

## Exam 2 Studyguide:

### Math Review:

-**Exponents:** the # of times the base # is used as a factor

-ex:  $5^3 = 5 \times 5 \times 5$  where 5 is the **BASE** and 3 is the exponent

### Special Case of Exponents:

-**Exponent is 1:** anything raised to the first power is itself ( $9^1=9$ )

-**Exponent is 0:** anything raised to the 0 power is 1 ( $9^0=1$ )

-**Exponent is negative:** causes the base number to equal its reciprocal ( $5^{-2} = 1/5^2$  or  $1/25$ )

-**Exponent is a fraction:** take the nth root of the base number ( $5^{1/2} =$  square root of 5)

### Properties of exponents:

-**Multiplication:** with the same base you add the exponents

-ex:  $a^x \times a^y = a^{x+y}$

-ex:  $5^3 \times 5^2 = 5^5$

-**Division:** when 2 numbers have the same base, subtract the exponent of the divisor (bottom #) from the exponent of the dividend (top #)

-**Raising a power to a power:** multiply exponents

-ex:  $(5^2)^4 = 5^8$

-To add terms with exponents, the bases of the 2 addition parts must be alike:

-ex:  $6.0 \times 10^2 + 4.5 \times 10^4$

-must switch one of the exponent terms to be the same as the other

-you can switch  $4.5 \times 10^4$  to  $450 \times 10^2$  and then

$6.0 \times 10^2 + 450 \times 10^2 = 456 \times 10^2$

### Logarithms:

-Mathematical shorthand when working with exponents. Only positive #s have logs

-Inverse of exponents

-exponential form  $\rightarrow x = a^y$

-log form  $\rightarrow y = \log_a X$

-In the log form the question is: What power do I have to raise **a** to get **x**? Answer **Y**

-ex: What is  $\log_5 25 = ?$

-since  $5^2 = 25$  answer is 2

-**Log of a product:** the sum of the logs of the factors

- $\log_a (x \times y) = \log_a X + \log_a Y$

-**Log of the p<sup>th</sup> power:** is the production of p and the log of the #

-Ex:  $\log 10^2 = 2 \log 10 = 2 \times 1 = 2$

-**Log of a quotient:** is the log of the dividend minus log of the divisor

-Ex:  $\log_2 \frac{1}{2} = \log_2 1 - \log_2 2$

$= 0 - 1$

$= -1$

### The Decibel:

-A logarithmic, interval scale that represents the ratio of 2 quantities

-Used to convert a sound power or intensity or pressure into manageable units

because the intensity difference between just detectable sounds to loudest you can tolerate can be over  $10^{15}$  units

-By switching from ratio to interval scale via logarithms, we end up with a usable scale

-Remember:

$$\begin{aligned} \text{-Power} &= \text{Work (or energy)} / \text{time} \\ &= \text{Force} \times \text{distance} / \text{time} \end{aligned}$$

$$\begin{aligned} \text{-Intensity} &= \text{Sound power} / \text{area} \\ &= \text{Force} \times \text{distance} / t \times \text{cm}^2 \end{aligned}$$

-Or: Intensity = Pressure X Volume Velocity where Volume Velocity =  $P/Z$  where Z is impedance

$$\text{-So intensity is also: } P \times P/Z \text{ or } P^2/Z$$

-Sound pressure = Force / Area (dynes/cm<sup>2</sup>)

-Lets look at a ratio series:

-1/100, 1/10, 1, 10, 100, 1000 (all #s are whole # multiples of 10)

-Could also write the series as  $10^{-2}$ ,  $10^{-1}$ ,  $10^1$ ,  $10^2$ ,  $10^3$

-The exponents form an **interval series** representing a ration

-Thus,  $x=a^y$  corresponds to the equation of a log,  $y=\log_a X$  which can convert the ratio scale into a more manageable one...but the interval scale **stands for** the original

-The log in the interval scale is defined as the # of **BELS** representing that ratio:

-Formula: **B=logR** where B is the # of BELS and R is the ratio of sound intensities

-Since a BEL is too large of a unit to work with, the decibel (dB) is used

-A decibel is 1/10 of a bel so that there are 10 times as many decibels as there are bels:

$$\text{-Formula: } \text{dB} = 10 \log R$$

-Where R is the ratio of 2 intensities

-Although we can express any intensity relative to any other, in practice an intensity corresponding to the **just audible amount** of sound is used as a reference level

-The intensity is:  $10^{-16}$  watts/cm<sup>2</sup>

-Any intensity compared with reference (hear 50% of the time) to that level is expressed in a scale called **intensity level**

-**EXAMPLE:** What is the intensity of  $1 \times 10^{-16}$  w/cm<sup>2</sup>?

$$\text{-dB IL} = 10 \log I/I_0 \text{ where } I_0 = 10^{-16} \text{ w/cm}^2$$

$$\text{-so } 10 \log (1 \times 10^{-16} / 1 \times 10^{-16}) =$$

$$\text{-} 10 (\log_{10} 1) \text{ and } 10^0 = 1$$

$$\text{-} 10 \times 0 = 0 \text{ dB IL}$$

-So when you have 0 dB, you still have a sound that can be measured

### **dB SPL:**

-Because its easier to measure **pressure**, the decibel is usually expressed in terms of **SOUND PRESSURE LEVEL- SPL**

-Since intensity is proportional to pressure squared ( $I= P^2/Z$ ) then:

$$\text{-dB} = 10 \log (I/I_0) = 10 \log (P_i^2/P_o^2)$$

$$\text{-} = 10 \log (P_i/P_o)^2$$

$$\text{-} = 2 \times 10 \log (P_i/P_o)$$

$$\text{-} = 20 \log P_i/P_o$$

-The standard **reference** for SPL is: **.0002 dynes/cm<sup>2</sup>** and this represents the least detectable mount of sound

### **Doubling Sound Pressure:**

-? dB=  $20 \log 2 * .0002/.0002$

=  $20 \log 2$

=  $20(3.01)$

= 6.02 dB

-When you **double pressure, you add 6dB**

### **Halving Pressure:**

-? dB SPL=  $20 \log .0001/.0002$

=  $20 \log \frac{1}{2}$

=  $20 \log 2^{-1}$

=  $-20 \log 2$

=  $-20(3.01)$

= - 6.02 dB, so **subtract 6dB when you half the pressure**

### **Vowels:**

-Modeled by the **Source Filter Theory**

-Has 3 parts: **source** (larynx), **filter** (upper articulatory system and allows the change the shape), **lip radiation effect** (end of vocal tract and acts as a pressure boost)

-**Source:** larynx has a spectrum roll-off of -12 dB/octave

-Contributions from the respiratory system, but source spectrum directly due to laryngeal output

### **Fundamental Frequency:**

-Spacing of harmonics corresponds to the **fundamental frequency (Fo)** which is the lowest harmonic in a group

-For voice it corresponds to the # of glottal openings per second

-Amplitude of contour depends in part on laryngeal/respiratory force

### **Average Fo:**

-**Adult Males: 125 Hz**

-**Adult Females: 220 Hz**

-**Children: 300 Hz**

### **Filter:**

-The articulation/resonance mechanism from the upper vocal tract

-Changes in upper vocal tract shape affect which frequencies are resonated and which are attenuated (weakened)

### **Lip Radiation Effect:**

-Provides a +6 dB/octave boost to output mechanism

-Due to air particle vibration being pressurized as exits a narrow lip opening

-B/c of the + sign, most of effect is to upper frequencies

### **Output Spectrum:**

-Has an overall spectral difference tilt of -6 dB/octave

-Takes into account laryngeal source spectrum and lip radiation effect

-The spectral tilt will change depending on proximity of the resonances due to upper vocal tract shape and other factors