University of British Columbia
Department of Electrical & Computer Engineering
MECH 464/563 EECE589 (Winter 2020): Introduction to Robotics
Homework Assignment #1, due Monday January 18^{th}.

Read Introduction to Robotics notes, Chapter 0 and Chapter 1.
If you need a matrix refresher, read matrix backgrounder "A primer on matrices" by Stephen Boyd (uploaded to Canvas).
Browse Corke Ch. 2 and set up the Robotics Toolbox and try some of the Matlab examples he provides on p. 61.
Solve, but do not hand in, Exercises 1,2 and 3.
Solve, and hand in, Exercises 4, 5, and 6.

Exercise # 1:
(a) Find, by hand, the eigenvalues and eigenvectors of A as well as e^{At} for

$$A = \begin{bmatrix} 0 & -\omega & 0 \\ \omega & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} .$$

b) Show that for any square matrix A, A and e^{At} commute; $[e^{At}]^T = e^{A^T t}$; and $e^{A(t_1+t_2)} = e^{At_1}e^{At_2}$.
c) Show that if C is orthonormal, *i.e.* if $C^TC = CC^T = I$, $e^{CAC^T} = Ce^AC^T$.

Exercise # 2: Show that for any rotation matrix Q and any $s \in I\!R^3$, $(Qs)\times = Q(s\times)Q^T$ (same as showing that $(Qs) \times (Qt) = Q(s \times t)$, for all $s, t \in I\!R^3$).

Exercise # 3: Show that, if $s \in I\!R^3$, with $s^Ts = 1$, then $e^{\theta(s\times)} = I + \sin\theta(s\times) + (1 - \cos\theta)(s\times)^2$. Compute the eigenvalues and eigenvectors of A. Give an intuitive geometrical interpretation of A as an operator.

Exercise # 4: Find a general procedure to find the axis/angle representation of a rotation matrix Q. Program it in MATLAB and verify it for a few examples. Clearly describe your algorithm and hand in your Matlab code as well as the working examples.

Exercise # 5: Consider a three link 3-DOF planar manipulator, where $l_1 > l_2 > l_3$ and the rotation angles θ_1, θ_2 and θ_3 are unconstrained. Find the reachable and dextrous workspaces.

Exercise # 6: Find on the web videos or images of: - Baxter from Rethink Robotics
- Cat 215B excavator
- Asimo walking
Draw a schematic representation one of Baxter's arms, the CAT 215 arm and cab, and Asimo's right leg using our conventions for joints (dimensions not required).