No notes, books, or information stored in calculator memories may be used. The NCSU academic integrity policies apply to this exam. As such, by taking this exam you are implicitly agreeing with the statement: “I have neither given nor received unauthorized aid on this test.”

All work must be written on these pages and turned in. To receive full or partial credit on numerical problems, you must show your calculations in step-by-step fashion. Units must be shown when applicable and plots must have labeled axes. Be sure that you read and answer all parts of each question. Constants, equations, and data are given at the end of the exam.

1. (5 points) What is the fundamental difference between a fusion weld and a solid state weld?
   
   **Answer.** In a fusion weld, the metal is melted. In a solid state weld, the metal is not melted.

2. (8 points) List four welding defects?

   **Answer.** Some of the important welding defects are (1) cracks, (2) cavities, (3) solid inclusions, (4) incomplete fusion, and (5) imperfect shape or contour of weld cross-section.

3. (6 points) What is the technical difference between brazing and soldering?

   **Answer.** In brazing the filler metal melts at a temperature above 450°C (840°F). In soldering the filler metal melts at a temperature of 450°C or below.

4. (6 points) How does increasing temperature affect the parameters in the flow curve equation?

   **Answer.** Increasing temperature decreases both $K$ and $n$ in the flow curve equation.

5. (16 points) In a tensile test, two pairs of values of stress and strain were measured for the specimen metal after it had yielded: (1) true stress = 217 MPa and true strain = 0.35, and (2) true stress = 259 MPa and true strain = 0.68. Based on these data points, determine the strength coefficient and strain-hardening exponent.

   **Solution:** Solve two equations, two unknowns: $\ln K = \ln \sigma - n \ln \varepsilon$

   \begin{align*}
   (1) \quad & \ln K = \ln 217 - n \ln 0.35 \\
   (2) \quad & \ln K = \ln 259 - n \ln 0.68 \\
   (3) \quad & \ln K = 5.3799 - (-1.0498)n = 5.3799 + 1.0498 n \\
   (4) \quad & \ln K = 5.5568 - (-0.3857)n = 5.5568 + 0.3857 n \\
   & 5.3799 + 1.0498 n = 5.5568 + 0.3857 n \\
   & 1.0498 n - 0.3857 n = 5.5568 - 5.3799 \\
   & 0.6641 n = 0.1769 \quad n = 0.2664 \\
   & \ln K = 5.3799 + 1.0498 (0.2664) = 5.6596 \quad K = 287 \text{ MPa}
   \end{align*}
6. (6 points) Why is flash desirable in impression die forging?

**Answer.** Because its presence constrains the metal in the die so that it fills the details of the die cavity.

7. (9 points) One way to classify forging operations is by the degree to which the work is constrained in the die. By this classification, name the three basic types.

**Answer.** The three basic types are (1) open die forging, (2) impression die forging, and (3) flashless forging.

8. (6 points) What is draft in a rolling operation?

**Answer.** Draft is the difference between the starting thickness and the final thickness as the workpiece passes between the two opposing rolls.

9. (21 points) A single-pass rolling operation reduces a 20 mm thick plate to 18 mm. The starting plate is 200 mm wide. Roll radius = 250 mm and rotational speed = 12 rev/min. The work material has a strength coefficient = 600 MPa and a strain hardening exponent = 0.22. Determine (a) roll force, (b) roll torque, and (c) power required for this operation.

**Solution:**
(a) Draft $d = 20 - 18 = 2.0$ mm, 
Contact length $L = (250 \times 2)^{0.5} = 22.36$ mm = 0.02236 m 
True strain $\varepsilon = \ln(20/18) = \ln 1.111 = 0.1054$

$\overline{\sigma} = 600(0.1054)^{0.22}/1.22 = 300$ MPa 
Rolling force $F = 300(0.02236)(0.2) = 1.34$ MN = $1.34 \times 10^6$ N

(b) Torque $T = 0.5(1340000)(0.02236) = 14,981$ N/m

(c) Given that $N = 12$ rev/min 
Power $P = 2\pi(12/60)(1340000)(0.02236) = 34,824$ W

10. (6 points) Define the “drawing ratio DR” and reduction $r$, using the figure in the right.

$$DR = \frac{D_b}{D_p}$$

$$r = \frac{(D_b - D_p)}{D_b}$$
11. **(9 points)** What are some of the possible defects in drawn sheet-metal parts?

**Answer.** Drawing defects include (1) wrinkling, (2) tearing, (3) earing, and (4) surface scratches, as described in Section 14.3.4.

12. **(6 points)** What is springback in sheet-metal bending?

**Answer.** Springback is the elastic recovery of the sheet metal after bending; it is usually measured as the difference between the final included angle of the bent part and the angle of the tooling used to make the bend, divided by the angle of the tooling.

**Constants and Equations**

\[ N_A = 6.02 \times 10^{23} \text{ mole}^{-1} \quad \text{k (or R)} = 8.62 \times 10^{-5} \text{ eV/atom-K} \quad \text{(or 8.31 J/mol•K)} \]

\[ K = C + 273 \]

\[ 10^9 \text{ nm} = 1 \text{ m} \quad 10^2 \text{ cm} = 1 \text{ m} \]

\[ \sigma = K \epsilon^n \]

\[ \sigma_f = \frac{K \epsilon^n}{1 + n} \]

\[ \epsilon = \ln \left( \frac{h_0}{h} \right) \]

\[ \epsilon = \ln \left( \frac{t_0}{t_f} \right) \]

\[ F = \sigma_w L, \]

\[ L = \sqrt{R(t_0 - t_f)} \]

\[ T = 0.5FL \]

\[ P = 2\pi NF \]

\[ d = t_o - t_f \]

\[ r = \frac{d}{t_o} \]

\[ r_x = \frac{A_o}{A_f} \]

\[ \epsilon = \ln \left( \frac{A_o}{A_f} \right) \]

\[ r = \frac{A_o - A_f}{A_o} \]

\[ c = 1.1 \text{ t}, \]

\[ \alpha_x = \alpha \left( 1 + \frac{\mu}{\tan \alpha} \right) \phi \]

\[ \phi = 0.88 + 0.12 \frac{D}{L_c} \]

\[ \epsilon = \ln \left( \frac{A_o}{A_f} \right) \ln \left( \frac{1}{1 - r} \right) \]

\[ L_c = \frac{D_o - D_f}{2 \sin \alpha} \]

\[ F = A_f \alpha_x \]

\[ D = \frac{D_b - D_f}{D_b} \]

\[ r = \frac{D_f}{D_b} \]

\[ S = \frac{\alpha - \alpha'_b}{\alpha'_b} \]

\[ c = at, \quad F = Sl, \quad A_b = 2\pi \frac{\alpha}{360} (R + K_b a t) \]

\[ F = \frac{K_b T S w t^2}{D} \]

\[ F_f = K_f \sigma_f A_f, \quad K_f = 1 + \frac{0.4 \mu D}{h}, \quad A_f = \frac{1}{4} \pi D_f^2 = V/h_f. \]