L-3/T-1/MME

Date: ~~31/03/2024~~ 13/5/2024

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **MME 301** (Metal Casting and Powder Processes)

Full Marks: 280 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 **Q. No. 1** and any **TWO** questions from the rest.

1. A large foundry in Bangladesh needs to produce 100 heavy duty gears from nodular cast iron per day. They took plan to produce nodular cast iron gear having 260 mm outer diameter, 19 mm face width and 1200 teeth. As an engineer, design an appropriate process technique for casting gear by considering melting, moulding, pouring and cleaning. **($46\frac{2}{3}$)**

2. (a) Differentiate between sand moulding and non-sand moulding methods of casting. **($20\frac{2}{3}$)**

(b) Alloy steel cylinders are to be cast. Determine the dimensions of the core print and chaplet area. Given that: **(14)**

Dimension of core (mm): Length = 400; internal dia = 225

Density (g/cm^3): Steel = 7.87; core sand = 1.68

Compressive strength (kg/cm^2): Core sand = 2.5; chaplet = 2.9

Factor of safety = 5

(c) Which process do you recommend for the production of spherical aluminium powder to be used in making mechanical parts? Explain the process. **(12)**

3. (a) You are appointed as an engineer to start a new production line of nickel alloy jet engines used in aerospace engineering. Choose the appropriate methods of production line starting from powder production to net-shaped jet engine by powder metallurgy technique. **($30\frac{2}{3}$)**

(b) Analyse the factors that are considered to design mould gating and feeding systems for casting a copper alloy component. **(16)**

4. (a) Contrast graphitization behaviour of grey cast iron and malleable cast iron that occur during solidification and correlate graphite morphology with the mechanical properties of both the cast irons. **($20\frac{2}{3}$)**

Contd P/2

MME 301

Contd... Q. No. 4

(b) Requirement of cast iron spout composition is C = 3.55%, Si = 2.10% and Mn = 0.75%. Foundry returns and pig iron to be used are 45% and 10% of the charge respectively. Si loss would be 10%, Mn loss would be 15% and C gain would be 20% of the charge respectively. Determine the charge make up for 1000 kg of charge. Composition of the charge materials are: **(12)**

Material	C	Si	Mn
Cast iron scrap	3.40	1.80	0.60
Steel	0.15	0.20	0.65
Pig iron	4.09	2.08	0.80
Foundry returns	3.55	2.20	0.75
Mn briquets	0	0	67.0
FeSi briquets	0	48.0	0

(c) You are requested to set up a cupola furnace for the production of grey cast iron. Among common metallic charges, choose one that would be the most suitable for Bangladesh with proper justification. **(14)**

SECTION – B

There are **FOUR** questions in this section. Answer **Q. No. 5** and any **TWO** questions from the rest.

Question No. **5** is **Compulsory.**

5. Answer all questions. **(80)**

(a) Obtain the relation for Chvorinov's rule and using this rule determine the most effective shape of a feeder.

(b) Analyse the influence of different types of defects on yield strength and ductility of cast materials.

(c) Give a comparative account of the characteristic differences, advantages, and limitations of unpressurised and naturally pressurised gating systems.

(d) Why do you prefer fine-grained equiaxed structure in castings? Discuss how an ingot structure consists entirely of fine-grained equiaxed crystals can be developed.

6. Obtain a relation between the free energy changes required for homogeneous and heterogeneous nucleation and then, using the relation, determine why oxides are not good nuclei for nucleation of solids but nitrides are. **(30)**

Contd P/3

7. Grey iron castings (see Fig. 1) are to be cast using greensand system with a flask height of 40 cm. With a yield not less than 75 percent, design an appropriate naturally pressurised gating system for this casting. Assume reasonable value for any missing data. List all basis and assumptions you made during the design. After design, sketch the 2D diagram of the mould layout showing the position of the casting and the gating system. **(30)**

Empirical formulae for pouring time (in seconds) calculations for grey iron castings are given below.

(i) For castings weights > 1000 lbs:

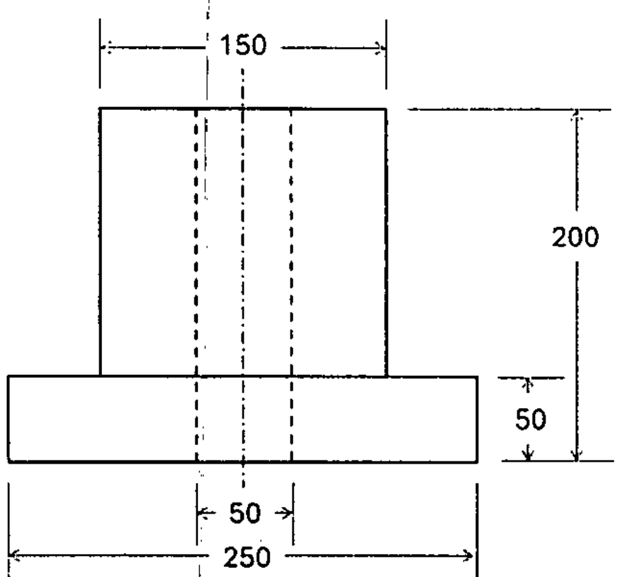
$$t = k\left(0.95 + \frac{T}{0.853}\right)W^{1/3}$$

(ii) For casting weights < 1000 lbs:

$$t = k\left(0.95 + \frac{T}{0.853}\right)\sqrt{W}$$

where, k is a fluidity factor (obtainable from the Fig. 2) = Fluidity (from figure) / 40; T is the average thickness of casting, inch, and W = weight of liquid metal poured, pound.

8. A cylindrical feeder is to be placed on top of a square plate casting having each side 10 in and thickness 0.75 in. The length of the cylinder is to be 1.5 times its diameter. If the casting alloy is Al-7Si-0.3Mg with density 2.70 g/cc and volume co-efficient of thermal expansion 7.0%, and the mould constant 16.0 min/in^2, determine the dimensions of the feeder so that it will take 40% longer for the feeder to solidify. **(30)**



Grey iron composition: C=3.8, Si=2.5, P=06 wt.%
Density: 7.15 g/cc
Moulding system: Greensand
Pouring temperature: 1380 °C

Figure 1 for Q.#7: All dimensions are in mm.

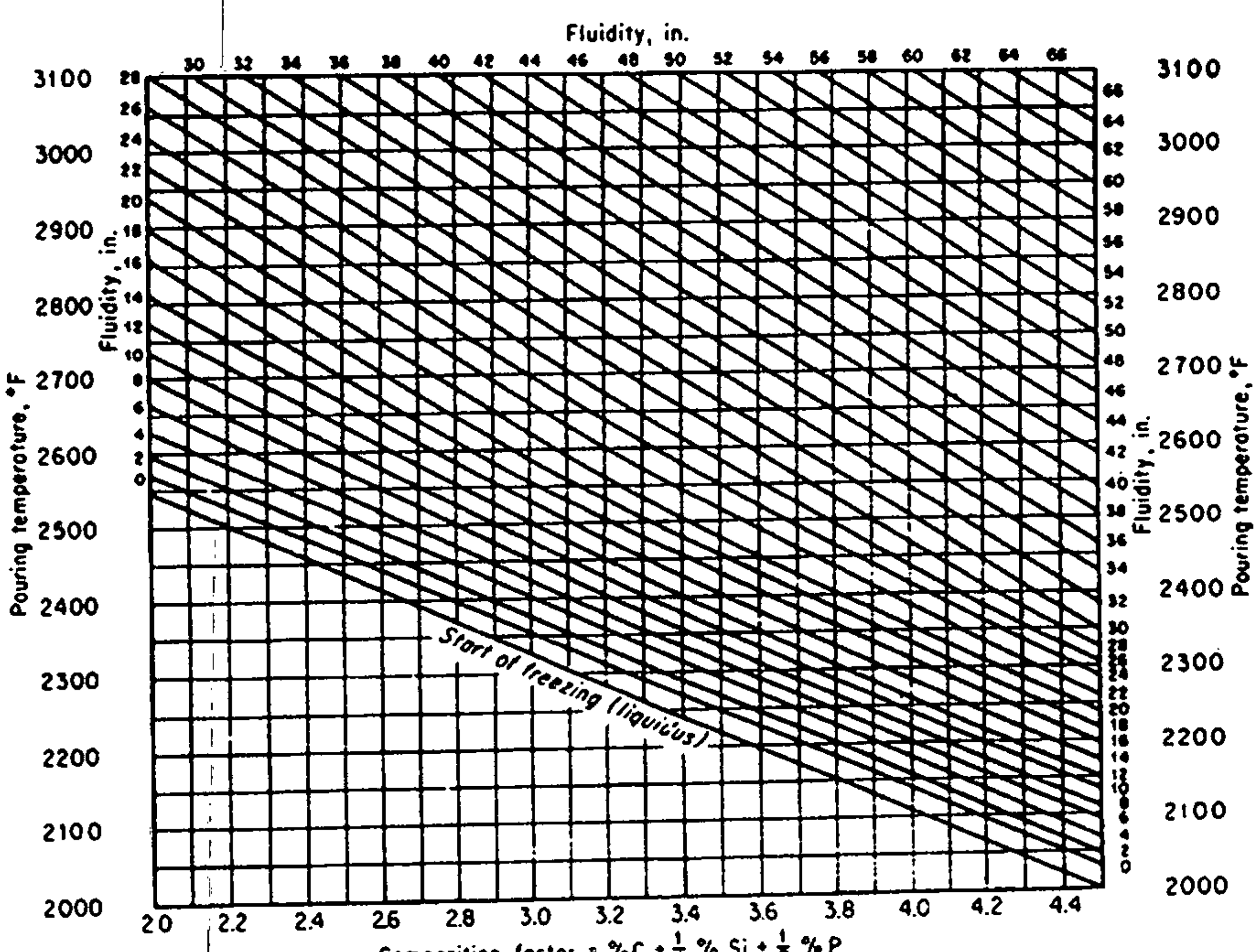


Fig. 2 for Q.#7: Fluidity related to pouring temperature and composition of grey cast iron.

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **MME 311** (Electrical, Optical and Magnetic Properties of Materials)

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) The band structure represents the energy levels of solids, and it is often used to determine whether a material is a conductor, semiconductor, or insulator. Schematically show band structure of metals, semiconductors, and insulators. Differentiate between two different types of band structures of metals with examples. Explain how band of silicon is formed and electrons fill those orbitals sequentially. **(20)**

   (b) Semiconductors are materials which have a conductivity between conductors (generally metals) and non-conductors or insulators (such as most ceramics). Semiconductors can be pure elements, such as silicon or germanium, or compounds such as gallium arsenide or cadmium selenide. These semiconductors can be either intrinsic or extrinsic type. Distinguish between intrinsic and extrinsic semiconductors with neat sketch of their band structures. Also, locate the fermi levels for different types of extrinsic semiconductors. Explain their differential conduction behaviour (using carrier concentration) with increasing temperature. **(15)**

2. (a) Antireflection coatings minimize the reflection of one or many wavelengths and are typically used on the surface of lenses so that less light is lost. Examine the working mechanism of antireflection coating. Briefly discuss few advantages of using this type of coating. Explain how anti-reflection quality can be improved by using hybrid materials. **(20)**

   (b) Define refractive index and explain the factors that can control the values of refractive index of materials. With example show how reflectance at interface can be calculated from refractive index values of two different materials. **(15)**

3. (a) Draw transmission spectra for crystalline insulator and semiconductor. Assess the detail shape of the curves to understand the phenomena observed. Analyse the spectra extending from UV to infrared zone. **(20)**

   (b) With neat sketches explain the two mechanisms: (i) double exchange and (ii) super exchange. Also, briefly discuss when we need these two mechanisms to explain the behaviour of magnetic materials. **(15)**

4. (a) Give an example of inverse-spinel structure. Discuss the structure in detail to show the evolution of magnetism from this structure. At least show the two different types of one-eighth-unit cell of inverse-spinel structure. **(20)**

Contd P/2

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Contd.......Q. No. 4

(b) Differentiate among five major types of magnetic materials by distinguishing among the mechanism. Use necessary sketches to illustrate the magnetic behaviour of each type of material. **(15)**

SECTION – B

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

5\. (a) Germanium (Ge) has the same crystal structure as silicon (Si), but its band gap is 0.67eV. If the total density of states in the conduction band (N_c) and in the valence band (N_v) are the same in Ge as they are for Si (E_g=1.12 eV, n_i=10^{10} cm^{-3}), what value of n_i would you expect for Ge at 300K? Equation for n_i is given below; **(20)**

$$n_i = (N_c N_v)^{1/2} \exp(-E_g / 2kT)$$

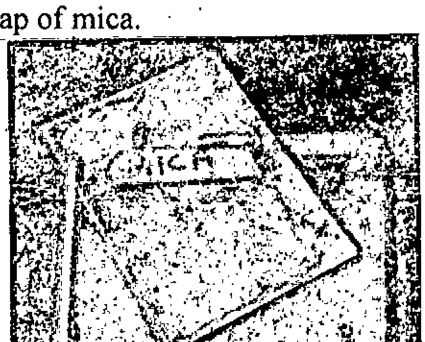
(b) The intrinsic carrier density of a semiconductor is 2.1×10^{19} m^{-3}. The electron and hole mobilities are 0.2 and 0.1 $m^2v^{-1}s^{-1}$ respectively. Calculate the conductivity. **(15)**

6\. (a) What happens to the particle ground state energy and wavefunction in an one-dimensional box if the length of the box doubles from L to 2L? **(15)**

(b) Make a calculated comment on the difference between particle eigen energies for an one-dimensional box with L=L and L=2L. In which case, are the energy levels more discrete? **(20)**

7\. (a) Is BCS theory applicable to high temperature superconductivity? Explain why? **(15)**

(b) Mica is a group of minerals with layered crystal structures that are visibly transparent. Below is a photo (in greyscale) of a sample of mica, with the label visible from underneath. Is mica a metal, semiconductor, or insulator? Make an educated guess for the band gap of mica. **(20)**



8\. (a) Using E-K plots show how the curvature of the bands affect the effective mass of electrons and holes. **(20)**

(b) Can Si be used for making LEDs? If so, explain your answer and if not, suggest an alternate material. **(15)**

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-3/T-1 B. Sc. Engineering Examinations 2022-2023

Sub: **MME 313** (Mechanical Behaviour of Materials)

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 **ALL** of the questions.

Symbols have their usual meaning.

1. For the following state of stress, determine the principal normal stresses, the principal axes and the principal shear stresses: $\sigma_x = 100$, $\sigma_y = -60$, $\sigma_z = 40$, $\tau_{xy} = 80$, $\tau_{yz} = \tau_{zx} = 0$ MPa. Also, determine the maximum normal stress and the maximum shear stress. Employ Mohr' Circle. **($26\frac{1}{4}$)**

OR,

In a plane stress condition for a thin plate, assume a point 'O'. Determine the state of stress at point 'O'. Consider two dimensions only. Find out the normal stresses and shear stresses. A cast iron pipe with closed ends has a wall thickness of 10 mm and an inner diameter of 0.60 m. It is filled with argon gas at 20 MPa pressure and is subjected to a torque about its long axis of 1200 kN.m. Determine the three principal normal stresses and the maximum shear stress. Neglect any effects of the discontinuity associated with the end closure. You may use Figure 1, Figure 2, and Table 1, if needed. **($10+16\frac{1}{4}=26\frac{1}{4}$)**

2. First, let's examine what occurs when a piece of ductile metal – a metal that flows easily and may undergo significant plastic deformations – is loaded. Examples of such metals are pure copper and mild steel at or above room temperature. A substantial load on the material might cause a fracture to initiate at the crack. Examining the metal's surfaces after breaking it (Figure 3) reveals that the fracture surface is incredibly rough, suggesting significant plastic work has occurred.

The above statement was your opening statement in a factory presentation where you work as a materials engineer. You were explaining why a steel bolt failed early by fast fracture using a plastic zone, r_y, developed before the crack and σ_{local} and K_c. Figure 3 raised some questions about the failure mode: ductile tearing or cleavage. At this point, one of your directors asked you to differentiate between ductile tearing and cleavage fracture. How would you clarify the topic for the audience? You shall draw schematic plots showing crack length 2c, r and σ_{local}. You shall also show the expression for r_y. **($26\frac{1}{4}$)**

OR,

For fast fracture, derive $K=K_c$. Now, evaluate the following statement: "Once a crack has

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Contd ... Q. No. 2(OR)

developed, the relative severity of the stress concentration can be reduced by drilling a hole through the crack tip". You should incorporate K_t and derivation of Inglish (1913) in your discussion. **$(10+16\frac{1}{4}=26\frac{1}{4})$**

3. Assume you are still working as a materials engineer in the ultra-high carbon steel plant. Most of your materials are brittle. You are investigating the premature failure of razor blades, made in your plant. As part of your work, you asked your lab to prepare and conduct a tensile test, and also send you microstructure of the failed surface. They emailed you the microstructure as shown in Figure 4. Are the images representative of your ultra-high carbon steel materials? Judge your answer.
Considering the responsibilities of the lab, you sent a memo for punishment for the personnel involved. The higher authority asked you why the micrographs were not suitable. They also asked why the micrographs were different (left image and right image). You decided to defend your action starting with the failure micro-mechanisms involved to obtain the shape of the micrographs. Prepare your statement accordingly. **$(26\frac{1}{4})$**

OR,

(a) "If you can increase surface energy, breaking stress increases." How does this statement help in mining operations and how can you establish this statement? Develop your answer based on Jofee Effect. **(10)**

(b) Two flat plates are being pulled in tension. (See Figure 5). The flow stress of the materials is 150 MPa. **(8)**

(i) Calculate the maximum stresses in the plate.

(ii) Will the material flow plastically?

(iii) For which configuration is the stress higher?

(c) The stress intensity for a partial-through thickness flaw is given by $K = \sigma\sqrt{\pi a}\sqrt{\sec \pi a/2t}$ where, a is the depth of penetration of flaw through a wall thickness t. If the flaw is 5 mm deep in a wall 12 mm thick, determine whether the wall will support a stress of 172 MPa if it is made from Ti-6Al-4V titanium alloy. You may use Table 2. **$(8\frac{1}{4})$**

4. (a) A microalloyed steel was subjected to two fatigue tests at ±400 MPa and ±250 MPa. Failure occurred after 2×10^4 and 1.2×10^6 cycles, respectively, at these two stress levels. Making appropriate assumptions, estimate the fatigue life at ±300 MPa of a part made from this steel that has already undergone 2.5×10^4 cycles at ±350 MPa. Use Palmgren-Miner's rule. **(10)**

(b) How does a fatigue crack grow by a striation mechanism? Construct your answer for a plain carbon steel. Draw necessary illustrations, highlighting the three stages of crack propagation in terms of microstructure. **$(16\frac{1}{4})$**

Contd P/3

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Contd ... Q. No. 4

OR.

(a) Draw the schematic of crack propagation rate da/dN versus alternating stress intensity factor ΔK. Inspect the plot and provide some significance of this plot. **(10)**

(b) Superposition of elastic and plastic curves to give the fatigue life in terms of total strain is shown in Figure 6. How do you construct this plot? Organise your answer based on Basquin relationship, Manson-Coffin relationship and stress-strain loop. **(8)**

(c) Consider long crack propagation under fatigue. Develop an expression for the number of cycles, ΔN, required for a crack to grow from an initial length a_i to a final length a_f. Given that $K = Y\Delta\sigma\sqrt{\pi a}$ and $\frac{da}{dN} = C\Delta K^m$, where the symbols have their usual significance. **($8\frac{1}{4}$)**

SECTION - B

There are **FOUR** questions in this section. Answer any **THREE**.
Assume reasonable value for any missing data.

5. (a) A typical creep curve has 3 stages. Explain the mechanisms involved that lead to change from one stage to another stage having different creep rates. **(12)**

(b) "More recently, the jet engine turbine blades have been produced by superalloys in single crystal form. The single crystal (SC) materials not only manifest better creep resistance, but they are also superior in terms of thermal fatigue resistance." – Analyze how SC superalloys serve the expected life requirement of jet engine in real service condition. **(18)**

(c) A solder joint between a computer chip and a printed circuit board is typically subjected to shear due to thermal expansion differences. For optical communication devices (those use LASERS to transmit information), dimensional stability is critical otherwise the components will lose alignment. A crude approximation of a circuit board, solder joint, and connector is shown in Figure 7 with the shear load indicated by arrows. The critical joint is 0.5 mm thick, 2 mm wide and 4 mm long. If the component is designed to last for 5 years under ordinary use, which is likely to be more important solder data: steady state creep rate or rupture life? Give reasoning to your answer. **(5)**

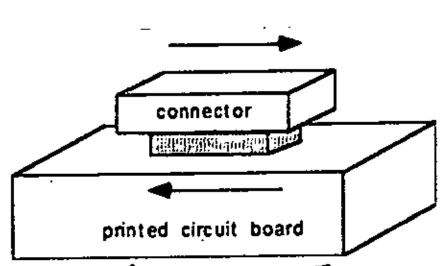

Figure 7 for Question 5(c)

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6. (a) Dislocations significantly contribute in plastic deformation mechanism of metals and alloys through the process 'slip'. The slip process, therefore, is particularly important in understanding the mechanical behaviour of metals and alloys. – Justify with examples. **(15)**

(b) Until 25 years ago or so, you could get frequent changing of incandescent light bulbs they had to be replaced so often. The addition of very low melting point element, potassium (MP_K = 64°C; VP_K = 773°C), to the tungsten filament of the incandescent light bulbs operates very successfully at temperatures of 2500°C or higher and is so much better now. – Explain the reason with necessary diagram/(s). **(20)**

7. (a) Three cylindrically shaped tensile samples, each 12 mm in diameter, were machined from three different spherically shaped single crystals. Samples A and B yielded with applied loads of 77.1 and 56 N, respectively. Does the difference in load level indicate that the crystals possessed different strength levels? Also, what load level would be necessary to cause sample C to deform and what is the controlling stress for yielding? Following data are given, where **(15)**

φ = angle between loading axis and normal to slip plane

λ = angle between loading axis and slip direction

F = force acting on crystal when yielding begins

Sample	φ	λ	F (newtons)
A	70.5	29	77.1
B	64	23	56
C	13	78	?

(b) The aluminium-zinc-magnesium alloy was used in the Comet aircraft. After facing a number of accidents (material failure), the TEM micrograph clearly shows the "precipitate-free zones" along both sides of the boundary. Explain which type of material failure occurred and why this was resulted. **(13)**

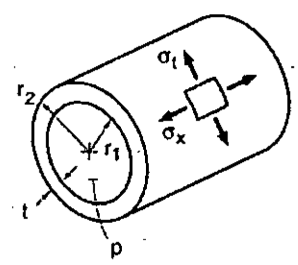
(c) The addition of carbon to iron greatly increases the room temperature strength of steel, but an equal amount of carbon added to silver has little effect. – Explain why. **(7)**

8. (a) What is the difference between an intrinsic and an extrinsic strengthening mechanism, and on which type do metal matrix composites depend? **(15)**

(b) Explain what the Larson-Miller parameter is used for and what assumption underlies the form of the expression that makes this parameter useful. **(8)**

(c) For a certain high temperature alloy, failure was reported after 4100 hrs. at 680°C when subjected to a stress level of 270 MPa. If the same stress was applied at 750°C, how long would the sample be expected to last? State any assumption(s) you must make to allow you to make this determination. **(12)**

(a)



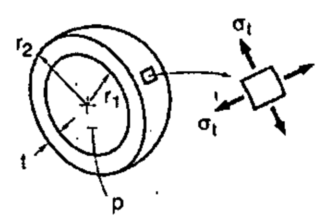
$\sigma_t = \dfrac{pr_1}{t}, \quad \sigma_x = \dfrac{pr_1}{2t}$

$(\sigma_x = 0$, open ends)

$\sigma_r = -p$ (inside)

$\sigma_r = 0$ (outside)

(b)



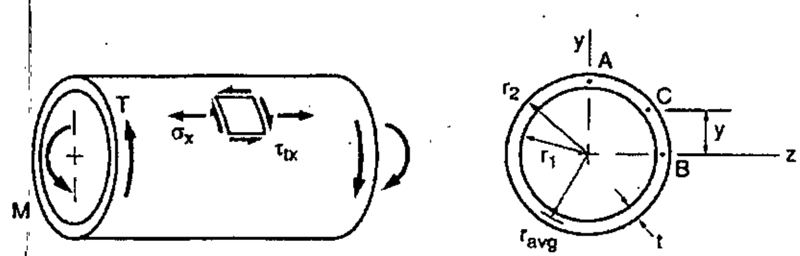
$\sigma_t = \dfrac{pr_1}{2t}$

$\sigma_r = -p$ (inside)

$\sigma_r = 0$ (outside)

Figure A.7 Approximate stresses in thin-walled pressure vessels, (a) tubular and (b) spherical. For (a), the approximations are within 5% for $t/r_1 < 0.1$, and 10% for $t/r_1 < 0.2$. For (b), they are within 5% for $t/r_1 < 0.3$, and 10% for $t/r_1 < 0.45$.

Figure 1 for Question 1



$\tau_{tx} = \dfrac{T}{2\pi r_{avg}^2 t}, \quad \sigma_x = \dfrac{My}{\pi r_{avg}^3 t}, \quad \sigma_{xA} = \dfrac{M}{\pi r_{avg}^2 t}, \quad \sigma_{xB} = 0$

Figure A.8 Approximate stresses in thin-walled tubes due to torsion and/or bending. These approximations are within 5% for $t/r_1 < 0.1$, and 10% for $t/r_1 < 0.25$.

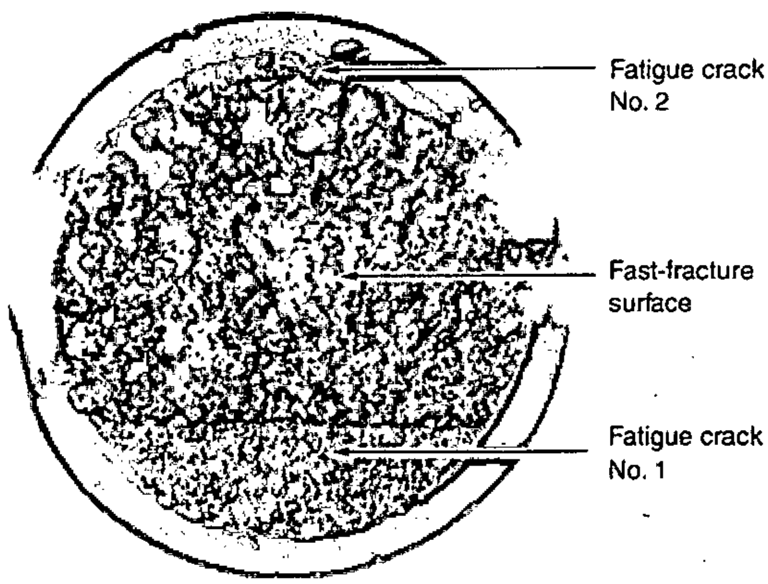
Figure 2 for Question 1

Table 1 for Question 1

Table 4.2 Tensile Properties for Some Engineering Metals

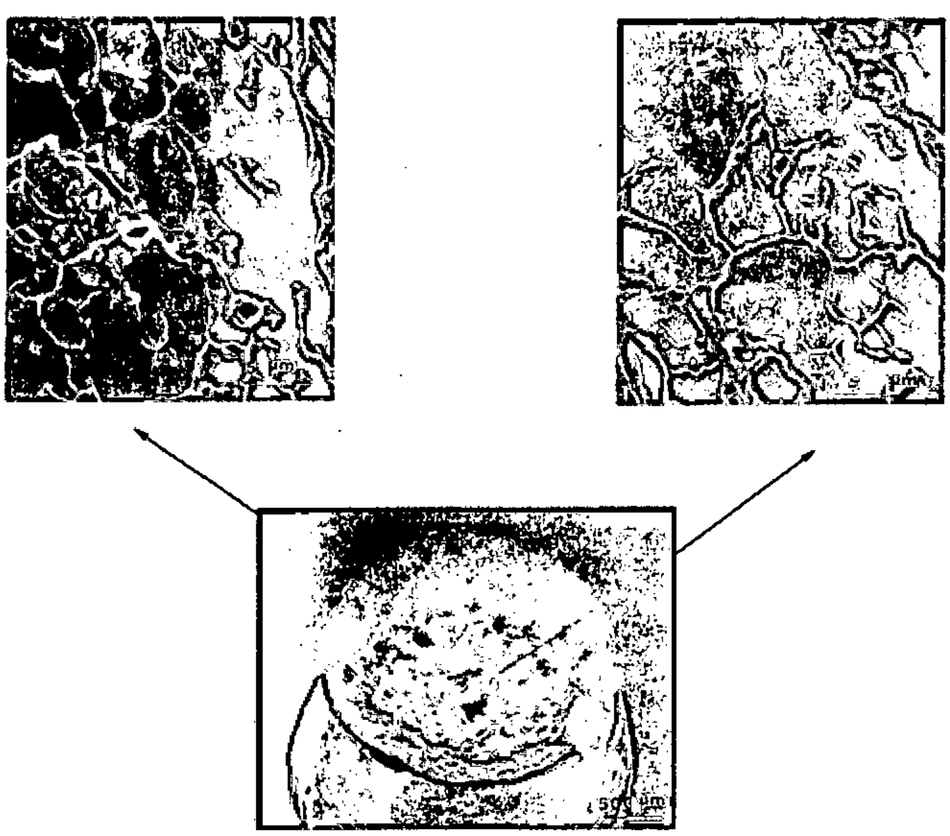
Material	Elastic Modulus E	0.2% Yield Strength σ_o	Ultimate Strength σ_u	Elongation[1] $100\varepsilon_f$	Reduction in Area $\%RA$
	GPa (10^3 ksi)	MPa (ksi)	MPa (ksi)	%	%
Ductile cast iron A536 (65-45-12)	159 (23)	334 (49)	448 (65)	15	19.8
AISI 1020 steel as rolled	203 (29.4)	260 (37.7)	441 (64)	36	61
ASTM A514, T1 structural steel	208 (30.2)	724 (105)	807 (117)	20	66
AISI 4142 steel as quenched	200 (29)	1619 (235)	2450 (355)	6	6
AISI 4142 steel 205°C temper	207 (30)	1688 (245)	2240 (325)	8	27
AISI 4142 steel 370°C temper	207 (30)	1584 (230)	1757 (255)	11	42
AISI 4142 steel 450°C temper	207 (30)	1378 (200)	1413 (205)	14	48
18 Ni maraging steel (250)	186 (27)	1791 (260)	1860 (270)	8	56
SAE 308 cast aluminum	70 (10.2)	169 (25)	229 (33)	0.9	1.5
2024-T4 aluminum	73.1 (10.6)	303 (44)	476 (69)	20	35
7075-T6 aluminum	71 (10.3)	469 (68)	578 (84)	11	33
AZ91C-T6 cast magnesium	40 (5.87)	113 (16)	137 (20)	0.4	0.4

Note: [1]Typical values from [Boyer 85] are listed in most cases.
Sources: Data in [Conle 84] and [SAE 89].



A steel bolt

Figure 3 for Question 2



Scanning electron micrographs at low magnification (centre) and high magnification (right and left) of AISI 1008 steel specimen ruptured in tension.

Figure 4 for Question 3

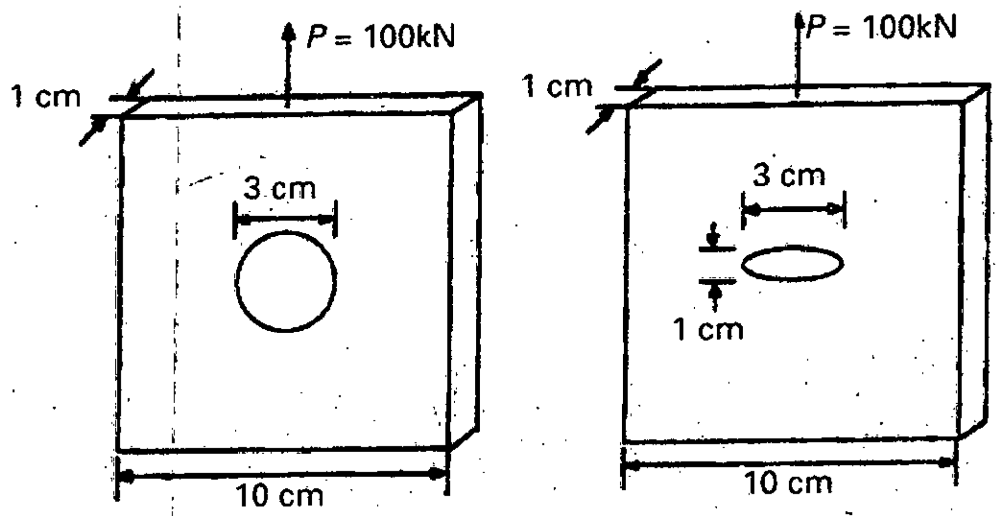


Figure 5 for Question 3

Table 2 for Question 3

Table 5-3 Typical values of K_{Ic}. Dieter.

Material	Yield strength, MPa	Fracture toughness K_{Ic} MPa $m^{1/2}$
4340 steel	1470	46
Maraging steel	1730	90
Ti-6Al-4V	900	57
2024-T3 Al alloy	385	26
7075-T6 Al alloy	500	24

Fig. 14.5 Superposition of elastic and plastic curves gives the fatigue life in terms of total strain. (Adapted with permission from R. W. Landgraf, in *American Society for Testing and Materials, Special Technical Publication* (ASTM STP) 467 (Philadelphia: ASTM, 1970), p. 3.)

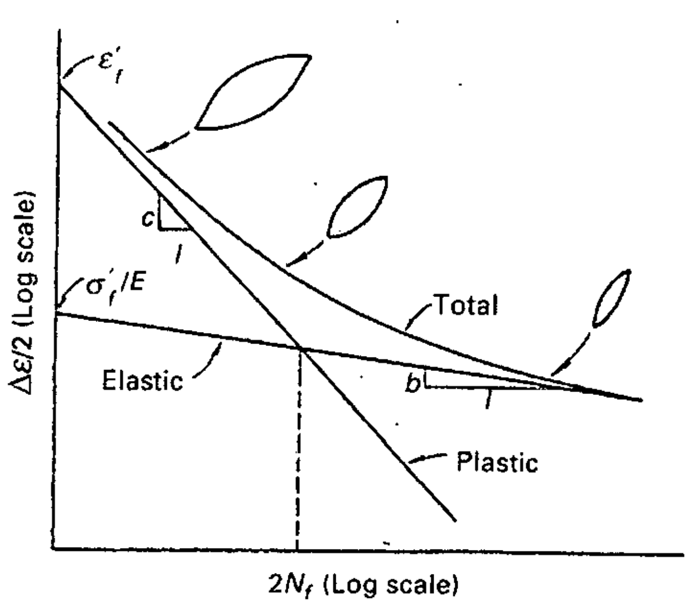


Figure 6 for Question 4