ESDU 77021

Issued October 1977
With Amendments A and B
March 2005
Supersedes Item No. Aero
00.01.02 to 04

Properties of a standard atmosphere

Endorsed by
The Royal Aeronautical Society

ESDU DATA ITEMS

Data Items provide validated information in engineering design and analysis for use by, or under the supervision of, professionally qualified engineers. The data are founded on an evaluation of all the relevant information, both published and unpublished, and are invariably supported by original work of ESDU staff engineers or consultants. The whole process is subject to independent review for which crucial support is provided by industrial companies, government research laboratories, universities and others from around the world through the participation of some of their leading experts on ESDU Technical Committees. This process ensures that the results of much valuable work (theoretical, experimental and operational), which may not be widely available or in a readily usable form, can be communicated concisely and accurately to the engineering community.

We are constantly striving to develop new work and review data already issued. Any comments arising out of your use of our data, or any suggestions for new topics or information that might lead to improvements, will help us to provide a better service.

THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item which supersedes ESDU Aero 00.01.02 to 04, was monitored and guided by the Aerodynamics Committee. This Committee first met in 1942 and now has the following membership:

Chairman
Mr J. Weir — Salford University

Vice-Chairman
Mr E.C. Carter — Aircraft Research Association

Members
Prof. L.F. Crabtree — Bristol University
Mr J.R.J. Dovey — British Aircraft Corporation Ltd, Preston
Mr H.C. Garner — Royal Aircraft Establishment
Mr A. Hipp — British Aircraft Corporation Ltd, Stevenage
Mr P.K. Jones — Hawker Siddeley Aviation Ltd, Woodford
Mr J. Kloos* — Saab-Scania, Linköping, Sweden
Prof. G.M .Lilley — Southampton University
Mr J.R.C. Pedersen — Independent
Mr M.R. Pike — Rolls-Royce Ltd, Derby
Mr D. Puyplat — Aérospatiale, Toulouse, France
Mr I.H. Rettie* — Boeing Aerospace Company, Seattle, Wash., USA
Mr J.J. Spillman — Carnfield Institute of Technology
Mr J.W.H. Thomas — Hawker Siddeley Aviation Ltd, Hatfield
Mr H. Vogel — British Aircraft Corporation Ltd, Weybridge.

* Corresponding Member

The construction and subsequent development of the Data Item was undertaken by

Mr R.W. Gilbey — Engineer.

The person with overall responsibility for the work in this subject area is Mr P.D. Chappell, Head of Aircraft Motion Group.

PROPERTIES OF A STANDARD ATMOSPHERE

CONTENTS

		Page
1.	NOTATION AND UNITS	1
2.	INTRODUCTION	2
3.	STATUS OF ATMOSPHERE	3
4.	ALTITUDE SCALE	3
5.	PRESENTATION	4
6.	DERIVATION AND REFERENCES	4
7.	SKETCHES	5
8.	TABLES	8
	FIGURES 1 and 2	17 to 18
APPENDIX A	EQUATIONS DEFINING STANDARD ATMOSPHERE FOR ALTITUDES UP TO 80 KM	19
A1.	ADDITIONAL NOTATION AND UNITS	19
A2.	EQUATIONS FOR STANDARD ATMOSPHERE	19

PROPERTIES OF A STANDARD ATMOSPHERE

1. NOTATION AND UNITS

		SI	*British*
a	speed of sound	m/s	ft/s
g	acceleration due to gravity	m/s^2	ft/s^2
H	geopotential altitude	m	ft
k	thermal conductivity	W/m K	ft lbf/ft s K
L	mean free path	m	ft
l	characteristic length	m	ft
m	mean molecular mass*	kg/kmol	slug/slug-mol
p	pressure	N/m^2	lbf/ft^2
$\mathscr{R}$	universal gas constant	N m/kmol K	ft lbf/slug-mol K
Re^*	Reynolds number at Mach 1, $(= \rho a l/\mu)$		
r_e	radius of earth	m	ft
T	temperature	K	K
$\bar{V}$	particle mean speed	m/s	ft
Z	geometric altitude	m	ft
μ	dynamic viscosity	N s/m^2	lbf s/ft^2
ν	kinematic viscosity	m^2/s	ft^2/s
ρ	density	kg/m^3	slug/ft^3

Subscript

0	denotes sea-level values

* Based upon the carbon-12 isotope scale for which the atomic mass of the nuclide $^{12}C = 12$. This scale was adopted in 1961 by the Conference of the International Union of Pure and Applied Chemistry.

Issued October 1977
With Amendments A and B, March 2005 – 21 pages
This page Amendment B

Constants and Sea-level Values

Quantity	*SI*	*British*
a_0	340.294 m/s	1116.45 ft/s
g_0	9.80665 m/s^2	32.174049 ft/s^2
k_0	2.5343×10^{-2} W/m K	5.6973×10^{-3} ft lbf/ft s K
$m_0{}^*$	28.96442 kg/kmol	28.96442 slug/slug-mol
p_0	1.01325×10^5 N/m^2	2.11622×10^3 lbf/ft^2
$\mathscr{R}$	8.31432×10^3 N m/kmol K	8.94946×10^4 ft lbf/slug-mol K
r_e	6.356766×10^6 m	2.085553×10^7 ft
T_0	288.15 K	288.15 K
μ_0	1.7894×10^{-5} N s/m^2	3.7372×10^{-7} lbf s/ft^2
ν_0	1.4607×10^{-5} m^2/s	1.5723×10^{-4} ft^2/s
ρ_0	1.225 kg/m^3	2.3768924×10^{-3} slug/ft^3

* The value adopted for m_0 is identical with that quoted in Derivation 1, and is derived by substituting the SI sea-level values for ρ_0, p_0 and T_0 into the perfect gas law. Derivation 2 quotes a value of 28.9644. For all practical purposes both values of m_0 will give the same results.

2. INTRODUCTION

This Item gives properties of a standard atmosphere for altitudes up to 1000 km. The information given is extracted from Derivations 1 and 2. The data in this Item, both in the intervals of altitude and the number of significant figures quoted are much less comprehensive than those in Derivation 2. Users who require more detailed information should refer to that Derivation or, for altitudes below 50 km, to Item Nos 68046 and 72018 (Reference 9) which give data for standard and non-standard atmospheres. For altitudes up to 80 km, Appendix A of this Item gives the equations needed to construct the atmospheric model, in a manner suitable for computer programming.

The atmosphere considered in the Item is an idealised, mean-annual, steady-state model assumed to exist in a period of moderate solar activity at a latitude of about 45°N and to rotate with the earth. The effects of dust and moisture in the atmosphere are neglected.

Up to 80 km the atmosphere is represented by the ideal gas law, a linearly segmented temperature-altitude profile (see Sketch 7.1) and the assumption of hydrostatic equilibrium in which the air is treated as a homogeneous mixture of the several constituent gases. At greater heights, where dissociation and diffusion processes produce significant departures from homogeneity the definitions governing the atmosphere are more sophisticated, involving the treatment of individual gas species (see Derivation 2). The temperature-altitude profile between 80 km and 1000 km is not expressed in linear segments but by functions chosen to fit the observed data and provide a continuous first derivative with respect to altitude for the entire altitude regime.

3. STATUS OF ATMOSPHERE

The data presented in Derivations 1 and 2 are the culmination of many years' work and represent the latest stage in a continuing process of defining a standard atmosphere. Standard atmospheres were originally developed in the 1920's in the United States and in Europe to satisfy a need for standardisation of aircraft instruments and aircraft performance. The US atmosphere was generated by the National Advisory Committee on Aeronautics (NACA), Reference 3 (and later supplements), while the European atmosphere was generated by the International Commission for Aerial Navigation (ICAN), Reference 4. There were slight differences between these two independently derived atmospheres. These differences were reconciled and international uniformity was achieved through adoption by the International Civil Aviation Organization (ICAO) in 1952 of a new international standard atmosphere for altitudes up to 20 km, Reference 5. Work on extending this atmosphere to an altitude of 300 km was undertaken by the US Committee on Extension of the Standard Atmosphere (COESA) and reported in Reference 6. The gathering of more data by rockets and satellites enabled a further extension to 700 km to be made by COESA, which was published in 1962, Reference 7. This atmosphere was adopted in 1964 as a new standard by ICAO for altitudes up to 32 km, Reference 8, superseding the 1952 ICAO atmosphere. Derivation 2 is a revision and extension to 1000 km of Reference 7 as a result of more experimental data being gathered. It is identical with Reference 7 up to an altitude of 51 km and therefore still agrees with the ICAO standard atmosphere. In 1975 the International Organization for Standardization (ISO) adopted a standard atmosphere, Derivation 1, which covers heights up to 80 km. For heights below 50 km the atmosphere is termed "International Standard Atmosphere" while for heights between 50 and 80 km it is termed "Interim Standard Atmosphere"*. For all practical purposes, the ISO atmosphere is identical with the data in Derivation 2. The World Meteorological Organization Standard Atmosphere, defined between –2 km and 32 km, is identical with the data in Derivation 1.

4. ALTITUDE SCALE

For atmosphere modelling it is common practice to work in terms of geopotential altitude, H. This is related to geometric altitude, Z, by the equation

$$H = \int_0^Z \frac{g}{g_0}\,\mathrm{d}Z\,. \tag{4.1}$$

By neglecting centrifugal acceleration and using only Newton's law of gravity, this reduces to

$$H = \frac{r_e Z}{r_e + Z}\,. \tag{4.2}$$

The advantage of working with H is that it enables a constant (sea-level) value of g to be assumed when solving the hydrostatic equation. That is

$$\mathrm{d}p = -g\rho\,\mathrm{d}Z \tag{4.3}$$

becomes

$$\mathrm{d}p = -g_0\rho\,\mathrm{d}H\,. \tag{4.4}$$

* No early revision of the "Interim" atmosphere is envisaged.

The basic equations defining the atmospheric temperature profile are defined in terms of H for altitudes up to 80 km, see Appendix A. Figures 1 (feet) and 2 (metres) show the difference between Z and H plotted against Z. At low altitudes the difference is very small. In this Item, atmospheric properties are tabulated against geopotential altitude up to H = 80 km, and then against geometric altitude. (See Item Nos 68046 and 77022 (Reference 9 and 10) for altitude scales in non-standard atmospheres.)

5. PRESENTATION

Table 8.1 presents atmospheric data for altitudes up to 2.5×10^5 ft at intervals of 1000 ft. Table 8.1 presents corresponding data for altitudes up to 80 km at intervals of 0.5 km. Table 8.3 gives atmospheric data from 80 km to 1000 km, at intervals of 5 km to 300 km and then at intervals of 10 km. In these tables, a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation. Sketches 7.1 to 7.11 indicate, roughly, the variation with altitude of the more important atmospheric parameters. The equations necessary to derive the data in Tables 8.1 and 8.1 are given in Appendix A in a manner suitable for programming.

6. DERIVATION AND REFERENCES

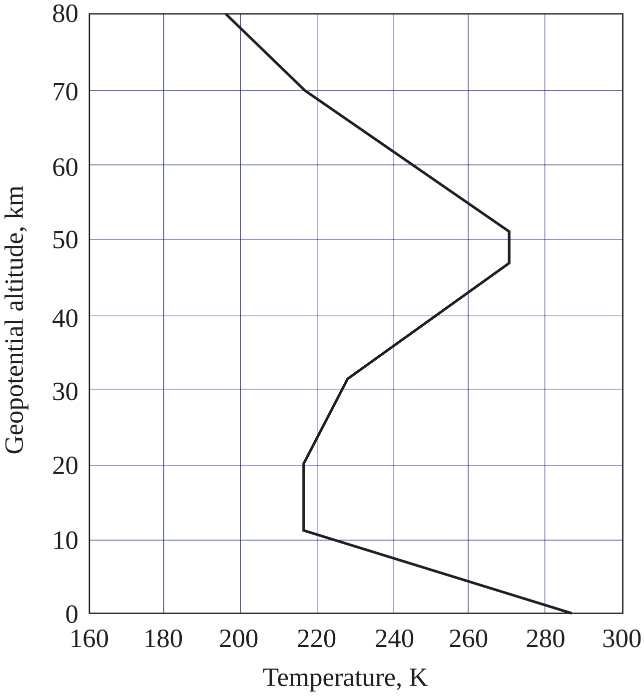
Derivation

1.	–	Standard Atmosphere. International Organization for Standardization, ISO-2533-1975(E), 1975.
2.	–	US Standard Atmosphere, 1976. US Committee on Extension to the Standard Atmosphere. US Government Printing Office, 1976.

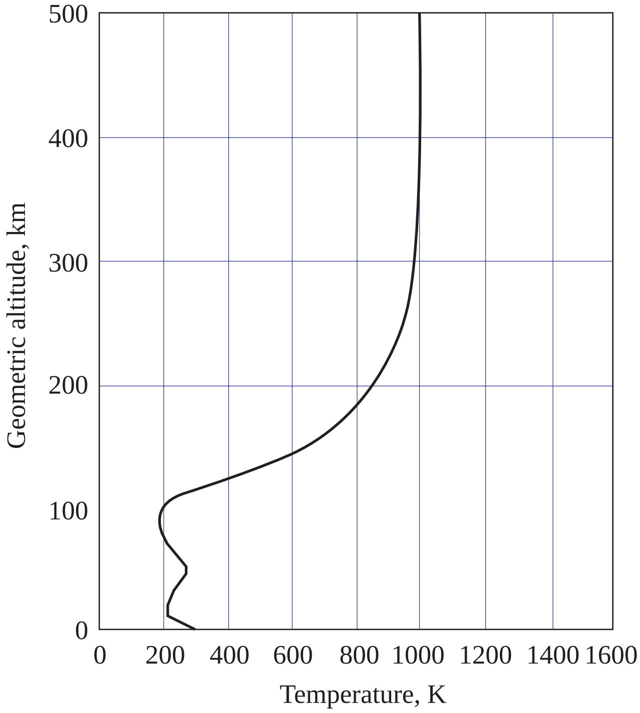
References

3.	GREGG, W.R.	Standard Atmosphere. NACA Rep. 147, 1922.
4.	–	ICAN Standard Atmosphere. Air Publication 1275, 1924. (See also ARC R & M 1891 (1941) Pankhurst R.C and Conn J.F.C. Physical properties of the Standard Atmosphere.)
5.	–	Manual of the ICAO Standard Atmosphere. Document 7488, International Civil Aviation Organization, 1954.
6.	MINZER, R.A. RIPLEY, W.S. CONDRON, T.P.	US extension to the ICAO Standard Atmosphere Tables and Data to 300 standard geopotential kilometres. Geophys. Res. Dir. and U.S. Weather Bureau, 1958.
7.	–	US Standard Atmosphere, 1962. US Committee on Extension to the Standard Atmosphere. US Government Printing Office, 1962.
8.	–	Manual of the ICAO Standard Atmosphere extended to 32 km. Document 7488/2, International Civil Aviation Organization, 1964.
9.	ESDU	Atmospheric data for performance calculations. ESDU Item No. 68046 (Performance Series), 1968. (See also Addendum Item 72018, height in feet data in SI units.)
10.	ESDU	Equations for calculation of international standard atmosphere and associated off-standard atmospheres. ESDU Item No. 77022 (Performance Series), 1977.

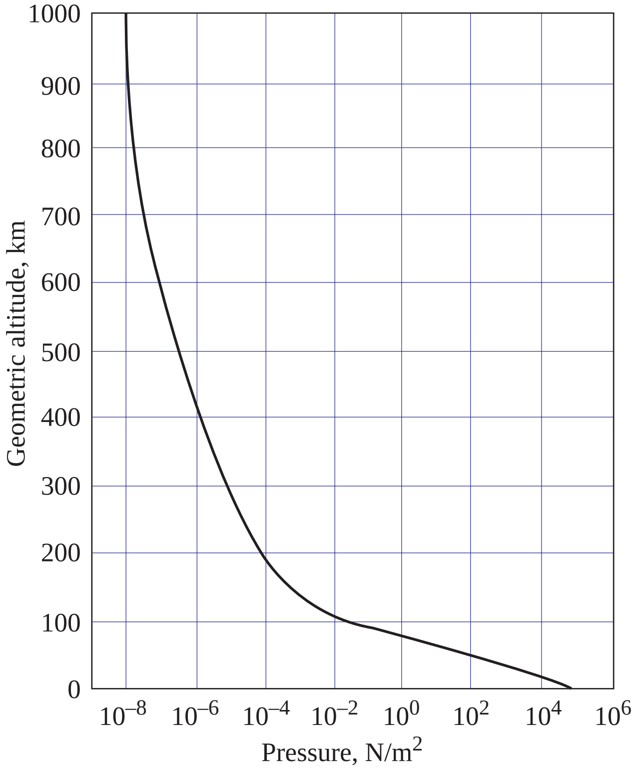
7. SKETCHES



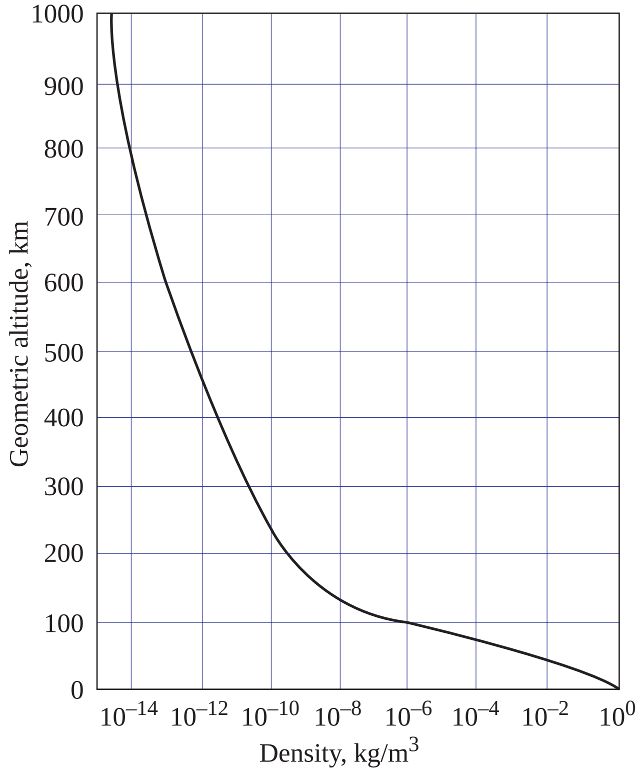
Sketch 7.1



Sketch 7.2

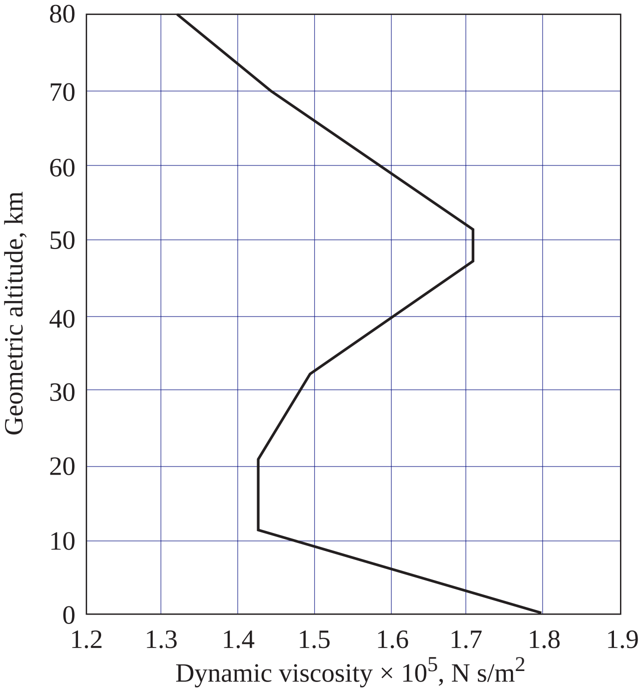


Sketch 7.3

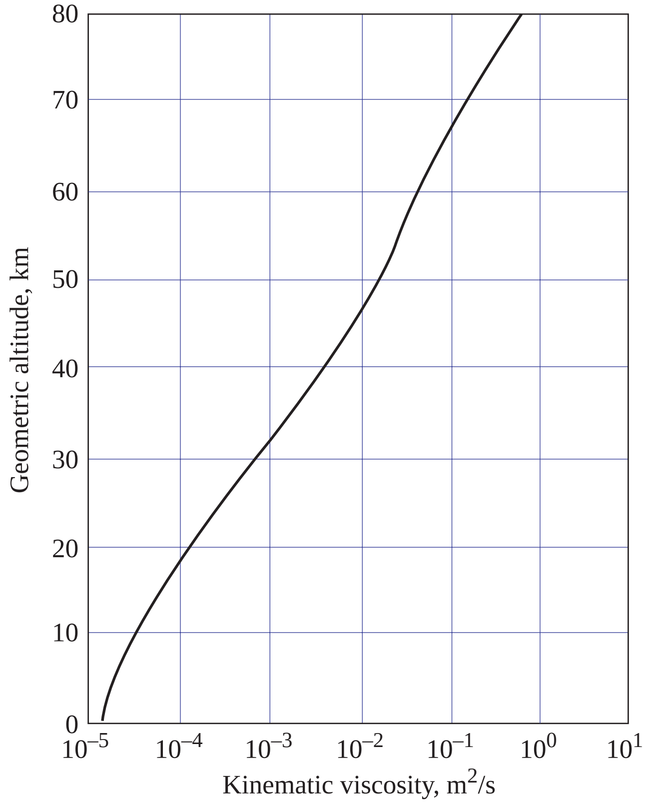


Sketch 7.4

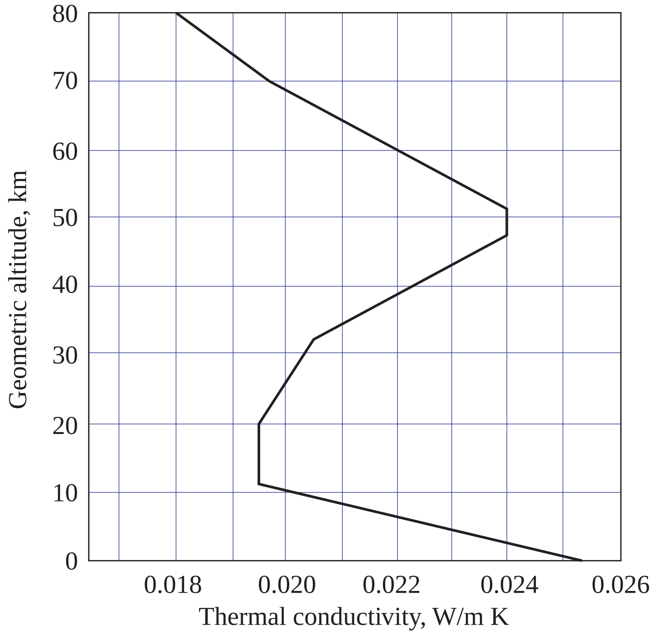
This page Amendment B



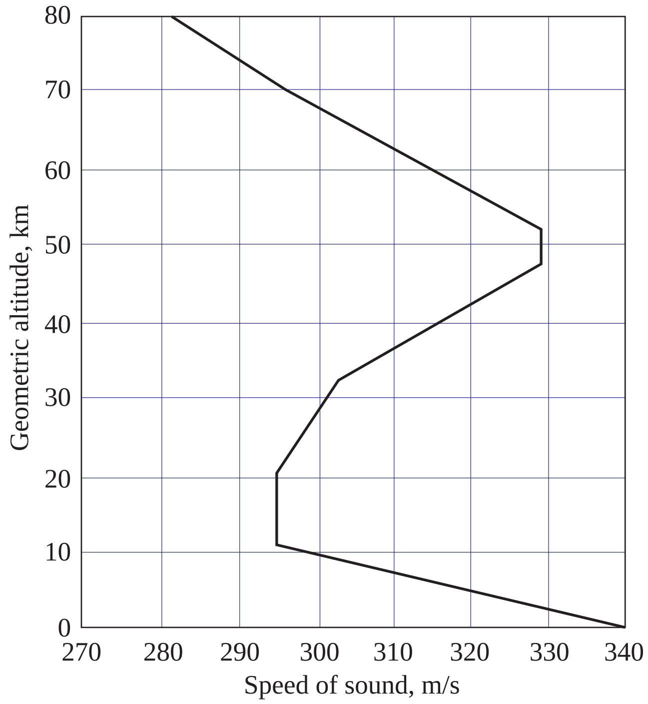
Sketch 7.5



Sketch 7.6

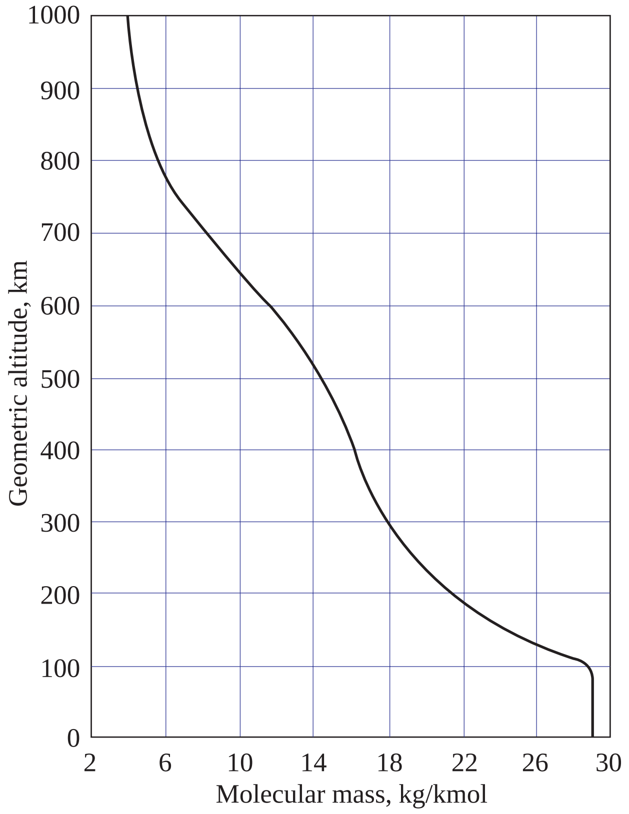


Sketch 7.7

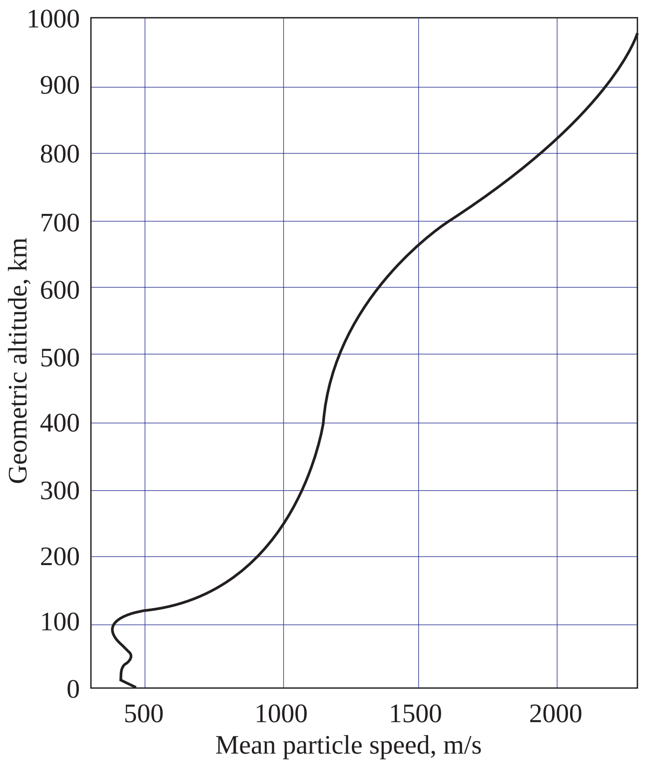


Sketch 7.8

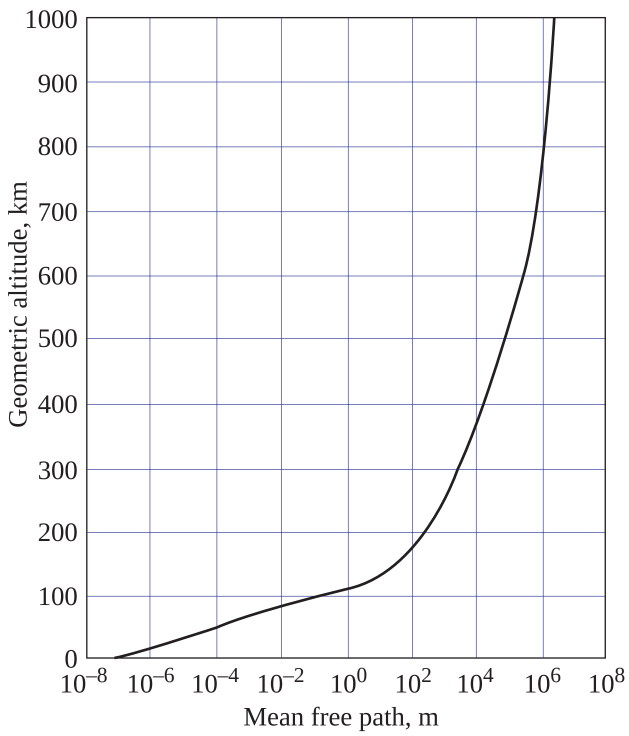
This page Amendment B



Sketch 7.9



Sketch 7.10



Sketch 7.11

This page Amendment B

8. TABLES

TABLE 8.1 Properties of a Standard Atmosphere: Geopotential Altitude in Feet (–2000 ft to 250 000 ft)

H (ft)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (ft^{-1})
-2.00 +3	292.1	1.007 0	1.074 0	1.060 0	9.536 -1	1.011 0	1.012 0	7.497 +6
-1.00	290.1	1.003	1.037	1.030	9.764	1.005	1.006	7.297
0.00 0	288.2	1.000 0	1.000 0	1.000 0	1.000 0	1.000 0	1.000 0	7.101 +6
1.00 +3	286.2	9.966 -1	9.644 -1	9.711 -1	1.024	9.946 -1	9.938 -1	6.909
2.00	284.2	9.931	9.298	9.428	1.049	9.893	9.877	6.720
3.00	282.2	9.896	8.962	9.151	1.075	9.839	9.815	6.536
4.00	280.2	9.862	8.637	8.881	1.102	9.785	9.753	6.355
5.00	278.2	9.827	8.320	8.617	1.129	9.731	9.691	6.179
6.00	276.3	9.792	8.014	8.359	1.158	9.676	9.629	6.006
7.00	274.3	9.756	7.716	8.106	1.187	9.622	9.567	5.837
8.00	272.3	9.721	7.428	7.860	1.217	9.567	9.504	5.671
9.00	270.3	9.686	7.148	7.620	1.248	9.512	9.442	5.509
1.00 +4	268.3	9.650 -1	6.877 -1	7.385 -1	1.281 0	9.457 -1	9.379 -1	5.351 +6
1.10	266.4	9.614	6.614	7.156	1.314	9.401	9.316	5.196
1.20	264.4	9.579	6.360	6.932	1.348	9.346	9.253	5.045
1.30	262.4	9.543	6.113	6.713	1.384	9.290	9.190	4.897
1.40	260.4	9.507	5.875	6.500	1.421	9.234	9.127	4.752
1.50	258.4	9.470	5.643	6.292	1.459	9.178	9.064	4.610
1.60	256.5	9.434	5.420	6.090	1.498	9.122	9.001	4.472
1.70	254.5	9.397	5.203	5.892	1.539	9.065	8.937	4.337
1.80	252.5	9.361	4.994	5.699	1.581	9.008	8.873	4.205
1.90	250.5	9.324	4.791	5.511	1.624	8.951	8.810	4.076
2.00 +4	248.5	9.287 -1	4.595 -1	5.328 -1	1.669 0	8.894 -1	8.746 -1	3.950 +6
2.10	246.5	9.250	4.406	5.150	1.716	8.837	8.682	3.828
2.20	244.6	9.213	4.223	4.976	1.764	8.779	8.618	3.708
2.30	242.6	9.175	4.046	4.807	1.814	8.721	8.554	3.591
2.40	240.6	9.138	3.876	4.642	1.866	8.663	8.489	3.476
2.50	238.6	9.100	3.711	4.481	1.920	8.605	8.425	3.365
2.60	236.6	9.062	3.552	4.325	1.976	8.547	8.360	3.256
2.70	234.7	9.024	3.398	4.173	2.034	8.488	8.295	3.150
2.80	232.7	8.986	3.250	4.025	2.094	8.429	8.231	3.047
2.90	230.7	8.948	3.107	3.881	2.157	8.370	8.166	2.946
3.00 +4	228.7	8.909 -1	2.970 -1	3.741 -1	2.221 0	8.311 -1	8.100 -1	2.848 +6
3.10	226.7	8.870	2.837	3.605	2.289	8.251	8.035	2.752
3.20	224.8	8.832	2.709	3.473	2.359	8.192	7.970	2.659
3.30	222.8	8.793	2.586	3.345	2.431	8.132	7.904	2.568
3.40	220.8	8.753	2.467	3.220	2.507	8.071	7.839	2.480
3.50	218.8	8.714	2.353	3.099	2.585	8.011	7.773	2.394
3.60	216.8	8.675	2.243	2.981	2.667	7.950	7.707	2.310
3.70	216.7	8.671	2.138	2.844	2.794	7.945	7.701	2.204
3.80	216.7	8.671	2.038	2.710	2.932	7.945	7.701	2.100
3.90	216.7	8.671	1.942	2.583	3.076	7.945	7.701	2.002
4.00 +4	216.7	8.671 -1	1.851 -1	2.462 -1	3.227 0	7.945 -1	7.701 -1	1.908 +6
4.10	216.7	8.671	1.764	2.346	3.386	7.945	7.701	1.818
4.20	216.7	8.671	1.681	2.236	3.553	7.945	7.701	1.733
4.30	216.7	8.671	1.602	2.131	3.728	7.945	7.701	1.652
4.40	216.7	8.671	1.527	2.031	3.911	7.945	7.701	1.574
4.50	216.7	8.671	1.455	1.936	4.104	7.945	7.701	1.500
4.60	216.7	8.671	1.387	1.845	4.306	7.945	7.701	1.430
4.70	216.7	8.671	1.322	1.758	4.518	7.945	7.701	1.363
4.80	216.7	8.671	1.260	1.676	4.741	7.945	7.701	1.299
4.90	216.7	8.671	1.201	1.597	4.974	7.945	7.701	1.238
5.00 +4	216.7	8.671 -1	1.145 -1	1.522 -1	5.219 0	7.945 -1	7.701 -1	1.180 +6
5.10	216.7	8.671	1.091	1.451	5.476	7.945	7.701	1.124
5.20	216.7	8.671	1.040	1.383	5.745	7.945	7.701	1.072
5.30	216.7	8.671	9.909 -2	1.318	6.028	7.945	7.701	1.021
5.40	216.7	8.671	9.444	1.256	6.325	7.945	7.701	9.734 +5
5.50	216.7	8.671	9.001	1.197	6.637	7.945	7.701	9.277
5.60	216.7	8.671	8.578	1.141	6.963	7.945	7.701	8.842
5.70	216.7	8.671	8.176	1.087	7.306	7.945	7.701	8.427
5.80	216.7	8.671	7.792	1.036	7.666	7.945	7.701	8.032
5.90	216.7	8.671	7.426	9.877 -2	8.043	7.945	7.701	7.655

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

This page Amendment B

TABLE 8.1 Properties of a Standard Atmosphere: Geopotential Altitude in Feet (continued)

H (ft)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (ft^{-1})
6.00 +4	216.7	8.671 -1	7.078 -2	9.414 -2	8.439 0	7.945 -1	7.701 -1	7.296 +5
6.10	216.7	8.671	6.746	8.972	8.855	7.945	7.701	6.953
6.20	216.7	8.671	6.429	8.551	9.291	7.945	7.701	6.627
6.30	216.7	8.671	6.127	8.150	9.748	7.945	7.701	6.316
6.40	216.7	8.671	5.840	7.767	1.023 +1	7.945	7.701	6.020
6.50	216.7	8.671	5.566	7.403	1.073	7.945	7.701	5.737
6.60	216.8	8.673	5.305	7.052	1.127	7.948	7.705	5.464
6.70	217.1	8.679	5.056	6.712	1.186	7.958	7.715	5.198
6.80	217.4	8.686	4.819	6.389	1.247	7.967	7.726	4.945
6.90	217.7	8.692	4.594	6.081	1.312	7.976	7.736	4.705
7.00 +4	218.0	8.698 -1	4.380 -2	5.789 -2	1.379 +1	7.986 -1	7.746 -1	4.477 +5
7.10	218.3	8.704	4.176	5.512	1.451	7.995	7.756	4.261
7.20	218.6	8.710	3.981	5.248	1.525	8.004	7.766	4.055
7.30	218.9	8.716	3.796	4.997	1.604	8.014	7.776	3.859
7.40	219.2	8.722	3.620	4.758	1.686	8.023	7.786	3.673
7.50	219.5	8.728	3.452	4.531	1.773	8.032	7.796	3.496
7.60	219.8	8.734	3.292	4.316	1.863	8.042	7.807	3.328
7.70	220.1	8.740	3.140	4.110	1.959	8.051	7.817	3.169
7.80	220.4	8.746	2.995	3.915	2.059	8.060	7.827	3.017
7.90	220.7	8.752	2.857	3.730	2.164	8.069	7.837	2.872
8.00 +4	221.0	8.758 -1	2.725 -2	3.553 -2	2.274 +1	8.079 -1	7.847 -1	2.735 +5
8.10	221.3	8.764	2.600	3.385	2.389	8.088	7.857	2.604
8.20	221.6	8.770	2.481	3.225	2.511	8.097	7.867	2.480
8.30	221.9	8.776	2.367	3.073	2.638	8.107	7.877	2.362
8.40	222.3	8.782	2.258	2.928	2.772	8.116	7.887	2.250
8.50	222.6	8.788	2.155	2.790	2.912	8.125	7.897	2.143
8.60	222.9	8.794	2.057	2.659	3.059	8.134	7.907	2.041
8.70	223.2	8.800	1.963	2.534	3.213	8.144	7.918	1.945
8.80	223.5	8.806	1.873	2.416	3.375	8.153	7.928	1.853
8.90	223.8	8.812	1.788	2.303	3.545	8.162	7.938	1.765
9.00 +4	224.1	8.818 -1	1.707 -2	2.195 -2	3.723 +1	8.171 -1	7.948 -1	1.682 +5
9.10	224.4	8.824	1.630	2.093	3.909	8.181	7.958	1.603
9.20	224.7	8.830	1.556	1.995	4.105	8.190	7.968	1.527
9.30	225.0	8.836	1.485	1.902	4.310	8.199	7.978	1.456
9.40	225.3	8.842	1.418	1.814	4.526	8.208	7.988	1.387
9.50	225.6	8.848	1.354	1.730	4.751	8.217	7.998	1.322
9.60	225.9	8.854	1.293	1.649	4.988	8.227	8.008	1.261
9.70	226.2	8.860	1.235	1.573	5.236	8.236	8.018	1.202
9.80	226.5	8.866	1.179	1.500	5.496	8.245	8.028	1.146
9.90	226.8	8.872	1.126	1.431	5.768	8.254	8.038	1.092
1.00 +5	227.1	8.878 -1	1.076 -2	1.365 -2	6.054 +1	8.263 -1	8.048 -1	1.041 +5
1.01	227.4	8.884	1.028	1.302	6.353	8.272	8.058	9.929 +4
1.02	227.7	8.890	9.818 -3	1.242	6.667	8.282	8.068	9.469
1.03	228.0	8.896	9.379	1.185	6.996	8.291	8.078	9.030
1.04	228.3	8.902	8.961	1.131	7.340	8.300	8.088	8.612
1.05	228.7	8.908	8.562	1.079	7.702	8.309	8.099	8.213
1.06	229.5	8.925	8.181	1.027	8.115	8.335	8.127	7.809
1.07	230.4	8.941	7.819	9.780 -3	8.548	8.360	8.155	7.427
1.08	231.2	8.958	7.474	9.314	9.003	8.386	8.183	7.065
1.09	232.1	8.974	7.145	8.872	9.481	8.411	8.211	6.721
1.10 +5	232.9	8.991 -1	6.832 -3	8.452 -3	9.982 +1	8.437 -1	8.239 -1	6.396 +4
1.11	233.8	9.007	6.534	8.054	1.051 +2	8.462	8.267	6.087
1.12	234.6	9.024	6.250	7.676	1.106	8.488	8.295	5.795
1.13	235.5	9.040	5.979	7.316	1.164	8.513	8.323	5.517
1.14	236.3	9.057	5.721	6.975	1.224	8.538	8.350	5.254
1.15	237.2	9.073	5.475	6.651	1.287	8.563	8.378	5.004
1.16	238.0	9.089	5.240	6.343	1.354	8.588	8.406	4.767
1.17	238.9	9.105	5.016	6.050	1.424	8.614	8.434	4.542
1.18	239.8	9.122	4.803	5.772	1.497	8.639	8.462	4.328
1.19	240.6	9.138	4.599	5.508	1.573	8.664	8.489	4.125

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

This page Amendment B

TABLE 8.1 Properties of a Standard Atmosphere: Geopotential Altitude in Feet (continued)

H (ft)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (ft^{-1})
1.20 +5	241.5	9.154 -1	4.405 -3	5.256 -3	1.653 +2	8.689 -1	8.517 -1	3.932 +4
1.21	242.3	9.170	4.219	5.017	1.737	8.714	8.545	3.749
1.22	243.2	9.186	4.042	4.789	1.825	8.739	8.573	3.575
1.23	244.0	9.203	3.873	4.573	1.916	8.764	8.600	3.410
1.24	244.9	9.219	3.711	4.367	2.012	8.788	8.628	3.253
1.25	245.7	9.235	3.557	4.171	2.113	8.813	8.656	3.103
1.26	246.6	9.251	3.410	3.984	2.218	8.838	8.683	2.961
1.27	247.4	9.267	3.269	3.807	2.328	8.863	8.711	2.826
1.28	248.3	9.283	3.134	3.638	2.443	8.887	8.738	2.698
1.29	249.1	9.299	3.006	3.476	2.564	8.912	8.766	2.576
1.30 +5	250.0	9.314 -1	2.883 -3	3.323 -3	2.689 +2	8.937 -1	8.793 -1	2.459 +4
1.31	250.9	9.330	2.766	3.177	2.821	8.961	8.821	2.349
1.32	251.7	9.346	2.653	3.038	2.958	8.986	8.848	2.243
1.33	252.6	9.362	2.546	2.905	3.102	9.010	8.876	2.143
1.34	253.4	9.378	2.443	2.778	3.252	9.035	8.903	2.048
1.35	254.3	9.394	2.345	2.658	3.409	9.059	8.931	1.957
1.36	255.1	9.409	2.251	2.543	3.572	9.084	8.958	1.870
1.37	256.0	9.425	2.161	2.433	3.744	9.108	8.985	1.788
1.38	256.8	9.441	2.075	2.328	3.922	9.132	9.013	1.709
1.39	257.7	9.456	1.993	2.229	4.109	9.157	9.040	1.634
1.40 +5	258.5	9.472 -1	1.914 -3	2.133 -3	4.303 +2	9.181 -1	9.067 -1	1.563 +4
1.41	259.4	9.488	1.839	2.043	4.506	9.205	9.094	1.495
1.42	260.2	9.503	1.766	1.956	4.719	9.229	9.122	1.430
1.43	261.1	9.519	1.697	1.873	4.940	9.253	9.149	1.368
1.44	261.9	9.534	1.631	1.794	5.171	9.277	9.176	1.309
1.45	262.8	9.550	1.568	1.719	5.412	9.301	9.203	1.253
1.46	263.7	9.565	1.507	1.647	5.663	9.325	9.230	1.199
1.47	264.5	9.581	1.449	1.578	5.925	9.349	9.257	1.148
1.48	265.4	9.596	1.393	1.512	6.198	9.373	9.285	1.099
1.49	266.2	9.612	1.339	1.450	6.483	9.397	9.312	1.053
1.50 +5	267.1	9.627 -1	1.288 -3	1.390 -3	6.780 +2	9.421 -1	9.339 -1	1.008 +4
1.51	267.9	9.643	1.239	1.332	7.090	9.445	9.366	9.658 +3
1.52	268.8	9.658	1.192	1.277	7.412	9.469	9.393	9.252
1.53	269.6	9.673	1.146	1.225	7.748	9.493	9.420	8.865
1.54	270.5	9.689	1.103	1.175	8.099	9.516	9.447	8.495
1.55	270.7	9.692	1.061	1.130	8.426	9.521	9.452	8.167
1.56	270.7	9.692	1.021	1.087	8.756	9.521	9.452	7.859
1.57	270.7	9.692	9.828 -4	1.046	9.100	9.521	9.452	7.563
1.58	270.7	9.692	9.457	1.007	9.457	9.521	9.452	7.277
1.59	270.7	9.692	9.100	9.688 -4	9.828	9.521	9.452	7.002
1.60 +5	270.7	9.692 -1	8.756 -4	9.322 -4	1.021 +3	9.521 -1	9.452 -1	6.738 +3
1.61	270.7	9.692	8.426	8.971	1.061	9.521	9.452	6.484
1.62	270.7	9.692	8.108	8.632	1.103	9.521	9.452	6.239
1.63	270.7	9.692	7.802	8.306	1.146	9.521	9.452	6.004
1.64	270.7	9.692	7.507	7.993	1.191	9.521	9.452	5.777
1.65	270.7	9.692	7.224	7.691	1.238	9.521	9.452	5.559
1.66	270.7	9.692	6.951	7.401	1.287	9.521	9.452	5.349
1.67	270.7	9.692	6.689	7.121	1.337	9.521	9.452	5.147
1.68	270.1	9.681	6.436	6.867	1.384	9.505	9.434	4.967
1.69	269.2	9.666	6.192	6.628	1.431	9.481	9.407	4.798
1.70 +5	268.4	9.651 -1	5.957 -4	6.396 -4	1.479 +3	9.457 -1	9.380 -1	4.635 +3
1.71	267.5	9.635	5.730	6.172	1.528	9.434	9.353	4.476
1.72	266.7	9.620	5.511	5.955	1.580	9.410	9.326	4.323
1.73	265.8	9.604	5.300	5.745	1.634	9.386	9.299	4.174
1.74	265.0	9.589	5.096	5.542	1.689	9.362	9.272	4.031
1.75	264.1	9.574	4.899	5.345	1.747	9.338	9.245	3.891
1.76	263.2	9.558	4.709	5.155	1.807	9.314	9.217	3.756
1.77	262.4	9.543	4.526	4.971	1.869	9.290	9.190	3.626
1.78	261.5	9.527	4.350	4.793	1.933	9.266	9.163	3.499
1.79	260.7	9.511	4.180	4.620	2.000	9.242	9.136	3.376
1.80 +5	259.8	9.496 -1	4.016 -4	4.454 -4	2.070 +3	9.218 -1	9.109 -1	3.258 +3
1.81	259.0	9.480	3.858	4.293	2.142	9.193	9.081	3.143
1.82	258.1	9.465	3.706	4.137	2.217	9.169	9.054	3.032
1.83	257.3	9.449	3.559	3.986	2.294	9.145	9.027	2.925
1.84	256.4	9.433	3.417	3.840	2.375	9.121	9.000	2.820
1.85	255.6	9.418	3.281	3.700	2.459	9.096	8.972	2.720
1.86	254.7	9.402	3.150	3.564	2.546	9.072	8.945	2.622
1.87	253.9	9.386	3.024	3.432	2.636	9.048	8.917	2.528
1.88	253.0	9.370	2.902	3.305	2.730	9.023	8.890	2.437
1.89	252.1	9.354	2.785	3.182	2.828	8.999	8.863	2.349

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

TABLE 8.1 Properties of a Standard Atmosphere: Geopotential Altitude in Feet (concluded)

H (ft)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (ft^{-1})
1.90 +5	251.3	9.339 -1	2.672 -4	3.064 -4	2.929 +3	8.974 -1	8.835 -1	2.264 +3
1.91	250.4	9.323	2.563	2.949	3.035	8.949	8.808	2.181
1.92	249.6	9.307	2.459	2.839	3.144	8.925	8.780	2.102
1.93	248.7	9.291	2.358	2.732	3.258	8.900	8.753	2.025
1.94	247.9	9.275	2.261	2.629	3.377	8.876	8.725	1.950
1.95	247.0	9.259	2.168	2.529	3.500	8.851	8.698	1.879
1.96	246.2	9.243	2.078	2.433	3.628	8.826	8.670	1.809
1.97	245.3	9.227	1.992	2.340	3.761	8.801	8.642	1.742
1.98	244.5	9.211	1.909	2.250	3.900	8.776	8.615	1.677
1.99	243.6	9.195	1.829	2.164	4.044	8.752	8.587	1.614
2.00 +5	242.8	9.179 -1	1.753 -4	2.081 -4	4.195 +3	8.727 -1	8.559 -1	1.554 +3
2.01	241.9	9.163	1.679	2.000	4.351	8.702	8.532	1.495
2.02	241.1	9.146	1.608	1.922	4.513	8.677	8.504	1.439
2.03	240.2	9.130	1.540	1.848	4.683	8.652	8.476	1.384
2.04	239.3	9.114	1.475	1.775	4.859	8.627	8.448	1.332
2.05	238.5	9.098	1.412	1.706	5.043	8.602	8.421	1.281
2.06	237.6	9.081	1.351	1.639	5.234	8.576	8.393	1.232
2.07	236.8	9.065	1.293	1.574	5.433	8.551	8.365	1.185
2.08	235.9	9.049	1.238	1.511	5.641	8.526	8.337	1.139
2.09	235.1	9.032	1.184	1.451	5.857	8.501	8.309	1.095
2.10 +5	234.2	9.016 -1	1.133 -4	1.393 -4	6.083 +3	8.475 -1	8.281 -1	1.053 +3
2.11	233.4	8.999	1.083	1.338	6.317	8.450	8.253	1.012
2.12	232.5	8.983	1.036	1.284	6.562	8.425	8.225	9.720 +2
2.13	231.7	8.967	9.905 -5	1.232	6.818	8.399	8.197	9.339
2.14	230.8	8.950	9.469	1.182	7.084	8.374	8.169	8.971
2.15	230.0	8.933	9.050	1.134	7.361	8.348	8.141	8.617
2.16	229.1	8.917	8.649	1.088	7.651	8.323	8.113	8.276
2.17	228.3	8.900	8.264	1.043	7.953	8.297	8.085	7.946
2.18	227.4	8.884	7.895	1.000	8.268	8.271	8.057	7.629
2.19	226.5	8.867	7.541	9.591 -5	8.597	8.246	8.029	7.324
2.20 +5	225.7	8.850 -1	7.201 -5	9.194 -5	8.940 +3	8.220 -1	8.001 -1	7.029 +2
2.21	224.8	8.833	6.876	8.812	9.299	8.194	7.973	6.745
2.22	224.0	8.817	6.564	8.445	9.673	8.168	7.945	6.472
2.23	223.1	8.800	6.266	8.091	1.006 +4	8.143	7.916	6.209
2.24	222.3	8.783	5.979	7.751	1.047	8.117	7.888	5.956
2.25	221.4	8.766	5.705	7.424	1.090	8.091	7.860	5.712
2.26	220.6	8.749	5.443	7.110	1.134	8.065	7.832	5.477
2.27	219.7	8.732	5.191	6.808	1.181	8.039	7.803	5.251
2.28	218.9	8.715	4.950	6.518	1.229	8.013	7.775	5.034
2.29	218.0	8.698	4.720	6.238	1.280	7.986	7.747	4.825
2.30 +5	217.2	8.681 -1	4.499 -5	5.970 -5	1.333 +4	7.960 -1	7.718 -1	4.623 +2
2.31	216.3	8.664	4.288	5.713	1.389	7.934	7.690	4.430
2.32	215.5	8.647	4.086	5.465	1.447	7.908	7.662	4.243
2.33	214.6	8.630	3.893	5.227	1.508	7.882	7.634	4.064
2.34	214.0	8.618	3.709	4.994	1.575	7.863	7.613	3.886
2.35	213.4	8.606	3.532	4.770	1.645	7.844	7.593	3.715
2.36	212.8	8.593	3.364	4.555	1.718	7.826	7.573	3.552
2.37	212.2	8.581	3.203	4.350	1.795	7.807	7.552	3.395
2.38	211.6	8.569	3.049	4.153	1.875	7.788	7.532	3.245
2.39	211.0	8.556	2.903	3.965	1.959	7.769	7.512	3.101
2.40 +5	210.3	8.544 -1	2.763 -5	3.784 -5	2.048 +4	7.750 -1	7.491 -1	2.963 +2
2.41	209.7	8.532	2.629	3.612	2.140	7.731	7.471	2.830
2.42	209.1	8.519	2.501	3.447	2.237	7.712	7.450	2.704
2.43	208.5	8.507	2.380	3.289	2.339	7.693	7.430	2.582
2.44	207.9	8.494	2.264	3.137	2.446	7.674	7.410	2.466
2.45	207.3	8.482	2.153	2.993	2.558	7.655	7.389	2.355
2.46	206.7	8.469	2.047	2.854	2.675	7.636	7.369	2.248
2.47	206.1	8.457	1.947	2.722	2.798	7.617	7.348	2.146
2.48	205.5	8.444	1.851	2.595	2.927	7.597	7.328	2.048
2.49	204.9	8.432	1.759	2.474	3.063	7.578	7.307	1.955
2.50 +5	204.2	8.419 -1	1.672 -5	2.358 -5	3.205 +4	7.559 -1	7.287 -1	1.865 +2

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

This page Amendment B

TABLE 8.2 Properties of a Standard Atmosphere: Geopotential Altitude in Metres (–500 m to 80 000 m)

H (m)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (m^{-1})
-5.00 +2	291.4	1.006 0	1.061 0	1.049 0	9.617 -1	1.009 0	1.010 0	2.436 +7
0.00 0	288.2	1.000 0	1.000 0	1.000 0	1.000 0	1.000 0	1.000 0	2.330 +7
5.00 +2	284.9	9.943 -1	9.421 -1	9.529 -1	1.040	9.912 -1	9.899 -1	2.227
1.00 +3	281.7	9.887	8.870	9.075	1.083	9.824	9.798	2.128
1.50	278.4	9.829	8.345	8.637	1.127	9.735	9.696	2.032
2.00	275.2	9.772	7.846	8.216	1.174	9.645	9.594	1.939
2.50	271.9	9.714	7.371	7.811	1.223	9.556	9.491	1.850
3.00	268.7	9.656	6.919	7.421	1.275	9.465	9.389	1.764
3.50	265.4	9.597	6.490	7.047	1.330	9.374	9.286	1.681
4.00	262.2	9.538	6.083	6.687	1.388	9.283	9.183	1.601
4.50	258.9	9.479	5.697	6.341	1.449	9.191	9.079	1.523
5.00 +3	255.7	9.419 -1	5.331 -1	6.009 -1	1.514 0	9.099 -1	8.975 -1	1.449 +7
5.50	252.4	9.359	4.985	5.691	1.583	9.006	8.871	1.378
6.00	249.2	9.299	4.656	5.385	1.655	8.912	8.766	1.309
6.50	245.9	9.238	4.346	5.093	1.732	8.818	8.661	1.243
7.00	242.7	9.177	4.052	4.812	1.813	8.723	8.556	1.179
7.50	239.4	9.115	3.775	4.544	1.899	8.628	8.450	1.118
8.00	236.2	9.053	3.513	4.287	1.990	8.532	8.344	1.060
8.50	232.9	8.990	3.267	4.042	2.087	8.436	8.238	1.003
9.00	229.7	8.927	3.034	3.807	2.190	8.339	8.131	9.495 +6
9.50	226.4	8.864	2.815	3.583	2.300	8.241	8.024	8.977
1.00 +4	223.2	8.800 -1	2.609 -1	3.369 -1	2.417 0	8.143 -1	7.917 -1	8.482 +6
1.05	219.9	8.736	2.415	3.165	2.542	8.044	7.809	8.007
1.10	216.7	8.671	2.234	2.971	2.674	7.945	7.701	7.553
1.15	216.7	8.671	2.064	2.746	2.894	7.945	7.701	6.981
1.20	216.7	8.671	1.908	2.537	3.131	7.945	7.701	6.452
1.25	216.7	8.671	1.763	2.345	3.388	7.945	7.701	5.962
1.30	216.7	8.671	1.629	2.167	3.666	7.945	7.701	5.510
1.35	216.7	8.671	1.506	2.003	3.967	7.945	7.701	5.093
1.40	216.7	8.671	1.392	1.851	4.292	7.945	7.701	4.706
1.45	216.7	8.671	1.286	1.711	4.644	7.945	7.701	4.350
1.50 +4	216.7	8.671 -1	1.189 -1	1.581 -1	5.025 0	7.945 -1	7.701 -1	4.020 +6
1.55	216.7	8.671	1.099	1.461	5.437	7.945	7.701	3.715
1.60	216.7	8.671	1.015	1.350	5.883	7.945	7.701	3.433
1.65	216.7	8.671	9.383 -2	1.248	6.366	7.945	7.701	3.173
1.70	216.7	8.671	8.672	1.153	6.888	7.945	7.701	2.933
1.75	216.7	8.671	8.014	1.066	7.453	7.945	7.701	2.710
1.80	216.7	8.671	7.407	9.851 -2	8.065	7.945	7.701	2.505
1.85	216.7	8.671	6.845	9.104	8.726	7.945	7.701	2.315
1.90	216.7	8.671	6.326	8.414	9.442	7.945	7.701	2.139
1.95	216.7	8.671	5.847	7.776	1.022 +1	7.945	7.701	1.977
2.00 +4	216.7	8.671 -1	5.403 -2	7.187 -2	1.105 +1	7.945 -1	7.701 -1	1.827 +6
2.05	217.2	8.681	4.994	6.627	1.201	7.960	7.718	1.684
2.10	217.7	8.691	4.617	6.112	1.305	7.975	7.735	1.552
2.15	218.2	8.701	4.269	5.638	1.417	7.991	7.751	1.430
2.20	218.7	8.711	3.947	5.202	1.539	8.006	7.768	1.319
2.25	219.2	8.721	3.651	4.801	1.671	8.021	7.784	1.216
2.30	219.7	8.731	3.378	4.431	1.814	8.037	7.801	1.121
2.35	220.2	8.741	3.125	4.091	1.968	8.052	7.818	1.034
2.40	220.7	8.751	2.892	3.777	2.136	8.067	7.834	9.544 +5
2.45	221.2	8.761	2.677	3.488	2.317	8.082	7.851	8.808

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

TABLE 8.2 Properties of a Standard Atmosphere: Geopotential Altitude in Metres (continued)

H (m)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (m^{-1})
2.50 +4	221.7	8.771 -1	2.478 -2	3.222 -2	2.513 +1	8.097 -1	7.867 -1	8.129 +5
2.55	222.2	8.780	2.295	2.976	2.726	8.113	7.884	7.504
2.60	222.7	8.790	2.125	2.750	2.956	8.128	7.900	6.929
2.65	223.2	8.800	1.968	2.541	3.204	8.143	7.917	6.398
2.70	223.7	8.810	1.823	2.349	3.473	8.158	7.933	5.910
2.75	224.2	8.820	1.689	2.172	3.764	8.173	7.950	5.459
2.80	224.7	8.830	1.566	2.008	4.078	8.188	7.966	5.044
2.85	225.2	8.839	1.451	1.857	4.417	8.204	7.983	4.662
2.90	225.7	8.849	1.345	1.718	4.785	8.219	7.999	4.309
2.95	226.2	8.859	1.247	1.589	5.181	8.234	8.016	3.983
3.00 +4	226.7	8.869 -1	1.157 -2	1.470 -2	5.610 +1	8.249 -1	8.032 -1	3.683 +5
3.05	227.2	8.879	1.073	1.361	6.073	8.264	8.049	3.406
3.10	227.7	8.888	9.950 -3	1.259	6.573	8.279	8.065	3.150
3.15	228.2	8.898	9.232	1.166	7.113	8.294	8.082	2.914
3.20	228.7	8.908	8.567	1.080	7.696	8.309	8.098	2.696
3.25	230.1	8.935	7.952	9.960 -3	8.384	8.351	8.144	2.483
3.30	231.5	8.962	7.384	9.193	9.129	8.393	8.190	2.287
3.35	232.9	8.989	6.861	8.490	9.935	8.434	8.236	2.108
3.40	234.3	9.016	6.377	7.844	1.081 +2	8.476	8.282	1.944
3.45	235.7	9.043	5.930	7.251	1.175	8.518	8.328	1.793
3.50 +4	237.1	9.070 -1	5.516 -3	6.705 -3	1.276 +2	8.559 -1	8.373 -1	1.655 +5
3.55	238.5	9.097	5.134	6.204	1.386	8.600	8.419	1.529
3.60	239.9	9.123	4.780	5.742	1.505	8.641	8.465	1.412
3.65	241.3	9.150	4.452	5.318	1.633	8.682	8.510	1.306
3.70	242.7	9.177	4.149	4.927	1.771	8.723	8.556	1.207
3.75	244.1	9.203	3.867	4.566	1.919	8.764	8.601	1.117
3.80	245.5	9.229	3.607	4.234	2.079	8.805	8.646	1.034
3.85	246.9	9.256	3.365	3.928	2.252	8.846	8.692	9.575 +4
3.90	248.3	9.282	3.141	3.645	2.438	8.886	8.737	8.870
3.95	249.7	9.308	2.932	3.385	2.637	8.927	8.782	8.222
4.00 +4	251.1	9.334 -1	2.739 -3	3.144 -3	2.852 +2	8.967 -1	8.827 -1	7.623 +4
4.05	252.5	9.360	2.559	2.921	3.083	9.007	8.872	7.072
4.10	253.9	9.386	2.392	2.715	3.332	9.047	8.917	6.563
4.15	255.3	9.412	2.237	2.525	3.598	9.087	8.962	6.093
4.20	256.7	9.438	2.093	2.349	3.885	9.127	9.007	5.659
4.25	258.1	9.463	1.958	2.187	4.192	9.167	9.052	5.259
4.30	259.5	9.489	1.833	2.036	4.522	9.207	9.096	4.888
4.35	260.9	9.515	1.717	1.896	4.876	9.246	9.141	4.546
4.40	262.3	9.540	1.608	1.767	5.256	9.286	9.186	4.229
4.45	263.7	9.565	1.507	1.647	5.662	9.325	9.230	3.936
4.50 +4	265.1	9.591 -1	1.413 -3	1.536 -3	6.098 +2	9.365 -1	9.275 -1	3.664 +4
4.55	266.5	9.616	1.325	1.433	6.564	9.404	9.319	3.413
4.60	267.9	9.641	1.243	1.337	7.064	9.443	9.364	3.180
4.65	269.3	9.666	1.166	1.248	7.598	9.482	9.408	2.964
4.70	270.7	9.692	1.095	1.165	8.170	9.521	9.452	2.763
4.75	270.7	9.692	1.028	1.094	8.702	9.521	9.452	2.594
4.80	270.7	9.692	9.648 -4	1.027	9.269	9.521	9.452	2.436
4.85	270.7	9.692	9.058	9.643 -4	9.873	9.521	9.452	2.287
4.90	270.7	9.692	8.504	9.053	1.052 +3	9.521	9.452	2.147
4.95	270.7	9.692	7.983	8.500	1.120	9.521	9.452	2.016

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

TABLE 8.2 Properties of a Standard Atmosphere: Geopotential Altitude in Metres (concluded)

H (m)	T (K)	a/a_0	p/p_0	ρ/ρ_0	ν/ν_0	μ/μ_0	k/k_0	Re^*/l (m^{-1})
5.00 +4	270.7	9.692 -1	7.495 -4	7.980 -4	1.193 +3	9.521 -1	9.452 -1	1.892 +4
5.05	270.7	9.692	7.037	7.492	1.271	9.521	9.452	1.777
5.10	270.7	9.692	6.606	7.033	1.354	9.521	9.452	1.668
5.15	269.3	9.666	6.201	6.637	1.429	9.482	9.408	1.576
5.20	267.9	9.641	5.819	6.260	1.508	9.443	9.364	1.489
5.25	266.5	9.616	5.459	5.903	1.593	9.404	9.319	1.406
5.30	265.1	9.591	5.119	5.565	1.683	9.365	9.275	1.328
5.35	263.7	9.565	4.799	5.244	1.778	9.325	9.230	1.253
5.40	262.3	9.540	4.497	4.941	1.879	9.286	9.186	1.183
5.45	260.9	9.515	4.212	4.653	1.987	9.246	9.141	1.115
5.50 +4	259.5	9.489 -1	3.945 -4	4.381 -4	2.101 +3	9.207 -1	9.096 -1	1.052 +4
5.55	258.1	9.463	3.693	4.123	2.223	9.167	9.052	9.916 +3
5.60	256.7	9.438	3.456	3.880	2.353	9.127	9.007	9.346
5.65	255.3	9.412	3.232	3.649	2.490	9.087	8.962	8.805
5.70	253.9	9.386	3.023	3.431	2.637	9.047	8.917	8.292
5.75	252.5	9.360	2.825	3.225	2.793	9.007	8.872	7.807
5.80	251.1	9.334	2.640	3.030	2.959	8.967	8.827	7.348
5.85	249.7	9.308	2.466	2.846	3.136	8.927	8.782	6.914
5.90	248.3	9.282	2.302	2.672	3.325	8.886	8.737	6.503
5.95	246.9	9.256	2.149	2.508	3.526	8.846	8.692	6.115
6.00 +4	245.5	9.229 -1	2.005 -4	2.354 -4	3.741 +3	8.805 -1	8.646 -1	5.747 +3
6.05	244.1	9.203	1.870	2.208	3.970	8.764	8.601	5.400
6.10	242.7	9.177	1.743	2.070	4.215	8.723	8.556	5.072
6.15	241.3	9.150	1.624	1.940	4.476	8.682	8.510	4.763
6.20	239.9	9.123	1.513	1.817	4.755	8.641	8.465	4.470
6.25	238.5	9.097	1.409	1.702	5.053	8.600	8.419	4.194
6.30	237.1	9.070	1.311	1.593	5.371	8.559	8.373	3.934
6.35	235.7	9.043	1.219	1.491	5.712	8.518	8.328	3.688
6.40	234.3	9.016	1.134	1.395	6.076	8.476	8.282	3.457
6.45	232.9	8.989	1.054	1.304	6.467	8.434	8.236	3.238
6.50 +4	231.5	8.962 -1	9.792 -5	1.219 -4	6.884 +3	8.393 -1	8.190 -1	3.033 +3
6.55	230.1	8.935	9.094	1.139	7.332	8.351	8.144	2.839
6.60	228.7	8.908	8.441	1.064	7.811	8.309	8.098	2.657
6.65	227.3	8.881	7.831	9.930 -5	8.325	8.267	8.052	2.485
6.70	225.9	8.853	7.263	9.266	8.876	8.225	8.006	2.324
6.75	224.5	8.826	6.732	8.643	9.467	8.182	7.960	2.172
6.80	223.1	8.798	6.237	8.058	1.010 +4	8.140	7.914	2.029
6.85	221.7	8.771	5.776	7.509	1.078	8.097	7.867	1.895
6.90	220.3	8.743	5.346	6.994	1.152	8.055	7.821	1.769
6.95	218.9	8.715	4.946	6.512	1.230	8.012	7.775	1.650
7.00 +4	217.5	8.687 -1	4.574 -5	6.061 -5	1.315 +4	7.969 -1	7.728 -1	1.539 +3
7.05	216.1	8.659	4.227	5.638	1.406	7.926	7.681	1.435
7.10	214.7	8.631	3.905	5.242	1.504	7.883	7.635	1.337
7.15	213.7	8.611	3.605	4.862	1.615	7.852	7.601	1.242
7.20	212.7	8.591	3.328	4.509	1.735	7.821	7.568	1.154
7.25	211.7	8.570	3.070	4.180	1.864	7.790	7.535	1.071
7.30	210.7	8.550	2.832	3.873	2.003	7.759	7.501	9.943 +2
7.35	209.7	8.530	2.611	3.588	2.154	7.728	7.468	9.226
7.40	208.7	8.509	2.406	3.323	2.317	7.697	7.434	8.557
7.45	207.7	8.489	2.216	3.075	2.493	7.666	7.401	7.934
7.50 +4	206.7	8.469 -1	2.041 -5	2.846 -5	2.683 +4	7.634 -1	7.367 -1	7.354 +2
7.55	205.7	8.448	1.879	2.632	2.888	7.603	7.334	6.813
7.60	204.7	8.427	1.728	2.434	3.111	7.572	7.300	6.311
7.65	203.7	8.407	1.590	2.249	3.352	7.540	7.266	5.843
7.70	202.7	8.386	1.462	2.078	3.613	7.509	7.233	5.407
7.75	201.7	8.365	1.343	1.919	3.896	7.477	7.199	5.002
7.80	200.7	8.345	1.234	1.772	4.202	7.445	7.165	4.626
7.85	199.7	8.324	1.133	1.635	4.534	7.413	7.132	4.277
7.90	198.7	8.303	1.040	1.508	4.894	7.382	7.098	3.952
7.95	197.7	8.282	9.538 -6	1.391	5.285	7.350	7.064	3.650
8.00 +4	196.7	8.261 -1	8.747 -6	1.282 -5	5.710 +4	7.318 -1	7.030 -1	3.371 +2

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

TABLE 8.3 Properties of a Standard Atmosphere: Geopotential Altitude in Metres (80 000 m to 1 000 000 m)

Z (m)	T (K)	$\sqrt{(T/T_0)}$	p/p_0	ρ/ρ_0	$\overline{V}$ (m/s)	L (m)	m (kg/kmol)
8.00 +4	198.6	8.303 -1	1.039 -5	1.507 -5	3.811 +2	4.40 -3	28.96
8.50	188.8	8.095	4.399 -6	6.710 -6	3.716	9.88	28.95
9.00	186.9	8.053	1.812	2.789	3.699	2.37 -2	28.91
9.50	188.4	8.086	7.497 -7	1.137	3.726	5.79	28.73
1.00 +5	195.1	8.228 -1	3.159 -7	4.575 -7	3.814 +2	1.42 -1	28.40
1.05	208.8	8.513	1.429	1.898	3.982	3.36	27.88
1.10	240.0	9.126	7.011 -8	7.925 -8	4.317	7.88	27.27
1.15	300.0	1.020 0	3.957	3.501	4.879	1.75 +0	26.68
1.20	360.0	1.118	2.505	1.814	5.393	3.31	26.20
1.25	417.2	1.203	1.713	1.054	5.851	5.6	25.80
1.30	469.3	1.276	1.234	6.655 -9	6.250	8.8	25.44
1.35	516.6	1.339	9.235 -9	4.461	6.603	1.3 +1	25.09
1.40	559.6	1.394	7.109	3.128	6.919	1.8	24.75
1.45	598.8	1.442	5.595	2.270	7.205	2.5	24.42
1.50 +5	634.4	1.484 0	4.483 -9	1.694 -9	7.465 +2	3.3 +1	24.10
1.55	666.8	1.521	3.645	1.294	7.703	4.2	23.79
1.60	696.3	1.554	3.000	1.007	7.922	5.3	23.49
1.65	723.1	1.584	2.495	7.959 -10	8.125	6.7	23.19
1.70	747.6	1.611	2.093	6.380	8.313	8.2	22.90
1.75	769.8	1.634	1.770	5.174	8.489	1.0 +2	22.62
1.80	790.1	1.656	1.507	4.240	8.653	1.2	22.34
1.85	808.5	1.675	1.291	3.506	8.806	1.4	22.07
1.90	825.3	1.692	1.112	2.923	8.951	1.7	21.81
1.95	840.6	1.708	9.622 -10	2.454	9.087	2.0	21.55
2.00 +5	854.6	1.722 0	8.363 -10	2.074 -10	9.216 +2	2.4 +2	21.30
2.05	867.3	1.735	7.298	1.763	9.337	2.7	21.06
2.10	878.8	1.746	6.391	1.507	9.452	3.2	20.83
2.15	889.4	1.757	5.616	1.294	9.562	3.6	20.60
2.20	899.0	1.766	4.950	1.116	9.665	4.2	20.37
2.25	907.8	1.775	4.374	9.665 -11	9.764	4.8	20.16
2.30	915.8	1.783	3.876	8.402	9.858	5.4	19.95
2.35	923.1	1.790	3.443	7.329	9.947	6.2	19.75
2.40	929.7	1.796	3.065	6.415	1.003 +3	7.0	19.56
2.45	935.8	1.802	2.735	5.631	1.011	7.9	19.37
2.50 +5	941.3	1.807 0	2.444 -10	4.957 -11	1.019 +3	8.9 +2	19.19
2.55	946.4	1.812	2.189	4.375	1.027	1.0 +3	19.02
2.60	951.0	1.817	1.963	3.871	1.034	1.1	18.85
2.65	955.2	1.821	1.764	3.433	1.040	1.2	18.69
2.70	959.0	1.824	1.587	3.052	1.047	1.4	18.53
2.75	962.5	1.828	1.430	2.718	1.053	1.5	18.38
2.80	965.8	1.831	1.291	2.425	1.059	1.7	18.24
2.85	968.7	1.833	1.166	2.168	1.064	1.9	18.11
2.90	971.3	1.836	1.055	1.941	1.070	2.1	17.97
2.95	973.8	1.838	9.549 -11	1.741	1.075	2.3	17.85
3.00 +5	976.0	1.840 0	8.656 -11	1.564 -11	1.080 +3	2.6 +3	17.73
3.10	979.9	1.844	7.134	1.267	1.089	3.2	17.50
3.20	983.2	1.847	5.901	1.032	1.097	3.8	17.29
3.30	985.9	1.850	4.898	8.447 -12	1.105	4.6	17.09
3.40	988.2	1.852	4.078	6.941	1.112	5.6	16.91
3.50	990.1	1.854	3.405	5.725	1.119	6.7	16.74
3.60	991.7	1.855	2.850	4.739	1.126	8.0	16.57
3.70	993.0	1.856	2.392	3.934	1.132	9.6	16.42
3.80	994.1	1.857	2.012	3.276	1.137	1.1 +4	16.27
3.90	995.0	1.858	1.696	2.734	1.143	1.4	16.13
4.00 +5	995.8	1.859 0	1.433 -11	2.288 -12	1.419 +3	1.6 +4	15.98
4.10	996.5	1.860	1.213	1.918	1.154	1.9	15.84
4.20	997.0	1.860	1.029	1.612	1.160	2.2	15.70
4.30	997.5	1.861	8.749 -12	1.357	1.165	2.6	15.55
4.40	997.9	1.861	7.453	1.144	1.171	3.1	15.40
4.50	998.2	1.861	6.363	9.668 -13	1.177	3.6	15.25
4.60	998.5	1.862	5.443	8.180	1.184	4.2	15.08
4.70	998.7	1.862	4.667	6.932	1.191	4.9	14.91
4.80	998.9	1.862	4.011	5.884	1.198	5.7	14.73
4.90	999.1	1.862	3.455	5.001	1.206	6.7	14.54

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation.

This page Amendment B

TABLE 8.3 Properties of a Standard Atmosphere: Geopotential Altitude in Metres (concluded)

Z (m)	T (K)	$\sqrt{(T/T_0)}$	p/p_0	ρ/ρ_0	$\overline{V}$ (m/s)	L (m)	m (kg/kmol)
5.00 +5	999.2	1.862 0	2.984 -12	4.257 -13	1.215 +3	7.7 +4	14.33
5.10	999.4	1.862	2.584	3.629	1.225	8.9	14.11
5.20	999.5	1.862	2.243	3.099	1.235	1.0 +5	13.88
5.30	999.5	1.862	1.953	2.650	1.246	1.2	13.63
5.40	999.6	1.863	1.706	2.269	1.258	1.3	13.37
5.50	999.7	1.863	1.494	1.946	1.272	1.5	13.09
5.60	999.7	1.863	1.313	1.672	1.286	1.8	12.80
5.70	999.8	1.863	1.158	1.439	1.302	2.0	12.49
5.80	999.8	1.863	1.024	1.241	1.319	2.2	12.18
5.90	999.8	1.863	9.095 -13	1.072	1.337	2.5	11.85
6.00 +5	999.9	1.863 0	8.106 -13	9.279 -14	1.356 +3	2.8 +5	11.51
6.10	999.9	1.863	7.251	8.048	1.378	3.2	11.16
6.20	999.9	1.863	6.511	6.996	1.400	3.5	10.80
6.30	999.9	1.863	5.868	6.096	1.424	3.9	10.44
6.40	999.9	1.863	5.310	5.325	1.449	4.3	10.08
6.50	999.9	1.863	4.823	4.663	1.476	4.8	9.72
6.60	999.9	1.863	4.397	4.094	1.504	5.2	9.36
6.70	1000	1.863	4.023	3.605	1.533	5.7	9.01
6.80	1000	1.863	3.695	3.183	1.564	6.2	8.66
6.90	1000	1.863	3.405	2.820	1.595	6.8	8.32
7.00 +5	1000	1.863 0	3.149 -13	2.506 -14	1.627 +3	7.3 +5	8.00
7.10	1000	1.863	2.922	2.234	1.660	7.9	7.69
7.20	1000	1.863	2.719	1.998	1.693	8.5	7.39
7.30	1000	1.863	2.538	1.793	1.727	9.1	7.10
7.40	1000	1.863	2.376	1.615	1.760	9.7	6.83
7.50	1000	1.863	2.230	1.460	1.794	1.0 +6	6.58
7.60	1000	1.863	2.099	1.324	1.827	1.1	6.34
7.70	1000	1.863	1.979	1.205	1.860	1.2	6.12
7.80	1000	1.863	1.871	1.100	1.892	1.2	5.91
7.90	1000	1.863	1.772	1.008	1.924	1.3	5.72
8.00 +5	1000	1.863 0	1.681 -13	9.272 -15	1.954 +3	1.4 +6	5.54
8.10	1000	1.863	1.598	8.554	1.984	1.4	5.38
8.20	1000	1.863	1.522	7.916	2.012	1.5	5.23
8.30	1000	1.863	1.451	7.348	2.039	1.6	5.09
8.40	1000	1.863	1.385	6.841	2.065	1.7	4.96
8.50	1000	1.863	1.324	6.387	2.090	1.7	4.85
8.60	1000	1.863	1.267	5.978	2.113	1.8	4.74
8.70	1000	1.863	1.214	5.611	2.135	1.9	4.65
8.80	1000	1.863	1.164	5.278	2.155	2.0	4.56
8.90	1000	1.863	1.117	4.976	2.175	2.1	4.48
9.00 +5	1000	1.863 0	1.073 -13	4.701 -15	2.193 +3	2.1 +6	4.40
9.10	1000	1.863	1.032	4.451	2.210	2.2	4.34
9.20	1000	1.863	9.923 -14	4.221	2.225	2.3	4.28
9.30	1000	1.863	9.551	4.010	2.240	2.4	4.22
9.40	1000	1.863	9.199	3.815	2.254	2.5	4.17
9.50	1000	1.863	8.864	3.635	2.266	2.6	4.12
9.60	1000	1.863	8.546	3.468	2.278	2.7	4.08
9.70	1000	1.863	8.243	3.313	2.289	2.8	4.04
9.80	1000	1.863	7.954	3.168	2.300	2.9	4.00
9.90	1000	1.863	7.679	3.033	2.309	3.0	3.97
1.00 +6	1000	1.863 0	7.416 -14	2.907 -15	2.318 +3	3.1 +6	3.94

In this table a one or two digit number (preceded by a plus or minus sign) following the initial entry of a block indicates the power of ten by which that and each succeeding entry in the block should be multiplied. A change of power occurring within a block is indicated by a similar notation

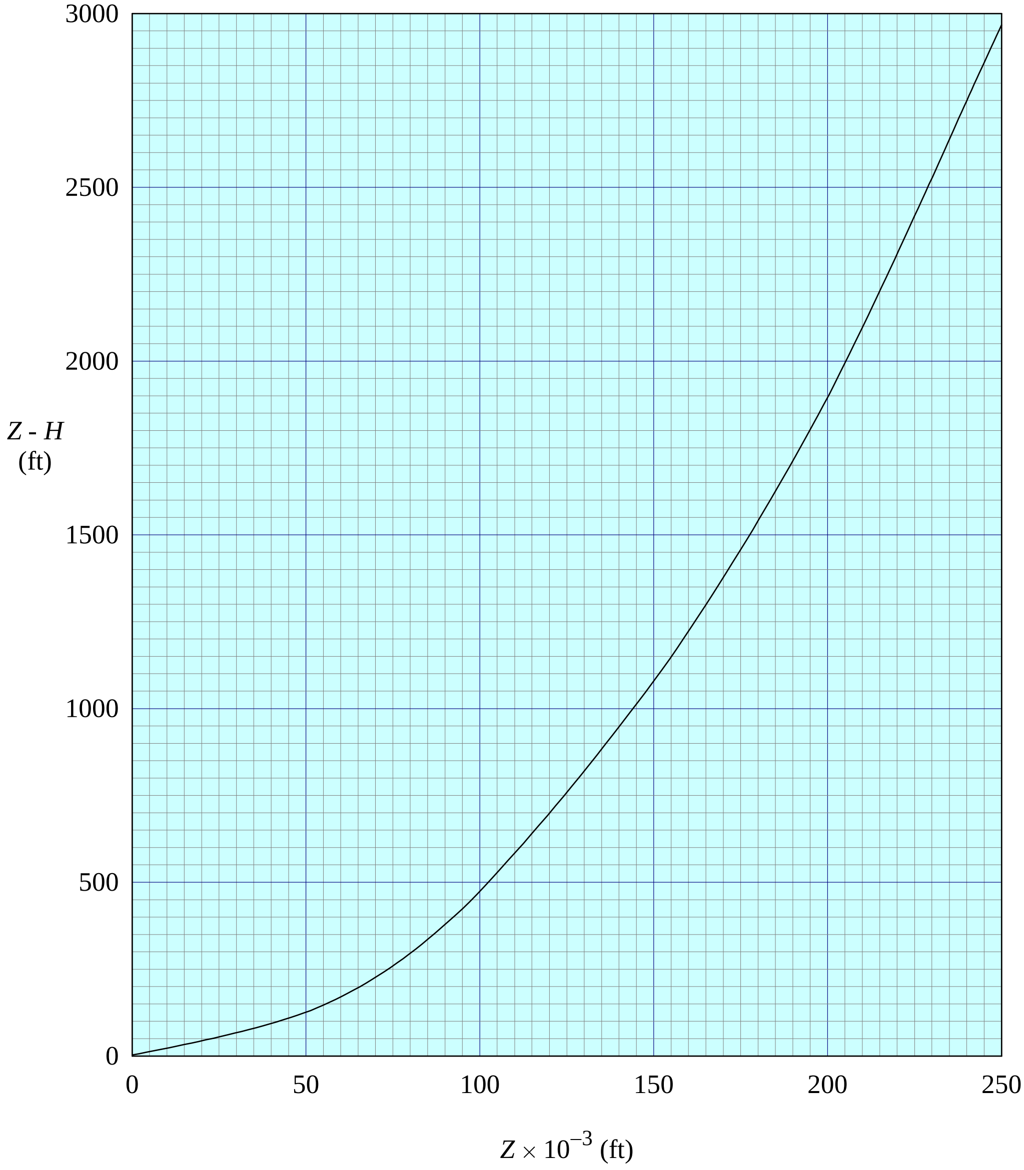


FIGURE 1 DIFFERENCE BETWEEN GEOMETRIC AND GEOPOTENTIAL ALTITUDES

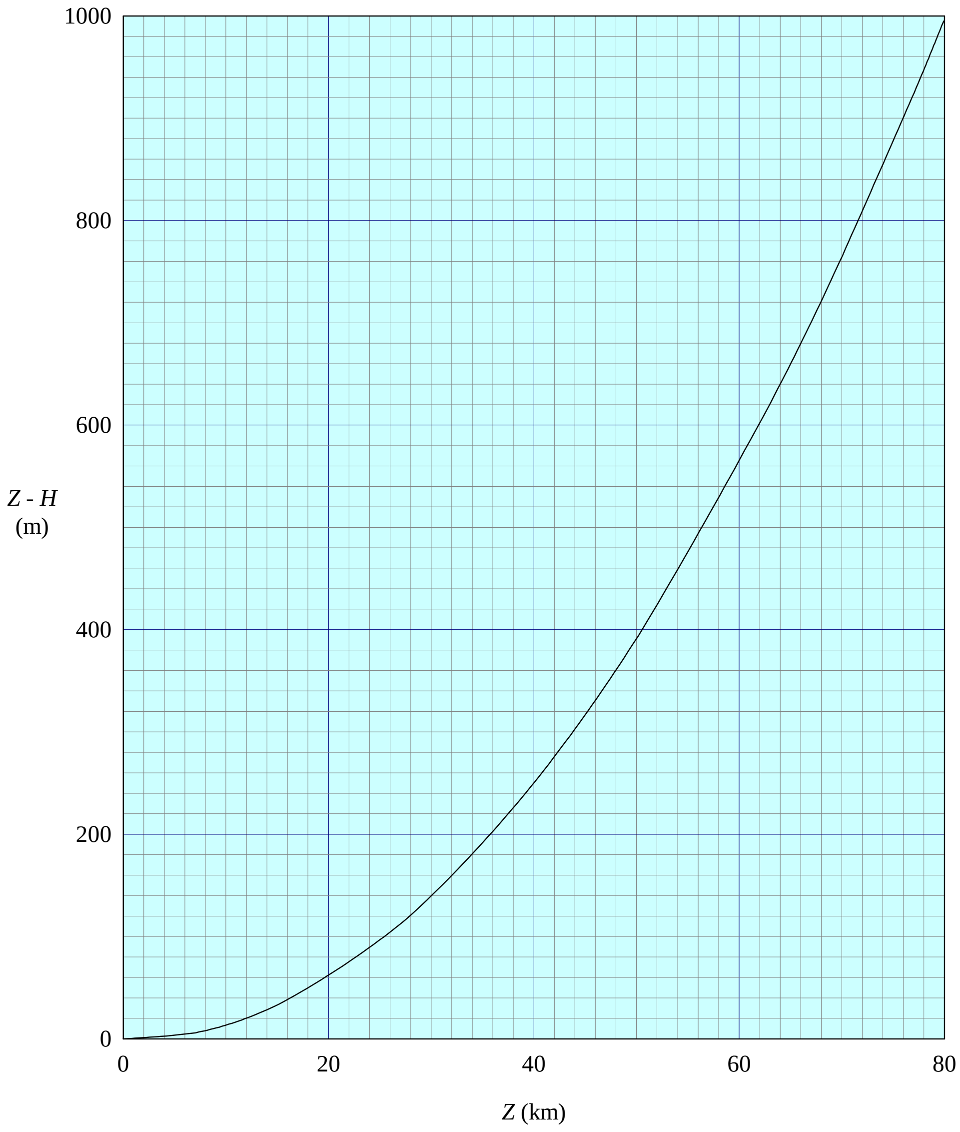


FIGURE 2 DIFFERENCE BETWEEN GEOMETRIC AND GEOPOTENTIAL ALTITUDES

APPENDIX A EQUATIONS DEFINING STANDARD ATMOSPHERE FOR ALTITUDES UP TO 80 km

A1. ADDITIONAL NOTATION AND UNITS

		SI	*British*
H_i	dividing altitude in temperature-altitude profile, i = 0, 1, 2, ... 7	m	ft
L_i	temperature gradient between altitudes H_i and H_{i+1}	K/m	K/ft
p_i	pressure at altitude H_i	N/m^2	lbf/ft^2
T_i	temperature at altitude H_i	K	K

A2. EQUATIONS FOR STANDARD ATMOSPHERE

The atmosphere defined in Derivations 1 and 2 is divided into seven layers for altitudes up to H = 80 km. Within each of these the temperature varies linearly with altitude and is expressed as

$$T = T_i + L_i(H - H_i), \tag{A2.1}$$

for $H_i \le H < H_{i+1}$, where i = 0, 1, 2, ... 7. The temperature at altitude H_i is T_i, and L_i is the temperature gradient between H_i and H_{i+1}. For altitudes up to 80 km the constituent gases of the air retain their sea-level proportions and the mean molecular mass is constant at m_0. Using the hydrostatic equation, the perfect gas law and Equation (A2.1), two analytic expressions for pressure as a function of altitude are obtained for $H_i \le H \le H_{i+1}$. If $L_i \ne 0$,

$$\frac{p}{p_i} = \left(\frac{T_i}{T}\right)^{(g_0 m_0 / \mathscr{R} L_i)}, \tag{A2.2}$$

and if $L_i = 0$, then

$$\frac{p}{p_i} = \exp\left(-\frac{g_0 m_0 (H - H_i)}{\mathscr{R} T_i}\right), \tag{A2.3}$$

where p_i is the pressure at altitude H_i.

Tables A2.1 (SI units) and A2.2 (British units) give the values of the constants required for solving Equations (A2.1) to (A2.3). If $H < 0$, then Equations (A2.1) and (A2.2) apply directly with i = 0.

Knowing T and p, other atmospheric data are calculated through the equations given in Table A2.3.

TABLE A2.1 Constants for Basic Equations (SI Units)

i	H_i (m)	T_i (K)	L_i (K/m)	p_i (N/m^2)	$g_0 m_0 / \mathscr{R} L_i$	$g_0 m_0 / \mathscr{R} T_i$ (m^{-1})
0	0	288.15	-6.5×10^{-3}	1.013250×10^5	–5.255880	–
1	11×10^3	216.65	0	2.263204×10^4	–	1.576885×10^{-4}
2	20×10^3	216.65	1.0×10^{-3}	5.474879×10^3	34.16322	–
3	32×10^3	228.65	2.8×10^{-3}	8.680160×10^2	12.20115	–
4	47×10^3	270.65	0	1.109058×10^2	–	1.262266×10^{-4}
5	51×10^3	270.65	-2.8×10^{-3}	6.693853×10	–12.20115	–
6	71×10^3	214.65	-2.0×10^{-3}	3.956392	–17.08161	–
7	80×10^3	196.65	–	8.862722×10^{-1}	–	–

TABLE A2.2 Constants for Basic Equations (British Units)

i	H_i (ft)	T_i (K)	L_i (K/ft)	p_i (lbf/ft^2)	$g_0 m_0 / \mathscr{R} L_i$	$g_0 m_0 / \mathscr{R} T_i$ (ft^{-1})
0	0	288.15	-1.9812×10^{-3}	2.11622×10^3	–5.255880	–
1	3.608924×10^4	216.65	0	4.726807×10^2	–	4.806346×10^{-5}
2	6.561680×10^4	216.65	3.048×10^{-4}	1.143454×10^2	34.16322	–
3	1.049869×10^5	228.65	8.5344×10^{-4}	1.812892×10	12.20115	–
4	1.541995×10^5	270.65	0	2.316319	–	3.847386×10^{-5}
5	1.673228×10^5	270.65	-8.5344×10^{-4}	1.398046	–12.20115	–
6	2.329396×10^5	214.65	-6.096×10^{-4}	8.263130×10^{-2}	–17.08161	–
7	2.624672×10^5	196.65	–	1.851025×10^{-2}	–	–

Minor inconsistencies exist between Tables A2.1 and A2.2 due to unit conversions. Table A2.1 gives the definitive values for the atmosphere, and any inconsistencies are minimised by using the composite parameters $g_0 m_0 / \mathscr{R} T_i$ and $g_0 m_0 / \mathscr{R} L_i$, rather than working with values of the individual parameters g_0, $\mathscr{R}$ and L_i in British units. For all practical purposes the values in the tables lead to equivalent atmospheric properties.

TABLE A2.3 Formulae for Atmospheric Data

Quality	*SI*		*British*	
a	$\left(\frac{1.4\mathscr{R}T}{m_0}\right)^{½}$	m/s	$\left(\frac{1.4\mathscr{R}T}{m_0}\right)^{½}$	ft/s
ρ	$\frac{pm_0}{\mathscr{R}T}$	kg/m^3	$\frac{pm_0}{\mathscr{R}T}$	slug/ft^3
μ	$\frac{1.458 \times 10^{-6} T^{3/2}}{T + 110.4}$	N s/m^2	$\frac{3.04509 \times 10^{-8} T^{3/2}}{T + 110.4}$	lbf s/ft^2
v	$\frac{\mu}{\rho}$	m^2/s	$\frac{\mu}{\rho}$	ft^2/s
k^*	$\frac{2.648151 \times 10^{-3} T^{3/2}}{T + 245.4 \times 10^{(-12/T)}}$	W/m K	$\frac{5.953280 \times 10^{-4} T^{3/2}}{T + 245.4 \times 10^{(-12/T)}}$	ft lbf/ft s K

* Following Derivation 1 which converts the equation for k given in Reference 7 from kg-cal/m s K units to W/m K units by using the relationship 1 cal (International Steam Table) = 4.1868 J, rather than Derivation 2 which quotes a conversion 1 cal (15°C) = 4.1858 J.

KEEPING UP TO DATE

Whenever Items are revised, subscribers to the service automatically receive the material required to update the appropriate Volumes. If you are in any doubt as to whether or not your ESDU holding is up to date, please contact us.

Please address all technical engineering enquiries and suggestions to:

ESDU International plc	Tel:	020 7490 5151 (from the UK)
		+44 20 7490 5151 (from outside the UK)
	Fax:	020 7490 2701 (from the UK)
		+44 20 7490 2701 (from outside the UK)
	E-Mail:	esdu@ihs.com
	Website:	www.ihsesdu.com

For users in the USA, please address all Customer Service and Support enquiries and suggestions to:

IHS Engineering Products	Tel:	1 800 447 3352 (toll free number)
and	Fax:	1 303 397 2599
Global Engineering Documents	Website:	www.ihs.com
		global.ihs.com

ESDU 77021

Properties of a standard atmosphere.
ESDU 77021

ISBN 978 0 85679 193 2, ISSN 0141-397X

Available as part of the ESDU Series on Aerodynamics. For information on all ESDU validated engineering data contact ESDU International plc, 27 Corsham Street, London N1 6UA.

ESDU 77021 gives properties of a standard atmosphere to 1000 km. Tables give as a function of geopotential altitude in either ft or m up to 250 000 ft (80 km) values of temperature, speed of sound, pressure, density, kinematic and dynamic viscosities, and thermal conductivity. Equations that can be readily programmed are also given for those properties as a function of altitude. A third table gives at geometric altitudes in m between 80 and 100 km values of temperature, pressure, density, particle mean speed and mean free path, and mean molecular mass. Graphs are also given plotting the difference between geopotential and geometric altitude as a function of geometric altitude in ft or m for altitudes to 250 000 ft (80 km) and sketches show the variation of all the properties with geometric height up to 100 km.