Welcome again, and thank you for participating in our study. By taking part in this study, you will be helping us measure several visualization methods. Please note that we will test our methods, not you. You can leave for a break or quit anytime during the experiment.

The study includes five parts. (1) background survey (you just finished it); (2) a short pre-study training; (3) the experiment; (4) a post-study questionnaire; and (5) an interview for your comments.

Let us start the training.

# 1. Introduction

What we will study today is the efficiency of four encoding approaches for three-dimensional (3D) vector field analysis. The vector field is taken from quantum physics simulations. No worries if you don't know what that simulation is. We will introduce the datasets after showing you the visualization approaches.

In all visual encoding approaches, **a cylinder** is drawn to represent a vector. **The height of the cylinder is mapped to the magnitude or a component in the magnitude**. All cylinders drawn in this training document are laid horizontally. In the program, you will see cylinders oriented in many directions.

In this study, we will use four approaches for showing the *vector magnitude*.

( **Interaction**: You can rotate the data using the left-mouse button dragging, and zoom in and out using the right mouse button dragging. To reset your view to its original viewpoint, press the 'h'. )

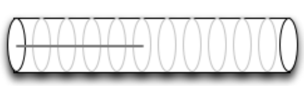
# 2. Four Visual Encoding Approaches

Now let's look at how ***the magnitude of a vector*** can be represented.

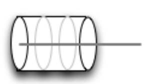
## 2.1. Linear or Direct Approach

The magnitude of the marker is linearly scaled to the **magnitude** of the vector.

Example 1: 11



Example 2: 2.8



Example 3: 570

Note: We cannot fit it in the paper. So we break it in the middle ONLY in this illustration. In the program, it is in its full length.

## 2.2 Logarithmic Approach

The length of the marker is scaled to the **log magnitude** of the vector. The base of 10 is used. Just to refresh your math:

$\log_{10}(10) = 1$; $\log_{10}(1000) = 3$; $\log_{10}(10000) = 4$;

$\log_{10} 1 = 0$; $\log_{10} 2 = 0.30$; $\log_{10} 3 = 0.48$; $\log_{10} 4 = 0.60$;

$\log_{10} 5 = 0.70$; $\log_{10} 6 = 0.78$; $\log_{10} 7 = 0.85$; $\log_{10} 8 = 0.90$; $\log_{10} 9 = 0.95$

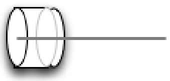
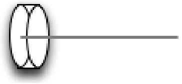
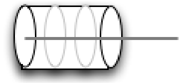
As you can see, log is not linear (the first approach shown in 2.1). So if the magnitude is 1000, our visualization will show the length of 3. If the magnitude is 2, visualization will show the length of 0.3.

Also notice that $\log_{10} 9 = \log_{10} 3^2 = 2 * \log_{10} 3$.

OK. I think you get the math path.

Now let's look at some visualization using this approach for the three numbers shown above.

Example 1 : $\log_{10}(11) = 1.04$ Example2: 2.8 : $\log_{10}(2.8) = 0.45$ Example3: 570 : $\log_{10}(570) = 2.76$

## 2.3 Split Vector Approach

Now let's look at the third approach.

The magnitude is drawn in two parts, as in the scientific notation: **the smaller cylinder (in diameter)** is mapped to the **digit term;** and the **larger cylinder (in diameter)** to the **exponential term.**

A vector magnitude can be written in Scientific Notation, e.g.,

$$A * 10^{B} \quad ,$$

where A, the digit term, is a real number with a range of [1, 10), and B, the exponential term, is an integer. In this study **the range of B is [0, 3] (inclusive).**

Here are some examples of data represented in scientific notations.

1000: $1.00 \times 10^{3}$ or 1.00e+3;

243.6: $2.44 \times 10^{2}$ or 2.44e+2

10: $1.00 \times 10^{1}$ or 1.00e+1

53: $5.30 \times 10^{2}$ or 5.30e+1

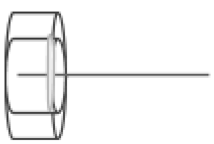
43897: $4.39 \times 10^{4}$ or 4.39e+4

2: $2.00 \times 10^{0}$ or 2.00e+0

Here are some example visualizations, using the same numerical values above.

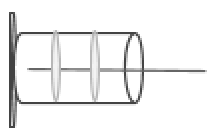
Example 1: 11

11 = 1.1e+1



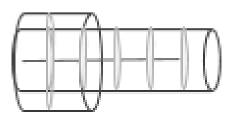
Example 2: 2.8

2.8 = 2.8e+0



Example 3: 570

570 = 5.7e+2



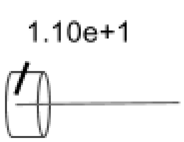
## 2.4 Text Approach

Simply, the last approach is just to write down the vector as it is.

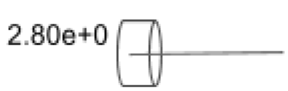
In visualization, since there is no length mapping, but the textural display, the length of the marker are **uniform** and each **magnitude** is shown as a **text label**.

Again, let's look at the same numerical values represented in the textural form. The length of these visual markers are all the same. A label are placed next to the starting point of each vector (e.g., Examples 2 and 3). When there is not enough space for the text label to be displayed at the beginning point of the vector, an explicit line will appear to point from the beginning point of the vector to its text label (as shown in Example 1).

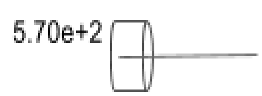
Example 1: 11




Example 2: 2.8




Example 3: 570



## 2.5 Graph Legend

A **graph legend** in general is a special object that help identify object in visualization. For example, geographic maps have legend; legend must used in nearly all scientific graphs.

In this work, we also draw a legend to provide a reference of vector magnitude. There is a dark grey line along the axis of the cylinder with a fixed length of 5 units.

In order to help you see the data, some light grey **circles** (or **band**) are drawn around the cylinders. The distance between two bands is 1 unit. This 1 unit length is also half size of the diameter of the cylinder.

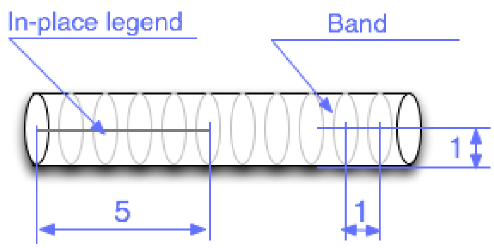



Figure 2. In-place legend and band

***Please stop here for the paper test to ensure we have provided enough instruction.***

## 3. Tasks

Now let's look at the tasks.

**Introduction**: There are **three task types**, under each of which includes eight sub-tasks. Half tasks use stereo whilst the other half use mono. Please wear the 3D glasses all the time in the testing phase.

Giving an answer is mandatory. All tasks ask you to input your confidence level, ranged from 1 to 7, with 1 being the least and 7 being the most confident for the most recent answer you provided.

### Task 1. What is the magnitude of point A?

Your task is to read the marked vector and type in the magnitude, given an encoding approach. The encoding approach is labeled on the bottom of the screen for each task.

To type in your answer, please click the "done" button to go to the next screen. Both numerical values or scientific notations are supported. You can edit your answer just like any other editing tools, i.e., use 'Backspace' on your keyboard to delete a symbol.

Please click "done" only if you know the answer, because you are not allowed to go back to see the data.

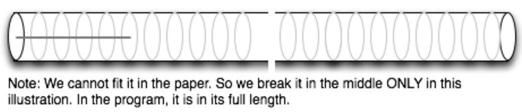
## Task 2 What is the ratio between the vector magnitudes at points A and B?

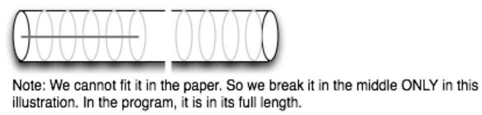
Your task is to calculate A/B in terms of magnitude.  Please note A is always larger than B.

We will look at two examples.

**Example 1: You will see one visualization at a time either in linear, log, split vector or text.**

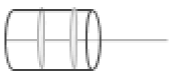
(1) Linear

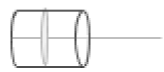
A : 


B : 

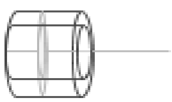

(2) Logarithm

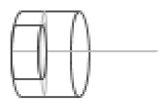
$\log_{10}(200) = 2.301$ $\log_{10}(100) = 2$

A : 

B: 

(3) Split Vector

A : 

B: 

(4) Text

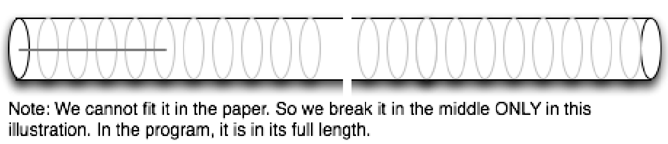
A: 

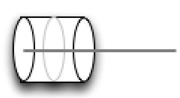

B: 


**As you may be able to tell, A = 200. B = 100. Thus, your answer is 2.**

**Example 2: You will see one visualization at a time either in linear, log, split vector or text.**

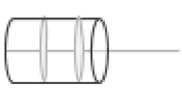
(1) Linear

A : 


B : 

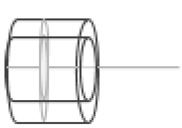
(2) Logarithm

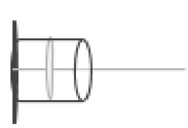
$\log_{10}(200) = 2.301$ $\log_{10}(2) = 0.3$

A : 

B: 

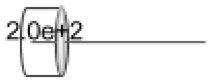
(3) Split Vector

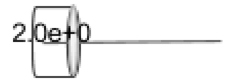
A : 

B: 

Please note that cylinders outside are mapped to power.

(4) Text

A: 


B: 


By comparing the two vectors, you may tell **A = 200. B = 2, so** the answer should be 100.

## Task 3. Which magnitude is larger, point A or point B?

Your task is to find whether or not there is a difference between A and B. If yes, which one is larger. There are three possible answers: “A”, “B” and “Same”. You are allowed to change your answer by selecting a different answer, before you go to the next screen.

Examples: Please refer to the training program.

This is the end of training.

Please do the tasks as fast and as accurate as you can. **Accuracy is more important than speed.**

If you need to take a break, please answer the current question, and then click the “Pause” button on the screen, and click “Resume” when you get back.

Are you ready to start the formal testing?