```
% Thomas Satterly
% AAE 537, HW 3
% Problem 3, Parts i - ii

clear;
close all;

% Cp property for air, J/mol*K
cp_air_f = @(T) 27.453 + 6.1839 * (T / 1000) + 0.89932 * (T /
 1000)^2; % Air CP relation, T in K

% Area function (total area at percent along duct)
area = @(x, R, R_h) pi * ((R - (R_h * x))^2 - (R_h - (R_h * x))^2);

MW_air = 28.97; % g/mol
R_air = 287.058; % J/kg*K
gamma_air = 1.4;
R = 8314; % J / mol*K, Universal gas constant


% Calculate entrance stream properties first


% Core stream properies
T_1 = 1200; % K
mdot_1 = 28.7; % kg/s
M_1 = 0.4; % Mach
P_1 = 2 * 101325; % Pa
rho_1 = P_1 / (R_air * T_1); % kg/m^3
cp_1 = cp_air_f(T_1) / MW_air * 1000; % J/kg*K
gamma_1 = cp_1 / (cp_1 - R_air);
v_1 = M_1 * sqrt(gamma_1 * R_air * T_1); % m/s
Tt_1 = aeroBox.isoBox.calcStagTemp('mach', M_1, 'Ts', T_1, 'gamma',
 gamma_1); % K
Pt_1 = aeroBox.isoBox.calcStagPressure('mach', M_1, 'Ps',
 P_1, 'gamma', gamma_1); % Pa

% Core entrance area
A_1 = mdot_1 / (rho_1 * v_1); % m^2
A_star_1 = A_1 / aeroBox.isoBox.calcARatio(M_1, gamma_1);

% Core mass flow parameter
MFP_1 = sqrt(gamma_1 / R_air) * (M_1 / ((1 + ((gamma_1 - 1) / 2) *
 M_1^2)^((gamma_1 + 1) / (2 * (gamma_1 - 1)))));

% Fan stream properties
T_2 = 350; % K
mdot_2 = 83.9; % kg/s
M_2 = 0.408; % Mach
P_2 = 2 * 101325; % Pa
rho_2 = P_2 / (R_air * T_2); % kg/m^3
cp_2 = cp_air_f(T_2) / MW_air * 1000; % J/kg*K
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gamma_2 = cp_2 / (cp_2 - R_air);
v_2 = M_2 * sqrt(gamma_2 * R_air * T_2); % m/s
Tt_2 = aeroBox.isoBox.calcStagTemp('mach', M_2, 'Ts', T_2, 'gamma',
 gamma_2); % K
Pt_2 = aeroBox.isoBox.calcStagPressure('mach', M_2, 'Ps',
 P_2, 'gamma', gamma_2); % Pa

% Fan entrance area
A_2 = mdot_2 / (rho_2 * v_2); % m^2
A_star_2 = A_2 / aeroBox.isoBox.calcARatio(M_2, gamma_2);

% Fan mass flow parameter
MFP_2 = sqrt(gamma_2 / R_air) * (M_2 / ((1 + ((gamma_2 - 1) / 2) *
 M_2^2)^((gamma_2 + 1) / (2 * (gamma_2 - 1)))));

% Total area
A_t = A_1 + A_2; % m^2

% Solve for the outer and hub radius
R = sqrt(A_t / pi * 16 / 15); % m
R_h = R / 4; % m

% Solve for lobe radius
r_lobe = R_h  * (pi / (24 - 2 * pi)); % m

% Solve for mixer perimeter
P = 24 * pi * r_lobe + 24 * (R - R_h - 4 * r_lobe); % m

% Guess at L_n
L_n = 0.4; % m
Lerr = inf;
tolerance = 1e-1;
numSteps = 100;

step = 0.1;
lastDirection = 1;
mdot_1_save = mdot_1;
mdot_2_save = mdot_2;
while (abs(Lerr) > tolerance)
    clearvars results;
    dx = L_n / numSteps;
    mdot_1 = mdot_1_save;
    mdot_2 = mdot_2_save;
    dmdot_1 = mdot_1 / numSteps;
    dmdot_2 = mdot_2 / numSteps;
    dmdot_mix = 0;
    T_oldMix = T_1; % just a starting point, number doesn't really
 matter
    v_oldMix = 0;
    x = 0;
    b = 0;
    i = 0;
    while b < r_lobe
        i = i + 1;
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        % Using last known state of core and fan, find the increase in
        % mixture area
        r = v_2 / v_1;
        s = rho_2 / rho_1;

        % Find M_r just for fun
        M_r = (2 * M_1 * (1 - r)) / (1 + (1 / sqrt(s)));

        lambda_s = ((1 - r) * (1 + sqrt(s))) / (2 * (1 + r *
sqrt(s)));
        db_dx_i = 0.161 * lambda_s;
        v_c = (v_1 + sqrt(s) * v_2) / (1 + sqrt(s));
        M_c = (v_1 - v_c) / v_1;
        db_dx_c = (0.2 + 0.8 * exp(-3 * M_c^2)) * db_dx_i;
        b = b + db_dx_c * dx;
        A_mix = b * P * 2; % Cross section area of mix stream tube,
m^2
        x = x + dx;
        if (b >= r_lobe) % If fully mixed, exit the loop
            break;
        end

        % Mix the streams together.
        dmdot_total = dmdot_1 + dmdot_2 + dmdot_mix;
        v_mix = (dmdot_1 * v_1 + dmdot_2 * v_2 + dmdot_mix *
v_oldMix) / dmdot_total;

        % Know a few parameters b/c mixing identical substance
        R_mix = R_air;
        MW_mix = MW_air;


        % Iterate to find the new cp_mix
        T_mix = (T_1 + T_2 + T_oldMix) / 3; % Starting guess
        err = inf;
        T_step = 10;
        lastDir = 1;
        while abs(err) > 1e-3
            % Calculate cps of everything
            cp_1 = cp_air_f(T_1) / MW_air * 1000;
            cp_2 = cp_air_f(T_2) / MW_air * 1000;
            cp_oldMix = cp_air_f(T_oldMix) / MW_air * 1000;

            % Calculate cp_mix on a mass basis
            cp_mix = (dmdot_1 / dmdot_total) * cp_1 + ...
                (dmdot_2 / dmdot_total) * cp_2 + ...
                (dmdot_mix / dmdot_total) * cp_oldMix;

            % Calculate energy balance error
            err = dmdot_1 * (cp_1 * T_1 + v_1^2 / 2) + ... % Core
stream tube
                dmdot_2 * (cp_2 * T_2 + v_2^2 / 2) + ... % Fan stream
tube
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                dmdot_mix * (cp_oldMix * T_oldMix + v_oldMix^2 / 2)
 - ... % Last stream tube
                dmdot_total * (cp_mix * T_mix + v_mix^2 / 2);

            if sign(err) ~= lastDir
                T_step = T_step / 2;
            end
            lastDir = sign(err);

            if err > 0
                T_mix = T_mix + T_step;
            else
                T_mix = T_mix - T_step;
            end
        end

        % Found new flow, let's finish it off
        gamma_mix = cp_mix / (cp_mix - R_mix);
        M_mix = v_mix / sqrt(gamma_mix * R_mix * T_mix);

        % Finally, solve for new parameters upon next step
        mdot_1 = mdot_1 - dmdot_1;
        mdot_2 = mdot_2 - dmdot_2;
%         A_left = area(x / L_n, R, R_h) - A_mix;
%         if A_left <= 0
%             keyboard;
%         end

        % Put that MF-P to use!
        A_1 = (mdot_1 * sqrt(Tt_1)) / (MFP_1 * Pt_1);
        A_2 = (mdot_2 * sqrt(Tt_2)) / (MFP_2 * Pt_2);
%          M_1 = aae537.hw3.p3.machFromMFP('MFP', MFP_1, 'gamma',
 gamma_1, 'R', R_air);
%         M_2 = aae537.hw3.p3.machFromMFP('MFP', MFP_2, 'gamma',
 gamma_2, 'R', R_air);


%         P_1 = aeroBox.isoBox.calcStaticPressure('mach', M_1,
 'gamma', gamma_1, 'Pt', Pt_1);
%         P_2 = aeroBox.isoBox.calcStaticPressure('mach', M_2,
 'gamma', gamma_2, 'Pt', Pt_2);
        P_1 = 2 * 101325 - (101325 * (x / L_n));
        P_2 = P_1;

        M_1 = aeroBox.isoBox.machFromPressureRatio('Prat', P_1 /
 Pt_1, 'gamma', gamma_1);
        M_2 = aeroBox.isoBox.machFromPressureRatio('PRat', P_1 /
 Pt_1, 'gamma', gamma_2);

        T_1 = aeroBox.isoBox.calcStaticTemp('mach', M_1, 'gamma',
 gamma_1, 'Tt', Tt_1);
        T_2 = aeroBox.isoBox.calcStaticTemp('mach', M_2, 'gamma',
 gamma_2, 'Tt', Tt_2);
```
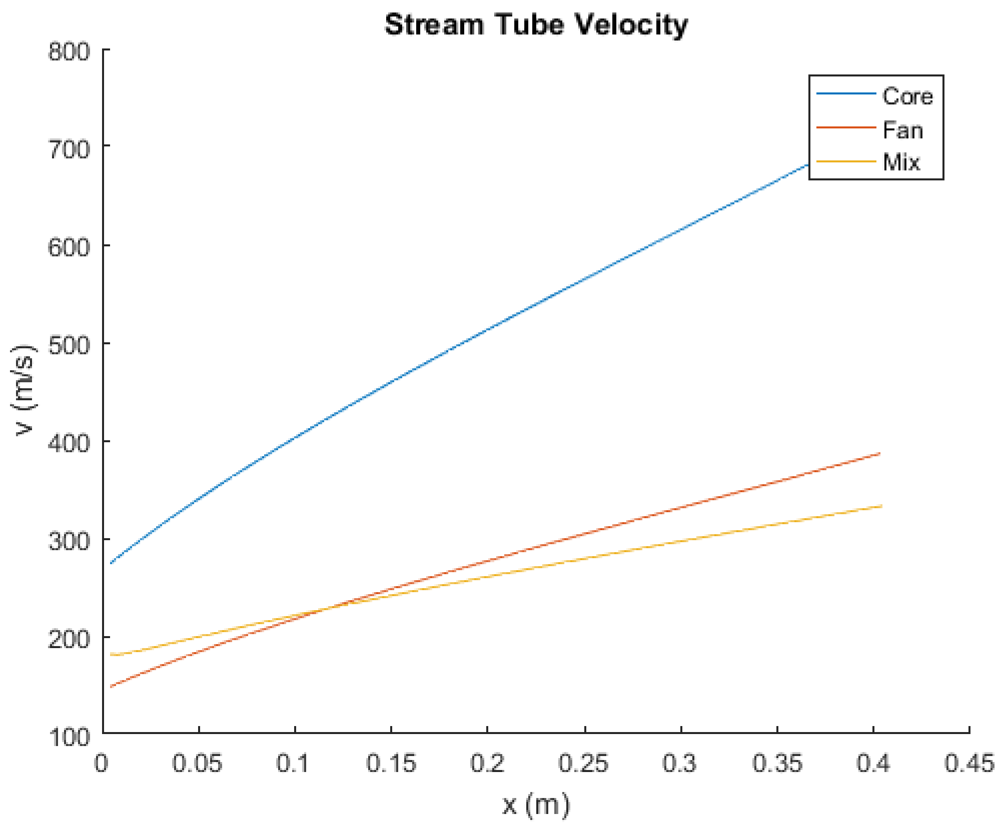
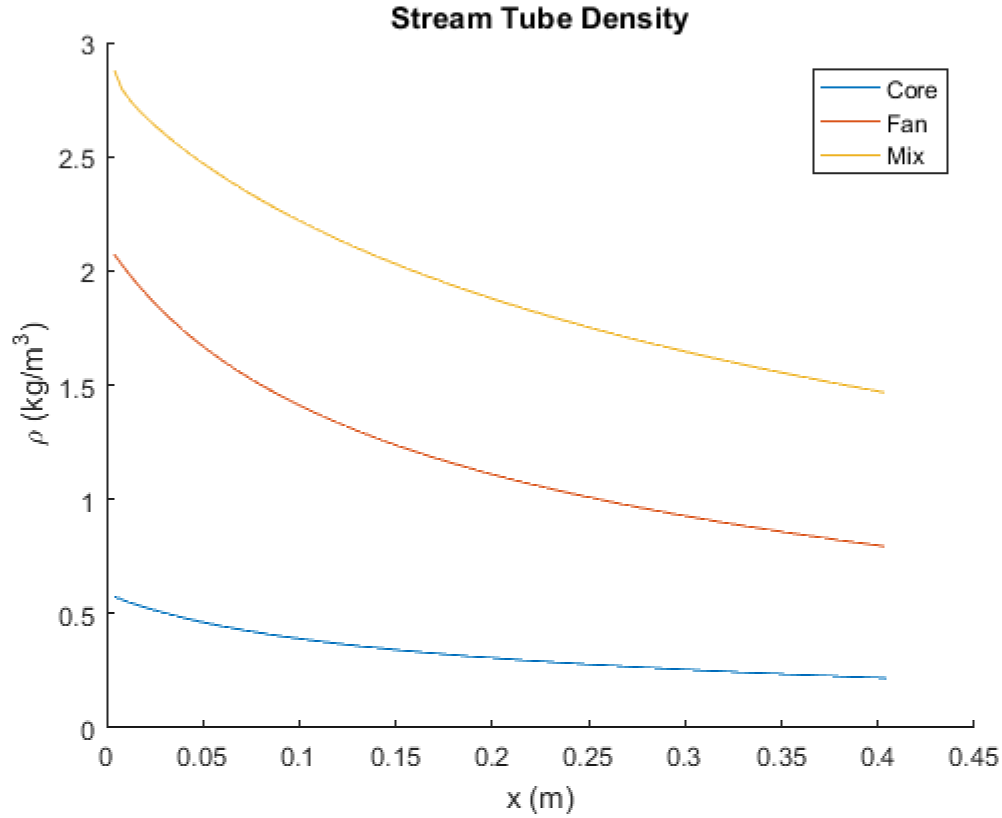
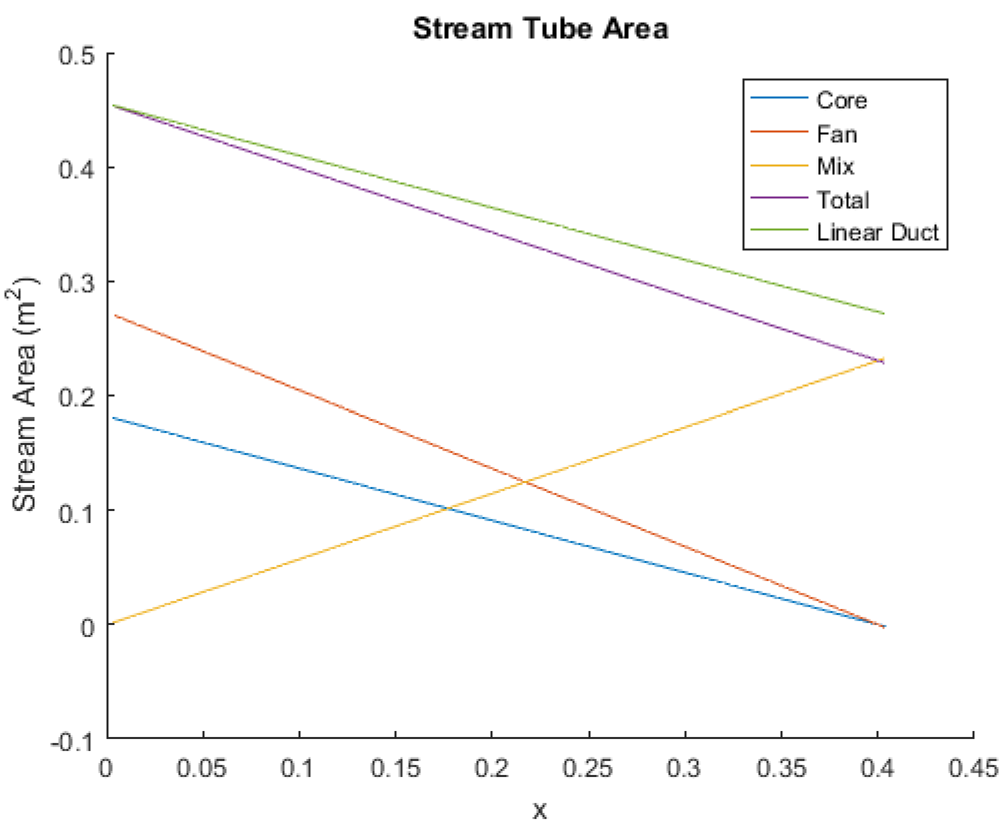

```
        v_1 = M_1 * sqrt(gamma_1 * R_air * T_1);
        v_2 = M_2 * sqrt(gamma_2 * R_air * T_2);
        rho_1 = mdot_1 / (A_1 * v_1);
        rho_2 = mdot_2 / (A_2 * v_2);
        rho_mix = dmdot_total / (A_mix * v_mix);

        % Update mixture params for next round
        dmdot_mix = dmdot_total;
        v_oldMix = v_mix;
        T_oldMix = T_mix;

        % Log parameters
        results(i).x = x;
        results(i).mdot_1 = mdot_1;
        results(i).mdot_2 = mdot_2;
        results(i).mdot_mix = dmdot_total;
        results(i).A_mix = A_mix;
        results(i).A_1 = A_1;
        results(i).A_2 = A_2;
        results(i).A_total = A_mix + A_1 + A_2;
        results(i).A_real = area(x / L_n, R, R_h);
        results(i).v_1 = v_1;
        results(i).v_2 = v_2;
        results(i).v_mix = v_mix;
        results(i).rho_1 = rho_1;
        results(i).rho_2 = rho_2;
        results(i).rho_mix = rho_mix;
        results(i).P_1 = P_1;
        results(i).P_2 = P_2;
        results(i).b = b;
        results(i).T_1 = T_1;
        results(i).T_2 = T_2;
        results(i).T_mix = T_mix;
        results(i).M_1 = M_1;
        results(i).M_2 = M_2;
        results(i).M_mix = M_mix;
        results(i).M_c = M_c;
        results(i).db_dx_c = db_dx_c;
        results(i).M_r = M_r;
    end

    Lerr = (L_n - x) / x;

    if sign(Lerr) ~= lastDirection
        step = step / 2;
    end
    lastDirection = sign(Lerr);

    if Lerr > 0
        L_n = L_n - step;
    else
        L_n = L_n + step;
    end
end
```

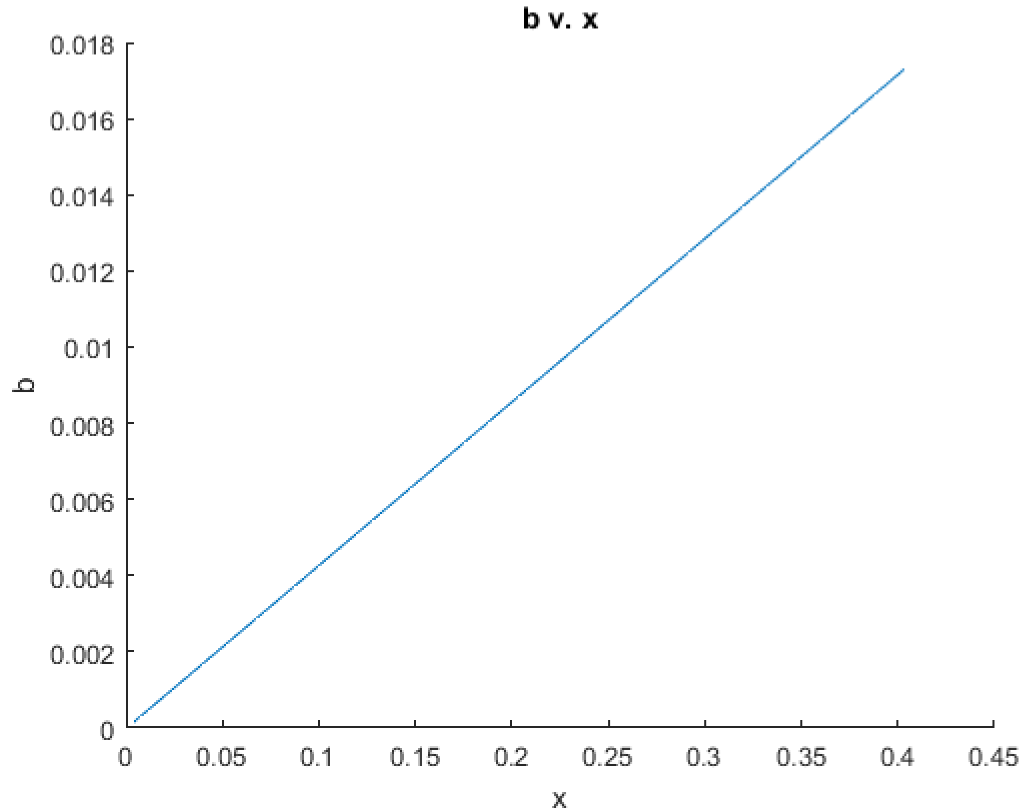
```
figure;
hold on;
plot([results.x], [results.v_1]);
plot([results.x], [results.v_2]);
plot([results.x], [results.v_mix]);
legend('Core', 'Fan', 'Mix');
xlabel('x (m)');
ylabel('v (m/s)');
title('Stream Tube Velocity');

figure;
hold on;
plot([results.x], [results.rho_1]);
plot([results.x], [results.rho_2]);
plot([results.x], [results.rho_mix]);
legend('Core', 'Fan', 'Mix');
xlabel('x (m)');
ylabel('\rho (kg/m^3)');
title('Stream Tube Density');

figure;
hold on;
plot([results.x], [results.A_1]);
plot([results.x], [results.A_2]);
plot([results.x], [results.A_mix]);
plot([results.x], [results.A_1] + [results.A_2] + [results.A_mix]);
plot([results.x], [results.A_real]);
xlabel('x');
ylabel('Stream Area (m^2)');
legend('Core', 'Fan', 'Mix', 'Total', 'Linear Duct');
title('Stream Tube Area');

figure;
hold on;
plot([results.x], [results.b]);
xlabel('x');
ylabel('b');
title('b v. x');

figure;
hold on;
plot([results.x], [results.db_dx_c]);
xlabel('x');
ylabel('db/dx_c');
title('db/dx_c v. x');

figure;
hold on;
plot([results.x], [results.T_1]);
plot([results.x], [results.T_2]);
plot([results.x], [results.T_mix]);
xlabel('x');
```

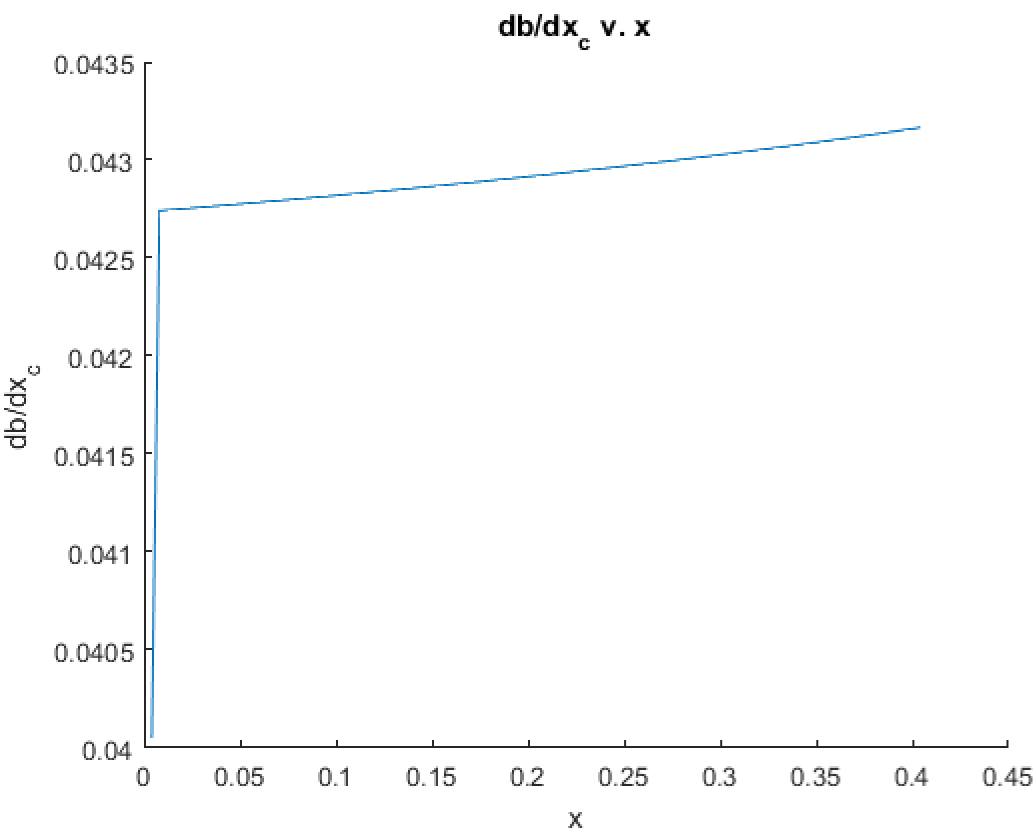
```
ylabel('T (K)');
legend('Core', 'Fan', 'Mix');
title('Static Temperature v. x');

% figure;
% hold on;
% plot([results.x], [results.M_1]);
% plot([results.x], [results.M_2]);
% plot([results.x], [results.M_mix]);
% xlabel('x');
% ylabel('Mach');
% legend('Core', 'Fan', 'Mix');
% title('Stream Mach v. x');

figure;
hold on;
plot([results.x], [results.M_r]);
xlabel('x');
ylabel('M_r');
title('M_r v. x');
```

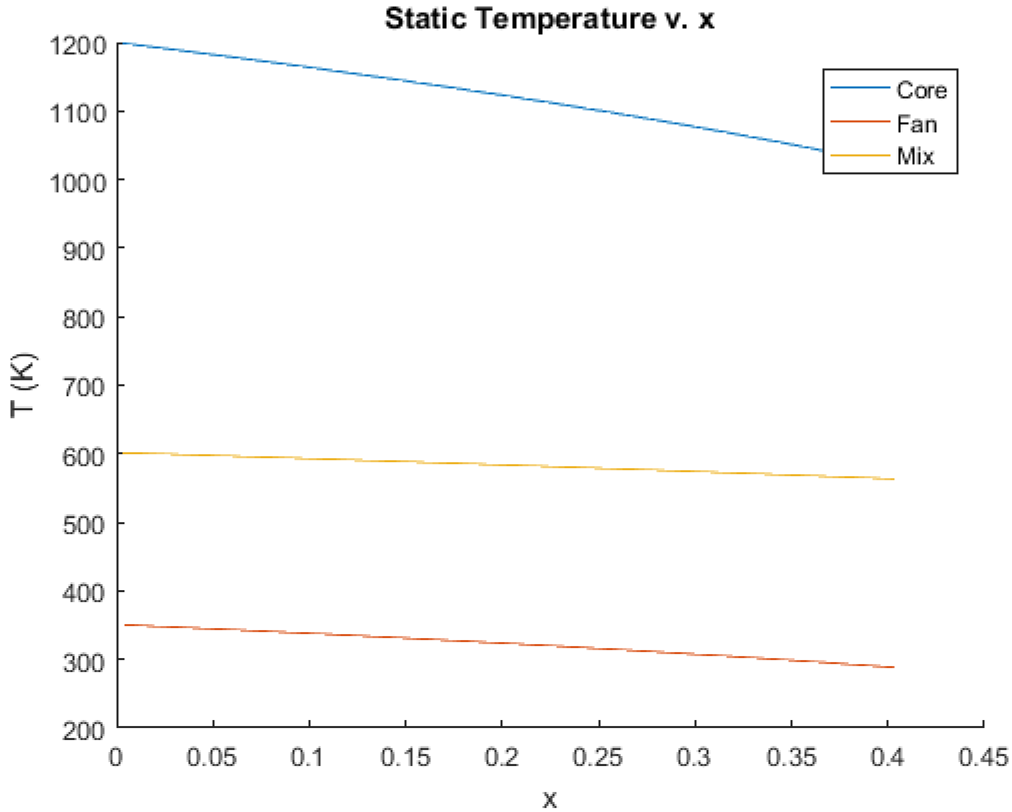


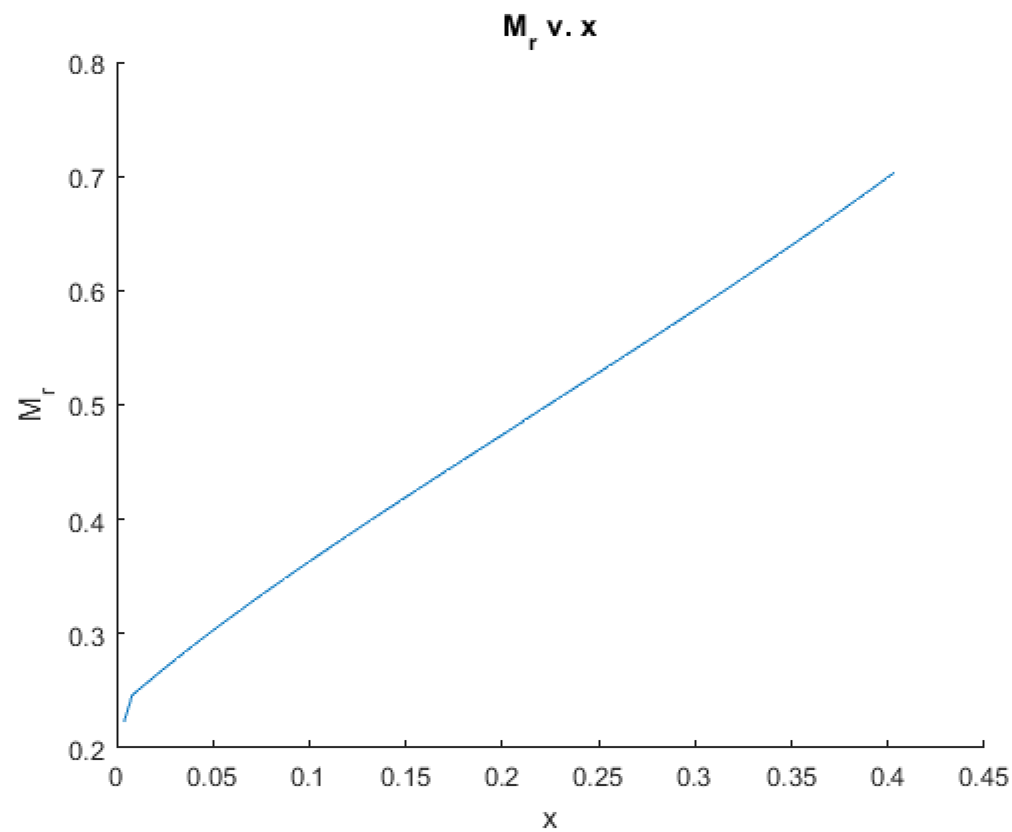

Stream Tube Density
Core
Fan
Mix
ρ (kg/m3)
x (m)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
1
1.5
2
2.5
3


Stream Tube Area
Core
Fan
Mix
Total
Linear Duct
Stream Area (m2)
x
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
-0.1
0.1
0.2
0.3
0.4
0.5


b v. x
b
x
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


db/dx$_c$ v. x
db/dx$_c$
x
0.0435
0.043
0.0425
0.042
0.0415
0.041
0.0405
0.04
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


Static Temperature v. x
T (K)
x
Core
Fan
Mix
1200
1100
1000
900
800
700
600
500
400
300
200
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


M_r v. x
M_r
x
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

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