### Q1:

CPU usage 100%. No IO instrucitons.

```
~/ostep/ostep-homework-forked/cpu-intro$ ./process-run.py -l 5:100,5:100 -c -p
                                            CPU
Time
            PID: 0
                           PID: 1
                                                           I0s
 1
           RUN:cpu
                            READY
                                              1
  2
                            READY
                                              1
           RUN:cpu
  3
           RUN:cpu
                           READY
                                              1
  4
                           READY
                                              1
           RUN:cpu
  5
           RUN:cpu
                           READY
                                              1
  6
              DONE
                         RUN:cpu
                                              1
  7
                                              1
              DONE
                         RUN:cpu
 8
                                              1
              DONE
                         RUN:cpu
 9
              DONE
                         RUN:cpu
                                              1
 10
              DONE
                                              1
                         RUN:cpu
```

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-homewo	rk-forked/cpu-intro	\$ ./process-	run.py -1 4:	100,1:0 -с -р
Time	PID: 0	PID: 1	CPU	I0s	
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:

~/oste	ep/ostep-homewor	k-forked/cpu-intro	\$ ./process-	run.py -l	1:0,4:100	-с -р
Time	PID: 0	PID: 1	CPU	I0s		
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.

~/oste	ep/ostep-homewo	ork-forked/cpu-intro\$	./proces	ss-run.py -l 1:0,4:100 -c -S SWITCH_ON_END
Time	PID: 0	PID: 1	CPU	I0s
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	
~/oste	ep/ostep-homewo	ork-forked/cpu-intro\$	./proces	ss-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:

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

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
  - o finish process 2 while process 0 is blocked waiting on the second i/O
  - o finish process 3 while process 0 is blocked waiting on the third i/O

1 2		PID: 1	PID: 2	PID: 3	CPU	I0s	
2	RUN:io	READY	READY	READY	1		
_	BLOCKED	RUN:cpu	READY	READY	1	1	
3	BLOCKED	RUN: cpu	READY	READY	1	1	
ļ	BLOCKED		READY	READY	1	1	
		RUN: cpu					
5	BLOCKED	RUN:cpu	READY	READY	1	1	
5	BLOCKED	RUN:cpu	READY	READY	1	1	
*	READY	DONE	RUN:cpu	READY	1		
3	READY	DONE	RUN:cpu	READY	1		
)	READY	DONE	RUN: cpu	READY	1		
)	READY	DONE	RUN: cpu	READY	1		
	READY	DONE		READY	1		
			RUN: cpu				
2	READY	DONE	DONE	RUN:cpu	1		
3	READY	DONE	DONE	RUN:cpu	1		
1	READY	DONE	DONE	RUN:cpu	1		
5	READY	DONE	DONE	RUN:cpu	1		
5	READY	DONE	DONE	RUN:cpu	1		
,	RUN:io_done	DONE	DONE	DONE	1		
					1		
	RUN:io	DONE	DONE	DONE	1	_	
)	BLOCKED	DONE	DONE	DONE		1	
)	BLOCKED	DONE	DONE	DONE		1	
	BLOCKED	DONE	DONE	DONE		1	
-	BLOCKED	DONE	DONE	DONE		1	
3	BLOCKED	DONE	DONE	DONE		1	
*	RUN:io_done	DONE	DONE	DONE	1	-	
5	RUN:io	DONE	DONE	DONE	1		
5	BLOCKED	DONE	DONE	DONE		1	
7	BLOCKED	DONE	DONE	DONE		1	
3	BLOCKED	DONE	DONE	DONE		1	
)	BLOCKED	DONE	DONE	DONE		1	
9	BLOCKED	DONE	DONE	DONE		1	
L*	RUN:io_done	DONE	DONE	DONE	1	-	
	Total Time 31	7.74%)			_		
ıts:	Total Time 31 CPU Busy 21 (6 IO Busy 15 (4				_		
ats: ats:	CPU Busy 21 (6 IO Busy 15 (4	8.39%)	ntro\$ /nrocess			O -S SWITCH ON TO	-c -n -T TO RIIN TAMEN
ats: ats: oste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homeworl	8.39%) c-forked/cpu-ir		-run.py -l 3:0,5	5:100,5:100,5:10		-с -р -I IO_RUN_IMMED
ats: ats: oste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homework PID: 0	8.39%) <-forked/cpu-ir PID: 1	PID: 2	-run.py -l 3:0,5 PID: 3	::100,5:100,5:10 CPU	0 -S SWITCH_ON_IO IOS	-с -р -I IO_RUN_IMMED
its: its: oste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homework PID: 0 RUN:io	8.39%) c-forked/cpu-ir PID: 1 READY	PID: 2 READY	-run.py -l 3:0,5 PID: 3 READY	::100,5:100,5:10 CPU 1	I0s	-с -р -I IO_RUN_IMMED
its: its: iste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homework PID: 0 RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu	PID: 2 READY READY	-run.py -l 3:0,5 PID: 3 READY READY	5:100,5:100,5:10 CPU 1 1	10s 1	-с -р -I IO_RUN_IMMED
its: its: ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu	PID: 2 READY READY READY	-run.py -l 3:0,5 PID: 3 READY READY READY	5:100,5:100,5:10 CPU 1 1 1	10s 1 1	-с -р -I IO_RUN_IMMED
its: its: iste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homework PID: 0 RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu	PID: 2 READY READY	-run.py -l 3:0,5 PID: 3 READY READY	5:100,5:100,5:10 CPU 1 1 1 1	10s 1 1 1	-с -р -I IO_RUN_IMMED
its: its: iste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu	PID: 2 READY READY READY	-run.py -l 3:0,5 PID: 3 READY READY READY	5:100,5:100,5:10 CPU 1 1 1	10s 1 1	-с -р -I IO_RUN_IMMED
its: its: iste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu	PID: 2 READY READY READY READY	-run.py -l 3:0,5 PID: 3 READY READY READY READY	5:100,5:100,5:10 CPU 1 1 1 1	10s 1 1 1	-с -р -I IO_RUN_IMMED
its: its: iste	CPU Busy 21 (6 IO Busy 15 (4 p/ostep-homeworl PID: 0 RUN:io BLOCKED BLOCKED BLOCKED BLOCKED BLOCKED BLOCKED BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu	PID: 2 READY READY READY READY READY READY READY	-run.py -l 3:0,5 PID: 3 READY READY READY READY READY READY	5:100,5:100,5:10 CPU 1 1 1 1 1	10s 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ts: ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE	PID: 2 READY READY READY READY READY READY READY READY READY	-run.py -l 3:0,5 PID: 3 READY READY READY READY READY READY READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1	10s 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE	PID: 2 READY	-run.py -l 3:0,5 PID: 3 READY READY READY READY READY READY READY READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1	10s 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste e	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io     BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE	PID: 2 READY	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1	10s 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io_bLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste e	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io_done     RUN:io_BLOCKED     BLOCKED BLOCKED BLOCKED BLOCKED BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste e *	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste e *	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io_done     RUN:io_BLOCKED     BLOCKED BLOCKED BLOCKED BLOCKED BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts: ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ts::ste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED     BLOCKED     BLOCKED     BLOCKED     RUN:io_done     RUN:io_done     RUN:io_BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
nts:: its:  steele	CPU Busy 21 (6 IO Busy 15 (4  P/Ostep-homeworl     PID: 0     RUN:io     BLOCKED     RUN:io_done     RUN:io_done     RUN:io_done	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
nts:: uts: uts: uts: uts: uts: uts: uts:	CPU Busy 21 (6 IO Busy 15 (4  P/Ostep-homeworl PID: 0 RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu RUN: cpu DONE DONE	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
nts:: its: its: its: its: its: its: its:	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu RUN: cpu DONE DONE DONE	-run.py -l 3:0,5 PID: 3 READY RUN: cpu RUN: cpu	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ats:: ats: aste pste pste pste pste pste pste pste p	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homeworl     PID: 0     RUN:io     BLOCKED     BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu RUN: cpu DONE DONE DONE DONE DONE	-run.py -1 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ats:: ats: ats: assete pseudo	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homework PID: 0 RUN:io BLOCKED BLOCKED BLOCKED BLOCKED RUN:io_done RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu DONE DONE DONE DONE DONE DONE	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
ats:: ats: asts: a	CPU Busy 21 (6 IO Busy 15 (4  P/Ostep-homeworl PID: 0 RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu	-run.py -l 3:0,5 PID: 3 READY RUN:cpu RUN:cpu RUN:cpu	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED
nts: nts: nste	CPU Busy 21 (6 IO Busy 15 (4  p/ostep-homework PID: 0 RUN:io BLOCKED BLOCKED BLOCKED BLOCKED RUN:io_done RUN:io BLOCKED	8.39%) c-forked/cpu-ir PID: 1 READY RUN:cpu RUN:cpu RUN:cpu RUN:cpu RUN:cpu DONE DONE DONE DONE DONE DONE DONE DONE	PID: 2 READY RUN: cpu RUN: cpu RUN: cpu RUN: cpu DONE DONE DONE DONE DONE DONE	-run.py -l 3:0,5 PID: 3 READY	5:100,5:100,5:10 CPU 1 1 1 1 1 1 1 1 1 1 1 1 1	10s  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	-с -р -I IO_RUN_IMMED

# 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).