Score: _____ Name: _____

ECE 3055 Quiz Wednesday, February 30

The program below is executed on the 5 stage pipelined MIPS processor design described in chapter 4. Answer the following questions about this program.

```
loop_top:   lw    $3,100($5)
            sub   $5,$3,$4
            srl   $2,$3,2
            lw    $9,200($5)
            bne   $2,$3,foobar
            add   $5,$5,$6
            addi  $6,$3,5
foobar:     srl   $7,$6,1
            addi  $10,$7,1
            sw    $9,10($0)
            slt   $1,$9,$0
            beq   $1,$0,loop_top
```

Assume the control unit **does not have** any hazard detection, forwarding, a new branch compare circuit, or automatic branch flushing, and that the register file **will not** write and then read a new register value in one clock cycle. Rewrite the code sequence by only adding the **minimum number** of NOP instructions (*do not reorder or change the instructions*) to eliminate all potential data and branch hazards. Assume other non-NOP instructions follow the last branch in the original code sequence above.

Minimum number of NOPs required 20

```
lw
  nop
  nop
  nop
sub
srl
  nop
  nop
lw
bne
  nop
  nop
  nop
```

```
add
addi
  nop
  nop
  nop
srl
  nop
  nop
  nop
addi
sw
slt
```

```
  nop
  nop
  nop
beq
  nop
  nop
  nop
```

Next, assume the control unit is fully improved as outlined in the text by adding the hazard and forwarding unit, adding automatic branch flushing with a new compare unit (with forwarding) to the decode stage along with the original register forwarding muxes, and the register file writes and then reads a new value in a single clock cycle. Determine the number of clock cycles required to complete ten executions of the loop code before it exits at the bottom of the loop. Assume the inner branch (i.e., bne) **is taken 50% of the time**. 5x12 + 5x10

If there were no hazards or branch flushing, the original program would only require 110 clock cycles for ten loop iterations. Assume it exits the loop on the tenth execution. (***do not include the time to initially fill the pipeline at power up***). 10 lw + 5 bne + 9 beq

But this program will need to stall and/or flush the pipeline an additional 24 clock cycles so

a total of 134 **clock cycles** is required for ten loop executions (***do not include the time to initially fill the pipeline***). 134/110

This program achieves a CPI (clocks per instruction) of 1.218 .(*do not include time to fill the pipeline here*)