National Exams - December 2018

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 and any non-communicating calculator is permitted.

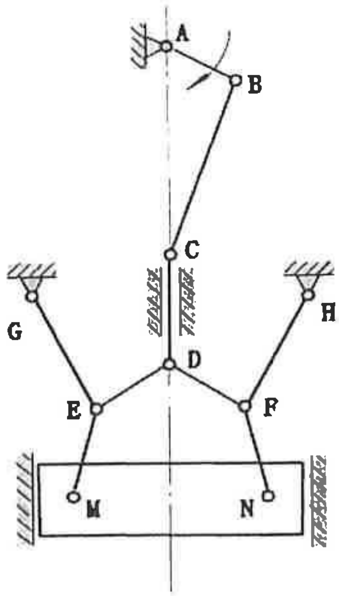
3. Every one answers question 1, and chooses three questions in Part A, and one question from part B. Question 1 is worth 40 points and each of the remaining questions are worth 20 points.

Part A

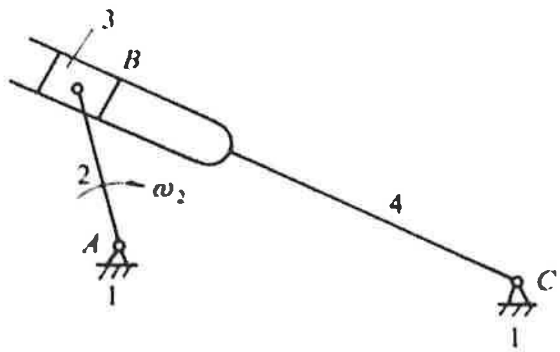
1. This question has four mini-questions with total marks of 40. Each mini-question carries 10.

(i) A mechanical engineer plans to design a 7-bar planar mechanism with eight revolute joints and one half-joint (pin in a slot). The mechanism produces a mobility of one (M = 1). Conduct a number synthesis/analysis using the Gruelber's equation and the equations of constraints, and identify and sketch neatly two valid configurations.

(ii) Determine the mobility of the mechanism shown below by means of the Gruebler's equation. You must number each valid link clearly and identify the total number of links, and the numbers and types of all joints. Explain clearly your arguments in decision making.

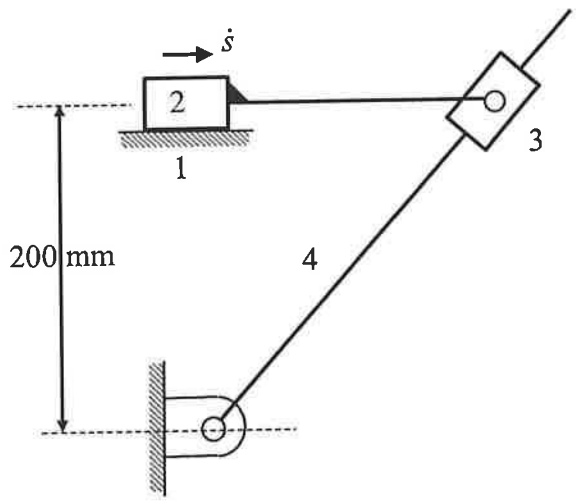


(iii) A four-bar inverted crank-slider mechanism is drawn to scale below with scale of 1:10. Assuming the link 2 as the driver (input) link, determine (a) the mechanical advantage (T_{out} / T_{in}) of the mechanism at the positions shown, (b) the range of motion of the output link in degrees, and (c) the range of the transmission angle in degrees.



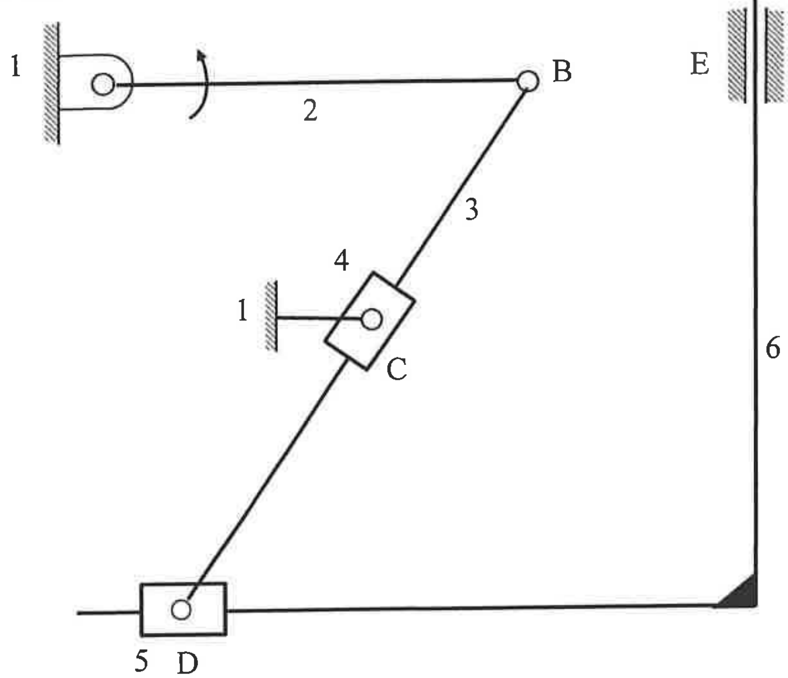
(iv) The input link moves at a constant linear velocity of 10 m/s in the direction shown in the below figure. When the follower is pushed to rotate 30 degrees clockwise (CW) from its initial vertical position, determine (the angular velocity and angular accelerations of the follower.

Not to scale



2. [20 mark]
All link dimensions can be measured directly from the diagram below.
For the planar mechanism shown below, link 2 rotates counterclockwise (CCW) at a rate of 50 rad/s.
(a) Determine the linear velocity of link 6, using the graphical velocity method.
(b) Based on the velocity diagram in (a), if the linear velocity of the follower is to be reversed with the same magnitude but opposite in direction, how would you relocate the slider joint D?

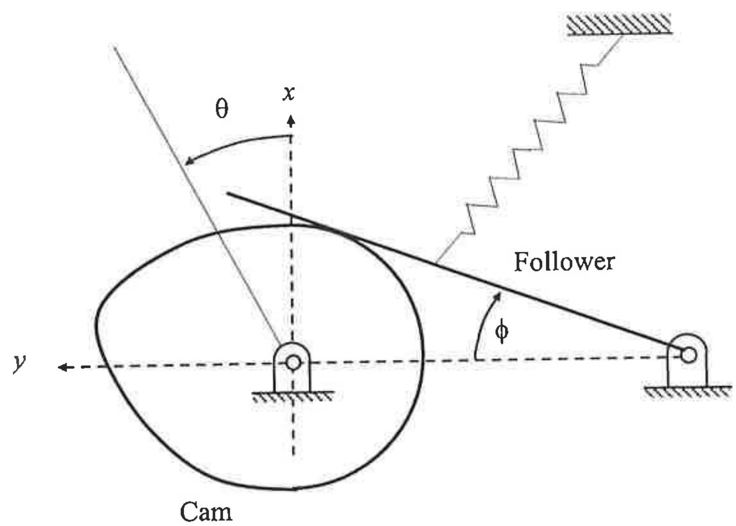
Scale 1:5



3. A rotating cam-follower is shown below. The cam rotates at a constant angular speed of 1500 rpm clockwise (CW). The distance between the two rotating axes is 24 inches. Through a guaranteed contact, the follower rotates in accordance with the following program

- rise from $\phi = 30°$ by 15° when the cam rotates from $\theta = 0°$ to $\theta = 75°$,
- fall back to the $\phi = 30°$ position when the camp rotates from $\theta = 75°$ to 180°
- dwell at the $\phi = 30°$ position when the cam rotates from $\theta = 180°$ to $\theta = 360°$.

(i) Choose a proper base circle based on the required dwelling position.
(ii) Decide the $\phi - \theta$ curve (*s*-curve) for the fall in accordance with the fundamental law of cam design with an additional objective to minimizing the maximum follower angular velocity, and sketch the $\phi - \dot{\phi} - \ddot{\phi} - \dddot{\phi}$ diagrams for the entire follower motion.

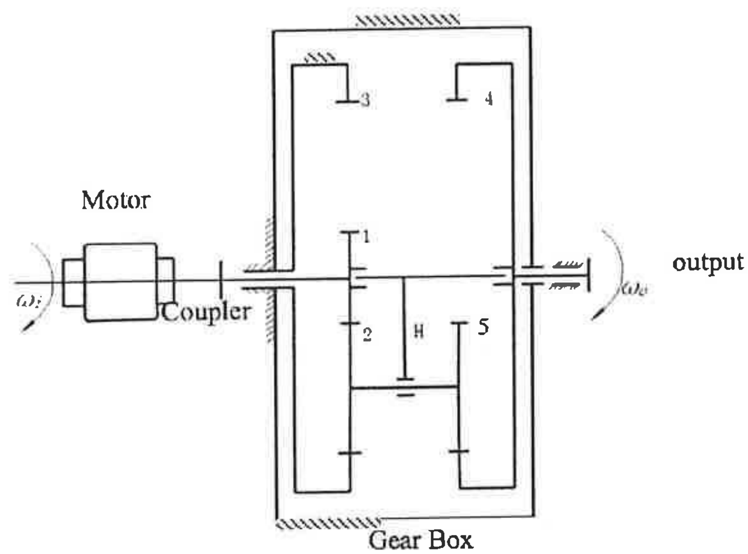


4. Shown below is a 2-stage planetary gear train (PGT) used in a steel-rolling plant. The input shaft rotates at 1500 rpm (counterclockwise, CCW, viewed from the output end). Assume that all gears have the same module or diametral pitch and pressure angle. All gear teeth have full depth (the addendum 1/P).

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

(ii) Compute the output angular velocity and its direction of rotation for: $N_1 = 21$, $N_2 = 34$, N_3 (not given), $N_4 = 81$, $N_5 = 32$.

(iii) Determine the maximum number of equally spaced planets in each stage of the PGT for the purpose of maximizing the power/torque transmission.



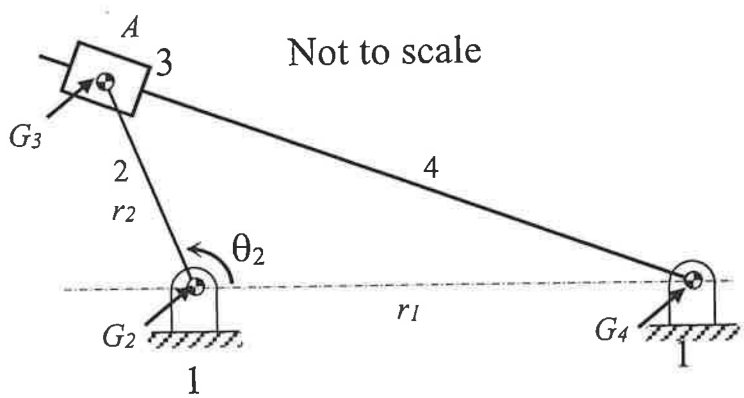
H stands for arm.

5. An inverted crank sider mechanism is shown below. The crank length is 50 cm. The length of the ground link is 90 cm. The crank rotates at a constant angular velocity of 1450 rpm (CCW). The crank shaft and the follower are considered massless in this problem. The slider as a coupler has a mass of 0.5 kg with a mass center as G_3, and a mass moment of inertia of 0.175 kg-m^2.

i) Conduct the kinematical analysis and find out he general expressions for displacements, velocities and accelerations in terms of the prescribed input motion and the given link dimensions.

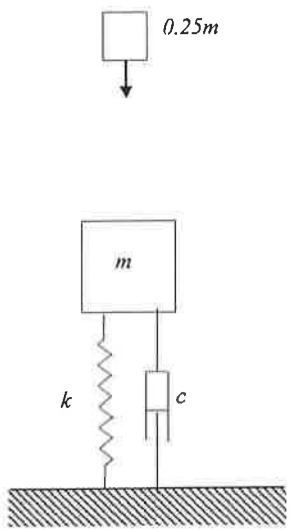
(ii) Determine the shaking forces for θ_2 =75°, and 135°. ·

(iii) Design a balancing scheme to reduce the shaking force magnitudes, say by 50%, and state clearly your reasons.



Part B

6. A small block falls at an initial velocity of $v = 2$ m/s from 10 m above the mass m in the gravitation field. The primary (mass-spring-damper) system is at rest when the block with a mass equal to $0.25m$ starts to fall. Assume that the collision is perfectly plastic. Determine the ensuring motion of the vibrating system after the impact is completed. The spring of the system obeys Hooke's law, and the damper is a viscous damper. In your calculations, use $m = 2$ kg, k =2000 N/m, and c =20 Ns/m.



7. A massless beam of circular cross section is designed to carry two point masses as shown. A linear spring is attached to the midpoint of the beam to stiffen the system. Determine the stiffening effect of the spring by calculating the percentage increases of the two natural frequencies. In your calculations, use d =30 mm, L =300 mm; E = 200 GPa, and, k = 500 N/m.