I have neither given nor received unauthorized assistance on this exam.

________________________________________________________
Name                Date
The first 8 question are 5-point multiple choice questions. Circle the letter corresponding to the single best response for each of these questions.

1. Statistical Process Control and Engineering Feedback Control
   a) are competing or rival technologies, amounting to different solutions for the same problem.
   b) can both be applied to reduce process variation.
   c) both require knowledge of engineering specifications in order to implement.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) None of responses a) through c) are correct completions of the sentence.

2. A "sample" or "rational subgroup" in a variables control charting application is a group of measurements
   a) representing a short enough time period that it is plausible to treat them as coming from "the same" process conditions.
   b) modeled as random draws from a fixed distribution/population/universe.
   c) can sometimes be of size $n = 1$.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) All of responses a) through c) are correct completions of the sentence.

3. Control limits for an "Individuals" chart
   a) are those for "an $n = 1$ x-bar chart."
   b) are based directly on product performance requirements.
   c) are equivalent to engineering specifications for individual measurements.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) All of responses a) through c) are correct completions of the sentence.

4. The ARL of a particular process monitoring scheme
   a) is a theoretical tool for quantifying what the scheme will do under some model for process behavior.
   b) is typically smaller for "not ALL-OK" circumstances than for "All-OK" circumstances.
   c) is typically smaller for "drastically not ALL-OK" circumstances than for "barely not ALL-OK" circumstances.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) All of responses a) through c) are correct completions of the sentence.

5. Normal plotting is useful in process capability analysis because
   a) it provides graphical ways of estimating both process mean and standard deviation.
   b) it can provide evidence that the process has been stable and thus that there is such a thing as 'capability.'
   c) it can provide evidence that the typical process capability measures are practically relevant descriptions of the process.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) All of responses a) through c) are correct completions of the sentence.
6. Below are 4 (bullet) statements about Statistical Process Control. How many of them are true?
   
   - SPC would be better named "Statistical Process Monitoring."
   - SPC provides a basis for capability analysis (in that without process stability/consistency it makes no sense to ask what it can be expected to do).
   - SPC provides a basis for experimentation for process improvement (in that without process stability/consistency there is no baseline against which to judge the effectiveness of physical process changes).
   - SPC is part of Six Sigma methodology in terms of making sure that processes that have been improved stay improved.

   a) All of the statements are true.
   b) Exactly 3 of the statements are true.
   c) Exactly 2 of the statements are true.
   d) Exactly 1 of the statements is true.
   e) None of the statements are true.

7. Below are 4 (bullet) statements about statistical intervals. How many of them are true?
   
   - Prediction intervals are intended to locate "most of" a process output.
   - Tolerance intervals are intended to locate a single additional value from a process.
   - Confidence intervals for a mean are intended to locate the center of a process distribution.
   - Intervals made from minimum and maximum sample values can be used as prediction and tolerance intervals even when a process distribution is clearly not normal.

   a) All of the statements are true.
   b) Exactly 3 of the statements are true.
   c) Exactly 2 of the statements are true.
   d) Exactly 1 of the statements is true.
   e) None of the statements are true.

8. Sets of "extra alarm rules" (like the set of "Western Electric Rules")
   
   a) are meant to allow detection of interpretable patterns on control charts.
   b) increase ARLs when used (in addition to the basic "one point outside control limits" rule).
   c) provide for standardization of how different individuals in an organization might look for patterns on a control chart.
   d) Exactly 2 of responses a) through c) are correct completions of the sentence.
   e) None of responses a) through c) are correct completions of the sentence.
9. Below are means and ranges of samples of size \( n = 4 \) journal diameters on tractor axels from a grinding process (units are \( 10^{-4} \) mm above 4.9000 mm).

<table>
<thead>
<tr>
<th>Sample</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \bar{x} )</td>
<td>815</td>
<td>815</td>
<td>810</td>
<td>778</td>
<td>748</td>
<td>725</td>
<td>778</td>
<td>790</td>
<td>785</td>
<td>795</td>
<td>7839</td>
</tr>
<tr>
<td>( R )</td>
<td>37</td>
<td>37</td>
<td>53</td>
<td>46</td>
<td>53</td>
<td>64</td>
<td>46</td>
<td>75</td>
<td>22</td>
<td>22</td>
<td>455</td>
</tr>
</tbody>
</table>

Is there evidence of process instability in these \( \bar{x} \) and \( R \) values? (Show appropriate calculations and explicitly say whether there is any evidence of instability in means and ranges.)

Evidence of instability? (Circle the correct response.)

In means? yes/no
In ranges? yes/no
10 pts

In the context of problem 9, ignoring any evidence of process instability you found there, do the following.

Give an estimate of the grinding process standard deviation of tractor axle journal diameters.

Based on your estimate of process standard deviation above, give $n = 5$ control limits for future (real-time) monitoring of sample medians, $\bar{x}$.
11. A paper collating machine jams at a standard rate of 1 jam per 10 minutes of running time. As means of process monitoring two different options are being considered. Find appropriate (3-sigma) control limits for these two options.

The first option is control charting

\[ X = \text{the number of jams encountered in 1 hour of running time} \]

The second option is control charting

\[ Y = \text{the number of minutes in an hour of running time that have at least 1 jam in them} \]
12. Vardeman's brown bag has $\mu = 5.0$ and $\sigma = 1.715$, while his blue bag has $\mu = 10.0$ and $\sigma = 3.47$. In $\bar{x}$ charting with $n = 4$ and the brown bag standards, what is the ARL if in fact one is sampling from the blue bag?
13. Paper helicopter drop times for a single helicopter dropped \( m = 10 \) times produce \( s = .120 \text{ sec} \), while (single) drop times for \( n = 10 \) other helicopters of the same design produce \( s_y = .160 \text{ sec} \). You may use (without showing the calculations needed to get them) the (Module 4) facts that an estimated production process standard deviation (not inflated by measurement noise) is \( \hat{\sigma}_x = .106 \text{ sec} \) with approximate degrees of freedom \( \hat{\nu} = 1.31 \). If specifications on helicopter drop times are

\[
\text{some value} \pm .30 \text{ sec}
\]

give approximate 95% confidence limits for the capability index \( C_p \) that are free of the influence of measurement noise.
14. A sample $n = 20$ of so-called bottle "pre-forms" from one cavity of a plastic injection molding machine have mean 22.34 g and standard deviation .008 g. The smallest weight observed is 22.1 g and the largest is 22.5 g.

What confidence do you have that the interval from 22.1 g to 22.5 g contains 90% of all future pre-form weights from this cavity?

Give a normal distribution 99% lower bound for 95% of all future pre-form weights from this cavity. (Plug in completely, but there is no need to simplify.)