Sri Lanka Institute of Information Technology

B.Sc. Eng. (Hons.) Degree in **Mechanical Engineering**
Specialization in **Mechatronics Engineering**

End Semester Examination

Year 3– Semester I

ME 3531–Solid Mechanics and Mechanical Design

Duration: 2 Hours + 10 minutes Reading Time

June 2019

Instructions to Candidates:

- This is a **CLOSED BOOK** examination.
- This paper contains **FOUR** questions in **SEVEN** pages including the cover page and annex.
- Answer **ALL** questions.
- Start each question on a new page of your answer sheet.
- **Clearly state all the assumptions** you make.
- No electronic devices are allowed other than the faculty approved calculator.
- Cell phone should be kept outside your writing area.
- This paper contributes **50%** towards the final grade.

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Question 1 [Total: 25 marks]

The simply supported beam shown in **Figure Q1** carries a uniformly distributed load of intensity 600 N/m. For the beam E = 100 GPa and I = 10×10^{-6} m^4 .

(a) Obtain the deflection curve for the beam. (15 marks)

(b) Compute the value of downward deflection at mid-span. (05 marks)

(c) Determine the smallest value of the second moment of area I for the beam that limits the mid-span displacement to $1/360^{th}$ of the span. (05 marks)

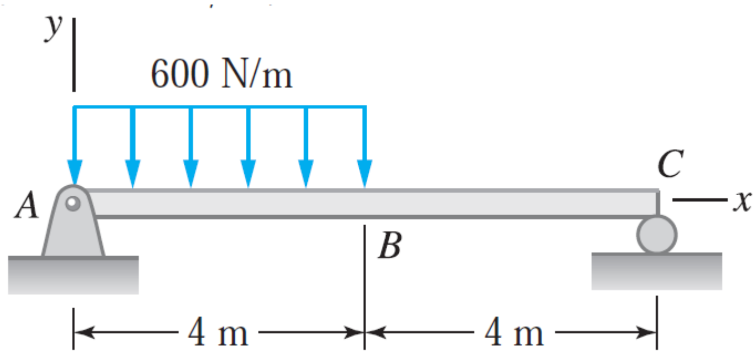

Figure Q1

Question 2 [Total: 30 marks]

A schematic diagram of a manually operating sluice gate and the handle which is used to raise and lower it are shown in **Figure Q2**. This sluice gate is used in an anicut to provide water for irrigation purposes. The amount of water which gets diverted at the anicut is controlled by raising and lowering the gate along vertical guides. It is lifted and lowered by means of a square threaded screw and nut pair. The bottom end of the screw is attached to the gate as shown in the Figure. As a consequence, the screw will not rotate but will translate vertically when the gate is lifted and lowered.

The nut is machined through the middle of a large wheel as shown. The wheel is supported on a thrust collar and the weight of the sluice gate will ensure that the nut will not move vertically. When the wheel is rotated by the handle, the nut will turn relative to the screw. The rotation of the nut will provide necessary vertical movement of the screw.

The sluice gate weighs 5000 kg. The force exerted by the water pressure on the gate when it is at its lowest position is 55 kN. The outer diameter of the screw which is used to lift the gate, is 52 mm and the pitch is 8 mm. The thread on the screw is single start. The outside and inside diameter of the thrust collar is 150 mm and 50 mm. The coefficient of friction between the gate and the guides is 0.2. The coefficient of friction at the screw and nut pair is 0.1 and for the thrust collar is 0.12.

The length of the handle (L) = 1m

Gravitational Force (g) = 9.81 ms^{-2}

Torque required to overcome the friction at the thrust collar $= \mu_b \times W \times R_m$
(where μ_b–The coefficient of friction at the thrust collar, W– Total Load,
R_m– Mean radius of the thrust collar)

$$\text{Torque required to raise load by square threaded screws } = T_{screw} = Wtan(\phi + \alpha) \times \frac{d_m}{2}$$

$$\text{Torque required to lower load by square threaded screws } = T_{screw} = Wtan(\phi - \alpha) \times \frac{d_m}{2}$$

Make reasonable assumptions whenever necessary, which should be clearly stated.

(a) Define following parameters. (04 marks)

(i) Pitch

(ii) Lead

(iii) Mean diameter

(iv) Helix angle

(b) Find the mean diameter of the screw. (01 mark)

(c) Find the helix angle of the screw. (01 mark)

(d) Is this a overhauling screw or a self locking screw? Justify your answer. (02 marks)

(e) For raising the gate, (07 marks)

(i) Calculate the total load acting on the screw.

(ii) Calculate the torque required to overcome friction at screw.

(iii) Calculate the mean radius of the thrust collar.

(iv) Calculate the torque required to overcome friction at the thrust collar.

(v) Find the **Force** required at the end of the handle.

(f) For the lowering the gate, find the **Force** required at the end of the handle. (06 marks)

(g) Find the efficiency of the arrangement for the raising of the load. (04 marks)

(h) Assume that the first thread of the screw and nut pair carries 30% of the total load, estimate the safety factor in the shearing mode of failure of the nut. Allowable shear stress of the nut is 60 MPa. (05 marks)

$$\text{Safety Factor} = \frac{\text{Allowable Shear Stress}}{\text{Calculated Shear Stress}}$$

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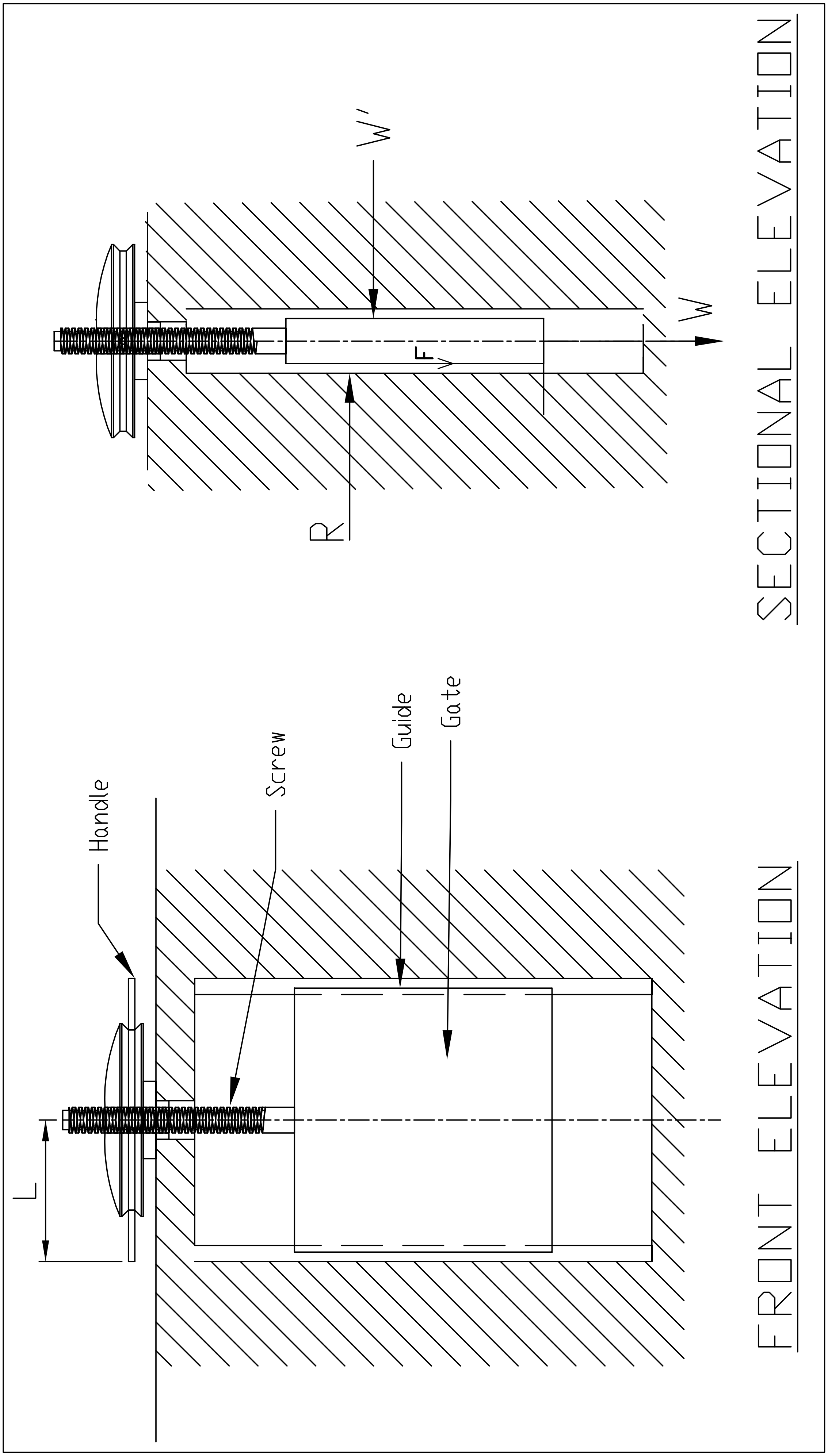

Handle
Screw
Guide
Gate
L
FRONT ELEVATION
W'
W
F
R
SECTIONAL ELEVATION

Figure Q2

Question 3 **[Total: 20 marks]**

(a) A plate 90 mm wide and 12.5 mm thick is joined with another plate by a single transverse weld and a double parallel fillet weld as shown in **Figure Q3 (a)**. The maximum tensile and shear stresses are 70 MPa and 56 MPa respectively.
Find the length of each parallel fillet weld, if the joint is subjected only to **static loading**. Assume, load is distributed evenly along the entire weld length and stress is spread evenly over its effective section. (08 marks)

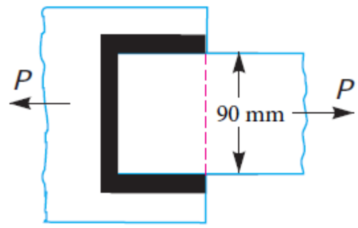

Figure Q3 (a)

Use the following expression where standard notation has been used.
Strength of a Single Transverse Fillet Welded Joint: P $= 0.707s \times l \times \sigma_t$
Strength of a Double Parallel Fillet Welded Joint: P $= 2 \times 0.707s \times l \times \tau$
Throat area for a rectangular fillet weld: A $= 0.707s(2b + 2l)$
The maximum shear stress: $\tau_{max} = \frac{1}{2}\sqrt{\sigma_b^2 + 4\tau^2}$

(b) A rectangular cross-section bar is welded to a support by means of fillet welds around the circumference of the beam as shown in **Figure Q3 (b)**. The permissible shear stress in the weld is limited to 80 MPa.

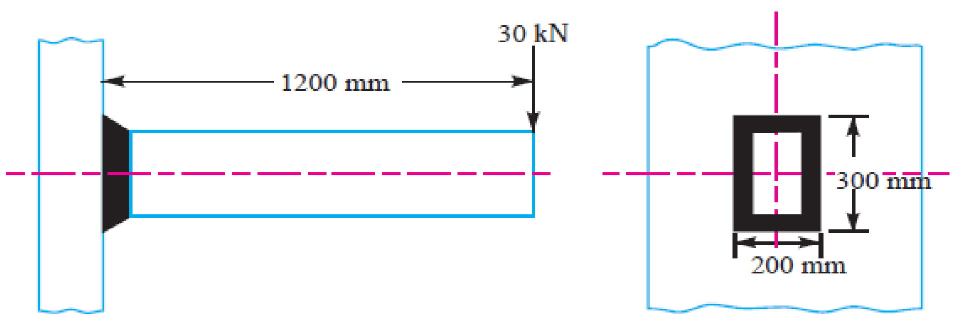

Figure Q3 (b)

(i) Find the throat area of the rectangular fillet weld (02 marks)
(ii) Determine the direct shear stress (02 marks)
(iii) Determine the bending moment of the rectangular section (02 marks)
(iv) If the section modulus $(Z) = 0.707\ s\left(b\ l + \frac{b^2}{3}\right)$, find the bending stress of the rectangular section. $b-$Width of the rectangular section and $l-$length of the rectangular section, Note that $\sigma_b = \frac{M}{Z}$ with usual notation. (04 marks)
(v) Determine the size of the weld. (02 marks)

Question 4 **[Total: 25 marks]**

(a) A horizontal nickel steel shaft rests on two bearings, A at the left and B at the right end and carries two gears C and D located at distances of 250 mm and 400 mm respectively from the centre line of the left and right bearings. The pitch diameter of the gear C is 600 mm and that of gear D is 200 mm. The distance between the centre lines of the bearings is 2400 mm. The shaft transmits 20 kW at 120 r.p.m. The power is delivered to the shaft at gear C and is taken out at gear D in such a manner that the tooth pressure F_{tC} of the gear C and F_{tD} of the gear D act vertically downwards.

The working stress is 100 MPa in tension and 56 MPa in shear. The gears C and D weighs 950 N and 350 N respectively. The combined shock and fatigue factors for bending and torsion may be taken as 1.5 and 1.2 respectively.

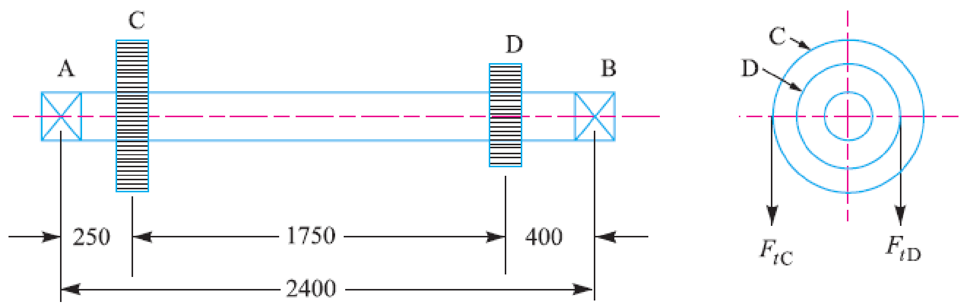

Figure Q4 (a)

(i) Calculate the torque transmitted by the shaft (02 marks)
(ii) Calculate the total load acting at gears C and D. (04 marks)
(iii) Find the reaction forces at A and B. (02 marks)
(iv) Find the Equivalent Twisting and Bending moments of the shaft. (04 marks)
(v) Based on the obtained results, determine the diameter of the shaft. (04 marks)

Tangential force acting at gear C, $F_{tC} = \dfrac{T}{R_C}$

Equivalent twisting moment $T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2}$

Equivalent bending moment; $M_e = \dfrac{1}{2}\left[K_m \times M + \sqrt{(K_m \times M)^2 + (K_t \times T)^2}\right]$

(b) (i) A shaft is subjected to a maximum load of 20 kN. It is designed to withstand a load of 25 kN. If the maximum load encountered is normally distributed with a standard deviation of 3.0 kN, and if shaft strength is normally distributed with a standard deviation of 2.0 kN, what failure percentage would be expected?
. (05 marks)

Assume that the failure rate calculated in **Q4 (b) (i)** *is unacceptable.*

(ii) To what value would the standard deviation of shaft strength have to be reduced in order to give a failure rate of 5%, with no other changes? (02 marks)

(iii) To what value would nominal shaft strength have to be increased in order to give a failure rate of only 5%, with no other changes? (02 marks)

Standard Normal Cumulative Probability Table

Cumulative probabilities for POSITIVE z-values are shown in the following table:

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

End of the Question Paper