CAPE LAB Assignment - 5

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sol-1)

Sol^n 1: Given ODEs

$$\frac{dy_1}{dt} = y_2$$

$$\frac{dy_2}{dt} = 1000(1-y_1^2)y_2 - y_1$$

Initial guess $y_1(0) = 2$, $y_2(0) = 0$

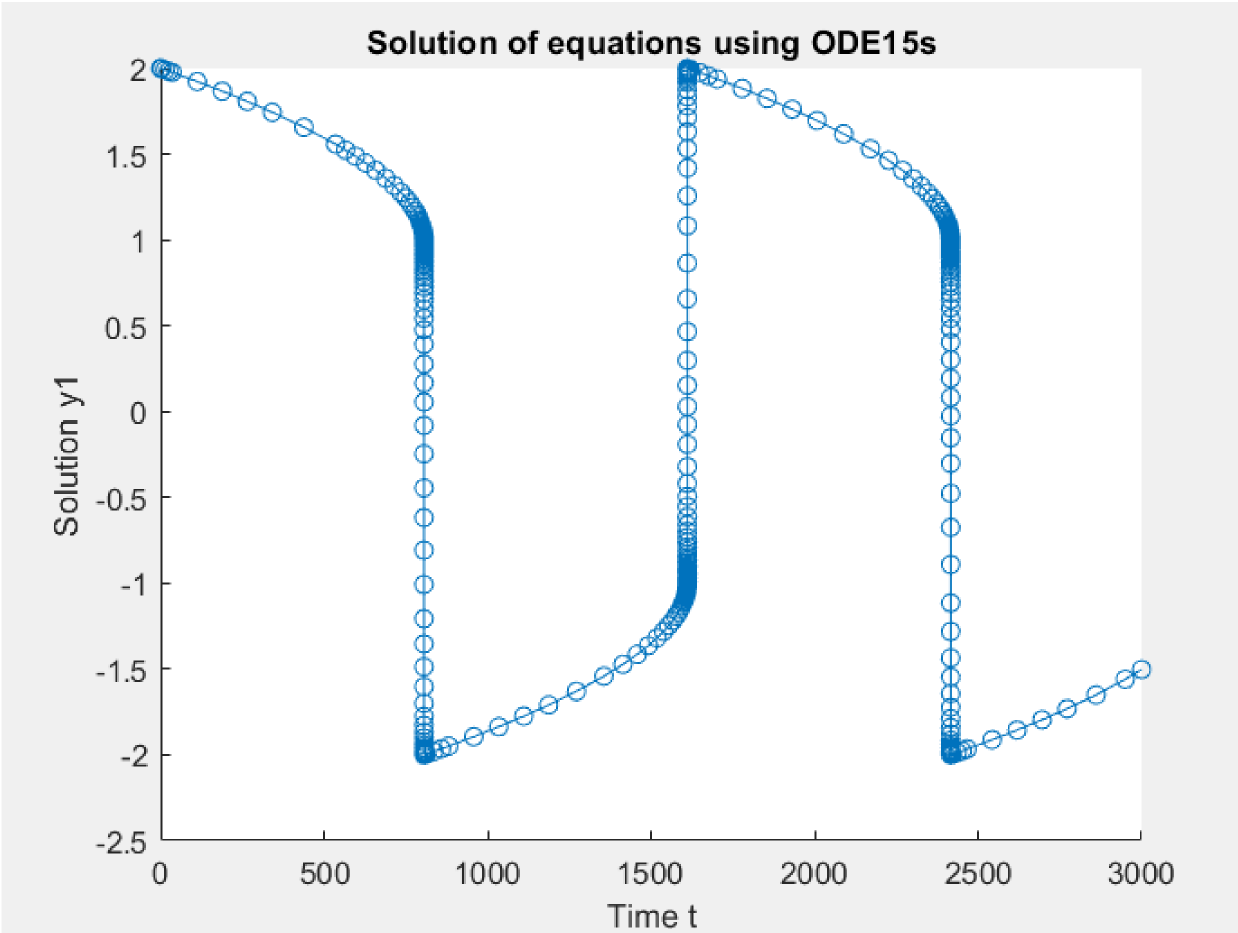
$$tspan = [0, 3000]$$

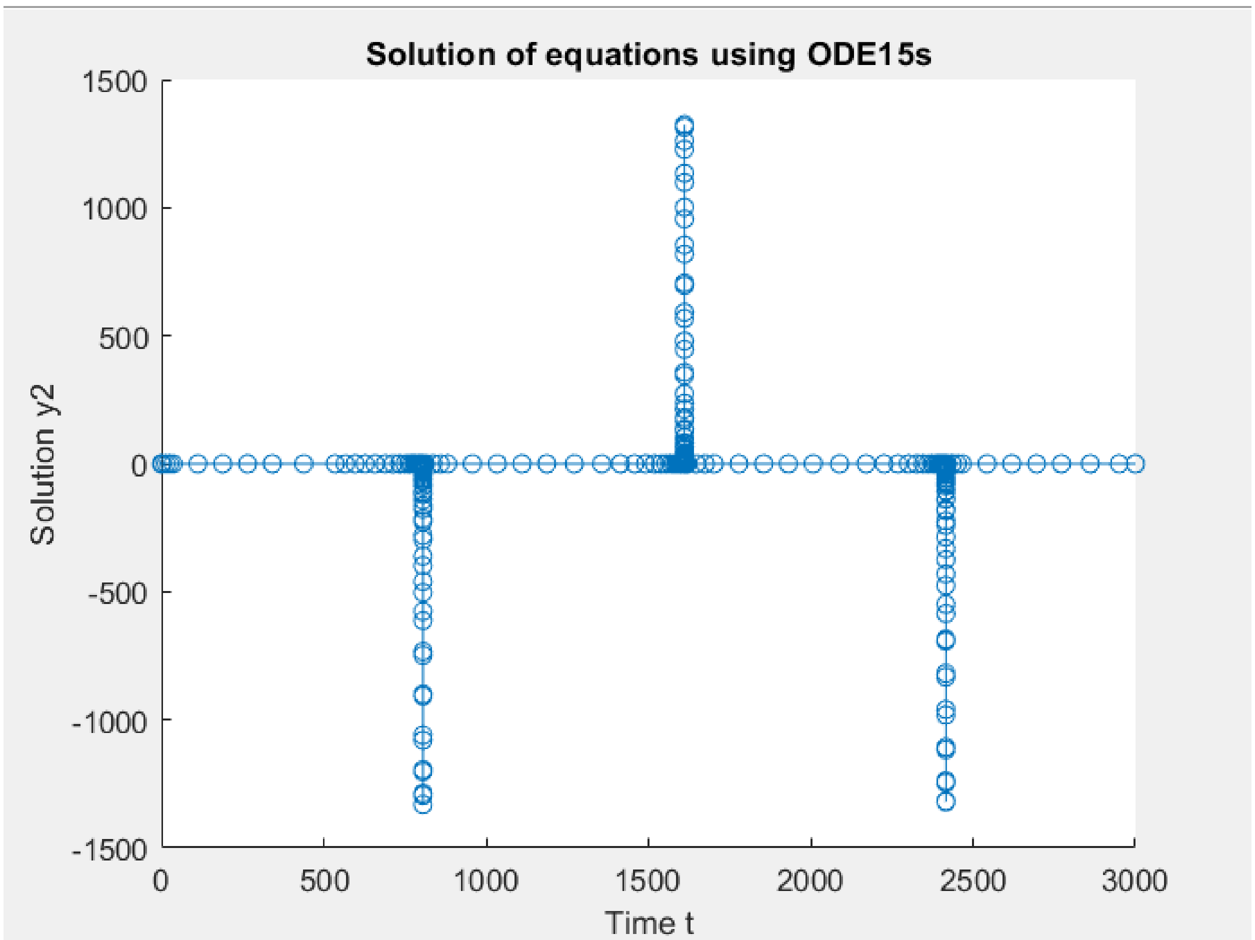
(a) If we use ODE45 for tspan = [0, 3000] than it will not be able to solve ODE45 while ODE15s will be able to solve. This means ODE15s is more efficient than ODE45 here

(b) plotting of y_1 & y_2 as a function of time

```matlab
function dydt = fun1(t,y)
dydt = [y(2); 1000*(1-y(1)^2)*y(2)-y(1)];
end
```

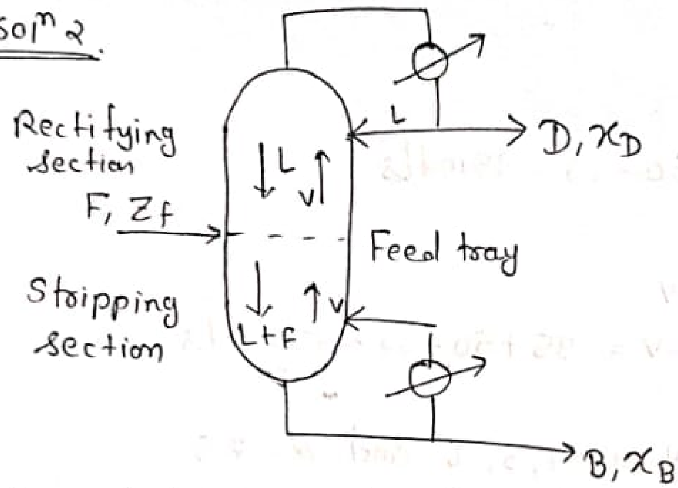
```matlab
[t,y] = ode15s(@fun1,[0 3000],[2;0]);
figure
hold on
plot(t,y(:,1),'-o');
title('Solution of equations using ODE15s');
xlabel('Time t');
ylabel('Solution y1');
hold off;

figure;
hold on;
plot(t,y(:,2),'-o');
title('Solution of equations using ODE15s');
xlabel('Time t');
ylabel('Solution y2');
hold off;

```


Solution of equations using ODE15s
Solution y1
Time t
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
500
1000
1500
2000
2500
3000


Solution of equations using ODE15s
Solution y2
Time t
1500
1000
500
0
-500
-1000
-1500
0
500
1000
1500
2000
2500
3000

sol-2)

Solⁿ 2.



$$y_i = \frac{\alpha x_i}{1+(\alpha-1)x_i}$$

Mass balance equation can be written in following way for each section

NOTE: Considering Tray-1 as condenser and Tray-10 as Reboiler

Condenser

$$\frac{d}{dt}(M_c x_D) = V y_2 - D x_D - L x_D$$

Rectifying section

$$\frac{d}{dt}(M_i x_i) = (V_{i+1} y_{i+1} + L_{i-1} x_{i-1}) - (V_i y_i + L_i x_i)$$

Feed Tray

$$\frac{d}{dt}(M_F Z_f) = (F Z_f + L_{i-1} x_{i-1} + V_{i+1} y_{i+1}) - (V_i y_i + (L+F)_i x_i)$$

Stripping section

$$\frac{d}{dt}(M_i x_i) = ((L+F)_{i-1} x_{i-1} + V_{i+1} y_{i+1}) - (V_i y_i + (L+F)_i x_i)$$

for trays $M = 400$
$M_c = 4000$
$M_R = 4000$

at Condenser -

$$L + D = V$$

$$\Rightarrow L = V - D = 60 - 25 = 35 \text{ mol/s}$$

at Reboiler -

$$L + F = B + V$$

$$\Rightarrow B = L + F - V = 35 + 50 - 60 = 25 \text{ mol/s}$$

(a) Considering Feed Tray as [4,5,6] and alpha = 2.5, the compositions at steady state

ans2.m

```matlab
function F = ans2(X)
V = 60;
f = 50;
D = 25;
Zf = 0.5;
M = 400;
Mc = 4000;
Mr = 4000;
alpha = 2.5; %can be changed according to alpha value
L = 35;
B = 25;
fT = 4; %can be changed according to feed tray number
Y = alpha*(X)./(1+(alpha-1)*X);
F(1) = (V*Y(2) - D*X(1) - L*X(1))/Mc;
for i = 2:(fT-1)
    F(i) = (V*Y(i+1) + L*X(i-1)-(V*Y(i)+L*X(i)))/M;
end
F(fT) = (f*Zf + L*X(fT-1) + V*Y(fT+1)-(V*Y(fT) + (L+f)*X(fT)))/M;
for i = (fT+1):9
    F(i) = (L+f)*X(i-1) + V*Y(i+1) - V*Y(i) - (L+f)*X(i);
end
F(10) = ((L+f)*X(9) - V*Y(10) - B*X(10))/Mr;
end
```

For Feed Tray = 4, Steady state compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Solver stopped prematurely.

fsolve stopped because it exceeded the function evaluation limit,
options.MaxFunctionEvaluations = 1.000000e+03.


ans =

    0.6969    0.6272    0.5688    0.5238    0.5156    0.5011    0.4765    0.4368    0.3785    0.3032
```

For Feed Tray = 5, Steady state compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Solver stopped prematurely.

fsolve stopped because it exceeded the function evaluation limit,
options.MaxFunctionEvaluations = 1.000000e+03.


ans =

    0.6955    0.6333    0.5805    0.5388    0.5079    0.4937    0.4698    0.4318    0.3763    0.3046
```

For Feed Tray = 6, Steady state compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Solver stopped prematurely.

fsolve stopped because it exceeded the function evaluation limit,
options.MaxFunctionEvaluations = 1.000000e+03.


ans =

    0.7045    0.6422    0.5886    0.5458    0.5136    0.4906    0.4654    0.4257    0.3684    0.2956
```

(b) For Feed tray = 4 and alpha = [1.5,3,4]

For alpha = 1.5, Steady state compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Equation solved.

fsolve completed because the vector of function values is near zero
as measured by the value of the function tolerance, and
the problem appears regular as measured by the gradient.

<stopping criteria details>

ans =

    0.6986    0.6071    0.5480    0.5112    0.4986    0.4801    0.4535    0.4163    0.3660    0.3014
```

For alpha = 3, Steady state Compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Solver stopped prematurely.

fsolve stopped because it exceeded the function evaluation limit,
options.MaxFunctionEvaluations = 1.000000e+03.


ans =

    0.6758    0.6209    0.5697    0.5262    0.5210    0.5110    0.4921    0.4580    0.4024    0.3243
```

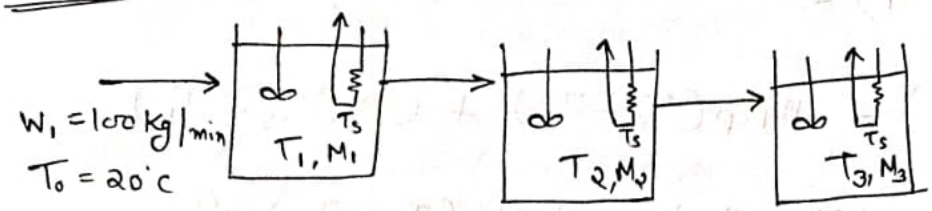
For alpha = 4, Steady state Compositions are -

```
>> fsolve(@ans2,[0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5,0.5])

Solver stopped prematurely.

fsolve stopped because it exceeded the function evaluation limit,
options.MaxFunctionEvaluations = 1.000000e+03.


ans =

    0.6816    0.6385    0.5881    0.5352    0.5325    0.5261    0.5113    0.4790    0.4163    0.3185
```

Hight Relative volatility means components can be easily separate in distillation column. Value of relative volatility near 1 means that it is very difficult to separate components.

sol-3)

Sol^n 3:



So Initial value of T_1, T_2, T_3 in Tank

$T_1 = 50^\circ C$, $T_2 = 50^\circ c$, $T_3 = 50^\circ c$

$UA = 10\ KJ/min^\circ c$, $C_p = 2\ KJ/Kg^\circ c$

$W = 100\ kg/min$

$T_s = 250^\circ c$

∵ The mass present inside the tank is constant ⇒

$$M_1 = M_2 = M_3 = M$$

So Energy Balance for individual Tanks:

$$\frac{d}{dt}(MC_pT_1) = WC_p(T_0 - T_1) + UA(T_s - T_1)$$

$$\frac{d}{dt}(MC_pT_2) = WC_p(T_1 - T_2) + UA(T_s - T_2)$$

$$\frac{d}{dt}(MC_pT_3) = WC_p(T_2 - T_3) + UA(T_s - T_3)$$

a) So The dynamic model equations are-

$$\frac{dT_1}{dt} = \frac{W}{M}(T_0 - T_1) + \frac{UA}{MC_p}(T_s - T_1) \quad -①$$

$$\frac{dT_2}{dt} = \frac{W}{M}(T_1 - T_2) + \frac{UA}{MC_p}(T_s - T_2) \quad -②$$

$$\frac{dT_3}{dt} = \frac{W}{M}(T_2 - T_3) + \frac{UA}{MC_p}(T_s - T_3) \quad -③$$

(b) for steady state temperatures -

$$\frac{dT_1}{dt} = \frac{dT_2}{dt} = \frac{dT_3}{dt} = 0$$

soving above equations in MATLAB using fsolve give steady state values of T_1, T_2 & T_3

$$\boxed{\begin{aligned} T_1 &= 30.9524\,^\circ C \\ T_2 &= 41.3832\,^\circ C \\ T_3 &= 51.3174\,^\circ C \end{aligned}}$$

(c) at 99% of steady state

$$T_3 = 51.3174 \times 0.99 = 50.804\,^\circ C$$

From the graph it can be seen that in $t \in [0, 0.08]$ it will reaches 99% of steady state of T_3.

(d) To increasing by 50% New steady states are -

$T1 = 40.4761$

$T2 = 50.4547$

$T3 = 59.96$

Code for 3(b)

```matlab
function F = ans3_2(T)
initialize();
F(1) = (T0-T(1))+(UA/(M*Cp))*(Ts-T(1));
F(2) = (T(1)-T(2))+(UA/(M*Cp))*(Ts-T(2));
F(3) = (T(2)-T(3))+(UA/(M*Cp))*(Ts-T(3));
end
```

```matlab
function T = solve3_2
%initial guess
T0 = [50,50,50];
T = fsolve(@ans3_2,T0);
end
```

```
>> solve3_2

Equation solved.

fsolve completed because the vector of function values is near zero
as measured by the value of the function tolerance, and
the problem appears regular as measured by the gradient.

<stopping criteria details>

ans =

   30.9524   41.3832   51.3174
```

So the steady-state temperatures are -

T1 = 30.9524 *C

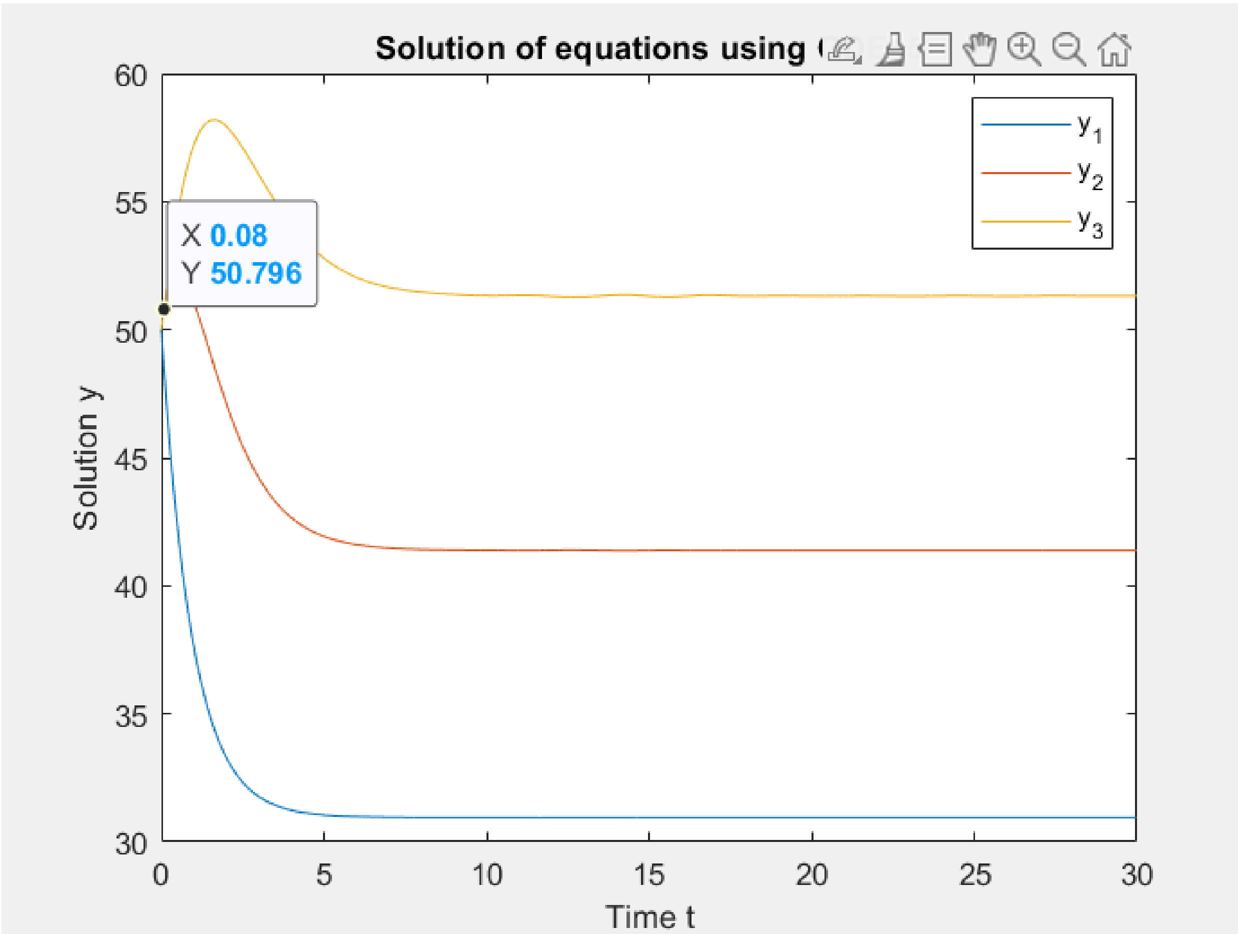
T2 = 41.3832 *C

T3 = 51.3174 *C

Code for 3(c)

```matlab
function dy_dt = ans3_3(t,T)
initialize();
dy_dt = [(W/M)*(T0-T(1)) + ((UA)/(M*Cp))*(Ts - T(1));
    (W/M)*(T(1)-T(2)) + ((UA)/(M*Cp))*(Ts - T(2));
    (W/M)*(T(2)-T(3)) + ((UA)/(M*Cp))*(Ts - T(3))];
end
```

```
[t,y] = ode45(@ans3_3,0:0.01:30,[50,50,50]);
plot(t,y(:,1),t,y(:,2),t,y(:,3));
title('Solution of equations using ODE45');
xlabel('Time t');
ylabel('Solution y');
legend('y_1','y_2','y_3');
```

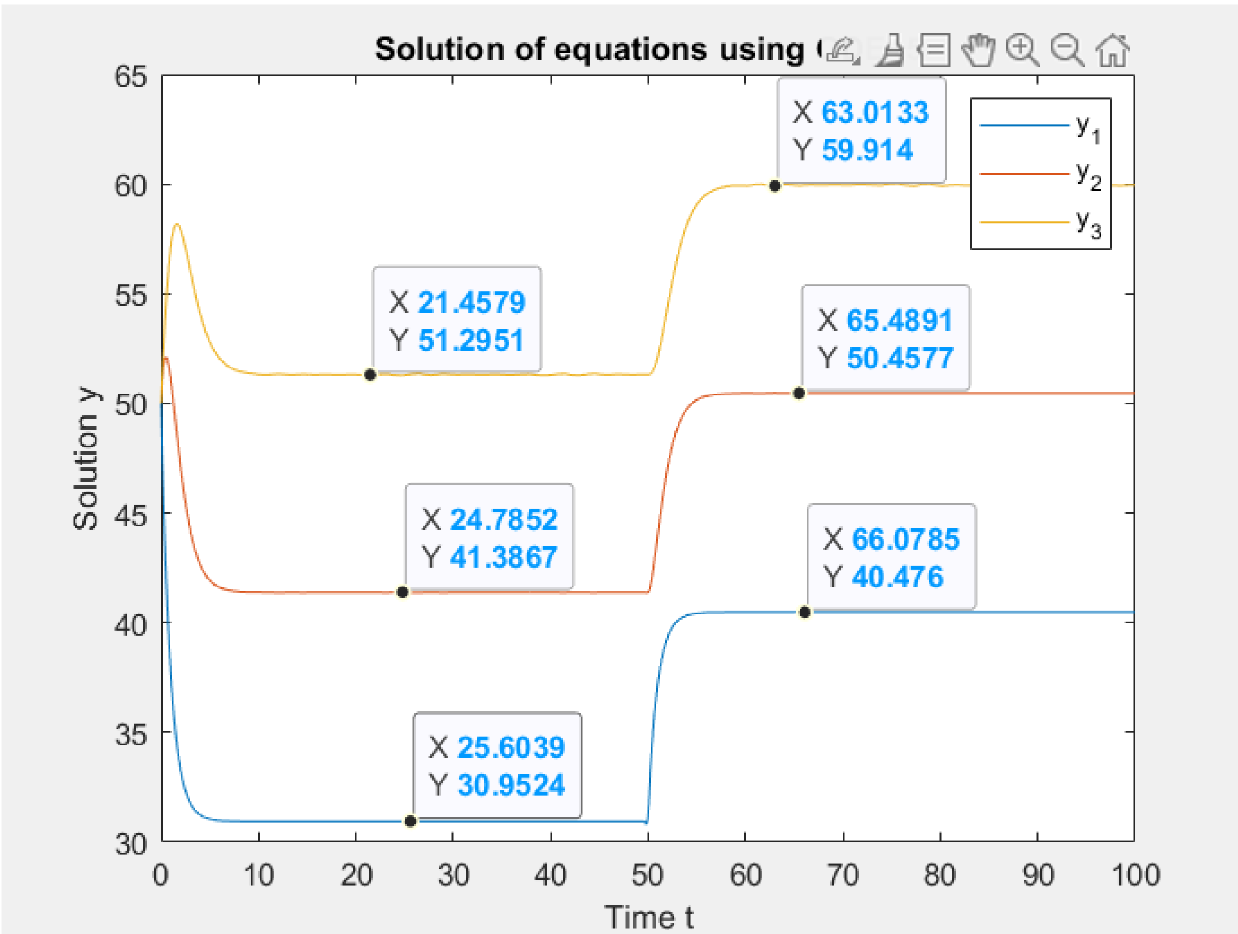


So in T = [0,0.08]min T3 will reach to 99% of steady state

Code for 3(d)

```
function dy_dt = ans3_3(t,T)
initialize();
if(t>50)
    T0 = T0 + 0.50*T0;
end
dy_dt = [(W/M)*(T0-T(1)) + ((UA)/(M*Cp))*(Ts - T(1));
    (W/M)*(T(1)-T(2)) + ((UA)/(M*Cp))*(Ts - T(2));
    (W/M)*(T(2)-T(3)) + ((UA)/(M*Cp))*(Ts - T(3))];
end
```

```
[t,y] = ode45(@ans3_3,[0,100],[50,50,50]);
plot(t,y(:,1),t,y(:,2),t,y(:,3));
title('Solution of equations using ODE45');
xlabel('Time t');
ylabel('Solution y');
legend('y_1','y_2','y_3');
```



So new stady states are -

T1 = 40.4761 *C

T2 = 50.4577 *C

T3 = 59.914 *C