UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: January 2022

Module Number: ME4305 **Module Name: Mechanics of Machines**

[Three Hours]

[Answer **all questions**, each question carries **12** marks]

Clearly state all the assumptions that you may make.
To get full marks, make sure that you have answered with correct SI units and standard notations. Take g = 9.8 m/s^2.

Q1. In the range of planar mechanisms, the simplest group of lower pair mechanisms are four bar linkages.

a) (i) Briefly explain with clear sketches, four (04) different examples of the use of a planar four-bar linkage in practice.

(ii) Sketch the four configurations of four bar linkage that satisfy the Grashof's law.

[4.0 Marks]

b) (i) Apply Kutzbach criterion to determine the mobility if the mechanism shown in Figure Q1(b).

(ii) Does the Kutzbach criterion provide the correct result for the planar mechanism? Briefly explain why or why not.

[4.0 Marks]

c) (i) Define the mechanical advantage for a mechanism.

(ii) Show that the mechanical advantage of the four-bar linkage shown in Figure Q1(c) is $\frac{CD\ \sin\gamma}{AB\ \sin\beta}$ where angles $\widehat{ABC} = \beta$ and $\widehat{BCD} = \gamma$.

(iii) Determine the mechanical advantage of the four-bar linkage in the posture if the link lengths are; AD = 180 mm, AB = 60 mm, BC = 210 mm and CD = 120 mm.

[4.0 Marks]

Q2. a) The offset slider-crank mechanism shown in Figure Q2(a) is driven by the crank 2.

(i) Copy the diagram and represent each link by corresponding position vectors.

(ii) Write the loop-closure equation.

(iii) Solve the above loop-closure equation and hence obtain the position of slider 4 as a function of θ_2.

(iv) Find the crank angles corresponding to the extreme values of the transmission angle of the mechanism.

[6.0 Marks]

b) The crank of the slider-crank linkage shown in Figure Q2(b) rotates at 400 rad/s. The mass of the piston is 800 g.

(i) Draw the velocity diagram showing velocity vectors of the links.

(ii) Draw the acceleration diagram showing acceleration vectors of the links.

(iii) Determine the acceleration of the piston.

(iv) Determine the inertia force needed for the piston.

[6.0 Marks]

Q3. a) Figure Q3(a) shows five basic gear types. Attach this page to you answer scripts and answer the following questions. Name type of gears (A, B, C, D and E), components (1, 2, 3 and 4) and sketch the moving directions.

[3.5 Marks]

b) A compound gear train is shown in Figure Q3(b). Gear A is the input and it rotates at 1200 rev/min clockwise viewed from the left end. The number of teeth of gears A, B, C and D are 50, 150, 30 and 60 respectively. If the input torque is 30 Nm and the efficiency of the gear train is 80%, calculate,

(i) the output speed and its direction,

(ii) the output power, and

(iii) the fixing torque.

[3.0 Marks]

c) Compare and contrast epicyclic gear trains with other types of gear trains by taking two characteristics and two advantages of it.

[2.0 Marks]

d) An epicyclic gear box is shown in Figure Q3(c). The input is the Arm/cage A. The planet gears B have 150 teeth. The internal gear C is the output gear with 400 teeth. The sun gear D is fixed. If the input power is 7 kW and the output must deliver 5 kW of power at 900 rpm, calculate the followings.

(i) The gear box ratio.

(ii) The input speed and its direction.

(iii) The efficiency of the gear box.

(iv) The holding torque.

[3.5 Marks]

Q4. a) Briefly explain why is balancing necessary for high-speed rotating machineries by giving three (3) reasons.

[3.0 Marks]

b) What do you mean by static unbalance and dynamic unbalance? Describe briefly by using mathematical equations.

[3.0 Marks]

c) The shaft shown in Figure Q4(c) is to be balanced by removing or adding masses in the two correction planes, L and R. Given that the three masses are m_1 = 6 g, m_2 = 7 g, and m_3 = 5 g. The dimensions are a = 25 mm, b = 300 mm, c = 600 mm, d =150 mm, e = 75 mm, R_1 = 125 mm, R_2 = 150 mm, and R_3 = 100 mm.

(i) Calculate the magnitudes and orientations of the correction masses if masses are to be removed in the two correction planes.

(ii) Repeat the above if masses are to be added in the two correction planes.

[6.0 Marks]

Q5. a) A 15 kg connecting rod of a gasoline engine is 300 mm long between its centres and has a mass moment of inertia 7000 kgmm^2. The centre of mass of the connecting rod is 200 mm away from its small end centre.

Determine the dynamically equivalent two masses system of the connecting rod if one of the masses is located at the small end centre and other mass at its crank pin end centre.

[3.0 Marks]

(b) Consider a graph (Figure Q5(b)) of torque against crank angle for a typical four (4) stroke engine. It is also indicated the mean torque horizontal line as "mean".

(i) Obtain a relationship for the greatest fluctuation of energy (W) of the flywheel connecting the engine using,

- the coefficient of fluctuation of speed,
- the coefficient of fluctuation of energy,
- mean speed, and
- mass moment of inertia of the flywheel.

(ii) Indicate W graphically.

[5.0 Marks]

(c) The crank shaft torque of a multi cylinder engine is given by $T_E = 75 + 10 \sin \theta$ Nm and the engine is coupled to a machine requiring a torque, $T_L = 75 + 40 \sin \theta$ Nm. If the rotating parts have a total moment of inertia of 1.25 kgm^2,

(i) sketch T_E and T_L in one graph,

(ii) determine the maximum fluctuation of energy, and

(iii) the maximum angular acceleration.

[4.0 Marks]

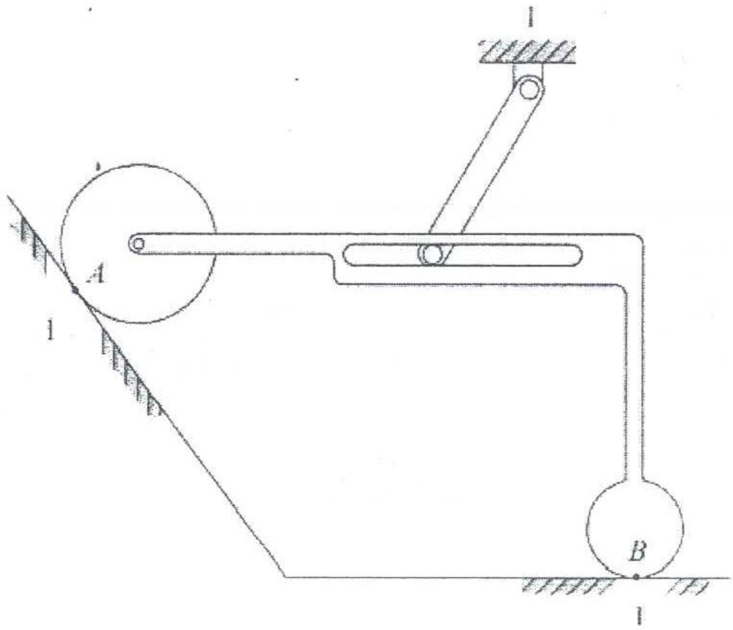

Figure Q1(b)

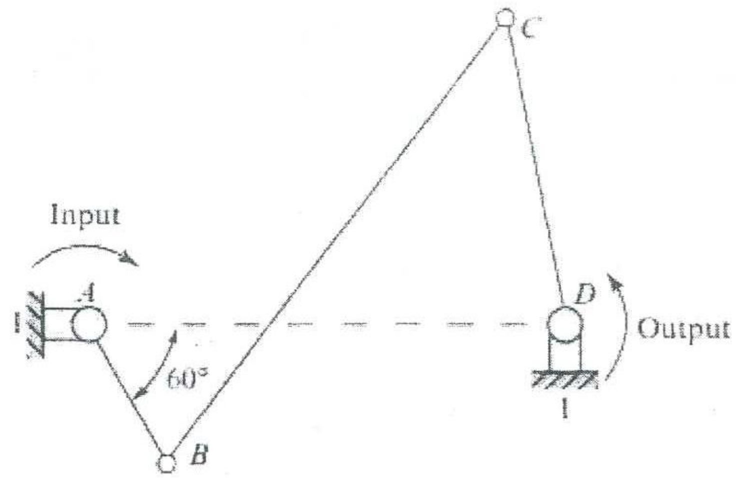

Figure Q1(c)

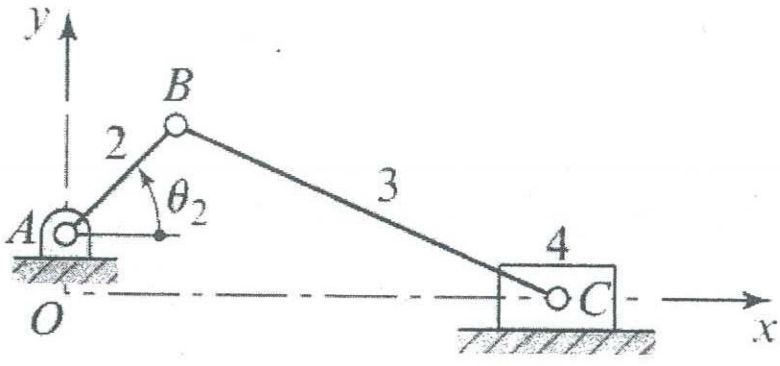

Figure Q2(a)

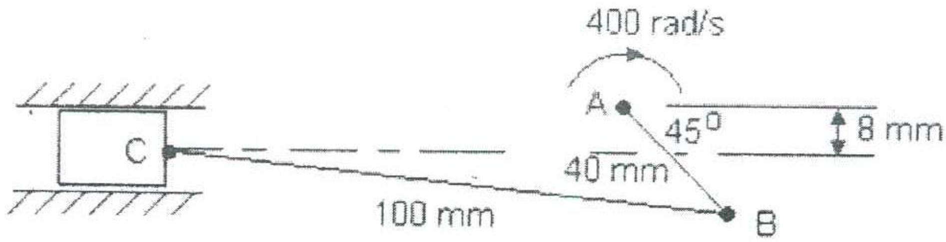

Figure Q2(b)

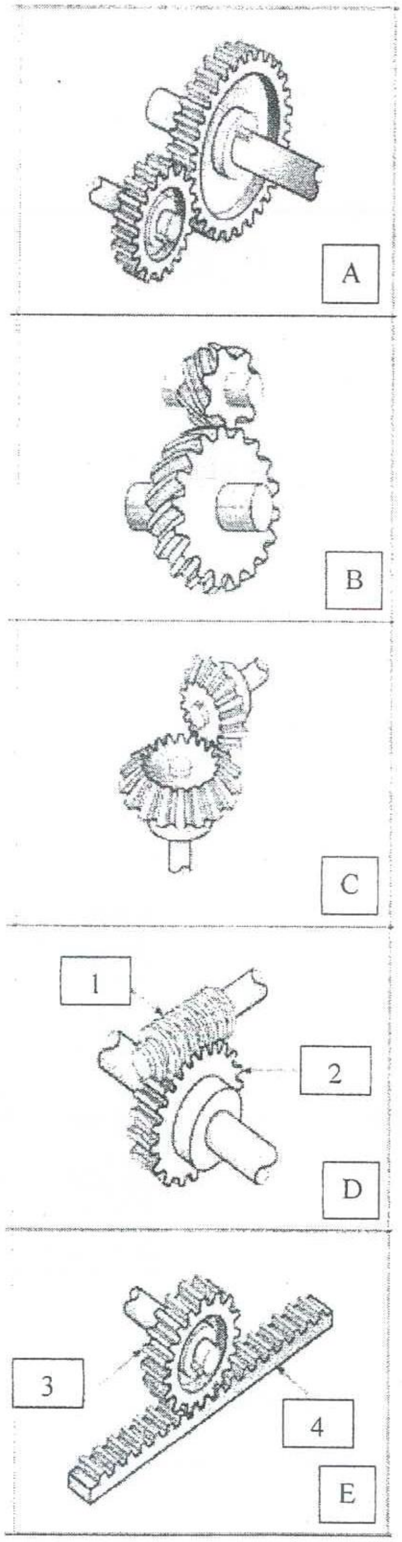

Figure Q3(a)

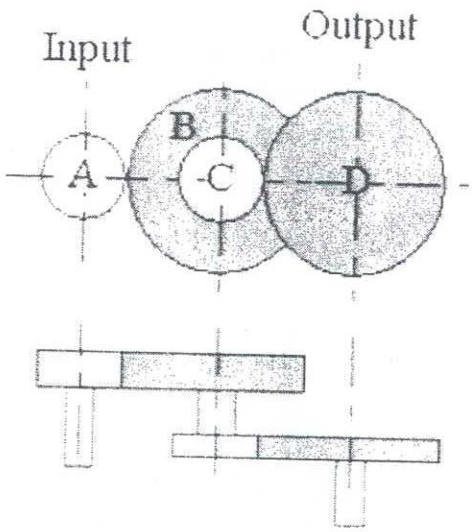

Figure Q3(b)

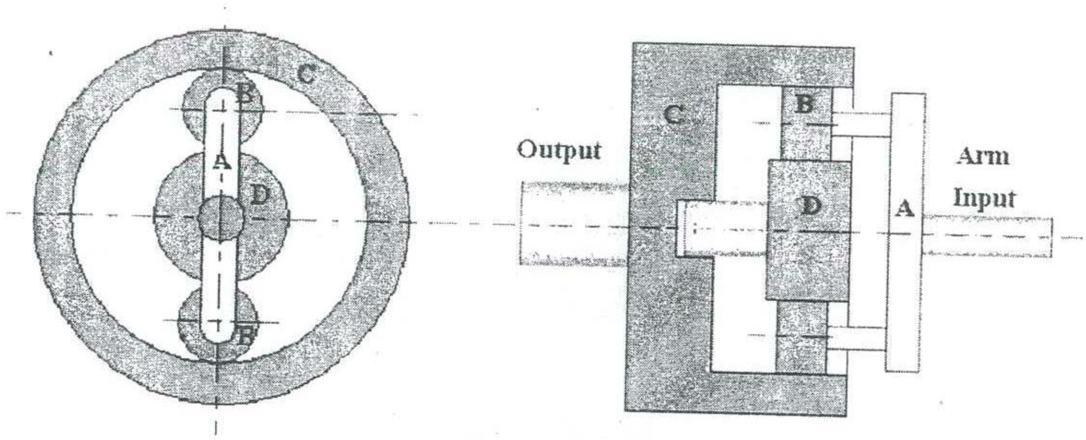

Figure Q3(c)

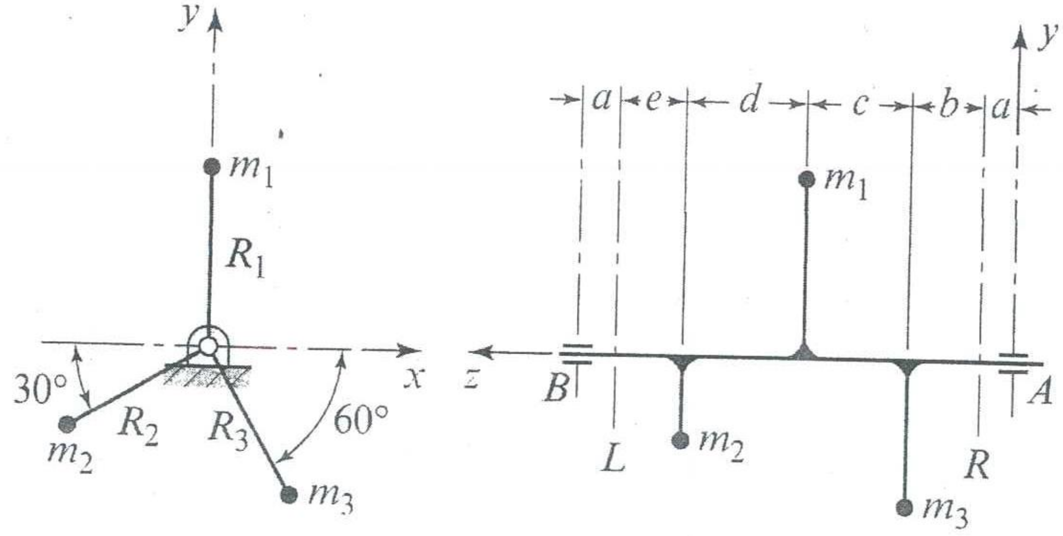

Figure Q4(c)

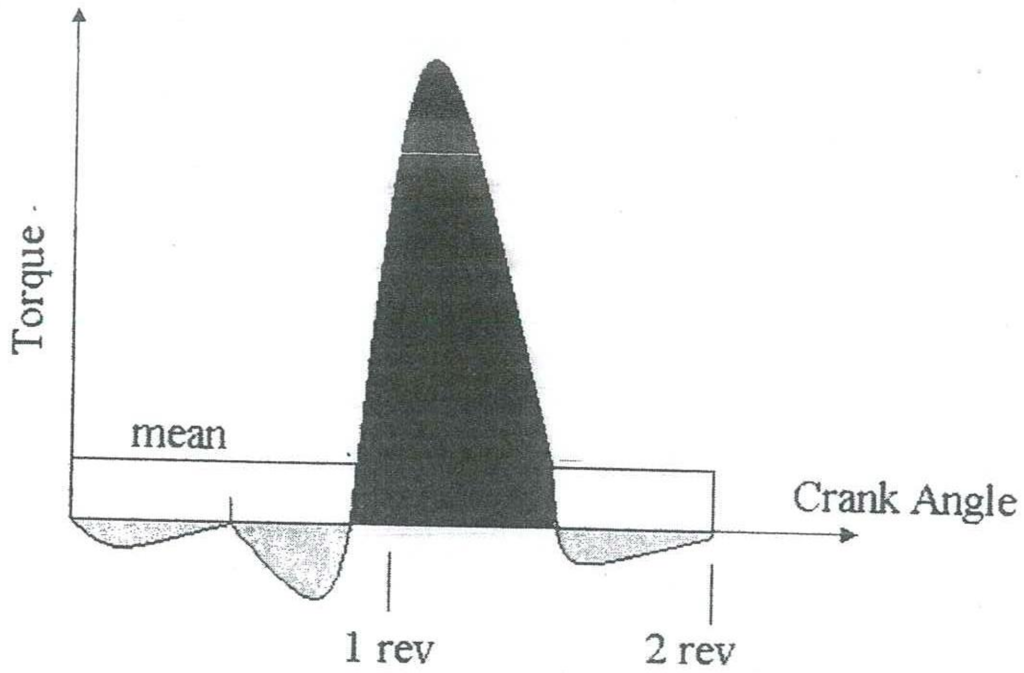

Figure Q5(b)