Tutorial - 4

① $x_D = 0.97$ (→ wt fraction), $x_B = 1 - 0.98 = 0.02$

$R = 3.5$

z_F (w/w) $= 0.4 \Rightarrow z_F$ (mol/mol) $= \frac{\frac{0.4}{78}}{\frac{0.4}{78} + \frac{0.6}{92}} = 0.44$

Since there are no plates in stripping we can't achieve $x_W = 0.02$.

Feed rates

$F_B = \frac{0.4 \times 13000}{78} = 69.04$ kmol/h.

$F_{toluene} = \frac{0.6 \times 13000}{92} = 88.56$ kmol/h.

Feed total = 158.21 kmol/h.

Using this, $z_F = 0.44$.

x_D (mol by mol) $= \frac{\frac{0.97}{78}}{\frac{0.97}{78} + \frac{0.03}{92}} = 0.9745$.

Some saturated vapour enters, $q = 0 \Rightarrow$ q-line is $y = 0.44$.

Also Rectification line is

$y = \frac{R}{R+1}(x - x_D) + x_D$ (∵ it passes through (x_D, x_D))

Using these we find that, to obtain 97% distillate we need $8 - 1 = \boxed{7}$ trays. (∵ last tray is partial reboiler)

a) Yes it is possible. (Because we have 7 trays in rectification.)

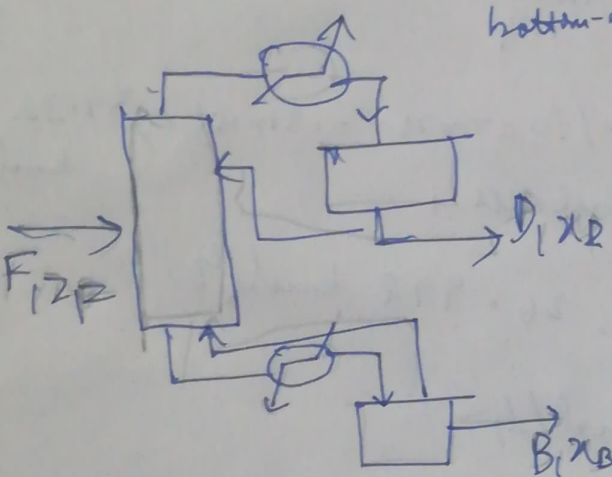
No. of theoretical trays $= \frac{\text{Actual}}{\text{Eo}} = \frac{14}{\text{Eo}} \times \frac{1}{2} = \boxed{7}$

(Also note that the last stage is very small.

~~So there could be~~ a ~~lot~~ few

So, it could be that even 6 trays would be enough to achieve required purity.

b) From graph, Bottoms composition can be obtained as $x_B \approx 0.25$ (x-coordinate of ~~the last~~ bottom-most point on the curve)



~~Using~~ Material balance:

$$F = B + D \quad \text{---} (1)$$

$$F z_F = B x_B + D x_D \quad \text{---} (2)$$

$$\Rightarrow B = D = \frac{F(z_F - x_B)}{(x_D - x_B)}$$

$\Rightarrow D =$ ~~44.7 kmol/h~~.

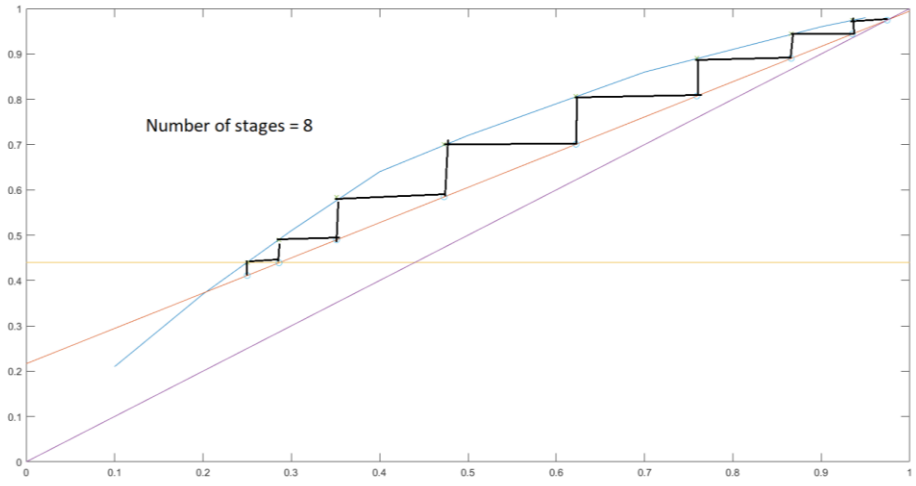
$$\Rightarrow D = \boxed{41.25 \text{ kmol/h}}.$$

c) From part (b) we infer that

$$x_{residue} = \boxed{x_B = 0.25}$$

Question 1

```
clear; close all;
F = 158.21;
xD = 0.9745;
R = 3.5;
m = R/(R+1);
yeqbm = [0.21 0.37 0.51 0.64 0.72 0.79 0.86 0.91 0.96 0.98];
xeqbm = [0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 0.95];
pp = spline(yeqbm,xeqbm);
fun = @(x)(m*(x-xD)+xD);
y = xD;
zF = 0.43;
xcoords = zeros(1,7);
ycoords = zeros(1,7);
xcoords2 = zeros(1,8);
ycoords2 = zeros(1,8);
xcoords2(1)= xD;
ycoords2(1) = xD;
i = 0;
while y >= zF
   i = i + 1;
   x = ppval(pp,y);
   xcoords(i) = x;
   xcoords2(i+1)=x;
   ycoords(i) = y;
   y = fun(x);
   ycoords2(i+1) = y;

end
x = linspace(0,1,15);
qline = @(x)(zeros(size(x))+zF);
plot(xeqbm,yeqbm,x,fun(x),x,qline(x),x,x,xcoords,ycoords,'x',xcoords2,ycoords2,'o');
```



② $q = \frac{L - L'}{F} = 1 - \frac{G}{F} \Rightarrow q = 0.7$

$x_D = 0.95$, $z_f = 0.5$, $x_w = 0.005$.
[all in wt by wt]

$M.W_{CS_2} = 76.14$ & $M.W_{CCl_4} = 154$ g mol^{-1}

Converting all compositions to mole fraction,

$x_D = 0.975$, $z_F = \frac{\frac{0.5}{76}}{\frac{0.5}{76} + \frac{0.5}{154}} = 0.67$

$x_w = 0.01$

$F = 4000$ kg/h $= 4000 / (0.67 \times 76 + 0.33 \times 154) = 39.32$ kmol/h.

Using material & species balances,

$D = F\left(\frac{z_F - x_w}{x_D - x_w}\right) = 26.998$ kmol/h

$W = F - D = 12.27$ kmol/h

∴ In kg/h, $D = 26.998 \times (76 \times 0.97 + 0.03 \times 154)$
$= 2115$ kg/h.

a) $W = 12.27 \times (76 \times 0.01 + 154 \times 0.99)$
$= 1880$ kg/h.

b) R_{min} can be obtained as follows:

i) Find intersection between q-line & eqbm curve

ii) Join that point with the distillate point (x_D, x_D)

iii) Slope of that line $= \frac{x_D R_{min}}{R_{min} + 1}$

& $R_{min} = 0.9070$

c) For min no. of theoritical trays,

$x = y$ line is the operating line

($R \longrightarrow \infty$)

the number of trays = 8 (obtained from graph)

(& N stages = 8; includes a partial reboiler)

d) $R = 2 R_{min} = 1.814$

Use this to get rectification line.

Stripping line will be the line joining the bottoms point to the point of intersection of q-line & stripping line.

Graphs are plot & number of theoritical trays = stages = 12

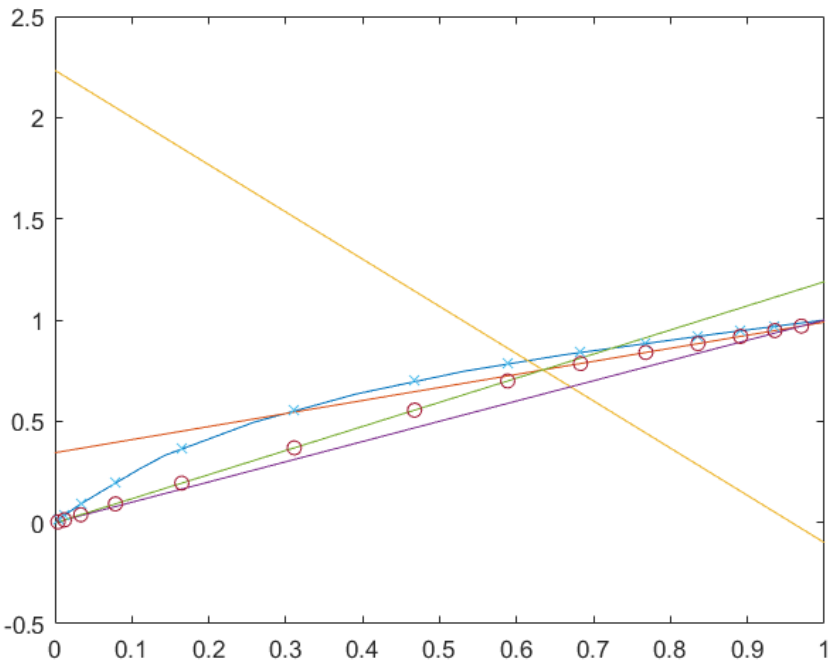
e) Optimum feed location is at the transition stage = tray no. 6

Question 2

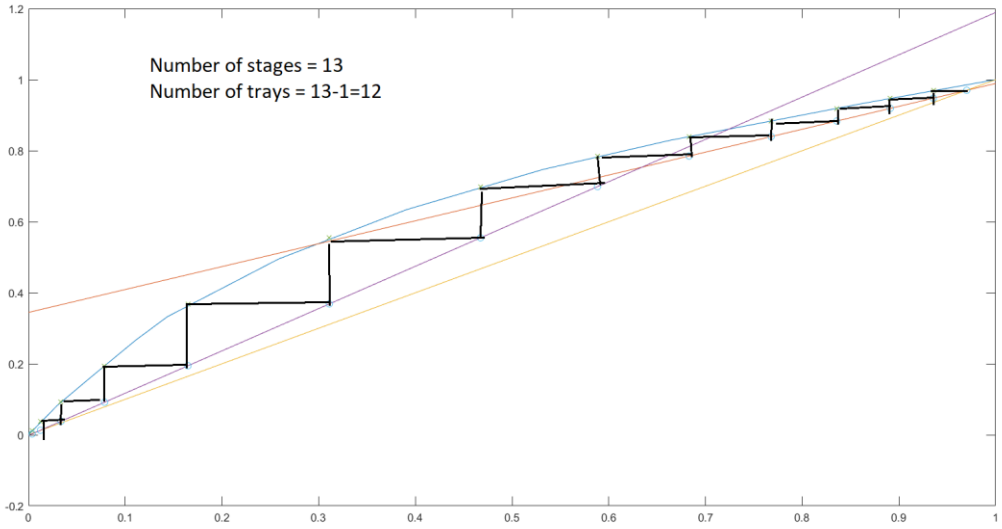
```
close all;clear;
xD = 0.97;
xW = 0.01;
zF = 0.67;
q = 0.7;
qline = @(x)(q/(q-1).*(x-zF) + zF);
xeqbm = [0,0.0296,0.0615,0.1106,0.1435,0.2585,0.3908,0.5318,0.663,0.7574,0.8604,1];
yeqbm = [0,0.0823,0.1555,0.266,0.3325,0.495,0.634,0.747, 0.829, 0.878, 0.932,1];
ec = spline(xeqbm,yeqbm);
%finding intersection of eqbm curve and q line
fun = @(x)(qline(x)-ppval(ec,x));
x_int = fsolve(fun,1);
m_min = (qline(x_int)-xD)/(x_int-xD);
ycept = (qline(x_int)-xD)/(x_int-xD)*(-xD) + xD;
R_min = (xD/ycept)-1;
R = 2*R_min;
R_OL = @(x)(R/(R+1)*(x-xD)+xD);
fun2 = @(x)(qline(x)-R_OL(x));
xint = fsolve(fun2,0);
yint = qline(xint);
pp = spline(yeqbm,xeqbm);
i = 0;
y = xD;
S_OL = @(x)((yint-xW)/(xint-xW)*(x-xW) + xW);
xcoords = zeros(1,13);
ycoords = zeros(1,13);
xcoords2 = zeros(1,14);
ycoords2 = zeros(1,14);
xcoords2(1)= xD;
ycoords2(1) = xD;
%Last stage wont be a tray but is the partial reboiler
while y>=xW
   i = i + 1;
   x = ppval(pp,y);
   xcoords(i) = x;
   xcoords2(i+1)=x;
   ycoords(i) = y;
   if x >= xint
      y = R_OL(x);
   else
      y = S_OL(x);
   end
   ycoords2(i+1) = y;

end
x = linspace(0,1,15);
N_actual = i-1;
figure();
plot(xeqbm,yeqbm,x,R_OL(x),x,qline(x),x,x,x,S_OL(x),xcoords,ycoords,'x',xcoords2,ycoords2,'o');
figure();
plot(xeqbm,yeqbm,x,R_OL(x),x,x,x,S_OL(x),xcoords,ycoords,'x',xcoords2,ycoords2,'o');
```

```
figure();
%Min number of trays => R->infinity
xcoords = zeros(1,7);
ycoords = zeros(1,7);
xcoords2 = zeros(1,8);
ycoords2 = zeros(1,8);
y = xD;
xcoords2(1)= xD;
ycoords2(1) = xD;
i = 0;
while y>=xW
   i = i + 1;
   x = ppval(pp,y);
   xcoords(i) = x;
   xcoords2(i+1)=x;
   ycoords(i) = y;
   y = x;
   ycoords2(i+1) = y;
end
N_th = i-1;
plot(xeqbm,yeqbm,xeqbm,xeqbm,xcoords,ycoords,'x',xcoords2,ycoords2,'o');
```

Plot of q-line, Rectification line and Stripping line



Theoretical number of trays plot (last tray which is the partial reboiler is not drawn)



Minimum number of trays (last tray which is the partial reboiler is not drawn)