Answer all the questions. The maximum credit for each question is as shown.

1. (15) Multiple Choice (3 points for each):
   1) Which of the following statement is true for DMA: ___ D __________
      A. In DMA, Processor checks status until operation is complete
      B. In DMA, Processor is interrupt when I/O module ready to exchange data
      C. In DMA, no interrupt is produced.
      D. In DMA, interrupt is sent when the task is complete.
      E. None of the above.
   2) Which of the following is volatile memory? ____A_________
      A. Main memory
      B. CD/DVD
      C. Hard disk
      D. Flash memory
      E. None of the above
   3) Which of the following is not control and status register? ____E_________
      A. Processor Status Word (PSW)
      B. Memory Address Register (MAR)
      C. Program Controller (PC)
      D. Instruction Register (IR)
      E. None of the above
   4) The earliest OS is ___A_________
      A. monolithic
      B. modular
      C. Microkernel
      D. Modules
      E. None of the above
   5) One process is waiting for the input from the user, which state is this process most probably in? ____C_________
      A. Ready
      B. Running
      C. Waiting
      D. New
      E. Terminated

2. (18) For each of the following statements indicate whether it is true or false, and give a one-sentence justification (3 points for each).
   a. A process is a program.
      Ans: False
      A process is a program in execution.
b. Suspending a process involves suspending all threads of the process since all threads share the same address space.

Ans: True
Suspended a process is to swap this process to disk to free up more memory. Since resources belong to the process, so if the process is suspended, all threads of the process will be suspended.

c. In a multithreaded environment, the unit of resource ownership and scheduling/execution is thread.

Ans: False
In a multithreaded environment, the unit of resource ownership is process, the unit of scheduling/execution is thread.

d. If one thread in a process is blocked, this prevents other threads in the process even if that other thread is in a ready state.

Ans: False
Depends on whether OS is involved when the thread is blocked. If OS is involved, then answer is “yes”.

e. Each thread of one process has to maintain a separate program counter, stack, and registers.

Ans: True
Thread control block contains a separate program counter, stack, and registers. These are necessary to keep the execution of the thread.

f. Round-robin scheduling never results in more context switches than FCFS.

Ans: False
It depends on the quantum. If every job has an execution time less than the quantum, then it has the same number as FCFS.

3. (10) Briefly describe one advantage and one disadvantage of kernel-level threads.

Ans:
Advantages:
• The kernel can schedule another thread when if one thread performs a blocking system call, e.g., to do I/O.
• Multiprocessing is easier because the kernel can directly schedule threads.

Disadvantage:
• More Overhead
• The kernel is unaware of the user-level application parallelism. Even if multiple processors are given, the kernel may not fully utilize them.
• The kernel should be modified to support different thread package.

4. (12) What are the difference between interrupts and exceptions? Give two examples of each.

   Ans:
   **Interrupts** are asynchronous events external the CPU (e.g., timer interrupt, device interrupt).
   **Exceptions** are synchronous events that occur as the result of executing instructions (e.g., divide by zero, system call).

5. (15) Explain what will be output for the following program?

   ```c
   #include <sys/types.h>
   #include <stdio.h>
   #include <unistd.h>

   int value = 5;

   int main()
   {
     pid_t pid;
     pid=fork();
     if(pid==0){
       printf("I am the child process. \n");
       value+=15;
     }
     else if (pid > 0) {
       wait(NULL);
       printf("I am the parent process, value=%d ", value);
       exit(0);
     }
   }
   
   Ans:
   I am the child process.
   I am the parent process, value=5
   ```

6. (30) Consider the following set of processes, with the length of the CPU burst given in milliseconds:

<table>
<thead>
<tr>
<th>Process</th>
<th>Burst Times</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>P2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>P3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>P4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>P5</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
The processes are assumed to have arrived in the order P1, P2, P3, P4, P5, all at time 0.

a. (15) Draw five Gantt charts that illustrate the execution of these processes using the following scheduling algorithms: FCFS, SJF, nonpreemptive priority (a small priority number implies a higher priority), RR(quantum=1) and Highest Response Ratio Next(HRRN).

b. (15) What is the turnaround time and normalized turn around time of each process for each of the scheduling algorithms in part a?

Ans:

a. The five Gantt charts are

**FCFS:**

```
P5 P4 P3 P2 P1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
```

**SJF:**

```
P4 P3 P1 P5 P2 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
```

**Priority:**

```
P1 P1 P1 P1 P1 P5 P1 P5 P1 P5 P1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
```

**RR:**

```
P4 P2 P3 P5 P1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
```

**Highest Response Ratio Next:**

```
P1 P5 P3 P2 P4 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
```

b. Turnaround time:

<table>
<thead>
<tr>
<th></th>
<th>FCFS</th>
<th>RR</th>
<th>SJF</th>
<th>Priority</th>
<th>HRRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>10</td>
<td>19</td>
<td>19</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>P2</td>
<td>11</td>
<td>2</td>
<td>19</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>P3</td>
<td>13</td>
<td>7</td>
<td>4</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>P4</td>
<td>14</td>
<td>4</td>
<td>2</td>
<td>19</td>
<td>18</td>
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<tr>
<td>P5</td>
<td>19</td>
<td>14</td>
<td>9</td>
<td>16</td>
<td>19</td>
</tr>
</tbody>
</table>

Normalized turnaround time (turnaround time/burst time):
<table>
<thead>
<tr>
<th></th>
<th>FCFS</th>
<th>RR</th>
<th>SJF</th>
<th>Priority</th>
<th>HRRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>1</td>
<td>1.9</td>
<td>1.9</td>
<td>1.6</td>
<td>1</td>
</tr>
<tr>
<td>P2</td>
<td>11</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>P3</td>
<td>13/2</td>
<td>7/2</td>
<td>2</td>
<td>9</td>
<td>17/2</td>
</tr>
<tr>
<td>P4</td>
<td>14</td>
<td>4</td>
<td>2</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td>P5</td>
<td>19/5</td>
<td>14/5</td>
<td>9/5</td>
<td>6/5</td>
<td>19</td>
</tr>
</tbody>
</table>