Homework Assignment #8 - Due Mon. 4/08/13

1) You decide to attend a rock concert without earplugs. You sit where the sound power level is 109 dB. How long until you have permanent hearing loss?

   $109dB \rightarrow 1.875\text{min}$,

   per "Decibel Exposure Time Guidelines"

2) At the rock concert in (1), you decide to sit in the back where the sound power level is only 103 dB. How long until you have permanent hearing loss?

   $103dB \rightarrow 7.5\text{min}$,

   per "Decibel Exposure Time Guidelines"

3) A doubled clamped spring style accelerometer consists of a Si proof mass (500μm thick and 1mm by 1mm) and a suspension system (2 rectangular beams, one on one side and one on the other side of the PM, 100μm long, 10μm wide and 5μm thick). For a Young's modulus of 190GPA and a density of $2.3g/cm^3$, what is the sensitivity of the accelerometer?

   $S = m/K_s$: $m = \rho * v$: $K_s = \frac{N_{LEG}}{N_{ZIG}} \frac{E \times w \times t^3}{L^3}$

   $m = 2.3g/cm^3 \times \frac{(100^3)cm^3 \times kg}{1000g \times m^3} \times (500\mu m)(1mm)^2$

   $m = 1.15 \times 10^{-6} kg$

   $K_s = \frac{2}{1} \times \frac{190 \times 10^9 (10 \times 10^{-6})(5 \times 10^{-6})^3}{(100 \times 10^{-6})^3}$

   $K_s = 475N/m$

   $S = m/K_s = \frac{1.15 \times 10^{-6}}{475N/m}$

   $S = 2.42 \times 10^{-9} s^2$

4) For an accelerometer with a natural frequency of 1000Hz, what is the proof mass / frame relative displacement for a 10 G acceleration (1G = 9.8 m/s^2)?

   $d = a \times S$: $\omega_n = 2\pi 1000$: $a = 10 \times 9.8 m/s^2$

   $S = \frac{1}{\omega_n^2} = \frac{1}{(2\pi 1000)^2} = 25.33 \times 10^{-9} s^2$

   $d = a \times S = 10 \times 9.8 \times 25.33 \times 10^{-9}$

   $d = 2.48\mu m$

5) What is the natural frequency (in Hz) for an accelerometer where a 10 G acceleration (1G = $9.8m/s^2$) results in a proof mass / frame relative displacement of 10μm?

   $d = 10\mu m$: $a = 10 \times 9.8 m/s^2$

   $S = d/a = \frac{10\mu m}{10 * 9.8} = 102.04 \times 10^{-9} s^2$

   $S = (\omega_n^2)^{-1} \rightarrow \omega_n = \sqrt{1/S}$

   $\omega_n = \sqrt{1/(102.04 \times 10^{-9} s^2)} = 3.13 krad/s$

   $f_n = \omega_n/(2\pi) = 498Hz$

6) For a(t) = 2u(t), what is Vout(t)? (See figure below)

   $E(s) = A(s) - V_{out}(s)$: $V_{out}(s) = E(s)(1/s)$

   $V_{out} = (A(s) - V_{out}(s))(1/s) \rightarrow V_{out}(s) = \frac{A(s)}{s+1}$

   $A(s) = 2 * (1/s) \rightarrow V_{out}(s) = \frac{2}{s^2+s}$

   $V_{out}(s) = \frac{2}{s} - \frac{2}{s+1}$

   $V_{out}(t) = \mathcal{L}^{-1}[\frac{2}{s} - \frac{2}{s+1}]$

   $V_{out}(t) = 2(1) - 2(e^{-t}) = 2(1 - e^{-t})$