National Exams May 2009
07-Mec-A2, Kinematics and Dynamics of Machines

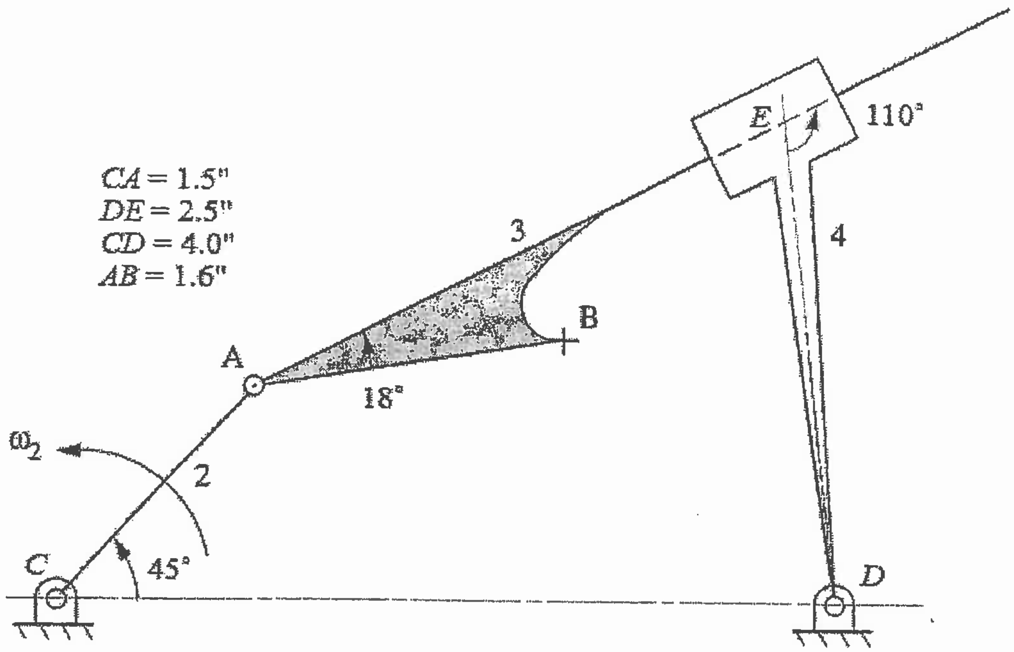
3 Hours in Duration

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 calculators are permitted.
3. FIVE questions in the following combinations constitute a complete exam paper: three from part A and two from part B, or four from part A and one from part B.
4. All questions are of equal value.

Part A

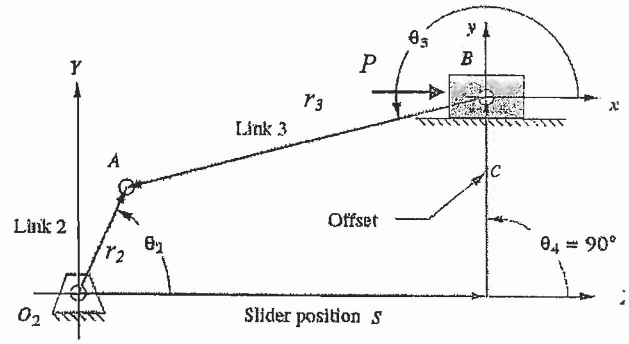
1. A four-bar inverted crank slider mechanism is shown below. The crank rotates at a constant angular velocity of 30 rad/s (CCW). For the position shown, determine
(i) all instant centers,
(ii) the transmission angle,
(iii) the angular velocity of the follower, and
(iv) the sliding velocity of E relative to link 3.



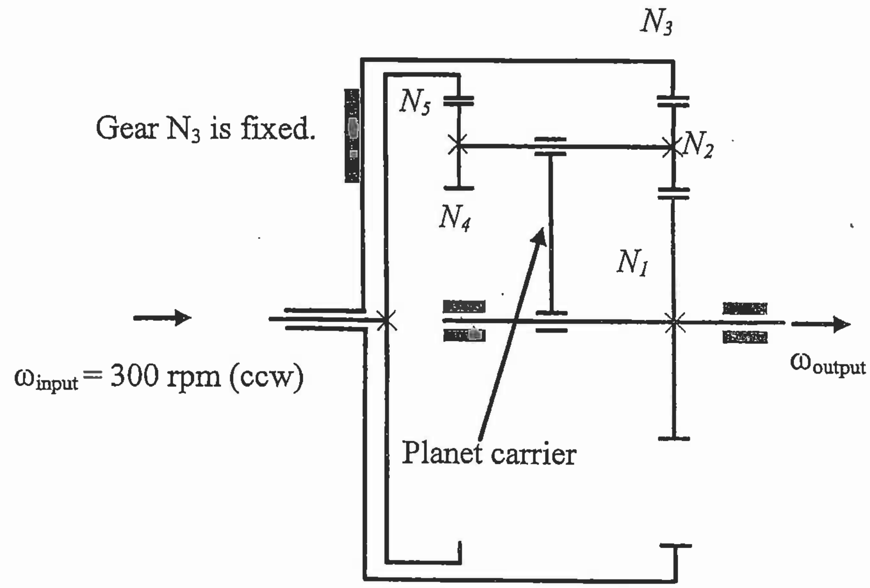
2. A four-bar crank slider mechanism with an offset is shown below. The crank rotates at a constant angular velocity of $\omega_2 = 20$ rad/s (CCW). Determine analytically the torque required to overcome load P = 1000 N and the inertia force when $\theta_2 = 75°$. Only the mass of the slider is to be considered.

$r_2 = 2$ inches, $r_3 = 5$ inches
$c = 3.5$ inches, $m_B = 0.5$ kg

Not to scale



3. For a planetary gear train shown below, gear 3 is fixed; gear 5 is attached to the input shaft. The tooth numbers for all gears are: $N_1 = 36$, $N_2 = 26$, $N_3 = 88$, $N_4 = 25$, $N_5 = 61$. Determine the speed and direction of the angular velocity of the output shaft.

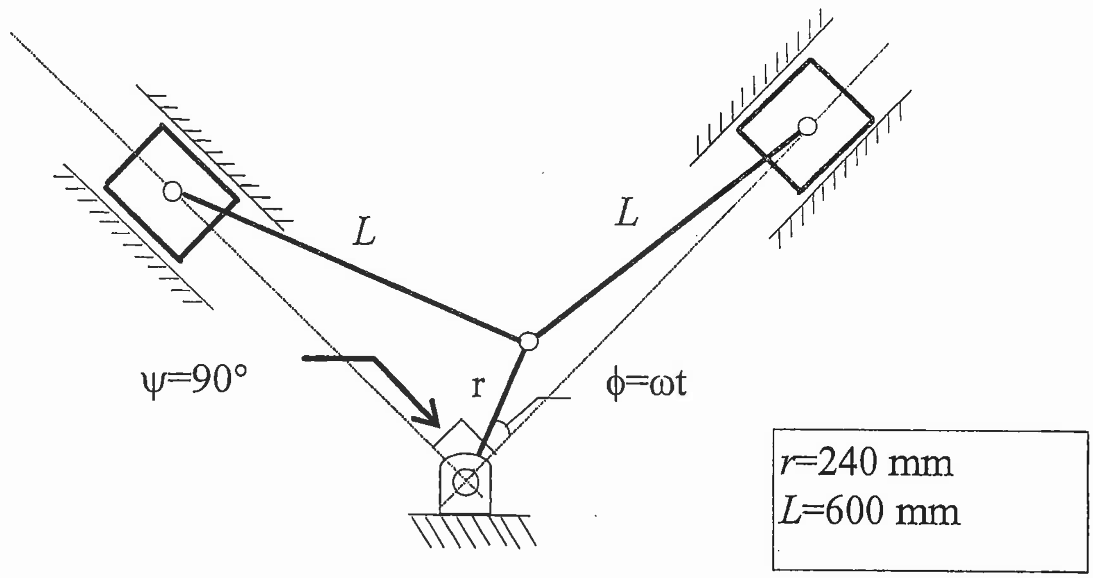


4. A cam, rotating at a constant angular velocity of 300 rad/s, is used to produce a 10 mm follower lift with the following specifications:

Rise: from 0 to 10 mm during [0, 75°],
Dwell: at the 10 mm lift during [75°, 255°], and
Fall: from 10 mm back to 0 mm during [255°, 360°]

Design the displacement profile of the cam during THE RISE ONLY. Since the cam is operated at a high speed, you are required to ensure that (i) the profile satisfies the law of cam design and (ii) both the jerk and the maximum acceleration be kept as small as possible.

5. A two-cylinder V-shape engine is located in the same axial plane. Determine, when $\phi = 35°$, the primary resultant shaking force caused by the reciprocating masses, namely, the two pistons of mass 1.5 kg each, as the crank shaft rotates at a constant angular speed of 1000 rpm.



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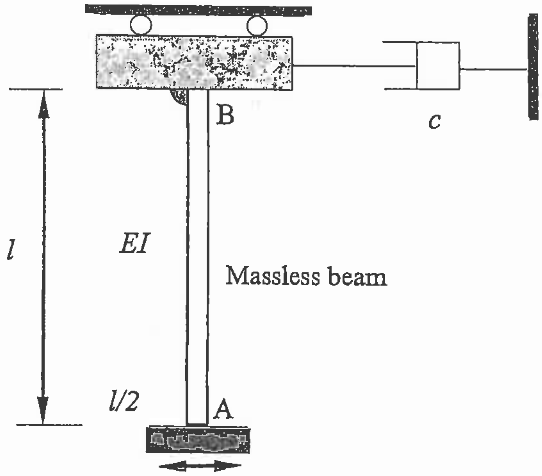
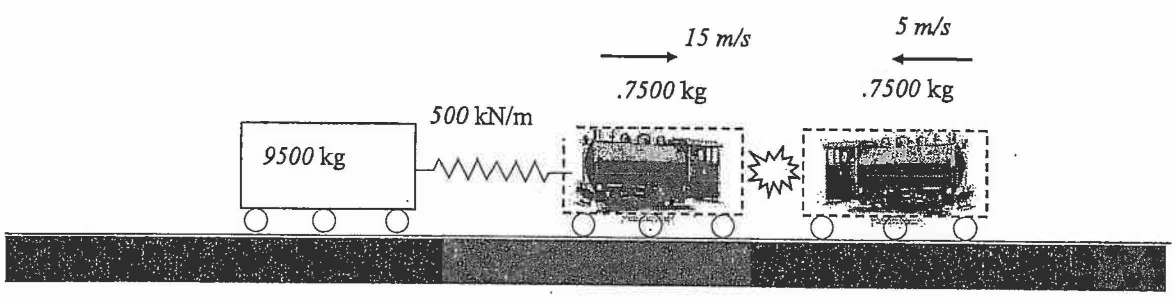
Part B

6. A vibration system consisting of a massless beam, a block constrained to move in the horizontal direction, and a dashpot. For $EI = 2{,}300$ Nm^2, $l = 2$ m, $m = 100$ kg, c = 125 Ns/m, determine (a) the response of the system due to the horizontal base motion $x_b = 10 \sin 10.5t$ (mm), and (b) the dynamic force acting on the block from the supporting beam.



7. One locomotive and one train carrying a single car travel on the same tracks at different speeds in the opposite direction. They come to collision at time $t = 0^-$. After the collision, the two locomotives become entangled and move as one body on the tracks. No derailment. Determine (i) the response of the dynamic system after the collision and (ii) the maximum dynamic force in the spring modeling the flexible connection between the locomotives and the car.



Marking Scheme

1. 20 marks
2. 20 marks
3. 20 marks
4. 20 marks
5. 20 marks
6. 20 marks
7. 20 marks