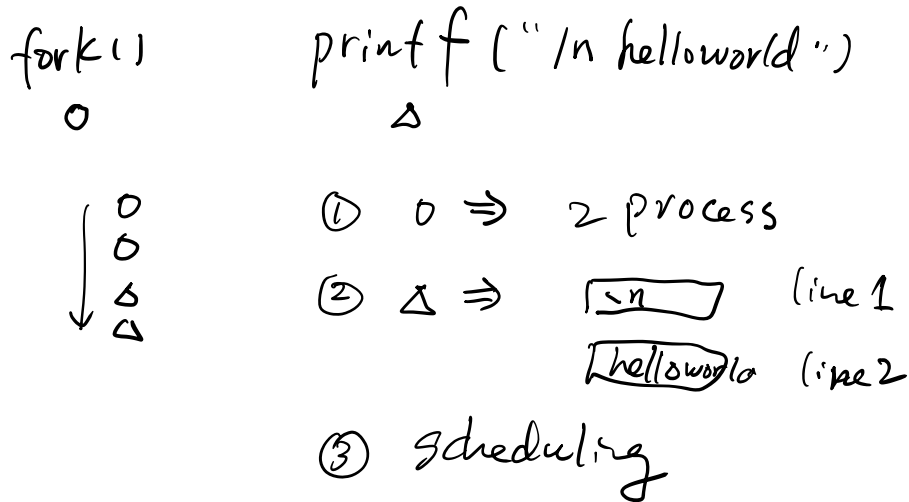


1. Last time ←
  2. Scheduling disciplines
    - FIFO
    - SJF
    - RR
    - Prio
    - MLFQ
    - Lottery
  3. Vote for your favorite scheduling algorithm ↷
- 

hw2, Q2

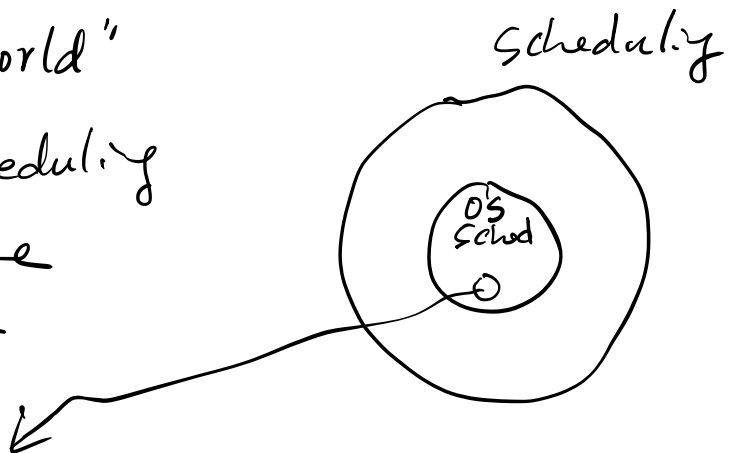


Mac OS.

3 "hello world"

### 3. metrics of scheduling

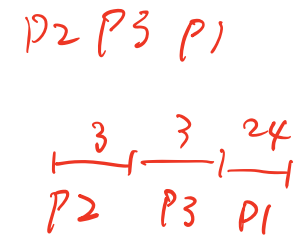
- turn around time
  - response time
  - fairness
- scheduling game (recall)
- 1 CPU
  - multiple processes: P1, P2, P3, ...
  - each with arrival time and running time
  - ignore context switches
  - assume no I/O
  - scheduling output:  
a sequence of scheduling decisions



A. FCFS/FIFO

| process | arrival | running |
|---------|---------|---------|
| P1      | 0       | 24      |
| P2      | 0 + ε   | 3       |
| P3      | 0 + 2ε  | 3       |

$0 \dots 23 \quad 24 \quad 25 \quad 26 \quad 27 \quad 28 \quad 29$   
 $P1 \quad P2 \quad P2 \quad P2 \quad P2 \quad P3 \quad P3 \quad P3$   
 $\uparrow \quad \uparrow \quad \uparrow \quad \uparrow \quad \uparrow \quad \uparrow \quad \uparrow$



turnaround =  $\frac{24 + 27 + 30}{3} = 27$

resp =  $\frac{0 + 3 + 6}{3}$

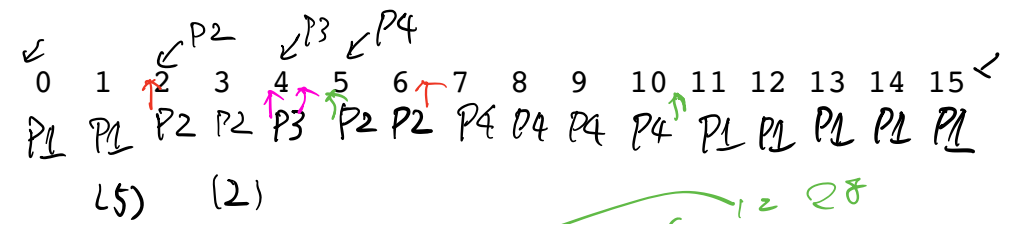
resp =  $\frac{0 + 24 + 27}{3} = 17$

Q:

|            |    |       |
|------------|----|-------|
| turnaround | 13 | 12    |
|            | 13 | 11    |
|            | 13 | 3 ∈ U |
|            | 13 | 10    |

B. SJF and SFCF

| process | arrival | running |
|---------|---------|---------|
| P1      | 0       | 7       |
| P2      | 2       | 4       |
| P3      | 4       | 1       |
| P4      | 5       | 4       |



$$\text{turnaround} = \frac{16 + 5 + 1 + 6}{4} = 7$$

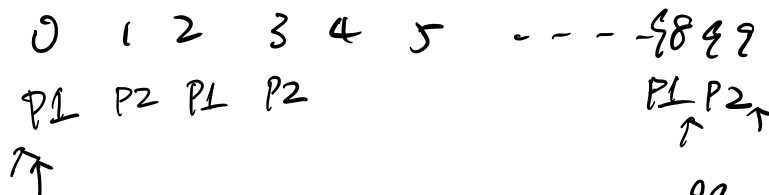
$$\text{resp time} = 15, \frac{3}{4}, 3, 1, 0.5, \text{Def}$$

$$\frac{0 + 0 + 0 + 2}{4} = 0.5$$

C. Round-robin (RR)

(with slice of 1 unit of time)

| process | arrival | running |
|---------|---------|---------|
| P1      | 0       | 50      |
| P2      | 0 + 2   | 50      |



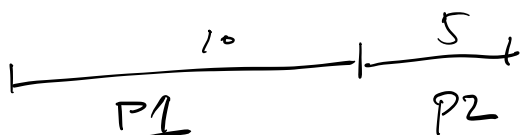
$$\text{turnaround time} = \frac{99 + 100}{2}$$

$$\text{resp time} = \frac{0 + 1}{2} = 0.5$$

50  
99.5  
49.5  
100

D. Priority → SJF

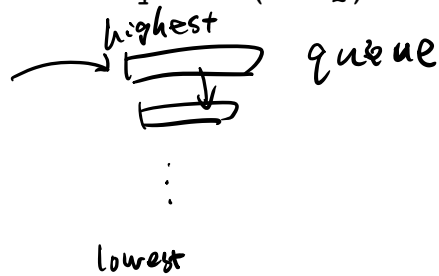
| process   | arrival | running |
|-----------|---------|---------|
| P1 (high) | 0       | 10      |
| P2 (low)  | 0       | 5       |



$$\text{turnaround} = \frac{20 + 15}{2} = 12.5$$



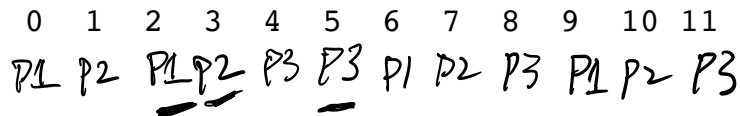
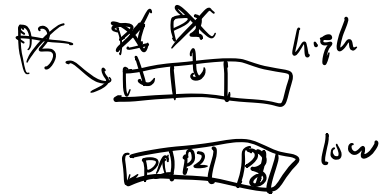
E. Multi-level feedback queue (MLFQ)



(with slice of 1 unit of time;  
2 units of time to change priority, i.e., "downgrade")

| process | arrival | running |
|---------|---------|---------|
| P1      | 0 ←     | 4       |
| P2      | 0 →     | 4       |
| P3      | 4 ←     | 4       |

} 12



F. Lottery (and stride scheduling)

1995

(with slice of 1 unit of time)

| process         | arrival | running |
|-----------------|---------|---------|
| P1 ( $t_1=20$ ) | 0       | 20      |
| P2 ( $t_2=10$ ) | 0       | 10      |

$\left. \begin{matrix} 10 \\ 20 \end{matrix} \right\} 20$

$$P_i = t_i$$

$$T = \sum t_i$$

$P1 P2 P1 P2 \dots$   
 $P1 P1 \dots P1 P2 \dots P2$   
 $P1 P1 P2 P1 P1 P2 \dots$

$$Pr(P_i) = \frac{t_i}{T}$$

Question: expected turnaround time for (P1, P2):

- A. (20, 30)
- B. (30, 20)
- C. (30, 30)

$$P1 = \frac{20}{\left(\frac{20}{20+10}\right) = \frac{2}{3}} = 30$$

$$P2 = \frac{10}{\left(\frac{10}{20+10}\right)} = 30$$

Candidates: FIFO, STCF, RR, Prio, MLFQ, and Lottery

Awards:

"Best Turnaround Time"

"Best Response Time"

"Best Fairness"

"Most popular algorithm"

|         | Best Turnaround Time         | Best Resp Time       | Best Fairness         | Your Favorite |
|---------|------------------------------|----------------------|-----------------------|---------------|
| FIFO    | 1                            |                      |                       | 11            |
| STCF    | ### ## # # #<br>### ## # # # |                      | 1                     | ###           |
| RR      |                              | ### ## # # #<br>## # | ### ### ## #<br>### # |               |
| Prio    |                              |                      | 1                     | ###           |
| MLFQ    |                              | ### ##               | ### ##                | ### ## #<br># |
| Lottery |                              |                      | ### #                 | ### #         |

 : Cheng's choices

| algos     | awards | Best Turnaround Time | Best Response Time | Best Fairness | Most Popular Algo |
|-----------|--------|----------------------|--------------------|---------------|-------------------|
| ① FIFO    | 1      |                      |                    | 1             | 11                |
| ② STCF    |        |                      |                    | 1             |                   |
| ③ RR      |        |                      |                    |               |                   |
| ④ Prio    | 11     |                      |                    | 1             |                   |
| ⑤ MLFQ    | 11     |                      |                    |               |                   |
| ⑥ Lottery |        |                      |                    |               |                   |