Homework – DC Motor Theory, Open-Loop Step Response, and Obstacle Avoidance

1. Fill in the blanks (10-points)

A. Lorentz's law states that a current-carrying wire in a _____ field will induce an electromotor force
B. In a DC motor, _____ allow the loops of copper wire to rotate 180 degrees
C. An _____ is another term for a coil or loop of wire
D. Inductors _____ the change in current
E. Induced ____ is called the back EMF
F. In DC motors, torque is _____ of voltage
G. Motor speed _____ then torque decreases
H. A DC motor with negligible inductance is a ____ order system
I. The rise time (or time constant) is the time to reach _____ of the steady-state value
J. It takes ___ time constants for the system to reach 99% of the steady-state value.

2. Given that the Open Loop Transfer Function for the NXT motor is given by $G_{OL} = \frac{b}{s+a} = \frac{\Omega(s)}{V(s)}$ where the input is the motor command $V(s)$and the output is motor velocity $\Omega(s)$ (10 points total)

Given a step input $v(t) = \begin{cases} 0: & t \leq 0 \\ M: & t > 0 \end{cases}$

A. Show using ordinary differential equations that $\omega(t) = \frac{Mb}{a}(1 - e^{-at})$

B. Show using Laplace transform techniques that $\omega(t) = \frac{Mb}{a}(1 - e^{-at})$

3. Below is an open-loop step response plot of an NXT motor to a 75% motor command. The X-axis is time in seconds and the Y-axis is the motor's RPM (10-points total)

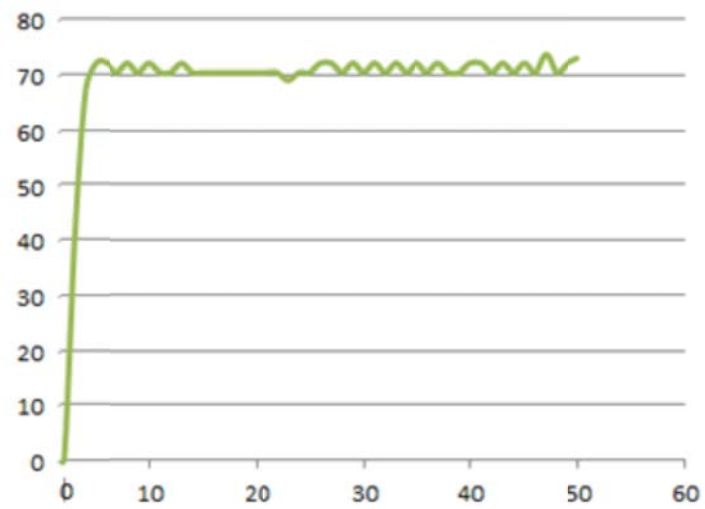

Figure 1A: Excel plot of `nxtMotorData.csv`

A. Eyeball the plot. What is the steady-state RPM?
B. Eyeball the plot. What is the value of the rise time?
C. Using the understanding of time constants, calculate how many seconds it takes for the motor to reach 99% of the steady-state RPM?

4. In lab, you demonstrated bang-bang and PID obstacle avoidance using an ultrasonic sensor mounted on the Domabot's bow. Complete the following table (20-points total)

Trial	`speedBase`	`oObst`	[`oKp`, `oKi`, `oKd`]	YouTube URL	Observations
A	50	30	[0, 0, 0]		
B	50	30	[20, 0.01, 0.5]		
C	30	30	[0, 0, 0]		
D	30	30	[20, 0.01, 0.5]		