Chapter 18

Radiation safety

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Unit of activity = Curie:

$1\,\text{Ci} = 3.7 \times 10^{10}$ disintegration s^{-1}.

Unit of exposure dose for X- and γ-radiation = Roentgen:

$1\,\text{R} = 1\,\text{esu cm}^{-3} = 87.8\,\text{erg g}^{-1}$ ($5.49 \times 10^7\,\text{MeV g}^{-1}$) of air.

Unit of absorbed dose = rad:

$1\,\text{rad} = 100\,\text{erg g}^{-1}$ ($6.25 \times 10^7\,\text{MeV g}^{-1}$) in any material.

Unit dose equivalent (for protection) = rem:

rems (Roentgen equivalent for man) = rad $\times$ QF,

where QF (quality factor) depends upon the type of radiation and other factors. For γ-rays and HE protons, $QF \simeq 1$; for thermal neutrons, $QF \simeq 3$; for fast neutrons, QF ranges up to 10; and for α particles and heavy ions, QF ranges up to 20.

Maximum *permissible occupational dose* for the whole body:

$5\,\text{rem yr}^{-1}$ (or $\sim 100\,\text{mrem wk}^{-1}$).

Fluxes (per cm^2) to liberate 1 rad in carbon:

3.5×10^7 minimum ionizing singly charged particles,
1.0×10^9 photons of 1 MeV energy

(These fluxes are correct to within a factor of 2 for all materials.)

Radiation exposure (mrem yr^{-1}) of a typical person in the US:

Natural sources		*Artificial sources*	
Cosmic radiation	28	Environmental	8
Terrestrial radiation	26	Medical	92
Internal isotopes	26	Occupational	1
		Nuclear power	0.3
		Miscellaneous	5

(This table has been adapted from *Particle Properties Data Booklet*, Lawrence Berkeley Laboratory, Berkeley, CA, 1980, and Upton, A. C., 'The biological effects of low-level ionizing radiation', *Sci. Amer.*, **246**, 41, Feb. 1982.)

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Maximum permissible flux for occupational exposure to various types of ionizing radiations

Type of radiation	QF or RBE[a]	Average exposure rate[b] (mrad wk^{-1})	Approximate flux to give a maximum permissible exposure in an 8-hr day[c]
X- and gamma-rays	1	100	[1400/E] photons $cm^{-2}s^{-1}$ in free air at 0 °C (error <13% for E = 0.07 to 2 MeV)
Beta-rays and electrons	1	100	[$(4.3 \times 10^7)/((RBE)P)$] electrons or beta-rays $cm^2 s^{-1}$ [d]
Thermal neutrons	2.5	40	700 thermal neutrons $cm^{-2}s^{-1}$ [d]
Fast neutrons	10	10	19 neutrons of 2-MeV energy $cm^{-2}s^{-1}$ [d]
Alpha particles	10	10	[$(4.3 \times 10^7)/((RBE)P)$] alpha particles $cm^{-2}s^{-1}$ [d]
Protons	10	10	[$(4.3 \times 10^7)/((RBE)P)$] protons $cm^{-2}s^{-1}$ [d]
Heavy ions	20	5	[$(4.3 \times 10^7)/((RBE)P)$] heavy ions $cm^{-2}s^{-1}$ [d]

[a] RBE, relative biological effectiveness.

[b] Average occupational exposure rate permissible to blood-forming organs (essentially total body exposure), gonads, and eyes of persons of age 18 or over. These values may be averaged over a year, provided the dose in any thirteen weeks does not exceed 3 rem (rem = RBE × rad). All rates may be increased by a factor of 6 if the exposure is primarily to the skin, thyroid, or bone. They may be increased by a factor of 3 if the exposure is limited to organs other than blood-forming organs, gonads, or eyes.

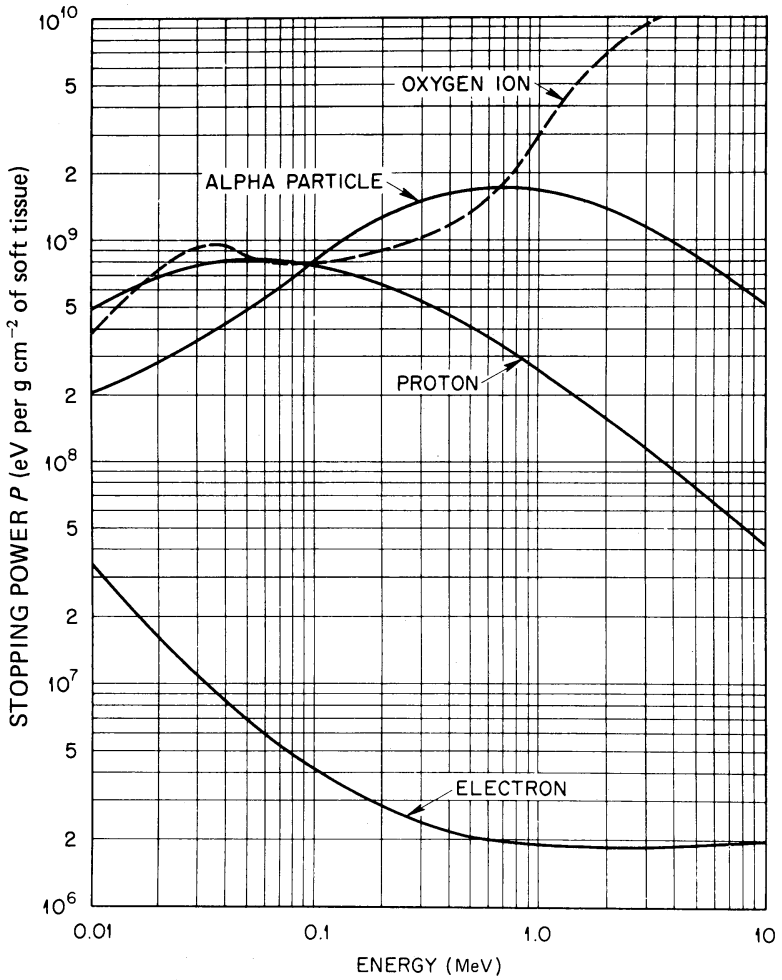
[c] Maximum permissible exposure rate based on a 20-mrem dose delivered to tissue in an 8-hr day. P is the stopping power in units of electron volts per $g\,cm^{-2}$ of soft tissue.

[d] Incident on tissue.

(Adapted from *Nuclear Instruments and Their Uses*, A. H. Snell, ed., John Wiley and Sons, 1962.)

Maximum permissible flux for occupational exposure to various types of ionizing radiations (*cont.*)

Stopping power as a function of energy. (Adapted from *Nuclear Instruments and Their Uses*, A. H. Snell, ed., John Wiley and Sons, 1962.)



Clinical effects of acute exposure to ionizing radiation

Dose (rem)	Probable effect
0–100	No illness
100–200	No or slight illness
200–600	0–90% deaths, 2–12 weeks
600–1000	90–100% deaths, 1–6 weeks
1000–5000	100% deaths, 2–14 days
> 5000	100% deaths, 0–2 days

(Adapted from Glasstone, S. & Dolan, P. J., *The Effects of Nuclear Weapons*, US Government Printing Office, 1977.)

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Chapter 19

Astronomical catalogs

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Astronomical catalogs

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Machine-readable astronomical catalogues

The Astronomical Data Center of the NASA-Goddard Space Flight Center, Greenbelt, MD 20771, maintains a large number of machine-readable astronomical catalogues. See *Astronomical Data Center Bulletin*, NSSDC/WDC NASA-Goddard Space Flight Center.

Selected astronomical catalog prefixes (see references in previous section)

X-ray and gamma-ray

IE	HEAO-2 (Einstein).
H	HEAO-1, A-2 experiment (GSFC).
XRS	Amnuel *et al.* compilation.
4U, 3U, etc.	Uhuru catalogs.
IM	OSO-7 catalog (MIT).
2A, A	Ariel catalogs.
2S	SAS-3 source (MIT).
CGS	Bradt *et al.* galactic sources.
MXB	MIT burst source (Bradt *et al.*).
CG	(cosmic gamma-ray), usually COS-B source.

Radio

G	(galactic coordinates), various sources – usually continuum surveys.
3C	(3rd Cambridge) 1959, *Mem. R.A.S.*, **68**, 37; 1962, **68**, 163.
4C	(4th Cambridge) 1965, *Mem. R.A.S.*, **69**, 183; 1967, **47**, 49.
W	(Dwingeloo) Westerhout 1958, *B.A.N.*, **14**, 215.

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CTA, CTB, CTD	(Cal Tech) 1960, *Publ. A.S.P.*, **72**, 237; *Cal. Tech. Radio. Obs. Reports* (#2) 1960–65. 1963, *A.J.*, **68**, 181.
NRAO	(Green Bank) 1966, *Ap. J. Suppl.*, **116**.
PKS	(Parkes) 1964, *Australian J. Phys.*, **17**, 340; 1965, **18**, 329; 1966, **19**, 35; 1966, **19**, 837; 1968, **21**, 377.
MSH	(Sydney) Mills, Slee & Hill, 1958, *Australian J. Phys.*, **11**, 360; 1960, **13**, 676; 1961, **14**, 497.
OA–OZ	(Ohio State) 1966, *Ap. J.*, **144**; 1967, *A.J.*, **72**, 536; 1968, **73**, 381; 1969, **74**, 612; 1970, **75**, 351; 1971, **76**, 777.
AMWW	(Bonn) Altenhoff, Mezger, Wendkar & Westerhout, 1960, *Publ. Univ. Obs. Bonn.*, No. 59.

Optical–stars–general

HD	*Henry Draper Catalog* 1918–25, *Harvard Ann., 91–100.*
AGK #	*Astronomische Gesellschaft Katalog.*
FK #	*Fundamental Katalog.*
SAO or # # # # # #	*Smithsonian Astrophysical Observatory Catalog.*
GC	*General Catalog*, Boss. 1936, Carnegie Inst. Wash. Publ. 468.
BD	*Bonner Durchmusterung*, 1860, *Beob. Bonn. Obs.*, **3**; **4**; **5**.
SD	*Southern Durchmusterung*, 1886, *Beob. Bonn. Obs.*, **8**.
CD (or CoD)	*Cordoba Durchmusterung*, 1892, *Result. Natl. Obs. Argentina*, **16**; **17**: **18**; **21a**; **21b**.
CPD	*Cape Photographic Durchmusterung*, 1896, *Ann. Cape Obs.*, **3**; **4**; **5**.
DM	BD, CP, CPD combined.
± # #°...	Usually DM catalogs.
HR	(Harvard revised) *Harvard Ann.*, 1908, **50**.
BS	(Bright star) *Yale Bright Star Catalog*. Follows HR numbering system (BS = HR #).

Optical–stars–proper motion

G # # # – # # # (or GD, HG)	Lowell P.M. Surveys.
BPM (or L)	Bruce P.M. Survey.
LP	(Luyten-Palomar) 1969a, 1969b, Luyten 1963, *P.M. Survey with the 48-Inch Schmidt*, Univ. Minn., Minneapolis.
LHS	(Luyten Half-Second) Luyten, 0.5″ yr^{-1}. P.M. Survey.
LTT	Luyten, 0.2″ yr^{-1}. P.M. Survey.
NLTT	Luyten, new P.M. Catalog.
LB, etc.	other Luyten P.M. Catalogs.

Optical–stars–miscellaneous

EG or GR	(White Dwarfs) Eggen and/or Greenstein; EG: *Ap. J.*, 1965, **141**, 83; 1965, **142**, 925; 1967, **150**, 927; 1969, **158**, 281. GR: *Ap. J.*, 1970, **162**, L55; 1974, **189**, L131; 1975, **196**, L117; 1976, **207**, L119; 1977, **218**, L21; 1979, **227**, 244. Also Greenstein, 1976, *A.J.*, **81**, 323; 1976, *Ap. J.*, **210**, 524.
GL	Gliese, W., 1969, *Catalog of Nearby Stars*, G. Braun, Karlsruhe.

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Y	(Yale) Jenkins, L. F., 1952, *General Catalog of Trigonometric Stellar Parallaxes*, Yale Univ. Obs., New Haven. (Also 1963, *Suppl.*)
	(Yerkes) van Altena *et al.*, *A.J.*, 1969, **74**, 2; 1971, **76**, 932; 1973, **78**, 781; 1973, **78**, 201; 1975, **80**, 647.
HZ	Humason & Zwicky, 1946, *Ap. J.*, **105**, 85–91.
Wolf (or W)	Nearby star discovered by Max Wolf (see Gliese catalog for data).
Ross (or R)	Nearby star discovered by Frank Ross (see Gliese catalog for data).
PHL (Ton, Tn, TS)	(Palomar-Haro-Luyten) Haro and Luyten, 1962, *Bol. Obs. Tonantzintla y Tacubaya*, **3**, 37. (Faint blue stars.)
VB	Van Biesbroeck, G., 1961, *A.J.*, **66**, 528.
Feige (or F)	Feige, 1958, *Ap. J.*, **128**, 267.

Optical–stars–variable

Naming convention (if no standard name):

Constellation preceded by the following combinations in order of variability discovery:
R, S, T, . . . , Z, RR, RS, . . . , RZ, SS, . . . , SZ, . . . , ZZ, AA, AB, . . . , AZ, BB, . . . , BZ, . . . , QQ, . . . , QZ, V335, V336, . . . (Note: the letter J is not used.)

Optical–miscellaneous galactic

TR	Trumpler, R., 1930, *Lick Obs. Bull.*, No. 420 (associations).
Coll	Collinder, P., 1931, *Ann. Obs. Lund.*, No. 2 (associations).
RCW	Rodgers, Campbell & Whiteoak, 1960, *M.N.R.A.S.*, **121**, 103 (H II regions).
R	Reflection nebula, preceded by constellation, as in Mon R2.
S	Sharpless, 1959, *Ap. J. Suppl.*, **4**, 257 (H II regions).
SS	Stevenson and Sanduleak object.
HH	Herbig-Haro object. Herbig, 1951, *Ap. J.*, **113**, 697; Haro, 1952, *Ap. J.*, **115**, 572; Herbig, 1974, *Lick Obs. Bull.*, **658**.

Optical–general–non-stellar

NGC	Dreyer's *New General Catalog*.
IC	Dreyer's *Index Catalog*.

Optical–extragalactic

Mrk (or Mkn)	Markarian, *Astrofizika* (in Russian), 1967, **3**, 55; 1969, **5**, 443; 1969, **5**, 581; 1971, **7**, 511; 1971, **8**, 155; 1973, **9**, 488; 1974, **10**, 307; 1976, **12**, 390; 1976, **12**, 657; 1977, **13**, 225.
Zw	Zwicky.
MCG	*Morphological Catalog of Galaxies*.

Infrared

IRC (or TMSS)	(Infrared Catalog) Neugebauer, G. & Leighton, R. B., 1969, *Two-Micron Sky Survey*, Cal. Tech., NASA SP-3047.
AFGL	Air Force Geophys. Lab.
GMS	Gillett, Merrill & Stein, 1971, *Ap. J.*, **164**, 83.
Hall	Hall, R. J., 1974, *A Catalog of 10-μm Celestial Objects*, Space and Missile Systems Org., SAMSO-TR-74-212.
MIRC	*Merged Infrared Catalog*.
BN	Becklin–Neugebauer object (in Orion Nebula), 1967, *Ap. J.*, **147**, 799.
KL	Kleinmann–Low object (in Orion Nebula), 1967, *Ap. J.*, **149**, L1.

(The material in this chapter was prepared by C. W. Maxson of the Harvard/Smithsonian Center for Astrophysics.)

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