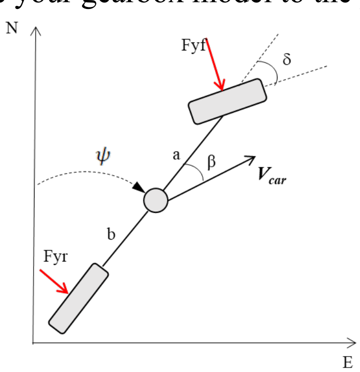
Mid-Semester Group (4 members) Project
(Due 10/29/2025 with 30 Minute Group Interview Quiz)

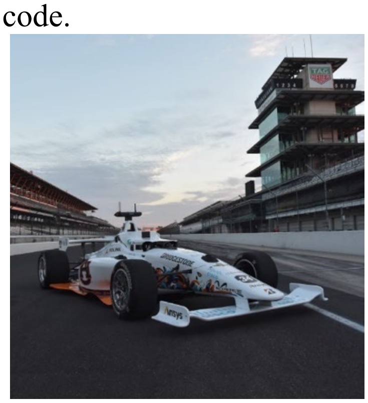
Part I. Develop models for a motor (from volts to speed).

a) Develop a model that includes the motor inductance.
b) Develop a model that neglects the motor inductance. What is J_{eff} and b_{eff}?
c) Look up the following values for the 24 volt Maxon motor RE-30, part # 268214 (https://www.maxongroup.com). Note any discrepancies in the published values.

	Values (Maxon's Units)	Values (SI Units)
K_b		
R		
K_I		
Stall Torque		
No Load Speed		
Mass Moment of Inertia		
b_θ		
Motor Time Constant		

e) What are the eigenvalue(s) for the system (for both models)? What are the corresponding time constant(s)?
f) Simulate the step response of the motor to an input voltage of 12 Volts. Compare the model that includes motor inductance and the model without the motor inductance (plot the speed output on the same graph). Explain the comparison.
g) How does the simulated system agree with the manufactures specification in terms of time constant and steady state velocity?
h) When is it reasonable (or not reasonable) to neglect the motor inductance?
i) Rederive the equations of motion for the motor with a gearbox (with a gear ratio N).
j) Compare your gearbox model to the provided .p code.





Part II. Design a controller to control the angular ***position*** of the motor (24 Volt RE-30 with GP 32 21:1 gearhead, part# 166160). Note that the gear inertia listed is the effective gear inertia measured at the output shaft and you can assume the bearing losses in the gearhead are negligible.

a) Design the controller such that the system has approximately 5% overshoot and settles in less than 0.025 seconds. What is the resulting closed-loop bandwidth?

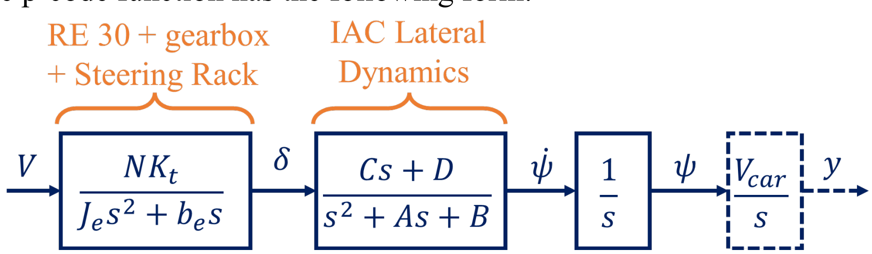
b) Simulate your controller on your motor model developed in Part I. Provide plots for a constant reference as well as a sinusoidal reference. How do the results compare to your predicted responses? Generate a Bode plot from experimental data.

c) Test your controller on the p-code `run_Indy_car.p` provided to the class (see `run_Indy_car_help.m`). The p-code is an encrypted m-file function that takes in a voltage (24 volt max) and returns the measured encoder angle after 1 ms (among other things). Note that the encoder (part # 110513) is a 500 count/revolution encoder which can utilize quadrature counting resulting in 4x resolution. Additionally, the simulation assumes a 12-bit counter (4096 max counts). See below for the block diagram, where the voltage input to the motor is the input, and steer angle (δ, aka the tire angle) is the output of the first block, yaw rate ($\dot{\psi}$) is the output of the second block, and the heading (ψ) is the output of the last block. Note that to just test the steering motor controller, only send `run_Indy_car.p` a voltage command (see the help file for more details).

Note: Use a desired angle of 30 degrees

Bonus: Use a desired angle of 1000 degrees. This will require correcting the output of the encoder, which is something you will have to fix by the final project.

The p-code function has the following form:




```
[GPS,yaw_gyro,motor_counts,WP,lat_err]=run_Indy_car(volts,Vel,X0_values,WP_FILE);
```

This means that the inputs are:

- Voltage to the steering motor (RE-30)
- Velocity of the car (m/s)
- Initial conditions (X0_values=[East0 (m), North0 (m), Heading0 (rad), yaw_rate0 (rad/s), motor_angle0 (rad)]; Default X0=[0 0 0 0 0])
- Waypoints the car will follow (*final project only, "WP_File"*)

The output relevant to the midterm project is:

- motor_counts = steering motor encoder counts (at the motor).
- GPS (vehicle position and heading)
- Gyro (yaw rate)

d) Plot and explain the vehicle output states (steer angle δ, yaw rate $\dot{\psi}$, and heading (yaw) ψ) given a constant input voltage of 12V and a velocity of 10 m/s. Note that the steering angle has physical constraints (i.e., a maximum steer angle exists and is coded into the p-code). Note that the steering rack ratio (η) is the overall steering ratio of 15:1 for the car (i.e., the gearbox output at the steering wheel turns 15 degrees for every 1 degree the tires turn).