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- b) Determine the shaft power which can be transmitted by a pair of helical gears, 20° full depth, 25° helix, having a normal module of 5 mm. Both the gears are made of forged C-30 steel and have a face width of 76.2 mm. The pinion speed is 2000 rev/min and it has 20 teeth. The velocity ratio to be 5 to 1. 5

13. Write short notes on any *three* of the following : 3 × 5

- Classification of pressure vessels based on Industrial code.
- Reynolds Equation.
- Differential band brake.
- Petroff equation.
- Centrifugal clutch.

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2013

MACHINE DESIGN

Time Allotted : 3 Hours

Full Marks : 70

The figures in the margin indicate full marks.

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

Missing data, if any, are to be reasonably assumed.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for the following : $10 \times 1 = 10$

i) The life of a ball bearing is inversely proportional to

- | | |
|---------------------------|--------------------------|
| a) $(\text{Load})^{3.33}$ | b) $(\text{Load})^3$ |
| c) $(\text{Load})^2$ | d) $(\text{Load})^{1/3}$ |

ii) The bearing characteristics number (BCN) relating oil viscosity (Z), Journal speed (N) and bearing pressure (p) is given by

- | | |
|-------------------|-------------------|
| a) $\frac{Z}{pN}$ | b) $\frac{ZN}{p}$ |
| c) $\frac{Zp}{N}$ | d) $\frac{p}{ZN}$ |

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- iii) In order to find the maximum bending moment on the arms of a flywheel, it is assumed as a
 - a) simply supported beam carrying a uniformly distributed load over the arm
 - b) fixed at both ends (i.e. at the hub and at the free end of the rim) and carrying a uniformly distributed load over the arm.
 - c) cantilever beam fixed at the hub and carrying a concentrated load at the free end of the rim.
 - d) none of these.
- iv) Autofrettage is a term associated with
 - a) Cast iron pressure vessels subjected to external pressure
 - b) Low pressure vessels subjected to external pressure
 - c) Low pressure spherical vessels
 - d) Pre-stressing of thick cylindrical vessels under internal pressure
- v) If Z is the actual number of teeth in transverse plane of a helical gear and Ψ is the helix angle, then the formative number of teeth is given by
 - a) $Z \sec^3 \Psi$
 - b) $Z \cos \Psi$
 - c) $Z / \sec^3 \Psi$
 - d) $Z \cos^2 \Psi$
- vi) Worm gears are employed for transmission of power between
 - a) parallel shafts
 - b) intersecting shafts
 - c) non-parallel and non-intersecting shafts
 - d) none of these.

- vii) Friction radius for a new clutch compared to worn out will be
 - a) same
 - b) more
 - c) less
 - d) depends on overall size of clutch.
- viii) A multi-disc clutch has three discs on the driving shaft and two discs on the driven shaft. Number of pair of contact surfaces is
 - a) 2
 - b) 3
 - c) 4
 - d) 5.
- ix) For a block brake, the equivalent co-efficient of friction is equal to
 - a) $4 \mu \sin \theta / (2 \theta + \sin 2 \theta)$
 - b) $2 \mu \sin \theta / (2 \theta + \sin 2 \theta)$
 - c) $4 \mu \sin 2 \theta / (2 \theta + \sin 2 \theta)$
 - d) $\sin 2 \theta / (4 \theta + \sin 2 \theta)$
 - e) $2 \mu \sin \theta / (4 \theta + \sin 2 \theta)$

where, θ = semi-block angle

μ = co-efficient of friction of material of block and wheel.
- x) A pressure vessel is said to be thin if the ratio of wall thickness of the shell to its internal diameter is :
 - a) equal to 1/15
 - b) less than 1/15
 - c) more than 1/15
 - d) none of these.

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GROUP - B

(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. Explain the mechanism of pressure development in a hydrodynamic bearing. Draw and explain Stribeck curve for sliding contact bearings.
3. Define static load capacity of rolling contact bearings. How does it differ from dynamic load capacity ? State and explain Stribeck equation.
4. Derive Lamé's equation for cylinder wall thickness of a pressure vessel. State the assumptions for the same.
5. State the advantages and disadvantages of a cone clutch. Explain self-energizing and self-locking block brakes.
6. Derive the equation of torque developed by a disc clutch assuming uniform pressure theory.
7. Explain why worm gear reduction units are not preferred over other types of gear boxes for transmitting large power. What are the materials for worm and worm wheel ? Explain why dissimilar materials are used for manufacturing worm and worm wheel ?

GROUP - C

(Long Answer Type Questions)

Answer any *three* of the following. $3 \times 15 = 45$

8. Design a spur gear drive transmitting 30 kW at 400 rpm to another shaft running approximately at 100 rpm. The load is steady and continuous. The materials for the pinion and gear are cast steel and cast iron respectively. Take module as 10 mm. Also check the design for dynamic load and wear. Assume the allowable static stress for pinion and gear as

140 MPa and 56 MPa respectively. Number of teeth for the pinion is 24. The tooth form factor is given by expression :

$y = 0.154 - (0.912/\text{No. of teeth})$ and the velocity factor $C_v = 3/(3 + v)$, where v is the peripheral speed in m/s. The flexural endurance limits for cast iron and cast steel are given as 84 MPa and 252 MPa respectively. Surface endurance limit is given as 630 MPa. Tooth error in action = 0.023 mm. The Young's moduli for pinion and gear are 0.2×10^6 MPa and 0.1×10^6 MPa respectively. Also assume the starting torque to be 25% higher than the running torque.

9. a) A single row deep groove ball bearing is subjected to a radial load of 8kN and thrust load of 3kN. The diameter of the shaft is 75 mm rotating at 1200 rpm. The bearing selected is 6315 for which the basic static load carrying capacity $C_0 = 72$ kN and the basic dynamic load carrying capacity C is 112kN. The radial load factor and thrust load factor X and Y are given below in the table. Determine the expected rated bearing life in million of revolutions.

$\left(\frac{F_a}{C_0}\right)$	$\left(\frac{F_a}{F_r}\right) \leq e$		$\left(\frac{F_a}{F_r}\right) > e$		e
	X	Y	X	Y	
0.025	1	0	0.56	2.0	0.22
0.040	1	0	0.56	1.8	0.24
0.070	1	0	0.56	1.6	0.27
0.130	1	0	0.56	1.4	0.31
0.250	1	0	0.56	1.2	0.37
0.500	1	0	0.56	1.0	0.44

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- b) A journal bearing is proposed for a centrifugal pump. The diameter of the journal is 0.15m and the load on it is 40 kN and its speed is 900 rev/min. Complete the design calculation for the bearing. Assume length as 1.6 times of diameter. Absolute viscosity of oil is 0.018 Ns/m² at the operating temperature of 55°C. Ambient temperature of oil is 15.5°C.

Calculate also mass of the lubricating oil required for artificial cooling, if rise of temperature of oil be limited to 10°C. Heat dissipation coefficient is 1232 W/m²/°C.

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10. A punching press pierces 35 holes per minute in a plate using 10 kN-m of energy per hole during each revolution. Each piercing takes 40% of the time needed to make one revolution. The punch receives power through a gear reduction unit which in turn is fed by a motor driven belt pulley 800mm diameter and turning at 210 r.p.m. Find the power of the electric motor if overall efficiency of the transmission unit is 80%. Design a cast iron flywheel to be used with the punching machine for a coefficient of steadiness of 5, if the space considerations limit the maximum diameter to 1.3 m.

Allowable shear stress in the shaft material = 50 MPa.

Allowable tensile stress for cast iron = 4 MPa.

Density of cast iron = 7200 kg/m³.

1. a) A cylindrical closed tank made of plane carbon steel having $\sigma_{yt} = 350$ MPa and $\sigma_{ut} = 400$ MPa. Poisson's ratio (μ) = 0.26 is of internal diameter 250 mm. The vessel contains a pressurized toxic gas, the pressure being limited to a maximum value of 16 MPa. Calculate the wall thickness of the cylinder assuming a factor of safety as high as 5 in view of the criticality of the service.

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- b) A highly pressurized compound cylinder consists of an inner steel tube with inner and outer diameters of 20 mm and 40 mm respectively and a jacketing tube having outer diameter of 60 mm. The tubes are assembled by shrinking process in such a way that the maximum principal stress induced in any tube is limited to 100 MPa.

Determine the shrinkage pressure and the original inner diameter of the jacketing tube.

(Given : $E = 2.1 \times 10^5$ MPa)

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12. a) Design a speed reducer unit of worm and worm wheel. The worm and gear of 20° involute teeth have to transmit 11.25kW between shafts which are 0.25m apart. Speed reducer is to be 10.5 to 1, and the rotation of the driving shaft to be 1200 rev/min. Check the design for dynamic load, wear, heat dissipation.

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