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Branch: - M.tech-CSE**(Data Science)**

Subject: - Complexity Theory & Algorithms

Practical-3

Aim: Randomized quick sort for the input size 10000, 50000 and 100000 for Ascending, Descending & Random order array. Plot the chart of the output data and do the analysis which algorithm is best and justify your reason.

Code for Randomized Quick Sort-

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

using namespace std;

int partition_low(vector<int> &array, int low, int high)
{
    int pivot = array[low];
    int start = low + 1;
    int end = high;

    while (true)
    {
        while (start <= end && array[end] >= pivot)
        {
            end = end - 1;
        }
        while (start <= end && array[start] <= pivot)
        {
            start = start + 1;
        }
        if (start <= end)
        {
            swap(array[start], array[end]);
        }
        else
        {
            break;
        }
    }

    swap(array[low], array[end]);
    return end;
}

int partition_high(vector<int> &array, int low, int high)
{
```

```
    int pivot = array[high];
    int start = low;
    int end = high - 1;

    while (true)
    {
        while (start <= end && array[start] <= pivot)
        {
            start = start + 1;
        }
        while (start <= end && array[end] >= pivot)
        {
            end = end - 1;
        }
        if (start <= end)
        {
            swap(array[start], array[end]);
        }
        else
        {
            break;
        }
    }

    swap(array[start], array[high]);
    return start;
}

int partition_mid(vector<int> &array, int low, int high)
{
    int mid = (low + high) / 2;
    int pivot = array[mid];
    int start = low;
    int end = high;

    while (true)
    {
        while (array[start] < pivot)
        {
            start = start + 1;
        }
        while (array[end] > pivot)
        {
            end = end - 1;
        }
```

```
        if (start >= end)
        {
            return end;
        }
        swap(array[start], array[end]);
        start = start + 1;
        end = end - 1;
    }
}

int partition_random(vector<int> &array, int low, int high)
{
    int pivot_index = low + rand() % (high - low + 1);
    int pivot = array[pivot_index];
    swap(array[pivot_index], array[high]);

    int start = low;
    int end = high - 1;

    while (true)
    {
        while (start <= end && array[start] <= pivot)
        {
            start = start + 1;
        }
        while (start <= end && array[end] >= pivot)
        {
            end = end - 1;
        }
        if (start <= end)
        {
            swap(array[start], array[end]);
        }
        else
        {
            break;
        }
    }

    swap(array[start], array[high]);
    return start;
}

void quick_sort(vector<int> &array, int start, int end, int pivot_choice)
{
```

```
    while (start < end)
    {
        int idx;

        switch (pivot_choice)
        {
        case 0: // Low
            idx = partition_low(array, start, end);
            break;
        case 1: // High
            idx = partition_high(array, start, end);
            break;
        case 2: // Mid
            idx = partition_mid(array, start, end);
            break;
        case 3: // Random
            idx = partition_random(array, start, end);
            break;
        }

        if (idx - start < end - idx)
        {
            quick_sort(array, start, idx - 1, pivot_choice);
            start = idx + 1;
        }
        else
        {
            quick_sort(array, idx + 1, end, pivot_choice);
            end = idx - 1;
        }
    }
}

int main()
{
    srand(static_cast<unsigned int>(time(nullptr)));

    vector<int> sizes = {10000, 50000, 100000};

    for (int size : sizes)
    {
        vector<int> ascending(size);
        vector<int> descending(size);
        vector<int> random(size);
```

```
        // Generate ascending order array
        for (int i = 0; i < size; ++i)
        {
            ascending[i] = i + 1;
        }

        // Generate descending order array
        for (int i = 0; i < size; ++i)
        {
            descending[i] = size - i;
        }

        // Generate random order array
        for (int i = 0; i < size; ++i)
        {
            random[i] = rand() % size + 1;
        }

        // Sort with different pivot choices
        for (int pivot_choice = 0; pivot_choice < 4; ++pivot_choice)
        {
            vector<int> ascending_copy = ascending;
            vector<int> descending_copy = descending;
            vector<int> random_copy = random;

            // Sort ascending order array
            clock_t start_time = clock();
            quick_sort(ascending_copy, 0, ascending_copy.size() - 1,
pivot_choice);
            clock_t end_time = clock();
            double elapsed_time = double(end_time - start_time) / CLOCKS_PER_SEC;

            cout << "Array Size: " << size << ", Pivot Choice: ";
            switch (pivot_choice)
            {
            case 0:
                cout << "Low";
                break;
            case 1:
                cout << "High";
                break;
            case 2:
                cout << "Mid";
                break;
            case 3:
```

```
            cout << "Random";
            break;
        }
        cout << "\nAscending Order, Time Taken: " << elapsed_time << "
seconds" << endl;

        // Print the first 200 sorted elements
        cout << "First 200 Sorted Elements: ";
        for (int i = 0; i < min(200, size); ++i)
        {
            cout << ascending_copy[i] << " ";
        }
        cout << "\n\n";

        // Sort descending order array
        start_time = clock();
        quick_sort(descending_copy, 0, descending_copy.size() - 1,
pivot_choice);
        end_time = clock();
        elapsed_time = double(end_time - start_time) / CLOCKS_PER_SEC;

        cout << "Array Size: " << size << ", Pivot Choice: ";
        switch (pivot_choice)
        {
        case 0:
            cout << "Low";
            break;
        case 1:
            cout << "High";
            break;
        case 2:
            cout << "Mid";
            break;
        case 3:
            cout << "Random";
            break;
        }
        cout << "\nDescending Order, Time Taken: " << elapsed_time << "
seconds" << endl;

        // Print the first 200 sorted elements
        cout << "First 200 Sorted Elements: ";
        for (int i = 0; i < min(200, size); ++i)
        {
            cout << descending_copy[i] << " ";
```

```
            }
            cout << "\n\n";

            // Sort random order array
            start_time = clock();
            quick_sort(random_copy, 0, random_copy.size() - 1, pivot_choice);
            end_time = clock();
            elapsed_time = double(end_time - start_time) / CLOCKS_PER_SEC;

            cout << "Array Size: " << size << ", Pivot Choice: ";
            switch (pivot_choice)
            {
            case 0:
                cout << "Low";
                break;
            case 1:
                cout << "High";
                break;
            case 2:
                cout << "Mid";
                break;
            case 3:
                cout << "Random";
                break;
            }
            cout << "\nRandom Order, Time Taken: " << elapsed_time << " seconds"
<< endl;

            // Print the first 200 sorted elements
            cout << "First 200 Sorted Elements: ";
            for (int i = 0; i < min(200, size); ++i)
            {
                cout << random_copy[i] << " ";
            }
            cout << "\n\n";
        }
    }

    return 0;
}
```

- **Output**

FOR 10000 Data

Pivot Choice LOW

```
Array Size: 10000, Pivot Choice: Low
Ascending Order, Time Taken: 0.187 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Low
Descending Order, Time Taken: 0.197 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Low
Random Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 1 2 3 4 4 5 6 6 8 8 10 14 14 14 14 15 15 15 15 15 17 18 18 20 21 22 22 22 22 24 24 24 25 27 28 28 28 29 30 3
0 30 31 31 34 36 36 37 39 39 40 40 40 41 45 45 46 46 47 47 52 53 53 55 55 55 58 58 58 59 60 61 63 65 68 68 69 69 73 75 75 75 75 75 76 77
77 78 79 79 79 80 81 81 82 84 84 85 86 88 89 89 91 92 93 93 95 95 96 96 96 97 99 101 101 102 105 105 105 106 106 107 108 108 109 109 111
112 115 116 117 117 118 118 119 120 120 124 125 125 125 126 126 126 127 128 129 130 130 130 131 131 131 132 133 133 134 138 139 139 139 1
40 141 142 143 146 146 147 148 148 148 149 152 152 152 152 152 153 153 154 155 155 155 156 157 157 158 159 159 162 162 164 164 165 165 16
5 166 166 168 168
```

PIVOT CHOICE HIGH

```
Array Size: 10000, Pivot Choice: High
Ascending Order, Time Taken: 0.212 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: High
Descending Order, Time Taken: 0.213 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: High
Random Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 1 2 3 4 4 5 6 6 8 8 10 14 14 14 14 15 15 15 15 15 17 18 18 20 21 22 22 22 22 24 24 24 25 27 28 28 28 29 30 3
0 30 31 31 34 36 36 37 39 39 40 40 40 41 45 45 46 46 47 47 52 53 53 55 55 55 58 58 58 59 60 61 63 65 68 68 69 69 73 75 75 75 75 75 76 77
77 78 79 79 79 80 81 81 82 84 84 85 86 88 89 89 91 92 93 93 95 95 96 96 96 97 99 101 101 102 105 105 105 106 106 107 108 108 109 109 111
112 115 116 117 117 118 118 119 120 120 124 125 125 125 126 126 126 127 128 129 130 130 130 131 131 131 132 133 133 134 138 139 139 139 1
40 141 142 143 146 146 147 148 148 148 149 152 152 152 152 152 153 153 154 155 155 155 156 157 157 158 159 159 162 162 164 164 165 165 16
5 166 166 168 168
```

PIVOT CHOICE MID

```
Array Size: 10000, Pivot Choice: Mid
Ascending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Mid
Descending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Mid
Random Order, Time Taken: 0 seconds
First 200 Sorted Elements: 2 3 4 5 6 6 4 8 10 14 8 14 14 15 14 15 15 15 17 1 18 18 20 21 15 22 22 22 24 24 24 27 25 28 28 1 28 30 30 29 3
1 30 34 31 36 39 39 37 40 40 41 40 45 45 46 36 47 47 46 52 53 55 58 55 58 59 58 60 61 63 65 55 68 68 69 69 73 75 75 75 75 75 76 77 78 79
77 79 79 80 53 81 81 82 84 85 84 86 22 88 89 91 89 92 93 93 95 95 96 96 97 99 96 101 101 105 105 106 107 106 108 108 109 109 111 115 112
116 117 117 105 118 119 118 124 120 125 120 125 126 125 126 126 127 129 128 130 130 130 102 131 131 132 133 133 134 139 139 140 141 142 1
46 143 147 139 148 148 131 148 149 152 152 152 152 152 153 154 155 155 153 155 156 157 157 158 159 159 162 164 164 165 165 165 162 166 16
6 168 168 169 169
```

PIVOT CHOICE RANDOM

```
Array Size: 10000, Pivot Choice: Random
Ascending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Random
Descending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 10000, Pivot Choice: Random
Random Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 1 2 3 4 4 5 6 6 8 8 10 14 14 14 14 15 15 15 15 15 17 18 18 20 21 22 22 22 22 24 24 24 25 27 28 28 28 29 30 3
0 30 31 31 34 36 36 37 39 39 40 40 40 41 45 45 46 46 47 47 52 53 53 55 55 55 58 58 58 59 60 61 63 65 68 68 69 69 73 75 75 75 75 75 76 77
77 78 79 79 79 80 81 81 82 84 84 85 86 88 89 89 91 92 93 93 95 95 96 96 96 97 99 101 101 102 105 105 105 106 106 107 108 108 109 109 111
112 115 116 117 117 118 118 119 120 120 124 125 125 125 126 126 126 127 128 129 130 130 130 131 131 131 132 133 133 134 138 139 139 139 1
40 141 142 143 146 146 147 148 148 148 149 152 152 152 152 152 153 153 154 155 155 155 156 157 157 158 159 159 162 162 164 164 165 165 16
5 166 166 168 168
```

FOR 50000 Data

PIVOT CHOICE LOW

```
Array Size: 50000, Pivot Choice: Low
Ascending Order, Time Taken: 4.713 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Low
Descending Order, Time Taken: 4.632 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Low
Random Order, Time Taken: 0.016 seconds
First 200 Sorted Elements: 1 1 2 4 4 4 6 7 7 7 9 11 11 12 13 13 13 15 15 19 21 21 21 22 22 23 25 27 28 28 30 30 30 30 31 31 31 31 33 35 3
5 35 36 36 37 37 38 38 42 42 43 44 44 44 44 45 45 46 47 47 47 48 49 49 50 50 51 51 52 54 54 55 55 56 56 58 58 59 59 60 61 61 61 62 62 63
63 64 64 65 65 66 66 67 68 68 69 71 71 72 72 72 73 74 75 75 75 78 78 79 79 80 81 81 81 82 84 84 84 85 85 85 85 86 86 86 87 87 87 87 88 89
 89 91 92 93 94 94 94 94 94 95 95 96 96 96 98 98 99 101 101 101 101 102 102 102 102 103 103 104 104 104 104 104 104 106 106 106 107 108 1
10 110 111 112 113 113 113 113 113 114 116 116 117 120 121 121 121 121 122 125 125 126 127 127 128 129 130 131 131 132
```

PIVOT CHOICE HIGH

```
Array Size: 50000, Pivot Choice: High
Ascending Order, Time Taken: 4.672 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: High
Descending Order, Time Taken: 4.614 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: High
Random Order, Time Taken: 0.024 seconds
First 200 Sorted Elements: 1 1 2 4 4 4 6 7 7 7 9 11 11 12 13 13 13 15 15 19 21 21 21 22 22 23 25 27 28 28 30 30 30 30 31 31 31 31 33 35 3
5 35 36 36 37 37 38 38 42 42 43 44 44 44 44 45 45 46 47 47 47 48 49 49 50 50 51 51 52 54 54 55 55 56 56 58 58 59 59 60 61 61 61 62 62 63
63 64 64 65 65 66 66 67 68 68 69 71 71 72 72 72 73 74 75 75 75 78 78 79 79 80 81 81 81 82 84 84 84 85 85 85 85 86 86 86 87 87 87 87 88 89
 89 91 92 93 94 94 94 94 94 95 95 96 96 96 98 98 99 101 101 101 101 102 102 102 102 103 103 104 104 104 104 104 104 106 106 106 107 108 1
10 110 111 112 113 113 113 113 113 114 116 116 117 120 121 121 121 121 122 125 125 126 127 127 128 129 130 131 131 132
```

PIVOT CHOICE MID

```
Array Size: 50000, Pivot Choice: Mid
Ascending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Mid
Descending Order, Time Taken: 0 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Mid
Random Order, Time Taken: 0.018 seconds
First 200 Sorted Elements: 1 1 2 4 4 6 7 7 7 4 11 12 9 13 13 11 13 15 15 19 21 21 21 23 25 27 28 28 30 22 30 30 30 22 31 31 31 33 31 35 3
5 35 36 36 37 37 38 38 42 42 43 44 44 44 44 45 45 46 47 47 47 49 48 49 50 50 51 52 51 54 55 54 56 56 58 58 55 59 60 61 61 61 59 62 62 63
64 65 65 66 66 67 68 68 63 69 71 72 72 72 73 75 75 75 78 74 79 79 71 80 78 81 81 81 82 84 64 84 84 85 85 85 85 86 86 87 87 87 87 86 88 89
 93 92 94 94 89 94 94 94 95 95 96 96 96 98 98 99 101 101 101 102 101 102 102 102 103 104 104 104 104 104 104 91 106 106 106 108 110 110 1
07 111 113 113 113 112 113 113 116 114 117 120 121 121 116 121 121 122 125 125 127 127 128 126 129 130 131 132 133 131
```

PIVOT CHOICE RANDOM

```
Array Size: 50000, Pivot Choice: Random
Ascending Order, Time Taken: 0.011 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Random
Descending Order, Time Taken: 0.013 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 50000, Pivot Choice: Random
Random Order, Time Taken: 0.026 seconds
First 200 Sorted Elements: 1 1 2 4 4 4 6 7 7 7 9 11 11 12 13 13 13 15 15 19 21 21 21 22 22 23 25 27 28 28 30 30 30 30 31 31 31 31 33 35 3
5 35 36 36 37 37 38 38 42 42 43 44 44 44 44 45 45 46 47 47 47 48 49 49 50 50 51 51 52 54 54 55 55 56 56 58 58 59 59 60 61 61 61 62 62 63
63 64 64 65 65 66 66 67 68 68 69 71 71 72 72 72 73 74 75 75 75 78 78 79 79 80 81 81 81 82 84 84 84 85 85 85 85 86 86 86 87 87 87 87 88 89
 89 91 92 93 94 94 94 94 94 95 95 96 96 96 98 98 99 101 101 101 101 102 102 102 102 103 103 104 104 104 104 104 104 106 106 106 107 108 1
10 110 111 112 113 113 113 113 113 114 116 116 117 120 121 121 121 121 122 125 125 126 127 127 128 129 130 131 131 132
```

FOR 100000 Data

PIVOT CHOICE LOW

```
Array Size: 100000, Pivot Choice: Low
Ascending Order, Time Taken: 19.273 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Low
Descending Order, Time Taken: 19.502 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Low
Random Order, Time Taken: 0.053 seconds
First 200 Sorted Elements: 1 1 1 2 2 2 3 3 3 4 5 5 5 6 7 7 8 8 9 9 9 9 9 9 9 10 11 11 11 12 12 12 12 13 13 13 13 14 15 15 15 15 16 16 16
17 17 17 17 18 18 18 18 18 19 19 20 20 20 20 21 21 22 23 24 24 24 24 24 24 25 25 26 26 27 27 27 27 27 27 27 27 28 28 28 28 28 29 29
 29 29 30 30 30 30 30 31 32 33 33 33 33 33 34 34 35 35 35 35 36 37 37 37 37 37 37 39 40 40 40 41 41 41 41 41 41 41 42 42 42 42 43 43 4
4 44 44 45 45 46 46 46 46 46 47 48 48 49 49 50 51 51 51 51 51 51 52 52 52 52 52 52 53 53 53 54 54 55 55 56 56 56 56 57 57 58 58 58 59 60
60 61 61 61 62 62 62 62 63 64 64 65 65 65 65 65 66 66
```

PIVOT CHOICE HIGH

```
Array Size: 100000, Pivot Choice: High
Ascending Order, Time Taken: 21.801 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: High
Descending Order, Time Taken: 24.512 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: High
Random Order, Time Taken: 0.045 seconds
First 200 Sorted Elements: 1 1 1 2 2 2 3 3 3 4 5 5 5 6 7 7 8 8 9 9 9 9 9 9 9 10 11 11 11 12 12 12 12 13 13 13 13 14 15 15 15 15 16 16 16
17 17 17 17 18 18 18 18 18 19 19 20 20 20 20 20 21 21 22 23 24 24 24 24 24 24 25 25 26 26 27 27 27 27 27 27 27 27 28 28 28 28 28 29 29
 29 29 30 30 30 30 30 31 32 33 33 33 33 33 33 34 34 35 35 35 35 36 37 37 37 37 37 37 39 40 40 40 41 41 41 41 41 41 41 42 42 42 42 43 43 4
4 44 44 45 45 46 46 46 46 46 47 48 48 49 49 50 51 51 51 51 51 51 52 52 52 52 52 52 53 53 53 54 54 55 55 56 56 56 56 57 57 58 58 58 59 60
60 61 61 61 62 62 62 62 63 64 64 65 65 65 65 65 66 66
```

PIVOT CHOICE MID

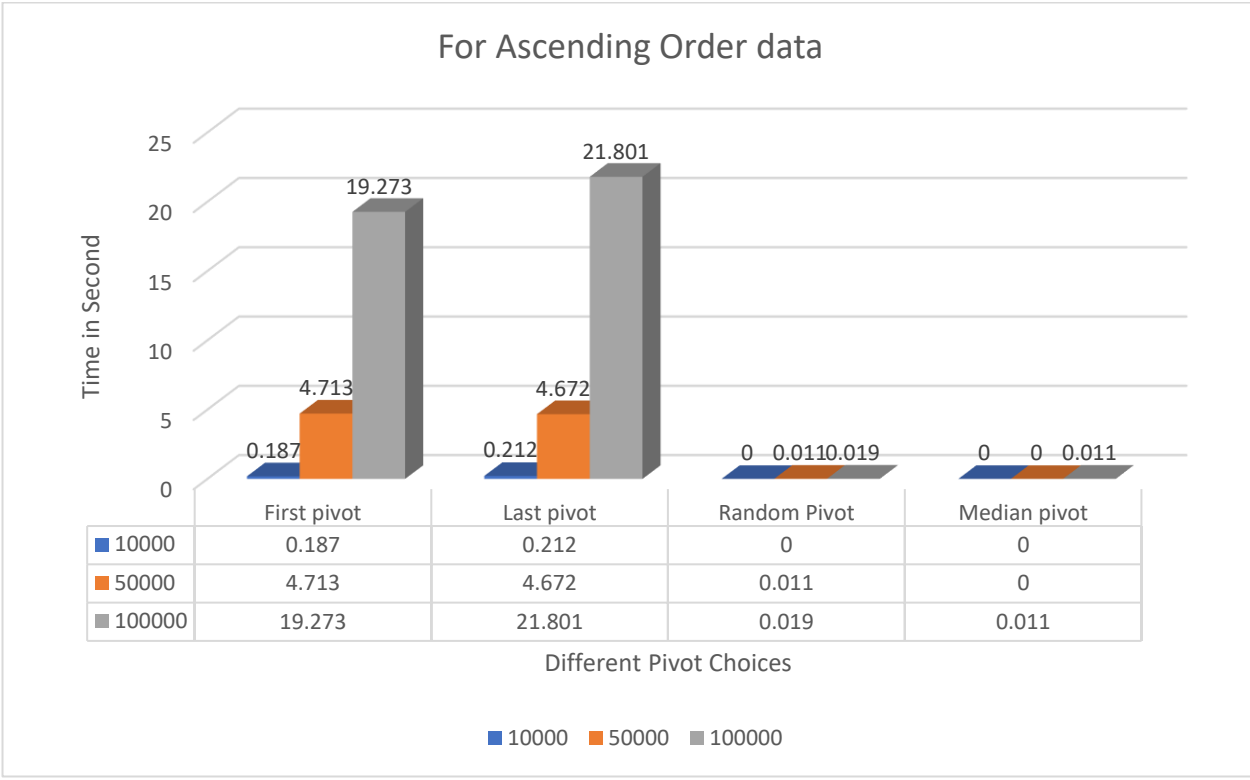
```
Array Size: 100000, Pivot Choice: Mid
Ascending Order, Time Taken: 0.011 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Mid
Descending Order, Time Taken: 0.014 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Mid
Random Order, Time Taken: 0.039 seconds
First 200 Sorted Elements: 1 1 2 2 2 3 3 3 5 4 5 5 1 6 7 7 8 9 9 9 9 9 8 9 11 11 11 12 12 13 13 13 13 10 14 15 15 12 15 15 16 16 16 17 17
 18 17 18 18 18 18 19 19 20 20 20 20 20 20 21 22 23 21 24 17 24 24 24 24 25 25 24 26 9 26 27 27 27 27 27 27 27 28 27 28 28 28 28 29 29 30 30
 29 30 30 31 32 29 33 33 12 33 33 33 34 34 35 35 35 35 36 37 37 37 37 27 37 37 40 40 39 41 41 41 41 41 41 42 41 42 42 42 43 43 44 44 41 4
5 45 46 46 46 44 46 47 48 49 51 51 50 51 51 51 52 48 52 52 52 52 52 53 51 53 53 54 54 55 55 56 46 56 56 56 40 57 57 58 59 60 61 61 62 61
62 62 62 58 63 64 64 65 65 65 65 65 66 66 58 67 67 67
```

PIVOT CHOICE RANDOM

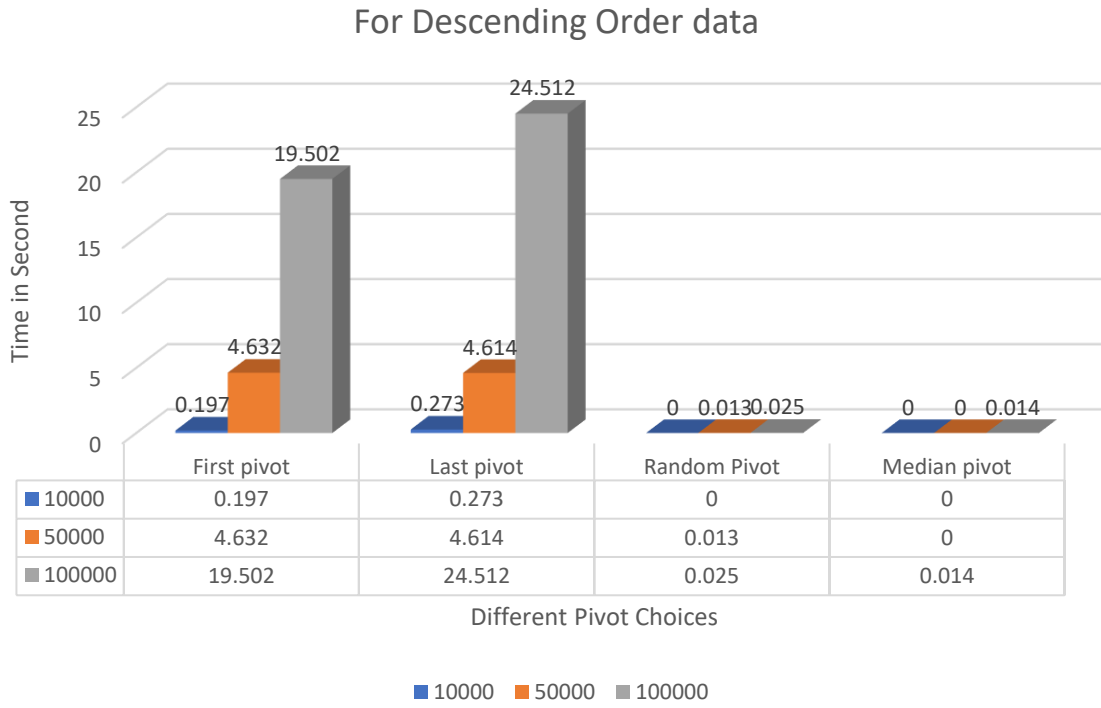
```
Array Size: 100000, Pivot Choice: Random
Ascending Order, Time Taken: 0.019 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Random
Descending Order, Time Taken: 0.025 seconds
First 200 Sorted Elements: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 8
6 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123
124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 1
58 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 19
2 193 194 195 196 197 198 199 200

Array Size: 100000, Pivot Choice: Random
Random Order, Time Taken: 0.06 seconds
First 200 Sorted Elements: 1 1 1 2 2 2 3 3 3 4 5 5 5 6 7 7 8 8 9 9 9 9 9 9 9 10 11 11 11 12 12 12 12 13 13 13 13 14 15 15 15 15 16 16 16
17 17 17 17 18 18 18 18 18 19 19 20 20 20 20 20 21 21 22 23 24 24 24 24 24 24 25 25 26 26 27 27 27 27 27 27 27 27 28 28 28 28 28 29 29
 29 29 30 30 30 30 31 32 33 33 33 33 33 34 34 35 35 35 35 36 37 37 37 37 37 37 39 40 40 40 41 41 41 41 41 41 41 41 42 42 42 42 43 43 4
4 44 44 45 45 46 46 46 46 46 47 48 48 49 49 50 51 51 51 51 51 51 52 52 52 52 52 52 53 53 53 54 54 55 55 56 56 56 56 57 57 58 58 58 59 60
60 61 61 61 62 62 62 62 63 64 64 65 65 65 65 65 66 66
```

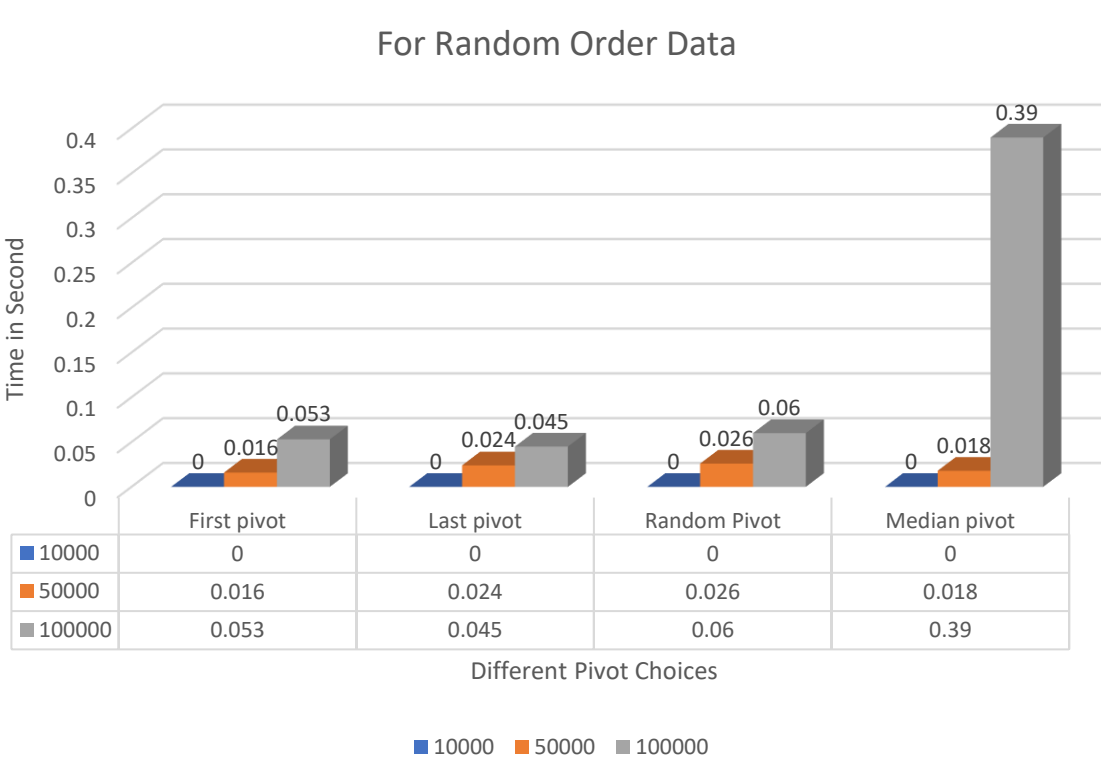
- **Graphs & Output Data**

FOR ASCENDING ORDER DATA



FOR DESCENDING ORDER DATA





- **Analysis**

  So the time taken by quick sort for sorting the array in ascending and descending order as first and last pivot choice is more because of the array is already in sorted manner so for the ascending order data if I take first element as a pivot then it is sorted so the pivot at its correct position so the left side of pivot there is nothing and right side of pivot there is entire array so the division made by recursion is unbalanced so its takes more time to sort an array as compare to balanced partition. For the descending order same scenario right side of pivot there is nothing and left side of pivot there is descending order array so it is unbalanced partition so it takes more time. So, if my array is in sorted manner like in ascending or descending order then it takes more time to sort as compare to random order array for the first and last choice of pivot.

  If I take random array and pivot as first so in most of cases the pivot elements correct position is in the array is somewhere middle index so it makes the balanced partition that takes less time than the unbalanced partition that makes in ascending and descending order array.

  And for the pivot choice mid and random it makes the balanced partition so it takes lesser time then the pivot choice high and low in all such cases.

  So, conclusion is Mid and Random pivot choice is better for sorting an array using quick sort