2021 年度　情報理工学実験 II

実験テーマ：　シミュレーションと並列処理

実験日：

氏名：　高柳奏和

学生番号：　02190367

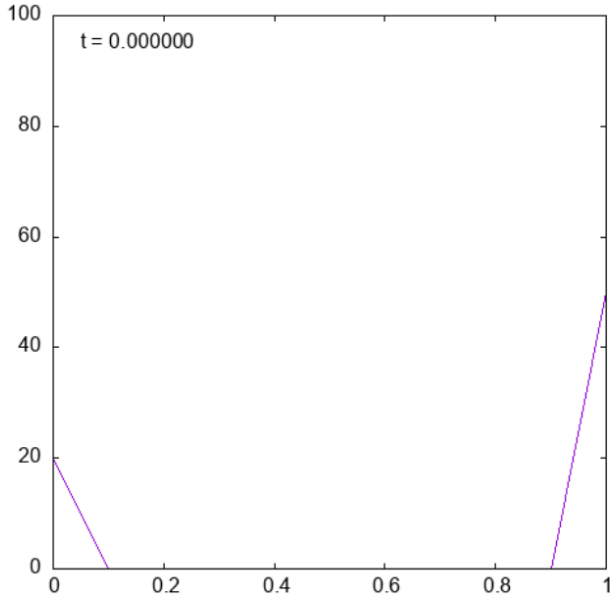
班名：

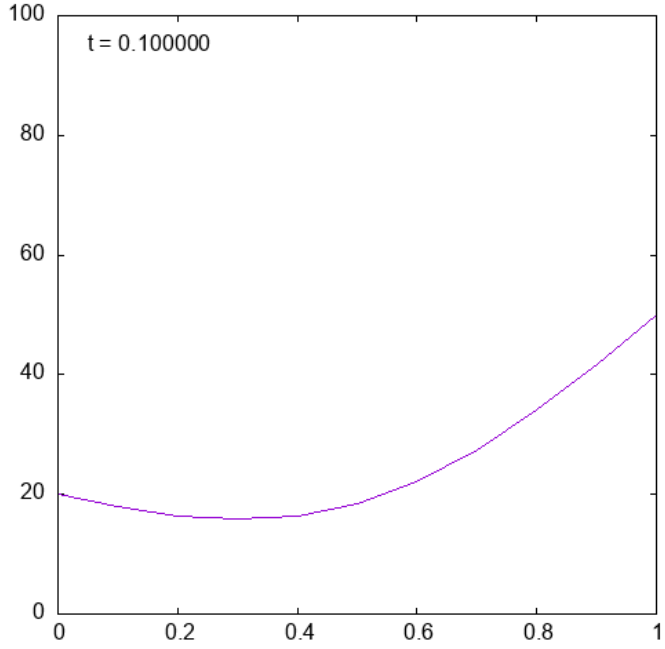
提出日：　2021/12/18

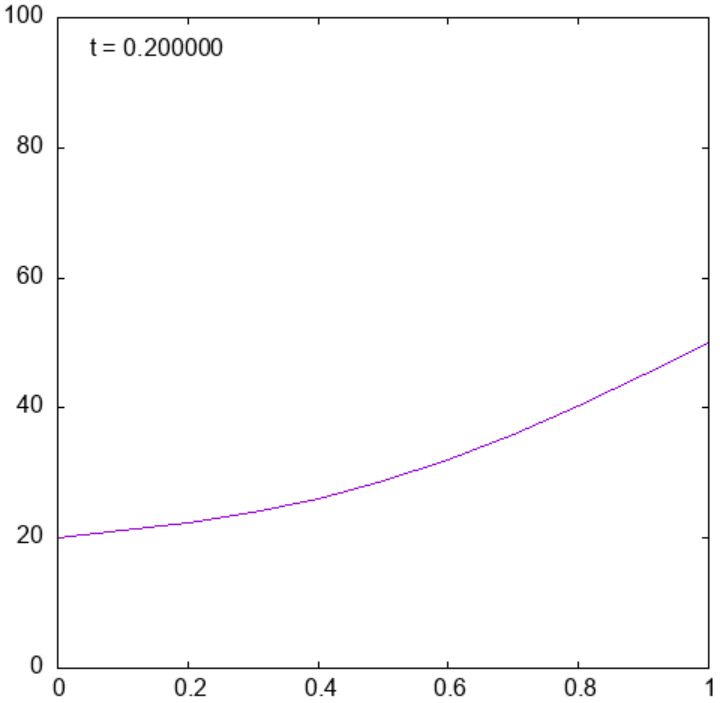
課題 1.1

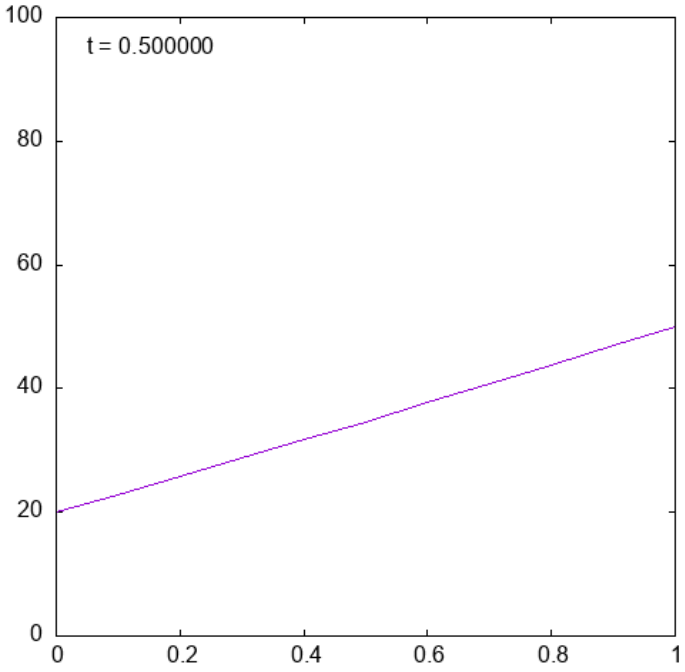
1.

t=0,0.1,0.2,0.5 における温度は以下（1_1_1_02190367.gif 参照）









2, NAN になりシミュレーションが破綻した。

3.

N=2000 NAN になりシミュレーションが破綻した。

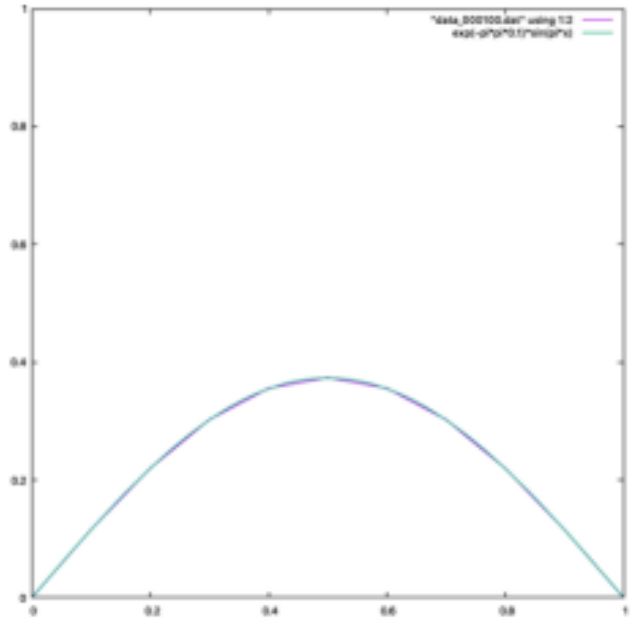
N=3000 NAN になりシミュレーションが破綻した。

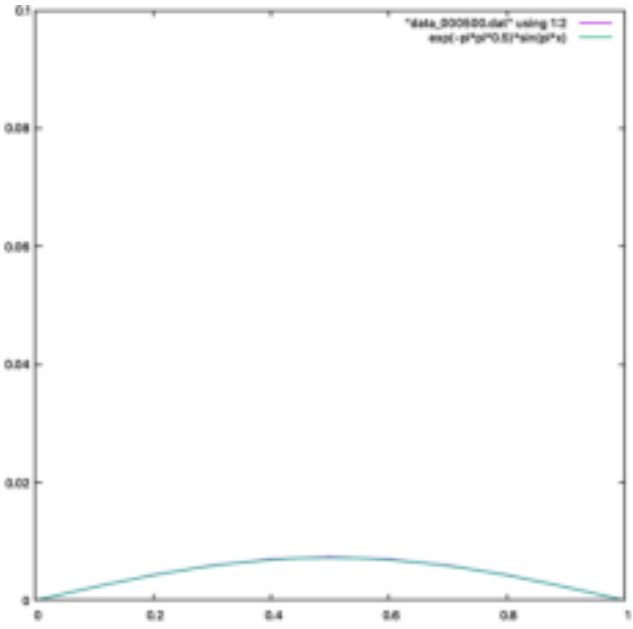
N=4000 NAN になりシミュレーションが破綻した。

N=5000 成功。（1_1_3_02190367.gif 参照）

課題 1.2

1 t=0.1, 0.5 における値をプロットしたものは以下





計算結果

(Mx, N)	$Max\dfrac{\left(\left\lvert u_i^{(n)}-u_i^{(n)}\right\rvert\right)}{\left\lvert u_i^{(n)}\right\rvert}$
(10, 200)	$1.65*10^{-2}$
(50, 5000)	$6.50*10^{-4}$
(100, 20000)	$1.63*10^{-4}$

課題 1.3

$$q(x,t)=\frac{\kappa\partial u}{\partial x}$$

$$S\Delta q=S\big(q(x,t)-q(x+h,t)\big)\simeq S\kappa\frac{\partial^2}{\partial x^2}u$$

$$\frac{\partial}{\partial t}u(x,t)=\frac{\Delta q}{c_p p}=\alpha\frac{\partial^2}{\partial x^2}u(x,t)$$

課題 1.4

前進差分

$$\frac{d}{dx}u(x)=\frac{u(x+\Delta x)-u(x)}{\Delta x}$$

後退差分

$$\frac{d}{dx}u(x)=\frac{u(x)-u(x-\Delta x)}{\Delta x}$$

中心差分

$$\frac{d}{dx}u(x)=\frac{u(x+\Delta x)-u(x-\Delta x)}{2\Delta x}$$

差分近似

$$\frac{d^2}{d^2x}u(x) = \frac{u(x+2\Delta x) - 2u(x) + u(x-2\Delta x)}{4\Delta x^2}$$

課題 1.5

計算式

$$\frac{u_i^{(n)} - u_i^{(n-1)}}{\Delta t} = \frac{\alpha\left(u_{i+1}^{(n)} - 2u_i^{(n)} - u_{i-1}^{(n)}\right)}{(\Delta x)^2}$$

このとき

$$u_i^{(n-1)} = u_i^{(n)} - \alpha\frac{\Delta t}{(\Delta x)^2}\left(u_{i+1}^{(n)} - 2u_i^{(n)} - u_{i-1}^{(n)}\right)$$

であるので$u(0,T), u(x,T)(0 < x < L), u(L,T)$を与え、T の大きいほうから 0 に減らして言って計算する

課題 1.6

1.6_02190367.c 参照

シミュレーションの結果は以下
Mx=My=10, N=1000→成功。1.6.1.1_02190367.gif, 1.6.1.2_02190367.gif 参照
Mx=My=20, N=1000→破綻
Mx=My=20, N=4000→成功。1.6.3.1_02190367.gif, 1.6.3.2_02190367.gif 参照

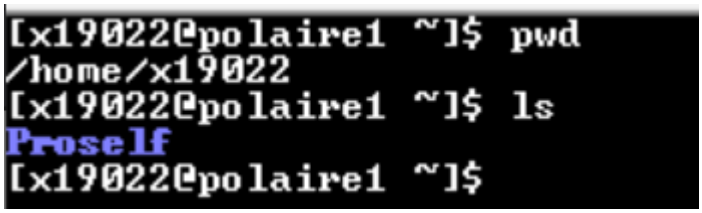
課題 1.7

1.予想：$u(x,y,t) = e^{-2\pi^2 t}\sin(\pi x)\sin(\pi y)$

2.

(Mx,My)	相対誤差の絶対値
(10,10)	$3.30 * 10^{-2}$
(20,20)	$8.17 * 10^{-3}$
(100,100)	$3.29 * 10^{-4}$

課題 1.8



課題 1.9

Hello_world.c

```
#include<stdio.h>
int main() {
    printf(“Hello world!”);
}
```

Hello_world.sh

```
#!/bin/sh
#PJM -L rscgrp=x19000b
#PJM -L node=1
#PJM -L elapse=00:15:00
#PJM -g x19000
#PJM -j
```

./a.out

実行結果ファイル hello_world.sh.o977677 を添付した

課題 1.10

結果は、手元で実行したものと同じものになった

課題 1.11

1　Mx=My=100 のときの実行時間: 5.530013 秒

2

(Mx,My)	実行時間（秒）
(100,100)	5.530013
(200,200)	79.105981
(300,300)	399.905202
(400,400)	制限時間超過
(500,500)	制限時間超過

3

ループ回数がそれぞれ 10 倍になるので Mx,My がそれぞれ 10 倍になると、N は 100 倍になる。

プログラムは O(Mx*My*N)なので、Mx,My がそれぞれ 10 倍になると実行時間は 10000 倍になると予想できる。

よって Mx=My=1000 のとき、予想実行時間は $5.530013*10^4$秒

4

3 と同様の予測をすると

(Mx,My)	予想実行時間（秒）
(10000 ,10000)	$5.530013*10^{8}$
(100000,100000)	$5.530013*10^{12}$
(1000000,1000000)	$5.530013*10^{16}$

必要なメモリ量は、Mx,My がそれぞれ１０倍になると２次元配列の要素数が１００倍になるので、配列２個だと 2*100 倍多く必要になると予想した。

予想メモリ量は以下

(Mx,My)	予想必要メモリ量（Byte）
(1,1)	2^4
(10,10)	$2^5 * 10^2$
(100,100)	$2^6 * 10^4$
(1000,1000)	$2^7 * 10^6$
(10000,10000)	$2^8 * 10^8$
(100000,100000)	$2^9 * 10^{10}$
(1000000,1000000)	$2^{10} * 10^{12}$

課題 1.12

実行結果は以下

プロセス数１

```
Hello world (rank: 0, random_num: 214)
```

、

プロセス数 2

```
Hello world (rank: 0, random_num: 604)
Hello world (rank: 1, random_num: 598)
```

プロセス数４

```
Hello world (rank: 0, random_num: 509)
Hello world (rank: 1, random_num: 780)
Hello world (rank: 2, random_num: 398)
Hello world (rank: 3, random_num: 290)
```

プロセス数８

```
Hello world (rank: 0, random_num: 531)
Hello world (rank: 1, random_num: 731)
Hello world (rank: 2, random_num: 603)
Hello world (rank: 3, random_num: 934)
Hello world (rank: 4, random_num: 530)
Hello world (rank: 5, random_num: 134)
Hello world (rank: 6, random_num: 563)
Hello world (rank: 7, random_num: 342)
```

プロセス数 16

```
Hello world (rank: 0, random_num: 539)
Hello world (rank: 1, random_num: 894)
Hello world (rank: 2, random_num: 340)
Hello world (rank: 3, random_num: 584)
Hello world (rank: 4, random_num: 192)
Hello world (rank: 5, random_num: 350)
Hello world (rank: 6, random_num: 539)
Hello world (rank: 7, random_num: 248)
Hello world (rank: 8, random_num: 914)
Hello world (rank: 9, random_num: 232)
Hello world (rank: 10, random_num: 602)
Hello world (rank: 11, random_num: 289)
Hello world (rank: 12, random_num: 340)
Hello world (rank: 13, random_num: 358)
```

```
Hello world (rank: 14, random_num: 438)
Hello world (rank: 15, random_num: 932)
```

課題 1.13

実行結果

```
My rank is 1. My num is 328. Your num is 245.
My rank is 0. My num is 245. Your num is 328.
```

課題 1.14

実行結果

プロセス数２

```
My rank is 0. My num is 359. Prev num is 135. Next num is 135.
My rank is 1. My num is 135. Prev num is 359. Next num is 135.
```

プロセス数３

```
My rank is 0. My num is 100. Prev num is 423. Next num is 982.
My rank is 1. My num is 982. Prev num is 100. Next num is 423.
My rank is 2. My num is 423. Prev num is 982. Next num is 100.
```

プロセス数４

```
My rank is 1. My num is 289. Prev num is 358. Next num is 523.
My rank is 0. My num is 358. Prev num is 726. Next num is 289.
My rank is 2. My num is 523. Prev num is 289. Next num is 726.
My rank is 3. My num is 726. Prev num is 523. Next num is 358.
```

プロセス数７

My rank is 1. My num is 394. Prev num is 429. Next num is 263.
My rank is 2. My num is 263. Prev num is 394. Next num is 714.
My rank is 3. My num is 714. Prev num is 263. Next num is 380.
My rank is 4. My num is 380. Prev num is 714. Next num is 983.
My rank is 0. My num is 429. Prev num is 457. Next num is 394.
My rank is 5. My num is 983. Prev num is 380. Next num is 457.
My rank is 6. My num is 457. Prev num is 983. Next num is 429.

プロセス数１０

My rank is 1. My num is 807. Prev num is 455. Next num is 832.
My rank is 2. My num is 832. Prev num is 807. Next num is 463.
My rank is 3. My num is 463. Prev num is 832. Next num is 959.
My rank is 4. My num is 959. Prev num is 463. Next num is 587.
My rank is 5. My num is 587. Prev num is 959. Next num is 232.
My rank is 6. My num is 232. Prev num is 587. Next num is 16.
My rank is 7. My num is 16. Prev num is 232. Next num is 509.
My rank is 0. My num is 455. Prev num is 319. Next num is 807.
My rank is 8. My num is 509. Prev num is 16. Next num is 319.
My rank is 9. My num is 319. Prev num is 509. Next num is 455.

プロセス数２３

My rank is 1. My num is 103. Prev num is 211. Next num is 257.
My rank is 2. My num is 257. Prev num is 103. Next num is 913.
My rank is 3. My num is 913. Prev num is 257. Next num is 538.
My rank is 4. My num is 538. Prev num is 913. Next num is 924.
My rank is 5. My num is 924. Prev num is 538. Next num is 622.
My rank is 6. My num is 622. Prev num is 924. Next num is 658.
My rank is 7. My num is 658. Prev num is 622. Next num is 522.
My rank is 8. My num is 522. Prev num is 658. Next num is 847.
My rank is 9. My num is 847. Prev num is 522. Next num is 499.
My rank is 10. My num is 499. Prev num is 847. Next num is 193.

My rank is 11. My num is 193. Prev num is 499. Next num is 103.
My rank is 12. My num is 103. Prev num is 193. Next num is 843.
My rank is 13. My num is 843. Prev num is 103. Next num is 284.
My rank is 14. My num is 284. Prev num is 843. Next num is 163.
My rank is 15. My num is 163. Prev num is 284. Next num is 315.
My rank is 16. My num is 315. Prev num is 163. Next num is 321.
My rank is 17. My num is 321. Prev num is 315. Next num is 429.
My rank is 18. My num is 429. Prev num is 321. Next num is 296.
My rank is 19. My num is 296. Prev num is 429. Next num is 731.
My rank is 20. My num is 731. Prev num is 296. Next num is 948.
My rank is 0. My num is 211. Prev num is 914. Next num is 103.
My rank is 21. My num is 948. Prev num is 731. Next num is 914.
My rank is 22. My num is 914. Prev num is 948. Next num is 211.

プロセス数６４

My rank is 1. My num is 386. Prev num is 819. Next num is 978.
My rank is 2. My num is 978. Prev num is 386. Next num is 889.
My rank is 3. My num is 889. Prev num is 978. Next num is 391.
My rank is 4. My num is 391. Prev num is 889. Next num is 243.
My rank is 5. My num is 243. Prev num is 391. Next num is 303.
My rank is 6. My num is 303. Prev num is 243. Next num is 720.
My rank is 7. My num is 720. Prev num is 303. Next num is 400.
My rank is 8. My num is 400. Prev num is 720. Next num is 38.
My rank is 9. My num is 38. Prev num is 400. Next num is 677.
My rank is 10. My num is 677. Prev num is 38. Next num is 347.
My rank is 11. My num is 347. Prev num is 677. Next num is 905.
My rank is 12. My num is 905. Prev num is 347. Next num is 753.
My rank is 13. My num is 753. Prev num is 905. Next num is 125.
My rank is 14. My num is 125. Prev num is 753. Next num is 722.
My rank is 15. My num is 722. Prev num is 125. Next num is 191.
My rank is 16. My num is 191. Prev num is 722. Next num is 270.
My rank is 17. My num is 270. Prev num is 191. Next num is 827.

My rank is 18. My num is 827. Prev num is 270. Next num is 653.
My rank is 19. My num is 653. Prev num is 827. Next num is 581.
My rank is 20. My num is 581. Prev num is 653. Next num is 787.
My rank is 21. My num is 787. Prev num is 581. Next num is 245.
My rank is 22. My num is 245. Prev num is 787. Next num is 731.
My rank is 23. My num is 731. Prev num is 245. Next num is 760.
My rank is 24. My num is 760. Prev num is 731. Next num is 388.
My rank is 25. My num is 388. Prev num is 760. Next num is 280.
My rank is 26. My num is 280. Prev num is 388. Next num is 712.
My rank is 27. My num is 712. Prev num is 280. Next num is 236.
My rank is 28. My num is 236. Prev num is 712. Next num is 967.
My rank is 29. My num is 967. Prev num is 236. Next num is 425.
My rank is 30. My num is 425. Prev num is 967. Next num is 460.
My rank is 31. My num is 460. Prev num is 425. Next num is 427.
My rank is 32. My num is 427. Prev num is 460. Next num is 84.
My rank is 33. My num is 84. Prev num is 427. Next num is 667.
My rank is 34. My num is 667. Prev num is 84. Next num is 425.
My rank is 35. My num is 425. Prev num is 667. Next num is 521.
My rank is 36. My num is 521. Prev num is 425. Next num is 398.
My rank is 37. My num is 398. Prev num is 521. Next num is 361.
My rank is 38. My num is 361. Prev num is 398. Next num is 137.
My rank is 39. My num is 137. Prev num is 361. Next num is 619.
My rank is 40. My num is 619. Prev num is 137. Next num is 660.
My rank is 41. My num is 660. Prev num is 619. Next num is 491.
My rank is 42. My num is 491. Prev num is 660. Next num is 559.
My rank is 43. My num is 559. Prev num is 491. Next num is 314.
My rank is 44. My num is 314. Prev num is 559. Next num is 302.
My rank is 45. My num is 302. Prev num is 314. Next num is 342.
My rank is 46. My num is 342. Prev num is 302. Next num is 550.
My rank is 47. My num is 550. Prev num is 342. Next num is 19.
My rank is 48. My num is 19. Prev num is 550. Next num is 19.
My rank is 49. My num is 19. Prev num is 19. Next num is 138.

```
My rank is 50. My num is 138. Prev num is    19. Next num is 315.
My rank is 51. My num is 315. Prev num is 138. Next num is 315.
My rank is 52. My num is 315. Prev num is 315. Next num is 900.
My rank is 53. My num is 900. Prev num is 315. Next num is 867.
My rank is 54. My num is 867. Prev num is 900. Next num is 954.
My rank is 55. My num is 954. Prev num is 867. Next num is 908.
My rank is 56. My num is 908. Prev num is 954. Next num is 292.
^[My rank is 57. My num is 292. Prev num is 908. Next num is    16.
My rank is 58. My num is    16. Prev num is 292. Next num is 348.
My rank is 59. My num is 348. Prev num is    16. Next num is 372.
My rank is 60. My num is 372. Prev num is 348. Next num is 122.
My rank is 61. My num is 122. Prev num is 372. Next num is 793.
My rank is 0. My num is 819. Prev num is 859. Next num is 386.
My rank is 62. My num is 793. Prev num is 122. Next num is 859.
My rank is 63. My num is 859. Prev num is 793. Next num is 819.
```

課題 1.15

1.15_02190367.c 参照

Sum は 49995000.000000 になった

課題 1.16

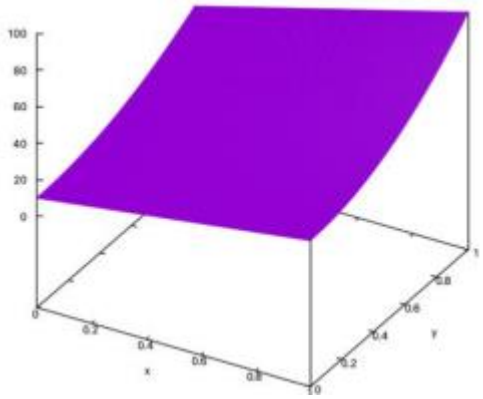
1.16_02190367.c 参照

Sum は 49995000.000000 になった

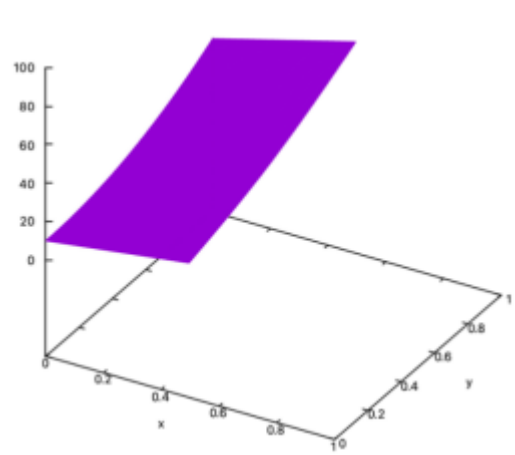
課題 1.17

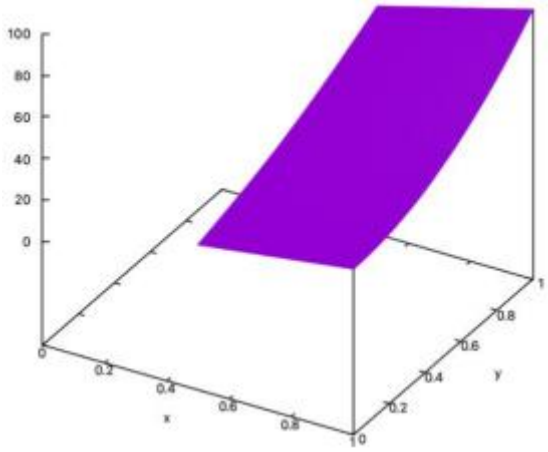
1.17_02190367.c 参照

プロセス数１

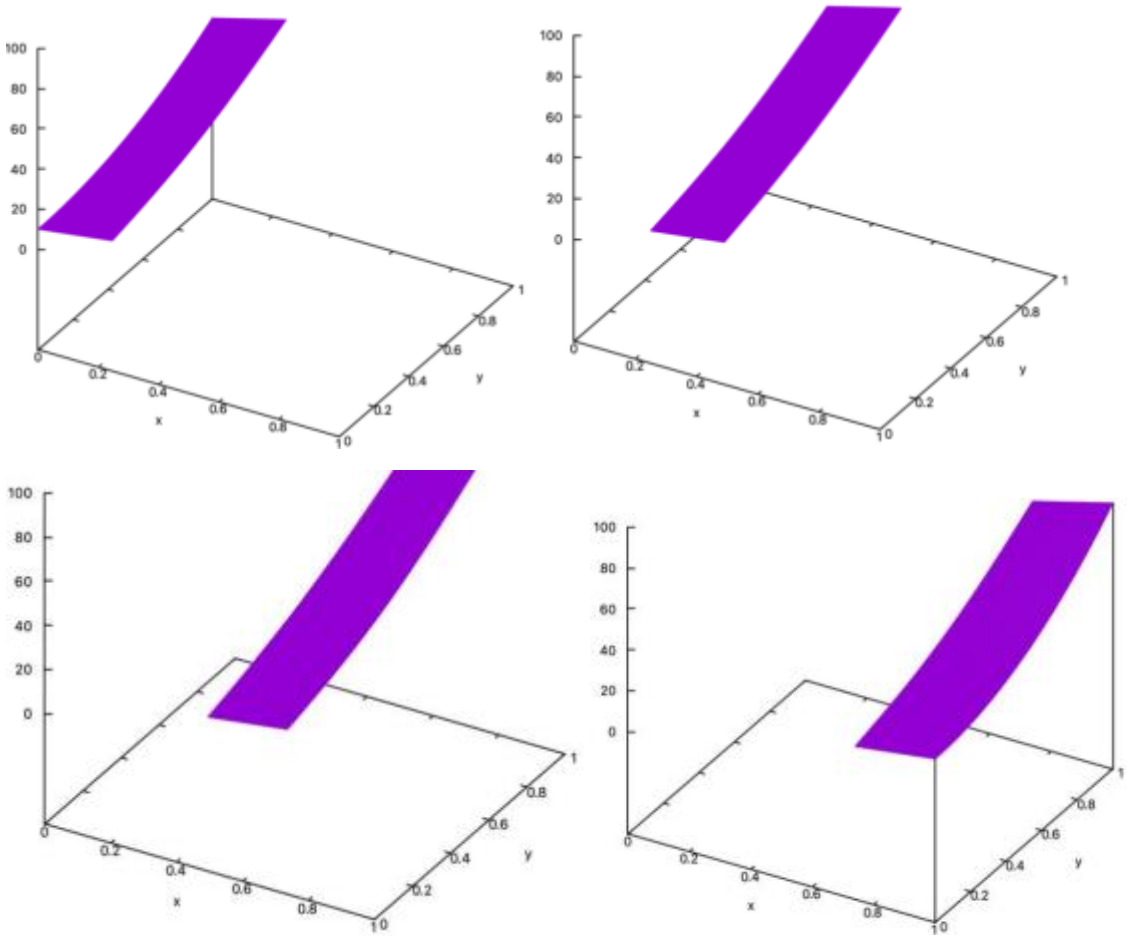


プロセス数２

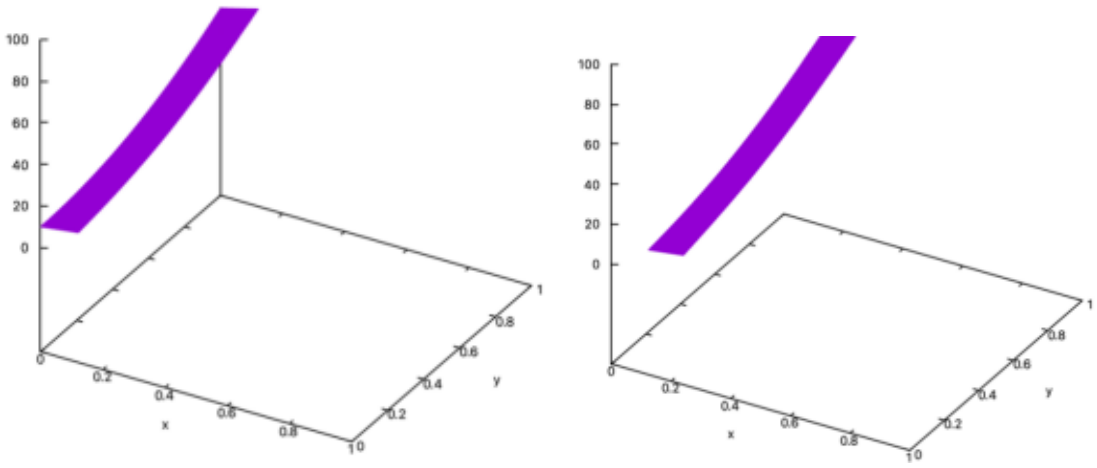


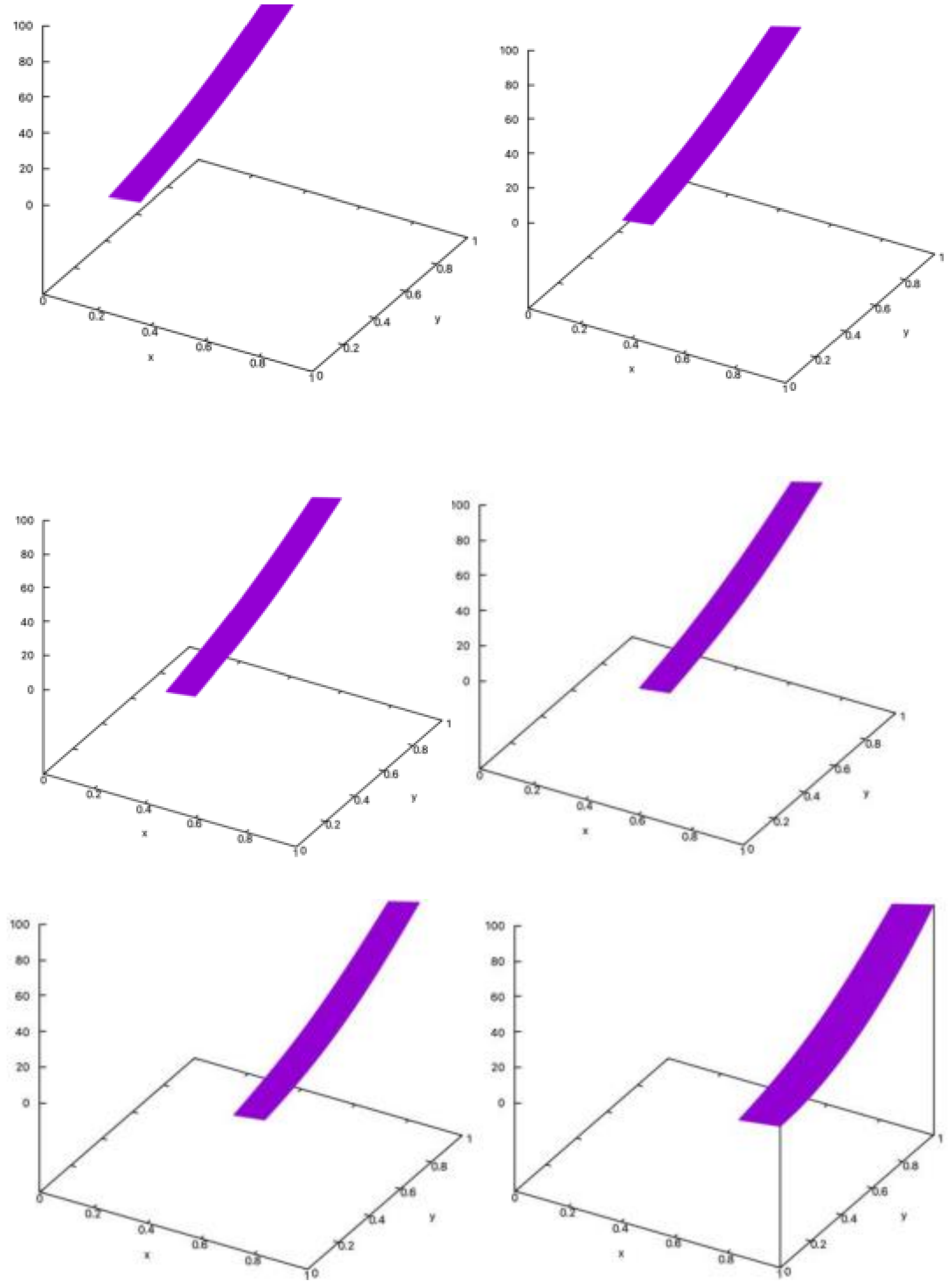


プロセス数４


100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
x
0
0.2
0.4
0.6
0.8
1
y

プロセス数８


100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1.0
x
0
0.2
0.4
0.6
0.8
1
y



100
80
60
40
20
0
0.2
0.4
0.6
0.8
1
x
y

プロセス数１

93.724319

平均: 93.724319

合計: 93.724319

プロセス数２

47.801674
47.801674

平均: 47.801674

合計: 95.603348

プロセス数４

25.078940
25.078932
25.078935
25.078939

平均: 25.078936499999998

合計: 100.31574599999999

プロセス数８

15.582347
15.582336
15.582336
15.582328
15.582334
15.582329
15.582331
15.582340

平均: 15.582335125

合計: 124.658681

プロセス数１６

9.958430
9.958391
9.958372
9.958388
9.958415
9.958374
9.958390
9.958389
9.958379
9.958403
9.958383
9.958397
9.958419
9.958394
9.958408
9.958404

平均: 9.958396

合計: 159.334336

プロセス数３２

8.213219
8.213195
8.213136
8.213134
8.213191
8.213130
8.213104
8.213147
8.213143
8.213149
8.213107
8.213152

8.213144
8.213135
8.213142
8.213137
8.213133
8.213138
8.213202
8.213115
8.213139
8.213112
8.213160
8.213115
8.213118
8.213140
8.213135
8.213137
8.213128
8.213156
8.213143
8.213139

平均: 8.213142968749999

合計: 262.82057499999996

プロセス数６４

11.147822
11.148057
11.148022
11.147988
11.147891

11.147851
11.147886
11.147974
11.147978
11.147858
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平均: 713.470866

合計: 11.14798228125

課題 1.18

1.18_02190367.c 参照

課題 1.19

1.19_02190367.c, 1.19_02190367.gif 参照