This test has 8 questions, weighted as indicated. The exam is closed book, except that you are allowed to use a one-page single-sided cheatsheet. No calculators or other electronic devices are permitted. Give your answers and show your work in the space provided.

*Print your name, login ID, and precept number on this page* (now), and write out and sign the Honor Code pledge before turning in this paper. It is a violation of the Honor Code to discuss this exam until everyone in the class has taken the exam. You have 50 minutes to complete the test.

*Write out and sign the Honor Code pledge before turning in the test:*
“*I pledge my honor that I have not violated the Honor Code during this examination.*”

Pledge: __________________________________________

Signature: __________________________ Name: ____________________________

NetID: __________________________

Precept: __________________________

<table>
<thead>
<tr>
<th>Problem</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/12</td>
</tr>
<tr>
<td>2</td>
<td>/10</td>
</tr>
<tr>
<td>3</td>
<td>/9</td>
</tr>
<tr>
<td>4</td>
<td>/9</td>
</tr>
<tr>
<td>5</td>
<td>/8</td>
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<tr>
<td>6</td>
<td>/9</td>
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<tr>
<td>7</td>
<td>/6</td>
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<tr>
<td>8</td>
<td>/7</td>
</tr>
<tr>
<td>Total</td>
<td>/70</td>
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</tbody>
</table>
1. **Java Expressions** (12 points)

For each of the Java expressions below, write down the type of the expression and its value. If the expression causes a syntax or run-time error, write an X in both boxes.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 + 2 + &quot;3&quot; + 4 + 5</td>
<td>String</td>
<td>&quot;3345&quot;</td>
</tr>
<tr>
<td>(double)(1 / 2 + 1.0)</td>
<td>double</td>
<td>1.0</td>
</tr>
<tr>
<td>false &amp;&amp; (!(!!true</td>
<td></td>
<td>(true</td>
</tr>
<tr>
<td>7 = 11</td>
<td>X (can't re-define 7)</td>
<td>X</td>
</tr>
<tr>
<td>true != false</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td>Double.parseDouble(&quot;1E1&quot;)</td>
<td>double</td>
<td>10.0</td>
</tr>
</tbody>
</table>
2. **Number Systems** (10 points)

For this problem, we ask you to perform several calculations on hexadecimal numbers. For each part, we are using a **16-bit twos-complement** representation.

(a) What is $0ABE$, expressed in binary?

```
0000 1010 1011 1110
```

(b) What is $FFEE$, expressed in decimal?

```
-18
```

(c) What is $F00D \land FEED$, expressed in hexadecimal?

```
0EE0
```

(d) What is $B0D1 \land FACE$, expressed in hexadecimal?

```
B0C0
```

(e) What is $B0D1 \lor FACE$, expressed in hexadecimal?

```
FADF
```
3. **Debugging** (9 points)

Recall that the absolute value function of \( x \) is defined by

\[
\text{abs}(x) = \begin{cases} 
  x, & \text{if } x \geq 0; \\
  -x, & \text{otherwise}.
\end{cases}
\]

For example, \( \text{abs}(4) = 4 \) and \( \text{abs}(-2) = 2 \).

The following program is supposed to compute the sum of the absolute values of its arguments. Here is a sample run and the expected output:

```java
% java AbsoluteSum 1 -2 4
The absolute sum is 7
```

However, your `AbsoluteSum` program is not working. Here is its source code:

```java
1 public class AbsoluteSum {
2     public static void main(String[] args) {
3         int n = args.length;
4         int sum = 0;
5         for (int i = 0; i < n; n++) {
6             int value = Integer.parseInt(args(i));
7             if (value < 0);  // Line: 6, Description: `args(i)` not valid syntax (should be `args[i]`)  
8                 value = -1 * value;
9                 sum = sum + value;
10         }
11         System.out.println("The absolute sum is " + sum);
12     }
13 }
```

For the three parts below, give the line number where there is a bug in the program, and a brief description of the bug. You do not need to write code to fix the bug.

(a) Find a syntax error that prevents the code from compiling.

Line: 6  Description: `args(i)` not valid syntax (should be `args[i]`)

(b) Find an error that causes the code to run forever (assuming the previous error was fixed).

Line: 5  Description: `i` does not change (`n++` should be `i++`)

After fixing these two bugs, you run the program and find it is computing the wrong value:

```java
% java AbsoluteSum 1 -2 4
The absolute sum is -3
```

(c) Find the error that causes this incorrect output.

Line: 7  Description: body of "if" statement is `;` (delete semicolon)
4. **Arrays** (9 points)

For this problem, you will trace the values stored in three arrays by the following program.

```java
public class ThreeArrays {
    public static void main(String[] args) {
        int n = args.length;

        int[] a = new int[n];
        int[] b = new int[n+1];
        int[] c = b;

        for (int i = 0; i < n; i++)
            a[n-i-1] = Integer.parseInt(args[n-i-1]);

        for (int i = 0; i < n; i++)
            b[i+1] = b[i] + a[i];

        for (int i = 0; i < n; i++)
            c[i+1] = b[i] + c[i+1];
    }
}
```

If we run

```
% java ThreeArrays 1 10 100
```

what are the values stored in the arrays at the **end** of the program? Enter your responses in the boxes below.

<table>
<thead>
<tr>
<th>a[0]</th>
<th>a[1]</th>
<th>a[2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>12</td>
<td>123</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>12</td>
<td>123</td>
</tr>
</tbody>
</table>
TOY Reference Card Use this for the next problem on the facing page.

TOY REFERENCE CARD

INSTRUCTION FORMATS

| . . . . | . . . . | . . . . | . . . . |
Format 1: | opcode | d | s | t | (0-6, A-B)
Format 2: | opcode | d | addr | (7-9, C-F)

ARITHMETIC and LOGICAL operations
1: add R[d] <- R[s] + R[t]
2: subtract R[d] <- R[s] - R[t]
3: and R[d] <- R[s] & R[t]
4: xor R[d] <- R[s] ^ R[t]
5: shift left R[d] <- R[s] << R[t]
6: shift right R[d] <- R[s] >> R[t]

TRANSFER between registers and memory
7: load address R[d] <- addr
8: load R[d] <- mem[addr]
9: store mem[addr] <- R[d]
A: load indirect R[d] <- mem[R[t]]
B: store indirect mem[R[t]] <- R[d]

CONTROL
0: halt halt
C: branch zero if (R[d] == 0) pc <- addr
D: branch positive if (R[d] > 0) pc <- addr
E: jump register pc <- R[d]
F: jump and link R[d] <- pc; pc <- addr

Register 0 always reads 0.
Loads from mem[FF] come from stdin.
Stores to mem[FF] go to stdout.
pc starts at 10

16-bit registers
16-bit memory locations
8-bit program counter
5. **TOY** (8 points)

A NOOP (no operation) in a TOY program is a command that has no effect, other than that the program counter advances just past this command. One use of NOOPs is as a quick alternative to renumbering all of the lines in your TOY program, when you want to delete a line in the middle.

When we call a command a NOOP, we cannot make any assumptions about the state of the machine. For example, the command 1BB0 is a NOOP since it adds zero to register B, which cannot possibly have any effect on any register or memory location. But the command 1BBA is not a NOOP because, depending on the contents of register A, this might change the value of register B.

Similarly, a pair of commands at memory locations $L$ and $L + 1$ forms a NOOP if reaching line $L$ means that we are guaranteed to get to line $L + 2$, with everything the same as it was at line $L$ (except the program counter).

*Determine which of the commands and pairs below are NOOPs.* The : symbols represent hidden parts of the program. Do not make any assumptions about the hidden parts or the initial state of the machine. Circle your YES/NO answer for each of the 8 possible NOOPs.

*Use the TOY reference card on the facing page.*

<table>
<thead>
<tr>
<th>Line 1</th>
<th>Line 2</th>
<th>YES/NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>20: D0D0</td>
<td>This line is a NOOP:</td>
<td>YES</td>
</tr>
<tr>
<td>30: BEEF</td>
<td>This line is a NOOP:</td>
<td>YES</td>
</tr>
<tr>
<td>40: 6991</td>
<td>41: 5991</td>
<td>This pair of lines is a NOOP:</td>
</tr>
<tr>
<td>50: 433E</td>
<td>51: 43E3</td>
<td>This pair of lines is a NOOP:</td>
</tr>
<tr>
<td>60: 2222</td>
<td>This line is a NOOP:</td>
<td>YES</td>
</tr>
<tr>
<td>70: 3333</td>
<td>This line is a NOOP:</td>
<td>YES</td>
</tr>
<tr>
<td>80: DA82</td>
<td>81: CB82</td>
<td>This pair of lines is a NOOP:</td>
</tr>
<tr>
<td>90: DA90</td>
<td>91: CA91</td>
<td>This pair of lines is a NOOP:</td>
</tr>
</tbody>
</table>
6. Methods and Input/Output (9 points)

In this problem, you will analyze the program below:

```java
public class Methodical {
    public static int transform(int x, int y) {
        x = x + 2;
        return (x + y);
    }
    public static int transform(double z) {  
        int y = (int) z;
        StdOut.println(y);
        z = z + 1;
        return (int) z;
    }
    public static void main(String[] args) {
        String w = args[0];
        int x = Integer.parseInt(StdIn.readString());
        int y = Integer.parseInt(args[1]);
        double z = StdIn.readDouble();
        transform(z);
        StdOut.println(z);
        StdOut.println(w + transform(x, y));
    }
}
```

The file numbers.txt contains the following three lines:

4
5
6

(a) What is printed when we run Methodical with the arguments and input below?

```bash
% java Methodical 1 2 3 < numbers.txt
```

First line: 5

Second line: 5.0

Third line: 18

(b) What type of error occurs if we run this command?

```bash
% java Methodical 1 2 3 < numbers.txt | java Methodical
```

Circle one of I, II, III or IV.

I. No such element in readString
II. Array index out of bounds
III. Number format exception in parseInt
IV. Program runs forever
7. **Recursion** (6 points)

For the first four parts of this problem, you will investigate the behaviour of the recursive method defined by:

```java
public static void f(int n) {
    // print n
    System.out.print(n + " "); // space to separate the outputs
    // recursive calls, but when n is zero, acts as the base case
    for (int i = 0; i < n; i++) {
        f(i);
    }
}
```

(a) What is printed when you call `f(0)`?

Output: 0

(b) What is printed when you call `f(1)`?

Output: 1 0

(c) What is printed when you call `f(2)`?

Output: 2 0 1 0

(d) What is printed when you call `f(3)`?

Output: 3 0 1 0 2 0 1 0

(e) For this part, we ask instead about the method `g`:

```java
public static int g(int n) {
    if (n % 2 == 0) return n/10;
    return g(g(n/10));
}
```

What is the value of `g(3122013)`?

Value: 31
Recursive Graphics (7 points)

Here is a method that draws squares recursively:

```java
public static void draw(int n, double x, double y, double r) {
    if (n==0) return; // base case
    draw(n-1, x, y, r/4);
    StdDraw.square(x, y, r); // draw a square
    draw(n-1, x - r/2, y, r/4);
    draw(n-1, x + r/2, y, r/4);
}
```

Below, we plot the picture produced when `draw(3, 0.5, 0.5, 0.5)` is called. It draws thirteen squares, which we have also labelled with dashed circles and arrows.

(a) What is the order in which the squares were drawn? Write all of the integers from 1 to 13 in the circles to indicate this order, with 1 labelling the first square drawn and 13 the last.

(b) Which of the follow expressions represents the order of growth of the running time of `draw` as a function of the first argument `n`? Circle one.

- $\log_3 n$
- $n \log_3 n$
- $n^3$
- $3^n$