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A SIMPLIFIED METHOD FOR KINEMATIC CALCULATIONS OF NUCLEAR REACTIONS

by

J. WINTER and H. SCHMID

1968

Joint Nuclear Research Center
Geel Establishment - Belgium

Central Bureau for Nuclear Measurements - CBNM

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reactions may be calculated by means of only one equation. To facilitate handling, this equation has been tabulated. In the single valued region ($0 \leq \eta \leq 1$) the incremental step of the parameter η is 0.01 and the angle Θ increases in steps of 5 deg. from 0 to 180 deg. In the double valued region ($\eta > 1$) tabulation of η is given only up to $\eta = 2$, the incremental steps being 0.02 and 5 deg.

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SUMMARY

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KEYWORDS

NUCLEAR REACTIONS
ANGULAR DISTRIBUTION
DIAGRAMS
EQUATIONS
TABLES
ENERGY
PARTICLES

A simplified method for kinematic calculations of nuclear reactions *

The formulas describing the non-relativistic kinematics of nuclear reactions are rather combersone. To facilitate handling they have been represented for some reactions in form of tables and diagrams [1-5]. The number of reactions and quantities of interest is numerous and therefore also the number of diagrams. A very general representation was proposed by Dickens [5] but even there for each type of reaction, e.g. (p,p), (p,d) ... another diagram must be used.

In this paper a general formula for all non-relativistic reactions is given in terms of normalized quantities. The formula may be represented by one nomogram or one table. The normalized quantities themselves are in simple relation to the physical quantities and can be calculated easily.

We consider the following case: A projectile particle with mass m_1 and kinetic energy E_1 collides with a target particle m_2 being at rest ($E_2 = 0$) in the lab. (laboratory) frame. Two particles of masses m_3 and m_4 are produced. The reaction shortly written 1(2,3)4 will be calculated under the following assumptions: conservation of: energy, linear momentum and mass. From these follows for the absolute velocity $|v'_3|$ and energy E'_3 of particle 3 in the CM (center of mass) frame and for the velocity of the center of mass $|v_{CM}|$

$$|v'_3| = [\{2\, m_2 m_4/(m_3 M^2)\}\, (E_1 - E_{th}]^{1/2};$$

$$E'_3 = \tfrac{1}{2}\, m_3\, |v'_3|^2 = (m_2\, m_4/M^2)\, (E_1 - E_{th}); \qquad (1a,\ b)$$

$$|v_{CM}| = m_1\, |v_1|/M \qquad (2)$$

With

$$m_1 + m_2 = m_3 + m_4 = M\ **;$$

$$E_{th} = -QM/m_2 = |Q|M/m_2 \text{ for } Q < 0$$

$$Q = E_3 + E_4 - E_1\ **. \qquad (3a,\ b)$$

The dynamical variables of a particle expressed in the CM frame will be distinguished by attaching primes to them. The following calculation is valid for particle 3. Interchanging the indices 3 and 4 yields the equations for particle 4. One observes that $|v'_3|$ and $|v_{CM}|$ are constant if E_1 is kept constant. As shown in fig. 1 the transition from the CM frame to lab. frame is simply the vector addition of v_{CM} to v'_3. The shape of the resulting vector diagram depends only on the ratio $|v_{CM}|/|v'_3|$. It is therefore convenient to introduce the kinematic parameter

$$\eta_3 = |v_{CM}|/|v'_3|; \qquad \eta_3{}^2 = \{(m_1\, m_3)/(m_2\, m_4)\}\, E_1/(E_1 - E_{th}) \qquad (4a,\ b)$$

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** In a non-relativistic calculation the conservation of energy and mass must be postulated separately. Q must be introduced by means of the relativistic eq. $Q = \Delta mc^2 = (m_1 + m_2 - m_3 - m_4)c^2$. The necessary condition for non-relativistic calculation is $\Delta m \ll M$.

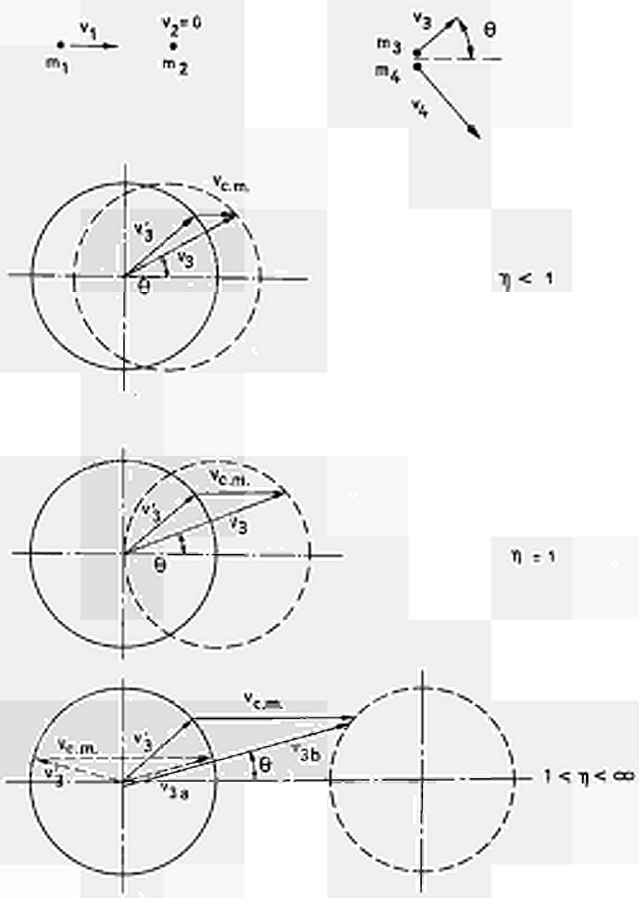

Fig. 1. Transition from the *cm* frame to the lab. frame for different values of the parameter η.

The six quantities m_1, m_2, m_3, m_4, E_1 and E_{th} are in this way combined in one single parameter. From fig. 1 one obtains.

$$|v_3|^2 \sin\theta = |v'_3|^2 - [|v_3| \cos\theta - |v_{CM}|]^2. \tag{5}$$

With eq. (3a) and a second normalized quantity x

$$x = |v_3|/|v'_3| = (E_3/E'_3)^{1/2}; \tag{6}$$

we obtain from eq. (6) finally the desired general relation

$$x = \pm (1 - \eta^2 \sin^2\theta)^{1/2} + \eta \cos\theta,$$

or

$$\cos\theta = (2x\eta)^{-1} (x^2 + \eta^2 - 1). \tag{7}$$

This equation in connection with the definitions of x and η is equivalent to the general formula [6]

$$Q = E_3 \{1 + (m_3/m_4)\} - E_1 \{1 - (m_1/m_4)\} - \{(2\cos\theta)/m_4\} (m_1 m_3 E_1 E_3)^{1/2} \tag{8}$$

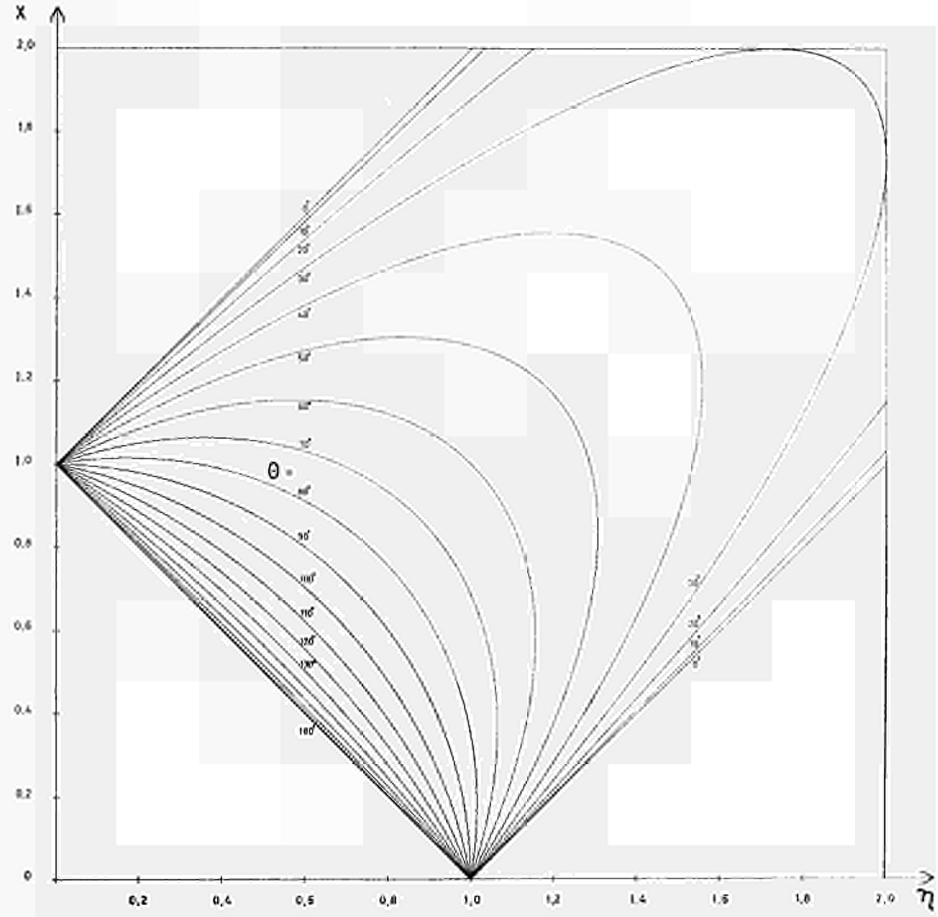

Fig. 2. Nomogram of eq. (7).

Eq. (7) allows to calculate the energy of particle 3 via the quantity x as a function of the angle θ of emission in the lab. frame.

In order to explain the meaning of η we consider e.g. the dependence of η on E_1 for reactions with a negative $Q (E_{th} > 0)$.

1. $\eta < 0$. No reaction. $E_1 < E_{th}$.

2. $\eta = \infty$. Beginning of the reaction. $E_1 = E_{th}$.

3. $1 < \eta < \infty$. Region of double valued energy. At each angle θ ($\theta < \theta_{max}$) there are particles with two different energies $E_{th} < E_1 < E_{b3}$.

4. $\eta = 1$. This condition gives that E_1 at which just no particle 3 can be found at angles θ greater than 90°. $E_1 = E_{b3}$.

5. $(m_1 m_3)/(m_2 m_4) \leqq \eta \leqq 1$. Region of single valued energy $E_1 > E_{b3}$.

For reactions with a positive Q value η increases with increasing E_1. The other aspects being the same. The possible range for x is also given by η.

$$x_{max} = 1 \pm \eta \text{ for } \eta < 1 \text{ and } x_{max} = \eta \pm 1 \text{ for } \eta > 1 \qquad (9)$$

For $1 < \eta < \infty$ the maximum angle θ_{max} at which particle 3 can be found may be calculated with

$$\sin \theta_{max} = 1/\eta_3; \qquad x_{max} = (\eta_3^2 - 1)^{1/2}. \tag{10}$$

Example: $^7Li(p,n)^7Be$.

Incident proton energy 2200 keV; Threshold energy $E_{th} = 1880.4$ keV. The kinematic parameter η is calculated with eq. (4b), $\eta = 0.37$. From this we conclude that E_3 is a single valued function of θ. With eq. (1b) one obtains for the neutron energy in the CM frame $E'_3 = 244.4$ keV. According to eqs. (6) and (9) the neutron energy E_3 in the lab. frame varies between $(1 - \eta)^2 E'_3 = 94.85$ keV and $(1 + \eta)^2 E'_3 = 463.4$ keV. The angle for one desired energy E_3 inside this range may easily be found by means of fig. 2 or by evaluating eq. (7).

The variation of E_3 with the variation of E_1 may be calculated from:

$$\partial E_3/\partial E_1 = (m_1 m_2/M^2) \times [\{M/(m_1 m_3)\}(m_4 - m_1) + \tfrac{1}{2}(x/\eta)^2]/\{1 - \tfrac{1}{2}(\eta/x)^2\} \tag{12}$$

which follows from eq. (8) and from eqs. (3b), (6) and (7).

One may conclude that especially for the kind of questions mentioned above kinematic calculations can be simplified by introducing normalized quantities.

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η \ θ	0.	5.	10.	15.	20.	25.	30.	35.	40.	45.	50.	55.	60. deg.
	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1
0.	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
0.01	1.01000	1.00996	1.00985	1.00966	1.00939	1.00905	1.00865	1.00818	1.00764	1.00705	1.00640	1.00570	1.00496
0.02	1.02000	1.01992	1.01969	1.01931	1.01877	1.01809	1.01727	1.01632	1.01524	1.01404	1.01274	1.01134	1.00985
0.03	1.03000	1.02988	1.02953	1.02895	1.02814	1.02711	1.02587	1.02443	1.02280	1.02099	1.01902	1.01691	1.01466
0.04	1.04000	1.03984	1.03937	1.03858	1.03749	1.03611	1.03444	1.03250	1.03031	1.02788	1.02524	1.02241	1.01940
0.05	1.05000	1.04980	1.04920	1.04821	1.04684	1.04509	1.04299	1.04055	1.03779	1.03473	1.03141	1.02784	1.02406
0.06	1.06000	1.05976	1.05903	1.05784	1.05617	1.05406	1.05151	1.04856	1.04522	1.04153	1.03751	1.03321	1.02865
0.07	1.07000	1.06972	1.06886	1.06745	1.06549	1.06300	1.06001	1.05653	1.05261	1.04827	1.04356	1.03851	1.03316
0.08	1.08000	1.07967	1.07869	1.07706	1.07480	1.07193	1.06848	1.06448	1.05996	1.05497	1.04954	1.04374	1.03760
0.09	1.09000	1.08963	1.08851	1.08666	1.08410	1.08084	1.07693	1.07239	1.06727	1.06161	1.05547	1.04890	1.04196
0.10	1.10000	1.09958	1.09833	1.09626	1.09338	1.08974	1.08535	1.08027	1.07454	1.06821	1.06134	1.05400	1.04624
0.11	1.11000	1.10954	1.10815	1.10585	1.10266	1.09861	1.09375	1.08811	1.08176	1.07475	1.06715	1.05903	1.05045
0.12	1.12000	1.11949	1.11796	1.11543	1.11192	1.10747	1.10212	1.09593	1.08895	1.08125	1.07290	1.06399	1.05459
0.13	1.13000	1.12944	1.12777	1.12500	1.12117	1.11631	1.11047	1.10371	1.09609	1.08769	1.07859	1.06888	1.05864
0.14	1.14000	1.13939	1.13758	1.13457	1.13041	1.12513	1.11879	1.11145	1.10319	1.09408	1.08422	1.07370	1.06262
0.15	1.15000	1.14934	1.14738	1.14414	1.13964	1.13394	1.12709	1.11917	1.11025	1.10043	1.08979	1.07846	1.06653
0.16	1.16000	1.15929	1.15718	1.15369	1.14885	1.14272	1.13536	1.12684	1.11726	1.10672	1.09531	1.08315	1.07035
0.17	1.17000	1.16924	1.16698	1.16324	1.15806	1.15149	1.14361	1.13449	1.12424	1.11296	1.10076	1.08776	1.07410
0.18	1.18000	1.17919	1.17678	1.17278	1.16725	1.16024	1.15183	1.14210	1.13117	1.11915	1.10615	1.09231	1.07778
0.19	1.19000	1.18914	1.18657	1.18232	1.17643	1.16897	1.16002	1.14968	1.13806	1.12528	1.11148	1.09679	1.08137
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0.24	1.24000	1.23887	1.23549	1.22989	1.22215	1.21236	1.20062	1.18709	1.17188	1.15520	1.13722	1.11814	1.09816
0.25	1.25000	1.24881	1.24526	1.23939	1.23126	1.22098	1.20866	1.19445	1.17852	1.16103	1.14219	1.12220	1.10128
0.26	1.26000	1.25875	1.25503	1.24887	1.24036	1.22959	1.21668	1.20180	1.18511	1.16680	1.14709	1.12619	1.10432
0.27	1.27000	1.26870	1.26480	1.25836	1.24944	1.23817	1.22467	1.20911	1.19166	1.17253	1.15193	1.13010	1.10728
0.28	1.28000	1.27864	1.27456	1.26783	1.25852	1.24674	1.23264	1.21638	1.19816	1.17819	1.15671	1.13394	1.11016
0.29	1.29000	1.28858	1.28433	1.27730	1.26758	1.25529	1.24058	1.22362	1.20463	1.18381	1.16142	1.13771	1.11295
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0.34	1.34000	1.33827	1.33309	1.32454	1.31271	1.29777	1.27989	1.25931	1.23628	1.21109	1.18403	1.15545	1.12567
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0.40	1.40000	1.39787	1.39151	1.38100	1.36648	1.34813	1.32621	1.30099	1.27280	1.24201	1.20901	1.17423	1.13808
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0.62	1.62000	1.61618	1.60477	1.58592	1.55987	1.52697	1.48767	1.44251	1.39210	1.33718	1.27854	1.21705	1.15362
0.63	1.63000	1.62609	1.61443	1.59515	1.56852	1.53488	1.49469	1.44850	1.39694	1.34077	1.28079	1.21790	1.15305
0.64	1.64000	1.63601	1.62408	1.60438	1.57715	1.54276	1.50167	1.45444	1.40173	1.34429	1.28296	1.21865	1.15235
0.65	1.65000	1.64592	1.63374	1.61360	1.58578	1.55063	1.50863	1.46035	1.40646	1.34774	1.28503	1.21929	1.15151
0.66	1.66000	1.65583	1.64338	1.62281	1.59439	1.55848	1.51556	1.46622	1.41114	1.35111	1.28701	1.21981	1.15055
0.67	1.67000	1.66574	1.65303	1.63202	1.60298	1.56630	1.52246	1.47204	1.41576	1.35442	1.28891	1.22023	1.14945
0.68	1.68000	1.67566	1.66267	1.64122	1.61157	1.57411	1.52932	1.47783	1.42033	1.35765	1.29071	1.22053	1.14821
0.69	1.69000	1.68556	1.67231	1.65041	1.62014	1.58189	1.53616	1.48357	1.42483	1.36080	1.29241	1.22071	1.14683
0.70	1.70000	1.69547	1.68195	1.65960	1.62870	1.58966	1.54297	1.48926	1.42928	1.36388	1.29402	1.22078	1.14530
0.71	1.71000	1.70538	1.69158	1.66878	1.63725	1.59740	1.54974	1.49492	1.43368	1.36689	1.29554	1.22072	1.14362
0.72	1.72000	1.71529	1.70122	1.67795	1.64578	1.60512	1.55649	1.50053	1.43801	1.36981	1.29695	1.22053	1.14179
0.73	1.73000	1.72520	1.71084	1.68712	1.65431	1.61283	1.56321	1.50610	1.44229	1.37266	1.29826	1.22022	1.13981
0.74	1.74000	1.73510	1.72047	1.69627	1.66281	1.62051	1.56989	1.51163	1.44650	1.37543	1.29947	1.21978	1.13766
0.75	1.75000	1.74501	1.73009	1.70542	1.67131	1.62817	1.57654	1.51711	1.45066	1.37812	1.30057	1.21921	1.13535
0.76	1.76000	1.75491	1.73971	1.71457	1.67979	1.63581	1.58317	1.52254	1.45475	1.38073	1.30157	1.21849	1.13286
0.77	1.77000	1.76482	1.74932	1.72370	1.68826	1.64343	1.58976	1.52793	1.45878	1.38325	1.30246	1.21764	1.13020
0.78	1.78000	1.77472	1.75894	1.73283	1.69672	1.65103	1.59632	1.53328	1.46275	1.38569	1.30323	1.21665	1.12736
0.79	1.79000	1.78462	1.76854	1.74196	1.70516	1.65860	1.60284	1.53858	1.46665	1.38804	1.30390	1.21551	1.12433
0.80	1.80000	1.79452	1.77815	1.75107	1.71359	1.66616	1.60934	1.54383	1.47049	1.39031	1.30444	1.21421	1.12111
0.81	1.81000	1.80442	1.78775	1.76018	1.72201	1.67369	1.61580	1.54904	1.47426	1.39248	1.30487	1.21276	1.11769
0.82	1.82000	1.81432	1.79735	1.76928	1.73042	1.68121	1.62223	1.55419	1.47797	1.39457	1.30517	1.21115	1.11406
0.83	1.83000	1.82422	1.80695	1.77837	1.73881	1.68870	1.62862	1.55931	1.48161	1.39656	1.30535	1.20938	1.11022
0.84	1.84000	1.83412	1.81654	1.78746	1.74716	1.69617	1.63499	1.56437	1.48518	1.39846	1.30541	1.20743	1.10615
0.85	1.85000	1.84402	1.82613	1.79654	1.75555	1.70361	1.64132	1.56938	1.48868	1.40026	1.30533	1.20531	1.10185
0.86	1.86000	1.85391	1.83572	1.80561	1.76390	1.71104	1.64761	1.57434	1.49211	1.40196	1.30512	1.20301	1.09731
0.87	1.87000	1.86381	1.84531	1.81467	1.77224	1.71844	1.65387	1.57926	1.49548	1.40357	1.30477	1.20052	1.09252
0.88	1.88000	1.87371	1.85489	1.82373	1.78056	1.72582	1.66010	1.58412	1.49876	1.40507	1.30428	1.19784	1.08746
0.89	1.89000	1.88360	1.86446	1.83278	1.78887	1.73318	1.66629	1.58893	1.50198	1.40647	1.30364	1.19495	1.08212
0.90	1.90000	1.89349	1.87404	1.84183	1.79717	1.74052	1.67245	1.59369	1.50512	1.40776	1.30285	1.19185	1.07650
0.91	1.91000	1.90339	1.88361	1.85086	1.80545	1.74783	1.67858	1.59840	1.50818	1.40894	1.30191	1.18854	1.07057
0.92	1.92000	1.91328	1.89318	1.85989	1.81372	1.75512	1.68466	1.60306	1.51117	1.41001	1.30081	1.18500	1.06432
0.93	1.93000	1.92317	1.90275	1.86891	1.82198	1.76239	1.69071	1.60766	1.51407	1.41097	1.29955	1.18123	1.05773
0.94	1.94000	1.93306	1.91231	1.87792	1.83022	1.76964	1.69673	1.61221	1.51690	1.41181	1.29811	1.17720	1.05078
0.95	1.95000	1.94295	1.92187	1.88693	1.83845	1.77686	1.70271	1.61670	1.51964	1.41253	1.29650	1.17292	1.04344
0.96	1.96000	1.95284	1.93142	1.89593	1.84667	1.78406	1.70865	1.62113	1.52231	1.41313	1.29471	1.16837	1.03570
0.97	1.97000	1.96273	1.94098	1.90492	1.85487	1.79123	1.71456	1.62551	1.52488	1.41360	1.29273	1.16353	1.02752
0.98	1.98000	1.97262	1.95053	1.91391	1.86305	1.79838	1.72043	1.62984	1.52737	1.41394	1.29055	1.15840	1.01887
0.99	1.99000	1.98250	1.96007	1.92288	1.87123	1.80551	1.72626	1.63410	1.52978	1.41414	1.28817	1.15294	1.00971
1.00	2.00000	1.99239	1.96962	1.93185	1.87939	1.81262	1.73205	1.63830	1.53209	1.41421	1.28558	1.14715	1.00000

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	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1
0.	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
0.01	1.00496	1.00419	1.00338	1.00254	1.00169	1.00082	0.99995	0.99908	0.99822	0.99737	0.99654	0.99573	0.99496
0.02	1.00985	1.00829	1.00666	1.00499	1.00328	1.00155	0.99980	0.99806	0.99633	0.99464	0.99298	0.99138	0.98985
0.03	1.01466	1.01231	1.00986	1.00735	1.00477	1.00217	0.99955	0.99694	0.99435	0.99182	0.98934	0.98695	0.98466
0.04	1.01940	1.01625	1.01297	1.00961	1.00617	1.00269	0.99920	0.99572	0.99228	0.98890	0.98561	0.98244	0.97940
0.05	1.02406	1.02010	1.01600	1.01177	1.00747	1.00312	0.99875	0.99440	0.99010	0.98589	0.98179	0.97784	0.97406
0.06	1.02865	1.02388	1.01893	1.01385	1.00867	1.00344	0.99820	0.99298	0.98783	0.98279	0.97789	0.97316	0.96865
0.07	1.03316	1.02757	1.02178	1.01583	1.00978	1.00367	0.99755	0.99146	0.98547	0.97959	0.97389	0.96840	0.96316
0.08	1.03760	1.03118	1.02453	1.01772	1.01078	1.00379	0.99679	0.98985	0.98300	0.97630	0.96981	0.96356	0.95760
0.09	1.04196	1.03470	1.02720	1.01951	1.01169	1.00382	0.99594	0.98813	0.98044	0.97292	0.96564	0.95863	0.95196
0.10	1.04624	1.03815	1.02978	1.02121	1.01250	1.00374	0.99499	0.98631	0.97777	0.96944	0.96137	0.95362	0.94624
0.11	1.05045	1.04151	1.03227	1.02281	1.01322	1.00357	0.99393	0.98439	0.97501	0.96587	0.95702	0.94853	0.94045
0.12	1.05459	1.04478	1.03466	1.02432	1.01383	1.00329	0.99277	0.98237	0.97215	0.96220	0.95258	0.94335	0.93459
0.13	1.05864	1.04798	1.03697	1.02573	1.01435	1.00291	0.99151	0.98025	0.96920	0.95844	0.94805	0.93809	0.92864
0.14	1.06262	1.05108	1.03919	1.02705	1.01476	1.00243	0.99015	0.97802	0.96614	0.95458	0.94343	0.93275	0.92262
0.15	1.06653	1.05411	1.04132	1.02827	1.01508	1.00185	0.98869	0.97570	0.96298	0.95063	0.93871	0.92732	0.91653
0.16	1.07035	1.05705	1.04336	1.02940	1.01529	1.00116	0.98712	0.97327	0.95972	0.94657	0.93391	0.92181	0.91035
0.17	1.07410	1.05991	1.04530	1.03043	1.01541	1.00037	0.98544	0.97074	0.95637	0.94243	0.92901	0.91621	0.90410
0.18	1.07778	1.06268	1.04716	1.03136	1.01542	0.99948	0.98367	0.96810	0.95291	0.93818	0.92403	0.91053	0.89778
0.19	1.08137	1.06536	1.04892	1.03219	1.01533	0.99848	0.98178	0.96536	0.94935	0.93384	0.91895	0.90476	0.89137
0.20	1.08489	1.06796	1.05059	1.03293	1.01514	0.99738	0.97980	0.96252	0.94568	0.92940	0.91378	0.89891	0.88489
0.21	1.08832	1.07047	1.05216	1.03356	1.01485	0.99618	0.97770	0.95957	0.94192	0.92486	0.90851	0.89297	0.87832
0.22	1.09168	1.07290	1.05364	1.03410	1.01445	0.99486	0.97550	0.95651	0.93805	0.92022	0.90315	0.88694	0.87168
0.23	1.09496	1.07524	1.05503	1.03454	1.01395	0.99344	0.97319	0.95335	0.93407	0.91548	0.89770	0.88083	0.86496
0.24	1.09816	1.07749	1.05632	1.03488	1.01334	0.99192	0.97077	0.95008	0.92999	0.91064	0.89215	0.87463	0.85816
0.25	1.10128	1.07965	1.05752	1.03511	1.01263	0.99028	0.96825	0.94670	0.92581	0.90570	0.88651	0.86834	0.85128
0.26	1.10432	1.08172	1.05862	1.03524	1.01181	0.98854	0.96561	0.94321	0.92152	0.90066	0.88077	0.86196	0.84432
0.27	1.10728	1.08371	1.05962	1.03527	1.01089	0.98668	0.96286	0.93962	0.91712	0.89551	0.87493	0.85549	0.83728
0.28	1.11016	1.08560	1.06053	1.03520	1.00985	0.98471	0.96000	0.93593	0.91261	0.89026	0.86900	0.84893	0.83015
0.29	1.11295	1.08740	1.06134	1.03502	1.00871	0.98264	0.95703	0.93209	0.90799	0.88491	0.86297	0.84228	0.82295
0.30	1.11566	1.08911	1.06205	1.03474	1.00746	0.98044	0.95394	0.92815	0.90327	0.87945	0.85684	0.83554	0.81566
0.31	1.11829	1.09073	1.06266	1.03435	1.00609	0.97814	0.95074	0.92410	0.89843	0.87388	0.85060	0.82871	0.80829
0.32	1.12083	1.09226	1.06317	1.03385	1.00461	0.97572	0.94742	0.91994	0.89348	0.86821	0.84427	0.82178	0.80083
0.33	1.12329	1.09369	1.06357	1.03325	1.00302	0.97318	0.94398	0.91566	0.88841	0.86243	0.83784	0.81476	0.79329
0.34	1.12567	1.09503	1.06388	1.03253	1.00132	0.97053	0.94043	0.91126	0.88324	0.85654	0.83130	0.80765	0.78567
0.35	1.12796	1.09627	1.06408	1.03171	0.99950	0.96775	0.93675	0.90674	0.87794	0.85053	0.82466	0.80044	0.77796
0.36	1.13016	1.09742	1.06417	1.03077	0.99756	0.96486	0.93295	0.90210	0.87253	0.84442	0.81791	0.79313	0.77016
0.37	1.13227	1.09847	1.06416	1.02972	0.99550	0.96184	0.92903	0.89734	0.86700	0.83819	0.81106	0.78573	0.76227
0.38	1.13430	1.09942	1.06404	1.02855	0.99332	0.95870	0.92499	0.89246	0.86135	0.83185	0.80411	0.77823	0.75430
0.39	1.13624	1.10027	1.06381	1.02727	0.99102	0.95543	0.92082	0.88745	0.85558	0.82539	0.79704	0.77063	0.74624
0.40	1.13808	1.10102	1.06348	1.02587	0.98860	0.95204	0.91652	0.88232	0.84968	0.81882	0.78986	0.76293	0.73808
0.41	1.13984	1.10167	1.06303	1.02435	0.98606	0.94852	0.91209	0.87705	0.84366	0.81212	0.78257	0.75513	0.72984
0.42	1.14150	1.10222	1.06247	1.02272	0.98338	0.94487	0.90752	0.87166	0.83752	0.80531	0.77517	0.74722	0.72150
0.43	1.14308	1.10266	1.06180	1.02096	0.98058	0.94108	0.90283	0.86613	0.83124	0.79837	0.76766	0.73921	0.71308
0.44	1.14455	1.10300	1.06101	1.01907	0.97765	0.93716	0.89800	0.86047	0.82484	0.79131	0.76003	0.73110	0.70455
0.45	1.14594	1.10323	1.06010	1.01706	0.97458	0.93311	0.89303	0.85467	0.81830	0.78412	0.75229	0.72288	0.69594
0.46	1.14722	1.10336	1.05908	1.01492	0.97138	0.92892	0.88792	0.84873	0.81163	0.77681	0.74442	0.71455	0.68722
0.47	1.14841	1.10337	1.05793	1.01265	0.96805	0.92458	0.88267	0.84265	0.80482	0.76936	0.73644	0.70611	0.67841
0.48	1.14951	1.10327	1.05667	1.01026	0.96457	0.92010	0.87727	0.83643	0.79787	0.76179	0.72833	0.69756	0.66951
0.49	1.15050	1.10307	1.05528	1.00772	0.96095	0.91547	0.87172	0.83006	0.79078	0.75408	0.72010	0.68890	0.66050
0.50	1.15139	1.10274	1.05376	1.00505	0.95719	0.91070	0.86603	0.82354	0.78354	0.74623	0.71174	0.68012	0.65139
0.51	1.15218	1.10230	1.05211	1.00224	0.95328	0.90577	0.86017	0.81687	0.77616	0.73825	0.70325	0.67123	0.64218
0.52	1.15286	1.10175	1.05034	0.99929	0.94922	0.90069	0.85417	0.81005	0.76863	0.73012	0.69464	0.66222	0.63286
0.53	1.15344	1.10107	1.04843	0.99619	0.94501	0.89545	0.84800	0.80306	0.76094	0.72185	0.68589	0.65309	0.62344
0.54	1.15391	1.10027	1.04638	0.99295	0.94064	0.89004	0.84167	0.79592	0.75310	0.71343	0.67700	0.64384	0.61391
0.55	1.15428	1.09935	1.04420	0.98956	0.93611	0.88447	0.83516	0.78860	0.74510	0.70486	0.66798	0.63447	0.60428
0.56	1.15453	1.09830	1.04188	0.98601	0.93142	0.87874	0.82849	0.78112	0.73694	0.69614	0.65881	0.62497	0.59453
0.57	1.15467	1.09712	1.03941	0.98231	0.92656	0.87282	0.82164	0.77347	0.72861	0.68726	0.64950	0.61534	0.58467
0.58	1.15470	1.09581	1.03679	0.97845	0.92154	0.86673	0.81462	0.76563	0.72010	0.67822	0.64005	0.60558	0.57470
0.59	1.15461	1.09437	1.03403	0.97442	0.91633	0.86046	0.80740	0.75762	0.71143	0.66901	0.63045	0.59568	0.56461
0.60	1.15440	1.09280	1.03111	0.97022	0.91095	0.85400	0.80000	0.74941	0.70257	0.65964	0.62069	0.58565	0.55440
0.61	1.15407	1.09108	1.02804	0.96586	0.90538	0.84735	0.79240	0.74102	0.69352	0.65010	0.61077	0.57549	0.54407
0.62	1.15362	1.08922	1.02481	0.96131	0.89962	0.84050	0.78460	0.73247	0.68429	0.64038	0.60070	0.56517	0.53362
0.63	1.15305	1.08722	1.02141	0.95658	0.89366	0.83344	0.77660	0.72361	0.67486	0.63047	0.59046	0.55472	0.52305
0.64	1.15235	1.08507	1.01784	0.95167	0.88751	0.82618	0.76838	0.71462	0.66524	0.62038	0.58005	0.54411	0.51235
0.65	1.15151	1.08276	1.01410	0.94657	0.88114	0.81869	0.75993	0.70533	0.65540	0.61010	0.56947	0.53336	0.50151
0.66	1.15055	1.08030	1.01018	0.94126	0.87457	0.81099	0.75127	0.69594	0.64535	0.59962	0.55871	0.52245	0.49055
0.67	1.14945	1.07768	1.00608	0.93575	0.86777	0.80305	0.74236	0.68620	0.63508	0.58894	0.54777	0.51138	0.47945
0.68	1.14821	1.07490	1.00179	0.93004	0.86074	0.79487	0.73321	0.67633	0.62458	0.57804	0.53664	0.50014	0.46821
0.69	1.14683	1.07195	0.99730	0.92410	0.85348	0.78644	0.72381	0.66617	0.61384	0.56693	0.52532	0.48874	0.45683
0.70	1.14530	1.06883	0.99262	0.91794	0.84597	0.77775	0.71414	0.65573	0.60286	0.55559	0.51379	0.47716	0.44530
0.71	1.14362	1.06552	0.98773	0.91154	0.83820	0.76880	0.70420	0.64507	0.59162	0.54402	0.50206	0.46541	0.43362
0.72	1.14179	1.06204	0.98263	0.90491	0.83017	0.75956	0.69397	0.63405	0.58012	0.53221	0.49012	0.45347	0.42179
0.73	1.13981	1.05836	0.97730	0.89802	0.82187	0.75003	0.68345	0.62278	0.56834	0.52014	0.47795	0.44134	0.40981
0.74	1.13766	1.05450	0.97174	0.89087	0.81327	0.74019	0.67261	0.61120	0.55627	0.50782	0.46555	0.42902	0.39766
0.75	1.13535	1.05043	0.96595	0.88345	0.80437	0.73003	0.66144	0.59929	0.54390	0.49522	0.45292	0.41650	0.38535
0.76	1.13286	1.04615	0.95991	0.87574	0.79516	0.71953	0.64992	0.58705	0.53121	0.48234	0.44004	0.40377	0.37286
0.77	1.13020	1.04165	0.95361	0.86773	0.78561	0.70867	0.63804	0.57445	0.51819	0.46915	0.42690	0.39082	0.36020
0.78	1.12736	1.03694	0.94705	0.85942	0.77572	0.69744	0.62578	0.56148	0.50482	0.45566	0.41350	0.37765	0.34736
0.79	1.12433	1.03199	0.94020	0.85077	0.76545	0.68581	0.61311	0.54811	0.49108	0.44184	0.39981	0.36425	0.33433
0.80	1.12111	1.02680	0.93306	0.84178	0.75479	0.67376	0.60000	0.53431	0.47695	0.42767	0.38583	0.35061	0.32111
0.81	1.11769	1.02135	0.92561	0.83242	0.74372	0.66126	0.58643	0.52007	0.46241	0.41313	0.37154	0.33671	0.30769
0.82	1.11406	1.01565	0.91784	0.82268	0.73220	0.64828	0.57236	0.50534	0.44742	0.39821	0.35693	0.32255	0.29406
0.83	1.11022	1.00967	0.90973	0.81252	0.72021	0.63477	0.55776	0.49010	0.43196	0.38288	0.34197	0.30812	0.28022
0.84	1.10615	1.00340	0.90125	0.80193	0.70772	0.62071	0.54259	0.47429	0.41599	0.36711	0.32666	0.29340	0.26615
0.85	1.10185	0.99683	0.89240	0.79087	0.69467	0.60605	0.52678	0.45788	0.39947	0.35088	0.31096	0.27838	0.25185
0.86	1.09731	0.98995	0.88313	0.77931	0.68103	0.59072	0.51029	0.44082	0.38236	0.33414	0.29486	0.26304	0.23731
0.87	1.09252	0.98273	0.87344	0.76721	0.66675	0.57467	0.49305	0.42302	0.36460	0.31686	0.27832	0.24737	0.22251
0.88	1.08746	0.97516	0.86328	0.75452	0.65176	0.55782	0.47497	0.40443	0.34614	0.29900	0.26133	0.23135	0.20746
0.89	1.08212	0.96721	0.85263	0.74119	0.63599	0.54008	0.45596	0.38494	0.32689	0.28049	0.24383	0.21495	0.19212
0.90	1.07650	0.95886	0.84144	0.72716	0.61934	0.52133	0.43589	0.36445	0.30678	0.26129	0.22580	0.19815	0.17650
0.91	1.07057	0.95009	0.82967	0.71236	0.60172	0.50144	0.41461	0.34281	0.28568	0.24131	0.20719	0.18093	0.16057
0.92	1.06432	0.94087	0.81726	0.69670	0.58299	0.48022	0.39192	0.31985	0.26347	0.22047	0.18794	0.16325	0.14432
0.93	1.05773	0.93116	0.80416	0.68006	0.56297	0.45745	0.36756	0.29534	0.23998	0.19866	0.16800	0.14509	0.12773
0.94	1.05078	0.92092	0.79029	0.66232	0.54144	0.43280	0.34117	0.26895	0.21498	0.17575	0.14729	0.12640	0.11078
0.95	1.04344	0.91011	0.77556	0.64331	0.51811	0.40584	0.31225	0.24024	0.18818	0.15156	0.12572	0.10713	0.09344
0.96	1.03570	0.89867	0.75986	0.62281	0.49257	0.37590	0.28000	0.20856	0.15917	0.12588	0.10318	0.08724	0.07570
0.97	1.02752	0.88654	0.74306	0.60052	0.46420	0.34193	0.24311	0.17284	0.12732	0.09841	0.07954	0.06666	0.05752
0.98	1.01887	0.87366	0.72498	0.57603	0.43201	0.30197	0.19900	0.13114	0.09166	0.06875	0.05462	0.04533	0.03887
0.99	1.00971	0.85993	0.70541	0.54873	0.39429	0.25165	0.14107	0.07908	0.05047	0.03627	0.02821	0.02314	0.01971
1.00	1.00000	0.84524	0.68404	0.51764	0.34730	0.17431	0.	0.	0.	0.	0.	0.	0.

η \ Θ	120.	125.	130.	135.	140.	145.	150.	155.	160.	165.	170.	175.	180. deg.
	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1	x_1
0.	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
0.01	0.99496	0.99423	0.99354	0.99290	0.99232	0.99179	0.99133	0.99093	0.99060	0.99034	0.99015	0.99004	0.99000
0.02	0.98985	0.98839	0.98703	0.98576	0.98460	0.98355	0.98263	0.98184	0.98118	0.98067	0.98030	0.98007	0.98000
0.03	0.98466	0.98249	0.98045	0.97856	0.97683	0.97528	0.97391	0.97273	0.97176	0.97099	0.97044	0.97011	0.97000
0.04	0.97940	0.97652	0.97382	0.97132	0.96903	0.96697	0.96516	0.96360	0.96232	0.96131	0.96058	0.96015	0.96000
0.05	0.97406	0.97048	0.96713	0.96402	0.96118	0.95863	0.95639	0.95446	0.95287	0.95162	0.95072	0.95018	0.95000
0.06	0.96865	0.96438	0.96038	0.95667	0.95329	0.95026	0.94759	0.94530	0.94341	0.94192	0.94086	0.94021	0.94000
0.07	0.96316	0.95820	0.95357	0.94928	0.94536	0.94185	0.93877	0.93612	0.93393	0.93222	0.93099	0.93025	0.93000
0.08	0.95760	0.95196	0.94670	0.94183	0.93739	0.93341	0.92992	0.92692	0.92445	0.92251	0.92112	0.92028	0.92000
0.09	0.95196	0.94566	0.93977	0.93433	0.92938	0.92494	0.92104	0.91771	0.91495	0.91280	0.91125	0.91031	0.91000
0.10	0.94624	0.93928	0.93278	0.92679	0.92133	0.91644	0.91215	0.90848	0.90545	0.90307	0.90137	0.90034	0.90000
0.11	0.94045	0.93284	0.92574	0.91919	0.91323	0.90790	0.90322	0.89923	0.89593	0.89334	0.89149	0.89037	0.89000
0.12	0.93459	0.92633	0.91863	0.91154	0.90510	0.89933	0.89428	0.88996	0.88639	0.88351	0.88161	0.88040	0.88000
0.13	0.92864	0.91975	0.91147	0.90384	0.89692	0.89073	0.88530	0.88067	0.87665	0.87386	0.87172	0.87043	0.87000
0.14	0.92262	0.91310	0.90424	0.89609	0.88870	0.88209	0.87630	0.87137	0.86730	0.86411	0.86183	0.86046	0.86000
0.15	0.91653	0.90639	0.89696	0.88829	0.88043	0.87342	0.86728	0.86204	0.85773	0.85436	0.85194	0.85049	0.85000
0.16	0.91035	0.89960	0.88961	0.88044	0.87213	0.86472	0.85823	0.85270	0.84815	0.84459	0.84204	0.84051	0.84000
0.17	0.90410	0.89275	0.88221	0.87254	0.86378	0.85598	0.84916	0.84334	0.83856	0.83482	0.83215	0.83054	0.83000
0.18	0.89778	0.88583	0.87475	0.86459	0.85540	0.84721	0.84006	0.83397	0.82896	0.82505	0.82225	0.82056	0.82000
0.19	0.89137	0.87883	0.86722	0.85658	0.84697	0.83841	0.83093	0.82457	0.81934	0.81526	0.81234	0.81059	0.81000
0.20	0.88489	0.87177	0.85964	0.84853	0.83849	0.82957	0.82178	0.81516	0.80972	0.80547	0.80244	0.80061	0.80000
0.21	0.87832	0.86464	0.85199	0.84042	0.82998	0.82070	0.81261	0.80573	0.80008	0.79568	0.79253	0.79063	0.79000
0.22	0.87168	0.85744	0.84428	0.83226	0.82142	0.81179	0.80341	0.79628	0.79043	0.78587	0.78261	0.78065	0.78000
0.23	0.86496	0.85017	0.83652	0.82405	0.81282	0.80286	0.79418	0.78681	0.78077	0.77606	0.77270	0.77067	0.77000
0.24	0.85816	0.84283	0.82869	0.81579	0.80418	0.79388	0.78493	0.7773	0.77110	0.76625	0.76278	0.76069	0.76000
0.25	0.85128	0.83541	0.82079	0.80747	0.79549	0.78488	0.77565	0.7678	0.76141	0.75642	0.75286	0.75071	0.75000
0.26	0.84432	0.82793	0.81284	0.79911	0.78676	0.77584	0.76635	0.75830	0.75172	0.74659	0.74293	0.74073	0.74000
0.27	0.83728	0.82037	0.80482	0.79069	0.77799	0.76676	0.75702	0.74877	0.74201	0.73676	0.73300	0.73075	0.73000
0.28	0.83015	0.81274	0.79675	0.78221	0.76918	0.75766	0.74766	0.73921	0.73229	0.72691	0.72307	0.72077	0.72000
0.29	0.82295	0.80504	0.78860	0.77369	0.76032	0.74851	0.73828	0.72963	0.72256	0.71706	0.71314	0.71078	0.71000
0.30	0.81566	0.79726	0.78040	0.76511	0.75142	0.73934	0.72888	0.72004	0.71281	0.70720	0.70320	0.70080	0.70000
0.31	0.80829	0.78941	0.77213	0.75648	0.74247	0.73013	0.71945	0.71043	0.70306	0.69734	0.69326	0.69081	0.69000
0.32	0.80083	0.78149	0.76380	0.74779	0.73348	0.72088	0.70999	0.70079	0.69329	0.68747	0.68332	0.68083	0.68000
0.33	0.79329	0.77349	0.75540	0.73905	0.72445	0.71160	0.70051	0.69115	0.68351	0.67759	0.67337	0.67084	0.67000
0.34	0.78567	0.76542	0.74694	0.73025	0.71537	0.70229	0.69100	0.68148	0.67372	0.66771	0.66342	0.66085	0.66000
0.35	0.77796	0.75727	0.73841	0.72140	0.70625	0.69294	0.68146	0.67179	0.66392	0.65781	0.65347	0.65087	0.65000
0.36	0.77016	0.74904	0.72982	0.71250	0.69708	0.68355	0.67190	0.66209	0.65410	0.64792	0.64351	0.64088	0.64000
0.37	0.76227	0.74074	0.72116	0.70354	0.68787	0.67414	0.66231	0.65236	0.64427	0.63801	0.63356	0.63089	0.63000
0.38	0.75430	0.73236	0.71243	0.69452	0.67861	0.66468	0.65269	0.64263	0.63444	0.62810	0.62359	0.62090	0.62000
0.39	0.74624	0.72390	0.70364	0.68545	0.66931	0.65519	0.64305	0.63286	0.62458	0.61818	0.61363	0.61091	0.61000
0.40	0.73808	0.71537	0.69478	0.67632	0.65996	0.64566	0.63339	0.62308	0.61472	0.60826	0.60366	0.60091	0.60000
0.41	0.72984	0.70675	0.68585	0.66714	0.65057	0.63610	0.62369	0.61329	0.60485	0.59832	0.59369	0.59092	0.59000
0.42	0.72150	0.69805	0.67686	0.65790	0.64113	0.62651	0.61397	0.60347	0.59496	0.58839	0.58372	0.58093	0.58000
0.43	0.71308	0.68927	0.66779	0.64860	0.63164	0.61687	0.60422	0.59364	0.58506	0.57844	0.57374	0.57093	0.57000
0.44	0.70455	0.68041	0.65866	0.63924	0.62211	0.60720	0.59445	0.58378	0.57515	0.56849	0.56376	0.56094	0.56000
0.45	0.69594	0.67147	0.64945	0.62983	0.61253	0.59750	0.58465	0.57391	0.56522	0.55853	0.55378	0.55094	0.55000
0.46	0.68722	0.66245	0.64017	0.62035	0.60291	0.58776	0.57482	0.56402	0.55529	0.54856	0.54379	0.54095	0.54000
0.47	0.67841	0.65334	0.63083	0.61082	0.59323	0.57798	0.56496	0.55411	0.54534	0.53859	0.53380	0.53095	0.53000
0.48	0.66951	0.64414	0.62141	0.60123	0.58351	0.56816	0.55508	0.5441	0.53538	0.52861	0.52381	0.52095	0.52000
0.49	0.66050	0.63486	0.61191	0.59157	0.57374	0.55831	0.54517	0.5342	0.52541	0.51862	0.51382	0.51095	0.51000
0.50	0.65139	0.62549	0.60235	0.58186	0.56392	0.54842	0.53523	0.5242	0.51542	0.50863	0.50382	0.50095	0.50000
0.51	0.64218	0.61603	0.59270	0.57209	0.55406	0.53849	0.52527	0.51428	0.50543	0.49863	0.49382	0.49095	0.49000
0.52	0.63286	0.60648	0.58299	0.56225	0.54414	0.52853	0.51528	0.5042	0.49542	0.48862	0.48381	0.48095	0.48000
0.53	0.62344	0.59684	0.57319	0.55235	0.53418	0.51852	0.50525	0.4942	0.48540	0.47861	0.47381	0.47095	0.47000
0.54	0.61391	0.58712	0.56332	0.54239	0.52416	0.50848	0.49521	0.4842	0.47536	0.46859	0.46380	0.46095	0.46000
0.55	0.60428	0.57729	0.55338	0.53237	0.51410	0.49840	0.48513	0.47414	0.46532	0.45856	0.45378	0.45094	0.45000
0.56	0.59453	0.56738	0.54335	0.52228	0.50398	0.48829	0.47503	0.46406	0.45526	0.44852	0.44377	0.44094	0.44000
0.57	0.58467	0.55736	0.53324	0.51213	0.49382	0.47813	0.46489	0.4539	0.44519	0.43848	0.43375	0.43093	0.43000
0.58	0.57470	0.54725	0.52306	0.50191	0.48360	0.46793	0.45473	0.4438	0.43511	0.42843	0.42373	0.42093	0.42000
0.59	0.56461	0.53705	0.51279	0.49163	0.47333	0.45770	0.44454	0.4336	0.42501	0.41838	0.41370	0.41092	0.41000
0.60	0.55440	0.52674	0.50244	0.48127	0.46301	0.44743	0.43432	0.4235	0.41490	0.40831	0.40367	0.40092	0.40000
0.61	0.54407	0.51633	0.49201	0.47086	0.45264	0.43711	0.42408	0.4133	0.40478	0.39824	0.39364	0.39091	0.39000
0.62	0.53362	0.50581	0.48149	0.46037	0.44221	0.42676	0.41380	0.4031	0.39465	0.38817	0.38361	0.38090	0.38000
0.63	0.52305	0.49520	0.47088	0.44982	0.43173	0.41636	0.40350	0.3929	0.38450	0.37808	0.37357	0.37089	0.37000
0.64	0.51235	0.48447	0.46019	0.43919	0.42119	0.40593	0.39316	0.3826	0.37435	0.36799	0.36353	0.36088	0.36000
0.65	0.50151	0.47364	0.44941	0.42850	0.41060	0.39545	0.38280	0.3724	0.36418	0.35790	0.35348	0.35087	0.35000
0.66	0.49055	0.46269	0.43853	0.41773	0.39996	0.38494	0.37240	0.3621	0.35399	0.34779	0.34344	0.34086	0.34000
0.67	0.47945	0.45164	0.42757	0.40689	0.38926	0.37438	0.36198	0.3518	0.34380	0.33768	0.33339	0.33084	0.33000
0.68	0.46821	0.44047	0.41652	0.39598	0.37850	0.36378	0.35153	0.3415	0.33359	0.32756	0.32333	0.32083	0.32000
0.69	0.45683	0.42918	0.40537	0.38499	0.36769	0.35314	0.34105	0.3311	0.32337	0.31744	0.31328	0.31082	0.31000
0.70	0.44530	0.41777	0.39412	0.37393	0.35682	0.34245	0.33053	0.3208	0.31313	0.30730	0.30322	0.30080	0.30000
0.71	0.43362	0.40624	0.38278	0.36280	0.34589	0.33172	0.31999	0.3104	0.30289	0.29716	0.29316	0.29079	0.29000
0.72	0.42179	0.39458	0.37133	0.35158	0.33491	0.32095	0.30941	0.30004	0.29263	0.28702	0.28309	0.28077	0.28000
0.73	0.40981	0.38280	0.35979	0.34029	0.32386	0.31014	0.29881	0.28962	0.28235	0.27686	0.27302	0.27075	0.27000
0.74	0.39766	0.37089	0.34814	0.32891	0.31275	0.29928	0.28817	0.27917	0.27207	0.26670	0.26295	0.26073	0.26000
0.75	0.38535	0.35884	0.33639	0.31746	0.30159	0.28838	0.27751	0.26871	0.26177	0.25653	0.25288	0.25072	0.25000
0.76	0.37286	0.34666	0.32453	0.30593	0.29036	0.27743	0.26681	0.25822	0.25146	0.24636	0.24280	0.24070	0.24000
0.77	0.36020	0.33433	0.31256	0.29431	0.27907	0.26644	0.25608	0.24771	0.24114	0.23618	0.23272	0.23068	0.23000
0.78	0.34736	0.32187	0.30048	0.28260	0.26772	0.25540	0.24532	0.23719	0.23080	0.22599	0.22263	0.22065	0.22000
0.79	0.33433	0.30925	0.28829	0.27081	0.25630	0.24432	0.23452	0.22664	0.22045	0.21579	0.21255	0.21063	0.21000
0.80	0.32111	0.29649	0.27598	0.25894	0.24482	0.23319	0.22369	0.21607	0.21009	0.20559	0.20246	0.20061	0.20000
0.81	0.30769	0.28357	0.26355	0.24697	0.23327	0.22201	0.21284	0.20547	0.19971	0.19538	0.19236	0.19059	0.19000
0.82	0.29406	0.27049	0.25100	0.23491	0.22166	0.21078	0.20194	0.19486	0.18932	0.18516	0.18227	0.18056	0.18000
0.83	0.28022	0.25724	0.23833	0.22276	0.20997	0.19951	0.19102	0.18423	0.17892	0.17494	0.17217	0.17054	0.17000
0.84	0.26615	0.24382	0.22552	0.21052	0.19823	0.18819	0.18006	0.17357	0.16850	0.16470	0.16207	0.16051	0.16000
0.85	0.25185	0.23023	0.21259	0.19818	0.18641	0.17682	0.16907	0.16289	0.15807	0.15446	0.15196	0.15049	0.15000
0.86	0.23731	0.21646	0.19952	0.18574	0.17452	0.16540	0.15805	0.15219	0.14763	0.14422	0.14185	0.14046	0.14000
0.87	0.22251	0.20250	0.18632	0.17320	0.16256	0.15393	0.14699	0.14147	0.13717	0.13396	0.13174	0.13043	0.13000
0.88	0.20746	0.18834	0.17297	0.16056	0.15052	0.14241	0.13590	0.13072	0.12670	0.12370	0.12162	0.12040	0.12000
0.89	0.19212	0.17398	0.15948	0.14782	0.13842	0.13084	0.12477	0.11995	0.11622	0.11343	0.11151	0.11037	0.11000
0.90	0.17650	0.15942	0.14583	0.13497	0.12624	0.11922	0.11361	0.10916	0.10572	0.10316	0.10139	0.10034	0.10000
0.91	0.16057	0.14463	0.13204	0.12201	0.11398	0.10755	0.10241	0.09835	0.09521	0.09288	0.09126	0.09031	0.09000
0.92	0.14432	0.12962	0.11808	0.10894	0.10164	0.09582	0.09118	0.08752	0.08469	0.08259	0.08113	0.08028	0.08000
0.93	0.12773	0.11437	0.10396	0.09575	0.08923	0.08404	0.07991	0.07666	0.07415	0.07229	0.07100	0.07025	0.07000
0.94	0.11078	0.09888	0.08967	0.08245	0.07674	0.07220	0.06860	0.06578	0.06360	0.06198	0.06087	0.06022	0.06000
0.95	0.09344	0.08313	0.07520	0.06903	0.06416	0.06031	0.05726	0.05487	0.05303	0.05167	0.05073	0.05018	0.05000
0.96	0.07570	0.06710	0.06055	0.05548	0.05150	0.04836	0.04588	0.04394	0.04245	0.04135	0.04059	0.04015	0.04000
0.97	0.05752	0.05079	0.04572	0.04181	0.03876	0.03636	0.03447	0.03299	0.03186	0.03102	0.03045	0.03011	0.03000
0.98	0.03887	0.03419	0.03068	0.02801	0.02593	0.02430	0.02302	0.02202	0.02126	0.02069	0.02030	0.02007	0.02000
0.99	0.01971	0.01726	0.01545	0.01407	0.01301	0.01218	0.01153	0.01102	0.01063	0.01035	0.01015	0.01004	0.01000
1.00	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

η \ θ	0. X_1/X_2	5. X_1/X_2	10. X_1/X_2	15. X_1/X_2	20. X_1/X_2	25. X_1/X_2	30. X_1/X_2	35. X_1/X_2	40. X_1/X_2	45. X_1/X_2
1.00	2.00000	1.99239	1.96962	1.93185	1.87939	1.81262	1.73205	1.63830	1.53209	1.41421
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.02	2.02000	2.01216	1.98869	1.94977	1.89566	1.82675	1.74352	1.64653	1.53644	1.41393
	0.02000	0.02008	0.02032	0.02072	0.02131	0.02212	0.02317	0.02454	0.02629	0.02857
1.04	2.04000	2.03193	2.00776	1.96766	1.91188	1.84079	1.75483	1.65452	1.54040	1.41303
	0.04000	0.04016	0.04064	0.04147	0.04268	0.04433	0.04650	0.04932	0.05297	0.05775
1.06	2.06000	2.05169	2.02681	1.98551	1.92804	1.85473	1.76599	1.66225	1.54396	1.41150
	0.06000	0.06024	0.06098	0.06225	0.06411	0.06664	0.06999	0.07436	0.08005	0.08757
1.08	2.08000	2.07145	2.04585	2.00334	1.94415	1.86857	1.77697	1.66971	1.54710	1.40928
	0.08000	0.08033	0.08134	0.08306	0.08559	0.08905	0.09364	0.09966	0.10756	0.11807
1.10	2.10000	2.09121	2.06488	2.02113	1.96019	1.88231	1.78779	1.67690	1.54980	1.40631
	0.10000	0.10042	0.10170	0.10390	0.10713	0.11157	0.11746	0.12523	0.13550	0.14933
1.12	2.12000	2.11096	2.08389	2.03890	1.97618	1.89595	1.79844	1.68382	1.55203	1.40253
	0.12000	0.12051	0.12208	0.12477	0.12873	0.13418	0.14146	0.15109	0.16391	0.18139
1.14	2.14000	2.13071	2.10289	2.05664	1.99211	1.90948	1.80891	1.69043	1.55376	1.39788
	0.14000	0.14061	0.14247	0.14567	0.15039	0.15690	0.16562	0.17723	0.19282	0.21432
1.16	2.16000	2.15046	2.12188	2.07434	2.00797	1.92291	1.81921	1.69675	1.55497	1.39226
	0.16000	0.16071	0.16287	0.16661	0.17211	0.17973	0.18997	0.20368	0.22226	0.24823
1.18	2.18000	2.17021	2.14086	2.09201	2.02378	1.93622	1.82931	1.70275	1.55562	1.38557
	0.18000	0.18081	0.18329	0.18757	0.19389	0.20266	0.21451	0.23045	0.25225	0.28321
1.20	2.20000	2.18995	2.15982	2.10966	2.03953	1.94943	1.83923	1.70842	1.55567	1.37768
	0.20000	0.20092	0.20372	0.20857	0.21574	0.22571	0.23923	0.25755	0.28284	0.31938
1.22	2.22000	2.20969	2.17877	2.12727	2.05521	1.96253	1.84895	1.71374	1.55508	1.36844
	0.22000	0.22103	0.22416	0.22959	0.23764	0.24886	0.26415	0.28499	0.31407	0.35690
1.24	2.24000	2.22942	2.19771	2.14485	2.07083	1.97551	1.85847	1.71870	1.55380	1.35765
	0.24000	0.24114	0.24462	0.25065	0.25961	0.27213	0.28927	0.31279	0.34599	0.39598
1.26	2.26000	2.24916	2.21663	2.16240	2.08639	1.98838	1.86779	1.72329	1.55177	1.34505
	0.26000	0.26125	0.26509	0.27174	0.28164	0.29552	0.31460	0.34098	0.37867	0.43686
1.28	2.28000	2.26889	2.23554	2.17992	2.10189	2.00113	1.87689	1.72747	1.54891	1.33030
	0.28000	0.28137	0.28557	0.29286	0.30373	0.31902	0.34014	0.36956	0.41216	0.47989
1.30	2.30000	2.28861	2.25444	2.19740	2.11732	2.01376	1.88577	1.73124	1.54516	1.31294
	0.30000	0.30149	0.30606	0.31401	0.32588	0.34264	0.36590	0.39856	0.44656	0.52554
1.32	2.32000	2.30834	2.27332	2.21485	2.13268	2.02626	1.89442	1.73456	1.54041	1.29227
	0.32000	0.32162	0.32657	0.33519	0.34811	0.36639	0.39189	0.42801	0.48195	0.57449
1.34	2.34000	2.32806	2.29219	2.23227	2.14798	2.03865	1.90284	1.73740	1.53454	1.26721
	0.34000	0.34174	0.34709	0.35641	0.37039	0.39026	0.41811	0.45793	0.51846	0.62784
1.36	2.36000	2.34778	2.31105	2.24966	2.16322	2.05090	1.91101	1.73975	1.52740	1.23589
	0.36000	0.36188	0.36763	0.37766	0.39275	0.41426	0.44458	0.48835	0.55624	0.68744
1.38	2.38000	2.36749	2.32990	2.26702	2.17838	2.06302	1.91892	1.74155	1.51882	1.19444
	0.38000	0.38201	0.38817	0.39894	0.41517	0.43839	0.47131	0.51931	0.59546	0.75717
1.40	2.40000	2.38720	2.34873	2.28434	2.19348	2.07502	1.92658	1.74278	1.50855	1.13137
	0.40000	0.40215	0.40873	0.42025	0.43766	0.46265	0.49829	0.55084	0.63637	0.84853
1.42	2.42000	2.40691	2.36755	2.30163	2.20851	2.08687	1.93396	1.74339	1.49628	
	0.42000	0.42228	0.42931	0.44160	0.46022	0.48705	0.52555	0.58300	0.67928	
1.44	2.44000	2.42661	2.38636	2.31889	2.22346	2.09858	1.94105	1.74332	1.48157	
	0.44000	0.44243	0.44989	0.46298	0.48285	0.51158	0.55310	0.61584	0.72464	
1.46	2.46000	2.44632	2.40515	2.33611	2.23835	2.11015	1.94784	1.74252	1.46379	
	0.46000	0.46257	0.47049	0.48440	0.50555	0.53626	0.58095	0.64940	0.77306	
1.48	2.48000	2.46601	2.42393	2.35330	2.25317	2.12158	1.95433	1.74091	1.44193	
	0.48000	0.48272	0.49110	0.50584	0.52832	0.56109	0.60911	0.68378	0.82556	
1.50	2.50000	2.48571	2.44269	2.37045	2.26791	2.13286	1.96048	1.73841	1.41431	
	0.50000	0.50287	0.51173	0.52733	0.55117	0.58607	0.63760	0.71905	0.88382	
1.52	2.52000	2.50540	2.46145	2.38757	2.28256	2.14398	1.96628	1.73491	1.37746	
	0.52000	0.52303	0.53237	0.54884	0.57409	0.61120	0.66644	0.75531	0.95132	
1.54	2.54000	2.52509	2.48019	2.40466	2.29717	2.15494	1.97172	1.73029	1.32153	
	0.54000	0.54319	0.55302	0.57039	0.59708	0.63649	0.69564	0.79270	1.03789	
1.56	2.56000	2.54478	2.49891	2.42171	2.31169	2.16573	1.97678	1.72439		
	0.56000	0.56335	0.57369	0.59198	0.62015	0.66195	0.72522	0.83137		
1.58	2.58000	2.56446	2.51762	2.43873	2.32613	2.17636	1.98143	1.71700		
	0.58000	0.58352	0.59437	0.61360	0.64330	0.68757	0.75521	0.87152		
1.60	2.60000	2.58414	2.53632	2.45571	2.34049	2.18682	1.98564	1.70787		
	0.60000	0.60368	0.61506	0.63525	0.66653	0.71336	0.78564	0.91342		
1.62	2.62000	2.60382	2.55501	2.47265	2.35477	2.19710	1.98939	1.69662		
	0.62000	0.62385	0.63577	0.65695	0.68983	0.73934	0.81653	0.95743		
1.64	2.64000	2.62349	2.57368	2.48956	2.36897	2.20719	1.99265	1.68275		
	0.64000	0.64403	0.65649	0.67867	0.71322	0.76550	0.84792	1.00407		
1.66	2.66000	2.64316	2.59234	2.50644	2.38309	2.21710	1.99537	1.66547		
	0.66000	0.66420	0.67723	0.70044	0.73669	0.79185	0.87984	1.05412		
1.68	2.68000	2.66283	2.61098	2.52327	2.39712	2.22680	1.99751	1.64350		
	0.68000	0.68439	0.69798	0.72224	0.76025	0.81839	0.91234	1.10886		
1.70	2.70000	2.68249	2.62961	2.54008	2.41107	2.23630	1.99903	1.61441		
	0.70000	0.70457	0.71874	0.74407	0.78388	0.84515	0.94546	1.17070		
1.72	2.72000	2.70216	2.64822	2.55684	2.42493	2.24559	1.99986	1.57239		
	0.72000	0.72476	0.73951	0.76595	0.80761	0.87211	0.97927	1.24549		
1.74	2.74000	2.72181	2.66683	2.57357	2.43871	2.25466	1.99994	1.48818		
	0.74000	0.74495	0.76031	0.78786	0.83142	0.89930	1.01383	1.36247		
1.76	2.76000	2.74147	2.68542	2.59025	2.45239	2.26350	1.99918			
	0.76000	0.76514	0.78111	0.80980	0.85533	0.92671	1.04923			
1.78	2.78000	2.76112	2.70399	2.60691	2.46598	2.27209	1.99749			
	0.78000	0.78533	0.80193	0.83179	0.87933	0.95436	1.08556			
1.80	2.80000	2.78077	2.72255	2.62352	2.47948	2.28044	1.99474			
	0.80000	0.80553	0.82276	0.85382	0.90342	0.98227	1.12296			
1.82	2.82000	2.80041	2.74110	2.64009	2.49288	2.28853	1.99077			
	0.82000	0.82574	0.84360	0.87588	0.92760	1.01043	1.16156			
1.84	2.84000	2.82006	2.75963	2.65663	2.50618	2.29634	1.98541			
	0.84000	0.84594	0.86446	0.89798	0.95189	1.03887	1.20157			
1.86	2.86000	2.83970	2.77815	2.67312	2.51939	2.30387	1.97837			
	0.86000	0.86615	0.88534	0.92012	0.97627	1.06759	1.24325			
1.88	2.88000	2.85933	2.79665	2.68958	2.53249	2.31109	1.96930			
	0.88000	0.88636	0.90623	0.94231	1.00075	1.09662	1.28695			
1.90	2.90000	2.87896	2.81514	2.70599	2.54549	2.31800	1.95770			
	0.90000	0.90658	0.92713	0.96453	1.02534	1.12597	1.33320			
1.92	2.92000	2.89859	2.83362	2.72237	2.55838	2.32457	1.94277			
	0.92000	0.92680	0.94805	0.98679	1.05004	1.15566	1.38277			
1.94	2.94000	2.91822	2.85208	2.73870	2.57116	2.33077	1.92319			
	0.94000	0.94702	0.96898	1.00909	1.07485	1.18570	1.43698			
1.96	2.96000	2.93784	2.87052	2.75499	2.58383	2.33660	1.89641			
	0.96000	0.96724	0.98992	1.03144	1.09976	1.21613	1.49841			
1.98	2.98000	2.95746	2.88895	2.77124	2.59639	2.34202	1.85580			
	0.98000	0.98747	1.01088	1.05382	1.12479	1.24696	1.57366			
2.00	3.00000	2.97708	2.90737	2.78745	2.60883	2.34701	1.73205			
	1.00000	1.00770	1.03186	1.07625	1.14994	1.27822	1.73205			

η \ θ	50. X_1/X_2	55. X_1/X_2	60. X_1/X_2	65. X_1/X_2	70. X_1/X_2	75. X_1/X_2	80. X_1/X_2	85. X_1/X_2	90. deg. X_1/X_2
1.00	1.28558	1.14715	1.00000	0.84524	0.68404	0.51764	0.34730	0.17431	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.02	1.27972	1.13449	0.97872	0.81241	0.63400	0.43515			
	0.03157	0.03561	0.04128	0.04973	0.06372	0.09284			
1.04	1.27289	1.12020	0.95451	0.77356	0.56765				
	0.06411	0.07284	0.08549	0.10549	0.14375				
1.06	1.26500	1.10403	0.92661	0.72561	0.45107				
	0.09771	0.11195	0.13339	0.17034	0.27402				
1.08	1.25593	1.08565	0.89384	0.66119					
	0.13249	0.15327	0.18616	0.25167					
1.10	1.24553	1.06461	0.85414	0.54307					
	0.16860	0.19725	0.24586	0.38669					
1.12	1.23362	1.04026	0.80331						
	0.20622	0.24456	0.31669						
1.14	1.21998	1.01159	0.72906						
	0.24558	0.29617	0.41094						
1.16	1.20429	0.97694							
	0.28697	0.35376							
1.18	1.18617	0.93311							
	0.33081	0.42053							
1.20	1.16501	0.87199							
	0.37768	0.50459							
1.22	1.13997	0.73538							
	0.42843	0.66414							
1.24	1.10963								
	0.48449								
1.26	1.07137								
	0.54846								
1.28	1.01910								
	0.62643								
1.30	0.92655								
	0.74470								

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Alfred Nobel

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