

Exercise 6

Problem 1

```
1.  typedef struct {
2.      float *data; /* points to an array */
3.      long capacity; /* the maximum length of the array */
4.      long length; /* number of elements in the array */
5.  } array_t;

6.  long get_length (array_t *arr) {return arr->length;}
7.  long get_capacity (array_t *arr) {return arr->capacity;}

8.  void copy_array(array_t *dst, array_t *src) {
9.      for (long i = 0; i < get_length(src); i++) {
10.         if (i >= get_capacity(dst))
11.             break;
12.         dst->data[i] = src->data[i];
13.     }
14.     dst->length = min(get_length(src), get_capacity(dst));
15. }

16. void sum_array(float *arr, long n, long *sum){
17.     float ans = 0;
18.     for (long i = 0; (i+1) < n; i += 2)
19.         ans = ans + (arr[i] + arr[i + 1]);
20.     if (i < n)
21.         ans += arr[i];
22.     *sum = ans;
23. }

24. .Loop:
25.     movss (%rax, %rdx, 8), %xmm0
26.     addss 8(%rax, %rdx, 8), %xmm0
27.     addss %xmm0, %xmm1
28.     addq $2, %rdx
29.     cmpq %rdx, %rbp
30.     jg .Loop
```

1. Please rewrite the function `copy_array` with what you have learned in the class. Comment briefly on the optimization. NOTE: your optimizations cannot change the functionality of code above.
2. The translation of code in line 18-19 is presented in line 24-30. Please abstract the operations as a data-flow graph and draw the graph. Please also mark the critical path(s) in the graph.
3. The code in line 19 is modified as the following code in the table. After the modification, the CPE measurement increases from X to 2X. Please point out why the CPE measurement increases.

<pre>ans = (ans + arr[i]) + arr[i + 1];</pre>

Problem 2

```
1  .L2:
2  mulsd a(,%rax,8), %xmm0 // a is the address of an array.
3  movsd %xmm0, a(,%rax,8)
4  addq $1, %rax
5  cmpq %rdx, %rax
6  jl .L2
```

Assume that there is only ONE double-precision multiplication unit in the processor. All other CPU resources are UNLIMITED. The latency and issue time of the units are given in the below table.

operation	Integer		Double-precision	
	latency	Issue	latency	issue
Addition	1	1	2	1
Multiplication	3	1	5	1
Load/Store	3	1	3	1

1. Draw the data flow graph and mark the critical path.
2. Please calculate the CPE on current CPU. If we have UNLIMITED number of multiplication units, how much is CPE?
3. Now we swap the instruction at line 3 and line 4, please give out the CPE with original LIMITED number of multiplication units and explain your answer.