

**UNIVERSITY COLLEGE (UC TATI)****FINAL EXAMINATION QUESTION BOOKLET**

COURSE CODE	: BME 3013
COURSE	: MECHANICS OF MACHINE
SEMESTER/SESSION	: 2-2023/2024
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO**THIS BOOKLET CONTAINS 12 PRINTED PAGES INCLUDING COVER PAGE**

QUESTION 1

- a) Gear A is input and revolves at 1500 rev/min clockwise from the left end shown in Figure 1. The input torque is 45 Nm and the efficiency is 65%. Given Gear A has 50 teeth, Gear B has 150 teeth, Gear C has 30 teeth and Gear D has 60 teeth. **Find** the following
- i. the output speeds and its direction (1 mark)
 - ii. the output power (2 marks)
 - iii. the holding torque (2 marks)

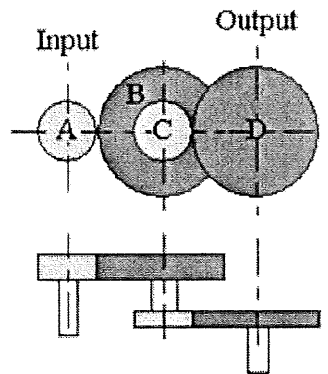


Figure 1

- b) Two pulleys, one 450 mm diameter and the other 200 mm diameter are on parallel shafts 1.95 m apart and are connected by a crossed belt. The larger pulley rotates at 200 rev/min with the maximum permissible tension in the belt is 1 kN. The coefficient of friction between the belt and pulley is 0.25. **Compute**
- i. the length of the belt required (3 marks)
 - ii. the angle of contact between the belt and each pulley (3 marks)
 - iii. the power can be transmitted by the belt (4 marks)

c)

An open belt running over two pulleys 240 mm and 600 mm diameter connects two parallel shafts 3 meters apart and transmits 4 kW from the smaller pulley that rotates at 300 rev/min. Given the coefficient of friction between the belt and the pulley is 0.3.

Determine

- i. the tension in both side (6 marks)
- ii. initial belt tension (2 marks)
- iii. length of the belt required (2 marks)

QUESTION 2

- a) Figure 2 shows a shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radius 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45° , B to C 70° and C to D 120° . The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, solve their magnitudes and angular positions. (7 marks)

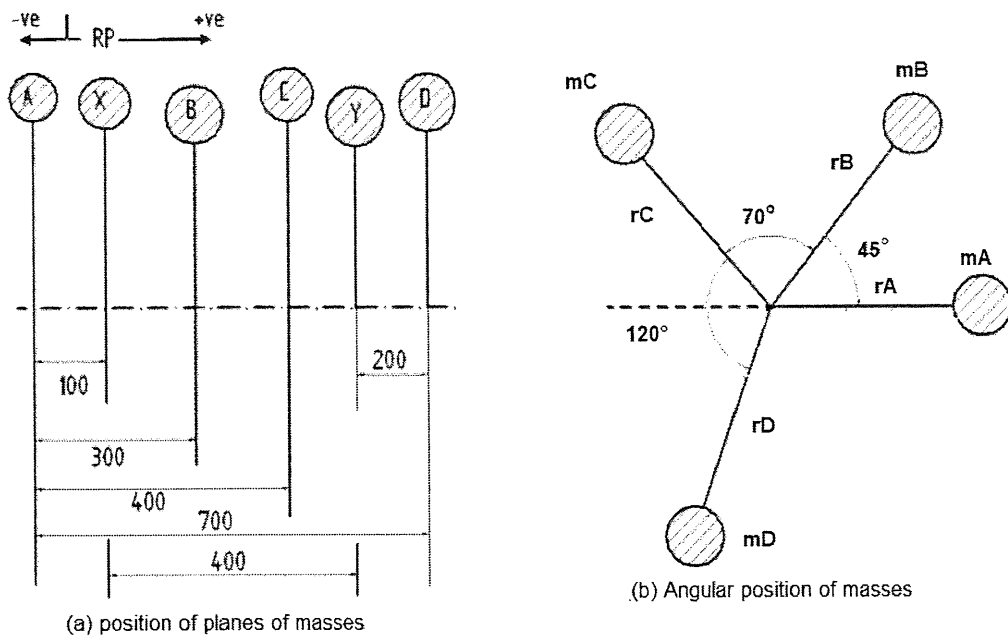


Figure 2

- b) A multi plate clutch must have five contact surfaces and transmits power at 2000 rev/min. The coefficient of friction is 0.25. The inner and outer diameters are 80 mm and 150 mm respectively. The axial force applied to the plate is 600 N. **Calculate** the power that can be transmitted without slipping using
- the uniform pressure theory (4 marks)
 - the uniform wear theory (4 marks)

- c) A rotating shaft at constant angular velocity carries four masses, A, B, C and D, rigidly attached to it as shown in Figure 3 and the centers of mass are at 30 mm, 36 mm, 39 mm and 33 mm respectively from the axis of rotation. The mass of A, C and D are 7.5 kg, 5 kg and 4 kg. The axial distance between A and B is 400 mm and that between B and C is 500 mm. The eccentricities of A and C are 90° to one another and B is starting point. If the system is fully balance, **determine**
- The axial distance, x between the planes of C and D. (5 marks)
 - The angles of mass B and mass D relative to mass C. (3 marks)
 - The mass B. (2 marks)

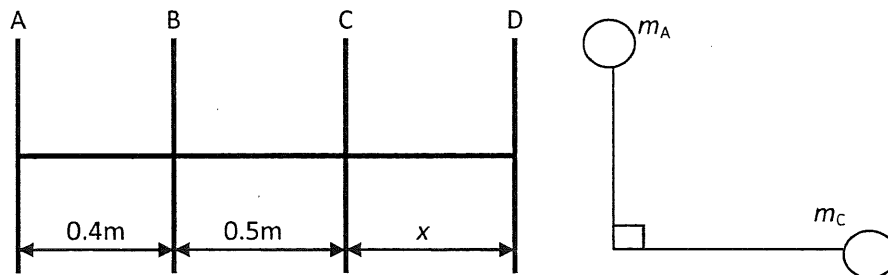


Figure 3

QUESTION 3

- a) A multi-cylinder engine is to run at a speed of 600 rev/min. Figure 4 shows the Turning Moment Diagram to a scale of 1 mm = 250 Nm and 1 mm = 3°, the areas above and below the mean torque line are: + 160 mm², - 172 mm², + 168 mm², - 191 mm², + 197 mm², - 162 mm² and given coefficient of speed, C_s is $\pm 1\%$. **Compute**
- the moment of inertia of a suitable flywheel (4 marks)
 - the mass required if the radius of gyration is to be 0.5 m (2 marks)

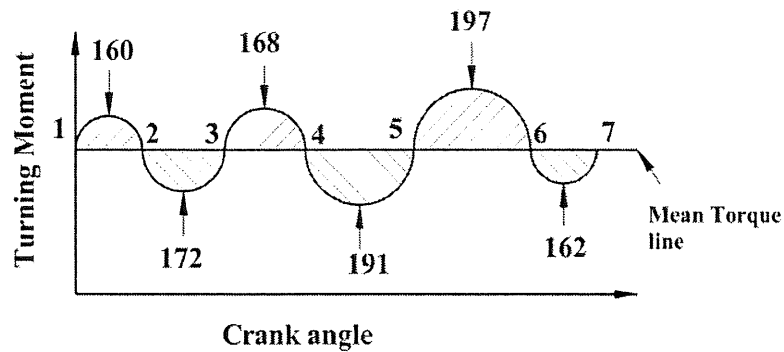


Figure 4

- b) A governor of the Proell type has each arm 300 mm long shown in Figure 5. The pivots of the upper and lower arms are pivot on the axis of the governor. The central load acting on the sleeve has a mass of 100 kg and the each rotating ball has a mass of 10 kg. When the governor sleeve is in mid-position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 180 mm. the vertical height of the governor is 200 mm. If the governor speed is 160 rev/min. when in mid-position, **solve**
- the length of extension link (6 marks)
 - the tension in the upper link (3 marks)

MECHANICS OF MACHINE (BME 3013)

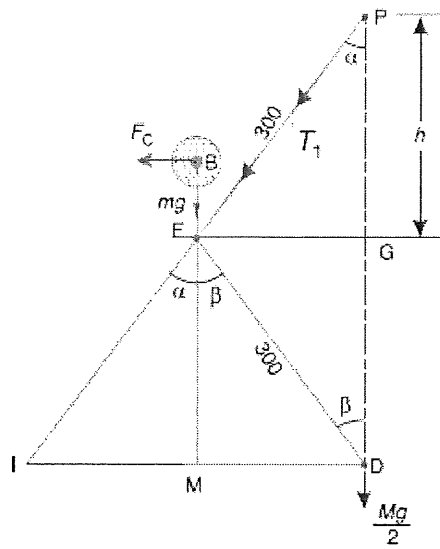


Figure 5

- c) The turning moment diagram for a petrol engine is drawn to the following scales: Turning moment, 1 mm = 5 Nm; crank angle, 1 mm = 3° horizontally shown in Figure 6. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295 mm², 685 mm², 40 mm², 340 mm², 960 mm², 270 mm² when the engine is running at a speed of 600 rev/min. If the total fluctuation of speed is not to exceed $\pm 1.5\%$ of the mean, **determine** the necessary mass of the flywheel of radius 0.5 m.

(10 marks)

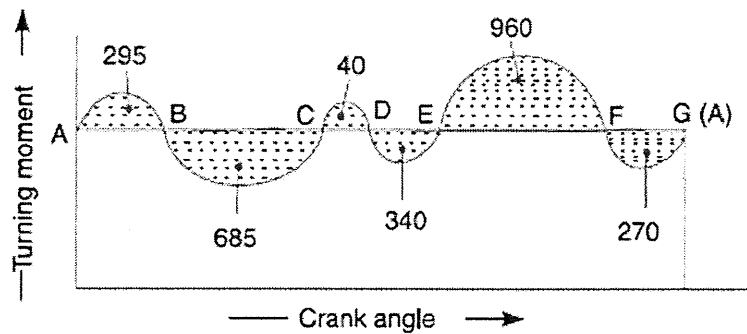


Figure 6

QUESTION 4

- a) The diagram in Figure 7 shows a mass-spring-dashpot system. The mass has a harmonic disturbing force applied to it given by the equation $F = 400 \sin(30t)$ Newton.

Compute

- i. the amplitude of the mass (5 marks)
- ii. The phase angle (2 marks)

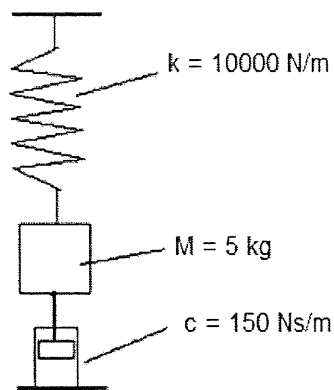


Figure 7

- b) Figure 8 shows a Proell governor has equal arms of length 300 mm. The upper and lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 80 mm long and parallel to the axis when the radii of rotation of the balls are 150 mm and 200 mm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. **Determine**
- i. the minimum and maximum speed of the governor (6 marks)
 - ii. the range of speed (2 marks)

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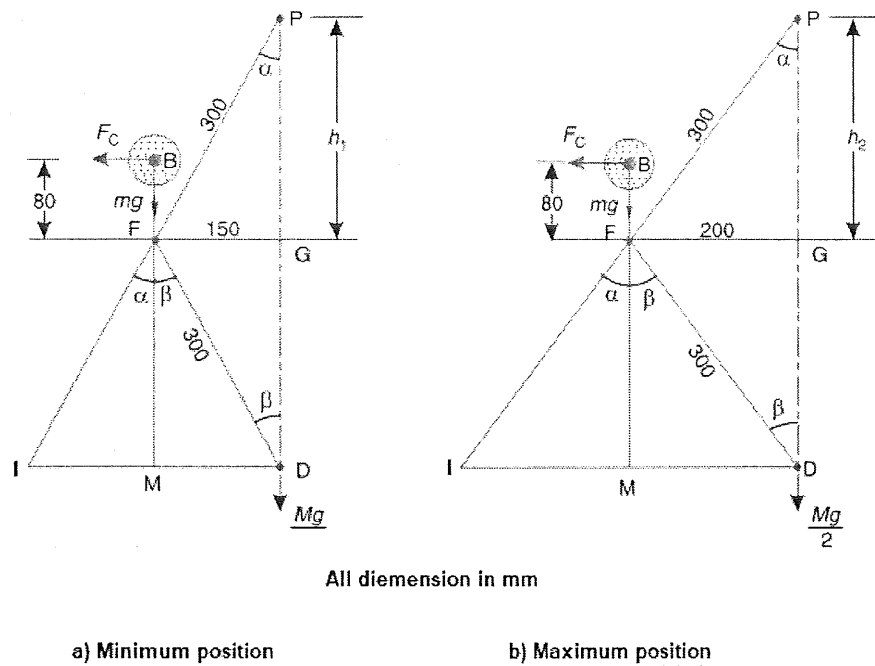


Figure 8

- c) A horizontal shaft is fixed at both end and carries a flywheel at the middle. The shaft is 1 m long either side of the flywheel and is 10 mm diameter. The flywheel has a moment of inertia of 1.9 kgm^2 . The system has proportional damping and it is observed that the amplitude reduces by 60% after one oscillation. The shaft material has a modulus of rigidity of 90 GPa. **Calculate**
- i. the damping ratio (2 marks)
 - ii. the natural frequency (2 marks)
 - iii. the actual frequency (2 marks)
 - iv. the critical damping coefficient (2 marks)
 - v. the actual damping coefficient (2 marks)

-----End of question-----

FORMULAE
Belting and power transmitted:

Angle of contact, $\theta_A = 180^\circ - 2\alpha$

$$\text{Open belt: } \sin\alpha = \frac{r_1 - r_2}{x}$$

$$\text{Cross belt: } \sin\alpha = \frac{r_1 + r_2}{x}$$

$$\text{V belt: } \frac{T_1}{T_2} = e^{\frac{\mu\theta}{\sin\beta}} \quad \text{Flat belt: } \frac{T_1}{T_2} = e^{\mu\theta}$$

$$P = (T_1 - T_2)v, \quad P = T\omega, \text{ where } \omega = \frac{2\pi N}{60} \quad P = T_1 - (1 - e^{-\mu\theta})v$$

$$\eta = \frac{P_o}{P_i}$$

$$v = \omega r; \quad v = \frac{\pi d N}{60}; \quad v = \sqrt{\frac{T}{3m}}$$

$$T_0 = \frac{T_1 + T_2}{2}$$

$$P = \frac{2\pi NT}{60}, \quad P = T\omega$$

$$T_c = \frac{T}{3}; \quad T_1 + T_c = T$$

$$T_c = mv^2$$

$$T = \sigma \cdot b \cdot t$$

For Plate/ multiplate:

$$T = nX \frac{2\mu W}{3} \left(\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2} \right), \text{ uniform pressure}$$

$$T = n\mu WR$$

$$W = 2\pi C(r_1 - r_2),$$

For Conical:

$$T = \frac{\mu W}{3 \sin \beta} \left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2} \right), \text{ uniform pressure}$$

$$T = \frac{\mu W}{4 \sin \beta} (D_o + D_i), \text{ uniform wear}$$

Gear:

$$\frac{\text{speed of first driver}}{\text{speed of last driven}} = \frac{\text{product of no. of teeth on drivers}}{\text{product of no. of teeth on driven}}$$

$$\frac{\omega_A}{\omega_B} = \frac{t_B}{t_A}$$

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = \text{G. R.}$$

Flywheel, Balancing, Governor and Vibration:

$$C_s = \frac{\omega_{\max} - \omega_{\min}}{\omega} = \frac{N_{\max} - N_{\min}}{N}$$

$$I = \frac{\beta W}{\omega^2 C_s} \quad I = mk^2 \text{ K.E} = \frac{I\omega^2}{2}$$

$$\text{Porter } (N)^2 = \left(\frac{m+M}{m} \right) \left(\frac{895}{h} \right) \quad \text{Proell } (N)^2 = \frac{FM}{BM} \left(\frac{m+M}{m} \right) \left(\frac{895}{h} \right)$$

$$\text{momentum} = I\omega$$

$$F = m\omega^2 r$$

$$I = \frac{\pi D^4}{64} \text{ circular}$$

$$f = \frac{1}{2} \sqrt{\frac{3EI}{ML^3}}$$

$$Cc = \sqrt{4IK_t}$$

$$C = Cc \times \delta$$

$$k_t = \frac{GJ}{L}$$

$$\omega_n = \sqrt{\frac{k}{I}}$$

$$\omega = \omega_n \sqrt{1 - \delta^2}$$

$$f_n = \frac{1}{2\pi} \sqrt{\frac{k_t}{I}}$$

$$\ln\left(\frac{\theta_1}{\theta_2}\right) = \frac{2\pi\delta m}{\sqrt{1 - \delta^2}}$$

$$\text{Sensitivity, } \alpha = \frac{\omega}{\omega_1 - \omega_2}$$