

1. non-pipelined (single cycle): $250+350+150+300+200=1250$

Pipelined: 350

Speedup: $1250/350$

2.

Without forwarding:

or r1,r2,r3 F D E M W

or r2,r1,r4 F D E M W

or r1,r1,r2 F D E M W

total: 11cycles

$11 * 250 = 2750\text{ps}$

With full forwarding:

or r1,r2,r3 F D E M W

or r2,r1,r4 F D E M W

or r1,r1,r2 F D E M W

total: 7cycles

$7 * 300 = 2100\text{ps}$

$\text{speedup} = (11*250)/(7*300)$

$= 2750/2100$

$= 1.31$

3. /a.

add \$3, \$1, \$2

```
nop
nop          -RAW $3
lw $4,-100($3)
nop
nop          -RAW $4
sw $4, 8($3)
```

b. If there is a full forwarding hardware, there is no nops between **add** and **lw**. If you also use the MEM stage to MEM stage forwarding, the two nops between **lw** and **sw** could be removed. Therefore no nops involved.
If you do not use MEM to MEM forwarding, the 2 nops are still there.