```
clc
clear
format long

% Givens
T_c_i = (18+20)/2 % C
T_h_i = (60+70)/2 % C
T_inf = 25; % C

TcK = T_c_i+273.15;
ThK = T_h_i +273.15;
T_inf_K = T_inf + 273.15;

D_i_in = 1*0.0254; % m
D_i_out = 1.125*0.0254; % m

D_o_in = 1.5*0.0254; % m
D_o_out = 1.625*0.0254; % m
%
% m_c = linspace(0.2,0.05,16); %L/s
% m_h = linspace(0.2,0.05,16); %L/s

m_c = 1
m_h = 0.25

L = linspace(0,1,100); % m

rho = 1000; %kg/m^3, density of water

k_cu = 398; % W/m · K


thermo_prop = [273.15, 0.00611, 1.000, 206.3, 2502, 4.217, 1.854, 1750,...
    8.02, 569, 18.2, 12.99, 0.815, 75.5, 68.05, 273.15; 275 0.00697,...
    1.000, 181.7, 2497, 4.211, 1.855, 1652, 8.09, 574, 18.3, 12.22, 0.817,...
    75.3, 32.74, 275; 280, 0.00990, 1.000, 130.4, 2485, 4.198, 1.858,...
    1422, 8.29, 582, 18.6, 10.26, 0.825, 74.8, 46.04, 280; 285, 0.01387,...
    1.000, 99.4, 2473, 4.189, 1.861, 1225, 8.49, 590, 18.9, 8.81, 0.833,...
    74.3, 114.1, 285; 290, 0.01917, 1.001, 69.7, 2461, 4.184, 1.864, 1080,...
    8.69, 598, 19.3, 7.56, 0.841, 73.7, 174.0, 290; 295, 0.02617, 1.002,...
    51.94, 2449, 4.181, 1.868, 959, 8.89, 606, 19.5, 6.62, 0.849, 72.7,...
    227.5, 295; 300, 0.03531, 1.003, 39.13, 2438, 4.179, 1.872, 855, 9.09,...
    613, 19.6, 5.83, 0.857, 71.7, 276.1, 300; 305, 0.04712, 1.005, 29.74,...
    2426, 4.178, 1.877, 769, 9.29, 620, 20.1, 5.20, 0.865, 70.9, 320.6,...
    305; 310, 0.06221, 1.007, 22.93, 2414, 4.178, 1.882, 695, 9.49, 628,...
    20.4, 4.62, 0.873, 70.0, 361.9, 310; 315, 0.08132, 1.009, 17.82, 2402,...
    4.179, 1.888, 631, 9.69, 634, 20.7, 4.16, 0.883, 69.2, 400.4, 315;
320,...
    0.1053, 1.011, 13.98, 2390, 4.180, 1.895, 577, 9.89, 640, 21.0, 3.77,...
    0.894, 68.3, 436.7, 320; 325, 0.1351, 1.013, 11.06, 2378, 4.182,...
    1.903, 528, 10.09, 645, 21.3, 3.42, 0.901, 67.5, 471.2, 325; 330,...
    0.1719, 1.016, 8.82, 2366, 4.184, 1.911, 489, 10.29, 650, 21.7, 3.15,...
```

```
    0.908, 66.6, 504.0, 330; 335, 0.2167, 1.018, 7.09, 2354, 4.186, 1.920,...
    453, 10.49, 656, 22.0, 2.88, 0.916, 65.8, 535.5, 335; 340, 0.2713,...
    1.021, 5.74, 2342, 4.188, 1.930, 420, 10.69, 660, 22.3, 2.66, 0.925,...
    64.9, 566.0, 340; 345, 0.3372, 1.024, 4.683, 2329, 4.191, 1.941,...
    389, 10.89, 664, 22.6, 2.45, 0.933, 64.1, 595.4, 345];

% Linear Interpolation Values
T_c_low = 0; T_c_up = 0; mu_c_low = 0; mu_c_up = 0; k_c_low = 0;...
    k_c_up = 0; Pr_c_low = 0; Pr_c_up = 0; C_c_up = 0; C_c_low = 0;
mu_h_low = 0; mu_h_up = 0; k_h_low = 0; k_h_up = 0; Pr_h_low = 0;...
    Pr_h_up = 0; C_h_up = 0; C_h_low = 0;
k_cu_low = 0; k_cu_up = 0;

for i = 1:16
    % Cold Values
    if abs(TcK-thermo_prop(i,1)) <= 5
        % x = value, y = temperature
        if (TcK-thermo_prop(i,1)) > 0
            % lower values
            T_c_low = thermo_prop(i,1);
            mu_c_low = thermo_prop(i,8);
            k_c_low = thermo_prop(i,10);
            Pr_c_low = thermo_prop(i,12);
            C_c_low = thermo_prop(i,6);
        else
            % upper values
            T_c_up = thermo_prop(i,1);
            mu_c_up = thermo_prop(i,8);
            k_c_up = thermo_prop(i,10);
            Pr_c_up = thermo_prop(i,12);
            C_c_up = thermo_prop(i,6);

        end
    end
     % Hot Values
    if abs(ThK-thermo_prop(i,1)) <= 5
        % x = value, y = temperature
        if (ThK-thermo_prop(i,1)) > 0
            % lower values
            T_h_low = thermo_prop(i,1);
            mu_h_low = thermo_prop(i,8);
            k_h_low = thermo_prop(i,10);
            Pr_h_low = thermo_prop(i,12);
            C_h_low = thermo_prop(i,6);
        else
            % upper values
            T_h_up = thermo_prop(i,1);
            mu_h_up = thermo_prop(i,8);
            k_h_up = thermo_prop(i,10);
            Pr_h_up = thermo_prop(i,12);
            C_h_up = thermo_prop(i,6);

        end
    end
```

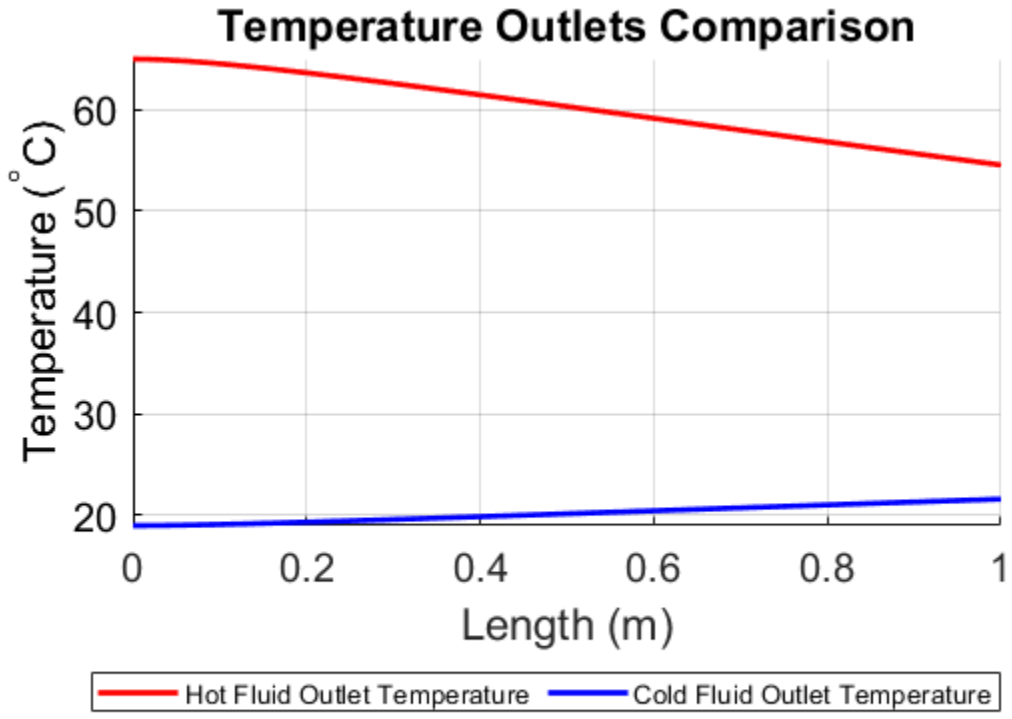
```
end

% Cold Interpolations
mu_c = ((((TcK-T_c_up)*(mu_c_low-mu_c_up))/(T_c_low-T_c_up))+mu_c_up)*10^-6;
% N · s/m2
k_c = ((((TcK-T_c_up)*(k_c_low-k_c_up))/(T_c_low-T_c_up))+k_c_up)*10^-3; %
W/m · K
Pr_c = (((TcK-T_c_up)*(Pr_c_low-Pr_c_up))/(T_c_low-T_c_up))+Pr_c_up;
C_c = ((((TcK-T_c_up)*(C_c_low-C_c_up))/(T_c_low-T_c_up))+C_c_up)*1000; %
kJ/kg · K

% Hot Interpolations
mu_h = ((((ThK-T_h_up)*(mu_h_low-mu_h_up))/(T_h_low-T_h_up))+mu_h_up)*10^-6;
% N · s/m2
k_h = ((((ThK-T_h_up)*(k_h_low-k_h_up))/(T_h_low-T_h_up))+k_h_up)*10^-3; %
W/m · K
Pr_h = (((ThK-T_h_up)*(Pr_h_low-Pr_h_up))/(T_h_low-T_h_up))+Pr_h_up;
C_h = ((((ThK-T_h_up)*(C_h_low-C_h_up))/(T_h_low-T_h_up))+C_h_up)*1000; %
kJ/kg · K

% Calculated Constants

ReD_h = (m_h*4)/((pi*D_i_in)*mu_h);
ReD_c = (m_c *4)/(pi*(D_o_in-D_i_out)*mu_c);


NuD_c = 0.023*(ReD_c^0.8)*(Pr_c^0.4); % cold water is getting heated
NuD_h = 0.023*(ReD_h^0.8)*(Pr_h^0.3); % hot water is getting cooled

h_c = (k_c*NuD_c)/D_o_in;
h_h = (k_h*NuD_h)/D_i_in;

A_o = pi*D_o_out*L;
% A_c = pi*D_c_i*L;
% A_h = pi*D_h_i*L;
%
% R_c_conv = 1./(h_c*A_c);
% R_i_cond = log(D_c_o/D_c_i)./(2*pi*L*k_cu);
% R_h_conv = 1./(h_h*A_h);
% R_o_cond = log(D_h_o/D_h_i)./(2*pi*L*k_cu);
% R_air_conv = 1./(h_air.*A_o);

% U = ((R_c_conv+R_i_cond+R_h_conv+R_o_cond+R_air_conv)).^-1
Ut = 1./((1/h_h)+(log(D_i_out/D_i_in)./(2*pi*L*k_cu))+(1./h_c)+...
    (log(D_o_out/D_o_in)./(2*pi*L*k_cu)));

if C_c < C_h
        C_min = C_c;
        C_max = C_h;
else
        C_min = C_h;
        C_max = C_c;
end
```

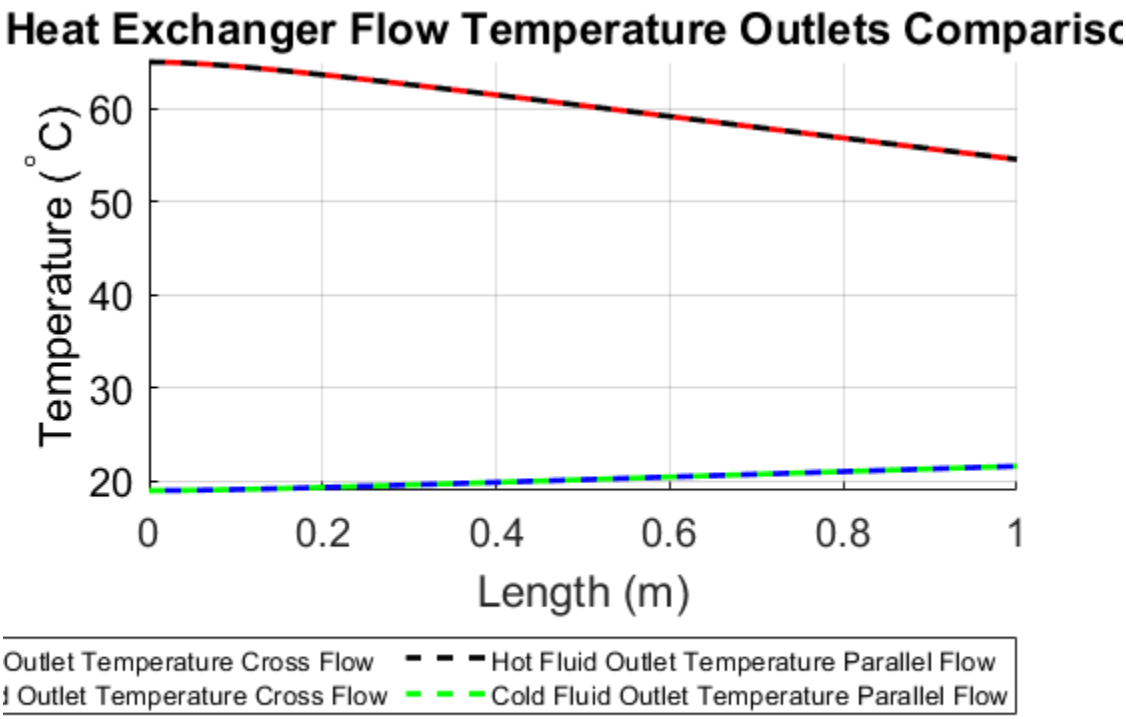
```
C_r = C_min/C_max;

NTU = (Ut.*A_o)/C_min;

q_max = C_min*(T_h_i-T_c_i);

% Parallel Flow
eps_p = (1-exp(-NTU*(1+C_r)))/(1+C_r);
q_p = eps_p*q_max;
T_c_o_p = (q_p/(m_c*C_min))+T_c_i;
T_h_o_p = (-q_p/(m_h*C_max))+T_h_i;

% Counter Flow
eps_c = (1-exp(-NTU*(1-C_r))./(1-(C_r*exp(-NTU*(1-C_r))));
q_c = eps_c*q_max;
T_c_o_c = (q_c/(m_c*C_min))+T_c_i;
T_h_o_c = (-q_c/(m_h*C_max))+T_h_i;

% printing
disp(['Length: ',num2str(L),' m'])
fprintf('\n')
disp(['U: ',num2str(Ut(length(Ut)))])
%fprintf('\n')
%disp(['Initial Hot Temperature: ',num2str(T_h_i)])
%disp(['Initial Cold Temperature: ',num2str(T_c_i)])

fprintf('\n Parallel Flow \n')
disp(['Heat Transfer Rate: ',num2str(q_p(100))])
disp(['Final Hot Temperature: ',num2str(T_h_o_p(100))])
disp(['Final Cold Temperature: ',num2str(T_c_o_p(100))])

fprintf('\n Counter Flow \n')
disp(['Heat Transfer Rate: ',num2str(q_c(100))])
disp(['Final Hot Temperature: ',num2str(T_h_o_c(100))])
disp(['Final Cold Temperature: ',num2str(T_c_o_c(100))])

%-------Plot 1--------------------------------------------------------------
figure(1)
hold on
plot(L,T_h_o_c,'r-','linewidth',2)
plot(L,T_c_o_c,'b-','linewidth',2);
ylabel('Temperature (^{\circ}C)');
xlabel('Length (m)');
ax = gca;
ax.YColor = 'k';
ax.FontSize = 15;
lgd = legend('Hot Fluid Outlet Temperature',...
'Cold Fluid Outlet Temperature','location','southoutside');
lgd.NumColumns = 3;
lgd.FontSize = 10;
title('Temperature Outlets Comparison');
grid on
hold off
```

```
%-------Plot 2----------------------------------------------------------------
figure(2)
hold on
plot(L,T_h_o_c,'r-','linewidth',2)
plot(L,T_c_o_c,'b-','linewidth',2);
plot(L,T_h_o_p,'k--','linewidth',2)
plot(L,T_c_o_p,'g--','linewidth',2);
ylabel('Temperature (^{\circ}C)');
xlabel('Length (m)');
ax = gca;
ax.YColor = 'k';
ax.FontSize = 15;
lgd = legend('Hot Fluid Outlet Temperature Cross Flow',...
'Cold Fluid Outlet Temperature Cross Flow',...
'Hot Fluid Outlet Temperature Parallel Flow',...
'Cold Fluid Outlet Temperature Parallel Flow',...
'location','southoutside');
lgd.NumColumns = 3;
lgd.FontSize = 10;
title('Heat Exchanger Flow Temperature Outlets Comparison');
grid on
hold off
```

```
T_c_i =

    19


T_h_i =

    65


m_c =

     1


m_h =

   0.250000000000000

Length: 0    0.010101    0.020202    0.030303    0.040404    0.050505
0.060606    0.070707    0.080808    0.090909     0.10101     0.11111
0.12121     0.13131     0.14141     0.15152     0.16162     0.17172
0.18182     0.19192     0.20202     0.21212     0.22222     0.23232
0.24242     0.25253     0.26263     0.27273     0.28283     0.29293
0.30303     0.31313     0.32323     0.33333     0.34343     0.35354
0.36364     0.37374     0.38384     0.39394     0.40404     0.41414
0.42424     0.43434     0.44444     0.45455     0.46465     0.47475
0.48485     0.49495     0.50505     0.51515     0.52525     0.53535
0.54545     0.55556     0.56566     0.57576     0.58586     0.59596
0.60606     0.61616     0.62626     0.63636     0.64646     0.65657
```

```
0.66667     0.67677     0.68687     0.69697     0.70707     0.71717
0.72727     0.73737     0.74747     0.75758     0.76768     0.77778
0.78788     0.79798     0.80808     0.81818     0.82828     0.83838
0.84848     0.85859     0.86869     0.87879     0.88889     0.89899
0.90909     0.91919     0.92929     0.93939     0.94949      0.9596
0.9697      0.9798      0.9899           1 m

U: 1944.1844

 Parallel Flow
Heat Transfer Rate: 10925.2962
Final Hot Temperature: 54.5633
Final Cold Temperature: 21.612

 Counter Flow
Heat Transfer Rate: 10937.7576
Final Hot Temperature: 54.5514
Final Cold Temperature: 21.615
```





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