UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

Module Number: MN4205 **Module Name: Mechanics of Machines**

[Three Hours]

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

This paper contains **5 questions** on **7 pages**.
Clearly state any assumptions that you may make.
In order to get **full marks**, make sure to use standard notations and SI units, where appropriate. Take $g = 9.81\ m/s^2$.

Q1. (a) Briefly describe the following terms relating to spur gear using an appropriate diagram.

i. Addendum
ii. Dedendum
iii. Clearance
iv. Pressure angle

[2.0 Marks]

(b) The compound gear train given in **Figure Q1(b)** is used to lift an 80 kg load at a constant velocity of 0.5 m/s using a motor attached to the input gear A. The diameter of the output pully is 10 cm. Assume that there are no losses between the gears and pulleys. Answer the following,

i. Find the torque required at the motor to support the weight.

ii. Determine the rotating direction of the motor to lift the load.

iii. Calculate the required rotational speed of the motor to lift the load at the given linear speed.

[7.0 Marks]

(c) Describe **three (3)** possible power transmission options for an epicyclic gear unit.

[3.0 Marks]

Q2. (a) Assume you were tasked with designing a cam and follower mechanism for a punching machine to achieve a specific punching tool movement. The desired movement of the punching tool (follower) is as follows,

- Lift of the tool is 50 mm during the first 60° of cam rotation

(Question Q2 is continued on page 2)

(Question Q2 is continued from page 1)

- Dwell for the next 90°
- During the next 60° of cam rotation, the tool returns to its original position.
- Dwell during the remaining 150°.

Take the radius of the base circle of the cam as 25 mm.

Design the profile of the cam to maintain a constant velocity for the follower during rising and falling.

[7.0 Marks]

(b) The Torque - Crank Angle diagram for a crank piston engine is given in **Figure Q2(b)**. The work done during each step is indicated in the diagram, and the crankshaft needs to maintain a speed within the range of 420 - 450 rev/ min.

i. Determine the moment of inertia of a suitable flywheel for the given application in order to maintain the required speed range.

ii. Find the mass of the flywheel with a radius of 0.25 m.

[5.0 Marks]

Q3. (a) Consider a disc spinning about the X – axis with an angular speed, ω_X as shown in **Figure Q3(a)**. If a torque is applied in Z – direction, show that the disc will rotate about Y – axis and the applied toque (T) should be equal to $I\omega_X\omega_Y$ to precess the disc (rotation about the Y – axis) with an angular speed, ω_Y.

[3.0 Marks]

(b) **Figure Q3(b)** shows a ship turning right on a radius 250 m with a velocity of 2.5 m/s. The turbine engine of the ship is mounted in the lengthways of the ship as shown. The effective mass of the engine is 1000 kg with the radius of the gyration of 0.5 m. If the engine rotates clockwise at 7200 rpm when viewed from the back,

i. Calculate the magnitude of the gyroscopic couple produced when the ship turns.

ii. Using suitable sketches, explain clearly the effect of the couple on the ship motion.

[4.0 Marks]

(c) A nosewheel assembly for a small aircraft designed based on the four-bar mechanism is shown in **Figure Q3(c)**.

i. Sketch the kinematic skeleton diagram showing all the links. Label the crank, rocker, and coupler.

ii. Determine the mobility of this mechanism through Gruebler's Equation.

iii. State the Grashof 's Theorem and check whether the above mechanism satisfies it or not. Briefly describe the result.

[5.0 Marks]

Q4 This question is related to the position, velocity, and acceleration analysis of a mechanism.

(a) A toggle clamp is used for securing a workpiece during a machining operation. **Figure Q4(a)** shows such a toggle clamp with main dimensions given in mm. Determine the angle at which the handle must be displaced in order to lift the clamp arm by 30°.
(Hint: You may draw the original and displaced configuration of the toggle clamp)

[4.0 Marks]

(b) A single cylinder reciprocating engine shown in Figure Q4(b) has a crank AB of 40 mm and a connecting rod BC of 100 mm. The crank rotates at 3000 rev/min clockwise. The mass of piston of the engine is 0.48 kg and the diameter is 80 mm. It also given that the gas pressure acting on the piston is 1.25 MPa at the moment shown.

i. Draw the velocity and acceleration diagram for the configuration shown.

ii. Determine the velocity and acceleration of the piston.

iii. Calculate the effective turning moment acting on the crank.

iv. State the all the assumptions.

[8.0 Marks]

Q5 (a) Breifly explain by giving four reasons why the balancing of reciprocating engines is important.

[2.0 Marks]

(b) **Figure Q5(b)** shows a long rotor with distributed mass that is mounted in bearings at A and B. Suppose that two equal masses m_1 and m_2 are placed at opposite ends of the rotor and at equal distances r_1 and r_2 from the axis of rotation. Show that why the rotor is statically balanced but dynamically unbalanced when $m_1 = m_2$ and $r_1 = r_2$.

[1.5 Marks]

(c) The shaft illustrated in **Figure Q5(c)** is to be balanced by placing masses in the correction planes L and R. The weights of the three masses m_1, m_2, and m_3 are 1.125 N, 0.85 N, and 1.4 N, respectively. The dimensions are R_1 = 125 mm, R_2 = 100 mm, R_3 = 125 mm, a = 25 mm, b = e = 200 mm, c = 250 mm, and d = 225 mm. Calculate the magnitudes of the corrections in Nmm and their angular orientations.

[4.0 Marks]

(d) **Figure Q5(d)** shows a compressure conguration that consists of with three inline pistons of mass 0.4 kg with a crank radius of 50 mm and connecting rod length to crank radius ratio (n) of 3. The cranks are equally spaced in angle and position as shown. When the crank rotates at 20 rad/s, determine,

i. the primary and secondary forces.

ii. the primary and secondary turning moment about the reference plane XX.

iii. the masses and angles of the cranks for primary balancing if the system to be balanced by placing mass in planes XX and YY with the same crank radius and ratio n.

[4.5 Marks]

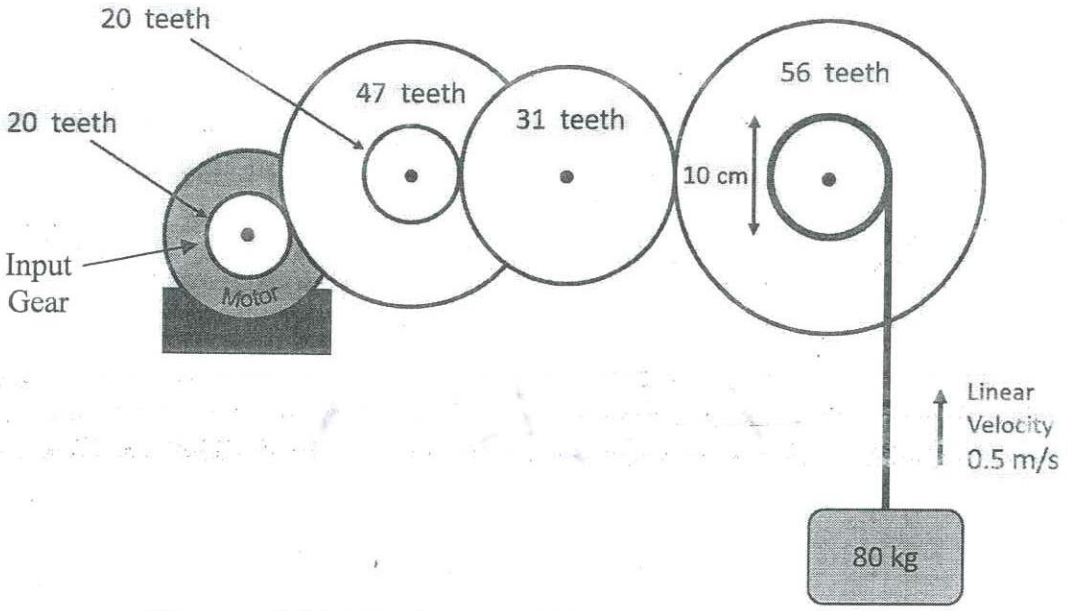

Figure Q1(b): The layout of the compound gear train

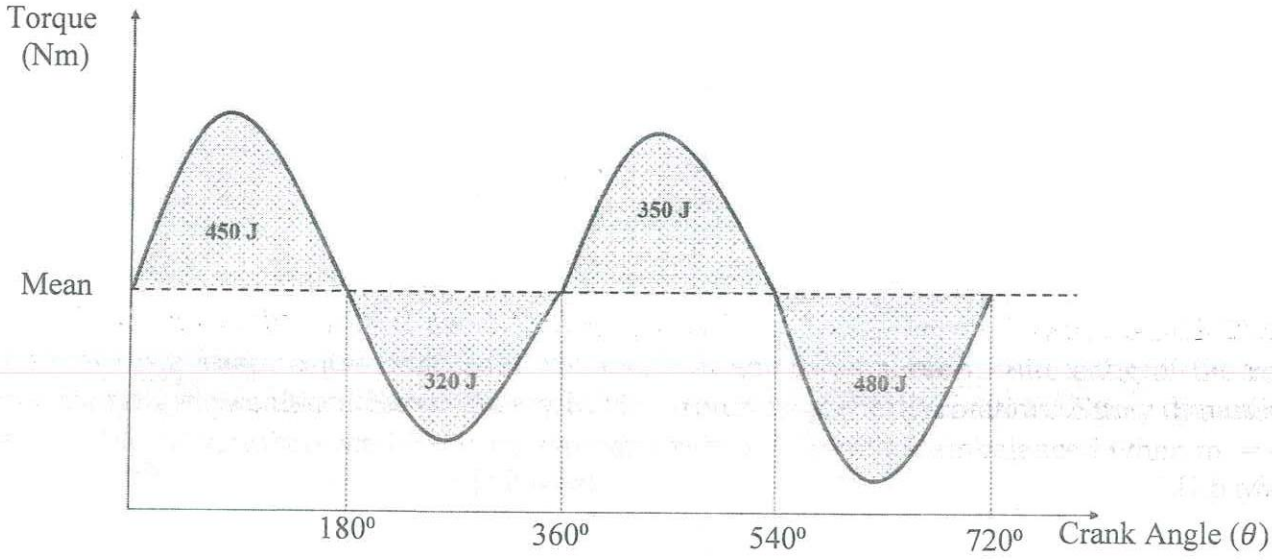

Figure Q2(b): Torque – Crank Angle diagram for a crank piston engine

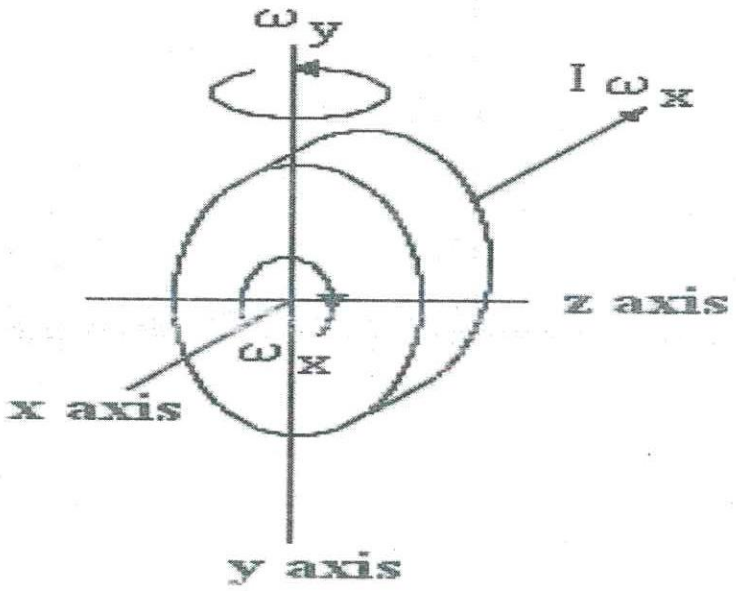

Figure Q3(a) - Spinning disc

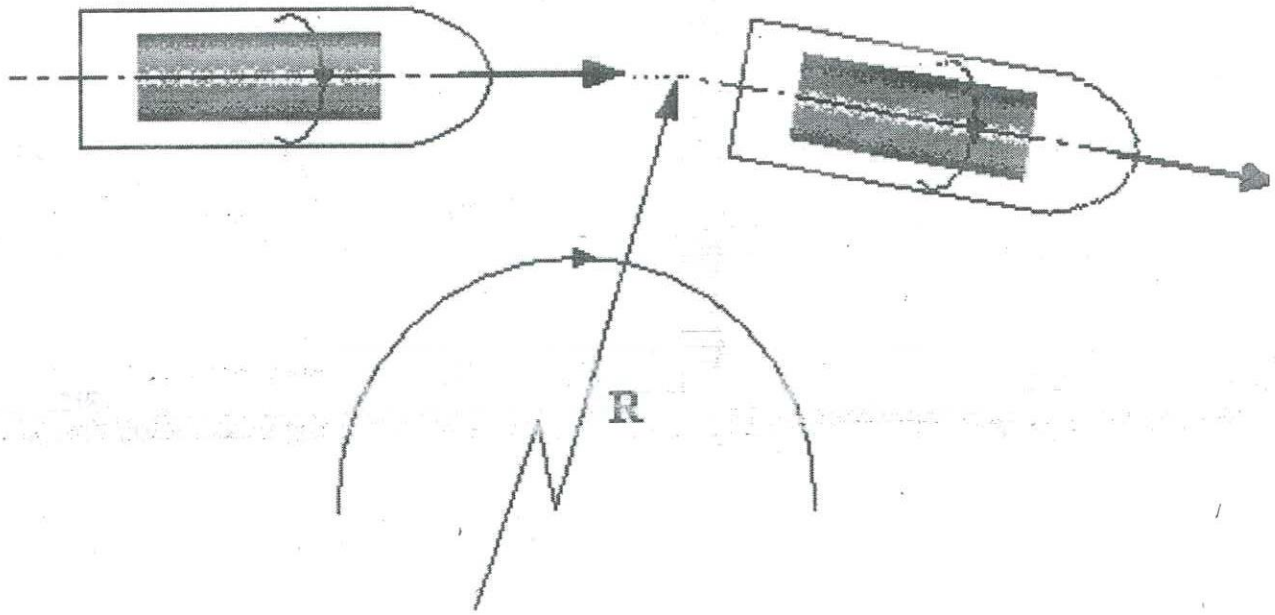

Figure Q3(b): Ship motion

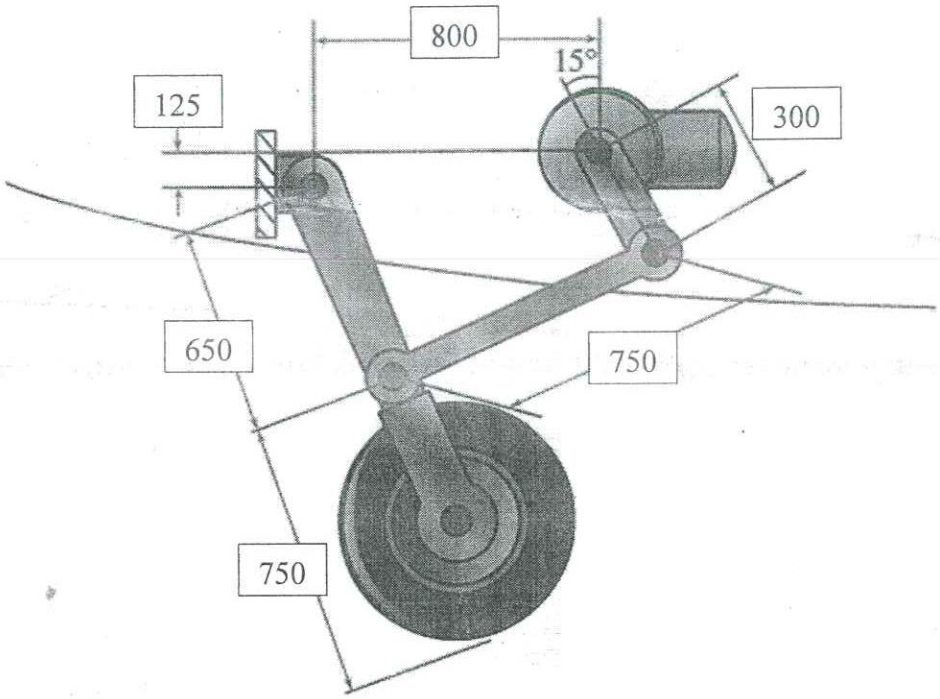

Figure Q3(c): Nosewheel assembly design for a small aircraft (all dimensions are in mm)

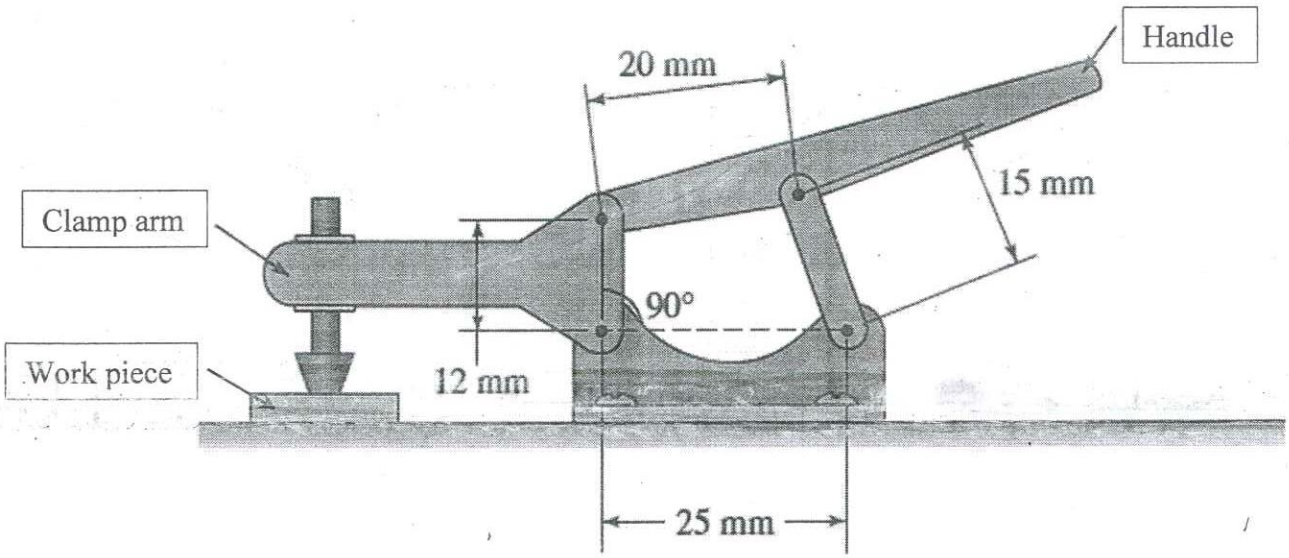

Figure Q4(a): A toggle clamp device

Figure Q4(b): A single-cylinder reciprocating engine

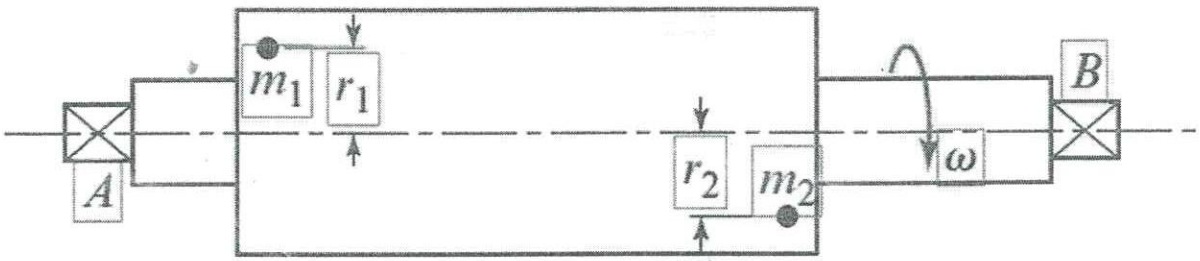

Figure Q5(b): Shaft with two masses

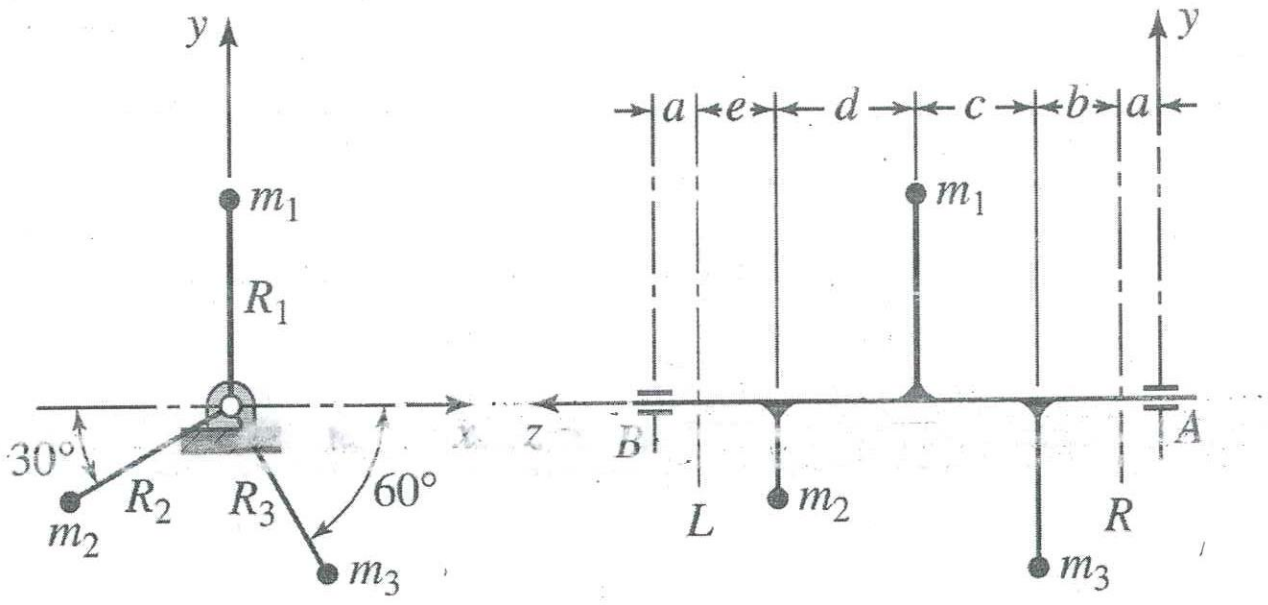

Figure Q5(c): Shaft with three masses

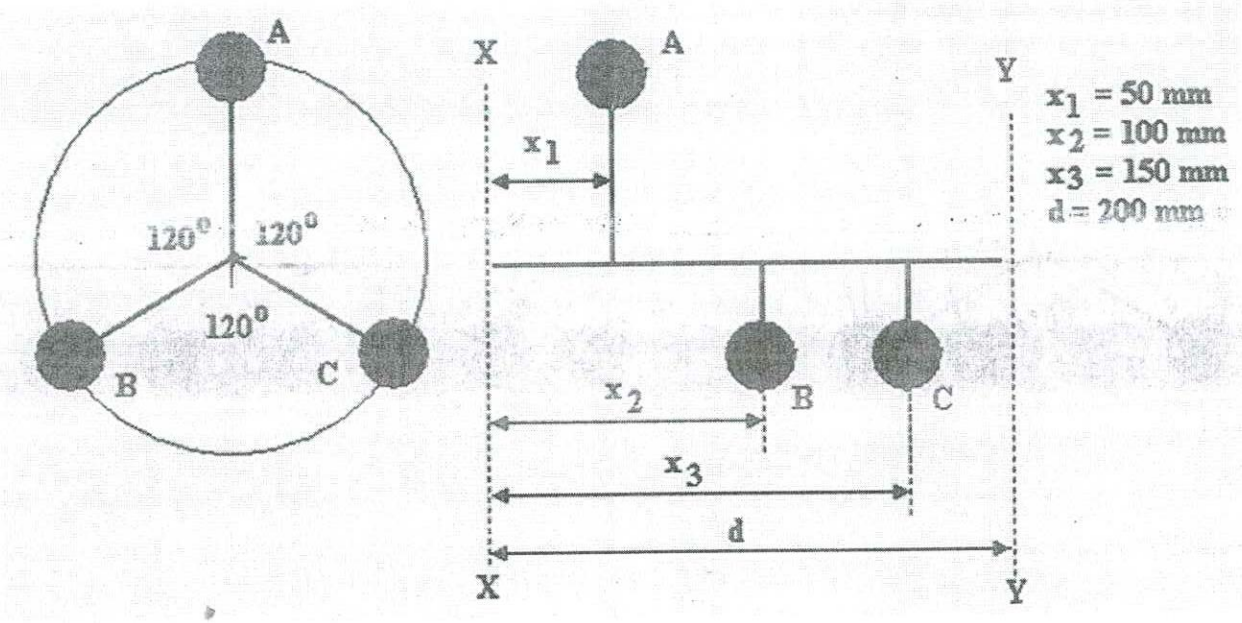

Figure Q5(d): Compressure piston configuration

End of the paper.