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

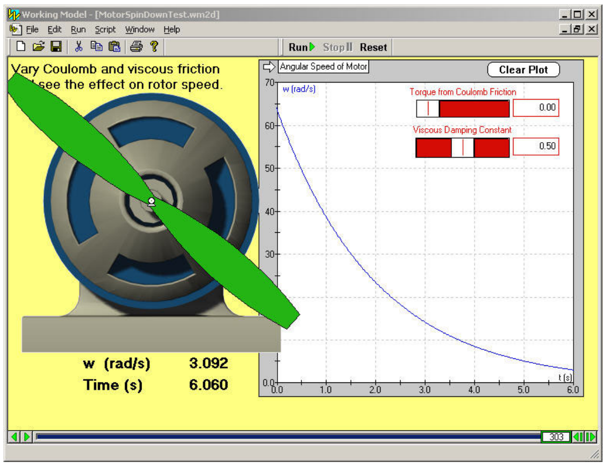
The objective of this laboratory is to gain physical insights into 1^{st}-order, linear, ODEs and to recognize how motor angular speed ω is influenced by:

- 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:

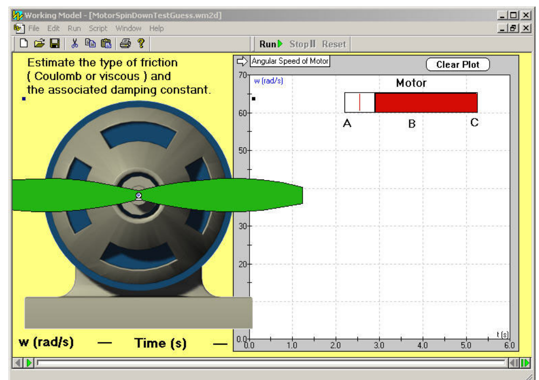
- How $\omega(t)$ decreases (circle linear, exponential, both, or neither)
- τ_c, the time required for the motor's speed to decrease to $e^{-1} \approx 0.37$ of its initial speed
- t_{stop}, the time it takes for the motor to stop spinning
- t_{settling}, the time required for $\omega(t)$ to settle 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 $t \geq t_{\text{settling}}$, $|\omega(t) - \omega_{\text{ss}}| \leq 0.01 * |\omega_{\text{ss}} - \omega(0)|$.
  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 =	$T_f \approx$