1. Suppose you have a memory system using fixed-size partitions with all partitions the same size, 2^{16} bytes and a total main memory size of 2^{24} bytes. In the process table there is a pointer to a partition for each resident process. How many bits are needed for this pointer?

2. A system has 2^{32} bytes of physical memory and uses paging. Each page is 2^{10} bytes and there are 2^{16} pages total in the virtual address space.

(a) How many bits are in a virtual address?

(b) How many bytes are in a frame?

(c) How many bits in the real address specify the start address of the frame?

3. From the abridged process list below, show the "trace of [process] ancestry" for the command "ps axl" (the command that produced the listing) back to process 0:

[HINT: Start with finding the PPID of the command below and trace back]

```
   F   UID   PID  PPID PRI  NI    VSZ   RSS WCHAN  STAT TTY        TIME COMMAND

4     0     1     0   20   0  1857   3616       Ss   ?          0:31 /sbin/
                                20      -                        init

1     0     2     0   20   0     0     0 -       S    ?          0:00
                                                                  [kthreadd]

1     0     3     2   20   0     0     0 -       S    ?          0:24
                                                                  [ksoftirqd/

1     0     5     2   0   -20    0     0 -       S<   ?          0:00 [kworker/
                                                                  0:

1     0     7     2   20   0     0     0 -       S    ?         29:18
                                                                  [rcu_sched]

1     0     8     2   20   0     0     0 -       S    ?          0:00 [rcu_bh]

4     0   112     1   20   0  2766   2756       SLsl ?          0:02 /usr/
              7                 76      -                        sbin/l

4     0   115   112   20     0 586404 166080 -   Rsl+ tty7     650:42 /usr/
              3     7   0                                        lib/xo

0   100   129   168   20     0 142444  2128 pipe_w Sl   ?        0:06 /usr/lib/
      0     6     2   0                                          li

0   100   131   129   20     0 6831448 226392 poll_s Sl ?       63:45 /usr/
      0     5     6   0                                          lib/li

4   109   142     1   20     0 373988  3888 -      Ss   ?          0:00 /usr/bin/
              7         0                          l               wh

4     0   144     1   20     0  15940   428 -      Ss   tty1       0:00 /sbin/
              9         0                          +               agett

4     0   145   112   20     0 230304  5712 -      Sl   ?          0:00 lightdm
              3     7   0                                          --s

5     0   153     1   20     0 336712  1008 -      Sl   ?          0:00 /opt/
              0         0                                        cisco/

4   118   153     1   21     1 183544  1460 -      SN   ?          0:31 /usr/lib/
              3         1                          sl              rt

4   100   166     1   20     0  45384  2120       Ss   ?          0:00 /lib/
      0     6         0   ep_pol                                 system

5   100   167   166   20     0 145728   152 -      S    ?          0:00 (sd-pam)
      0     3     6   0
```

```
1  100   168     1   2    0 278948  3556 -    Sl   ?          0:00 /usr/bin/
     0     0         0                                        gn

4  100   168   145   2    0  46456  2740      Ss   ?          0:01 /sbin/
     0     2     3   0    poll_s                              upsta

1  100   200   168     9 -11 723448 11856 poll_s   ?        498:27 /usr/
     0     4     2     S<l                                   bin/pu

0  100   202   168   2    0 178792  2728 poll_s   ?          0:01 /usr/lib/
     0     3     2   0    Sl                                  dc

0  100   205   190   2    0 1369200 74768 poll_s  ?          1:01 /usr/bin/
     0     3     3   0    SLl                                 gn

0  100   210   190   2    0 579940 24748 poll_s   ?          0:46 /usr/bin/
     0     9     3   0    Sl                                  py

0  100   250   168   2    0 698044 34464 poll_s   ?         10:07 /usr/
     0     7     2   0    Sl                                  lib/gn

0  100   251   250   2    0  21400  1936 wait   Ss pts/2     0:03 bash
     0     4     7   0

1  100   273   168   2    0  97216   888 poll_s   ?       0:00 /usr/bin/sp
     0     0     2   0    Ssl

0  100   274   250   2    0  21436  2260 wait_w   pts/      0:28 bash
     0     5     7   0    Ss+                     21

0  100   548   134   2    0 1125916 54940 poll_s  pts/   0:05 evince a3.p
     0     7    88   0    Sl                      18

0  100   619   134   2    0  32212  3620 poll_s   pts/      0:00 vi
     0     8    88   0    S+                      18        a3.tex

0  100    6243       2    0  28912  1456 -    R+  pts/2     0:00 ps axl
     0    2514       0

0  100    6271       2    0  32152  1244 signal T  pts/      0:00 vi ../
     0   13488       0    18                                 log

0  100    9824       2    0 2901792 506040 poll_s Sl ?     582:53 /usr/
     0    1682       0                                      lib/fi

0   1000 12261       2    0 3297516 727420 poll_s Sl ?     310:08 /usr/
    1682             0                                      lib/th

0   1000 13367       2    0 362548  4004 poll_s Sl   ?       0:45 /usr/lib/
    1682             0                                      gv

0   1000 13488       2    0  21312  2088 wait   Ss   pts/    0:01 bash
    2507             0    18

0   1000 25363       2    0 1347316 76036 poll_s Sl          0:25 gimp
    2745             0    pts/21

0   1000 25372       2    0 288632 10308 poll_s Sl   pts/ 0:00 /usr/lib/gi
    25363            0    21
```

4. Suppose a process is running and has eight user-level threads in it. When the process exits, how many of these threads continue running?

5. There are two ways to know where the end of a variable length item, like a message payload, is. What are they? Which one does the Internet Protocol v4 use? [One way has been told lectures, another you need to research]

6. A computer uses virtual memory, using a new solid-state drive (SSD) as space for paging. Refer to 'Time Cost of Page Fault' from Virtual Memory video in Module 2. In the case presented there, the hard disk drive (HDD) required 25 ms to read in a page, and a rate of 1 pf per 1000 references introduced a 250 × slowdown.

(a) If the SSD offers a time of only 80 µs, what is the slowdown in performance caused by 1 pf per 1000 references? (you are not concerned with dirty vs. clean pages: assume pages are always clean). [WRITE STEPS]

(b) What is the maximum rate of page faults you can accept if you want no more than a 10% slowdown in execution using virtual memory? [WRITE STEPS]