National Exams December 2019

16-Mec-A2, Kinematics and Dynamics of Machines

3 Hours in Duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an OPEN BOOK exam. Any non-communicating calculator is permitted.

3. Five questions constitute a complete set. Every one answers question #1 in Part A, and one of the two questions in Part B, and chooses three additional questions from the remaining six.

Part A

1. This question has three mini-questions. Marks for each mini-question are given in brackets.

(a) For the mechanism shown below, (i) identify the number of each of the four types of links in the table below and explain clearly your answer, and (ii) determine its degree(s) of freedom using Gruebler's equation. [5]


Pin in slot
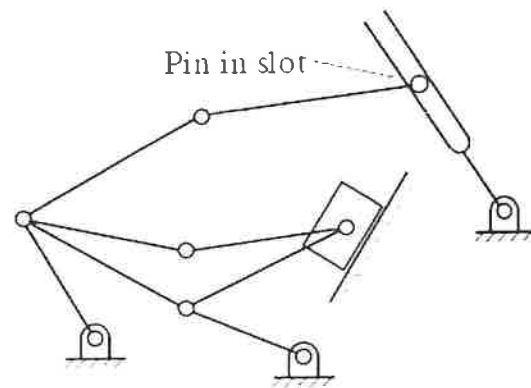
Type →	B	T	Q	P	...
Number →					

b) An eight-bar mechanism shown below consists of two four-bar loops connected by a binary link. (i) Show clearly on the diagram all transmission angles that apply in order for the rotational motion to be effectively transferred from link 2 to link 8; (ii) determine the type of each four-bar loop by means the Grahof criterion. [10]
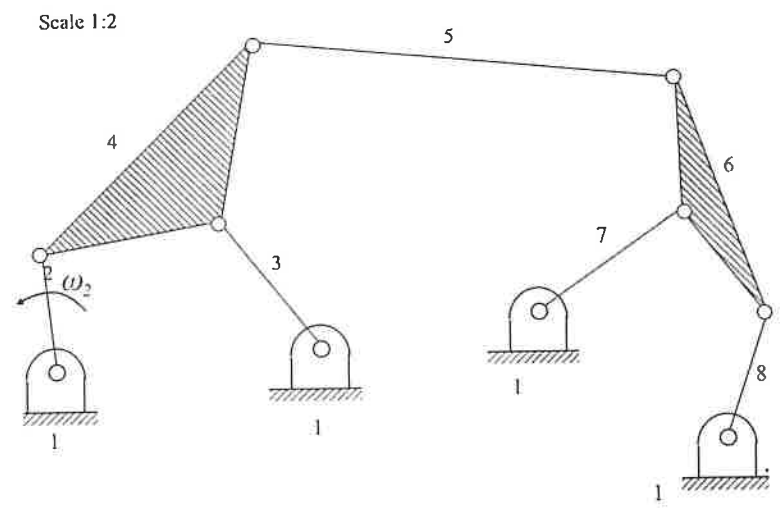
(c) A planar 8-bar mechanisms with 10 full joints and a degree of freedom of one have several families of valid configurations. Sketch clearly and neatly TWO valid mechanisms with mixed revolute and prismatic joints in family (6, 0, 2, 0, 0), or B=6, T=0, Q=2, P=0, H=0. [5]

2. A mechanical press is designed to exert large forces to insert a small part into a larger part. Determine the mechanical advantage of the device at the position shown. Suggestion: assume a unit input angular velocity (1 rad/s) and use the available space to draw a velocity diagram. [20]

Scale 1:15

F_{in}

F_{out}
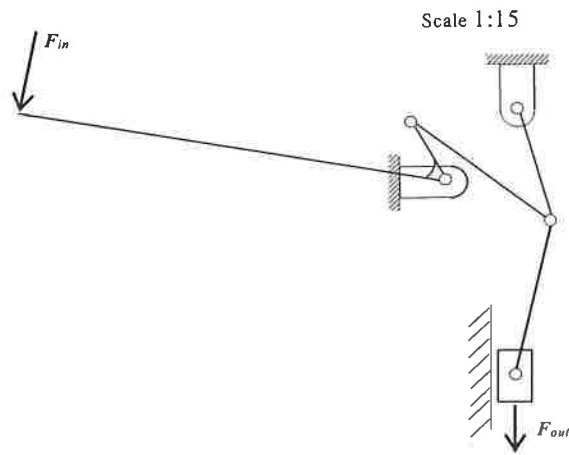
3. A four-bar inverted crank-slider mechanism is shown below. Node A is the R joint between the input link and the coupler. B is a point on the coupler (link 3). Using a proper velocity scale and draw a velocity diagram. Determine (i) the angular velocity of link 4 and the relative velocity of link 3 to link 4, (ii) the linear velocity of point B by means of the velocity image theorem or the relative velocity diagram, (iii) the Coriolis acceleration $\vec{a}^c_{A3/A4}$, and (iv) the relative slidign acceleration $\vec{a}^s_{A3/A4}$. [20]

A

3

B

2

4

A_o

1

B_o

1

Scale: 1:10
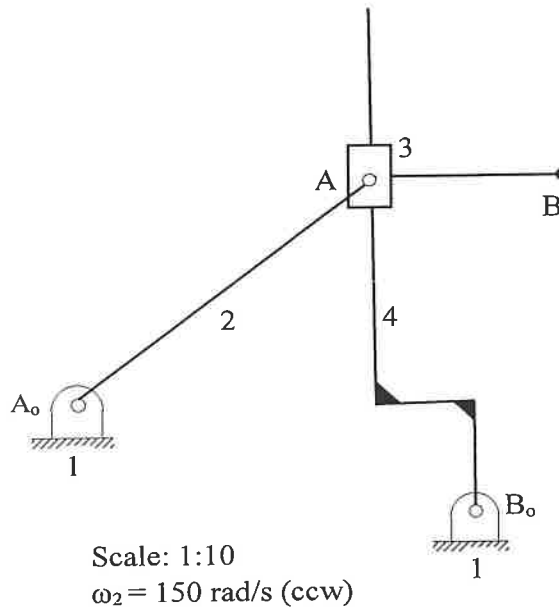
$\omega_2 = 150$ rad/s (ccw)

4. A 3-cylinder engine is shown below. All cylinders lie in a single transverse plane. The three cylinder centerlines are 120 degrees apart. The crank of length 0.06 m rotates at a constant angular velocity of 100 rad/s (ccw). The length of the three identical connecting rods is 0.6 m. The mass centers of the connecting rods are at their midpoints. The crank and the rotational mass of the coupler have been balanced with a mass center at the mainline of rotation. The combined reciprocating mass (the translating mass of each connecting rod and the piston mass) is 2.5 kg. Determine (i) the shaking force magnitudes when the crank rotates to coincide with the three cylinder centerlines, (ii) devise a balancing scheme and recalculate the shaking force magnitudes at the same three crank positions as in (i), and (iii) comment on the effectiveness of your balancing scheme. [20]
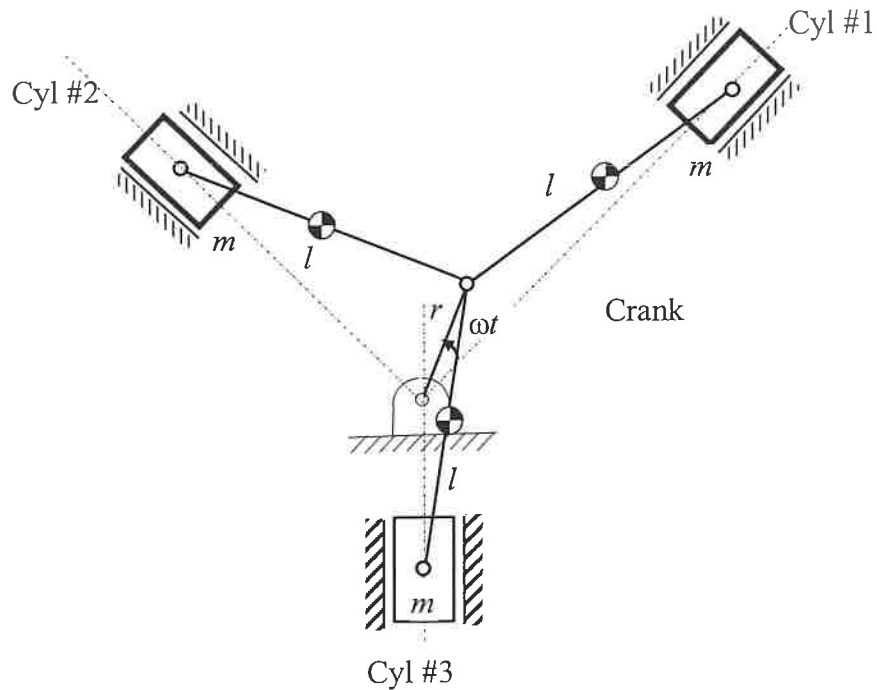
5. A radial cam-follower drive is used for producing the following motion: rise upward by 4 cm during the time interval [0, 0.015s], dwell during the time interval [0.015s, 0.020s], and fall back to 0 cm elevation during the time interval [0.020,0.030s]. The motion repeats itself for every complete rotation of the cam. The cam rotates clockwise at a constant angular velocity.

    a) Design a displacement-curve for the rise or the fall (not both) to satisfy the fundamental law of cam design. It is desired that the follower maximum acceleration be made as small as possible during the rise motion, and its maximum velocity be made as small as possible during the fall motion. Sketch the s-v-a-j curves for the motion of your choice with maximum values indicated on the diagram.

    b) Choose a proper base circle and lay a cam profile for the displacement-curve for the motion of your choice in part a), and estimate the max pressure angle. If you believe your cam profile does not meet the appropriate requirements, list the modifications you may do for improvement, but do not carry out further calculations.
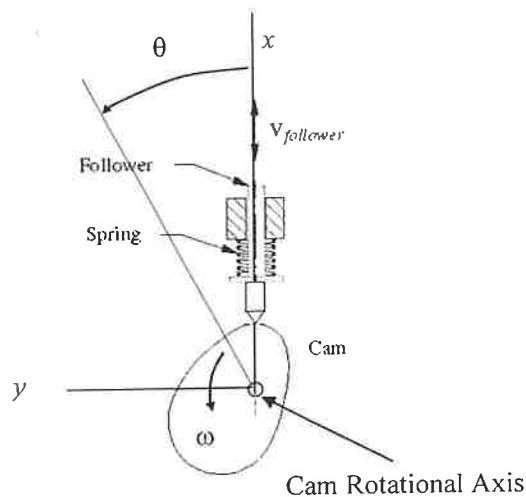
6. A compound PGT is shown below. Determine the speed ratio between the output and input shafts. Teeth numbers for all gears are $N_1 = 100$, $N_2 = 31$, $N_3 = 15$, $N_4 = 60$, $N_5 = 58$, $N_6 = 50$, $N_7 = 90$, and $N_8 = 29$. [20]
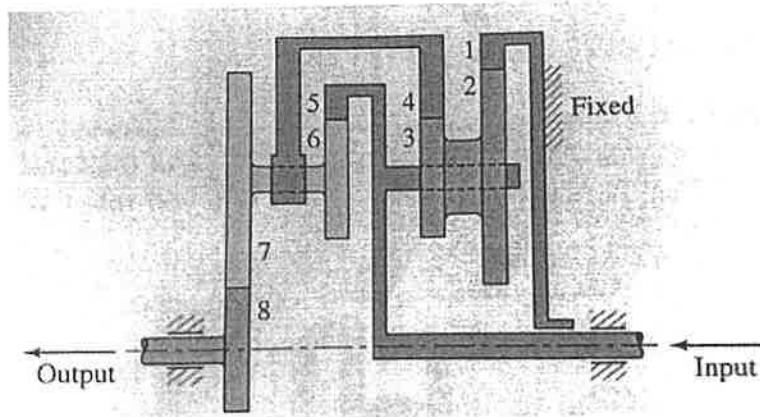
Part B

7. A simple pendulum consisting of a massless string of 1 meter and a point mass (4 kg) is released from rest at $\theta_0 = 8°$. Assume that (i) the coefficient of restitution (COR) between the mass and the vertical wall is 0.9, and (ii) the duration of each impact is 10 mili second. Determine the free vibration of the pendulum for the 1st and 2nd cycle. [20]
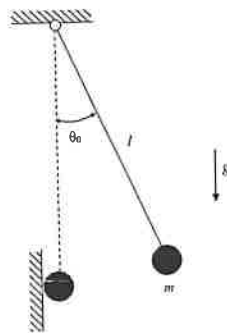
8. A patient on a medical bed (total combined mass M) is transported by a helicopter to a hospital. The drive train and the rotating blades are known to produce oscillations at two dominating frequencies ω and 4ω, with ω varying between 10 Hz and 20 Hz. Design the compressive springs to avoid disastrous bouncing and pitching motion during the transport and give considerations to the static deflections of the springs induced by the weight of the patient-bed. In your calculations, use $L = 2\,m$, and $I_G = 0.2ML^2$. [20]