National Exams May 2019

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.

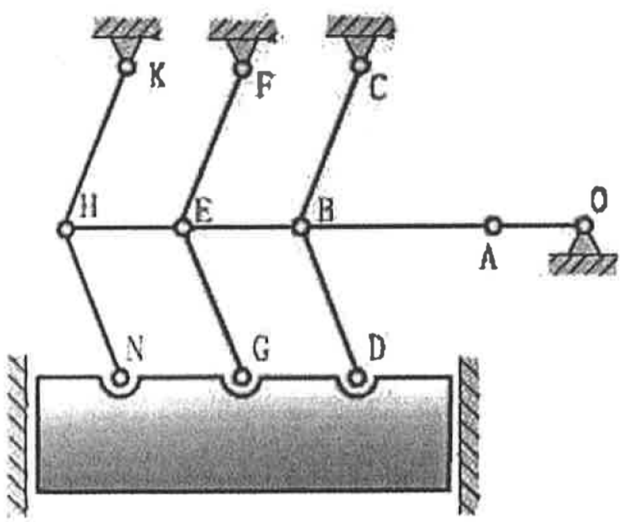
2. This is an OPEN BOOK exam. Any non-communicating calculator is permitted.

3. Five questions constitute a complete set. Every one answers question #1, and chooses four additional questions from the remaining six

1. This question has four mini-questions. Each mini-question carries 5 marks.

(i) A designer plans to design a 6-bar planar mechanism with a single degree of freedom. Sketch neatly a valid mechanism from the Stevenson family involving at least one prismatic joint.

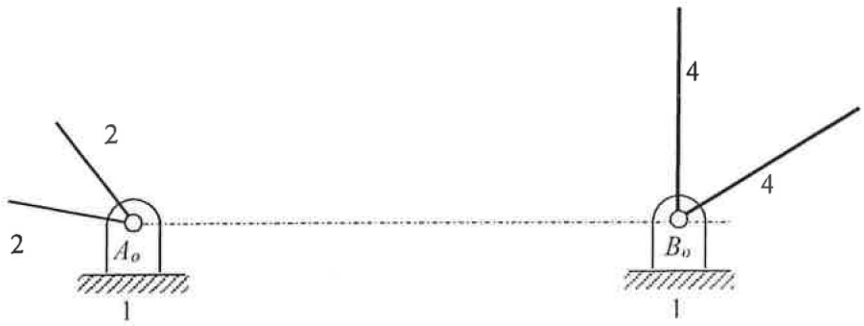
(ii) Determine the number of degrees of freedom of the mechanism shown below by means of the Gruebler's equation. You must number each valid link clearly and identify the total number links, and the numbers and types of all joints.



(iii) Below is a typical manual door lock. Sketch clearly a skeleton diagram of the mechanism used to accommodate the closing and opening operations.

(iv) Complete the design of a four-bar (RRRR) mechanism so that when its input link (link 2) rotates from 135 deg to 175 deg, the follower (link 4) rotates from 45 deg to 90 deg. All angles are measured CCW from the ground link. The ground link is pre-determined to be 120 mm; the follower link is pre-determined to be 60 mm.

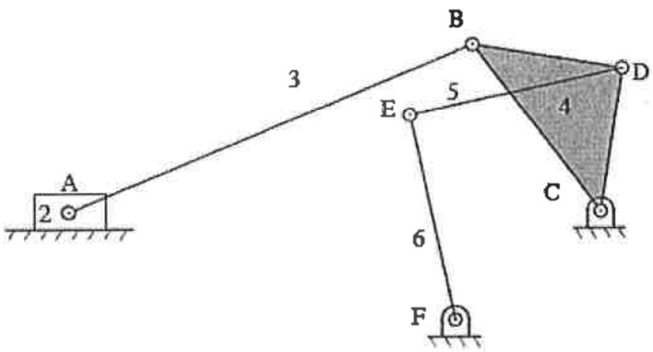
Once the design is completed, determine (i) the type of mechanism, (ii) range of motion for the follower.



2. [20 mark]

The slider (input link) of a six-bar mechanism shown below moves to the right at a velocity of 10 m/s. Determine the angular velocities of links 4, 5, and 6 using the graphical velocity analysis.

Scale 1:10

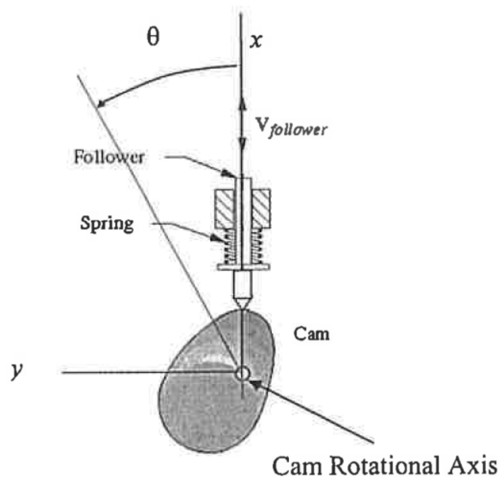


3. [20 marks] The cam in a high-speed radial cam-follower linkage rotates at 3600 rpm clockwise to produce the following follower motion

- sinusoidal motion $x = 10 \sin \theta$ (cm) from $\theta = 0$ deg to $\theta = 180$ deg
- unconstrained continuous motion from $\theta = 180$ deg to $\theta = 360$ deg

(i) Design the *s*-curve for the fall in accordance with the law of cam design, and sketch the *s-v-a-j* curves for the entire motion program with the maximum values computed and indicated on the diagrams.

(ii) Choose a proper base circle and estimate the maximum pressure angle during the sinusoidal motion during [0,180] and the unconstraint motion during [180,360]. If the pressure angle is not satisfactory, point out clearly what you would do to limit the pressure to 20 deg. But do not carry out any additional analysis.

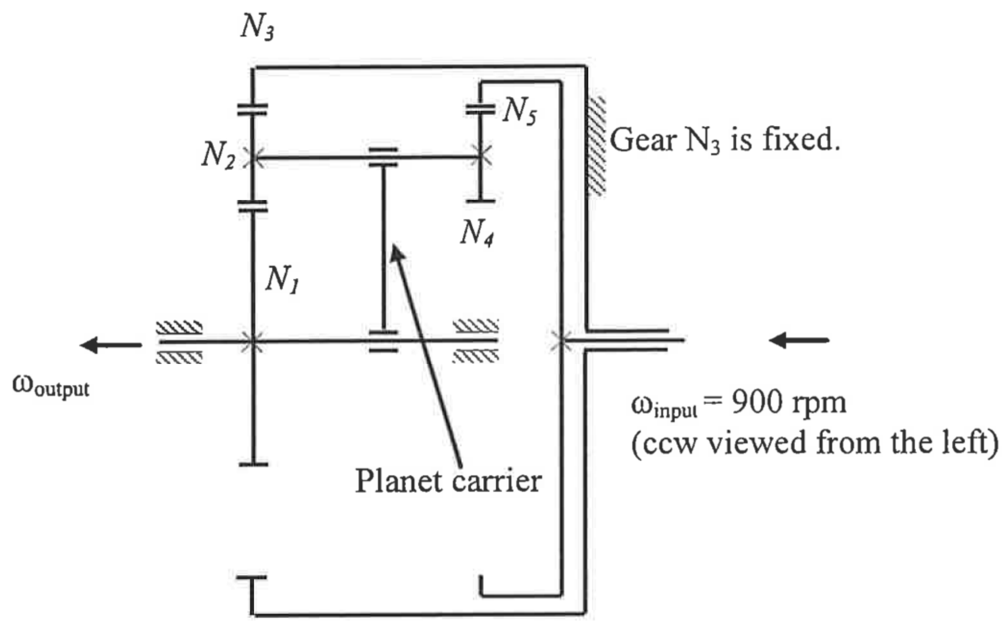


4. [20 marks] For a planetary gear train shown below, gear 3 is fixed; gear 5 is attached to the input shaft. If the numbers of teeth are $N_1 = 32$, $N_3 = 80$, $N_4 = 23$, $N_5 = 59$, determine

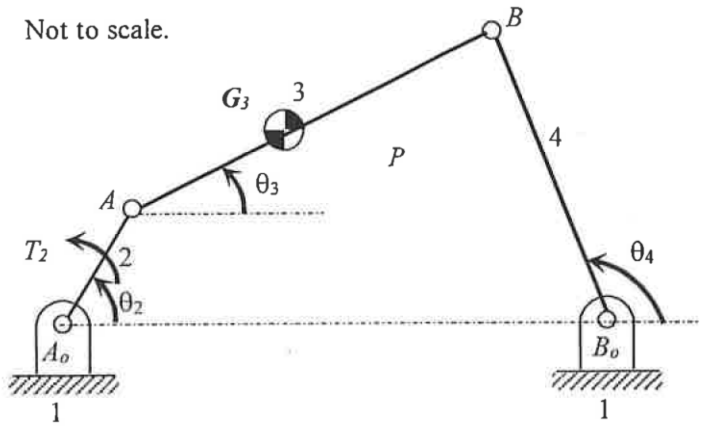
(a) the speed and direction of rotation of the output shaft, and

(b) relative rotational speed of planet carrier (arm) with respect to gear 1.

Not to scale



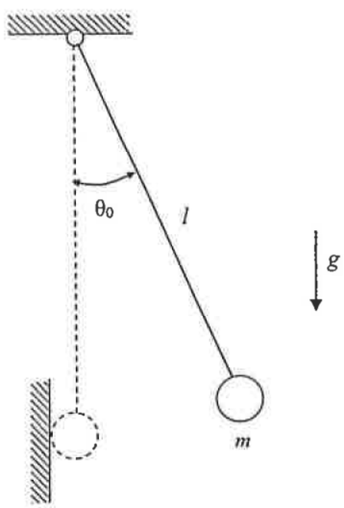
5. [20 marks] For the four bar crank-rocker mechanism shown below, determine (i) the shaking force magnitude due to the coupler mass and mass moment of inertia when the mechanism is at the configuration corresponding to the smallest transmission angle, (ii) a balancing strategy to reduce the shaking force at the same configuration as (i). You must provide meaningful calculations to support your strategy.
For simplicity, the effects of the crank and the rocker are dealt with separately and will not be considered in this problem.



Geometry and material property parameters:
$A_oB_o = 228$ mm
$A_oA = 57$ mm
$AB = 165$ mm
$B_oB = 129$ mm
$BC = 33$ mm
$AG_3 = 82.5$ mm
$m_3 = 0.5$ kg
$I_{G3} = 0.05$ kg•m^2

Configuration and operational parameters:
$\omega_2 = 30$ rad/s(ccw), $\alpha_2 = 0$ rad/s^2

6. [20 marks] A pendulum consisting of a massless string of 2 meter and a point mass (1 kg) is released from rest at $\theta_0 = 10^\circ$. Assume that (i) the coefficient of restitution (COR) between the mass and the vertical wall is 0.85, and (ii) the duration of each impact is 5 ms. Determine the natural periods of oscillation of the pendulum for the 1st and 2nd cycle.



7. [20 marks] A torsional system consists of a massless steel shaft and two identical gears. Choose a proper set of coordinates and establish the equations of motion for the torsional vibration of the two-DOF system; (ii) find the two natural frequencies and their corresponding mode shape in terms of the geo-material parameters given in the diagram below.

If the second torsional mode is found to be responsible for large amplitude oscillation, present a feasible way to alter the second natural frequency by +15% or -15%.

Symbols: G – shear modulus; J polar moment of area shaft; I mass moment of inertial of each gear about its axis of rotation; L length of concerned shaft segment.