Laboratory 4

Due: before class, Wednesday, Oct. 11

25 pts (1) The following data was collected by one of your colleagues and your advisor has asked you to analyze it by looking for a *trend* in the data. You decide to analyze it in several ways. Specifically, find the least squares fit to these data using:

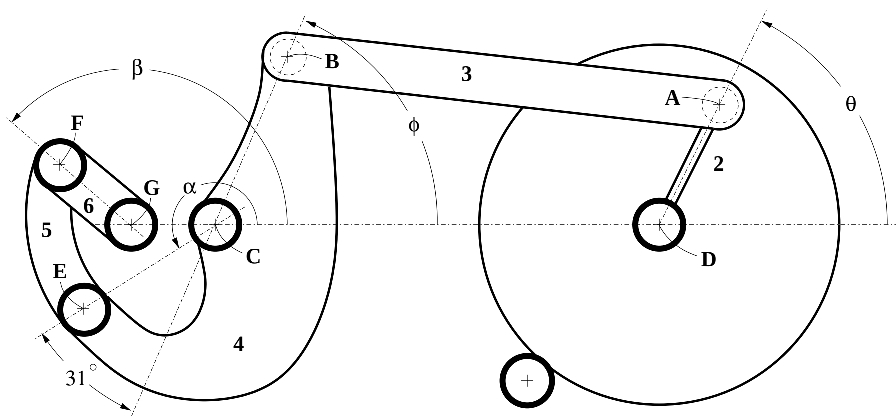
- a linear polynomial fit
- a cubic polynomial fit
- a linear polynomial fit to the "linearized" data

x	y
0	2.5237305e+03
5	2.0864229e+02
6	1.8697888e+02
13	3.9214807e+00
16	1.5271976e+00
22	6.8035297e-02
35	7.3126314e-05
38	1.4585192e-05
42	3.0299061e-06
44	8.6349502e-07
47	2.4089013e-07
50	4.6306127e-08

For the cubic least-squares fit, write down the normal equations and explain how you arrived at your solution for the best-fit cubic polynomial.

Finally, after presenting your results, your advisor asks you why you didn't do a non-linear least-squares fit to the data and whether or not it will give you the same answer the "linearized" fit gave you. Answer your advisor's question by either performing the non-linear fit or comparing the errors of an individual data point using both methods and demonstrating whether or not the best-fit non-linear functions are the same.

25 pts (2) An automatic washer transmission uses the linkage shown in the accompanying figure to convert rotary motion from the drive motor to a large oscillating output of the agitator shaft G. Links 2, 4, and 6 rotate or oscillate about fixed axes. Links 2, 3, and 4 (DA, AB, and BC) along with the fixed base (CD) constitute a four-bar linkage identical to that from *Laboratory 2, part 3* where θ_4 (from Lab2) $= \theta$ (Fig below) $+ \pi$ (Note, however, that the order of the linkage numbers may be different). A second four-bar linkage involving links 4, 5, and 6 (CE, EF, and FG) along with a fixed base (GC) can also be identified and is also identical to that of *Laboratory 2, part 3* where $\theta_4 = \alpha + \pi$. It is of interest to find the angular velocity and the angular acceleration of the agitator shaft for design purposes. Note that for any given θ, the angle ϕ can be found by solving the first four-bar linkage. The angle α is equal to the angle ϕ plus a constant (149°) and given the angle α, the angle β can be found using the second four-bar linkage system.



Automatic Washing Machine Drive

DA = 1.84 in	AB = 6.86 in	CB = 2.36 in	EF = 1.82 in
GF = 1.26 in	DC = 7.00 in	CG = 1.25 in	CE = 2.41 in

10 pts (*i*) Increment θ from 0 to 360° in steps of 1° and compute ϕ and $d\phi/d\theta$ at each point. Report plots of ϕ and $d\phi/d\theta$ versus θ. For the first derivative, compute both a first forward difference and a centered difference approximation and plot the two curves on the same graph. How do the two curves compare? Which do you expect to be more accurate? Also plot the *difference* between the forward and centered difference solution (probably on a log scale) and describe your findings.

When using your Newton algorithm from *Laboratory 2*, as you increment θ use the previously found solution as an initial starting guess for the next value of θ. Make sure your initial guess is physically reasonable and **be careful of your linkage order**.

15 pts (*ii*) Now solve the second linkage problem, by determining α from your computed values of ϕ and using Newton's method on the second linkage system to compute β, $d\beta/dt$ (i.e., the angular velocity in rad/sec) and $d^2\beta/dt^2$ (i.e., the angular acceleration in rad/sec^2). Make plots of these quantities as a function of θ and in the case of the derivatives, compute and plot both forward and centered approximations as before. Note that

$$\frac{d\beta}{dt} = \omega\frac{d\beta}{d\theta} \qquad \text{and} \qquad \frac{d^2\beta}{dt^2} = \omega^2\frac{d^2\beta}{d\theta^2}$$

where ω is the rotating speed of the driving gear (assume that $\omega = 550$ radians per minute). Again plot the difference between your two methods and comment on your results.

Watch your units!