Assignment #3
Submission: Moodle

Question 1. For each basic block given below, rewrite it in single-assignment form, and then draw the data flow graph for that form.

a) **[5pts]**
```
r = a + b – c;
s = 2 * r;
t = b – d;
r = d + e;
```

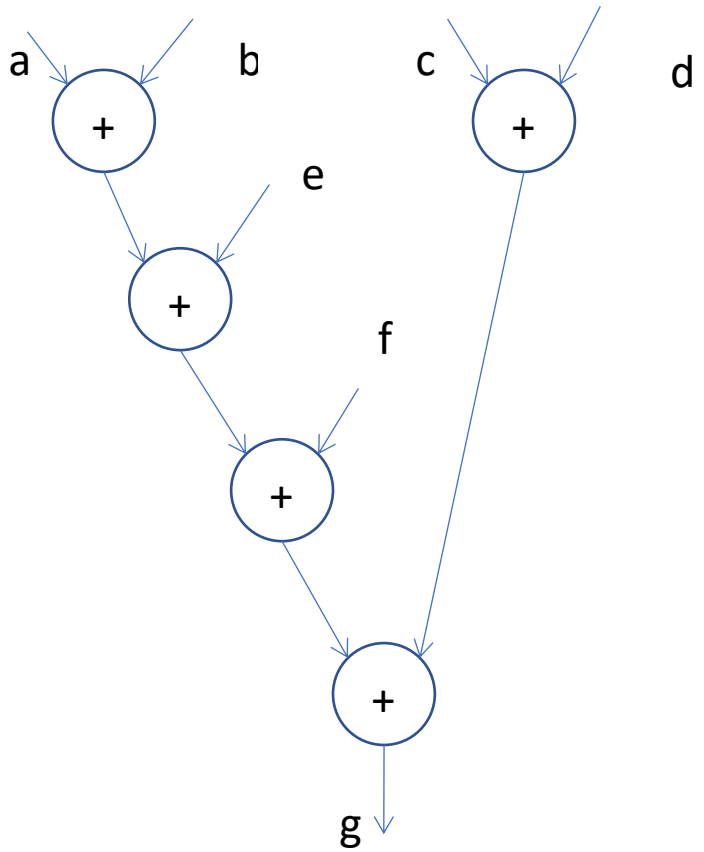
b) **[5pts]**
```
a = q – r;
b = a + t;
a = r + s;
c = t – u;
```

Question 2. Draw the CDFG for the following code fragments:

a) **[6pts]**
```
if (y == 2) { r = a + b; s = c - d; }
else r = a – c;
```

b) **[6pts]**
```
for (i = 0; i < N; i++) {
    if (a[i] == 0) {
      x[i] = 5;
    } else {
      x[i] = a[i] * b[i];
    }
}
```

Question 3 [10pts]. Provide the required order of execution of operations in these data flow graphs. If several operations can be performed in arbitrary order, show them as a set: {***a*** + ***b***, ***c*** - ***d***}.



Question 4 [10pts]. Unroll the loop below two times and three times.

```
for (i = 0; i < 32; i++) {
     x[i] = a[i]*c[i]
}
```

Question 5 [15pts]. For the below basic block, determine the minimum number of registers required to perform the operations when they are executed in the order shown in the code. (You can assume that all computed values are used outside the basic blocks, so that no assignments can be eliminated.

```
r = a + b – c;
s = 2 * r;
t = b – d;
r = d + e;
```

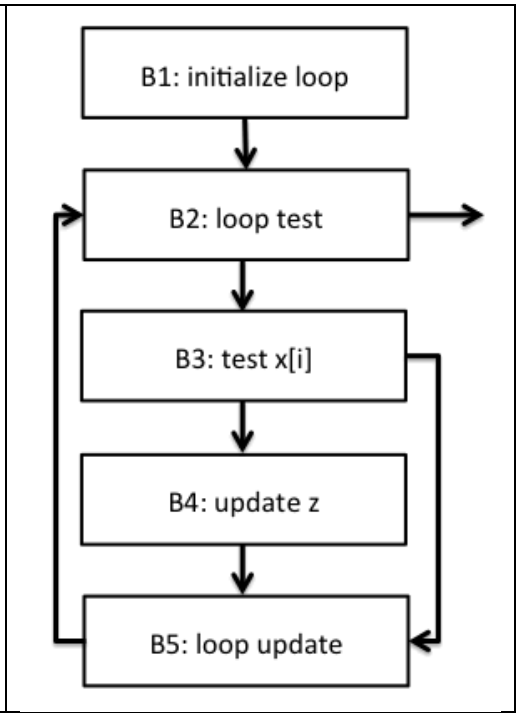
Question 6 [15pts]. Determine the longest path through the code fragment below, assuming that all statements can be executed in equal time and that all branch directions are equally probable.

```
if (a < CONST3) {
   if (b < CONST4)
      w = r + s;
   else {
```

```
      w = r - s;
      x = s + t;
   }
} else {
   if (c > CONST5) {
      w = r + t;
      x = r - s;
      y = s + u;
   }
}
```

Question 7. You are given this program and its flowchart:

```
for (i=0, z=0; i<16; i++) {
     if (x[i] > 2)
          z = z + x[i]*c[i];
}
```



The execution time of the blocks is: B1 = 6 cycles, B2 = 2 if branch taken, 5 if not taken, B3 = 3 if branch taken, 6 if not taken, B4 = 7, B5 = 1

a) **[7pts]** What is the maximum number of times that each block in your flowchart executed?
b) **[7pts]** What is the minimum number of times that each block in your flowchart executed?
c) **[7pts]** What is the maximum execution time of the program in clock cycles?
d) **[7pts]** What is the minimum execution time of the program in clock cycles?