Intro to VR Fall 2019 Name: ______________________

Linear Algebra for VR Worksheet

1. What is $\|x\|$ when $x = \begin{bmatrix} 4 \\ -3 \end{bmatrix}$

2. $\begin{bmatrix} -1 \\ 2 \end{bmatrix} + \begin{bmatrix} -3 \\ -2 \end{bmatrix} =$

3. TRUE or FALSE: If x and y are perpendicular (orthogonal) then $x^T y = 0$.
Hint: what operation is equivalent to $x^T y$? What is the geometric definition of this operation?

4. $\begin{bmatrix} 1 & 2 & 3 \end{bmatrix} \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix} =$

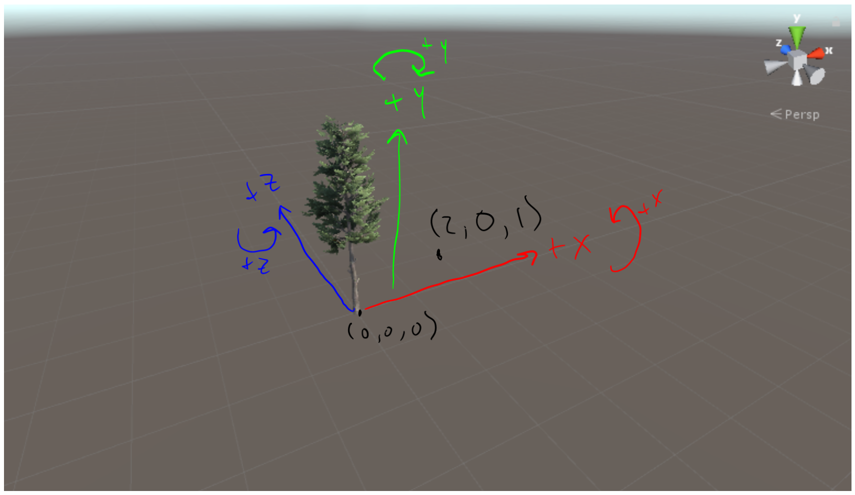
5. $\begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix} \begin{bmatrix} 1 & 2 & 3 \end{bmatrix} =$

6. $\begin{bmatrix} 0 & 2 \\ -2 & -5 \end{bmatrix} \begin{bmatrix} 6 & -6 \\ 3 & 0 \end{bmatrix} =$

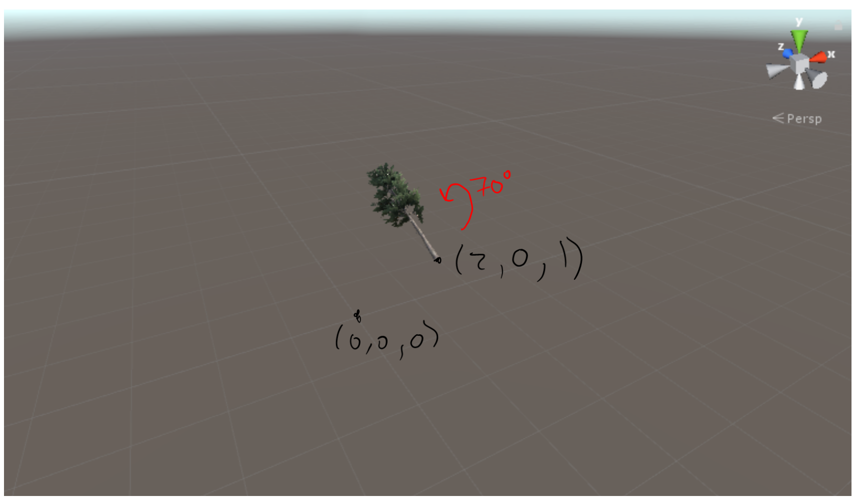
7. $\begin{bmatrix} 3 & 2 & 5 \\ 2 & 3 & 1 \end{bmatrix} \begin{bmatrix} 4 & 5 & -5 \\ 5 & -1 & 6 \end{bmatrix} =$

8. $\begin{bmatrix} -4 & -y \\ -2x & -4 \end{bmatrix} \begin{bmatrix} -4x & 0 \\ 2y & -5 \end{bmatrix} =$

9. Consider the following scene in Unity:



This scene shows a tree located at the origin, position (0, 0, 0) in world space, with no rotation. We would like to apply a translation and rotation transformation to move the tree such that it is located at position (2, 0, 1) in world space and is rotated 70°around the x axis, as in the following figure (remember that for rotation Unity uses a *left-handed* coordinate system):



To accomplish this transformation, we can first apply a *translation* and then apply a *rotation*. Fill in the translation and rotation matrices below that would accomplish this transformation:

$$\underset{\textit{Translation}}{\begin{bmatrix} \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \end{bmatrix}} \qquad \underset{\textit{Rotation}}{\begin{bmatrix} \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \\ \_\_ & \_\_ & \_\_ & \_\_ \end{bmatrix}}$$

10. What would the world space coordinates of the tree be if we reversed the order of multiplication in Problem 9 (i.e., if we first rotated the tree and then translated it)?

Hint: You can think about this either as an affine transformation or as a conversion to a new coordinate system. If we consider it a conversion to a new coordinate system, we first rotate our local coordinate system around the global $x - axis$ by $70°$. What does that do to our local x, y, and z axis? What does one unit of translation along each of these new basis vectors represent in terms of translation along our original basis vectors? If we translate from (0, 0, 0) to (2, 0, 1) in the new coordinate space, that's the same as saying move two units along our new local $x - axis$ and one unit along our new local z axis, so what is our new coordinate in world space?