Date:12.09.2022

Final Year B. Tech., Sem VII 2021-22

High Performance Computing Lab

Assignment submission

PRN No: 2019BTECS00064

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Batch: B3

Assignment: 3

Title of assignment: Study and Implementation of schedule, nowait, reduction, ordered and collapse clauses

1. Analyse and implement a Parallel code for below program using openMP

```
// C Program to find the minimum scalar product of two vectors (dot product)
#include<stdio.h>
int sort(int arr[], int n)
{
        int i, j;
        for (i = 0; i < n-1; i++)
                for (j = 0; j < n-i-1; j++)
                        if (arr[j] > arr[j+1])
                        {
                                int temp = arr[j];
                                arr[j] = arr[j+1];
                                arr[j+1] = temp;
```

```
            }
}

int sort_des(int arr[], int n)
{
    int i,j;
    for (i = 0; i < n; ++i)
    {
        for (j = i + 1; j < n; ++j)
        {
            if (arr[i] < arr[j])
            {
                int a = arr[i];
                arr[i] = arr[j];
                arr[j] = a;
            }
        }
    }
}

int main()
{
    //fill the code;
    int n;
    scanf(“%d”,&n);
    int arr1[n], arr2[n];
    int i;
    for(i = 0; i < n ; i++)
    {
        scanf(“%d”,&arr1[i]);
    }
    for(i = 0; i < n ; i++)
    {
        scanf(“%d”,&arr2[i]);
    }
    sort(arr1, n);
    sort_des(arr2, n);
    int sum = 0;
    for(i = 0; i < n ; i++)
    {
        sum = sum + (arr1[i] * arr2[i]);
    }
    printf(“%d”,sum);
    return 0;
}
```

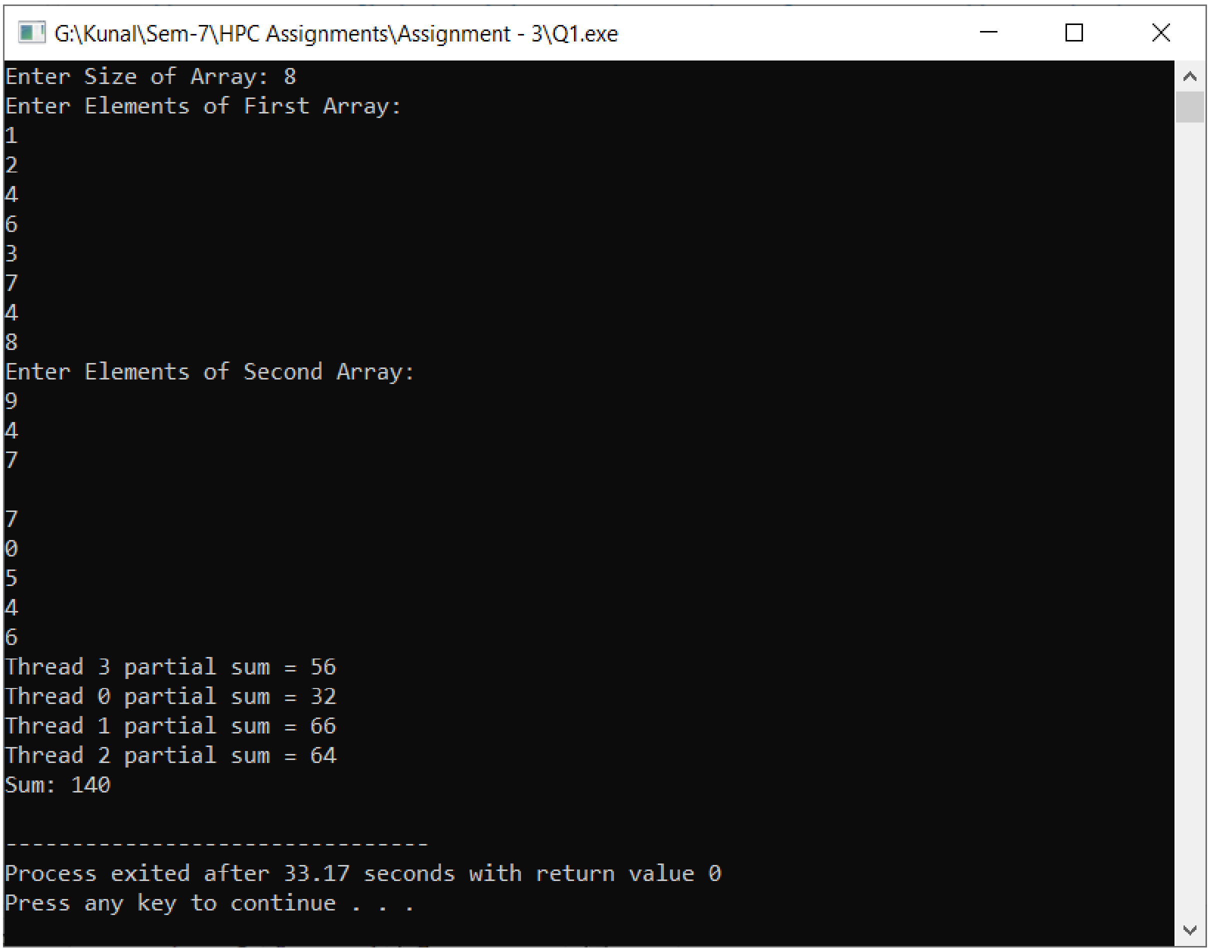
Ans:

Code:

```
// C Program to find the minimum scalar product of two vectors (dot
product)
#include<bits/stdc++.h>
#include <omp.h>

using namespace std;

int sort(int arr[], int n)
{
    int i, j;
    #pragma omp parallel shared(arr) private(j)
    #pragma omp for schedule(dynamic)
    for (i = 0; i < n-1; i++)
        for (j = 0; j < n-i-1; j++)
            if (arr[j] > arr[j+1])
            {
                int temp = arr[j];
                arr[j] = arr[j+1];
                arr[j+1] = temp;
            }
```

```
}

int sort_des(int arr[], int n)
{
    int i,j;
    #pragma omp parallel shared(arr) private(j)
    #pragma omp for schedule(dynamic)
    for (i = 0; i < n; ++i)
    {
        for (j = i + 1; j < n; ++j)
        {
            if (arr[i] < arr[j])
            {
                int a = arr[i];
                arr[i] = arr[j];
                arr[j] = a;
            }
        }
    }
}

int main()
{
    //fill the code;
    int i,tid,n,psum;
    int threads = 4;
    cout<<"Enter Size of Array: ";
    cin>>n;
    int arr1[n], arr2[n];
    cout<<"Enter Elements of First Array:\n";
    for(i = 0; i < n ; i++)
    {
        cin>>arr1[i];
    }
    cout<<"Enter Elements of Second Array:\n";
    for(i = 0; i < n ; i++)
    {
        cin>>arr2[i];
    }
    sort(arr1, n);
    sort_des(arr2, n);
    int sum = 0;
    #pragma omp parallel private(i,tid,psum) num_threads(threads)
    {
        psum=0;
        tid = omp_get_thread_num();
        #pragma omp for reduction(+:sum)
        for(int i=0; i<n; i++)
        {
            sum += arr1[i] * arr2[i];
            psum+=sum;
        }
        printf("Thread %d partial sum = %d\n",tid,psum);
    }
    cout<<"Sum: "<<sum<<endl;

    return 0;
}
```

Output:



```
Enter Size of Array: 8
Enter Elements of First Array:
1
2
4
6
3
7
4
8
Enter Elements of Second Array:
9
4
7

7
0
5
4
6
Thread 3 partial sum = 56
Thread 0 partial sum = 32
Thread 1 partial sum = 66
Thread 2 partial sum = 64
Sum: 140

--------------------------------
Process exited after 33.17 seconds with return value 0
Press any key to continue . . .
```

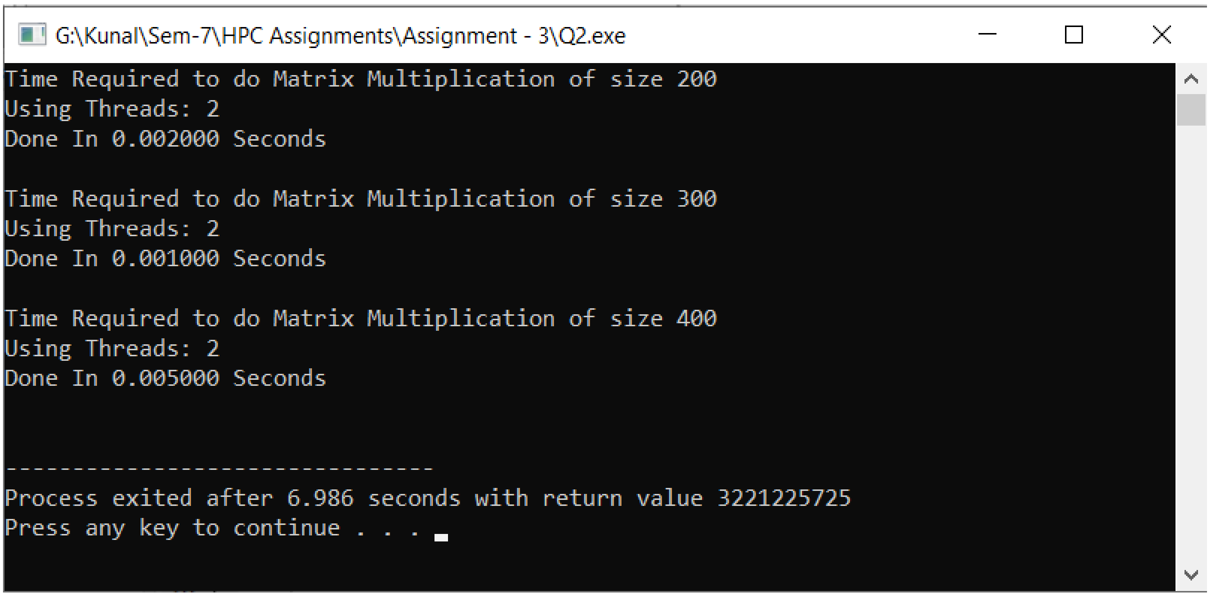
2. Write OpenMP code for two 2D Matrix addition, vary the size of your matrices from 250, 500, 750, 1000, and 2000 and measure the runtime with one thread (Use functions in C in calculate the execution time or use GPROF)
    i. For each matrix size, change the number of threads from 2,4,8., and plot the speedup versus the number of threads.
    ii. Explain whether or not the scaling behaviour is as expected.

Ans:

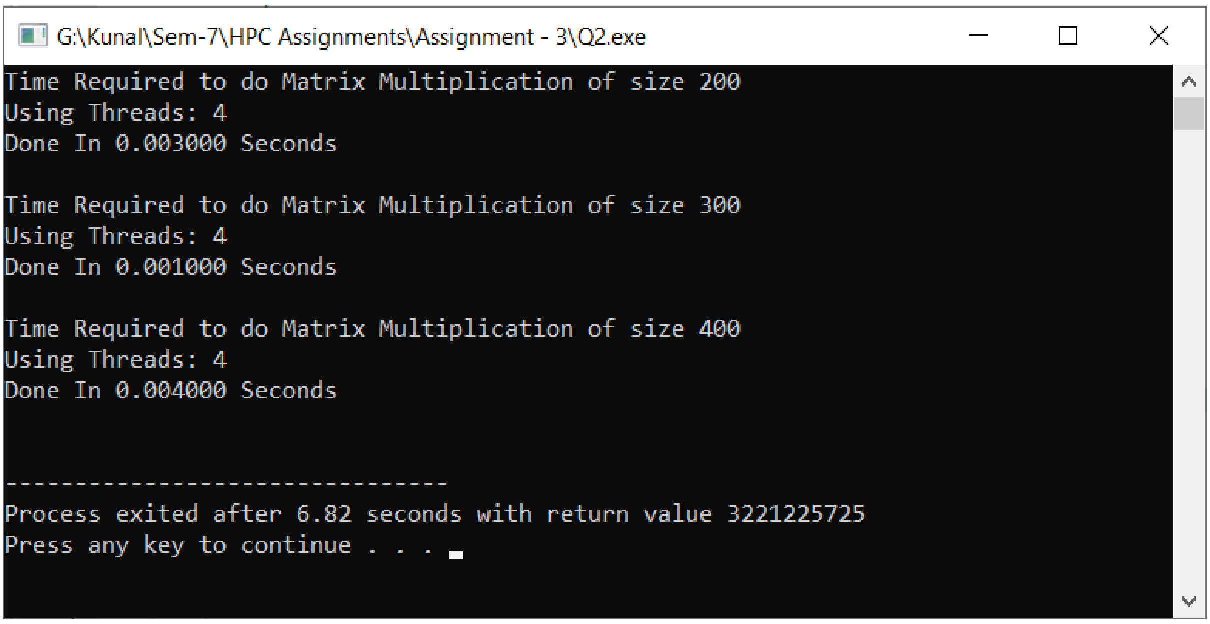
Code:

```
#include <bits/stdc++.h>
#include <omp.h>

using namespace std;

int main()
{

        int tid, nthreads , i, j;
        int n=100;
        while(1){
                if(n==500)
                        break;
                else
                        n+=100;
                nthreads=4;
                int a[n][n], b[n][n], c[n][n];

                int index = 0;

                for (i = 0; i < n; i++)
                {

                        for (j = 0; j < n; j++)
                {
                    a[i][j] = b[i][j] = (i+j);
                }
            }

            printf("Time Required to do Matrix Multiplication of size %d\nUsing Threads: %d",n,nthreads);

            double time = omp_get_wtime();

            #pragma omp parallel shared(a, b, c, nthreads) private(tid, i, j) num_threads(nthreads)
            {
                # pragma omp parallel for
                for (int i = 0; i < n; i++)
                {
                    for (int j = 0; j < n; j++)
                    {
                        c[i][j] = a[i][j] + b[i][j];
                    }
                }
            }

            printf("\nDone In %f Seconds\n\n", omp_get_wtime() - time);

        }
        return 0;
}
```

Output:



```
Time Required to do Matrix Multiplication of size 200
Using Threads: 2
Done In 0.002000 Seconds

Time Required to do Matrix Multiplication of size 300
Using Threads: 2
Done In 0.001000 Seconds

Time Required to do Matrix Multiplication of size 400
Using Threads: 2
Done In 0.005000 Seconds


--------------------------------
Process exited after 6.986 seconds with return value 3221225725
Press any key to continue . . .
```



```
Time Required to do Matrix Multiplication of size 200
Using Threads: 4
Done In 0.003000 Seconds

Time Required to do Matrix Multiplication of size 300
Using Threads: 4
Done In 0.001000 Seconds

Time Required to do Matrix Multiplication of size 400
Using Threads: 4
Done In 0.004000 Seconds


--------------------------------
Process exited after 6.82 seconds with return value 3221225725
Press any key to continue . . .
```

3. For 1D Vector (size=200) and scalar addition, Write a OpenMP code with the following:
   i. Use STATIC schedule and set the loop iteration chunk size to various sizes when changing the size of your matrix. Analyze the speedup.
   ii. Use DYNAMIC schedule and set the loop iteration chunk size to various sizes when changing the size of your matrix. Analyze the speedup.
   iii. Demonstrate the use of nowait clause

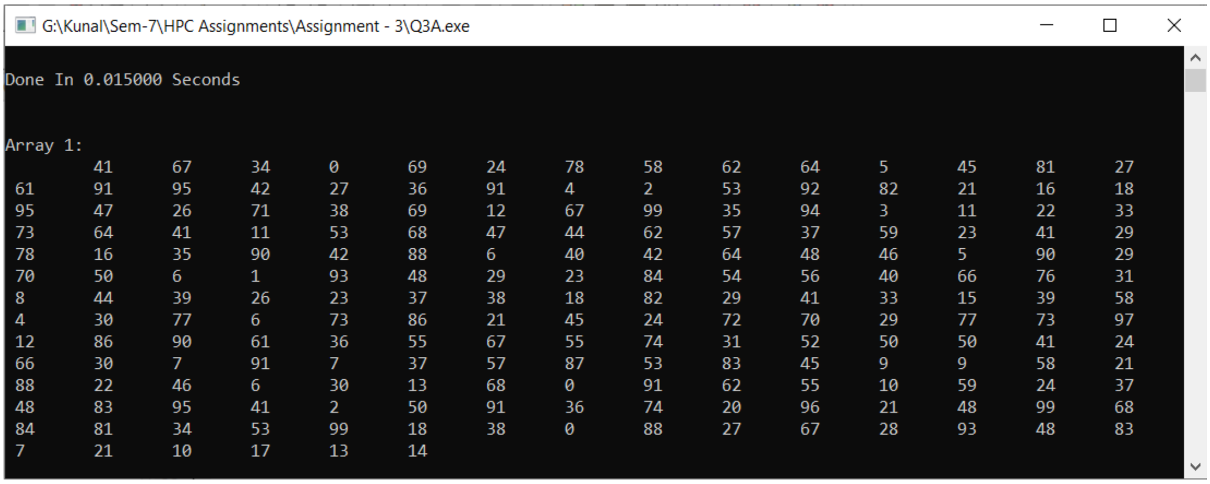
Ans:

Use of Static Schedule

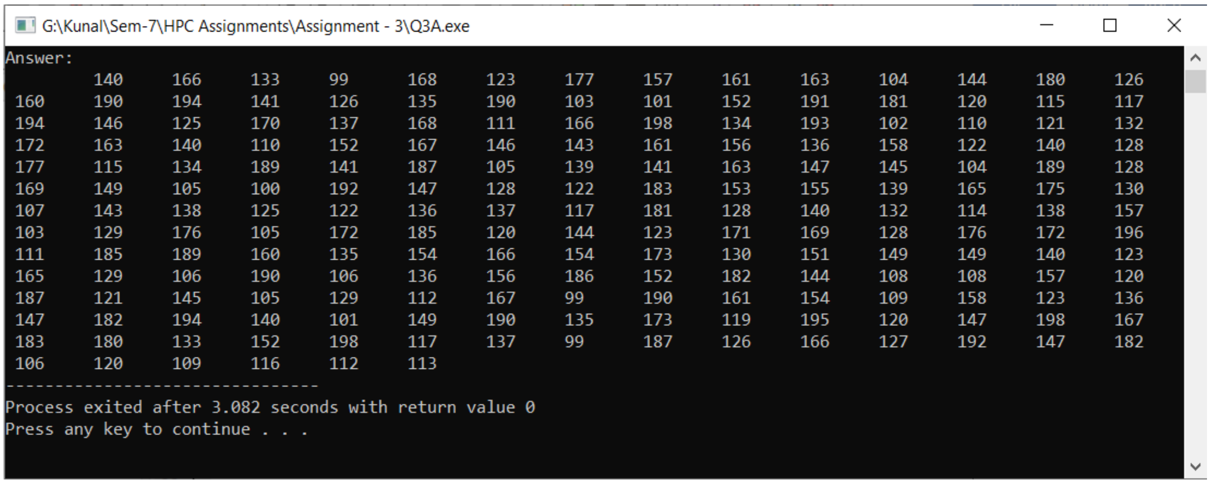
Code:

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

int main(){
  int n = 200, i ,j=99;

  int arr1[n], answer[n];

      for(i = 0; i < n; i++){
    arr1[i] = rand()%100;
  }

  double time = omp_get_wtime();
  #pragma omp parallel for schedule(static,20) shared(arr1, answer,j) private(i)

      for(i = 0; i < n; i++)
  {
        answer[i] = arr1[i] + j;
    }

    printf("\nDone In %f Seconds\n\n", omp_get_wtime() - time);

    printf("\nArray 1: \n");
    for(i = 0; i < n; i++){
        printf("\t %d", arr1[i]);
    }

    printf("\nAnswer: \n");
    for(i = 0; i < n; i++){
        printf("\t %d", answer[i]);
    }
    return 0;
}
```

Output:



```
Done In 0.015000 Seconds


Array 1:
         41      67      34      0       69      24      78      58      62      64      5       45      81      27
 61      91      95      42      27      36      91      4       2       53      92      82      21      16      18
 95      47      26      71      38      69      12      67      99      35      94      3       11      22      33
 73      64      41      11      53      68      47      44      62      57      37      59      23      41      29
 78      16      35      90      42      88      6       40      42      64      48      46      5       90      29
 70      50      6       1       93      48      29      23      84      54      56      40      66      76      31
 8       44      39      26      23      37      38      18      82      29      41      33      15      39      58
 4       30      77      6       73      86      21      45      24      72      70      29      77      73      97
 12      86      90      61      36      55      67      55      74      31      52      50      50      41      24
 66      30      7       91      7       37      57      87      53      83      45      9       9       58      21
 88      22      46      6       30      13      68      0       91      62      55      10      59      24      37
 48      83      95      41      2       50      91      36      74      20      96      21      48      99      68
 84      81      34      53      99      18      38      0       88      27      67      28      93      48      83
 7       21      10      17      13      14
```



```
Answer:
        140     166     133     99      168     123     177     157     161     163     104     144     180     126
 160    190     194     141     126     135     190     103     101     152     191     181     120     115     117
 194    146     125     170     137     168     111     166     198     134     193     102     110     121     132
 172    163     140     110     152     167     146     143     161     156     136     158     122     140     128
 177    115     134     189     141     187     105     139     141     163     147     145     104     189     128
 169    149     105     100     192     147     128     122     183     153     155     139     165     175     130
 107    143     138     125     122     136     137     117     181     128     140     132     114     138     157
 103    129     176     105     172     185     120     144     123     171     169     128     176     172     196
 111    185     189     160     135     154     166     154     173     130     151     149     149     140     123
 165    129     106     190     106     136     156     186     152     182     144     108     108     157     120
 187    121     145     105     129     112     167     99      190     161     154     109     158     123     136
 147    182     194     140     101     149     190     135     173     119     195     120     147     198     167
 183    180     133     152     198     117     137     99      187     126     166     127     192     147     182
 106    120     109     116     112     113
--------------------------------
Process exited after 3.082 seconds with return value 0
Press any key to continue . . .
```

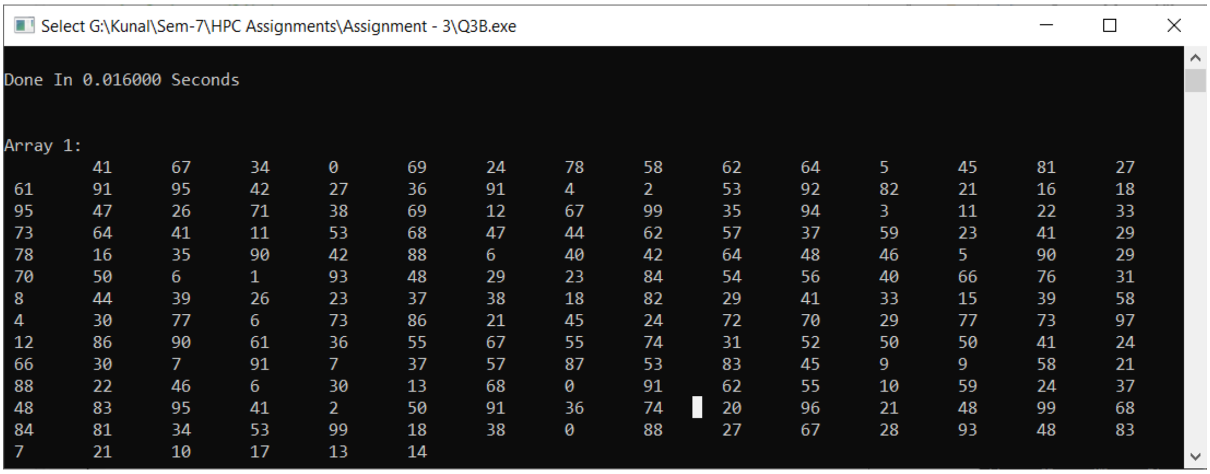
Use of Dynamic Schedule

Code:

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

int main(){
   int n = 200, i ,j=99;

         int arr1[n], answer[n];

         for(i = 0; i < n; i++)
         {
      arr1[i] = rand()%100;
   }
```

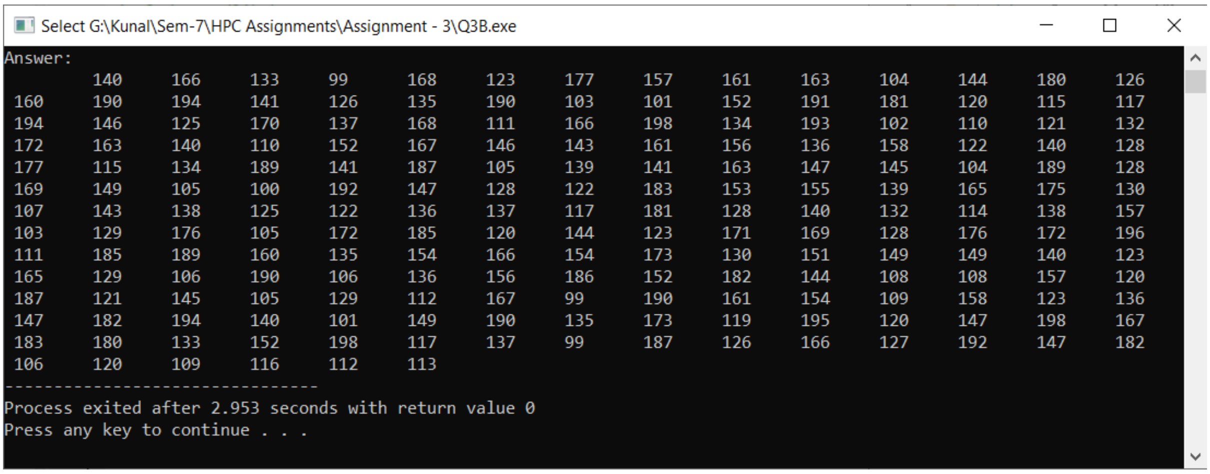
```
    double time = omp_get_wtime();

          #pragma omp parallel for schedule(dynamic,20) shared(arr1,
answer,j) private(i)
    for(i = 0; i < n; i++)
    {
       answer[i] = arr1[i] + j;
    }

    printf("\nDone In %f Seconds\n\n", omp_get_wtime() - time);

          printf("\nArray 1: \n");
    for(i = 0; i < n; i++)
          {
       printf("\t %d", arr1[i]);
    }

          printf("\nAnswer: \n");
    for(i = 0; i < n; i++)
          {
       printf("\t %d", answer[i]);
    }
    return 0;
}
```

Output:



Select G:\Kunal\Sem-7\HPC Assignments\Assignment - 3\Q3B.exe

```
Done In 0.016000 Seconds


Array 1:
         41      67      34      0       69      24      78      58      62      64      5       45      81      27
 61      91      95      42      27      36      91      4       2       53      92      82      21      16      18
 95      47      26      71      38      69      12      67      99      35      94      3       11      22      33
 73      64      41      11      53      68      47      44      62      57      37      59      23      41      29
 78      16      35      90      42      88      6       40      42      64      48      46      5       90      29
 70      50      6       1       93      48      29      23      84      54      56      40      66      76      31
 8       44      39      26      23      37      38      18      82      29      41      33      15      39      58
 4       30      77      6       73      86      21      45      24      72      70      29      77      73      97
 12      86      90      61      36      55      67      55      74      31      52      50      50      41      24
 66      30      7       91      7       37      57      87      53      83      45      9       9       58      21
 88      22      46      6       30      13      68      0       91      62      55      10      59      24      37
 48      83      95      41      2       50      91      36      74      20      96      21      48      99      68
 84      81      34      53      99      18      38      0       88      27      67      28      93      48      83
 7       21      10      17      13      14
```



Select G:\Kunal\Sem-7\HPC Assignments\Assignment - 3\Q3B.exe

```
Answer:
         140     166     133     99      168     123     177     157     161     163     104     144     180     126
 160     190     194     141     126     135     190     103     101     152     191     181     120     115     117
 194     146     125     170     137     168     111     166     198     134     193     102     110     121     132
 172     163     140     110     152     167     146     143     161     156     136     158     122     140     128
 177     115     134     189     141     187     105     139     141     163     147     145     104     189     128
 169     149     105     100     192     147     128     122     183     153     155     139     165     175     130
 107     143     138     125     122     136     137     117     181     128     140     132     114     138     157
 103     129     176     105     172     185     120     144     123     171     169     128     176     172     196
 111     185     189     160     135     154     166     154     173     130     151     149     149     140     123
 165     129     106     190     106     136     156     186     152     182     144     108     108     157     120
 187     121     145     105     129     112     167     99      190     161     154     109     158     123     136
 147     182     194     140     101     149     190     135     173     119     195     120     147     198     167
 183     180     133     152     198     117     137     99      187     126     166     127     192     147     182
 106     120     109     116     112     113
--------------------------------
Process exited after 2.953 seconds with return value 0
Press any key to continue . . .
```

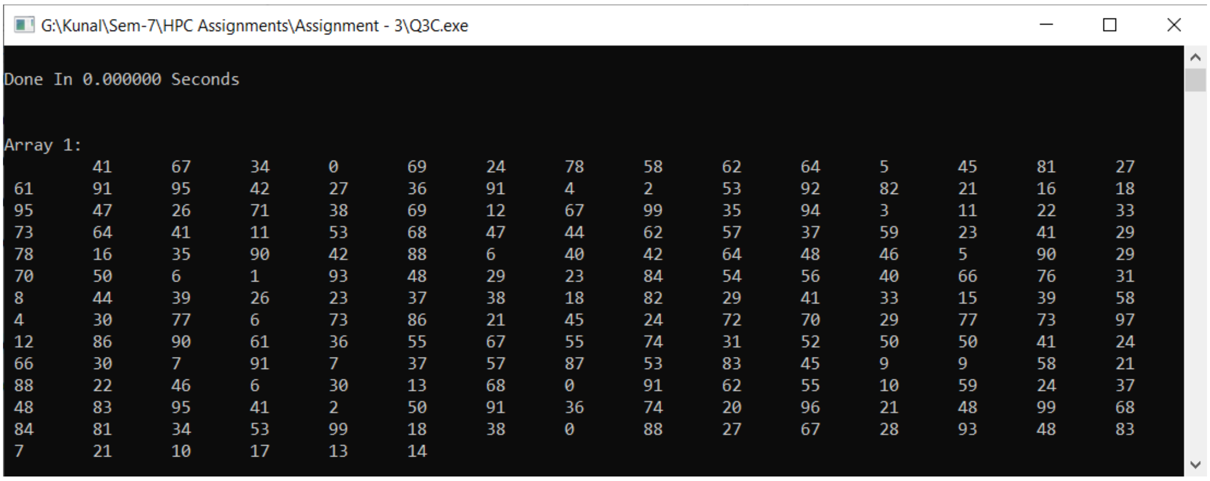
Use of Nowait Clause

Code:

```
#include <omp.h>
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

int main()
```

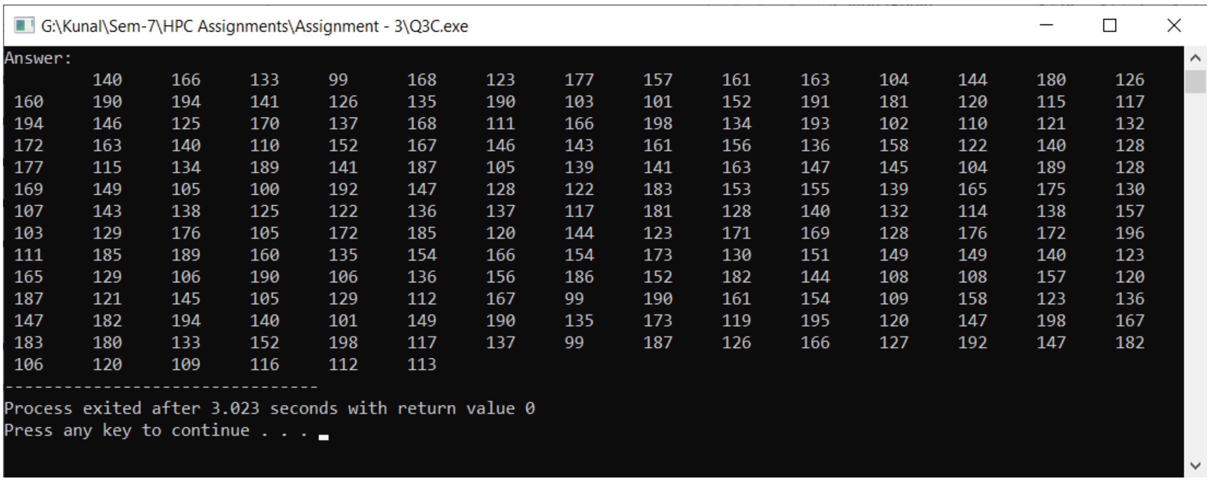
```
{
    int n = 200, i ,j=99;

    int arr1[n], answer[n];

            for(i = 0; i < n; i++)
            {
        arr1[i] = rand()%100;
    }

    double time = omp_get_wtime();

            #pragma omp parallel
    {
                #pragma omp for nowait
                for(i = 0; i < n; i++)
                {
                    answer[i] = arr1[i] + j;
                }
    }

    printf("\nDone In %f Seconds\n\n", omp_get_wtime() - time);

    printf("\nArray 1: \n");
    for(i = 0; i < n; i++){
        printf("\t %d", arr1[i]);
    }

    printf("\nAnswer: \n");
    for(i = 0; i < n; i++){
        printf("\t %d", answer[i]);
    }
    return 0;
}
```

Output:



G:\Kunal\Sem-7\HPC Assignments\Assignment - 3\Q3C.exe

```
Done In 0.000000 Seconds


Array 1:
         41      67      34      0       69      24      78      58      62      64      5       45      81      27
 61      91      95      42      27      36      91      4       2       53      92      82      21      16      18
 95      47      26      71      38      69      12      67      99      35      94      3       11      22      33
 73      64      41      11      53      68      47      44      62      57      37      59      23      41      29
 78      16      35      90      42      88      6       40      42      64      48      46      5       90      29
 70      50      6       1       93      48      29      23      84      54      56      40      66      76      31
 8       44      39      26      23      37      38      18      82      29      41      33      15      39      58
 4       30      77      6       73      86      21      45      24      72      70      29      77      73      97
 12      86      90      61      36      55      67      55      74      31      52      50      50      41      24
 66      30      7       91      7       37      57      87      53      83      45      9       9       58      21
 88      22      46      6       30      13      68      0       91      62      55      10      59      24      37
 48      83      95      41      2       50      91      36      74      20      96      21      48      99      68
 84      81      34      53      99      18      38      0       88      27      67      28      93      48      83
 7       21      10      17      13      14
```



G:\Kunal\Sem-7\HPC Assignments\Assignment - 3\Q3C.exe

```
Answer:
         140     166     133     99      168     123     177     157     161     163     104     144     180     126
 160     190     194     141     126     135     190     103     101     152     191     181     120     115     117
 194     146     125     170     137     168     111     166     198     134     193     102     110     121     132
 172     163     140     110     152     167     146     143     161     156     136     158     122     140     128
 177     115     134     189     141     187     105     139     141     163     147     145     104     189     128
 169     149     105     100     192     147     128     122     183     153     155     139     165     175     130
 107     143     138     125     122     136     137     117     181     128     140     132     114     138     157
 103     129     176     105     172     185     120     144     123     171     169     128     176     172     196
 111     185     189     160     135     154     166     154     173     130     151     149     149     140     123
 165     129     106     190     106     136     156     186     152     182     144     108     108     157     120
 187     121     145     105     129     112     167     99      190     161     154     109     158     123     136
 147     182     194     140     101     149     190     135     173     119     195     120     147     198     167
 183     180     133     152     198     117     137     99      187     126     166     127     192     147     182
 106     120     109     116     112     113
--------------------------------
Process exited after 3.023 seconds with return value 0
Press any key to continue . . .
```