ANNEX 1
Exposure limit values and action levels for electromagnetic fields

Static magnetic fields in the frequency range 0–1 Hz

Exposure limit value

The exposure limit value is determined as the external magnetic flux density.

Table 1.1. The exposure limit value as the external magnetic flux density in the frequency range 0–1 Hz.

Frequency range	**Magnetic flux density mT**
0–1 Hz	400

Action level

Table 1.2. Action level for magnetic flux density of 0−1 Hz to prevent the malfunctioning of implanted devices, such as cardiac pacemakers, and for limiting the risk of the gravitational effect caused by a magnetic field.

Frequency range	**Magnetic flux density mT**
0–1 Hz	0.5

Electromagnetic fields in the frequency range 1 Hz–300 GHz

Exposure limit values

The exposure limit values are determined as the strength of the internal electric field, induced in the body by the external electromagnetic field, in the frequency range 1 Hz–10 MHz (Table 1.3) and as the power absorbed from an external electromagnetic field by the body per unit of mass, i.e., as the specific absorption rate (SAR), in the frequency range 100 kHz–6 GHz (Table 1.4) and as the power density of an electromagnetic field in the frequency range 6–300 GHz (Table 1.5).

Table 1.3. Exposure limit values as the peak values of the strength of the electric field induced in the body by an electromagnetic field in the frequency range 1 Hz–10 MHz.

Frequency range	**Head V/m**	**Other parts of the body V/m**
1–10 Hz	0.14/f	0.57
10–25 Hz	0.014	0.57
25–1,000 Hz	$5.7 \cdot 10^{-4}f$	0.57
1–3 kHz	0.57	0.57
3 kHz–10 MHz	$1.9 \cdot 10^{-4}f$	$1.9 \cdot 10^{-4}f$

Note: In Table 1.3, f is the frequency in hertz.

Table 1.4. Exposure limit values as the specific absorption rate (SAR) induced in the body by an electromagnetic field in the frequency range 100 kHz–6 GHz.

Frequency range	**Average whole body SAR W/kg**	**Local SAR in the head and trunk W/kg**	**Local SAR in the limbs W/kg**
100 kHz–6 GHz	0.08	2	4

Note 1: In Table 1.4, SAR is determined as an average over six-minute periods.
Note 2: In Table 1.4, local SAR is determined as an average over 10 g of tissue.
Note 3: In Table 1.4, the exposure limit value of a pulsed electromagnetic field in the frequency range 0.3–6 GHz as the specific absorption induced in the head by a pulse less than 30 µs is 2 mJ/kg determined as an average over 10 g of tissue.

Table 1.5. Exposure limit value as the power density of an electromagnetic field in the frequency range 6–300 GHz.

Frequency range	**Power density W/m^2**
6–300 GHz	10

Note 1: In Table 1.5, the power density is determined in the frequency range 6−10 GHz as an average over six-minute periods and in the frequency range 10–300 GHz as an average over $68/f^{1.05}$-minute periods, where f is the frequency in gigahertz.
Note 2: In Table 1.5, the power density is determined as an average over an area of 20 cm^2.
Note 3: In Table 1.5, the local power density, determined as an average over an area of 1 cm^2, may not be greater than 200 W/m^2.

Action levels

Action levels are expressed as the root-mean-square values of the external electric and magnetic field strength as well as the external magnetic flux density in the frequency range 1 Hz–10 MHz in Table 1.6 and in the frequency range 10 MHz–300 GHz in Table 1.7. Action levels are also expressed as the equivalent power densities of the electric and magnetic field in Table 1.8. A more limiting action level of the action levels laid down in Tables 1.6 and 1.7 is applied in the frequency range 100 kHz–10 MHz.

Table 1.6. Action levels as the root-mean-square values of the electric and magnetic field strength as well as the magnetic flux density in the frequency range 1 Hz–10 MHz.

Frequency range	**Electric field strength V/m**	**Magnetic field strength A/m**	**Magnetic flux density µT**
1–8 Hz	5,000	$32{,}000/f^2$	$40{,}000/f^2$
8–25 Hz	5,000	4,000/f	5,000/f
25–50 Hz	5,000	160	200
50–400 Hz	250,000/f	160	200
400 Hz–3 kHz	250,000/f	64,000/f	80,000/f
3 kHz–10 MHz	83	21	27

Note 1: In Table 1.6, f is the frequency in hertz.
Note 2: In Table 1.6, the peak value of the electric and magnetic field strength as well as the magnetic flux density in the frequency range 1 Hz–10 MHz may not exceed *k* multiplied by the action level. In the frequency range 1 Hz−100 kHz $k=\sqrt{2}$. In the frequency range 0.1–10 MHz k = 3.05f + 1.11, where f is the frequency in megahertz.

Table 1.7. Action levels as the root-mean-square values of the electric and magnetic field strength as well as the magnetic flux density and as equivalent power densities in the frequency range 100 kHz–300 GHz.

Frequency range	**Electric field strength V/m**	**Magnetic field strength A/m**	**Magnetic flux density µT**	**Equivalent power density W/m²**
0.1–0.15 MHz	87	5	6.25	-
0.15–1 MHz	87	0.73/f	0.92/f	-
1–10 MHz	$87/f^{1/2}$	0.73/f	0.92/f	-
10–400 MHz	28	0.073	0.092	2
400–2,000 MHz	$1.38f^{1/2}$	$0.0037f^{1/2}$	$0.0046f^{1/2}$	f/200
2–300 GHz	61	0.16	0.20	10

Note 1: In Table 1.7, f is the frequency in megahertz.
Note 2: In Table 1.7, the equivalent power density is the square of the electric field strength divided by the wave impedance of free space (377 Ω) or the square of the magnetic field strength divided by the wave impedance of free space.
Note 3: In Table 1.7, the square of the electric and magnetic field strength, the root-mean-square value of the magnetic flux density and the equivalent power density are determined as an average over six minute periods in the frequency range 100 kHz–10 GHz.
Note 4: In Table 1.7, the equivalent power density at frequencies greater than 10 GHz is determined as an average over $68/f^{1.05}$-minute periods, where f is the frequency in gigahertz.
Note 5: In Table 1.7, the peak value of the equivalent power density may be, at maximum, 1,000 times the action level of the equivalent power density and the peak value of the electric field and magnetic field strength may be, at maximum, 32 times the action level of the electric or magnetic field strength. The peak value of the magnetic flux density may be, at maximum, 32 times the action level of the magnetic flux density.
Note 6: In Table 1.7, the equivalent power density at frequencies greater than 6 GHz is determined as an average over an area of 20 cm^2.
Note 7: In Table 1.7, the local power density, determined as an average over an area of 1 cm^2, may not be greater than 200 W/m^2 at frequencies greater than 6 GHz.

The root-mean-square values of the action levels of continuous contact current and an induced limb current are presented in Table 1.8. A continuous contact current is a current born when a person is in continuous contact with an object in an electromagnetic field. An induced limb current is a current which the electromagnetic field induces in the limb even without a contact with an object in an electromagnetic field.

Table 1.8. Action levels for the root-mean-square values of continuous contact current and induced limb current up to a maximum frequency of 110 MHz.

Frequency range	**Continuous contact current mA**	**Induced limb current mA**
At most 2.5 kHz	0.5	-
2.5–100 kHz	0.2f	-
100 kHz–10 MHz	20	-
10 MHz–110 MHz	20	45

Note 1: In Table 1.8, f is the frequency in kilohertz.
Note 2: In Table 1.8, the square of the root-mean-square value of the continuous contact current is determined as an average over one-second periods.
Note 3: In Table 1.8, the square of the root-mean-square value of the induced limb current is determined as an average over six-minute periods.

ANNEX 2
Exposure limit values and action levels for optical radiation

Noncoherent optical radiation

The exposure limit values for optical radiation are determined according to the formulae below. The use of a particular formula depends on the area of the radiation source in question, and the results should be compared with the corresponding exposure limit values presented in Table 2.1. More than one exposure limit value may be applied to some sources of optical radiation.

Definitions:

$E\lambda(\lambda,t)$, E_λ	*spectral irradiance* or *spectral power density*: the radiant power incident per unit area upon a surface, expressed in watts per square meter per nanometer [W m^{-2} nm^{-1}], the values of $E\lambda(\lambda,t)$ and E_λ derive from measurements or may be provided by the equipment's manufacturer
E_{eff}	*effective irradiance (UV range)*: the calculated irradiance spectrally weighted by $S(\lambda)$ in the UV wavelength range 180–400 nm, expressed in watts per square meter [W m^{-2}]
H	*radiant exposure*: the time integral of the irradiance, expressed in joules per square meter [J m^{-2}]
H_{eff}	*effective radiant exposure*: radiation exposure spectrally weighted by $S(\lambda)$, expressed in joules per square meter [J m^{-2}]
E_{UVA}	*total irradiance (UVA)*: calculated irradiance in the UVA wavelength range 315–400 nm, expressed in watts per square meter [W m^{-2}]
H_{UVA}	*radiant exposure (UVA)*: the time and wavelength integral of the irradiance within the UVA wavelength range 315–400 nm, expressed in joules per square meter [J m^{-2}]
$S(\lambda)$	*spectral weighting*, taking into account the wavelength dependence of the health effects of UV radiation on eye and skin, (Table 2.2) [dimensionless]
t, Δt	*time, duration of exposure*, expressed in seconds [s]
λ	*wavelength*, expressed in nanometers [nm]
$\Delta\lambda$	*bandwidth*, expressed in nanometers [nm], calculation or measurement interval
$L_\lambda(\lambda)$, L_λ	*spectral radiance of the source*, expressed in watts per square meter per steradian per nanometer [W m^{-2} sr^{-1} nm^{-1}]
$B(\lambda)$	*spectral weighting*, taking into account the wavelength dependence of the photochemical injury caused to the eye by blue light radiation (Table 2.3) [dimensionless]
L_B	*effective radiance (blue light)*: The calculated radiance spectrally weighted by $B(\lambda)$, expressed in watts per square meter per steradian [W m^{-2} sr^{-1}]

D_B	*effective radiance dose (blue light):* Time integral of the radiance spectrally weighted by *B(λ)*, expressed in joules per square meter per steradian [J m^{-2} sr^{-1}]
E_B	*effective irradiance (blue light)*: The calculated irradiance spectrally weighted by *B(λ)*, expressed in watts per square meter [W m^{-2}]
H_B	*effective radiant exposure (blue light)*: Radiation exposure spectrally weighted by *B(λ)*, expressed in joules per square meter [J m^{-2}]
R(λ)	*spectral weighting*, taking into account the wavelength dependence of the thermal injury caused to the eye by visible and IRA radiation (Table 2.3) [dimensionless]
L_R	*effective radiance (thermal injury)*: The calculated radiance spectrally weighted by *R(λ)*, expressed in watts per square meter per steradian [W m^{-2} sr^{-1}]
D_R	*effective radiance dose (thermal injury):* Time integral of the radiance spectrally weighted by *R(λ)*, expressed in joules per square meter per steradian [J m^{-2} sr^{-1}]
E_{IR}	*total irradiance (thermal injury)*: the calculated irradiance of infrared radiation in the wavelength range 780 nm–3,000 nm, expressed in watts per square meter [W m^{-2}]
E_{iho}	*total irradiance (visible, IRA and IRB)*: the calculated irradiance of visible and infrared radiation in the wavelength range 380 nm–3,000 nm, expressed in watts per square meter [W m^{-2}]
H_{iho}	*radiant exposure*: time and wavelength integral of the irradiance in the visible and infrared radiation wavelength range 380–3,000 nm, expressed in joules per square meter [J m^{-2}]
α	*angular subtense*: the angle subtended by an apparent source, as viewed at a point in space, expressed in milliradians (mrad). An apparent source is a real or virtual object which forms the smallest possible retinal image
γ_{ph}	*acceptance angle*: the angle limiting the radiation beam used in the measurement of radiance which depends on the exposure time. Expressed in milliradians [mrad].

The exposure limit values for the following items a–n are presented in Table 2.1

a)	$$H_{eff} = \int_{0}^{t} \int_{\lambda=180\ \text{nm}}^{\lambda=400\ \text{nm}} E_\lambda(\lambda, t) \cdot S(\lambda) \cdot d\lambda \cdot dt$$	(H_{eff} is relevant only between 180 nm and 400 nm)
b)	$$H_{UVA} = \int_{0}^{t} \int_{\lambda=315\ \text{nm}}^{\lambda=400\ \text{nm}} E_\lambda(\lambda, t) \cdot d\lambda \cdot dt$$	(H_{UVA} is relevant only between 315 nm and 400 nm)
c)	$$D_B = \int_{0}^{t} \int_{\lambda=300\ \text{nm}}^{\lambda=700\ \text{nm}} L_\lambda(\lambda, t) \cdot B(\lambda) \cdot d\lambda \cdot dt$$	(D_B is relevant only between 300 nm and 700 nm)
d)	$$L_B = \int_{\lambda=300\ \text{nm}}^{\lambda=700\ \text{nm}} L_\lambda(\lambda) \cdot B(\lambda) \cdot d\lambda$$	(L_B is relevant only between 300 nm and 700 nm)
e)	$$H_B = \int_{0}^{t} \int_{\lambda=300\ \text{nm}}^{\lambda=700\ \text{nm}} E_\lambda(\lambda, t) \cdot B(\lambda) \cdot d\lambda \cdot dt$$	(H_B is relevant only between 300 nm and 700 nm)
f)	$$E_B = \int_{\lambda=300\ \text{nm}}^{\lambda=700\ \text{nm}} E_\lambda(\lambda) \cdot B(\lambda) \cdot d\lambda$$	(E_B is relevant only between 300 nm and 700 nm)
h,i)	$$D_R = \int_{0}^{t} \int_{\lambda=380\ \text{nm}}^{\lambda=1{,}400\ \text{nm}} L_\lambda(\lambda, t) \cdot R(\lambda) \cdot d\lambda \cdot dt$$	(D_R is relevant only between 380 nm and 1,400 nm)
g, j, k)	$$L_R = \int_{\lambda_1}^{\lambda_2} L_\lambda(\lambda) \cdot R(\lambda) \cdot d\lambda$$	(λ_1 and λ_2 : see Table 2.1 for the appropriate values)
l, m)	$$E_{IR} = \int_{\lambda=780\ \text{nm}}^{\lambda=1{,}000\ \text{nm}} 0.3 \cdot E_\lambda(\lambda) \cdot d\lambda + \int_{\lambda=1{,}000\ \text{nm}}^{\lambda=3{,}000\ \text{nm}} E_\lambda(\lambda) \cdot d\lambda$$	(E_{IR} is relevant only between 780 nm and 3,000 nm)
n)	$$H_{iho} = \int_{0}^{t} \int_{\lambda=380\ \text{nm}}^{\lambda=3{,}000\ \text{nm}} E_\lambda(\lambda, t) \cdot d\lambda \cdot dt$$	(H_{iho} is relevant only between 380 nm and 3,000 nm)

Instead of the above formulae, the following expressions and the values presented in Tables 2.1–2.3 may also be used:

a)	$E_{eff} = \sum_{\lambda=180\text{ nm}}^{\lambda=400\text{ nm}} E_\lambda \cdot S(\lambda) \cdot \Delta\lambda$	and $H_{eff} = E_{eff} \cdot \Delta t$
b)	$E_{UVA} = \sum_{\lambda=315\text{ nm}}^{\lambda=400\text{ nm}} E_\lambda \cdot \Delta\lambda$	and $H_{UVA} = E_{UVA} \cdot \Delta t$
c, d)	$L_B = \sum_{\lambda=300\text{ nm}}^{\lambda=700\text{ nm}} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda$	and $D_B = L_B \cdot \Delta t$
e, f)	$E_B = \sum_{\lambda=300\text{ nm}}^{\lambda=700\text{ nm}} E_\lambda \cdot B(\lambda) \cdot \Delta\lambda$	and $H_B = E_B \cdot \Delta t$
g-k)	$L_R = \sum_{\lambda_1}^{\lambda_2} L_\lambda \cdot R(\lambda) \cdot \Delta\lambda$	and $D_R = L_R \cdot \Delta t$ (λ_1 and λ_2 : see Table 2.1 for the appropriate values)
l, m)	$E_{IR} = \sum_{\lambda=780\text{ nm}}^{\lambda=1{,}000\text{ nm}} 0.3 \cdot E_\lambda \cdot \Delta\lambda + \sum_{\lambda=1{,}000\text{ nm}}^{\lambda=3{,}000\text{ nm}} E_\lambda \cdot \Delta\lambda$	
n)	$E_{iho} = \sum_{\lambda=380\text{ nm}}^{\lambda=3{,}000\text{ nm}} E_\lambda \cdot \Delta\lambda$	and $H_{iho} = E_{iho} \cdot \Delta t$

Table 2.1. Exposure limit values for noncoherent optical radiation.

Item	Wavelength [nm]	Exposure limit value	Units	Note	Body region	Injury
a.	180–400 (UVA, UVB and UVC)	H_{eff} = 30 daily value (8 h)	[J m^{-2}]		cornea conjunctiva lens skin	photoceratitis conjunctivitis cataractogenesis erythema elastosis skin cancer
b.	315–400 (UVA)	H_{UVA} = 10^4 daily value (8 h)	[J m^{-2}]		lens of the eye	cataractogenesis
c.	300–700 (blue light) *Note 1*	D_B=10^6 $t \leq$ 10,000 s	D_B: [J m^{-2} sr^{-1}] t: [seconds]	when $\alpha \geq \gamma_{ph}$, γ_{ph} = 11 mrad, when t < 100 s, γ_{ph} = 1.1·$t^{0,5}$ mrad, when 100 ≤ t ≤ 10,000 s, γ_{ph} = 110 mrad, when t > 10,000 s,	retina of the eye	photoretinitis
d.	300–700 (blue light) *Note 1*	L_B=100 t > 10,000 s	[W m^{-2} sr^{-1}]			
e.	300–700 (blue light) *Note 1*	H_B = 100 t <100 s	H_B: [J m^{-2}] t: [seconds]	when $\alpha < \gamma_{ph}$,		
f.	300–700 (blue light) *Note 1*	E_B = 1 t ≥ 100 s	[W m^{-2}]			
g.	380–1,400 (visible and IRA)	$L_R = \frac{2.8 \cdot 10^7}{C_\alpha}$ when t ≥ 0.25 s	[W m^{-2} sr^{-1}]	C_α = 1.5, when $\alpha \leq$ 1.5 mrad $C_\alpha = \alpha$, when 1.5 < $\alpha \leq \alpha_{max}$ $C_\alpha = \alpha_{max}$, when $\alpha > \alpha_{max}$ α_{max} = 5 mrad, when t < 625 ×10^{-6} s α_{max} = 200·$t^{0.5}$ mrad, when 625 ×10^{-6} s ≤ t < 0.25 s	retina of the eye	retinal burn
h.	380–1,400 (visible and IRA)	$D_R = \frac{2.0 \cdot 10^7 \cdot t^{0.75}}{C_\alpha}$ when 10^{-6} s ≤ t < 0.25 s	D_R: [J m^{-2} sr^{-1}] t: [seconds]			

Item	Wavelength [nm]	Exposure limit value	Units	Note	Body region	Injury
i.	380–1,400 (visible and IRA)	$D_R = \frac{630}{C_\alpha}$ when $t < 10^{-6}$ s	[J m^{-2} sr^{-1}]	α_{max} = 100 mrad, when t ≥ 0.25 s λ_1 = 380 nm, λ_2 = 1,400 nm		
j.	780–1,400 (IRA)	$L_R = \frac{2 \cdot 10^7 \cdot t^{-0.25}}{C_\alpha}$ when 0.25< t < 100 s	L_R: [W m^{-2} sr^{-1}] t: [seconds]	C_α = 11, when α ≤ 11 mrad C_α = α, when 11 < α ≤ 100 $C_\alpha = \alpha_{max}$, when α > 100 mrad acceptance angle γ_{ph} = 11 mrad λ_1 = 780 nm, λ_2 = 1,400 nm	retina of the eye	retinal burn
k.	780–1,400 (IRA)	$L_R = \frac{6.3 \cdot 10^6}{C_\alpha}$ when t ≥ 100 s	[W m^{-2} sr^{-1}]			
l.	780–3,000 (IRA and IRB)	$E_{IR} = 18{,}000\ t^{-0.75}$ when t <1,000 s	E_{IR}: [W m^{-2}] t: [seconds]		the eye cornea lens of the eye	corneal burn cataractogenesis
m.	780–3,000 (IRA and IRB)	E_{IR} = 100 when t ≥ 1,000 s	[W m^{-2}]			
n.	380–3,000 (visible, IRA and IRB)	$H_{iho} = 20{,}000\ t^{0.25}$ when t ≤ 10 s	H_{iho}: [J m^{-2}] t: [seconds]		skin	burn

Note 1: In Table 2.1, the range 300–700 nm covers part of the UVB radiation, UVA radiation in its entirety, and the majority of visible radiation. However, the risk related to the above is usually referred to with the expression “blue light”. In precise terms, blue light covers only a range of approximately 400–490 nm.

Table 2.2. The spectral weighting of UV radiation.

λ(nm)	S(λ)	λ(nm)	S(λ)	λ(nm)	S(λ)	λ(nm)	S(λ)	λ(nm)	S(λ)
180	0.0120	228	0.1737	276	0.9434	324	0.000520	372	0.000086
181	0.0126	229	0.1819	277	0.9272	325	0.000500	373	0.000083
182	0.0132	230	0.1900	278	0.9112	326	0.000479	374	0.000080
183	0.0138	231	0.1995	279	0.8954	327	0.000459	375	0.000077
184	0.0144	232	0.2089	280	0.8800	328	0.000440	376	0.000074
185	0.0151	233	0.2188	281	0.8568	329	0.000425	377	0.000072
186	0.0158	234	0.2292	282	0.8342	330	0.000410	378	0.000069
187	0.0166	235	0.2400	283	0.8122	331	0.000396	379	0.000066
188	0.0173	236	0.2510	284	0.7908	332	0.000383	380	0.000064
189	0.0181	237	0.2624	285	0.7700	333	0.000370	381	0.000062
190	0.0190	238	0.2744	286	0.7420	334	0.000355	382	0.000059
191	0.0199	239	0.2869	287	0.7151	335	0.000340	383	0.000057
192	0.0208	240	0.3000	288	0.6891	336	0.000327	384	0.000055
193	0.0218	241	0.3111	289	0.6641	337	0.000315	385	0.000053
194	0.0228	242	0.3227	290	0.6400	338	0.000303	386	0.000051
195	0.0239	243	0.3347	291	0.6186	339	0.000291	387	0.000049
196	0.0250	244	0.3471	292	0.5980	340	0.000280	388	0.000047
197	0.0262	245	0.3600	293	0.5780	341	0.000271	389	0.000046
198	0.0274	246	0.3730	294	0.5587	342	0.000263	390	0.000044
199	0.0287	247	0.3865	295	0.5400	343	0.000255	391	0.000042
200	0.0300	248	0.4005	296	0.4984	344	0.000248	392	0.000041
201	0.0334	249	0.4150	297	0.4600	345	0.000240	393	0.000039
202	0.0371	250	0.4300	298	0.3989	346	0.000231	394	0.000037
203	0.0412	251	0.4465	299	0.3459	347	0.000223	395	0.000036
204	0.0459	252	0.4637	300	0.3000	348	0.000215	396	0.000035
205	0.0510	253	0.4815	301	0.2210	349	0.000207	397	0.000033
206	0.0551	254	0.5000	302	0.1629	350	0.000200	398	0.000032
207	0.0595	255	0.5200	303	0.1200	351	0.000191	399	0.000031
208	0.0643	256	0.5437	304	0.0849	352	0.000183	400	0.000030
209	0.0694	257	0.5685	305	0.0600	353	0.000175		
210	0.0750	258	0.5945	306	0.0454	354	0.000167		
211	0.0786	259	0.6216	307	0.0344	355	0.000160		
212	0.0824	260	0.6500	308	0.0260	356	0.000153		
213	0.0864	261	0.6792	309	0.0197	357	0.000147		
214	0.0906	262	0.7098	310	0.0150	358	0.000141		
215	0.0950	263	0.7417	311	0.0111	359	0.000136		
216	0.0995	264	0.7751	312	0.0081	360	0.000130		
217	0.1043	265	0.8100	313	0.0060	361	0.000126		
218	0.1093	266	0.8449	314	0.0042	362	0.000122		
219	0.1145	267	0.8812	315	0.0030	363	0.000118		
220	0.1200	268	0.9192	316	0.0024	364	0.000114		
221	0.1257	269	0.9587	317	0.0020	365	0.000110		
222	0.1316	270	1.0000	318	0.0016	366	0.000106		
223	0.1378	271	0.9919	319	0.0012	367	0.000103		
224	0.1444	272	0.9838	320	0.0010	368	0.000099		
225	0.1500	273	0.9758	321	0.000819	369	0.000096		
226	0.1583	274	0.9679	322	0.000670	370	0.000093		
227	0.1658	275	0.9600	323	0.000540	371	0.000090		

Table 2.3. The spectral weighting of optical radiation on the eye for the photochemical effect and thermal injury.

λ (nm)	**B(λ)**	**R(λ)**
300 ≤ λ < 380	0.01	-
380	0.01	0.01
385	0.0125	0.0125
390	0.025	0.025
395	0.05	0.05
400	0.1	0.1
405	0.2	0.2
410	0.4	0.4
415	0.8	0.8
420	0.9	0.9
425	0.95	0.95
430	0.98	0.98
435	1	1
440	1	1
445	0.97	1
450	0.94	1
455	0.9	1
460	0.8	1
465	0.7	1
470	0.62	1
475	0.55	1
480	0.45	1
485	0.4	1
490	0.22	1
495	0.16	1
500	0.1	1
500 < λ ≤ 600	$10^{0.02\cdot(450-\lambda)}$	1
600 < λ ≤ 700	0.001	1
700 < λ ≤ 1,050	-	$10^{0.002\cdot(700-\lambda)}$
1,050 < λ ≤ 1,150	-	0.2
1,150 < λ ≤ 1,200	-	$0.2\cdot 10^{0.02\cdot(1150-\lambda)}$
1,200 < λ ≤ 1,400	-	0.02

Laser radiation

The exposure limit values for laser radiation are determined according to the formulae below. The selection of the formula to be used is influenced by the wavelength and exposure time of the radiation emitting from the source of the laser radiation. The results of the determination must be compared to the corresponding exposure limit values, presented in Tables 2.4–2.5. More than one exposure limit value applies to some sources of laser radiation.

The factors used in the calculations of Tables 2.4–2.5 are presented in Table 2.6. The size of the measurement aperture used in assessing the exposure is presented in Table 2.7. The correction factors used in assessing repetitive exposure are presented in Table 2.9.

Definitions

dP	*power*, expressed in watts [W];
dA	*area*, expressed in square meters [m^2];
$E(t)$, E	*irradiance* or *power density*: the radiated power targeted at a particular surface per unit area, expressed in watts per square meter [$W\ m^{-2}$], the values of $E(t)$ and E derive from measurements or may be provided by the equipment's manufacturer;
H	*radiant exposure*: time integral of the irradiance, expressed in joules per square meter [$J\ m^{-2}$];
t	*time,* duration of exposure, expressed in seconds [s];
λ	*wavelength*, expressed in nanometers [nm];
γ	*limiting cone angle of measurement field-of-view*, expressed in milliradians [mrad];
γ_m	*measurement field-of-view*, expressed in milliradians [mrad];
α	*angular subtense of a source*, expressed in milliradians [mrad];
	limiting aperture, the circular area over which irradiance and radiant exposure are averaged.

The exposure limit values for laser radiation are determined as follows:

$$E = \frac{dP}{dA}$$

$$H = \int_0^t E(t) \cdot dt$$

Table 2.4. The exposure limit values for laser radiation on eye.

Wavelength [nm]		Exposure time [s]										
		10^{-13}–10^{-11}	10^{-11}–10^{-9}	10^{-9}–10^{-7}	10^{-7}–$5 \cdot 10^{-6}$	$5 \cdot 10^{-6}$–$13 \cdot 10^{-6}$	$13 \cdot 10^{-6}$–10^{-3}	10^{-3}–10	10–100	100 - 1,000	1,000–10^4	10^4–$3 \cdot 10^4$
UVC and UVB	180 – 302.5	$3 \cdot 10^{10}$ Wm^{-2}		30 Jm^{-2}								
	302.5–315			if $t \leq T_1$, then C_1 Jm^{-2} if $t > T_1$, then C_2 Jm^{-2}					C_2 Jm^{-2}			
UVA	315–400			C_1 Jm^{-2}					10^4 Jm^{-2}			
visible	400–600	$10^{-3} \cdot C_6$ Jm^{-2}	$2 \cdot 10^{-3} \cdot C_6$ Jm^{-2}			$18 \cdot t^{0.75} \cdot C_6$ Jm^{-2}			Photochemical retinal damage (400–600 nm)			
									$100 \cdot C_3$ Jm^{-2} (γ = 11 mrad)	C_3 Wm^{-2} ($\gamma = 1.1\ t^{0.5}$ mrad)		C_3 Wm^{-2} (γ = 110 mrad)
	400–700								Thermal retinal damage 400 nm–700 nm)			
									if $\alpha \leq 1.5$ mrad, then 10 Wm^{-2} if $\alpha > 1.5$ mrad and $t \leq T_2$, then $18 \cdot t^{0.75} \cdot C_6$ Jm^{-2} if $\alpha > 1.5$ mrad and $t > T_2$, then $18 \cdot T_2^{-0.25} \cdot C_6$ Wm^{-2}			
IRA	700–1,050	$10^{-3} \cdot C_6$ Jm^{-2}	$2 \cdot 10^{-3} \cdot C_4 \cdot C_6$ Jm^{-2}			$18 \cdot t^{0.75} \cdot C_4 \cdot C_6$ Jm^{-2}			if $\alpha \leq 1.5$ mrad, then $10 \cdot C_4 \cdot C_7$ Wm^{-2} if $\alpha > 1.5$ mrad and $t \leq T_2$, then $18 \cdot t^{0.75} \cdot C_6 \cdot C_4 \cdot C_7$ Jm^{-2} if $\alpha > 1.5$ mrad and $t > T_2$, then $18 \cdot T_2^{-0.25} \cdot C_6 \cdot C_4 \cdot C_7$ Wm^{-2}			
	1,050–1,400*)	$10^{-3} \cdot C_6 \cdot C_7$ Jm^{-2}	$2 \cdot 10^{-2} \cdot C_6 \cdot C_7$ Jm^{-2}				$90 \cdot t^{0.75} \cdot C_6 \cdot C_7$ Jm^{-2}					
IRB and IRC	1,400–1,500	10^{12} Wm^{-2}		1,000 Jm^{-2}				$5{,}600 \cdot t^{0.25}$ Jm^{-2}	1,000 Wm^{-2}			
	1,500–1,800	10^{13} Wm^{-2}		10,000 Jm^{-2}								
	1,800–2,600	10^{12} Wm^{-2}		1,000 Jm^{-2}				$5{,}600 \cdot t^{0.25}$ Jm^{-2}				
	2,600–10^6	10^{11} Wm^{-2}		100 Jm^{-2}	$5{,}600 \cdot t^{0.25}$ Jm^{-2}							

*) At wavelengths greater than 1,250 nm, the exposure limit values for laser radiation on skin may be smaller than the exposure limit values for the eye presented in the table. In such cases, the exposure limit values for laser radiation on skin are applied. If only the eyes are exposed to laser radiation, two-fold exposure limit values for laser radiation on skin are used when they are smaller than the exposure limit values for laser radiation on eye.

Table 2.5. The exposure limit values for laser radiation on skin.

Wavelength [nm]		**Exposure time [s]**				
		$< 10^{-9}$	10^{-9}–10^{-7}	10^{-7}–10^{-3}	10^{-3}–10	10– $3 \cdot 10^{4}$
UVC and UVB	180–302.5	$3 \cdot 10^{10}$ Wm^{-2}	30 Jm^{-2}			
	302.5–315		if $t \leq T_1$, then C_1 Jm^{-2} if $t > T_1$, then C_2 Jm^{-2}			C_2 Jm^{-2}
UVA	315–400		C_1 Jm^{-2}			10^{4} Jm^{-2}
visible	400–700	$2 \cdot 10^{11}$ Wm^{-2}	200 Jm^{-2}	$1.1 \cdot 10^{4} \cdot t^{0.25}$ Jm^{-2}		2,000 Wm^{-2}
IRA	700–1,400	$2 \cdot 10^{11} \cdot C_4$ Wm^{-2}	$200 \cdot C_4$ Jm^{-2}	$1.1 \cdot 10^{4} \cdot t^{0.25} \cdot C_4$ Jm^{-2}		$2{,}000 \cdot C_4$ Wm^{-2}
IRB and IRC	1,400–1,500	10^{12} Wm^{-2}	1,000 Jm^{-2}		$5{,}600 \cdot t^{0.25}$ Jm^{-2}	1,000 Wm^{-2}
	1,500–1,800	10^{13} Wm^{-2}	10,000 Jm^{-2}			
	1,800–2,600	10^{12} Wm^{-2}	1,000 Jm^{-2}		$5{,}600 \cdot t^{0.25}$ Jm^{-2}	
	2,600–10^{6}	10^{11} Wm^{-2}	100 Jm^{-2}	$5{,}600 \cdot t^{0.25}$ Jm^{-2}		

Table 2.6. Limiting apertures used in assessing exposure.

Wavelength range		**Diameter of limiting aperture**	
		The eye	**Skin**
UV	180 nm–400 nm	1 mm, when $t \leq 0.35$ s $1.5 \cdot t^{0.375}$, when $0.35 \text{ s} < t \leq 10$ s 3.5 mm when $t > 10$ s	3.5 mm
Visible	400 nm–700 nm	7 mm	3.5 mm
IRA	700 nm–1,400 nm	7 mm	3.5 mm
IRB and IRC	1,400 nm–100,000 nm	1 mm, when $t \leq 0.35$ s $1.5\ t^{0.375}$, when $0.35 \text{ s} < t \leq 10$ s 3.5 mm when $t > 10$ s	3.5 mm
	0.1 mm–1 mm	11 mm	11 mm

Table 2.7. Applied correction factors and other calculation parameters.

Correction factors	**Wavelength range [nm]**	**Value**
C_1	302.5–400	$C_1 = 5{,}6 \cdot 10^{3} \cdot t^{0.25}$
C_2	302.5–315	$C_2 = 10^{0.2 \cdot (\lambda - 295)}$
T_1	302.5–315	$T_1 = 10^{0.8 \cdot (\lambda - 295)} \cdot 10^{-15}$ s
C_6	400–1,400	if $\alpha \leq 1.5$ mrad, then $C_6 = 1$ if 1.5 mrad $< \alpha \leq \alpha_{max}$, then $C_6 = \alpha/1.5$ mrad if $\alpha > \alpha_{max}$, then $C_6 = \alpha_{max}/1.5$ mrad, $\alpha_{max} = 5$ mrad, kun $t < 625$ µs $\alpha_{max} = 200 \cdot t^{0.5}$ mrad, kun 625 µs $\leq t \leq 0.25$ s $\alpha_{max} = 100$ mrad, kun $t > 0.25$ s
C_3	400–600	if 400 nm $\leq \lambda <$ 450 nm, then $C_3 = 1$ if 450 nm $\leq \lambda \leq$ 600 nm, then $C_3 = 10^{0.02(\lambda - 450)}$
T_2	400–1,400	if $\alpha < 1.5$ mrad, then $T_2 = 10$ s if 1.5 mrad $\leq \alpha \leq$ 100 mrad, then $T_2 = 10 \cdot 10^{[(\alpha - 1.5)/98.5]}$ s if $\alpha > 100$ mrad, then $T_2 = 100$ s
C_4	700–1,400	if $700 \leq \lambda <$ 1,050 nm, then $C_4 = 10^{0.002(\lambda - 700)}$ if 1,050 nm $\leq \lambda \leq$ 1,400 nm, then $C_4 = 5$
C_7	700–1,400	if 700 nm $\leq \lambda <$ 1,150 nm, then $C_7 = 1$ if 1,150 nm $\leq \lambda <$ 1,200 nm, then $C_7 = 10^{0.018(\lambda - 1{,}150)}$ if 1,200 nm $\leq \lambda \leq$ 1,400 nm, then $C_7 = 8 + 10^{0.04(\lambda - 1{,}250)}$

Correction factors for repetitive exposure

Each of the following three general rules should be applied to all repetitive exposures caused by repetitively pulsed or scanning laser systems:

1. The exposure from any single pulse in a train of pulses shall not exceed the exposure limit value for a single pulse of that pulse duration.

2. The exposure from any group of pulses (or sub-group of pulses in a train) delivered in time *t* shall not exceed the exposure limit value for time *t*.

3. The exposure from any single pulse within a group of pulses shall not exceed the single-pulse exposure limit value multiplied by a cumulative-thermal correction factor C_p. The factor C_p depends on the number of pulses *N*. This rule applies only to exposure limit values to protect against thermal injury, where all pulses delivered in less than T_{min} are treated as a single pulse. In this case, the duration of the pulse is T_{min} and the energy is the energy of the pulses accumulated during T_{min}.

Table 2.8. Minimum duration of pulse T_{min} for the cumulative thermal correction factor presented in Table 2.9.

Wavelength [nm]	**Minimum duration of pulse T_{min} [s]**	**Accumulation time of pulses [s]**
$400 \leq \lambda < 700$	$5 \cdot 10^{-6}$	0.25 s or T_2 *)
$700 \leq \lambda < 1,400$	$5 \cdot 10^{-6}$	T_2
$1,050 \leq \lambda < 1,400$	$13 \cdot 10^{-6}$	T_2
$1,400 \leq \lambda < 1,500$	10^{-3}	10
$1,500 \leq \lambda < 1,800$	10	10
$1,800 \leq \lambda < 2,600$	10^{-3}	10
$2,600 \leq \lambda \leq 10^6$	10^{-7}	10
*) if the exposure is intentionally prolonged, the accumulation time of pulses used is T_2.		

Table 2.9. Cumulative thermal correction factor C_p.

Duration of pulse t	**cumulative correction factor C_p.**
$t \leq T_{min}$	if accumulation time of pulses ≤ 0.25 s, $C_p = 1$ if accumulation time of pulses > 0.25 s, N ≤ 600, then $C_p = 1$ 600 < N ≤ 24,414, then $C_p = 5 \cdot N^{-0.25}$ N > 24,414, then $C_p = 0.4$
$t > T_{min}$	if $\alpha \leq 5$ mrad, then $C_p = 1$ if 5 mrad $< \alpha \leq \alpha_{max}$, $C_p = N^{-0.25}$, when N ≤ 40 $C_p = 0.4$, when N > 40 if $\alpha > \alpha_{max}$, then $C_p = N^{-0.25}$, kun N ≤ 625 $C_p = 0.2$, when N > 625 if $\alpha > 100$ mrad, then $C_p = 1$

Laser radiation may cause the radiation damage presented in Table 2.10.

Table 2.10. Radiation hazards caused by laser radiation.

Wavelength [nm] λ	**Radiation range**	**Affected organ**	**Hazard**
180–400	UV	the eye	photochemical damage and thermal injury
180–400	UV	skin	erythema
400–700	visible	the eye	retinal damage
400–600	visible	the eye	photochemical damage
400–700	visible	skin	thermal injury
700–1,400	IRA	the eye	thermal injury
700–1,400	IRA	skin	thermal injury
1,400–10^6	IRB, IRC	the eye	thermal injury
1,400–10^6	IRB, IRC	skin	thermal injury

ANNEX 3
Exposure limit values for ultrasound

Table 3.1. Exposure limit values for airborne ultrasound pressure level (SPL). The limit values are expressed on the decibel scale with sound pressure 20 μPa used as a reference level. The frequencies are expressed as 1/3 octave band centre frequencies.

1/3 octave band centre frequency [kHz]	**Ultrasound pressure level (SPL) [dB]**
20	70
25	100
31.5	100
40	100
50	100
63	100
80	100
100	100

Table 3.2. Exposure limit values when ultrasound is applied to the body through skin contact or a medium that effectively transfers ultrasound energy to the body. The limit values are indicated for the ultrasound's intensity as well as the mechanical (MI) and thermal (TI) index.

Part of the body	**Ultrasound intensity [W/cm2]**	**Mechanical index (MI)**	**Thermal index (TI)**
The eyes	0.05	0.2	0.7
Other regions	0.1	0.4	

Note 1: The exposure may not be higher than the exposure limit value in terms of any quantity.
Note 2: According to standard IEC 62359, 'Ultrasonics - Field characterization - Test methods for the determination of thermal and mechanical indices related to medical diagnostic ultrasonic fields', the mechanical index (MI) is determined with the formula:

$$MI = \frac{\text{negative } maximum\ pressure\ (MPa)}{\sqrt{pulse's\ band\ centre\ frequency\ (MHz)}}$$

and the thermal index (TI) with the formula:

$$TI = \frac{transmitter\ output\ power\ (W)}{the\ power\ required\ to\ achieve\ a\ 1\ °\text{C}\ rise\ in\ termperature\ (W)}$$