INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR
Mid-Spring Semester 2016-17

Date of Examination : 15th Feb, 2017 **Session:** AN **Duration:** 2 hrs **Total Marks:** 60

Subject No.: ME30602 **Subject Name :** Design of Machine Elements

Department/Center/School : Mechanical Engineering

Note: Question paper consists of two parts. **Answer any three out of four questions in each part**. Each question carriers 10 marks. Make any assumptions necessary, however, state your assumptions clearly. Answer legibly. Highlight the answers. Questions will not be entertained by invigilators during the exam.

PART A - Answer any three out of following four questions

Q 1) Match the following. For each application shown in left column below, select suitable material from the list of materials given in right column (see the matching done for first application, do the same for rest).

1. Roller bearing raceways	A. Polycarbonate
2. Gears	B. Teflon
3. Outdoor water tanks	C. SS 304
4. Automobile head lamps	D. Silicon carbide
5. Journal bearings	E. Yttria stabilized zirconia
6. Heating elements in high temperature furnaces	F. AISI 52100
7. Thermal barrier coatings on gas turbine blades	G. Ti-6Al-4V
8. Heat exchangers	H. Copper
9. Knee implants	I. AISI 1080
10. Hand saw blades	J. High density polyethyelene (HDPE)
11. Cutlery	K. AISI 4340

Q 2) The bending moment a machine element is subjected to, is known with an uncertainty of 15%. In experiments, the bending moment that causes failure of the element is seen to lie between 200±40 N·m. Find the design factor and the maximum allowable bending moment for this element, accounting for uncertainties. Take the loss-of-function bending moment as 200 N·m.

160 × 0.85

⇒ 1.47 ≃

Q 3) State whether the following statements are TRUE or FALSE

(a) For ductile materials, yield strength is different from ultimate strength (T)
(b) Strength is a material property, whereas stress is not (T)
(c) Effect of stress concentration due to notches can be ignored for brittle materials (F)
(d) Maximum principal stress is identical to maximum normal stress that can act on any plane passing through the point (T)
(e) E/ρ (where E is the Youngs modulus of a material and ρ its density) must be minimized when the aim is to minimize the weight of a beam with square section, subjected to bending. (T)
(f) In Euler-Bernoulli beam theory, planes perpendicular to neutral axis, before deformation, are taken to remain planar and perpendicular to neutral axis even after deformation (T)
(g) Superposition principle can be used for linear as well as non-linear material behavior (F)
(h) In a circular bar subjected to torsion, resulting shear stress is constant along the radius (T)
(i) Hardness of a material has a significant effect on beam deflections even for elastic deformations (F)
(j) Three elastic constants are needed to fully describe the linear elastic behavior of isotropic materials (T)

Q 4) A circular rod needs to support an axial load of 500 kN in an application. The dimensions of the rod should be such that the stress in the rod is below the yield strength of the material.

Estimate the *minimum* mass per unit length of the rod, needed to support the stated axial load without yielding, for each of the materials listed in Table 1. Which material results in the lowest mass per unit length needed to support the stated load?

List of Materials	Young's Modulus (GPa)	Yield Strength (Mpa)	Density (kg/m^3)
1020 CD steel	205	390	7860
4140 Q&T at 425°C	205	1140	7860
Ti-6Al-4V	114	850	4460
AA 2017-O	70	70	2790
Tungsten	406	750	19300

Table 1

PART B - Answer any three out of following four questions

Q 5) A cantilever beam of solid circular cross-section with diameter d and length 300 mm is subjected to a transverse load of 5 kN at its tip (free end). It is also subjected to a torque, along its axis, of 2 kN.m. Determine the diameter d of the beam if the requirement is to have a factor of safety of 2.5 against yielding. Use Mises yield criterion. The material for the beam is AISI 1030 annealed steel with yield strength of 320 MPa.

Q 6) Consider a cantilever beam of length L of solid square cross-section that is loaded with a transverse force F at its tip. The following materials are being considered for the beam: Tungsten carbide, AISI 1095 high-carbon heat treated steel, 7075 aluminum alloy and polycarbonate. Using the data provided in Table 2, recommend the best material for minimizing the weight of the bar, for a design in which failure occurs by exceeding the strength of the material.

List of Materials	Young's Modulus (GPa)	Yield Strength (MPa)	Density (kg/m³)
Tungsten carbide	600	370 in Tension, 3350 in Compression	15200
AISI 1095, Q&T at 315°C	205	765	7860
AA 7075 T6	70	540	2700
Polycarbonate	13.5	120	1270

Table 2

Q7 A spherical ball of mass m is dropped from height h above a circular bar of diameter d and length L as shown in Figure 1. Estimate the maximum force exterted by the ball on circular bar if the ball were to be dropped exactly along the axis of the bar. Take bar to be made of AISI 1095 steel (see Table 2). Assume that the material behavior of the bar remains purely elastic during the entire event.

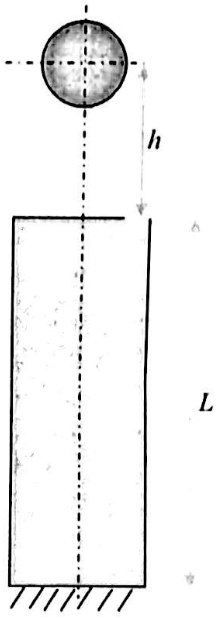

Figure 1

Q8 The connecting-link shown in Figure 2 is subject to an axial force F = 80 kN. It has a thickness t and the other dimensions are a = 60 mm, b = 90 mm, r = 6 mm, and hole diameter d = 20 mm.

Identify the critical locations in the link. Further, determine the minimum thickness of the link needed to have a factor of safety of at least 3 against yielding. Take yield strength of link material as 360 MPa. Charts for getting the required stress concentration factors are given in Figures A-15-1 and A-15-5.

3.086

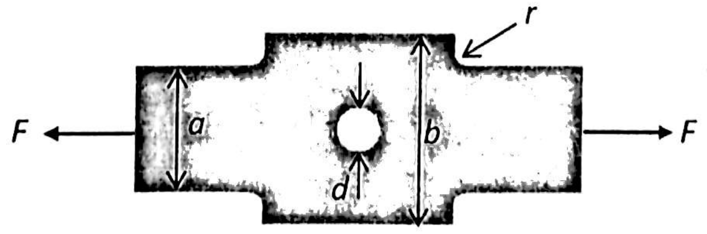

Figure 2

Figure A-15-1

Bar in tension or simple compression with a transverse hole. $\sigma_0 = F/A$, where $A = (w - d)t$ and t is the thickness.

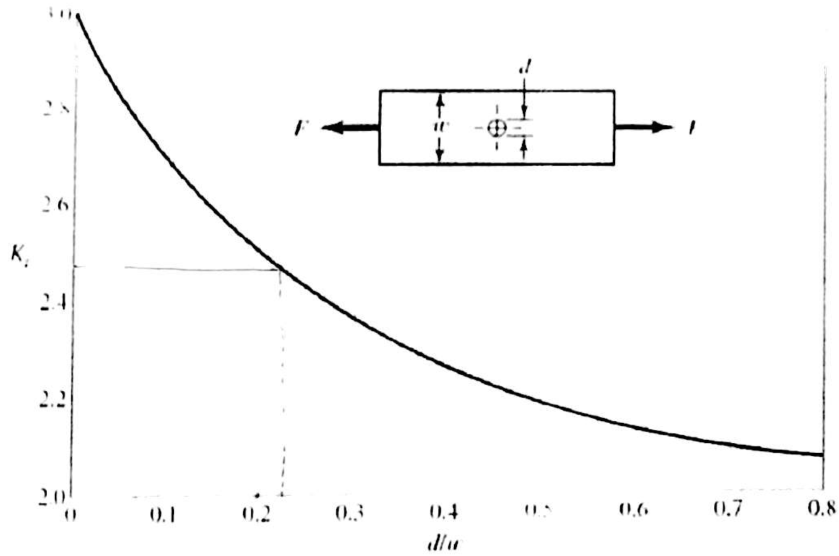

Figure A-15-5

Rectangular filleted bar in tension or simple compression. $\sigma_0 = F/A$, where $A = dt$ and t is the thickness.