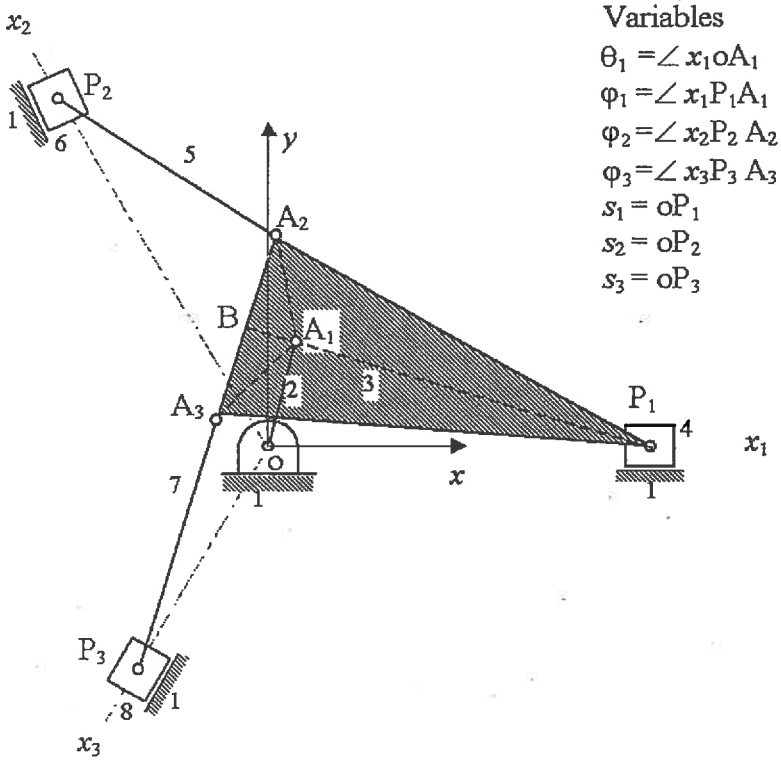
National Exams May 2012
Mec-A2, Kinematics and Dynamics of Machines
3 Hours in Duration

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. Answer any FIVE questions from the six questions provided.
4. All questions are of equal value.

Part A

1. Below is an eight-bar planar mechanism employed in a reciprocating engine. At the position shown, determine (a) the total number of instant centers, (b) all primary instant centers by inspection, and (c) at two secondary instant centers by means of Kenney's theorem.



Variables	Constants
$\theta_1 = \angle x_1 oA_1$	$r_0 = oA_1 = 15.73$ mm
$\varphi_1 = \angle x_1 P_1 A_1$	$r_1 = P_1A_1 = 56.09$ mm
$\varphi_2 = \angle x_2 P_2 A_2$	$r_2 = P_2A_2 = 39.52$ mm
$\varphi_3 = \angle x_3 P_3 A_3$	$r_3 = P_3A_3 = 39.52$ mm
$s_1 = oP_1$	$\beta_1 = \angle A_2A_1B = 60°$
$s_2 = oP_2$	$b_1 = A_1A_2 = 15.88$ mm
$s_3 = oP_3$	$\beta_2 = \angle A_3A_1B = 60°$
	$b_2 = A_1A_3 = 15.88$ mm

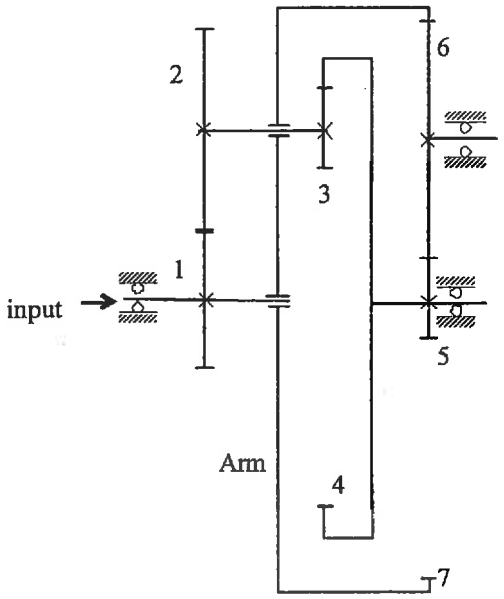
2. A high speed radial cam, rotating at an angular velocity of 3600 rpm, is used to produce the following motion of the follower:

Rise from 0 to 30 mm during [0, 120°],
Dwell during [120°, 210°], and
Fall back to 0 mm during [210°, 360°].

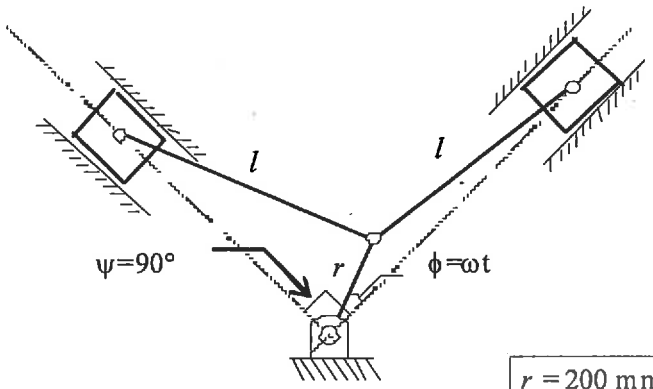
Design the displacement profile for the rise period only. Since the cam is operated at a high speed, it is required that that (i) the profile satisfies the law of cam design and (ii) the maximum jerk and maximum acceleration are kept as small as possible.

You must present the equations of displacement, velocity, and acceleration and jerk of your cam profile, sketch the rise profile for s, v, a, and j, and compute the maximum acceleration and the maximum jerk for the follower during the period of rise.

3. A gear reduction box for an electric winding machine is a compound planetary gear train shown below. When gear 1 rotates at 1000 rpm (ccw), determine the angular speed and direction of rotation (ccw or cw) of gear 7. Use the tooth numbers $z_1 = 26$, $z_2 = 50$, $z_3 = 18$, $z_4 = 80$, $z_5 = 18$, $z_6 = 35$, and $z_7 = 88$ in your calculations. To earn credits, you must clearly present the correct law of gearing for every pair of engaged gears.



4. A two-cylinder V-shape engine is located in the same axial plane. Determine, when $\phi = 45^{\circ}$, the primary resultant shaking force caused by the two reciprocating pistons of 1.1 kg in mass as the crank shaft rotates at a constant angular speed of 3000 rpm.

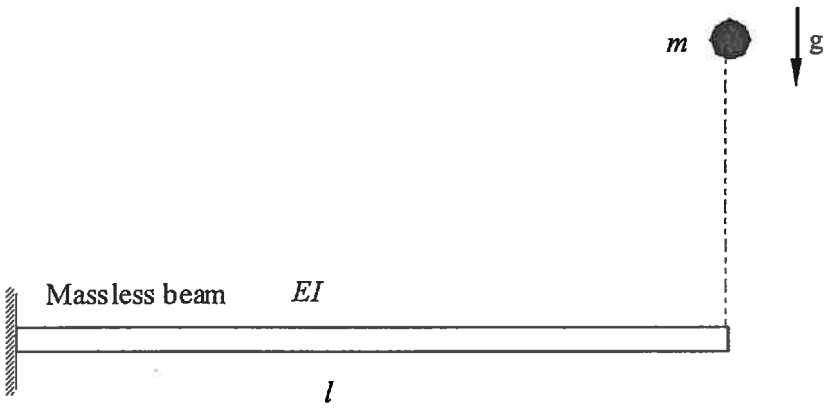


$r = 200$ mm

$l = 600$ mm

Part B

5. A 2 kg point mass starts to fall in the gravitational field from a height of 2 m above the cantilever beam of rectangular cross section (width 6 cm, thickness 1 cm, l = 0.5 m, Young's modulus E =200 GPa). The point mass strikes the beam at the free end and sticks permanently to it. Determine the motion of the point mass immediately after the impact, the maximum deflection of the beam, and the largest bending stress developed as a result of impact.



6. A two-car run-away train travels at a speed of 60 km/h in the direction shown The distant end of the spring strikes the wall and sticks to it during the ensuing motion (free vibration). Determine the ensuing free vibration using the modal summation method. Ignore friction everywhere. Use m = 2000 kg, and k = 800 000 N/m in your calculations.