Carleton University
SYSC 2006 C – Foundations of Imperative Programming – Winter 2018
Midterm Exam Solutions and Comments

Name:_____

Student Number:_____

INSTRUCTIONS:

1. **Exam questions will not be explained, and no hints will be given. If you think something is unclear or ambiguous, make a reasonable assumption (one that does not contradict the question), write it at the start of your solution, and answer the question.**
2. Do not write anything on this page other than your name and student number.
3. Answer all questions on the question paper. You can use pen or pencil.
4. This exam is closed book. Calculators are permitted. You are not permitted to use the calculator/clock apps on your cell phone. The time will be written on the blackboard and updated periodically throughout the exam.
5. For all questions, assume that all required `#include` statements are in the source code. The crib sheet on the last page of this question paper summarizes some C functions that you may find useful.
6. An attendance sheet will be distributed after the exam begins. If you finish your exam early, do not leave until you have signed the attendance sheet.
7. If you need to go to the washroom during the exam, bring your question paper to the teaching console at the front of the classroom.
8. When you have finished your exam, give it to one of the proctors. Show your campus card to the proctor, who will verify that the name and student number on your card match what is written on this page. You must leave the exam room as soon as you have turned in your paper.
9. Do not detach any sheets from the question paper. All pages of this question paper must be turned in.

Mark: _____ / 32

Question 1 [4 marks]

```
void do_that(int *m, int n)
{
    *m = *m + 1;
    n = n + 2;
    printf("*m: %d, n: %d\n", *m, n);
}

void do_this(int x, int *y)
{
    x = x + 3;
    *y = *y + 4;
    do_that(&x, *y);
}
```

```
int main(void)
{
    int a = 2;
    int b = 7;
    do_that(&a, b);
    printf("a: %d, b: %d\n", a, b);
    a = 2;
    b = 7;
    do_this(a, &b);
    printf("a: %d, b: %d\n", a, b);
    return 0;
}
```

Here is an incomplete transcript of the console output from this program. On the ruled lines, write the missing parts of the output produced by the `printf` calls. (0.5 marks will be awarded for each correct part.)

*m: _____3_____, n: _____9_____

a: _____3_____, b: _____7_____

*m: _____6_____, n: _____13_____

a: _____2_____, b: _____11_____

Comment: This question examined whether students understands how function function arguments are passed to the corresponding function parameters. Some of the arguments are the *contents* of integer variables; others are *pointers to* (that is, addresses of) integer variables.

To answer this question, you trace the execution of the program, starting with first statement in `main`. Drawing a C Tutor-style memory diagram will help you keep track of the contents of the frames and variables.

Multiple-choice Questions [28 marks]

For Questions 2 through 14, put a check mark, ✔, or an ✗, in the box, ☐, beside the correct answer. For each question, 2 marks will be awarded for selecting the correct answer and 0 marks will be awarded for selecting an incorrect answer. 0 marks will be awarded if you select more than one answer, even if one of the answers is correct.

Question 2

The C statement:

```
double &x;
```

☐ declares a variable named `&x` with type `double`.
☐ declares a variable named `x` with type "pointer-to-`double`".
☐ declares a variable named `x` that can store the address of a variable of type `double`.
☐ calculates the address of variable `x` and converts it to a value of type `double`.
☑ causes a compilation error.

Comment: Choice 1 is clearly incorrect (C identifiers can't contain the character `&`), which leads directly to choice 5 being the correct one.

The unary operators `&` and `*` can both be used in expressions; e.g., `&a` yields the address of `a`, and `*p` yields the object pointed to by `p`. We suspect this was the reason that some students thought `&` can be used in a variable's type declaration (choices 2 and 3). It can't.

Question 3

```
int f(int a)
{
    return a * 4;
}
```

```
int main(void)
{
    int x = 6;
    double y;

    y = f(x);
    return 0;
}
```

This program:

☐ causes a compilation error (mismatch between the declared return type of `f` and the declared type of `y`).
☐ terminates with a run-time error when it executes `y = f(x);`
☐ assigns function `f` to `y`.
☐ assigns the expression, `a * 4`, to `y`.
☐ assigns `24` to `y`.
☑ assigns `24.0` to `y`.

Comment: `f` returns the integer `24`. C converts this to a value of type `double` (either `24.0` or a real number that is very close to `24.0`) and assigns that value to `y`. So, the last choice is the correct one.

Question 4

What does this program display?

```
void mystery(int a)
{
    a = 10;
    printf("%d ", a);
}
```

```
int main(void)
{
    int a = 20;
    printf("%d ", a);
    mystery(a);
    printf("%d ", a);
    return 0;
}
```

☐	`20 10 10`	☐	`10 20 10 10`
☑	`20 10 20`	☐	`10 20 10 20`
☐	`20 20 10`	☐	`10 20 20 10`
☐	`20 20 20`	☐	`10 20 20 20`

Comment: this question checked if students understands pass-by-value: assigning a value to parameter `a` (in `mystery`) doesn't modify the corresponding argument (variable `a` in `main`).

Only a few students picked any of the choices in the right-hand column. Perhaps students who did this think that the program starts by calling `mystery`, then calls `main` when `mystery` returns.

Question 5

A student was asked to write a function that returns the sum `a` + (`a` + 1) + (`a` + 2) + … + `b`, where `a` and `b` are integers. Here is the student's code:

```
int sum_integers(int a, int b)
{
    int sum;
    for (sum = 1; b > a; b = b - 1) {
        sum = sum + b;
    }
    return sum;
}
```

The student is provided with this sput test suite and a `main` function that calls `test_sum_integers`:

```
void test_sum_integers(void)
{
    sput_fail_unless(sum_integers(1, 1) == 1, "sum_integers(1, 1)");
    printf("Expected: 1, actual: %d\n", sum_integers(1, 1));
    sput_fail_unless(sum_integers(1, 5) == 15, "sum_integers(1, 5)");
    printf("Expected: 15, actual: %d\n", sum_integers(1, 5));
    sput_fail_unless(sum_integers(2, 4) == 9, "sum_integers(2, 4)");
    printf("Expected: 9, actual: %d\n", sum_integers(2, 4));
}
```

Select the correct statement:

☐ No output is displayed by sput, because Pelles C reports errors when `sum_integers` is compiled.

☐ The output displayed by sput is:

```
[1:1]  test_sum_integers:#1  "sum_integers(1, 1)"  pass
Expected: 1, actual: 1
[1:2]  test_sum_integers:#2  "sum_integers(1, 5)"  pass
Expected: 15, actual: 15
[1:3]  test_sum_integers:#3  "sum_integers(2, 4)"  pass
Expected: 9, actual: 9
```

☐ The output displayed by sput is:

```
[1:1]  test_sum_integers:#1  "sum_integers(1, 1)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(1, 1) == 1
Expected: 1, actual: 2
[1:2]  test_sum_integers:#2  "sum_integers(1, 5)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(1, 5) == 15
Expected: 15, actual: 20
[1:3]  test_sum_integers:#3  "sum_integers(2, 4)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(2, 4) == 9
Expected: 9, actual: 15
```

☑ The output displayed by sput is:

```
[1:1]  test_sum_integers:#1  "sum_integers(1, 1)"  pass
Expected: 1, actual: 1
[1:2]  test_sum_integers:#2  "sum_integers(1, 5)"  pass
Expected: 15, actual: 15
[1:3]  test_sum_integers:#3  "sum_integers(2, 4)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(2, 4) == 9
Expected: 9, actual: 8
```

☐ The output displayed by sput is:

```
[1:1]  test_sum_integers:#1  "sum_integers(1, 1)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(1, 1) == 1
Expected: 1, actual: 0
[1:2]  test_sum_integers:#2  "sum_integers(1, 5)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(1, 5) == 15
Expected: 15, actual: 0
[1:3]  test_sum_integers:#3  "sum_integers(2, 4)"  FAIL
!     Type:       fail-unless
!     Condition: sum_integers(2, 4) == 9
Expected: 9, actual: 0
```

Comment: to answer this question, you had to trace the execution of `test_sum_integers`, including its three calls to `sum_integers`.

`sum_integers` has two bugs, so it calculates 1 + (`a` + `1`) + (`a` + `2`) + … + `b`,
not 0 + `a` + (`a` + 1) + (`a` + 2) + … + `b`.

In the first two test cases, the first argument (which is assigned to parameter `a`) is 1. The function returns the expected result and the test cases pass, even though the function is incorrect.

When the first argument isn't 1 (see the third test case), the function doesn't return the expected result and the test case fails.

Choice 4 is the only one that follows this pattern (pass, pass, fail).

Some students wrote in "none of the above", noting that the condition for the first test case should be `sum_integers(1, 1) == 2` (`sum_integers` should return 1 + 1). The question didn't ask you to determine whether the test suite provided in the question was correct; instead, it asked you to determine the output produced by the test suite. (Aside: this is one of the interesting issues in software testing. How do you ensure that your test cases are correct? When a test fails, is the failure caused by the test case, the software being tested, or both?)

Question 6

Given an array named `arr`, consider the expression: `arr[i]`. Unlike many languages, C doesn't cause a run-time error if `i` is not valid and `arr[i]` accesses memory "outside" the array, but we can use an `assert` statement to do this.

If `n` is the array's capacity and all elements in the array have been initialized, which `assert` statement will cause a program to terminate if `i` is not valid?

☐ `assert(i < 0 && i >= n);`
☑ `assert(i >= 0 && i < n);`
☐ `assert(i >= 0 && i <= n);`
☐ `assert(i == 0 && i == n);`
☐ `assert(i != 0 && i != n);`

Comment: many students picked choice 3. Remember, when an array has capacity `n`, the index of the last element is `n-1`, not `n`.

Question 7

A function contains the declaration, `int numbers[10];` and the statement:

```
numbers[5] = 2;
```

Select the equivalent statement that uses the * operator.

☐ `*numbers + 5 = 2;`
☑ `*(numbers + 5) = 2;`
☐ `(*numbers + 5) = 2;`
☐ `(*numbers) + 5 = 2;`

Comment: `array_name[index]` is equivalent to `*(array_name + index)`, so choice 2 is correct. Choices 3 and 4 are the same as choice 1 (the parentheses are completely superfluous); all three choices cause a compilation error.

Questions 8 and 9 use these declarations:

```
typedef struct {
    int red;
    int green;
    int blue;
} RGB_colour_t;

RGB_colour_t colour;
```

Question 8

The statement, `colour = (RGB_colour_t) {100, 50, 170};`

- ☐ initializes an array named `colour` that has three integer elements.
- ☑ initializes a struct named `colour` that has three integer members.
- ☐ initializes a variable named `colour` with the product of `RGB_colour_t` and `{100, 50, 170}`.
- ☐ initializes a variable named `colour` with the value returned by function `RGB_colour_t` when it is called with arguments `100`, `50` and `170`.
- ☐ causes a compilation error.

Comment: Most students picked the correct choice.

Question 9

Select the statement that is equivalent to `colour.red = 100;`

- ☐ `colour[0] = 100;`
- ☐ `colour[red] = 100;`
- ☐ `colour->red = 100;`
- ☑ `(&colour)->red = 100;`
- ☐ None of the above.

Comment: Many students picked choice 3. The expression `colour->red` is equivalent to `(*colour).red`, so this choice causes a compilation error (`colour` is not a pointer).

Choice 4 is correct because `(&colour)->red` is equivalent to `(*(&colour)).red` which is equivalent to `colour.red`.

Question 10

How many arrays will we have when the following code is executed?

```
int first[10];
int *second = first;
int *third = &first[0];
int *fourth = malloc(10 * sizeof(int));
int *fifth = fourth;
int *sixth = &fourth[0];
```

- ☐ 0
- ☐ 1
- ☑ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6

Comment: `int first[10];` declares an array that is local to a function (or is located in global memory, if the declaration is external to any function).

`int *fourth = malloc(10 * sizeof(int));` allocates an array from the heap.

All the other statements initialize pointer variables with the address of the first element of one of the two arrays; none of them create arrays.

Question 11

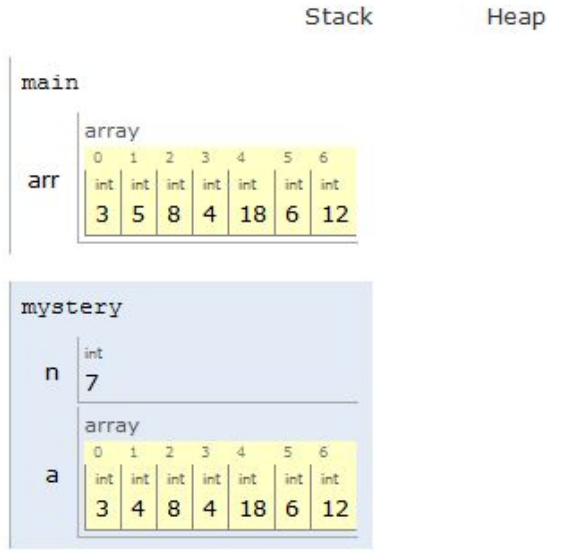
This program is executed using C Tutor:

```
void mystery(int a[], int n)
{
  a[1] = a[n-1] - a[2];  // Line A
  printf("Leaving mystery\n");
}
```

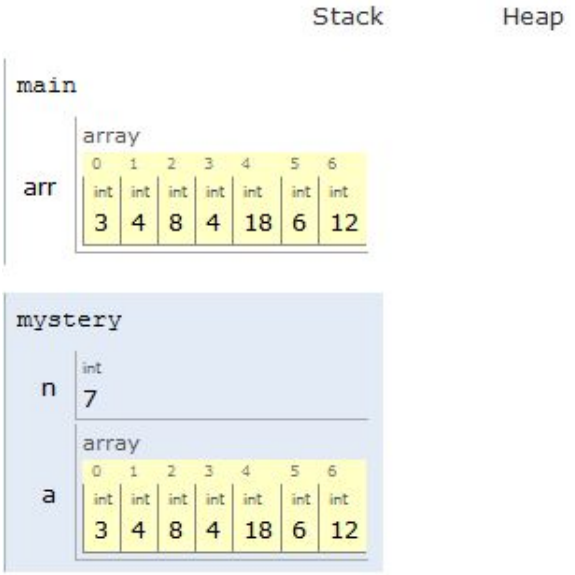
```
int main(void)
{
  int arr[] = {3, 5, 8, 4, 18, 6, 12};
  mystery(arr, 7);
  return 0;
}
```

Which diagram is displayed by C Tutor immediately <u>after</u> the assignment statement at Line A is executed, but <u>before</u> `printf` is called?

☐

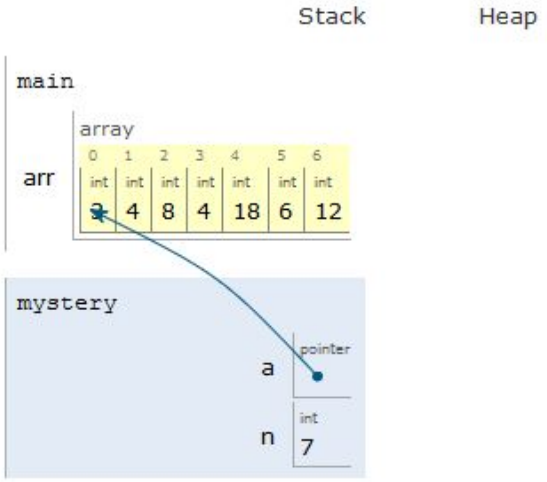


☐



☑

Note: the number partly obscured by the arrowhead is 3



☐

None of these solutions correspond to the diagram displayed by C Tutor.

Comment: Most students picked one of the top two diagrams. C arrays are never passed by value. The parameter declaration `int a[]` declares that `a` is a pointer to an `int`, not an array. Students who know either of these facts could immediately rule out the top two diagrams. Trace the code to determine that the second element in the array is assigned `a[6] - a[2]`, which is `12 - 8`, which is `4`. The lower-left diagram is therefore correct.

Question 12

Consider this code fragment, which calls `mystery`:

```
int arr[] = {1, 2, 3, 4, 5};
mystery(arr, sizeof(arr)/sizeof(arr[0]));
printf("Finished!");

void mystery(int a[], int n)
{
    int temp;
    for (int i = 0; i < n / 2; i += 1) {
        temp = a[i];
        a[i] = a[n - (i + 1)];
        a[n - (i + 1)] = temp;
    }
}
```

After `mystery` returns, what does `arr` contain?

☐ `{1, 2, 3, 4, 5}`
☐ `{2, 1, 4, 3, 5}`
☐ `{3, 2, 1, 4, 5}`
☐ `{2, 3, 4, 5, 1}`
☐ `{5, 1, 2, 3, 4}`
☑ `{5, 4, 3, 2, 1}`

Comment: Tracing the execution of the loop shows that the function swaps `arr[0]` with `arr[4]`, and `arr[1]` with `arr[3]`.

Question 13

Function `find_max` contains a logic error in one of the four lines indicated by comments:

```
/* This function returns the position of the maximum element in the
 * subsection of the array arr, starting at position "first" and
 * ending at position "last".
 */
int find_max(int arr[], int first, int last)
{
    int best_so_far = first;              // line 1

    for (int i = first + 1; i <= last; i += 1) {
        if (arr[i] > best_so_far) {       // line 2
            best_so_far = i;              // line 3
        }
    }
    return best_so_far;                   // line 4
}
```

Which one of the four lines indicated by the comments contains the logic error?

☐ `line 1`
☑ `line 2`
☐ `line 3`
☐ `line 4`

Comment: If `best_so_far` stores the value of the largest array element, both lines 1 and 3 would be incorrect. If `best_so_far` stores the position of the largest element, line 2 is the only incorrect statement (the condition should be `arr[i] > arr[best_so_far]`).

Question 14

Students were asked to finish `main` by adding one or more statements before the `printf` call, so that `point2` is a copy of `point1`.

```
typedef struct {
    int x;
    int y;
} point_t;
```

```
int main(void)
{
    point_t point1, point2;
    point_t *src, *dest;

    point1.x = 100;
    point1.y = 200;
    // One or more missing statements
    _________________________
    _________________________
    printf("(%d, %d)\n", point2.x, point2.y);
    // Outputs (100, 200)
    return 0;
}
```

Here are the solutions written by several students:

Jack's solution:	`point2 = point1;`

Gwen's solution:	`src = &point1;` `point2 = *src;`

Owen's solution:	`dest = &point2;` `*dest = point1;`

Toshiko's solution:	`src = &point1;`
	`dest = &point2;`
	`dest = src;`

Ianto's solution:	`dest = malloc(sizeof(point_t));`
	`*dest = point1;`
	`src = dest;`
	`point2 = *src;`
	`free(dest);`

How many solutions are correct?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☑ 4
- ☐ 5

Comment: Only Toshiko's solution is incorrect. It initializes `src` and `dest` to point to `point1`. All the other solutions assign 100 to `point2.x` and 200 to `point2.y` (Jack's solution is by far the simplest and Ianto's solution is convoluted.)

Question 15

This question is worth 2 marks. For each part, put a check mark, ✔, or an ✗, in the box, ☐, beside the correct answer. For each part, 0.5 marks will be awarded for selecting the correct answer and 0 marks will be awarded for selecting an incorrect answer.

Assume that `point_t` is the `typedef`'d name of a `struct` "type". A program contains this code:

```
point_t *p1 = malloc(sizeof(point_t));
point_t *p2 = malloc(sizeof(point_t));
```

(a) The statements:
`free(p1);`
`free(p2);`
correctly deallocate the structs.
	☑ True
	☐ False

Comment: This one should have been obvious.

(b) The statements:
`free(p2);`
`free(p1);`
correctly deallocate the structs.
	☑ True
	☐ False

Comment: Heap memory does not have to be freed in the same order that is was allocated.

(c) The statements:
`p1 = NULL;`
`p2 = NULL;`
correctly deallocate the structs.
	☐ True
	☑ False

Comment: C does not provide garbage collection. Assigning `NULL` to the two pointers does not cause the heap memory to which they pointed to be automatically freed. Instead, this code causes a memory leak.

(d) The statements:
`free(&p1[0]);`
`free(&p2[0]);`
correctly deallocate the structs.
	☑ True
	☐ False

Comment: Most students got this one wrong. I suspect these students thought, "`p1` and `p2` are pointers to structs, not pointers to arrays, so the expression `p1[0]` will cause a compilation error". This is incorrect.

`p1` is a pointer of type `point_t *`. It could point to a `point_t` struct or an element in an array of `point_t` structs. So, the expression `&p1[0]` is equivalent to `&(*(p1 + 0))`, which is equivalent to `&(*p1)`, which is equivalent to `p1`.

In other words, the pointer passed to `free` when it is called this way: `free(&p1[0])` is identical to the pointer passed when the function is called this way: `free(p1)`.

`void *malloc(int size);`

Allocates *size* bytes from the heap and returns a pointer to the memory. The memory is not initialized. On error, the function returns `NULL`.

`void free(void *ptr);`

Frees the memory pointed to by `ptr`, which must have been returned by a previous call to `malloc`. Otherwise, or if `free(ptr)` has already been called, undefined behaviour occurs. If *ptr* is `NULL`, no operation is performed.