Chapter 4 problem 9: forwarding

1.

The first dependency is that the first instruction changes r1, while the second instruction needs r1 to execute. This is a type la hazard. This is because we have that EX/MEM Register.Rd = ID/EX Register. Rs.

The second dependency is that r1 is also needed for the third instruction. Here we have MEM/WB Register.Rd = ID/EX Register.Rs, so this is a type 2a hazard.

The last dependency is that r2 is needed for the third instruction, and we set r2 in the second instruction. Therefore, we have that EX/MEM Register.Rd = ID/EX Register.Rs, so this is a type 1b hazard.

2.

Since the dependency between the first and the second instruction causes a type 1 hazard, we must add three nops between them (because the second instruction cannot enter the ID phase until the correct values of registers are put in place that is, after the first instruction finishes its WB phase). We use similar line of thinking for the second and the third instruction. Notice that the addition of three nops between the second and the third instruction also takes care of the type 2 hazard caused by the dependency between the first and the third instruction. Finally, the modified code is as follows:

```
or      r1, r2, r3
nop
nop
nop
or      r2, r1, r4
nop
nop
nop
or      r1, r1, r2
```

3.

Notice that we can completely remove the nops. For the second instruction, we just forward the result of the EX phase of the first instruction as r1. Similarly, for the third instruction, we forward the result of the EX phase of the second instruction as r2. What about r1? Well, the first instruction is in the MEM phase while the third is in the ID phase, but the processor still remembers what the first Instruction got as a result of the EX phase

4.

The first instruction needs 5 cycles to complete, while each subsequent instruction adds only 1 additional cycle. Thus, when we don't have forwarding implemented, we use

5+8 = 13 cycles.

The total execution time is 13x250 3250 ps

On the other hand, when we have forwarding, we use 5+2 = 7 cycles. The total execution time is 7 x 300 = 2100 ps.

The speedup is

3250/2100 = 1.55