1. A.

```
        and $x5, $x5, $x0
LOOP: sw $x5, 0($x12)
        addi $x12, $x12, 4
        addi $x5, $x5, 1
        bne $x5, $x13, LOOP
        jalr $x0, 0($x1)
```

2. A.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lw | IF | ID | EX | MEM | WB | | | | | | | | | | | | | | |
| lw | | IF | ID | ID | EX | MEM | WB | | | | | | | | | | | | |
| addi | | | IF | IF | ID | EX | MEM | WB | | | | | | | | | | | |
| bne | | | | | IF | ID | EX | MEM | WB | | | | | | | | | | |
| lw | | | | | | IF | ID | EX | MEM | WB | | | | | | | | | |
| lw | | | | | | | IF | ID | ID | EX | MEM | WB | | | | | | | |
| addi | | | | | | | | IF | IF | ID | EX | MEM | WB | | | | | | |
| bne | | | | | | | | | | IF | ID | EX | MEM | WB | | | | | |
| lw | | | | | | | | | | | IF | ID | Nop | Nop | Nop | | | | |
| lw | | | | | | | | | | | | IF | ID | ID | Nop | Nop | Nop | | |
| add | | | | | | | | | | | | | IF | IF | ID | EX | MEM | WB | |
| addi | | | | | | | | | | | | | | | IF | ID | EX | MEM | WB |

B. number of cycle = 9 * 9,999 + 14 = 90005
Number of instructions = 4 * 10000 + 2 = 40002
**CPI = 2.25**

3. A.

| I | Branch | State | Predicted | Actual |
|---|---|---|---|---|
| 0 | X | 000 | NT | NT |
| 1 | Z | 000 | NT | T |
| 1 | X | 000 | NT | T |
| 1 | Y | 000 | NT | NT |
| 2 | Z | 001 | NT | T |
| 2 | X | 001 | NT | T |
| 2 | Y | 000 | NT | T |
| 3 | Z | 010 | NT | T |
| 3 | X | 010 | NT | NT |
| 4 | Z | 011 | NT | T |
| 4 | X | 001 | NT | T |
| 4 | Y | 001 | NT | NT |
| 5 | Z | 100 | T | T |
| 5 | X | 010 | NT | T |
| 5 | Y | 000 | NT | T |
| 6 | Z | 101 | T | T |
| 6 | X | 011 | NT | NT |
| 7 | Z | 110 | T | T |

| | | | | |
|---|---|---|---|---|
| 7 | X | 010 | NT | T |
| 7 | Y | 001 | NT | NT |
| 8 | Z | 111 | T | T |
| 8 | X | 011 | NT | T |
| 8 | Y | 000 | NT | T |
| 9 | Z | 111 | T | T |
| 9 | X | 100 | T | NT |
| 10 | Z | 111 | T | T |
| 10 | X | 011 | NT | T |
| 10 | Y | 001 | NT | NT |
| 11 | Z | 111 | T | T |
| 11 | X | 100 | T | T |
| 11 | Y | 000 | NT | T |
| 12 | Z | 111 | T | T |
| 12 | X | 101 | T | NT |
| 13 | Z | 111 | T | T |
| 13 | X | 100 | T | T |
| 13 | Y | 001 | NT | NT |
| 14 | Z | 111 | T | T |
| 14 | X | 101 | T | T |

| | | | | |
|---|---|---|---|---|
| 14 | Y | 000 | NT | T |
| 15 | Z | 111 | T | T |
| 15 | X | 110 | T | NT |

| | Number of Predictions | Number of Correct Predictions | Prediction Accuracy |
|---|---|---|---|
| Branch X | 100,000 | 33,333 * 2 – 8 + 3 = 66,661 | |
| Branch Y | 66,666 | 33,333 (50%) | |
| Branch Z | 100,000 | 99,996 (only first 4 are wrong) | |
| total | 266,666 | 199,990 | **~.7499644%** |

4. A.
   C = ABS
   C = 64K; A = 8; B = 64 bytes
   64K = 8 * 64 * S
   S = 128
   **Offset** = log(B) = log(64) = **6 bits**
   **Index** = log(S) = log(128) = **7 bits**
   **Tag** = 32 – offset – index = 32 – 6 – 7 = **19 bits**