RAFFLES UNIVERSITY

TEACHING PLAN: Design of Machine Element B.Tech. 4th Sem.

SCHOOL OF ENGINEERING & TECHNOLOGY		**ACADEMIC SESSION: 2022 – 2023**		**FOR STUDENTS' BATCH: 2021-25**	
1	**Course No.**	PCC-ME 215			
2	**Course Title**	**Design of Machine Element**			
3	**Credits**	**4**			
4	**Learning Hours**	**Contact Hours** 3 **Practical Teaching** 0 **Projects, Tutorials and Assessments** 1 **Total Hours** 4			
5	**Course Objective**	1. Enable students to attain the basic knowledge required to understand, analyse, design and select machine elements required in transmission systems. 2. Reinforce the philosophy that real engineering design problems are open-ended and challenging 3. Impart design skills to the students to apply these skills for the problems in real life industrial applications 4. Inculcate an attitude of team work, critical thinking, communication, planning and scheduling through design projects 5. Develop an holistic design approach to find out pragmatic solutions to realistic domestic and industrial problems			
6	**Course Outcomes**	CO1 - To understand and apply principles of gear design for Spur, Helical, Bevel and Worm gear CO2 – To understand and analyse the concepts of Mechanical Joints like Riveted Joint, Welded Joints and Screwed Joints CO-3 To develop capability to design and analyse the Shaft diameter and different spring parameters. CO4 - To inculcate an ability to design belt drives and selection of belt, rope and chain drives. CO5 - To achieve an expertise in design of Sliding contact bearing in industrial applications.			
7	**Outline syllabus:** Design considerations, Variable Loading in Machine Parts, Mechanical Joints, Design of Shaft and Springs, Design of Gears, Clutches and Brakes.				
7.01	**Paper Code**	**Unit**	**Introduction**	**Page Numbers**	**Teaching Aids**
7.02	**PCC-ME-215**	Unit I Design considerations	Unit-1: Design considerations - limits, fits and standardization, Review of failure theories for static and dynamic loading (including fatigue failure) and Design Against Static Load: Modes of failure, factor of safety, principle stresses, stresses due to bending and torsion, theory of failures.	Machine Design by R.S. Khurmi & J.K Gupta Pg. No. 120-180	White Board, PPT Slides, Projector
		Unit II Variable Loading in Machine Parts	Unit-2: Cyclic stresses, fatigue and endurance limit, stress concentration factor, stress concentration factor for various machine parts, Notch sensitivity, Design for finite and infinite life, Soderberg, Goodman & Gerber criteria.	Machine Design by R.S. Khurmi & J.K Gupta Pg. No. 181-223	White Board, PPT Slides, Projector
		Unit III Mechanical	Riveting methods, materials, types of rivet heads, types of riveted joints, failure of riveted joints, efficiency of riveted	Machine Design by	White Board,

		Joints	joints, design of boiler joints, eccentric loaded riveted joint, Welded joints and Screwed fasteners.	R.S. Khurmi & J.K Gupta Pg No. 281-340, 341-376, 377-430	PPT Slides, Projector
7.03		Unit IV Design of Shaft and Springs	Cause of failure in shaft, materials for shaft, stress in shaft, and design of shafts subjected to twisting moment, bending moment and combined twisting and bending moments, shaft subjected to fatigue loads, design for rigidity. Design of springs: helical compression, tension, torsional and leaf springs	Machine Design by R.S. Khurmi & J.K Gupta Pg. No.509-557, 820-884	White Board, PPT Slides, Projector
		Unit V Design of Gears, Clutches and Brakes	Design of transmission elements: spur, helical, bevel and worm gears; belt and chain drives. Analysis and applications of power screws and couplings. Analysis of clutches and brakes	Machine Design by R.S. Khurmi & J.K Gupta Pg No.1023-1065,1066-1079, 1080-1100, 1101-1124 and 885-961	White Board, PPT Slides, Projector

8	**Course Evaluation**	
8.1	**CA: 20%**	
8.11	**Attendance**	10%
8.12	**Homework**	2 Assignments, 10%
8.13	**Quizzes**	-
8.14	**Projects**	-
8.15	**Presentation**	-
8.13	**Any other**	-
8.2	**MTE**	20%
8.3	**End-term examination: 60%**	
9	**Text Books & References**	
9.1	**Text book**	1. A textbook of Machine Design by R.S. Khurmi & J.K Gupta, EURASIA PUBLISHING HOUSE (PVT.) LTD 2. Design of Machine Elements by V. B. Bhandari, TMH Publishing Co. Ltd., New Delhi 3. Sharma PC and Aggarwal DK, ―Machine Design‖, Kataria Publishers (2002) 4. Machine Design by Dr Abdul Mubeen Khanna Publishers 5. Machine Design 1st Edition by U.C. Jindal, Pearson Publications
9.2	**References**	1. Machine Design by Norton, Prentice Hall. 2. Machine Design by Shigley Tata McGraw hill 3. Machine Design Databook - Second Edition K. Lingaiah, Mcgrew Hill 4. Design Data Handbook for Mechanical Engineering in SI and Metric Units by M Mahadevan CMS Publishers and Distributors.
9.3	**Video References**	https://www.youtube.com/watch?v=V9NP5_TiU8U https://www.youtube.com/watch?v=6CLEWA2WNqM https://www.youtube.com/watch?v=XpfZrZUDY4I https://www.youtube.com/watch?v=2AYOYTPR6Y0 https://www.youtube.com/watch?v=StBa7Wb2ubo https://www.youtube.com/watch?v=NU0pG-XmJKE

		https://www.youtube.com/watch?v=T4IgtIkBnOo https://www.youtube.com/playlist?list=PL3D4EECEFAA99D9BE

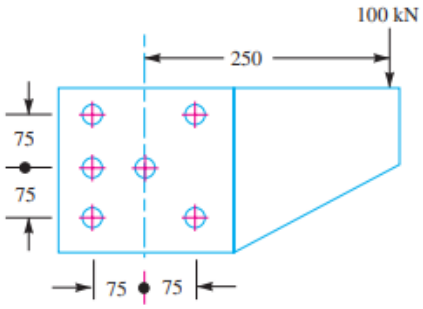
CO-PO Mapping

Course Outcome	Program Outcome												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO 1	3	3	3	3	2	2	2		2	1	2	2	3	3	2	2
CO 2	3	3	3	3	2	2	2		2	1	2	2	3	3	2	2
CO 3	3	3	3	3	2	2	2		2	1	2	3	3	3	2	2
CO 4	3	3	3	3	2	2	1		2	2	1	2	3	3	2	2
CO 5	3	3	3	3	1	1	2		1	1	1	1	3	3	2	1

QUESTION BANK

1. What are fits and tolerances? How are they designated?
2. Discuss the Indian standard system of limits and fits.
3. A medium force fit on a 75 mm shaft requires a hole tolerance and shaft tolerance each equal to 0.225 mm and average interference of 0.0375 mm. Find the hole and shaft dimensions.
4. Calculate the tolerances, fundamental deviations and limits of sizes for the shaft designated as 40 H8 / f7.
5. A hollow shaft of 40 mm outer diameter and 25 mm inner diameter is subjected to a twisting moment of 120 N-m, simultaneously, it is subjected to an axial thrust of 10 kN and a bending moment of 80 N-m. Calculate the maximum compressive and shear stresses.
6. . The load on a bolt consists of an axial pull of 10 kN together with a transverse shear force of 5 kN. Find the diameter of bolt required according to 1. Maximum principal stress theory; 2. Maximum shear stress theory; 3. Maximum principal strain theory; 4. Maximum strain energy theory; and 5. Maximum distortion energy theory.
7. Explain the following terms in connection with design of machine members subjected to variable loads: (a) Endurance limit, (b) Size factor, (c) Surface finish factor, and (d) Notch sensitivity
8. Write Soderberg's equation and state its application to different type of loadings.
9. A machine component is subjected to a flexural stress which fluctuates between + 300 MN/m2 and – 150 MN/m2. Determine the value of minimum ultimate strength according to 1. Gerber relation; 2. Modified Goodman relation; and 3. Soderberg relation. Take yield strength = 0.55 Ultimate strength; Endurance strength = 0.5 Ultimate strength; and factor of safety = 2
10. A circular bar of 500 mm length is supported freely at its two ends. It is acted upon by a central concentrated cyclic load having a minimum value of 20 kN and a maximum value of 50 kN. Determine the diameter of bar by taking a factor of safety of 1.5, size effect of 0.85, surface finish factor of 0.9. The material properties of bar are given by: ultimate strength of 650 MPa, yield strength of 500 MPa and endurance strength of 350 MPa.
11. A simply supported beam has a concentrated load at the centre which fluctuates from a value of P to 4 P. The span of the beam is 500 mm and its cross-section is circular with a diameter of 60 mm. Taking for the beam material an ultimate stress of 700 MPa, a yield stress of 500 MPa, endurance limit of 330 MPa for reversed bending, and a factor of safety of 1.3, calculate the maximum value of P. Take a size factor of 0.85 and a surface finish factor of 0.9.
12. What do you understand by the term riveted joint? Explain the necessity of such a joint.

13. What are the various permanent and detachable fastenings? Give a complete list with the different types of each category.
14. Enumerate the different types of riveted joints and rivets
15. What is the difference between caulking and fullering? Explain with the help of neat sketches.
16. Explain the procedure for designing a longitudinal and circumferential joint for a boiler.
17. What is an eccentric riveted joint? Explain the method adopted for designing such a joint?
18. A double riveted double cover butt joint is made in 12 mm thick plates with 18 mm diameter rivets. Find the efficiency of the joint for a pitch of 80 mm, if σt = 115 MPa ; τ = 80 MPa and σc = 160 MPa
19. A triple riveted lap joint with zig-zag riveting is to be designed to connect two plates of 6 mm thickness. Determine the dia. of rivet, pitch of rivets and distance between the rows of rivet. Indicate how the joint will fail. Assume: σt = 120 MPa ; τ = 100 MPa and σc = 150 MPa.
20. Design a triple riveted double strap butt joint with chain riveting for a boiler of 1.5 m diameter and carrying a pressure of 1.2 N/mm2. The allowable stresses are : σt = 105 MPa ; τ = 77 MPa and σc = 162.5 MPa
21. Design the longitudinal and circumferential joint for a boiler whose diameter is 2.4 metres and is subjected to a pressure of 1 N/mm2. The longitudinal joint is a triple riveted butt joint with an efficiency of about 85% and the circumferential joint is a double riveted lap joint with an efficiency of about 70%. The pitch in the outer rows of the rivets is to be double than in the inner rows and the width of the cover plates is unequal. The allowable stresses are : σt = 77 MPa ; τ = 56 MPa and σc = 120 MPa Assume that the resistance of rivets in double shear is 1.875 times that of single shear. Draw the complete joint
22. Two mild steel tie bars for a bridge structure are to be joined by a double cover butt joint. The thickness of the tie bar is 20 mm and carries a tensile load of 400 kN. Design the joint if the allowable stresses are : σt = 90 MPa ; τ = 75 MPa and σc = 150 MPa. Assume the strength of rivet in double shear to be 1.75 times that of in single shear.
23. A bracket is riveted to a columm by 6 rivets of equal size as shown in Fig.1. It carries a load of 100 kN at a distance of 250 mm from the column. If the maximum shear stress in the rivet is limited to 63 MPa, find the diameter of the rivet.



All dimensions in mm.

Fig. 1

24. Determine the length of the weld run for a plate of size 120 mm wide and 15 mm thick to be welded to another plate by means of 1. A single transverse weld; and 2. Double parallel fillet welds when the joint is subjected to variable loads.

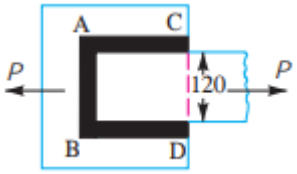


Fig .2

25. A bracket carrying a load of 15 kN is to be welded as shown in Fig.3. Find the size of weld required if the allowable shear stress is not to exceed 80 MPa.

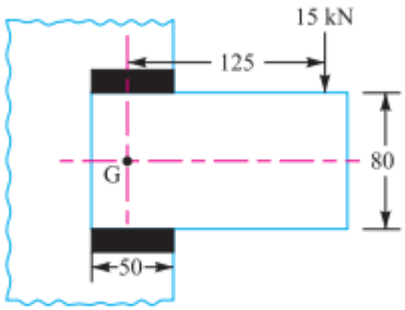
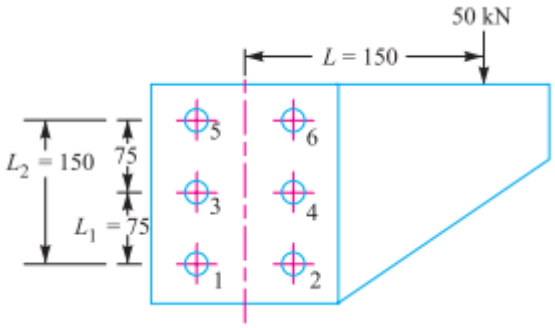


Fig. 3

26. A circular steel bar 50 mm diameter and 200 mm long is welded perpendicularly to a steel plate to form a cantilever to be loaded with 5 kN at the free end. Determine the size of the weld, assuming the allowable stress in the weld as 100 MPa
27. A low carbon steel plate of 0.7 m width welded to a structure of similar material by means of two parallel fillet welds of 0.112 m length (each) is subjected to an eccentric load of 4000 N, the line of action of which has a distance of 1.5 m from the centre of gravity of the weld group. Design the required thickness of the plate when the allowable stress of the weld metal is 60 MPa and that of the plate is 40 MPa
28. What are the assumptions made in the design of welded joint?
29. What is an eccentric loaded welded joint? Discuss the procedure for designing such a joint.
30. The cylinder head of a steam engine is subjected to a pressure of 1 N/mm2. It is held in position by means of 12 bolts. The effective diameter of the cylinder is 300 mm. A soft copper gasket is used to make the joint leak proof. Determine the size of the bolts so that the stress in the bolts does not exceed 100 MPa.
31. What do you understand by the single start and double start threads?
32. Derive an expression for the maximum load in a bolt when a bracket with circular base is bolted to a wall by means of four bolts.
33. Explain the method of determining the size of the bolt when the bracket carries an eccentric load perpendicular to the axis of the bolt.
34. A steam engine cylinder of 300 mm diameter is supplied with steam at 1.5 N/mm2. The cylinder cover is fastened by means of 8 bolts of size M 20. The joint is made leak proof by means of suitable gaskets. Find the stress produced in the bolts
35. A steam engine cylinder has an effective diameter of 200 mm. It is subjected to a maximum steam pressure of 1.75 N/mm2. Calculate the number and size of studs required to fix the cylinder cover onto the cylinder flange assuming the permissible stress in the studs as 30 MPa. Take the pitch circle diameter of the studs as 320 mm and the total load on the studs as 20% higher than the external load on the joint. Also check the circumferential pitch of the studs so as to give a leak proof joint
36. A bracket is bolted to a column by 6 bolts of equal size as shown in Fig. 4. It carries a load of 50 kN at a distance of 150 mm from the centre of column. If the maximum stress in the bolts is to be limited to 150 MPa, determine the diameter of bolt.



37. What size of hole must be drilled in a M 42 bolt so as to make the bolt of uniform strength?

38. A solid shaft is transmitting 1 MW at 240 r.p.m. Determine the diameter of the shaft if the maximum torque transmitted exceeds the mean torque by 20%. Take the maximum allowable shear stress as 60 MPa.
39. A shaft supported at the ends in ball bearings carries a straight tooth spur gear at its mid span and is to transmit 7.5 kW at 300 r.p.m. The pitch circle diameter of the gear is 150 mm. The distances between the centre line of bearings and gear are 100 mm each. If the shaft is made of steel and the allowable shear stress is 45 MPa, determine the diameter of the shaft. Show in a sketch how the gear will be mounted on the shaft; also indicate the ends where the bearings will be mounted? The pressure angle of the gear may be taken as 20°.
40. A shaft made of mild steel is required to transmit 100 kW at 300 r.p.m. The supported length of the shaft is 3 metres. It carries two pulleys each weighing 1500 N supported at a distance of 1 metre from the ends respectively. Assuming the safe value of stress, determine the diameter of the shaft
41. A shaft is supported on bearings A and B, 800 mm between centres. A 20° straight tooth spur gear having 600 mm pitch diameter, is located 200 mm to the right of the left hand bearing A, and a 700 mm diameter pulley is mounted 250 mm towards the left of bearing B. The gear is driven by a pinion with a downward tangential force while the pulley drives a horizontal belt having 180° angle of wrap. The pulley also serves as a flywheel and weighs 2000 N. The maximum belt tension is 3000 N and the tension ratio is 3 : 1. Determine the maximum bending moment and the necessary shaft diameter if the allowable shear stress of the material is 40 MPa.
42. Design a shaft to transmit power from an electric motor to a lathe head stock through a pulley by means of a belt drive. The pulley weighs 200 N and is located at 300 mm from the centre of the bearing. The diameter of the pulley is 200 mm and the maximum power transmitted is 1 kW at 120 r.p.m. The angle of lap of the belt is 180° and coefficient of friction between the belt and the pulley is 0.3. The shock and fatigue factors for bending and twisting are 1.5 and 2.0 respectively. The allowable shear stress in the shaft may be taken as 35 MPa.
43. Compare the weight, strength and stiffness of a hollow shaft of the same external diameter as that of solid shaft. The inside diameter of the hollow shaft being half the external diameter. Both the shafts have the same material and length
44. A line shaft rotating at 200 r.p.m. is to transmit 20 kW. The allowable shear stress for the material of the shaft is 42 MPa. If the shaft carries a central load of 900 N and is simply supported between bearing 3 metre apart, determine the diameter of the shaft. The maximum tensile or compressive stress is not to exceed 56 MPa
45. Discuss the various types of shafts and the standard sizes of transmissions shafts
46. Define equivalent twisting moment and equivalent bending moment. State when these two terms are used in design of shafts.
47. What do you understand by torsional rigidity and lateral rigidity?
48. A hollow shaft has greater strength and stiffness than solid shaft of equal weight. Explain.
49. How the shaft is designed when it is subjected to twisting moment only?
50. A helical spring is made from a wire of 6 mm diameter and has outside diameter of 75 mm. If the permissible shear stress is 350 MPa and modulus of rigidity 84 kN/mm2, find the axial load which the spring can carry and the deflection per active turn.
51. Discuss the materials and practical applications for the various types of springs.
52. Explain the following terms of the spring: (i) Free length; (ii) Solid height; (iii) Spring rate; (iv) Active and inactive coils; (v) Spring index; and (vi) Stress factor.
53. What is nipping in a leaf spring? Discuss its role. List the materials commonly used for the manufacture of the leaf springs.
54. Explain what you understand by A.M. Wahl's factor and state its importance in the design of helical springs?
55. A railway wagon weighing 50 kN and moving with a speed of 8 km per hour has to be stopped by four buffer springs in which the maximum compression allowed is 220 mm.

Find the number of turns in each spring of mean diameter 150 mm. The diameter of spring wire is 25 mm. Take G = 84 kN/mm2.

56. A load of 2 kN is dropped axially on a close coiled helical spring, from a height of 250 mm. The spring has 20 effective turns, and it is made of 25 mm diameter wire. The spring index is 8. Find the maximum shear stress induced in the spring and the amount of compression produced. The modulus of rigidity for the material of the spring wire is 84 kN/mm2.
57. A helical compression spring made of oil tempered carbon steel, is subjected to a load which varies from 600 N to 1600 N. The spring index is 6 and the design factor of safety is 1.43. If the yield shear stress is 700 MPa and the endurance stress is 350 MPa, find the size of the spring wire and mean diameter of the spring coil.
58. The free end of a torsional spring deflects through 90° when subjected to a torque of 4 N-m. The spring index is 6. Determine the coil wire diameter and number of turns with the following data : Modulus of rigidity = 80 GPa ; Modulus of elasticity = 200 GPa; Allowable stress = 500 MPa
59. A flat spiral steel spring is to give a maximum torque of 1500 N-mm for a maximum stress of 1000 MPa. Find the thickness and length of the spring to give three complete turns of motion, when the stress decreases from 1000 to zero. The width of the spring strip is 12 mm. The Young's modulus for the material of the strip is 200 kN/mm2.
60. A semi-elliptical laminated spring 900 mm long and 55 mm wide is held together at the centre by a band 50 mm wide. If the thickness of each leaf is 5 mm, find the number of leaves required to carry a load of 4500 N. Assume a maximum working stress of 490 MPa. If the two of these leaves extend the full length of the spring, find the deflection of the spring. The Young's modulus for the spring material may be taken as 210 kN/mm2.
61. A reciprocating compressor is to be connected to an electric motor with the help of spur gears. The distance between the shafts is to be 500 mm. The speed of the electric motor is 900 r.p.m. and the speed of the compressor shaft is desired to be 200 r.p.m. The torque, to be transmitted is 5000 N-m. Taking starting torque as 25% more than the normal torque, determine: 1. Module and face width of the gears using 20 degrees stub teeth, and 2. Number of teeth and pitch circle diameter of each gear. Assume suitable values of velocity factor and Lewis factor.
62. What are the various terms used in spur gear terminology?
63. Write the expressions for static, limiting wear load and dynamic load for spur gears and explain the various terms used there in.
64. Discuss the design procedure of spur gears
65. A motor shaft rotating at 1440 r.p.m. has to transmit 15 kW to a low speed shaft rotating at 500 r.p.m. The teeth are 20° involute with 25 teeth on the pinion. Both the pinion and gear are made of cast iron with a maximum safe stress of 56 MPa. A safe stress of 35 MPa may be taken for the shaft on which the gear is mounted. Design and sketch the spur gear drive to suit the above conditions. The starting torque may be assumed as 1.25 times the running torque.
66. A micarta pinion rotating at 1200 r.p.m. is to transmit 1 kW to a cast iron gear at a speed of 192 r.p.m. Assuming a starting overload of 20% and using 20° full depth involute teeth, determine the module, number of teeth on the pinion and gear and face width. Take allowable static strength for micarta as 40 MPa and for cast iron as 53 MPa. Check the pair in wear.
67. Explain the following terms used in helical gears: (a) Helix angle; (b) normal pitch; and (c) axial pitch.
68. Define formative or virtual number of teeth on a helical gear. Derive the expression used to obtain its value.
69. A pair of helical gears consist of a 20 teeth pinion meshing with a 100 teeth gear. The pinion rotates at 720 r.p.m. The normal pressure angle is 20° while the helix angle is 25°. The face width is 40 mm and the normal module is 4 mm. The pinion as well as gear are made of steel having ultimate strength of 600 MPa and heat treated to a surface hardness of 300 B.H.N. The service factor and factor of safety are 1.5 and 2 respectively. Assume that

the velocity factor accounts for the dynamic load and calculate the power transmitting capacity of the gears.

70. What are the various forces acting on a bevel gear?
71. Write the procedure for the design of a shaft for bevel gears.
72. A speed reducer unit is to be designed for an input of 1.1 kW with a transmission ratio 27. The speed of the hardened steel worm is 1440 r.p.m. The worm wheel is to be made of phosphor bronze. The tooth form is to be 20° involute.
73. Define the following terms used in worm gearing: (a) Lead; (b) Lead angle; (c) Normal pitch; and (d) Helix angle.
74. What are the various forces acting on worm and worm gears?
75. Design worm and gear speed reducer to transmit 22 kW at a speed of 1440 r.p.m. The desired velocity ratio is 24 : 1. An efficiency of atleast 85% is desired. Assume that the worm is made of hardened steel and the gear of phosphor bronze.
76. What are the thermal considerations in brake design?
77. How does the function of a brake differ from that of a clutch?
78. What is a self-energizing brake? When a brake becomes self-locking.
79. The drum of a simple band brake is 450 mm. The band embraces 3/4th of the circumference of the drum. One end of the band is attached to the fulcrum pin and the other end is attached to a pin B as shown in Fig. 25.41. The band is to be lined with asbestos fabric having a coefficient of friction 0.3. The allowable bearing pressure for the brake lining is 0.21 N/mm2. Design the band shaft, key, lever and fulcrum pin. The material of these parts is mild steel having permissible stresses as follows : $\sigma t = \sigma c = 70$ MPa, and $\tau = 56$ MPa
80. In a band and block brake, the band is lined with 14 blocks, each of which subtends an angle of 20° at the drum centre. One end of the band is attached to the fulcrum of the brake lever and the other to a pin 150 mm from the fulcrum. Find the force required at the end of the lever 1 metre long from the fulcrum to give a torque of 4 kN-m. The diameter of the brake drum is 1 metre and the coefficient of friction between the blocks and the drum is 0.25.
81. A cone clutch is mounted on a shaft which transmits power at 225 r.p.m. The small diameter of the cone is 230 mm, the cone face is 50 mm and the cone face makes an angle of 15° with the horizontal. Determine the axial force necessary to engage the clutch to transmit 4.5 kW if the coefficient of friction of the contact surfaces is 0.25. What is the maximum pressure on the contact surfaces assuming uniform wear?