IMPORTANT: Explain your answer briefly. Do not just write a short answer or fill the assembly code.

1. [10pts] The following code fragment has a potential vulnerability.

```
void* copy_elements(void *ele_src[], int ele_cnt, size_t ele_size) {
    /*
     * Allocate buffer for ele_cnt objects, each of ele_size bytes
     * and copy from locations designated by ele_src
     */
    void *result = malloc(ele_cnt * ele_size);
    if (result == NULL)
            /* malloc failed */
            return NULL;
    void *next = result;
    int i;
    for (i = 0; i < ele_cnt; i++) {
        /* Copy object i to destination */
        memcpy(next, ele_src[i], ele_size);
            /* Move pointer to next memory region */
            next += ele_size;
    }
    return result;
}
```

A. [4pts] Write possible values for ele_cnt and ele_size to crash the application/system. Explain the reason.

B. [6pts] Write extra C codes to add before the malloc call to prevent the crash.

2. [10pts][floating point data representation]

   A. [4pts] Assume variables x, f, and d are of type `int`, `float`, and `double`, respectively. (Neither f nor d equals to +infinity, -infinity, or NaN). For each of the following expressions, either argue that it is always true or give a counterexample if it is not.

   ```
   A-1) x == (int) (double) x

   A-2) f == -(-f)

   A-3) 1.0/2 == 1/2.0

   A-4) d*d >= 0.0

   A-5) (f+d) – f == d
   ```

   B. [3pts] Write the rounded binary numbers for the following values. They should be rounded to nearest 1/4 (2 bits fright of binary point, and must use "round-to-even" rule.

   Explain the advantage of such "round-to-even" rule, compared to round-down or round-up.

10.00011	=>	______________
10.00110	=>	______________
10.11100	=>	______________
10.10100	=>	______________

   C. [3pts] Explain how a floating point compare instruction (fcmp) can be implemented for the IEEE fp format. How will it be different from the integer compare instruction (cmp)?

3. [8pts] Answer the two questions for the following C function and the corresponding assembly code.

```
long rfun(unsinged long x) {

    if ( ______________________ )
        return ________________;

    unsigned long nx = _____________;
    long rv = rfun(nx);
    return ____________;
}
```

```
rfun:
        pushq      %rbx
        moveq      %rdi, %rbx
        movl       $0, %eax
        testq      %rdi, %rdi
        je         .L2
        shrq       $2, %rdi
        call       rfun
        addq       %rbx, %rax
.L2:
        popq       %rbx
        ret
```

A. [3pts] What value in the C code does rfun store in %rbx?

B. [5pts] Fill in the missing expressions in the C code.

5. [10pts] Find the minimum number of operations to implement the given functions.

- Points will not be given if functions are implemented more than your minimum number of operations.
- You should justify your solution by implementing the functions.
- Assignment operator ‘=’ is legal. But it will not be counted as an operator.

(1) addOK [5pts]

Description	Determine if can compute x+y without overflow
Examples	addOK(0x80000000,0x80000000) = 0 addOK(0x80000000,0x70000000) = 1
Legal Ops	! ~ & ^ | + << >>

The minimum number of operations to implement this function is ________.

int addOK(int, int)
{
 	
}

6. [10pts] Solve the following problems with the given assembly code.

C code

```
void phase(char *input)
{
   int i;
   int numbers[6];
   read_six_numbers(input, numbers);
   for(i = 1; i < 6; i++) {
     if ( [                ] )
        explode_bomb();
   }
}
```

Assembly

```
Dump of assembler code for function phase:
   0x000055555555522a <+0>:     push   %rbp
   0x000055555555522b <+1>:     push   %rbx
   0x000055555555522c <+2>:     sub    $0x28,%rsp
   0x0000555555555230 <+6>:     mov    %fs:0x28,%rax
   0x0000555555555239 <+15>:    mov    %rax,0x18(%rsp)
   0x000055555555523e <+20>:    xor    %eax,%eax
   0x0000555555555240 <+22>:    mov    %rsp,%rbp
   0x0000555555555243 <+25>:    mov    %rsp,%rsi
   0x0000555555555246 <+28>:    callq  0x555555555820 <read_six_numbers>
   0x000055555555524b <+33>:    mov    %rsp,%rbx
   0x000055555555524e <+36>:    add    $0x14,%rbp
   0x0000555555555252 <+40>:    jmp    0x55555555525d <phase+51>
   0x0000555555555254 <+42>:    add    $0x4,%rbx
   0x0000555555555258 <+46>:    cmp    %rbp,%rbx
   0x000055555555525b <+49>:    je     0x55555555526f <phase+69>
   0x000055555555525d <+51>:    mov    (%rbx),%eax
   0x000055555555525f <+53>:    lea    0x2(%rax,%rax,2),%eax
   0x0000555555555263 <+57>:    cmp    %eax,0x4(%rbx)
   0x0000555555555266 <+60>:    je     0x555555555254 <phase+42>
   0x0000555555555268 <+62>:    callq  0x5555555557fa <explode_bomb>
   0x000055555555526d <+67>:    jmp    0x555555555254 <phase+42>
   0x000055555555526f <+69>:    mov    0x18(%rsp),%rax
   0x0000555555555274 <+74>:    xor    %fs:0x28,%rax
   0x000055555555527d <+83>:    jne    0x555555555286 <phase+92>
   0x000055555555527f <+85>:    add    $0x28,%rsp
   0x0000555555555283 <+89>:    pop    %rbx
   0x0000555555555284 <+90>:    pop    %rbp
   0x0000555555555285 <+91>:    retq
   0x0000555555555286 <+92>:    callq  0x555555554ed8
End of assembler dump.
```

A. Fill the C statement in the blank, based on the corresponding assembly codes. [5pts]

B. What is the solution if the first number of the solution is “1”? [5pts]

7. [7pts] Solve the following problems with the given C code and assembly code

C code

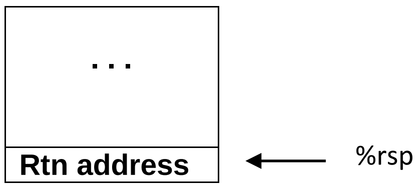
```
long mul(long *p,long val)
{
        long x=*p;
        long y=x*val;
        *p=y;
        return x;
}
long call_mul(long x)
{
        long v1=10;
        long v2=mul(&v1,300);
        return x+v2;
}
```

Assembly

```
mul:
        movq (%rdi), %rax
        imul   %rax,  %rsi
        movq %rsi, (%rdi)
        ret
call_mul:
        subq $16, %rsp
        movq $1000, 8(%rsp)
        [                    ]
        [                    ]
        call mul  ←
        addq 8(%rsp), %rax
        addq $16, %rsp
        ret
```

A. [3pts] Fill the assembly code in the blank(Assembly) [3pts]

B. [4pts] Assume that the program starts with the call_mul function. Draw the stack frame when the program **finishes executing “`call mul`” instructions.**



Initial Stack Structure