NATIONAL UNIVERSITY OF SINGAPORE

SCHOOL OF COMPUTING
FINAL ASSESSMENT FOR
Semester 1 AY2021/2022

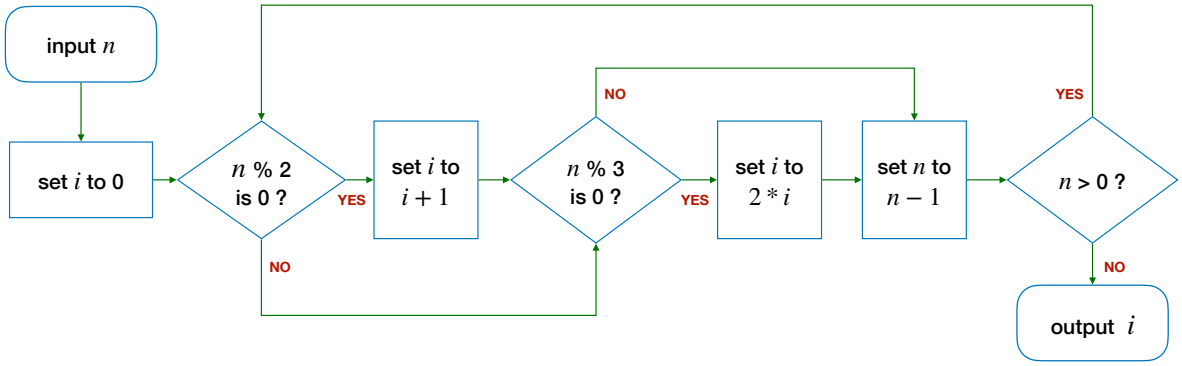
CS1010 Programming Methodology

November 2021 Time Allowed 120 Minutes

INSTRUCTIONS TO CANDIDATES

1. This assessment paper contains 19 questions and comprises 26 printed pages, including this page.
2. Write all your answers in the answer sheet provided.
3. The total marks for this assessment is 60. Answer **ALL** questions.
4. This is an **OPEN BOOK** assessment.
5. You can assume that in all the code given, no overflow nor underflow will occur during execution. In addition, you can assume that all given inputs are valid and fits within the specified variable type.
6. State any additional assumption that you make.
7. Please write your student number only. Do not write your name.

1. (3 points) Consider the flowchart below:



Which of the following function implements the flowchart above correctly? (Select all correct options)

A.
```
long foo(long n) {
  long i = 0;
  do {
    if (n % 2 == 0) {
      i += 1;
    } else if (n % 3 == 0) {
      i *= 2;
    }
    n -= 1;
  } while (n > 0);
  return i;
}
```

B.
```
long foo(long n) {
  long i = 0;
  do {
    if (n % 2 == 0) {
      i += 1;
      if (n % 3 == 0) {
        i *= 2;
      }
    }
    n -= 1;
  } while (n > 0);
  return i;
}
```

C.
```
long foo(long n) {
  long i = 0;
  do {
    if (n % 2 == 0) {
      i += 1;
    }
    if (n % 3 == 0) {
      i *= 2;
    }
    n -= 1;
  } while (n > 0);
  return i;
```

```
}
```

D.
```
long foo(long n) {
  long i = 0;
  while (n > 0) {
    if (n % 2 == 0) {
      i += 1;
    } else if (n % 3 == 0) {
      i *= 2;
    }
    n -= 1;
  }
  return i;
}
```

E.
```
long foo(long n) {
  long i = 0;
  while (n > 0) {
    if (n % 2 == 0) {
      i += 1;
      if (n % 3 == 0) {
        i *= 2;
      }
    }
    n -= 1;
  }
  return i;
}
```

F.
```
long foo(long n) {
  long i = 0;
  while (n > 0) {
    if (n % 2 == 0) {
      i += 1;
    }
    if (n % 3 == 0) {
      i *= 2;
    }
    n -= 1;
  }
  return i;
}
```

G. None of the above

2. (3 points) Suppose `m` and `n` are `long` variables holding positive integers. Which of the following expressions return `true` if and only if m and n have the same number of digits (excluding leading zeros)?

   (Select all correct options)

   A. `m / n == 0`

   B. `m / n < 10`

   C. `m / n <= 1`

   D. `(m / n <= 1) || (n / m <= 1)`

   E. `(m / n < 10) && (n / m < 10)`

   F. None of the above.

3. (3 points) Consider the code snippet below.

```
bool in_range = false;
if (x > 10) {
  if (y < 20) {
    in_range = true;
  }
}
if (!in_range) {
  // Line A
}
```

What assertion must be true at Line A?

(Select all correct options)

A. `(x > 10) && (y < 20)`

B. `(x > 10) || (y < 20)`

C. `(x <= 10) || (y >= 20)`

D. `(x <= 10) && (y >= 20)`

E. None of the above.

4. (3 points) Consider the function below:

```
void foo(long x, long y) {
  while (x * y > 0 && x != y) {
    x += 1;
    y -= 1;
    if (x > y) {
      return;
    }
  }
  // Line B
}
```

Which of the following is/are correct assertions at Line B?

(Select all correct options)

A. `x * y > 0 && x != y`

B. `x * y > 0 || x != y`

C. `x * y <= 0 && x == y`

D. `x * y <= 0 || x == y`

E. `x < y`

F. `x <= y`

5. (3 points) Consider the recursive function above.

```
long recurse(long n) {
  if (n == 1) {
    return 1;
  }
  return 2 + recurse(recurse(n - 1));
}
```

What is the output of `recurse(2)` and `recurse(3)`?

Write "no output" if you think the function would run forever (until stack overflow occurs).

6. (3 points) Each of the following five functions aims to sum up the values in a given array.

   Which of the functions could potentially lead to memory errors or returning of incorrect results when an empty array (len is 0) is given?

   (Select all correct options)

   A.
```
long tata(long len, long a[len]) {
  long sum = 0;
  for (long i = 0; i <= len - 1; i += 1) {
    sum += a[i];
  }
  return sum;
}
```

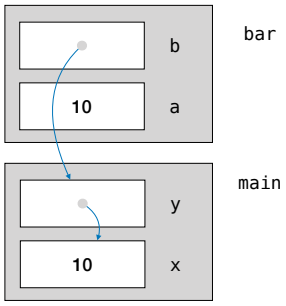
   B.
```
long tete(long len, long a[len]) {
  long sum = 0;
  for (long i = len - 1; i >= 0; i -= 1) {
    sum += a[i];
  }
  return sum;
}
```

   C.
```
long titi(long len, long a[len]) {
  long sum = a[0];
  long i = 1;
  do {
    sum += a[i];
    i += 1;
  } while (i <= len - 1);
  return sum;
}
```

   D.
```
long toto(long len, long a[len]) {
  long sum = 0;
  long i = 0;
  do {
    sum += a[i];
    i += 1;
  } while (i <= len - 1);
  return sum;
}
```

   E.
```
long tutu(long len, long a[len]) {
  long sum = 0;
  long i = 0;
  while (i <= len - 1) {
    sum += a[i];
    i += 1;
  }
  return sum;
}
```

7. (3 points) Consider the diagram below, which depicts the stack frames of two functions, main and bar. bar is called from main. The arrows depict pointer variables and where they are pointing to.



Which of the following program would lead to the stack frames above at Line C?

Note that some options below might give compilation errors.

(Select all correct options)

A.
```
void bar(long a, long **b) {
  // Line C
}

int main() {
  long x = 10;
  long *y = &x;
  bar(x, &y);
}
```

B.
```
void bar(long a, long **b) {
  // Line C
}

int main() {
  long x = 10;
  long *y = &x;
  bar(*y, &y);
}
```

C.
```
void bar(long a, long **b) {
  // Line C
}

int main() {
  long x = 10;
  long *y = &x;
  bar(x, &(&x));
}
```

D.
```
void bar(long a, long *b) {
  // Line C
}

int main() {
  long x = 10;
  long *y = &x;
```

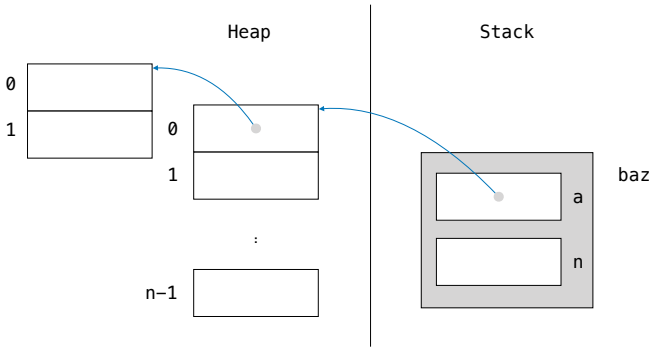
```
  bar(*x, y);
}
```

E.
```
void bar(long a, long *b) {
  // Line C
}

int main() {
  long x = 10;
  long *y = &x;
  bar(x, y);
}
```

F. None of the above.

8. (3 points) Consider the diagram below, which depicts the stack and heap of a program. Only the stack frame of the function baz is shown. Irrelevant details (such as value of n) are omitted. Assume that malloc always completes successfully .



Which of the following implementation of baz correctly allocates memory and would lead to the stack and heap as depicted in the diagram at Line D of the function?

Note that some options below might give compilation errors.

(Select all correct options)

A.
```
void baz(size_t n) {
  long a[n];
  long b[2];
  a[0] = b;
  // Line D
}
```

B.
```
void baz(size_t n) {
  long a[n];
  a[0] = malloc(2 * sizeof(long));
  // Line D
}
```

C.
```
void baz(size_t n) {
  long *a = malloc(n * sizeof(long *));
  a[0] = malloc(sizeof(long)*2);
  // Line D
}
```

D.
```
void baz(size_t n) {
  long a[n][2];
  // Line D
}
```

E.
```
void baz(size_t n) {
  long **a = malloc(n * sizeof(long *));
  a[0] = malloc(2 * sizeof(long));
  // Line D
}
```

F. None of the above.

9. (3 points) Consider the code snippet below.

```
void fred(long n) {
  for (long i = 0; i < n * n; i += n) {
    cs1010_println_long(i);
  }
}
```

How many times will `i` be printed? Express your answer in big-O notation in terms of the input parameter `n`.

A. $O(\log n)$
B. $O(\log^2 n)$
C. $O(n)$
D. $O(n^2)$
E. $O(n^3)$

10. (3 points) Consider the code snippet below.

```
void corge(long n) {
  for (long j = 1; j < n; j *= 2) {
    cs1010_println_long(j);  // Line E
  }
}

void qux(long n)
{
  long i = 1;
  while (i < n) {
    i *= 2;
    corge(n);
  }
}
```

How many times would Line E be called if `qux` is invoked? Express your answer using the big-O notation.

A. $O(n^2)$

B. $O(n \log n)$

C. $O(\log^2 n)$

D. $O(\log n)$

E. $O(n)$

11. (3 points) Consider the following function:

```
long thud(long n) {
  if (n == 1) {
    return 0;
  }
  long sum = 0;
  for (long i = 0; i < n; i += 1) {
    sum += thud(n / 2);
  }
  return sum;
}
```

Let the running time of the function be $T(n)$.

Which of the following is the correct recurrence relation expression for $T(n)$ when $n > 1$?

A. $T(n) = 2T(n/2) + 1$

B. $T(n) = T(n/2) + 1$

C. $T(n) = T(n/2) + n$

D. $T(n) = nT(n/2) + 1$

E. $T(n) = nT(n/2) + n$

F. None of the above.

12. (3 points) Consider the following recurrence relation:

    $T(n) = T(n/4) + \sqrt{n}$

    and

    $T(1) = 1$

    Express $T(n)$ in big O-notation.

    A. $O(n)$
    B. $O(\log n)$
    C. $O(4^n)$
    D. $O(\sqrt{n})$
    E. $O(\sqrt{n} \log n)$
    F. None of the above.

13. (3 points) Which of the following program would lead to illegal access of memory?
(Select all correct options)

A.
```c
int main() {
  char *s;
  s[4] = 'x';
}
```

B.
```c
int main() {
  char *s = "hello";
  s[4] = 'x';
}
```

C.
```c
int main() {
  char s[5];
  s[4] = 'x';
}
```

D.
```c
char *get() {
  char t[6] = "hello";
  return t;
}

int main() {
  char *s = get();
  s[4] = 'x';
}
```

E.
```c
char *get() {
  char *t = malloc(sizeof(char));
  return t;
}

int main() {
  char *s = get();
  s[4] = 'x';
}
```

F. None of the above

14. (3 points) Consider the program below:

```c
typedef struct box {
  int x;
} box;

void modify(box *b) {
  b->x = 2;
}

void modify_again(box b) {
  b.x = 3;
}

struct box modify_some_more(box b) {
  b.x = 4;
  return b;
}

int main()
{
  box a;
  a.x = 1;
  modify(&a);
  // Line F
  modify_again(a);
  // Line G
  a = modify_some_more(a);
  // Line H
}
```

What are the values of `a.x` at Lines F to H?

15. (1 point) Consider the function below:

```
long mystery(size_t len, long *a) {
  size_t l = 0;
  size_t r = len - 1;
  while (l != r) {
    if (a[l] < a[r]) {
      r -= 1;
    } else {
      l += 1;
    }
  }
  return a[l];
}
```

What would the function return if the input array `a` is `{50, 40, 20, 30}` and `len` is 4?

16. (4 points) Consider the snippet taken from the function in the previous question:

```
if (a[l] < a[r]) {
  r -= 1;
  // Line U
} else {
  l += 1;
  // Line V
}
```

What can you assert at Lines U and V based only on the snippet above?

17. (5 points) Let's denote the set of consecutive elements `a[i]`, `a[i+1]`, `a[i+2]`, ... `a[j]` as `a[i..j]`.

We extend the comparison operator `<`, `>`, `<=`, `>=` to denote that an element is less than, greater than, less than or equal to, greater than or equal to, every element in a set respectively.

For example, if `a[3] < a[0]` and `a[3] < a[1]`, we can write `a[3] < a[0..1]` using our new notation.

Furthermore, if `j < i`, then `a[i..j]` is an empty set.

```
long mystery(size_t len, long *a) {
  size_t l = 0;
  size_t r = len - 1;
  // Line W
  while (l != r) {
    // Line X
    if (a[l] < a[r]) {
      r -= 1;
    } else {
      l += 1;
    }
    // Line Y
  }
  // Line Z
  return a[l];
}
```

Consider the following assertion:

```
a[l] < a[r+1 .. len-1] && a[r] <= a[0 .. l-1]
```

Is the assertion above an invariant for the loop in the function above? If yes, explain why by referring to the assertion at Lines W, X, Y, and Z. If not, modify it into the correct invariant and explain your answer.

18. (2 points) Using the invariant from the previous question, explain why the function `mystery` always returns the minimum element from the given array.

19. (6 points) In this question, we want to write a function that print out all possible string as the result of interleaving characters from two given strings. The relative order of the characters from the same string must be preserved in the interleaved string. For instance, if the input strings are ab and 123, then our function should print:

```
ab123
a1b23
a12b3
a123b
1ab23
1a2b3
1a23b
12ab3
12a3b
123ab
```

Part of the code of interleave has been given:

```
#include "cs1010.h"

void interleave(char *s, char *t, char *out, size_t last) {
  if (s[0] == '\0') {
    out[last] = '\0';
    cs1010_print_string(out);
    cs1010_println_string(t);
    return;
  }

  if (t[0] == '\0') {
    out[last] = '\0';
    cs1010_print_string(out);
    cs1010_println_string(s);
    return;
  }

  // COMPLETE THE CODE HERE

}
```

The function `interleave` is a recursive function that takes in two strings `s` and `t`. The string `out` is a string that stores an interleaving of characters from `s` and `t`. You may assume that `out` has been properly allocated. The 4th parameter `last` stores the total number of characters from either `s` or `t` (or both) that has been interleaved and stored in `out`.

The base case has been written for you. Here, we reach the base case if either `s` or `t` is an empty string. Since we are out of characters to interleave, we simply print what we constructed so far (out) followed by the remaining characters from the other string.

The first call to the function interleave looks like this:

```
interleave(s, t, out, 0);
```

Complete the implementation of the function interleave. There should be at most four lines of code. Write `;` in the blank below if your solution has less than four lines and you want to leave the blanks empty. You may print out the interleaving strings in any order (not necessary the same order as the example above).

Hint: if `s` is a string, then `s+1` is the rest of s without the first character.

END OF PAPER

This page is intentionally left blank.