L-4/T-2/MME **Date : 14/01/2017**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2014-2015

Sub : **MME 447** (Industrial Metal Working Processes)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

The questions are of equal value.

1. Among Sendzimir, Tandem and Planetary rolling mills which one will be the best for the economical production of thin sheet and why? A sheet of 250 mm thickness is rolled by two high rolling mill having 500 mm diameter rolls. If the maximum draft of the rolling process is 130 mm, what will be the co-efficient of friction for this rolling process? Assume reasonable value for any missing data.

2. Is it possible to reduce the action of roll flattening by applying back tension? A 0.2% carbon steel of 5 mm thick and 100 mm wide is to be rolled to 3.5 mm at 1200°C in one pass by steel rolls of 500 mm diameter having $\frac{R'}{R} = 1 + \frac{2.2\,P'}{W\Delta h}$. Considering homogeneous yield strength of the steel at the rolling temperature as 1000 N/mm^2, find out the flattened roll diameter. All symbols have their usual meanings. Assume reasonable value for any missing data.

3. Define mean absolute and mean relative draughts in roll pass design. A 0.35% C steel billet of 100 mm diameter and 10 m long is to be rolled from 1050°C to produce 40 mm bar with equal percentage of deformation in each pass. For the first pass, the rolling speed is 4m/sec, whereas for the subsequent rolling the speed is just sufficient to be synchronized with the whole rolling process. Calculate the heat loss of the bar due to heat radiation before reacting to the cooling bed. Assume reasonable value for any missing data.

4. Mention the factors responsible for the higher overall strength of quenched and tempered steel bars over that of the conventional hot rolled bars. Discuss the importance of the temperature of the finished hot rolled bar and water flow rate of the quenching chamber on the properties and microstructures of the rolled product.

5. Define classical strain hardening. With necessary sketches discuss the effects of carbon content on their unusual behaviours in cold working.

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6. What are the factors that control the possibility of Chevron cracking in extrusion? A round copper billet of 100 mm diameter is to be extruded to 20 mm diameter at 1500°F. Calculate the load needed for this metal working process with the help of the diagram given in the Figure for Q. No. 6. Assume reasonable value for any missing data.

7. Do you think that TMCP contributes a lot for direct and indirect social benefits? Discuss. Low carbon steel sheet has to be manufactured from stock material of the following chemical compositions. C = 0.05%, Mn = 0.3%, Al = 0.05% and N = 0.006%. Suggest the minimum soaking temperature for this operation.

8. What is steel wire patenting? Discuss the whole process of patenting for high strength wire production from fully pearlitic steel stock. The CCT diagram of the steel is given in Figure for Q. No. 8.

SECTION – B

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

The figures in the margin indicate full marks.

9. What do you understand by the term 'plane strain flow stress'? With neat sketch describe the effect of bending on the strain along the circumference. **($17\frac{1}{2}$)**

10. (a) Draw the figure that depicts the effect of internal pressure on the strain mode and failure mechanism during hydroforming. **($7\frac{1}{2}$)**

    (b) Describe the plane strain deformation zone of a cylindrical cup during deep drawing. **(10)**

11. Differentiate between redrawing and wall ironing. A 0.4 mm thick sheet is to be drawn with a LDR of 1.9 to produce a container with an inside diameter of 50 mm and a height of 75 mm. Tensile strength is 150 MPa. Assume the thickness of the bottom and the walls of the container remain unchanged (i.e., 0.4 mm). **($17\frac{1}{2}$)**

    (a) Calculate the diameter of the initial circular blank necessary.

    (b) For drawing the same initial circular blank, check if single drawing is enough and, if not, calculate the smallest possible punch diameter for the first step and estimate the number of redrawing necessary.

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12. (a) Describe the defect that occurs in sheet metal forming process by internal compressive stress. How can you avoid it? **($7\frac{1}{2}$)**

(b) A tensile test on a certain metal is carried out at a temperature of 540°C. At a strain rate of 10/s the stress is measured as 160 MPa. At a strain rate of 300/s, the stress is measured as 310 MPa. **(10)**

(i) Determine the strength constant C in MPa and the strain rate sensitivity exponent M.

(ii) If the temperature were 580°C, what change would you expect in values of C and M?

13. 'With an increase in dislocation density we can expect a maximum value of Bawschinger effect but it will decrease after some level of pre strain'. Explain. **($17\frac{1}{2}$)**

14. (a) Briefly describe the influence of flash properties on the forging pressure. **($7\frac{1}{2}$)**

(b) Differentiate the structures that are obtained during impact forging and press forging. **(10)**

15. Describe briefly the influence of stacking fault energy on the amount of recovery of a single phase material. Write down the main structural changes that occur during recovery. **($17\frac{1}{2}$)**

16. Write short notes on **($17\frac{1}{2}$)**

(a) Particle stimulated nucleation

(b) Zener drag

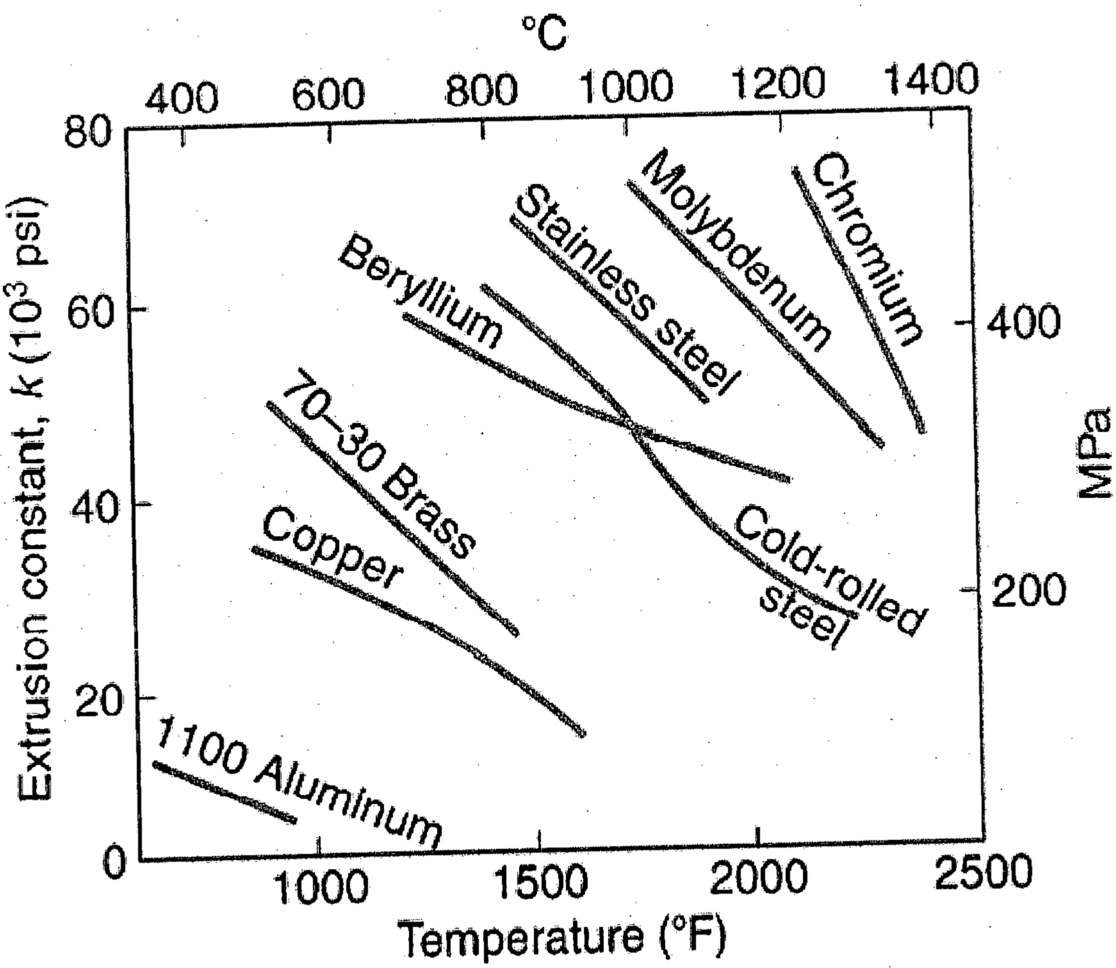

Figure for Question No. 6

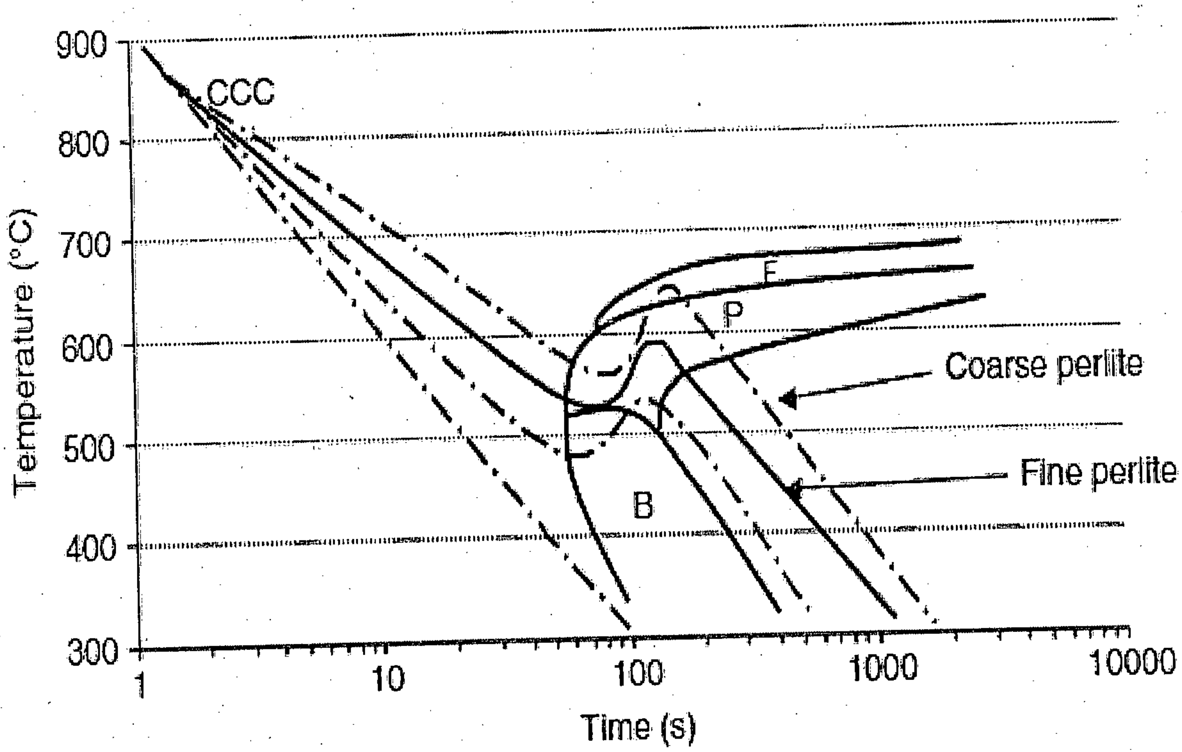

Figure for Question No. 8

L-4/T-2/MME **Date : 18/01/2017**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2014-2015

Sub : **IPE 483** (Production Planning and Control)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) A company has three manufacturing plants in three different places and two distribution centers in two target markets. The company is planning to build a central warehouse where manufactured products will be stored and then will be sending to distribution centers to provide better customer service. Location, capacity and per unit distance cost of each existing locations are as follows: **(12)**

Location	X-Location	Y-Location	Capacity (Tons)	Cost (Tk/Per Ton Mile)
P1	340	230	45000	230
P2	560	980	65000	340
P3	890	460	85000	120
DC1	100	760	110000	340
DC2	1200	1100	85000	580

Determine the possible location of the central warehouse using center of gravity method if the company wants to save transportation cost.

(b) A manufacturing company produces Product "L". It uses a raw material at the rate of 2 per piece of Product "L". The demands of Product "L" for the last 8 weeks are as follows: 5400, 5320, 5890, 4900, 5020, 5540, 5760, and 5230. The raw material is ordered once a month. The supplier takes 10 days to supply the material. At the beginning of this month, there are 890 units of the raw material on hand. The company wants to ensure that 95% of the time the required amount of raw material should be on hand. How many units should be ordered this month? **(16)**

(c) Mention scheduling and control functions in a production floor. **(7)**

2. (a) Services to the customers are provided in two different workstations. Schedule is developed at the beginning of each week for all the orders coming prior to that. 10 orders need to be scheduled in this week. Service times of each order are as follows: **(15)**

Order	Service Time in Workstation 1(hrs)	Service Time in Workstation 2 (hrs)
A	8.5	3.5
B	12	6.5
C	1.5	9.5
D	3.5	4.5
E	6.5	11.5

Contd P/2

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Contd ... Q. No. 2(a)

Order	Service Time in Workstation 1(hrs)	Service Time in Workstation 2 (hrs)
F	4	6
G	2.5	5.5
H	3	7.5
I	8	10.5
J	2	9.5

Determine the sequence of performing orders, the detailed schedule, and total idle time of the workstations using Johnson's rule.

(b) A spare parts manufacturing company produces product "Y" to be used in automobiles. The company wants to develop an annual production schedule using the following information: **(20)**

Month	1	2	3	4	5	6	7	8	9	10	11	12
D_t	34	45	37	3	87	30	22	56	5	7	23	7
C_t	400	400	410	410	410	390	390	390	400	400	415	415
S_t	12	12	12	15	15	15	125	15	18	18	18	18
h_t	4	4	4	4	4.5	4.5	4.5	4.5	4.5	5	5	5

D_t = Forecasted demand at month t (value is in hundred)

C_t = Unit production cost at month t

S_t = Ordering cost at month t (value is in thousands)

h_t = Per unit per month holding cost at month t

Determine the optional production quantity for each month of the year.

3. (a) Explain capacity management with strategic importance. **(12)**

(b) Differentiate frequent and infrequent capacity expansions. **(8)**

(c) Q Inc. is considering the possibility of building an additional factory that would produce a new edition to its product line. The company is currently considering two options. The first is a small facility that it could build at a cost of \$8 million. If demand for new product is low, the company expects to receive \$12 million revenues with the small facility. On the other hand, if demand is high, it expects \$15 million revenues using the small facility. The second option is to build a large factory at a cost of \$10 million. Were demand to be low, the company would expect \$13 million in revenues with the large plant. If demand is high, the company estimates that the revenues would be \$17 million. For both options, the probability of demand being high is 0.60. Not constructing a new factory would result in no additional revenue. Construct a decision tree for this problem and determine the optional decision. **(15)**

4. (a) Describe the ABC inventory planning model. **(10)**

   (b) A company wants to build a spare parts manufacturing factory. Which type of layout would you suggest and why? **(5)**

   (c) A hardware store packages handyman bags of screws, bolts, nuts and washers. Screws come in 100-lb boxes and cost \$110 each box, bolts come in 100-lb boxes and cost \$150 each box, nuts come in 80-lb boxes and cost \$70 each box, and washers come in 30-lb boxes and cost \$20 each box. The handyman package weighs at least 1 lb and must include, by weight, at least 10% screws and 25% bolts, and at most 15% nuts and 10% washers. To balance the package, the number of bolts cannot exceed the number of nuts or the number of washers. A bolt weighs 10 times as much as a nut and 50 times as much as a washer. Formulate this problem as a linear programming model to minimize the cost of each handyman package. **(20)**

SECTION – B

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

5. (a) A manufacturing firm produces a variety of recreational and leisure products. The production manager has developed an aggregate forecast: **(12)**

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Forecast	50	44	55	60	50	40	51	350

Use the following information to model the aggregate planning problem of the firm as a balanced transportation model.

Regular Production Cost	\$80 per unit
Overtime Production Cost	\$120 per unit
Regular capacity	40 units per month
Overtime capacity	8 units per month
Subcontracting cost	\$140 per unit
Subcontracting capacity	12 units per month
Holding Cost	\$10 per unit per month
Backorder Cost	\$20 per unit per month
Beginning Inventory	0 units

Develop an aggregate plan using regular production strategy. Supplement using inventory, overtime, and subcontracting as needed. No backlogs allowed. Compute the total cost for the plan.

(b) Outline the advantages and disadvantages of the three pure strategies of aggregate planning. **(12)**

(c) Briefly describe the key features of computer integrated production planning and control (CIPPC). **(11)**

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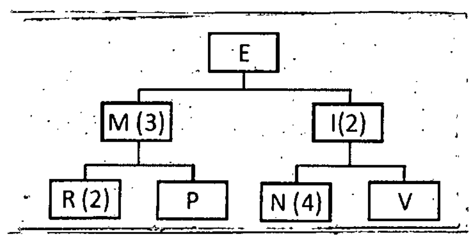
6. (a) What is KPI? Explain some common production KPIs. **(12)**

(b) The product structure tree for end item E follows. The manager wants to know the material requirement for ordered part R that will be needed to complete 120 units of E by the start of week 5. Lead times for items are one week for level 0 items, one week for level 1 items and two weeks for level 2 items. There is a scheduled receipt of 60 units of M at the end of week 1 and 100 units of R at the start of week 1. Lot for lot ordering is used. **(16)**



(c) Differentiate MRP from MRP II. **(7)**

7. (a) In an attempt to increase productivity and reduce costs, Rho Sigma Corporation is planning to install an incentive pay plan in its manufacturing plant. In developing standards for one operation, time-study analysts observed a worker for 30 minutes. During that time the worker completed 42 parts. The analysts rated the worker as producing at 130 percent. The base wage rate of the worker is $5 per hour. The firm has established 15 percent as a fatigue and personal time allowance. **(15)**

(i) What is the normal time for the task?

(ii) What is the standard time for the task?

(iii) If the worker produced 500 units during an eight-hour day, what wages would the worker have earned?

(b) Describe the procedure followed in method study. **(10)**

(c) Briefly discuss the JIT building blocks. **(10)**

8. (a) A company is considering building a new steel plant. Describe different factors that it should consider in choosing a location. **(14)**

(b) Define forward and backward scheduling. How can you compare different scheduling systems? **(4+8=12)**

(c) Explain the factor rating system of selecting location to build a facility. **(9)**

Standard Normal Probabilities

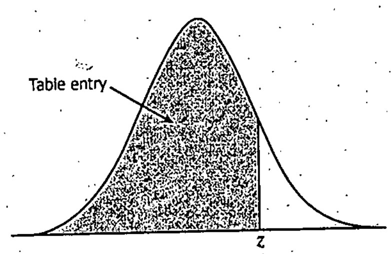


Table entry for z is the area under the standard normal curve to the left of z.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

L-4/T-2/MME **Date : 24/01/2017**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2014-2015

Sub : **MME 467** (Ceramics for Advanced Applications)

Full Marks: 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) Briefly illustrate the structural transformations of $BaTiO_3$ with temperature variations. **(15)**

   (b) Compare and contrast the ferroelectric polarization of single crystal and polycrystalline $BaTiO_3$. **(8)**

   (c) Classify ceramic capacitors based on their properties. **(12)**

2. (a) Discuss the effects of porosity, inclusions and surface flaws on the mechanical properties of ceramic materials. **(25)**

   (b) A sharp edge notch of 120 mm deep is introduced in a thin magnesia plate. The plate is then loaded in tension normal to the plane of the notch. **(10)**

   (i) If the stress is 150 MPa, will the plate survive.

   (ii) Would your answer change if the notch were of the same length but was as internal notch instead of an edge notch.

   [Given K_{IC} = 2.5 MPa $m^{½}$]

3. (a) Structural ceramics (e.g. partially stabilized zirconia) are used for medical implants that experience high loads and extreme wear conditions. Explain the mechanism of transformation toughening phenomena for ceramics containing tetragonal $Z_r\ O_2$. **(15)**

   (b) The relationship between average grain size and yield strength has been given by the Hall-Petch equation, **(10)**

   $$\sigma_{yield} = \sigma_{96} + k/\left(d^{0.5}\right)$$

   what is the yield point for transformation-toughened ZrO_2 with the following physical properties: 96% dense ceramic, σ_{96} = 260 MPa; k = 0.8 MPa $m^{½}$; and d = 4 μm? How does this compare to same material, ZrO_2 made with nanoparticles (grain size = 20 nm)?

   (c) Explain the mechanism of vapor-liquid-solid (VLS) method of whisker growth with neat sketches. **(10)**

4. (a) Elaborate the conditions needed in a hydrothermal process of power synthesis. **(10)**

   (b) Compare the pros and cons of different heat sources in vapor-phase synthesis techniques. **(15)**

   (c) From the different melt-technique processes of growing single crystal, some of them uses crucibles to contain the melt. What are the constraints of using such crucibles for producing the single crystals? **(10)**

Contd P/2

ME 467

SECTION-B

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

5. (a) "Iron-Silicon alloys and ceramic soft ferrites are superior compared to pure Iron for transformer core application" — give reasoning. **(10)**

   (b) Explain the anamoly between theoretical and experimental magnetic moments of $(1-x)NiFe_2O_4 - xZnFe_2O_4; [x = 0.5-1]$ solid solution system. **(20)**

   (c) Write short note on "Magnetic anisotropy". **(5)**

6. (a) What information is conveyed by the term transference number' for ceramic materials? Briefly explain the ionic conduction mechanism for ceramic materials. **(15)**

   (b) Mention the important factors for selecting cathode, anode and electrolyte materials for solid-oxide-fuel cell. **(20)**

7. (a) "Microstructure of Bi_2O_3 based ZnO varistor controls its electrical behavior" — explain. **(18)**

   (b) Why are type II superconductors more suitable than type I superconductors for magnetic levitation applications? **(10)**

   (c) "BCS theory of superconductivity is not applicable for high-temperature superconductors" — explain the statement. **(7)**

8. (a) State the limitations of using ZrO_2 based ceramics for biomedical implants. **(5)**

   (b) Explain different aspects of using bioceramic coatings on biomedical implant substrate. **(15)**

   (c) Briefly discuss about various nanoceramics for biomedical applications. **(15)**

L-4/T-2/MME **Date : 29/01/2017**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2014-2015

Sub : **MME 457** (Powder Metallurgy)

Full Marks: 140 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

1. (a) What is cermet? Narrate in short different types of cermets based on oxides and carbides. **($6\frac{1}{3}$)**

   (b) Describe briefly the manufacturing process of cermets. Mention a few important engineering applications of cermets. **(7)**

   (c) Discuss in detail the various steps for the production of porous bronze bearings. Mention the drawbacks of dry lubricated bearings. **(10)**

2. (a) What are ferrites? Why magnetite, Fe_3O_4 is magnetic? Explain with cation distribution in the spinel sublattice by calculating the net magnetic moment. **(5)**

   (b) Show the flow diagram for the synthesis of ferrites. Calculate the magnetic moment of barium ferrite, $BaFe_{12}O_{19}$ and yttrium garnet, $Y_3Fe_5O_{12}$ showing the cation distribution. Why rare earth cations go to the dodecahedral sites? **($8\frac{1}{3}$)**

   (c) Explain how ferro-fluid from magnetite, Fe_3O_4 nano-scale powders are used in cancer treatment by hyperthermia therapy. Also discuss how these nanoparticles can be functionalized with chemotherapy drugs for targeted drug delivery to cancer cells for more efficient cancer treatment. **(10)**

3. (a) Describe the synthesis process of cerium oxide, CeO_2 nanoparticles. **(6)**

   (b) How nanoceria play a crucial role in the reduction of carbon and other noxous exhaust emissions from diesel engine. Explain in short how nanoceria can act as an antioxidant agent to reduce oxidative stress responsible for human diseases i.e. alzheimer/parkinson as well as aging effect. **(10)**

   (c) Discuss the reversible character of TiO_2 nanoparticles as functional material in thin films for fabricating anti-fogging and self-cleaning surfaces with the manifestation of both hydrophobic and hydrophilic character depending upon the wavelength of light. **($7\frac{1}{3}$)**

4. (a) Write down a few advantages and disadvantages of ceramic nuclear fuel elements. **($3\frac{1}{3}$)**

   (b) Discuss in detail with flow chart the various steps in the processing of ceramic nuclear fuel pellets using uranium oxide, UO_3 or uranium hexafluoride, UF_6 through sol-gel microsphere pelletization process by dry and wet methods. **(15)**

   (c) Write a short note on nuclear reactor spent fuel storage and the possibility of reprocessing them. **(5)**

Contd P/2

MME 457

SECTION-B

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

5. (a) Classify the widely used methods for metal/ceramic powder production. What are the factors that determine the choice of a specific technique for powder production? **(7⅓)**

   (b) Write down the processing steps in powder metallurgy. Why is powder metallurgy becoming increasingly competitive with conventional manufacturing process? **(6**

   (c) What is sintering? Mention the criteria of sintering. Explain the factor that must be controlled to achieve maximum removal of porosity. **(10**

6. (a) Suggest a pressing process that is suitable for making spark plug insulators. Draw figures to show the steps employed for making spark plugs. **(7⅓)**

   (b) What are the factors that promote powdery deposits in electrodeposition? Mention the disadvantages of electroposition methods in powder production. **(10)**

   (c) What is sol-gel technique? Mention the main benefits of sol-gel processing. **(6)**

7. (a) What is cemented carbide? Discuss the production of cemented carbides with flow chart. **(10)**

   (b) With the help of necessary figures, explain the effect of Co content on mechanical properties of WC-Co compositions cemented carbide. **(5)**

   (c) Describe the powder production method used most extensively for producing Fe and Ni powders. **(8⅓)**

8. (a) Briefly explain mechanical alloying. Mention its unique application. **(4)**

   (b) Describe the sponge iron powder production with the help of a flow sheet. **(7)**

   (c) What is atomization? Mention its advantages. Compare gas atomization and water atomization in respect of atomizing media, powder characteristics, economy and process energy efficiency. **(12⅓)**

L-4/T-2/MME **Date : 04/02/2017**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-2 B. Sc. Engineering Examinations 2014-2015

Sub : **MME 445** (Metallic Alloys and Materials Selection)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

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

Chart should be attached to the answer script if used.

1. (a) Define materials index. Explain how a material index is developed and used in the materials selection process. **(20)**

(b) The mid-point deflection δ of a spherical shell (Fig. 1) of diameter 2a and thickness *t* under a load W applied over a small central, circular area can be described as **(15)**

$$\delta = A \frac{W a}{E t^2}\left(1 - \nu^2\right)$$

in which A ≈ 0.35 is a constant and ν is Poisson's ratio, which is also almost the same for all structural materials and can be treated as a constant. Derive the material index for the shell with a prescribed stiffness S = W/δ and of minimum mass. Once the material index is determined, select the top three candidate materials for this spherical shell.

2. (a) Using helmet visor as an example, discuss the stages of material selection process. **(15)**

(b) It is sometimes suggested that architects live in the past; that in the 21st Century they should be building with fiberglass (GFRP), aluminum alloys and stainless steel. Consider the possibility of replacing wooden or concrete column (Fig. 2) of a building with AA 6061 aluminium alloys or AISI 304 stainless steel. The table below summarizes the needs. **(20)**

Function	Column
Constraints	Must not fail by compressive crushing
	Must not buckle
	Height H and compressive load F specified
Objective	Minimise material cost C
Free variables	Diameter D
	Choice of material

Data for the four candidates for the column are listed below. Use these to identify the best candidate material when $F = 10^5$ N and H = 3 m.

Material	Density, ρ (kg/m^3)	Unit Cost, C_m (\$/kg)	Modulus, M (MPa)	Compressive Strength, σ_c (MPa)
Wood	700	0.50	10,000	25
Poured concrete	2300	0.08	20,000	13
AA 6061-T6 Al-alloy	2700	4.45	69,000	155
AISI 304 Stainless steel	7850	1.00	200,000	250

Contd P/2

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3. (a) In strength-limited applications, deflection is acceptable provided the component does not fail; strength is the active constraint. Starting by listing the function, the objective and the constraints of the problem, derive the material index for selecting materials for a beam of length L, specified strength and minimum weight (Fig. 3). For simplicity, assume the beam to have a solid square cross-section t × t. The failure load of a beam is given by the equation **(15)**

$$F_f = \frac{I\,\sigma_f}{y_m\,L}$$

where y_m = distance between the neutral axis of the beam and its outer filament, σ_f = failure stress, and $I = t^4/12$ (= $A^2/12$) = the second moment area.

(b) Compressed air cylinder (Fig. 4) used for braking and other power-actuated systems in trucks are usually made of low carbon steel, and they are heavy. The task is to explore the potential of alternative materials for lighter air tanks, recognizing the there must be a trade-off between mass and cost – if it is too expensive, the truck owner will not want it even if it is lighter. The table summarizes the design requirements.

Function	Air cylinder for truck
Constraints	Must not fail by yielding
	Diameter 2R and length L specified
Objective	Minimise mass m
	Minimise material cost C
Free variables	Wall thickness t
	Choice of material

(i) Show that the mass and material cost of the tank relative to one made of low-carbon steel are given by **(10)**

$$\frac{m}{m_0} = \left(\frac{\rho}{\sigma_y}\right)\left(\frac{\sigma_{y,0}}{\rho_o}\right)$$

$$\frac{C}{C_o} = \left(\frac{C_m\,\rho}{\sigma_y}\right)\left(\frac{\sigma_{y,0}}{C_{m,0}\,\rho_0}\right)$$

where ρ is the density, σ_y the yield strength and C_m the cost per kg of the material, and the subscript "0" indicates values for mild steel.

(ii) Explore the trade-off between relative cost and relative mass, considering the replacement of a low carbon steel tank with one made, first, of low alloy steel, and, second, one made of filament-wound CFRP, using a relative exchange constant α^* for 1 and 100 and the material properties in the table below: **(10)**

Material	Density, ρ (kg/m^3)	Yield Strength, σ_y (MPa)	Price/kg, C_m (\$/kg)
Low carbon steel	7850	314	0.66
Low alloy steel	7850	775	0.85
CFRP	1550	760	42.1

Contd P/3

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4. (a) Calculate the change in structural efficiency for both bending stiffness and strength when a solid flat panel of unit area and thickness t is foamed to give a foam panel of unit area and thickness h, at constant mass. The modulus E and strength σ_f of foams scale with relative density ρ/ρ_s as **(16)**

$$E = \left(\frac{\rho}{\rho_s}\right)^2 E_s \qquad \text{and} \qquad \sigma_f = \left(\frac{\rho}{\rho_s}\right)^{3/2} \sigma_{f,s}$$

(b) Figure 5 shows a concept for a lightweight display stand. The stalk must support a mass m of 100 kg, to be placed on its upper surface at a height h, without failing by elastic buckling. The buckling load for a slender column of height h is given as

$$F_{cr} = \frac{n^2 \pi^2 E I}{h^2}$$

It is to be made of stock tubing and must be as light as possible.

(i) Derive a material index for the tubular material of the stand that meets these requirements, and that includes the shape of the section, described by the shape factor $\Phi_B^e = 12\, I / A^2$, where I is the second moment of area and A is the section area. The table summarizes the requirements: **(10)**

Function	Light weight column
Constraints	Specified buckling load, F
	Specified height, h
Objective	Minimum mass m
Free variables	Choice of material
	Choice of section and shape

(ii) Cylindrical tubing is available from stock in the following materials and sizes. Use this information and the material index to identify the best stock material for the column of the stand. **(9)**

Material	E (GPa)	ρ (kg/m³)	r (mm)	t/r ratio
Al-alloys	70	2700	25	0.20
Steels	210	7900	30	0.10
Polycarbonate	3	1200	20	0.30

Contd P/4

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SECTION – B

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

5. (a) You have been assigned the following task. **(17½)**

"A device is required to allow access to a typical liquid in a corked bottle with convenience, at modest cost, and without contaminating the liquid"

Using the design flow chart, discuss how you can provide a few solutions, and provide a summary of function structure.

(b) There are several holes in material-property charts. What you can achieve by developing new materials for these regions. Give examples of achievements of two new materials with reference to neatly drawn schematic material-property charts. **(17½)**

6. (a) Non-heat treatable aluminium alloys cannot be strengthened by ageing. Suggest suitable alternate methods for increasing strengths in these alloys, with short descriptions. **(15)**

(b) What are the reasons for modification of shape of silicon (primary or eutectic) phase in aluminium alloys? How can you modify this structure? **(5)**

(c) Write a short note on rare earth containing magnesium alloys. **(5)**

(d) What is the working principle of shape memory alloys? **(10)**

7. (a) Explain how micro-alloying elements in HSLA steels contribute in strengthening. **(20)**

(b) Briefly discuss how adding of nickel tends to modify microstructure of stainless steels from ferritic to austenitic via duplex structure. **(15)**

8. (a) For manufacturing a turbine blade in jet engine, what types of alloys are most appropriate? Write down their common characteristics, and explain with neat sketches of microstructure how creep resistance is obtained. **(15)**

(b) How addition of alloying elements modify microstructure of titanium to obtain different types of titanium alloys? **(12)**

(c) Describe the hydrogen embrittlement effect in titanium alloys. **(8)**

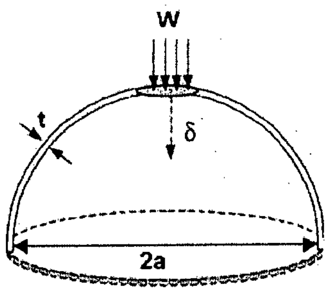


Fig. 1 for Q. 1(b)

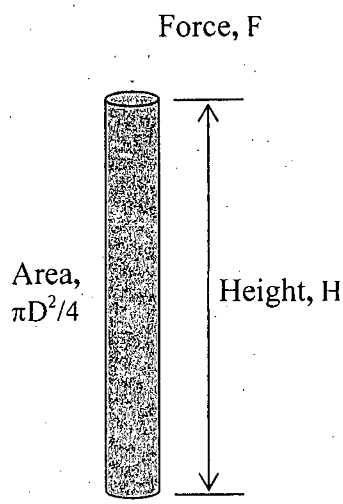


Fig. 2 for Q. 2(b)

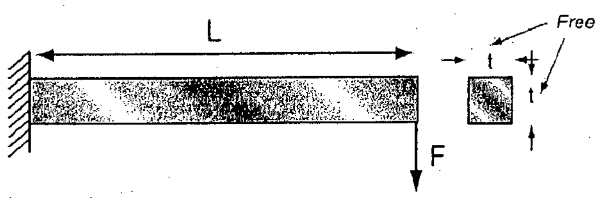


Fig. 3 for Q. 3(a)

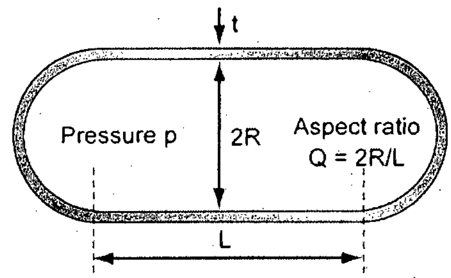


Fig. 4 for Q. 3(b)

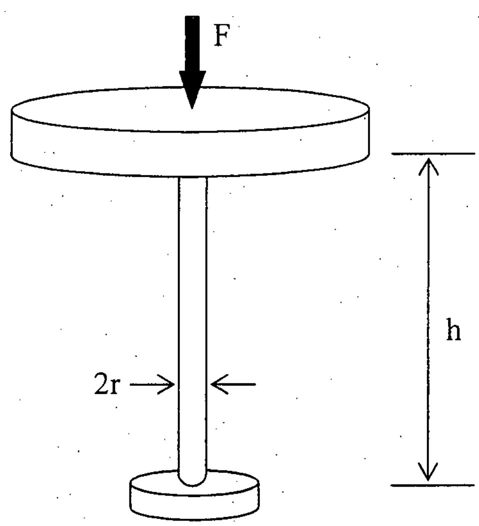
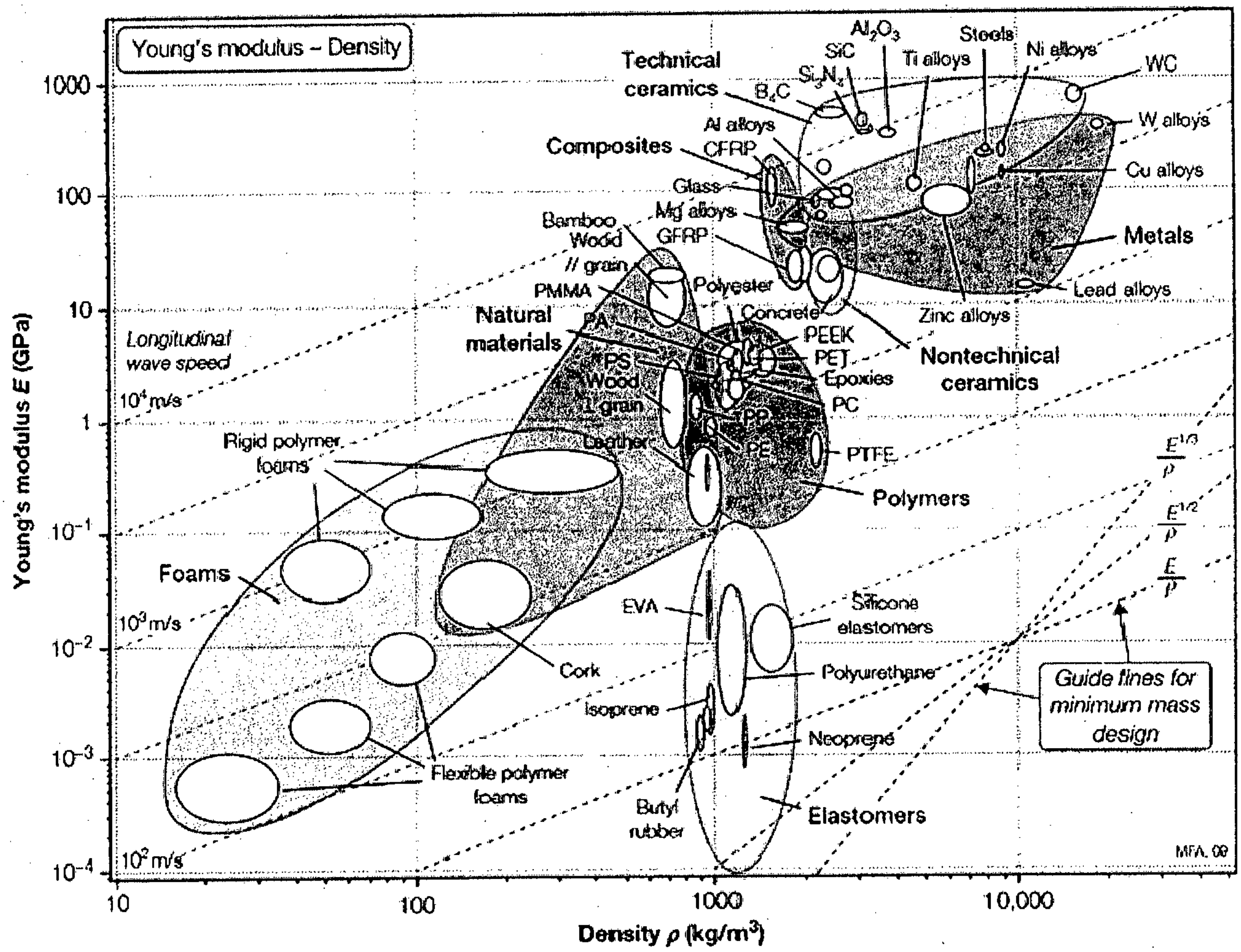


Fig. 5 for Q. 4(b)



Modulus – Density Chart of Materials