Homework 5

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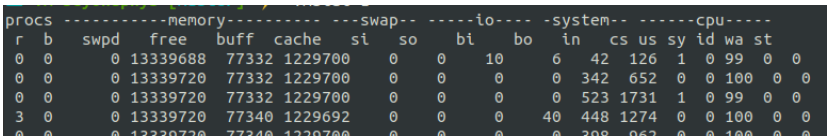
Question 1.

vmstat 1 의 화면이다.



```
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 13339688  77332 1229700    0    0    10     6   42  126  1  0 99  0  0
 0  0      0 13339720  77332 1229700    0    0     0     0  342  652  0  0 100  0  0
 0  0      0 13339720  77332 1229700    0    0     0     0  523 1731  1  0 99  0  0
 3  0      0 13339720  77340 1229692    0    0     0    40  448 1274  0  0 100  0  0
```

man vmstat 으로 확인한 결과 아래와 같다.

r: The number of runnable processes (running or waiting for run time).

b: The number of processes in uninterruptible sleep.

swpd: the amount of virtual memory used.

free: the amount of idle memory.

buff: the amount of memory used as buffers.

cache: the amount of memory used as cache.

si: Amount of memory swapped in from disk (/s).

so: Amount of memory swapped to disk (/s)

bi: Blocks received from a block device (blocks/s).

bo: Blocks sent to a block device (blocks/s).

in: The number of interrupts per second, including the clock.

cs: The number of context switches per second.

us: Time spent running non-kernel code. (user time, including nice time)

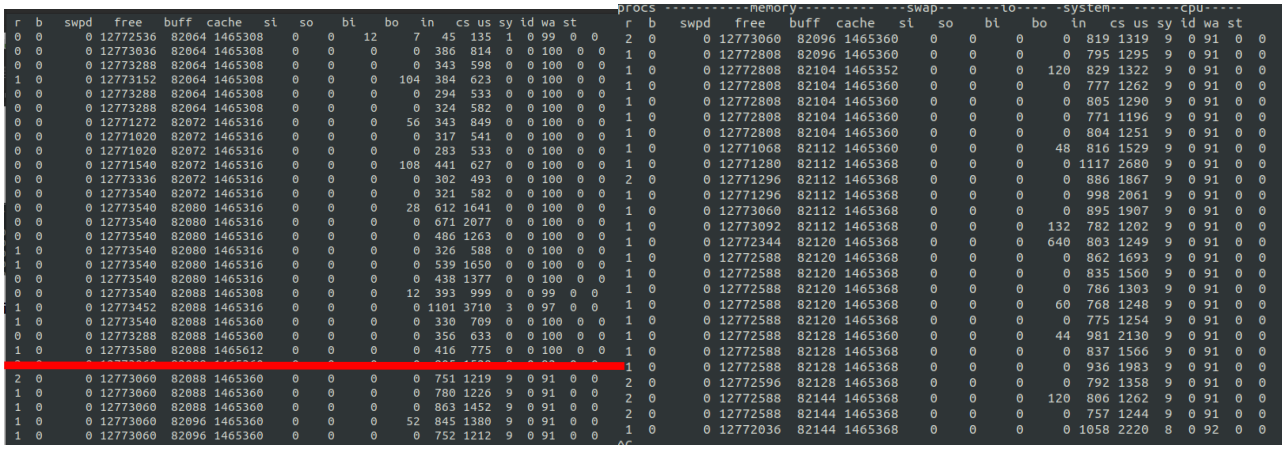
sy: Time spent running kernel code. (system time)

id: Time spent idle. Prior to Linux 2.5.41, this includes IO-wait time.

wa: Time spent waiting for IO. Prior to Linux 2.5.41, included in idle.

st: Time stolen from a virtual machine. Prior to Linux 2.6.11, unknown.

./mem 1 을 실행했을 때의 vmstat 의 값은 아래와 같았다.

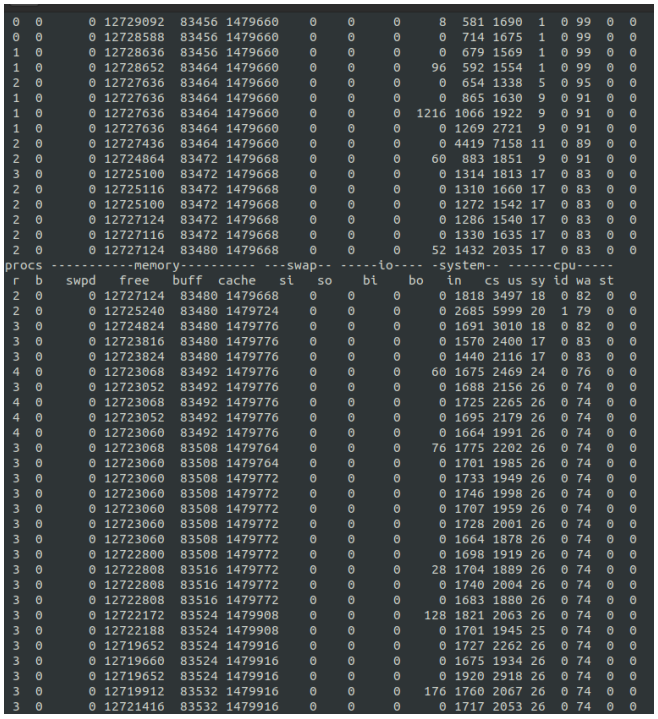


```
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 12772536  82064 1465308    0    0    12     7   45  135  1  0 99  0  0
 0  0      0 12773036  82064 1465308    0    0     0     0  386  814  0  0 100  0  0
 0  0      0 12773288  82064 1465308    0    0     0     0  343  598  0  0 100  0  0
 1  0      0 12773152  82064 1465308    0    0     0   104  384  623  0  0 100  0  0
 0  0      0 12773288  82064 1465308    0    0     0     0  294  533  0  0 100  0  0
 0  0      0 12773288  82064 1465308    0    0     0     0  324  582  0  0 100  0  0
 0  0      0 12771272  82072 1465316    0    0     0    56  343  849  0  0 100  0  0
 0  0      0 12771020  82072 1465316    0    0     0     0  317  541  0  0 100  0  0
 0  0      0 12771020  82072 1465316    0    0     0     0  283  533  0  0 100  0  0
 0  0      0 12771540  82072 1465316    0    0     0   108  441  627  0  0 100  0  0
 0  0      0 12773336  82072 1465316    0    0     0     0  302  493  0  0 100  0  0
 0  0      0 12773540  82072 1465316    0    0     0     0  321  582  0  0 100  0  0
 0  0      0 12773540  82080 1465316    0    0     0    28  612 1641  0  0 100  0  0
 0  0      0 12773540  82080 1465316    0    0     0     0  671 2077  0  0 100  0  0
 0  0      0 12773540  82080 1465316    0    0     0     0  486 1263  0  0 100  0  0
 1  0      0 12773540  82080 1465316    0    0     0     0  326  588  0  0 100  0  0
 1  0      0 12773540  82080 1465316    0    0     0     0  539 1650  0  0 100  0  0
 0  0      0 12773540  82080 1465316    0    0     0     0  438 1377  0  0 100  0  0
 0  0      0 12773540  82088 1465308    0    0     0    12  393  999  0  0 99  0  0
 1  0      0 12773452  82088 1465316    0    0     0     0 1101 3710  3  0 97  0  0
 1  0      0 12773540  82088 1465360    0    0     0     0  330  709  0  0 100  0  0
 0  0      0 12773288  82088 1465360    0    0     0     0  356  633  0  0 100  0  0
 1  0      0 12773580  82088 1465612    0    0     0     0  416  775  0  0 100  0  0
 2  0      0 12773060  82088 1465360    0    0     0     0  751 1219  9  0 91  0  0
 1  0      0 12773060  82088 1465360    0    0     0     0  780 1226  9  0 91  0  0
 1  0      0 12773060  82088 1465360    0    0     0     0  863 1452  9  0 91  0  0
 1  0      0 12773060  82096 1465360    0    0     0    52  845 1380  9  0 91  0  0
 1  0      0 12773060  82096 1465360    0    0     0     0  752 1212  9  0 91  0  0
```

```
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 2  0      0 12773060  82096 1465360    0    0     0     0  819 1319  9  0 91  0  0
 1  0      0 12772808  82096 1465360    0    0     0     0  795 1295  9  0 91  0  0
 1  0      0 12772808  82104 1465352    0    0     0   120  829 1322  9  0 91  0  0
 1  0      0 12772808  82104 1465360    0    0     0     0  777 1262  9  0 91  0  0
 1  0      0 12772808  82104 1465360    0    0     0     0  805 1290  9  0 91  0  0
 1  0      0 12772808  82104 1465360    0    0     0     0  771 1196  9  0 91  0  0
 1  0      0 12772808  82104 1465360    0    0     0     0  804 1251  9  0 91  0  0
 1  0      0 12771068  82112 1465360    0    0     0    48  816 1529  9  0 91  0  0
 1  0      0 12771280  82112 1465368    0    0     0     0 1117 2680  9  0 91  0  0
 2  0      0 12771296  82112 1465368    0    0     0     0  886 1867  9  0 91  0  0
 1  0      0 12771296  82112 1465368    0    0     0     0  998 2061  9  0 91  0  0
 1  0      0 12773060  82112 1465368    0    0     0     0  895 1907  9  0 91  0  0
 1  0      0 12773092  82112 1465368    0    0     0   132  782 1202  9  0 91  0  0
 1  0      0 12772344  82120 1465368    0    0     0   640  803 1249  9  0 91  0  0
 1  0      0 12772588  82120 1465368    0    0     0     0  862 1693  9  0 91  0  0
 1  0      0 12772588  82120 1465368    0    0     0     0  835 1560  9  0 91  0  0
 1  0      0 12772588  82120 1465368    0    0     0     0  786 1303  9  0 91  0  0
 1  0      0 12772588  82120 1465368    0    0     0    60  768 1248  9  0 91  0  0
 1  0      0 12772588  82120 1465368    0    0     0     0  775 1254  9  0 91  0  0
 1  0      0 12772588  82128 1465360    0    0     0    44  981 2130  9  0 91  0  0
 1  0      0 12772588  82128 1465368    0    0     0     0  837 1566  9  0 91  0  0
 1  0      0 12772588  82128 1465368    0    0     0     0  936 1983  9  0 91  0  0
 2  0      0 12772596  82128 1465368    0    0     0     0  792 1358  9  0 91  0  0
 2  0      0 12772588  82144 1465368    0    0     0   120  806 1262  9  0 91  0  0
 2  0      0 12772588  82144 1465368    0    0     0     0  757 1244  9  0 91  0  0
 1  0      0 12772036  82144 1465368    0    0     0     0 1058 2220  8  0 92  0  0
```

빨간 선에서 ./mem 1 을 실행했으며 그 후, user time 인 us 의 값은 9 이다.

./mem 2 을 동시에 세 터미널에 실행시킨 후 vmstat 결과를 살펴 보았다.

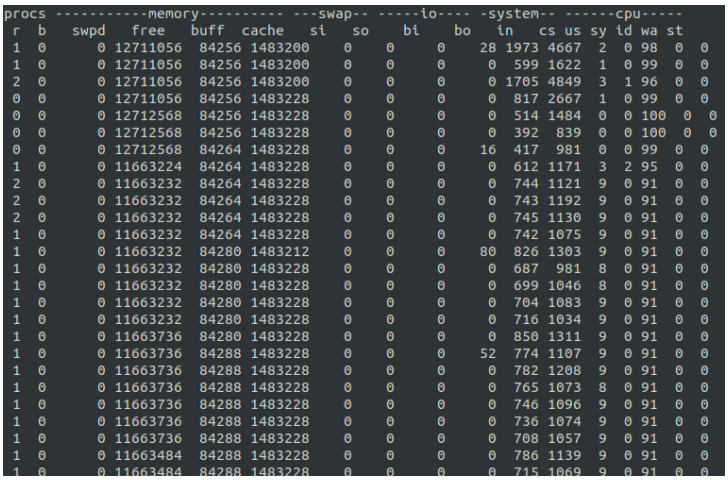


```
0  0      0 12729092  83456 1479660    0    0     0     8  581 1690  1  0 99  0  0
0  0      0 12728588  83456 1479660    0    0     0     0  714 1675  1  0 99  0  0
1  0      0 12728636  83456 1479660    0    0     0     0  679 1569  1  0 99  0  0
1  0      0 12728652  83464 1479660    0    0     0    96  592 1554  1  0 99  0  0
2  0      0 12727636  83464 1479660    0    0     0     0  654 1338  5  0 95  0  0
1  0      0 12727636  83464 1479660    0    0     0     0  865 1630  9  0 91  0  0
1  0      0 12727636  83464 1479660    0    0     0  1216 1066 1922  9  0 91  0  0
1  0      0 12727636  83464 1479660    0    0     0     0 1269 2721  9  0 91  0  0
2  0      0 12727436  83464 1479660    0    0     0     0 4419 7158 11  0 89  0  0
2  0      0 12724864  83472 1479668    0    0     0    60  883 1851  9  0 91  0  0
3  0      0 12725100  83472 1479668    0    0     0     0 1314 1813 17  0 83  0  0
2  0      0 12725116  83472 1479668    0    0     0     0 1310 1660 17  0 83  0  0
2  0      0 12725100  83472 1479668    0    0     0     0 1272 1542 17  0 83  0  0
2  0      0 12727124  83472 1479668    0    0     0     0 1286 1540 17  0 83  0  0
2  0      0 12727116  83472 1479668    0    0     0     0 1330 1635 17  0 83  0  0
2  0      0 12727124  83480 1479668    0    0     0    52 1432 2035 17  0 83  0  0
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
2  0      0 12727124  83480 1479668    0    0     0     0 1818 3497 18  0 82  0  0
2  0      0 12725240  83480 1479724    0    0     0     0 2685 5999 20  1 79  0  0
3  0      0 12724824  83480 1479776    0    0     0     0 1691 3010 18  0 82  0  0
3  0      0 12723816  83480 1479776    0    0     0     0 1570 2400 17  0 83  0  0
3  0      0 12723824  83480 1479776    0    0     0     0 1440 2116 17  0 83  0  0
4  0      0 12723068  83492 1479776    0    0     0    60 1675 2469 24  0 76  0  0
3  0      0 12723052  83492 1479776    0    0     0     0 1688 2156 26  0 74  0  0
4  0      0 12723068  83492 1479776    0    0     0     0 1725 2265 26  0 74  0  0
4  0      0 12723052  83492 1479776    0    0     0     0 1695 2179 26  0 74  0  0
4  0      0 12723060  83492 1479776    0    0     0     0 1664 1991 26  0 74  0  0
3  0      0 12723068  83508 1479764    0    0     0    76 1775 2202 26  0 74  0  0
3  0      0 12723060  83508 1479764    0    0     0     0 1701 1985 26  0 74  0  0
3  0      0 12723060  83508 1479772    0    0     0     0 1733 1949 26  0 74  0  0
3  0      0 12723060  83508 1479772    0    0     0     0 1746 1998 26  0 74  0  0
3  0      0 12723060  83508 1479772    0    0     0     0 1707 1959 26  0 74  0  0
3  0      0 12723060  83508 1479772    0    0     0     0 1728 2001 26  0 74  0  0
3  0      0 12723060  83508 1479772    0    0     0     0 1664 1878 26  0 74  0  0
3  0      0 12722800  83508 1479772    0    0     0     0 1698 1919 26  0 74  0  0
3  0      0 12722808  83516 1479772    0    0     0    28 1704 1889 26  0 74  0  0
3  0      0 12722808  83516 1479772    0    0     0     0 1740 2004 26  0 74  0  0
3  0      0 12722808  83516 1479772    0    0     0     0 1683 1880 26  0 74  0  0
3  0      0 12722172  83524 1479908    0    0     0   128 1821 2063 26  0 74  0  0
3  0      0 12722188  83524 1479908    0    0     0     0 1701 1945 25  0 74  0  0
3  0      0 12719652  83524 1479916    0    0     0     0 1727 2262 26  0 74  0  0
3  0      0 12719660  83524 1479916    0    0     0     0 1675 1934 26  0 74  0  0
3  0      0 12719652  83524 1479916    0    0     0     0 1920 2918 26  0 74  0  0
3  0      0 12719912  83532 1479916    0    0     0   176 1760 2067 26  0 74  0  0
3  0      0 12721416  83532 1479916    0    0     0     0 1717 2053 26  0 74  0  0
```

처음 하나를 실행시켰을 때는 9, 두 개를 실행시켰을 때는 17, 세 개째까지 실행시켰을 때에는 26 의 us 를 기록한다.

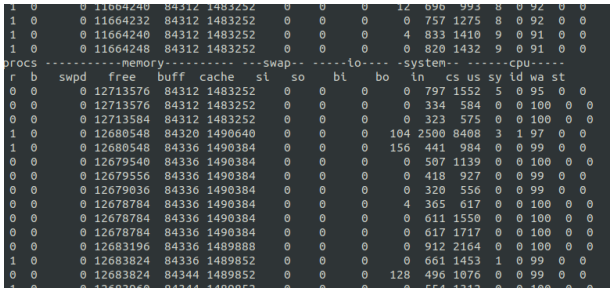
Question 2.

./mem 1024 를 실행시켜 보았다. 결과는 아래와 같았다.



```
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 1  0      0 12711056  84256 1483200    0    0     0    28 1973 4667  2  0 98  0  0
 1  0      0 12711056  84256 1483200    0    0     0     0  599 1622  1  0 99  0  0
 2  0      0 12711056  84256 1483200    0    0     0     0 1705 4849  3  1 96  0  0
 0  0      0 12711056  84256 1483228    0    0     0     0  817 2667  1  0 99  0  0
 0  0      0 12712568  84256 1483228    0    0     0     0  514 1484  0  0 100  0  0
 0  0      0 12712568  84256 1483228    0    0     0     0  392  839  0  0 100  0  0
 0  0      0 12712568  84264 1483228    0    0     0    16  417  981  0  0 99  0  0
 1  0      0 11663224  84264 1483228    0    0     0     0  612 1171  3  2 95  0  0
 2  0      0 11663232  84264 1483228    0    0     0     0  744 1121  9  0 91  0  0
 2  0      0 11663232  84264 1483228    0    0     0     0  743 1192  9  0 91  0  0
 2  0      0 11663232  84264 1483228    0    0     0     0  745 1130  9  0 91  0  0
 1  0      0 11663232  84264 1483228    0    0     0     0  742 1075  9  0 91  0  0
 1  0      0 11663232  84280 1483212    0    0     0    80  826 1303  9  0 91  0  0
 1  0      0 11663232  84280 1483228    0    0     0     0  687  981  8  0 91  0  0
 1  0      0 11663232  84280 1483228    0    0     0     0  699 1046  8  0 91  0  0
 1  0      0 11663232  84280 1483228    0    0     0     0  704 1083  9  0 91  0  0
 1  0      0 11663232  84280 1483228    0    0     0     0  716 1034  9  0 91  0  0
 1  0      0 11663736  84280 1483228    0    0     0     0  850 1311  9  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0    52  774 1107  9  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0     0  782 1208  9  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0     0  765 1073  8  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0     0  746 1096  9  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0     0  736 1074  9  0 91  0  0
 1  0      0 11663736  84288 1483228    0    0     0     0  708 1057  9  0 91  0  0
 1  0      0 11663484  84288 1483228    0    0     0     0  786 1139  9  0 91  0  0
 1  0      0 11663484  84288 1483228    0    0     0     0  715 1069  9  0 91  0  0
```

사용되는 virtual memory 의 양을 뜻하는 swpd 는 그대로 0 을 유지했고, idle memory 의 양인 free 값은 12712568 에서 11663224 로 감소했다. 차이는 1049344 로 1024MB 와 비슷한 수치이다. 프로그램을 종료했을 때의 결과이다.



다시 12713576 으로 idle memory 가 증가하는 것을 볼 수 있었다. 생각한 대로 free memory 양이 줄고 늘었다.

Question 3.

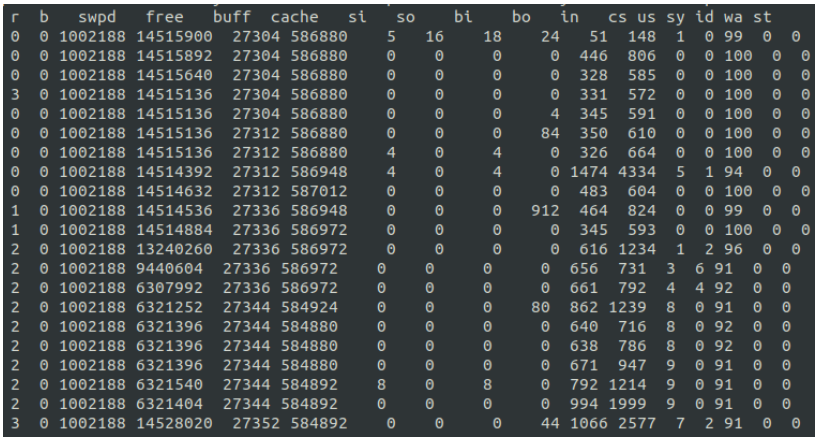
cat */proc/*meminfo 로 확인한 결과

MemTotal: 16302856 kB (16.3GB)

MemFree: 12606132 kB (12.6GB)

MemAvailable: 13798832 kB(13.7 GB)이었다.

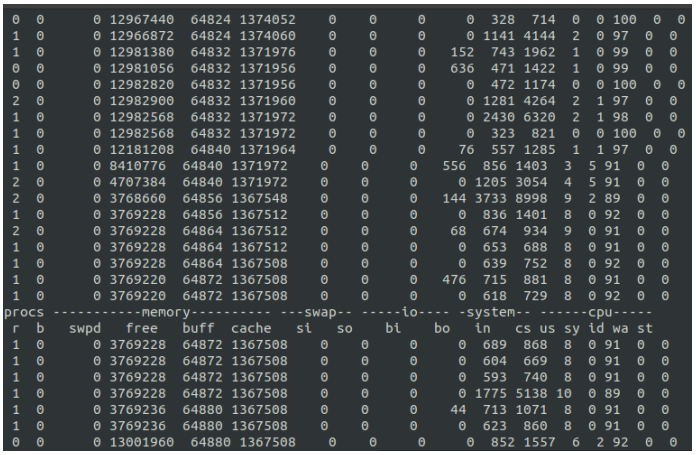
./mem 8000 을 실행해 보았다. vmstat 의 결과는 아래와 같았다.



r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	id	wa	st
0	0	1002188	14515900	27304	586880	5	16	18	24	51	148	1	0	99	0	0
0	0	1002188	14515892	27304	586880	0	0	0	0	446	806	0	0	100	0	0
0	0	1002188	14515640	27304	586880	0	0	0	0	328	585	0	0	100	0	0
3	0	1002188	14515136	27304	586880	0	0	0	0	331	572	0	0	100	0	0
0	0	1002188	14515136	27304	586880	0	0	0	4	345	591	0	0	100	0	0
0	0	1002188	14515136	27312	586880	0	0	0	84	350	610	0	0	100	0	0
0	0	1002188	14515136	27312	586880	4	0	4	0	326	664	0	0	100	0	0
0	0	1002188	14514392	27312	586948	4	0	4	0	1474	4334	5	1	94	0	0
0	0	1002188	14514632	27312	587012	0	0	0	0	483	604	0	0	100	0	0
1	0	1002188	14514536	27336	586948	0	0	0	912	464	824	0	0	99	0	0
1	0	1002188	14514884	27336	586972	0	0	0	0	345	593	0	0	100	0	0
2	0	1002188	13240260	27336	586972	0	0	0	0	616	1234	1	2	96	0	0
2	0	1002188	9440604	27336	586972	0	0	0	0	656	731	3	6	91	0	0
2	0	1002188	6307992	27336	586972	0	0	0	0	661	792	4	4	92	0	0
2	0	1002188	6321252	27344	584924	0	0	0	80	862	1239	8	0	91	0	0
2	0	1002188	6321396	27344	584880	0	0	0	0	640	716	8	0	92	0	0
2	0	1002188	6321396	27344	584880	0	0	0	0	638	786	8	0	92	0	0
2	0	1002188	6321396	27344	584880	0	0	0	0	671	947	9	0	91	0	0
2	0	1002188	6321540	27344	584892	8	0	8	0	792	1214	9	0	91	0	0
2	0	1002188	6321404	27344	584892	0	0	0	0	994	1999	9	0	91	0	0
3	0	1002188	14528020	27352	584892	0	0	0	44	1066	2577	7	2	91	0	0

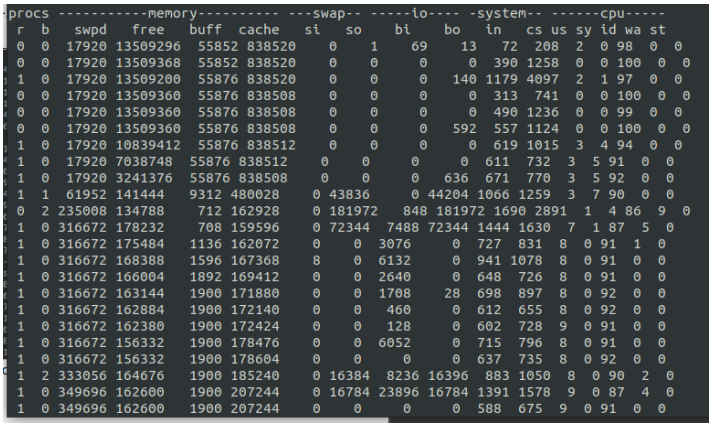
free 의 값이 첫 번째 loop 에서는 13240260 으로, 두 번째 loop 부터는 6307992 로 감소하며 ./mem 8000 이 실행되었지만, si, so 값에는 변화가 없었다. 즉 어떤 데이터도 메모리에서 스왑되어 들어오거나 나가지 않았다는 것을 의미한다.

./mem 9000 을 실행해 보았다.



r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	id	wa	st
1	0	0	3769228	64872	1367508	0	0	0	0	689	868	8	0	91	0	0
1	0	0	3769228	64872	1367508	0	0	0	0	604	669	8	0	91	0	0
1	0	0	3769228	64872	1367508	0	0	0	0	593	740	8	0	91	0	0
1	0	0	3769228	64872	1367508	0	0	0	0	1775	5138	10	0	89	0	0
1	0	0	3769236	64880	1367508	0	0	0	44	713	1071	8	0	91	0	0
1	0	0	3769236	64880	1367508	0	0	0	0	623	860	8	0	91	0	0
0	0	0	13001960	64880	1367508	0	0	0	0	852	1557	6	2	92	0	0

si 와 so 는 여전히 0 의 값을 유지했다. Free 는 12181208 에서 첫 번째 loop 에는 4704384 로, 두 번째 loop 부터 3768660 으로 감소했다.
./mem 14000 에서 so 의 값이 0 이 아닌 값을 나타냈다. 위에서 확인한 사용가능한 메모리 양이 13.7GB 였기 때문이라고 생각한다.

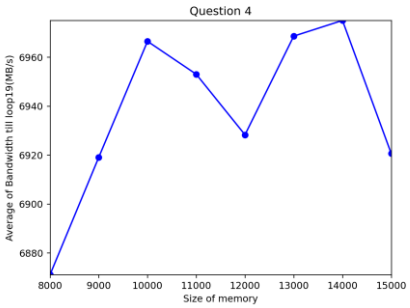


```
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0  17920 13509296  55852 838520    0    1    69    13   72  208  2  0 98  0  0
 0  0  17920 13509368  55852 838520    0    0     0     0  390 1258  0  0 100  0  0
 1  0  17920 13509200  55876 838520    0    0     0   140 1179 4097  2  1 97  0  0
 0  0  17920 13509360  55876 838508    0    0     0     0  313  741  0  0 100  0  0
 0  0  17920 13509360  55876 838508    0    0     0     0  490 1236  0  0 99  0  0
 0  0  17920 13509360  55876 838508    0    0     0   592  557 1124  0  0 100  0  0
 1  0  17920 10839412  55876 838512    0    0     0     0  619 1015  3  4 94  0  0
 1  0  17920 7038748  55876 838512     0    0     0     0  611  732  3  5 91  0  0
 1  0  17920 3241376  55876 838508     0    0     0   636  671  770  3  5 92  0  0
 1  1  61952 141444   9312 480028     0 43836     0 44204 1066 1259  3  7 90  0  0
 0  2 235008 134788    712 162928     0 181972   848 181972 1690 2891  1  4 86  9  0
 1  0 316672 178232    708 159596     0 72344  7488 72344 1444 1630  7  1 87  5  0
 1  0 316672 175484   1136 162072     0     0  3076     0  727  831  8  0 91  1  0
 1  0 316672 168388   1596 167368     8     0  6132     0  941 1078  8  0 91  0  0
 1  0 316672 166004   1892 169412     0     0  2640     0  648  726  8  0 91  0  0
 1  0 316672 163144   1900 171880     0     0  1708    28  698  897  8  0 92  0  0
 1  0 316672 162884   1900 172140     0     0   460     0  612  655  8  0 92  0  0
 1  0 316672 162380   1900 172424     0     0   128     0  602  728  9  0 91  0  0
 1  0 316672 156332   1900 178476     0     0  6052     0  715  796  8  0 91  0  0
 1  0 316672 156332   1900 178604     0     0     0     0  637  735  8  0 92  0  0
 1  2 333056 164676   1900 185240     0 16384  8236 16396  883 1050  8  0 90  2  0
 1  0 349696 162600   1900 207244     0 16784 23896 16784 1391 1578  9  0 87  4  0
 1  0 349696 162600   1900 207244     0     0     0     0  588  675  9  0 91  0  0
```

디스크로 swap 되는 양이 늘어났다가 다시 0 의 값으로 돌온다.

Question 4.
user time 은 증가하고, system time 은 그대로 0 이다.
Block device 로 보내는 block 들은 첫 번째 루프에서 증가하며, 그 이후에는 block device 로부터 받는 block 들이 증가한다.

Question 5.
메모리에 여유있는 input 으로 8000 을 선택했다. 결과는 아래와 같았다.
loop 0 in 2174.60 ms (bandwidth: 3678.83 MB/s)
loop 1 in 1131.43 ms (bandwidth: 7070.68 MB/s)
loop 2 in 1124.81 ms (bandwidth: 7112.30 MB/s)
loop 3 in 1127.47 ms (bandwidth: 7095.53 MB/s)
메모리를 넘어서는 input 으로 14000 을 선택했다. 결과는 아래와 같았다.
loop 0 in 3799.27 ms (bandwidth: 3684.91 MB/s)
loop 1 in 1959.23 ms (bandwidth: 7145.68 MB/s)
loop 2 in 1953.03 ms (bandwidth: 7168.35 MB/s)
loop 3 in 1955.82 ms (bandwidth: 7158.11 MB/s)
우선 두 경우 모두 loop0 에서 속도가 두배 가량 느리고 bandwidth 도 두 배 가량 좁았다. loop1 부터는 첫 번째 경우가 확실히 더 빨랐지만 bandwidth 에서는 큰 차이가 없었다.



Question 6.

swapon -s 를 실행한 결과는 아래와 같다.

```
vm-beyondphys [master] ⚡ swapon -s
Filename                                Type            Size    Used    Priority
/swapfile                               file            2097148 1194680 -2
```

size 는 2097148 이고 used 가 1194680 이므로 사용 가능한 공간은 902468 이다.

```
vm-beyondphys [master] ⚡ ./mem 16000
allocating 16777216000 bytes (16000.00 MB)
  number of integers in array: 4194304000
[1]    6966 killed     ./mem 16000
```

16000 MB 를 allocate 하려하면 allocation fail 이 일어난다.