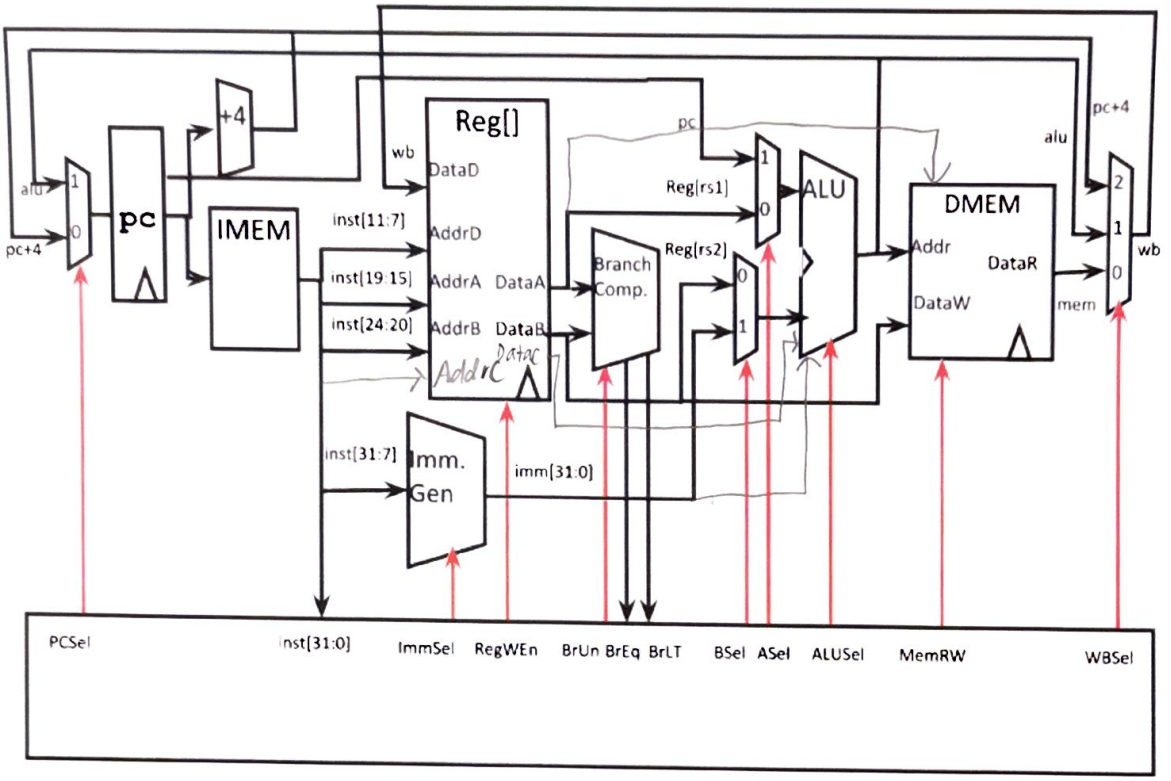

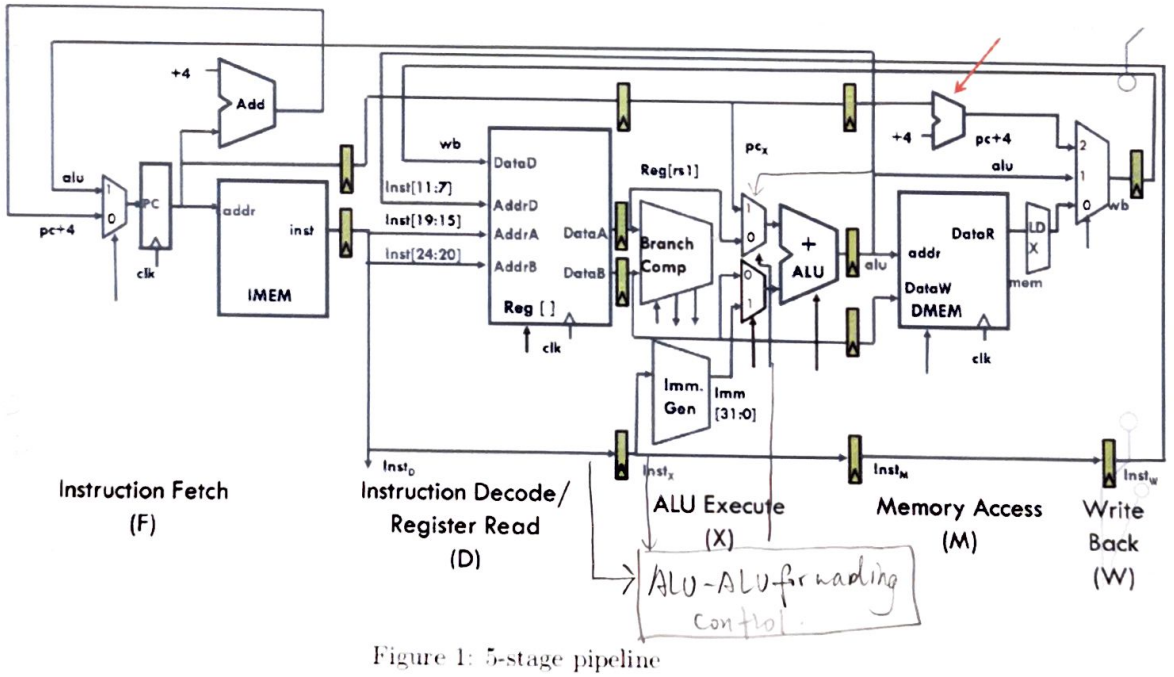

Figure 1: 5-stage pipeline

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Problem 1: Hazards:

b)

a) beq: PC = PC + {imm, 12'b0} won't work.
sw: M[R[rs1]+imm](31:0) = R[rs2](31:0) won't work.
jal: PC = PC + {imm, 1'b0} won't work.

b) lw: R[rd] = {32'bM[](31), M[R[rs1]+imm](31:0)} won't work.
add R[rd] = R[rs1] + R[rs2] won't work.

c) beq: PC = PC+{imm, 1'b0} won't work.
auipc: R[rd] = PC + {imm, 12'b0} won't work.

Problem 2: Pipelines.

a)

Cycle	IF	EX	WB
1	add	-	-
2	sub	add	-
3	-	sub	add
4	add	-	sub
5	or	add	-
6	and	or	add
7	-	and	or
8	xor	-	and
9	-	xor	-
10	add	-	xor
11	-	add	-
12	-	-	add

b)

Cycle	F	D	X	M	W
1	add	-	-	-	-
2	sub	add	-	-	-
3	add	sub	add	-	-
4	or	add	sub	add	-
5	-	or	add	sub	add
6	-	-	or	add	sub
7	and	-	-	or	add
8	xor	and	-	-	or
9	add	xor	and	-	-
10	-	add	xor	and	-
11	-	-	add	xor	and
12	-	-	-	add	xor
13	-	-	-	-	add

Problem 3: Branch Prediction

1) PC+4 always taken.

Cycle	F	D	X	M	W
1	li	-	-	-	-
2	li	li	-	-	-
3	-	li	li	-	-
4	-	-	li	li	-
5	-	-	-	li	li
6	add	-	-	-	li
7	li	add	-	-	-
8	-	li	add	-	-
9	-	-	li	add	-
10	-	-	-	li	add
11	bne	-	-	-	li
12	addi	bne	-	-	-
13	-	addi	bne	-	-
14	-	-	addi	bne	-
15	subi	-	-	addi	bne
16	addi	subi	-	-	addi
17	-	addi	subi	-	-
18	-	-	addi	subi	-

	F	D	X	M	W
19	-	-	-	addi	subi
20	-	-	-	-	addi

2) branch always taken

cycle	F	D	X	M	W
1	li	-	-	-	-
2	li	li	-	-	-
3	-	li	li	-	-
4	-	-	li	li	-
5	-	-	-	li	li
6	add	-	-	-	li
7	li	add	-	-	-
8	-	li	add	-	-
9	-	-	li	add	-
10	-	-	-	li	add
11	bne	-	-	-	li
12	addi	bne	-	-	-
13	-	addi	bne	-	-
14	-	-	addi	bne	-
15	subi	-	-	addi	bne
16	addi	-	-	-	-
17	-	addi	-	-	-
18	-	-	addi	-	-
19	-	-	-	addi	-
20	-	-	-	-	addi