# FLIGHT MECHANICS: HOMEWORK 1 REPORT

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Author Note

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Abstract

This homework contains MATLAB codes and explanations on calculating atmosphere properties, operating speed types in aerospace engineering, $C_L$ and $C_D$ values and drag force itself. All the code here and in the zip file belongs to the author himself.

*Keywords*: Flight Mechanics, Atmosphere Model, ISA, Drag Polar Model, Homework

Flight Mechanics: Homework-I Report

## Atmosphere Model

In order to use the expressions to calculate the atmosphere properties, it is necessary to obtain some ISA conditions that occur at the point where $H_p$ is zero.

Standard atmospheric temperature at MSL: $T_0 = 288.15$ [K]

Standard atmospheric pressure at MSL: $p_o = 101325$ [Pa]

Standard atmospheric density at MSL: $\rho_o = 1.225$ [kg/m³]

Speed of sound: $a_o = 340.294$ [m/s]

To obtain temperature;

$$T_< = T_0 + \Delta T + \beta_{T,<}\ H_{p,<} \qquad (3.1\text{-}13)$$

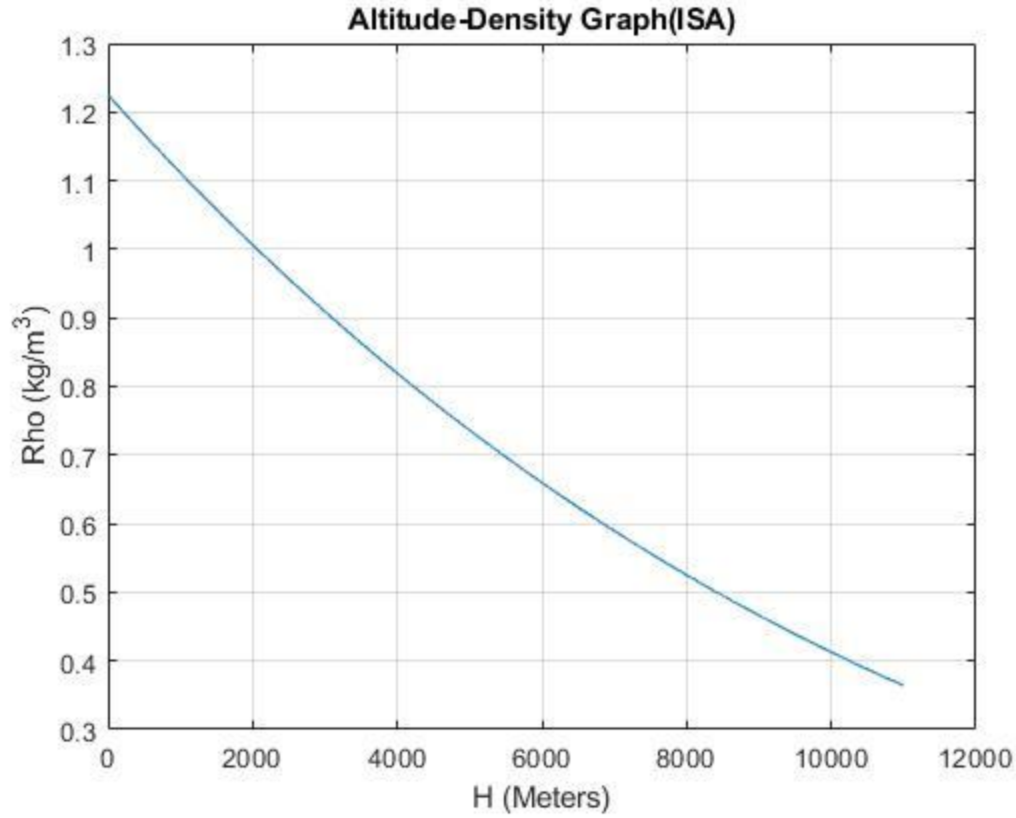
$\Delta T$ should be set to zero when ISA conditions are wanted. For non-ISA conditions $\Delta T$ can be set to some value like -10ºC as it was stated in the homework description file.

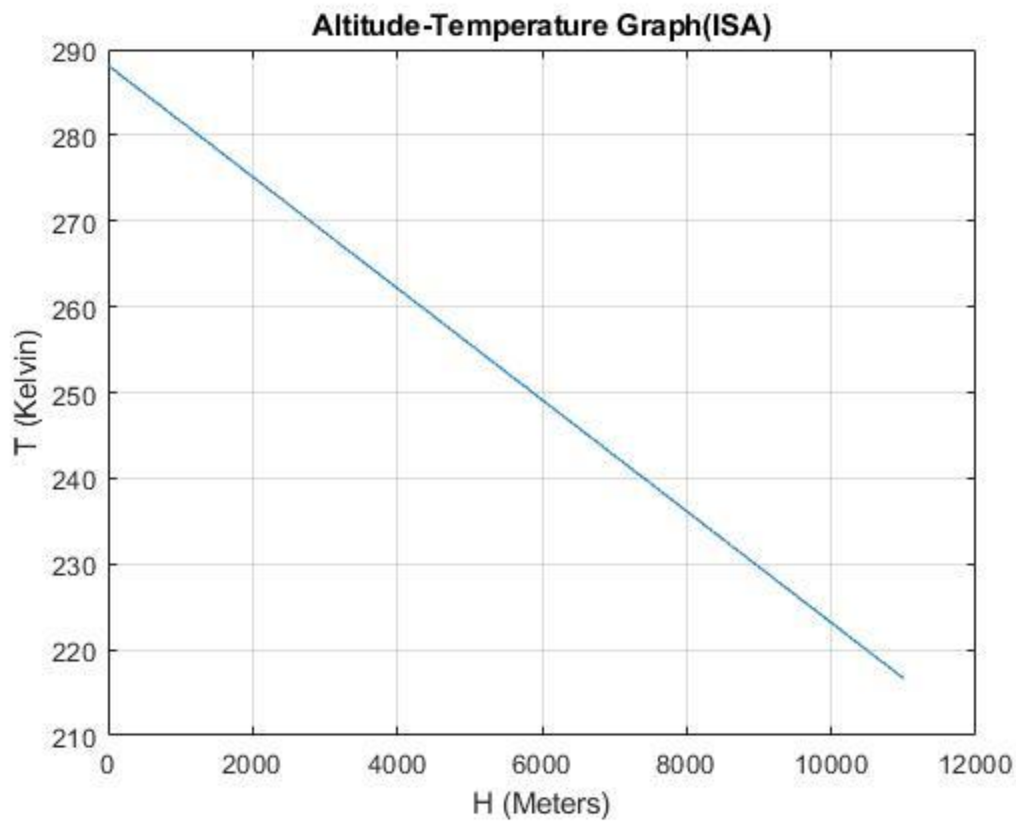
Also equations (3.1-18), (3.1-21) and (3.1-22) are used in order to calculate the pressure, air density and speed of sound as a function of the altitude respectively. (EEC Technical/Scientific Report No.13/04/16-01, p.10)

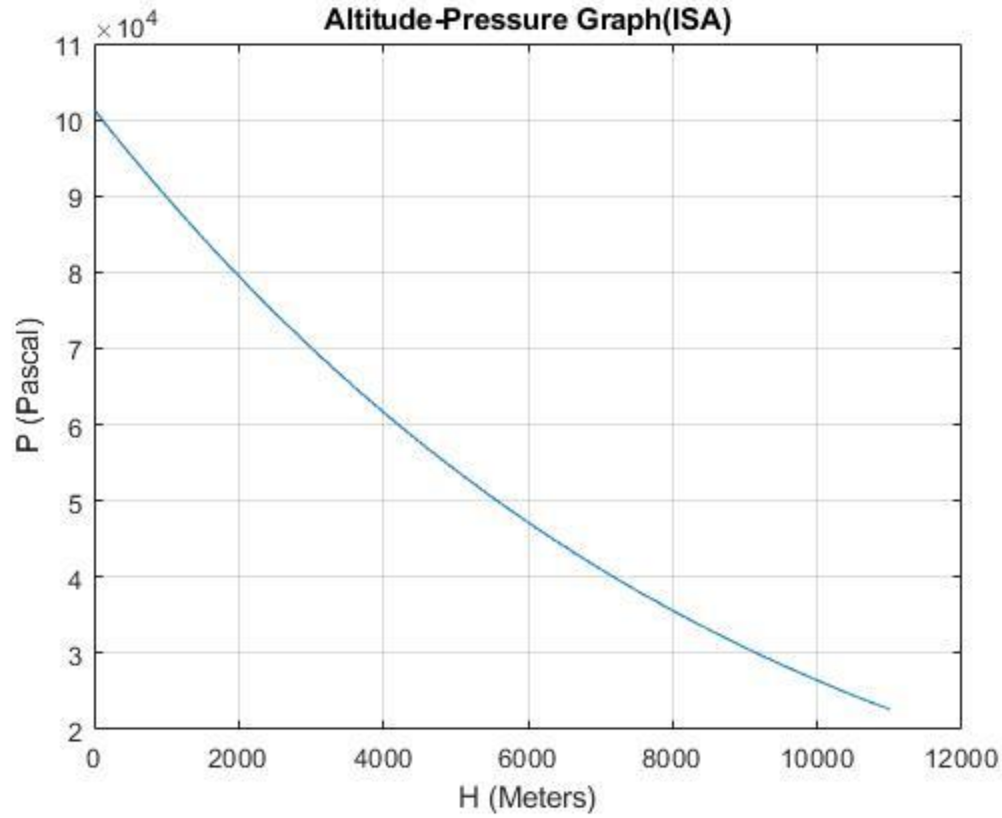
The function named "atm_model" takes two inputs (H,delta_t) which are altitude(in meters) and $\Delta T$. Its outputs are temperature, pressure, air density and speed of sound. (T,P,rho,a). In the file "atm_call.m", an example of calling the function is exhibited. Also all the graphics are generated in that file.For instance "atm_model" can be called as:

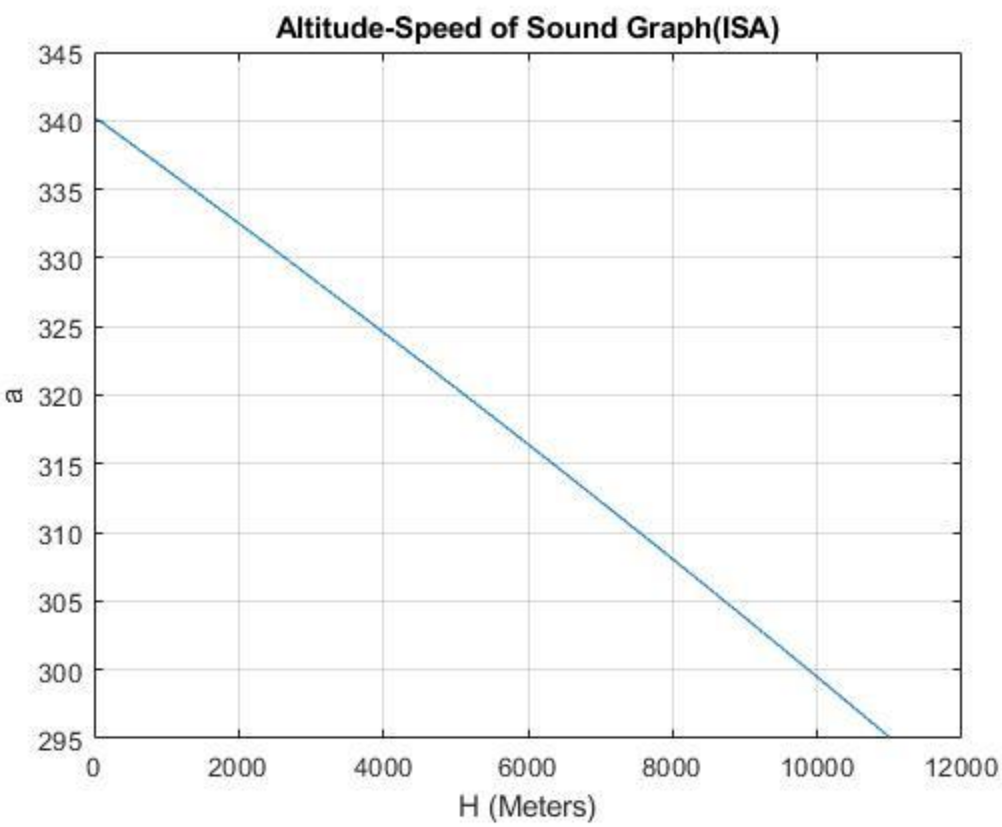
*[T,P,rho,a]=atm_model(H,0);*

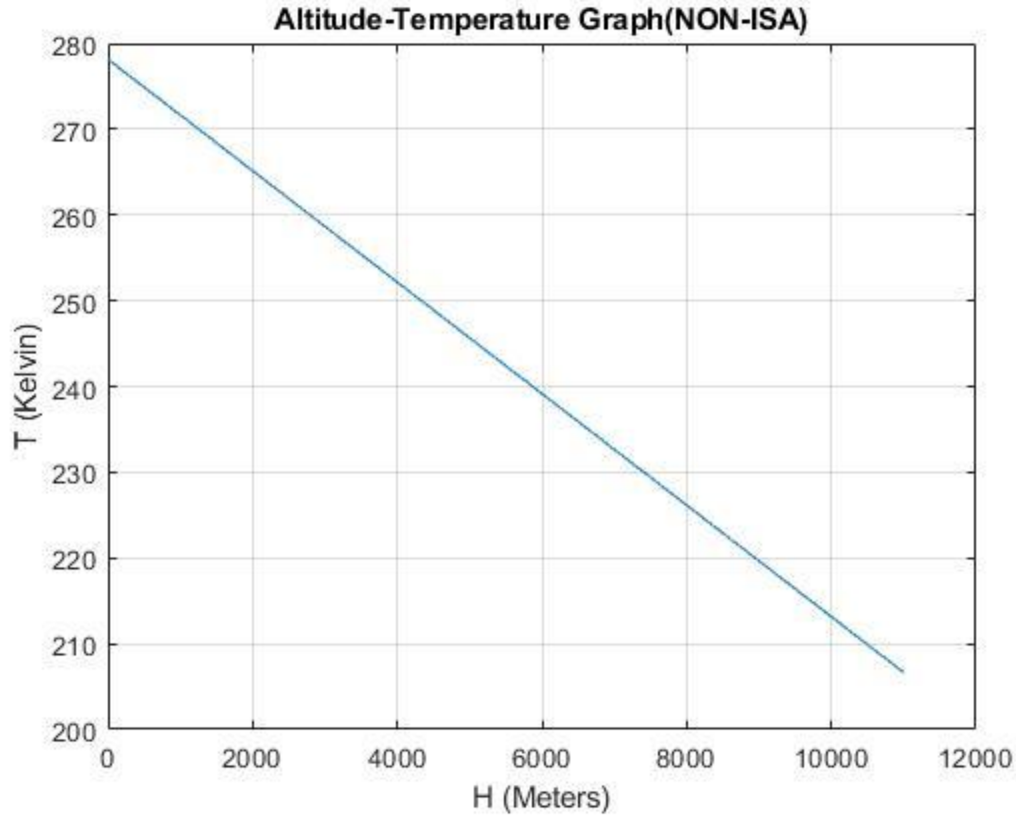
Outputs are the graphics below.There are eigth graphics. The first four represents ISA conditions and the second four represents the conditions in which $\Delta T$ equals to -10ºC.

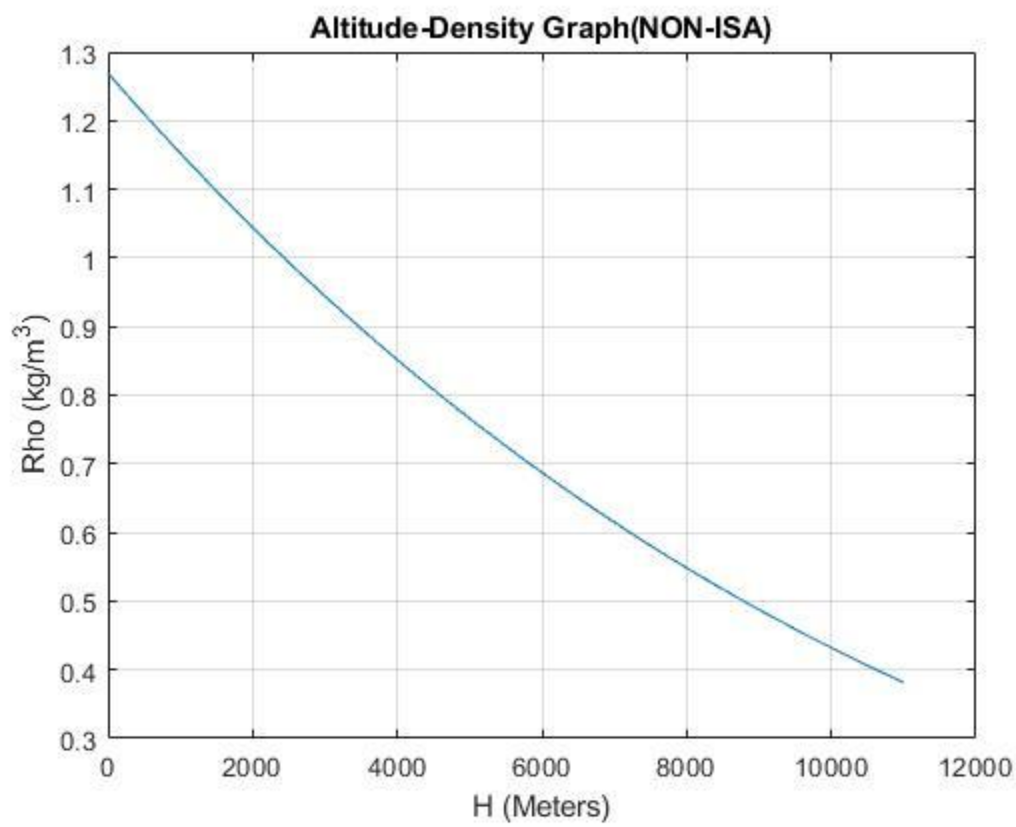

Altitude-Density Graph(ISA)
Rho (kg/m^3)
H (Meters)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
2000
4000
6000
8000
10000
12000

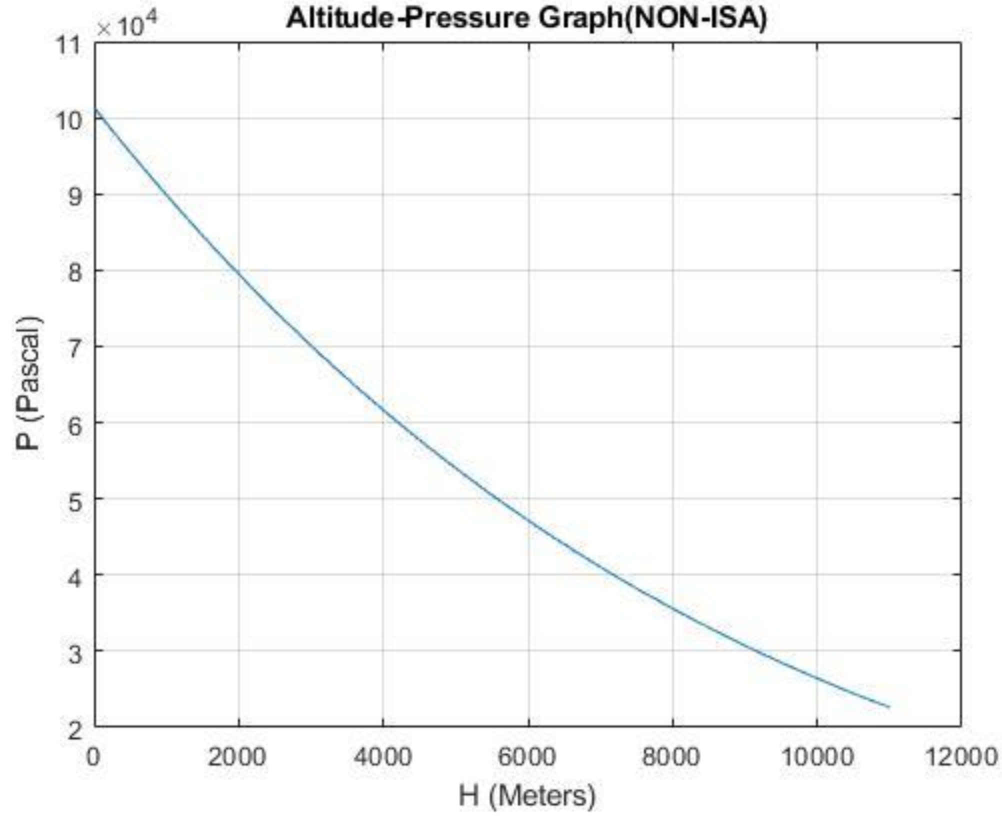

Altitude-Temperature Graph(ISA)
T (Kelvin)
H (Meters)
290
280
270
260
250
240
230
220
210
0
2000
4000
6000
8000
10000
12000

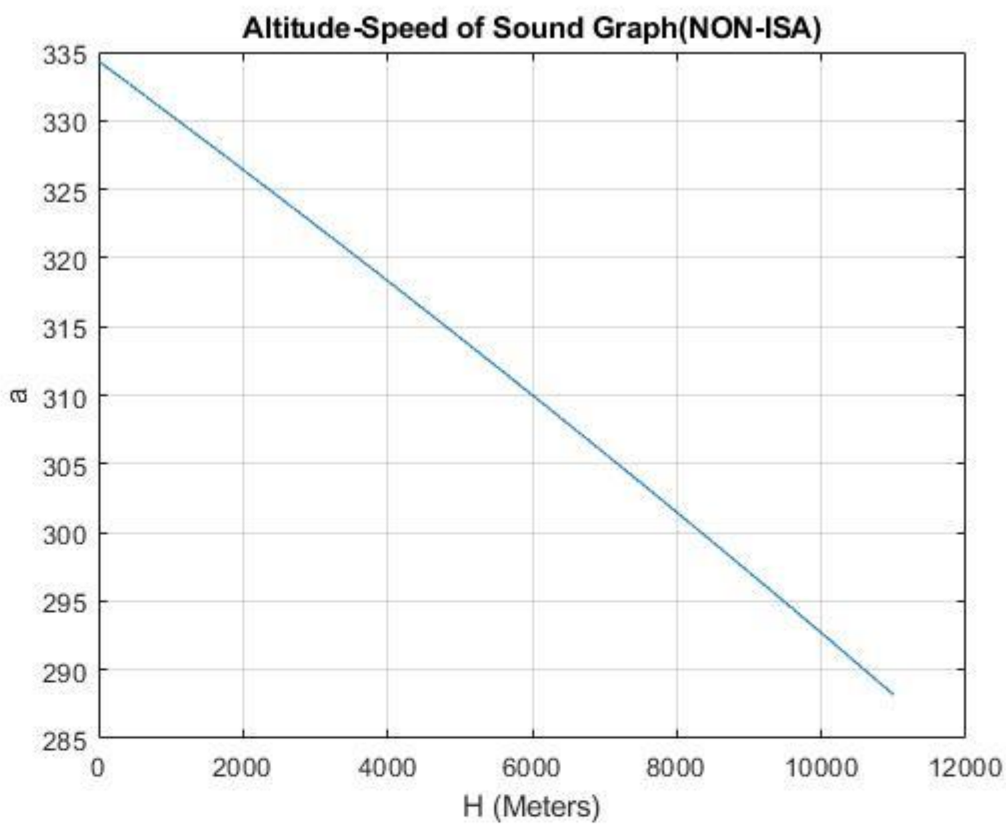

Altitude-Pressure Graph(ISA)
$\times 10^4$
11
10
9
8
7
6
5
4
3
2
P (Pascal)
0
2000
4000
6000
8000
10000
12000
H (Meters)


Altitude-Speed of Sound Graph(ISA)
345
340
335
330
325
320
315
310
305
300
295
a
0
2000
4000
6000
8000
10000
12000
H (Meters)


Altitude-Temperature Graph(NON-ISA)
T (Kelvin)
H (Meters)
280
270
260
250
240
230
220
210
200
0
2000
4000
6000
8000
10000
12000


Altitude-Density Graph(NON-ISA)
Rho (kg/m3)
H (Meters)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
2000
4000
6000
8000
10000
12000


Altitude-Pressure Graph(NON-ISA)
×10^4
P (Pascal)
H (Meters)
11
10
9
8
7
6
5
4
3
2
0
2000
4000
6000
8000
10000
12000


Altitude-Speed of Sound Graph(NON-ISA)
a
H (Meters)
335
330
325
320
315
310
305
300
295
290
285
0
2000
4000
6000
8000
10000
12000

**Operating Speeds**

IAS (Indicated Air Speed) is the speed indicated by the airspeed indicator in the cockpit, which is based on the Pitot - static tube attached to the airplane. CAS (Calibrated Air Speed) is the indicated airspeed correct for the position and instrument errors. In standard atmospheric conditions, this is equal to the True Air Speed (TAS). Finally, TAS is the airspeed of the airplane relative to the undisturbed air. (NPTEL,2015)

For this section there are 3 MATLAB functions. First one is named “Cas_to_Tas” and it converts CAS to TAS. It can be called as:

*tas= Cas_to_Tas(cas,H)*

Second one is “Tas_to_Cas” and it can be called as:

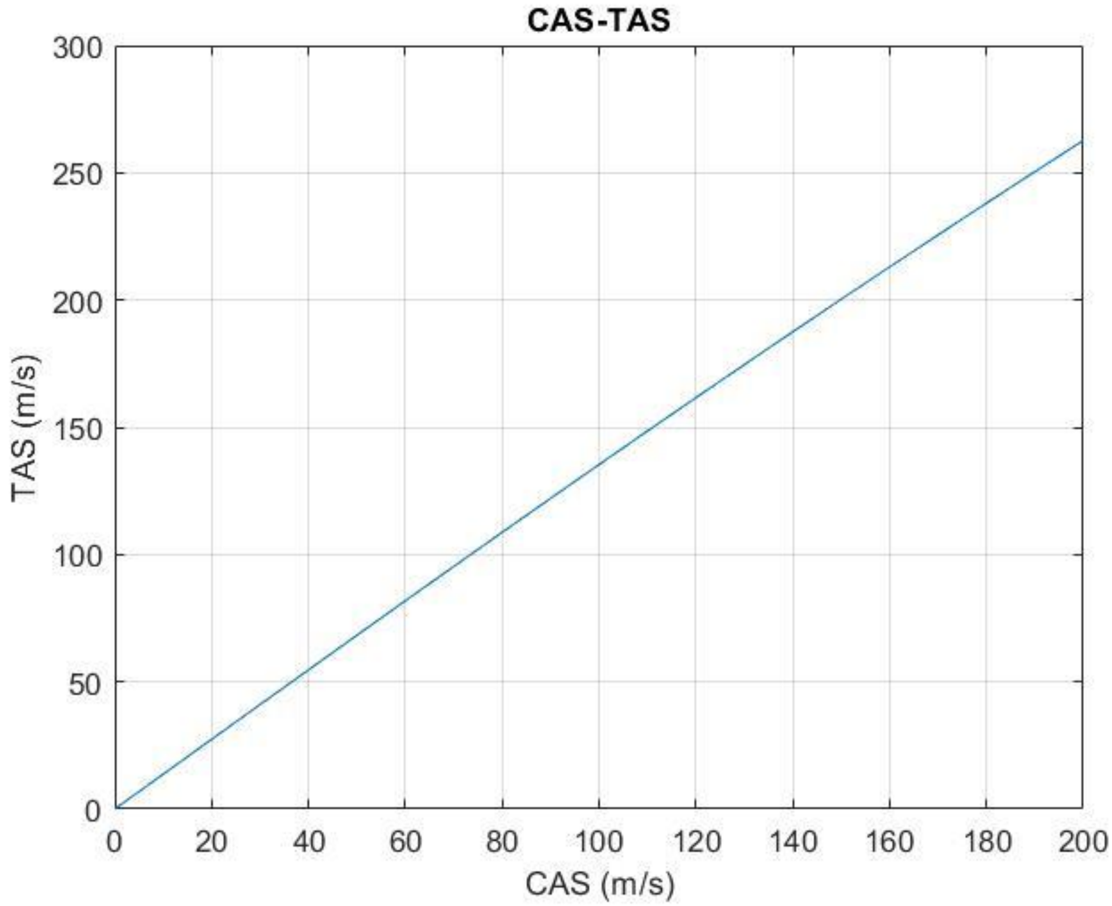
*cas = Tas_to_Cas(tas,H)*

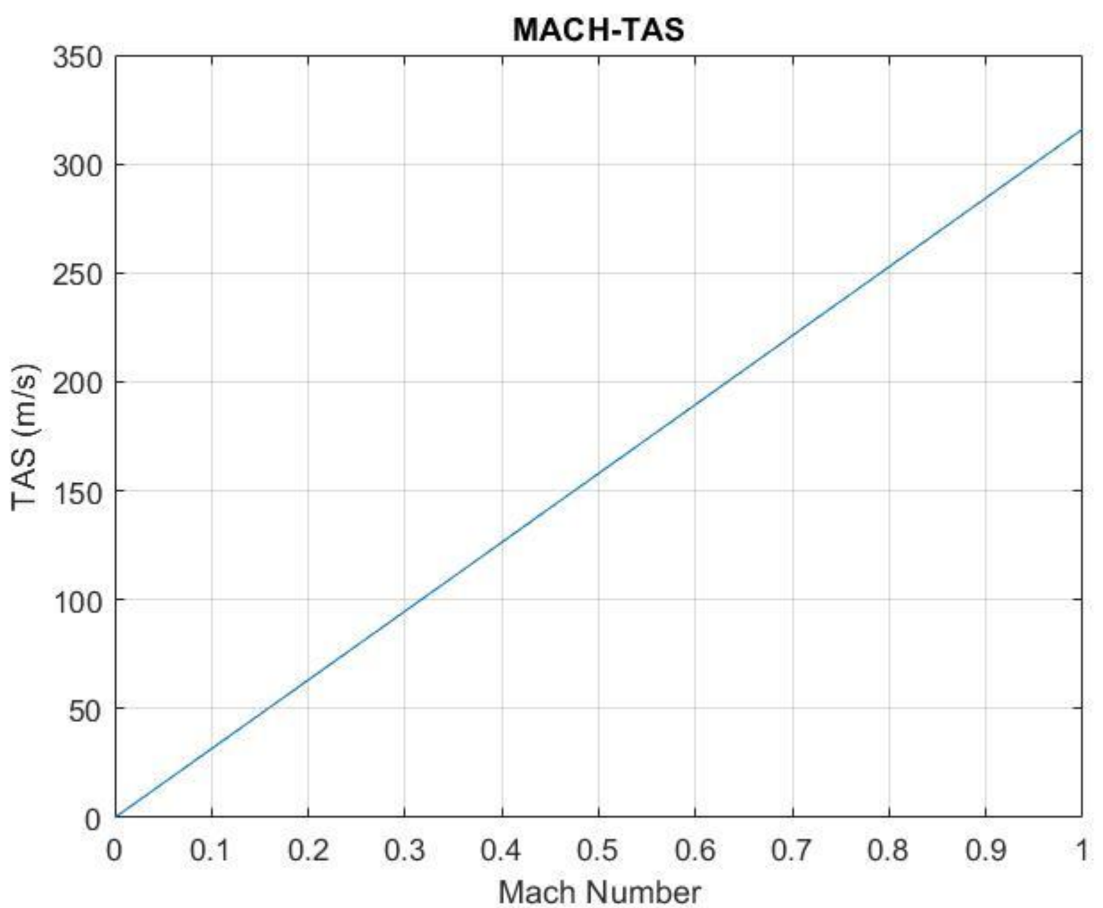
Third one is named “Mach_to_Tas” and it can be called as:

*tas = Mach_to_Tas(mach,H)*

In all three functions, H represents the altitude in meters. Cas and tas corresponds to Calibrated Air Speed and True Air Speed respectively.

For the graphics, 20000 Feets were converted in to meters: 6096 meters. Equations in the BADA manuel were followed.


CAS-TAS
TAS (m/s)
CAS (m/s)
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140
160
180
200


MACH-TAS
TAS (m/s)
Mach Number
0
50
100
150
200
250
300
350
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

**Drag Polar Model**

For part a, one function will be introduced. Its name is "cl_calc" and it calculates the lift coefficient $C_l$ for given conditions: altitude and CAS. It can be called as:

*cl = cl_calc(H,cas)*

For H = 33000ft with VCAS = 290kt (H=10058.4 meters, VCAS=149.06 m/s) the output is:

*cl =0.5485*

To solve part b,the new function is named "cd_calc" and it calculates the drag coefficient. It can be called as:

*cd = cd_calc(cl,cd0,cd2)*

cd0 and cd2 values could be obtained from the Aircraft.OPF file which was provided beforehand. For cruise these values were :

*cd0_cr=0.022913;*

*cd2_cr=0.042347;*

Under the same conditions as above, $C_d$ can be calculated with the "cd_calc" function and the output is:

*cd = 0.0357*

Drag force was calculated within the MATLAB file "cl_cd_drag_calls.m" as:

*altitude=33000*0.3048;*

*cas=0.514*290;*

```
cl=cl_calc(altitude,cas);
tas=Cas_to_Tas(cas,altitude);
cd0_cr=0.022913;
cd2_cr=0.042347;
cd=cd_calc(cl,cd0_cr,cd2_cr);
display(cl)
display(cd)
surf=427.82;
[T,P,rho,a]=atm_model(altitude,0);
drag_force=cd*rho*(tas^2)*surf*0.5;
display(drag_force)
```

And its output is:

*drag_force=1.8505e+05 (Newtons)*

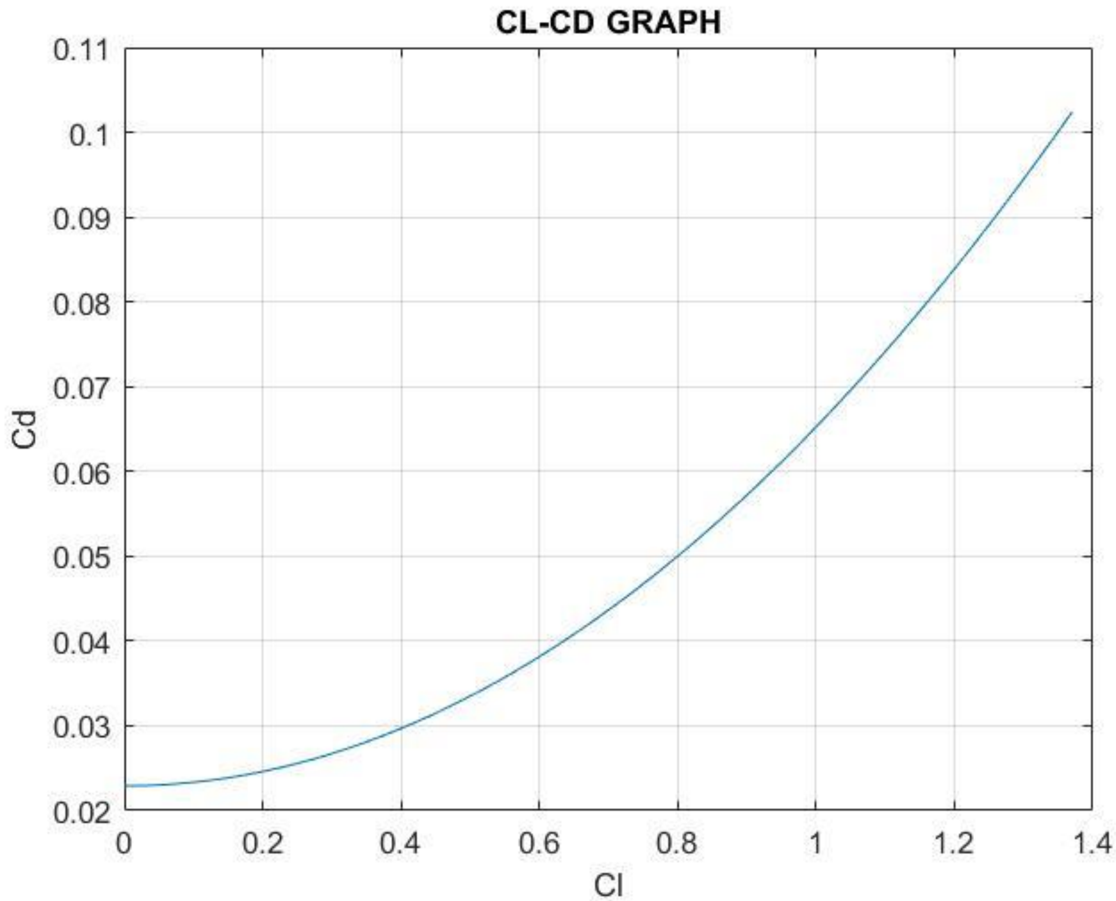
For part c, “cl_calc” function can be used again but with different parameters: H = 35000ft and $V_{stall}$=178 knots.The calculations for this part is again inside MATLAB file “cl_cd_drag_calls.m” and it follows as:

```
altitude2=35000*0.3048;
stall_cas=178*0.514;
cl_max=cl_calc(altitude2,stall_cas);
display(cl_max)
```

The output is:

*cl_max=1.3701*

For part d, $C_L$ -$C_D$ graph for CL at [0;$C_{Lmax}$] were produced as below:




For part e, one CAS distribution is converted to two different TAS distributions due to two different altitude values.Then, two different $C_L$ and $C_D$ distributions are calculated. Finally two drag force distributions are obtained. The process is also in MATLAB file “cl_cd_drag_calls.m” and it follows as:

*cas_general=linspace(0,300,1000);*

*tas_general=Cas_to_Tas(cas_general,25000*0.3048);*

*tas_general2=Cas_to_Tas(cas_general,altitude);*

*cl1=cl_calc(25000*0.3048,cas);*

*cl2=cl_calc(altitude,cas);*

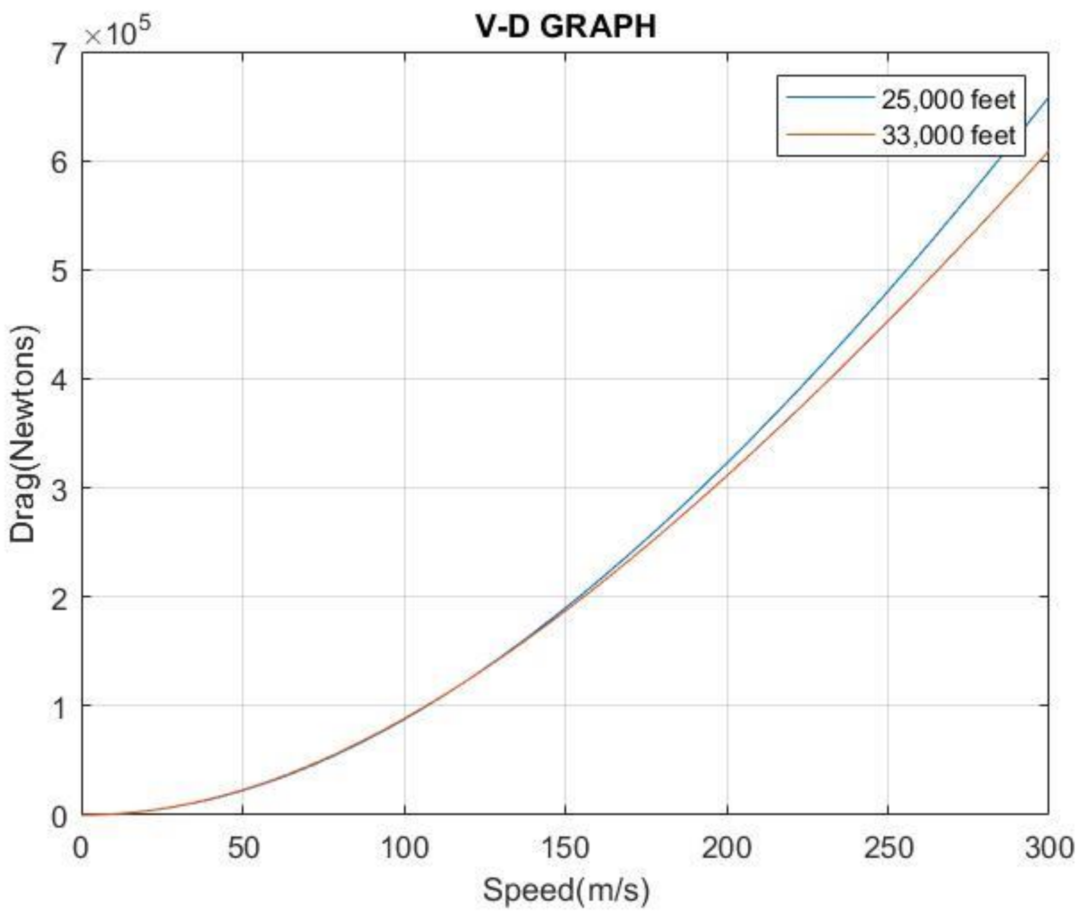
*cd1=cd_calc(cl1,cd0_cr,cd2_cr);*

*cd2=cd_calc(cl2,cd0_cr,cd2_cr);*

*drag_general=cd1.*rho1.*(tas_general.^2).*surf.*0.5;*

*drag_general2=cd2.*rho2.*(tas_general2.^2).*surf.*0.5;*

The output as the graphic is below:



# References

EEC Technical/Scientific Report No.13/04/16-01(BADA3.11)

Dr. A. K. Ghosh, NPTEL Flight Mechanics Lecture Notes, 2015