ME:4140 Modern Robotics & Automation
Homework #2

Due: see ICON

Make sure to upload any supporting documents, e.g., hand work, codes, sketches, etc.

Instructions (READ THESE FIRST!)

- To complete this homework, you can use an **Adobe** pdf reader or **Google Chrome** (after completing make sure to download with changes).
- Answer all questions by typing or selecting radio buttons in this document.
- Upload your completed document and any supporting documents, code, sketches, etc., to ICON.
- Round all values to 3 decimal places.

  Example #1: what is the value of Pi? Answer: 3.142
  Example #2: what is 100/3? Answer: 33.333

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1. In terms of the $\hat{x}_s$, $\hat{y}_s$, $\hat{z}_s$ coordinates of a fixed space frame $\{s\}$ (given as I_3), a frame $\{a\}$ has its $\hat{x}_a$-axis pointing in the direction $(0, 0, 1)$ and its $\hat{y}_a$-axis pointing in the direction $(-1, 0, 0)$, and a frame $\{b\}$ has its $\hat{x}_b$-axis pointing in the direction $(1, 0, 0)$ and its $\hat{y}_b$-axis pointing in the direction $(0, 0, -1)$. (25)

   Determine the following:

   (a) R_{sa}

0	-1	0
0	0	-1
1	0	0

   (b) R_{sb}

1	0	0
0	0	1
0	-1	0

   (c) R_{bs}

1	0	0
0	0	-1
0	1	0

   (d) R_{ab}

0	-1	0
-1	0	0
0	0	-1

   (e) Change the representation of the point $p_a = (3, 2, 1)$ to $\{s\}$ coordinates.

-2
-1
3

2. The orientation of frame $\{a\}$ has undergone a rotation $R = \text{Rot}(\hat{x}, \pi/4)\text{Rot}(\hat{z}, \pi/2)$ relative to the space frame $\{s\}$. (10)

   Determine the following:

   (a) R_{sa}

0	-1	0
0.707	0	-0.707
0.707	0	0.707

   (b) The orientation of $\{s\}$ relative to $\{a\}$, e.i., R_{as}

0	0.707	0.707
-1	0	0
0	-0.707	0.707

3. The orientation of frame $\{b\}$ has undergone a rotation relative to the space frame $\{s\}$ given by (10)

$$R = Rot(\hat{z}, 60^\circ)Rot(\hat{x}, 30^\circ)Rot(\hat{y}, 90^\circ).$$

   Determine the following:

   (a) R_{sb}

-0.433	-0.75	0.5
0.25	0.433	0.866
-0.866	0.5	0

   (b) R_{bs}

-0.433	0.25	-0.866
-0.75	0.433	0.5
0.5	0.866	0

4. Using your results from #2 and #3, determine the following: (10)

(a) R_{ab}

-0.436	0.66	0.612
0.433	0.75	-0.5
-0.789	0.047	-0.612

(b) R_{ba}

-0.436	0.433	-0.789
0.66	0.75	0.047
0.612	-0.5	-0.612