CS 211: Computer Architecture
Fall 2015
Midterm Exam (100 points)
Total Time: 80 minutes

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NAME:____

DIRECTIONS

This is a closed book, closed notes exam. Calculators are permitted. Please write legibly, concisely; furthermore, please follow directions that ask you to answer questions with a set number of sentences. Overly verbose responses will result in negative marking.

Question	**Points**
1	/10
2	/10
3	/4
4	/6
5	/7
6	/3
7	/5
8	/5
9	/5
10	/10
11	/10
12	/5
13	/5
14	/5
15	/5
16	/5
TOTAL	/100

Please sign below to take the exam: I understand the Rutgers academic honesty policy and hereby attest to having followed it. This means (among other things) that I did not consult any peers, plagiarize, use study aids not permitted, and have not maintained copies of the questions here. I understand that failure to comply by these rules means that I will have to face the university academic disciplinary bodies.

SIGNATURE:____

Question 1 (10 points)

Multiple-choice questions, each one point; circle the correct answer. No partial credit per question.

1. A Von Neumann machine:
(a) Has a heap and a stack.
(b) Stores instructions in the register file.
(c) Maintains both instructions and data in main memory.
(d) Requires a solid-state drive.
Ans: c

2. A computer system's ISA stands for:
(a) Instruction Set Architecture.
(b) Integrated System Architecture.
(c) Integer Support Architecture.
(d) Instruction Stack Architecture.
Ans: a

3. A computer system's ISA is:
(a) The contract between hardware and software on what instructions are supported.
(b) Impacts system performance and power.
(c) Different for x86 machines and ARM machines.
(d) All of the above.
Ans: d

4. A stack:
(a) Grows towards higher addresses in IA32.
(b) Grows towards lower addresses in IA32.
(c) Never grows in IA32.
(d) Grows inside the heap in IA32.
Ans: b

5. A heap, in terms of memory management in a computer system, is:
(a) A specialized, tree-based data structure.
(b) Located in the stack.
(c) Is stored in registers.
(d) Is a region of main memory where dynamic memory is allocated.
Ans: d

6. An activation record:
(a) Is present per function invocation.
(b) Is placed inside the register file.
(c) Is in the arithmetic logic unit.
(d) Is in the heap.
Ans: a

7. Pointers are:
(a) Memory addresses of variables.
(b) Must be declared to match the data type it points to.
(c) Both (a) and (b).
(d) None of the above.
Ans: a

8. Twos complement notation:
(a) Has two representations of zero.
(b) Has one representation of zero.
(c) Is the current standard in computer architecture.

(d) Both (b) and (c).
Ans: d

9. Which of the following should be performed for good programming practice.
(a) All regions claimed with malloc( ) should be released with free( ).
(b) One should use the debugger instead of print statements to check that code is correct.
(c) One should cast data types so that the items they are assigned to have matching data types.
(d) All of the above.
Ans: d
10. A floating point number is representing using:
(a) An exponent field.
(b) A sign field.
(c) A mantissa field.
(d) All of the above.
Ans: d

Question 2 (10 points)
Discuss the benefits and disadvantages of the following computer systems components. One benefit and one disadvantage (one point for each). ONLY one sentence for a benefit or disadvantage.

1. Register file.
Benefit: **Quickly accessible**

Disadvantage: **Small capacity**

2. Main memory. **Large capacity**
Benefit:

Disadvantage: **Slow access**

3. Dynamically allocated memory (memory allocated using malloc( )).
Benefit: **Available for all function invocations**

Disadvantage: **Must be freed or memory leaks occur**.

4. Sign and magnitude representation.
Benefit: **Easy to understand**.

Disadvantage: **Two copies of zero.**

5. Secondary storage (e.g., hard-disk).
Benefit: **Massive capacity and persistent.**

Disadvantage: **Extremely slow**

Question 3 (4 points)

A device is connected to a computer that can return various temperatures related to the weather. The GetTemps function returns the daily high temperature in bits 20–29, the daily low temperature in bits 10–19, and the current temperature in bits 0–9, all as 10-bit integers. In the following program fragment, lines 8 and 9 are incomplete. They should store thehigh temperature in highTemp and the current temperature in currTemp, so that these temperatures can be printed in line 10. Please complete lines 8 and 9, and **implement code efficiently**.

```
#include <stdio.h>                                                          // Line 1
                                                                            // Line 2
int GetTemps(void);                                                         // Line 3
                                                                            // Line 4
int main( ) {                                                               // Line 5
        int w, highTemp, currTemp;                                          // Line 6
        w = getTemps( );                                                    // Line 7
        highTemp = (w >> 20) & 0x3FF;                                                       // Line 8
        currTemp = w & 0x3FF;                                                       // Line 9
        printf ( “High: %d\nCurrent: %d\n”, highTemp, currTemp)             // Line 10
        return 0;
}
```

Question 4 (6 points)
Consider the following data structure, whose individual elements are declared as follows:

```
struct node {
        int value;
        struct node *next;
}
```

Assuming this declaration, implement the C function to insert a new node into a linked list

```
struct node * insert_node(struct node * head, int key) {

struct node * newnode = (struct node *)malloc(sizeof(struct node));
newnode->value = key;
newnode->next = head;
return newnode;

}
```

Question 5 (7 points)
What is the output of the following program?

```
#include <stdio.h>

int main(void)
{
        const int N = 6;
        int i, j;

        for (i = 1; i <= N + 1; i++)
        {
                for (j = 1; j <= N; j++)
                {
                        printf("%c", 'A' + ((i + j - 2) % N));
                }

        printf("\n");
        }
return 0;
}
```

Solution:

```
ABCDEF
BCDEFA
CDEFAB
DEFABC
EFABCD
FABCDE
ABCDEF
```

Question 6 (3 points)
Answer the following multiple- choice questions.

1. Which of the following kinds of values does not have a corresponding primitive (built-in) data type in C?
(a) Integers.
(b) Floating point numbers.
(c) Single characters.
(d) Character strings.
Ans: d

2. To selectively execute exactly one of five alternative statements with a chain of if/else statements, how many test expressions are needed?
(a) 3.
(b) 4.
(c) 5.
(d) 6.
Ans: 4 or 5

3. C has a bool data type.
(a) True.
(b) False.
(c) True but you cannot have a bool return type from a function.
(d) True but you cannot allocate variables of type bool on the heap.
Ans: b

Question 7 (5 points)
First, consider the following declarations.

```
// declarations
int i,j,k[10]={2,4,6,8,10,12,14,16,18,20};
int *ip;
char a,b,c[10]={11,12,13,14,15,16,17,18,19,20};
char *cp;
void *vp;

typedef struct stst {
        int i;
        char *p;
} st;

// assignment statements
st x;
ip = &k[4];
vp = ip;
cp = &c[0];
x.p = cp+3;
x.i = 27;
```

Evaluate the following expressions (if the expression is an error, indicate that with ”X”):

*(ip+2) + c[3] ; _14 + 14 = 28_________

(*cp +1); ___11 + 1 = 12_______

*(ip) + 6; __10 + 6 = 16________

vp = &x ; ((st*)vp)->p; __X or undefined________

*(ip-2) ; __6_________

Question 8 (5 points)
For the following program fragment, specify whether each line allocates a variable, and if so, whether it’s on the heap, stack, or global section.

```
int a = 99;                          // Line 1   glob
int b =10;                           // Line 2   glob
int c = 37;                          // Line 3   glob
                                     // Line 4  nothing
int foo (int d) {                    // Line 5  stack
        double e;                    // Line 6  stack
        int g = 17;                  // Line 7  stack
        int *h;                      // Line 8  stack
        h = (int *) malloc ( e );    // Line 9  heap.
        h[5] = 10;                   // Line 10  nothing
}
```

Question 9 (5 points)

1. The IA32 push instruction:
(a) Adds 4 to the stack pointer and then stores a value on the stack.
(b) Stores a value on the stack and then adds 4 to the stack pointer.
(c) Subtracts 4 from the stack pointer and stores a value on the stack.
(d) All of the above.
Ans: c

2. IA32 implements a jump table for which of the following constructs?
(a) For loop.
(b) While loop.
(c) Switch statement.
(d) Linked list traversal.
Ans: c

3. The stack is used for:
(a) Passing function arguments.
(b) Saving local variables.
(c) Saving registers for later restoration.
(d) All of the above.
Ans: d

4. The offset of each structure member is determined at:
(a) Compile time.
(b) Assembly time.
(c) Link time.
(d) Execution.
Ans: a

5. The portion of memory between %esp and %ebp represents:
(a) The caller stack.
(b) The current activation record.
(c) The callee heap.
(d) The register file.
Ans: b

Question 10 (10 points)

1. Convert FBCC (base hexadecimal, twos complement, 16-bit word) into the following (3 points).
Binary: 1111 1011 1100 1100
Octal: 175714
Decimal: -1076

2. Convert -128 (base decimal, 16-bit word), into hexadecimal with: (3 points)
Sign and magnitude representation: 0x8080
One’s complement: 0xFF7F
Two’s complement: 0xFF80

3. Given the following initial values and IA32 instructions, use these initial values for each question given below (each question is based on the initial values, not any changes the previous question might or might not implement). (4 points)

Address	Value
0x100	0xFF
0x104	0xAB
0x108	0x13
0x10C	0x11

Register	Value
%eax	0x100
%ebc	0x104
%ecx	0x001
%edx	0x003

movl 0x100, %eax — What is stored in eax? 0x100
movl (%eax, %edx, 4), %ecx — What is stored in %ecx? (Eax + edx * 4) = (0x10C) = 0x11
decl %ecx — What is stored in %ecx? 0x0
leal (0, %ebx, 5), %ecx — What is stored in %ecx? Ebx * 5 + 0 = 0x104 * 5 = 0x514

Question 11 (10 points)
Given the following C code, fill in the blanks to create equivalent IA32 code.

C code

```
int fact_while (int x){
        int result = 1;
        while (x > 1) {
                result *= x;
                x = x – 1;
        }
        return result;
}
```

Instruction memory references: 4 + 3 + 5 * x = 5*x + 7
Data memory references: 4
Total: 5*x + 11.
Assembly
fact_while:

```
                pushl   %ebp
                movl    %esp , %ebp
                movl    8 (%ebp), %edx
                movl    $1, %eax
.L0
                cmpl    $1, %edx
                jle .L3

.L6             imull   %edx, %eax
                subl    $1, %edx
                jmp .L0

.L3             movl %ebp, %esp

                popl %ebp
                ret
```

How many memory references are in this assembly snippet? (**Answer: remember to count instructions references too).**

5x + 11

Question 12 (5 points)
Implement the instruction leal 0x4(%eax, %ecx, 8), %ebx using other instructions. You are only allowed to use registers eax, ebx, and ecx and the movl, imull, and addl instructions. Your implementation should be no more than four instructions.

0x4 + eax + ecx * 8

```
addl $0x4, %eax
imull $8, %ecx
addl %ecx, %eax
movl %eax, %ebx
```

Question 13 (5 points)
What is the minimum-cost sum of products form of Σm(1, 2, 4, 7)? List the prime implications and essential prime implicants of this function.

AB C	00	01	11	10
0	0	1 1	3	1 2
1	1 4	5	1 7	6

Prime implicants:

$\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

Essential prime implicants:

$\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

min SOP: $\bar{A}\bar{B}C + \bar{A}B\bar{C} + ABC + A\bar{B}\bar{C}$.

Question 14 (5 points)
What is the minimum-cost product of sums form of πM(0, 2, 5)? List the prime implicants and the essential prime implicants of this function.

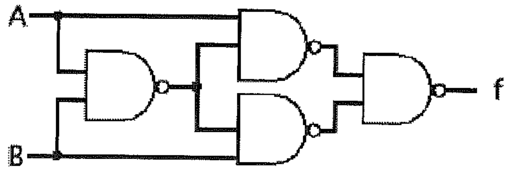
AB C	00	01	11	10
0	0 0	1	3	0 2
1	4	0 5	7	6

Prim implicants: $(B+C), (A+\bar{B}+\bar{C})$

Essential prime implicants: $(B+C), (A+\bar{B}+\bar{C})$

min POS: $(B+C)(A+\bar{B}+\bar{C})$

Question 15 (5 points)
What does this circuit do?



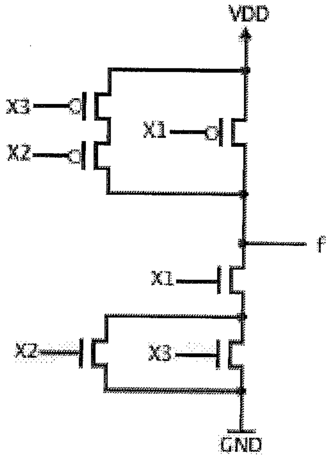
A	B	f
0	0	0
0	1	1
1	0	1
1	1	0

$A \cdot \bar{B} + B\bar{A} = A \otimes B$

$\Downarrow$

XOR

Question 16 (5 points)
What is the truth table for the following circuit? What is the minimum cost product of sums form of this circuit? What is the minimum cost sum of products form of this circuit?



$X_3 \backslash X_1X_2$	00	01	11	10
0	1	1	0	1
1	1	1	0	0

SoP : $\bar{X}_1 + \bar{X}_2 \bar{X}_3$

PoS : $(\bar{X}_1 + \bar{X}_2)(\bar{X}_1 + \bar{X}_3)$