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**Road vehicles — Safety glazing
materials — Method for the determination
of solar transmittance**

*Véhicules routiers — Vitrages de sécurité — Méthode de détermination
du facteur de transmission du rayonnement solaire*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13837 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 11, *Safety glazing materials*.

This corrected version of ISO 13837:2008 incorporates the following correction:

- Equation (B.4) on page 15 has been corrected.

Introduction

A review of existing standards and industry specifications and procedures reveals a lack of agreement with respect to the basis for defining and measuring the ultraviolet (UV), visible (VIS) and infrared (IR) transmittance properties of glazing materials. To avoid the continued preparation and promulgation of conflicting standards by individual entities, there is an interest in the automotive and glazing industries to harmonize on a worldwide basis the test procedures and protocol used to assess the solar transmittance properties of glazing materials.

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Road vehicles — Safety glazing materials — Method for the determination of solar transmittance

1 Scope

This International Standard specifies test methods to determine the direct and total solar transmittance of safety glazing materials for road vehicles. Two computational conventions (denoted convention “A” and convention “B”) are included, both of which are consistent with current international needs and practices.

This International Standard applies to monolithic or laminated, clear or tinted samples of safety glazing materials. Essentially flat sections of glazing parts can be used in this test, as well as flat samples of the same materials.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9845-1:1992, *Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5*

CIE 85:1989, *Solar spectral irradiance*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1

standardize

adjust an instrument output to correspond to a previously established calibration, using one or more homogeneous specimens or reference materials

3.1.2

transmittance

ratio of transmitted flux to incident flux, under specified geometric and spectral conditions

3.1.3

air mass (ratio)

ratio of the mass of atmosphere in the actual observer-sun path to the mass that would exist if the observer were at sea level, at standard barometric pressure, and the sun were directly overhead

3.1.4

solar indirect transmittance

fraction of the solar radiation absorbed by the safety glazing materials and reradiated to the interior

NOTE The fraction is the secondary heat transfer factor as defined in ISO 9050.

3.2 Symbols

Symbol	Definition
T_{UV}	ultraviolet (UV) direct solar energy transmitted through a glazing
T_{DS}	direct solar (DS) energy transmitted through a glazing
q_i	secondary heat transfer to the inside of a glazing
T_{TS}	total solar energy ($T_{DS} + q_i$) transmitted to the inside of a glazing
λ	wavelength, in nm
$\Delta\lambda$	uniform λ interval
E_λ	solar energy within a $\Delta\lambda$
E'_λ	E_λ in trapezoidal form ($E_1/2, E_2 \dots E_{n-1}, E_n/2$)
$E'_\lambda(n)$	normalized $\left[E'_\lambda / \sum (E'_{300} \dots E'_{2500}) \right]$
NOTE Additional definitions are specific to the computational convention chosen and are defined with the appropriate convention.	

4 Computational conventions

4.1 Convention "A"

Convention "A" defines the UV range from 300 nm to 400 nm for air mass 1,5 global. This definition is consistent with ISO 3917 and CIE 20:1972, and the best average solar flux specified in ISO 9845-1:1992, Table 1, Column 5.

4.2 Convention "B"

Convention "B" defines the UV range from 300 nm to 380 nm for air mass 1,0 global. This definition is consistent with ISO 9050 and EN 410, and the maximum possible solar flux found in CIE 85:1989, Table 4.

NOTE This International Standard defines each convention and computations are based on established methods (see Annex A). The tables incorporated in each computational convention simplify the calculations, leading to high accuracy with minimum effort. Since the results will differ depending on which convention is chosen, it is essential that the convention chosen be clearly identified when results are reported.

5 Apparatus

This method requires spectral transmittance data to be obtained from samples of glazing materials using a scanning spectrophotometer. This instrument, preferably equipped with an integrating sphere, shall be capable of measuring transmittance over that part of the electromagnetic spectrum in which the sun's energy is transmitted to the earth's surface.

6 Procedure

6.1 Sample preparation

Cut out (if necessary) and clean the flattest area of curved test specimens with distilled water and reagent grade methanol, or use an alternate procedure appropriate to the material, if necessary. Cut and clean flat samples similarly.

6.2 Measurement

Standardize the spectrophotometer in accordance with the manufacturer's instructions. Place a clean sample normal to the measuring beam in the transmittance sample position. Note its film side and curvature orientation, if applicable. Record the sample spectral data in accordance with the instrument manufacturer's recommendation.

6.3 Calculation by computational convention "A"

6.3.1 Definitions specific to computational convention "A"

6.3.1.1 Solar UV transmittance [$T_{UV}(400)$]

See Table 1. The transmittance is weighted interval by interval and derived from ISO 9845-1:1992, Table 1, Column 5 (with air mass 1,5 global) from 300 nm to 400 nm, at intervals of 5 nm.

6.3.1.2 Solar direct transmittance [$T_{DS}(1,5)$]

See Table 2. The transmittance is weighted interval by interval and derived from ISO 9845-1:1992, Table 1, Column 5 (with air mass 1,5 global) from 300 nm to 2 500 nm, at intervals of 5 nm, 10 nm and 50 nm.

6.3.1.3 Solar total transmittance [$T_{TS}(1,5)$]

The transmittance is the sum of the direct transmittance as defined in 6.3.1.2 and the indirect transmittance as defined in 3.1.4.

6.3.2 Computation method

6.3.2.1 Compute direct solar transmittance by integration using the solar weight data in Tables 1 and 2. Transmission (T) for each solar range (λ_1 to λ_n) is determined by the following functions:

$$\%T_{UV}(400) = \sum_{300}^{400} \%T_{\lambda} \times E'_{\lambda}(n) \{ \text{Table 1} \} \quad (1)$$

$$\%T_{DS}(1,5) = \sum_{300}^{2500} \%T_{\lambda} \times E'_{\lambda}(n) \{ \text{Table 2} \} \quad (2)$$

where $E'_{\lambda}(n)$ is the normalized solar energy computed trapezoidally in wavelength interval ($\Delta\lambda$).

6.3.2.2 Transmittance shall be measured to at least 2 300 nm. If it is not possible to measure transmittance to the recommended 2 500 nm, the last value shall be multiplied by the remaining $E'_{\lambda}(n)$ weight values in Table 2.

6.4 Calculation by computational convention "B"

6.4.1 Definitions specific to computational convention "B"

6.4.1.1 Solar UV transmittance [$T_{UV}(380)$]

See Table 3. The transmittance is weighted interval by interval and derived from CIE 85:1989, Table 4 (with air mass 1,0 global) from 300 nm to 380 nm, at intervals of 5 nm.

6.4.1.2 Solar direct transmittance [$T_{DS}(1,0)$]

See Table 4. The transmittance is weighted interval by interval and derived from CIE 85:1989, Table 4 (with air mass 1,0 global) from 300 nm to 2 500 nm, at intervals of 5 nm, 10 nm and 50 nm.

6.4.1.3 Solar total transmittance [$T_{TS}(1,0)$]

The transmittance is the sum of the direct transmittance as defined in 6.4.1.2 and the indirect transmittance as defined in 3.1.4.

6.4.2 Computation method

6.4.2.1 Compute direct solar transmittance by integration using the solar weight data in Tables 3 and 4. Transmission (T) for each solar range (λ_1 to λ_n) is determined by the following functions:

$$\%T_{UV}(380) = \sum_{300}^{380} \%T_{\lambda} \times E'_{\lambda}(n) \{ \text{Table 3} \} \tag{3}$$

$$\%T_{DS}(1,0) = \sum_{300}^{2500} \%T_{\lambda} \times E'_{\lambda}(n) \{ \text{Table 4} \} \tag{4}$$

where $E'_{\lambda}(n)$ is the normalized solar energy computed trapezoidally in wavelength interval ($\Delta\lambda$).

6.4.2.2 Transmittance shall be measured to at least 2 300 nm. If it is not possible to measure transmittance to the recommended 2 500 nm, the last value shall be multiplied by the remaining $E'_{\lambda}(n)$ weight values in Table 4.

6.5 Total solar transmittance

This International Standard defines the determination of the direct solar transmittance of safety glazing materials computed by either of two computational conventions (“A” or “B”). If it is necessary to compute total solar transmittance, use the equations in Annex B and the direct solar transmittance results from 6.3 or 6.4, whichever is appropriate.

7 Expression of results

Record thickness, type, construction, and curvature orientation if applicable, of the specimen; the instrument and computational convention used (“A” or “B”); and the specimen’s total UV and direct solar transmittance, and, if necessary, the specimen’s total solar properties rounded to 0,1 %, in accordance with the rounding convention in Reference [6].

Table 1 — Solar global radiation through air mass 1,5 and partitioned into uniform spectral trapezoidal intervals

λ nm	$E'_{\lambda}(n)$
300	0,000 000
305	0,001 045
310	0,004 634
315	0,011 800
320	0,019 807
325	0,027 019
330	0,043 271
335	0,042 703
340	0,047 644
345	0,048 041
350	0,052 948
355	0,054 947
360	0,056 946
365	0,064 930
370	0,072 925
375	0,075 901
380	0,077 991
385	0,075 890
390	0,073 777
395	0,092 335
400	0,055 446
$\%T_{UV}(400) = \sum_{300}^{400} \%T_{\lambda} \times E'_{\lambda}(n)$	
NOTE Modified wavelength intervals in ISO 9845-1:1992, Table 1, Column 5.	

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Table 2 — Solar global radiation through air mass 1,5 and partitioned into uniform spectral trapezoidal intervals

λ , nm	$E'_{\lambda}(n)$	λ , nm	$E'_{\lambda}(n)$	λ , nm	$E'_{\lambda}(n)$
300	0,000 000	410	0,011 712	850	0,049 016
305	0,000 048	420	0,011 973	900	0,039 872
310	0,000 214	430	0,010 839	950	0,016 652
315	0,000 545	440	0,013 166	1 000	0,037 501
320	0,000 915	450	0,015 431	1 050	0,034 127
325	0,001 248	460	0,016 175	1 100	0,020 859
330	0,001 999	470	0,015 988	1 150	0,012 512
335	0,001 973	480	0,016 466	1 200	0,021 415
340	0,002 201	490	0,015 565	1 250	0,023 934
345	0,002 219	500	0,015 661	1 300	0,018 651
350	0,002 446	510	0,016 043	1 350	0,001 642
355	0,002 538	520	0,015 016	1 400	0,000 136
360	0,002 630	530	0,015 900	1 450	0,003 746
365	0,002 999	540	0,015 681	1 500	0,009 548
370	0,003 369	550	0,015 790	1 550	0,013 934
375	0,003 506	560	0,015 539	1 600	0,012 093
380	0,003 603	570	0,015 184	1 650	0,011 636
385	0,003 506	580	0,014 646	1 700	0,010 440
390	0,003 408	590	0,014 112	1 750	0,008 111
395	0,004 265	600	0,014 568	1 800	0,001 553
400	0,007 684	610	0,015 020	1 850	0,000 231
		620	0,014 760	1 900	0,000 000
		630	0,014 502	1 950	0,000 682
		640	0,014 525	2 000	0,001 878
		650	0,014 547	2 050	0,004 040
		660	0,014 333	2 100	0,004 507
		670	0,014 079	2 150	0,004 134
		680	0,012 749	2 200	0,003 604
		690	0,011 426	2 250	0,003 583
		700	0,012 375	2 300	0,003 468
		710	0,013 315	2 350	0,003 242
		720	0,010 313	2 400	0,002 251
		730	0,011 094	2 450	0,001 070
		740	0,012 248	2 500	0,000 433
		750	0,012 119		
		760	0,009 197		
		770	0,010 675		
		780	0,011 438		
		790	0,011 201		
		800	0,032 812		

$$\%T_{DS}(1,5) = \sum_{300}^{2\,500} \%T_{\lambda} \times E'_{\lambda}(n)$$

NOTE Modified wavelength intervals in ISO 9845-1:1992, Table 1, Column 5.

Table 3 — Solar global radiation through air mass 1,0 and partitioned into uniform spectral trapezoidal intervals

λ nm	$E'_{\lambda}(n)$
300	0,000 000
305	0,005 026
310	0,014 169
315	0,027 622
320	0,040 070
325	0,049 865
330	0,070 579
335	0,067 061
340	0,072 643
345	0,071 541
350	0,077 316
355	0,078 834
360	0,080 353
365	0,090 180
370	0,100 040
375	0,102 521
380	0,052 180
$\%T_{UV}(380) = \sum_{300}^{380} \%T_{\lambda} \times E'_{\lambda}(n)$	
NOTE	Modified wavelength intervals in CIE 85:1989, Table 4.

Table 4 — Solar global radiation through air mass 1,0 and partitioned into uniform spectral trapezoidal intervals

λ , nm	$E'_{\lambda}(n)$	λ , nm	$E'_{\lambda}(n)$	λ , nm	$E'_{\lambda}(n)$
300	0,000 000	410	0,013 072	850	0,045 890
305	0,000 215	420	0,013 715	900	0,042 634
310	0,000 606	430	0,012 238	950	0,018 065
315	0,001 181	440	0,014 670	1 000	0,033 953
320	0,001 714	450	0,016 974	1 050	0,030 606
325	0,002 133	460	0,017 279	1 100	0,020 713
330	0,003 018	470	0,016 900	1 150	0,011 434
335	0,002 868	480	0,017 266	1 200	0,020 192
340	0,003 107	490	0,016 186	1 250	0,021 564
345	0,003 060	500	0,016 186	1 300	0,017 439
350	0,003 307	510	0,016 483	1 350	0,002 378
355	0,003 372	520	0,015 351	1 400	0,000 279
360	0,003 437	530	0,016 203	1 450	0,004 445
365	0,003 857	540	0,015 918	1 500	0,009 458
370	0,004 278	550	0,015 982	1 550	0,012 435
375	0,004 385	560	0,015 581	1 600	0,010 940
380	0,004 463	570	0,015 133	1 650	0,010 588
385	0,004 438	580	0,014 649	1 700	0,009 403
390	0,004 412	590	0,014 168	1 750	0,007 222
395	0,005 246	600	0,014 414	1 800	0,001 912
400	0,009 117	610	0,014 659	1 850	0,000 348
		620	0,014 379	1 900	0,000 000
		630	0,014 099	1 950	0,000 892
		640	0,013 966	2 000	0,002 044
		650	0,013 833	2 050	0,003 782
		660	0,013 624	2 100	0,004 029
		670	0,013 363	2 150	0,003 659
		680	0,012 234	2 200	0,003 224
		690	0,011 111	2 250	0,003 151
		700	0,011 826	2 300	0,003 028
		710	0,012 536	2 350	0,002 858
		720	0,010 445	2 400	0,002 131
		730	0,010 972	2 450	0,001 116
		740	0,011 707	2 500	0,000 000
		750	0,011 484		
		760	0,009 045		
		770	0,010 192		
		780	0,010 732		
		790	0,010 526		
		800	0,030 876		

$$\%T_{DS}(1,0) = \sum_{300}^{2\,500} \%T_{\lambda} \times E'_{\lambda}(n)$$

NOTE Modified wavelength intervals in CIE 85:1989, Table 4.

Annex A (informative)

Derivation of solar weight tables in this International Standard

A.1 The solar weight tables in this International Standard were derived as follows:

- a) Tables 1 and 2 were derived from ISO 9845-1:1992 (air mass 1,5 global);
- b) Tables 3 and 4 were derived from CIE 85:1989 (air mass 1,0 global).

A.2 The list below explains each column of the two spreadsheets in Tables A.1 and A.2, which show derivations of Tables 1 to 4.

- **Column (1):** Ultraviolet and visible wavelengths, in micrometers, from 295 nm to 790 nm.
- **Column (2):** Ultraviolet and visible energy levels at corresponding wavelengths from ISO 9845-1:1992 or from CIE 85:1989. $E_{\lambda 1}$ values at missing wavelengths from either publication were determined by picking point values from a wavelength versus energy spline fit curve.
- **Column (3):** Column (2) calculated in trapezoidal form (E'_{λ}), in accordance with the following technique:

$$E'_{\lambda} = 0,5 \times \{E_{300/2}, E_{305}, E_{310}, \dots, E_{395}, E_{400/2}\}; \quad \Delta\lambda = 5 \text{ nm};$$

$$E'_{\lambda} = 1,0 \times \{E_{400/2}, E_{410}, E_{420}, \dots, E_{790}\}; \quad \Delta\lambda = 10 \text{ nm}.$$

- **Column (4):** Column (3) normalized (portion of 300 nm to 2 500 nm normalization):

$$E'_{\lambda}(n) = E'_{\lambda} / \sum (E'_{300} \dots E'_{2500}).$$

- **Column (5):** Infrared and ultraviolet wavelengths, in micrometers:
 - for infrared, from 800 nm to 2 500 nm, and
 - for ultraviolet, from 295 nm to 400 nm (Table A.1) or from 295 nm to 380 nm (Table A.2).
- **Column (6):** Infrared and ultraviolet energy levels at corresponding wavelengths from ISO 9845-1:1992 or from CIE 85:1989. $E_{\lambda 1}$ values at missing wavelengths from either publication were determined by picking point values from a wavelength versus energy spline fit curve.
- **Column (7):** Column (6) calculated in trapezoidal form (E'_{λ}), in accordance with the following technique:

$$E'_{\lambda} = 1,0 \times \{E_{800/2}\} + 5,0 \times \{E_{800/2}, E_{850}, E_{900}, \dots, E_{2450}, E_{2500/2}\}; \quad \Delta\lambda = 50 \text{ nm};$$

$$E'_{\lambda} = 0,5 \times \{E_{300/2}, E_{305}, E_{310}, \dots, E_{395}, E_{400/2}\}; \quad \Delta\lambda = 5 \text{ nm} \quad (\text{see Table A.1});$$

$$E'_{\lambda} = 0,5 \times \{E_{300/2}, E_{305}, E_{310}, \dots, E_{375}, E_{380/2}\}; \quad \Delta\lambda = 5 \text{ nm} \quad (\text{see Table A.2}).$$

- **Column (8):** Column (7) normalized [portion of 300 nm to 2 500 nm normalization (DS), or UV regions normalized from 300 nm to 400 nm or normalized from 300 nm to 380 nm]:

$$E'_{\lambda}(n) = E'_{\lambda} / \sum (E'_{300} \dots E'_{2500}).$$

A.3 Solar integration process The equations below are overview examples for Table A.1 [300 nm to 400 nm (UV) and 300 nm to 2 500 nm (DS)]:

$$\%T(\lambda_{300} \text{ to } \lambda_{400}) = \frac{\sum_{\lambda=300}^{395} (\%T_{\lambda} \times E_{\lambda}) + \frac{\%T_{400} \times E_{400}}{2}}{\sum_{\lambda=300}^{395} (E_{\lambda}) + \frac{E_{400}}{2}}$$

$$\%T(\lambda_{300} \text{ to } \lambda_{2\,500}) = \left(\frac{0,5 \sum_{\lambda=300}^{400} (\%T_{\lambda} \times E_{\lambda}) + \sum_{\lambda=410}^{800} (\%T_{\lambda} \times E_{\lambda}) + 5 \sum_{\lambda=850}^{2\,500} (\%T_{\lambda} \times E_{\lambda})}{0,5 \sum_{\lambda=300}^{400} E_{\lambda} + \sum_{\lambda=410}^{800} E_{\lambda} + 5 \sum_{\lambda=850}^{2\,500} E_{\lambda}} \right)$$

A.4 The graph in Figure A.1 illustrates normalized energy within specified wavelength intervals versus wavelength. The graph in Figure A.2 illustrates hemispherical solar spectral irradiance.

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Table A.1 — Derivation table of $\Delta\lambda$ versus $E'_\lambda(n)$ for global air mass 1,5

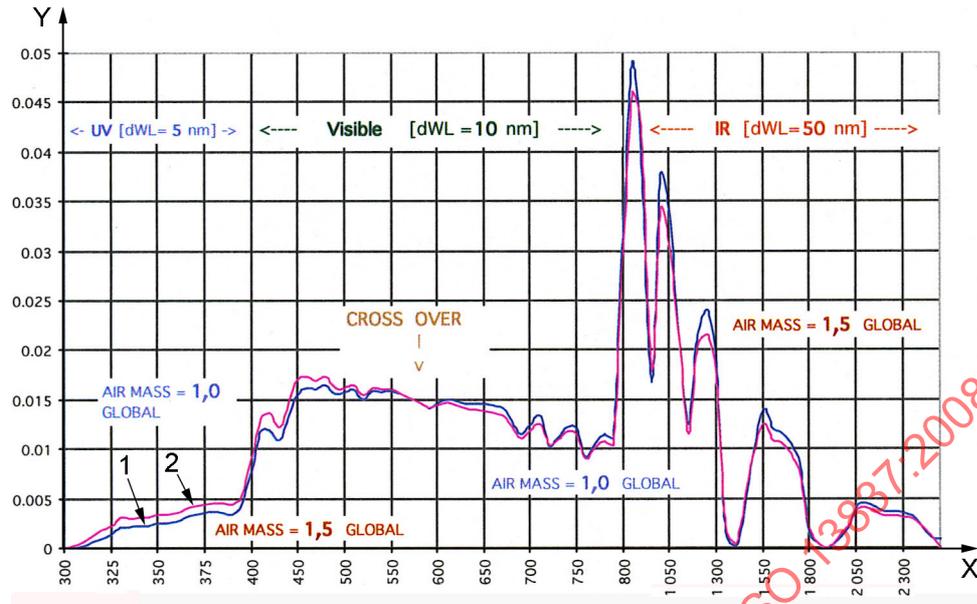
Light	(1)	(2)	(3)	(4)	Light	(5)	(6)	(7)	(8)	
	λ , nm ^a	E_λ ^b	E'_λ ^c	$E'_\lambda(n)$ ^d		λ , nm ^a	E_λ ^b	E'_λ ^e	$E'_\lambda(n)$ ^d	
Ultraviolet	295	0,0	0,00	0,000 000	Infrared	800	1 042,4	3 127,20	0,032 812	
	300	0,0	0,00	0,000 000		850	934,3	4 671,50	0,049 016	
	305	9,2	4,60	0,000 048		900	760,0	3 800,00	0,039 872	
	310	40,8	20,40	0,000 214		950	317,4	1 587,00	0,016 652	
	315	103,9	51,95	0,000 545		1 000	714,8	3 574,00	0,037 501	
	320	174,4	87,20	0,000 915		1 050	650,5	3 252,50	0,034 127	
	325	237,9	118,95	0,001 248		1 100	397,6	1 988,00	0,020 859	
	330	381,0	190,50	0,001 999		1 150	238,5	1 192,50	0,012 512	
	335	376,0	188,00	0,001 973		1 200	408,2	2 041,00	0,021 415	
	340	419,5	209,75	0,002 201		1 250	456,2	2 281,00	0,023 934	
	345	423,0	211,50	0,002 219		1 300	355,5	1 777,50	0,018 651	
	350	466,2	233,10	0,002 446		1 350	31,3	156,50	0,001 642	
	355	483,8	241,90	0,002 538		1 400	2,6	13,00	0,000 136	
	360	501,4	250,70	0,002 630		1 450	71,4	357,00	0,003 746	
	365	571,7	285,85	0,002 999		1 500	182,0	910,00	0,009 548	
	370	642,1	321,05	0,003 369		1 550	265,6	1 328,00	0,013 934	
	375	668,3	334,15	0,003 506		1 600	230,5	1 152,50	0,012 093	
	380	686,7	343,35	0,003 603		1 650	221,8	1 109,00	0,011 636	
	385	668,2	334,10	0,003 506		1 700	199,0	995,00	0,010 440	
	390	649,6	324,80	0,003 408		1 750	154,6	773,00	0,008 111	
395	813,0	406,50	0,004 265	1 800	29,6	148,00	0,001 553			
400	976,4	732,30	0,007 684	1 850	4,4	22,00	0,000 231			
410	1 116,2	1 116,20	0,011 712	1 900	0,0	0,00	0,000 000			
420	1 141,1	1 141,10	0,011 973	1 950	13,0	65,00	0,000 682			
430	1 033,0	1 033,00	0,010 839	2 000	35,8	179,00	0,001 878			
440	1 254,8	1 254,80	0,013 166	2 050	77,0	385,00	0,004 040			
450	1 470,7	1 470,70	0,015 431	2 100	85,9	429,50	0,004 507			
460	1 541,6	1 541,60	0,016 175	2 150	78,8	394,00	0,004 134			
470	1 523,7	1 523,70	0,015 988	2 200	68,7	343,50	0,003 604			
480	1 569,3	1 569,30	0,016 466	2 250	68,3	341,50	0,003 583			
490	1 483,4	1 483,40	0,015 565	2 300	66,1	330,50	0,003 468			
500	1 492,6	1 492,60	0,015 661	2 350	61,8	309,00	0,003 242			
510	1 529,0	1 529,00	0,016 043	2 400	42,9	214,50	0,002 251			
520	1 431,1	1 431,10	0,015 016	2 450	20,4	102,00	0,001 070			
530	1 515,4	1 515,40	0,015 900	2 500	16,5	41,25	0,000 433			
540	1 494,5	1 494,50	0,015 681	Sums:					95 305,20	1,000 000
550	1 504,9	1 504,90	0,015 790	Trapezoidal: $E'_\lambda(n)$ at 2 500 nm = $0,5 \times (16,5 \times 5,0)$						
560	1 480,9	1 480,90	0,015 539	Ultraviolet	λ , nm ^a	E_λ ^b	E'_λ ^f	$E'_\lambda(n)$ ^d		
570	1 447,1	1 447,10	0,015 184		295	0,0	0,00	0,000 000		
580	1 395,8	1 395,80	0,014 646		300	0,0	0,00	0,000 000		
590	1 344,9	1 344,90	0,014 112		305	9,2	4,60	0,001 045		
600	1 388,4	1 388,40	0,014 568		310	40,8	20,40	0,004 634		
610	1 431,5	1 431,50	0,015 020		315	103,9	51,95	0,011 800		
620	1 406,7	1 406,70	0,014 760		320	174,4	87,20	0,019 807		
630	1 382,1	1 382,10	0,014 502		325	237,9	118,95	0,027 019		
640	1 384,3	1 384,30	0,014 525		330	381,0	190,50	0,043 271		
650	1 386,4	1 386,40	0,014 547		335	376,0	188,00	0,042 703		
660	1 366,0	1 366,00	0,014 333		340	419,5	209,75	0,047 644		
670	1 341,8	1 341,80	0,014 079		345	423,0	211,50	0,048 041		
680	1 215,0	1 215,00	0,012 749		350	466,2	233,10	0,052 948		
690	1 089,0	1 089,00	0,011 426		355	483,8	241,90	0,054 947		
700	1 179,4	1 179,40	0,012 375		360	501,4	250,70	0,056 946		
710	1 269,0	1 269,00	0,013 315		365	571,7	285,85	0,064 930		
720	982,9	982,90	0,010 313		370	642,1	321,05	0,072 925		
730	1 057,3	1 057,30	0,011 094		375	668,3	334,15	0,075 901		
740	1 167,3	1 167,30	0,012 248		380	686,7	343,35	0,077 991		
750	1 155,0	1 155,00	0,012 119		385	668,2	334,10	0,075 890		
760	876,5	876,50	0,009 197	390	649,6	324,80	0,073 777			
770	1 017,4	1 017,40	0,010 675	395	813,0	406,50	0,092 335			
780	1 090,1	1 090,10	0,011 438	400	976,4	244,10	0,055 446			
790	1 067,5	1 067,50	0,011 201	Sums:					4 402,45	1,000 000
-	-	-	-	Trapezoidal: $E'_\lambda(n)$ at 400 nm = $0,5 \times (976,4 \times 0,5)$						
-	-	-	-							
-	-	-	-							
-	-	-	-							

a See ISO 9845-1:1992, Table 1, Column 5.
 b Air mass 1,5 g.
 c $E'_\lambda = E_\lambda \times D$, where $D = 0,5$ for UV ; $D = 1,0$ for VIS.
 d $E'_\lambda(n) = E'_\lambda / \sum E'_\lambda$.
 e $E'_\lambda = E_\lambda \times D$, where $D = 5,0$ for IR.
 f $E'_\lambda = E_\lambda \times D$, where $D = 0,5$ for UV.

Table A.2 — Derivation table of $\Delta\lambda$ versus $E'_\lambda(n)$ for global air mass 1,0

Light	(1)	(2)	(3)	(4)	Light	(5)	(6)	(7)	(8)
	λ, nm^a	E_λ^b	E'_λ^c	$E'_\lambda(n)^d$		λ, nm^a	E_λ^b	E'_λ^e	$E'_\lambda(n)^d$
Ultraviolet	295	0,0	0,00	0,000 000	Infrared	800	1 125,2	3 375,60	0,030 876
	300	0,0	0,00	0,000 000		850	1 003,4	5 017,00	0,045 890
	305	47,0	23,50	0,000 215		900	932,2	4 661,00	0,042 634
	310	132,5	66,25	0,000 606		950	395,0	1 975,00	0,018 065
	315	258,3	129,15	0,001 181		1 000	742,4	3 712,00	0,033 953
	320	374,7	187,35	0,001 714		1 050	669,2	3 346,00	0,030 606
	325	466,3	233,15	0,002 133		1 100	452,9	2 264,50	0,020 713
	330	660,0	330,00	0,003 018		1 150	250,0	1 250,00	0,011 434
	335	627,1	313,55	0,002 868		1 200	441,5	2 207,50	0,020 192
	340	679,3	339,65	0,003 107		1 250	471,5	2 357,50	0,021 564
	345	669,0	334,50	0,003 060		1 300	381,3	1 906,50	0,017 439
	350	723,0	361,50	0,003 307		1 350	52,0	260,00	0,002 378
	355	737,2	368,60	0,003 372		1 400	6,1	30,50	0,000 279
	360	751,4	375,70	0,003 437		1 450	97,2	486,00	0,004 445
	365	843,3	421,65	0,003 857		1 500	206,8	1 034,00	0,009 458
	370	935,5	467,75	0,004 278		1 550	271,9	1 359,50	0,012 435
	375	958,7	479,35	0,004 385		1 600	239,2	1 196,00	0,010 940
	380	975,9	487,95	0,004 463		1 650	231,5	1 157,50	0,010 588
385	970,3	485,15	0,004 438	1 700		205,6	1 028,00	0,009 403	
390	964,8	482,40	0,004 412	1 750		157,9	789,50	0,007 222	
395	1 147,0	573,50	0,005 246	1 800		41,8	209,00	0,001 912	
400	1 329,0	664,50	0,006 117	1 850		7,6	38,00	0,000 348	
410	1 429,1	714,55	0,006 572	1 900		0,0	0,00	0,000 000	
420	1 499,4	749,70	0,006 915	1 950		19,5	97,50	0,000 892	
430	1 337,9	665,95	0,005 238	2 000		44,7	223,50	0,002 044	
440	1 603,8	801,90	0,007 670	2 050		82,7	413,50	0,003 782	
450	1 855,7	927,85	0,009 974	2 100		88,1	440,50	0,004 029	
460	1 889,0	944,50	0,010 279	2 150		80,0	400,00	0,003 659	
470	1 847,6	923,80	0,010 000	2 200		70,5	352,50	0,003 224	
480	1 887,6	943,80	0,010 266	2 250		68,9	344,50	0,003 151	
490	1 769,5	884,75	0,009 186	2 300		66,2	331,00	0,003 028	
500	1 769,6	884,80	0,009 186	2 350		62,5	312,50	0,002 858	
510	1 802,0	901,00	0,009 483	2 400		46,6	233,00	0,002 131	
520	1 678,3	839,15	0,008 351	2 450		24,4	122,00	0,001 116	
530	1 771,4	885,70	0,009 203	2 500		0,0	0,00	0,000 000	
540	1 740,3	870,15	0,008 918	Sums: 109 326,1 1,000 000					
550	1 747,2	873,60	0,008 982	Trapezoidal: $E'_\lambda(n)$ at 2 500 nm = $0,5 \times (0 \times 5,0)$					
560	1 703,4	851,70	0,008 581	Ultraviolet		λ, nm^a	E_λ^b	E'_λ^f	$E'_\lambda(n)^d$
570	1 654,4	827,20	0,008 133		295	0,0	0,00	0,000 000	
580	1 601,5	800,75	0,007 649		300	0,0	0,00	0,000 000	
590	1 548,9	774,45	0,007 168		305	47,0	23,50	0,005 026	
600	1 575,8	787,90	0,007 414		310	132,5	66,25	0,014 169	
610	1 602,6	801,30	0,007 659		315	258,3	129,15	0,027 622	
620	1 572,0	786,00	0,007 379		320	374,7	187,35	0,040 070	
630	1 541,4	760,70	0,007 099		325	466,3	233,15	0,049 865	
640	1 526,9	753,45	0,007 013		330	660,0	330,00	0,070 579	
650	1 512,3	746,15	0,006 927		335	627,1	313,55	0,067 061	
660	1 489,5	734,75	0,006 782		340	679,3	339,65	0,072 643	
670	1 460,9	715,45	0,006 583		345	669,0	334,50	0,071 541	
680	1 337,5	668,75	0,006 111		350	723,0	361,50	0,077 316	
690	1 214,7	607,35	0,005 574		355	737,2	368,60	0,078 834	
700	1 292,9	646,45	0,005 986		360	751,4	375,70	0,080 353	
710	1 370,5	685,25	0,006 398		365	843,3	421,65	0,090 180	
720	1 141,9	570,95	0,005 714		370	935,5	467,75	0,100 040	
730	1 199,5	599,75	0,005 997		375	958,7	479,35	0,102 521	
740	1 279,9	639,95	0,006 399	380	975,9	487,95	0,052 180		
750	1 255,5	627,75	0,006 288	Sums: 4 675,63 1,000 000					
760	988,8	494,40	0,005 045	Trapezoidal: $E'_\lambda(n)$ at 380 nm = $0,5 \times (975,9 \times 0,5)$					
770	1 114,3	557,15	0,005 586						
780	1 173,3	586,65	0,005 932						
790	1 150,8	575,40	0,005 826						

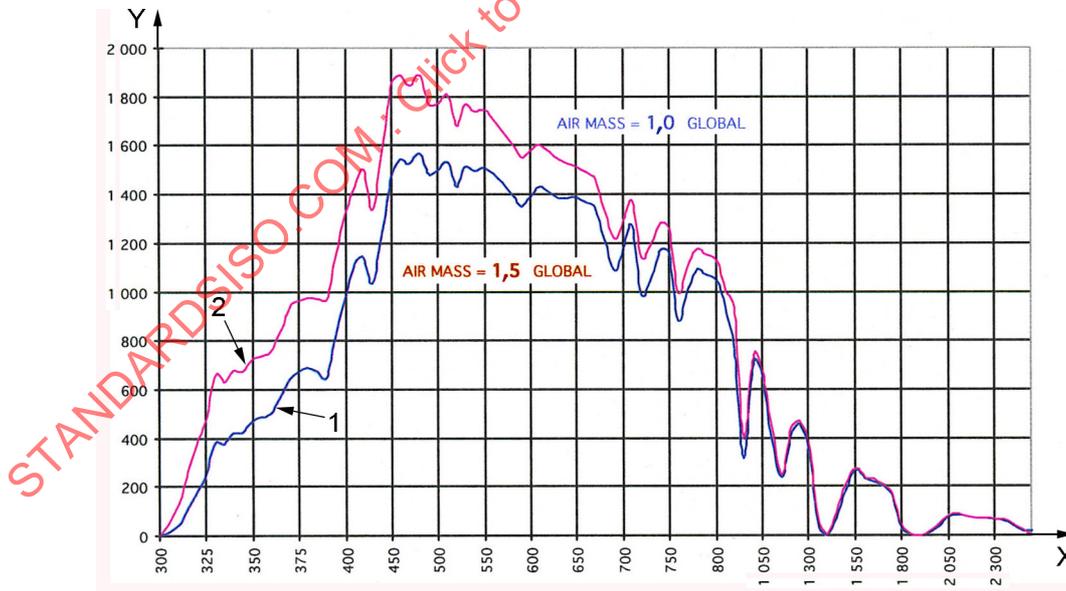
a See CIE 85:1989, Table 4, Column 2.
 b Air mass 1,0 g.
 c $E'_\lambda = E_\lambda \times D$, where $D = 0,5$ for UV; $D = 1,0$ for VIS.
 d $I E'_\lambda(n) = E'_\lambda / \sum E'_\lambda$.
 e $E'_\lambda = E_\lambda \times D$, where $D = 5,0$ for IR.
 f $E'_\lambda = E_\lambda \times D$, where $D = 0,5$ for UV.



Key

- X wavelength, λ , in nm
- Y normalized energy, $E'_{\lambda}(n)$
- 1 air mass 1,5 global
- 2 air mass 1,0 global

Figure A.1 — Normalized energy



Key

- X wavelength, λ , in nm
- Y solar energy within a uniform λ interval, E_{λ}
- 1 air mass 1,5 global
- 2 air mass 1,0 global

Figure A.2 — Hemispherical solar spectral irradiance (watts per square meter per micrometer)