MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Department of Mechanical Engineering

Course 2.05 Kinematics and Dynamics of Mechanisms and Manipulators
Fall 2000

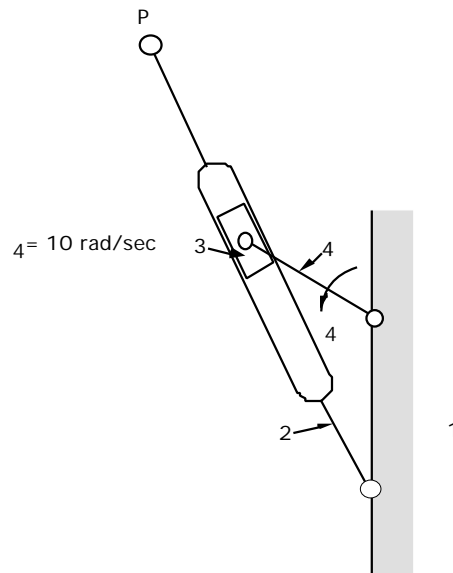Problem Set No. 2   Assigned: 09/19/00
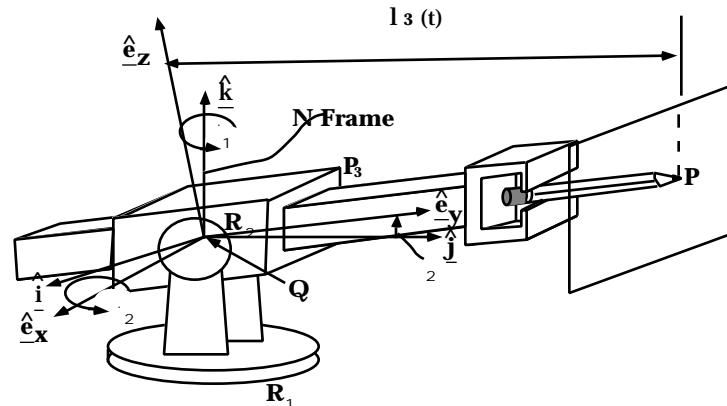   Due: 09/26/00

Problem 2.1

For the mechanism shown:

(a)   How many instant centers are there?
(b)   Find them all.
(c)   Given the angular velocity of link4 with respect to ground, using the principles of instant centers, find the velocity of P with respect to ground. (Both magnitude and direction are required.)

Problem 2.2

This manipulator has three joints

        R_1 with joint angle θ_1 (t),

        R_2 with joint angle θ_2 (t)

and   P with joint displacement l_3 (t)

(a)   The N frame is fixed in inertial space, and has unit base vectors: $\hat{\underline{i}}$, $\hat{\underline{j}}$ and $\hat{\underline{k}}$. It's origin is at point Q. The M frame is attached to the link holding the pencil. It has unit base vectors, $\hat{\underline{e}}_x$, $\hat{\underline{e}}_y$ and $\hat{\underline{e}}_z$.

    Write the position vector of P with respect to Q, $\underline{r}_{P/Q}$, in terms of $\hat{\underline{e}}_x, \hat{\underline{e}}_y, \hat{\underline{e}}_z$ base vectors.

    Develop a vector expression for $^N\underline{V}_P$ as a function of the joint positions, θ_1, θ_2, l_3 and joint velocities $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{l}_3$

(b)   If $\theta_1 = 0$ then the transformation between the N and M base vectors can be written as:

$$\hat{\underline{e}}_x = \hat{\underline{i}}$$

$$\hat{\underline{e}}_y = \cos\theta_2\hat{\underline{j}} + \sin\theta_2\hat{\underline{k}}$$

$$\hat{\underline{e}}_z = -\sin\theta_2\hat{\underline{j}} + \cos\theta_2\hat{\underline{k}}$$

Write the velocity $^N\underline{V}_P$ in terms of the N frame base vectors (world coordinates).

Find a relationship between $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{l}_3$ so that the pencil tip will have a vertical velocity in world coordinates, meaning parallel to $\hat{\underline{k}}$ base vector (for $\theta_1 = 0$).

Problem 2.3

For the mechanism shown:
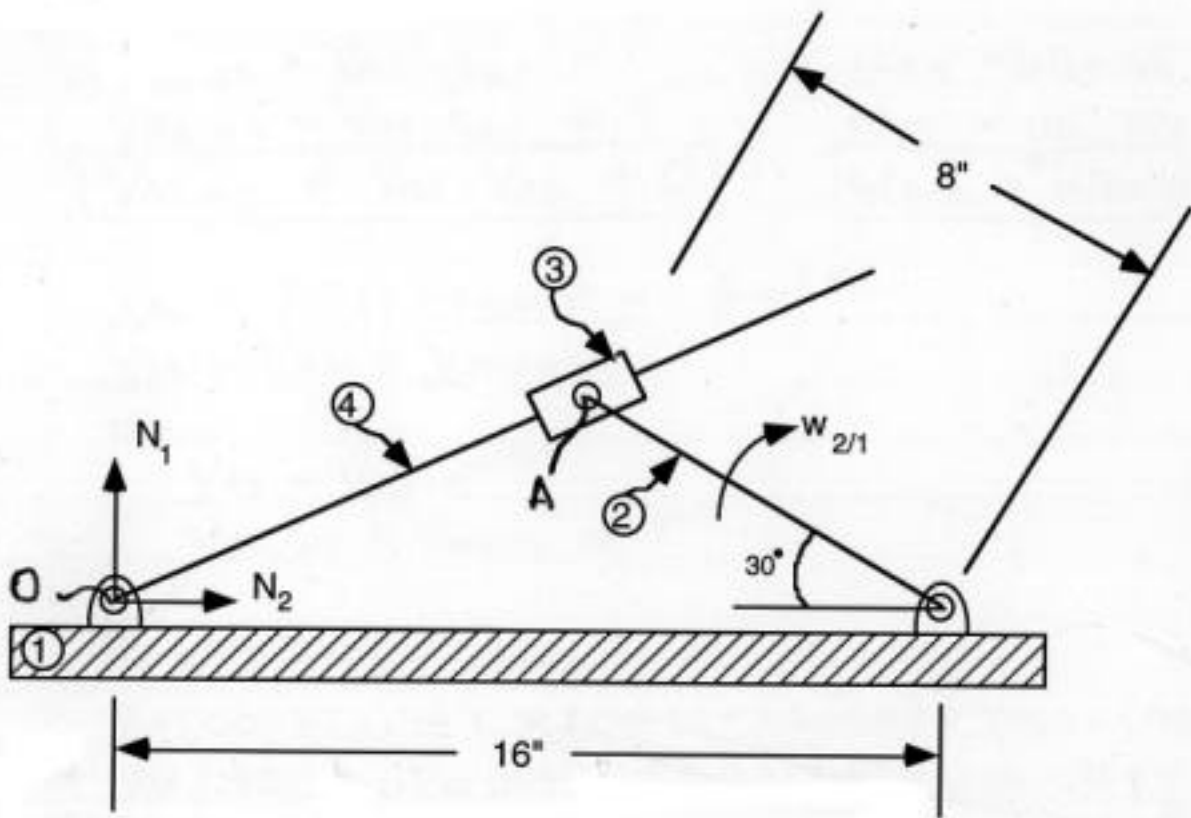a) use an analytical vector method to determine the values of:

$N_{\underline{V}_{A_2/A_4}} = ? \quad \angle_{-3/2} = ?$

$N_{\underline{V}_{A_3/A_4}} = ? \quad \angle_{-2/4} = ?$

$N_{\underline{V}_{A_2/A_3}} = ? \quad \angle_{-3/4} = ?$

$N_{\underline{V}_{A_4/A_1}} = ?$

b) Solve for these same factor variables graphically

Problem 2.4

The mechanical advantage of a mechanism is defined as the ratio output force to input fofce: M.A. = Fout/Fin. The input force on the clamp shown is 10 lbs, and the output presses on the scale. The formula for the M.A. of this clamp can be obtained from the ratio of torques of two gears in contact at the point denoted I_{24}., one attached to link 2 with center at I_{12} and one attached to link 4 with center at I_{14}. (I_{12}, I_{14}, I_{24}, are labeled (1,2), (1,4), and (2,4) in the figure.)

a) Sketch the two gears on the figure.
b) Determine the ration M.A. = Fout/Fin in terms of the torque ration of two gears.
c) Measure the distances r_2, r_4, r_{in} and r_{out} and compute mechanical advantage of the clamp.
d) What makes this clamp better than a simple lever that has M.A. = r_{out}/r_{in}?
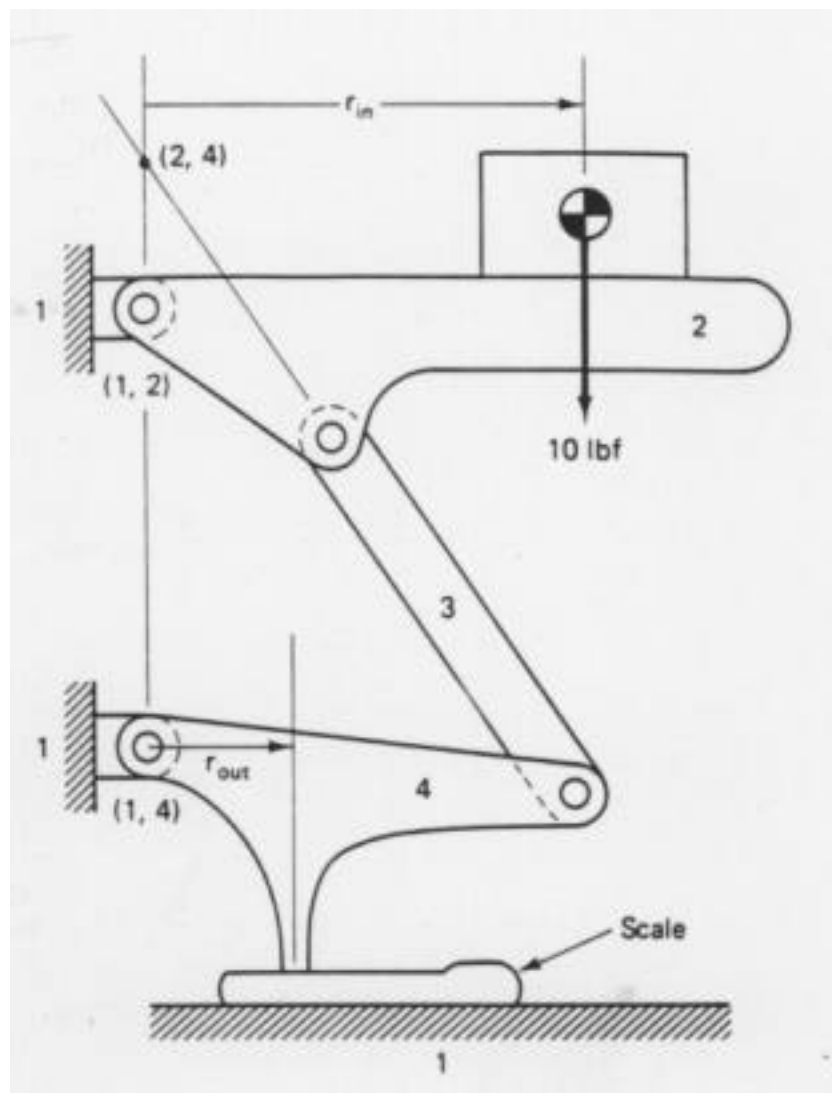
Problem 2.5

In the gear train shown below, gears B and C are compound and free to rotate on the shaft which is attached rigidly to the arm. The input and output angular velocities are shown, as are the numbers of teeth on each gear.

a) Give the general name for this type of gear train.
b) Is it reverted? (Yes/No) [extra credit - 1 point]
c) Must all the gears have the same diametrical pitch? (Yes/No)
d) Calculate the number of instant centers for this system.
e) Using the numerical designations for the bodies (1, 2, 3, and 4) show all these instant centers on Figure A.
f) Find the Transmission Ratio (TR) for this system including its sign. You may assume that all the gears have the same diametrical pitch.

FIGURE A

FIGURE B