Question 1

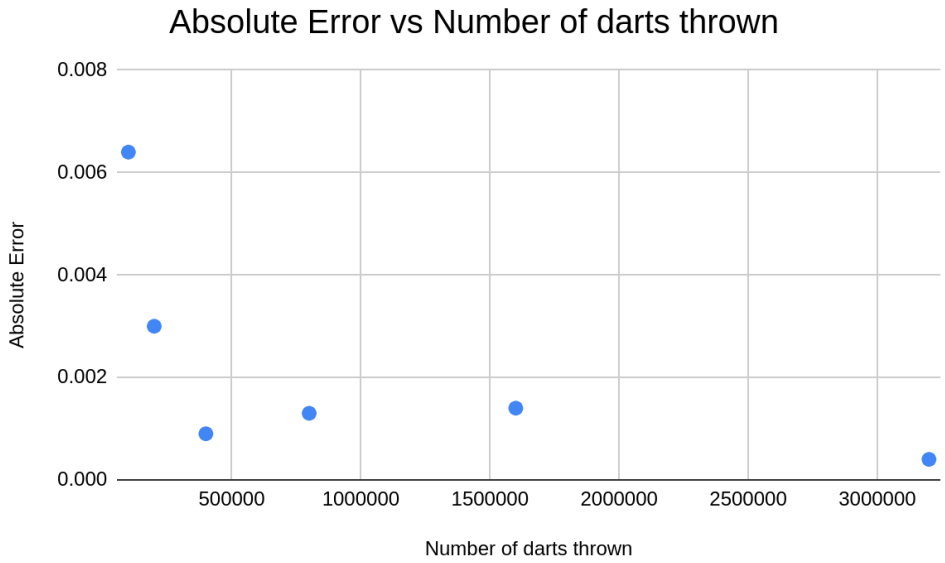
The platform used to run experiments for this question is the **Discovery Cluster** using sbatch. More information on the code and how to run is provided in the Readme and in the log file.

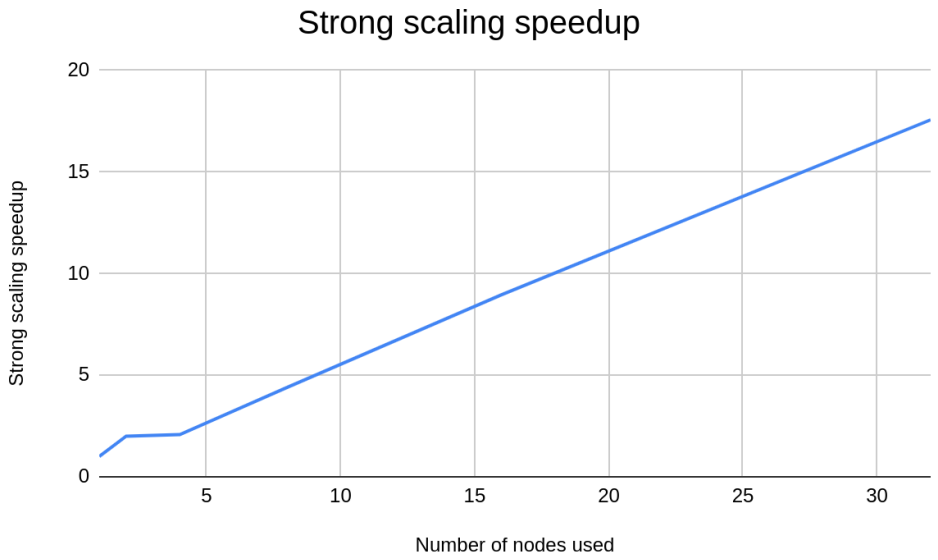
Below table shows the absolute error and time elapsed for increasing number of nodes and increasing number of darts. The strong scaling properties were also evaluated.

Number of Darts (x 10^5)	Number of nodes	Absolute Error	Time elapsed (seconds)
1	1	0.0064	0.0028
2	2	0.0030	0.0028
4	**4**	**0.0009**	**0.0054**
8	8	0.0013	0.0051
16	16	0.0014	0.0050
32	**32**	**0.0004**	**0.0051**

Below plot shows the variation in absolute error with increase in the number of darts. As we increase the number of darts, the absolute error between calculated pi value using darts and the actual pi value decreases.
Actual Pi value(upto 25 digits): **3.14159265358979323846264 3**

The absolute error in calculating pi using darts is minimum when using 3.2M darts. The next minimum absolute error in calculating pi using darts is minimum when using 400,000 darts.


Absolute Error vs Number of darts thrown
0.008
0.006
0.004
0.002
0.000
Absolute Error
500000
1000000
1500000
2000000
2500000
3000000
Number of darts thrown

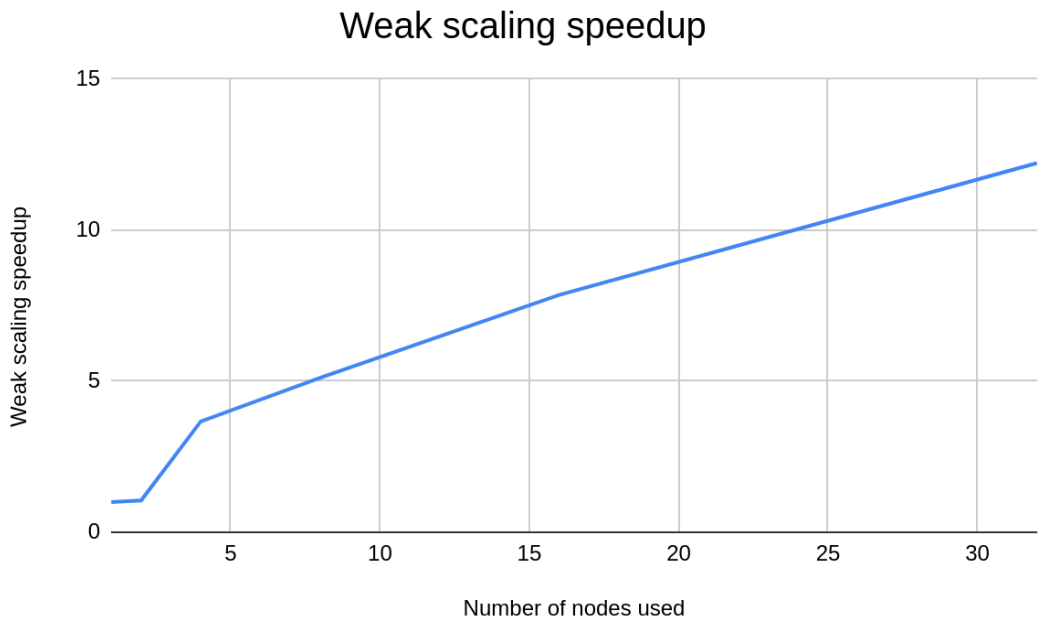

Strong scaling speedup
20
15
10
5
0
Strong scaling speedup
5
10
15
20
25
30
Number of nodes used

As each node has a copy of the program and executed in their own address space, contention due to shared memory is negligible. As a result, strong scaling speedup always increases.

Below table shows the time taken to calculate pi using **800, 000** darts with an increasing number of nodes.

Number of nodes	Time elapsed (seconds)
1	0.022
2	0.021
4	0.0061
8	0.0043
16	0.0028
32	0.0018

Below plot shows weak scaling speedup for throwing 800, 000 darts with an increasing number of nodes. As each node has a copy of the program and executed in their own address space, contention due to shared memory is negligible. As a result, weak scaling speedup keeps increasing with increasing number of nodes.


Weak scaling speedup
15
10
5
0
Weak scaling speedup
5
10
15
20
25
30
Number of nodes used