National Exams December 2017

16-Mec-A2, Kinematics and Dynamics of Machines

3 Hours in Duration

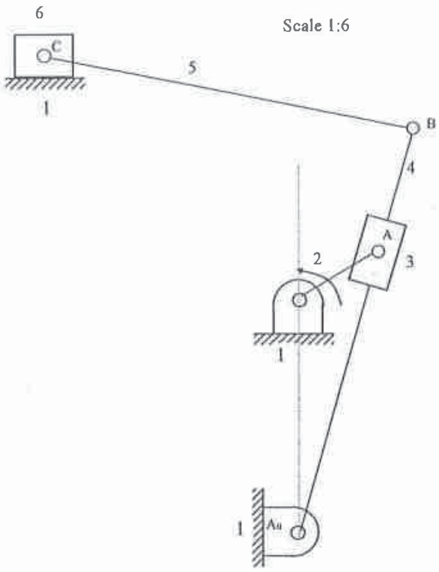
Notes:

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 questions provided; **at least one of which must be from Part B**.
4. Marks for each question are 20.

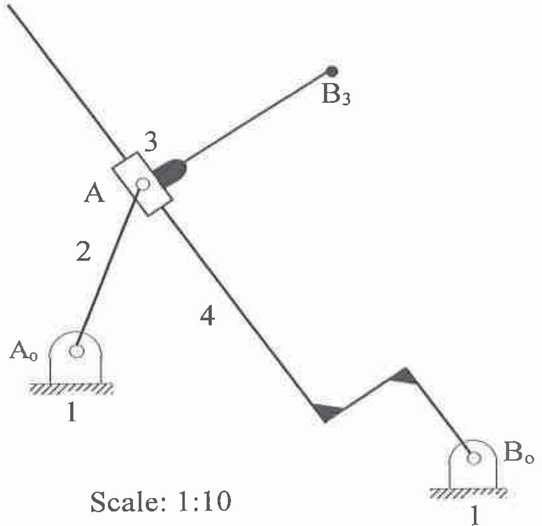
Part A

1. A six-bar mechanism shown below is the heart of a punch machine. The power stroke is associated with the movement of link 6 from its right dead centre (RDC) to the left dead center (LDC); the return stroke is associated with movement of link 6 from the LDC to the RDC. Determine (i) the time ratio, (ii) all seven primary instantaneous centers, (iii) the following secondary instantaneous centers I2,4 and I4,6 using the Kennedy's theorem. All dimensions can be directly measured from the diagram below.

If the time ratio is to be increased by 15%, how would you redesign or modify the existing design at lowest cost and clearly present your reasons.



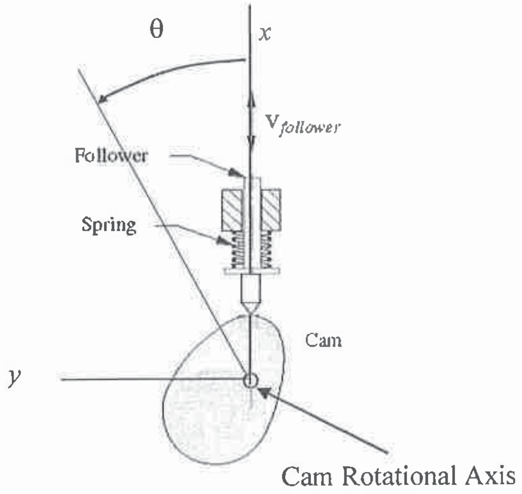
2. A four-bar inverted crank-slider mechanism is shown below. Node A is an R joint between the input link and the coupler. B is a point on the coupler (link 3). Using a proper velocity scale and draw a velocity diagram, determine (i) the angular velocity of link 4 and the relative velocity of link 3 to link 4, (ii) the linear velocity of point B by means of the velocity image theorem or the relative velocity diagram.



Scale: 1:10
$\omega_2 = 100$ rad/s (ccw)

3. 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.

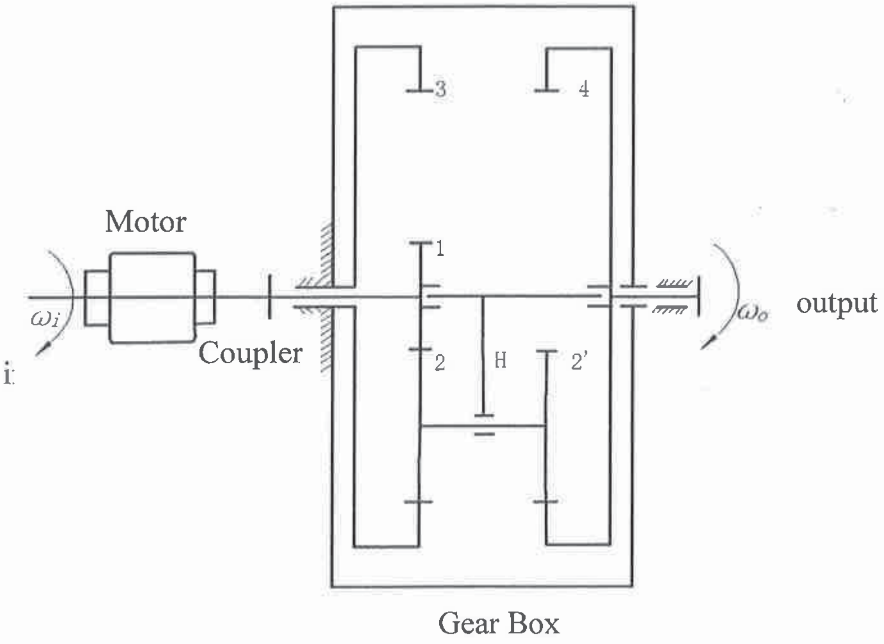


Choose a proper base circle and sketch the cam profile. Compute the pressure angles at $\theta = 45^\circ$ and $\theta = 315^\circ$. If the pressure angles are too large (i.e., greater than 30°), state how the design can be modified to meet the pressure angle requirement, but do not undertake or attempt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

4. Shown below is a 2-stage PGT used in a steel-rolling plant. The input shaft rotates at 1750 rpm (CCW viewed from the output end). The output shaft is expected to rotate at 60 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 ±2% 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.

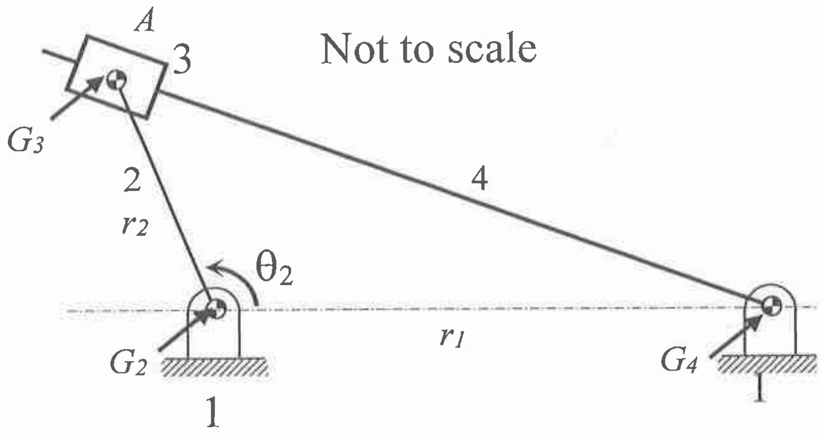


5. An inverted crank sider mechanism is shown below. The crank length is 20 cm. The length of the ground link is 50 cm. The crank rotates at a constant angular velocity of 2000 rpm (ccw). The crank shaft and the follower are considered massless in this problem. The slider as a coupler has a mass of 0.25 kg with a mass center as A3, and a mass moment of inertia of 0.125 kg-m^2.

i) Conduct the kinematical analysis by relating the positions of the coupler and the follower to θ_2 , the velocities (linear and angular) of the coupler and the follower to θ_2 and $\dot{\theta}_2$, and the accelerations (linear and angular) of the coupler and the following to θ_2 and $\dot{\theta}_2$. Note that the crank acceleration (angular) $\ddot{\theta}_2$ is zero.

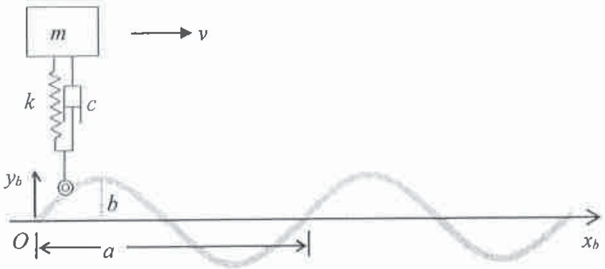
(ii) Determine the shaking force in terms of θ_2 and $\dot{\theta}_2$, and then compute its magnitudes for $\theta_2 = 45°$, and $\theta_2 = 90°$.

(iii) Design a balancing scheme to reduce the shaking force magnitudes and state clearly your reasons. Recalculate the shaking force magnitudes for $\theta_2 = 45°$, and $\theta_2 = 90°$ and conclude the effectiveness of your balancing scheme with reference to the answers in (ii)



Part B

6. Determine the amplitudes of the 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 in the horizontal direction at a constant velocity v for the following three different values: $\frac{2\pi v}{a} = 0.95\omega_n, 1.0\omega_n$, and $1.15\omega_n$, 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. Take $m = 100$ kg, $k = 10000$ N/m, $c = 100$ Ns/m, $a = 2.75$ m, $b = 0.025$ m, and the curve $y_b = b\sin\frac{2\pi x_b}{a} = b\sin\frac{2\pi vt}{a}$.



7. A shafting system consists of a massless steel (circular) shaft and two gears. We are concerned with the torsional vibration behavior of the rotor system and ignoring lateral bending. Therefore, only the torsional strain energy and the rotational kinetic energies of the two gears about the shaft axes of rotation are considered. (i) Choose a proper set of coordinates and establish the equations of motion for torsional vibration of the two-DOF system; (ii) find the two natural frequencies and their corresponding mode shapes (vector). Take d =48 mm, L = 150 mm; G = 70 GPa, J =0.0075 kg m^2.