Operating Systems, PhD Qualifying Exam, Spring 2012

- This is a 60-minute test.
- This exam has 5 questions for a total of 100 points.

1. [15 points] Consider the C program below. (For space reasons, we are not checking error return codes, so assume that all functions return normally.)

   Hint: For `fork()`, on success, the PID (process ID) of the child is returned in the parent, and 0 is returned in the child. For `wait()`, on success, returns the PID of the terminated child.

```
main() {

    if (fork() == 0) {
        if (fork() == 0) {
            printf("3");
        }
        else {
            pid_t pid;
            int status;
            if ((pid = wait(&status)) > 0) {
                printf("4");
            }
        }
    }
    else {
        if (fork() == 0) {
            printf("1");
            exit(0);
        }
        printf("2");
    }

    printf("0");
}
```

   Out of the 6 outputs listed below, choose only the valid outputs of this program. Assume that all processes run to normal completion.

A. 2030401	B. 1234000	C. 2300140
D. 2034012	E. 3200410	F. 4030120

2. [25 points] A semaphore `S` is defined with two atomic operations, `P(S)` and `V(S)`.

```
P(S): if S >= 1 then S := S - 1
      else block the process on the semaphore queue;

V(S): if some processes are blocked on the semaphore S
      then unblock a process
      else S:= S + 1
```

With three semaphores, `X`, `Y`, and `Z`, the following code solves the producer-consumer problem. A set of producer processes (`producer`) generate data items and put them into shared buffer. A set of consumer processes (`consumer`) receive data items from shared buffer and uses them. All the processes communicate using a shared buffer of maximum size, N.

```
producer:                                   consumer:

    P(X);                                       P(Y);
    P(Z);                                       P(Z);
    Put item into shared buffer;                Remove item from shared buffer;
    V(Z);                                       V(Z);
    V(Y);                                       V(X);
```

(a) [5 points] What are the initial values of the three semaphores for correct execution and maximum performance?

(b) [10 points] Explain the function of each semaphore.

(c) [10 points] In the implementation of a `P()` operation, some processors continuously execute an atomic instruction (*spinlock*) instead of blocking the process. Provide the advantages and disadvantages of this spinlock implementation.

3. [20 points] With a 32-bit virtual address space, 4KB page, and 4 bytes per page table entry in virtual memory, answer the following questions.

   (a) [5 points] Compute the number of page table entries.

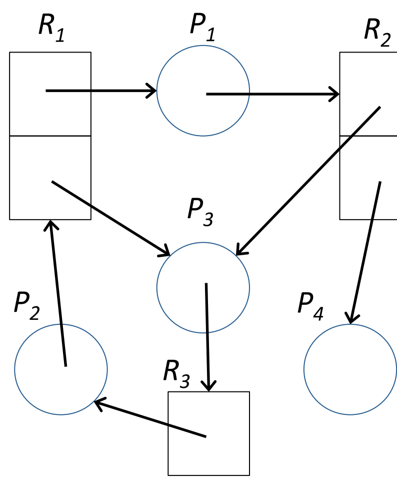
   (b) [5 points] Compute the total size of page table.

   (c) [5 points] In the above virtual memory system, a running program accesses the 4MB physical memory with the following virtual addresses in order: 0x283802, 0x2848C2, 0x283142, 0x285478, 0x38580A, 0x2839E0, 0x2848C2. We assume that the physical memory is initially empty and pages in virtual memory do not share same frame in physical memory. Pages are replaced with LRU scheme. What is the number of page faults?

   (d) [5 points] Describe how the OS handles the page fault exception. Include architectural support (if any) in your answer.

4. [20 points] Answer the four questions regarding deadlock.

(a) [5 points] The following resource allocation graph (RAG) shows the resource allocation/request status for four processes (P_1, P_2, P_3, P_4) and three resources (R_1, R_2, R_3). Each resource has a fixed number of units. For example, R_1 and R_2 has two units. Does the RAG have deadlocks? Provide explanations supporting your answer.



(b) [5 points] What are the four conditions for deadlock? Explain each condition briefly.

(c) [5 points] What are the possible solutions that prevent deadlock for each condition?

(d) [5 points] Provide description for how Banker's Algorithm solves deadlock problems.

5. [20 points] The following four jobs arrive at the same time in the run queue. Jobs can be scheduled under three scheduling policies: 1) shortest job first without preemption, 2) priority without preemption, and 3) round robin with preemption and a small time quantum.

Job	Run Time	Priority
A	5	1
B	10	4
C	7	3
D	11	2

(a) [10 points] Give the completion order of the jobs under each of three scheduling policies.

(b) [10 points] Which policy gives the shortest average response time?