BACHELOR OF CHEMICAL ENGINEERING EXAMINATION, 2018

(2^{nd} Year, 1^{st} Semester)

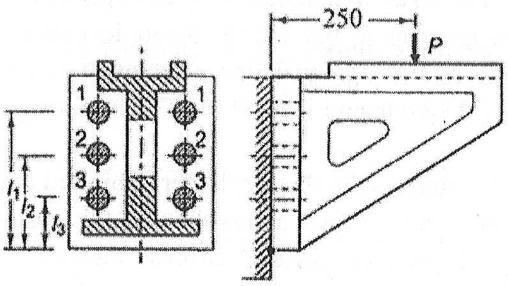
MACHINE DESIGN

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.
Answer any **Four (4)** questions

1. *a*) Write down the failure modes of the different components in socket and spigot cotter joint under axial loading. Draw a neat sketch of the above-mentioned cotter joint showing various design dimensions and derive the design equations corresponding to the different types of failure for its components. [04+16]
b) Which part of the cotter joint is the weakest and why? Why is cotter provided with a taper? Why is the taper provided only on one side? [02+02+01]

2. *a*) A metal bracket is connected to vertical wall by a group of identical bolts, as shown in Figure Q2(*a*). The joint is under eccentric loading, where, the magnitude of the vertical force (*P*) is 50 kN. Material of the threaded fasteners is C-steel having S_{yt} = 400 N/mm^2 (Consider a Factor of safety of 2.5). Determine the dimension of the bolts. [10]
b) How coarse and fine series threads are specified – Explain with examples. [02]



l_1 = 300 mm, l_2 = 200 mm, l_3 = 100 mm

Figure Q2(*a*)

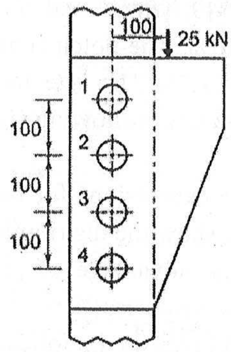


Figure Q2(*d*)

c) In a schematic sketch of double riveted lap joint with zig-zag arrangement show the following: Pitch, Back pitch and Diagonal pitch. [03]
d) Figure Q2(*b*) shows a plate attached to a vertical surface by means of a group of identical rivets. The joint is under eccentric loading of 25 kN in the plane of the rivets. The permissible shear stress of the rivet material is 60 N/mm^2. Determine: (*i*) Which rivet is subjected to maximum shear force, (*ii*) Magnitude of the maximum shear force and (*iii*) Diameter of the rivets. [10]

3. *a*) Discuss alignment and misalignments of shafts. Discuss the function of spigot and recess as used in rigid shaft coupling. Write down the purposes of using rubber bush and brass lining in bushed-pin type flexible coupling. [04+02+02]
b) A rigid coupling is used to transmit 50 kW power at 720 rpm (Consider a service factor of 1.5). There are four bolts. The bolts are made of C-steel having tensile yield strength of 400 N/mm^2. The yield strength in compression can be taken as 1.5 times the yield strength in tension. The factor of safety can be taken as 2.5. Assume empirical relations for required flange dimensions.
(*i*). Assuming that the bolts are fitted tightly into ground and reamed holes determine the diameter of the bolts.
(*ii*). Design the keys required to connect the flanges to the transmission shaft. [14]
c) Define: Resilience and Toughness. [03]

4. *a*) Prove that for a flat belt drive, the maximum tension developed in the belt is given by the following expression: $T_1 = (P/v)\left(e^{\mu\theta}/e^{\mu\theta} - 1\right) + mv^2$. (The symbols in the expressions have their usual meaning) [10]

b) A horizontal flat belt drive is to be designed such that it is capable of transmitting a rated power of 25 kW at 980 rpm between two parallel shafts separated by 1.75 m. The pulleys are to be made of Cast Iron and a chrome tanned leather belt, which is joined by machine lacing, is available for use. Allowable tensile strength of belt material is 3.0 N/mm^2 and density of leather is 1.0 gm/cc. Driving pulley diameter is fixed as 224 mm. Speed ratio is approximately 2 and belt slip over pulley is 1.5% (at driving pulley only). Both the pulleys rotate in same direction. Consider an overload factor of 1.25 and the service condition is such that the load is jerky in nature. Select a suitable belt from the given table to be used in the drive. Also find out the following parameters: Angle of contact for both pulleys, Length of belt, Belt tensions on both sides, Centrifugal tension. (Necessary tables are provided at the end of the question paper) [15]

5. *a*) What do you understand by fatigue failure? Define: S-N diagram. Draw a typical S-N diagram for a steel specimen in a standard rotating beam test and explain the term endurance limit. Also mark the different zones on the curve clearly. [02+02+03+02]

b) A transmission shaft carries a pulley midway between two bearings. The bending moment at the pulley varies from 200 N-m to 450 N-m, as the torsional moment varies from 100 N-m to 275 N-m. The shaft is made of C-steel having S_{ut} = 540 N/mm^2 and S_{yt} = 400 N/mm^2. The shaft is manufactured through machining and the expected reliability is 90%. The notch sensitivity factor can be taken as 0.8 and the theoretical stress concentration factor is determined as 1.55. The size factor is assumed to be 0.85. Considering a factor of safety of 2.5, determine the diameter of the shaft following (*i*) Soderberg Line (*ii*) Goodman Line and (*iii*) Gerber Line. [16]

6. *a*) Deduce the expressions for radial and tangential stress for a thick cylinder subjected to external pressure only. Schematically show the distribution of radial and tangential stresses across the wall thickness of the cylinder. [10]

b) What is the advantage of pre-stressing of thick pressure vessels? Discuss methods of pre-stressing a thick cylindrical pressure vessel. [02+03]

b) Write short notes on the following: (***any 2***) [05×2=10]

(*i*). Standard tensile test

(*ii*). Distortion energy theory

(*iii*). Factor of safety

Table 1: Basic dimensions for ISO Metric thread (Coarse Series)

Designation	*Nominal or major dia d/D (mm)*	*Pitch (p) (mm)*	*Pitch diameter d_p/ D_p (mm)*	*Minor diameter (mm)* d_c	D_c	*Tensile stress area (mm^2)*
M 4	4	0.70	3.545	3.141	3.242	8.78
M 5	5	0.80	4.480	4.019	4.134	14.20
M 6	6	1.00	5.350	4.773	4.917	20.10
M 8	8	1.25	7.188	6.466	6.647	36.60
M 10	10	1.50	9.026	8.160	8.376	58.00
M 12	12	1.75	10.863	9.853	10.106	84.30
M 16	16	2.00	14.701	13.546	13.835	157
M 20	20	2.50	18.376	16.933	17.294	245
M 24	24	3.00	22.051	20.319	20.752	353
M 30	30	3.50	27.727	25.706	26.211	561
M 36	36	4.00	33.402	31.093	31.670	817
M 42	42	4.50	39.077	36.479	37.129	1120
M 48	48	5.00	44.752	41.866	42.587	1470
M 56	56	5.50	52.428	49.252	50.046	2030
M 64	64	6.00	60.103	56.639	57.505	2680
M 72	72	6.00	68.103	64.639	65.505	3460

Table 2: Rivet and Rivet hole Diameter as per Indian Standard

Rivet diameter (mm)	12	14	16	18	20	22	24	27	30	33	36
Rivet hole diameter (mm) **[For Boiler work]**	13	15	17	19	21	23	25	28.5	31.5	34.5	37.5
Rivet hole diameter (mm) **[For general purpose]**	13.5	15.5	17.5	19.5	21.5	23.5	25.5	29	32	35	38

Standard Pulley Diameters (mm)

40, 45, 50, 56, 63, 71, 80, 90, 100, 112, 125, 140, 160, 180, 200, 224, 250, 280, 315, 355, 400, 450, 500, 560, 630, 710, 800, 900, 1000, 1120, 1250, 1400.

Table 3: Service Factors

Service Condition	**Service factor**
Normal Load	1.00
Jerky Load	1.20
Shock & Reverse Load	1.40
Oily & Wet/Dusty environment	1.35

Table 4: Friction Coefficients

Belt Material	**Coefficient of friction against CI or steel pulley**
Leather (oak tanned)	0.25
Leather (chrome tanned)	0.35
Rubber	0.30
Balata	0.32

Table 5: Joint Efficiency

Type of joining	**Efficiency**
Cemented by belt maker	1.00
Cemented	0.98
Wire laced by m/c	0.90
Wire laced by hand	0.82
Raw hide laced	0.60
Metal hooks	0.35

Table 6: Standard Belt Dimensions

Standard belt thickness (mm)	**Standard belt widths (mm)**
5	25, 32, 40, 50, 63
6	50, 63, 71, 80, 90, 100, 112, 125, 140
8	90, 100, 112, 125, 140, 160, 180, 200, 224
10	125, 140, 160, 180, 200, 224, 250, 280, 315, 355, 400
12	250, 280, 315, 355, 400, 450, 500, 560, 600

Table 7: Surface Finish Modification Factor ($k_a = a(S_{ut})^b$)

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 8: 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