CHAPTER 1

Knowledge and Comprehension Problems:

1.1 What are the main classes of engineering materials?
Answer1.1: Metallic, polymeric, ceramic, composite, and electronic materials are the five main classes.

1.2 What are some of the important properties of each of the five main classes of engineering materials?
Answer1.2:
Metallic Materials
- many are relatively strong and ductile at room temperature
- some have good strength at high temperature
- most have relatively high electrical and thermal conductivities

Polymeric Materials
- generally are poor electrical and thermal conductors
- most have low to medium strengths
- most have low densities
- most are relatively easy to process into final shape
- some are transparent

Ceramic Materials
- generally have high hardness and are mechanically brittle
- some have useful high temperature strength
- most have poor electrical and thermal conductivities

Composite Materials
- have a wide range of strength from low to very high
- some have very high strength-to-weight ratios (e.g. carbon-fiber epoxy materials)
- some have medium strength and are able to be cast or formed into a variety of shapes (e.g. fiberglass-polyester materials)
- some have useable strengths at very low cost (e.g. wood and concrete)

Electronic Materials
- able to detect, amplify and transmit electrical signals in a complex manner
- are light weight, compact and energy efficient

1.3 What are materials? List eight commonly encountered engineering materials.
Answer1.3: Materials are substances of which something is composed or made. Steels, aluminum alloys, concrete, wood, glass, plastics, ceramics and electronic materials.

1.4 Provide a list of characteristics for structural materials to be used in space applications.
Answer1.4: Some of the common characteristics of these materials are

i) Light weight to reduce thrust requirement at take-off,
ii) Strong and shock resistant to sustain take-off loads
iii) Ability to function appropriately at very high and very low (cyclic) temperatures of the space
iv) Resist radiation damage in space
v) Resist micro meteor impact

1.5 Give an example of an electronic material that has a great impact on computer technological development.
Answer1.5: Silicon is an important electronic material that has triggered computer development revolution.
Over the years, integrated circuits have been made with a greater density of transistors located on a single silicon chip with a corresponding decrease in transistor width. These chips play a vital role in computerized manufacturing.

1.6 Define a composite material. Give an example of composite material.
Answer1.6: A composite material is a materials system composed of a mixture or combination of two or more materials. Two examples are carbon-fiber epoxy and fiberglass polyester materials.

1.7 What are nanomaterials? What are some proposed advantages of using nanomaterials over their conventional counterparts?
Answer1.7: Are defined as materials with a characteristic length scale smaller than 100 nm. The length scale could be particle diameter, grain size in a material, layer thickness in a sensor, etc. These materials have properties different than that at bulk scale or at the molecular scale. These materials have often enhanced properties and characteristics because of their nano-features in comparison to their micro-featured counterparts. The structural, chemical, electronic, and thermal properties (among other characteristics) are often enhanced at the nano-scale.

1.8 Nickel-base superalloys are used in the structure of aircraft turbine engines. What are the major properties of this metal that make it suitable for this application?
Answer1.8: Some of the major properties of nickel-based superalloys for the stressful, hot, and corrosive environment of the aircraft turbine engine are i) high temperature strength, ii) resistance to corrosion, and iii) resistance to damage under cyclic loading fatigue.

1.9 What are MEMs? Give an application for MEMs.
Answer1.9: Micro-Electromechanical systems (MEMs) are devices that consist of micro-machines or microscopic mechanical elements fabricated on a semiconductor chip. Various applications include micro-pumps, locking systems, motors, mirrors, and sensors.

1.10 Make a list of major components in your computer (at least 5 components). For each component, determine the class of materials used in its structure (identify the specific material if you can).
Answer1.10:

1- The keyboard, monitor, and tower housing –polymers (ABS, high impact polystyrene, blends)
2- Tower casing – metal (aluminum alloy)
3- Cable, cord covers – polymers (polyethylene, Teflon, PVC, etc.)
4- Chip materials – metals, ceramics, electronic materials (silicon, silicon dioxide, copper, gold, silver, etc…)
5- Monitor (cathode-ray tube type)- Polymers and metals (Glass, steel, copper, PVC, rubber)

1.11 Make a list of items that you find in your kitchen (at least 10 items). In each item, determine the class of materials (identify the specific material if you can) used in the structure of the item.
Answer1.11:

1- Eating utensils – mostly metals (stainless steel and titanium)
2- Plates – mostly ceramics (mixture of clay, silica, feldspar)
3- Cabinets – mostly composites materials (wood a natural composite material)
4- Ovens heating elements – temperature resistant metal alloys (stainless steel or nickel-chromium alloy)
5- Pans and pots coatings– mostly polymer (non-stick) coating (Teflon coating)
6- Picnic utensils – mostly polymers (polystyrene, polypropylene, and nylon)
7- Dishwasher – corrosion resistant metals, polymer seals
8- Digital clocks – light emitting diodes (silicon)
9- Food storage wraps – polymers and metals (aluminum foil and polyethylene)
10- Refrigerator seal – magnetic metals and polymers

1.12 Make a list of all the major components of your school's varsity basketball court. For each major component, determine the class of materials used in its structure (identify the specific material if you can).
Answer1.12:

1- The basket support structure – mostly metals (steel and aluminum alloys)
2- Net – polymer (nylon)
3- Court – mostly composites materials (wood and other synthetic composites)
4- Ball – a polymer composite made of rubber and fibers
5- Digital clock – electronic materials for light emitting diodes (silicon based)

1.13 Make a list of major components in your classroom including the constructional elements (at least 10 components). For each component, determine the class of materials used in its structure (identify the specific material if you can).

Answer1.13:

1- Chairs – Polymers and metals (polycarbonate, polystyrene, steel for frames)
2- Board – synthetic wood or polymers
3- Walls – Composte materials and ceramics (Wood, gypsum [a calcium mineral], plaster)
4- Structural frame – metal (Steel beams)
5- Electrical wiring – polymers and metals

1.14 Make a list of major components in your automobile (at least 5 components). For each component, determine the class of materials used in its structure (identify the specific material if you can).

Answer1.14:

1- The engine –metal (cast iron or aluminum alloys)
2- Body – metal (thin steel or aluminum alloys) also advanced composites (carbon fiber composites)
3- Front panel – mostly polymeric materials (polycarbonates)
4- Tires – polymeric composite (synthetic rubber, polyester fabric, steel belts)
5- Light fixture – polymeric glass (Plexiglass)
6- Wires- metals (high conductivity copper)
7- Windshield – laminated glass (ceramic glass, acrylic and cellulose)
8- Springs – mostly steel alloys

1.15 a) What kind of material is OFHC copper? b) What are the desirable properties of OFHC copper? c) What are the applications of OFHC copper in the power industry?

Answer1.15: (a) Oxygen Free High Conductivity (OFHC) Copper is a 99.9% pure copper (a metal). (b) It has very high conductivity, highly machineable, easily welded, easily deforms (hot or cold). (c) It is used for high electrical conductivity applications such as power lines, vacuum tube, and solid state devices.

1.16 a) What are the characteristics of ceramic materials? b) What are the advantages of ceramic materials? c) Give an example of advanced ceramics and their applications.

Answer1.16: (a) Ceramic materials are inorganic materials that consist of metallic and nonmetallic elements chemically bonded together. Most ceramic materials have high-hardness and high-temperature strength but tend to be brittle. (b) Advantages of ceramic materials include light weight, high strength and hardness, good heat and wear resistance, reduced friction, and insulative peoperties. (c) Silicon nitride. It has a high thermal shock resistance and fracture toughness that makes it an excellent cutting tool material.

Application and Analysis Problems:

1.17 List some of the material usage changes that you have observed over a period of time in some manufactured products. What reasons can you give for the changes that have occurred?

Answer1.17:

- The modern automobile is being constructed with more and more plastic materials and less metallic due to the lower cost and weight of plastics.
- The modern airplane is using more composite materials and plastics and less metallic materials to reduce plane weight.
- Modern electronics equipment uses a great number of solid state devices made with electronic materials. These materials are more compact, weigh less, and provide higher overall and energy efficiency. In many cases, they are the only type of material that can be used for specific applications such as complex computer memories.

1.18 Why should Mechanical Engineers be knowledgeable about composition, properties, and processing of materials?

Answer1.18: All branches of mechanical engineering will require selection of materials for a variety of applications in automobiles, power plants, and machines (to name a few) based on a variety of requirements including weight, strength, stiffness, deformability, corrosion, conductivity, magnetism, etc. Knowledge of composition, properties, and processing is critical to select, modify, and apply materials to various applications. (you can highlight many more reasons for the importance of materials knowledge in your field)

1.19 Why should Civil Engineers be knowledgeable about composition, properties, and processing of materials?

Answer1.19: Civil engineers focus on problems and issues related to the nation's infrastructure (bridges, highways, buildings, etc.). Perhaps two of the major concerns is the structural safety and durability of the civil infrastructure. Knowledge of composition, properties, and processing of materials such as steel alloys, concrete, composites, is crucial from structural, chemical (corrosion), and safety point of view. (you can highlight many more reasons for the importance of materials knowledge in your field)

1.20 Why should Industrial Engineers be knowledgeable about composition, properties, and processing of materials?

Answer1.20: Industrial engineers are very concerned about usage, taxonomy, assembly, recycling, and ergonomics issues related to materials. Industrial engineers should know composition, properties, and processing techniques to design the most affordable products, assure ease of recycling at the end of product's life, and assure appropriate and safe environment for human materials interaction (worker safety). As an example, consider the materials issues in recycling of the materials in old computers (chips and housing). (you can highlight many more reasons for the importance of materials knowledge in your field)

1.21 Why should Petroleum Engineers be knowledgeable about composition, properties, and processing of materials?
Answer1.21: Four important areas related to petroleum engineering that require extensive materials knowledge are drilling, production, refining, and distribution. The use of materials in drilling requires extensive knowledge of metals, ceramics, and their interaction. In production and drilling extensive knowledge of geologic materials is also required. Offshore drilling tasks introduce many new challenges regarding corrosion, strength, and durability of machines and components on offshore platforms. Refining would require knowledge of materials selection for design of heat exchangers, boilers, cooling towers, all in the presence of some very caustic chemicals. (you can highlight many more reasons for the importance of materials knowledge in your field)

1.22 Why should Chemical Engineers be knowledgeable about composition, properties, and processing of materials?
Answer1.22: Many chemical engineers become heavily involved in process design related to polymer design, production, and component manufacturing. Such engineers not only should be knowledgeable about composition, properties, and processing of polymers but also how integrate these materials in different application in a safe and environmentally friendly manner. (you can highlight many more reasons for the importance of materials knowledge in your field)

1.23 Why should Biomedical Engineers be knowledgeable about composition, properties, and processing of materials?
Answer1.23: Biomedical engineers are principally concerned about the biocompatibility of the various materials in inside the human body (a very corrosive environment). They must be aware of composition (for toxicity), properties (for weight bearing applications in orthopedics), and processing (which method of processing produces the best part). In addition, biomedical engineers are using polymeric scaffolds in addition to biologic materials to produce new tissue (tissue engineering). (you can highlight many more reasons for the importance of materials knowledge in your field)

1.24 Why should Electrical Engineers be knowledgeable about composition, properties, and processing of materials?
Answer1.24: Electrical engineers would be interested in materials issues because of their interest in designing integrated circuits at very small scales. Although they mostly deal with electronic materials, other classes of materials including metals, ceramics, polymers, and composites are also extensively used. Electrical engineers would be very interested in electrical (conductive, semiconductive, and insulative) properties of all classes of materials. In addition to electrical properties, structural and thermodynamic issues are also of importance to electrical engineers. (you can highlight many more reasons for the importance of materials knowledge in your field)

Synthesis and Evaluation Problems:

1.25 Consider the common household component in a light bulb: a) identify various critical components of this item, b) determine the material selected for each critical component, and c) design a process that would be used to assemble the light bulb.
Answer1.25: (a and b) The bulb itself is a ceramic glass (sometimes coated with silica to reduce glare). The screw thread contact is aluminum alloy. The filament is made of tungsten (a metal). The structure that holds the wire is also ceramic glass. Stiff metallic wires (nickel-iron alloy) connect the filament to the electrical contact at the bottom of the screw. The bulb is filled with inert gas argon/nitrogen mixture. (c) Glass is blown through holes into molds to form casing. The filament base (stem assembly to hold wires) is also made using molds. The filament is manufactures using a process called wire-drawing. The filament is placed on the stem. The glass bulb is placed on the stem and the filament. Air is extracted. Argon/nitrogen is introduced. The base is sealed.

1.26 a) Name the important factors in selecting materials of fishing rod. b) Determine the margin weaknesses and strengths by using CFRP, aluminum alloy and wood.
Answer1.26: (a) Consider the materials selection issues for fishing rod. The selected materials must be strong enough to support the load with yielding or fracture. The weight of the fishing rod is also an important factor. The corrosion resistance of the materials may be a consideration over the life of the fishing rod. (b) CFRP is stiff, light-weight and corrosion resistant, but it is costly. Aluminum alloy is lighter but not as strong or stiff.Wood is also lighter and cheaper but not as strong or stiff .

1.27 What factors might cause materials usage predictions to be incorrect?
Answer1.27:

- If a war breaks out and, as a consequence, a raw material's supply is cut off. For example, if a major war broke out in the Middle East, the price of oil would increase, and hence the price of plastic materials would also increase.
- If a major new discovery is made, some materials' usage may change.

If defects show up in a specific material after a certain length of its service, the material's usage may decrease. For example, a high strength composite material used for aircraft may start showing some delamination defects.

1.29 A certain application requires a material that must be very hard and corrosion resistant at room temperature and atmosphere, while it would be only beneficial if it is impact resistant. a) If you only consider the major requirements, which classes of materials would you search for this selection? b) If you consider both major and minor requirements which classes would you search? c) Suggest a material.
Answer1.29: (a) If we are looking to satisfy the major requirements, hard and corrosion resistant materials, we can look to some metals and ceramics. Some metal alloys such as heat treated stainless steel or ceramics such as silicon carbide are both hard and corrosion resistant. (b) To satisfy the minor requirement as well, we should search in metals because they are more impact resistant (less brittle) than ceramics that are more brittle.

1.30 a) Name the important criteria in selecting materials for a protective sports helmet. b) Identify materials that would satisfy the above criteria. c) Why would a solid metal helmet not be a good choice?
Answer1.30: (a) The material or combination of material must first and foremost absorb a significant amount of the energy due to impact and not allow that energy to transfer to the skull. The material must also be light weight. (b) The helmet material is the polymer polycarbonate. There is also a polymer foam (vinyl) placed inside the helmet. The helmet and the foam absorb a great deal of impact energy by deforming. The form also protects the skull from a sharp directed blow and distributes the blow. The face mask is made of metal (steel wire coated with plastic) or another hard polymer such as ABS. (c) A solid metal helmet will not distribute the blow or deform substantially from an impact and will transfer most of the energy to the skull. It is also too heavy.

1.31 Why is it important or helpful to classify materials into different groups as we have done in this chapter?
Answer1.31: Classification of materials allows the engineer to associate certain general characteristics with a specific material. This knowledge is very important. For instance one you realized that material x is classified as a ceramic, without actually knowing the exact properties, you will immediately know that it will be brittle, low density, chemically stable, low friction etc. You will also know the nature of its atomic structure (chapters 2 and 3). In general it gives you the ability to seek candidates for your materials selection applications.