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Properties of a standard atmosphere

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PROPERTIES OF A STANDARD ATMOSPHERE

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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	$N\ s/m^2$	$lbf\ s/ft^2$
v	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.

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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.

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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.

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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.

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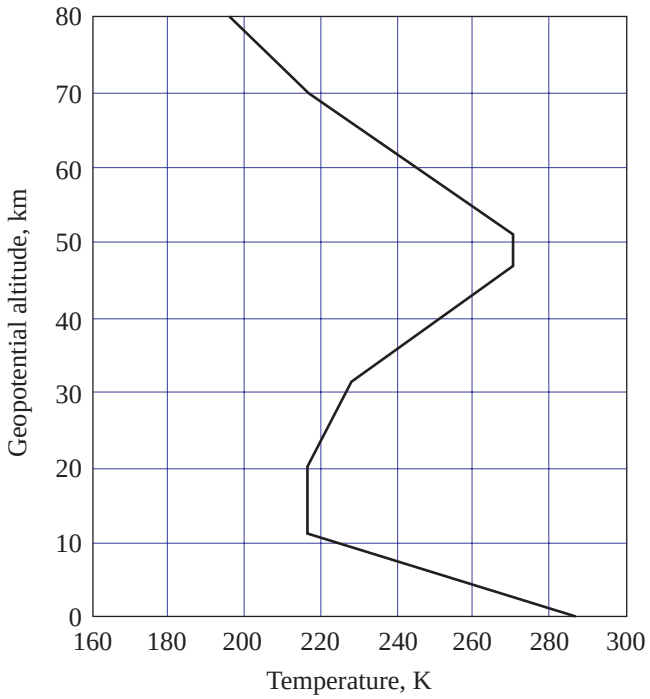
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9. ESDU Atmospheric data for performance calculations. ESDU Item No. 68046 (Performance Series), 1968. (See also Addendum Item 72018, height in feet data in SI units.)
10. ESDU Equations for calculation of international standard atmosphere and associated off-standard atmospheres. ESDU Item No. 77022 (Performance Series), 1977.

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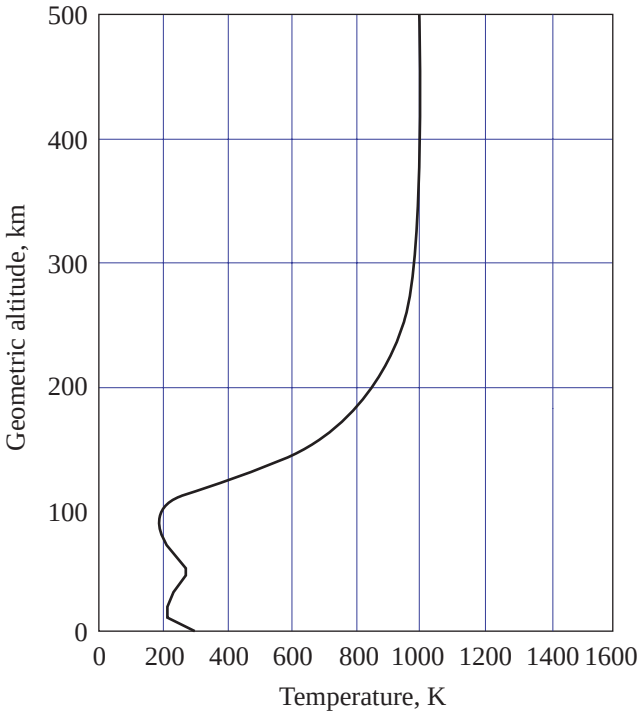
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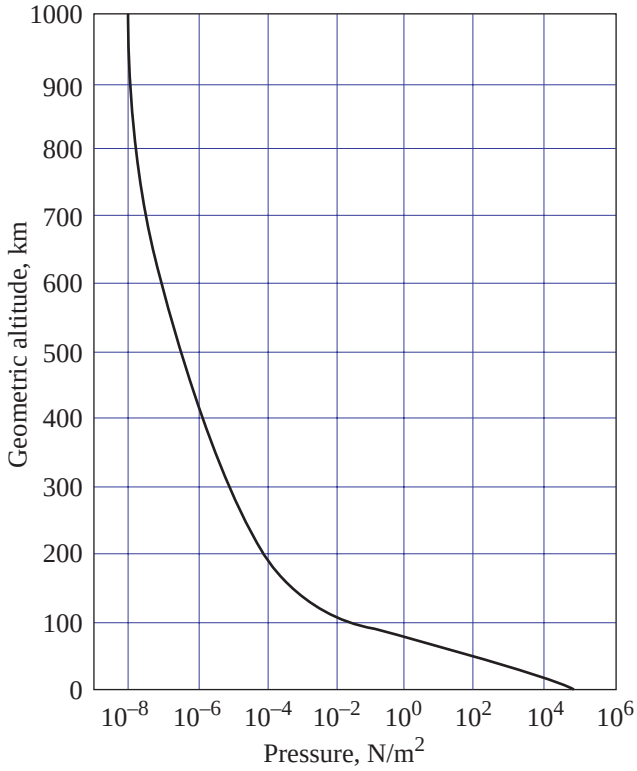
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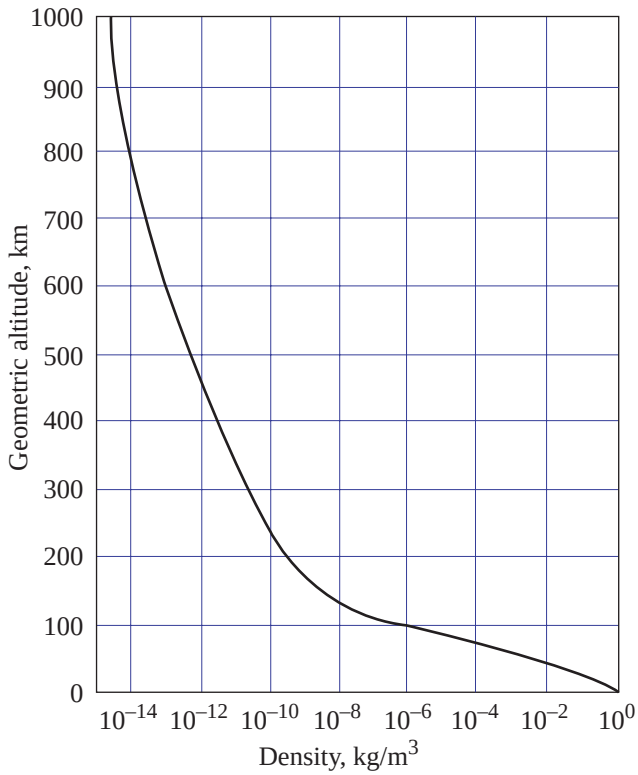
Sketch 7.1



Sketch 7.2



Sketch 7.3



Sketch 7.4

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