HW#4 solution

Ideal Turbojet Performance Analysis

Student name : *******

ABSTRACT

Turbojet engine is analysed which is used in a supersonic aircraft. Ideal engine performance analysis is conducted . The performance variation with changes in the design parameters is done and suitable plots are generated.

The three varying parameters are the compressor pressure ratio, the turbine inlet temperature ratio and Mach no. Programming is done in Matlab to generate the data and create plots for varying conditions.

From the first question, which has constant Mach no. 2 and increasing compressor pressure ratio, it linearly reduces Specific Thrust, exponentially reduces Thrust Specific Fuel Consumption, linearly increases propulsive efficiency and exponentially increases thermal efficiency.

For the second question Mach no was varied from 0.1 to 2.5 to calculate specific thrust, thrust specific fuel consumption. As mach number increases we find linear fall in thrust and thrust specific fuel consumption first increasing and reaching an optimum value near Mach no 2.0.

In third question that Taulemda must be kept in range of 5 to 12 as per thrust requirement. Thrust specific fuel consumption increases linearly with increase in Taulemdac.

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NOMENCLATURE

- M = Mach Number
- taulamda (τ_{λ})= Turbine Stagnation Temperature Ratio
- T_0 = Atmospheric Air Temperature (K)
- Cp = Specific Heat At Constant Pressure
- Gamma（γ）= Ratio Of Specific Heat/Angle
- R = Gas Constant
- Pic= Compressor Pressure Ratio
- a_0 = Speed Of Sound
- ST = Specific Thrust
- f = Fuel/Air Ratio
- TSFC = Thrust Specific Fuel Consumption
- np = Propulsive Efficiency
- nth = Thermal Efficiency

INTRODUCTION

A turbojet engine is desired for powering supersonic interceptor. Here analyses is conducted to examine the ideal engine performance. The objective of this project is to determine the variation of performance curves with the design parameters and flight conditions.

Default values chosen:

Flight Mach Number (M0): 2

Turbine stagnation temperature ratio $\lambda\ \tau$: 7

Atmospheric air temperature: 222.2 K

c p =1004.9 J /(K kg)

hPR = 4.4194×10 J/kg

γ =1.4

h_{PR} = 4.4194×10^7 J/kg

γ = 1.4

In the first question the given conditions were kept all other parameters as constant but varied compressor ratio (pic) was varied from 5 to 60 to calculate specific thrust, thrust specific fuel consumption.

In the second question the given conditions were kept all other parameters as constant but varied the Mach no from 0.1 to 2.5 to calculate specific thrust, thrust specific fuel consumption.

In the third question the given conditions were kept all other parameters as constant but varied the taulamda from 5 to 12 to calculate specific thrust, thrust specific fuel consumption.

RESULTS AND DISCUSSION

1) **Determine ST, TSFC, n_p, and n_{th} for π_c from 5 to 60**
   The following parameters are kept constant

```
Mo = 2;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
```

We can see from the results of table no 1 and plots that Pai_C must be kept in range of 5 to 20 as per thrust requirement. Thrust varies linearly while thrust specific fuel consumption falls in exponential manner. Figure 1 shown the plots.

Table no 1 : ST and TSFC for required values of Pai_C

Pai_C	ST	TSFC
5	392.4181	2.77E-05
10	320.0255	2.41E-05
15	251.9385	2.2E-05
20	188.2753	2.05E-05
25	127.3992	1.92E-05
30	67.91886	1.81E-05
35	8.622577	1.71E-05
40	-51.7016	1.6E-05
45	-114.488	1.5E-05
50	-181.765	1.4E-05
55	-257.045	1.29E-05
60	-348.381	1.16E-05

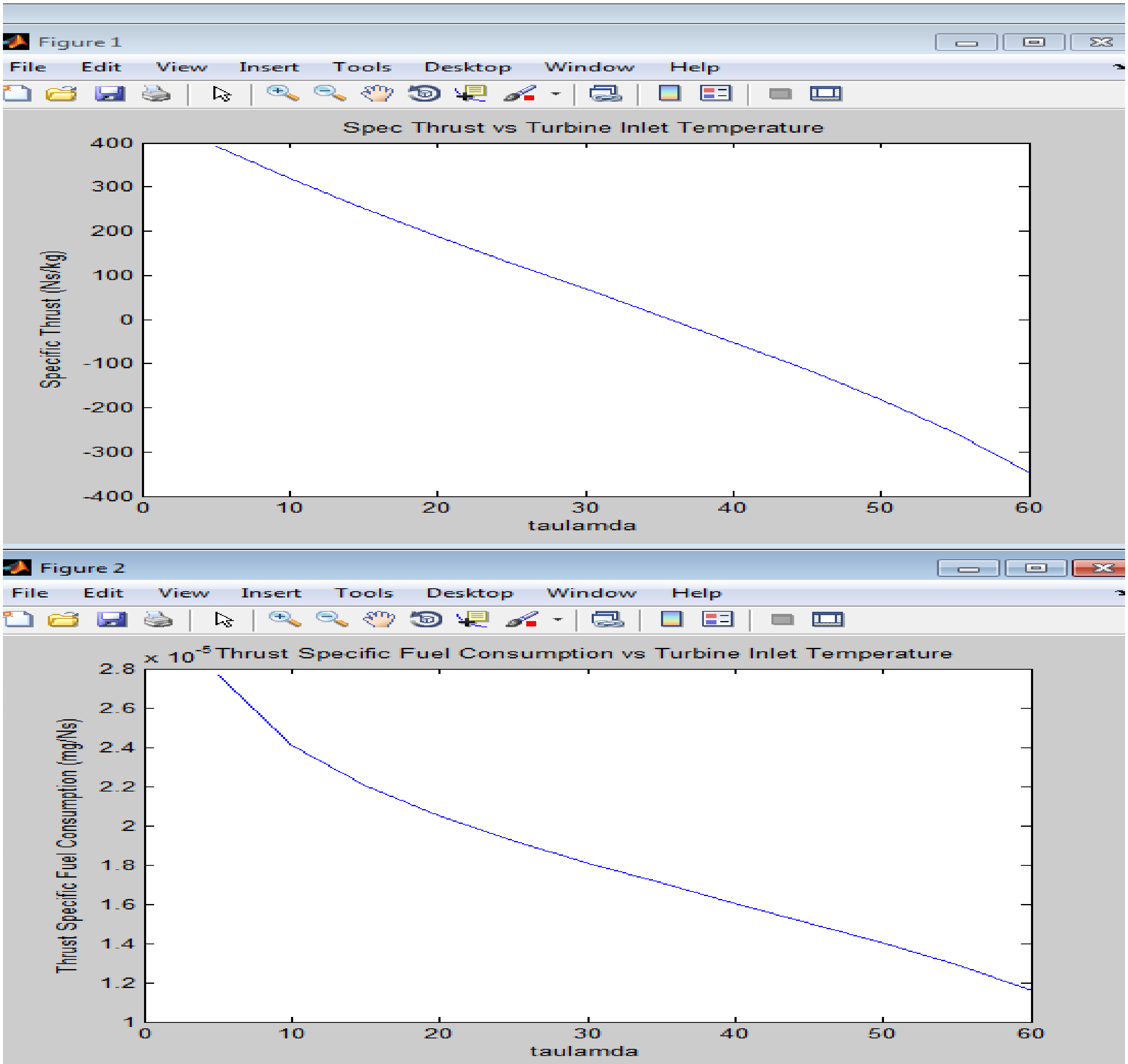

Figure 1 : plot of ST and TSFC for required values of Pai_C

2) Determine ST, TSFC, and Mach no is varied from 0.1to 2.5

Fixed parameters are

```
taulamda = 7;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
piC = 20;
```

We can see from the results of table no 2 and plots that Mach No, that Specific thrust falls with increase in Mach No.
Thrust specific fuel consumption increases with increase in Mach No.
Figure 2 shown the plots of ST and TSFC vs Mach No .

Table No 2 : Plot of ST and TSFC vs Mach No

Mach No	ST	TSFC
0.1	1063.181	2.21E-05
0.3	1008.504	2.31E-05
0.5	957.9913	2.39E-05
0.7	910.0248	2.45E-05
0.9	862.6665	2.5E-05
1.1	814.0056	2.53E-05
1.3	762.3878	2.55E-05
1.5	706.5099	2.57E-05
1.7	645.4093	2.57E-05
1.9	578.3954	2.57E-05
2.1	504.9592	2.57E-05
2.3	424.6811	2.57E-05
2.5	337.1438	2.55E-05

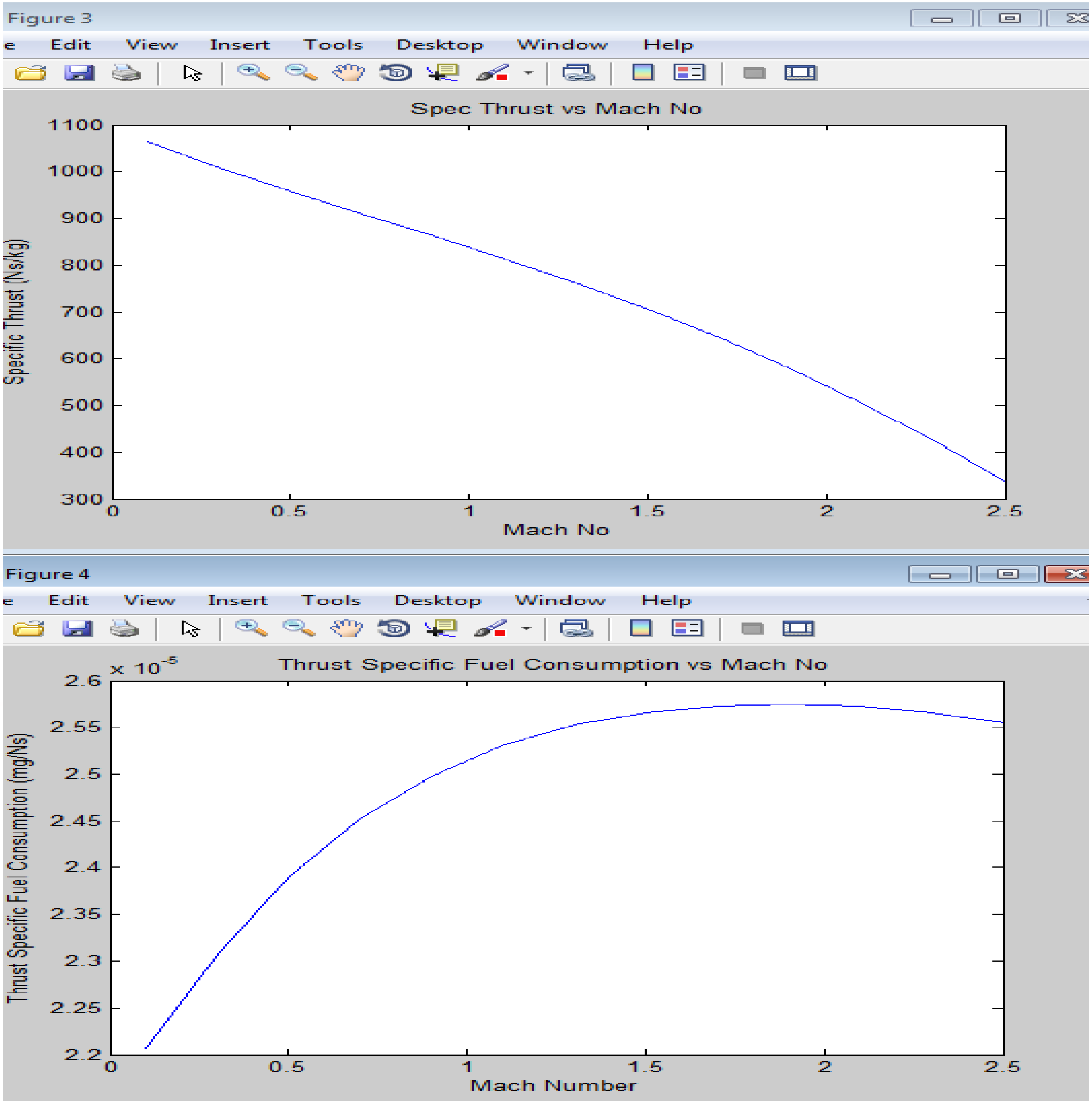

Figure 2 : PLot of TS and TSFC vs Mach No

3) Determine TS and TSFC**, and Taulemda is varied from 5 to 12**

Fixed parameters are

```
Mo = 2;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
piC = 20;
```

We can see from the results of table no 3 and plots that Taulemda must be kept in range of 5 to 12 as per thrust requirement.
Thrust specific fuel consumption increases with increase in Taulemdac
Figure3 shown the plots.

Table No 3: St and TSFC with change it Taulamda

Taulamda	TS	TSFC
5	188.2753	2.05E-05
6	381.5418	2.34E-05
7	542.5074	2.57E-05
8	683.4056	2.78E-05
9	810.274	2.97E-05

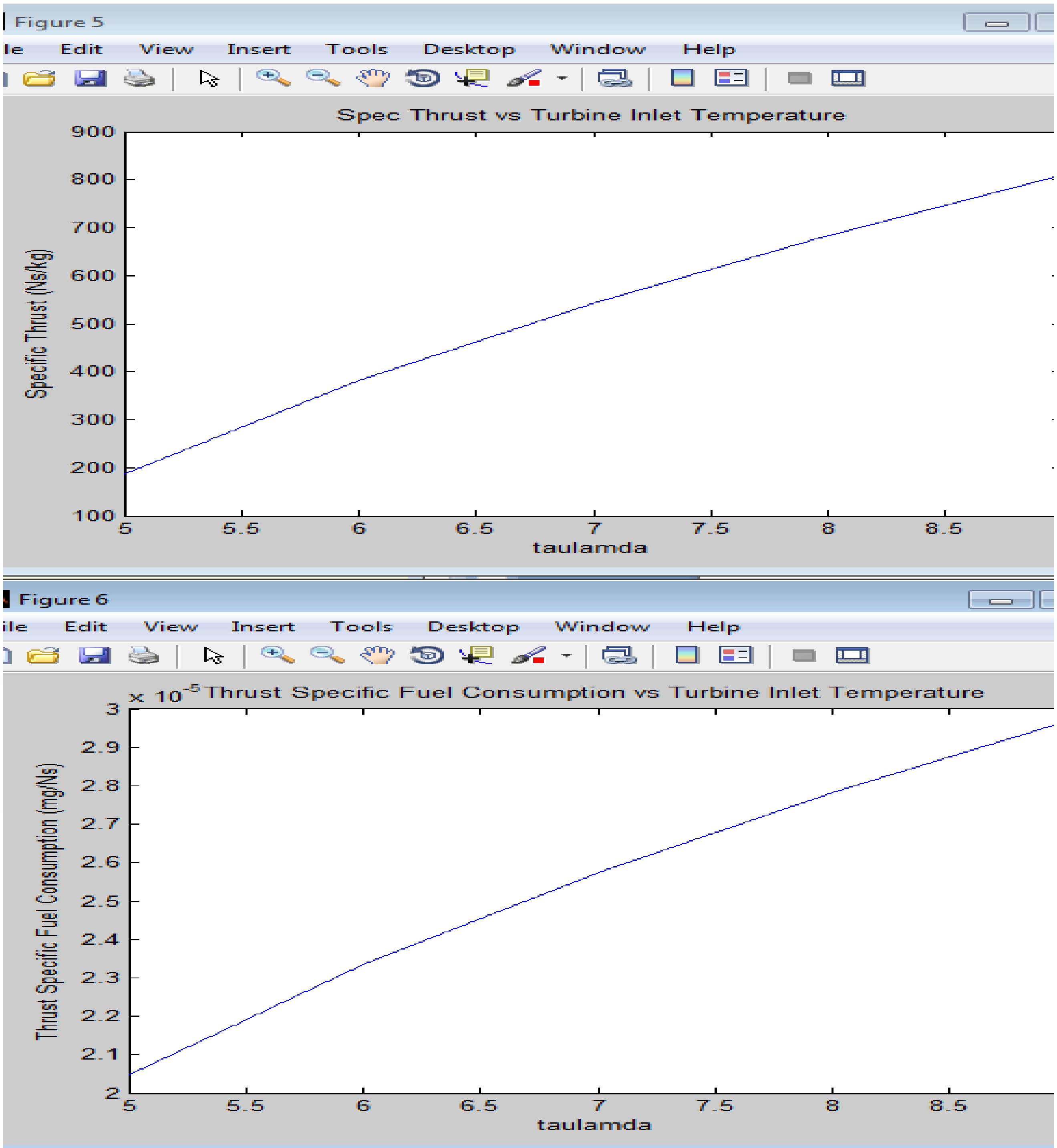

Figure 3 : Plat of TS and TSFC vs taulamda

CONCLUSION

In problem 1 : **We can see from the results of table no 1 and plots that Pai_C must be kept in range of 5 to 20 as per thrust requirement. Thrust varies linearly while thrust specific fuel consumption falls in exponential manner.**

In problem no 2 : We can see from the results of table no 2 and plots that Mach No, that Specific thrust falls with increase in Mach No. Thrust specific fuel consumption increases with increase in Mach No.

In problem no 3 : We can see from the results of table no 3 and plots that Taulemda must be kept in range of 5 to 12 as per thrust requirement. Thrust specific fuel consumption increases with increase in Taulemdac

APPENDICES

Question 1

```
%% --- HOMEWORK 4 (Due 11/2/2016) ----
clear
taulamda= 5;
pic(1)=5;pic_inc=5;
taulamda_inc=1;
Mo = 2;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
R = ((gamma-1)/gamma)*Cp;
%% --- Calculation Problem 3 --- %%
for n=1:12
    pic(n+1)=pic(n)+pic_inc
tauC = pic(n)^((gamma-1)/gamma);
tauR = 1 + ((gamma-1)/2)*Mo^2;
tauT = 1. - ((tauR./taulamda)*(tauC-1));
T9 = To*(taulamda/(tauR.*tauC));
M9 = sqrt((2/(gamma-1))*(taulamda/(tauR.*tauC)).*((tauR.*tauC.*tauT)-1));
u9 = M9.*sqrt(gamma*R.*T9);
a0 = sqrt(gamma*R.*To);
u0 = Mo*a0;
ST(n) = a0*(M9-Mo);
f = (Cp*To/hPR)*(taulamda-(tauR*tauC));
TSFC(n) = f./ST(n);
np = 2*Mo./(M9+Mo);
nth = 1-(1./(tauR.*tauC));
x(n)=pic(n)
y1(n)=ST(n)
y2(n)=TSFC(n)
end
figure (1)
plot(x,y1)
title('Spec Thrust vs Turbine Inlet Temperature')
ylabel('Specific Thrust (Ns/kg)')
xlabel('taulamda')
figure (2)
plot(x,y2)
title('Thrust Specific Fuel Consumption vs Turbine Inlet Temperature')
ylabel('Thrust Specific Fuel Consumption (mg/Ns)')
xlabel('taulamda')

xlswrite('HW4Results_Q1.xls',taulamda','HW4question2', 'A2');
xlswrite('HW4Results_Q1.xls',ST', 'HW4question2', 'B2');
xlswrite('HW4Results_Q1.xls',TSFC', 'HW4question2', 'C2');
```

Question 2

```
%% PEI LING, CHEW %%--- HOMEWORK 4 (Due 11/2/2016) ----
taulamda = 7;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
piC = 20;
R = ((gamma-1)/gamma)*Cp;

%% --- Calculation Problem 2 --- %%
Mo_0=0.1;Mo_inc=0.2;Mo(1)=Mo_0;
for n=1:13
    Mo(n+1)=Mo(n)+Mo_inc
tauC = piC.^((gamma-1)/gamma);
tauR = 1 + ((gamma-1)/2)*Mo(n)^2;
tauT(n) = 1. - ((tauR./taulamda)*(tauC-1));
T9 = To*(taulamda./(tauR.*tauC));
M9 = sqrt((2/(gamma-1))*(taulamda./(tauR.*tauC)).*((tauR.*tauC.*tauT(n))-1));
u9 = M9.*sqrt(gamma*R.*T9);
a0 = sqrt(gamma*R.*To);
u0 = Mo*a0;
ST(n) = a0*(M9-Mo(n));
f = (Cp*To/hPR)*(taulamda-(tauR*tauC));
TSFC(n) = f./ST(n);
np = 2*Mo./(M9+Mo);
nth = 1-(1./(tauR.*tauC));
x(n)=Mo(n)
y1(n)=ST(n)
y2(n)=TSFC(n)
end
figure (3)
plot(x,y1)
title('Spec Thrust vs Mach No')
ylabel('Specific Thrust (Ns/kg)')
xlabel('Mach No')
figure (4)
plot(x,y2)
title('Thrust Specific Fuel Consumption vs Mach No')
ylabel('Thrust Specific Fuel Consumption (mg/Ns)')
xlabel('Mach Number')

xlswrite('HW4Results_Q2.xls',Mo','HW4question2', 'A2');
xlswrite('HW4Results_Q2.xls',ST', 'HW4question2', 'B2');
xlswrite('HW4Results_Q2.xls',TSFC', 'HW4question2', 'C2');
```

Question 3

```
%% PEI LING, CHEW %%--- HOMEWORK 4 (Due 11/2/2016) ----
clear
taulamda(1)= 5;
taulamda_inc=1;
Mo = 2;
To = 222.2; % in Kelvin
Cp = 1004.9; % in J/kg.K
hPR = 4.4194*10^7; % in J/kg
gamma = 1.4;
R = ((gamma-1)/gamma)*Cp;

%% --- Calculation Problem 3 --- %%
piC = 20;
for n=1:5
    taulamda(n+1)=taulamda(n)+taulamda_inc
tauC = piC.^((gamma-1)/gamma);
tauR = 1 + ((gamma-1)/2)*Mo^2;
tauT = 1. - ((tauR./taulamda(n))*(tauC-1));
T9 = To*(taulamda(n)/(tauR.*tauC));
M9 = sqrt((2/(gamma-1))*(taulamda(n)/(tauR.*tauC)).*((tauR.*tauC.*tauT)-1));
u9 = M9.*sqrt(gamma*R.*T9);
a0 = sqrt(gamma*R.*To);
u0 = Mo*a0;
ST(n) = a0*(M9-Mo);
f = (Cp*To/hPR)*(taulamda(n)-(tauR*tauC));
TSFC(n) = f./ST(n);
np = 2*Mo./(M9+Mo);
nth = 1-(1./(tauR.*tauC));
x(n)=taulamda(n)
y1(n)=ST(n)
y2(n)=TSFC(n)
end
figure (5)
plot(x,y1)
title('Spec Thrust vs Turbine Inlet Temperature')
ylabel('Specific Thrust (Ns/kg)')
xlabel('taulamda')

figure (6)

plot(x,y2)
title('Thrust Specific Fuel Consumption vs Turbine Inlet Temperature')
ylabel('Thrust Specific Fuel Consumption (mg/Ns)')
xlabel('taulamda')

xlswrite('HW4Results_Q3.xls',taulamda','HW4question3', 'A2');
xlswrite('HW4Results_Q3.xls',ST', 'HW4question3', 'B2');
xlswrite('HW4Results_Q3.xls',TSFC', 'HW4question3', 'C2');
```