Logarithm Math and pK_a

Definitions:

log means $\log_{10}$, or "base 10 log"
ln (or natural log) means $\log_e$, or "base *e* log" where $e \sim 2.718\ldots$

For base 10 log,
$\log(10^x) = x$ and $10^{\log x} = x$ (e.g., $\log(2365) = 3.374$, so $10^{3.374} = 2365$)

Similarly, for base *e* log,
$\ln(e^x) = x$ and $e^{\ln x} = x$ (e.g., $e^{2.453} = 11.623$, so $\ln(11.623) = 2.453$)

In Chemistry,

$[H_3O^+] = [H^+]$ = hydronium ion (hydrogen ion) concentration in terms of molarity (M, or mol/L)

$pH = -\log[H_3O^+] = -\log[H^+]$ = negative log base 10 of $[H^+]$

If $[H^+] = 1.0 \times 10^{-3}$ M, then pH = 3.0 (and is a "unitless" number)

If pH = 6.4, then $[H^+] = 1.0 \times 10^{-6.4}$ M (a very small concentration)

K_a, the acidity constant, is defined as:

$K_a = \dfrac{[H^+][A^-]}{[HA]}$ and describes the dissociation for an acid HA shown below:

$$HA \underset{}{\overset{K_a}{\rightleftharpoons}} H^+ + A^-$$

$pK_a = -\log(K_a)$ and is a useful number to describe the acidity of any acid, especially weak ones.

Acetic acid (CH_3CO_2H) has a pK_a of 4.74 so the value of K_a is $10^{-4.74} = 1.82 \times 10^{-5}$ and is a weak acid.

Negative pK_a means a strong acid (e.g., H_2SO_4 has p$K_a = -3$)

Question 1: How much stronger an acid is trifluoroacetic acid (TFA), pK_a 0.23, compared to acetic acid (CH_3CO_2H), pK_a 4.74?

Answer:
The difference in the pK_a's shows the magnitude.
4.74 – 0.23 = 4.51 "orders of magnitude," so TFA is $10^{4.51}$ (or 32,400) times more acidic than HOAc

Question 2: Derive the Henderson-Hasselbach equation $pH = pK_a + \log [A^-]/[HA]$ from the definition of K_a.