MACHINE DESIGN - II
(MECH 3201)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

REFER THE TABLES AND DATA CHARTS GIVEN AT THE END OF THE QUESTION PAPER.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Lewis equation in spur gears is used to find the
(a) tensile stress in bending (b) shear stress
(c) compressive stress in bending (d) fatigue stress.

(ii) Involute profile is widely used for gear tooth because
(a) pressure angle remains constant (b) face and flank form a continuous curve
(c) involute rack has straight sided teeth (d) (a), (b) & (c).

(iii) Which of the following gears have zero axial thrust?
(a) Herringbone gears (b) Bevel gears
(c) Worm gears (d) Helical gears.

(iv) Two bevel gears with 25 and 50 teeth are in mesh with each other. The pitch angle of gear is
(a) $\left[\frac{\pi}{2} - \tan^{-1}(0.5)\right]$ (b) $\tan^{-1}(0.5)$
(c) $\sin^{-1}(0.5)$ (d) $\left[\frac{\pi}{2} - \sin^{-1}(0.5)\right]$

(v) The friction moment in a clutch with uniform wear as compared to friction moment with uniform pressure is
(a) more (b) equal
(c) less (d) more or less depends on speed.

(vi) A jaw clutch is essentially a
(a) positive action clutch (b) cone clutch
(c) friction clutch (d) disc clutch.

(vii) A seamless cylinder of storage capacity of 0.03 m^3 is subjected to an internal pressure of 21 MPa. The ultimate strength of material of cylinder is 350 N/mm^2. Determine the length of the cylinder if it is twice the diameter of the cylinder.
(a) 540 mm (b) 270 mm
(c) 400 mm (d) 350 mm.

(viii) In which of the following bearing, the bearing pressure is acting perpendicular to the axis of the shaft?
(a) Journal bearing (b) Foot step bearing
(c) Thrust bearing (d) Ball bearing.

(ix) Which type of bearing is used in a crank shaft?
(a) Fluid bearing (b) Magnetic bearing
(c) Plain bearing (d) Ball bearing.

(x) In a thick cylindrical shell, the maximum radial stress at the outer surfaces of the shell is
(a) zero (b) p (c) – p (d) 2p.

Group- B

2. A pair of spur gears with 20° full-depth involute teeth consists of a 19 teeth pinion meshing with a 40 teeth gear. The pinion is mounted on a crankshaft of 7.5 kW single cylinder diesel engine running at 1500 rpm. The driven shaft is connected to a two-stage compressor. Assume the service factor as 1.5. The pinion as well as the gear is made of steel 40C8 (Sut = 600 N/mm^2). The module and face width of the gears are 4 and 40 mm, respectively.
(i) Using the velocity factor to account for the dynamic load, determine the factor of safety.
(ii) If the factor of safety is two for pitting failure, recommend surface hardness for the gears.
(iii) If the gears are machined to meet the specifications of Grade 8, determine the factor of safety for bending using Buckingham's equation for dynamic load.

(iv) Is the gear design satisfactory? If not, what is the method to satisfy the design conditions? How will you modify the design?

[(CO1)(Evaluate/HOCQ)]

(3 + 3 + 3 + 3) = 12

3. All the gears of the gear assembly shown in the Fig.1 is having a module of 16 mm and a 20° pressure angle. Gear 1, mounted on shaft 'a', is the pinion which is having 18 number of teeth. The pinion receives 200 kW of power from a motor at a speed of 1800 rev/min and transmits it to gear 4 on shaft c through the idler pair of gears 2 and 3 mounted on a single shaft b. The pinion rotates in clockwise direction. Draw the side view of the gear assembly showing direction of rotation of each gears and determine what forces do gears 2 and 3 transmit to the idler shaft 'b'? Also draw the FBD of sub-assembly of gears 2, 3 and shaft 'b' showing forces.

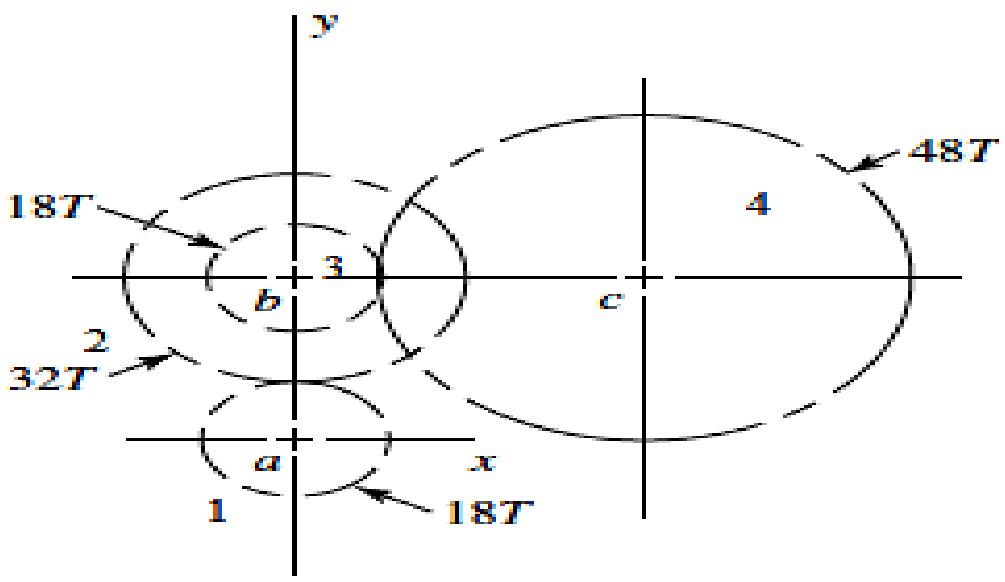

Fig:1

[(CO1)(Understand/IOCQ)]

2 + 8 + 2 = 12

Group - C

4. A pair of helical gears are to transmit 15 kW. The teeth are 20° stub in diametral plane and have a helix angle of 35°. The pinion runs at 10 000 r.p.m. and has 80 mm pitch diameter. The gear has 320 mm pitch diameter. If the gears are made of cast steel having allowable static strength of 120 MPa and Modulus of Elasticity of 200 GPa; determine a suitable module and face width from static strength considerations and check the gears for wear, given surface endurance strength σ_{es} = 618 MPa.
The tooth form factor may be taken as $\left(0.175 - \frac{0.841}{z}\right)$ for 20° stub depth tooth profile where z is the number of teeth on the gear.

[(CO2) (Analyse/HOCQ)]

(6 + 2 + 4) = 12

5. (a) A pair of straight bevel gears has a velocity ratio of 2:1. The pitch circle diameter of the pinion is 100 mm at the large end of the tooth. 7 kW power is supplied to the pinion, which rotates at 900 rpm. The face width is 50 mm and the pressure angle is 20°. Calculate the tangential, radial and axial components of the resultant tooth force acting on the pinion.
The tooth form factor may be taken as $\left(0.154 - \frac{0.912}{z}\right)$ for 20° full depth tooth profile where z is the number of teeth on the gear. *[(CO2)(Estimate/IOCQ)]*

(b) What do you understand by formative spur gear of a bevel gear? *[(CO2)(Remember/LOCQ)]*

(4 + 3 + 3) + 2 = 12

Group - D

6. (a) What are the types of stresses in closed end thick cylinders? Show the distribution of stresses in a thick cylinder under internal pressure with proper sketch. *[(CO3)(Repeat/LOCQ)]*

(b) A hydraulic cylinder with closed ends is subjected to an internal pressure of 20 MPa. The inner and outer diameters of the cylinder are 210 mm and 250 mm, respectively. The cylinder material is cast iron FG 300. Determine the factor of safety used in design. If the cylinder pressure is further increased by 40%, what will be the factor of safety?

[(CO3)(Assess/LOCQ)]

4 + (4 + 4) = 12

7. A multi-disk clutch consists of two steel disks with one bronze disk. The inner and outer diameters of the contacting surfaces are 200 and 250 mm, respectively. The coefficient of friction is 0.1 and the maximum pressure between the contacting surfaces is limited to 0.4 N/mm^2. Assuming uniform wear theory, calculate the required force to engage the clutch and the power transmitting capacity at 720 rpm. *[(CO3)(Assess/HOCQ)]*

(6 + 6) = 12

Group - E

8. (a) State any two advantages of hydrostatic bearing over hydrodynamic bearings. Write down Stribeck's Equation.

[(CO5)(Remember/LOCQ)]

(b) The following data is given for a hydrostaticthrust bearing:
shaft speed = 720 rpm

shaft diameter = 400 mm
recess diameter = 250 mm
film thickness = 0.15 mm
viscosity of lubricant = 30 cP
specific gravity = 0.86
specific heat = 1.75 kJ/kg°C
supply pressure = 5 MPa
Calculate:
(i) load carrying capacity of the bearing; (ii) flow requirement; (iii) pumping power loss; (iv) frictional power loss; (v) total power loss and (vi) temperature rise. Assume that the total power loss in the bearing is converted into frictional heat.

[(CO5)(Evaluate/IOCQ)]

(4 + 2) + 6 = 12

9. (a) What is L_{10} life and L_{50} life? State the difference between dynamic load carrying capacity and equivalent bearing load for ball bearing.

[(CO6)(Estimate/LOCQ)]

(b) In a particular application, the radial load acting on a ball bearing is 5 kN and the expected life for 90% of the bearings is 8000 h. Calculate the dynamic load carrying capacity of the bearing, when the shaft rotates at 1450 rpm.

[(CO6)(Design/IOCQ)]

6 + 6 = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*27.08*	*35.42*	*37.5*

Course Outcome (CO):

On completion of this course students will be able to

1. Choose suitable material of a product to be designed as per the application and strength requirement.
2. Relate relevant 'Mode of Failure' and 'Theory of Failure' when solving a problem regarding design of machine components under different types of loadings and boundary conditions.
3. Identify proper stress intensity factors for objects with dimensional discontinuity subjected to different loadings and boundary conditions.
4. Analyse life of a machine component with or without dimensional discontinuity subjected to various dynamic loadings constrained with different boundary conditions.
5. Evaluate detailed specifications for fasteners like screw, nut-n-bolt, for welding and power screw by analysing the machine component subjected to various loading and boundary conditions.
6. Design a solid and hollow shaft, coil and leaf spring, shaft couplings and various belts for a belt drive for given power rating, loadings and boundary conditions.

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

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 gears $Q = 2z_g/(z_g + z_p)$
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 helical gears
$P_d = \{21v(Ceb\cos^2\psi + P_t)\cos\psi\} / \{21v + \sqrt{(Ceb\cos^2\psi + P_t)}\}$.