MACHINE DESIGN II
(MECH 3201)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) In helical gears, the distance between two similar points on adjacent teeth, measured in a plane perpendicular to tooth element, is called
(a) normal circular pitch (b) transverse circular pitch
(c) axial pitch (d) diametral pitch.

(ii) The interference in cycloidal tooth gears
(a) depends upon pressure angle (b) depends upon number of teeth
(c) is completely absent (d) is maximum.

(iii) The backlash for spur gears depend upon
(a) module (b) pitch line velocity
(c) tooth profile (d) both (a) and (b).

(iv) A thin film bearing is a bearing
(a) where the surfaces of journal and the bearing are completely separated by a film of lubricant
(b) where the surfaces of journal and the bearing are partially separated by a film of lubricant and there is partial metal to metal contact
(c) where the surfaces of journal and the bearing are separated by a film created by elastic deflection of parts
(d) where there is no lubricant.

(v) The form factor of a spur gear tooth depends upon
(a) circular pitch only (b) pressure angle only
(c) number of teeth and circular pitch (d) number of teeth and the system of teeth.

(vi) In case of single plate new clutches and brakes, the friction radius is equal to?
(a) $\frac{1}{3}\frac{(D^3-d^3)}{(D^2-d^2)}$ (b) $\frac{1}{2}\frac{(D^3-d^3)}{(D^2-d^2)}$ (c) $\frac{1}{4}\frac{(D^3-d^3)}{(D^2-d^2)}$ (d) $\frac{1}{4}(D+d)$.

(vii) The catalogue life of a bearing is
(a) minimum life that 90% of the bearings will reach or exceed
(b) maximum life for 90% of the bearings
(c) average life
(d) median life.

(viii) When the frictional force helps to apply the brake, the brake is said to be
(a) partially self-energizing (b) self-locking (c) back-stop (d) self-acting.

(ix) The thickness of thick cylinder shell with closed ends and made of brittle material is determined by
(a) Lame's equation (b) Clavarino's equation
(c) Birnie's equation (d) Barlow's equation.

(x) A bearing number XX10 indicates that the bearing is having
(a) bore diameter of 10 mm (b) outer diameter of 10 mm
(c) thickness of 10 mm (d) pitch diameter of 10 mm.

Fill in the blanks with the correct word

(xi) The number of starts on the worm for a velocity ratio of 40 should be_____.

(xii) If b denotes the face width and L denotes the cone distance, then the bevel factor is written as _____.

(xiii) Torque transmitting capacity of the clutch is maximum, when ratio of inner Dia and outer Dia (d/D) is equal to _____.

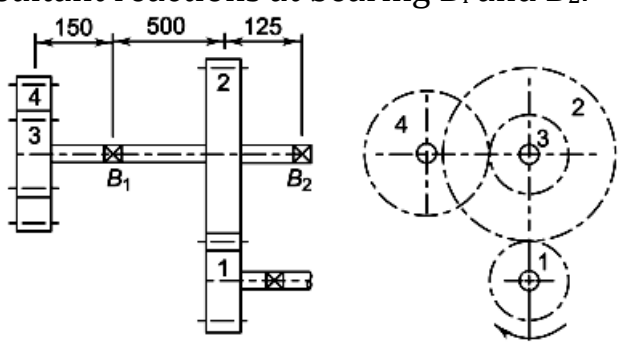
(xiv) For a band brake, the width of the band for a drum diameter greater than 1 m, should not exceed_____.

(xv) If absolute viscosity of bearing oil of a journal bearing rotating at N rpm is μ and unit bearing pressure is p, then its bearing characteristics number is _____.

Group - B

2. (a) State the Law of Conjugate action for gears. *[(CO1)(Understand/LOCQ)]*

(b) A train of spur gears with 20° full-depth involute teeth is shown in Fig. 1. Gear 1 is the driving gear and transmits 50 kW power at 300 rpm to the gear train. The number teeth on gears 1, 2, 3 and 4 are 30, 60, 25 and 50 respectively, while the module for all gears is 8 mm. Gears 2 and 3 are mounted on the same shaft. Gear 1 is rotating in the clockwise direction when seen from the left side of the page. Calculate(i) tangential and radial components of tooth forces between gears 1 and 2 and gears 3 and 4; and (ii) resultant reactions at bearing B_1 and B_2. *[(CO1)(Apply/IOCQ)]*



All Dimensions are in mm

Fig. 1

4 + (4 + 4) = 12

3. It is required to design a spur gear speed reducer for a compressor running at 350 rpm driven by a 9 kW, 1000 rpm electric motor. The centre distance between the axes of the gear shafts should be exactly 250 mm. The starting torque of the motor can be assumed to be 150% of the rated torque. The gears are made of carbon steel 50C4 (S_{ut} = 700 N/mm²). The pressure angle is 20°. The factor of safety is 2 for preliminary design based on the use of velocity factor.

(i) Design the gears and specify their dimensions.

(ii) Assume that the gears are manufactured to meet the requirements of Grade 6 and calculate the dynamic load by using Buckingham's equation.

(iii) Calculate the effective load.

(iv) What is the actual factor of safety against bending failure?

(v) Using the same factor of safety against pitting failure, specify suitable surface hardness for the gears. *[(CO1)(Create/HOCQ)]*

12

Group - C

4. (a) A pair of parallel helical gears consists of 18 teeth pinion meshing with a 63 teeth gear. The normal module is 3 mm. The helix angle is 23° while the normal pressure angle is 20°. Calculate (i) the transverse module; (ii) the transverse pressure angle; and (iii) the axial pitch. *[(CO1)(Apply/IOCQ)]*

(b) A pair of parallel helical gears is shown in Fig. 2. A 10 kW power at 720 rpm is supplied to the pinion A through its shaft. The normal module is 5 mm and the normal pressure angle is 20°. The pinion has right-hand teeth, while the gear has left-hand teeth. The helix angle is 30°. The pinion rotates in the clockwise direction when seen from the left side of the page. Determine the components of the tooth force and draw a free-body diagram showing the forces acting on the pinion and the gear.

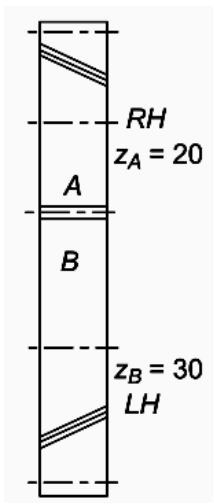


Fig. 2

[(CO1)(Apply/IOCQ)]

6 + 6 = 12

5. (a) State the advantages and disadvantages of straight bevel gears over spiral bevel gears. *[(CO2)(Remember/LOCQ)]*

(b) A pair of straight bevel gears has a velocity ratio of 2:1. The pitch circle diameter of the pinion is 80 mm at the large end of the tooth. 5 kW power is supplied to the pinion, which rotates at 800 rpm. The face width is 40 mm and the pressure angle is 20°. Calculate the tangential, radial and axial components of the resultant tooth force acting on the pinion. *[(CO2)(Apply/IOCQ)]*

5 + 7 = 12

Group - D

6. (a) Sketch the variation of Principal Stresses in a thick Cylinder with Internal Pressure. *[(CO3)(Understand/LOCQ)]*

(b) A seamless steel pipe of 100 mm internal diameter is subjected to internal pressure of 12 MPa. It is made of steel (S_{yt} = 230 N/mm^2 and ν = 0.27) and the factor of safety is 2.5. Determine the thickness of the pipe. *[(CO3)(Assess/IOCQ)]*

4 + 8 = 12

7. An automotive-type internally-expanding brake is shown in Fig. 3. The face width of the friction lining is 50 mm and the coefficient of friction is 0.4. The maximum intensity of pressure on the lining is 0.8 N/mm^2. The angle θ_1 can be assumed to be zero. Calculate: (i) the actuating force; (ii) the torque capacity of the brake. Take all dimensions in the figure in mm.

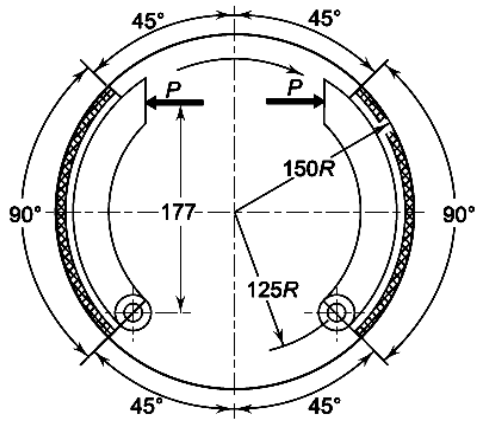


Fig. 3

[(CO3) (Analyse/IOCQ)]

(5 + 7) = 12

Group - E

8. (a) Write a short note on Petroff's equation? *[(CO5)(Remember/LOCQ)]*

(b) A ball bearing operates on the following work cycle:

Element no.	Radial Load (N)	Speed (RPM)	Element time (%)
1	3000	720	30
2	7000	1440	40
3	5000	900	30

The dynamic load capacity of the bearing is 16600 N. Calculate (i) The average speed of rotation; (ii) The equivalent radial load; and (iii) The bearing life.
Also select the bearing number from the manufacture's catalogue if this bearing is to be fit into a 30mm diameter shaft. Refer table 6 below to solve this problem. *[(CO5)(Analyse/IOCQ)]*

3 + (3 + 2 + 2 + 2) = 12

9. (a) Write a short note on Stribeck's equation. *[(CO6)(Remember/LOCQ)]*

(b) The following data is given for a 360° hydrodynamic bearing:
journal diameter = 100 mm
bearing length = 100 mm
radial load = 50 kN
journal speed = 1440 rpm
radial clearance = 0.12 mm
viscosity of lubricant = 16 cP
Calculate
(i) minimum film thickness;
(ii) coefficient of friction; and
(iii) power lost in friction. *[(CO6)(Analyse/IOCQ)]*

4 + (4 + 2 + 2) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	20.83	66.67	12.5

Course Outcome (CO):

After the completion of the course students will be able to
1 Explain the method of force analysis and determination of design-parameters of Spur and Helical gears
2 Illustrate the method of Bevel and Worm wheel design along with the force analysis in torque transmission.
3 Apply the technical knowledge in the process of pressure vessel design with pressure loading only.
4 Work on the process of designing and/or selection of Clutch and Brake for a drive system.
5 Evaluate design-parameters of rolling contact bearing for proper selection of it under a given loading and boundary condition.
6 Determine design-parameters of sliding contact bearing for proper selection of it under a given loading and boundary condition.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*

Refer the empirical relationships & tables given below for appropriate data wherever suitable.

Table 1: Values of Lewis form factor Y for 20° full-depth involute system

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

Ratio factor for external spur gears $Q = 2z_g/(z_g + z_p)$ & helical gears $Q = 2 z_g/(z_g + z_p \tan\gamma)$

Load stress factor $K = 0.16 (BHN/100)^2$

The values of velocity factor are as follows:

(i) For $v < 10$ m/s $C_v = 3/(3+v)$

(ii) For $v < 20$ m/s $C_v = 6/(6+v)$

(iii) For $v > 20$ m/s $C_v = 5.6/ (5.6+\sqrt{v})$

Table 2: Tolerances on the adjacent pitch

Grade	e (microns)
6	8.00 + 0.63 φ
8	16.00 + 1.25 φ

$\varphi = m + 0.25 \sqrt{d'}$ where φ = tolerance factor, m = module (mm), d' = pitch circle diameter

Table 3: Values of deformation factor C (N/mm^2)

Materials		14.5° full depth teeth	20° full depth teeth	20° stub teeth
Pinion material	Gear material			
Grey CI	Grey CI	5500	5700	5900
Steel	Grey CI	7600	7900	8100
Steel	Steel	11000	11400	11900

Buckingham equation for dynamic load in spur gears

$P_d = \{21v(Ceb + P_t) / \{21v + \sqrt{(Ceb + P_t)}\}$

Buckingham equation for dynamic load in helical gears

$P_d = \{21v(Ceb \cos^2\psi + P_t) \cos\psi\} / \{21v + \sqrt{(Ceb \cos^2 \psi + P_t)}\}$

Table 4: Recommended series of module (mm)

Choice-1	1.0	1.25	1.5	2.0	2.5	3.0	4.0
Preferred	5.0	6.0	8.0	10	12	16	20
Choice-2	1.125	1.375	1.75	2.25	2.75	3.5	4.5
	5.5	7	9	11	14	18	

Table 5: Proportions of standard involute teeth (in terms of module m)

	20° full depth system
Pressure angle	20°
Addendum	m
Dedendum	1.25 m
Clearance	0.25 m
Working depth	2 m
Whole depth	2.25 m
Tooth thickness	1.5708 m

Table 6: Dimensions and static and dynamic load capacities of single-row deep groove ball bearings

Principal dimensions (mm)			*Basic load ratings (N)*		*Designation*
d	*D*	*B*	*C*	C_0	
40	52	7	4160	3350	61808
	68	9	13300	7800	16008
	68	15	16800	9300	6008
	80	18	30700	16600	6208
	90	23	41000	22400	6308
	110	27	63700	36500	6408

Table 7: Dimensionless performance parameters for full journal bearing with side flow

$\left(\frac{l}{d}\right)$	ε	$\left(\frac{h_o}{c}\right)$	S	ϕ	$\left(\frac{r}{c}\right)f$	$\left(\frac{Q}{rcn_s l}\right)$	$\left(\frac{Q_s}{Q}\right)$	$\left(\frac{p}{p_{max.}}\right)$
1	0	1.0	∞	(85)	∞	π	0	–
	0.1	0.9	1.33	79.5	26.4	3.37	0.150	0.540
	0.2	0.8	0.631	74.02	12.8	3.59	0.280	0.529
	0.4	0.6	0.264	63.10	5.79	3.99	0.497	0.484
	0.6	0.4	0.121	50.58	3.22	4.33	0.680	0.415
	0.8	0.2	0.0446	36.24	1.70	4.62	0.842	0.313
	0.9	0.1	0.0188	26.45	1.05	4.74	0.919	0.247
	0.97	0.03	0.00474	15.47	0.514	4.82	0.973	0.152
	1.0	0	0	0	0	0	1.0	0