Atmospheric Properties

Atmospheric Properties

Aircraft Performance calculations rely directly on atmospheric parameters:

Aerodynamic Forces ~ f (density, temperature)

Propulsive Forces ~ f (pressure, temperature)

Atmospheric Parameters

p ~ pressure (lbs/ft^2)
T ~ temperature (degrees)
h ~ altitude (ft)
a ~ speed of sound (ft/sec)

ρ ~ density (slugs/ft^3)
θ ~ temperature ratio
δ ~ pressure ratio
σ ~ density ratio

Ratios are value at altitude / value at sea level

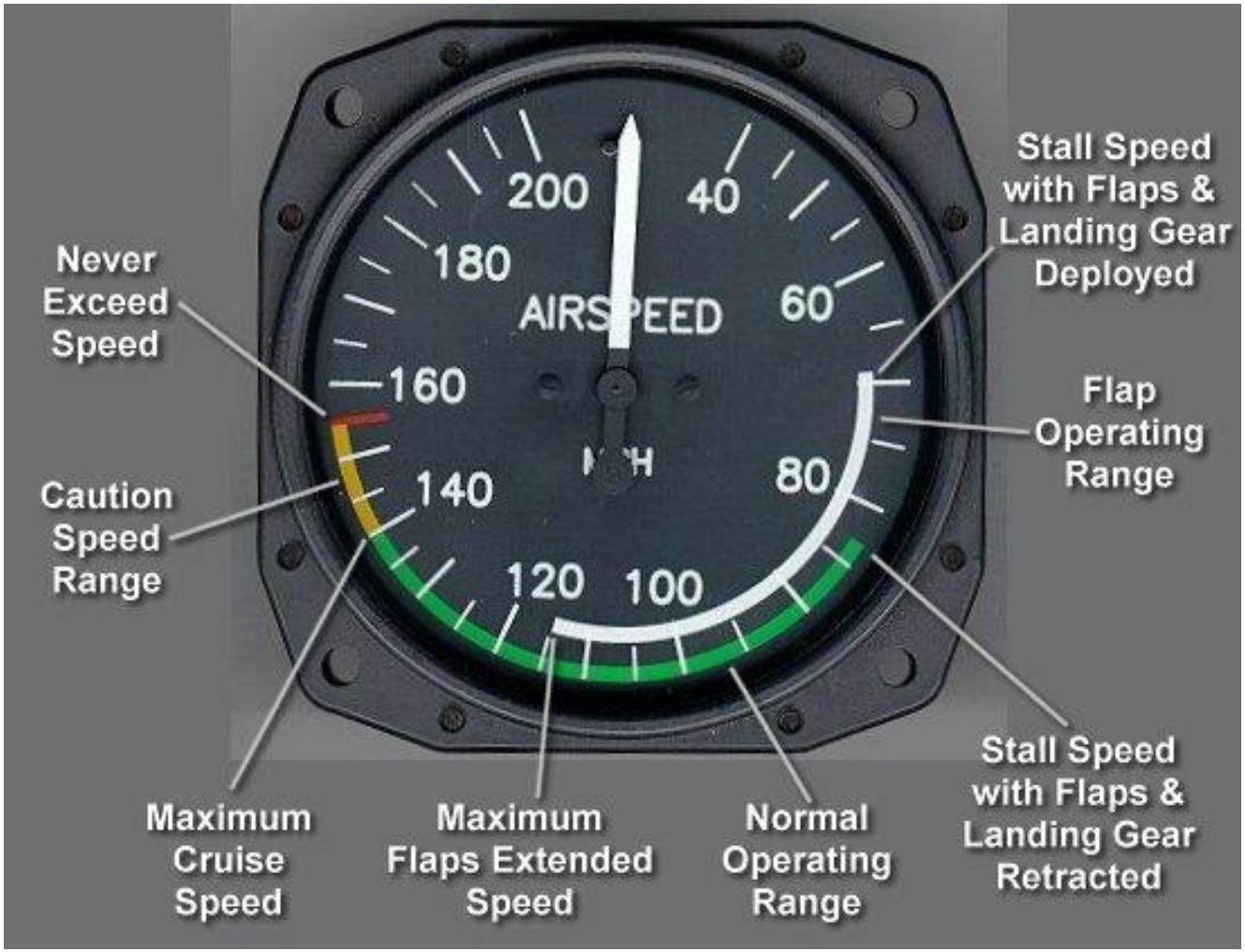
Altitude Definitions

Geometric altitude – measured with a tape measure

Geopotential altitude – “pressure altitude”

We will always use “pressure altitude” in this class

Airspeed Definitions



http://www.aerospaceweb.org/question/instruments/q0251.shtml

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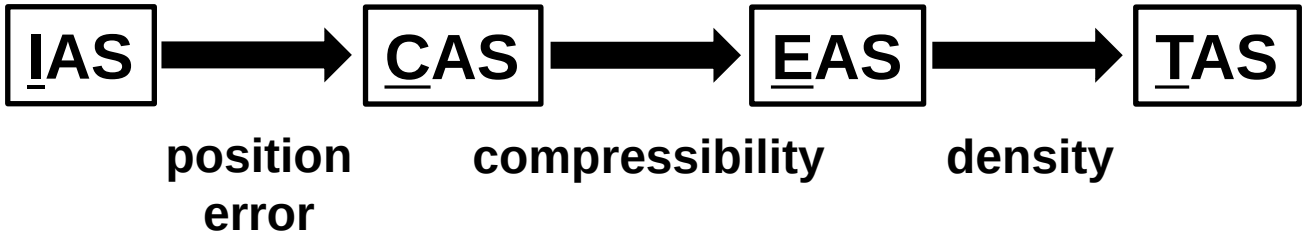
Airspeed Definitions



"ICET"

Indicated Airspeed (IAS): read from cockpit instruments

Calibrated Airspeed (CAS): IAS corrected for instrumentation position error

Equivalent Airspeed (EAS): CAS corrected for compressibility effects

True Airspeed (TAS): EAS corrected for density

$$\text{Mach Number} = \frac{\text{TAS}}{\text{a}}$$

$$\text{TAS} = \frac{\text{EAS}}{\sqrt{\frac{\rho}{\rho_{SL}}}}$$

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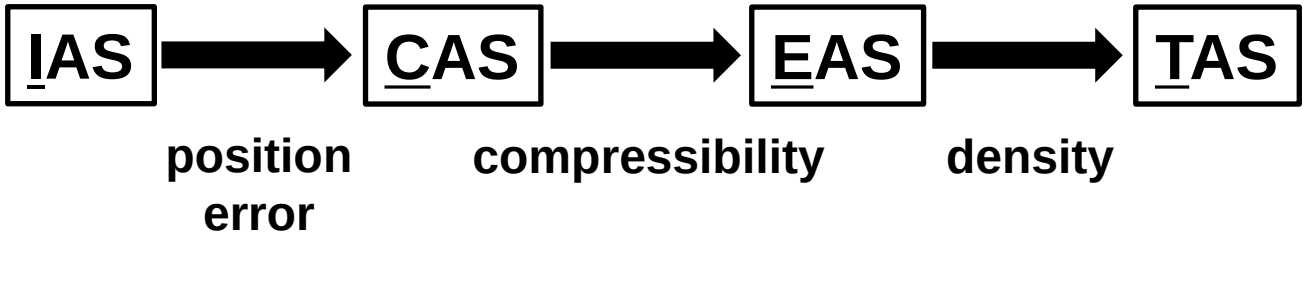
Airspeed Definitions



Indicated Airspeed (IAS): Pilots read IAS or CAS on the instrument panel

Calibrated Airspeed (CAS): Pilots use CAS to fly the aircraft

Equivalent Airspeed (EAS): Constant EAS = Constant dynamic pressure (q)
Used in aerodynamics & structures calculations

True Airspeed (TAS): Actual speed of the aircraft relative to the air

Airspeed is usually expressed in knots (NM/hr)

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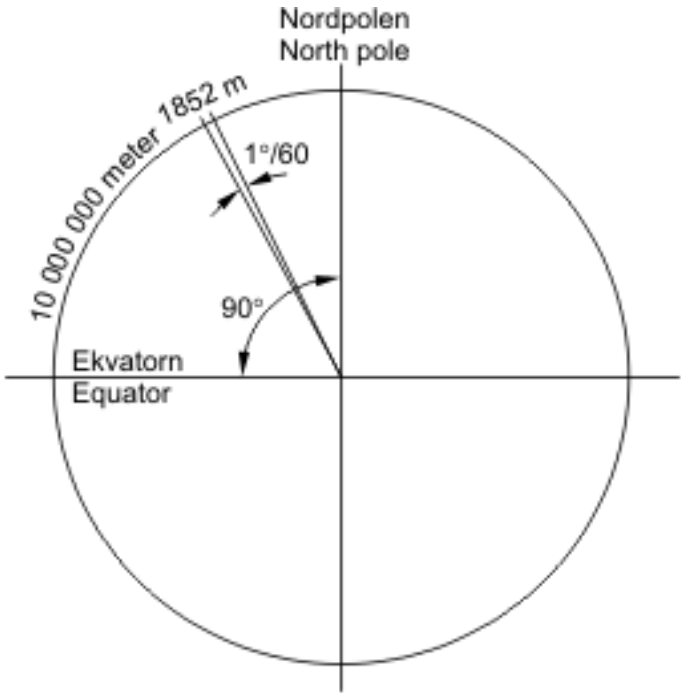
More Definitions

Nautical Mile (NM) is defined as one minute of arc along a meridian of the Earth

1/60 of 1 degree = 1,852 m
= 6,076.4 ft



$$1\ \text{knot}\left(\frac{\text{NM}}{\text{hr}}\right)\left(\frac{1\ \text{hr}}{3600\ \text{sec}}\right)\left(\frac{6076.4\ \text{ft}}{1\ \text{NM}}\right) = 1.6879\,\frac{\text{ft}}{\text{sec}}$$

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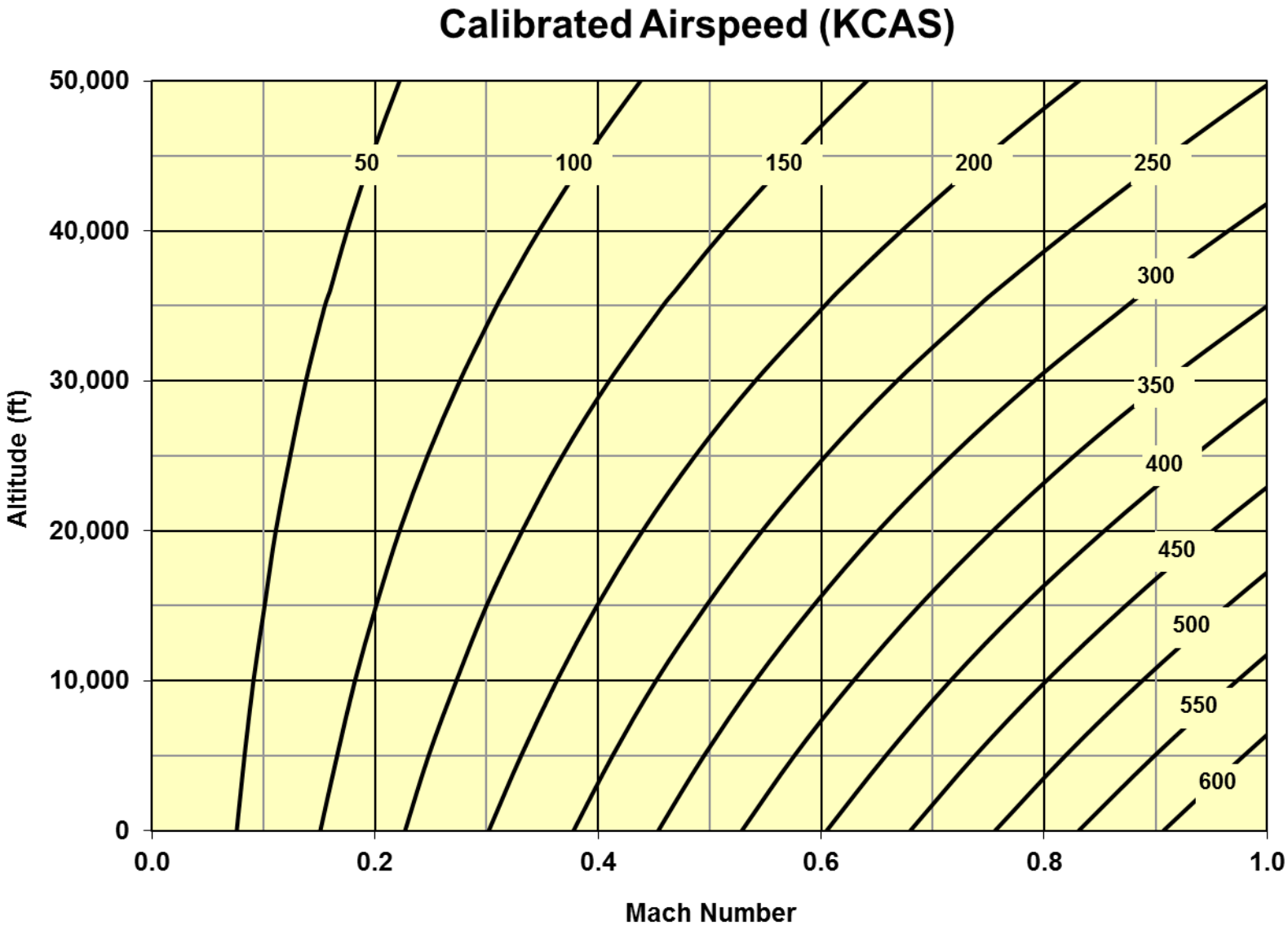
The Standard Atmosphere



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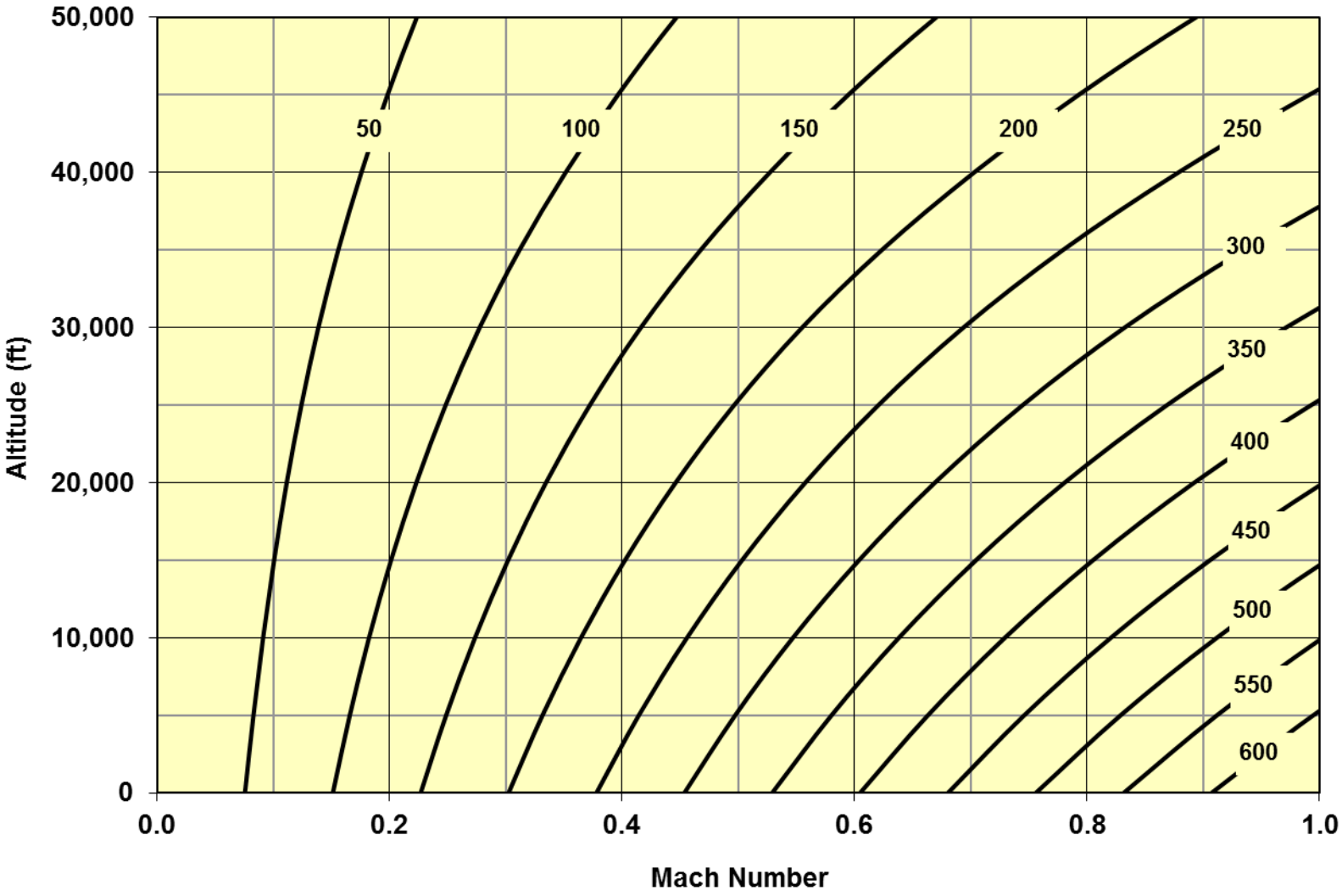
The Standard Atmosphere



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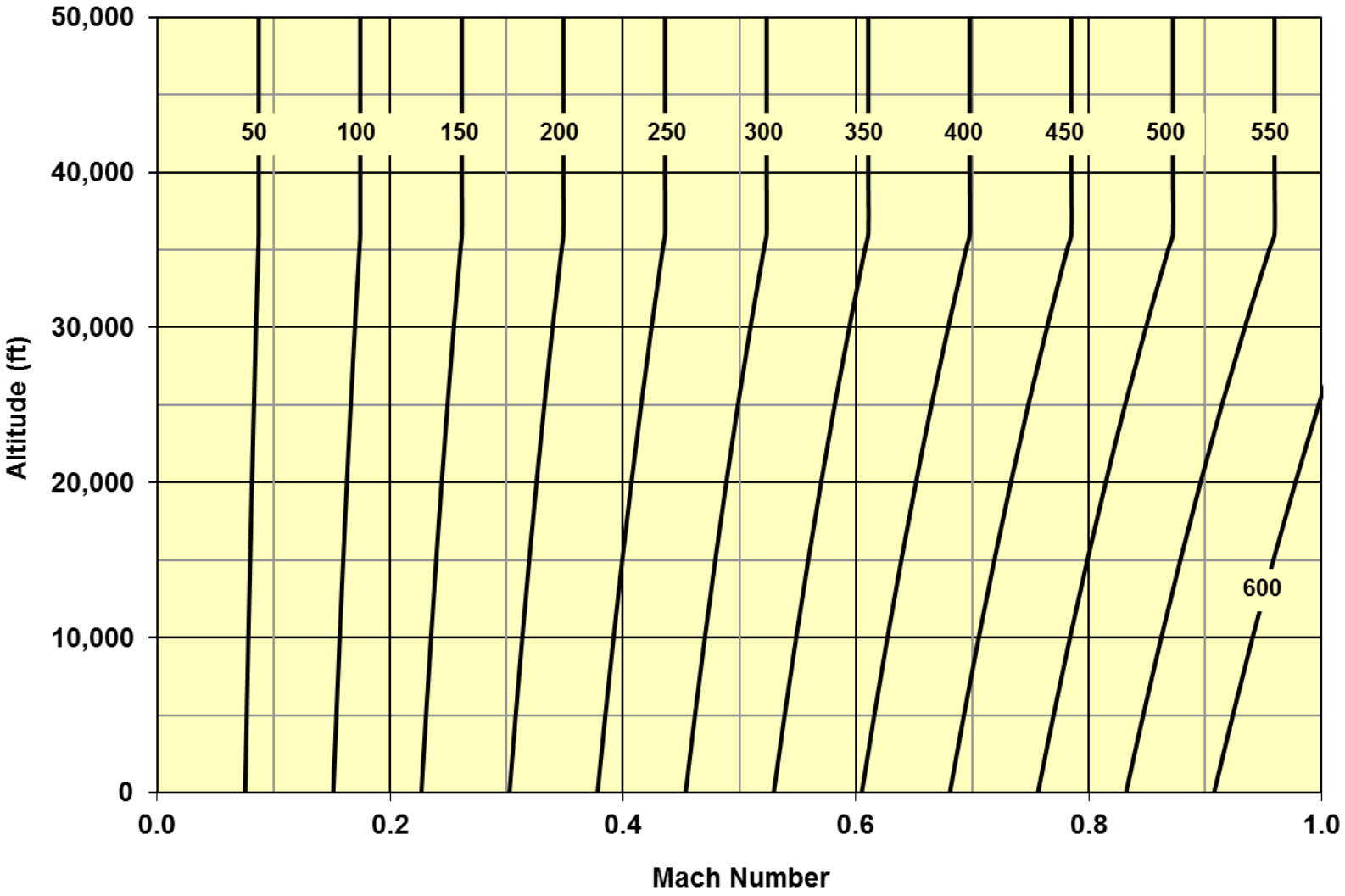
The Standard Atmosphere



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The Standard Atmosphere

U.S. Standard Atmosphere

- **Established in 1958, updated in 1962, 1966, & 1976**

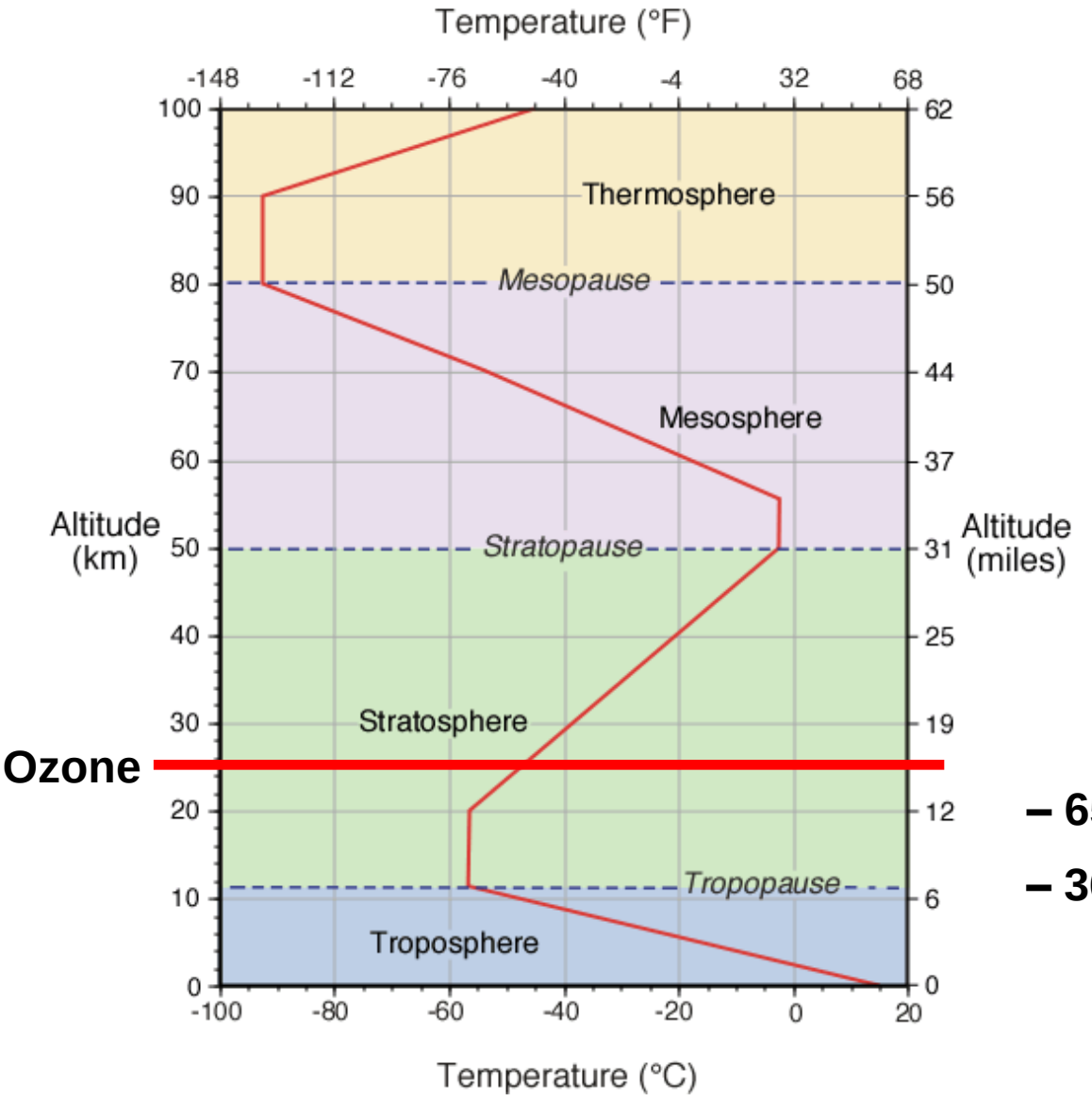
International Standard Atmosphere (1975)

ICAO Standard Atmosphere (1993)

Hypothetical vertical distribution of atmospheric temperature, pressure, and density that is representative of the atmosphere for the purpose of altimeter calibrations, aircraft design, and performance calculations

Ideal air devoid of moisture, water vapor, and dust
Obeys the perfect gas law

The Standard Atmosphere



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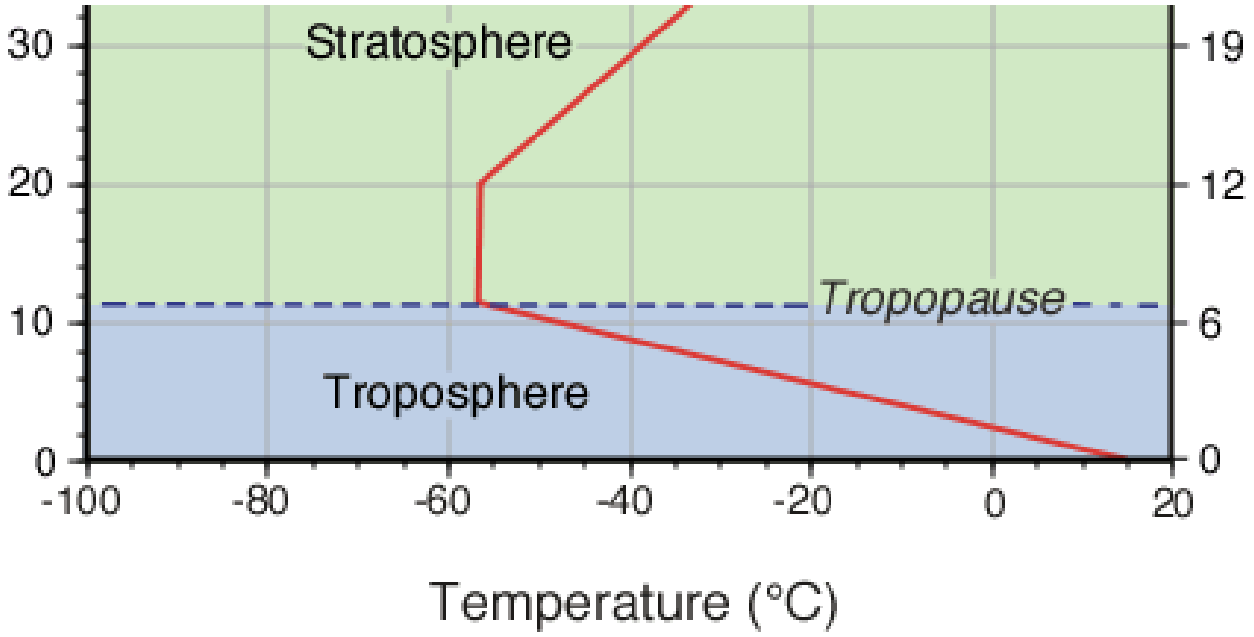
The Standard Atmosphere



– 65,617 ft

– 36,089 ft

Troposphere: **Sea Level to 36,089 ft**
Temperature Lapse rate (dT/dh) = 3.566° R / 1,000 ft

Tropopause: **36,089 ft**
Boundary between troposphere and stratosphere

Lower Stratosphere: **36,089 to 65,617 ft**
Isothermic layer, temperature = 389.99° R

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The Standard Atmosphere

Troposphere: Sea Level – 36,089 ft

$T_{SL} = 518.67\ °R = 59.0\ °F$ $\qquad \rho_{SL} = 0.0023769\ \text{slugs/ft}^3$

$p_{SL} = 2116.22\ \text{lbs/ft}^2$ $\qquad a_{SL} = 1116.45\ \text{ft/sec}$

$$T\ (°R) = T_{SL} - \frac{dT}{dh}h = 518.67 - 3.566\ \frac{h}{1000}$$ "Lapse Rate"

Temperature Ratio: $\theta = \dfrac{T\ (°R)}{T_{SL}(°R)} = \dfrac{T\ (°R)}{518.67}$

Pressure Ratio: $\delta = \dfrac{p}{p_{SL}} = \dfrac{p}{2116.22} = \theta^x$ where $x = \dfrac{g}{\frac{dT}{dh}R} = 5.2562$

Density Ratio: $\sigma = \dfrac{\rho}{\rho_{SL}} = \dfrac{\rho}{0.0023769} = \dfrac{\delta}{\theta}$

Speed of Sound: $a = a_{SL}\sqrt{\theta} = 1116.45\sqrt{\theta}$

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The Standard Atmosphere

Stratosphere: 36,089 – 65,617 ft

$T_{SL} = 518.67\ ^\circ R = 59.0\ ^\circ F$ $\qquad \rho_{SL} = 0.0023769\ slugs/ft^3$

$p_{SL} = 2116.22\ lbs/ft^2$ $\qquad a_{SL} = 1116.45\ ft/sec$

$T\ (^\circ R) = 389.99$

Temperature Ratio: $\theta = \frac{T\ (^\circ R)}{T_{SL}(^\circ R)} = \frac{389.99}{518.67} = 0.7519$

Pressure Ratio: $\delta = \frac{p}{p_{SL}} = \frac{p}{2116.22} = \delta_{trop}\, e^x = 0.223361\, e^x$

where $x = -\frac{g}{R\,T}(h - h_{trop}) = -\frac{0.0481}{1000}(h - h_{trop})$

Density Ratio: $\sigma = \frac{\rho}{\rho_{SL}} = \frac{\rho}{0.0023769} = \frac{\delta}{\theta}$

Speed of Sound: $a = a_{SL}\sqrt{\theta} = 1116.45\sqrt{\theta} = 968.1\ ft/sec$

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The Standard Atmosphere

h	TEMPF	TEMPR	TEMPC	TR	PR	PRESHG	PRES	RHO	DR	SQRTDR	QMS	SPW	ASPEED	VELA
0	59.0	518.7	15.0	1.0000	1.0000	29.92	2116.22	0.00237688	1.0000	1.0000	1481.4	0.0765	1116.45	661.1
2000	51.8	511.5	11.0	0.9862	0.9298	27.82	1967.68	0.00224086	0.9428	0.9710	1377.4	0.0721	1108.75	656.5
4000	44.7	504.4	7.1	0.9725	0.8637	25.84	1827.70	0.00211087	0.8881	0.9424	1279.4	0.0679	1100.99	651.9
6000	37.6	497.3	3.1	0.9587	0.8014	23.98	1695.89	0.00198673	0.8359	0.9143	1187.1	0.0639	1093.18	647.3
8000	30.4	490.1	-0.9	0.9450	0.7428	22.22	1571.89	0.00186826	0.7860	0.8866	1100.3	0.0601	1085.31	642.6
10000	23.3	483.0	-4.8	0.9312	0.6877	20.58	1455.33	0.00175527	0.7385	0.8593	1018.7	0.0565	1077.39	637.9
12000	16.2	475.9	-8.8	0.9175	0.6360	19.03	1345.87	0.00164758	0.6932	0.8326	942.1	0.0530	1069.40	633.2
14000	9.0	468.7	-12.8	0.9037	0.5875	17.58	1243.18	0.00154502	0.6500	0.8062	870.2	0.0497	1061.36	628.4
16000	1.9	461.6	-16.7	0.8900	0.5420	16.22	1146.93	0.00144742	0.6090	0.7804	802.8	0.0466	1053.25	623.6
18000	-5.2	454.5	-20.7	0.8762	0.4994	14.94	1056.80	0.00135461	0.5699	0.7549	739.8	0.0436	1045.09	618.8
20000	-12.4	447.3	-24.6	0.8625	0.4595	13.75	972.49	0.00126642	0.5328	0.7299	680.7	0.0407	1036.85	613.9
22000	-19.5	440.2	-28.6	0.8487	0.4223	12.64	893.72	0.00118269	0.4976	0.7054	625.6	0.0381	1028.56	609.0
24000	-26.6	433.1	-32.6	0.8350	0.3876	11.60	820.19	0.00110326	0.4642	0.6813	574.1	0.0355	1020.19	604.1
26000	-33.7	426.0	-36.5	0.8212	0.3552	10.63	751.64	0.00102798	0.4325	0.6576	526.1	0.0331	1011.75	599.1
28000	-40.9	418.8	-40.5	0.8075	0.3250	9.72	687.81	0.00095670	0.4025	0.6344	481.5	0.0308	1003.25	594.0
30000	-48.0	411.7	-44.5	0.7937	0.2970	8.89	628.43	0.00088926	0.3741	0.6117	439.9	0.0286	994.67	588.9
32000	-55.1	404.6	-48.4	0.7800	0.2709	8.11	573.28	0.00082551	0.3473	0.5893	401.3	0.0266	986.02	583.8
34000	-62.3	397.4	-52.4	0.7662	0.2467	7.38	522.11	0.00076533	0.3220	0.5674	365.5	0.0246	977.29	578.7
36000	-69.4	390.3	-56.3	0.7525	0.2243	6.71	474.71	0.00070856	0.2981	0.5460	332.3	0.0228	968.48	573.4
38000	-69.7	390.0	-56.5	0.7519	0.2038	6.10	431.20	0.00064415	0.2710	0.5206	301.8	0.0207	968.08	573.2
40000	-69.7	390.0	-56.5	0.7519	0.1851	5.54	391.68	0.00058512	0.2462	0.4962	274.2	0.0188	968.08	573.2
42000	-69.7	390.0	-56.5	0.7519	0.1681	5.03	355.78	0.00053149	0.2236	0.4729	249.0	0.0171	968.08	573.2
44000	-69.7	390.0	-56.5	0.7519	0.1527	4.57	323.18	0.00048278	0.2031	0.4507	226.2	0.0155	968.08	573.2
46000	-69.7	390.0	-56.5	0.7519	0.1387	4.15	293.56	0.00043853	0.1845	0.4295	205.5	0.0141	968.08	573.2
48000	-69.7	390.0	-56.5	0.7519	0.1260	3.77	266.65	0.00039834	0.1676	0.4094	186.7	0.0128	968.08	573.2
50000	-69.7	390.0	-56.5	0.7519	0.1145	3.42	242.21	0.00036183	0.1522	0.3902	169.5	0.0116	968.08	573.2

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Homework Assignment

HW #1 – Atmosphere
(due by 11:59 pm ET on Monday)

<u>HW Help Sessions</u>
Friday 1:00 – 2:00 pm ET
Monday 1:00 – 2:00 pm ET

<u>Posted on Canvas</u>
HW #1 Assignment with instructions, tips, and checklist
HW #1 Template for Excel

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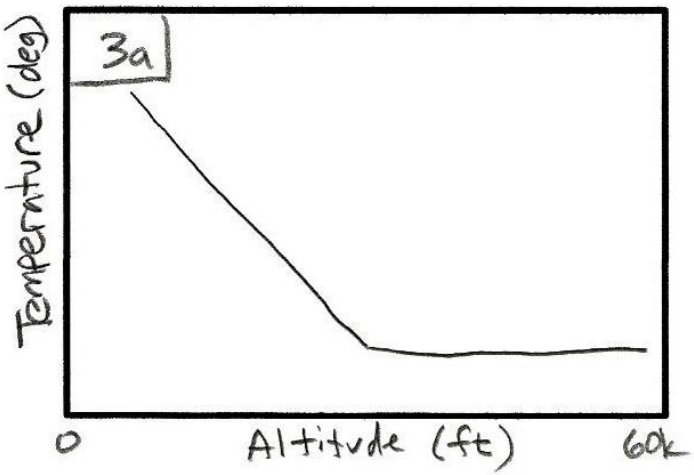
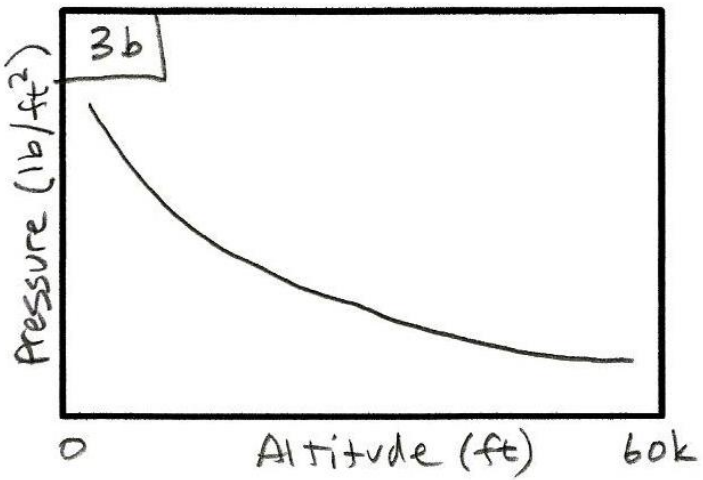
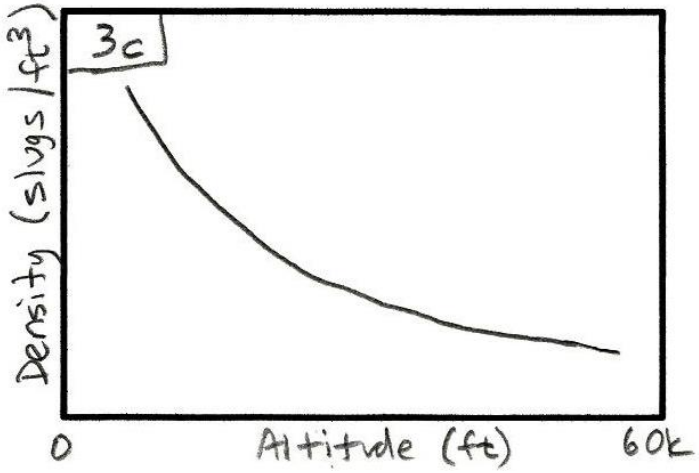
Homework Assignment







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Questions?

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