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Some applications of logarithms in real life

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ABSTRACT
In this paper, we restate some applications of logarithms in Richter scale, pH scale and sound intensity level (Decibel scale).
Keywords: *application of logarithms in real life, pH scale, sound intensity level, Richter scale*

1 Introduction

"Learning Math for what?" or "Is Math applicable in real life?" - These are issues that Vietnamese students and parents are very concerned about in recent years. Besides the view that learning Math is necessary, there are also many people who have opposite opinions. The proof is that recently, universities have increasingly reduced the duration of math courses, even eliminated them altogether.

The purpose of this article is to give some examples of applying Math to real life. It helps math teachers, especially high school teachers, have more examples to create excitement for learners. At the same time, it can help students see seemingly simple but very useful applications of math in real life.

2 Preliminaries and Main results

2.1 Logarithmic summary

Definition 2.1. (ref. [3]) Given two positive real numbers a, b such that $a \neq 1$. A real number n that satisfies $a^n = b$ is called the logarithm of b to base a, and denoted as $\log_a b$. Thus, $n = \log_a b$ iff $a^n = b$

Example 2.2. (i) $\log_2 8 = 3$, since $2^3 = 8$;

(ii) $\log_{10} 100 = 2$, since $10^2 = 100$;

(iii) $\log_{10} 0,01 = -2$, since $10^{-2} = 0,01$.

Remark 2.3. Common logarithm: The common logarithm is the logarithm with base 10. $\log_{10} b$ is usually as $\log b$ or $\lg b$.

2.2 pH scale

2.2.1 Acidic medium, basic medium and neutral medium (ref. [2])

Neutral medium is one in which the hydrogen ion H^+ and the hydroxyl ion OH^- concentrations are equal, and each is equal to 10^{-7}(mol/l). Specifically,

$$[H^+] = [0H^-] = 10^{-7} \text{ (mol/l).}$$

Acidic medium is one in which the hydrogen ion H^+ concentrations is higher than the hydroxyl ion OH^- concentrations. Specifically,

$$[H^+] > 10^{-7} \text{ (mol/l).}$$

Basic medium is one in which the hydrogen ion H+ concentrations is less than the hydroxyl ion OH^- concentrations. Specifically,

$$[H^+] < 10^{-7} \text{ (mol/l).}$$

Determining whether the environment is acidic or alkaline is very important in practice. For example, plants and animals can only grow normally when living in an environment (soil, water) with a specific concentration of H^+ for each type; The rate of metal corrosion in water depends a lot on the acidity or alkalinity of the water that the metal is in contact with, thus affecting the durability of the material; If the human body loses alkalinity and turns acidic, the excess acid in the body can cause diseases such as cancer, diabetes, stomach and intestinal diseases, etc.

Example 2.4. (ref. [6]) The concentration of H^+ in some commonly used solutions is as follows:

Solutions	**Concentration of** H^+ (mol/l)
Vinegar	$0,001259$
Orange juice	$0,000316$
Pure water	$0,0000001$
Milk	$0,00000031623$
Sea water	$0,00000001$

2.2.2 Application of logarithms in pH scale

Experimentally, scientists found that commonly used solutions have very small concentrations of H^+. This makes it difficult to both read and take notes. However, if we take the common logarithm of the above numbers, then multiply by -1, the result will be more compact and nice.

Solutions	**Concentration of** H^+ (mol/l)	$\lg[\mathbf{H}^+]$	$-\log[\mathbf{H}^+]$
Vinegar	$0,001259$	$-2,9$	$2,9$
Orange juice	$0,000316$	$-3,5$	$3,5$
Pure water	$0,0000001$	-7	7
Milk	$0,00000031623$	$-6,5$	$6,5$
Sea water	$0,00000001$	-8	8

The value $-\lg[H^+]$ is called pH level of the solution. The pH of commonly used solutions ranges from 1 to 14. From there, we have the following pH scale:

$[H^+]$	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}
pH	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Increasingly acidic Neutral Increasingly akaline

2.3 Sound intensity level (Decibel scale)

2.3.1 Sound intensity level

Our ears can hear (without pain) sounds ranging in intensity from $0,000000000001\ (W/m^2)$ to $10\,(W/m^2)$. The value $I_0 = 0,000000000001\ (W/m^2)$ is called the standard sound intensity (minimum hearing threshold). The higher the sound intensity I, the louder the sound.

Example 2.5. (ref. [1])

Sound sources	**Sound intensity** (W/m^2)
The sound of falling leaves or the sound of whisper at 1m distance	$0,00000000001$
Soft music or house noises	$0,00000001$
Street noises	$0,0001$
Jet engine	10

2.3.2 Application of logarithms in Sound intensity level (Decibel scale)

The higher the sound intensity I, the louder the sound, but physicists have demonstrated that the perception of loudness (to the human ear) does not increase with the intensity of sound I but increases according to the value of the ratio of the sound intensity I to I_0. For example, when the sound intensity is increased by 10^2, 10^3,... times (compared to the minimum hearing threshold I_0), the perception of loudness increases by 2, 3, ... times.

Therefore, to establish a scale of loudness, the concept of sound intensity level is introduced. The level of standard sound intensity I_0 is taken as level 0. Sound with intensity $I = 10I_00$ is taken as level 1. Sound with intensity $I = 100I_0$ is taken as level 2 .... Thus,

Sound sources	$\mathbf{I/I_0}$	**Sound intensity level (B)**	$\mathbf{\log(I/I_0)}$
The sound of falling leaves or the sound of whisper at 1m distance	10	1	1
Soft music or house noises	10^4	4	4
Street noises	10^8	8	8
Jet engine	10^{13}	13	13

Notice that, if we take the common logarithm of the ratio I/I_0, the result will be exactly the levels that have been set. So the quantity $\log(I/I_0)$ is defined as the negative intensity level of I relative to I_0.

The unit of sound intensity is Ben (B). Ben is large, so in practice, people often use decibels (dB) and $10dB = 1B$. The formula for calculating the sound intensity level in dB will be

$$L(dB) = 10\log(I/I_0).$$

Our ears can hear (without pain) sounds ranging in intensity from $0(dB)$ to $130(dB)$.

2.4 Richter scale

2.4.1 Earthquake

Earthquakes happen every day on Earth. They can have vibrations as small as barely perceptible to enough to completely destroy cities. The direct effect of an earthquake is ground roll, which usually causes the most damage. These vibrations have a large amplitude, exceed the elastic limit of the soil or rock environment and cause cracking. The secondary effects of earthquakes are inciting landslides, avalanches, tsunamis.... Finally, fires due to the destruction of energy supply systems (electricity, gas).

To determine the magnitude (destructive force) of an earthquake, scientists use seismometers (instruments that detect motion in the earth) to record the amplitude of seismic waves. The smallest motion that can be detected will show up on the seismometer as a wave of amplitude A_0 (called reference amplitude). The scientists then calculate the ratio between the maximum amplitude A measured by the seismometer and the minimum amplitude A_0 recorded on the seismometer. The higher the ratio, the more destructive the earthquake will be.

Example 2.6. (ref. [5]) Intensities of some of the major earthquakes that have occurred:

Time and place of earthquakes	**The ratio of A to A_0 (A/A_0)**
Alaska – America, 1958	$10^6.\sqrt[10]{10^3}$
Sumatra, Indonesia, 1833	$10^8.\sqrt[10]{10^7}$
Japan, 2011	10^9
Valdivia – Chile, 1960	$10^9.\sqrt{10}$

2.4.2 Application of logarithms in Richter scale

Experimentally, scientists have found that the A/A_0 ratios are often very large, making it difficult to read and take notes. Therefore, similar to how to set up the scale of sound intensity, Charles Francis Richter proposed a scale to determine the destructive power of an earthquake. This scale will make it easier to visualize the severity of an earthquake and assess the damage.

Reference amplitude A_0 is taken as level 0. Seismic waves with amplitude $A = 10A_0$ are taken as level 1. Waves with amplitude $A = 100A_0$ are taken as level 2, etc. If we take the common logarithm of the ratio A/A_0 then we will get the result that the levels have been set.

Time and place of earthquakes	**The ratio of A to $\mathbf{A_0}$**	**Magnitude level**	**$\log(\mathbf{A}/\mathbf{A_0})$**
Alaska – America, 1958	$10^7.\sqrt[10]{10^3}$	$7,3$	$7,3$
Sumatra, Indonesia, 1833	$10^8.\sqrt[10]{10^7}$	$8,7$	$8,7$
Japan, 2011	10^9	9	9
Valdivia – Chile, 1960	$10^9.\sqrt{10}$	$9,5$	$9,5$

Thus, on the Richter scale, a magnitude 6 earthquake will cause tremors 10 times stronger than a magnitude 5 earthquake.

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