Explain your system:

Hardware and Software	**Specification**
Processor	Intel®core™ i3-5005U CPU @2.00GHz
Number of cores	2
Logical processors	4
RAM	4.00 GB
OS	Windows 10
Python	3.6

Basic Parallel Vector Operations with MPI:

The results obtained are as follows:

a) Add two vectors and store results in a third vector.

N	No of workers:	Processes	Execution time(in sec)
10^7	2	0	0.48377054918091744
		1	0.7713456408528145
10^7	4	0	0.6726023263472598
		1	0.8268860289826989
		2	1.0048808950814418
		3	1.1765133032749873
10^7	10	0	1.6840843099926133
		1	1.8019108927692287
		2	1.8743878995301202
		3	1.9023769666673616
		4	1.9989130758331157
		5	2.0911959142249543
		6	2.2113313127483707
		7	2.286720126779983
		8	2.3374642951821443
		9	2.436765440943418
10^{12}	2	0	Memory error
		1	Memory error
10^{15}	2	0	Memory error
		1	Memory error

```
(base) C:\Users\saikiran\.spyder-py3>mpiexec -n 2 python untitled0.py
my rank is: 0
start time is: 151547.44891918273
my vector sum is: [ 1.51162889  1.63593652  1.59875905 ...,  0.56791052  1.25744901
  0.91116183]
end time is: 151547.90742310704
total execution time is : 0.45850392431020737
sending vector1 data [ 0.94412999  0.39351486  0.04149968 ...,  0.7016828   0.45616281
  0.14553608] data to process1
sending vector2 data [ 0.18265264  0.89114063  0.99060797 ...,  0.4931287   0.78431561
  0.64490948] data to process1
Data has been sent to all processes succesfully
my rank is: 1
start time is: 151547.44891918273
received vector1 data is [ 0.94412999  0.39351486  0.04149968 ...,  0.7016828   0.45616281
  0.14553608]
received vector2 data is [ 0.18265264  0.89114063  0.99060797 ...,  0.4931287   0.78431561
  0.64490948]
my  vector sum is: [ 1.12678263  1.28465549  1.03210765 ...,  1.1948115   1.24047842
  0.79044556]
end time is: 151548.16966178082
total execution time is : 0.720742598088691
vector sum using parallel processes is completed successfully
```

b) Find an average of numbers in a vector

N	No of workers:	processes	Execution time(in sec)
10^7	2	0	0.20696565465186723
		1	0.34075483240303583
10^7	4	0	0.312748830212513
		1	0.38610338198486716
		2	0.45604166644625366
		3	0.5303789660101756
10^7	8	0	0.6656445747648831
		1	0.8684816623863298
		2	0.8857677595224231
		3	0.8228590724465903
		4	0.8177657190826721
		5	1.0303543331683613
		6	0.8803623901621904
		7	1.058783199172467
10^{12}	2	0	Memory Error
		1	Memory Error
10^{15}	2	0	Memory Error
		1	Memory Error

```
(base) C:\Users\saikiran\.spyder-py3>mpiexec -n 2 python vector_average.py
my rank is: 0
start time is: 151877.9432726168
my vector average is: 0.499997796931
end time is: 151878.19320821218
total execution time is : 0.2499355953768827
sending vector1 data [ 0.94412999  0.39351486  0.04149968 ...,  0.7016828   0.45616281
  0.14553608] data to process1
Data has been sent to all processes succesfully
my rank is: 1
start time is: 151877.94325362897
received vector1 data is [ 0.94412999  0.39351486  0.04149968 ...,  0.7016828   0.45616281
  0.14553608]
my  vector average is: 0.500001322462
end time is: 151878.340787163
total execution time is : 0.3975335340364836
vector average using parallel processes is completed successfully
```

Parallel Matrix Operation using MPI-point to point communication:

The results obtained are as follows:

Matix A	No of workers:	processes	Execution time(in sec)
10^2	2	0	0.00699216005159542
		1	0.008929437433835119
10^2	4	0	0.008957662677858025
		1	0.009878318465780467
		2	0.015088183310581371
		3	0.021409096021670848
10^3	2	0	0.031167328939773142
		1	0.03851820604177192
10^3	4	0	0.032725874974858016
		1	0.05183333155582659
		2	0.0961428422597237
		3	0.13099022844107822
10^4	2	0	Memory error
		1	Memory error
10^4	4	0	Memory error
		1	Memory error
		2	Memory error
		3	Memory error

```
(base) C:\Users\saikiran\.spyder-py3>mpiexec -n 2 python vector_multiplication.py
my rank is: 0
start time is: 153101.07432446996
my vector product is: [[  3.71994869e-01   1.93106831e-01   4.43148031e-01 ...,   5.11448471e-03
    4.81026939e-02   2.03979292e-03]
 [  1.71117791e-01   4.98017459e-01   2.27694974e-01 ...,   1.73365558e-02
    8.06491910e-01   4.51157626e-03]
 [  4.97529900e-01   5.53590421e-01   2.00807697e-01 ...,   7.17250027e-03
    1.35353495e-02   8.69753973e-04]
 ...,
 [  2.24968557e-01   6.88378558e-01   3.33221069e-01 ...,   1.36360510e-02
    8.26746390e-01   3.66231352e-04]
 [  4.16532359e-01   5.84613316e-01   1.70100693e-01 ...,   3.96899360e-03
    3.30487796e-01   4.50105109e-03]
 [  2.01293937e-01   2.12857648e-01   4.13493210e-02 ...,   1.51515394e-02
    4.09087335e-01   1.67409937e-03]]
end time is: 153101.0758604303
total execution time is : 0.0015359603567048907
sending vector1 data [ 0.77037589  0.38012993  0.62219227 ...,  0.29310578  0.12380606
  0.85159298] data to process1
Data has been sent to all processes succesfully
```

```
Data has been sent to all processes succesfully
my rank is: 1
start time is: 153101.0742279913
received vector1 data is [[ 0.77037589  0.38012993  0.62219227 ...,  0.92515618  0.74933685
   0.00863659]
 [ 0.62892557  0.23211187  0.26718466 ...,  0.90646773  0.24778176
   0.5075565 ]
 [ 0.75611165  0.2240344   0.21169364 ...,  0.12946952  0.01540645
   0.38674234]
 ...,
 [ 0.26969792  0.73882539  0.80714479 ...,  0.94836806  0.88130699
   0.1419334 ]
 [ 0.88498232  0.19701397  0.56861333 ...,  0.75842952  0.02378743
   0.81357508]
 [ 0.74826798  0.18020271  0.38902314 ...,  0.29310578  0.12380606
   0.85159298]]
my  vector product is: [[  4.22792690e-01   2.71864883e-01   3.75034713e-01 ...,   1.86026206e-02
    6.21155311e-01   4.05529108e-05]
 [  3.45162845e-01   1.66003940e-01   1.61049127e-01 ...,   1.82268417e-02
    2.05396217e-01   2.38321946e-03]
 [  4.14964286e-01   1.60227018e-01   1.27601174e-01 ...,   2.60331440e-03
    1.27710197e-02   1.81593943e-03]
 ...,
 [  1.48013861e-01   5.28400060e-01   4.86517316e-01 ...,   1.90693546e-02
    7.30550644e-01   6.66444878e-04]
 [  4.85690247e-01   1.40902297e-01   3.42739290e-01 ...,   1.52501566e-02
    1.97183508e-02   3.82012242e-03]
 [  4.10659573e-01   1.28879060e-01   2.34488904e-01 ...,   5.89363808e-03
    1.02627799e-01   3.99863457e-03]]
end time is: 153101.07924641977
total execution time is : 0.005018428462790325
vector multiplication using point to point is completed successfully
```

Parallel Matrix Operation using MPI-collective communication:

The results obtained are as follows:

Matix A	No of workers:	processes	Execution time(in sec)
10^2	2	0	0.13183548545930535
		1	0.13260218266805168
10^2	4	0	0.007314414615393616
		1	0.010356057464377955
		2	0.005719951266655698
		3	0.012103962915716693
10^3	2	0	0.10295450416742824
		1	0.1017351784685161
10^3	4	0	0.11273733487178106
		1	0.10260143342020456
		2	0.0975860840844689
		3	0.10902598661778029
10^4	2	0	Memory Error
		1	Memory Error

```
(base) C:\Users\saikiran\.spyder-py3>mpiexec -n 2 python matrix_multiplication.py
my rank is: 0
start time is: 154401.11473977967
matrix1 is: [ 0.5488135   0.71518937  0.60276338 ...,  0.75842952  0.02378743
  0.81357508]
matrix2 is: [ 0.74826798  0.18020271  0.38902314 ...,  0.44645576  0.36012661
  0.62588665]
process=0,variable shared from matrix1=[[ 0.5488135   0.71518937]
 [ 0.60276338  0.54488318]
 [ 0.4236548   0.64589411]
 ...,
 [ 0.69291755  0.21815575]
 [ 0.23545348  0.19738826]
 [ 0.39868722  0.9585931 ]]
process=0,variable shared from matrix2=[[ 0.74826798  0.18020271]
 [ 0.38902314  0.03760018]
 [ 0.01178774  0.99626787]
 ...,
 [ 0.68893807  0.33428212]
 [ 0.19549847  0.53242997]
 [ 0.37411674  0.10671197]]
product is : [[ 0.41065957  0.12887906]
 [ 0.2344889   0.02048771]
 [ 0.00499393  0.64348355]
 ...,
 [ 0.47737728  0.07292557]
 [ 0.04603079  0.10509543]
 [ 0.14915556  0.10229336]]
end time is: 154401.1184583125
total execution time is : 0.0037185328255873173
```

```
total execution time is : 0.0037185328255873173
my rank is: 1
start time is: 154401.11125217975
process=1,variable shared from matrix1=[[ 0.36678022  0.29762418]
 [ 0.06859959  0.35252753]
 [ 0.23219605  0.76292734]
 ...,
 [ 0.73550223  0.55044682]
 [ 0.39715133  0.75842952]
 [ 0.02378743  0.81357508]]
process=1,variable shared from matrix2=[[ 0.38613786  0.71247659]
 [ 0.58098534  0.46313774]
 [ 0.94364596  0.74239641]
 ...,
 [ 0.95355073  0.74817451]
 [ 0.29826661  0.44645576]
 [ 0.36012661  0.62588665]]
product is : [[ 0.14162773  0.21205026]
 [ 0.03985536  0.1632688 ]
 [ 0.21911086  0.56639452]
 ...,
 [ 0.70133869  0.41183028]
 [ 0.11845698  0.33860523]
 [ 0.00856649  0.50920578]]
end time is: 154401.11859071403
total execution time is : 0.007338534283917397
```