National Exams December 2016

07-Mec-A2, Kinematics and Dynamics of Machines

3 Hours in Duration

Notes:

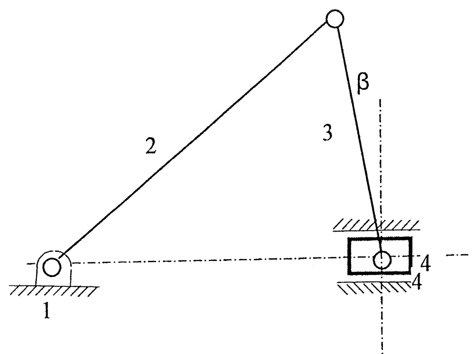
1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK exam. Any Sharp or Casio approved calculators are permitted.
3. Answer FIVE questions from the seven questions provided. At least one question must be from Part B.
4. Marks for each question are 20.

Part A

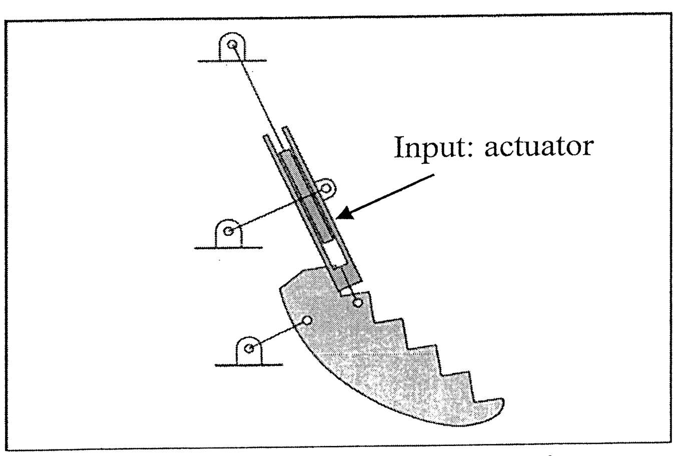
1. Answer three mini-questions below.

1.1 Sketch two valid configurations of five-bar planar mechanism with mobility of one and 5 low-pair joints and one high-pair joint. (6 marks)

1.2 Below is a four bar RRRP mechanism. When link 2 is the input link, what is the angle β? If the coefficient of kinetic friction between the slider and the cylinder is 0.25, explain clearly whether power (force and motion) can be transmitted from link 2 to link 4 if $-14^\circ < \beta < 14^\circ$. (8 marks)



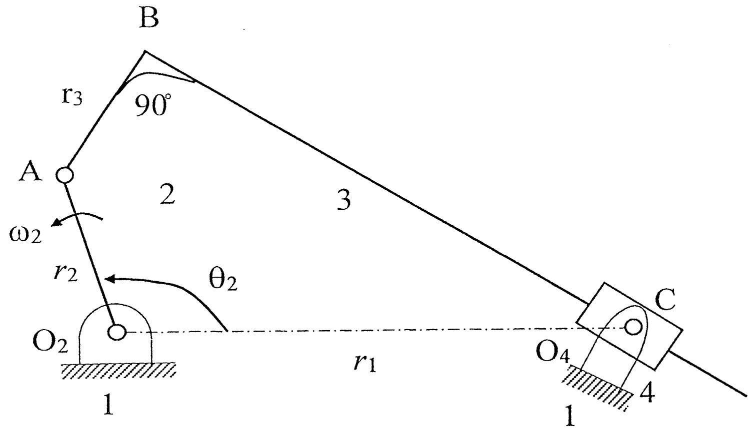
1.3 Determine the mobility of the mechanisms below by means of Gruebler's equation. [8 marks]



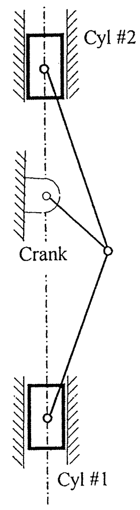
(a) Extension/retrieving of a stair ware for a small passenger aircraft

2. Below is an inverted crank-slider mechanism. The crank rotates at a constant angular velocity.
(i) Choose a proper set of positional parameters and conduct a comprehensive kinematical analysis including displacements, velocities and accelerations.
(ii) Compute the values of the (angular and linear) displacements/velocities/accelerations of the follower and the coupler for $\theta_2 = 110^{\circ}$, $r_1 = 13.5\,\text{cm}$, $r_2 = 5\,\text{cm}$, $r_3 = 4.25\,\text{cm}$, $\omega_2 = 200\,\text{rpm}$. (20 marks)

Not to scale



3. A two-cylinder opposed engine is shown below. The crank length is r. The connecting rod lengths (both equal) are l. The combined reciprocating mass of each rod-piston is m. The rotating masses are considered balanced. Both cylinders lie in a single transverse plane. Determine the shaking force associated with the two pistons and conclude whether the engine can be balanced for the first two harmonics. (20marks)



4. A radial cam, shown in Fig. (a), rotating at a constant angular velocity of 100 rad/s, is used to produce the following follower motion:

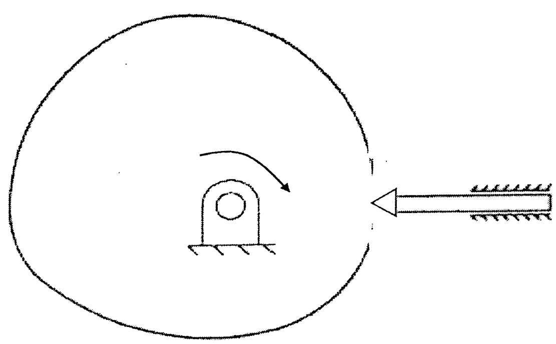
- rise by 15 cm from 0 cm position during [0,90°],
- dwell at 15 cm position during [90°, 180°]
- fall back to the 0 cm position during [180°, 360°]

Design the displacement profile for the rise with an objective to minimizing the maximum velocity. You may use Fig. (b) below as a source of information to justify your choice. You must clearly present the equations of displacement and velocity for the follower, and determine the maximum velocity during the rise.

Choose a proper base circle and compute the pressure angle at the $\theta = 45^\circ$. If this pressure angle is not satisfactory (i.e., greater than 30 degrees), state clearly how the design can be modified to meet the pressure angle requirement, but do not undertake or attempt any iterations due to time limitation.

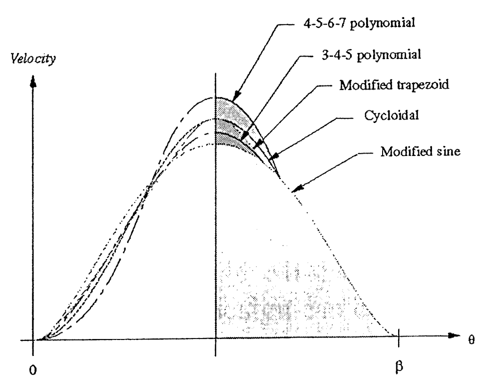
Sketch neatly the cam profile.

(20 marks)



Reference radial line is chosen to be at the beginning of rise.

(a)



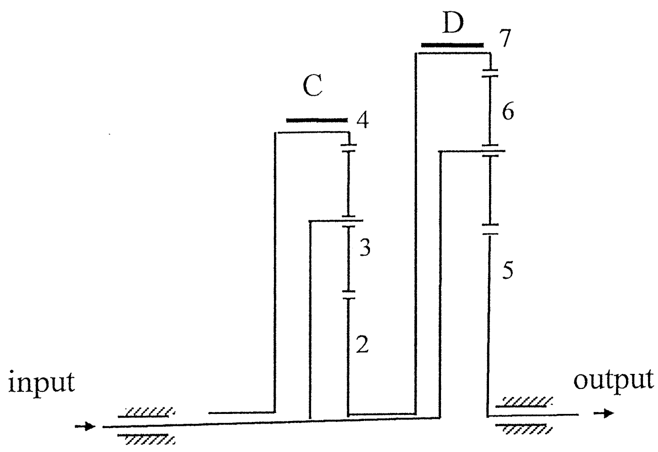
(b)

5. Shown below is a 2-stage PGT. The input shaft rotates at 1800 rpm (CCW viewed from the output end). C and D represent two brake pads, which are used to stop gear 4 or gear 7 in order to achieve different speed ratios. All gears in the PGT have identical pitch and a pressure angle of 20 degrees. All gear teeth have full depth (the addendum is α / P, $\alpha = 1.0$). The numbers of teeth for the sun and ring gear in each stage are: N2 = 18; N4 = 60, N5 = 32, N7 = 86.

Determine

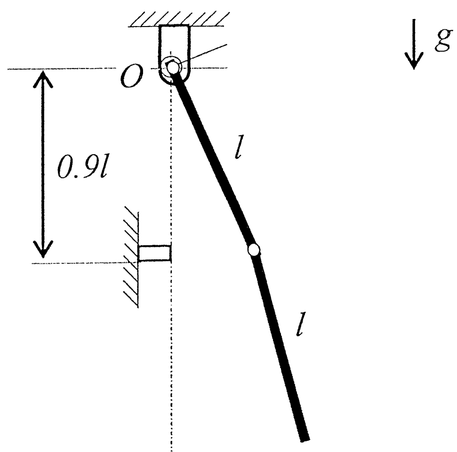
(i) the number of teeth of each planet gear,
(ii) the maximum number of equally spaced planets in each stage,
(iii) the output angular velocity when C is activated, and
(iv) the output velocity when D is activated.

(20 marks)



Part B

6. A double pendulum consisting of two identical uniform bars of mass m and length l starts to move under the influence of gravity from $\theta_{1,0}$ and $\theta_{2,0}$ (small). A stopper is placed at the position shown. Assume that the coefficient of restitution is e and the duration of impact is $\Delta\tau$. Determine the free vibration of the system just prior to the second impact. (20 marks)



7. The powerline between the two electric transmission towers has a constant tension of 2000 N. If the powerline (string) has a length 100 m and linear density 0.4 kg/m, determine

(a) the first three natural frequencies of lateral vibration of the cable

(b) the mode shapes corresponding to the first three natural frequencies

(c) the free vibration of the powerline (retaining only the first mode in the modal solution) under the following initial conditions

$$v(x,t)\big|_{t=0} = 0 \text{ (m)}; \quad \dot{v}(x,t)\big|_{t=0} = 5\frac{x}{L}\left(1-\frac{x}{L}\right) \text{ (m/s)}$$

(20 marks)