PE mechanical engineering: machine design and materials practice exam
CONTENTS

Introduction to NCEES Exams ................................................................. 1
About NCEES
Exam format
Examinee Guide
Updates on exam content and procedures
Scoring and reporting
Staying connected

Exam Specifications .................................................................................. 3

Practice Exam ........................................................................................... 7

Solutions .................................................................................................... 57
About NCEES
The National Council of Examiners for Engineering and Surveying (NCEES) is a nonprofit organization made up of engineering and surveying licensing boards from all U.S. states and territories. Since its founding in 1920, NCEES has been committed to advancing licensure for engineers and surveyors in order to protect the health, safety, and welfare of the American public.

NCEES helps its member licensing boards carry out their duties to regulate the professions of engineering and surveying. It develops best-practice models for state licensure laws and regulations and promotes uniformity among the states. It develops and administers the exams used for engineering and surveying licensure throughout the country. It also provides services to help licensed engineers and surveyors practice their professions in other U.S. states and territories.

Exam format
Beginning in April 2020, the PE Mechanical Machine Design and Materials exam will be computer-based. It will contain 80 questions and be administered year-round via computer at approved Pearson VUE test centers. A 9-hour appointment time includes a tutorial, the exam, and a break. You’ll have 8 hours to complete the actual exam.

In addition to traditional multiple-choice questions with one correct answer, the exam will use common alternative item types such as

- Multiple correct options—allows multiple choices to be correct
- Point and click—requires examinees to click on part of a graphic to answer
- Drag and drop—requires examinees to click on and drag items to match, sort, rank, or label
- Fill in the blank—provides a space for examinees to enter a response to the question

All questions have the same point value; no partial credit will be given.

To familiarize yourself with the format, style, and navigation of a computer-based exam, view the demo on ncees.org/ExamPrep.

Examinee Guide
The NCEES Examinee Guide is the official guide to policies and procedures for all NCEES exams. All examinees are required to read this document before starting the exam registration process. You can download it at ncees.org/exams. It is your responsibility to make sure that you have the current version.

Updates on exam content and procedures
Visit us at ncees.org/exams for updates on everything exam-related, including specifications, exam-day policies, scoring, and corrections to published exam preparation materials. This is also where you will register for the exam and find additional steps you should follow in your state to be approved for the exam.

Scoring and reporting
Exam results for computer-based exams are typically available 7–10 days after you take the exam. You will receive an email notification from NCEES with instructions to view your results in your MyNCEES account. All results are reported as pass or fail.
2. A hydraulic cylinder is made up of a tube section with two ends and is held together by four tie rods as shown in the figure. The piston rod end is pressurized. Which data from the list below are necessary and sufficient to determine the shear stress in the threads at the piston rod to piston attachment?

Select all that apply.

- □ A. Diameter of cylinder, $d_{cyl}$ 4.0 in.
- □ B. Wall thickness of cylinder, $t_{wall}$ 0.25 in.
- □ C. Length of cylinder, $l$ 12.0 in.
- □ D. Piston thickness, $T_{piston}$ 2.0 in.
- □ E. Piston rod diameter, $d_{rod}$ 1.5 in.
- □ F. Thickness of rod end, $t_{rod\ end}$ 3.0 in.
- □ G. Fluid pressure, $P$ 2,500 psi
- □ H. Piston rod thread 1–8 UNC
3. Table 1 shows the means for each subgroup from a measurement process over a 12-hr period. Each subgroup is made up of a sample size of 4.

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>6:00 a.m.</th>
<th>10:00 a.m.</th>
<th>2:00 p.m.</th>
<th>6:00 p.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.30</td>
<td>8.40</td>
<td>8.70</td>
<td>6.70</td>
</tr>
<tr>
<td>2</td>
<td>7.00</td>
<td>7.50</td>
<td>8.20</td>
<td>7.30</td>
</tr>
<tr>
<td>3</td>
<td>6.80</td>
<td>7.80</td>
<td>7.90</td>
<td>7.10</td>
</tr>
<tr>
<td>4</td>
<td>7.10</td>
<td>8.20</td>
<td>8.50</td>
<td>7.30</td>
</tr>
<tr>
<td>5</td>
<td>7.20</td>
<td>8.70</td>
<td>8.50</td>
<td>6.90</td>
</tr>
</tbody>
</table>

Table 2 is an abbreviated list of the anti-biasing statistical constants.

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>A₂</th>
<th>D₄</th>
<th>D₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1.88</td>
<td>3.27</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>1.02</td>
<td>2.57</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>0.73</td>
<td>2.28</td>
<td>0.00</td>
</tr>
<tr>
<td>5</td>
<td>0.58</td>
<td>2.11</td>
<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>0.48</td>
<td>2.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Using the data provided in Tables 1 and 2, label the upper control limit (UCL) and the lower control limit (LCL) of the process range (an R chart) with the correct value from the list below.

UCL

-3.42
-1.09
0
1.09
3.42
17.0

LCL

4. A manufacturing production department operates 80 hr/week. The process has a production rate of 60 units/hr, with a scrap rate of 1 out of 20 units. With a 10% lost production time allowance, the number of good units that can be made per week is ________________.

Enter your response in the blank.
5. A project consists of assembling a system using parts from Source X and Source Y.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Follows Task</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Acquire parts from Source X</td>
<td>None</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>Acquire parts from Source Y</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>Inspect parts</td>
<td>B</td>
<td>7</td>
</tr>
<tr>
<td>D</td>
<td>Test parts from Source X</td>
<td>A</td>
<td>11</td>
</tr>
<tr>
<td>E</td>
<td>Assemble parts and complete project</td>
<td>C and D</td>
<td>2</td>
</tr>
</tbody>
</table>

If the delivery of parts from Source Y is delayed by 3 days, the total completion delay (days) will be ________________.

Enter your response in the blank.

6. A manufacturing production department makes a family of similar parts. Part material cost is $12 for each part scrapped.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Labor Cost (per hour)</th>
<th>Production Rate (units per hour)</th>
<th>Part Scrap Rate</th>
<th>Part Setup Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manual</td>
<td>$20</td>
<td>10</td>
<td>1 out of 32</td>
<td>$10</td>
</tr>
<tr>
<td>2. CNC* with manual load</td>
<td>$18</td>
<td>12</td>
<td>1 out of 80</td>
<td>$5</td>
</tr>
<tr>
<td>3. CNC* with auto load</td>
<td>$15</td>
<td>15</td>
<td>1 out of 60</td>
<td>$15</td>
</tr>
<tr>
<td>4. Dedicated automation</td>
<td>$12</td>
<td>60</td>
<td>1 out of 120</td>
<td>$250</td>
</tr>
</tbody>
</table>

*CNC–Computer Numerically Controlled Machine

The number of good parts per 80-hr workweek that can be made on the CNC with manual load (Machine No. 2) is most nearly:

○ A. 600
○ B. 948
○ C. 960
○ D. 1,180
12. A steel \((E = 30 \times 10^6 \text{ psi})\) bar having a cross-sectional area of 0.375 in\(^2\) is mounted as shown in the figure. The spring has a spring constant of 10,000 lb/in. If the nominal coefficient of thermal expansion is \(6 \times 10^{-6} \text{ in.}/(\text{in.-}^\circ\text{F})\), the increase in force (lb) produced in the bar by a temperature increase of 300°F is most nearly:

- A. 24
- B. 324
- C. 624
- D. 724

13. The figure shown represents the stress-strain relationship of which of the following materials?

Select all that apply:

- A. Aluminum alloys
- B. Cast iron
- C. Copper alloys
- D. Mild steels
- E. Tungsten
23. The 2,500-lbf load shown in the figure is supported by a beam that is secured by six 3/4-in.-diameter bolts in a hexagonal array with neighboring bolts 3 in. apart.

Select the bolt with the greatest shear stress.
1. Option C shows the position symbol specified, for example in ASME Y14.5, *Dimensioning and Tolerancing*.

THE CORRECT ANSWER IS: C

2. To determine the shear load in the thread, the following data must be known: cylinder diameter, piston thickness, piston rod diameter, fluid pressure, and thread size (pitch and length under load).

THE CORRECT ANSWER IS: A, D, E, G, H

3. 

<table>
<thead>
<tr>
<th>Subgroup #</th>
<th>Subgroup Minimum</th>
<th>Subgroup Maximum</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.7</td>
<td>8.7</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>7.0</td>
<td>8.2</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>6.8</td>
<td>7.9</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>7.1</td>
<td>8.5</td>
<td>1.4</td>
</tr>
<tr>
<td>5</td>
<td>6.9</td>
<td>8.7</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Average range = \( R_{\text{bar}} \) = mean of ranges = 1.5

From Table 2:

Need \( D_4 \) and \( D_3 \) for sample size 4 to get control limits for range

\[
\begin{align*}
D_4 &= 2.28 \\
D_3 &= 0 \\
UCL &= D_4 \times R_{\text{bar}} = 3.42 \\
LCL &= D_3 \times R_{\text{bar}} = 0
\end{align*}
\]

THE CORRECT ANSWERS ARE SHOWN ABOVE.

4. 80 hr – 10% lost production time = 72 hr

\[
72 \times 60 \text{ units/hr} = 4,320 \text{ units} \Rightarrow (1 \text{ scrap/20 units}) \times 4,320 \text{ units} = 216 \text{ scrap units}
\]

\[
4,320 - 216 \text{ units} = 4,104 \text{ units}
\]

THE CORRECT ANSWER IS: 4,104
5. If Task C is delayed by 3 days, but Task C has 2 days of slack from initial critical path, then ABCE becomes the new critical path, and the total completion delay will be 1 day.

THE CORRECT ANSWER IS: 1

6. \[
\frac{\text{Good Parts}}{\text{Week}} = \frac{12 \text{ units}}{80 \text{ hr}} \times \frac{80 \text{ hrs}}{79 \text{ week}} = 948
\]

THE CORRECT ANSWER IS: B

7. \[
1 \text{ ksi} = 6.8948 \text{ MPa} \\
1 \text{ in.} = 0.15937 \text{ m} \\
1 \text{ ksi in.} = 1.0989 \text{ MPa m} \\
35 \text{ ksi in.} = 38.46 \text{ MPa m}
\]

THE CORRECT ANSWER IS: D
11. Rod volume = $AL = \pi \frac{d^2}{4} L = \pi \frac{0.375^2}{4} 10 = 1.105 \text{ in}^3$

Rod weight = rod volume × material density
Strength-to-weight ratio = yield strength/rod weight
Rod cost = rod weight × material cost/lb

<table>
<thead>
<tr>
<th>Material</th>
<th>Rod Weight</th>
<th>Strength-to-Weight Ratio</th>
<th>Rod Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>0.33</td>
<td>144,600</td>
<td>$0.05</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.11</td>
<td>360,000</td>
<td>$0.09</td>
</tr>
<tr>
<td>Titanium</td>
<td>0.22</td>
<td>795,000</td>
<td>$0.60</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.07</td>
<td>314,000</td>
<td>$0.06</td>
</tr>
</tbody>
</table>

The two materials meeting the cost requirement are steel and magnesium. Of the two, magnesium has the highest strength-to-weight ratio. Note that the ordering of the strength-to-weight ratio will also be correct if a strength-to-density ratio is used.

**THE CORRECT ANSWER IS: D**

12. $K\delta_s = \frac{AE}{\ell}(\alpha/\Delta T - \delta_s)$

$\delta_s = \frac{\alpha/\Delta T}{1 + \frac{K\ell}{AE}} = \frac{(6 \times 10^{-6})(36)(300)}{(10,000)(36)} = 0.0628 \text{ in.}$

$F = K\delta_s = (10,000)(0.0628) = 628 \text{ lb}$

**THE CORRECT ANSWER IS: C**

13. Lüders bands, or stretcher strains, are found in mild steels and some Al-Mg alloys.

**THE CORRECT ANSWERS ARE: A, D**
23. Draw a free-body diagram.

Forces due to load:

![Free-body diagram showing forces due to load](image1)

Plus forces due to torsion:

![Free-body diagram showing forces due to torsion](image2)

Add vectors:

![Addition of vectors](image3)

Bolt 4 has additive vectors and the greatest shear stress.

**THE CORRECT ANSWER IS: BOLT 4**

24. 

\[ k_b = \frac{AE}{L} = \frac{0.142(30 \times 10^6)}{1} = 4.26 \times 10^6 \]

\[ k_b = k_m \text{ (given) } \]

Preload = 5,000 lb  
Applied load = \( p_l A = 500 \frac{\pi(12)^2}{4} = 56,500 \)  
Applied load per bolt = 7,070 lb  
Bolt force:  
\[ F_b = F_l + \frac{k_b}{k_b + k_m} (7,070) = 5,000 + \frac{1}{2} (7,070) = 8,535 \text{ lb} \]

Bolt stress:  
\[ \sigma_b = \frac{F_b}{A_s} = \frac{8,535}{0.142} = 60,100 \text{ psi} \]

**THE CORRECT ANSWER IS: C**