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Program: B. Sc. Eng. (ME)
Semester: 6th

Date: 20 May 2024 (Monday)
Time: 10:00 AM – 1:00 PM

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination | **Summer Semester: 2022 - 2023**
Course Code: ME 4609 | **Full Marks: 150**
Course Title: Machine Design I | **Time: 3 Hours**

There are **six** questions. Answer **all** of them. The symbols have their usual meanings. Marks of each question and corresponding CO and PO are written in the brackets. All sub-questions carry equal marks. This is an **OPEN BOOK Exam** (Only Textbook allowed, No notes or handouts). **Assume reasonable design data if necessary.** State all assumptions (if any) clearly. Programmable calculators are not allowed.

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1. **Figure 1** shows a basketball backboard and goal attached to a steel pipe that is firmly cemented into the ground. The force, $F = 230$ *lb*, represents a player hanging from the back of the rim. *Determine* the maximum and minimum stresses of the curved beam. **(20)** **(CO2)** **(PO2)** **K3, K4** **P1, P2**

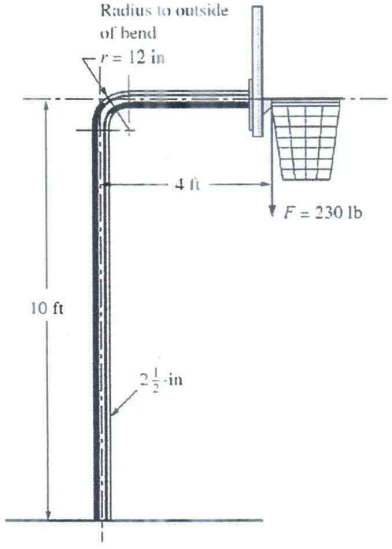

Figure 1

2. The hydraulic cylinder shown in the **Figure 2** has a **50 mm** bore and is to operate at a pressure of **5 MPa**. With the clevis mount shown, the piston rod should be sized as a column with one end fixed and one end rounded for any plane of buckling. The rod is to be made of forged **AISI 1050** steel without further heat treatment. **(20)** **(CO3)** **(PO3)** **K5** **P1, P2**

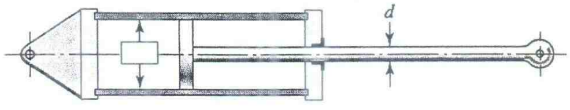

Figure 2

(i) *Design* the rod diameter, d using a design factor $n_d = 2.5$, if the column length is **1.27 m**.

(ii) Repeat part (i) if the column length is halved.

(iii) *Calculate* factor of safety that results for each of the cases above?

3. A constant diameter shaft, is loaded with forces at ***A*** and ***B*** as shown in **Figure 3**, with ground reaction forces at ***O*** and ***C***. The shaft also transmits a torque of **169.5 N·m** throughout the length of the shaft. The shaft is to be made of **AISI 1035 CD** steel. Using a conservative failure theory with a design factor of 2,
Design the minimum shaft diameter to avoid yielding. **(25) (CO3) (PO3) K5 P1, P2**

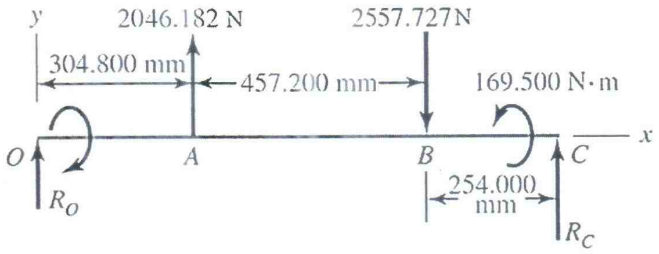

Figure 3

4. A horizontal cantilever beam has a hole of radius ***r =10* mm** and is fixed to a vertical wall as shown in **Figure 4**. The length of the beam is **L = OB = 600 mm** and the square cross-section is **80 mm × 80 mm**. A repeated vertical load ***F***, with an alternating component F_a = ***20 kN***, is acting at point **B**. The beam is **AISI 1080** hot-rolled steel, operating at room temperature, with a reliability of **99.99%,** and miscellaneous effects can be ignored. **(30) (CO4) (PO3) K5, K7 P1, P5**

(i) *Determine* the fully corrected endurance strength of the beam.
(ii) *Determine* the fatigue stress concentration factor $\mathbf{K_f}$ for the critical element **A**, as shown in Figure 5.
(iii) *Determine* the fatigue factor of safety for element **A** using the ASME elliptic criterion.
(iv) Is the beam safe for *infinite life*? If not, then *determine* the number of cycles to failure and show your answer on an S-N diagram.

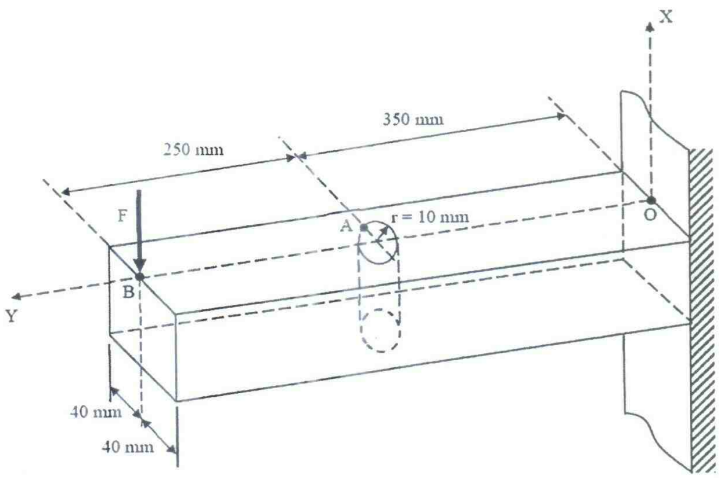

Figure 4 (A repeated load **F** acting at the end of a beam)

5. A gear reduction unit (**Figure 5**) has input shaft **AB** and output shaft **CD**, with an input torque of $T_i = 35.02$ **N·mm** at constant speed $\omega_i = 60$ **rev/min** driving an output load torque T_o at output speed ω_o. Shaft **AB** (shown separately with dimensions) is supported by deep-groove angular contact ball bearings at **A** and **B**, which can be treated as simple supports. The pitch radii of the gears are $r_i = 25.4$ **mm** and $r_2 = 35.02$ **mm**. The targeted combined reliability for the entire set of four bearings is **92** percent, for a life of **30 000** hours of operation. **(25)** **(CO1) (PO2) K3, K4 P1, P5**

(i) *Determine* the target reliability for each individual bearing.

(ii) *Determine* the radial force to be carried by the bearing at A and B.

(iii) *Design* the ***02*** **series** bearings at A and B for an L_{10} life of **1 million** cycles.

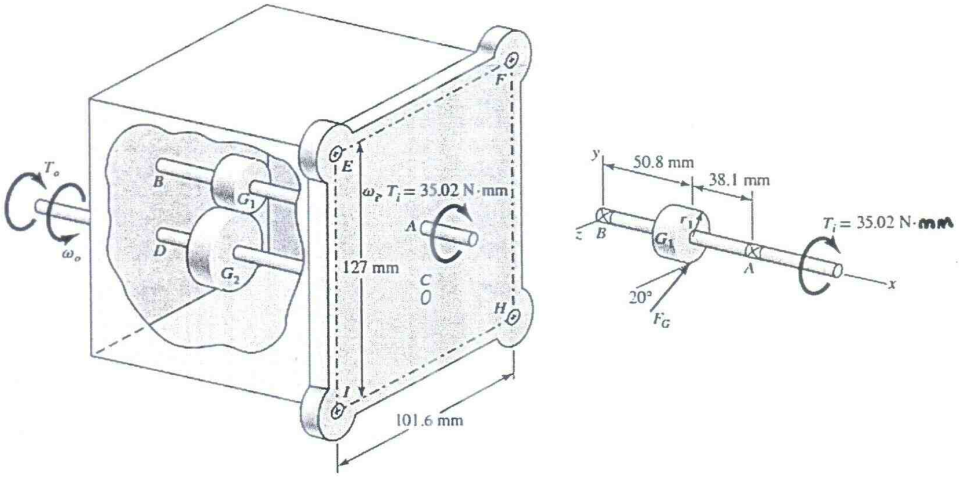

Figure 5

6. Design the countershaft of a gear reduction unit as illustrated in **Figure 6. Gear A** receives power from another gear with the transmitted force F_A applied with pressure angle as shown. The power is transmitted through the shaft and delivered through **Gear B** with transmitted force F_B at the pressure angle shown. *Design* the **diameter** of the countershaft using a design factor, $n_d = 1.6$ based on infinite life using a conservative fatigue failure criteria. The shaft rotation is considered constant, the shaft has a constant diameter and made of **AISI 1035** Hot-Rolled steel. Also, find the factor of safety guarding against yielding for the design diameter. **(30)** **(CO4) (PO3) K5, K7 P1, P5**

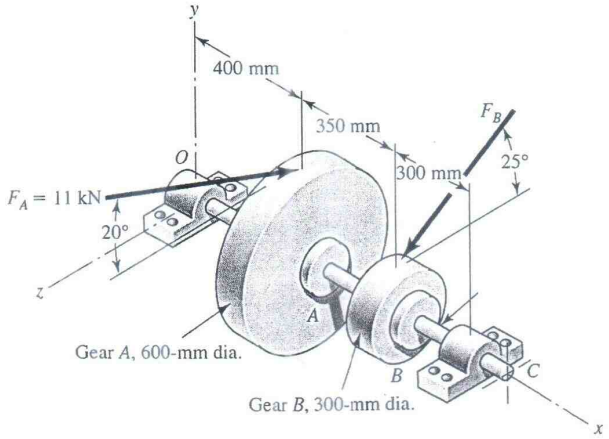

Figure 6