B.E. MECHANICAL ENGINEERING SECOND YEAR SECOND SEMESTER EXAM 2025

DESIGN OF MACHINE ELEMENTS - 1

Time: **Three hours** Full Marks: **100**

Missing data, if any, are to be reasonably chosen.
Different parts of a question must be answered together. Give sketches wherever applicable.

Section – A (10 × 4 = 40)

1. Justify the following statement: (Answer Any **5**)

(*a*) Stress concentration factors may not be required at all for ductile materials under static loading, but stress concentration factors must be used for brittle materials subjected to static loads. [02]

(*b*) The taper of the cotter is provided on one side only. [02]

(*c*) Maximum Shear Stress theory always predicts a factor of safety equal to or less than the Distortion Energy theory. [02]

(*d*) For design under general fluctuating stresses, modified Goodman diagram is a better option than the Goodman diagram. [02]

(*e*) Machining of cast components should be minimized. [02]

(*f*) Forged component should be provided with an adequate draft. [02]

2. A solid shaft transmits 22.5 kW power at 720 rpm and it is simultaneously subjected to a bending moment of 350 N-m. The shaft is made of plain carbon steel (S_{ut} = 650 N/mm^2, S_{yt} = 380 N/mm^2). The shaft has a keyway for mounting of a pulley. Estimate a suitable diameter for the shaft following ASME Code. Consider, k_b = 1.5 and k_t = 1.0. [10]

3. (*a*) Explain the role and significance of material selection in the context of design. [03]

(*b*) Define the following material properties: Ductility and Malleability. [03]

(*c*) Write a short note on manufacturing aspects of design. [04]

4. Define slenderness ratio of a column and write down its expression. Explain what is meant by critical slenderness ratio. Discuss the design principle for columns against buckling with appropriate schematic representation of the design curve. [03+02+05]

Section – B (Answer either Q5 or Q6 and the rest: 15 × 3 = 45)

5. (*a*) What do you understand by fatigue failure? Describe the differences between static and fatigue failure. [03]

(*b*) A machine component is subjected to completely reversed bending stresses at a critical location. The details of the stress cycles are as follows – [12]

(*i*) σ_{max} = 175 N/mm^2, σ_{min} = - 175 N/mm^2 (for 30% of time)

(*ii*) σ_{max} = 350 N/mm^2, σ_{min} = - 350 N/mm^2 (for 50% of time)

(*iii*) σ_{max} = 125 N/mm^2, σ_{min} = - 125 N/mm^2 (for 20% of time)

The material (S_{ut} = 650 N/mm^2, S_{yt} = 380 N/mm^2.) has a corrected endurance limit of 160 N/mm^2. Determine the life of the component.

Or

6. (*a*) A flat plate with machined surface made of mild steel 45C8 (S_{ut} = 630 N/mm^2) is shown in Figure Q6. It is subjected to fluctuating axial forces as shown in the figure. Determine the modified endurance limit for the component following Marin Equation using suitable charts and tables as provided at the end of the question paper. Consider 90% reliability and a size factor of 0.85. Notch sensitivity factor can be taken as 0.8. [05]

[Turn over

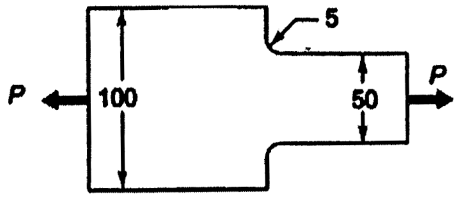

Figure Q6

(b) A machine component is subjected to fluctuating stresses that varies from 50 to 120 N/mm^2. The corrected endurance limit for the machine component is 285 N/mm^2, whereas, the ultimate tensile strength and yield strength of the material are 625 N/mm^2 and 465 N/mm^2, respectively. Find the factor of safety using the following: (i). Soderberg Line, (ii). Goodman Line and (iii). Gerber Line. [10]

7. A knuckle joint is used to connect two mild steel rods under a tensile load of 90 kN. The yield strength of the material is 400 N/mm^2. Yield strength in compression can be considered as 1.5 times the yield strength in tension. Factor of safety for fork and eye is 2.5, whereas factor of safety for knuckle pin is 2.0. Design the different parts of the joint. [15]

8. (a) Describe the significance of failure theories in design. [03]
(b) A circular beam, having a diameter of 20 mm and length 100 mm, is simultaneously subjected to a transverse bending moment of 55 N-m and a torsional moment of 75 N-m. The material of the beam has a yield point strength in tension of 350 MPa, Ultimate tensile strength of 585 MPa and Poisson's ratio of 0.3. Calculate the factor of safety based upon maximum shear stress theory, maximum principal strain theory and distortion energy theory. [12]

Section – C

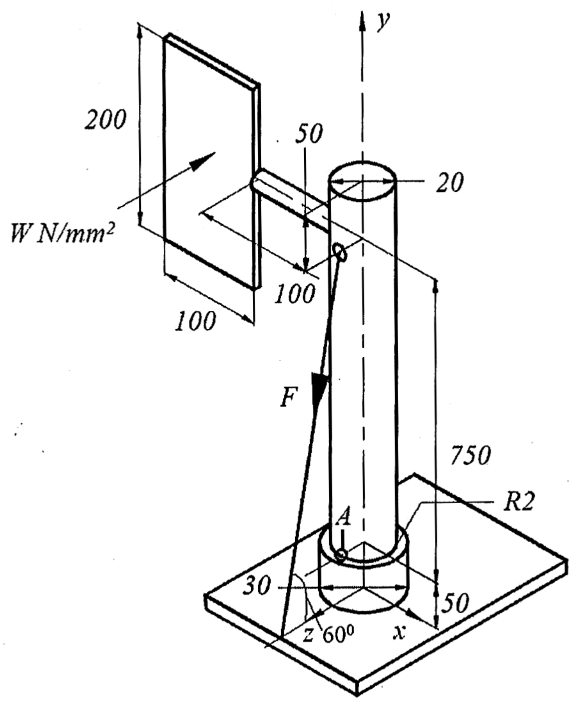

Figure Q9

9. Figure Q9 (dimensions are not to scale and all the dimensions are in mm) shows a vertical post with circular cross-section (diameter 20 mm and the larger diameter near the base is 30 mm). There is a circular rod (can be considered as rigid and unlikely to fail) that projects horizontally near the top end of the post and carries an advertising board. Maximum pressure applied on the board by wind is 0.0125 N/mm^2. There is also a wire (attached from near the top of the post to the ground) that is provided as support and tension along the wire is given by 100 N. The wire makes an angle of 60^0 with the ground. The material of the post has an ultimate tensile strength of 490 MPa, tensile yield strength of 420 MPa and a percentage elongation at failure of 18%.

(*i*). What type of stresses are developed at point A as shown in the Figure?

(*ii*). Calculate the values of the different types of stresses at point A.

(*iii*). Obtain the value of Factor of Safety at point A according to an appropriate failure theory. [03+06+06]

Relevant Data, Charts and Tables for Design:

Standard Shaft Diameters: 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 25, 28, 30, 32, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85 ...

Table 1: Relationship between endurance limit (S'_e) and ultimate strength (S_{ut}) for different materials under rotating beam test

Material	Endurance Limit (S'_e)
Steel	$0.5S_{ut}$
Cast iron and cast steel	$0.4S_{ut}$
Wrought Aluminium alloys	$0.4S_{ut}$
Cast Aluminium alloys	$0.3S_{ut}$

Table 2: Surface Finish Modification Factor

Surface Finish	Factor *a*	Exponent *b*
Ground	1.58	-0.085
Machined or Cold Drawn	4.51	-0.265
Hot Rolled	57.7	-0.718
Forged	272	-0.995

Table 3: Size Modification Factor

Diameter (d)	k_b
$d \le 7.50$	1.00
$7.5 < d \le 50$	0.85
$50 < d$	0.75

Table 4: Reliability Factor

Reliability (%)	Reliability Factor
50	1.000
90	0.897
95	0.868
99	0.814
99.9	0.753
99.99	0.702

Load Modification Factor

k_c = 1.00 (Bending)
= 0.85 (Axial)
= 0.59 (Torsion)

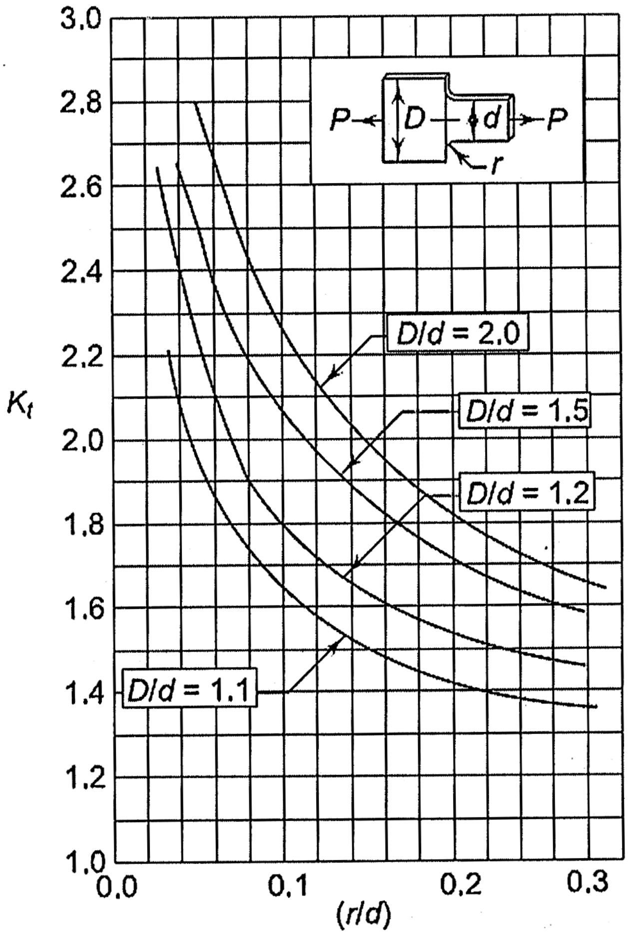

Chart 1: Rectangular filleted bar in tension or simple compression.