Single-cycle
multi-cycle
Pipelined

Doing Laundry

Laundry steps

1) Wash   each step takes 30 mins
2) Dry
3) Fold
4) Put away

20	30	30	30	1 load
W	D	F	P	2 hrs
				120 mins
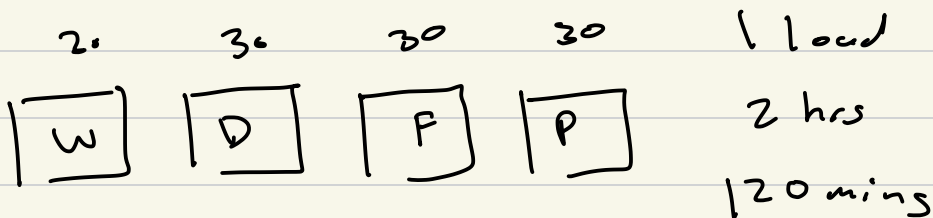
[W] [D] [F] [P] [W] [D] [F] [P]   4 hrs
                                    2 load

Pipeline Laundry

         30   30   30   30   30 ↓ 30   30 ↓
1st   [W][D][F][P]

2nd   [W][D][F][P]

3rd   [W][D][F][P]

4th   [W][D][F][P]
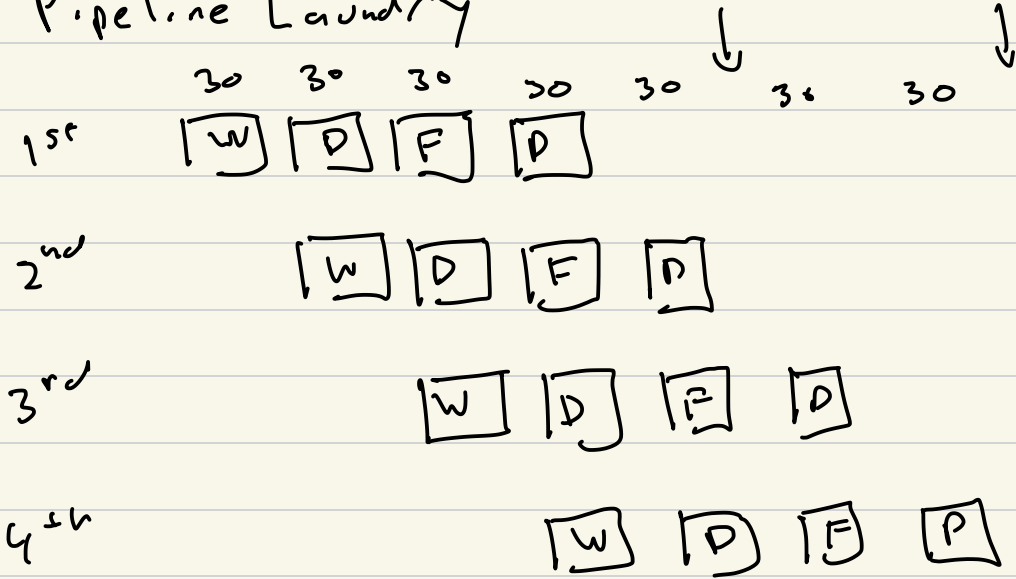
Pipeline   Serial

  2 loads   2.5   4 hrs
  4 loads   3.5   8 hrs

100 loads ?

    (4 × 0.5) + (100−1) × (0.5)
      = 2 hrs   +   99 · 0.5
      = 2 hrs + 49.5 = | 51.5 hrs |

Serial?

$$100 \times 2 = \boxed{200 \text{ hrs}}$$

$$\frac{1}{4}$$

Generally, with n stages

we can get $\frac{1}{n}$ speed up.

Processor Pipeline Hazards
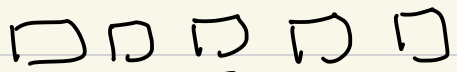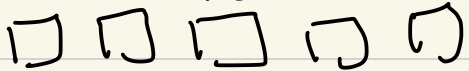
Data Hazards
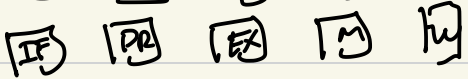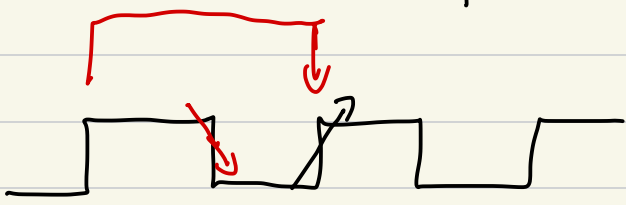Control Hazards

time —>

addi a1, 1   IF DR EX M W

nop

nop

add a0, a1, a1   IF DR EX M W

invert CLK

CLK

⌐CLK

to RegFile   WB   DR