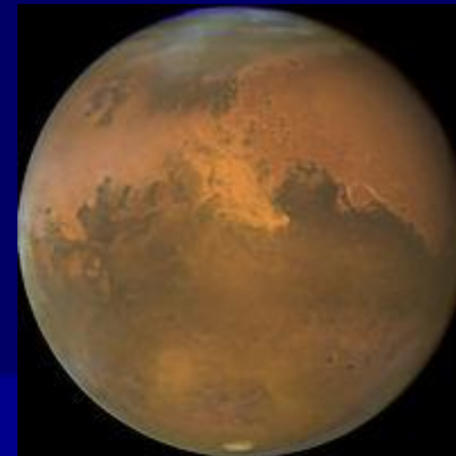
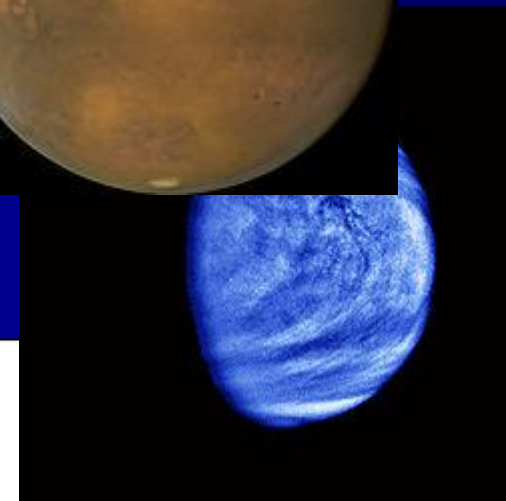
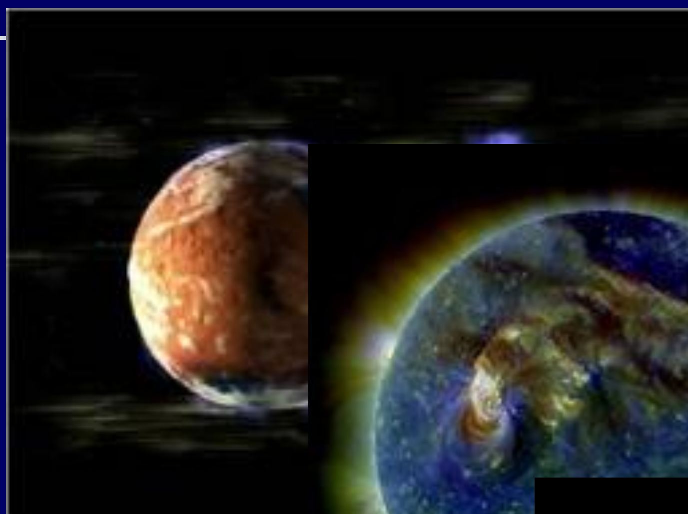
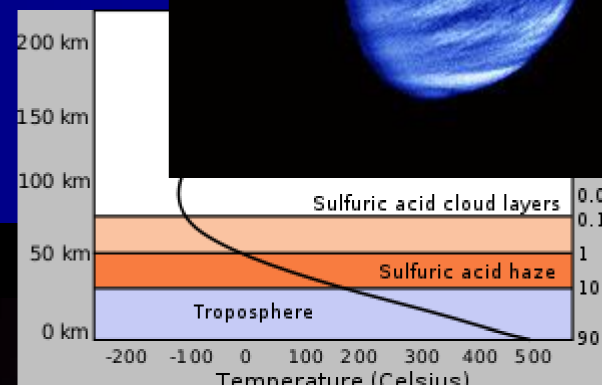
Space Physics

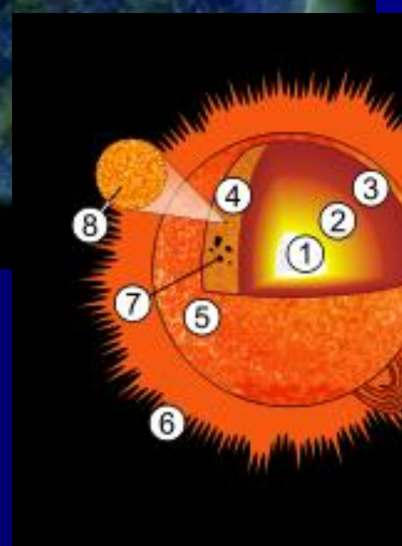
Space Physics - I

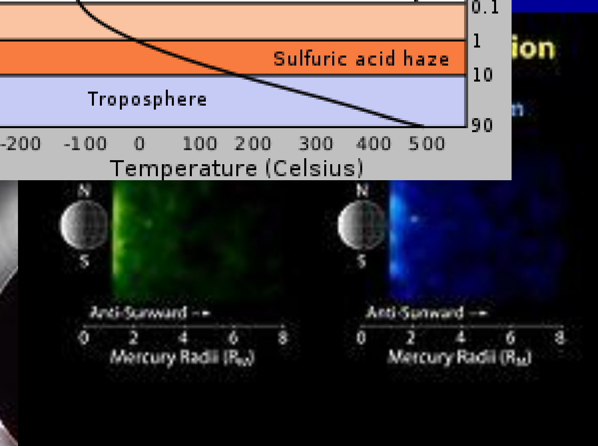








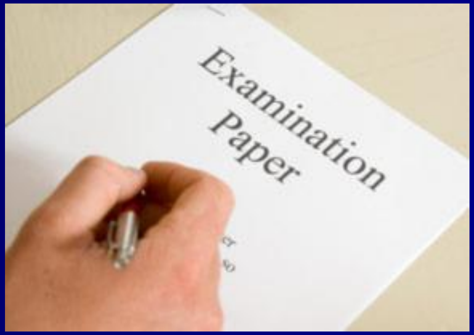




Lecture – 01

PHY 310 1.0 & PHY 373 1.0
Space Physics I

Examination Paper



Duration

01 hour

You should Answer

All the Questions

PHY 310 1.0 & PHY 373 1.0 - Space Physics I

Course Contents:

Planetary Atmospheres
(Formation and Evolution of Planetary Atmospheres, The structure of the Terrestrial Atmosphere, The Escape of the Atmospheric Gases, The Atmospheres of the Earth)

Earth's Atmosphere
(Retaining of Gases in the Earth, Barometric Equation & Scale Height, Number Density Profiles, Atmospheric Regions, Temperature Profiles)

The Ionosphere of the Earth
(Introduction, The Chapman Layer Theory, Plasma Frequency, Collision Frequency and Absorption)

The Magnetosphere of the Earth
(The Dipole Magnetic Field, The Earth's Magnetic Fields, The Radiation Belts)

The Active Sun
(Introduction of the Active Sun, The Main Regions of the Sun, Sunspots and the Solar Cycle, Radio and X-ray Bursts from the Sun, Effect of the Solar Cycle)

Radio Wave Communication
(Reflection of Radio Waves, Absorption of Radio Waves, Complex Refractive Index, Reflection Heights, Ionosphere – Sounding Techniques, Pulse Reflection Methods, Expectable Crisis of Radio Wave Communication)

PHY 310 1.0 & PHY 373 1.0 - Space Physics I

References:

* Space Physics and Space Astronomy – Michael D. Papagiannis
* Space Physics - May-Britt Kallenrode
* Horizons - Exploring the Universe – Michael A. Seeds
* Sun, Solar Cycle, Ionosphere, Absorption cross section, Maxwell's equations, Atmospheric dispersion modeling, Wave plate – Wikipedia (Internet)
* Sunspot Numbers - IPS - Solar Conditions (Monthly Sunspot Numbers) (Internet)
* Solar Physics – NASA - Marshall Solar Physics (Internet)
* Ionospheric Physics of Radio Wave Propagation - Edwin C. Jones (Internet)

Method of Assessment: End of the Semester Theory Examination - 100%

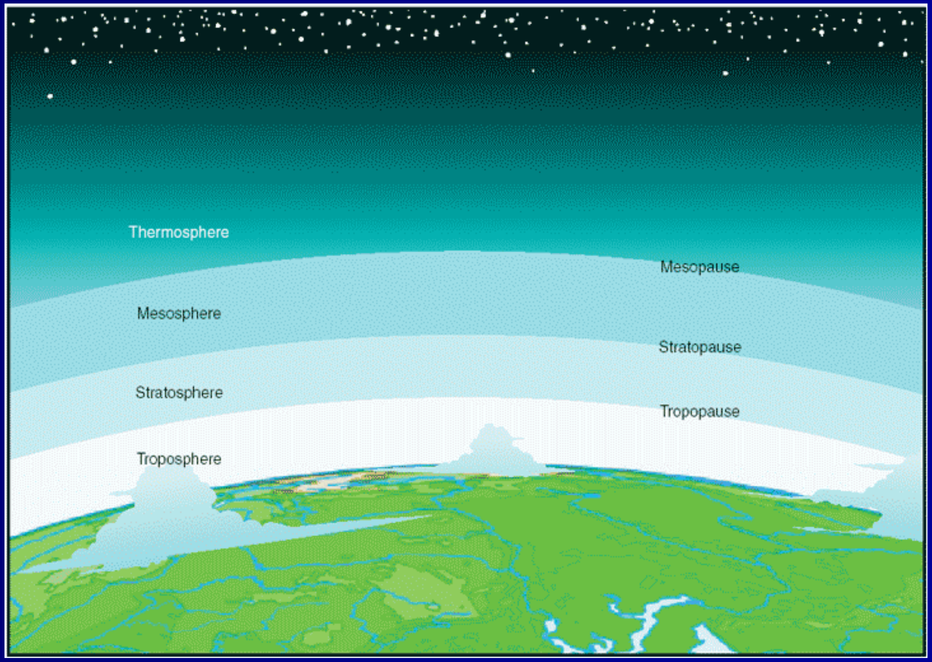
Planetary Atmospheres

Planetary Atmospheres

- The Structure of the Terrestrial Atmosphere
- The Temperature of the Neutral Atmosphere
- The Escape of the Atmospheric Gases
- The Atmospheres of the Earth

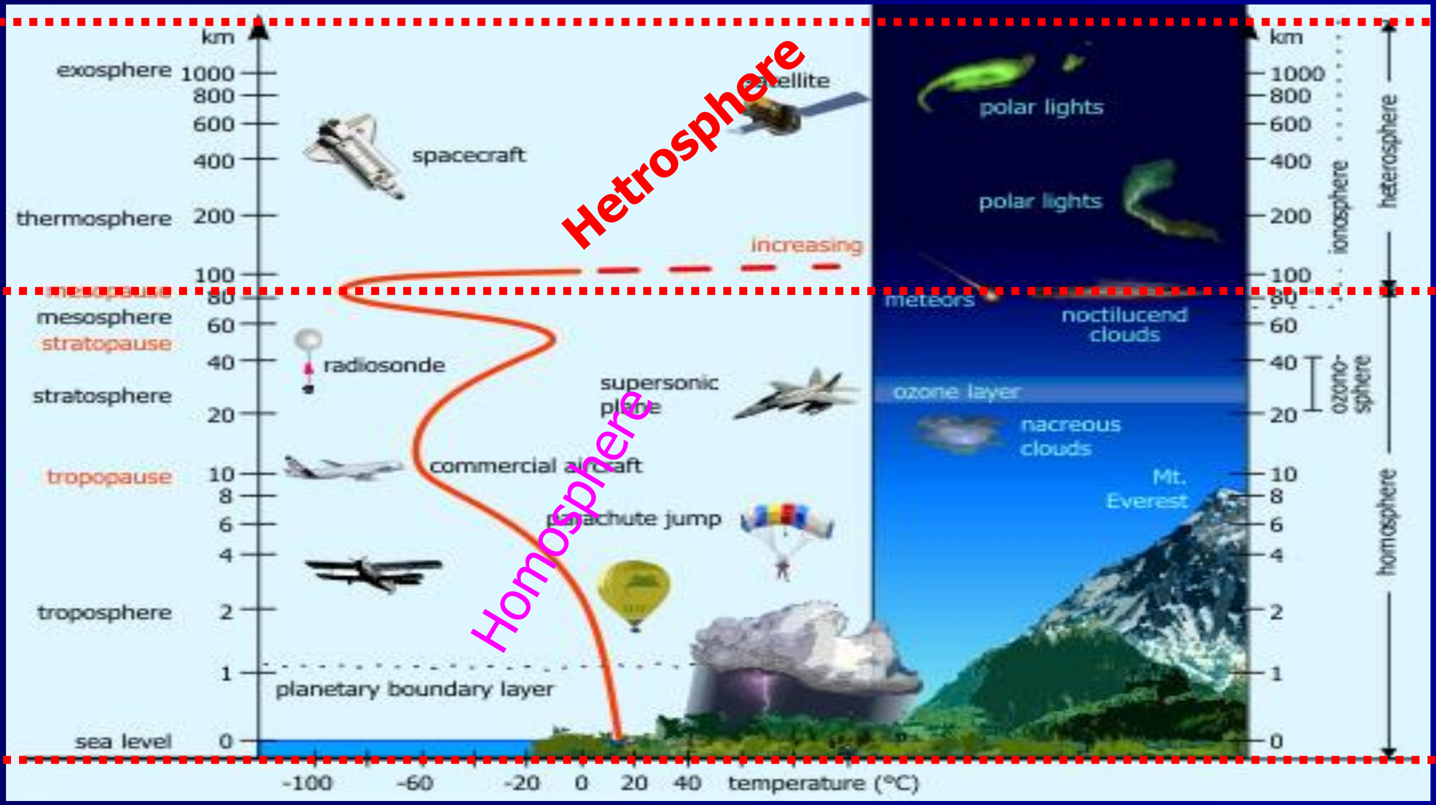
The Structure of the Terrestrial Atmosphere

To facilitate the study of the atmosphere, we usually divide it into shells with common properties. These shells bear names ending in sphere (e.g., stratosphere) and the boundaries between them follow the name of the lower layer with the ending pause (e.g., stratopause). The several layers into which the atmosphere is divided vary depending on the principle properties of the atmosphere under investigation. One of the most common classifications is when the temperature is used as the guiding parameter. In this case we recognize the following regions of the terrestrial atmosphere:



The Structure of the Terrestrial Atmosphere

As we mentioned earlier, the atmosphere is divided in to different layers for different subjects of study. We have already seen the division according to temperature. When our main interest is the chemical composition of the terrestrial atmosphere, we recognize the following regions.

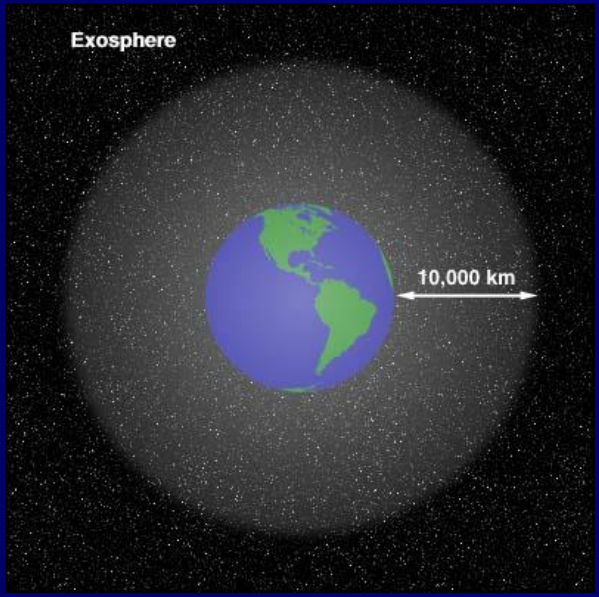


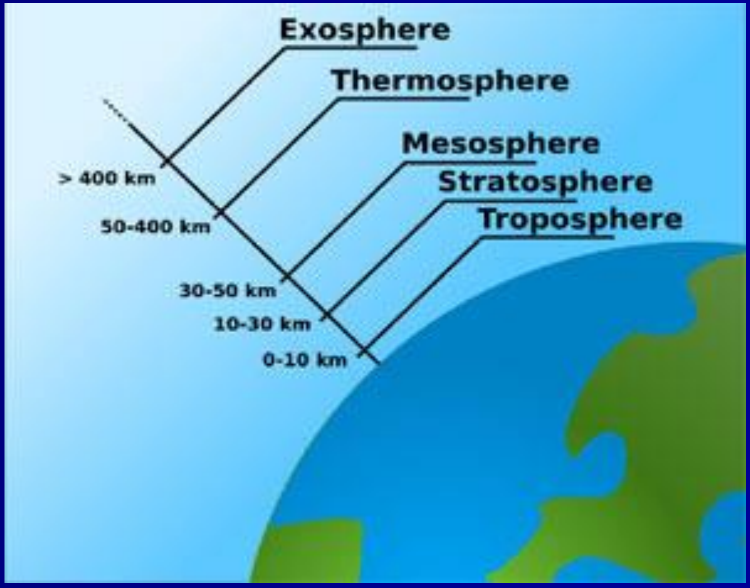
The Structure of the Terrestrial Atmosphere

Other regions of the upper atmosphere characterized by some common property other than temperature or chemical composition are the following:

Exosphere:

It defines the regions from which neutral atoms can escape the gravitational attraction of the Earth and extends from approximately 600 km on up.

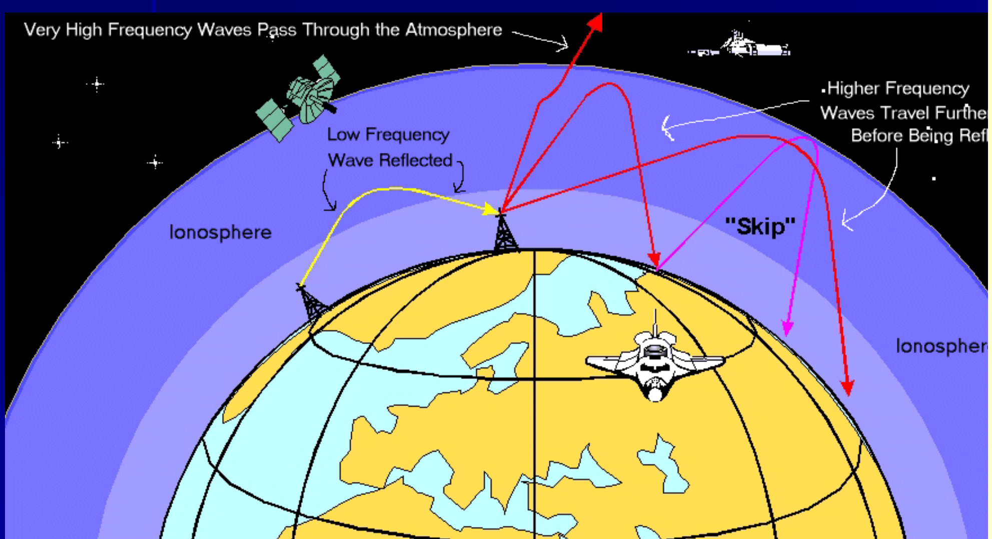


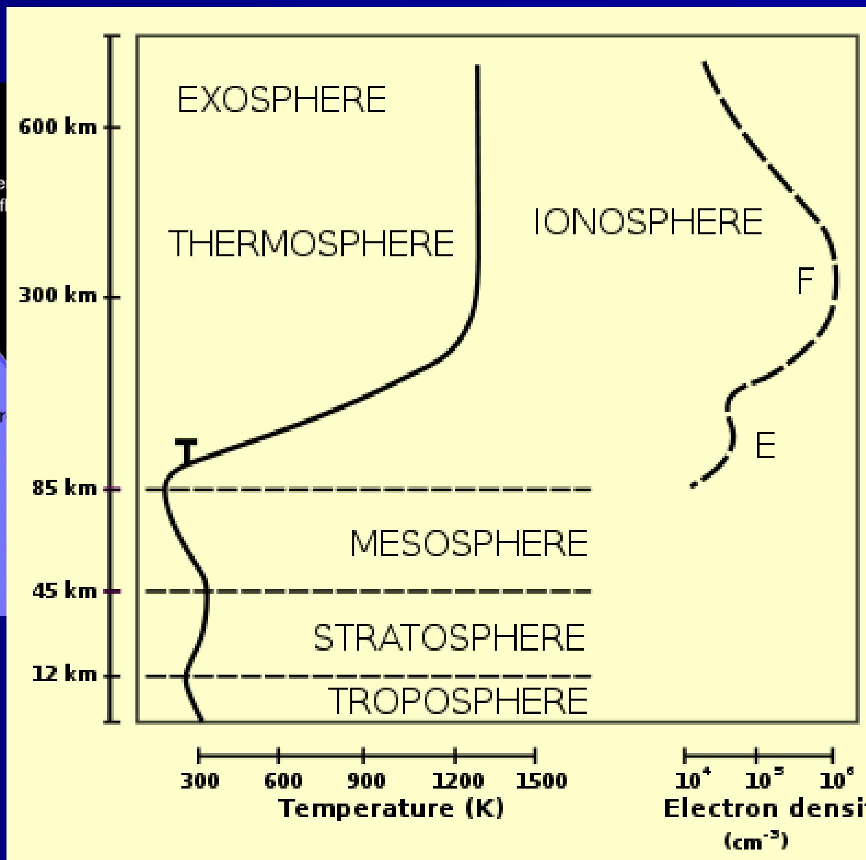


The Structure of the Terrestrial Atmosphere

Ionosphere:

This is the region where a partial ionization of the atmospheric constituents takes place. The ionosphere extends from about 70 km on up and reaches a maximum of ionized particle density around 300 km.

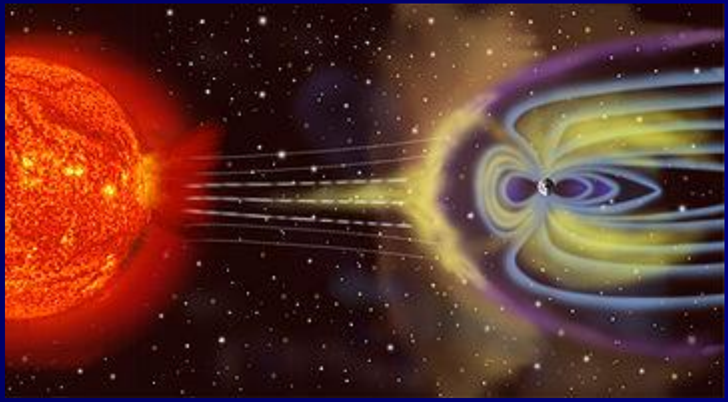


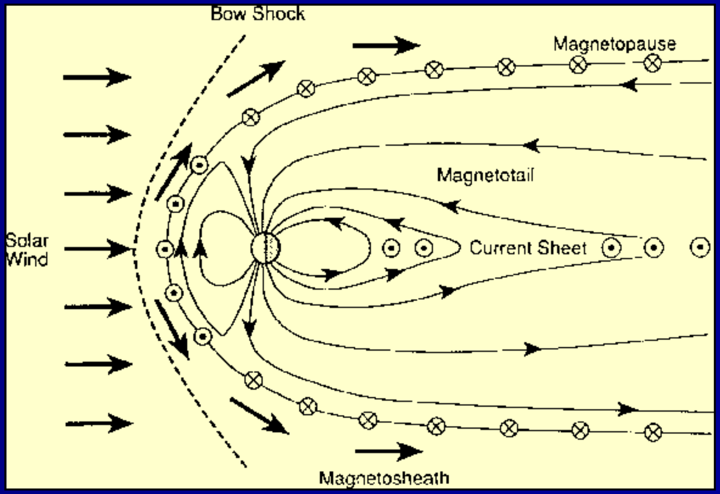


The Structure of the Terrestrial Atmosphere

Magnetosphere:

This is the region where the motion of the ionized particles is governed by the Earth's magnetic field. It is rather difficult to define the beginning of the magnetosphere, and one can only roughly place it near 1000 km. The upper limit of the magnetosphere is clearly defined and as expected it is called the magnetopause. On the sunlit side of the Earth the magnetopause occurs at approximately 10 earth radii, whereas, on the night side of our planet it takes the shape of a long (100 earth radii) cylindrical magnetic tail. The magnetopause defines the boundary of the terrestrial domain beyond which, after a transitional region which is called the magneto-sheath, stars the vast realm of the interplanetary space.





The physical parameters of an average atmosphere.

TABLE 1.2-I

Altitude in km	Temperature in °K	Density in gr/cm^{-3}	Mean Mol. Weight	Pressure in dyn/cm^2	Mean Free Path in m	Accel. Grav. in cm/s^2
0	288	1.23×10^{-3}	28.96	1.01×10^{6}	6.63×10^{-8}	981
2	275	1.01×10^{-3}	28.96	7.95×10^{5}	8.07×10^{-8}	980
4	262	8.19×10^{-4}	28.96	6.17×10^{5}	9.92×10^{-8}	979
6	249	6.60×10^{-4}	28.96	4.72×10^{5}	1.23×10^{-7}	979
8	236	5.26×10^{-4}	28.96	3.57×10^{5}	1.55×10^{-7}	978
10	223	4.14×10^{-4}	28.96	2.65×10^{5}	1.96×10^{-7}	978
20	217	8.89×10^{-5}	28.96	5.53×10^{4}	9.14×10^{-7}	975
40	250	4.00×10^{-6}	28.96	2.87×10^{3}	2.03×10^{-5}	968
60	256	3.06×10^{-7}	28.96	2.25×10^{2}	2.66×10^{-4}	962
80	181	2.00×10^{-8}	28.96	1.04×10	4.07×10^{-3}	956
100	210	4.97×10^{-10}	28.88	3.01×10^{-1}	1.63×10^{-1}	951
140	714	3.39×10^{-12}	27.20	7.41×10^{-3}	2.25×10	939
180	1156	5.86×10^{-13}	26.15	2.15×10^{-3}	1.25×10^{2}	927
220	1294	1.99×10^{-13}	24.98	8.58×10^{-4}	3.52×10^{2}	916
260	1374	8.04×10^{-14}	23.82	3.86×10^{-4}	8.31×10^{2}	905
300	1432	3.59×10^{-14}	22.66	1.88×10^{-4}	1.77×10^{3}	894
400	1487	6.50×10^{-15}	19.94	4.03×10^{-5}	8.61×10^{3}	868
500	1499	1.58×10^{-15}	17.94	1.10×10^{-5}	3.19×10^{4}	843
600	1506	4.64×10^{-16}	16.84	3.45×10^{-6}	1.02×10^{5}	819
700	1508	1.54×10^{-16}	16.17	1.19×10^{-6}	2.95×10^{5}	796

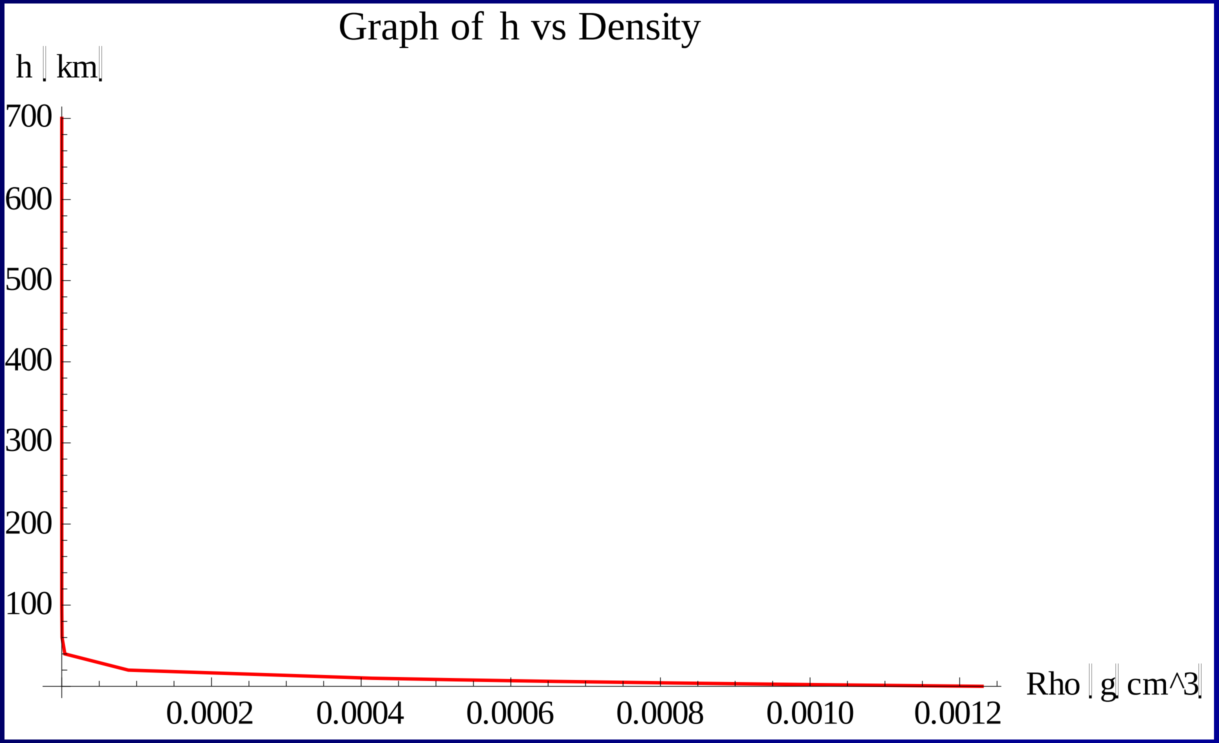
The graph of h (in km) vs Density (in gr cm^(-3))

Altitude in km	Density in gr/cm^{-3}
0	1.23×10^{-3}
2	1.01×10^{-3}
4	8.19×10^{-4}
6	6.60×10^{-4}
8	5.26×10^{-4}
10	4.14×10^{-4}
20	8.89×10^{-5}
40	4.00×10^{-6}
60	3.06×10^{-7}
80	2.00×10^{-8}
100	4.97×10^{-10}
140	3.39×10^{-12}
180	5.86×10^{-13}
220	1.99×10^{-13}
260	8.04×10^{-14}
300	3.59×10^{-14}
400	6.50×10^{-15}
500	1.58×10^{-15}
600	4.64×10^{-16}
700	1.54×10^{-16}

The graph of h (in km) vs Density (in gr cm^(-3))

```
d1 = Transpose[{rho, hgh}]; (* to get the h vs Rho data set *)
ListPlot[d1, PlotJoined → True,
 PlotStyle → {RGBColor[1, 0, 0], PointSize[0.02]},
 PlotLabel → "Graph of h vs Density",
 AxesLabel → {"Rho (g/cm^3)", "h (km)"}]
(* To Plot the h vs Rho graph *)
```

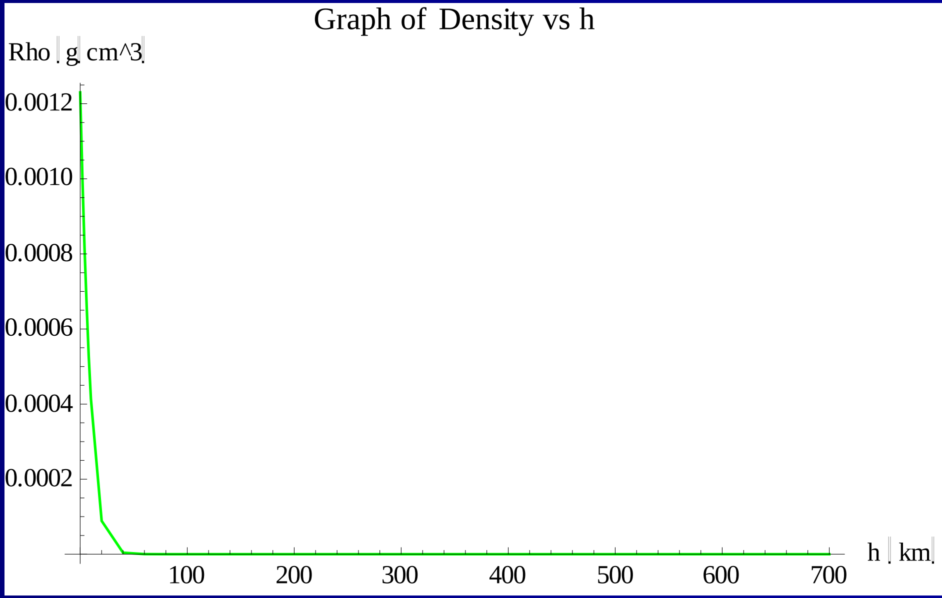
Plot the graph…..



To model the data set …

```
(* To model the data set in Rho vs h format *)
data = Transpose[{hgh, rho}];
g1 = ListPlot[data, PlotJoined → True,
  PlotStyle → {RGBColor[0, 1, 0], PointSize[0.02]},
  PlotLabel → "Graph of Density vs h",
  AxesLabel → {"h (km)", "Rho (g/cm^3)"}]
(* To Plot the Rho vs h graph *)
```

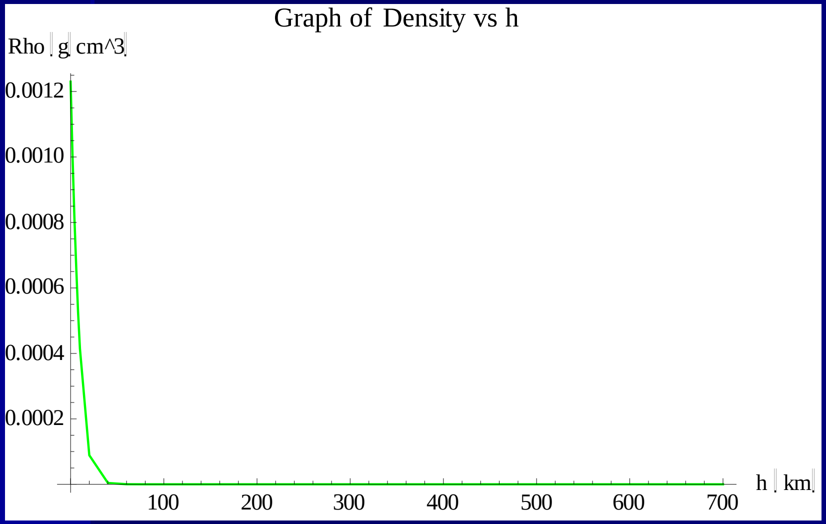
To Model …..



Modeling Part …

```
f = Fit[data, {h, 1}, h]
(* To find a suitable polynomial or relationship *)
g2 = Plot[f, {h, hgh[[1]], hgh[[Length[hgh]]]},
  PlotStyle → {RGBColor[0, 0, 1], PointSize[0.02]}]
(* To plot the predicted model *)
Show[{g1, g2}]
```

Modeling …..



Exp[- a x]

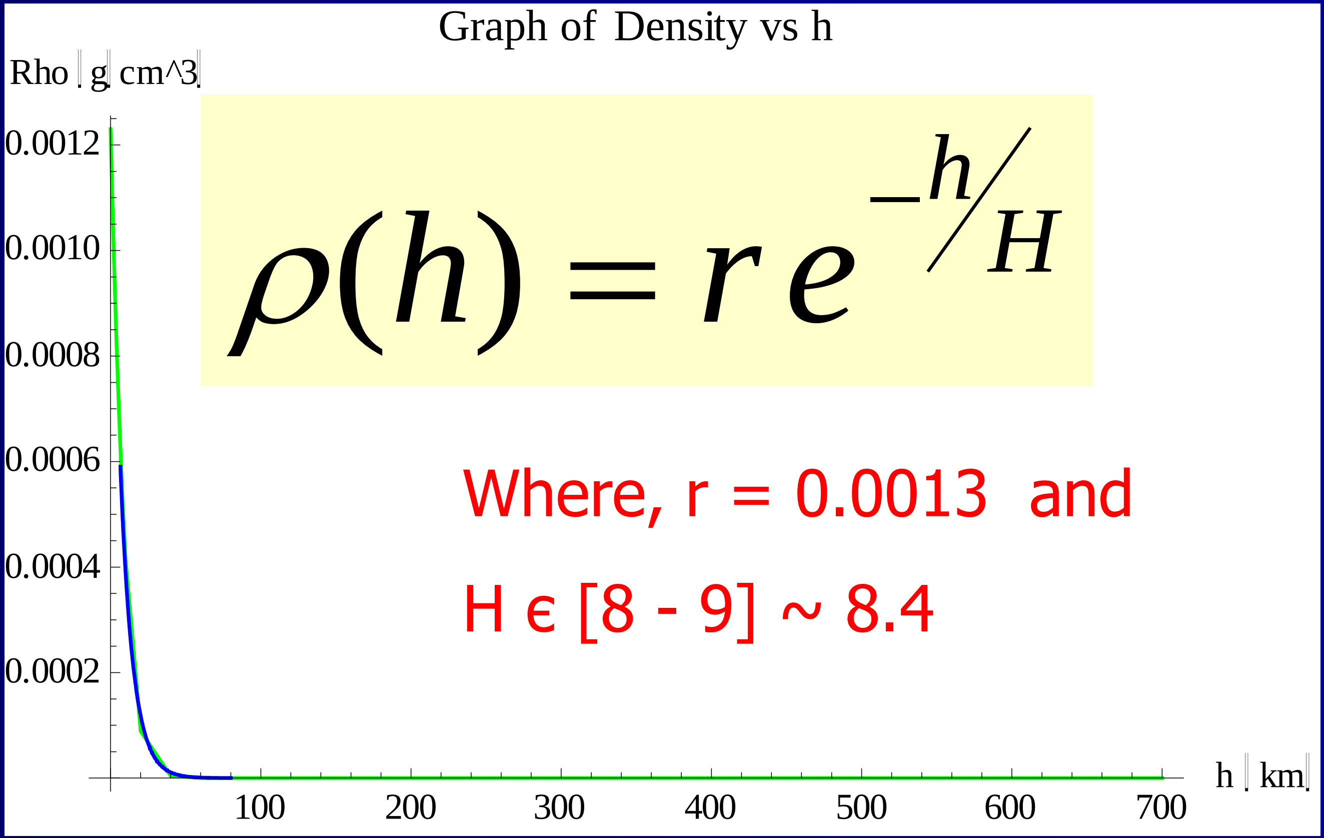
a = 1, 2, 3, …..

a = ½, 1/3, …

a = 1/8 - 1/9

The graph of Density (in gr cm^(-3)) vs h (in km)

Altitude in km	Density in gr/cm^{-3}
0	1.23×10^{-3}
2	1.01×10^{-3}
4	8.19×10^{-4}
6	6.60×10^{-4}
8	5.26×10^{-4}
10	4.14×10^{-4}
20	8.89×10^{-5}
40	4.00×10^{-6}
60	3.06×10^{-7}
80	2.00×10^{-8}
100	4.97×10^{-10}
140	3.39×10^{-12}
180	5.86×10^{-13}
220	1.99×10^{-13}
260	8.04×10^{-14}
300	3.59×10^{-14}
400	6.50×10^{-15}
500	1.58×10^{-15}
600	4.64×10^{-16}
700	1.54×10^{-16}



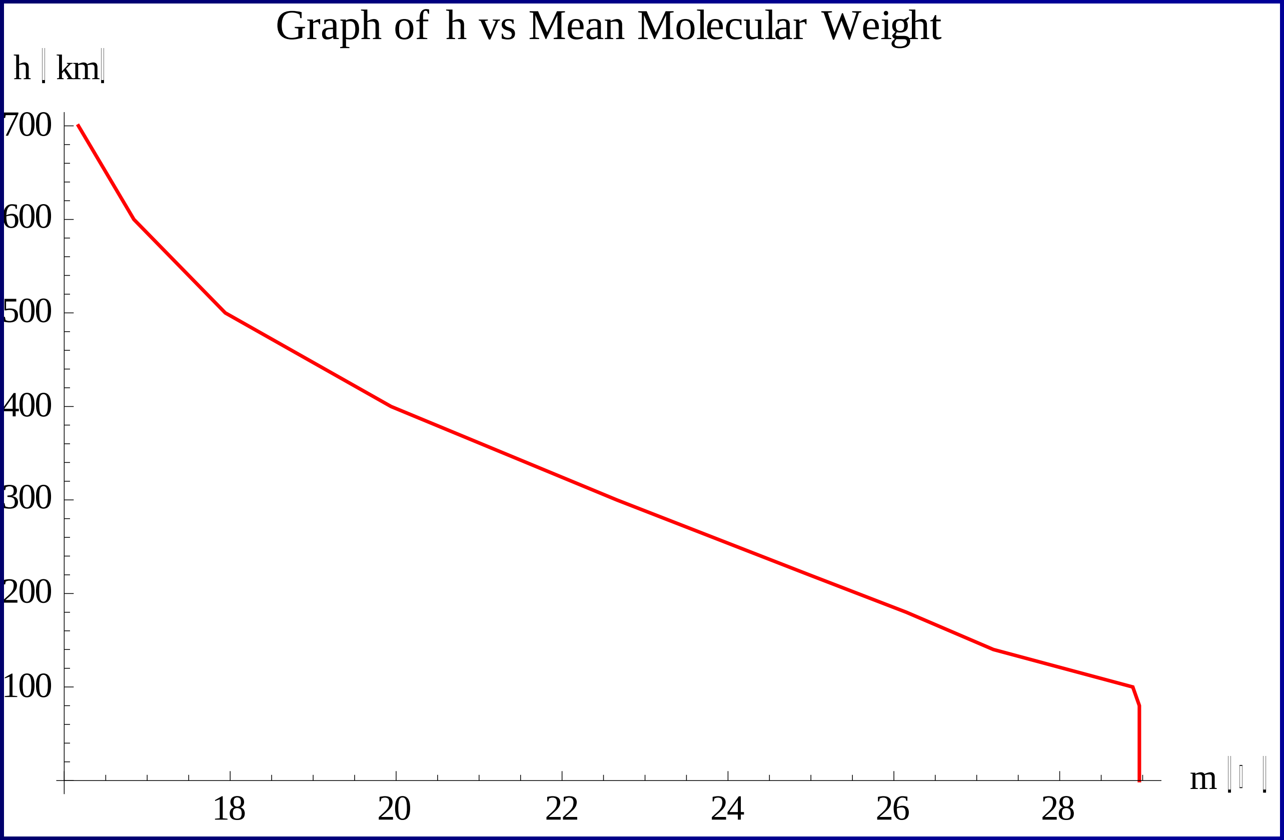
$$\rho(h) = r\,e^{-h/H}$$

Where, r = 0.0013 and

H ϵ [8 - 9] ~ 8.4

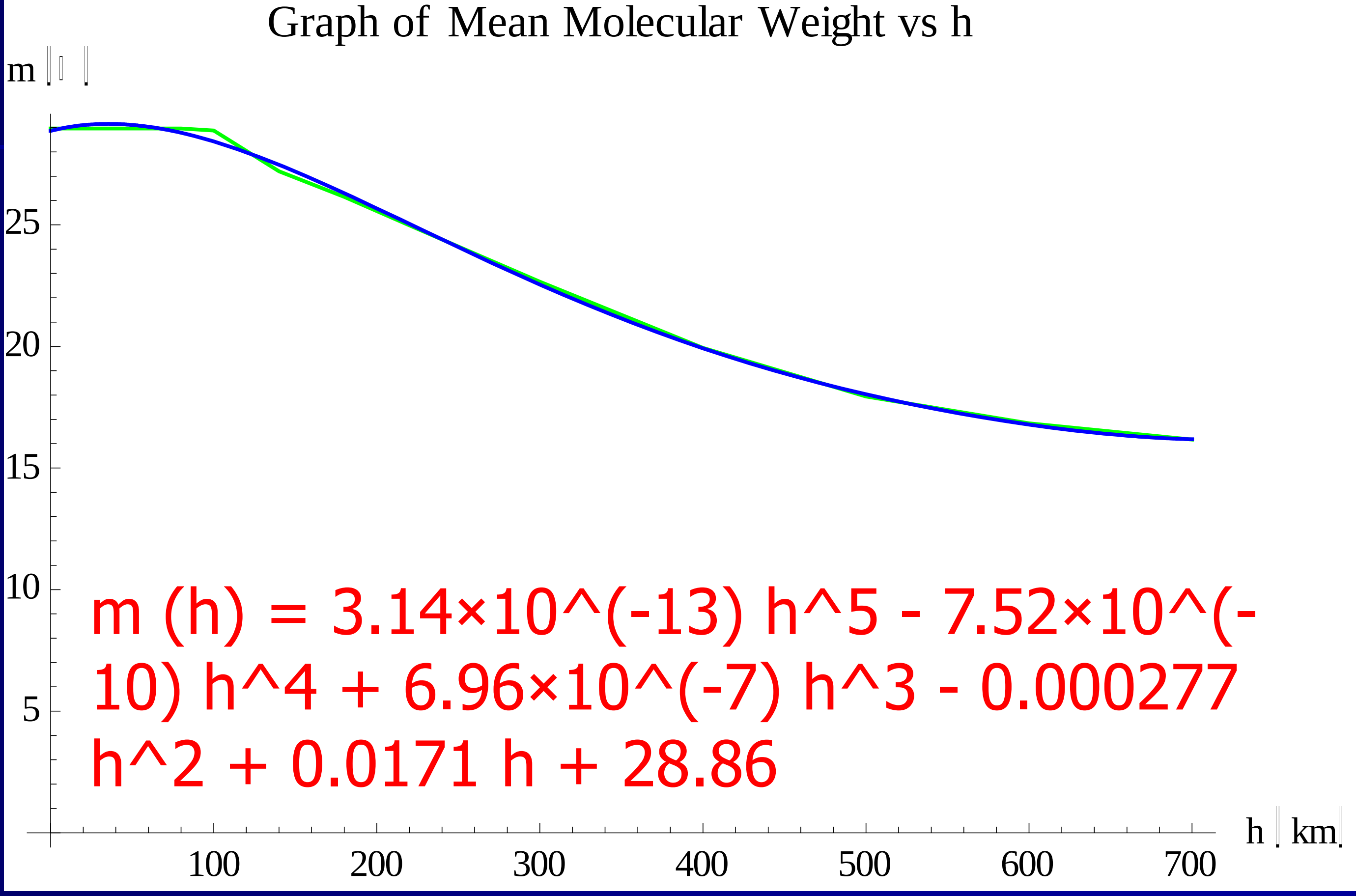
The graph of h (in km) vs mmw

Altitude in km	Mean Mol. Weight
0	28.96
2	28.96
4	28.96
6	28.96
8	28.96
10	28.96
20	28.96
40	28.96
60	28.96
80	28.96
100	28.88
140	27.20
180	26.15
220	24.98
260	23.82
300	22.66
400	19.94
500	17.94
600	16.84
700	16.17



The graph of mmw vs h (in km)

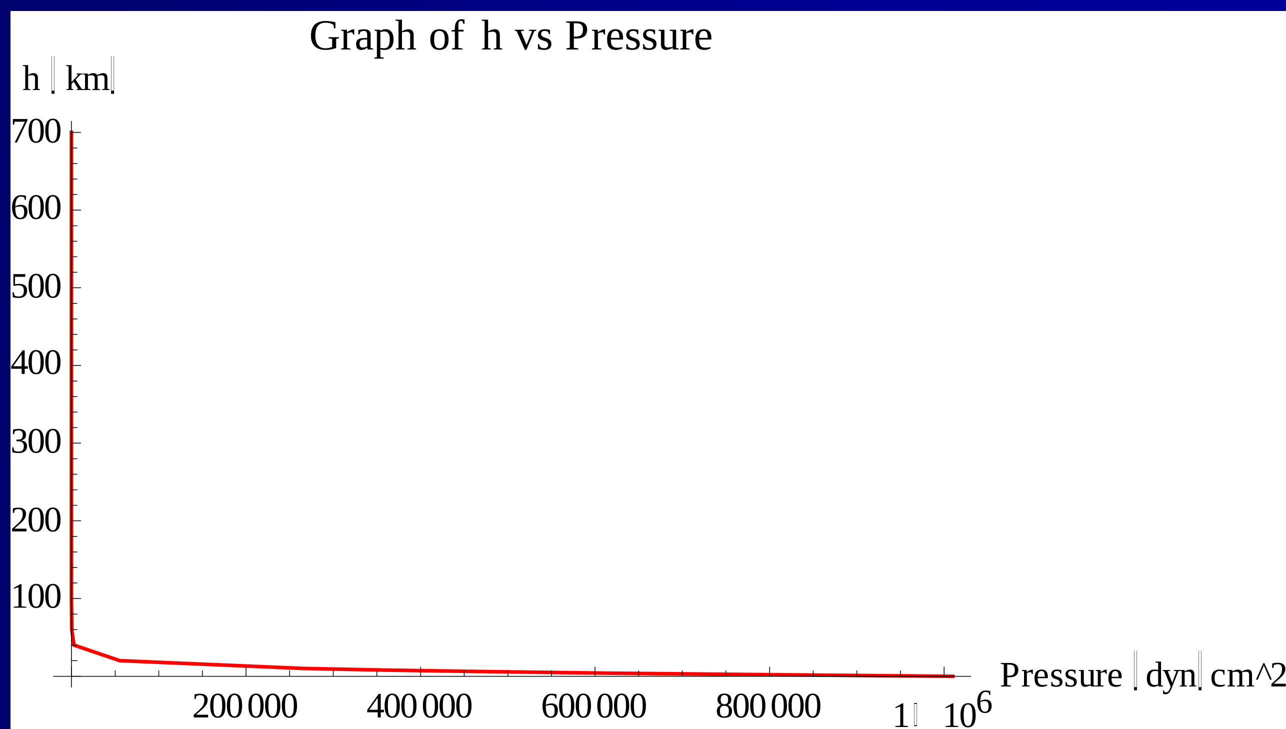
Altitude in km	Mean Mol. Weight
0	28.96
2	28.96
4	28.96
6	28.96
8	28.96
10	28.96
20	28.96
40	28.96
60	28.96
80	28.96
100	28.88
140	27.20
180	26.15
220	24.98
260	23.82
300	22.66
400	19.94
500	17.94
600	16.84
700	16.17



$$m(h) = 3.14\times10^{(-13)} h^5 - 7.52\times10^{(-10)} h^4 + 6.96\times10^{(-7)} h^3 - 0.000277 h^2 + 0.0171 h + 28.86$$

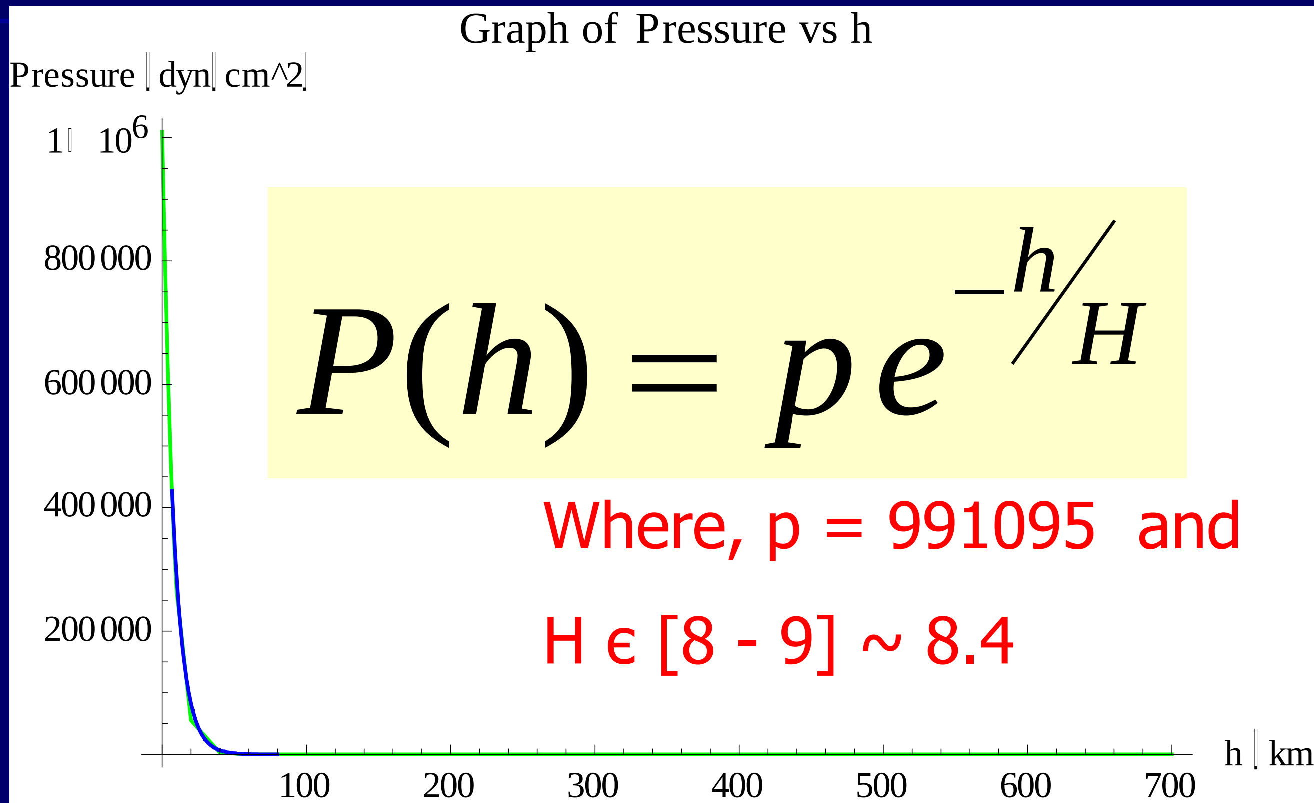
The graph of h (in km) vs Pressure (in dyn/cm^2)

Altitude in km	Pressure in dyn/cm²
0	1.01×10^{6}
2	7.95×10^{5}
4	6.17×10^{5}
6	4.72×10^{5}
8	3.57×10^{5}
10	2.65×10^{5}
20	5.53×10^{4}
40	2.87×10^{3}
60	2.25×10^{2}
80	1.04×10
100	3.01×10^{-1}
140	7.41×10^{-3}
180	2.15×10^{-3}
220	8.58×10^{-4}
260	3.86×10^{-4}
300	1.88×10^{-4}
400	4.03×10^{-5}
500	1.10×10^{-5}
600	3.45×10^{-6}
700	1.19×10^{-6}



The graph of Pressure (in dyn/cm^2) vs h (in km)

Altitude in km	Pressure in dyn/cm²
0	1.01×10^6
2	7.95×10^5
4	6.17×10^5
6	4.72×10^5
8	3.57×10^5
10	2.65×10^5
20	5.53×10^4
40	2.87×10^3
60	2.25×10^2
80	1.04×10
100	3.01×10^{-1}
140	7.41×10^{-3}
180	2.15×10^{-3}
220	8.58×10^{-4}
260	3.86×10^{-4}
300	1.88×10^{-4}
400	4.03×10^{-5}
500	1.10×10^{-5}
600	3.45×10^{-6}
700	1.19×10^{-6}



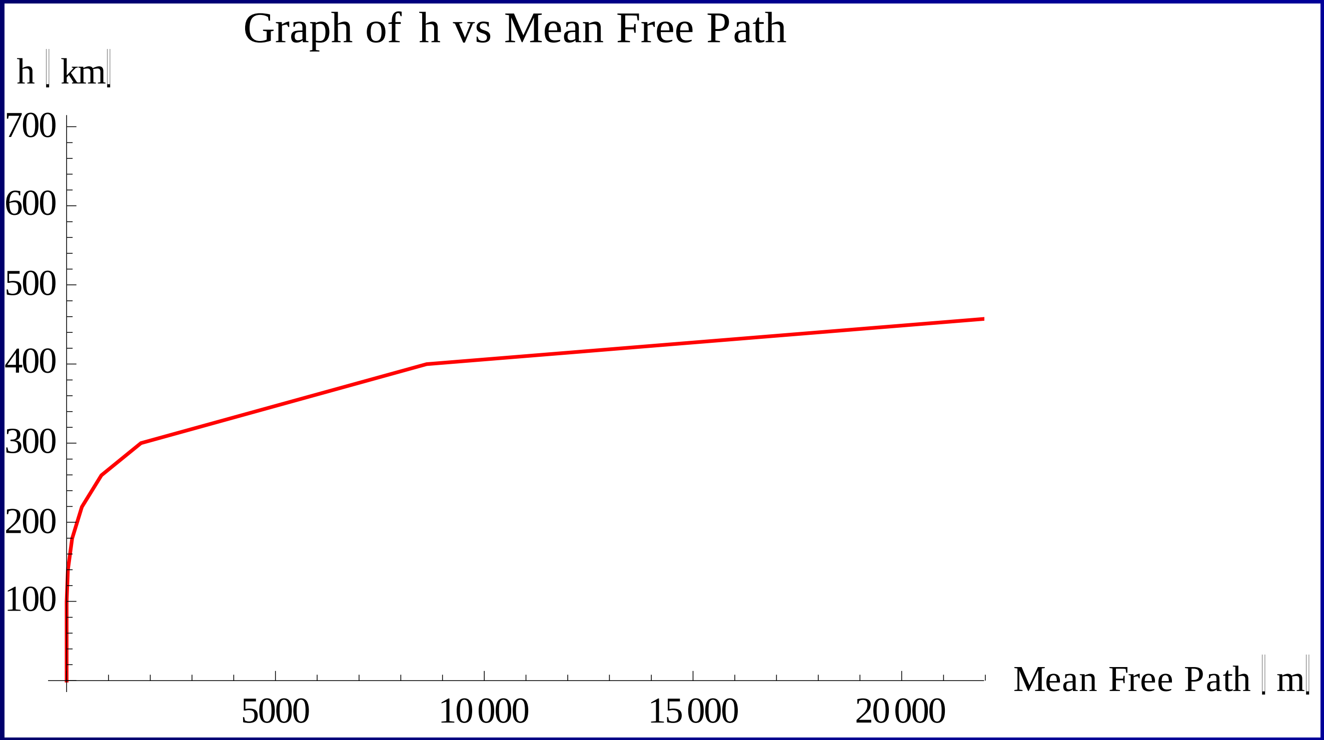
$$P(h) = p\, e^{-h/H}$$

Where, p = 991095 and

H ϵ [8 - 9] ~ 8.4

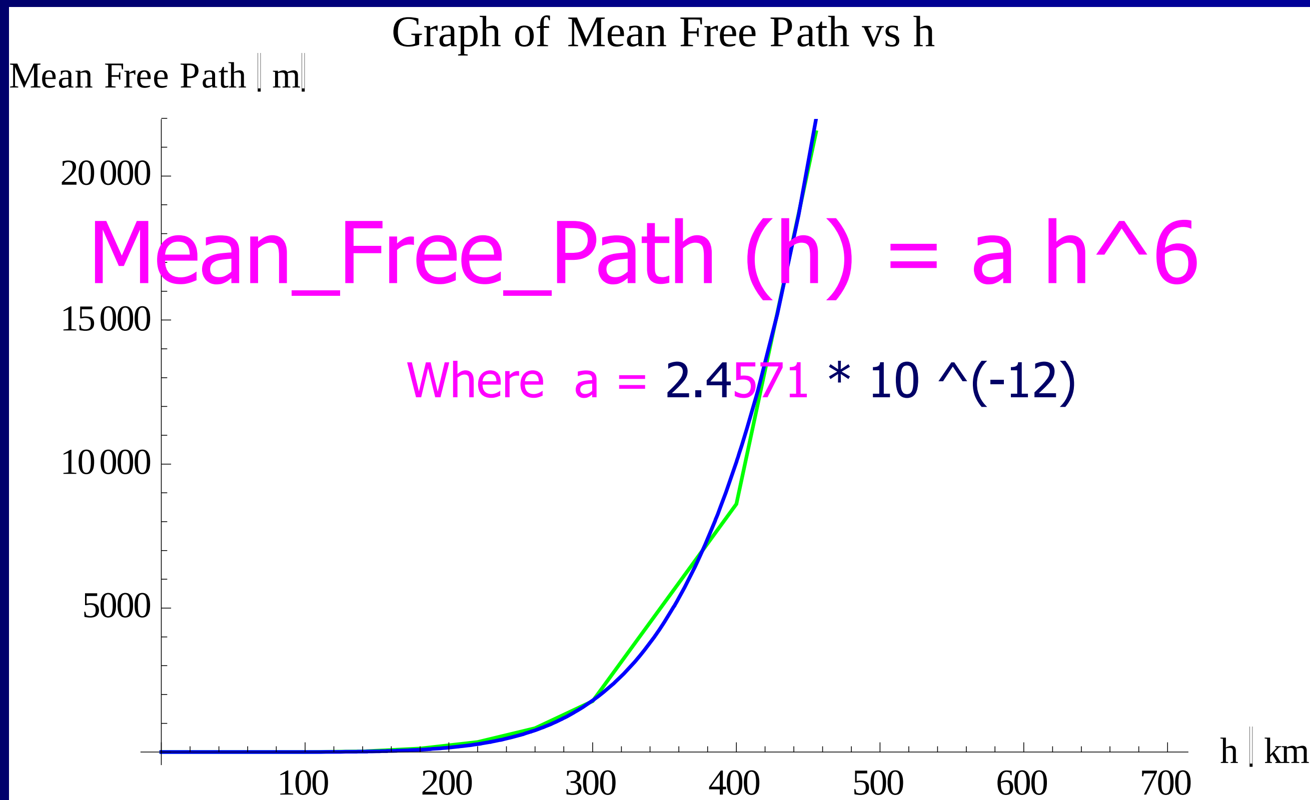
The graph of h (in km) vs Mean Free Path (in m)

Altitude in km	Mean Free Path in m
0	6.63×10^{-8}
2	8.07×10^{-8}
4	9.92×10^{-8}
6	1.23×10^{-7}
8	1.55×10^{-7}
10	1.96×10^{-7}
20	9.14×10^{-7}
40	2.03×10^{-5}
60	2.66×10^{-4}
80	4.07×10^{-3}
100	1.63×10^{-1}
140	2.25×10
180	1.25×10^{2}
220	3.52×10^{2}
260	8.31×10^{2}
300	1.77×10^{3}
400	8.61×10^{3}
500	3.19×10^{4}
600	1.02×10^{5}
700	2.95×10^{5}



The graph of Mean Free Path (in m) vs h (in km)

Altitude in km	Mean Free Path in m
0	6.63×10^{-8}
2	8.07×10^{-8}
4	9.92×10^{-8}
6	1.23×10^{-7}
8	1.55×10^{-7}
10	1.96×10^{-7}
20	9.14×10^{-7}
40	2.03×10^{-5}
60	2.66×10^{-4}
80	4.07×10^{-3}
100	1.63×10^{-1}
140	2.25×10
180	1.25×10^{2}
220	3.52×10^{2}
260	8.31×10^{2}
300	1.77×10^{3}
400	8.61×10^{3}
500	3.19×10^{4}
600	1.02×10^{5}
700	2.95×10^{5}

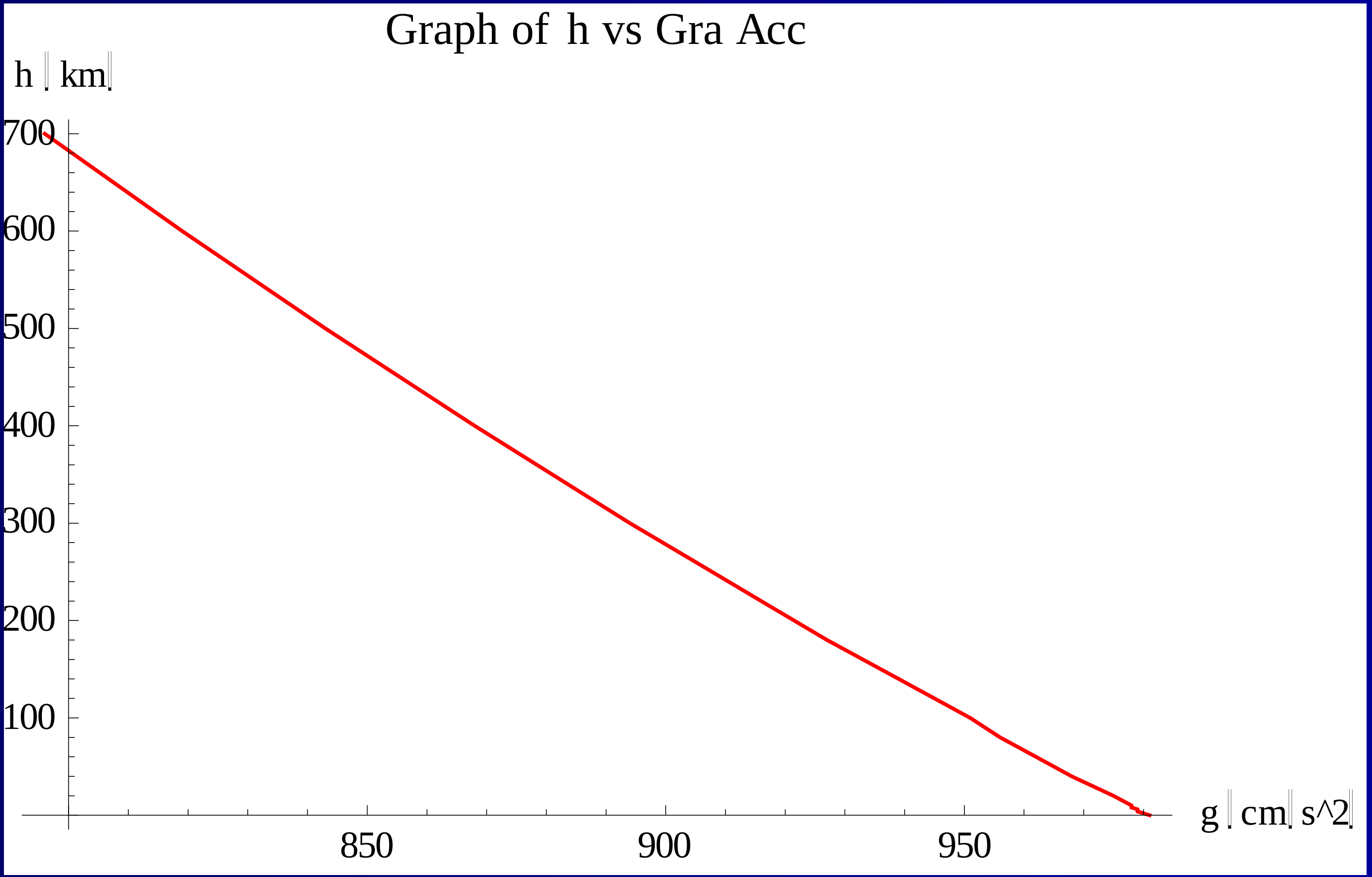


Mean_Free_Path (h) = a h^6

Where a = 2.4571 * 10 ^(-12)

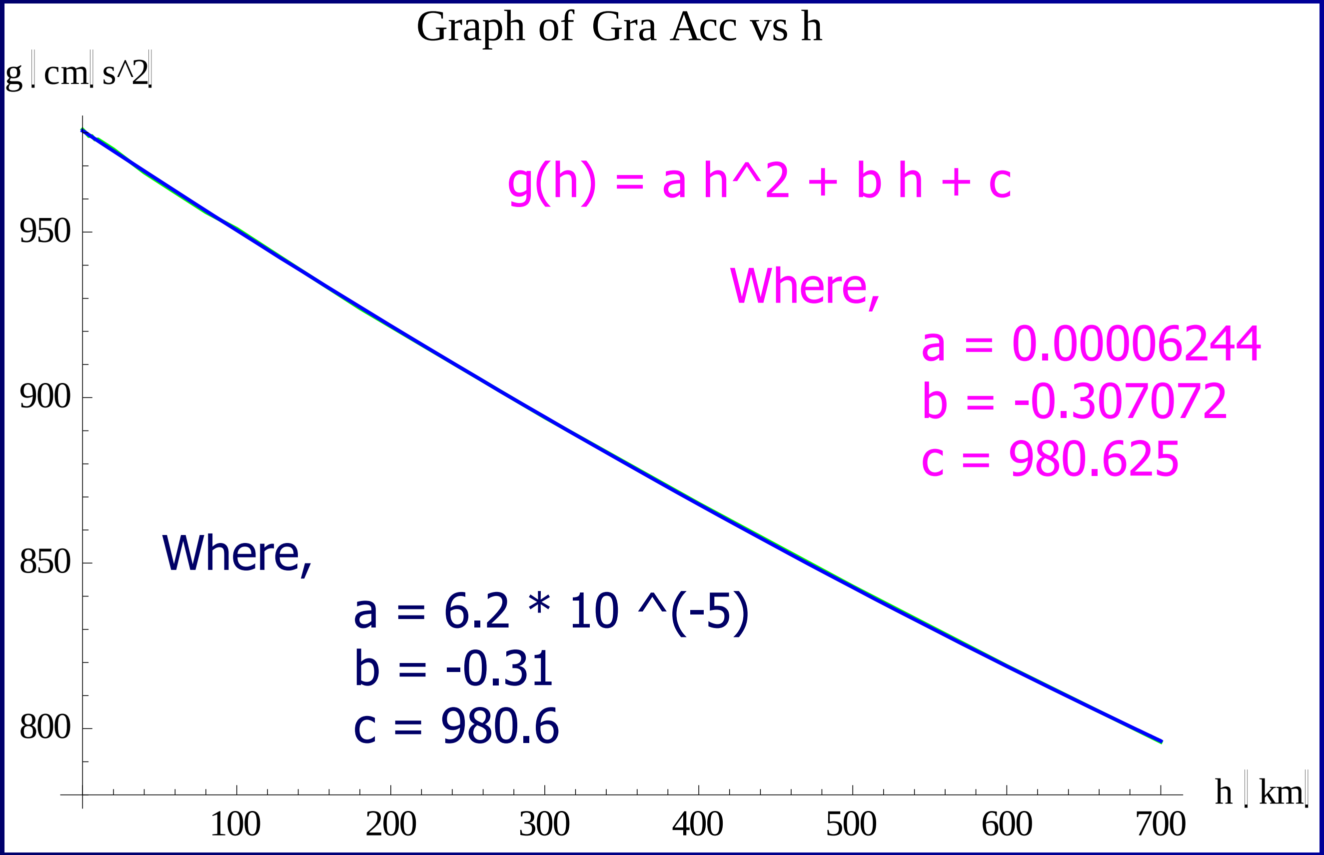
The graph of h (in km) vs Gravitational Acceleration (in cm/s^2)

Altitude in km	Accel. Grav. in cm/s^2
0	981
2	980
4	979
6	979
8	978
10	978
20	975
40	968
60	962
80	956
100	951
140	939
180	927
220	916
260	905
300	894
400	868
500	843
600	819
700	796



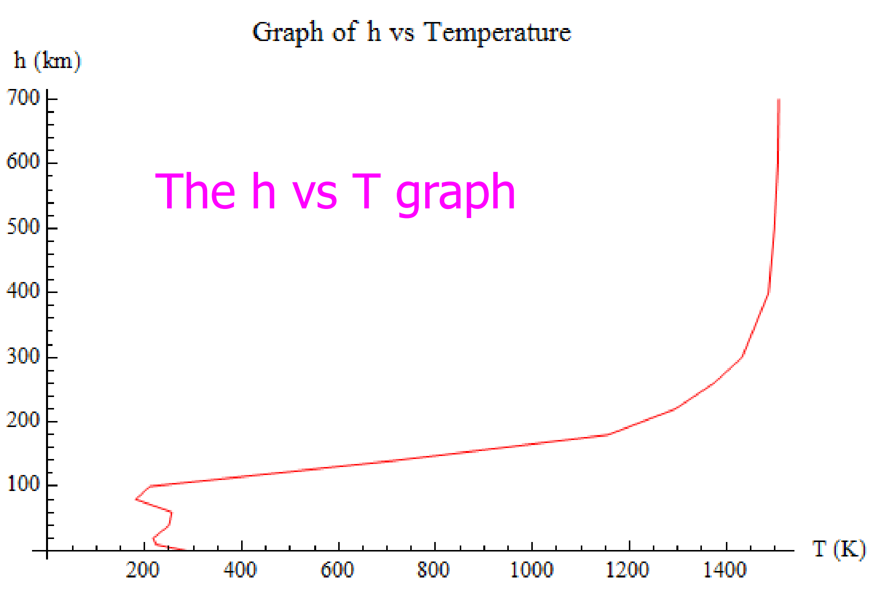
The graph of Gravitational Acceleration (in cm/s^2) vs h (in km)

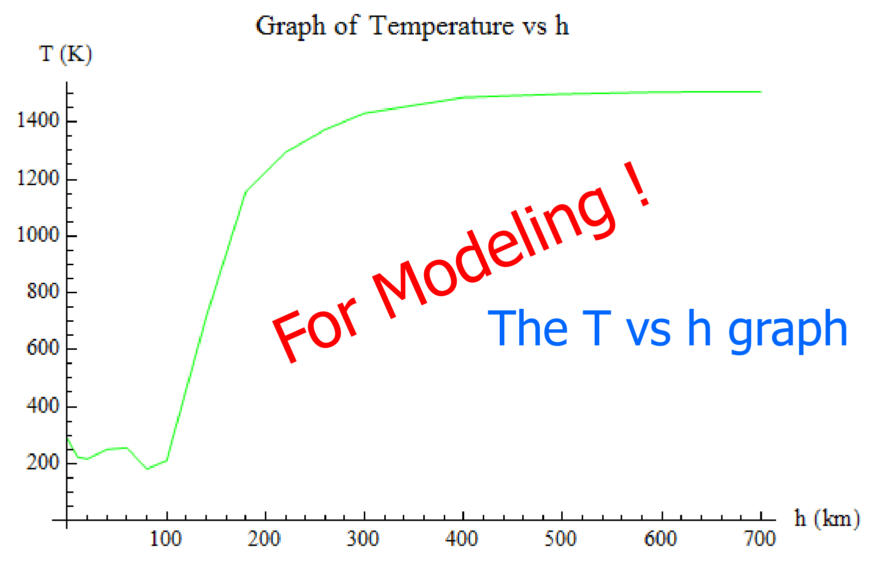
Altitude in km	Accel. Grav. in cm/s^2
0	981
2	980
4	979
6	979
8	978
10	978
20	975
40	968
60	962
80	956
100	951
140	939
180	927
220	916
260	905
300	894
400	868
500	843
600	819
700	796



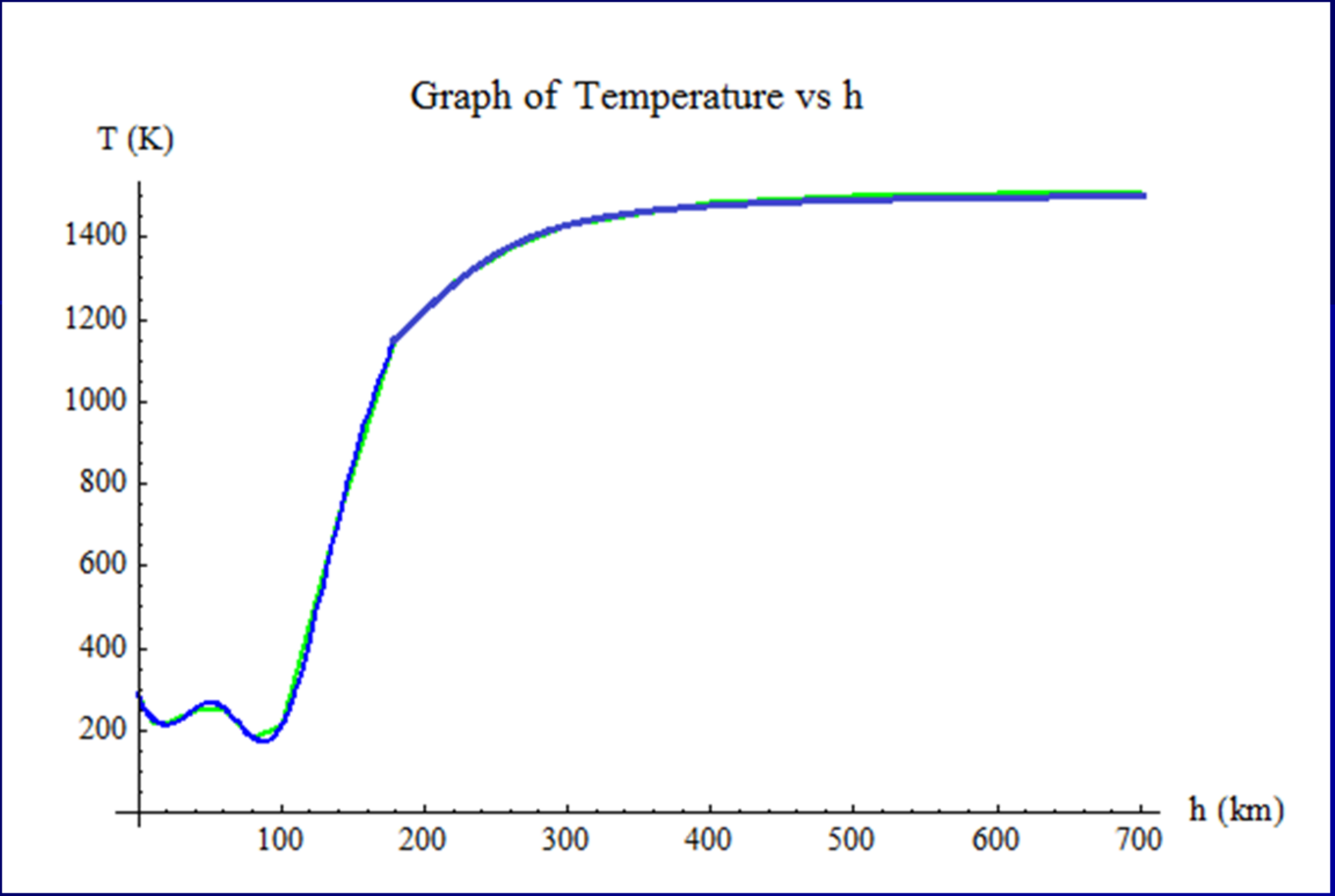
The graph of h (in km) vs T (in K)

Altitude in km	Temperature in °K
0	288
2	275
4	262
6	249
8	236
10	223
20	217
40	250
60	256
80	181
100	210
140	714
180	1156
220	1294
260	1374
300	1432
400	1487
500	1499
600	1506
700	1508

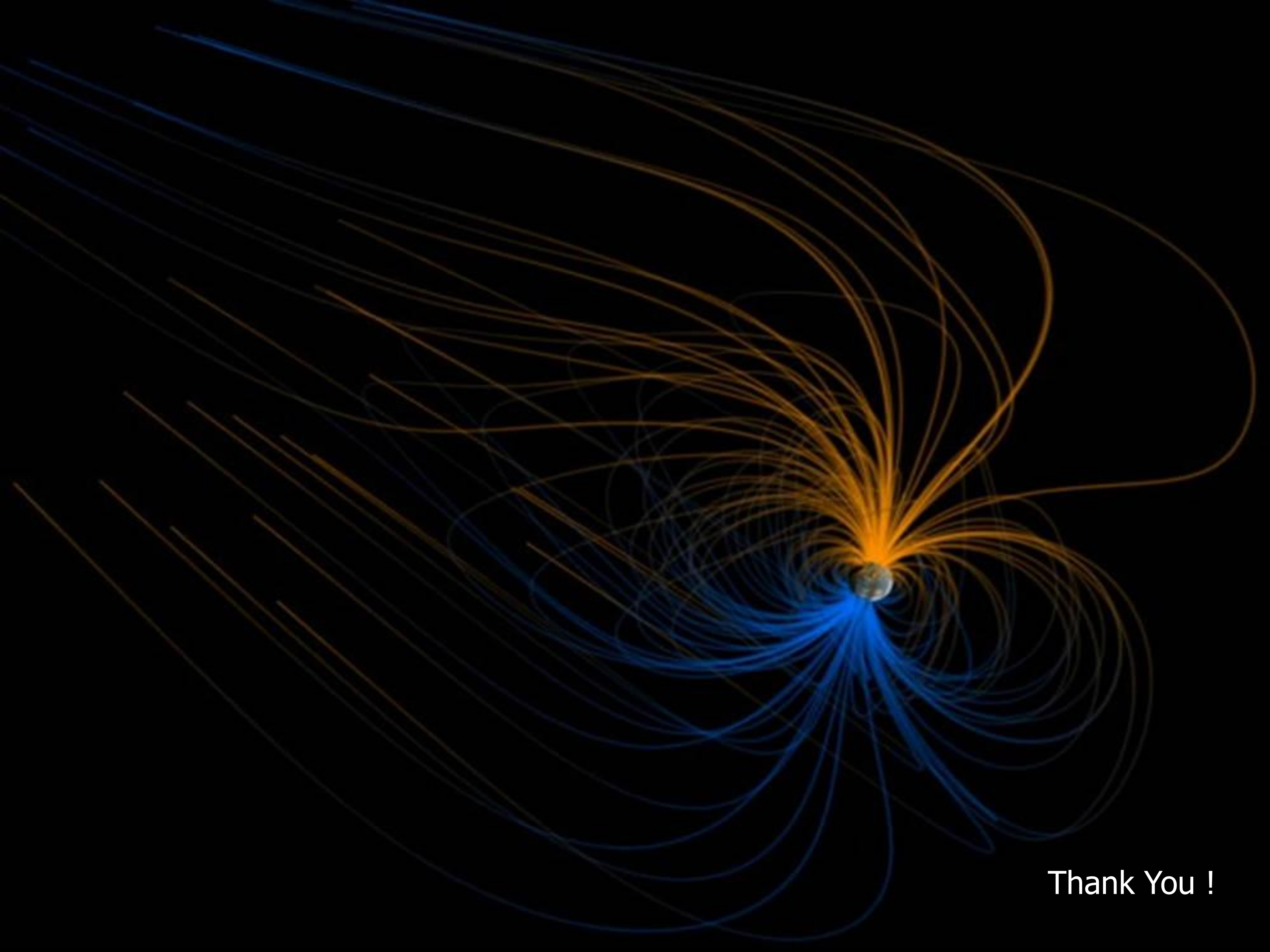




Altitude in km	Temperature in °K
0	288
2	275
4	262
6	249
8	236
10	223
20	217
40	250
60	256
80	181
100	210
140	714
180	1156
220	1294
260	1374
300	1432
400	1487
500	1499
600	1506
700	1508



$$T(h) = \begin{cases} 3.4\times10^{-7}h^5 - 4.2\times10^{-5}h^4 - 1.3\times10^{-3}h^3 + 2.9\times10^{-1}h^2 - 8.98h + 290.3 & 0km \le h \le 100km \\ 2.0\times10^{-10}h^5 - 4.8\times10^{-7}h^4 + 4.5\times10^{-4}h^3 - 2.1\times10^{-1}h^2 + 47.7h - 2895.7 & 100km < h \le 700km \end{cases}$$


Thank You !