Ref. No.: Ex/ME(M2)/PC/B/T/323/2025

B.E. MECHANICAL ENGINEERING THIRD YEAR SECOND SEMESTER - 2025

Subject: DESIGN OF MACHINE ELEMENTS-III

Time: 3hr **Full Marks: 100**

Instructions: Answer any **five** questions. Assume data if any missing

1. (a) A railway wagon moving at a velocity of 1.5 m/s is brought to rest by a bumper consisting of two helical springs arranged in parallel. The mass of the wagon is 1500 kg. The springs are compressed by 150 mm in bringing the wagon to rest. The spring index can be taken as 6. The springs are made of oil-hardened and tempered steel wire with ultimate tensile strength of 1250 N/mm^2 and modulus of rigidity of 81370 N/mm^2. The permissible shear stress for the spring wire can be taken as 50% of the ultimate tensile strength. Design the spring and calculate: (i) wire diameter; (ii) mean coil diameter; (iii) number of active coils; (iv) total number of coils; (v) solid length; (vi) free length; (vii) pitch of the coil; (viii) required spring rate; and (ix) actual spring rate

(b) What is the Wahl factor? Why is it used?

(c) Distinguish between closely coiled and open coiled helical springs? **[15+2+3]**

2. (a) A semi-elliptic leaf spring used for automobile suspension consists of three extra full-length leaves and 15 graduated-length leaves, including the master leaf. The centre-to-centre distance between two eyes of the spring is 1 m. The maximum force that can act on the spring is 75 kN. For each leaf, the ratio of width to thickness is 9:1. The modulus of elasticity of the leaf material is 2,07,000 N/mm2. The leaves are pre-stressed in such a way that when the force is maximum, the stresses induced in all leaves are same and equal to 450 N/mm2. Determine (i) the width and thickness of the leaves; (ii) the initial nip; and (iii) the initial pre-load required to close the gap C between extra full-length leaves and graduated-length leaves.

(b) Deduce the stress and deflection equation for Helical Spring. **[13+7]**

3. (a) A pair of spur gears with 20° pressure angle, consists of a 25 teeth pinion meshing with a 60 teeth gear. The module is 5 mm, while the face width is 45 mm. The pinion rotates at 500 rpm. The gears are made of steel and heat treated to a surface hardness of 220 BHN. Assume that dynamic load is accounted by means of the velocity factor. The service factor and the factor of safety are 1.75 and 2 respectively. Calculate (i) wear strength of gears; (ii) the static load that the gears can transmit without pitting; and (iii) rated power that can be transmitted by gears.

(b) What is the significance of Lewis Form Factor? In a gear drive design for different gear-pinion material, which will be designed, gear or pinion and why? **[15+5]**

4. (a) The following data is given for a pair of parallel helical gears made of steel: power transmitted = 20 kW, speed of pinion = 720 rpm, number of teeth on pinion = 35, number of teeth on gear = 70, centre distance = 285 mm, normal module = 5 mm, face width = 50 mm, normal pressure angle = 20°, ultimate tensile strength = 600 N/mm^2, surface hardness = 300 BHN, grade of machining = Gr. 6, service factor = 1.25. Calculate - (i) the helix angle; (ii) the beam strength; (iii) the wear strength; (iv) the static load; (v) the dynamic load by Buckingham's equation; (vi) the effective load; (vii) the effective factor of safety against bending failure; and (viii) the effective factor of safety against pitting failure.

(b) What is the difference between double and herringbone helical gears?

(c) Explain significance of Lewis Form Factor in gear design. **[15+2+3]**

5 (a) A pair of straight bevel gears consist of a 24-teeth pinion meshing with a 48 teeth gear. The module at the outside diameter is 6 mm, while the face width is 50 mm. The gears are made of grey cast iron FG 220 (Sut = 220 N/mm^2). The pressure angle is 20°. The teeth are generated and assume that velocity factor accounts for the dynamic load. The pinion rotates at 300 rpm and the service factor is 1.5. Calculate - **(i)** the beam strength of the tooth; **(ii)** the static load that the gears can transmit with a factor of safety of 2 for bending consideration; and **(iii)** the rated power that the gears can transmit

(b) Deduce the expression for wear strength of bevel gears? **[14+6]**

6. (a) A pair of worm and worm wheel is designated as,

1/30/10/10

The input speed of the worm is 1200 rpm. The worm wheel is made of centrifugally cast, phosphor bronze and the worm are made of case-hardened carbon steel 14C6 (Sb = 28.20). Determine the power transmitting capacity based on the beam strength.

(b) Deduce the expression for force analysis of worm gear?

(c) What are the advantages of worm gear drives? **[8+8+4]**

7. (a) Prove that the thickness of a cylinder wall with closed ends as per Distortion energy theory of failure

$$t = \frac{D_i}{2}\left[\sqrt{\frac{\sigma}{\sigma - P_i\sqrt{3}}} - 1\right]$$

(b) Prove that $\sigma_t = A + B/r^2$ *and* $\sigma_r = A - B/r^2$ for a thick cylindrical pressure vessel subjected to internal pressure, terms have usual meaning Draw the tangential stress distribution in both cases when it is subjected to internal pressure p_i and external pressure p_o respectively. Assume radii ratio = 2.0

[8+12]

z	*Y*	*z*	*Y*	*z*	*Y*
15	0.289	27	0.348	55	0.415
16	0.295	28	0.352	60	0.421
17	0.302	29	0.355	65	0.425
18	0.308	30	0.358	70	0.429
19	0.314	32	0.364	75	0.433
20	0.320	33	0.367	80	0.436
21	0.326	35	0.373	90	0.442
22	0.330	37	0.380	100	0.446
23	0.333	39	0.386	150	0.458
24	0.337	40	0.389	200	0.463
25	0.340	45	0.399	300	0.471
26	0.344	50	0.408	Rack	0.484

Module (m) (mm)	*Class - 1*	*Class - 2*	*Class - 3*
Up to 4	0.050	0.025	0.0125
5	0.056	0.025	0.0125
6	0.064	0.030	0.0150
7	0.072	0.035	0.0170
8	0.080	0.038	0.0190
9	0.085	0.041	0.0205
10	0.090	0.044	0.0220

Grade	*e (microns)*
1	$0.80 + 0.06\ \phi$
2	$1.25 + 0.10\ \phi$
3	$2.00 + 0.16\ \phi$
4	$3.20 + 0.25\ \phi$
5	$5.00 + 0.40\ \phi$
6	$8.00 + 0.63\ \phi$
7	$11.00 + 0.90\ \phi$
8	$16.00 + 1.25\ \phi$
9	$22.00 + 1.80\ \phi$
10	$32.00 + 2.50\ \phi$
11	$45.00 + 3.55\ \phi$
12	$63.00 + 5.00\ \phi$