ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2013 SESSION

Open-book examination Non-programmable calculators : authorized models only Duration : 3 hours

07-Mec-A2 KINEMATICS AND DYNAMICS OF MACHINES.

Question 1) (25 points)

A two-stroke cycle single-cylinder engine drives a pump. Figure 1 below shows the driving torque and the load torque along the angular position. The pump should be operated at 1000 rpm within ± 2%. A 20 cm radius flywheel will be used to control the speed.

a. Calculate the average value of the engine torque ($T_{avg\text{-}engine}$).

b. Reproduce the graph of Fig.1 and add $T_{avg\text{-}engine}$.

c. Qualitatively sketch the angular velocity fluctuations of the original system (no flywheel) as a function of angular position. Also, indicate the maximum and minimum speed angular positions on the same graph.

d. Calculate the total energy variation between the minimum and maximum angular speed.

e. Calculate the flywheel mass moment of inertia required to maintain the speed variation between ± 2% rpm.

Describe and comment on each step of the solution (in words).

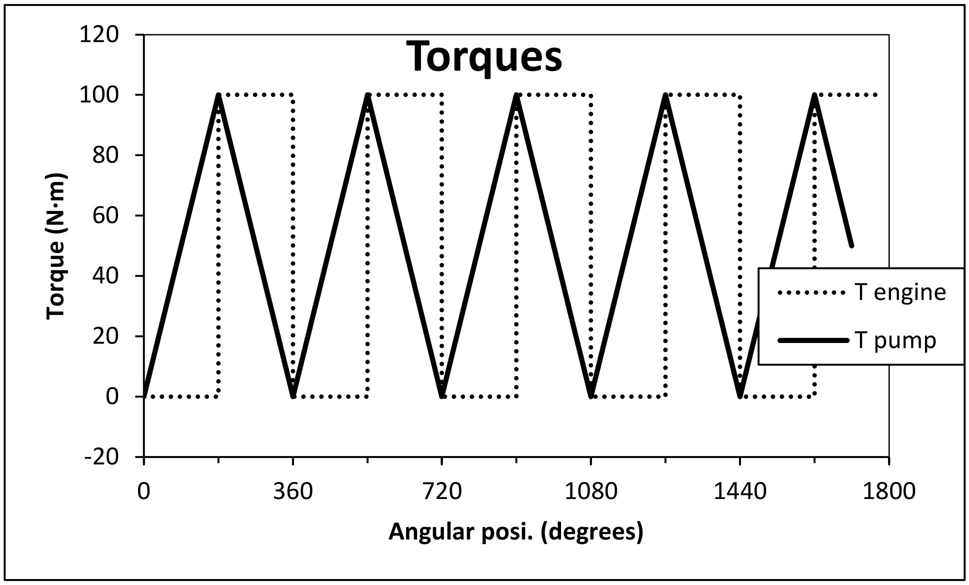


Figure 1 : Torques fluctuations.

Question 2) (25 points)

The mechanism shown in Fig. 2 includes a translating follower (0,5 Kg). The cam provides a rise of h = 10 mm from a cycloidal profile in 90^{o} of rotation. The return profile is the mirror image of the rise profile. The cam has a 25 mm base radius and includes a high dwell for 180^{o}. At the maximum acceleration point during the rise, the dynamic force generated by the load acceleration is $\boldsymbol{F_d}$ = 11 N. The cam is driven at a constant speed of 600 rpm. The bending moment generated by $\boldsymbol{F_d}$ is taken by the follower support and has no effect on the cam movement. Calculate the maximum torque (**T**) required to drive this cam, if the friction coefficient at the cam-follower contact is $\mu = 0,05$. To do this, answer to following questions:

a. Write the torque equation **T** in a variables form.

b. To find the maximum $\mathbf{T_{max}}$ value, identify and verify different critical positions. Justify these choices and present the complete calculation.

Describe and comment on each step of the solution (in words).

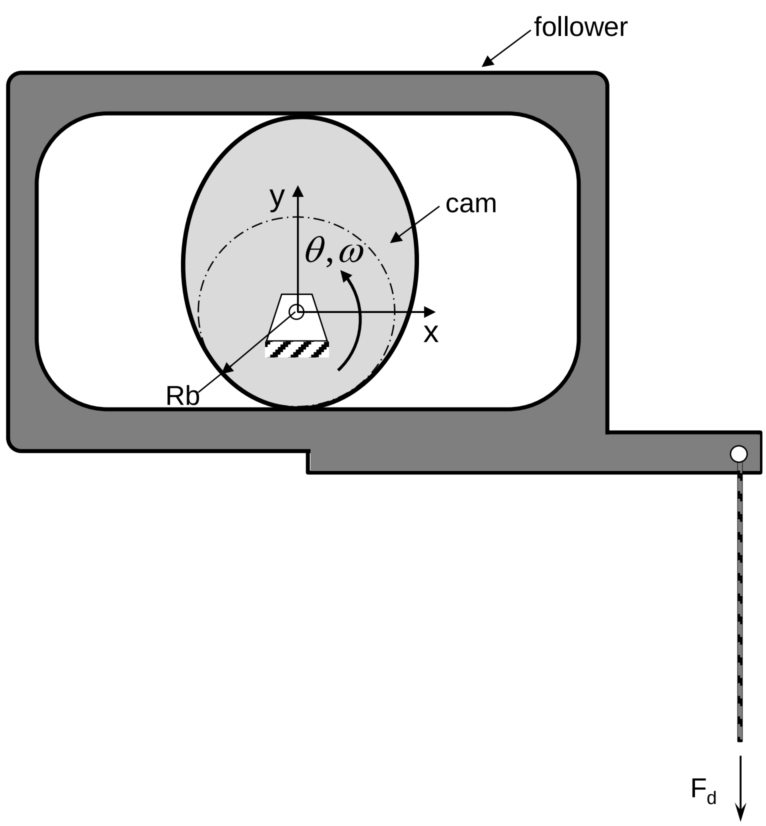


Figure 2 Cam system

Question 3) (25 points)

A planetary train is illustrated in the next figure. Carrier 2 is driven, while sun gear 1 is fixed and ring gear 6 serves as the output from the train. Gears 4 and 5 are tied. The tooth numbers are given below. The module of all gear wheels is 1,5 mm.

The tooth numbers are: $N_1 = 20$; $N_3 = 42$; $N_4 = 21$; $N_5 = 18$; $N_6 = 143$

a. Verify the center distances of this planetary train.

b. Write the expression (variables form) of the gear ratio for the train $\frac{\omega_{output}}{\omega_{input}} = \frac{\omega_6}{\omega_2}$.

c. Calculate the absolute output angular velocity, if carrier 2 is driven at 1000 rpm clockwise.

d. Considering the conditions in question c), present a three-dimensional sketch of the train and show the forces (sense and direction) acting on all gear wheels.

Comment and describe each step of the solution (in words).

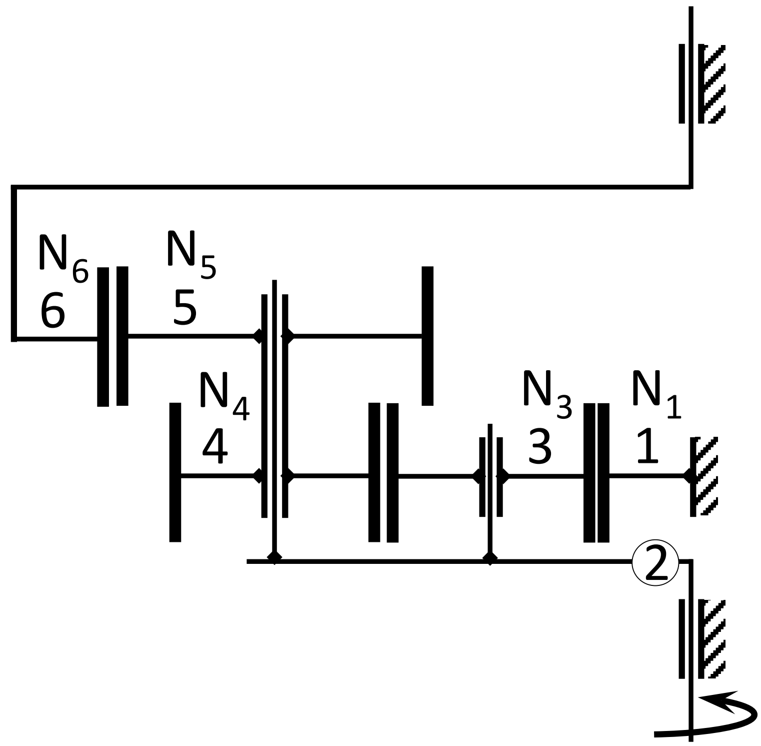
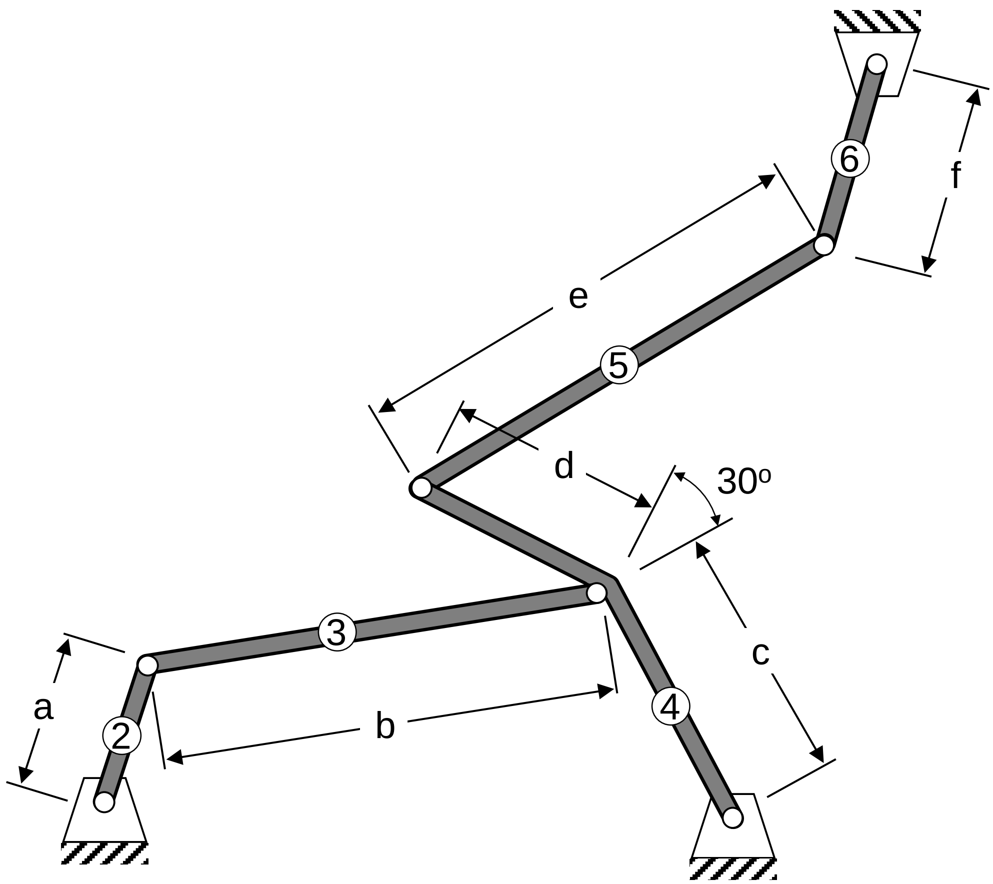


Figure 3 : Transmission

Question 4) (25 points)

Bar 2 of the mechanism shown in figure 4 is driven at a constant speed. All bars in the mechanism have a constant cross-section and are made of a homogenous material. Calculate the balance masses to be added to bars ***2***, ***4*** and ***6*** in order to reduce the resulting shaking force (transmitted to the support of the mechanism) to zero. The balance masses will be located at a 20 cm radius. On a sketch of the linkage, show the precise position of the correction masses relative to the three bars.

Describe and comment on each step of the solution (in words).



Length:	Mass
a = 0,1 m	m_2 = 0,4 Kg
b = 0,4 m	m_3 = 1,0 Kg
c = 0,3 m	m_4 = 1,2 Kg
d = 0,3 m	m_5 = 1,5 Kg
e = 0,6 m	m_6 = 0,8 Kg
f = 0,2 m	

Figure 4 Mechanism.