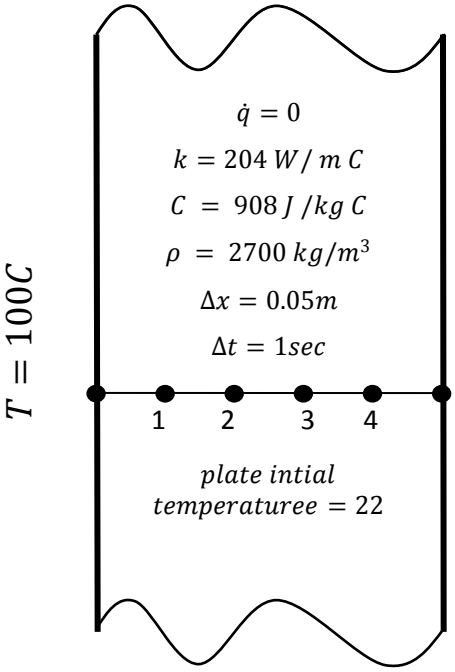
Sheet seven

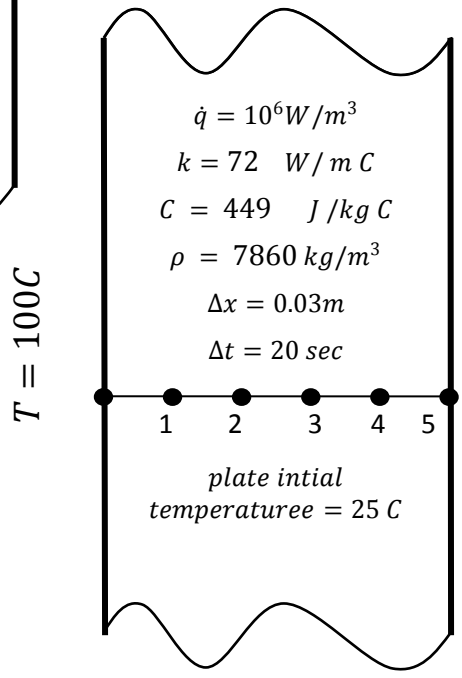
1) Explicit method

1) A thin plate is subjected to boundary conditions as shown in the following problems where the plate is large relative to its thickness (one dimension unsteady state)
Use the explicit method to determine

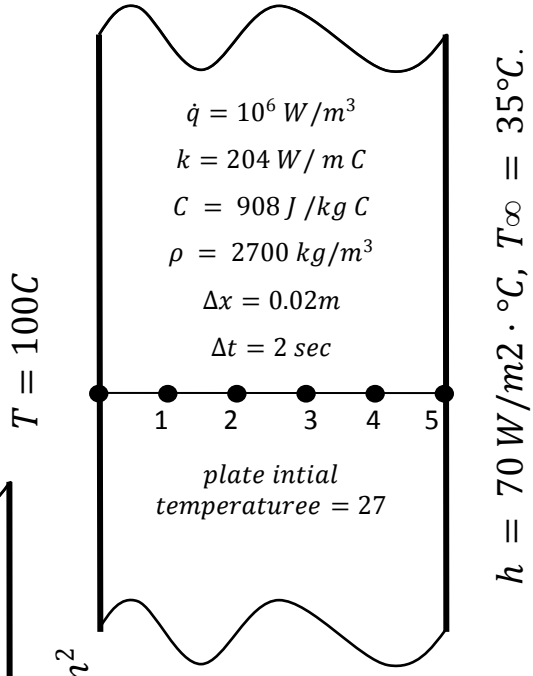
a) The nodal finite-difference equations
b) The nodal temperatures after two time steps (i.e. at $t = 2\Delta t$)



Problem 1.a



Problem 1.c

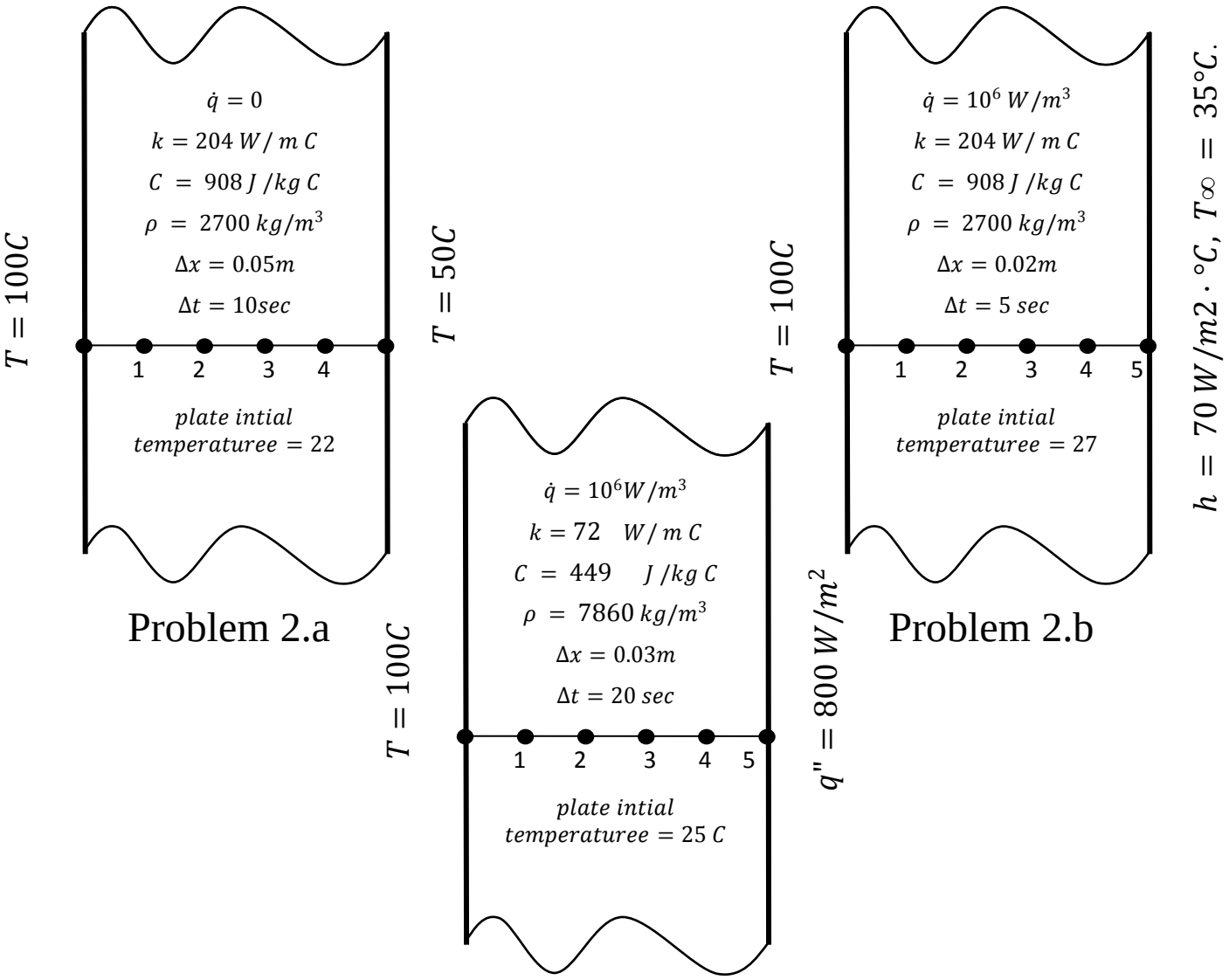


Problem 1.b

2)Implicit method

2) A thin plate is subjected to boundary conditions as shown in the following problems where the plate is large relative to its thickness (one dimension unsteady state)
Use the implicit method to determine

a) The nodal finite-difference equations
b) The nodal temperature after two time steps (i.e. at $t = 2\Delta t$) using Gauss-Seidel Iteration with relative error of $(2.a\ \varepsilon = 0.001,\quad 2.b\ \varepsilon = 0.005,\ and\ 2.c\ \ \varepsilon = 0.005,)$.



Problem 2.a

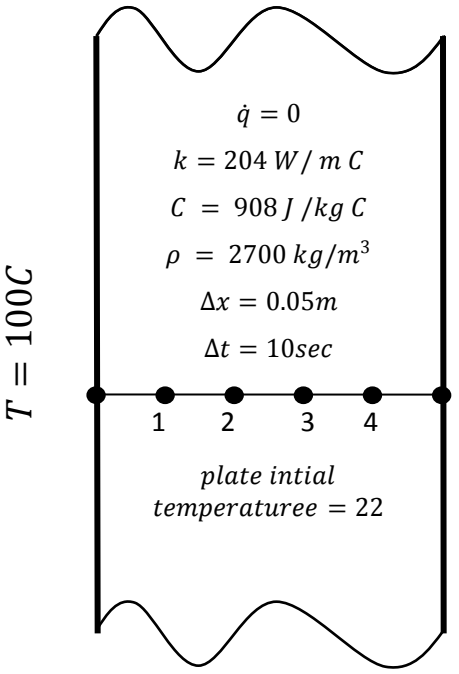
Problem 2.b

Problem 2.c

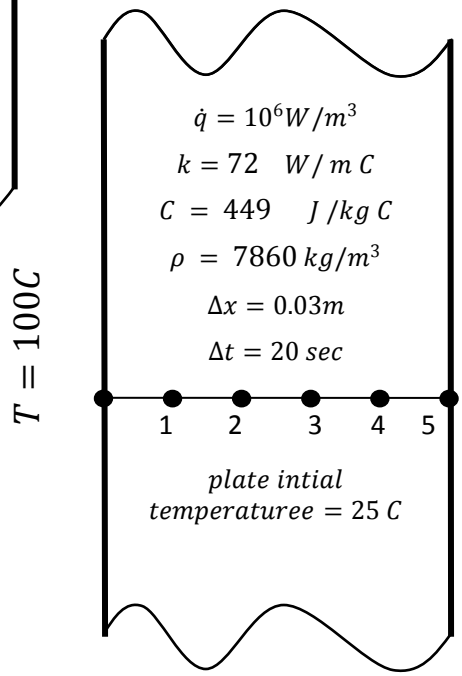
3)Crank-Nicolson method

3) A thin plate is subjected to boundary conditions as shown in the following problems where the plate is large relative to its thickness (one dimension unsteady state)
Use the Crank-Nicolson method to determine

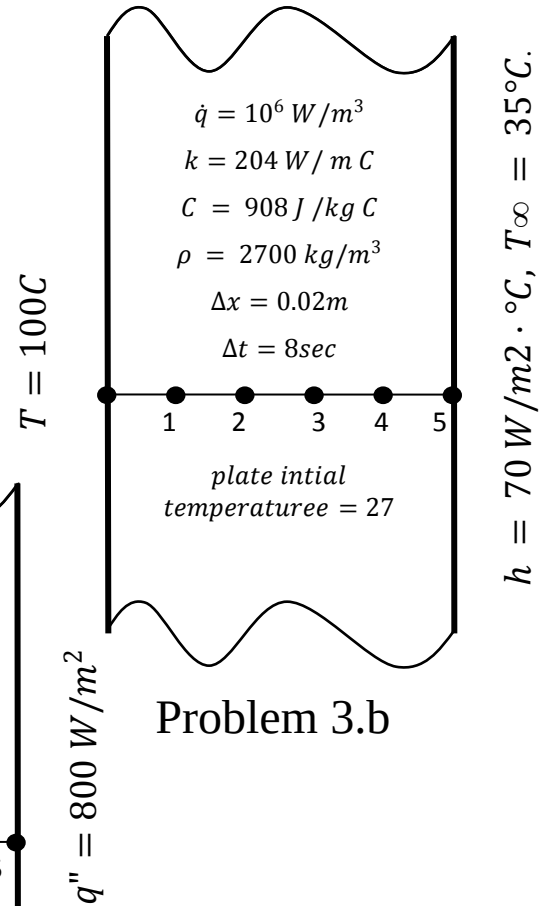
a) The nodal finite-difference equations
b) The nodal temperature after two time steps (i.e. at $t = 2\Delta t$) using Gauss-Seidel Iteration with relative error of ($3.a\ \varepsilon = 0.001,\quad 3.b\ \varepsilon = ,0.005\ \ and\ 3.c\ \ \varepsilon = 0.001$).



Problem 3.a



Problem 3.c



Problem 3.b

1.a

$T_1^0 = T_2^0 = T_3^0 = T_4^0 = 22$

$$\alpha = \frac{k}{\rho * c} = \frac{204}{2700 \times 908} = 8.3211 \times 10^{-5} m^{2/s}$$
$$\lambda = \frac{\alpha \Delta t}{\Delta x^2} = \frac{8.3211 \times 10^{-5} \times 1}{0.05^2} = 0.0332844 < 0.5$$
$$\frac{1}{\lambda} = 30.04$$

$a)$ *The nodal finite − difference equations*

Node 1

$$k\frac{100 - T_1^i}{\Delta x} + k\frac{T_2^i - T_1^i}{\Delta x} = \rho\, \Delta x\, c\frac{T_1^{i+1} - T_1^i}{\Delta t} \qquad \times \frac{\Delta x}{k}$$
$$100 - T_1^i + T_2^i - T_1^i = \frac{1}{\lambda}T_1^{i+1} - \frac{1}{\lambda}T_1^i$$
$$(30.04 - 1 - 1)T_1^i + 100 + T_2^i = 30.04\ T_1^{i+1}$$
$$T_1^{i+1} = 3.33 + 0.93T_1^i + 0.03T_2^i$$

Node 2

$$k\frac{T_1^i - T_2^i}{\Delta x} + k\frac{T_3^i - T_2^i}{\Delta x} = \rho\, \Delta x\, c\frac{T_2^{i+1} - T_2^i}{\Delta t} \qquad \times \frac{\Delta x}{k}$$
$$T_1^i - T_2^i + T_3^i - T_2^i = \frac{1}{\lambda}T_2^{i+1} - \frac{1}{\lambda}T_2^i$$
$$(30.04 - 1 - 1)T_2^i + T_1^i + T_3^i = 30.04\ T_2^{i+1}$$
$$T_2^{i+1} = 0.93T_2^i + 0.03T_1^i + 0.03T_3^i$$

Node 3

$$k\frac{T_2^i - T_3^i}{\Delta x} + k\frac{T_4^i - T_3^i}{\Delta x} = \rho\, \Delta x\, c\frac{T_3^{i+1} - T_3^i}{\Delta t} \qquad \times \frac{\Delta x}{k}$$
$$T_2^i - T_3^i + T_4^i - T_3^i = \frac{1}{\lambda}T_3^{i+1} - \frac{1}{\lambda}T_3^i$$
$$(30.04 - 1 - 1)T_3^i + T_2^i + T_4^i = 30.04\ T_3^{i+1}$$
$$T_3^{i+1} = 0.93T_3^i + 0.03T_2^i + 0.03T_4^i$$

Node 4

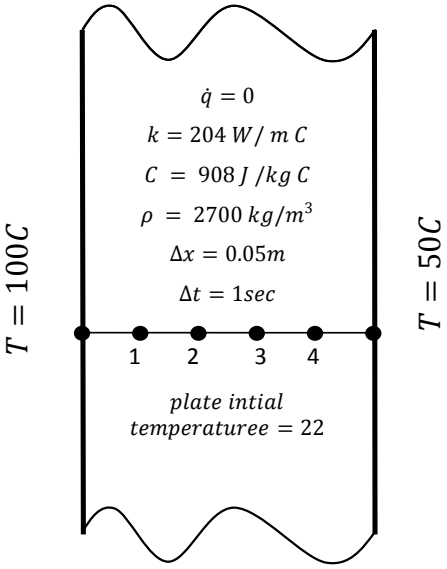
$$k\frac{T_3^i - T_4^i}{\Delta x} + k\frac{50 - T_4^i}{\Delta x} = \rho\, \Delta x\, c\frac{T_4^{i+1} - T_4^i}{\Delta t} \qquad \times \frac{\Delta x}{k}$$
$$T_3^i - T_4^i + 50 - T_4^i = \frac{1}{\lambda}T_4^{i+1} - \frac{1}{\lambda}T_4^i$$
$$(30.04 - 1 - 1)T_4^i + T_3^i + 50 = 30.04\ T_4^{i+1}$$
$$T_4^{i+1} = 1.66 + 0.93T_4^i + 0.03T_3^i +$$

$b)$ *The nodal temperature*

$$T_1^{i+1} = 3.33 + 0.93T_1^i + 0.03T_2^i$$
$$T_2^{i+1} = 0.93T_2^i + 0.03T_1^i + 0.03T_3^i$$
$$T_3^{i+1} = 0.93T_3^i + 0.03T_2^i + 0.03T_4^i$$
$$T_4^{i+1} = 1.66 + 0.93T_4^i + 0.03T_3^i +$$

after time $= 1\ sec.$

$$T_1^1 = 3.33 + 0.93T_1^0 + 0.03T_2^0 = 3.33 + 0.93 \times 22 + 0.03 \times 22 = 24.60$$

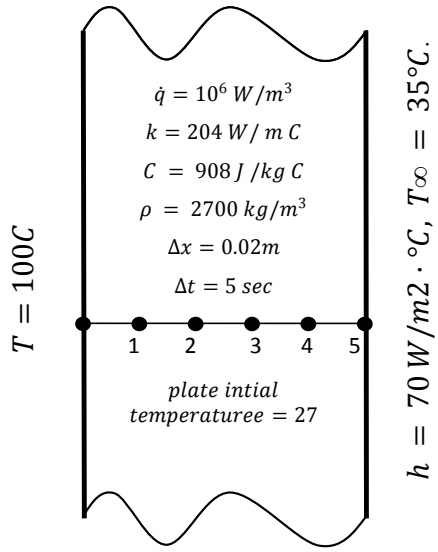


Problem 1.a

$T_2^1 = 0.93T_2^0 + 0.03T_1^0 + 0.03T_3^0 = 0.93 \times 22 + 0.03 \times 22 + 0.03 \times 22 = 22$
$T_3^1 = 0.93T_3^0 + 0.03T_2^0 + 0.03T_4^0 = 0.93 \times 22 + 0.03 \times 22 + 0.03 \times 22 = 22$
$T_4^1 = 1.66 + 0.93T_4^0 + 0.03T_3^0 + = 1.66 + 0.93 \times 22 + 0.03 \times 22 + = 22.93$

$after\ time\ = 2\ sec.$
$T_1^2 = 3.33 + 0.93T_1^1 + 0.03T_2^1 = 3.33 + 0.93 \times 24.60 + 0.03 \times 22 = 27.02$
$T_2^2 = 0.93T_2^1 + 0.03T_1^1 + 0.03T_3^1 = 0.93 \times 22 + 0.03 \times 24.60 + 0.03 \times 22 = 22.09$
$T_3^2 = 0.93T_3^1 + 0.03T_2^1 + 0.03T_4^1 = 0.93 \times 22 + 0.03 \times 22 + 0.03 \times 22.93 = 22.03$
$T_4^2 = 1.66 + 0.93T_4^1 + 0.03T_3^1 + = 1.66 + 0.93 \times 22.93 + 0.03 \times 22 + = 23.80$

2.b



Problem 2.b

$T_1^0 = T_2^0 = T_3^0 = T_4^0 = T_5^0 = 27$

$\alpha = \frac{k}{\rho * c} = \frac{204}{2700 \times 908} = 8.3211e-005 \frac{m^2}{s}$

$\lambda = \frac{\alpha \Delta t}{\Delta x^2} = \frac{8.3211e-005 \times 5}{0.02^2} = 1.04014$

$\frac{1}{\lambda} = 0.961$

$a)\ The\ nodal\ finite\ -\ difference\ equations$

$Node\ 1$

$\dot{q}\Delta x + k\frac{100 - T_1^{i+1}}{\Delta x} + k\frac{T_2^{i+1} - T_1^{i+1}}{\Delta x} = \rho\,\Delta x\, c\frac{T_1^{i+1} - T_1^i}{\Delta t} \quad \times \frac{\Delta x}{k}$

$\frac{\dot{q}\Delta x^2}{k} + 100 - T_1^{i+1} + T_2^{i+1} - T_1^{i+1} = \frac{1}{\lambda}T_1^{i+1} - \frac{1}{\lambda}T_1^i$

$\frac{1000000 \times 0.020^2}{204} + 0.961\,T_1^i + 100 + T_2^{i+1} = (1 + 1 + 0.961)\,T_1^{i+1}$

$T_1^{i+1} = 34.430 + 0.325T_1^i + 0.338T_2^{i+1}$

$Node\ 2$

$\dot{q}\Delta x + k\frac{T_1^{i+1} - T_2^{i+1}}{\Delta x} + k\frac{T_3^{i+1} - T_2^{i+1}}{\Delta x} = \rho\,\Delta x\, c\frac{T_2^{i+1} - T_2^i}{\Delta t} \quad \times \frac{\Delta x}{k}$

$\frac{\dot{q}\Delta x^2}{k} + T_1^{i+1} - T_2^{i+1} + T_3^{i+1} - T_2^{i+1} = \frac{1}{\lambda}T_2^{i+1} - \frac{1}{\lambda}T_2^i$

$\frac{1000000 \times 0.020^2}{204} + 0.961\,T_2^i + T_1^{i+1} + T_3^{i+1} = (1 + 1 + 0.961)\,T_2^{i+1}$

$T_2^{i+1} = 0.662 + 0.325T_2^i + 0.338T_1^{i+1} + 0.338T_3^{i+1}$

$Node\ 3$

$\dot{q}\Delta x + k\frac{T_2^{i+1} - T_3^{i+1}}{\Delta x} + k\frac{T_4^{i+1} - T_3^{i+1}}{\Delta x} = \rho\,\Delta x\, c\frac{T_3^{i+1} - T_3^i}{\Delta t} \quad \times \frac{\Delta x}{k}$

$\frac{\dot{q}\Delta x^2}{k} + T_2^{i+1} - T_3^{i+1} + T_4^{i+1} - T_3^{i+1} = \frac{1}{\lambda}T_3^{i+1} - \frac{1}{\lambda}T_3^i$

$\frac{1000000 \times 0.020^2}{204} + 0.961\,T_3^i + T_2^{i+1} + T_4^{i+1} = (1 + 1 + 0.961)\,T_3^{i+1}$

$T_3^{i+1} = 0.662 + 0.325T_3^i + 0.338T_2^{i+1} + 0.338T_4^{i+1}$

$Node\ 4$

$\dot{q}\Delta x + k\frac{T_3^{i+1} - T_4^{i+1}}{\Delta x} + k\frac{T_5^{i+1} - T_4^{i+1}}{\Delta x} = \rho\,\Delta x\, c\frac{T_4^{i+1} - T_4^i}{\Delta t} \quad \times \frac{\Delta x}{k}$

$\frac{\dot{q}\Delta x^2}{k} + T_3^{i+1} - T_4^{i+1} + T_5^{i+1} - T_4^{i+1} = \frac{1}{\lambda}T_4^{i+1} - \frac{1}{\lambda}T_4^i$

$\frac{1000000 \times 0.020^2}{204} + 0.961\,T_4^i + T_3^{i+1} + T_5^{i+1} = (1 + 1 + 0.961)\,T_4^{i+1}$

$T_4^{i+1} = 0.662 + 0.325T_4^i + 0.338T_3^{i+1} + 0.338T_5^{i+1}$

$Node\ 5$

$\frac{\dot{q}\Delta x}{2} + h\left(T_{\infty} - T_5^{i+1}\right) + k\frac{T_4^{i+1} - T_5^{i+1}}{\Delta x} = \rho\frac{\Delta x}{2}\, c\frac{T_5^{i+1} - T_5^i}{\Delta t} \quad \times \frac{2\Delta x}{k}$

$$\frac{\dot{q}\Delta x^2}{k}+\frac{2\Delta xhT_\infty}{k}-\frac{2\Delta xh}{k}T_5^{i+1}+2T_4^{i+1}-2T_5^{i+1}=\frac{1}{\lambda}T_5^{i+1}-\frac{1}{\lambda}T_5^{i}$$

$$\frac{1000000\times 0.020^2}{204}+\frac{2\times 0.020\times 70\times 35}{204}+0.961\,T_5^i+\,2T_4^{i+1}=\left(2\,+\frac{1}{1.040}+\frac{2\times 0.020\times 70}{204}\right)T_5^{i+1}$$

$$T_5^{i+1}=0.821+0.323\,T_5^i+0.672T_4^{i+1}$$

b) The nodal temperature using Gauss − Seidel Iteration with relative error of 0.005

$$T_1^{i+1}=34.430+\,0.325T_1^i+0.338T_2^{i+1}$$
$$T_2^{i+1}=0.662+\,0.325T_2^i+0.338T_1^{i+1}+\,0.338T_3^{i+1}$$
$$T_3^{i+1}=0.662+\,0.325T_3^i+0.338T_2^{i+1}+\,0.338T_4^{i+1}$$
$$T_4^{i+1}=0.662+\,0.325T_4^i+0.338T_3^{i+1}+\,0.338T_5^{i+1}$$
$$T_5^{i+1}=0.821+0.323\,T_5^i+0.672T_4^{i+1}$$

after time $=5\,sec.$

$$T_1^1=34.430+\,0.325T_1^0+0.338T_2^1=43.195+\,0.338T_2^1$$
$$T_2^1=0.662+\,0.325T_2^0+0.338T_1^1+\,0.338T_3^1=9.428+\,0.338T_1^1+\,0.338T_3^1$$
$$T_3^1=0.662+\,0.325T_3^0+0.338T_2^1+\,0.338T_4^1=9.428+\,0.338T_2^1+\,0.338T_4^1$$
$$T_4^1=0.662+\,0.325T_4^0+0.338T_3^1+\,0.338T_5^1=9.428+\,0.338T_3^1+\,0.338T_5^1$$
$$T_5^1=0.821+0.323\,T_5^0+0.672T_4^1=9.546+0.672T_4^1$$

$$error\;=\left|\frac{t_{new}\;-\;t_{old}}{t_{old}}\right|$$

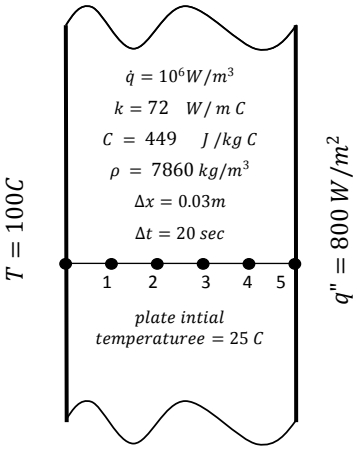
i	0	1	error	2	error	3	error	4	error	5	error
T_1^1	27	52.313	0.9375	55.422	0.0594	56.207	0.0142	56.461	0.0045	56.563	0.0018
T_2^1	27	36.21		38.533		39.284		39.588	0.0077	39.712	0.0031
T_3^1	27	30.772		32.21		32.856		33.121		33.23	0.0033
T_4^1	27	28.936		30.096		30.577		30.776		30.858	0.0027
T_5^1	27	28.997		29.777		30.101		30.234		30.289	0.0018

after time $=10\,sec.$

$$T_1^2=34.430+\,0.325T_1^1+0.338T_2^2=52.793+\,0.338T_2^2$$
$$T_2^2=0.662+\,0.325T_2^1+0.338T_1^2+\,0.338T_3^2=13.554+\,0.338T_1^2+\,0.338T_3^2$$
$$T_3^2=0.662+\,0.325T_3^1+0.338T_2^2+\,0.338T_4^2=11.450+\,0.338T_2^2+\,0.338T_4^2$$
$$T_4^2=0.662+\,0.325T_4^1+0.338T_3^2+\,0.338T_5^2=10.680+\,0.338T_3^2+\,0.338T_5^2$$
$$T_5^2=0.821+0.323\,T_5^1+0.672T_4^2=10.608+0.672T_4^2$$

$$error\;=\left|\frac{t_{new}\;-\;t_{old}}{t_{old}}\right|$$

i	0	1	error	2	error	3	error	4	error	5	error
T_1^2	56.563	66.202	0.1704	68.708	0.0378	69.513	0.0117	69.804	0.0042	69.932	0.0018
T_2^2	39.712	47.13		49.514		50.378		50.757	0.0075	50.916	0.0031
T_3^2	33.23	37.785		39.538		40.367		40.711		40.853	0.0035
T_4^2	30.858	33.667		35.256		35.896		36.158		36.265	0.003
T_5^2	30.289	33.241		34.309		34.739		34.915		34.987	0.0021



Problem 3.c

3c

$T_1^0 = T_2^0 = T_3^0 = T_4^0 = T_5^0 = 25$

$\alpha = \frac{k}{\rho * c} = \frac{72}{7860 \times 449} = 2.04016 \times 10^{-5} \frac{m^2}{s}$

$\lambda = \frac{\alpha \Delta t}{\Delta x^2} = \frac{2.04016 \times 10^{-5} \times 20}{0.03^2} = 0.453368$

$\frac{1}{\lambda} = 2.206 \qquad \frac{2}{\lambda} = 4.411$

$a)\ The\ nodal\ finite\ -\ difference\ equations$

$Node\ 1$

$$\dot{q}\Delta x + k\frac{\frac{(100+100)}{2} - \frac{(T_1^{i+1} + T_1^i)}{2}}{\Delta x} + k\frac{\frac{(T_2^{i+1} + T_2^i)}{2} - \frac{(T_1^{i+1} + T_1^i)}{2}}{\Delta x} = \rho\,\Delta x\, c\frac{T_1^{i+1} - T_1^i}{\Delta t} \qquad \frac{2\Delta x}{k}$$

$$\frac{2\dot{q}\Delta x^2}{k} + 100 + 100 - T_1^{i+1} - T_1^i + T_2^{i+1} + T_2^i - T_1^{i+1} - T_1^i = \frac{2}{\lambda}T_1^{i+1} - \frac{2}{\lambda}T_1^i$$

$$\frac{2 \times 1000000 \times 0.030^2}{72} + (4.411 - 2)T_1^i + 100 + 100 + T_2^{i+1} + T_2^i = (4.411 + 2)\,T_1^{i+1}$$

$$T_1^{i+1} = 35.094 + 0.376T_1^i + 0.156T_2^{i+1} + 0.156T_2^i$$

$Node\ 2$

$$\dot{q}\Delta x + k\frac{\frac{(T_1^{i+1} + T_1^i)}{2} - \frac{(T_2^{i+1} + T_2^i)}{2}}{\Delta x} + k\frac{\frac{(T_3^{i+1} + T_3^i)}{2} - \frac{(T_2^{i+1} + T_2^i)}{2}}{\Delta x} = \rho\,\Delta x\, c\frac{T_2^{i+1} - T_2^i}{\Delta t} \qquad \frac{2\Delta x}{k}$$

$$(2q^{\cdot}\Delta x\hat{}2)/k + (T_1^{i+1} + T_1^i - T_2^{i+1} - T_2^i + T_3^{i+1} + T_3^i - T_2^{i+1} - T_2^i = \frac{2}{\lambda}T_2^{i+1} - \frac{2}{\lambda}T_2^i$$

$$\frac{2 \times 1000000 \times 0.030^2}{72} + (4.411 - 2)T_2^i + T_1^{i+1} + T_1 + T_3^{i+1} + T_3^i = (4.411 + 2)\,T_2^{i+1}$$

$$T_2^{i+1} = 3.899 + 0.376T_2^i + 0.156T_1^{i+1} + 0.156T_1^i + 0.156T_3^{i+1} + 0.156T_3^i$$

$Node\ 3$

$$\dot{q}\Delta x + k\frac{\frac{(T_2^{i+1} + T_2^i)}{2} - \frac{(T_3^{i+1} + T_3^i)}{2}}{\Delta x} + k\frac{\frac{(T_4^{i+1} + T_4^i)}{2} - \frac{(T_3^{i+1} + T_3^i)}{2}}{\Delta x} = \rho\,\Delta x\, c\frac{T_3^{i+1} - T_3^i}{\Delta t} \qquad \frac{2\Delta x}{k}$$

$$(2q^{\cdot}\Delta x\hat{}2)/k + (T_2^{i+1} + T_2^i - T_3^{i+1} - T_3^i + T_4^{i+1} + T_4^i - T_3^{i+1} - T_3^i = \frac{2}{\lambda}T_3^{i+1} - \frac{2}{\lambda}T_3^i$$

$$\frac{2 \times 1000000 \times 0.030^2}{72} + (4.411 - 2)T_3^i + T_2^{i+1} + T_2 + T_4^{i+1} + T_4^i = (4.411 + 2)\,T_3^{i+1}$$

$$T_3^{i+1} = 3.899 + 0.376T_3^i + 0.156T_2^{i+1} + 0.156T_2^i + 0.156T_4^{i+1} + 0.156T_4^i$$

$Node\ 4$

$$\dot{q}\Delta x + k\frac{\frac{(T_3^{i+1} + T_3^i)}{2} - \frac{(T_4^{i+1} + T_4^i)}{2}}{\Delta x} + k\frac{\frac{(T_5^{i+1} + T_5^i)}{2} - \frac{(T_4^{i+1} + T_4^i)}{2}}{\Delta x} = \rho\,\Delta x\, c\frac{T_4^{i+1} - T_4^i}{\Delta t} \qquad \frac{2\Delta x}{k}$$

$$(2q^{\cdot}\Delta x\hat{}2)/k + (T_3^{i+1} + T_3^i - T_4^{i+1} - T_4^i + T_5^{i+1} + T_5^i - T_4^{i+1} - T_4^i = \frac{2}{\lambda}T_4^{i+1} - \frac{2}{\lambda}T_4^i$$

$$\frac{2 \times 1000000 \times 0.030^2}{72} + (4.411 - 2)T_4^i + T_3^{i+1} + T_3 + T_5^{i+1} + T_5^i = (4.411 + 2)\,T_4^{i+1}$$

$$T_4^{i+1} = 3.899 + 0.376T_4^i + 0.156T_3^{i+1} + 0.156T_3^i + 0.156T_5^{i+1} + 0.156T_5^i$$

$Node\ 5$

$$\frac{\dot{q}\Delta x}{2} + q'' + k\frac{\frac{T_4^{i+1}+T_4^i}{2} - \frac{T_5^{i+1}+T_5^i}{2}}{\Delta x} = \rho\,\frac{\Delta x}{2}\,c\frac{T_5^{i+1} - T_5^i}{\Delta t} \quad \times\frac{2\Delta x}{k}$$

$$\frac{\dot{q}\Delta x^2}{k} + \frac{2\Delta x q''}{k} + T_4^{i+1} + T_4^i - T_5^{i+1} - T_5^i = \frac{1}{\lambda}T_5^{i+1} - \frac{1}{\lambda}T_5^i$$

$$\frac{1000000\times 0.030^2}{72} + \frac{2\times 0.030\times 800}{72} + (2.206-1)T_5^i + T_4^{i+1} + T_4^i = (2.206+1)T_5^{i+1}$$

$$T_5^{i+1} = 4.107 + 0.376\,T_5^i + 0.312T_4^{i+1} + 0.312T_4^i$$

b) The nodal temperature using Gauss\u00f9Seidel Iteration with relative error of 0.001

$$T_1^{i+1} = 35.094 + 0.376T_1^i + 0.156T_2^{i+1} + 0.156T_2^i$$
$$T_2^{i+1} = 3.899 + 0.376T_2^i + 0.156T_1^{i+1} + 0.156T_1^i + 0.156T_3^{i+1} + 0.156T_3^i$$
$$T_3^{i+1} = 3.899 + 0.376T_3^i + 0.156T_2^{i+1} + 0.156T_2^i + 0.156T_4^{i+1} + 0.156T_4^i$$
$$T_4^{i+1} = 3.899 + 0.376T_4^i + 0.156T_3^{i+1} + 0.156T_3^i + 0.156T_5^{i+1} + 0.156T_5^i$$
$$T_5^{i+1} = 4.107 + 0.376\,T_5^i + 0.312T_4^{i+1} + 0.312T_4^i$$

after time $= 20\ sec.$

$$T_1^1 = 35.094 + 0.376T_1^0 + 0.156T_2^1 + 0.156T_2^0 = 48.396 + 0.156T_2^1$$
$$T_2^1 = 3.899 + 0.376T_2^0 + 0.156T_1^1 + 0.156T_1^0 + 0.156T_3^1 + 0.156T_3^0 = 21.101 + 0.156T_1^1 + 0.156T_3^1$$
$$T_3^1 = 3.899 + 0.376T_3^0 + 0.156T_2^1 + 0.156T_2^0 + 0.156T_4^1 + 0.156T_4^0 = 21.101 + 0.156T_2^1 + 0.156T_4^1$$
$$T_4^1 = 3.899 + 0.376T_4^0 + 0.156T_3^1 + 0.156T_3^0 + 0.156T_5^1 + 0.156T_5^0 = 21.101 + 0.156T_3^1 + 0.156T_5^1$$
$$T_5^1 = 4.107 + 0.376\,T_5^0 + 0.312T_4^1 + 0.312T_4^0 = 21.309 + 0.312T_4^1$$

$$error = \left|\frac{t_{new} - t_{old}}{t_{old}}\right|$$

i	0	1	error	2	error	3	error	4	error
T_1^1	25	52.295	1.0918	53.567	0.0243	53.724	0.0029	53.749	0.0005
T_2^1	25	33.157		34.162		34.325		34.357	0.0009
T_3^1	25	30.171		31.062		31.245		31.262	0.0005
T_4^1	25	29.706		30.714		30.792		30.798	0.0002
T_5^1	25	30.575		30.89		30.914		30.916	0.0001

after time $= 40\ sec.$

$$T_1^2 = 35.094 + 0.376T_1^1 + 0.156T_2^2 + 0.156T_2^1 = 60.668 + 0.156T_2^2$$
$$T_2^2 = 3.899 + 0.376T_2^1 + 0.156T_1^2 + 0.156T_1^1 + 0.156T_3^2 + 0.156T_3^1 = 30.081 + 0.156T_1^2 + 0.156T_3^2$$
$$T_3^2 = 3.899 + 0.376T_3^1 + 0.156T_2^2 + 0.156T_2^1 + 0.156T_4^2 + 0.156T_4^1 = 25.820 + 0.156T_2^2 + 0.156T_4^2$$
$$T_4^2 = 3.899 + 0.376T_4^1 + 0.156T_3^2 + 0.156T_3^1 + 0.156T_5^2 + 0.156T_5^1 = 25.181 + 0.156T_3^2 + 0.156T_5^2$$
$$T_5^2 = 4.107 + 0.376\,T_5^1 + 0.312T_4^2 + 0.312T_4^1 = 25.343 + 0.312T_4^2$$

$$error = \left|\frac{t_{new} - t_{old}}{t_{old}}\right|$$

i	0	1	error	2	error	3	error	4	error
T_1^2	53.749	66.027	0.2284	67.727	0.0257	67.924	0.0029	67.953	0.0004
T_2^2	34.357	45.255		46.522		46.707		46.741	0.0007
T_3^2	31.262	37.682		38.672		38.862		38.88	0.0005
T_4^2	30.798	35.88		36.911		36.991		36.998	0.0002
T_5^2	30.916	36.535		36.857		36.882		36.884	0.0001

1 - السؤال 1.a,2.b,3.c محلولين حل نموذجى (مرفق مع الشيت)
2 - السؤال 1.b,2c,3a سيتم شرحهم فى السكشن
3 - السؤال 1c,2a,3bسيحلهم الطالب ويقدمهم فى تقرير منظم فى الموعد الذى سيحدده المعيد
4 - فى حالة تقديم التقرير بعد الموعد المحدد فلن يقبل منه مهما كانت الاعذار ولن توضع له درجة