1. (a) Deduce an expression for the defect concentrations as a function of the equilibrium constant, thermodynamic parameters and temperature. Also explain how these concentrations are influenced by temperature. (17)

(b) A non-stoichiometric oxide Fe_{1-y}O has a lattice parameter of 429 pm and a density of 5.63 g/cm³. Moreover, Fe_{1-y}O has rock salt structure.

(i) What is the composition of the oxides? (ii) Calculate the density of defects (no. per unit volume). Assume any missing data.

(c) Write the defect reactions:

(i) For the formation of fully ionised oxygen vacancies and electrons when oxygen is lost in the reaction, MO₂(s) = MO₂-ₓ + (x/2)O₂(g).

(ii) for dissolution of ZrO₂ substitutionally into the anion-Frenkle dominated Y₂O₃.

2. (a) Illustrate an effective way to improve the conductivity of MgO ceramics. (8)

(b) The conductivity of La³⁺ doped ZnS semiconductor largely depends on the operating temperature. The La³⁺ dopant act as donor and its concentration is \( N_d = 10^{16} \) cm⁻³. Calculate the conductivity of ZnS for the following conditions:

(i) Operating temperature is 100 °C and 30% of the donors is ionized. (17)

(ii) Operating temperature is 400 °C and all donors are ionized.

(iii) Operating temperature is 700 °C and electrons excited from valence band to conduction band.

The energy difference between conduction band and valence band equals to 0.3 eV and the ionization energy of donor level is 0.001 eV. The mobility of the electron is 100 cm²/Ns and effective mass of the electrons is 9.1 x 10⁻³¹ kg. Assume any missing data.

(c) Derive a generalized expression for electrical conductivity. Mention the driving forces for electrical conduction in solids? (10)

3. (a) Using the Figure 1 calculate the maximum polarization per cubic centimeter and the total charge that can be stored per square centimeter for barium titanate. (15)

(b) 'BaTiO₃ has gained great attention due to its electrical properties'. Discuss this statement.

(c) How do acidic and basic media affect the hydrolysis and gelation steps of sol-gel process? (10)

Contd .......... P/2
MME 467

Contd... Q. No. 4

4. (a) Show that nonmagnetic Zn substitution in \( \text{Cu}_1-x\text{Zn}_x\text{Fe}_2\text{O}_4 \) ferrites (where \( x = 0, 0.2, 0.4, 0.6, 0.8 \) and 1) increases the theoretical magnetic moments gradually. Explain why experimental values decrease when \( x \geq 0.5 \) with the help of Yafet-Kittel model. Atomic number of Zn, Cu, Fe is 30, 29 and 26 respectively.

(b) Using the Heisenberg exchange energy equation, explain how magnetic order varies with exchange integral, \( J_{ex} \).

(c) The chemical formula for copper ferrite may be written as \( \text{(Cu Fe}_2\text{O}_4)_8 \) because there are eight formula units per unit cell. If this material has a saturation magnetization of \( 1.35 \times 10^5 \) A/m and a density of 5.40 g/cm\(^3\), estimate the number of Bohr magnetons associated with each \( \text{Cu}^{2+} \) ion in a formula unit. Molar mass of Cu, Fe and O is 63.56, 55.845 and 16 g/mol respectively.

SECTION-B

There are FOUR questions in this section. Answer any THREE questions.

5. (a) Examine the necessity and importance of using advanced ceramics.

(b) “The inherent obstacles associated with the use of ceramics dictates judicious applications of certain rules while designing with engineering ceramics:” - Explain.

(c) Using Energy-Interatomic Distance diagram explain the melting point and thermal expansion behavior of ceramic materials.

6. (a) State and explain Pauling’s Rules for determining ceramics structures based on the packing of its ions.

(b) “The deformation of ceramic materials is difficult and complex” – Explain.

(c) Ceramic materials always have a reduced strength and fracture toughness because they almost always contain internal or surface cracks and other flaws. Analyse how such flaws affect the strength of ceramic materials.

7. (a) Examine the concept of Weibull modulus in determining the reliability of brittle ceramic materials. Discuss the effect of fracture toughness of ceramic material, microstructure, size and number of test samples on Weibull modulus.

(b) Why do toughening is necessary for ceramics? What are the basic principles and means of toughening ceramic materials? Explain how \( \text{Si}_3\text{N}_4 \) can be toughened by self-reinforcing.

8. (a) Analyse the suitability of using ceramic materials for biological applications. List and discuss different types of bio ceramics based on their chemical reactivity in the body.

(b) Discuss the typical creep curve of ceramic material. List and examine how the factors affect the creep rate of ceramic material.
Figure 1: (a) In tetragonal BaTiO$_3$, the oxygen ions are at face centers, Ba$^{2+}$ ions are at cube corners and Ti$^{4+}$ is at center.
(b) The Ti$^{4+}$ is off-center in tetragonal BaTiO$_3$ and the unit cell has a net polarization.
L-4/T-2/MME Date: 15/07/2017

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
Sub: MME 447 (Industrial Metal Working Processes)

Full Marks: 210 Time: 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION
The questions are of equal value.

SECTION – A

There are EIGHT questions in this section. Answer any SIX.

1. For sheet product rolling, in final pass, the neutral point should be as close as possible to the exit point—why? Prove that $\Delta h_{\text{max}} \approx \mu^2 R$. All symbols have their usual meanings.

2. What do you understand by the term "homogeneous deformation" in rolling? In a particular sheet rolling under homogeneous deformation the sheet is reduced to 24 mm from 30 mm thickness by 800 mm diameter roll. Calculate the rolling load under sticking friction condition. Given that the flow stress of the material is 150 MPa. Assume reasonable value for any missing data.

3. Define mill modulus. Metal Strip 4.0 mm thick is to be cold rolled from stock material by a rolling mill having the following responses under working conditions.

<table>
<thead>
<tr>
<th>Rolling Load (kN)</th>
<th>Roll Gap Setting (mm)</th>
<th>Rolled Gauge of Strip (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>3.63</td>
<td>3.83</td>
</tr>
<tr>
<td>450</td>
<td>3.10</td>
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<tr>
<td>800</td>
<td>1.65</td>
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</tr>
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</table>

Calculate the mill modulus and also show how these data are used for precision rolling of gauge 3.25 mm.

4. Mention various special features of TMT bar over conventional one. With neat sketches explain how these special features are industrially incorporated in the production system.

5. For the production of conventional normalized steel bar having 0.3%C three different final rolling temperatures as just above the upper critical, just below upper critical and just above lower critical temperatures were selected. Compare and contrast the microstructures and mechanical properties of the bars thus produced.

Contd ........... P/2
6. Define billet and bloom. A mild steel (0.35%C) workpiece of dimensions 200×250×2000 mm is rolled to a section of 150×150 mm in single pass within 10 sec time at 1000°C. Calculate the final temperature of the rolled product. Given: \( S = 0.16 \) k cal/kg°C, \( C_p = 0.6 \). Assume reasonable value for any missing data.

7. What are the benefits of slit rolling? For wire drawing prove that \( r_{\text{max}} = 48\% \) when the wire deformation efficiency is 0.65.

8. In dieless wire drawing production, conditions must be monitored and controlled very vigorously—why? Discuss the TMCP process for the production of high strength dual phase steel.

**SECTION – B**

There are **FOUR** questions in this section. Answer any **THREE**.

9. (a) How can you effectively use stress-strain curves of a metallic material to evaluate the parameters of Bauschinger effect?
(b) In a tensile test of metallic alloy, two pairs of values of stress and strain were measured after the specimen had yielded: (i) true stress 217 MPa and true strain 0.35; and (ii) true stress 259 MPa and true strain 0.68. Determine the strength coefficient and strain-hardening exponent.

10. Distinguish between hardening mechanism and softening mechanism. Justify the reasons for choosing these terms to explain mechanical behaviour of metallic materials. Also, clarify in your opinion the roles of second phases particles played in these hardening and softening mechanisms.

11. (a) Validate the role and importance of flash in forging processes. You should make use of forging stroke against forging load schematic diagram.
(b) Derive an equation for the mean forging load experienced during a typical forging operation.

12. (a) Draw a neat sketch of stress and strain distribution at various points of a flange/cup during a typical deep drawing operation. Now, identify and narrate different zones based on your sketch. Which zone does play the most crucial role in a drawing operation and why?
(b) In forging operation, fibre flow lines following contour are preferred and generally observed. What do you think of fibre flow lines? Using schematic figures, draw fibre flow lines for as-cast product, CNC-machined component and forged part, and make use of these diagrams to explain the reasons for choosing forging method to produce high strength bolts.
SECTION – A

There are FOUR questions in this section. Answer any THREE.

1. (a) Do you think JIT is applicable for a service organization? How? (05)
   (b) How can you distinguish push system from pull system in a manufacturing environment? Provide example for both. (10)
   (c) What are the requirements for effective inventory management? (10)
   (d) What are the main building blocks of JIT? Briefly explain with appropriate example. (10)

2. (a) Define design capacity, efficiency and utilization. (05)
   (b) The owner of a small hardware store has noted a sales pattern for window locks that seems to parallel the number of break-ins reported each week in the newspaper. The data are:

<table>
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<tr>
<th>Sales</th>
<th>46</th>
<th>18</th>
<th>20</th>
<th>22</th>
<th>27</th>
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<td>3</td>
<td>5</td>
<td>4</td>
<td>7</td>
<td>2</td>
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</table>

   (i) Obtain a regression equation for this data. (10)
   (ii) Estimate sales for window locks when the number of break-ins is eight (8). (10)
   (c) Explain the trend effects in moving average method and exponential smoothing method. (10)
   (d) Briefly describe main layout types with example. (10)

3. (a) Do you think workers should be informed before time study? Explain your logic. (05)
   (b) Briefly describe different alternatives if the capacity is saturated for a service organization. (10)
   (c) What are the quantitative methods of forecasting? Explain “exponential smoothing” method. (10)
   (d) From the following table of produced parts in an hour time, calculate normal time and standard time with performance rating of 1.20 using an allowance of 15% of normal time. (10)

<table>
<thead>
<tr>
<th>Worker</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<td>25</td>
<td>24</td>
<td>28</td>
<td>26</td>
<td>26</td>
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</table>
4. (a) Cellular layout can be termed as a miniature version of product/process layout—justify. (05)
  (b) Name different types of planning based on time length. Capacity planning and aggregate planning fall in which categories and why? (10)
  (c) List the major assumptions of the EOQ model. (8)
  (d) The housekeeping department of a motel uses approximately 400 washcloths per day. The actual number tends to vary with the number of guests on any given night. Usage can be approximated by a normal distribution that has a mean of 400 and a standard deviation of nine washcloths per day. A linen supply company delivers towels and washcloths with a lead time of three days. If the motel policy is to maintain a stock-out risk of 3%, what is the minimum number of washcloths that must be on hand at reorder time, and how much of that amount can be considered as safety stock? (12)

SECTION-B
There are FOUR questions in this section. Answer any THREE questions.

5. (a) Define ‘Lean System’. Explain five basic differences between intermittent and mass production. (10)
  (b) Give some examples of ethical issues that may arise on projects. What can a project manager do to minimize such issues? (10)
  (c) The tasks shown in the following precedence diagram are to be assigned to workstations with the intent of minimizing idle time. Management has designed an output rate of 275 units per day. Assume 440 minutes are available per day. Assign tasks using the “positional weight” rule. Break ties using greatest number of following tasks. Compute minimum no of stations, idle time for each workstation and overall efficiency. The assigned tasks must be shown in corresponding workstations. (15)

6. (a) How do you classify the control charts? Describe any four of them. (15)
  (b) What is meant by the term service level? How is service level related to the amount of safety stock held? (10)

Contd .......... P/3
(c) Determine the number of containers needed for a workstation that uses 100 parts per hour if the time for a container to complete a cycle (move, wait, empty, return, fill) is 90 minutes and a standard container holds 84 parts. An efficiency factor of .10 is currently being used.

7. (a) Why is it not necessary to include product cost in the EOQ model? (5)
    (b) Time study is calculation whereas work sampling is estimation – discuss. (10)
    (c) How can you distinguish Government barrier from trade block in selecting a suitable location for a manufacturing facility? (10)
    (d) Wang Distribution has an annual demand for an airport metal detector of 1,400 units. The cost of a typical detector to Wang is $400. Carrying cost is estimated to be 20% of the unit cost, and the ordering cost is $25 per order. If Ping Wang, the owner, orders in quantities of 300 or more, he can get a 5% discount on the cost of the detectors. Should Wang take the quantity discount? (10)

8. (a) What are the objectives of work-center scheduling? (10)
    (b) What are the functions of shop-floor control? Explain. (10)
    (c) A university must develop forecasts for the next year’s quarterly enrollments. It has collected quarterly enrollments for the past two years. The enrollment for Year 3 was forecasted using exponential smoothing method. Fill in the blanks in following table. [Given, forecasted total enrollment for Year 2 is 91500 and $\alpha = 0.2$] (15)

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</table>
SECTION - A

There are FOUR questions in this section. Answer any THREE.

Fig. 2 should be attached to the answer script if used

1. (a) A furnace is required to sinter powder-metal parts. It operates continuously at 650°C while the parts are fed through on a moving belt. You are asked to select a material for furnace insulation to minimize heat loss and thus make the furnace as energy efficient as possible. For reasons of space the insulation is limited to a maximum thickness of $x = 0.2$ m. List the function, constraints, objective, and free variable. (8)

(b) Explain the concepts of penalty function and exchange constant. Examine how these concepts are utilised in the material selection processes. (9+10=19)

(c) The exchange constant for weight saving in light trucks is $\alpha = \$12/\text{kg}$. A maker of such vehicles offers three models. The first uses steel panels for the body work. The second uses aluminium, costs $2,500$ more but weighs $300$ kg less. The third offers carbon-fiber paneling, costs $8,000$ more, and weighs $500$ kg less. Which is the best buy? (8)

2. (a) Derive the material index for a torsional bar with a solid circular cross section. The length $L$ and torsional stiffness $S^*$ are specified, and the torsion bar is to be as light as possible. The torsional stiffness $S^* = T/ (\theta/L) = GK$, where $T = \text{applied torque}$, $\theta = \text{angle of twist}$, $G = \text{shear modulus}$, and $K = \text{torsion moment for circular cross-section} = \pi r^4/2$. (10)

(b) Pressure vessels, as shown in Fig. 1, are usually made of low alloy steels where the conditions are that the vessel must not fail by yielding under an internal pressure $p$ below $250$ MPa or by fast fracture due to the presence of a crack of length $2a_c$ more than $1$ mm. Explore the possibility of replacing low alloy steel with low carbon steel and AA 6061-T6 Al-alloy to make such a pressure vessel of radius $R = 450$ mm. Data for the material properties are listed in the table below: (25)
3. (a) Explain the concept of percolation and, using suitable example, examine its importance as a design tool for hybrid materials.

(b) Use the 4-segment chart for stiffness-limited design of Fig. 2 to compare the mass per unit length, \( m/L \), of a section with \( EI = 10^5 \text{ N.m}^2 \) made from (i) structural steel with a shape factor \( \phi \) of 20, modulus \( E = 210 \text{ GPa} \) and density \( \rho = 7900 \text{ kg/m}^3 \) (ii) carbon fiber reinforced plastic with a shape factor \( \phi \) of 10, modulus \( E = 70 \text{ GPa} \) and density \( \rho = 1600 \text{ kg/m}^3 \), and (iii) structural timber with a shape factor \( \phi \) of 2, modulus \( E = 9 \text{ GPa} \) and density \( \rho = 520 \text{ kg/m}^3 \).

[You should attach the 4-segment chart to the answer script if used]

(c) Show, by direct calculation, that the conclusions of part (b) are consistent with the idea that to minimize mass for a given stiffness one should maximize \( \sqrt{E^*/\rho^*} \) with \( E^* = E/\phi \) and \( \rho^* = \rho/\phi \).

4. (a) If you wish to make stiff, strong structures that are efficient (using as little material as possible), the general theory is to make the shape-efficiency factors as large as possible. But there are limits of increasing the value of shape factor. Examine the factors that set these limits to the shape efficiency factor of material.

(b) A slender, solid cylindrical column of height \( L \) supports a load \( F \). If overloaded, the column fails by elastic bucking. By how much is the load-bearing capacity increased or decreased if the solid cylinder is replaced by a hollow circular tube of the same cross-section \( A \)? For hollow cylindrical tube with \( r > > t \), use \( I = \pi r^4 t \) and \( A = 2\pi rt \).

(c) Calculate the gain in bending efficiency, \( \eta_B \), when a solid is formed into small, thin-walled tubes of radius \( r \) and wall thickness \( t \) that are then assembled and bonded into a large array, part of which is shown in Fig. 3. Let the solid of which the tubes are made have modulus \( E_s \) and density \( \rho_s \). Express the result in terms of \( r \) and \( t \).
5. (a) What is design? In your opinion, what does drive the materials engineers: market pull or technology push? Give one example where design historically changes the shape and look for a product.
(b) Using a design flow chart, correlate among design tools, market need and material data. Why is material data important in preparing a design flow chart?

6. (a) What do you understand by constructional steels? Maraging steels derive strength from heat treatment, not from carbon – typical in steel. Do you agree? Clarify your answer with explanation of different heat treatment cycles for maraging steels.
(b) Why does nickel-based alloys receive different strengthening from different mechanisms? Discuss with explanations. Why does some nickel-based alloys are termed superalloys? What are the reasons for such terminology?

7. Magnesium alloys are prone to corrosion attack, even though they are receiving good responses from manufacturers of automobiles. What are the reasons? Why do you add aluminium in magnesium? What are the effects of aluminium during heat treatment of magnesium alloys. What are the advantages of adding rare earth elements in magnesium alloy system.

8. (a) Select an appropriate material for aerospace industries, especially for airframes and engines. Why do these alloys receive such high reputation in aerospace industries? Evaluate you answer with justification.
(b) Validate the underlying mechanism for shape memory alloy with examples.
Fig. 1 for Q. 2(b): A pressure vessel containing flaw.

Fig. 2 for Q. 3(b): 4-segment chart for selecting structured section

(You should attach this 4-segment chart to the answer script if used)

Fig. 3 for Q. 4(c)
SECTION A

There are FOUR questions in this section. Answer any THREE.

1. (a) Assume a compact is sintered in argon at pressure 2 atm with a pore diameter of 2 \( \mu \text{m} \) at pore closure, which occurs at 8\% porosity. Calculate the peak sintered density as a percentage of theoretical density. Given solid vapour surface energy is 1 J/m\(^2\). (12)
   (b) 'Smaller particles undergo sintering at lower temperature in comparison to large particles' – Explain. (8)
   (c) Write down the three main criteria of an additive for activated sintering. (3 \( \frac{1}{3} \))

2. (a) Discuss in detail with flow chart the various steps in the processing of ceramic nuclear fuel pellets using nitrates of uranium through sol-gel micro-sphere pelletisation process. (12)
   (b) Draw a curve which depicts the relationship between sintering shrinkage and green density. (4 \( \frac{1}{3} \))
   (c) Mention few engineering applications of cermet. (7)

3. (a) With schematic diagram briefly explain the pore structure evolution process during sintering. (12)
   (b) What are ferrites? Why magnetite, Fe\(_3\)O\(_4\) is magnetic? Explain with cation distribution in the spinel sublattice by calculating the net magnetic moment. (8)
   (c) Write down the disadvantages of the immersion technique of oil impregnation of porous bronze bearing. (3 \( \frac{1}{3} \))

4. (a) Briefly describe the effect of grain boundary attached pores on the amount of grain growth during intermediate stage of sintering. (7)
   (b) Describe how radioactive yttrium alumino silicate (YAS) is used in malignant tumor treatment in the liver. (10)
   (c) Define stress shielding. (6 \( \frac{1}{3} \))

Contd ......... P/2
MME 457

There are FOUR questions in this section. Answer any THREE.

5. (a) Write down the processing steps that should be followed in gear manufacturing by powder metallurgy method.

(b) Discuss the advantages and limitations of powder metallurgy process?

(c) List the basic characteristics of metal powders. How does the shape of powders influence the apparent density and flow rate?

6. (a) How is the size distribution of powders ranging from 0.3 μm to 300 μm measured?

(b) Discuss a physical method that are followed in manufacturing Fe and Ni powders.

(c) Explain how cobalt powders are precipitated by hydrometallurgical method.

7. (a) How are powder size and shape controlled during manufacturing of powder by atomization process?

(b) Why is preliminary heat treatment of powder needed before mixing of metallic powders?

(c) If powders are of different specific gravities, the heavier one will be separated and fall to the bottom of the mixture. Explain how you will obtain a uniform mixture of powders having different specific gravities.

(d) Suggest a pressing process that is suitable for the compaction of alumina powder.

8. (a) Describe a method of shaping technique that is used for the production of ceramic articles.

(b) What is the effect of stress distribution on the products compacted by unidirectional pressing and isostatic pressing?

(c) Explain the component shape design for obtaining better quality finished product.