**Andrew login ID:** _____

**Full Name:** _____

# CS 15-213, Fall 2003

# Exam 1

October 7, 2003

**Instructions:**

- Make sure that your exam is not missing any sheets, then write your full name and Andrew login ID on the front.
- Write your answers in the space provided below the problem. If you make a mess, clearly indicate your final answer.
- The exam has a maximum score of 55 points.
- The problems are of varying difficulty. The point value of each problem is indicated. Pile up the easy points quickly and then come back to the harder problems.
- This exam is OPEN BOOK. You may use any books or notes you like. You may use a calculator, but no laptops or other wireless devices. Good luck!

| | |
|---|---|
| 1 (09): | |
| 2 (10): | |
| 3 (04): | |
| 4 (08): | |
| 5 (06): | |
| 6 (06): | |
| 7 (08): | |
| 8 (04): | |
| TOTAL (55): | |

## Problem 1. (9 points):

For this problem, assume the following:

- We are running code on a 6-bit machine using two's complement arithmetic for signed integers.
- `short` integers are encoded using 3 bits.
- Sign extension is performed whenever a `short` is casted to an `int`
- Right shifts `int`s are arithmetic.

Fill in the empty boxes in the table below. The following definitions are used in the table:

```
short sy = -3;
int y = sy;
int x = -17;
unsigned ux = x;
```

Note: You need not fill in entries marked with "–".

| Expression | Decimal Representation | Binary Representation |
|---|---|---|
| Zero | 0 | |
| – | $-6$ | |
| – | | `01 0010` |
| $ux$ | | |
| $y$ | | |
| $x >> 1$ | | |
| TMax | | |
| $-$TMin | | |
| TMin + TMin | | |

## Problem 2. (10 points):

Consider the following 12-bit floating point representation based on the IEEE floating point format:

- There is a sign bit in the most significant bit.
- The next $k = 4$ bits are the exponent. The exponent bias is 7.
- The last $n = 7$ bits are the significand.

Numeric values are encoded in this format as a value of the form $V = (-1)^s \times M \times 2^E$, where $s$ is the sign bit, $E$ is exponent after biasing, and $M$ is the significand.

### Part I

How many FP numbers are in the following intervals $[a, b)$?

For each interval $[a, b)$, count the number of $x$ such that $a \leq x < b$.

A. Interval $[1, 2)$ : _____

B. Interval $[2, 3)$ : _____

### Part II

Answer the following problems using either decimal (e.g., $1.375$) or fractional (e.g., $11/8$) representations for numbers that are not integers.

A. For denormalized numbers:

   (a) What is the value $E$ of the exponent after biasing? _____

   (b) What is the largest value $M$ of the significand? _____

B. For normalized numbers:

   (a) What is the smallest value $E$ of the exponent after biasing? _____

   (b) What is the largest value $E$ of the exponent after biasing? _____

   (c) What is the largest value $M$ of the significand? _____

## Part II

Fill in the blank entries in the following table giving the encodings for some interesting numbers.

| Description | $E$ | $M$ | $V$ | Binary Encoding |
|---|---|---|---|---|
| Zero | | $0$ | $0$ | `0 0000 0000000` |
| Smallest Positive (nonzero) | | | | |
| Largest denormalized | | | | |
| Smallest positive normalized | | | | |

## Problem 3. (4 points):

Consider the following C functions and assembly code:

```
int fun4(int *ap, int *bp)
{
    int a = *ap;
    int b = *bp;
    return a+b;
}

int fun5(int *ap, int *bp)
{
    int b = *bp;
    *bp += *ap;
    return b;
}

int fun6(int *ap, int *bp)
{
    int a = *ap;
    *bp += *ap;
    return a;
}
```

```
pushl %ebp
movl %esp,%ebp
movl 8(%ebp),%edx
movl 12(%ebp),%eax
movl %ebp,%esp
movl (%edx),%edx
addl %edx,(%eax)
movl %edx,%eax
popl %ebp
ret
```

Which of the functions compiled into the assembly code shown? _____

## Problem 4. (8 points):

Consider the following four C and IA32 functions. Next to each of the four IA32 functions, write the name of the C function that it implemnts. If the assembly routine doesn't match any of the above functions, write NONE. To save space, the startup code for each IA32 function is omitted:

```
   pushl %ebp
   movl %esp,%ebp
```

```
int winter(int foo[8][12],
           int i, int j)
{
  return foo[i][j];
}
```

```
movl 8(%ebp),%edx
movl 12(%ebp),%eax
movl %ebp,%esp
popl %ebp
movl (%edx,%eax,4),%eax
ret
```

```
int *spring(int foo[8][12],
            int i, int j)
{
  return foo[i];
}
```

```
movl 8(%ebp),%ecx
movl 12(%ebp),%eax
movl 16(%ebp),%edx
movl (%ecx,%eax,4),%eax
movl %ebp,%esp
popl %ebp
movl (%eax,%edx,4),%eax
ret
```

```
int summer(int** foo,
           int i, int j)
{
  return foo[i][j];
}
```

```
movl 12(%ebp),%eax
leal (%eax,%eax,2),%eax
sall $4,%eax
addl 8(%ebp),%eax
movl %ebp,%esp
popl %ebp
ret
```

```
int *fall(int** foo,
          int i, int j)
{
  return foo[i];
}
```

```
movl 8(%ebp),%eax
movl 12(%ebp),%edx
movl 16(%ebp),%ecx
sall $2,%ecx
leal (%edx,%edx,2),%edx
sall $4,%edx
addl %edx,%ecx
movl %ebp,%esp
popl %ebp
movl (%eax,%ecx),%eax
ret
```

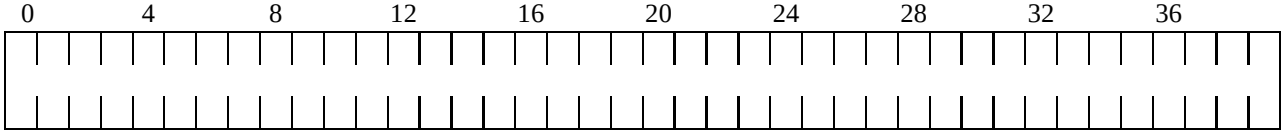
## Problem 5. (6 points):

Consider the following data type definition:

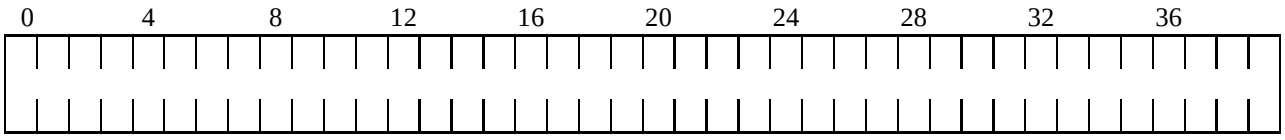
```
typedef struct {
    char c;
    double d;
    short s;
    double *pd;
    float f;
    char *pc;
} struct1;
```

Using the template below (allowing a maximum of 40 bytes), indicate the allocation of data for a structure of type `struct1`. Mark off and label the areas for each individual element (there are 6 of them). Cross hatch the parts that are allocated, but not used (to satisfy alignment). **Clearly indicate the right hand (end) boundary of the data structure with a vertical line**.

Byte Offset - Assume IA32 Windows alignment conventions




Byte Offset - Assume IA32 Linux alignment conventions



## Problem 6. (6 points):

Consider the following IA32 code for a procedure called `mystery`:

```
mystery:
  pushl %ebp
  movl %esp,%ebp
  movl 12(%ebp),%edx
  movl 16(%ebp),%eax
  addl 8(%ebp),%edx
  testl %edx,%edx
  jle .L4
.L6:
  incl %eax
  decl %edx
  testl %edx,%edx
  jg .L6
.L4:
  movl %ebp,%esp
  popl %ebp
  ret
```

Based on the assembly code, fill in the blanks below in `mystery`'s C source code. (Note: you may only use symbolic variables from the source code in your expressions below - do *not* use register names.)

```
int mystery(int a, int b, int c) {
    int x, y;

    y = _____________;


    for (_____________; _____________; _____________) {


         _____________;

    }


   return _____________;
}
```

The next problem concerns the following C code:

```
/* copy string x to buf */
void foo(char *x) {
  int buf[1];
  strcpy((char *)buf, x);
}

void callfoo() {
  foo("abcdefghi");
}
```

Here is the corresponding machine code on a Linux/x86 machine:

```
080484f4 <foo>:
080484f4: 55              pushl  %ebp
080484f5: 89 e5           movl   %esp,%ebp
080484f7: 83 ec 18        subl   $0x18,%esp
080484fa: 8b 45 08        movl   0x8(%ebp),%eax
080484fd: 83 c4 f8        addl   $0xfffffff8,%esp
08048500: 50              pushl  %eax
08048501: 8d 45 fc        leal   0xfffffffc(%ebp),%eax
08048504: 50              pushl  %eax
08048505: e8 ba fe ff ff  call   80483c4 <strcpy>
0804850a: 89 ec           movl   %ebp,%esp
0804850c: 5d              popl   %ebp
0804850d: c3              ret

08048510 <callfoo>:
08048510: 55              pushl  %ebp
08048511: 89 e5           movl   %esp,%ebp
08048513: 83 ec 08        subl   $0x8,%esp
08048516: 83 c4 f4        addl   $0xfffffff4,%esp
08048519: 68 9c 85 04 08  pushl  $0x804859c   # push string address
0804851e: e8 d1 ff ff ff  call   80484f4 <foo>
08048523: 89 ec           movl   %ebp,%esp
08048525: 5d              popl   %ebp
08048526: c3              ret
```

## Problem 7. (8 points):

This problem tests your understanding of the stack discipline and byte ordering. Here are some notes to help you work the problem:

- `strcpy(char *dst, char *src)` copies the string at address `src` (including the terminating '`\0`' character) to address `dst`. It does **not** check the size of the destination buffer.
- Recall that Linux/x86 machines are Little Endian.
- You will need to know the hex values of the following characters:

| Character | Hex value | Character | Hex value |
|---|---|---|---|
| 'a' | 0x61 | 'f' | 0x66 |
| 'b' | 0x62 | 'g' | 0x67 |
| 'c' | 0x63 | 'h' | 0x68 |
| 'd' | 0x64 | 'i' | 0x69 |
| 'e' | 0x65 | '\0' | 0x00 |

Now consider what happens on a Linux/x86 machine when `callfoo` calls `foo` with the input string "`abcdefghi`".

A. List the contents of the following memory locations immediately after `strcpy` returns to `foo`. Each answer should be an unsigned 4-byte integer expressed as 8 hex digits.

`buf[0] = 0x`_____

`buf[1] = 0x`_____

`buf[2] = 0x`_____

B. Immediately **before** the `ret` instruction at address `0x0804850d` executes, what is the value of the frame pointer register `%ebp`?

`%ebp  = 0x`_____

C. Immediately **after** the `ret` instruction at address `0x0804850d` executes, what is the value of the program counter register `%eip`?

`%eip  = 0x`_____

## Problem 8. (4 points):

Consider the following fragment of IA32 code taken directly from the C standard library:

```
0x400446e3: call   0x400446e8
0x400446e8: popl   %eax
```

After the `popl` instruction completes, what hex value does register `%eax` contain?