B.E. (ME) Part – III 5th Semester Examination, 2012
Design of Machine Element – I
(ME – 501)

Time: 3 hours **Full Marks: 70**

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

FIRST HALF

1. (a) Define 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
   $u_x = kx(y+z)$, $u_y = ky(z+x)$ and $u_z = kz(x+y)$
   where , k is a constant small enough to ensure applicability of small deformation theory, determine the strain matrix. What is the strain, ε in the direction $n_x = n_y = n_z = \frac{1}{\sqrt{3}}$?
2. (a) Define the 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 630 MPa, yield tensile strength of 450 MPa and endurance strength of 210 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.

3. (a) How do you estimate the size factor, K_b of a rotating member having a major dimension, d under the variable loading? How is it estimated if the member is stationary?
   (b) A hot rolled steel shaft is subjected to an applied bending moment at a critical section that varies from 400 N-m to 200 N-m. A key-way is present at the critical section for which the fatigue stress concentration factor in bending may be taken as 1.4. The shaft is made of 40C8 steel for which the ultimate tensile strength is 630 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 obtain solution.
   For the 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.

4. (a) How do you designate a V-belt having a selected profile as per IS Code, citing an example?

(b) A V-belt drive is to transmit 12 kW to an industrial fan. The motor speed is 2400 rpm and the fan runs at 800 rpm. The centre distance between the pulleys is approximately 1600 mm. The service factor may be taken as 1.5. The overall slip of the drive is 2%. The belt pitch length can be obtained from the following formula: -

$$L_p = 2C + 3.1416\left(\frac{D+d}{2}\right) + \frac{(D+d)^2}{4C}$$

The following data may be assumed:

(i) arc of contact factor = 0.975 (ii) belt length correction factor = 1.04

(iii) maximum power rating of a 'C' section belt = 5.83 kW per belt at a speed of 21 m / s

(iv) For 'C' type belt section, t = 14 mm

It is required to find the pitch diameters of pulleys, the specifications of belts and the no. of belts required.

The recommended pitch diameters of pulleys in mm:

140, 160, 170, 180, 190, 200, 212, ..., 450, 475, 500, 530, 600,.....etc.

Assume any other data that may be necessary.

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.

(b) The dimensions of a gasketed pressure vessel joint as shown in Fig. 1 are: A = 150 mm, B = 200 mm, C = 26 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 bolts 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 atleast 13 MPa. For bolts, $A_t = 160\ mm^2$, $E_s = 210$ 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 bolts and that of the connecting parts of the pressure vessel

(ii) bolted joint stiffness constant

(iii) number of bolts required to develop necessary gasket pressure

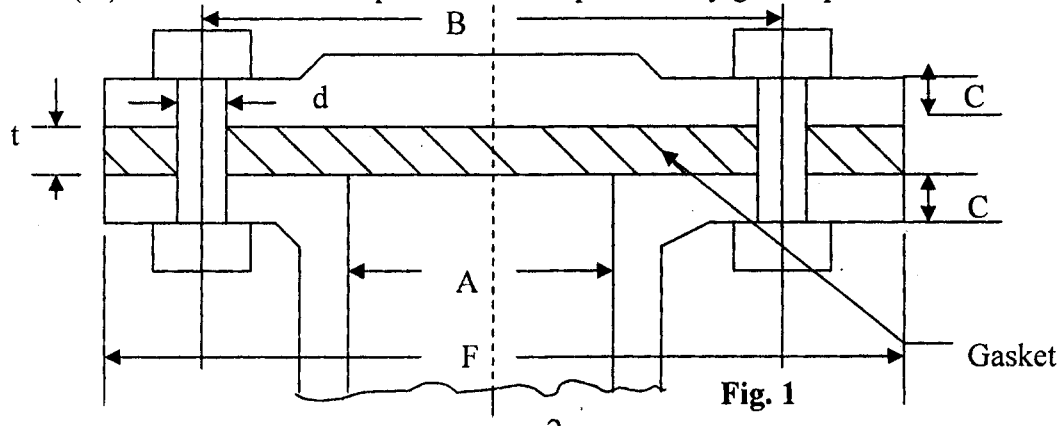
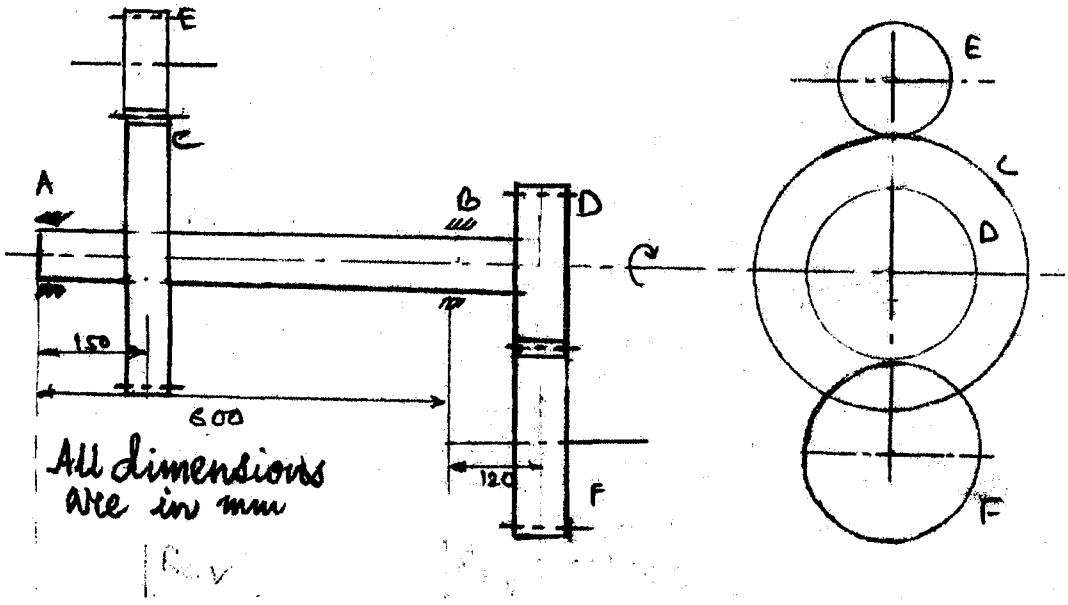


Fig. 1

SECOND HALF

6. (a) Explain the resultant effect, if a very big rotor shaft, carrying with large masses of turbine blades of high pressure zone, intermediate pressure zone & low pressure zone, rotating with a very high speed of 3000 rpm, used in 210MW thermal power plant, has an eccentricity.

(b) A shaft is required to transmit a 30kW power at 500 r.p.m. Two spur gears are keyed on the shaft which is supported on two bearings A & B, 600 mm apart, as shown in the figure below. A pinion D, having 18 teeth, 20^0 pressure angle, 5 mm module, is located at 120 mm to the right of the right bearing B and delivers power to a gear F, directly below the shaft. A gear C, having 72 teeth, 20^0 pressure angle, 5 mm module, is located at 150 mm to the right of the left bearing A and receives power from another pinion E, directly above the shaft. The material of the shat is plain carbon steel 50C4, having S_{ut}= 700 MPa and S_{yt}= 460 MPa. Determine the diameter of the shaft according to the ASME code, if K_b = 1.5 & K_t = 1.25



7. (a) What is the difference between the failure criteria of "Maximum Elastic Energy Theory" and "Distortion Energy Theory"? Write their final equations in terms of principal stresses and other relevant mechanical properties.

(b) Explain the boundary of "Distortion Energy Theory (Von Mises Criterion)" under biaxial stresses and draw a neat diagram, showing clearly the boundaries of "Maximum Principal Stress Theory" and "Maximum Shear Stress Theory (Tresca Criterion)" therin.

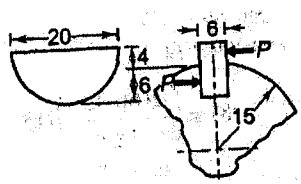
(b) Suggest the spring wire materials used for operating clutch, and valves in automobiles for its frequent closing and opening.

8. (a) State the objective of application of multi-leaf spring. Draw a clear diagram of a multi-leaf spring showing all its important elements.

(b) A helical compression spring, used for a cam mechanism, is subjected to an initial preload of 50 N. The maximum operating force during the load cycle is 150 N. The wire diameter and mean coil diameter are 3 mm & 18 mm respectively. Given that S_{sy} = 644 MPa and S_{se} = 315 MPa for the spring wire material used. Determine the factor of safety used in the design on the basis of fluctuating stresses.

9. (a) A shaft, 40 mm in diameter, is transmitting 35 kW power at 300 rpm by means of Kennedy Keys of 10x10 mm cross section. The keys are made of 45C8 steel (S_{yt} = S_{yc} = 380 MPa) and the factor of safety is 3. Determine the required length of the keys.

(b) The dimensions of a semicircular Woodruff Key for a 30 mm diameter shaft are as shown below. The shaft is transmitting 10 kW power at 600 rpm. The key is made of 50C4 steel (S_{yt} = S_{yc} = 460 MPa). Find the factors of safety against compression & shear failures.



(All dimensions are in mm)
Woodruff Key

10. Write short notes on the followings:

(i) Rayleigh-Ritz equation for evaluation of the first critical speed of a transmission shaft.
(ii) Effects of spring indices of very low & high values for designing helical compression springs
(iii) Failures due to torsional & lateral rigidity of a shaft
(iv) Difference between a Feather Key & a Splined Shaft
(v) Effects of "Nip" & "Surge" in Springs
(vi) Difference between rigid and flexible couplings