MECH 4420
Homework #6
(Due Friday 11/20/2009)

To be performed in your teams. Turn in one report that lists the names of all team members.

The purpose of this assignment is to relate the discussion of linkage and steering kinematics to the characteristics of a real car. Each team should choose ***two*** distinctly different vehicles (such as a sports car, inexpensive compact car, pickup truck, SUV, etc.). Make sure the other teams in the class are selecting different types of vehicles. Try and pick one vehicle that is similar to a vehicle you can find data for (from Road and Track, Car and Driver, etc.). Model and follow through the steps outlined below to produce a parameter set. You may want to pick a car that you will be taking to the "lab day" at the NCAT test track. Note detailed data/calculations are only required for one vehicle (for the second vehicle just answer the base questions).

a) ***Suspension type***. What type of front suspension does the car have? Rear suspension? Do they have stabilizer bars? Why do you think these types were chosen for this particular car? What is the approximate frequency of the body mode, tire mode, and ride rate of the front and rear suspensions?

$$\omega_{body} \approx \sqrt{\frac{K_{eff}}{M_{body}}} \qquad \omega_{tire} \approx \sqrt{\frac{K_s + K_t}{m_{tire}}} \qquad K_{eff} = \frac{K_s K_t}{K_s + K_t} \quad \text{(ride rate)}$$

b) ***Suspension kinematics***. Draw (to scale) a front view of the suspension kinematics for both the front and rear suspensions. Include all link points, the vehicle centerline, the tire, the linkage's instantaneous center in this configuration (as you measure it, at rest) and the roll center. How high is the roll center off of the ground? What does this tell you about scrub? Where is the instantaneous center of the suspension? What do you predict happens with camber change? Estimate the equivalent trailing arm dimensions (*e* and *d*) for the front and rear suspensions.

c) ***Steering kinematics***. Locate the ball joints where the tie rod connects to the wheel body and the inboard elements of the steering system (the rack, for instance) on a scale front view of the suspension. Is it a front steer or rear steer arrangement? Do these two ball joint points lie along the line to the instantaneous center? If not, is this an understeer or oversteer effect? Explain. In this front view, locate the kingpin axis, the kingpin inclination angle and the scrub radius. In a side view, draw the caster angle, kingpin offset and mechanical trail.

d) ***Suspension stiffness***. Estimate/measure the spring rate and spacing of the front and rear springs. If you have a stabilizer bar, estimate/measure the additional stiffness due to this element. About how much compression can the spring or suspension handle before you hit a bump stop? Calculate the spring stiffness and stabilizer bar stiffness. Estimate the pitch rate (K_θ) of the vehicle in deg/g under acceleration and braking.

e) ***Other parameters***. The last things you need are the wheelbase (easily measured), vehicle mass, cg location and cg height. These can often be found in reviews of the vehicle (except for cg height). If you can track down these numbers, state where you found them. Otherwise, use some engineering judgment and explain how you estimated the numbers. Check out the paper on the class website and the paper handed out in class!

f) ***Handling analysis***. Using the program for assignment #4, plot the steer angle versus lateral acceleration curve and roll angle versus lateral acceleration curves for your vehicle. Do they seem reasonable? If your roll plot indicates that you hit a bump stop, include a nonlinear stiffness to indicate that the vehicle can't roll much beyond this point. What kind of feedback might this give you? To get an idea of the steering torque required, plot the moment on the steering axis at lateral accelerations of 0.1g and 0.3g assuming a constant pneumatic trail of 4cm. Which has the larger contribution: the mechanical trail or the pneumatic trail?

g) ***Experimental***. See if you can find any information on your vehicle (from *Road and Track* for example) on the handling of the car you modeled. How does the data compare to your simulation?

Provide plots of the suspension and steering kinematics and a plot of the vehicle handling analysis (steer angle vs. lateral acceleration). Provide an excel table with the following (each team will need to email me the table provided on the class webpage):

- Track Width (front and rear)
- CG Height
- Weight
- Weight Distribution (a, b, L)
- front suspension type (sway bar – yes or no)
- rear suspension type (sway bar – yes or no)
- h_f and h_r
- h_1=d_1
- S_f and S_r
- K_{stab_f} and K_{stab_r}
- $K\phi f$ and $K\phi r$
- ay (simulated)
- ay (experimental, if available from Road and Track for example)
- roll rate
- ride rate (front and rear)
- ω_{body} (front and rear)
- ω_{tire} (front and rear)
- front trailing arm dimensions (e_f,d_f)
- rear trailing arm dimensions (e_r,d_r)
- acceleration pitch rate (K_{θ_ax})
- braking pitch rate (K_{θ_dx})