CSE 333 Midterm Exam 2/12/16 Sample Solution

Question 1. (12 points) Preprocessor. Consider the following C (*not* C++ files).

```
======
func.h
======
#ifndef _FUNC_H_
#define _FUNC_H_
#define FUN(a,b) a*b
#endif

======
nums.h
======
#ifndef _NUMS_H_
#define _NUMS_H_
#ifdef BIG
typedef long int num;
#else
typedef int num;
#endif
#define NBR 3
#endif
```

```
======
test.c
======
#include <stdio.h>
#include "nums.h"
#include "func.h"

#define BIG

num compute(int x) {
  return FUN(x+1,NBR);
}

int main() {
  printf("%d\n", compute(2));
  return 0;
}
```

(a) (10 points) Give the output produced by the preprocessor (`cpp -P test.c`) when it reads and processes the file `test.c`. Ignore the `#include <stdio.h>` line – it will insert the declarations from `stdio.h` and do nothing further. Otherwise, your answer should show all of the output from the preprocessor. There are no preprocessor errors in this program, and the resulting program compiles and executes without errors.

```
typedef int num;
num compute(int x) {
  return x+1*3;
}
int main() {
  printf("%d\n", compute(2));
  return 0;
}
```

(b) (2 points) What does this program print when it is compiled and executed?

5

Question 2. (24 points) C programming – with HashTables this time! This question involves the data structures from the HW1 and HW2 projects. Copies of the `LinkedList.h`, `HashTable.h`, and `HashTable_priv.h` header files have been provided on separate pages.

For this problem give the implementation of a new function `HashTableValues` to be added to `HashTable.c`. This function should return a newly-allocated array containing copies of the values stored in the `HashTable` and also return the number of values in (i.e., the size of) the new array. The function result should be 1 if it is able to successfully allocate an array of the proper size and fill it with copies of the values found in the `HashTable` (just the values, not the keys or <key,value> pairs). The function result should be 0 if some error occurs. The array might, of course, wind up containing some duplicate values if the same value occurs more than once in the `HashTable` in separate <key,value> pairs. The order of the values is not specified since the elements of a `HashTable` are not ordered.

Here is some sample code that shows how this function could be used to retrieve the values in a `HashTable` and process them:

```
HTValue_t *values;
HWSize_t  nvalues;

// get value array and number of values
int res = HashTableValues(ht, &values, &nvalues);
Verify333(res == 1);

// use returned values
for (HWSize_t i = 0; i < nvalues; ++i) {
  HTValue_t val = values[i];
  // do something with val...
}

// free array when done
free(values);
```

Your answer may use any of the functions or data declared in the `LinkedList.h`, `HashTable.h`, and `HashTable_priv.h` headers. Don't be alarmed if the solution turns out to be fairly short.

Write your answer on the next page. You may remove this page from the exam while you are working on the question, but please return it at the end of the hour.

Question 2. (cont.) Write an implementation of function `HashTableValues`, below.

```
// Store in parameter nvalues the number of values in
// HashTable ht, and store in parameter values a pointer
// to a newly allocated array containing those values.
//
// Return 1 if the function is successful.
// Return 0 if some error occurs.

int HashTableValues(HashTable ht,
                    HTValue_t **values, HWSize_t *nvalues){
  if (ht == NULL)  // optional - during the test we said it
    return 0;      // was ok to assume a non-empty table

  HWSize_t size = NumElementsInHashTable(ht);

  HTValue_t* vals =
             (HTValue_t*)malloc(sizeof(HTValue_t)*size);
  if (vals == NULL)
    return 0;

  HTIter it = HashTableMakeIterator(ht);

  if (it == NULL) {
    free(vals);
    return 0;
  }

  HWSize_t i;
  for (i = 0; i < size; ++i) {
    HTKeyValue kv;
    HTIteratorGet(it, &kv);
    vals[i] = kv.value;
    HTIteratorNext(it);
  }
  HTIteratorFree(it);

  *values  = vals;
  *nvalues = size;

  return 1;
}
```

Notes: in production code we should check the results of the iterator functions each time to be sure they return a new value and advance to the next element. For this exam question we assumed that once the number of items in the table was known it would be possible to retrieve exactly that many items successfully.

Another way to access the items in the table would be to use the iterator to control the loop and continue as long as there was a next item, incrementing an array subscript each time. Solutions that did that correctly also received full credit.

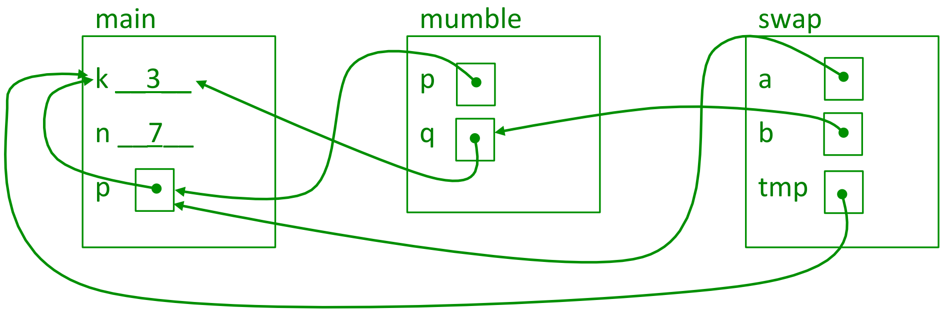
Question 3. (22 points) Pointy things. Consider the following program, which, in the customary manner, compiles and executes with no warnings or errors:

```
#include <stdio.h>

void swap(int **a, int **b) {
  printf("swap1: **a = %d, **b = %d\n", **a, **b);
  int *tmp = *a; *b = *a; *a = tmp;
  //HERE!!!
  printf("swap2: **a = %d, **b = %d\n", **a, **b);
}

void mumble(int **p, int *q) {
  swap(p, &q);
  **p = *q;
}

int main() {
  int k = 3;
  int n = 7;
  int *p = &k;
  mumble(&p, &n);
  printf("main: k = %d, n = %d, *p = %d\n", k, n, *p);
  return 0;
}
```



(a) (14 points) Draw a boxes 'n arrows diagram showing the memory layout and contents at the point just before the *second* `printf` in function `swap` is executed (marked with `HERE!!!` in the comment). Be sure your diagram clearly shows the values of all variables in all active functions and has a separate box (i.e., stack frame) for each active function. For each pointer, draw an arrow from the pointer to the variable that it references. Use the space below the code and/or to the right for your diagram.

(b) (8 points) What does this program print when it is executed?

swap1: **a = 3, **b = 7
swap2: **a = 3, **b = 3
main: k = 3, n = 7, *p = 3

(Of course, the "swap" function doesn't actually swap its arguments. That was not intended, but since the question just asked what it did, we decided not to fix it.)

Question 4. (22 points) The program on this page and the next opens two files, one for reading and one for writing, and copies the contents of the first file to the second. Your job is to complete the code by filling in the blanks lines with the correct POSIX I/O function calls to handle the files (open, close, read, write).

Here is a summary of some key POSIX I/O functions for your reference.

`int open(const char *`*name*`, int `*mode*`);`
    mode is one of `O_RDONLY`, `O_WRONLY`, `O_RDWR`
`int creat(const char *`*name*`, int `*mode*`);`
    create a new file
`int close(int `*fd*`);`
`ssize_t read(int `*fd*`, void *`*buffer*`, size_t `*count*`);`
    returns # bytes read or 0 (eof) or -1 (error)
`ssize_t write(int `*fd*`, void *`*buffer*`, size_t `*count*`);`
    returns # bytes written or -1 (error)

Below is the code you are to complete. You should assume that all necessary header files have been `#include`d and you do not need write any other `#include`s.

```
#define SIZE 1024
int main(int argc, char** argv) {
  int fd1, fd2;
  char buf[SIZE];
  ssize_t rlen, total, wlen;

  if (argc != 3) {
    fprintf(stderr, "Usage: ./a.out <file1> <file2>\n");
    exit(1);
  }
  // open first file for reading

  fd1 = open(argv[1], O_RDONLY);

  if (fd1 == -1) {
    fprintf(stderr, "Could not open file for reading\n");
    exit(1);
  }
  // create the second file
  fd2 = creat(argv[2], 0777);
  if (fd2 == -1) {
    close(fd1);
    fprintf(stderr, "Could not create file for writing\n");
    exit(1);
  }
```

(code continued on next page)

Question 4. (cont.) Continued from previous page.

```
  // Copy all data from fd1 to fd2
  do {
      // read next data from fd1 into buf

      rlen = read(fd1, buf, SIZE);
      if (rlen == -1) {
        if (errno != EINTR) {
          close(fd1);
          close(fd2);
          perror(NULL);
          exit(1);
        }
        continue;
      }
      // Write newly read data from buf to fd2
      total = 0;

      while ( total < rlen ) {

        wlen = write(fd2, buf + total, rlen - total);
        if (wlen == -1) {
          if (errno != EINTR) {
            close(fd1);
            close(fd2);
            perror(NULL);
            exit(1);
          }
          continue;
        }

        total += wlen;
      }
  } while ( rlen > 0 );
  // Close input and output files
  close(fd1);
  close(fd2);
  return 0;
}
```

A few short-answer questions to finish up.

Question 5. (15 points) Here are three C functions that are supposed to return a pointer to a new C string value (null-terminated array of characters) that the caller is responsible for freeing when the caller is done with it. For each function, if it behaves as specified by the comment, say so. If there are one or more bugs in the code, explain what's wrong and show how to fix the function so it works properly.

(a)
```
// return a new string with a copy of str
char *clone(char *str) {
  char *result = (char *)malloc(sizeof(str)+1);
  strcpy(result, str);
  return result;
}
```
Bug: `malloc` argument should be `strlen(str)+1`. `sizeof(str)` returns the number of bytes in the pointer `str`, not the number of bytes in the string (`char` array) it references. (In this and other parts of the question we assumed that `malloc` would always succeed. That's ok for these questions, although in production code we should always check.)

(b)
```
// return a new string containing "hello"
char *hello() {
  char *result = (char *)malloc(5);
  result = "hello";
  return result;
}
```
Two bugs: (minor) `malloc` argument should be 6, not 5, to allow for the '\0' at the end of the string. (major) The assignment to `result` overwrites the pointer to the allocated array with a pointer to a constant string. That results in a memory leak, and will cause an error later when the client tries to free the pointer to the constant data. Fix: Change `malloc(5)` to `malloc(strlen("hello")+1)` or at least to `malloc(6)`, then replace the assignment with `strcpy(result, "hello");`

(c)
```
// return a new string containing "cse333"
char *cse333() {
  char result[] = "cse333";
  return result;
}
```
Bug: This one returns a pointer properly, but, as with (b), the pointer references constant data so it cannot be freed later by the caller. Fix: Same as previous functions: use `malloc` to allocate an array of the proper length, then use `strcpy` or some other appropriate function to copy the string data.

Question 6. (5 points) In one of the C++ exercises we defined assignment for `Vector`s. The function heading for assignment specified that it returned a reference:

```
Vector &Vector::operator=(const Vector &rhs) {
  if (this != &rhs) {
    x_ = rhs.x_;
    y_ = rhs.y_;
    z_ = rhs.z_;
  }
  return *this;
}
```

Suppose we accidentally omitted the `&` and wrote the function heading like this:

```
Vector Vector::operator=(const Vector &rhs) { ... }
```

Now assume we have three vectors, `v1`, `v2`, and `v3` and we write the following chained assignment:

```
v1 = v2 = v3;
```

Amazingly enough everything still compiles and executes without crashing (although maybe not with exactly the right behavior). But something must be different. Describe exactly what's different when the chained assignment statement `v1=v2=v3;` is executed using the second definition of `operator=` compared to the first one.

If the `&` is omitted, the result type of the assignment is now `Vector`, not a reference to a `Vector`. That means that a new `Vector` object will be created and initialized by the copy constructor, and then that new, anonymous `Vector` would be returned as the result of `operator=`. This temporary object will be the argument to the chained assignment to `v1`. In this particular case, since it is a copy of `v2` the correct values will actually be stored in `v1` after which the temporary `Vector` will be discarded. The second assignment will return yet another temporary `Vector`, which will be immediately discarded (although a smart compiler might optimize away this extra object creation and destruction).

In any case, the chained assignment operator will not have a proper reference to object `v2` as its argument. In this case the code "accidentally" works, but only because this particular sequence of assignments does not depend on the specific `Vector` objects involved or their memory addresses.

Answers that were shorter and to the point were fine as long they clearly explained the problem.