B.E. (Mechanical) Part III 5th Semester Examination, 2011
Design of Machine Elements – I
(ME – 501)

Time : 3 hours | Full Marks: 70

Use separate answer scripts for each half.
Answer any **SIX** questions, taking **THREE** from each half.
The questions are of equal value.
Assume any other data that may be necessary.

FIRST HALF

1. (a) Define endurance strength of materials.
   (b) Draw a neat sketch of modified Goodman diagram. What is the significance of this diagram?
   (c) A steel alloy has an ultimate tensile strength of 650 MPa, yield tensile strength of 450 MPa and endurance strength of 250 MPa under the reversed bending. Find the fatigue strength for the released type of loading by the geometrical method using the above modified Goodman diagram. Find the minimum stress, σ_{min} and mean stress, σ_m when the fatigue strength under the fluctuating type of loading becomes equal to the yield strength of the above alloy steel.

2. (a) Mention only various factors that affect the endurance strength of materials.
   (b) A hot rolled rotating steel shaft is subjected to an applied bending moment at a critical section that varies from 360 N-m to 180 N-m. A key way is present at the critical section, for which the fatigue stress concentration factor in bending may be taken as 1.5. The shaft is made of 40C8 steel for which the ultimate tensile strength is 600 MPa and the yield strength in tension is 450 MPa. Find the safe diameter of shaft for an infinite life using a factor of safety as 2.0. Assume the reliability of fatigue life of shaft as 90% for safe operation. Use two iterations of calculation to get solution.
   For hot rolled surface finish, a = 57.7 MPa, b = -0.718, a and b having usual meanings. Take reliability factor, K_r = 0.897 for 90% reliability of expected life.

3. (a) Deduce the generalized expression for strain, ε of any linear element at a point in space in terms of six strain components.
   (b) If the displacement field is given by $u_x = kxy$, $u_y = kxy$, $u_z = 2kz(x + y)$, where k is a constant small enough to ensure applicability of the small deformation theory,
   (i) determine the strain matrix.
   (ii) What is the strain, ε in the direction, $n_x = n_y = n_z = \dfrac{1}{\sqrt{3}}$?

4. (a) What are the advantages of V – belt drive?
   How do you designate a V – belt having a selected profile as per IS code, citing an example?
   (b) Explain the designation of a bolt having a fine thread as per IS code.
   (c) A bracket is fastened to a column by 6 bolts of identical size as shown in Fig. 1. A load of 48 KN acts on the bracket at a distance of 220 mm from the centre of gravity, G of the group of bolts. If the permissible shear stress for the bolt material is 80 MPa, determine the diameter of bolts. Assuming the course thread of bolts, show the result as per IS code.

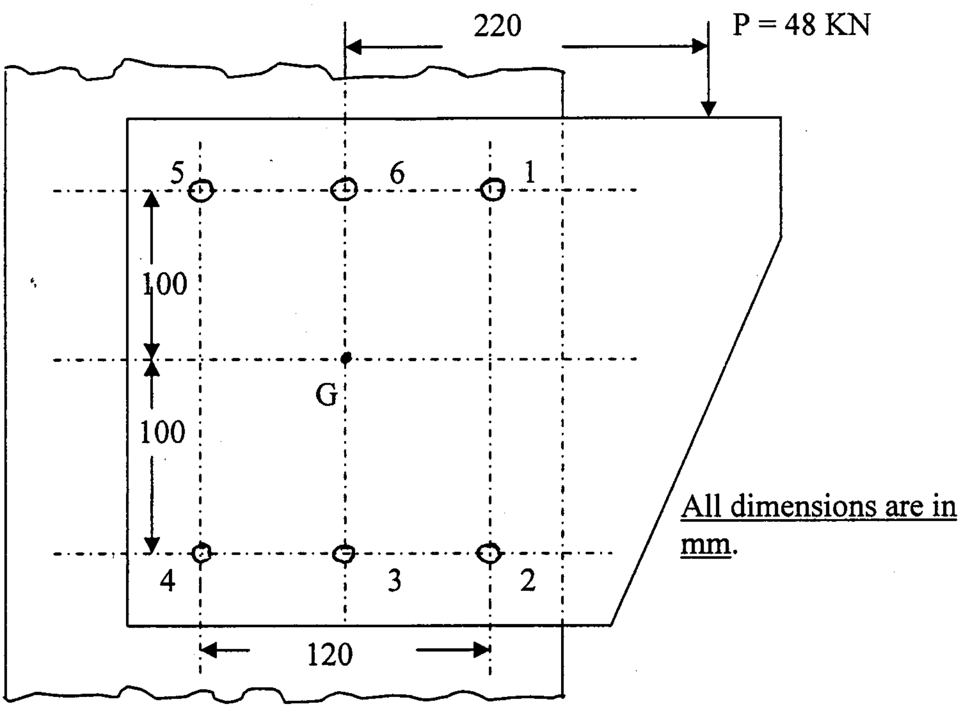

Fig. 1: Bolted Bracket

5. (a) Establish the expression for the stiffness of a fastened member in the grip of a bolt using the pressure cone method with a constant cone angle. What is the gasket factor?

(b) The dimensions of a gasketed pressure vessel joint shown in Fig. 2 are: A = 140 mm, B = 180 mm, C = 28 mm, t = 4 mm and F = 240 mm. The connection between a cylinder head and a gasketed pressure vessel is made by a number of cap screws of nominal diameter of 16 mm. The pressure vessel is used to store gas at a static pressure of 8 MPa. A leak proof seal can be obtained if the average gasket pressure is at least 14 MPa. For cap screws, A_t = 160 mm^2, E_c = 210 GPa, S_p = 600 MPa, S_{yt} = 660 MPa. The gasket is made of asbestos for which E_g is 480 MPa. Assuming a load-multiplication factor as 2, determine –

(i) stiffness of cap screws and that of the connecting parts of the pressure vessel

(ii) screwed joint stiffness constant

(iii) no. of cap screws required for developing necessary gasket pressure

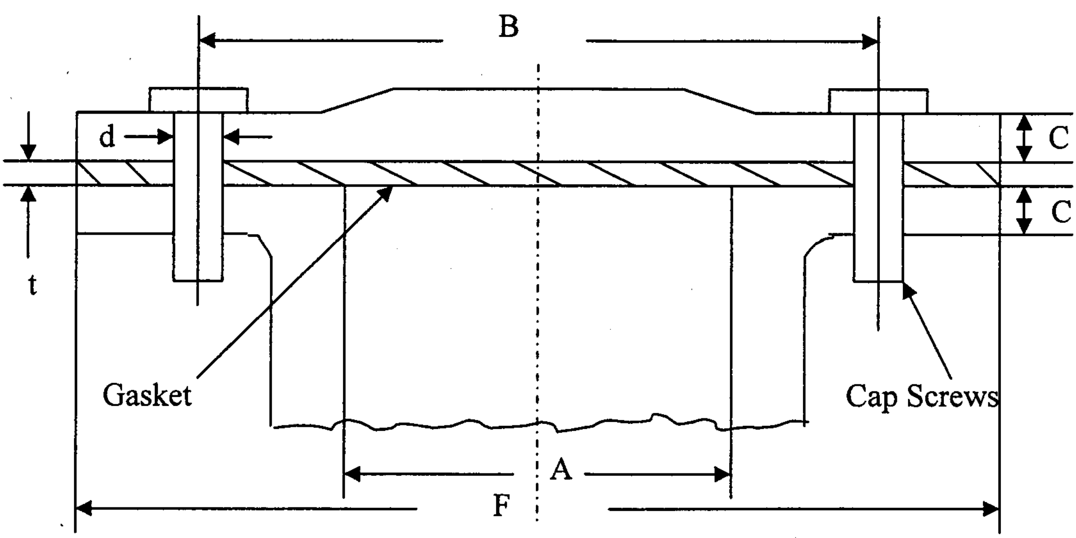

Fig. 2 : Pressure Vessel

SECOND HALF

6.(a) Define the critical speed of a shaft. Write Rayleigh-Ritz equation for finding the first critical speed of a shaft.

(b) Three pulleys, A, B and C are mounted on a simply supported shaft of 3 m span; at a distance of 1 m, 1.5 m and 2.0 m respectively from the left bearing as shown in Fig. 3. The diameters of pulleys, A, B, C are 500, 700 and 350 mm respectively. An electric motor supplies 15 kW power to the shaft at A, and machines take 9 kW power from B, and 6 kW power from C. A horizontal drive is arranged for A; the drive B is vertically downwards, and the drive from C is at 45° to the drive A, and in a downward direction. The speed of the shaft is 240 r. p. m. The shaft is made of plain carbon steel 40C8 (S_{ut} = 650 N/mm^2 and S_{yt}= 380 N/mm^2). The pulleys are keyed to the shaft. Determine the diameter of the shaft according to the ASME code, if K_b = 1.5 & K_t = 1.0
Assume angle of lap on each pulleys as 180° and coefficient of friction between the belts and pulleys as 0.3.

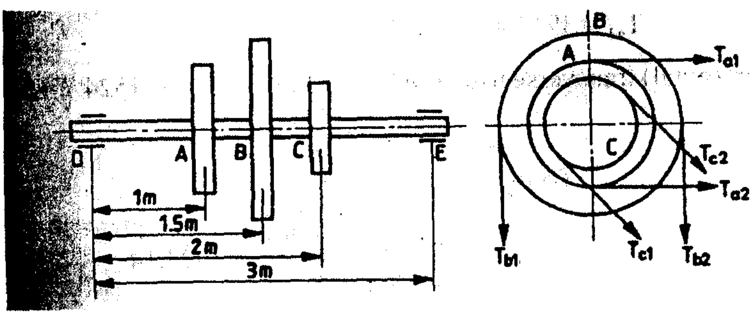

Fig. 3

7.(a) The valve-spring used in operating the exhaust valve, requires a pre-compression (P_{min}) to close the valve and a maximum compression (P_{max}) to open the valve completely.
To have minimum weight of the valve spring, find the relationship between P_{min} and P_{max}.
Neglect the effect of inactive coils.

(b) A concentric spring consists of two helical compression springs one inside the other. The free length of the outer spring is 15 mm greater than that of the inner spring. The wire diameter and mean coil diameter of the inner spring are 4.5 and 27 mm respectively. Also, the wire diameter and mean coil diameter of the outer spring are 6.5 and 39 mm respectively. The numbers of active coils in the inner and outer springs are 8 and 10 respectively. Assume same material for two springs and the modulus of rigidity of spring material is 81370 N/mm^2. The composite spring is subjected to a maximum axial force

1000 N. Calculate: (i) the compression of each spring; (ii) the force transmitted by each spring; and (iii) the maximum torsional shear stress induced in each spring.

8.(a) What is the objective of nipping of leaf spring? Find the expressions of the initial nip for equalization of stresses of a given leaf spring and stresses in all leaves.

(b) A semi-elliptic spring used for automobile suspension, consists of two extra full-length leaves and eight graduate-length leaves, including the master leaf. The centre-to-centre distance between the two eyes is 1 m. The leaves are made of alloyed steel (S_{yt} = 1500 N/mm^2 and E = 207000 N/mm^2) and the factor of safety is 2. The maximum spring load is 30 kN. The leaves are pre-stressed so as to equalize stresses in all leaves under maximum load. Determine the dimensions of the cross-section of the leaves and the deflection at the end of the spring.

9. (a) Write the names of six main theories of failures and their applicability to ductile & brittle materials.

(b) What is Distortion Energy Theory? From the first principle, derive the expression of failure criterion due to distortion energy. Draw the boundary for distortion energy theory under biaxial stresses & show also the boundaries of maximum principal stress theory and maximum shear stress theory under same condition.

10. Write short notes on the followings:

(i) Spring materials
(ii) Surge in helical springs
(iii) Torsional & lateral rigidity of a shaft
(iv) Woodruff key and its application
(v) Shear and compressive stresses developed in Kennedy key for a given transmission of torque
(vi) Rigid & Flexible couplings.