CS2040S — Algorithms and Data Structures
School of Computing
National University of Singapore

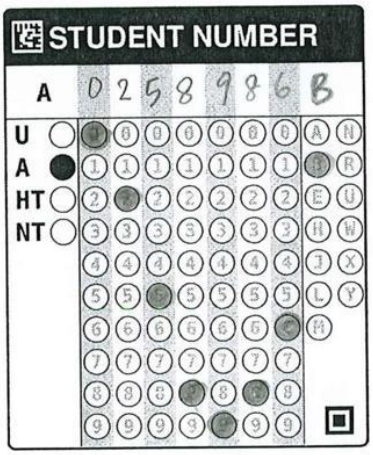
Midterm Assessment — Answer Sheet

2022/2023 Semester 2

Time allowed: 2 hours

Instructions (please read carefully):

1. Write down your **student number** on the right and using ink or pencil, shade the corresponding circle in the grid for each digit or letter. DO NOT WRITE YOUR NAME!
2. This answer booklet comprises **TEN (10) pages**, including this cover page.
3. All questions must be answered in the space provided; no extra sheets will be accepted as answers. You may use the extra page behind this cover page if you need more space for your answers.
4. You must submit only the **ANSWER SHEET** and no other documents. The question set may be used as scratch paper.
5. An excerpt of the question may be provided to aid you in answering in the correct box. It is not the exact question. You should still refer to the original question in the question booklet.
6. You are allowed to use pencils, ball-pens or fountain pens, as you like as long as it is legible (no red color, please).
7. **Marks may be deducted** for unreadable answers.



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Question	Marks
Q1	12 / 12
Q2	15 / 18
Q3	12 / 14
Q4	15 / 17
Q5	14 / 14
Q6	11 / 14
Q7	11 / 11
Q8	/ 0
Total	90 /100

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Use it ONLY if you need extra space for your answers, and indicate the **question number clearly** as well as in the original answer box. **Do NOT** use it for your rough work.

2 / 2

Question 1A What sort was used on Column A? [2 marks]

- ○ BubbleSort
- ○ SelectionSort
- ● InsertionSort
- ○ MergeSort
- ○ QuickSort (first element pivot)
- ○ None of the above.

2 / 2

Question 1B What sort was used on Column B? [2 marks]

- ○ BubbleSort
- ○ SelectionSort
- ○ InsertionSort
- ○ MergeSort
- ● QuickSort (first element pivot)
- ○ None of the above.

2 / 2

Question 1C What sort was used on Column C? [2 marks]

- ○ BubbleSort
- ● SelectionSort
- ○ InsertionSort
- ○ MergeSort
- ○ QuickSort (first element pivot)
- ○ None of the above.

2 / 2

Question 1D What sort was used on Column D? [2 marks]

- ○ BubbleSort
- ○ SelectionSort
- ○ InsertionSort
- ○ MergeSort
- ○ QuickSort (first element pivot)
- ● None of the above.

2 / 2

Question 1E What sort was used on Column E? [2 marks]

- ○ BubbleSort
- ○ SelectionSort
- ○ InsertionSort
- ● MergeSort
- ○ QuickSort (first element pivot)
- ○ None of the above.

2 / 2

Question 1F What sort was used on Column F? [2 marks]

- ● BubbleSort
- ○ SelectionSort
- ○ InsertionSort
- ○ MergeSort
- ○ QuickSort (first element pivot)
- ○ None of the above.

2 / 2

Question 2A Tightest bound from the available options: [2 marks]

○ $O(\log n)$ ○ $O(n)$ ○ $O(n \log n)$ ● $O(n^2)$ ○ $O(n^3)$ ○ $O(2^n)$

2 / 2

Question 2B Tightest bound from the available options: [2 marks]

○ $O(n)$ ○ $O(n \log n)$ ○ $O(n \log^2 n)$ ● $O(n^2)$ ○ $O(n^3)$ ○ $O(2^n)$

2 / 2

Question 2C True or false: [2 marks]

○ True ● False

3 / 3

Question 2D Tightest bound from the available options: [3 marks]

○ $O(1)$ ● $O(n)$ ○ $O(n \log^2 n)$ ○ $O(n^3)$
○ $O(\log n)$ ○ $O(n \log n)$ ○ $O(n^2)$ ○ $O(2^n)$

3 / 3

Question 2E Tightest bound from the available options: [3 marks]

○ $O(1)$ ○ $O(n)$ ○ $O(n \log^2 n)$ ○ $O(n^3)$
○ $O(\log n)$ ● $O(n \log n)$ ○ $O(n^2)$ ○ $O(2^n)$

0 / 3

Question 2F Asymptotic running time. [3 marks]

○ $O(1)$ ○ $O(n)$ ● $O(n^2)$ ○ $O(2^n)$
○ $O(\log n)$ ○ $O(n \log n)$ ○ $O(n^3)$

3 / 3

Question 2G Which recurrence best describes this function? [3 marks]

○ $T(n) \leq T(n/2) + O(n)$. ○ $T(n) \leq T(n/4) + O(n^2)$.
○ $T(n) \leq T(n/2) + O(n^2)$. ○ $T(n) \leq 4T(n/4) + O(n)$.
○ $T(n) \leq 2T(n/2) + O(n^2)$. ● $T(n) \leq 2T(n/4) + O(n^2)$.
○ $T(n) \leq T(n/4) + O(n)$. ○ None of the above.

2 / 2

Question 3A Worst-case for InsertionSort on array containing only 2 elements: [2 marks]

○ $O(1)$ ○ $O(n)$ ○ $O(n \log^2 n)$ ○ $O(n^3)$
○ $O(\log n)$ ○ $O(n \log n)$ ● $O(n^2)$ ○ $O(2^n)$

0 / 2

Question 3B MergeSort on partially sorted array: [2 marks]

- ○ $O(1)$
- ○ $O(\log n)$
- ● $O(n)$ ✗
- ○ $O(n \log n)$
- ○ $O(n \log^2 n)$
- ○ $O(n^2)$
- ○ $O(n^3)$
- ○ $O(2^n)$

3 / 3

Question 3C Paranoid QuickSort on a deck of kn cards: [3 marks]

- ○ $\Theta(n)$
- ○ $\Theta(n \log(k))$
- ○ $\Theta(n \log(n))$
- ○ $\Theta(nk)$
- ○ $\Theta(nk \log(k))$
- ● $\Theta(nk \log(n))$
- ○ $\Theta(nk \log(nk))$
- ○ None of the above.

2 / 2

Question 3D Worst-case running time for inserting a string of length? [2 marks]

- ○ $O(1)$
- ○ $O(L)$
- ○ $O(\log n)$
- ● $O(L \log n)$
- ○ $O(\log n + L)$
- ○ $O(nL)$

2 / 2

Question 3E Rotations on insertion. [2 marks]

- ● $O(1)$
- ○ $O(\log n)$
- ○ $O(n)$
- ○ $O(n \log n)$
- ○ $O(n^2)$

3 / 3

Question 3F Building an AVL tree. [3 marks]

- ○ $O(1)$
- ○ $O(\log n)$
- ● $O(n)$
- ○ $O(n \log n)$
- ○ $O(n \log^2 n)$
- ○ $O(n^2)$
- ○ $O(n^3)$

3 / 3

Question 4A Good loop invariant? [3 marks]

- ○ For all k such that $k < i$: $A[k] \leq A[k+1]$.
- ● For all k such that $k < i$: $A[k] \geq A[k+1]$.
- ○ The subarray $A[0..i]$ contains the $i+1$ smallest elements in the array.
- ○ The subarray $A[0..i-1]$ contains the i smallest elements in the array.
- ○ The subarray $A[0..i]$ contains the $i+1$ largest elements in the array.
- ○ The subarray $A[0..i-1]$ contains the i largest elements in the array.
- ○ None of the above.

2 / 2

Question 4B Stable or not? [2 marks]

- ○ Stable
- ● Not stable

3 / 3

Question 4C Invariants for an AVL tree. [3 marks]

- ○ Only I.
- ○ Only II.
- ○ Only III.
- ○ Only IV.
- ○ I and II.
- ● I and III.
- ○ I and IV.
- ○ II and III.
- ○ II and IV.
- ○ III and IV.
- ○ I, II, and III.
- ○ I, II, and IV.
- ○ II, III, and IV.
- ○ I, II, III, and IV.
- ○ None of the above is accurate.

3 / 3

Question 4D Invariants for an (a,b)-tree. [3 marks]

- ○ Only I.
- ○ Only II.
- ○ Only III.
- ○ Only IV.
- ○ I and II.
- ○ I and III.
- ○ I and IV.
- ○ II and III.
- ○ II and IV.
- ○ III and IV.
- ● I, II, and III.
- ○ I, II, and IV.
- ○ II, III, and IV.
- ○ I, II, III, and IV.
- ○ None of the above is accurate.

0 / 2

Question 4E Balanced or not? [2 marks]

- ● Balanced
- ○ Not balanced

4 / 4

Question 4F Special search? [4 marks]

- ○ The algorithm works correctly: when invoked on array A with $low = 0$ and $high = A.length - 1$, a search for a key k will return the index of k if k is in A and return -1 otherwise.
- ○ The algorithm sometimes fails to find a key: when invoked on array A with $low = 0$ and $high = A.length - 1$, a search for a key k will sometimes return -1 even when k is in A.
- ○ The algorithm sometimes returns the wrong index: when invoked on array A with $low = 0$ and $high = A.length - 1$, a search for a key k will sometimes return an index j where $A[j] \neq k$.
- ● The algorithm does not terminate: when invoked on array A with $low = 0$ and $high = A.length - 1$, a search for a key k will sometimes never return.
- ○ None of the above options is a good description of the situation.

4 / 4

Question 5A Highest out-of-balance node? [4 marks]

○ F	○ P	○ U	○ None of these listed.
○ H	○ Q	○ W	
○ L	● R	○ X	
○ M	○ S	○ Y	
○ N	○ T	○ Z	

4 / 4

Question 5B How to balance? [4 marks]

○ right-rotate(R)	○ left-rotate(K), right-rotate(N)
○ left-rotate(H)	○ right-rotate(N), left-rotate(K)
○ right-rotate(N)	○ right-rotate(K), left-rotate(H)
○ left-rotate(T)	○ left-rotate(T), right-rotate(R)
● right-rotate(R), left-rotate(H)	○ No rotations occur.
○ left-rotate(H), right-rotate(R)	○ None of the above.

2 / 2

Question 5C How many split? [2 marks]

○ 0	● 3	○ 6
○ 1	○ 4	
○ 2	○ 5	

2 / 2

Question 5D What keys are in the root node? [2 marks]

- ○ (17, 50, 91)
- ● (50)
- ○ (17, 50, 78, 91)
- ○ (50, 78, 82)
- ○ (86)
- ○ (90)
- ○ (17, 50, 90, 91)
- ○ (50, 78)
- ○ None of the above.

2 / 2

Question 5E What is the height of the tree? [2 marks]

- ○ 0
- ○ 1
- ○ 2
- ● 3
- ○ 4
- ○ 5
- ○ 6

3 / 3

Question 6A Worst-case tree height: [3 marks]

- ○ $O(1)$
- ○ $O(\log n)$
- ○ $O(\log^2 n)$
- ○ $O(\sqrt{n})$
- ● $O(n)$
- ○ $O(n \log n)$
- ○ $O(n^2)$

0 / 3

Question 6B Which statements are true? [3 marks]

- ○ I only.
- ○ II only.
- ○ III only.
- ○ I and II.
- ● I and III.
- ○ II and III.
- ○ I and II and III.
- ○ None of the three statements are true.

3 / 3

Question 6C Upper bound on (3/4)-weight-balanced tree? [3 marks]

- ○ $\log_2(n)+1$
- ○ $2\log_2(n)+1$
- ● $\log_{4/3}(n)+1$
- ○ $\log_{3/4}(n)+1$
- ○ $\log_{3/2}(n)+1$
- ○ $(4/3)\log_2(n)+1$
- ○ $(4/3)\log_{4/3}(n)+1$
- ○ $(4/3)\log_{3/4}(n)+1$
- ○ $(3/4)\log_{3/4}(n)+1$
- ○ None of the above is a reasonable upper bound on the height.

3 / 3

Question 6D Random temperatures? [3 marks]

- ○ 0
- ○ 1/4
- ○ 1/3
- ● 1/2
- ○ 2/3
- ○ 3/4
- ○ 1
- ○ None of the above.

2 / 2

Question 6E Does it work? [2 marks]

- ○ Yes, after the rotation, the temperature ordering property and binary search tree property both hold.
- ● No, after the rotation, there (still) may be temperature violations.
- ○ No, after the rotation, there may be binary-search-tree property violations.

3 / 3

Question 7A What is the best use of the special variable? [3 marks]

- ○ The maximum right endpoint of any interval stored in $I[k]$ where $k \leq j$.
- ○ The maximum right endpoint of any interval stored in $I[k]$ where $k \geq j$.
- ○ The minimum left endpoint of any interval stored in $I[k]$ where $k \leq j$.
- ● The minimum left endpoint of any interval stored in $I[k]$ where $k \geq j$.
- ○ None of these are useful.

3 / 3

Question 7B Which properties are true of the IntervalRay? [3 marks]

- ● Only I.
- ○ Only II.
- ○ Only III.
- ○ Only IV.
- ○ I and II.
- ○ I and III.
- ○ II and III.
- ○ II and IV.
- ○ I, II and III.
- ○ II, III and IV.
- ○ None of the above indicates properties that are always true.

3 / 3

Question 7C Which do you think will work? [3 marks]

- ○ Binary search I, comparing $I[j].left$ to x.
- ○ Binary search I, comparing $I[j].right$ to x.
- ● Binary search I, comparing $I[j].special$ to x.
- ○ Binary search I, comparing $I[j].count$ to x.
- ○ None of these strategies work properly.

2 / 2

Question 7D What is your evaluation of this approach? [2 marks]

- ○ The approach works, and is a reasonable alternative, assuming that the binary search does not work.
- ◉ The approach works, but even assuming binary search does not work, there are better solutions.
- ○ The approach does not work.

Question 8 [0 marks]

The Dark Room

Take 26 cards and put 13 each into each box.

Highest expected probability of winning.

— END OF ANSWER SHEET —