Multiple choice:

1.4 Ferrous materials include which of the following (two correct answers): (a) aluminum, (b) cast iron, (c) copper, (d) gold, and (e) steel.

1.5 Which one of the following engineering materials is defined as a compound containing metallic and nonmetallic elements: (a) ceramic, (b) composite, (c) metal, or (d) polymer?

1.6 Which of the following processes start with a material that is in a fluid or semifluid state and solidifies the material in a cavity (two best answers): (a) casting, (b) forging, (c) machining, (d) molding, (e) pressing, and (f) turning?

1.7 Particulate processing of metals and ceramics involves which of the following steps (two best answers): (a) adhesive bonding, (b) deformation, (c) forging, (d) material removal, (e) melting, (f) pressing, and (g) sintering?

1.8 Deformation processes include which of the following (two correct answers): (a) casting, (b) drilling, (c) extrusion, (d) forging, (e) milling, (f) painting, and (g) sintering?

1.9 Which one of the following is a machine used to perform extrusion: (a) forge hammer, (b) milling machine, (c) rolling mill, (d) press, and (e) torch?

2.5 Which of the following bond types are classified as primary bonds (three correct answers): (a) covalent bonding, (b) hydrogen bonding, (c) ionic bonding, (d) metallic bonding, and (e) van der Waals forces?

2.6 How many atoms are there in the unit cell of the face-centered cubic (FCC) unit cell: (a) 8, (b) 9, (c) 10, (d) 12, and (e) 14?

2.7 Which of the following is useful in explaining mechanical behavior in metals: (a) dislocation, (b) interstitialcy, (c) Schottky defect, and (d) vacancy?

2.8 Which one of the following crystal structures has the fewest slip directions and therefore the metals with this structure are generally more difficult to deform at room temperature: (a) BCC, (b) FCC, or (c) HCP?

5.1 A tolerance is which one of the following: (a) clearance between a shaft and a mating hole, (b) measurement error, (c) total permissible variation from a specified dimension, and (d) variation in manufacturing?

5.3 Surface texture includes which of the following characteristics of a surface (three correct answers): (a) small, finely spaced deviations from the nominal surface, (b)
feed marks of the tool that produced the surface, (c) hardness variations, (d) oil films, and (e) surface cracks?

modified 5.5 Surface texture and surface integrity are the same concept: (a) true, or (b) false?

modified 5.8 Which one of the following manufacturing processes will likely result in the worst surface finish: (a) cold rolling, (b) grinding, (c) boring, (d) sand casting, and (e) chemical milling?

6.3 The predominate phase in the iron-carbon alloy system for a composition with 99% Fe at room temperature is which of the following: (a) austenitic, (b) cementite, (c) delta, (d) ferrite, or (e) gamma.

6.6 Plain carbon steels are designated in the AISI code system by which of the following: (a) 01XX, (b) 10XX, (c) 11XX, (d) 20XX, or (e) 30XX.

6.9 Solid solution alloying is the principal strengthening mechanism in high-strength low-alloy (HSLA) steels: (a) true; or (b) false?

6.10 Which of the following alloying elements are most commonly associated with stainless steel (two best answers): (a) chromium, (b) manganese, (c) molybdenum, (d) nickel, and (e) tungsten?

6.11 Which of the following is the most important cast iron commercially: (a) ductile cast iron, (b) gray cast iron, (c) malleable iron, or (d) white cast iron?

6.12 Which one of the following metals has the lowest density: (a) aluminum, (b) magnesium, (c) tin, or (d) titanium?

6.13 Which of the following metals has the highest density: (a) gold, (b) lead, (c) platinum, (d) silver, or (e) tungsten?

6.14 From which of the following ores is aluminum derived: (a) alumina, (b) bauxite, (c) cementite, (d) hematite, or (e) scheelite?

modified 27.1 Which of the following are the usual objectives of heat treatment (three best answers): (a) increase hardness, (b) increase melting temperature, (c) increase recrystallization temperature, (d) soften the material i.e. restore ductility, (e) reduce density, and (f) relieve stress.

27.4 The treatment in which the brittleness of martensite is reduced is called which one of the following: (a) aging, (b) annealing, (c) austenizing, (d) normalizing, (e) quenching, or (f) tempering?

27.6 In precipitation hardening, the hardening and strengthening of the metal occurs in which one of the following steps: (a) aging, (b) quenching, or (c) solution treatment.
Problems:

3.3 A test specimen in a tensile test has a gage length of 2.0 in and an area = 0.5 in$^2$. During the test the specimen yields under a load of 32,000 lbs. The corresponding gage length = 2.0083 in. This is the 0.2% yield point. The maximum load = 60,000 lbs is reached at a gage length = 2.60 in. Determine (a) yield strength, (b) modulus of elasticity, and (c) tensile strength.

Solution:

(a) $Y = 32,000/0.5 = 64,000$ lb/in$^2$

(b) $\sigma = E e$
Subtracting the 0.2% offset, $e = (2.0083 - 2.0)/2.0 - 0.002 = 0.00215$

$E = \sigma/e = 64,000/0.00215 = 29.77 \times 10^6$ lb/in$^2$

(c) $TS = 60,000/0.5 = 120,000$ lb/in$^2$

3.6 In Problem 3.5, determine the strength coefficient and the strain-hardening exponent in the flow curve equation. Be sure not to use data after the point at which necking occurs.

Solution:

Starting volume of test specimen $V = 125(62.5) = 7812.5$ mm$^3$.
Select two data points: (1) $F = 23042$ N and $L = 131.25$ mm; (2) $F = 28913$ N and $L = 147.01$ mm.

(1) $A = V/L = 7812.5/131.25 = 59.524$ mm$^2$.
Stress $\sigma = 23042/59.524 = 387.1$ MPa. Strain $\varepsilon = \ln(131.25/125) = 0.0488$

(2) $A = 7812.5/147.01 = 53.143$ mm$^2$.
Stress $\sigma = 28913/53.143 = 544.1$ MPa. Strain $\varepsilon = \ln(147.01/125) = 0.1622$

Substituting these values into the flow curve equation, we have

(1) $387.1 = K(0.0488)^n$ and (2) $544.1 = K(0.1622)^n$

$544.1/387.1 = (0.1622/0.0488)^n$

$1.4056 = (3.3238)^n$

$\ln(1.4056) = n \ln(3.3238) 0.3405 = 1.2011$ $n = 0.283$

Substituting this value with the data back into the flow curve equation, we obtain the value of the strength coefficient $K$:

$K = 387.1/(0.0488)^{0.283} = 909.9$ MPa

$K = 544.1/(0.1622)^{0.283} = 910.4$ MPa Use average $K = 910.2$ MPa

The flow curve equation is: $\sigma = 910.2 \varepsilon^{0.283}$

3.25 A piece of metal is deformed in shear to an angle of 42° as shown in Figure P3.25 (page 65). Determine the shear strain for this situation.

Solution: $\gamma = a/b = \tan 42° = 0.9004$. 
3.30 In a Brinell hardness test, a 1500-kg load is pressed into a specimen using a 10-mm-diameter hardened steel ball. The resulting indentation has a diameter = 3.2 mm. Determine the Brinell hardness number for the metal.

Solution: \[ HB = \frac{2(1500)}{(10\pi)(10 - (10 - 3.2)^2)^{.5}} = \frac{3000}{(10\pi \times 0.5258)} = 182 \text{ BHN} \]

3.31 Suppose in Problem 3.30 that the specimen is steel. Based on the Brinell hardness number determined in that problem, estimate the tensile strength of the steel.

Solution: The estimating formula is: \[ TS = 500(HB) \]. For a tested hardness of \( HB = 182 \), \[ TS = 500(182) = 91,000 \text{ lb/in}^2 \].

Comparing Manufacturing Processes:

BKP.1. Using the rubric (scale of 1 to 5) in lecture 1 on slide 33, rate grinding and forging in terms of their cycle time, quality, flexibility, materials utilization and operating costs. Provide a short justification for each.

**Grinding**
- Cycle time: 2
- Quality: 5
- Flexibility: 5
- Materials Util: 1
- Op. Cost: 4

**Forging**
- Cycle time: 2 (open die) 4 (closed die)
- Quality: 2 (hot) 4 (cold)
- Flexibility: 4 (open die) 1 (closed die)
- Materials Util: 3 (hot) 5 (cold)
- Op. Cost: 2

BKP.2. Based on your analysis in BKP.1, provide a short (no more than 5 sentences) comparison of the two processes.

Cycle time: Forging can make a much wider variety of shapes in a shorter time than grinding.
Quality: The dimensional accuracy of grinding is superior to forging. The material properties of forgings are generally better than machined parts.
Flexibility: Open die forging does not have dedicated tooling. Grinding can be performed on many different surfaces.
Materials utilization: Cold forging can be near net shape. Machining processes generally offer poor material utilization.
Operating cost: Hard to compare. Labor and machine costs for forging can be high. Costs for grinding depends of geometry and degree of automation.