

## **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](http://www.efomp.org)

European Society for Therapeutic Radiology and Oncology (ESTRO)  
Brussels, Belgium [www.estro.be](http://www.estro.be)

International Atomic Energy Agency (IAEA)  
Vienna [www.iaea.org](http://www.iaea.org)

International Commission on Radiation Units and Measurements (ICRU)  
Bethesda, Maryland, USA [www.icru.org](http://www.icru.org)

International Commission on Radiological Protection (ICRP)  
Stockholm, Sweden [www.icrp.org](http://www.icrp.org)

International Electrotechnical Commission (IEC)  
Geneva, Switzerland [www.iec.ch](http://www.iec.ch)

International Federation for Medical and Biological Engineering (IFMBE)  
[www.ifmbe.org](http://www.ifmbe.org)

International Organization for Standardization (ISO)  
Geneva, Switzerland [www.iso.org](http://www.iso.org)

International Organization for Medical Physics (IOMP)  
[www.iomp.org](http://www.iomp.org)

International Radiation Protection Association (IRPA)  
Fontenay-aux-Roses, France [www.irpa.net](http://www.irpa.net)

International Society of Radiology (ISR)  
Bethesda, Maryland, USA [www.isradiology.org](http://www.isradiology.org)

International Union for Physical and Engineering Sciences in Medicine (IUPESM)  
[www.iupesm.org](http://www.iupesm.org)

Pan American Health Organization (PAHO)  
Washington, DC [www.paho.org](http://www.paho.org)

Radiological Society of North America (RSNA)  
Oak Brook, Illinois, USA [www.rsna.org](http://www.rsna.org)

United Nations Scientific Committee on the Effects of Atomic Radiation  
(UNSCEAR)  
Vienna [www.unscear.org](http://www.unscear.org)

World Health Organization (WHO)  
Geneva [www.who.int](http://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

## ABBREVIATIONS

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

## ABBREVIATIONS

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 $10 \times 10 \text{ cm}^2$ field
PDR	pulsed dose rate
PET	positron emission tomography
PMT	photomultiplier tube
PSDL	primary standards dosimetry laboratory
PSF	peak scatter factor

## ABBREVIATIONS

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 <sub>20,10</sub>	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

## ABBREVIATIONS

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

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## SYMBOLS

### Roman symbols

$a$	radius of atom; specific activity; scattering coefficient
$a_0$	Bohr radius of hydrogen atom
$a_{\text{eq}}$	side of equivalent square
$A$	ampere (SI unit of current)
$\text{\AA}$	ångström (unit of distance: $1 \text{\AA} = 10^{-10} \text{ m}$ )
$A$	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
$B_{\text{leak}}$	leakage barrier transmission factor
$B_{\text{pri}}$	primary barrier transmission factor
$B_{\text{scat}}$	scatter barrier transmission factor
$\text{Bq}$	becquerel (SI unit of activity)
$c$	speed of light
$C$	coulomb (SI unit of charge)
$C$	capacitance; cema (converted energy per unit mass)
$^{\circ}\text{C}$	degree Celsius (unit of Celsius temperature)
$\text{Ci}$	curie (unit of activity: $1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$ )
$C_{\text{pl}}$	material dependent scaling factor: plastic to water
$C_E$	dose to water correction factor for megavoltage electron beams (old concept)
$C_{\lambda}$	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
$d_{\text{pri}}$	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
$D_{\text{air}}$	absorbed dose to air
$D_{\text{cav}}$	dose to cavity
$D_{\text{gas}}$	dose to gas

## SYMBOLS

$D_{\text{med}}$	dose to medium
$D_{\text{T}}$	organ dose
$D_{\text{w}}$	dose to water
$D_{\text{wall}}$	dose to wall
$D'_{\text{med}}$	dose to small mass of medium in air
$D_{\alpha-n}$	distance of closest approach between the $\alpha$ particle and the nucleus
e	electron
$e$	charge of electron ( $1 e = 1.602 \times 10^{-19} \text{ C}$ )
$E$	total energy; effective dose
$E_{\text{B}}$	binding energy
$E_{\text{B}}(\text{K})$	binding energy of the K shell electron
$\bar{E}_{\text{d}}$	average energy of electrons incident on an interface
$E_{\text{K}}$	kinetic energy
$\bar{E}_{\text{K}}$	average kinetic energy
$E_{\text{K}}^{\text{thr}}$	threshold kinetic energy
$E_n$	energy level of orbital electron with principal quantum number $n$
$E_{\text{R}}$	binding energy of electron in ground state of hydrogen (Rydberg energy)
$E_0$	rest energy
$\bar{E}_{\text{ab}}$	mean (average) absorbed energy
$\bar{E}_{\text{tr}}$	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
$f_{\text{g}}$	collection efficiency in general recombination
fm	femtometre (unit of distance: $1 \text{ fm} = 10^{-15} \text{ m}$ )
$f_{\text{med}}$	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

## SYMBOLS

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

## SYMBOLS

$m_0$	rest mass
$m_p$	proton mass
$m_n$	neutron mass
$m_T$	mass of organ or tissue
$m_\alpha$	$\alpha$ 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 $\mathcal{M}\mathcal{U}$ )
$\mathcal{M}\mathcal{U}$	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 $^{60}\text{Co}$ 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)

## SYMBOLS

$P_K$	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
$Q_{\text{sat}}$	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
$r_{\text{eq}}$	equivalent radius
R	roentgen (unit of exposure)
$R$	resistance; particle range in medium
$R_p$	practical range
$R_\infty$	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
$s_{\text{w,air}}$	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
$S_{\text{c,p}}$	total scatter factor
Sv	sievert (unit of equivalent dose and unit of effective dose)
$(S/\rho)$	mass stopping power
$(S/\rho)_{\text{col}}$	mass collision stopping power
$(S/\rho)_{\text{rad}}$	mass radiative stopping power
$(S/\rho)_{\text{tot}}$	total mass stopping power
$(S_\Delta/\rho)$	restricted mass stopping power
$t$	time; thickness
$t_{\text{max}}$	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
$(T/\rho)$	mass angular scattering power

## SYMBOLS

$T_0$	standard air temperature (273.2K or 0°C)
$u$	atomic mass unit
$U$	unit of air kerma strength given as: $1 U = 1 \text{ cGy}\cdot\text{cm}^2\cdot\text{h}^{-1}$
$u_A$	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
$v$	velocity
$V$	volt (unit of voltage)
$V$	voltage; potential; volume
$V_{\text{eff}}$	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
$(W_{\text{air}}/e)$	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
$z_{\text{max}}$	depth of dose maximum
$z_{\text{ref}}$	reference depth
$z_\alpha$	atomic number of the $\alpha$ particle
$Z$	atomic number
$Z_{\text{eff}}$	effective atomic number
$Z^0$	transmitted particle in weak interaction

## SYMBOLS

### Greek symbols

$\alpha$	alpha particle; fine structure constant; initial slope of cell survival curve; fractional contribution to ionization by the chamber wall; electron arc angle
$\beta$	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
$\gamma$	gamma ray
$\Gamma$	specific gamma ray constant
$\Gamma_X$	exposure rate constant
$\Gamma_{AKR}$	specific air kerma rate constant
$\delta$	delta ray
$\Delta$	cut-off energy
$\epsilon$	permittivity; photon energy normalized to the rest energy of the electron
$\epsilon_0$	permittivity of vacuum
$\theta$	scattering angle
$\theta_{max}$	angle of maximum photon emission intensity
$\kappa$	linear pair production attenuation coefficient; homogeneity coefficient
$\lambda$	decay constant
$\lambda_C$	Compton wavelength of the electron
$\Lambda$	dose rate constant
$\mu$	permeability; linear attenuation coefficient
${}_a\mu$	atomic attenuation coefficient
${}_e\mu$	electronic attenuation coefficient
$\mu_0$	permeability of vacuum
$\mu_{ab}$	linear energy absorption coefficient
$\mu_{en}$	linear energy absorption coefficient
$\mu_{tr}$	linear energy transfer coefficient
$\nu$	photon frequency
$\rho$	density
$\sigma$	cross-section
$\sigma_C$	linear Compton attenuation coefficient
$\sigma_R$	linear Rayleigh attenuation coefficient
$\tau$	average (mean) life of radioactive nucleus; linear photoelectric attenuation coefficient; fractional contribution to ionization by the chamber sleeve; kinetic energy normalized to rest energy

## SYMBOLS

$\tau_s$	shutter correction time
$v$	velocity
$\phi$	fluence
$\psi$	energy fluence
$\omega$	angular frequency; fluorescent yield
$\omega_K$	K shell fluorescent yield
$\Omega$	solid angle



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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.