i.En variant le nombre de threads (2, 4, 8, 16) pour un nombre de particules = 500. Nombre d'itérations = 400.

1 -

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 500


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 2


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 500
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0   124433.847243        0.000000    0.000000e+00
       40   124244.521135     1261.977812    8.620257e-03
       80   124589.861837     1261.409496    1.139099e-02
      120   124712.954747     1215.629632    1.201230e-02
      160   124737.617850     1209.146002    1.215840e-02
      200   124743.793304     1210.432323    1.221837e-02
      240   124747.806292     1208.848522    1.223789e-02
      280   124749.448048     1207.553512    1.224068e-02
      320   124748.834586     1209.154327    1.224861e-02
      360   124749.794722     1209.341428    1.225783e-02
      400   124749.999367     1209.093603    1.225748e-02

 Elapsed time for main computation:
 7.475321 seconds.
```

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 500


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 4


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 500
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy E

        0   124433.847243        0.000000    0.000000e+00
       40   124244.521135     1261.977812    8.620257e-03
       80   124589.861837     1261.409496    1.139099e-02
      120   124712.954747     1215.629632    1.201230e-02
      160   124737.617850     1209.146002    1.215840e-02
      200   124743.793304     1210.432323    1.221837e-02
      240   124747.806292     1208.848522    1.223789e-02
      280   124749.448048     1207.553512    1.224068e-02
      320   124748.834586     1209.154327    1.224861e-02
      360   124749.794722     1209.341428    1.225783e-02
      400   124749.999367     1209.093603    1.225748e-02

 Elapsed time for main computation:
 7.502234 seconds.
```

2 -

3 -

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 500


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 8


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 500
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0   124433.847243        0.000000    0.000000e+00
       40   124244.521135     1261.977812    8.620257e-03
       80   124589.861837     1261.409496    1.139099e-02
      120   124712.954747     1215.629632    1.201230e-02
      160   124737.617850     1209.146002    1.215840e-02
      200   124743.793304     1210.432323    1.221837e-02
      240   124747.806292     1208.848522    1.223789e-02
      280   124749.448048     1207.553512    1.224068e-02
      320   124748.834586     1209.154327    1.224861e-02
      360   124749.794722     1209.341428    1.225783e-02
      400   124749.999367     1209.093603    1.225748e-02

 Elapsed time for main computation:
 8.267904 seconds.
```

4 -

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 500


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 16


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 500
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0   124433.847243        0.000000    0.000000e+00
       40   124244.521135     1261.977812    8.620257e-03
       80   124589.861837     1261.409496    1.139099e-02
      120   124712.954747     1215.629632    1.201230e-02
      160   124737.617850     1209.146002    1.215840e-02
      200   124743.793304     1210.432323    1.221837e-02
      240   124747.806292     1208.848522    1.223789e-02
      280   124749.448048     1207.553512    1.224068e-02
      320   124748.834586     1209.154327    1.224861e-02
      360   124749.794722     1209.341428    1.225783e-02
      400   124749.999367     1209.093603    1.225748e-02

 Elapsed time for main computation:
 8.155169 seconds.
```

ii. En variant la taille des particules (200, 500, 1000) pour un nombre de threads= 4. Nombre d'itérations = 400.

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 200


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 4


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 200
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0    19849.695286        0.000000    0.000000e+00
       40    19792.693106      174.560544    5.922427e-03
       80    19841.466234      182.256028    8.767237e-03
      120    19870.213058      188.827633    1.054653e-02
      160    19889.444106      189.256856    1.153699e-02
      200    19894.904829      190.400827    1.186972e-02
      240    19897.226369      190.618816    1.199766e-02
      280    19899.479046      189.178079    1.203856e-02
      320    19899.992946      189.011261    1.205605e-02
      360    19899.996664      189.368894    1.207425e-02
      400    19899.393284      190.368438    1.209421e-02

 Elapsed time for main computation:
 1.345414 seconds.
```

5-

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 500


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 4


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 500
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0   124433.847243        0.000000    0.000000e+00
       40   124244.521135     1261.977812    8.620257e-03
       80   124589.861837     1261.409496    1.139099e-02
      120   124712.954747     1215.629632    1.201230e-02
      160   124737.617850     1209.146002    1.215840e-02
      200   124743.793304     1210.432323    1.221837e-02
      240   124747.806292     1208.848522    1.223789e-02
      280   124749.448048     1207.553512    1.224068e-02
      320   124748.834586     1209.154327    1.224861e-02
      360   124749.794722     1209.341428    1.225783e-02
      400   124749.999367     1209.093603    1.225748e-02

 Elapsed time for main computation:
 7.384180 seconds.
```

6-

```
Enter ND, the spatial dimension : 3


Enter NP, the number of particles  : 1000


Enter step_num, the number of time steps : 400


Enter DT, the size of the time step (0.1, for instance) : 0.1


Enter nbrThreads, the number of threads to use : 4


ND, the spatial dimension, is 3
NP, the number of particles in the simulation, is 1000
STEP_NUM, the number of time steps, is 400
DT, the size of each time step, is 0.100000

 Initializing positions, velocities, and accelerations.

 Computing initial forces and energies.

 At each step, we report the potential and kinetic energies.
 The sum of these energies should be a constant.
 As an accuracy check, we also print the relative error
 in the total energy.

     Step      Potential       Kinetic        (P+K-E0)/E0
               Energy P        Energy K       Relative Energy Error

        0   498159.395148        0.000000    0.000000e+00
       40   497938.061734     5564.472483    1.072576e-02
       80   499298.289524     5046.970762    1.241744e-02
      120   499461.763696     4979.830517    1.261082e-02
      160   499486.607188     4975.818833    1.265264e-02
      200   499494.166781     4973.664134    1.266349e-02
      240   499498.370122     4971.844320    1.266827e-02
      280   499498.813404     4972.176829    1.266983e-02
      320   499499.209733     4972.321851    1.267092e-02
      360   499499.990024     4971.894047    1.267162e-02
      400   499499.116976     4972.943401    1.267198e-02

 Elapsed time for main computation:
 30.716481 seconds.
```

7-