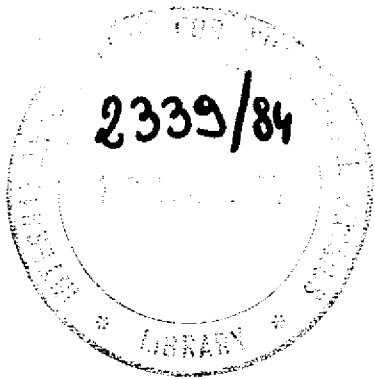


REFERENCE



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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

TABLE FOR MONTHLY AVERAGE DAILY EXTRATERRESTRIAL IRRADIATION
ON HORIZONTAL SURFACE AND THE MAXIMUM POSSIBLE SUNSHINE DURATION *

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ABSTRACT

The monthly average daily values of the extraterrestrial irradiation on a horizontal surface (H_0) and the maximum possible sunshine duration are two important parameters that are frequently needed in various solar energy applications. These are generally calculated by scientists each time they are needed and by using the approximate short-cut methods. Computations for these values have been made once and for all for latitude values of 60°N to 60°S at interval of 1° and are presented in a convenient tabular form. Values of the maximum possible sunshine duration as recorded on a Campbell Stoke's sunshine recorder are also computed and presented. These tables should avoid the need for repetition and approximate calculations and serve as a useful ready reference for solar energy scientists and engineers.

1. INTRODUCTION

The monthly average daily values of the extraterrestrial irradiation on a horizontal plane, H_0 , and the maximum possible sunshine duration (MPSD), S_0 , are two important parameters that are frequently needed in various solar energy applications. For instance, any attempts for estimating the global irradiation and the diffuse irradiation at a place invariably require the knowledge of one or both of these parameters at that place. The values of H_0 have been tabulated by Duffie and Beckman [1] for latitude intervals of 5° . The same authors also present graphs for the values of H_0 for recommended days of each month and nomogram for calculating the values of S_0 . However, these are often not convenient enough and it is observed that most of the solar energy scientists do their own calculations for the values of H_0 and S_0 at their location. For reducing the amount of calculations, short cut methods of using the middle day of each month or a single recommended day for each month [2] are generally employed to obtain approximate values of H_0 and S_0 . The purpose of this note is to provide these values once for all in a convenient tabular form so as to avoid the need of the repetitive and approximate calculations. Hopefully, this would serve as a useful ready reference for the solar energy scientists and engineers. Some authors prefer to calculate the modified values of the MPSD by taking into account the fact that the chart on the Campbell-Stokes sunshine recorder does not burn when the elevation of the sun is less than 5° [4,5]. We have therefore provided the monthly averages of the modified MPSD values as well.

2. COMPUTATIONS

All the calculations were done on the ICTP computer Gould 32/87. A computer programme was written and run on this computer. The values of H_0 for a given day and latitude value were computed using the equation

$$H_0 = \frac{24 \times 3600}{\pi} \times I_{sc} \left[1 + 0.033 \cos\left(\frac{360n}{365}\right) \right] \times (\cos \phi \cos \delta \sin \omega_s + \frac{2\pi \omega_s}{360} \sin \phi \sin \delta), \quad (1)$$

where n is the day of the year starting from January 1, ϕ , the latitude, ω_s , the sunset hour angle in degrees, I_{sc} , the solar constant and δ , the declination, is given by

$$\delta = 23.45 \sin \left(360 \frac{284+n}{365} \right). \quad (2)$$

The monthly averages for each of the month were then computed. The number of days in the month of February was taken to be 28 and the value of the solar constant as 1.353 KW/m^2 in all the computations. The results of the computations are presented in the first rows against each ϕ -value in Table 1.

The values of the solar constant have undergone revisions several times in the past. An account of these is given by Garg [3]. While we have used the presently accepted value of 1.353 KW/m^2 , it cannot be ruled out that there may be further revisions in the value of the solar constant in future. However, the values of H_0 corresponding to any other value of the solar constant can be easily obtained from the ones presented here simply by multiplying the tabulated values by the ratio of the new value of the solar constant to 1.353.

The values of S_0 for a given day and latitude value were computed using the relation

$$S_0 = \frac{2}{15} \cos^{-1} (-\tan \phi \tan \delta) \quad (3)$$

and the appropriate monthly averages were taken. The results of the computations are provided in second rows against each ϕ -value in Table 1.

The chart on the Campbell-Stokes sunshine recorder does not burn when the solar elevation is less than 5° . Therefore the value of the MPSD recorded on a sunshine recorder, S'_0 , is less than S_0 . Some authors prefer the use of S'_0 values to the S_0 values for the MPSD [4,5]. Therefore the values of S'_0 were also computed using the relation

$$S'_0 = \frac{2}{15} \cos^{-1} \left(\frac{\cos 85^\circ - \sin \phi \sin \delta}{\cos \phi \cos \delta} \right). \quad (4)$$

The values of the monthly averages are provided in the third rows against each ϕ -value in Table 1.

The north latitude values have been taken positive and the south ones negative.

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REFERENCES

- [1] J.A. Duffie and W.A. Beckman, Solar Engineering of Thermal Processes (John Wiley 1980).
- [2] S.A. Klein, Calculation of monthly average insolation on tilted surfaces, Solar Energy 19, 325-329 (1977).
- [3] H.P. Garg, Treatise on Solar Energy, Vol. 1, 65-70, John Wiley 1982.
- [4] J.E. Hay, Calculation of monthly mean solar radiation for horizontal and inclined surfaces. Solar Energy 23, 301-307 (1979).
- [5] A. Mani and S. Rangarajan, Techniques for the precise estimation of hourly values of global, diffuse and direct solar radiation. Solar Energy 31, N°6, 577-595 (1983).

TABLE 1: MONTHLY AVERAGE DAILY VALUES OF EXTRATERRESTRIAL RADIATION ON HORIZONTAL PLANE AND MAXIMUM POSSIBLE SUNSHINE DURATION.

φ	EXTRATERRESTRIAL RADIATION (IN MEGAJOULES)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00.0	2.45	8.23	16.74	27.29	36.27	40.56	38.39	30.60	20.27	10.67	4.46	3.26
	2.47	11.44	17.44	14.26	16.85	18.34	17.61	15.25	12.47	9.65	7.07	5.95
	4.22	7.14	10.08	12.87	15.21	16.44	15.85	13.79	11.12	8.16	5.06	3.90
10.0	3.97	8.82	17.32	27.71	36.46	40.61	38.51	30.93	20.79	11.24	5.00	3.75
	4.74	11.46	14.17	14.17	16.63	18.02	17.35	15.11	12.45	9.74	7.30	6.22
	4.67	7.35	10.14	12.83	15.06	16.22	15.67	13.70	11.14	8.31	5.42	4.35
20.0	4.49	9.42	17.89	28.13	36.55	40.69	38.63	31.26	21.32	11.89	5.35	4.11
	5.98	11.01	11.48	14.09	16.43	17.73	16.50	14.99	12.43	9.83	7.31	6.07
	5.06	7.54	10.20	12.78	14.92	16.03	15.50	13.62	11.16	8.45	5.74	4.67
30.0	5.03	10.02	18.46	28.53	36.85	40.72	38.75	31.59	21.84	12.46	6.10	4.83
	7.20	11.13	11.50	14.00	16.24	17.47	16.87	14.87	12.41	9.92	7.53	6.25
	5.40	7.71	10.26	12.74	14.79	15.84	15.34	13.55	11.18	8.58	5.63	4.51
40.0	5.58	10.62	19.02	28.93	37.03	40.78	38.87	31.91	22.35	13.05	6.27	4.93
	7.71	11.24	11.82	14.59	16.66	17.89	16.99	14.74	12.40	10.00	7.68	6.37
	5.71	7.87	10.31	12.69	14.66	15.67	15.19	13.47	11.20	8.70	5.82	4.69
50.0	6.14	11.32	19.57	29.33	37.22	40.84	38.99	32.23	22.85	13.54	7.24	5.77
	7.90	11.85	11.54	14.85	16.90	17.80	16.47	14.55	12.38	10.07	8.03	6.53
	5.98	8.03	10.36	12.65	14.54	15.51	15.05	13.40	11.21	8.81	5.93	4.83
60.0	6.71	11.83	20.13	29.72	37.40	40.90	39.11	32.54	23.35	14.24	7.82	6.54
	8.24	12.45	11.56	13.72	15.74	16.79	16.29	14.55	12.31	10.14	8.23	6.75
	6.24	8.17	10.41	12.62	14.43	15.36	14.92	13.34	11.23	8.92	6.75	5.54
70.0	7.29	12.43	20.67	30.10	37.58	40.96	39.23	32.84	23.84	14.82	8.41	7.40
	8.47	13.05	11.57	13.72	15.60	16.59	16.12	14.45	12.36	10.21	8.95	7.82
	6.47	8.30	10.45	12.56	14.33	15.21	14.79	13.27	11.24	9.02	6.82	5.82
80.0	7.87	13.03	21.21	30.47	37.75	41.02	39.34	33.13	24.32	15.41	9.00	8.43
	9.40	13.64	11.59	14.54	16.46	17.41	16.67	14.53	12.33	10.28	9.49	8.08
	6.69	8.43	10.49	12.54	14.23	15.07	14.67	13.21	11.25	9.12	7.14	6.08
90.0	8.46	13.63	21.74	30.83	37.92	41.07	39.45	33.42	24.80	15.99	9.59	9.00
	9.89	14.22	11.60	13.60	15.33	16.30	15.80	14.47	12.32	10.34	9.82	8.32
	6.89	8.55	10.53	12.51	14.13	14.94	14.56	13.15	11.27	9.21	7.76	6.32
100.0	9.05	14.23	22.27	31.19	38.08	41.12	39.55	33.70	25.27	16.57	10.18	9.58
	9.39	14.82	11.62	13.48	15.04	16.02	15.45	14.10	12.32	10.40	9.74	8.54
	7.08	8.66	10.57	12.48	13.64	14.82	14.45	13.10	11.11	9.30	7.74	6.54

FIRST ROW: EXTRATERRESTRIAL RADIATION (IN MEGAJOULES)
 SECOND ROW: ACTUAL MAXIMUM POSSIBLE SUNSHINE DURATION (IN HOURS)
 THIRD ROW: MAXIMUM POSSIBLE SUNSHINE DURATION ON SUNSHINE RECORDER (IN HOURS)

φ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
49.0	9.55 8.53 7.26	14.83 9.88 8.77	22.79 11.63 10.60	31.54 19.49 12.44	38.23 15.08 13.95	41.17 15.91 14.70	39.65 15.52 14.34	39.98 14.11 13.04	25.73 12.31 11.24	17.15 10.46 9.38	10.78 9.57 8.35	9.18 8.97 7.74
48.0	10.25 8.56 7.43	15.42 9.96 8.87	23.30 11.64 10.64	31.88 13.43 12.41	38.58 14.97 13.86	41.21 15.34 14.58	39.74 15.34 14.24	34.24 14.04 12.99	25.18 12.00 11.30	17.32 10.51 9.44	11.38 9.79 8.80	9.28 9.03 7.84
47.0	10.85 8.78 7.59	15.02 10.03 8.97	23.81 11.66 10.67	32.21 12.38 12.38	38.52 14.86 13.78	41.25 15.22 14.47	39.82 15.26 14.15	34.50 12.94 12.94	24.63 11.31 11.31	18.32 10.56 9.53	11.99 9.97 8.94	9.35 9.12 7.92
46.0	11.45 9.74 7.74	15.61 10.10 9.06	24.31 11.67 10.70	32.54 12.35 12.35	38.65 14.76 13.70	41.28 15.49 14.37	39.90 15.40 14.08	34.75 12.89 12.89	27.07 12.38 11.31	18.85 10.61 9.60	12.58 9.28 8.08	9.55 9.28 7.99
45.0	12.04 9.77 7.88	17.20 10.17 9.15	24.80 11.68 10.73	32.85 12.33 12.33	38.78 14.62 13.62	41.30 15.36 14.26	39.97 15.09 13.96	34.99 12.84 12.84	27.50 11.32 11.32	19.41 10.67 9.67	13.18 9.30 8.20	10.55 9.63 7.45
44.0	12.67 8.02	17.78 9.23	25.27 10.75	33.16 12.30	38.89 13.55	41.31 14.17	40.03 13.88	35.22 12.80	27.92 11.33	19.97 10.74	13.79 8.33	11.15 9.74
43.0	13.28 8.15	18.39 9.31	25.76 10.78	33.45 12.27	38.90 13.48	41.32 14.07	40.07 13.79	35.44 12.75	28.34 11.33	20.53 10.80	14.39 8.44	11.76 9.76
42.0	13.89 8.27	18.94 9.39	26.23 10.81	33.74 12.24	39.10 13.41	41.33 13.98	40.14 13.71	35.65 12.71	28.74 11.34	21.04 10.84	14.99 8.55	12.37 9.90
41.0	14.42 8.39	19.51 9.47	26.70 10.83	34.02 12.22	39.19 13.34	41.34 13.89	40.18 13.63	35.85 12.67	29.14 11.35	21.60 10.92	15.57 8.66	13.08 9.03
40.0	15.01 8.50	20.08 9.54	27.15 10.85	34.28 12.19	39.28 13.27	41.35 13.80	40.21 13.56	36.05 12.63	29.59 11.36	22.12 10.93	16.19 8.77	13.66 9.14
39.0	15.71 8.61	20.64 9.61	27.59 10.88	34.54 12.17	39.35 13.21	41.36 13.72	40.23 13.48	36.23 12.59	29.91 11.36	22.64 10.93	16.78 8.86	14.31 9.24
38.0	16.32 8.72	21.20 9.68	28.03 10.90	34.79 12.14	39.41 13.15	41.37 13.64	40.24 13.41	36.41 12.55	30.28 11.36	23.13 10.98	17.38 8.96	14.82 9.40
37.0	16.92 8.82	21.76 9.74	28.46 10.92	35.03 12.12	39.47 13.09	41.38 13.56	40.25 13.34	36.57 12.51	30.64 11.36	23.69 10.93	17.97 9.05	15.43 9.52
36.0	17.52 8.92	22.30 9.80	28.88 10.94	35.26 12.10	39.51 13.03	41.40 13.48	40.24 13.27	36.73 12.47	30.99 11.37	24.20 10.98	18.56 9.14	16.04 9.63
φ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
35.0	18.12 9.01	22.85 9.86	29.38 10.96	35.48 12.07	39.55 12.97	41.41 13.40	40.23 13.20	36.88 12.43	31.33 11.37	24.70 10.92	19.14 9.23	16.66 9.74
34.0	18.72 9.11	23.39 9.92	29.79 10.97	35.67 12.05	39.57 12.91	41.42 13.33	40.21 13.13	37.01 12.40	31.68 11.37	25.20 10.92	19.73 9.31	17.26 9.84
33.0	19.32 9.20	23.92 9.98	30.19 10.99	35.88 12.03	39.59 12.85	41.43 13.26	40.17 13.07	37.18 12.36	31.99 11.38	25.67 10.91	20.30 9.39	17.87 9.94
32.0	19.91 9.28	24.44 10.04	30.58 11.01	36.07 12.00	39.59 12.80	41.44 13.19	40.13 13.00	37.35 12.32	32.34 11.38	26.17 10.93	20.84 9.47	18.48 9.04
31.0	20.50 9.37	24.96 10.09	30.95 11.03	36.25 11.98	39.59 12.75	41.45 13.12	40.08 12.94	37.50 12.29	32.64 11.38	26.64 10.94	21.45 9.55	19.08 9.13
30.0	21.08 9.45	25.47 10.14	31.32 11.04	36.42 11.94	39.58 12.69	41.46 13.05	40.02 12.88	37.65 12.25	32.90 11.38	27.10 10.94	22.02 9.62	19.68 9.22
29.0	21.66 9.53	25.98 10.19	31.68 11.05	36.57 11.94	39.55 12.64	41.47 12.98	39.95 12.82	37.83 12.22	33.15 11.38	27.56 10.94	22.58 9.69	20.28 9.31
28.0	22.24 9.61	26.48 10.24	32.03 11.07	36.72 11.92	39.52 12.59	41.48 12.91	39.87 12.76	37.97 12.19	33.44 11.38	28.04 10.94	23.14 9.76	20.88 9.40
27.0	22.81 9.68	27.07 10.29	32.38 11.08	36.86 11.89	39.47 12.54	41.49 12.85	39.78 12.70	37.67 12.15	33.74 11.38	28.49 10.95	23.69 9.83	21.47 9.48
26.0	23.38 9.75	27.45 10.34	32.74 11.10	36.98 11.87	39.42 12.49	41.50 12.78	39.67 12.65	37.72 12.12	33.97 11.39	28.87 10.95	24.23 9.90	22.05 9.56
25.0	23.95 9.83	27.93 10.39	33.09 11.11	37.09 11.85	39.35 12.44	41.51 12.72	39.56 12.59	37.85 12.09	34.23 11.39	29.31 10.96	24.78 9.97	22.64 9.64
24.0	24.50 9.90	28.40 10.43	33.44 11.12	37.19 11.83	39.28 12.39	41.52 12.66	39.44 12.53	37.97 12.06	34.45 11.39	29.73 10.96	25.31 10.03	23.23 9.72
23.0	25.04 9.97	28.86 10.48	33.78 11.14	37.28 11.81	39.19 12.34	41.53 12.60	39.31 12.48	37.81 12.02	34.67 11.39	30.14 10.97	25.84 10.09	23.79 9.80
22.0	25.60 10.03	29.31 10.52	34.11 11.15	37.37 11.79	39.09 12.29	41.54 12.53	39.17 12.42	37.83 11.99	34.89 11.39	30.54 10.97	26.33 10.15	24.36 9.88
21.0	26.14 10.10	29.76 10.56	34.44 11.16	37.44 11.77	38.99 12.25	41.55 12.47	39.04 12.37	37.82 11.96	35.09 11.39	30.93 10.97	26.88 10.21	24.93 9.95

φ	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
20.0	26.68 10.94 10.16	30.20 10.20 10.20	34.35 11.88 11.17	37.47 12.75 11.47	39.87 12.20 12.20	39.12 12.41 12.31	38.86 12.08 12.31	37.81 12.63 11.93	35.28 12.10 11.39	31.21 11.52 10.79	27.39 11.27 10.24	25.49 10.81 10.02
19.0	27.21 10.23 10.23	30.53 10.24 10.24	34.61 11.88 11.18	37.54 12.44 11.73	39.74 12.15 12.15	38.91 12.32 12.32	38.69 12.08 12.26	37.79 12.60 11.90	35.46 12.09 11.39	31.67 10.82 10.82	27.87 11.33 10.33	26.04 10.87 10.09
18.0	27.73 10.29 10.29	31.05 10.48 10.48	34.85 11.90 11.19	37.58 12.42 11.71	39.61 12.11 12.11	38.69 12.30 12.30	38.51 12.04 12.21	37.76 12.59 11.87	35.63 12.09 11.39	32.09 10.85 10.85	28.39 11.39 10.39	26.59 10.94 10.16
17.0	28.25 10.55 10.55	31.45 10.72 10.72	35.09 11.20 11.20	37.61 12.68 11.68	39.46 12.06 12.06	38.47 12.24 12.24	38.33 12.04 12.14	37.71 12.54 11.84	35.79 12.08 11.38	32.41 10.89 10.89	28.98 11.44 10.44	27.14 11.00 10.23
16.0	28.76 10.41 10.41	31.88 10.78 10.78	35.32 11.21 11.21	37.62 12.67 11.66	39.39 12.05 12.05	38.24 12.19 12.19	38.12 12.05 12.10	37.66 12.52 11.81	35.94 12.09 11.39	32.75 10.91 10.91	29.36 11.50 10.50	27.67 11.06 10.30
15.0	29.26 10.47 10.47	32.25 10.80 10.80	35.59 11.22 11.22	37.63 12.64 11.64	39.13 11.97 11.97	37.98 12.12 12.12	37.91 12.05 12.05	37.59 12.45 11.75	36.07 12.07 11.37	33.07 10.94 10.94	29.84 11.55 10.55	28.20 11.13 10.43
14.0	29.76 10.53 10.53	32.64 10.84 10.84	35.74 11.23 11.23	37.64 12.62 11.62	38.92 11.92 11.92	37.72 12.07 12.07	37.64 12.00 12.00	37.51 12.75 11.75	36.20 12.07 11.37	33.07 10.97 10.97	30.30 11.54 10.54	28.73 11.19 10.43
13.0	30.24 10.59 10.59	33.01 10.87 10.87	35.93 11.24 11.24	37.65 12.60 11.60	38.76 11.88 11.88	37.46 12.01 12.01	37.46 12.00 11.99	37.49 12.42 11.71	36.32 12.08 11.38	33.73 11.66 11.66	30.76 11.56 10.56	29.29 11.25 10.50
12.0	30.72 10.65 10.65	33.39 10.91 10.91	36.11 11.25 11.25	37.66 12.58 11.58	38.55 11.83 11.83	37.18 12.05 11.95	37.22 12.00 11.90	37.22 12.75 11.75	36.42 12.07 11.37	34.04 11.65 11.65	31.22 11.57 10.57	29.76 11.31 10.56
11.0	31.20 10.70 10.70	33.74 10.95 10.95	36.39 11.26 11.26	37.67 12.56 11.56	38.35 11.79 11.79	36.83 12.03 11.90	36.87 12.00 11.85	37.25 12.75 11.75	36.51 12.07 11.37	34.33 11.65 11.65	31.66 11.58 10.58	30.29 11.32 10.57
10.0	31.66 10.76 10.76	34.08 10.98 10.98	36.44 11.26 11.26	37.68 12.54 11.54	38.14 11.74 11.74	36.97 12.00 11.84	36.71 12.00 11.80	37.10 12.72 11.72	36.60 12.07 11.37	34.60 11.68 11.68	32.09 11.61 10.61	30.76 11.33 10.58
9.0	32.12 10.81 10.81	34.42 11.02 11.02	36.59 11.27 11.27	37.69 12.52 11.52	38.01 11.70 11.70	36.92 12.00 11.78	36.44 12.00 11.74	37.26 12.72 11.72	36.67 12.07 11.37	34.89 11.70 11.70	32.56 11.63 10.63	31.46 11.35 10.60
8.0	32.57 10.87 10.87	34.75 11.05 11.05	36.73 11.28 11.28	37.70 12.50 11.50	37.87 11.66 11.66	35.78 12.00 11.73	36.19 12.00 11.69	36.89 12.70 11.70	36.78 12.03 11.33	35.16 11.63 11.63	33.05 11.66 10.66	32.31 11.38 10.63
7.0	33.01 10.92 10.92	35.07 11.08 11.08	36.86 11.29 11.29	37.71 12.48 11.48	36.42 11.61 11.61	35.66 12.00 11.67	35.89 12.00 11.64	37.28 12.70 11.70	36.88 12.03 11.33	35.42 11.65 11.65	33.54 11.68 10.68	33.01 11.41 10.67
6.0	33.44 10.97 10.97	35.37 11.12 11.12	36.99 11.29 11.29	37.72 12.45 11.45	36.16 11.57 11.57	35.33 12.00 11.61	35.58 12.00 11.59	37.52 12.70 11.70	36.81 12.03 11.33	35.66 11.68 11.68	34.01 11.71 10.71	33.68 11.43 10.68
5.0	33.97 11.03 11.03	35.67 11.15 11.15	37.08 11.30 11.30	37.73 12.43 11.43	35.89 11.52 11.52	34.99 12.00 11.56	35.27 12.00 11.54	37.69 12.70 11.70	36.84 12.03 11.33	35.90 11.70 11.70	34.14 11.74 10.74	33.13 11.45 10.70
4.0	34.28 11.08 11.08	35.96 11.18 11.18	37.18 11.31 11.31	37.74 12.41 11.41	35.61 11.48 11.48	34.64 12.00 11.50	34.96 12.00 11.49	37.86 12.70 11.70	36.86 12.03 11.33	36.12 11.73 11.73	34.52 11.77 11.77	33.57 11.47 11.04
3.0	34.67 11.13 11.13	36.24 11.22 11.22	37.28 11.31 11.31	37.75 12.39 11.39	35.32 11.43 11.43	34.28 12.00 11.45	34.63 12.00 11.44	38.03 12.70 11.70	36.86 12.03 11.33	36.33 11.75 11.75	34.90 11.81 11.81	34.03 11.50 11.10
2.0	35.08 11.18 11.18	36.50 11.25 11.25	37.33 11.32 11.32	37.76 12.37 11.37	35.03 11.39 11.39	33.91 12.00 11.39	34.30 12.00 11.39	38.20 12.70 11.70	36.85 12.03 11.33	36.54 11.78 11.78	35.26 11.84 11.84	34.49 11.16 11.16
1.0	35.47 11.23 11.23	36.76 11.28 11.28	37.39 11.33 11.33	37.77 12.35 11.35	34.72 11.34 11.34	33.54 12.00 11.33	33.96 12.00 11.34	38.39 12.70 11.70	36.84 12.03 11.33	36.72 11.80 11.80	35.95 11.91 11.91	34.89 11.22 11.22
0	35.85 11.29 11.29	37.01 12.31 12.31	37.44 11.33 11.33	37.78 12.32 11.32	34.40 11.30 11.30	33.16 12.00 11.28	33.61 12.00 11.28	38.58 12.70 11.70	36.81 12.03 11.33	36.91 11.82 11.82	35.96 12.00 11.29	35.71 12.00 11.28
-1.0	36.22 11.34 11.34	37.24 12.35 12.35	37.48 11.34 11.34	37.79 12.30 11.30	34.08 11.25 11.25	32.77 12.00 11.23	33.25 12.00 11.23	38.77 12.70 11.70	36.77 12.03 11.33	37.08 11.85 11.85	36.30 12.00 11.34	35.71 12.06 11.33
-2.0	36.58 11.39 11.39	37.47 12.38 12.38	37.50 11.34 11.34	37.80 12.28 11.28	33.74 11.20 11.20	32.88 11.18 11.18	32.88 11.18 11.18	38.96 12.70 11.70	36.71 12.03 11.33	37.24 11.87 11.87	36.09 12.00 11.39	35.11 12.11 11.39
-3.0	36.93 11.44 11.44	37.68 12.41 12.41	37.52 11.35 11.35	37.81 12.25 11.25	33.40 11.16 11.16	32.50 11.10 11.10	32.50 11.10 11.10	39.15 12.70 11.70	36.65 12.03 11.33	37.39 11.90 11.90	35.94 12.00 11.43	35.50 12.14 11.45
-4.0	37.27 11.49 11.49	37.88 12.44 12.44	37.52 11.35 11.35	37.82 12.23 11.23	33.05 11.11 11.11	32.12 11.08 11.08	32.12 11.08 11.08	39.34 12.70 11.70	36.58 12.03 11.33	37.53 11.93 11.93	35.88 12.00 11.48	35.09 12.18 11.50
-5.0	37.60 12.54 12.54	38.07 12.47 12.47	37.51 11.36 11.36	37.83 12.21 11.21	32.68 11.06 11.06	31.73 10.99 10.99	31.73 10.99 10.99	39.53 12.70 11.70	36.51 12.03 11.33	37.65 12.00 11.44	35.82 12.00 11.52	34.26 12.26 11.56
-6.0	37.93 12.59 12.59	38.26 12.50 12.50	37.49 11.36 11.36	37.84 12.18 11.18	32.31 11.02 11.02	31.22 10.93 10.93	31.22 10.93 10.93	39.72 12.70 11.70	36.40 12.03 11.33	37.79 12.00 11.46	35.77 12.00 11.57	33.42 12.34 11.61
-7.0	38.24 12.64 12.64	38.43 12.53 12.53	37.46 11.37 11.37	37.85 12.16 11.16	31.93 10.97 10.97	30.91 10.87 10.87	30.91 10.87 10.87	39.91 12.70 11.70	36.29 12.03 11.33	37.97 12.00 11.48	35.71 12.00 11.61	32.77 12.40 11.67

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-8.0	38.54 12.41 11.69	38.58 12.25 11.56	37.42 12.04 11.37	34.69 11.82 11.14	31.55 11.63 10.92	29.80 11.34 10.81	30.49 11.37 10.86	33.18 11.05 11.05	34.17 11.29 11.29	37.97 12.19 11.50	38.37 12.37 11.66	38.22 12.46 11.73
-9.0	38.83 11.74	38.73 12.09 11.59	37.37 12.05 11.37	34.43 11.80 11.11	31.15 11.59 10.87	29.35 11.48 10.75	30.07 11.33 10.80	32.87 11.02 11.02	34.04 11.28 11.28	38.05 12.21 11.53	38.63 12.42 11.70	38.65 12.52 11.78
-10.0	39.11 12.51 11.79	38.87 12.32 11.62	37.30 12.06 11.38	34.17 11.77 11.09	30.75 11.54 10.82	28.89 11.43 10.68	29.64 11.48 10.75	32.55 11.28 11.28	35.05 11.27 11.27	38.12 12.23 11.55	38.87 12.47 11.75	38.97 12.58 11.84
-11.0	39.38 12.57 11.84	38.99 12.39 11.65	37.23 12.06 11.38	33.89 11.75 11.06	30.34 11.49 10.77	28.43 11.37 10.62	29.20 11.43 10.69	32.22 11.25 11.25	35.75 11.27 11.27	38.18 12.26 11.57	39.11 12.51 11.80	39.29 12.63 11.90
-12.0	39.64 12.62 11.89	39.11 12.42 11.69	37.14 12.07 11.38	33.60 11.73 11.03	29.92 11.45 10.72	27.47 11.31 10.56	28.29 11.37 10.64	31.88 11.23 11.23	35.84 11.25 11.25	38.23 12.28 11.59	39.33 12.56 11.84	39.59 12.69 11.95
-13.0	39.89 12.67 11.94	39.21 12.42 11.72	37.04 12.07 11.39	33.31 11.70 11.01	29.49 11.40 10.67	27.47 11.30 10.55	28.29 11.36 10.63	31.53 11.23 11.23	35.42 11.25 11.25	38.27 12.31 11.61	39.54 12.61 11.89	39.87 12.75 12.01
-14.0	40.13 12.71 11.99	39.30 12.45 11.75	36.93 12.08 11.39	33.00 11.68 10.98	29.05 11.35 10.62	26.99 11.19 10.43	27.83 11.26 10.52	31.17 11.15 11.15	35.24 11.24 11.24	38.29 12.33 11.63	39.75 12.66 11.93	40.17 12.81 12.07
-15.0	40.36 12.74 12.04	39.49 12.49 11.78	36.81 12.09 11.39	32.69 11.66 10.95	28.61 11.30 10.56	26.49 11.13 10.44	27.36 11.21 10.48	30.81 11.11 11.11	35.04 11.24 11.24	38.31 12.36 11.66	39.94 12.71 11.98	40.45 12.87 12.12
-16.0	40.58 12.78 12.09	39.46 12.49 11.81	36.68 12.09 11.40	32.36 11.63 10.93	28.16 11.25 10.51	25.99 11.06 10.30	26.87 11.15 10.40	30.48 11.08 10.75	34.84 11.23 11.23	38.31 12.38 11.68	39.74 12.76 12.02	40.71 12.94 12.18
-17.0	40.79 12.81 12.14	39.51 12.55 11.84	36.54 12.10 11.40	32.03 11.60 10.90	27.70 11.20 10.46	25.49 11.00 10.23	26.41 11.10 10.34	30.05 11.05 10.72	34.62 11.22 11.22	38.30 12.41 11.70	39.80 12.81 12.07	40.97 13.00 12.24
-18.0	40.99 12.84 12.20	39.56 12.59 11.87	36.38 12.10 11.40	31.69 11.58 10.87	27.24 11.15 10.40	24.98 11.04 10.28	25.92 11.04 10.28	29.66 11.01 10.68	34.40 11.21 11.21	38.28 12.42 11.72	39.45 12.84 12.12	41.21 13.06 12.30
-19.0	41.17 12.87 12.25	39.60 12.63 11.90	36.22 12.11 11.40	31.33 11.56 10.84	26.77 11.10 10.35	24.46 10.88 10.09	25.43 10.98 10.21	29.26 11.01 10.64	34.16 11.20 11.20	38.25 12.44 11.74	39.60 12.91 12.16	41.44 13.13 12.36
-20.0	41.35 12.90 12.30	39.62 12.66 11.93	36.04 12.12 11.41	30.97 11.54 10.81	26.29 11.05 10.29	23.94 10.81 10.02	24.93 10.92 10.15	28.85 11.01 10.60	33.91 11.19 11.19	38.21 12.46 11.76	39.19 12.94 12.21	41.67 13.21 12.42
-21.0	41.53 12.93 12.35	39.63 12.70 11.96	35.85 12.12 11.41	30.60 11.51 10.78	25.80 11.00 10.23	23.42 10.74 9.95	24.42 10.86 10.08	28.43 11.30 10.56	33.66 11.18 11.18	38.16 12.48 11.78	39.16 13.02 12.26	41.88 13.26 12.48

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-22.0	41.71 12.97 12.41	39.64 12.73 11.99	35.66 12.13 11.41	30.22 11.48 10.75	25.31 11.17 10.17	22.89 10.88 9.88	23.81 10.82 10.02	28.01 11.27 10.52	33.39 11.17 11.17	38.09 12.54 11.81	40.99 13.07 12.31	42.08 13.34 12.54
-23.0	41.89 12.99 12.46	39.69 12.77 12.03	35.45 12.14 11.41	29.83 11.46 10.72	24.82 10.99 10.11	22.31 10.71 9.80	23.24 10.74 9.95	27.57 11.23 10.48	33.12 11.16 11.16	38.02 12.55 11.83	41.02 13.09 12.36	42.39 13.39 12.60
-24.0	41.95 12.99 12.52	39.61 12.76 12.06	35.23 12.14 11.41	29.44 11.43 10.68	24.31 10.85 10.05	21.81 10.54 9.72	22.87 10.88 10.43	27.13 11.19 10.43	32.83 11.15 11.15	37.29 12.58 11.85	41.18 13.18 12.40	42.46 13.46 12.68
-25.0	42.07 12.97 12.57	39.57 12.75 12.09	35.09 12.15 11.41	29.03 11.40 10.65	23.80 10.98 9.98	21.27 10.47 9.65	22.35 10.81 9.81	26.69 11.15 10.39	32.53 11.14 11.14	37.84 12.61 11.87	41.27 13.24 12.45	42.63 13.72 12.72
-26.0	42.19 12.93 12.63	39.53 12.74 12.12	34.76 12.16 11.41	28.62 11.37 10.61	23.32 10.92 9.92	20.72 10.57 9.75	21.83 10.95 9.75	26.23 11.11 10.34	32.23 11.12 11.12	37.73 12.63 11.90	41.34 13.29 12.50	42.79 13.60 12.79
-27.0	42.29 12.93 12.68	39.48 12.73 12.16	34.51 12.16 11.41	28.20 11.36 10.58	22.77 10.85 9.85	20.17 10.33 9.48	21.28 10.46 9.66	25.77 11.07 10.29	31.91 11.11 11.11	37.61 12.68 11.92	41.41 13.35 12.55	42.97 13.85 12.85
-28.0	42.38 12.96 12.74	39.41 12.71 12.19	34.24 12.17 11.41	27.77 11.32 10.54	22.25 10.94 9.94	19.61 10.25 9.40	20.74 10.48 9.58	25.30 11.03 10.29	31.59 11.10 11.10	37.49 12.64 11.94	41.46 13.41 12.61	43.08 13.94 12.87
-29.0	42.49 12.93 12.80	39.34 12.71 12.22	33.97 12.18 11.41	27.33 11.31 10.51	21.73 10.92 9.92	19.05 10.16 9.31	20.35 10.35 9.50	24.83 10.96 10.20	31.23 11.09 11.09	37.34 12.66 11.96	41.50 13.47 12.63	43.21 14.02 12.93
-30.0	42.59 12.90 12.86	39.25 12.70 12.26	33.69 12.18 11.41	26.88 11.27 10.47	21.18 10.84 9.84	18.49 10.10 9.22	19.25 10.28 9.42	24.35 10.94 10.14	30.90 11.05 11.05	37.19 12.67 11.99	41.53 13.50 12.71	43.33 14.10 13.05
-31.0	42.57 12.77 12.92	39.15 12.69 12.29	33.40 12.19 11.41	26.43 11.23 10.43	20.64 10.82 9.82	17.93 10.03 9.13	19.10 10.21 9.34	23.86 10.91 10.09	30.55 11.04 11.04	37.02 12.80 12.01	41.55 13.60 12.77	43.44 14.18 13.12
-32.0	42.64 12.84 12.98	39.04 12.68 12.33	33.10 12.20 11.41	25.97 11.20 10.39	20.10 10.76 9.76	17.36 9.94 9.04	18.54 10.14 9.26	23.36 10.86 10.04	30.19 11.03 11.03	36.85 12.83 12.03	41.56 13.68 12.82	43.54 14.26 13.19
-33.0	42.68 13.01 13.04	38.92 12.68 12.36	32.78 12.21 11.41	25.50 11.17 10.35	19.55 10.72 9.72	16.77 9.86 8.94	17.97 10.17 9.17	22.86 10.82 9.98	29.81 11.03 11.03	36.67 12.87 12.06	41.56 13.73 12.88	43.63 14.34 13.26
-34.0	42.71 13.09 13.11	38.79 12.67 12.40	32.46 12.22 11.41	25.02 11.13 10.30	19.00 10.69 9.69	16.22 9.77 8.84	17.43 10.08 9.08	22.35 10.73 9.93	29.43 11.02 11.01	36.47 12.90 12.08	41.55 13.80 12.93	43.72 14.43 13.33
-35.0	42.73 13.06 13.17	38.65 12.68 12.43	32.13 12.22 11.41	24.54 11.10 10.26	18.45 10.66 9.66	15.65 9.69 8.74	16.86 10.06 9.06	21.84 10.73 9.87	29.04 11.01 11.01	36.27 12.93 12.11	41.53 13.87 12.99	43.79 14.51 13.41

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-36.0	42.74 13.24	38.50 12.47	31.79 11.41	24.05 10.22	17.89 9.17	15.08 8.63	16.30 8.89	21.32 10.81	28.64 10.98	36.05 12.13	41.50 13.05	43.85 14.48
-37.0	42.74 13.51	38.37 12.51	31.44 11.40	23.55 10.17	17.33 9.08	14.50 8.52	15.73 8.79	20.80 10.94	28.23 10.96	35.83 12.16	41.49 13.11	43.90 13.56
-38.0	42.74 13.58	38.17 12.55	31.08 11.40	23.05 10.12	16.74 8.99	13.93 8.41	15.16 8.68	20.27 10.58	27.82 10.94	35.59 12.18	41.14 13.17	43.74 13.64
-39.0	42.70 13.45	37.98 12.59	30.71 11.40	22.54 10.07	16.20 8.90	13.35 8.39	14.57 8.58	19.74 10.72	27.39 10.92	35.35 12.21	41.34 13.24	43.98 13.72
-40.0	42.67 13.52	37.79 12.63	30.33 11.40	22.03 10.02	15.63 8.80	12.78 8.16	14.02 8.47	19.20 10.54	26.86 10.90	35.09 12.25	41.27 13.30	44.00 13.81
-41.0	42.64 13.80	37.59 12.67	29.94 11.39	21.51 9.98	15.06 8.70	12.20 8.04	13.45 8.35	18.66 10.47	26.52 11.88	34.83 12.28	41.19 13.37	44.02 13.89
-42.0	42.59 13.88	37.38 12.71	29.54 11.39	20.99 9.91	14.49 8.59	11.62 7.90	12.89 8.25	18.12 10.39	26.17 10.86	34.55 12.29	41.10 13.44	44.01 13.98
-43.0	42.53 13.78	37.15 12.72	29.13 11.38	20.45 9.85	13.91 8.48	11.08 7.78	12.31 8.10	17.57 10.32	25.81 10.83	34.27 12.32	41.00 13.51	44.03 14.07
-44.0	42.48 13.84	36.92 12.80	28.72 11.38	19.91 9.79	13.34 8.37	10.49 7.61	11.73 7.97	17.01 10.23	25.14 11.81	33.97 12.34	40.90 13.58	44.01 14.17
-45.0	42.39 13.92	36.68 12.85	28.30 11.37	19.37 9.72	12.76 8.25	9.72 7.46	11.16 7.83	16.45 10.15	24.68 11.78	33.67 12.37	40.78 13.66	44.00 14.27
-46.0	42.31 14.01	36.43 12.89	27.86 11.37	18.82 9.66	12.19 8.12	9.35 7.30	10.59 7.69	15.89 10.06	24.20 11.75	33.36 12.40	40.66 13.74	43.97 14.37
-47.0	42.22 14.10	36.17 12.94	27.42 11.36	18.27 9.59	11.61 7.99	8.79 7.12	10.03 7.54	15.33 10.07	23.71 11.73	33.04 12.44	40.53 13.82	43.94 14.48
-48.0	42.12 14.20	35.90 12.99	26.98 11.36	17.71 9.52	11.04 7.89	8.23 7.38	9.46 7.98	14.76 9.87	23.22 11.70	32.71 12.47	40.38 13.90	43.90 14.59
-49.0	42.02 14.30	35.62 13.05	26.52 11.35	17.15 9.44	10.47 7.78	7.68 6.75	8.90 7.20	14.20 9.77	22.72 11.67	32.37 12.50	40.24 13.99	43.86 14.70

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-50.0	41.91 14.40	35.34 13.10	26.06 11.34	16.58 9.36	9.90 7.54	7.13 6.54	8.34 7.02	13.63 8.66	22.21 10.68	32.02 12.63	40.08 14.08	43.81 14.82
-51.0	41.79 14.51	35.04 13.16	25.58 11.33	16.02 9.28	9.33 7.38	6.77 6.32	7.79 6.83	13.05 8.55	21.70 10.60	31.66 12.67	39.92 14.17	43.76 14.95
-52.0	41.67 14.62	34.74 13.22	25.10 11.32	15.44 9.19	8.76 7.20	6.09 6.08	7.24 6.62	12.48 8.43	21.18 10.58	31.30 12.61	39.75 14.27	43.70 15.08
-53.0	41.55 14.74	34.43 13.28	24.62 11.31	14.87 9.10	8.20 7.02	5.52 5.83	6.69 6.40	11.91 8.30	20.64 10.52	30.93 12.64	39.58 14.38	43.60 15.21
-54.0	41.42 14.86	34.12 13.34	24.14 11.30	14.29 9.00	7.64 6.81	5.00 5.55	6.15 6.16	11.33 8.17	20.12 10.48	30.62 12.64	39.40 14.48	43.54 15.36
-55.0	41.28 14.99	33.79 13.41	23.62 11.29	13.71 8.89	7.08 6.60	4.49 5.24	5.65 5.90	10.76 8.03	19.59 10.44	30.30 12.72	39.21 14.60	43.51 15.51
-56.0	41.15 15.13	33.46 13.48	23.12 11.28	13.13 8.78	6.53 6.36	3.98 4.90	5.12 5.62	10.18 7.88	19.04 10.39	29.97 12.77	39.02 14.72	43.45 15.68
-57.0	41.01 15.28	33.13 13.55	22.60 11.26	12.54 8.66	5.99 6.11	3.50 4.52	4.39 5.31	9.61 7.71	18.57 10.34	29.77 12.81	38.84 14.84	43.37 15.85
-58.0	40.87 15.43	32.79 13.63	22.08 11.25	11.95 8.54	5.46 5.83	3.03 4.08	4.08 4.95	9.04 7.54	17.97 10.29	29.59 12.86	38.64 14.98	43.34 16.03
-59.0	40.73 15.60	32.44 13.71	21.55 11.23	11.37 8.40	4.93 5.51	2.57 3.56	3.59 4.55	8.47 7.35	17.37 10.23	29.40 12.91	38.45 15.12	43.27 16.23
-60.0	40.59 15.78	32.09 13.79	21.02 11.21	10.78 8.28	4.41 5.16	2.13 3.11	3.11 4.08	7.90 7.14	16.81 10.17	29.23 12.98	38.26 15.27	43.23 16.46

