1355–1360.

INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE (York, United Kingdom)

The IPEMB code of practice for electron dosimetry for radiotherapy beams of initial energy from 2 to 50 MeV based on air kerma calibration, Phys. Med. Biol. **41** (1996) 2557–2603.

The IPEMB code of practice for the determination of absorbed dose for x-rays below 300 kV generating potential (0.035 mm Al–4 mm Cu HVL; 10–300 kV generating potential), Phys. Med. Biol. **41** (1996) 2605–2625.

A Guide to Commissioning and Quality Control of Treatment Planning Systems (SHAW, J.E., Ed.), Rep. 68 (1996).

The Design of Radiotherapy Treatment Room Facilities (STEDEFORD, B., MORGAN, H.M., MAYLESS, W.P.M., Eds) (1997).

Physics Aspects of Quality Control in Radiotherapy (MAYLES, H.M., et al., Eds), Rep. 81 (1998).

INTERNATIONAL ATOMIC ENERGY AGENCY (Vienna)

Absorbed Dose Determination in Photon and Electron Beams, Technical Reports Series No. 277 (1987).

Calibration of Dosimeters Used in Radiotherapy, Technical Reports Series No. 374 (1995).

Absorbed Dose Determination in Photon and Electron Beams, 2nd edn, Technical Reports Series No. 277 (1997).

Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents, IAEA-TECDOC-953 (1997).

The Use of Plane Parallel Chambers in High Energy Electron and Photon Beams, Technical Reports Series No. 381 (1997).

Design and Implementation of a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA-TECDOC-1040 (1998).

Assessment of Occupational Exposure Due to External Sources of Radiation, IAEA Safety Standards Series No. RS-G-1.3 (1999).

Occupational Radiation Protection, IAEA Safety Standards Series No. RS-G-1.1 (1999).

"Recommendations on standardized procedures for calibration of brachytherapy sources at SSDLs and hospitals", Calibration of Brachytherapy Sources, IAEA-TECDOC-1079 (1999).

Standardized Quality Audit Procedures for On-site Dosimetry Visits to Radiotherapy Hospitals, DMRP-199907-IU (1999).

Absorbed Dose Determination in External Beam Radiotherapy, Technical Reports Series No. 398 (2000).

Aspectos Físicos de la Garantía de Calidad en Radioterapia: Protocolo de Control de Calidad, IAEA-TECDOC-1151 (2000).

Calibration of Radiation Protection Monitoring Instruments, Safety Reports Series No. 16 (2000).

Lessons Learned from Accidental Exposures in Radiotherapy, Safety Reports Series No. 17 (2000).

Calibration of Photon and Beta Ray Sources Used in Brachytherapy, IAEA-TECDOC-1274 (2002).

Radiological Protection for Medical Exposure to Ionizing Radiation, IAEA Safety Standards Series No. RS-G-1.5, IAEA (2002).

Regulations for the Safe Transport of Radioactive Material, 1996 Edition (As Amended 2003), IAEA Safety Standards Series No. TS-R-1 (2003).

INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS (Bethesda, MD)

Measurement of Absorbed Dose Measured in a Phantom Irradiated by a Single Beam of X or Gamma Rays, Rep. 23 (1973).

Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures, Rep. 24 (1976).

Radiation Dosimetry: Electron Beams with Energies Between 1 and 50 MeV, Rep. 35 (1984).

Stopping Powers for Electrons and Positrons, Rep. 37 (1984).

Dose and Volume Specification for Reporting Intracavitary Therapy in Gynecology, Rep. 38 (1985).

Use of Computers in External Beam Radiotherapy Procedures with High-energy Photons and Electrons, Rep. 42 (1987).

Determination of Dose Equivalents Resulting from External Radiation Sources, Rep. 43 (1988).

Measurement of Dose Equivalents from External Photon and Electron Radiations, Rep. 47 (1992).

Prescribing, Recording and Reporting Photon Beam Therapy, Rep. 50 (1993).

Quantities and Units in Radiation Protection Dosimetry, Rep. 51 (1993).

Dose and Volume Specification for Reporting Interstitial Therapy, Rep. 58 (1997).

Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50), Rep. 62 (1999).

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Protection Against Ionizing Radiation from External Sources Used in Medicine, Publication 33, Pergamon Press, Oxford and New York (1982).

1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press, Oxford and New York (1991).

Conversion Coefficients for Use in Radiological Protection Against External Radiation: Adopted by the ICRP and ICRU in 1995, Publication 74, Pergamon Press, Oxford and New York (1997).

General Principles for the Radiation Protection of Workers, Publication 75, Pergamon Press, Oxford and New York (1997).

Pregnancy and Medical Radiation, Publication 84, Pergamon Press, Oxford and New York (2000).

Prevention of Accidental Exposure to Patients Undergoing Radiation Therapy, Publication 86, Pergamon Press, Oxford and New York (2002).

INTERNATIONAL ELECTROTECHNICAL COMMISSION (Geneva)

Medical Electrical Equipment — Part 2: Particular Requirements for the Safety of Therapeutic X-ray Generators, IEC 601-2-8 (1987).

Medical Electrical Equipment — Medical Electron Accelerators — Functional Performance Characteristics, IEC 976 (1989).

Medical Electrical Equipment — Medical Electron Accelerators in the Range 1 MeV to 50 MeV — Guidelines for Performance Characteristics, IEC 977 (1989).

Safety of Medical Electrical Equipment, Part 2: Particular Requirements for Medical Electron Accelerators in the Range 1 MeV to 50 MeV, Section 1: General, Section 2: Radiation Safety for Equipment, IEC 601-2-1 (1996).

General Requirements for Safety. 4. Collateral Standard: Programmable Electrical Medical Systems, IEC 60601-1-4 (1997).

Medical Electrical Equipment — Part 2: Particular Requirements for the Safety of Gamma Beam Therapy Equipment, IEC 60601-2-11 (1997).

Medical Electrical Equipment — Dosimeters with Ionization Chambers as Used in Radiotherapy, IEC 60731 (1997).

Guidelines for Radiotherapy Treatment Rooms, IEC 61859 (1997).

Medical Electrical Equipment — Part 2-1: Particular Requirements for the Safety of Electron Accelerators in the Range of 1 MeV to 50 MeV, IEC 60601-2-1, IEC (1998).

Medical Electrical Equipment — Part 2-17: Particular Requirements for the Safety of Remote-controlled Automatically-driven Gamma-ray Afterloading Equipment, IEC 60601-2-17 (1998).

Medical Electrical Equipment — Part 2: Particular Requirements for the Safety of Radiotherapy Simulators, IEC-60601-2-29 (1999).

Medical Electrical Equipment: Requirements for the Safety of Treatment Planning Systems, Publication IEC 62C/62083 (in preparation).

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (Geneva)

Basic Ionizing Radiation Symbol, ISO 361 (1975).

X and Gamma Reference Radiations for Calibrating Dosemeters and Dose Ratemeters and for Determining their Response as a Function of Energy, ISO 4037. See also High Rate Series of Filtered X-radiations, ISO 4037-1979/Addendum 1 (1983); and Low Rate Series of Filtered X-radiations, ISO 4037-1979/Amendment 1-1983 (E) (1979).

Reference Beta Radiations for Calibrating Dosimeters and Dose Rate Meters and for Determining their Response as a Function of Beta Radiation Energy, ISO 6980 (1984).

Dosimetry of the Reference Radiation Fields Used for Determining the Response of Protection Level Dosimeters and Dose-rate Meters at Photon Energies Between 4 and 9 MeV, ISO/DP 9991 (1988).

Dosimetry of X and Gamma Reference Radiations for Radiation Protection over the Energy Range from 9 keV to 1.3 MeV, ISO/DIS 8963 (1988).

Guide to Expression of Uncertainty in Measurement (1992).

Quantities and Units — Part 0: General Principles, ISO 31-0 (1992).

Radiation Protection — Sealed Sources — Leakage Test Methods, ISO 9978 (1992).

Quality Management and Quality Assurance Standards — Part I. Guidelines for Selection and Use, ISO 9000 (1994).

Radiation Protection — Sealed Radioactive Sources — General Requirements and Classification, ISO 2919 (1998).

JOHNS, H.E., CUNNINGHAM, J.R., The Physics of Radiology, Thomas, Springfield, IL (1984).

KARZMARK, C.J., NUNAN, C.S., TANABE, E., Medical Electron Accelerators, McGraw-Hill, New York (1993).

KASE, K.R., BJARNGARD, B.E., ATTIX, F.H. (Eds), The Dosimetry of Ionizing Radiation, Academic Press, San Diego, CA (1985).

KHAN, F., The Physics of Radiation Therapy, 4th edn, Lippincott, Williams and Wilkins, Baltimore, MD (2003).

KHAN, F.M., POTISH, R.A. (Eds), Treatment Planning in Radiation Oncology, Lippincott Williams and Wilkins, Philadelphia, PA (1998).

KLEVENHAGEN, S.C., Physics and Dosimetry of Therapy Electron Beams, Medical Physics Publishing, Madison, WI (1993).

KNOLL, G.F., Radiation Detection and Measurement, Wiley, New York (1979).

MACKIE, T.R., SCRIMGER, J.W., BATTISTA, J.J., A convolution method of calculating dose for 15-MV x rays, Med. Phys. **47** (1985) 188–196.

MAYLES, W.P.M., HEISIG, S., MAYLES, H.M.O., "Treatment verification and in-vivo dosimetry", Radiotherapy Physics in Practice (WILLIAMS, J.R., THWAITES, D.I., Eds), Oxford Univ. Press, Oxford (2000) 220–246.

McCULLOUGH, E.C., "Intraoperative electron beam radiation therapy (IORT)", Advances in Radiation Oncology Physics — Dosimetry, Treatment Planning, and Brachytherapy (PURDY, J., Ed.), American Institute of Physics, New York (1992).

McGINLEY, P.H., Shielding Techniques for Radiation Oncology Facilities, Medical Physics Publishing, Madison, WI (1998).

McKENZIE, A., KEHOE, T., THWAITES, D.I., "Quality assurance in radiotherapy physics", Radiotherapy Physics in Practice (WILLIAMS, J.R., THWAITES, D.I., Eds), Oxford Medical Publishing, Oxford (2000).

MEIJER, G., VAN KLEFFENS, H., MIJNHEER, B., Consistency in quality control programmes for electron accelerators in radiotherapy centres, Radiother. Oncol. **48** (1998) 103–110.

MIJNHEER, B., BATTERMANN, J., WAMBERSIE, A., What degree of accuracy is required and can be achieved in photon and neutron therapy, Radiother. Oncol. **8** (1987) 237–252.

MILAN, J., BENTLEY, R.E., The storage and manipulation of radiation dose data in a small digital computer, Br. J. Radiol. **47** (1974) 115–121.

MOULD, R.F., Radiotherapy Treatment Planning, Adam Hilger, Bristol (1981).

MUNRO, P., "Megavoltage radiography for treatment verification", The Modern Technology in Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists (VAN DYK, J., Ed.), Medical Physics Publishing, Madison, WI (1999) 481–508.

NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS (Bethesda, MD)

Protection Against Radiation from Brachytherapy Sources, Rep. 40 (1972).

Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies up to 10 MeV, Rep. 49 (1976).

Radiation Protection Design Guidelines for 0.1 MeV–100 MeV Particle Accelerator Facilities, Rep. 51 (1977).

NIAS, A.W., An Introduction to Radiobiology, Wiley, New York (1998).

NATIONAL RADIOLOGICAL PROTECTION BOARD, New Radiation Quantities Recommended by ICRU for Practical Use in Radiation Protection: Their Implementation in the United Kingdom, NRPB, Didcot (1986).

PODGORSAK, E.B., METCALFE, P., VAN DYK, J., "Medical accelerators", The Modern Technology in Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists (VAN DYK, J., Ed.), Medical Physics Publishing, Madison, WI (1999) 349–435.

PODGORSAK, E.B., PODGORSAK, M.B., "Stereotactic irradiation", ibid., pp. 589–640.

— "Special techniques in radiotherapy", ibid., pp. 641–693.

STEEL, G.G., Basic Clinical Radiobiology, Arnold, London (2002).

STERLING, T.D., PERRY, H., KATZ, L., "Automation of radiation treatment planning", Br. J. Radiol. **37** (1964) 544–550.

STERNICK, E.S. (Ed.), The Theory and Practice of Intensity Modulated Radiation Therapy, Advanced Medical Publishing, Madison, WI (1997).

in water phantoms in off-axis planes of rectangular fields of open and wedged photon beams, Phys. Med. Biol. **40** (1995) 511–527.

VAN DYK, J. (Ed.), The Modern Technology for Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists, Medical Physics Publishing, Madison, WI (1999).

VAN DYK, J., "Radiation oncology overview", ibid., pp. 1–18.

VAN DYK, J., BARNETT, R.B., BATTISTA, J., "Computerized radiation treatment planning systems", ibid., pp. 231–286.

VAN DYK, J., BARNET, R., CYGLER, J., SHRAGGE, P., Commissioning and quality assurance of treatment planning computers, Int. J. Radiat. Oncol. Biol. Phys. **26** (1993) 261–273.

VAN DYK, J., PURDY, J., "Clinical implementation of technology and the quality assurance process", The Modern Technology for Radiation Oncology: A Compendium for Medical Physicists and Radiation Oncologists (VAN DYK, J., Ed.), Medical Physics Publishing, Madison, WI (1999) 19–52.

VEETH, J.M., "Intraoperative radiation therapy in treatment of cancer", Frontiers of Radiation Therapy and Oncology, Vol. 31, Karger, Basle (1997).

VENSELAAR, J., WELLEWEERD, H., MIJNHEER, B., Tolerances for the accuracy of photon beam dose calculation of treatment planning systems, Radiother. Oncol. **60** (2001) 203–214.

WEBB, S., The Physics of Conformal Radiotherapy, Institute of Physics Publishing, Bristol (1997).

WILLIAMS, J.R., THWAITES, D.I. (Eds), Radiotherapy Physics in Practice, Oxford Univ. Press, Oxford (2000).

WOLKOV, H.B., "Intraoperative radiation therapy", Textbook of Radiation Oncology (LEIBEL, S.A., PHILIPS, T.L., Eds), W.B. Saunders, Philadelphia, PA (1998).

WORLD HEALTH ORGANIZATION, Quality Assurance in Radiotherapy, WHO, Geneva (1988).

YAYARAMAN, S., LANZL, L.H., Clinical Radiotherapy Physics, CRC Press, Boca Raton, FL (1996).

BLANK

INDEX

This publication is aimed at students and teachers involved in programmes that train professionals for work in radiation oncology. It provides a comprehensive overview of the basic medical physics knowledge required in the form of a syllabus for modern radiation oncology. It will be particularly useful to graduate students and residents in medical physics programmes, to residents in radiation oncology, as well as to students in dosimetry and radiotherapy technology programmes. It will assist those preparing for their professional certification examinations in radiation oncology, medical physics, dosimetry or radiotherapy technology. It has been endorsed by several international and national organizations and the material presented has already been used to define the level of knowledge expected of medical physicists worldwide.

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 92–0–107304–6