National Exams May 2017

16-Mec-A2, Kinematics and Dynamics of Machines

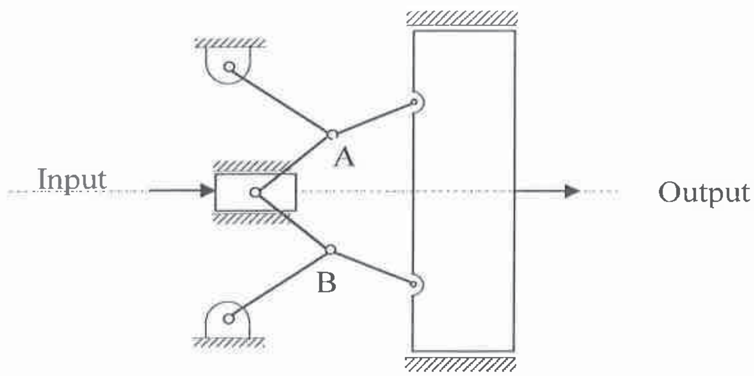
3 Hours in Duration

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 Sharp or Casio approved calculators are permitted.
3. Answer FIVE questions from the six questions provided.
4. Marks for each question are 20.

Part A

1. A planar mechanism is designed to have two branches symmetrical to the centerline as shown. Explain briefly and clearly the main purpose of the redundant design, determine the mobility using Gruebler's equation, and then find the mechanical advantage at the position shown using a method of your choice.



Note: The top and bottom branches are symmetric w.r.t. the centreline

2. A radial cam (flat-faced follower), rotating at a constant angular velocity of 1500 rpm, is used to produce the following translational motion of the follower:

- rise by 2 inch from 0 inch elevation during [0,90°],
- dwell at 2 inch elevation during [90°, 270°]
- fall back to the 0 inch elevation during [270°, 360°]

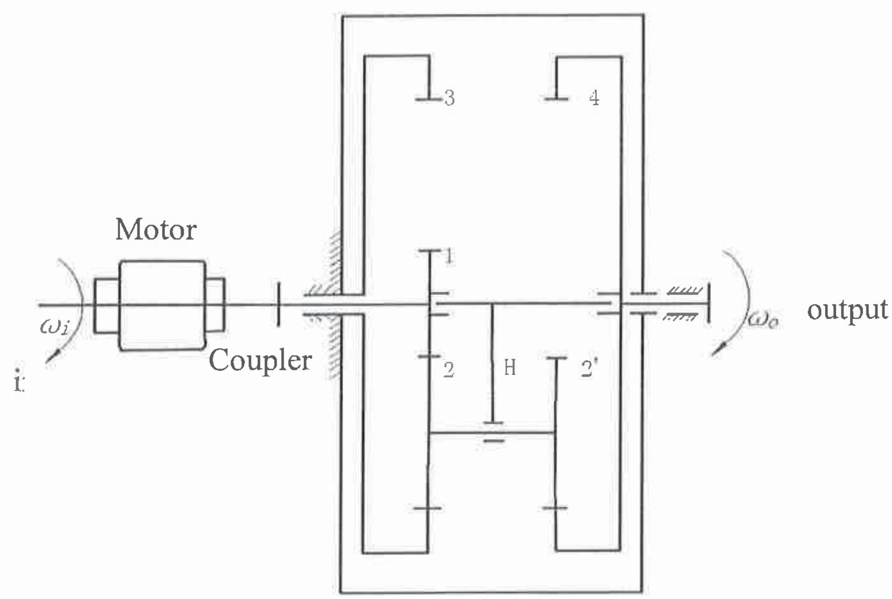
Design the displacement profiles for the rise and fall with an objective to minimize the maximum accelerations for compactness. You must clearly present the equations of displacement, velocity, and acceleration and jerk of your cam for both rise and fall, sketch the rise profile for *s*, *v*, *a*, and *j*, and compute the maximum jerks for the rise and fall.

Choose a proper base circle and sketch the cam profile. Compute the pressure angles at $\theta = 45^\circ$ and $\theta = 315^\circ$. If the pressure angles are too large (i.e., greater than 30 degrees), state how the design can be modified to meet the pressure angle requirement, but do not undertake or attempt any iterations due to time limitation.

3. Shown below is a 2-stage PGT used in a steel-rolling plant. The input shaft rotates at 1500 rpm (CCW viewed from the output end). The output shaft is expected to rotate at 39 rpm. Assume that all gears have the same module (or diametral pitch) and pressure angle.

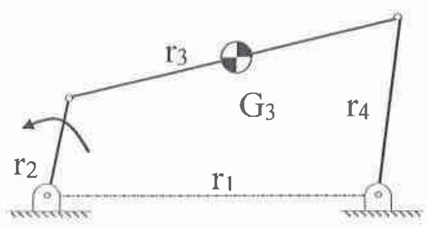
Determine the general expression for the output shaft angular velocity in terms of the input angular velocity and the gear teeth.

Your design must take into consideration the following: (i) satisfaction of the geometric constraint at the first stage, (ii) the speed ratio requirement within ±3% error, (iii) the use of non-integer teeth ratio between all mating gears, and (iv) the elimination of meshing interferences due to too few teeth of the pinion and too many teeth of the gear.



Gear Box

4. A four-bar mechanism is shown below. The input link rotates at an angular velocity of 3450 rpm (CCW). The masses of the crank and the follower are negligible. The coupler is modelled as a uniform rod with a mass of 0.25 kg. Determine the maximum shaking force and devise an effective balancing scheme to reduce the shaking forces by at least 35% at the two configurations corresponding to the smallest and largest transmission angles.

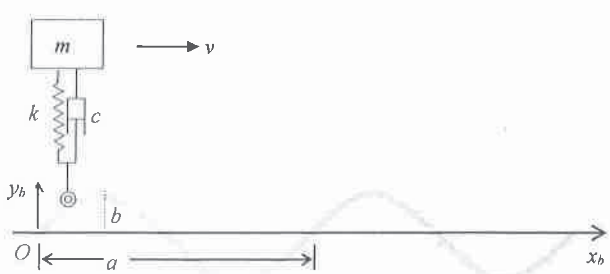


r_1 =135 mm
r_2 = 30 mm
r_3 =150 mm
r_4 = 80 mm

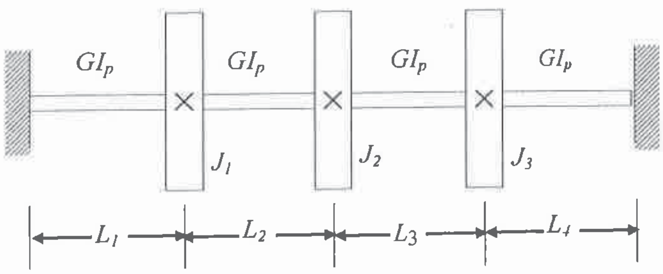
Not to scale

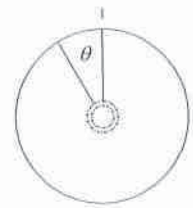
Part B

5. Determine the amplitudes of steady state responses of the shown *m-c-k* vibration system (which is a simplified model of the bouncing motion of a mono-cycle with a rider) traveling at a constant velocity v in the horizontal direction, for the following three different values: $\frac{2\pi v}{a} = 0.8\omega_n, 1.0\omega_n$, and $1.1\omega_n$, where ω_n is the undamped natural frequency of the simple one DOF system. You may ignore the size of the small wheel and its mass. In your calculations, use the following values parameters: m = 100 kg, k = 10000 N/m, c =100 Ns/m, a = 1.75 m, and b = 0.05 m. The curve is $y_b = b\sin\frac{2\pi x_b}{a} = b\sin\frac{2\pi vt}{a}$.



6. A shafting system consists of a massless steel (circular) shaft and three rotors. We are concerned with the torsional vibration behaviors of the rotor system. Therefore, only the torsional strain energy and the rotational kinetic energies of the three disks about the shaft axis are considered. Lateral bending is ignored in this problem. Choose a proper set of coordinates and establish the equations of motion for torsional vibration of the multiple DOF system. Find one of the natural frequencies and its corresponding mode shape (vector). Values of parameters are d =48 mm, $L_1 = L_2 = L_3 = L_4 = 100$ mm; G = 70 GPa, $J_1 = J_2 = J_3 = 0.01$ kg m^2.





Side View