(1) The given data is,

x	0	0.059	0.145	0.257	0.398	0.594	0.867	1
y^*	0	0.271	0.521	0.701	0.831	0.925	0.984	1
$\frac{1}{y^* - x}$	∞	4.72	2.66	2.24	2.28	3.02	8.55	∞

Feed = 100 mol

$x_F = 0.6$

Distillate = 40 mol

Residue = 60 mol

a) Differential Distillate : $\ln \frac{F}{W} = \int_{x_W}^{x_F} \frac{dx}{y^* - x}$

$$\ln \frac{100}{60} = \int_{x_W}^{0.6} \frac{dx}{y^* - x} = 0.511$$

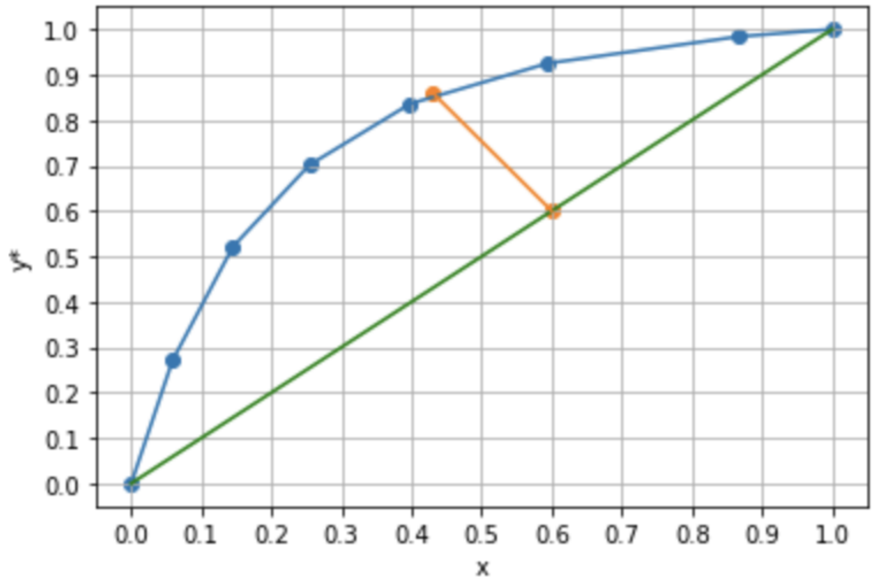
We need to find x_W such that area under the curve of $\frac{1}{y^* - x}$ vs x is 0.511

For $x_W = 0.398$, Area $= \frac{1}{2}(0.2)(2.28 + 3.2) = 0.53$

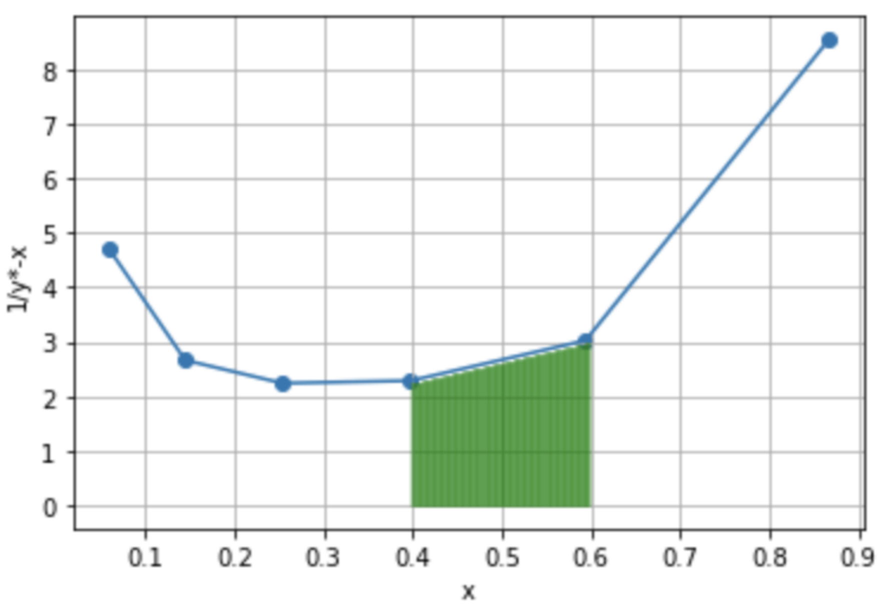
$x_W \approx 0.4$

$F x_F = D y_D + W x_W$

$\Rightarrow 60 = 40 y_D + 0.4 \times 60 \Rightarrow y_D = 0.9$


y*
x
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

x


1/y*-x
x
0
1
2
3
4
5
6
7
8
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

b) Plotting x vs y^*

Flash Distillation, $-\frac{W}{D} = -\frac{60}{40} = -\frac{3}{2} = \frac{y_D - z_F}{x_w - z_F}$

At $x = z_F = 0.6$, line of slope $-3/2$ is drawn and where it intersects the curve is the point x_w and corresponding y_D.

From graph, $x_w = 0.43$, $y_D = 0.86$

② Feed Basis = 100 mol

$z_F = 0.6$, $F = 100$, $P_T = 760$ mm of Hg

$W = 50$, $D = 50$

T (°C)	90.4	105	110	120	125.6
P_A (mm Hg)	760	940	1200	1350	1540
P_B (mm Hg)	333	417	561	650	760
x_A $\left(\frac{P_T - P_A}{P_A - P_B}\right)$	1	0.656	0.311	0.157	0
y_A $\left(\frac{P_A x_A}{P_T}\right)$	1	0.811	0.491	0.299	0
$\frac{1}{y_A - x_A}$	∞	6.452	5.556	8.197	∞

$-\frac{W}{D} = -\frac{50}{50} = -1$

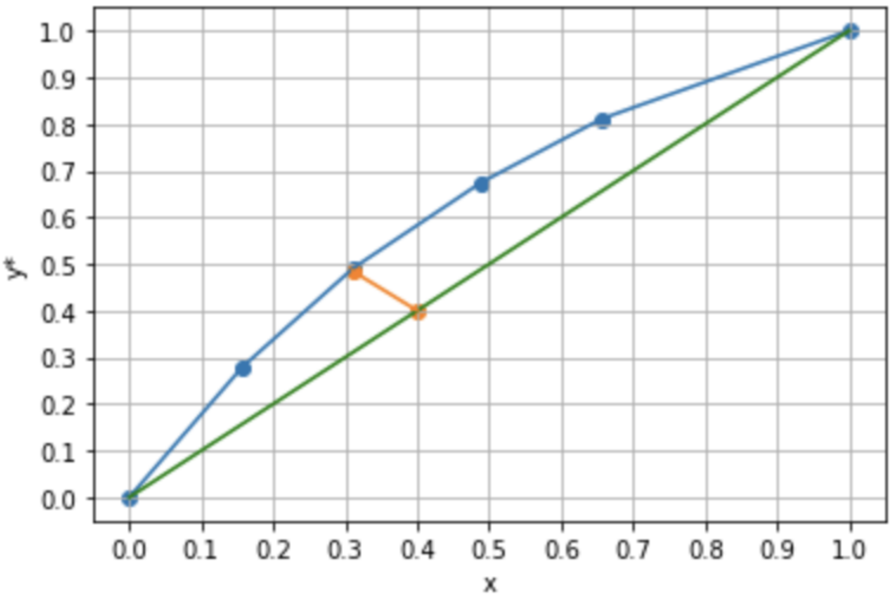
Flash Distillation,

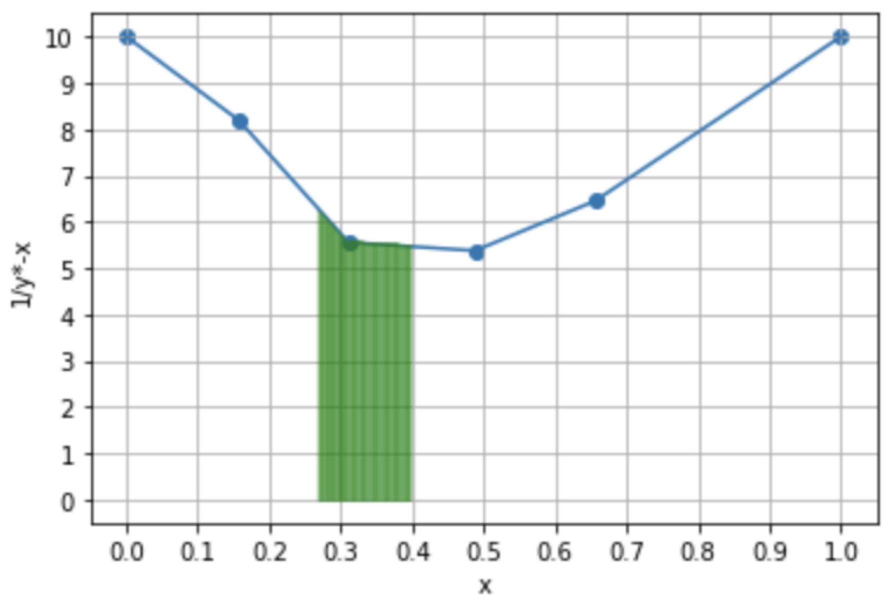
From x vs y^*, $x_w = 0.31$, $y_D = 0.48$

Differential Distillation,

$$\ln \frac{F}{W} = \ln 2 = 0.693 = \int_{x_w}^{0.4} \frac{dx}{y^* - x}$$

Area is 0.693 at approx, $x_w = 0.27$


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
y*
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
x


10
9
8
7
6
5
4
3
2
1
0
1/y*-x
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
x

$$W x_W + D y_D = F z_F$$

$$50 \times 0.27 + 50 y_D = 100 \times 0.4$$

$$\therefore \; y_D = 0.53$$

(3) Basis : 100 mole of Feed

$D = 60$ mol

$W = 40$ mol

$\alpha = 2.16$ (Relative volatility)

$x_F = 0.5$

$$\log\left(\frac{F x_F}{W x_W}\right) = \alpha \log\left(\frac{F}{W} \frac{(1-x_F)}{(1-x_W)}\right)$$

$$\frac{100 \times 0.5}{40 x_W} = \left[\frac{100}{40} \frac{(1-0.5)}{(1-x_W)}\right]^{2.16}$$

$$\frac{1.25}{x_W} = \frac{1}{(4(1-x_W))^{2.16}}$$

$$\therefore \; x_W = 0.33$$

$$y_D D + W x_W = F x_F$$

$$60 y_D + 40 \times 0.33 = 100 \times 0.5$$

$$\Rightarrow y_D = 0.6133$$

(5)

Ideal soln: 10% methanol (A)
80% ethanol (B)
10% n-propanol (C)

@ 80°C, 1atm → distillation

component	V.P (mm Hg)	$m = P/760$	z_F
A	1302	1.713	0.1
B	784	1.036	0.8
C	364	0.479	0.1

Now, WKT,

$$y_D^* = \frac{z_F\,(1+W/D)}{1+\frac{1}{m}\left(\frac{W}{D}\right)} \quad -(1)$$

Also $\Sigma y_D^* = 1$ -(2)

So $(y_D^*)_A + (y_D^*)_B + (y_D^*)_C = 1$

$$\left(1+\frac{W}{D}\right)\left[\frac{0.1}{1+\frac{W/D}{1.713}} + \frac{0.8}{1+\frac{W/D}{1.036}} + \frac{0.1}{1+\frac{W/D}{0.479}}\right] = 1$$

Using trail and error method,

$x \approx -1.748$
$x \approx 3.319\times10^{-15}$
$x \approx 0.593$
$x \approx 0$

$W/D = x$

$\Rightarrow x = W/D \approx 0.6$

W/D	y*(A)	y*(B)	y*(C)	Total
0.2	0.107	0.805	0.085	0.997
0.4	0.113	0.808	0.076	0.998
0.6	0.118	0.811	0.071	1.0
0.8	0.123	0.813	0.067	1.003
1.0	0.126	0.814	0.065	1.005
1.2	0.129	0.815	0.063	1.008
1.4	0.132	0.817	0.061	1.01

W/D	x(A)	x(B)	x(C)	Total
0.2	0.063	0.777	0.177	1.016
0.4	0.066	0.78	0.159	1.005
0.6	0.069	0.782	0.148	1.0
0.8	0.072	0.784	0.141	0.997
1.0	0.074	0.786	0.135	0.995
1.2	0.076	0.787	0.131	0.994
1.4	0.077	0.788	0.128	0.993

Table for Q5

component	$y^*_{D_i}$	$x_{D_i} = y^*_{Di}/m_i$
A	0.118	0.069
B	0.811	0.783
C	0.071	0.148
	$\Sigma y^*_D = 1$	$\Sigma x_D = 1$

From material balance

For A $\Rightarrow$ $0.1 \times 100 = (D \times 0.118) + (W \times 0.069)$ — ①

For B $\rightarrow$ $0.8 \times 100 = (D \times 0.811) + (W \times 0.783)$ — ②

On solving, $D = 62.5\%$, $W = 37.5\%$ } $W/D = 0.6$

$D = 62.5\%$

$x_{AW} = 0.069$

$x_{BW} = 0.783$

$x_{CW} = 0.148$

$W = 37.5\%$

$y_{AD} = 0.118$

$y_{BD} = 0.811$

$y_{CD} = 0.071$