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UNIVERSITY COLLEGE TATI

UNIVERSITY COLLEGE (UC TATI)

FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BME 3013
COURSE	: MECHANICS OF MACHINE
SEMESTER/SESSION	: 1-2022/2023
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 11 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a) A gear box must produce an output power and torque of 55 kW and 75 Nm when the input shaft rotates at 1200 rev/min. **Find** the following

   i. the gear ratio (3 marks)

   ii. the input power assuming an efficiency of 60% (2 marks)

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**

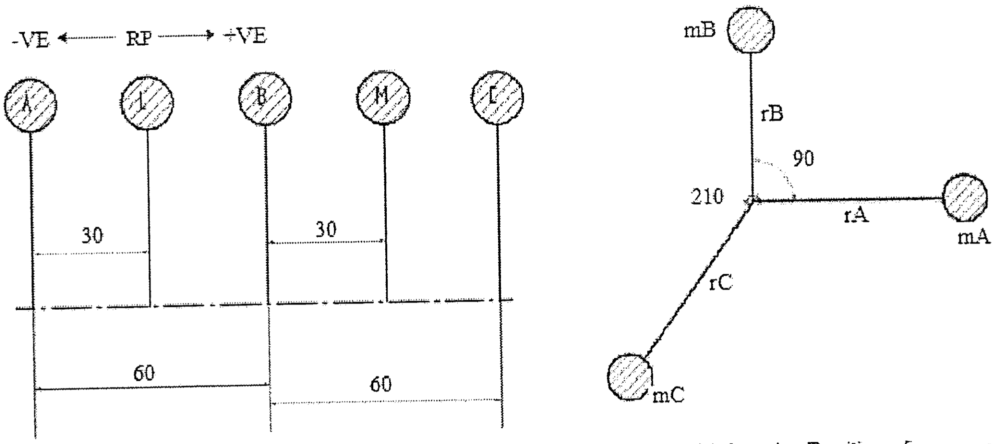
   i. the tension in both side (6 marks)

   ii. initial belt tension (2 marks)

   iii. length of the belt required (2 marks)

QUESTION 2

a) Figure 1 shows A shaft carries three masses A, B and C. Planes B and C are 60 cm and 120 cm from A. A, B and C are 50 kg, 40 kg and 60 kg respectively at a radius of 2.5 cm. The angular position of mass B and mass C with A are 90° and 210°. respectively. **Solve** the position and magnitude of balancing mass required at 10 cm radius in planes L and M midway between A and B, and B and C. (7 marks)



a) position of plane of masses

b) Angular Position of masses

Figure 1

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

i. the uniform pressure theory (4 marks)

ii. 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 2 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**

i. The axial distance, x between the planes of C and D. (5 marks)

ii. The angles of mass B and mass D relative to mass C. (3 marks)

iii. The mass B. (2 marks)

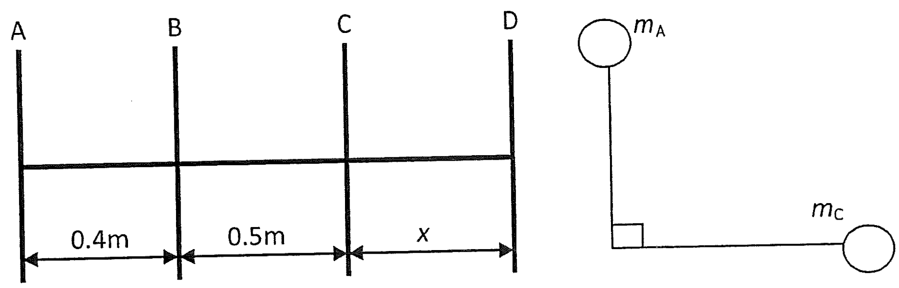


Figure 2

QUESTION 3

a) A multi-cylinder engine is to run at a speed of 600 rev/min. Figure 3 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 mm^2, – 172 mm^2, + 168 mm^2, – 191 mm^2, + 197 mm^2, – 162 mm^2 and given coefficient of speed, Cs is ± 1%. **Compute**

i. the moment of inertia of a suitable flywheel (4 marks)

ii. the mass required if the radius of gyration is to be 0.5 m (2 marks)

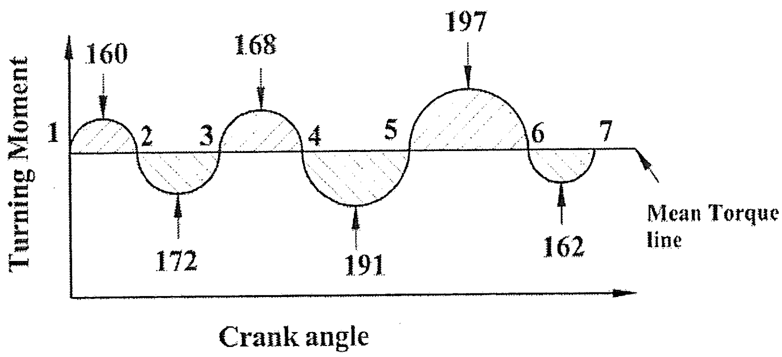


Figure 3

b) A governor of the Proell type has each arm 300 mm long shown in Figure 4. 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**

i. the length of extension link (6 marks)

ii. the tension in the upper link (3 marks)

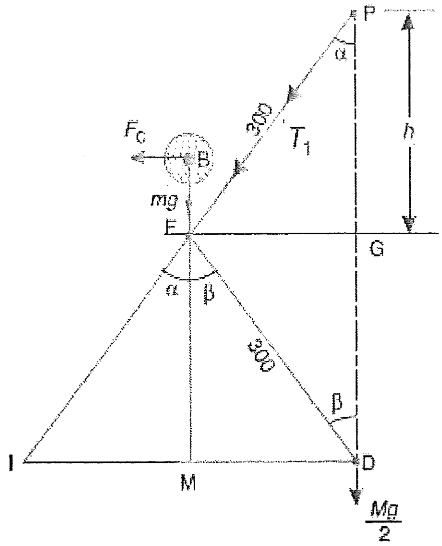


Figure 4

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 5. 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 mm^2, 685 mm^2, 40 mm^2, 340 mm^2, 960 mm^2, 270 mm^2 when the engine is running at a speed of 600 rev/min. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, **determine** the necessary mass of the flywheel of radius 0.5 m.

(10 marks)

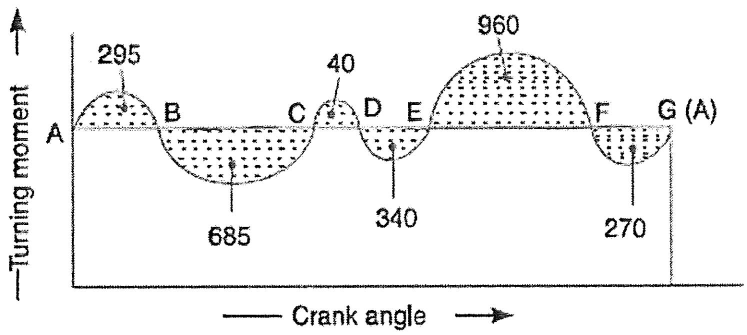


Figure 5

QUESTION 4

a) The diagram in Figure 6 shows a mass-spring-dashpot system. The mass has a harmonic disturbing force applied to it given by the equation F= 400 sin (30 t) Newton. **Compute**

i. the amplitude of the mass (5 marks)

ii. The phase angle (2 marks)

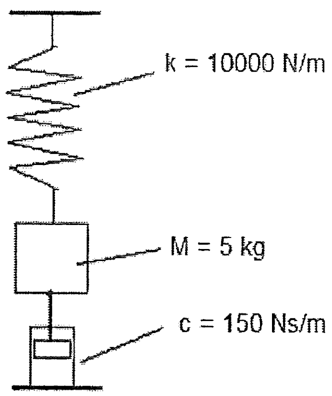


Figure 6

b) Figure 7 shows a loaded Porter governor has four links each 250 mm long, two revolving masses each of 3 kg and a central dead weight of mass 20 kg. All the links are attached to respective sleeves at radial distances of 40 mm from the axis of rotation. The masses revolve at a radius of 150 mm at minimum speed and at a radius of 200 mm at maximum speed. **Determine**

i. the minimum and maximum speed of the governor (6 marks)

ii. the range of speed (2 marks)

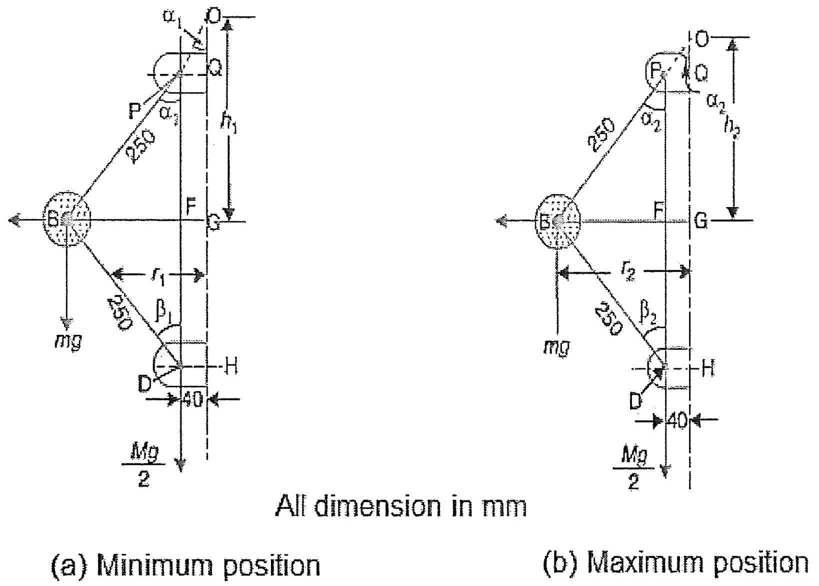


Figure 7

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-------------------------------------

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Criteria	Marks
All questions answered will be marking according to the answer scheme	/100

FORMULAE

Belting and power transmitted:

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

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

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

$V\ belt: \dfrac{T1}{T2} = e^{\frac{\mu\theta}{\sin\beta}}\quad Flat\ belt: \dfrac{T1}{T2} = e^{\mu\theta}$

$P = (T1 - T2)v,\quad P = T\omega, \text{where } \omega = \dfrac{2\pi N}{60}\quad P = T_1 - \left(1 - e^{-\mu\theta}\right)v$

$\eta = \dfrac{Po}{Pi}$

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

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

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

$Tc = \dfrac{T}{3}\ ; T1 + Tc = T$

$Tc = mv^2$

$T = \sigma.b.t$

For Plate/ multiplate:

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

$T = n\mu WR$

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

For Conical:

$$T = \frac{\mu W}{3\sin\beta}\left(\frac{D_0^3 - D_i^3}{D_0^2 - D_i^2}\right), \text{uniform pressure}$$

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

Gear:

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

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

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

Flywheel, Balancing, Governor and Vibration:

$$Cs = \frac{\omega_{max} - \omega_{min}}{\omega}, = \frac{N_{max} - Nmin}{N},$$

$$I = \frac{\beta W}{\omega^2 Cs} \qquad I = mk^2\ K.E = \frac{I\omega^2}{2}$$

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

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

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

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

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

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

$$C = Cc \times \delta$$

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

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

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

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

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

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