Homework Assignment #6 - Due Wed. 3/27/13

1) A parallel plate actuator (PPA) consists of two square electrodes, 500μm on a side, separated by 10μm, in a vacuum. What is the force produced if 100V DC is applied across the electrodes

$F = \frac{\varepsilon_0 \varepsilon_r A V^2}{2x^2}$

$F = \frac{8.854e{-}12{*}0{*}(500\mu m)^2{*}100^2}{2{*}(10\mu m)^2}$

$F = 110.6\mu N$

2) If a sinusoidal voltage with a 100V amplitude is applied to the PPA in (1), where the frequency of the voltage signal is much higher than the natural frequency of the mechanical system, what is the average force produced by the PPA?

$V^2(t) \approx {V_s}^2/2 = 100^2/2 = 5000VRMS$

$F = \frac{\varepsilon_0 \varepsilon_r A V^2}{2x^2}$

$F = \frac{8.854e{-}12{*}0{*}(500\mu m)^2{*}5000}{2{*}(10\mu m)^2}$

$F = 55.33\mu N$

3) For the PPA in (1), if the system spring constant is 50N/m, what is the pull-in voltage?

$V_p = \sqrt{\frac{8{*}k{*}{x_0}^3}{27{*}A{*}\varepsilon_r\varepsilon_0}}$

$V_p = \sqrt{\frac{8{*}50{*}10e{-}6^3}{27{*}(500e{-}6)^2{*}8.854e{-}12}}$

$V_p = 81.8V$

4) If the PPA in (1) is used with the spring in (3), what applied DC voltage will decrease the distance between the electrodes by 1μm.

$F = \frac{\varepsilon_0 \varepsilon_r A V^2}{2(x_0 - x(t))^2} = kx(t)$

$\frac{8.854e{-}12{*}0{*}(500\mu m)^2{*}V^2}{2{*}(10\mu m - 1\mu m)^2} = 50N/m * 1\mu m$

$V^2 = \frac{8.1e{-}15}{2.2135e{-}18} = 3.659e3$

$V = 60.49V$

5) An object is moving away from a 20KHz sound source at 10m/s. If the speed of sound in air is 331m/s, what is the frequency of the reflected sound wave?

$f_d = \frac{f_s}{1+\dot{x}/c}$

$f_d = \frac{20kHz}{1+10/331}$

$f_d = 19.41kHz$

6) If the object in (5) is moving toward the sound source, what is the frequency of the return sound wave?

$f_d = \frac{f_s}{1+\dot{x}/c}$

$f_d = \frac{20kHz}{1-10/331}$

$f_d = 20.62kHz$