Ref. No.: Ex/ME(M2)/PC/B/T/411/2025

B. E. MECH. ENGG. 4TH YR 1ST SEMESTER EXAM 2025

Design of Machine Elements IV

Time: Three hours Full Marks: 100

Use separate answer-scripts for Part A and Part B.

All parts of a question must be answered at a place. Missing data may be assumed.

Part A

In Part A, **Question No 1 is compulsory** and answer any **TWO** questions from the rest.

1 a) Describe Tower experiment. State the observations.

b) Draw and explain Stribeck diagram.

c) Define Sommerfeld number. How is it related to bearing characteristic number?

d) Compare journal bearing, ball bearing and roller bearing in terms of friction behavior. 10

2 a) Explain the mechanism for pressure development in a hydrodynamic bearing.

b) Explain the Full-Sommerfeld boundary conditions for hydrodynamic journal bearing analysis. State its limitation. How can it be overcome?

c) Sketch the schematic of a typical hydrostatic bearing with all essential components.

d) Explain why a hydrostatic thrust bearing with constant flow rate is self-compensating in nature. 20

3 a) Explain dynamic load carrying capacity of rolling element bearings. State its relation to bearing load and bearing life.

b) The radial load acting on a ball bearing is 2500 N for the first five revolutions and reduces to 1500 N for the next ten revolutions. The load variation then repeats itself. The expected life of the bearing is 20 million revolutions. Determine the dynamic load carrying capacity of the bearing.

c) Explain different types of rolling contact bearings. 20

4 A full journal bearing is to be used for a shaft with diameter 80 mm, rotating at 1000 rpm and supporting a radial load of 36 kN. In the application area, ambient temperature is 25 deg C and there is no space restriction and no provision for artificial cooling arrangement. Design the appropriate bearing using the available data given in Tables 1-3. 20

[Turn over

Table 1: Raimondi-Boyd Performance Characteristics for full journal bearings

Length/ Dia	Eccentricity ratio	Sommerfeld No	Friction variable	Attitude angle (deg)	Flow variable
0.5	0.1	4.30	-	81	3.43
	0.2	2.01	40.9	75	3.72
	0.3	1.235	25.7	68	4.00
	0.4	0.785	17.11	62	4.29
	0.5	0.497	11.95	55	4.57
	0.6	0.320	8.08	48	4.85
	0.7	0.185	5.48	41	5.13
	0.8	0.092	3.25	33	5.41
	0.9	0.032	1.59	23	5.69
1	0.1	1.35	-	79	3.37
	0.2	0.632	12.9	74	3.59
	0.3	0.382	8.04	68	3.79
	0.4	0.261	5.80	62	3.99
	0.5	0.179	4.31	56	4.16
	0.6	0.120	3.21	50	4.33
	0.7	0.0765	2.36	43	4.48
	0.8	0.0448	1.71	36	4.62
	0.9	0.0191	1.06	25	4.76
∞	0.1	0.247	-	69	3.03
	0.2	0.123	2.57	67	2.83
	0.3	0.0823	1.90	64	2.52
	0.4	0.0628	1.53	62	2.26
	0.5	0.0483	1.32	58	1.91
	0.6	0.0389	1.20	54	1.56
	0.7	0.0297	1.10	49	1.16
	0.8	0.0211	0.962	42	0.76
	0.9	0.00114	0.721	32	0.41

Table 2: Available Bearing Materials

Bearing Materials	Maximum Unit Load in kN/m^2	Recommended Radial clearance ratio
Lead base babbit	4200-5600	0.0004
Tin base babbit	5600-7000	0.0005
Cadmium base metal	8400-10500	0.0008
Copper-lead (55:45)	14000-21000	0.0010
Copper-lead-tin (72:25:3)	21000-28000	0.0010
Silver (lead-indium overlay)	>35000	0.0010
Bronzes	70000	0.0011

Table 3: Oil viscosity (cP) – temperature variation [linear] data

Oil Grade	20 deg C	100 deg C	
A	40	15	**mass density: 880 kg/m^3; specific heat: 1.88 J/g-K**
B	50	16	
C	60	18	

Part B

In Part B, **Question No 5 is compulsory** and answer any **TWO** questions from the rest.

5 Write down short notes on **any two**:
i) Steps to be followed for optimum design ii) N.L.P of an Optimum design .
iii) Golden Section method iv) Considerations for design of high speed rotor.
v) Weighted Sum method of multi-objective optimization

5x2 =10

6 a) Compare local and global optima.
b) Explain Cauchy's Steepest Descent method for optimization.
c) Show two iterations for Bisection **OR** Interval halving method for the following objective function: $f(x) = x^3 - 6x + 15$ within the interval (0,5) 4+6+10

7 a) Explain Genetic Algorithm **OR** Simulated Annealing method used for optimization.
b) Explain the role of penalty multiplier in exterior and interior penalty function method for constrained optimization.
c) What is meant by non-dominated set of solutions **OR** explain Pareto optimal front.

10+5+5

8 a) Derive the expression for stresses in a hollow rotor assuming variation of stress across the thickness for a hi-speed rotor
b) Find out the critical speed for which the shrink fit is completely loosened up.
c) Derive the expression of maximum σ_t for a very small hole in a solid disc.

10+5+5