Laboratory 4

Due: 5 p.m., Wednesday, Oct. 15

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

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  x       y
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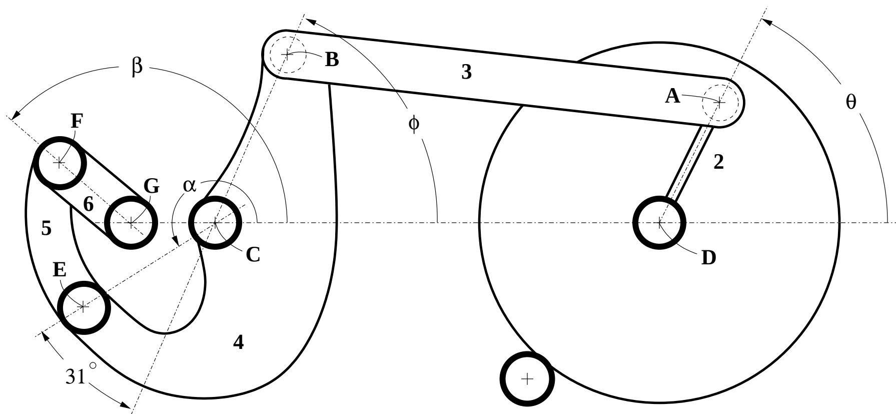
  0   9.9096816e+03
  4   8.0288293e+02
  6   3.2994196e+02
  7   1.2437454e+02
 13   4.7990217e+00
 15   1.2273452e+00
 18   1.3521287e-01
 21   1.8341061e-02
 22   1.4652968e-02
 27   4.9403019e-04
 29   1.7287294e-04
 32   2.2708755e-05
 35   3.2690255e-06
 36   1.3780727e-06
 37   8.2726513e-07
 42   3.4272876e-08
 47   1.6249468e-09
 50   2.8535191e-10
```

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.

Be sure to plot the data and your fits on both linear and semilog scales.

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 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 indeed 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 = 1.94 in	AB = 6.68 in	CB = 2.36 in	EF = 1.82 in
GF = 1.26 in	DC = 7.10 in	CG = 1.23 in	CE = 2.35 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!