Lab 2 (associated with Hw 2): Motor spin-down test

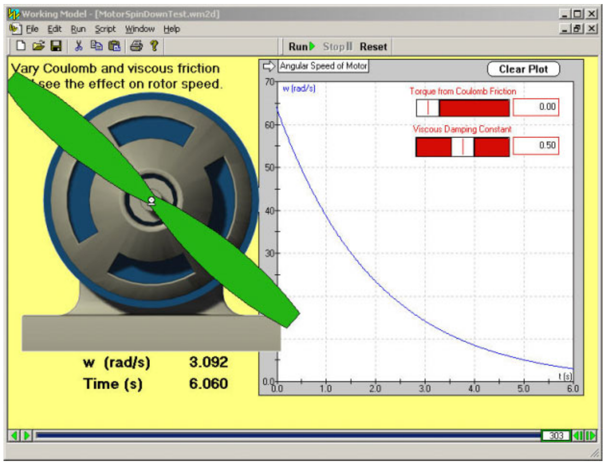
The objective of this laboratory is to gain physical insights into 1^{st}-order, linear, ODEs and to recognize how motor angular speed ω is influenced by:

- b, the motor's linear viscous damping constant
- T_f, the Coulomb friction torque on the motor

and to determine numerical values for b and T_f from experimental data (***system identification***).

Lab 2.1 **Effect of viscous friction and Coulomb friction on a motor's speed.**

To begin this problem, double-click on the Working Model file `MotorSpinDownTest.wm2d`.
In the following table, record τ_c and t_{stop} or t_{settling} in units of seconds.



To answer each question with Working Model, click the **Reset** button (if necessary) and click and drag the sliders that control the values of b (measured in n∗m∗sec) and T_f (measured in n∗m).

To start the simulation, click the **Run** button, and to stop it, click the **Stop** button.

For finer control of simulation time, use the  arrow or  arrows to rewind or advance the simulation.

For each simulation that follows, use the plot of the motor's angular speed versus time to determine:

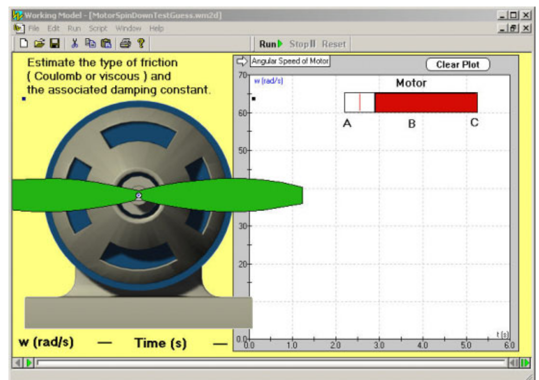
- How $\omega(t)$ decreases (circle linear, exponential, both, or neither)
- τ_c, the time required for the motor's speed to decrease to $e^{-1} \approx 0.37$ of its initial speed
- t_{stop}, the time it takes for the motor to stop spinning
- t_{settling}, the time required for $\omega(t)$ to settle within 1% of ω_{ss} [the steady-state value of $\omega(t)$], i.e., t_{settling} is the minimum value of t such that for $t \geq t_{\text{settling}}$, $\left|\omega(t) - \omega_{\text{ss}}\right| \leq 0.01 * \left|\omega_{\text{ss}} - \omega(0)\right|$.
  Note: Since $\omega_{\text{ss}} = 0$ and $\omega(0) = 64$, t_{settling} is the time required for $\omega(t) \leq 0.64$.
  If $t_{stop} \neq \infty$, skip t_{settling}.

	T_f=0	T_f=15	T_f=30
b=0	linear/exponential $\tau_c = \infty$ $t_{stop} = \infty$	**linear/exponential** $\tau_c =$ $t_{stop} =$	**linear/exponential** $\tau_c =$ $t_{stop} =$
b=0.5	**linear/exponential** $\tau_c =$ $t_{\text{settling}} =$	**linear/exponential** $\tau_c = 1.13$ $t_{stop} = 2.28$	**linear/exponential** $\tau_c =$ $t_{stop} =$
b=1.0	**linear/exponential** $\tau_c =$ $t_{\text{settling}} =$	**linear/exponential** $\tau_c =$ $t_{stop} =$	**linear/exponential** $\tau_c = 0.56$ $t_{stop} = 1.14$

Based on your observations, circle the correct answer in the following statements:

- Linear viscous damping causes the motor's speed to decrease **linearly/exponentially**
- Coulomb friction causes the motor's speed to decrease **linearly/exponentially**
- For a motor that has both linear viscous damping and Coulomb friction, the dominant reason the motor slows down at *small* values of ω is probably **viscous damping/Coulomb friction,** whereas at *large* values of ω, it is probably **viscous damping/Coulomb friction**
- When the motor drives a ***propeller***, a better model of the total torque $T_{resistance}$ that slows the motor is $T_{resistance} = T_f + b\,\omega + c\,\omega^2$ where c is a constant. The physical phenomenon responsible for the $c\,\omega^2$ term in driving a propellar is mostly likely ________________.
- At very large values of ω, the dominant term in $T_{resistance}$ is $T_f / b\,\omega / c\,\omega^2$ (circle one).

Lab 2.2 Determining the linear viscous damping constant and Coulomb friction torque.



One task performed by an engineer when building or using a motor is determining numerical values for b and T_f from laboratory data and from a known value of I, the moment of inertia of the motor and its attachments about its axis.

For each motor in `MotorSpinDownTestGuess.wm2d`, determine:

- How $\omega(t)$ decreases (circle linear, exponential, or both)
- What causes the decrease in $\omega(t)$ (circle viscous, Coulomb, or both)
- Numerical values for τ_c, and either t_{stop} or t_{settling} (in seconds).
- Based on your values of τ_c, t_{stop}, and t_{settling}, find exact values for b (n∗m∗sec) and T_f (n∗m) for motors A and B (use I = 1 kg∗m^2).
- The point of this lab is to be able to determine numerical values for b and T_f from experimental data (***system identification***). You have run several simulations to correlate the effect of b and T_f on system response. In addition, you determined b and T_f for Motor A and Motor B. However, neither Motor A or B has both viscous and Coulomb friction. You now do a system identification on a more realistic motor having both viscous and Coulomb friction.

  Use your values of τ_c, t_{stop}, and t_{settling}, find approximate values for b and T_f for motor C.
  Note: Homework 2.13 analyzes the problem of finding b and T_f for motor C.

Motor A	Motor B	Motor C
linear/exponential	**linear/exponential**	**linear/exponential**
viscous/Coulomb	**viscous/Coulomb**	**viscous/Coulomb**
τ_c =	τ_c =	τ_c =
t_{stop} =	t_{stop} =	t_{stop} =
t_{settling} =	t_{settling} =	t_{settling} =
b =	b =	$b \approx$
T_f =	T_f =	$T_f \approx$