1 INTRODUCTION

Review Questions

1.1 What are the differences between primary, secondary, and tertiary industries? Give an example of each category.

Answer. A primary industry is one that cultivates and exploits natural resources, such as agriculture or mining. A secondary industry takes the outputs of primary industries and converts them to consumer and capital goods. Examples of secondary industries are textiles and electronics. A tertiary industry is in the service sector of the economy. Examples of tertiary industries are banking and education.

1.2 What is a capital good? Provide an example.

Answer. Capital goods are those purchased by companies to produce goods or provide services. Examples of capital goods are aircraft and construction equipment.

1.3 How are product variety and production quantity related when comparing typical factories?

Answer. Generally production quantity is inversely related to product variety. A factory that produces a large variety of products will produce a smaller quantity of each. A company that produces a single product will produce a large quantity.

1.4 Define manufacturing capability.

Answer. Manufacturing capability refers to the technical and physical limitations of a manufacturing firm and each of its plants. Three categories of capability mentioned in the text are (1) technological processing capability, (2) physical size and weight, and (3) production capacity.

1.5 Name the three basic categories of materials.

Answer. The three basic categories of engineering materials are (1) metals, (2) ceramics, and (3) polymers. A fourth category, composites, is a non-homogeneous mixture of the other types and therefore is not a basic category.

1.6 How does a shaping process differ from a surface processing operation?

Answer. A shaping process changes the geometry of the work material (machining or forging). A surface processing operation does not alter the geometry, but instead alters surface of the work (painting or plating).

1.7 What are two subclasses of assembly processes? Provide an example process for each subclass.

Answer. The two subclasses of assembly processes are (1) permanent joining and (2) mechanical fastening. Examples of permanent joining include welding or adhesive bonding. Examples of mechanical fastening include threaded fasteners, such as nuts and bolts, and rivets.

1.8 Define batch production and describe why it is often used for medium-quantity production products.

Answer. Batch production is where groups, lots, or batches or materials or parts are processed together through the manufacturing operations. All units in the batch are processed at a given station before the group proceeds to the next station. In a medium or low quantity production situation, the same machines are used to produce many types of products. Whenever a machine switches from one product to another, a changeover occurs. The changeover requires the machine setup to be torn down and set up for the new product. Batch production allows the changeover time

to be distributed across a larger number of parts and hence reduce the average operation time per part.

1.9 What is the difference between a process layout and a product layout in a production facility?

Answer. A process layout is one where the machinery in a plant is arranged based on the type of process it performs. To produce a product it must visit the departments in the order of the operations that must be performed. This often includes large travel distances within the plant. A process layout is often used when the product variety is large the operation sequences of products are dissimilar. A product layout is one where the machinery is arranged based on the general flow of the products that will be produced. Travel distance is reduced because products will generally flow to the next machine in the sequence. A product layout works well when all products tend to follow the same sequence of production.

1.10 Name two departments that are typically classified as manufacturing support departments.

Answer. A common organizational structure includes the following three manufacturing support departments: (1) manufacturing engineering, (2) production planning and control, and (3) quality control.

Multiple Choice Quiz

There are 18 correct answers in the following multiple choice questions (some questions have multiple answers that are correct). To attain a perfect score on the quiz, all correct answers must be given. Each correct answer is worth 1 point. Each omitted answer or wrong answer reduces the score by 1 point, and each additional answer beyond the correct number of answers reduces the score by 1 point. Percentage score on the quiz is based on the total number of correct answers.

1.1 Which of the following industries are classified as secondary industries (three correct answers): (a) beverages (b) financial services, (c) fishing, (d) mining, (e) power utilities, (f) publishing, and (g) transportation?

Answer. (a), (e), and (f).

1.2 Mining is classified in which one of the following industry categories: (a) agricultural industry, (b) manufacturing industry, (c) primary industry, (d) secondary industry, (e) service industry, or (f) tertiary industry?

Answer. (c).

1.3 Inventions of the Industrial Revolution include which one of the following: (a) automobile, (b) cannon, (c) printing press, (d) steam engine, or (e) sword?

Answer. (d).

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

Answer. (c) and (e).

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?

Answer. (a).

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?

Answer. (a) and (d).

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?

Answer. (f) and (g).

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?

Answer. (c) and (d).

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, (e) torch?

Answer. (d).

1.10 High-volume production of assembled products is most closely associated with which one of the following layout types: (a) cellular layout, (b) fixed position layout, (c) process layout, or (d) product layout?

Answer. (d).

1.11 A production planning and control department accomplishes which of the following functions in its role of providing manufacturing support (two best answers): (a) designs and orders machine tools, (b) develops corporate strategic plans, (c) orders materials and purchased parts, (d) performs quality inspections, and (e) schedules the order of products on a machine?

Answer. (c) and (e).

2 THE NATURE OF MATERIALS

Review Questions

2.1 The elements listed in the Periodic Table can be divided into three categories. What are these categories and give an example of each?

Answer. The three types of elements are metals (e.g., aluminum), nonmetals (e.g., oxygen), and semimetals (e.g., silicon).

2.2 Which elements are the noble metals?

Answer. The noble metals are copper, silver, and gold.

2.3 What is the difference between primary and secondary bonding in the structure of materials?

Answer. Primary bonding is strong bonding between atoms in a material, for example to form a molecule; while secondary bonding is not as strong and is associated with attraction between molecules in the material.

2.4 Describe how ionic bonding works?

Answer. In ionic bonding, atoms of one element give up their outer electron(s) to the atoms of another element to form complete outer shells.

2.5 What is the difference between crystalline and noncrystalline structures in materials?

Answer. The atoms in a crystalline structure are located at regular and repeating lattice positions in three dimensions; thus, the crystal structure possesses a long-range order which allows a high packing density. The atoms in a noncrystalline structure are randomly positioned in the material, not possessing any repeating, regular pattern.

2.6 What are some common point defects in a crystal lattice structure?

Answer. The common point defects are (1) vacancy - a missing atom in the lattice structure; (2) ion-pair vacancy (Schottky defect) - a missing pair of ions of opposite charge in a compound; (3) interstitialcy - a distortion in the lattice caused by an extra atom present; and (4) Frenkel defect - an ion is removed from a regular position in the lattice and inserted into an interstitial position not normally occupied by such an ion.

2.7 Define the difference between elastic and plastic deformation in terms of the effect on the crystal lattice structure.

Answer. Elastic deformation involves a temporary distortion of the lattice structure that is proportional to the applied stress. Plastic deformation involves a stress of sufficient magnitude to cause a permanent shift in the relative positions of adjacent atoms in the lattice. Plastic deformation generally involves the mechanism of slip - relative movement of atoms on opposite sides of a plane in the lattice.

2.8 How do grain boundaries contribute to the strain hardening phenomenon in metals?

Answer. Grain boundaries block the continued movement of dislocations in the metal during straining. As more dislocations become blocked, the metal becomes more difficult to deform; in effect it becomes stronger.

2.9 Identify some materials that have a crystalline structure.

Answer. Materials typically possessing a crystalline structure are metals and ceramics other than glass. Some plastics have a partially crystalline structure.

2.10 Identify some materials that possess a noncrystalline structure.

Answer. Materials typically having a noncrystalline structure include glass (fused silica), rubber, and certain plastics (specifically, thermosetting plastics).

2.11 What is the basic difference in the solidification (or melting) process between crystalline and noncrystalline structures?

Answer. Crystalline structures undergo an abrupt volumetric change as they transform from liquid to solid state and vice versa. This is accompanied by an amount of energy called the heat of fusion that must be added to the material during melting or released during solidification. Noncrystalline materials melt and solidify without the abrupt volumetric change and heat of fusion.

Multiple Choice Questions

There are 20 correct answers in the following multiple choice questions (some questions have multiple answers that are correct). To attain a perfect score on the quiz, all correct answers must be given. Each correct answer is worth 1 point. Each omitted answer or wrong answer reduces the score by 1 point, and each additional answer beyond the correct number of answers reduces the score by 1 point. Percentage score on the quiz is based on the total number of correct answers.

2.1 The basic structural unit of matter is which one of the following: (a) atom, (b) electron, (c) element, (d) molecule, or (e) nucleus?

Answer. (a).

2.2 Approximately how many different elements have been identified (one best answer): (a) 10, (b) 50, (c) 100, (d) 200, or (e) 500?

Answer. (c).

2.3 In the Periodic Table, the elements can be divided into which of the following categories (three best answers): (a) ceramics, (b) gases, (c) liquids, (d) metals, (e) nonmetals, (f) polymers, (g) semi-metals, and (h) solids?

Answer. (d), (e), and (g).

2.4 The element with the lowest density and smallest atomic weight is which one of the following: (a) aluminum, (b) argon, (c) helium, (d) hydrogen, or (e) magnesium?

Answer. (d).

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?

Answer. (a), (c), and (d).

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

Answer. (e).

2.7 Which of the following are not point defects in a crystal lattice structure (three correct answers): (a) edge dislocation, (b) grain boundaries, (c) interstitialcy, (d) Schottky defect, (e) screw dislocation, or (f) vacancy?

Answer. (c), (d), and (f).

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?

Answer. (c).

2.9 Grain boundaries are an example of which one of the following types of crystal structure defects: (a) dislocation, (b) Frenkel defect, (c) line defects, (d) point defects, or (e) surface defects?

Answer. (e).

2.10 Twinning is which of the following (three best answers): (a) elastic deformation, (b) mechanism of plastic deformation, (c) more likely at high deformation rates, (d) more likely in metals with HCP structure, (e) slip mechanism, and (f) type of dislocation?

Answer. (b), (c), and (d).

2.11 Polymers are characterized by which of the following bonding types (two correct answers): (a) adhesive, (b) covalent, (c) hydrogen, (d) ionic, (e) metallic, and (f) van der Waals?

Answer. (b) and (f).

3 MECHANICAL PROPERTIES OF MATERIALS

Review Questions

3.1 What is the dilemma between design and manufacturing in terms of mechanical properties?

Answer. To achieve design function and quality, the material must be strong; for ease of manufacturing, the material should not be strong, in general.

3.2 What are the three types of static stresses to which materials are subjected?

Answer. tensile, compressive, and shear.

3.3 State Hooke's law.

Answer. Hooke's Law defines the stress-strain relationship for an elastic material: $\sigma = E\varepsilon$, where E = a constant of proportionality called the modulus of elasticity.

3.4 What is the difference between engineering stress and true stress in a tensile test?

Answer. Engineering stress divides the load (force) on the test specimen by the original area; while true stress divides the load by the instantaneous area which decreases as the specimen stretches.

3.5 Define tensile strength of a material.

Answer. The tensile strength is the maximum load experienced during the tensile test divided by the original area.

3.6 Define yield strength of a material.

Answer. The yield strength is the stress at which the material begins to plastically deform. It is usually measured as the 0.2% offset value, which is the point where the stress-strain curve for the material intersects a line that is parallel to the straight-line portion of the curve but offset from it by 0.2%.

3.7 Why cannot a direct conversion be made between the ductility measures of elongation and reduction in area using the assumption of constant volume?

Answer. Because of necking that occurs in the test specimen.

3.8 What is work hardening?

Answer. Work hardening, also called strain hardening, is the increase in strength that occurs in metals when they are strained.

3.9 In what case does the strength coefficient have the same value as the yield strength?

Answer. When the material is perfectly plastic and does not strain harden.

3.10 How does the change in cross-sectional area of a test specimen in a compression test differ from its counterpart in a tensile test specimen?

Answer. In a compression test, the specimen cross-sectional area increases as the test progresses; while in a tensile test, the cross-sectional area decreases.

3.11 What is the complicating factor that occurs in a compression test?

Answer. Barreling of the test specimen due to friction at the interfaces with the testing machine platens.

3.12 Tensile testing is not appropriate for hard brittle materials such as ceramics. What is the test commonly used to determine the strength properties of such materials?

Answer. A three-point bending test is commonly used to test the strength of brittle materials. The test provides a measure called the transverse rupture strength for these materials.

3.13 How is the shear modulus of elasticity G related to the tensile modulus of elasticity E, on average?

Answer. $G = 0.4\ E$, on average.

3.14 How is shear strength S related to tensile strength TS, on average?

Answer. $S = 0.7\ TS$, on average.

3.15 What is hardness, and how is it generally tested?

Answer. Hardness is defined as the resistance to indentation of a material. It is tested by pressing a hard object (sphere, diamond point) into the test material and measuring the size (depth, area) of the indentation.

3.16 Why are different hardness tests and scales required?

Answer. Different hardness tests and scales are required because different materials possess widely differing hardnesses. A test whose measuring range is suited to very hard materials is not sensitive for testing very soft materials.

3.17 Define the recrystallization temperature for a metal.

Answer. The recrystallization temperature is the temperature at which a metal recrystallizes (forms new grains) rather than work hardens when deformed.

3.18 Define viscosity of a fluid.

Answer. Viscosity is the resistance to flow of a fluid material; the thicker the fluid, the greater the viscosity.

3.19 What is the defining characteristic of a Newtonian fluid?

Answer. A Newtonian fluid is one for which viscosity is a constant property at a given temperature. Most liquids (water, oils) are Newtonian fluids.

3.20 What is viscoelasticity, as a material property?

Answer. Viscoelasticity refers to the property most commonly exhibited by polymers that defines the strain of the material as a function of stress and temperature over time. It is a combination of viscosity and elasticity.

Multiple Choice Quiz

There are 15 correct answers in the following multiple choice questions (some questions have multiple answers that are correct). To attain a perfect score on the quiz, all correct answers must be given. Each correct answer is worth 1 point. Each omitted answer or wrong answer reduces the score by 1 point, and each additional answer beyond the correct number of answers reduces the score by 1 point. Percentage score on the quiz is based on the total number of correct answers.

3.1 Which of the following are the three basic types of static stresses to which a material can be subjected (three correct answers): (a) compression, (b) hardness, (c) reduction in area, (d) shear, (e) tensile, (f) true stress, and (f) yield?

Answer. (a), (d), and (e).