4.1 a) basic: 10
bubble: 10
forward: 10

4.1 b) basic: 9
bubble: 11
forward: 9

4.1 c) the second add instruction needs the value of $2 before it has been written back into the register by the first ADD instruction. this is a Data Hazard.

4.2 a) basic: 5, jump made at 6.
bubble: 5, jump made at 6.
forward: 4, jump made at 4.

4.2 b) for the basic mode, the addi is executed and results in the branch instruction not being taken on the following loop.
for the other 2 modes, the addi doesn't enter the pipeline.

4.2 c) this is a Control Hazard, we don't know which instruction to fetch before the branch is taken or not.

4.3 a) basic: 10
bubble: 12
forward: 10

4.3 b) basic: 8
bubble: 10
forward: 8

4.3 c) Data Hazard, ADDI instuction needs the result of the LW instruction before it is done.

5.1 (alligned better as a table in .txt file)

| | | |
|---|---|---|
| Basic: | | |
| | Instructions: | 206 |
| | Cycles: | 212 |
| | CPI: | 1.029126167297363 |
| Bubbles: | | |
| | Instructions: | 76 |
| | Cycles: | 182 |
| | CPI: | 2.394736766815185 |
| Bubbles with Branch Assumption: | | |
| | Instructions: | 76 |
| | Cycles: | 154 |
| | CPI: | 2.026315689086914 |
| Forwarding: | | |
| | Instructions: | 120 |
| | Cycles: | 126 |
| | CPI: | 1.049999952316284 |
| Forwarding with Branch Assumption: | | |
| | Instructions: | 115 |
| | Cycles: | 127 |
| | CPI: | 1.104347825050354 |

5.2 a) the program instuctions are only executed during clock cycles, so the less cycles used, the faster the program will be executed. instuctions are depentent on cycles.

5.2 b) because the different datapaths all have different optimisations to speed up the execution of the program through the pipeline. each optimisation condenses the instructions on the pipeline, to allow more instructions to be executed simultaniously.

5.3 (alligned better as a table in .txt file)

```
Forwarding Optimized:
    Instructions:   114
    Cycles:         120
    CPI:            1.0526316165924072
Forwarding, Branch Assumption Optimized:
    Instructions:   96
    Cycles:         109
    CPI:            1.1354166269302368
```