**MEEN 673**

**Homework 3**

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**Problem 1:**

Boundary conditions:



Box1.1 Input file for 4×4 linear elements.

4 2 1 1 1 0 2 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

4 4 NX, NY

0.0 0.045 0.045 0.045 0.045 X0, (DX(I), I=1,NX)

0.0 0.025 0.025 0.025 0.025 Y0, (DY(I), I=1,NY)

10 NSPV and next lines ISPV, VSPV

1 1 6 1 11 1 16 1 21 1 5 1 10 1 15 1 20 1 25 1

500.0 500.0 500.0 500.0 500.0 300.0 300.0 300.0 300.0 300.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-4 0.0 0.0 4.0E-4 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 GLU(I)

Box1.2 Input file for 2×2 quadratic elements.

9 3 2 1 1 0 2 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

2 2 NX, NY

0.0 0.09 0.09 X0, (DX(I), I=1,NX)

0.0 0.05 0.05 Y0, (DY(I), I=1,NY)

10 NSPV and next lines ISPV, VSPV

1 1 6 1 11 1 16 1 21 1 5 1 10 1 15 1 20 1 25 1

500.0 500.0 500.0 500.0 500.0 300.0 300.0 300.0 300.0 300.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-4 0.0 0.0 4.0E-4 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 GLU(I)

Box1.3 Input file for 8×8 linear elements.

4 2 1 1 1 0 2 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

8 8 NX, NY

0.0 0.0225 0.0225 0.0225 0.0225 0.0225 0.0225 0.0225 0.0225 X0, (DX(I), I=1,NX)

0.0 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 Y0, (DY(I), I=1,NY)

18 NSPV and next lines ISPV, VSPV

1 1 10 1 19 1 28 1 37 1 46 1 55 1 64 1 73 1

9 1 18 1 27 1 36 1 45 1 54 1 63 1 72 1 81 1

500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0

300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-4 0.0 0.0 4.0E-4 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 GLU(I)

Box1.4 Input file for 4×4 quadratic elements.

9 3 2 1 1 0 2 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

4 4 NX, NY

0.0 0.045 0.045 0.045 0.045 X0, (DX(I), I=1,NX)

0.0 0.025 0.025 0.025 0.025 Y0, (DY(I), I=1,NY)

18 NSPV and next lines ISPV, VSPV

1 1 10 1 19 1 28 1 37 1 46 1 55 1 64 1 73 1

9 1 18 1 27 1 36 1 45 1 54 1 63 1 72 1 81 1

500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0

300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-4 0.0 0.0 4.0E-4 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 GLU(I)

The numerical results of Problem 1 are given in Table 1.1. Both direct iteration and Newton iteration give essentially the same results. Note that the solution is independent of the mesh in the y-direction.

Table 1.1. Numerical results of Problem 1 (Primary variable).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| X(m) | Linear | Direct Iteration | | | | Newton Iteration | | | |
| 4×4L4 | 2×2Q9 | 8×8L4 | 4×4Q9 | 4×4L4 | 2×2Q9 | 8×8L4 | 4×4Q9 |
| 0.0000 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0225 | 475.00 | - | - | 477.24 | 477.24 | - | - | 477.24 | 477.24 |
| 0.0450 | 450.00 | 453.94 | 453.94 | 453.94 | 453.94 | 453.94 | 453.94 | 453.94 | 453.94 |
| 0.0675 | 425.00 | - | - | 430.06 | 430.06 | - | - | 430.05 | 430.05 |
| 0.0900 | 400.00 | 405.54 | 405.54 | 405.54 | 405.54 | 405.54 | 405.54 | 405.54 | 405.54 |
| 0.1125 | 375.00 | - | - | 380.35 | 380.35 | - | - | 380.34 | 380.34 |
| 0.1350 | 350.00 | 354.40 | 354.40 | 354.40 | 354.40 | 354.40 | 354.40 | 354.40 | 354.40 |
| 0.1575 | 325.00 | - | - | 327.65 | 327.65 | - | - | 327.65 | 327.65 |
| 0.1800 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 |

Table 1.2. Numerical results of Problem 1 (Secondary variable, 4×4 linear elements).

The orientation of gradient vector is measured from the positive x-axis

x-coord. y-coord. -a11(du/dx) -a22(du/dy) Flux Mgntd Orientation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

0.2250E-01 0.1250E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.6750E-01 0.1250E-01 0.4000E+03 -0.6765E-12 0.4000E+03 -0.00

0.1125E+00 0.1250E-01 0.4000E+03 -0.3201E-12 0.4000E+03 -0.00

0.1575E+00 0.1250E-01 0.4000E+03 -0.3009E-12 0.4000E+03 -0.00

0.2250E-01 0.3750E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.6750E-01 0.3750E-01 0.4000E+03 0.6765E-12 0.4000E+03 0.00

0.1125E+00 0.3750E-01 0.4000E+03 -0.3201E-12 0.4000E+03 -0.00

0.1575E+00 0.3750E-01 0.4000E+03 -0.3009E-12 0.4000E+03 -0.00

0.2250E-01 0.6250E-01 0.4000E+03 -0.7108E-12 0.4000E+03 -0.00

0.6750E-01 0.6250E-01 0.4000E+03 -0.6765E-12 0.4000E+03 -0.00

0.1125E+00 0.6250E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.1575E+00 0.6250E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.2250E-01 0.8750E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.6750E-01 0.8750E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.1125E+00 0.8750E-01 0.4000E+03 -0.6403E-12 0.4000E+03 -0.00

0.1575E+00 0.8750E-01 0.4000E+03 -0.3009E-12 0.4000E+03 -0.00

Table 1.3. Numerical results of Problem 1 (Secondary variable, 2×2 quadratic elements).

The orientation of gradient vector is measured from the positive x-axis

x-coord. y-coord. -a11(du/dx) -a22(du/dy) Flux Mgntd Orientation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

0.1902E-01 0.1057E-01 0.4000E+03 0.1427E-11 0.4000E+03 0.00

0.1902E-01 0.3943E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.7098E-01 0.1057E-01 0.4000E+03 0.1348E-11 0.4000E+03 0.00

0.7098E-01 0.3943E-01 0.4000E+03 0.1348E-11 0.4000E+03 0.00

0.1090E+00 0.1057E-01 0.4000E+03 0.0000E+00 0.4000E+03 0.00

0.1090E+00 0.3943E-01 0.4000E+03 0.6434E-12 0.4000E+03 0.00

0.1610E+00 0.1057E-01 0.4000E+03 0.1797E-11 0.4000E+03 0.00

0.1610E+00 0.3943E-01 0.4000E+03 -0.1797E-11 0.4000E+03 -0.00

0.1902E-01 0.6057E-01 0.4000E+03 0.2855E-11 0.4000E+03 0.00

0.1902E-01 0.8943E-01 0.4000E+03 0.7136E-12 0.4000E+03 0.00

0.7098E-01 0.6057E-01 0.4000E+03 0.2696E-11 0.4000E+03 0.00

0.7098E-01 0.8943E-01 0.4000E+03 0.6740E-12 0.4000E+03 0.00

0.1090E+00 0.6057E-01 0.4000E+03 0.1287E-11 0.4000E+03 0.00

0.1090E+00 0.8943E-01 0.4000E+03 -0.1287E-11 0.4000E+03 -0.00

0.1610E+00 0.6057E-01 0.4000E+03 0.1797E-11 0.4000E+03 0.00

0.1610E+00 0.8943E-01 0.4000E+03 -0.5991E-12 0.4000E+03 -0.00

Note: the other results with 8×8 linear elements and 4×4 quadratic elements are presented in the output files.

**Problem 2:**

Boundary conditions:



Box2.1 Input file for 4×4 linear elements.

4 2 1 1 1 0 1 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

4 4 NX, NY

0.0 0.05 0.05 0.05 0.05 X0, (DX(I), I=1,NX)

0.0 0.025 0.025 0.025 0.025 Y0, (DY(I), I=1,NY)

13 NSPV and next lines ISPV, VSPV

1 1 6 1 11 1 16 1 21 1 5 1 10 1 15 1 20 1 25 1

22 1 23 1 24 1

500.0 500.0 500.0 500.0 500.0 300.0 300.0 300.0 300.0 300.0

450.0 400.0 350.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-2 0.0 0.0 4.0E-2 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 GLU(I)

Box2.2 Input file for 2×2 quadratic elements.

9 3 2 1 1 0 1 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

2 2 NX, NY

0.0 0.1 0.1 X0, (DX(I), I=1,NX)

0.0 0.05 0.05 Y0, (DY(I), I=1,NY)

13 NSPV and next lines ISPV, VSPV

1 1 6 1 11 1 16 1 21 1 5 1 10 1 15 1 20 1 25 1

22 1 23 1 24 1

500.0 500.0 500.0 500.0 500.0 300.0 300.0 300.0 300.0 300.0

450.0 400.0 350.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-2 0.0 0.0 4.0E-2 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 GLU(I)

Box2.3 Input file for 8×8 linear elements.

4 2 1 1 1 0 1 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

8 8 NX, NY

0.0 0.025 0.025 0.025 0.025 0.025 0.025 0.025 0.025 X0, (DX(I), I=1,NX)

0.0 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 0.0125 Y0, (DY(I), I=1,NY)

25 NSPV and next lines ISPV, VSPV

1 1 10 1 19 1 28 1 37 1 46 1 55 1 64 1 73 1

9 1 18 1 27 1 36 1 45 1 54 1 63 1 72 1 81 1

74 1 75 1 76 1 77 1 78 1 79 1 80 1

500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0

300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0

475.0 450.0 425.0 400.0 375.0 350.0 325.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-2 0.0 0.0 4.0E-2 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 GLU(I)

Box2.4 Input file for 4×4 quadratic elements.

9 3 2 1 1 0 1 NPE,NGPF,NGPR,MESH,NPRNT,IGRAD,NONLIN

4 4 NX, NY

0.0 0.05 0.05 0.05 0.05 X0, (DX(I), I=1,NX)

0.0 0.025 0.025 0.025 0.025 Y0, (DY(I), I=1,NY)

25 NSPV and next lines ISPV, VSPV

1 1 10 1 19 1 28 1 37 1 46 1 55 1 64 1 73 1

9 1 18 1 27 1 36 1 45 1 54 1 63 1 72 1 81 1

74 1 75 1 76 1 77 1 78 1 79 1 80 1

500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0 500.0

300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0 300.0

475.0 450.0 425.0 400.0 375.0 350.0 325.0

0 NSSV

0.2 0.0 0.0 A10, A1X, A1Y

0.2 0.0 0.0 A20, A2X, A2Y

0.0 0.0 0.0 A00, A0X, A0Y

0 ICONV

0.0 0.0 0.0 F0, FX, FY

4.0E-2 0.0 0.0 4.0E-2 0.0 0.0 A1U,A1UX,A1UY, A2U,A2UX,A2UY

1 10 0.001 0.0 NLS, ITMAX, EPS, GAMA

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

0.0 GLU(I)

Table 2.1. Numerical results of Problem 2 (Primary variable).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| X(m) | Y(m) | Direct Iteration | | | | Newton Iteration | | | |
| 4×4L4 | 2×2Q9 | 8×8L4 | 4×4Q9 | 4×4L4 | 2×2Q9 | 8×8L4 | 4×4Q9 |
| 0.0000 | 0.0000 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0250 | 0.0000 | - | - | 477.92 | 477.90 | - | - | 477.92 | 477.90 |
| 0.0500 | 0.0000 | 455.16 | 455.01 | 455.05 | 455.02 | 455.15 | 455.01 | 455.05 | 455.01 |
| 0.0750 | 0.0000 | - | - | 431.49 | 431.45 | - | - | 431.48 | 431.44 |
| 0.1000 | 0.0000 | 407.45 | 407.21 | 407.28 | 407.22 | 407.44 | 407.19 | 407.27 | 407.21 |
| 0.1250 | 0.0000 | - | - | 382.34 | 382.29 | - | - | 382.33 | 382.27 |
| 0.1500 | 0.0000 | 356.63 | 356.41 | 356.47 | 356.42 | 356.62 | 356.40 | 356.46 | 356.40 |
| 0.1750 | 0.0000 | - | - | 329.25 | 329.21 | - | - | 329.24 | 329.21 |
| 0.2000 | 0.0000 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 |
| 0.0000 | 0.0125 | - | - | 500.00 | 500.00 | - | - | 500.00 | 500.00 |
| 0.0250 | 0.0125 | - | - | 477.89 | 477.87 | - | - | 477.89 | 477.87 |
| 0.0500 | 0.0125 | - |  | 454.99 | 454.95 | - | - | 454.99 | 454.95 |
| 0.0750 | 0.0125 | - | - | 431.41 | 431.36 | - | - | 431.40 | 431.35 |
| 0.1000 | 0.0125 | - | - | 407.18 | 407.13 | - | - | 407.17 | 407.12 |
| 0.1250 | 0.0125 | - | - | 382.25 | 382.19 | - | - | 382.23 | 382.17 |
| 0.1500 | 0.0125 | - | - | 356.39 | 356.34 | - | - | 356.38 | 356.32 |
| 0.1750 | 0.0125 | - | - | 329.20 | 329.17 | - | - | 329.20 | 329.16 |
| 0.2000 | 0.0125 | - | - | 300.00 | 300.00 | - | - | 300.00 | 300.00 |
| 0.0000 | 0.0250 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0250 | 0.0250 | - | - | 477.79 | 477.77 | - | - | 477.79 | 477.77 |
| 0.0500 | 0.0250 | 454.90 | 454.76 | 454.80 | 454.76 | 454.90 | 454.76 | 454.80 | 454.76 |
| 0.0750 | 0.0250 | - | - | 431.15 | 431.11 | - | - | 431.14 | 431.10 |
| 0.1000 | 0.0250 | 407.06 | 406.82 | 406.89 | 406.84 | 407.05 | 406.80 | 406.88 | 406.83 |
| 0.1250 | 0.0250 | - | - | 381.96 | 381.90 | - | - | 381.94 | 381.89 |
| 0.1500 | 0.0250 | 356.31 | 356.09 | 356.15 | 356.10 | 356.30 | 356.08 | 356.14 | 356.08 |
| 0.1750 | 0.0250 | - | - | 329.06 | 329.02 | - | - | 329.05 | 329.02 |
| 0.2000 | 0.0250 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 |
| 0.0000 | 0.0375 | - | - | 500.00 | 500.00 | - | - | 500.00 | 500.00 |
| 0.0250 | 0.0375 | - | - | 477.62 | 477.60 | - | - | 477.62 | 477.60 |
| 0.0500 | 0.0375 | - | - | 454.47 | 454.44 | - | - | 454.47 | 454.44 |
| 0.0750 | 0.0375 | - | - | 430.72 | 430.67 | - | - | 430.71 | 430.67 |
| 0.1000 | 0.0375 | - |  | 406.40 | 406.35 | - | - | 406.38 | 406.33 |
| 0.1250 | 0.0375 | - | - | 381.47 | 381.41 | - | - | 381.45 | 381.40 |
| 0.1500 | 0.0375 | - | - | 355.73 | 355.68 | - | - | 355.72 | 355.67 |
| 0.1750 | 0.0375 | - | - | 328.81 | 328.77 | - | - | 328.80 | 328.77 |
| 0.2000 | 0.0375 | - | - | 300.00 | 300.00 | - | - | 300.00 | 300.00 |
| 0.0000 | 0.0500 | 500.00 | 50000 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0250 | 0.0500 | - | - | 477.36 | 477.34 | - | - | 477.36 | 477.34 |
| 0.0500 | 0.0500 | 454.10 | 453.97 | 454.00 | 453.97 | 454.10 | 453.96 | 454.00 | 453.96 |
| 0.0750 | 0.0500 | - | - | 430.08 | 430.04 | - | - | 430.07 | 430.03 |
| 0.1000 | 0.0500 | 405.81 | 405.60 | 405.68 | 405.63 | 405.80 | 405.58 | 405.67 | 405.62 |
| 0.1250 | 0.0500 | - | - | 380.75 | 380.70 | - | - | 380.74 | 380.69 |
| 0.1500 | 0.0500 | 355.28 | 355.08 | 355.13 | 355.07 | 355.28 | 355.07 | 355.12 | 355.06 |
| 0.1750 | 0.0500 | - | - | 328.44 | 328.40 | - | - | 328.44 | 328.40 |
| 0.2000 | 0.0500 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 |
| 0.0000 | 0.0625 | - | - | 500.00 | 500.00 | - | - | 500.00 | 500.00 |
| 0.0250 | 0.0625 | - | - | 477.01 | 476.99 | - | - | 477.01 | 476.99 |
| 0.0500 | 0.0625 | - | - | 453.35 | 453.32 | - | - | 453.35 | 453.32 |
| 0.0750 | 0.0625 | - | - | 429.22 | 429.19 | - | - | 429.22 | 429.19 |
| 0.1000 | 0.0625 | - | - | 404.71 | 404.67 | - | - | 404.70 | 404.66 |
| 0.1250 | 0.0625 | - | - | 379.78 | 379.74 | - | - | 379.77 | 379.73 |
| 0.1500 | 0.0625 | - | - | 354.30 | 354.25 | - | - | 354.29 | 354.24 |
| 0.1750 | 0.0625 | - | - | 327.93 | 327.89 | - | - | 327.93 | 327.89 |
| 0.2000 | 0.0625 | - | - | 300.00 | 300.00 | - | - | 300.00 | 300.00 |
| 0.0000 | 0.0750 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0250 | 0.0750 | - | - | 476.54 | 476.52 | - | - | 476.54 | 476.52 |
| 0.0500 | 0.0750 | 452.59 | 452.49 | 452.50 | 452.47 | 452.59 | 452.49 | 452.49 | 452.47 |
| 0.0750 | 0.0750 | - | - | 428.12 | 428.09 | - | - | 428.11 | 428.09 |
| 0.1000 | 0.0750 | 403.53 | 403.38 | 403.47 | 403.44 | 403.53 | 403.37 | 403.46 | 403.43 |
| 0.1250 | 0.0750 | - | - | 378.53 | 378.50 | - | - | 378.52 | 378.49 |
| 0.1500 | 0.0750 | 353.34 | 353.19 | 353.20 | 353.16 | 353.34 | 353.18 | 353.20 | 353.16 |
| 0.1750 | 0.0750 | - | - | 327.24 | 327.20 | - | - | 327.24 | 327.20 |
| 0.2000 | 0.0750 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 |
| 0.0000 | 0.0875 | - | - | 500.00 | 500.00 | - | - | 500.00 | 500.00 |
| 0.0250 | 0.0875 | - | - | 475.90 | 475.88 | - | - | 475.90 | 475.88 |
| 0.0500 | 0.0875 | - | - | 451.39 | 451.38 | - | - | 451.39 | 451.37 |
| 0.0750 | 0.0875 | - | - | 426.72 | 426.71 | - | - | 426.72 | 426.71 |
| 0.1000 | 0.0875 | - | - | 401.91 | 401.89 | - |  | 401.91 | 401.89 |
| 0.1250 | 0.0875 | - | - | 376.95 | 376.93 | - | - | 376.95 | 376.93 |
| 0.1500 | 0.0875 | - | - | 351.79 | 351.76 | - | - | 351.79 | 351.76 |
| 0.1750 | 0.0875 | - | - | 326.31 | 326.28 | - | - | 326.31 | 326.28 |
| 0.2000 | 0.0875 | - | - | 300.00 | 300.00 | - | - | 300.00 | 300.00 |
| 0.0000 | 0.1000 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 | 500.00 |
| 0.0250 | 0.1000 | - | - | 475.00 | 475.00 | - | - | 475.00 | 475.00 |
| 0.0500 | 0.1000 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 | 450.00 |
| 0.0750 | 0.1000 | - | - | 425.00 | 425.00 | - | - | 425.00 | 425.00 |
| 0.1000 | 0.1000 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 | 400.00 |
| 0.1250 | 0.1000 | - | - | 375.00 | 375.00 | - | - | 375.00 | 375.00 |
| 0.1500 | 0.1000 | 350.00 | 350.00 | 350.00 | 350.00 | 350.00 | 350.00 | 350.00 | 350.00 |
| 0.1750 | 0.1000 | - | - | 325.00 | 325.00 | - | - | 325.00 | 325.00 |
| 0.2000 | 0.1000 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 300.00 | 30000 | 300.00 |

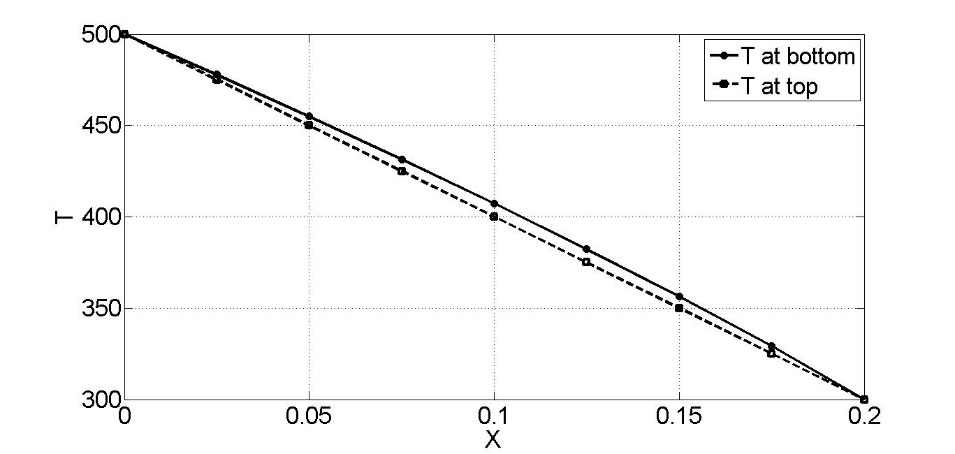


Figure 2.1 Temperature vs X with 4×4 quadratic 9-node element mesh

and Newton Iteration.

Table 2.2. Numerical results of Problem 2 (Secondary variable, 4×4 linear elements).

The orientation of gradient vector is measured from the positive x-axis

x-coord. y-coord. -a11(du/dx) -a22(du/dy) Flux Mgntd Orientation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

0.2500E-01 0.1250E-01 0.1736E+05 0.9751E+02 0.1736E+05 0.32

0.7500E-01 0.1250E-01 0.1667E+05 0.2256E+03 0.1667E+05 0.78

0.1250E+00 0.1250E-01 0.1572E+05 0.2212E+03 0.1572E+05 0.81

0.1750E+00 0.1250E-01 0.1505E+05 0.8554E+02 0.1505E+05 0.33

0.2500E-01 0.3750E-01 0.1755E+05 0.3101E+03 0.1756E+05 1.01

0.7500E-01 0.3750E-01 0.1675E+05 0.7135E+03 0.1676E+05 2.44

0.1250E+00 0.3750E-01 0.1564E+05 0.7005E+03 0.1566E+05 2.56

0.1750E+00 0.3750E-01 0.1486E+05 0.2727E+03 0.1486E+05 1.05

0.2500E-01 0.6250E-01 0.1798E+05 0.5827E+03 0.1799E+05 1.86

0.7500E-01 0.6250E-01 0.1690E+05 0.1315E+04 0.1695E+05 4.45

0.1250E+00 0.6250E-01 0.1549E+05 0.1295E+04 0.1554E+05 4.78

0.1750E+00 0.6250E-01 0.1443E+05 0.5147E+03 0.1444E+05 2.04

0.2500E-01 0.8750E-01 0.1873E+05 0.9940E+03 0.1876E+05 3.04

0.7500E-01 0.8750E-01 0.1710E+05 0.2111E+04 0.1723E+05 7.04

0.1250E+00 0.8750E-01 0.1530E+05 0.2097E+04 0.1544E+05 7.81

0.1750E+00 0.8750E-01 0.1368E+05 0.8836E+03 0.1370E+05 3.70

Table 2.3. Numerical results of Problem 2 (Secondary variable, 2×2 quadratic elements).

The orientation of gradient vector is measured from the positive x-axis

x-coord. y-coord. -a11(du/dx) -a22(du/dy) Flux Mgntd Orientation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

0.2113E-01 0.1057E-01 0.1743E+05 0.7668E+02 0.1743E+05 0.25

0.2113E-01 0.3943E-01 0.1767E+05 0.3129E+03 0.1767E+05 1.01

0.7887E-01 0.1057E-01 0.1664E+05 0.1976E+03 0.1664E+05 0.68

0.7887E-01 0.3943E-01 0.1671E+05 0.7903E+03 0.1673E+05 2.71

0.1211E+00 0.1057E-01 0.1576E+05 0.2023E+03 0.1576E+05 0.74

0.1211E+00 0.3943E-01 0.1569E+05 0.8103E+03 0.1571E+05 2.96

0.1789E+00 0.1057E-01 0.1497E+05 0.7183E+02 0.1497E+05 0.27

0.1789E+00 0.3943E-01 0.1473E+05 0.2927E+03 0.1474E+05 1.14

0.2113E-01 0.6057E-01 0.1801E+05 0.5238E+03 0.1802E+05 1.67

0.2113E-01 0.8943E-01 0.1890E+05 0.9980E+03 0.1893E+05 3.02

0.7887E-01 0.6057E-01 0.1683E+05 0.1310E+04 0.1688E+05 4.45

0.7887E-01 0.8943E-01 0.1699E+05 0.2247E+04 0.1714E+05 7.53

0.1211E+00 0.6057E-01 0.1557E+05 0.1344E+04 0.1563E+05 4.93

0.1211E+00 0.8943E-01 0.1541E+05 0.2321E+04 0.1558E+05 8.57

0.1789E+00 0.6057E-01 0.1439E+05 0.4897E+03 0.1439E+05 1.95

0.1789E+00 0.8943E-01 0.1350E+05 0.9237E+03 0.1353E+05 3.91

Note: the other results with 8×8 linear elements and 4×4 quadratic elements are presented in the output files.

Modified code in the subroutine ELMATRCS2D:

DO 200 NI = 1,NGPF

DO 200 NJ = 1,NGPF

XI = GAUSPT(NI,NGPF)

ETA = GAUSPT(NJ,NGPF)

CALL INTERPLN2D(NPE,XI,ETA,DET,ELXY)

CNST = DET\*GAUSWT(NI,NGPF)\*GAUSWT(NJ,NGPF)

C

C Compute x, y, U, UX, UY needed

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*\*

X = 0.0

Y = 0.0

U = 0.0

UX = 0.0

UY = 0.0

DO 140 I=1,NPE

IF(NONLIN.GT.0)THEN

U = U + ELU(I)\*SFL(I)

UX = UX + ELU(I)\*GDSFL(1,I)

UY = UY + ELU(I)\*GDSFL(2,I)

ENDIF

X = X + ELXY(I,1)\*SFL(I)

140 Y = Y + ELXY(I,2)\*SFL(I)

C

C Define the coefficients of the differential equation

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*\*

FXY = F0 + FX\*X + FY\*Y

A00 = A00 + A0X\*X + A0Y\*Y

A11 = A10 + A1X\*X + A1Y\*Y

A22 = A20 + A2X\*X + A2Y\*Y

IF(NONLIN.GT.0)THEN

AXX = A11 + A1U\*U + A1UX\*UX + A1UY\*UY

AYY = A22 + A2U\*U + A2UX\*UX + A2UY\*UY

ENDIF

C

C Define the element source vector and coefficient matrix

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*

DO 180 I=1,NPE

ELF(I) = ELF(I) + FXY\*SFL(I)\*CNST

DO 160 J=1,NPE

S00 = SFL(I)\*SFL(J)\*CNST

S11 = GDSFL(1,I)\*GDSFL(1,J)\*CNST

S22 = GDSFL(2,I)\*GDSFL(2,J)\*CNST

ELK(I,J) = ELK(I,J) + AXX\*S11 + AYY\*S22 + A00\*S00

C

C Define the part needed to be added to [K] in order to define [T]

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*\*

IF(NONLIN.GT.1)THEN

S10 = GDSFL(1,I)\*SFL(J)\*CNST

S20 = GDSFL(2,I)\*SFL(J)\*CNST

S12 = GDSFL(1,I)\*GDSFL(2,J)\*CNST

S21 = GDSFL(2,I)\*GDSFL(1,J)\*CNST

TANG(I,J) = TANG(I,J) + UX\*(A1U\*S10 + A1UX\*S11 + A1UY\*S12)

\* + UY\*(A2U\*S20 + A2UX\*S21 + A2UY\*S22)

ENDIF

160 CONTINUE

180 CONTINUE

200 CONTINUE

Modified code in the subroutine POSTPROCS2D:

DO 100 NI=1,NGPR

DO 100 NJ=1,NGPR

XI = GAUSPT(NI,NGPR)

ETA = GAUSPT(NJ,NGPR)

CALL INTERPLN2D(NPE,XI,ETA,DET,ELXY)

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*\*

C

XC = 0.0

YC = 0.0

U = 0.0

UX = 0.0

UY = 0.0

DO 60 I=1,NPE

IF(NONLIN.GT.0)THEN

U = U + ELU(I)\*SFL(I)

UX = UX + ELU(I)\*GDSFL(1,I)

UY = UY + ELU(I)\*GDSFL(2,I)

ENDIF

XC = XC + ELXY(I,1)\*SFL(I)

60 YC = YC + ELXY(I,2)\*SFL(I)

C

C Define the coefficients of the differential equation

C

C\* \*\*\*\*\* YOUR STATEMENTS \*\*\*\*\*

A11 = A10 + A1X\*XC + A1Y\*YC

A22 = A20 + A2X\*XC + A2Y\*YC

IF(NONLIN.GT.0)THEN

AXX = A11 + A1U\*U + A1UX\*UX + A1UY\*UY

AYY = A22 + A2U\*U + A2UX\*UX + A2UY\*UY

ENDIF

SX = -AXX\*UX

SY = -AYY\*UY

VALUE = DSQRT(SX\*SX + SY\*SY)

IF(IGRAD.EQ.1)THEN

QX = SX

QY = SY

ELSE

QX = -SY

QY = SX

ENDIF

IF(DABS(QX).LE.0.0001)THEN

IF(QY.LT.0.0)THEN

ANGLE = -90.0

ELSE

ANGLE = 90.0

ENDIF

ELSE

ANGLE = ATAN2(QY,QX)\*CONST

ENDIF

WRITE(IT,200) XC,YC,QX,QY,VALUE,ANGLE

100 CONTINUE

C

200 FORMAT(5E13.4,3X,F7.2)

300 FORMAT(6E13.4)

400 FORMAT(26X,2E13.4)