Q1:

CPU usage 100%. No IO instrucitons.

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 5:100,5:100 -c -p
Time        PID: 0        PID: 1           CPU           IOs
  1        RUN:cpu         READY             1
  2        RUN:cpu         READY             1
  3        RUN:cpu         READY             1
  4        RUN:cpu         READY             1
  5        RUN:cpu         READY             1
  6           DONE       RUN:cpu             1
  7           DONE       RUN:cpu             1
  8           DONE       RUN:cpu             1
  9           DONE       RUN:cpu             1
 10           DONE       RUN:cpu             1

Stats: Total Time 10
Stats: CPU Busy 10 (100.00%)
Stats: IO Busy  0 (0.00%)
```

Q2:

Process 0: 4 clock ticks.
Process 1: 2 clock ticks for IO initiation and completion. 5 clock ticks (default) for IO action.
Total: 11

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 4:100,1:0 -c -p
Time        PID: 0        PID: 1           CPU           IOs
  1        RUN:cpu         READY             1
  2        RUN:cpu         READY             1
  3        RUN:cpu         READY             1
  4        RUN:cpu         READY             1
  5           DONE        RUN:io             1
  6           DONE       BLOCKED                           1
  7           DONE       BLOCKED                           1
  8           DONE       BLOCKED                           1
  9           DONE       BLOCKED                           1
 10           DONE       BLOCKED                           1
 11*          DONE   RUN:io_done             1

Stats: Total Time 11
Stats: CPU Busy 6 (54.55%)
Stats: IO Busy  5 (45.45%)
```

Q3:

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 1:0,4:100 -c -p
Time        PID: 0        PID: 1           CPU           IOs
  1         RUN:io         READY             1
  2        BLOCKED       RUN:cpu             1             1
  3        BLOCKED       RUN:cpu             1             1
  4        BLOCKED       RUN:cpu             1             1
  5        BLOCKED       RUN:cpu             1             1
  6        BLOCKED          DONE                           1
  7*   RUN:io_done          DONE             1

Stats: Total Time 7
Stats: CPU Busy 6 (85.71%)
Stats: IO Busy  5 (71.43%)
```

Process 0 issues an I/O, giving the other process a chance to run. OS here virtualizes the CPU efficiently to reduce the CPU idle time and maximize the CPU usage, improving resource utilization.

Q4-5:

With SWITCH_ON_IO, CPU switched to the other process while the current process is waiting for I/O completion. Better CPU utilization.

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 1:0,4:100 -c -S SWITCH_ON_END
Time        PID: 0        PID: 1           CPU           IOs
  1         RUN:io         READY             1
  2        BLOCKED         READY                           1
  3        BLOCKED         READY                           1
  4        BLOCKED         READY                           1
  5        BLOCKED         READY                           1
  6        BLOCKED         READY                           1
  7*   RUN:io_done         READY             1
  8           DONE       RUN:cpu             1
  9           DONE       RUN:cpu             1
 10           DONE       RUN:cpu             1
 11           DONE       RUN:cpu             1
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 1:0,4:100 -c -S SWITCH_ON_IO
Time        PID: 0        PID: 1           CPU           IOs
  1         RUN:io         READY             1
  2        BLOCKED       RUN:cpu             1             1
  3        BLOCKED       RUN:cpu             1             1
  4        BLOCKED       RUN:cpu             1             1
  5        BLOCKED       RUN:cpu             1             1
  6        BLOCKED          DONE                           1
  7*   RUN:io_done          DONE             1
```

Q6-7:

No, CPU is idle after the second and third I/O instructions are issued. To improve the resource utilization, a better scheduling logic would be to

- Resume process 0 immediately on I/O completion so that the CPU can
    - finish process 2 while process 0 is blocked waiting on the second i/O
    - finish process 3 while process 0 is blocked waiting on the third i/O

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 3:0,5:100,5:100,5:100 -S SWITCH_ON_IO -c -p -I IO_RUN_LATER
Time        PID: 0        PID: 1        PID: 2        PID: 3           CPU           IOs
  1         RUN:io         READY         READY         READY             1
  2        BLOCKED       RUN:cpu         READY         READY             1             1
  3        BLOCKED       RUN:cpu         READY         READY             1             1
  4        BLOCKED       RUN:cpu         READY         READY             1             1
  5        BLOCKED       RUN:cpu         READY         READY             1             1
  6        BLOCKED       RUN:cpu         READY         READY             1             1
  7*         READY          DONE       RUN:cpu         READY             1
  8          READY          DONE       RUN:cpu         READY             1
  9          READY          DONE       RUN:cpu         READY             1
 10          READY          DONE       RUN:cpu         READY             1
 11          READY          DONE       RUN:cpu         READY             1
 12          READY          DONE          DONE       RUN:cpu             1
 13          READY          DONE          DONE       RUN:cpu             1
 14          READY          DONE          DONE       RUN:cpu             1
 15          READY          DONE          DONE       RUN:cpu             1
 16          READY          DONE          DONE       RUN:cpu             1
 17    RUN:io_done          DONE          DONE          DONE             1
 18         RUN:io          DONE          DONE          DONE             1
 19        BLOCKED          DONE          DONE          DONE                           1
 20        BLOCKED          DONE          DONE          DONE                           1
 21        BLOCKED          DONE          DONE          DONE                           1
 22        BLOCKED          DONE          DONE          DONE                           1
 23        BLOCKED          DONE          DONE          DONE                           1
 24*   RUN:io_done          DONE          DONE          DONE             1
 25         RUN:io          DONE          DONE          DONE             1
 26        BLOCKED          DONE          DONE          DONE                           1
 27        BLOCKED          DONE          DONE          DONE                           1
 28        BLOCKED          DONE          DONE          DONE                           1
 29        BLOCKED          DONE          DONE          DONE                           1
 30        BLOCKED          DONE          DONE          DONE                           1
 31*   RUN:io_done          DONE          DONE          DONE             1

Stats: Total Time 31
Stats: CPU Busy 21 (67.74%)
Stats: IO Busy  15 (48.39%)
```

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 3:0,5:100,5:100,5:100 -S SWITCH_ON_IO -c -p -I IO_RUN_IMMEDIATE
Time        PID: 0        PID: 1        PID: 2        PID: 3           CPU           IOs
  1         RUN:io         READY         READY         READY             1
  2        BLOCKED       RUN:cpu         READY         READY             1             1
  3        BLOCKED       RUN:cpu         READY         READY             1             1
  4        BLOCKED       RUN:cpu         READY         READY             1             1
  5        BLOCKED       RUN:cpu         READY         READY             1             1
  6        BLOCKED       RUN:cpu         READY         READY             1             1
  7*   RUN:io_done          DONE         READY         READY             1
  8          RUN:io          DONE         READY         READY             1
  9        BLOCKED          DONE       RUN:cpu         READY             1             1
 10        BLOCKED          DONE       RUN:cpu         READY             1             1
 11        BLOCKED          DONE       RUN:cpu         READY             1             1
 12        BLOCKED          DONE       RUN:cpu         READY             1             1
 13        BLOCKED          DONE       RUN:cpu         READY             1             1
 14*   RUN:io_done          DONE          DONE         READY             1
 15         RUN:io          DONE          DONE         READY             1
 16        BLOCKED          DONE          DONE       RUN:cpu             1             1
 17        BLOCKED          DONE          DONE       RUN:cpu             1             1
 18        BLOCKED          DONE          DONE       RUN:cpu             1             1
 19        BLOCKED          DONE          DONE       RUN:cpu             1             1
 20        BLOCKED          DONE          DONE       RUN:cpu             1             1
 21*   RUN:io_done          DONE          DONE          DONE             1

Stats: Total Time 21
Stats: CPU Busy 21 (100.00%)
Stats: IO Busy  15 (71.43%)

~/ostep/ostep-homework-forked/cpu-intro$
```

Q8:

Make a table to summarize the s = {1,2,3} with -l 3:50,3:50
Evaluate different combinations of IO_RUN_{IMMEDIATE, LATER} and SWITCH_ON_{IO, END}.

Compare the Total Time (less is better) and CPU Busy time (more is better).