1. A.

```
          and $x5, $x5, $x0             #let i = 0
          add $x6, $x0, $x13            #temp = dimension
LOOP: sw $zero, 0($x12)                 #a[i] = 0
          addi $x5, $x5, 1              #i = i + 1
          bne $x6, $x5, LOOP            #if i < dimension
```

B.

If the value of dimension is 512, then there will be (512 * 3) + 2 = **1538** dynamic instructions executed.

C.

```
    .section    __TEXT,__text,regular,pure_instructions
    .build_version macos, 11, 0 sdk_version 11, 3
    .globl  _matrix_init                    ## -- Begin function matrix_init
    .p2align    4, 0x90
_matrix_init:                           ## @matrix_init
    .cfi_startproc
## %bb.0:
    pushq   %rbp
    .cfi_def_cfa_offset 16
    .cfi_offset %rbp, -16
    movq    %rsp, %rbp
    .cfi_def_cfa_register %rbp
    movq    %rdi, -8(%rbp)
    movl    %esi, -12(%rbp)
    movl    $0, -16(%rbp)
LBB0_1:                                 ## =>This Inner Loop Header: Depth=1
    movl    -16(%rbp), %eax
    cmpl    -12(%rbp), %eax
    jge LBB0_4
## %bb.2:                               ##   in Loop: Header=BB0_1 Depth=1
    movq    -8(%rbp), %rax
    movslq  -16(%rbp), %rcx
    movl    $0, (%rax,%rcx,4)
## %bb.3:                               ##   in Loop: Header=BB0_1 Depth=1
    movl    -16(%rbp), %eax
    addl    $1, %eax
    movl    %eax, -16(%rbp)
    jmp LBB0_1
LBB0_4:
    popq    %rbp
    retq
    .cfi_endproc
                                        ## -- End function
.subsections_via_symbols
```

D.

```
	.section	__TEXT,__text,regular,pure_instructions
	.build_version macos, 11, 0 sdk_version 11, 3
	.globl	_matrix_init                    ## -- Begin function matrix_init
	.p2align	4, 0x90
_matrix_init:                           ## @matrix_init
	.cfi_startproc
## %bb.0:
	testl	%esi, %esi
	jle	LBB0_2
## %bb.1:
	pushq	%rbp
	.cfi_def_cfa_offset 16
	.cfi_offset %rbp, -16
	movq	%rsp, %rbp
	.cfi_def_cfa_register %rbp
	movl	%esi, %esi
	shlq	$2, %rsi
	callq	___bzero
	popq	%rbp
LBB0_2:
	retq
	.cfi_endproc
                                        ## -- End function
.subsections_via_symbols
```

E.
Without optimization, if the dimension is 512, 8 + (10 * 512) + 5 = **5133** dynamic instructions executed.
With optimization, if the dimension is 512, (10 * 512) + 3 = **5123** dynamic instructions executed.

2. A.
ET = IC * CPI * CR
We will set IC = 1 since they are equal for all three processors so does not affect which one has highest performance.
P1: $1 \frac{instruction}{program} * 1.5 \frac{cycles}{instruction} * \frac{1}{3*10^9 cycles/sec}$ = 5 * 10^{-10} seconds/program
P2: $1 \frac{instruction}{program} * 1.0 \frac{cycles}{instruction} * \frac{1}{2.5*10^9 cycles/sec}$ = **4 * 10^{-10} seconds/program**
P3: $1 \frac{instruction}{program} * 2.2 \frac{cycles}{instruction} * \frac{1}{4*10^9 cycles/sec}$ = 5.5 * 10^{-10} seconds/program

Since P2 has the least seconds per program, it has the highest performance.

B.

P1: $IC = \frac{10}{1.5\frac{cycles}{instruction} * \frac{1}{3*10^9 cycles/sec}}$ = **2 * 10^{10} instructions in program**

2 * 10^{10} instructions * 1.5 cycles/instruction = **3 * 10^{10} cycles in program**

P2: $IC = \frac{10}{1.0\frac{cycles}{instruction} * \frac{1}{2.5*10^9 cycles/sec}}$ = **2.5 * 10^{10} instructions in program**

2.5 * 10^{10} instructions * 1.0 cycles/instruction = **2.5 * 10^{10} cycles in program**

P3: $IC = \frac{10}{2.2\frac{cycles}{instruction} * \frac{1}{4*10^9 cycles/sec}}$ = **1.82 * 10^{10} instructions in program**

1.82 * 10^{10} instructions * 1.0 cycles/instruction = **4.004 * 10^{10} cycles in program**

C.

Reduce execution time by 30%:
P1: 5 * 10^{-10} seconds/program * .7 = 3.5 * 10^{-10} seconds/program
P2: 4 * 10^{-10} seconds/program * .7 = 2.8 * 10^{-10} seconds/program
P3: 5.5 * 10^{-10} seconds/program * .7 = 3.85 * 10^{-10} seconds/program

Increase CPI by 20%:
P1: 1.5 * 1.2 = 1.8
P2: 1.0 * 1.2 = 1.2
P3: 2.2 * 1.2 = 2.64

Clock Rate:
Set IC as 1 again

P1: $CR = \frac{3.5 * 10^{-10}\frac{\text{seconds}}{\text{program}}}{1.8\frac{cycles}{instruction} * 1\frac{instruction}{program}}$ = **5.14 GHz**

P2: $CR = \frac{2.8 * 10^{-10}\frac{\text{seconds}}{\text{program}}}{1.2\frac{cycles}{instruction} * 1\frac{instruction}{program}}$ = **4.29 GHz**

P3: $CR = \frac{3.85 * 10^{-10}\frac{\text{seconds}}{\text{program}}}{2.64\frac{cycles}{instruction} * 1\frac{instruction}{program}}$ = **6.85 GHz**

3. A.

Average CPI = (1 * .6) + (12 * .3) + (5 * .1) = **4.7 cycles/instruction**

B.

ET = $5 * 10^9 \frac{instructions}{program} * 4.7 \frac{cycles}{instruction} * \frac{1}{2*10^9 cycles/sec}$ = **11.75 seconds**