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## Air Turbo Rocket Ramjet

Aerospace Propulsion Final Project - Part 2

```
clear, clc, close all
run('startup')
```

```
phis = [1 2 10];
```

```
% Properties Override
%phis = 2;
```

## Initialize Constants

```
% Load the standard atmosphere
atm = readtable('std_atm.csv');

% gamma
g = 1.4;

% Universal gas constant
RR = 3.406*1000; % % lb ft/(kmol*R)

% Molar masses
M_DryAir = 1.9850755; % slugs/kmol (28.97 kg/kmol)
O2.MM = 2.1927; % slugs/kmol (32)
N2.MM = 1.92984701; % slugs/kmol (28.164)
H2.MM = 0.137044; % slugs/kmol (2)

% Mass fraction of air constituents:
O2.m_frac = 0.232;
N2.m_frac = 0.768;

% Mixture properties: air.prop
R_dryair = RR/M_DryAir; % lb ft / (slug*R)
cp_dryair = R_dryair*g/(g-1);
```

## Run the Simulation

```
% Iterator Variable
```

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```

PIs_fan = 1.1:0.1:4;

% Properties Override
% PIs_fan = 2;

% DEBUG OVERRIDE
% PIs_fan = 2;

% Turbomachinery Efficiencies
etaF = 0.95; % Fan
etaT = 0.90; % Turbine
etaS = 0.99; % Shaft

% Specify flight condition values
% Launch (flight condition 1)
h1 = 30000; % 30000 ft
M1 = 0.8;
pid = 0.96; % Diffuser (inlet) recovery
Cd = 0.2;
FN_g = 4000; % Required thrust

% Freestream conditions (station 0) (flight condition 1)
Ttrto = M_Tt_T_inv(M1,g);
Ptrto = M_Pt_P_inv(M1,g);

Tt0 = Ttrto * interp1(atm.h,atm.t,h1);
Pt0 = Ptrto * interp1(atm.h,atm.P,h1);

T0 = Tt0/Ttrto;
P0 = Pt0/Ptrto;

u0 = M1*sqrt(g*R_dryair*T0);
rho0 = P0/(R_dryair*T0);

mft0 = mft_calc(M1,g);

% Begin Iteration
for m = 1:length(phis)
    for n = 1:length(PIs_fan)

        % Select specific phi and PIfan
        phi = phis(m);
        pif = PIs_fan(n);

        % Inlet (Pressure Recovery and Isenthalpic Assumption)
        Pt12 = pid*Pt0;
        Tt12 = Tt0;

        % Station 13 (Fan pressure rise)
        Pt13 = pif*Pt12;

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% Station 15 (Isentropic flow)
Pt15 = Pt13;
M15 = 0.2; % Given
P15 = Pt15/M_Pt_P_inv(M15,g);

% Station X
Mx = 1; % Given
Px = P15;
Ptx = Px*M_Pt_P_inv(Mx,g);
mftx = mft_calc(Mx,g); % Choaked throat

% Station C (The Combustion Problem)
Ptc = 2E5; % psf total chamber pressure

% Turbine
pit = Ptx/Ptc; % Turbine pressure ratio (Ptx = Pt5 by
isentropic flow)
g1 = (g-1)/g;
taut = 1 - etaT*(1-pit^g1); % Turbine temperature ratio

% Mass Fractions
yO = 32/(4*phi+32);
yH = 4*phi/(4*phi+32);
yN = 0;

% Compute Ttc.
CpH = g*(RR/H2.MM)/(g-1);
CpO = g*(RR/O2.MM)/(g-1);

T_inject = 540;
hc = (yH*CpH*T_inject + yO*CpO*T_inject);
Ttc = Ttbrn_yHyOyNhi(yH,yO,yN,hc,g);

MWT = MWT_yHyOyN(yH,yO,yN);
R_mix = 49710/MWT; % CL
Cp_mix = R_mix*g/(g-1);

% Calculate Specific Work
wt = Cp_mix*Ttc*(1-taut);

% Find A0 by regula falsi
A0_l = 0.0; % m^2
A0_h = 1000; % m^2
A0_g = (A0_l+A0_h)/2;

% DEBUG OVERRIDE
% A0_g = 2.11;

exit = false;
while exit == false

    % Rubber Inlet
    A1 = A0_g;

```

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```

% Fan Airflow
mdot0 = Pt0*A0_g*mft0 / sqrt(R_dryair*Tt0);
tauf = (-1+pif^g1)/etaF + 1; % Fan Temperature Ratio
Tt13 = tauf*Tt12;
WdotF = mdot0*cp_dryair*(Tt13-Tt12); % Fan Power

% Turbine
mdott = WdotF/(etaS*wt); % Turbine mass flow
Tt5 = taut*Ttc;

% Station X
mdotx = mdott;
Ttx = Tt5;
Ax = mdotx*sqrt(Ttx*R_mix)/(Ptx*mftx);
Tx = Ttx/M_Tt_T_inv(Mx,g);
ux = Mx*sqrt(g*R_mix*Tx);
Ix = mdotx*ux+Px*Ax;

% Station 15
mdot15 = mdot0 - mdott;
mft15 = mft_calc(M15,g);
Tt15 = Tt13;
T15 = Tt15/M_Tt_T_inv(M15,g);
A15 = mdot15*sqrt(R_dryair*Tt15)/(mft15*Pt15);
u15 = M15 * sqrt(g*R_dryair*T15);
I15 = mdot15*u15 + P15*A15;

% Mass Flow Accounting
mdotO = yO*mdotx;
mdotH = yH*mdotx;

% Mixer Flow
Amixer = A15 + Ax;
mdot_mixer = mdotx + mdot15;
Imixer = Ix + I15;
hi = (mdotH*CpH*T_inject + mdotO*CpO*T_inject...
      + mdot15*cp_dryair*Tt12 - mdott*wt*(1-etaS))/
mdot_mixer;

% Station 7 (Mixer Combustion Propagation)
% Find Cp7
mdot7 = mdot_mixer;

yO15 = O2.m_frac;
yN15 = N2.m_frac;

mdotO15 = mdot15*yO15;
mdotN15 = mdot15*yN15;

species
yO7 = (mdotO15 + mdotO)/mdot7; % combine the oxygen
yN7 = mdotN15/mdot7; % only comes from air
yH7 = mdotH/mdot7; % only comes from fuel

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```

MWT = MWT_yHyOyN(yH7,yO7,yN7);
R7 = 49710/MWT; % CL
Cp7 = R7*g/(g-1);

% Find Tt7
Tt7 = Ttbrn_yHyOyNhi(yH7,yO7,yN7,hi,g);

ht7 = Cp7*Tt7;
I7 = Imixer;
mfi7 = ht7*(mdot7/I7)^2;
M7 = m_sub_mfi(mfi7,g);
A7 = Amixer;

T7 = Tt7/M_Tt_T_inv(M7,g);
u7 = M7*sqrt(g*R7*T7);
rho7 = mdot7/(u7*Amixer);
P7 = rho7*R7*T7;
Pt7 = P7*M_Pt_P_inv(M7,g);

% Station 8 Properties
M8 = 1; % Given
R8 = R7;
A8 = A7*mft_calc(M7,g)/mft_calc(M8,g);
Tt8 = Tt7;
Pt8 = Pt7;
P8 = Pt8/M_Pt_P_inv(M8,g);
T8 = Tt8/M_Tt_T_inv(M8,g);
u8 = M8*sqrt(g*R8*T8);

% Station 9 Properties
P9 = interp1(atm.h,atm.P,h1); % ambient pressure BC
mdot9 = mdot_mixer;
Tt9 = Tt7;
Pt9 = Pt8;
M9 = M_Pt_P(Pt9/P9,g);
T9 = Tt9/M_Tt_T_inv(M9,g);
u9 = M9*sqrt(g*R7*T9);
A9 = A8*mft_calc(M8,g)/mft_calc(M9,g);

% Gross Thrust
Cfg = 0.96; % Given
Fg = Cfg*mdot9*u9; % Pressures equal and cancel out

% Subtract ram drag and cowl drag to get net thrust, FN.
Acowl = 0.1*A0_g;
Dram = mdot0*u0;
Dcowl = .5*rho0*u0^2*Cd*Acowl;
FN = Fg-Dram-Dcowl; % Last equation on slide 5 on slide

set d.

% If FN does not match required for the flight condition,
update A0.
if FN < FN_g - 0.001 || FN > FN_g + 0.001

```

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```

        if FN < FN_g
            A0_l = A0_g;
        else
            A0_h = A0_g;
        end

        A0_g = (A0_h+A0_l)/2;

    else
        exit = true;
    end

end

% Data Collection
% mc is now known, get outputs
A0s(m,n) = A0_g;
mdotxs(m,n) = mdotx;
TSFC(m,n) = mdotx*32.174*3600/FN; % --> lbm/hr
Isp(m,n) = 3600/TSFC(m,n);
ST(m,n) = FN/mdot0;
end
end

```

## Plotting

```

for i = 1:length(phis)
    figure(1); hold on
    plot(PIs_fan,TSFC(i,:), 'DisplayName',['Phi = ', num2str(phis(i))])
    legend('show')

    figure(2); hold on
    plot(PIs_fan,Isp(i,:), 'DisplayName',['Phi = ', num2str(phis(i))])
    legend('show')

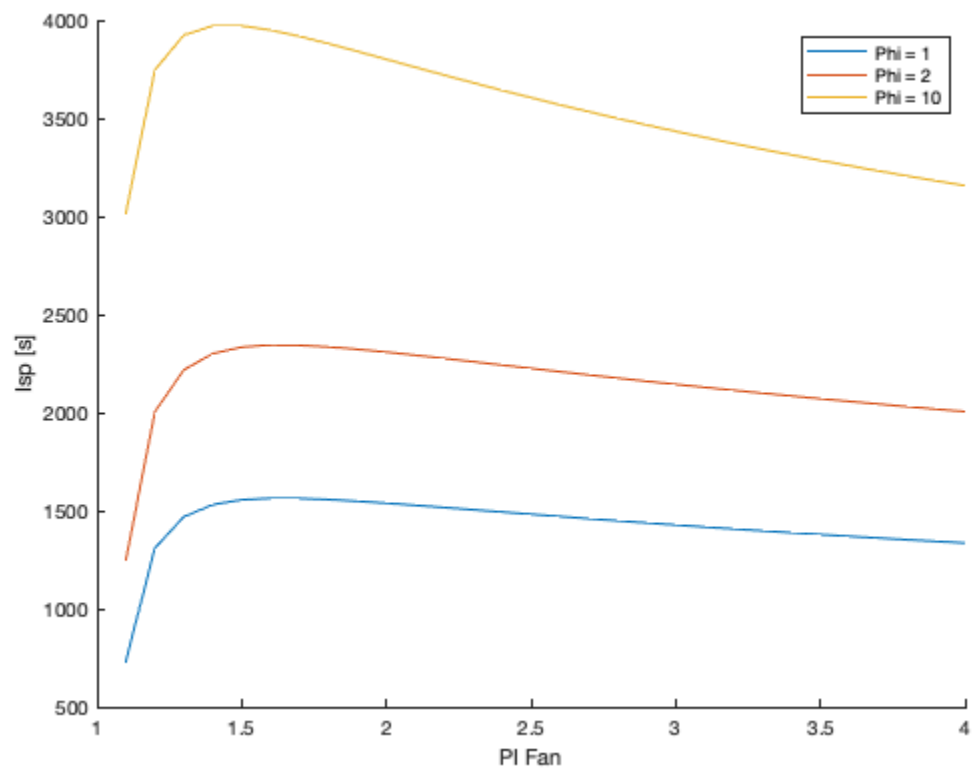
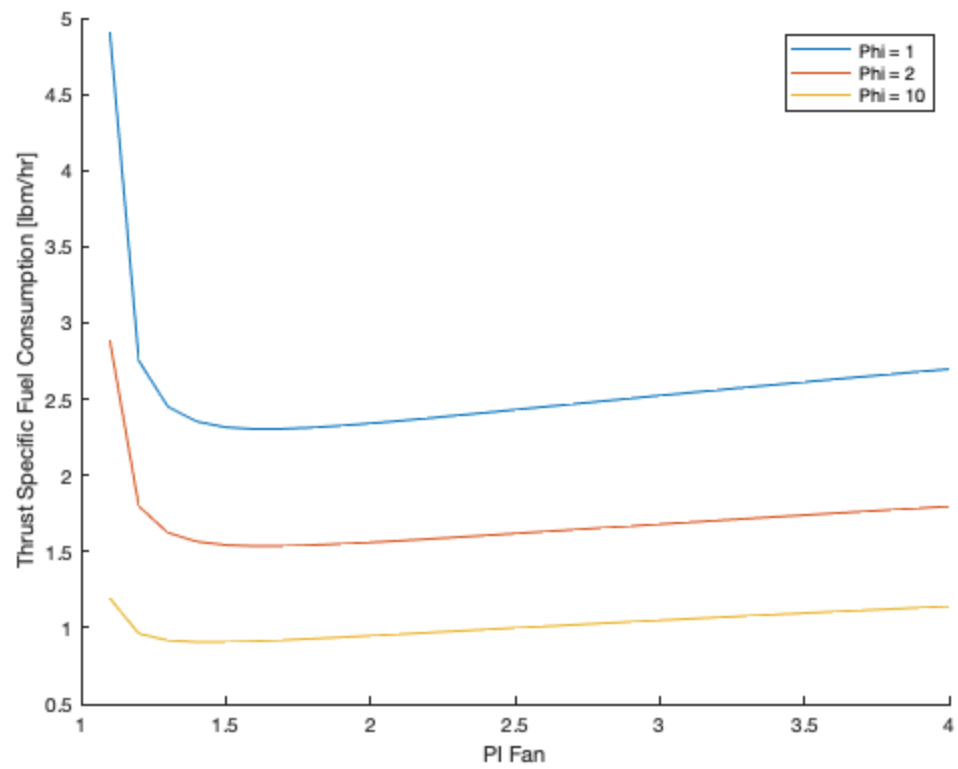
    figure(3); hold on
    plot(PIs_fan,ST(i,:), 'DisplayName',['Phi = ', num2str(phis(i))])
    legend('show')
end

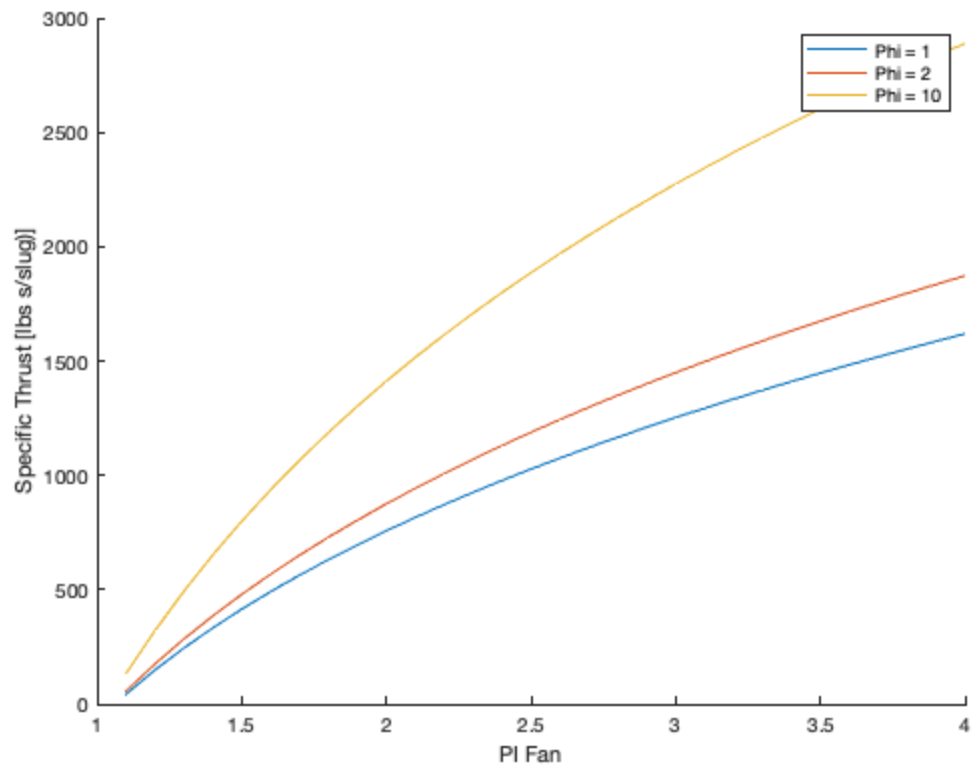
figure(1)
xlabel('PI Fan')
ylabel('Thrust Specific Fuel Consumption [lbm/hr]')

figure(2)
xlabel('PI Fan')
ylabel('Isp [s]')

figure(3)
xlabel('PI Fan')
ylabel('Specific Thrust [lbs s/slug]')

```





## Test Plots

```

for i = 1:length(phis)
    figure(4); hold on
    plot(A0s(i,:),TSFC(i,:), 'DisplayName', ['Phi = ',
        num2str(phis(i))])
    legend('show')

    figure(5); hold on
    plot(A0s(i,:),Isp(i,:), 'DisplayName', ['Phi = ',
        num2str(phis(i))])
    legend('show')

    figure(6); hold on
    plot(A0s(i,:),ST(i,:), 'DisplayName', ['Phi = ', num2str(phis(i))])
    legend('show')
end

figure(4)
xlabel('A0 [ft^2]')
ylabel('Thrust Specific Fuel Consumption [lbm/hr]')

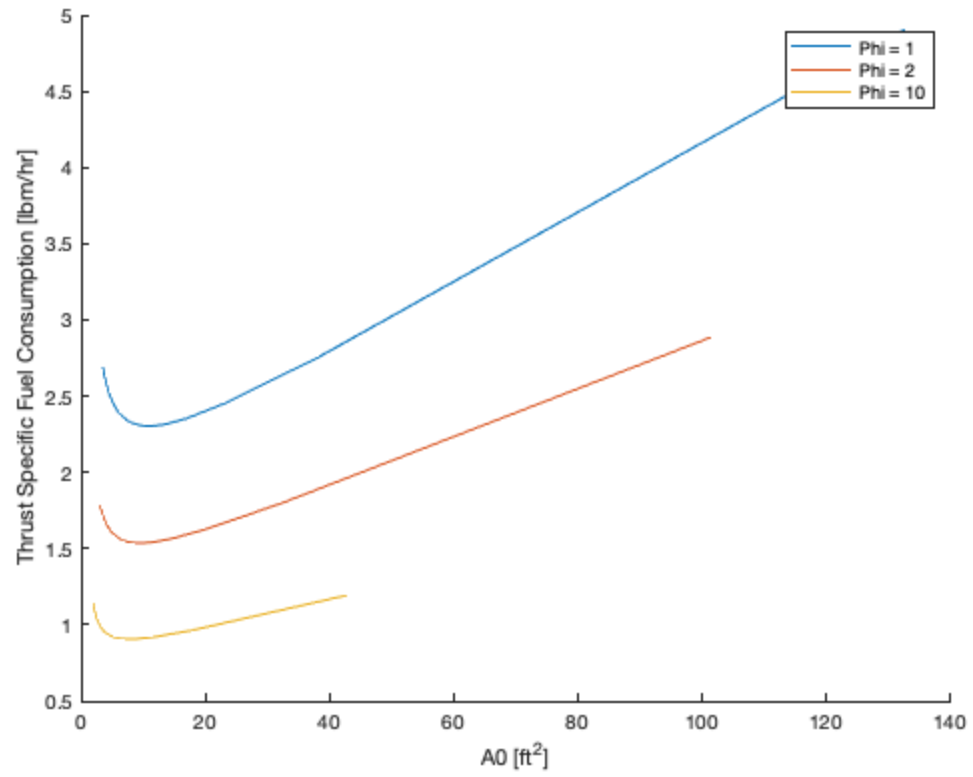
figure(5)
xlabel('A0 [ft^2]')
ylabel('Isp [s]')

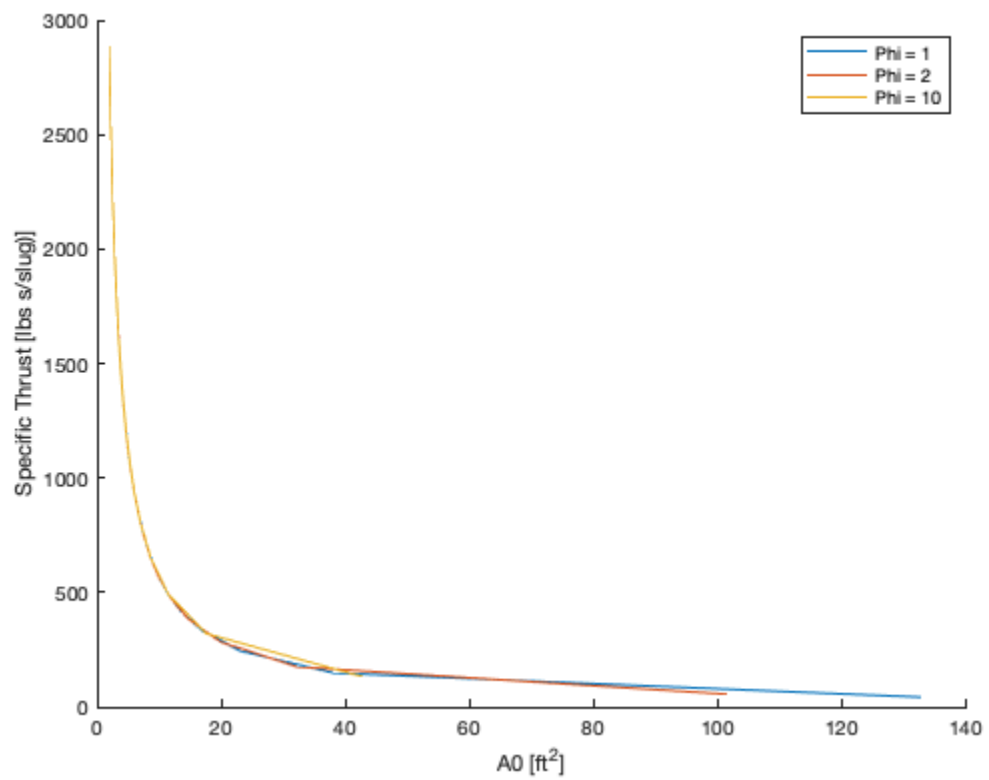
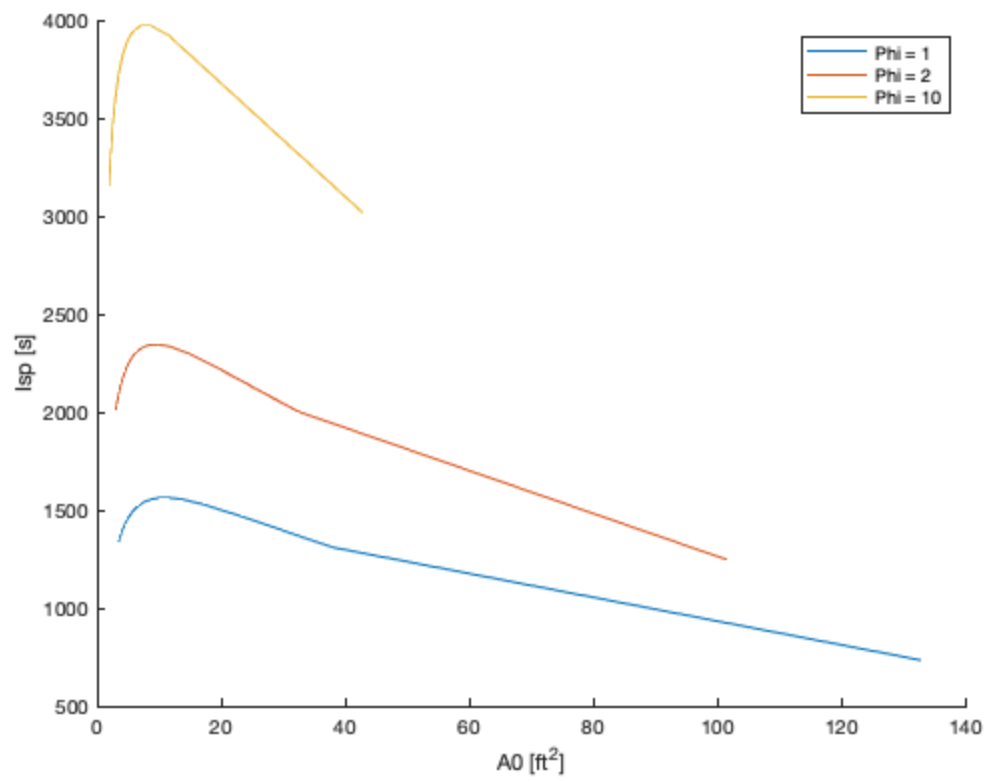
```



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```
figure(6)
xlabel('A0 [ft^2]')
ylabel('Specific Thrust [lbs s/slug]]')
```





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