PHYS 5061 Homework 2. Due Friday, March 1.

(1) I have a analog-to-digital converter that has 12 bits of resolution and accepts input voltages over the range of 0 to +5.0 volts (unipolar). Using such a device often requires some signal conditioning to be able to measure voltages over a different range and of both signs (bipolar).
(a) Design an op-amp based circuit that will allow signals falling anywhere in the -10 to +10 V range to be mapped into the 0 to 5 V range suitable for the ADC. You'll need to compress and shift the input signal, so that an original $V_{in} = -10\,\mathrm{V}$ is turned into 0 V at the ADC input and $V_{in} = +10\,\mathrm{V}$ is turned into +5.0 V at the ADC. Think about making a design that does not load the signal source - *i.e* does not draw a lot of current from the signal source (or has a high input impedance, if you like that kind of language.) (b) What ΔV in the original input signal does the least significant bit in the binary output of the ADC represent?

(2) Piezoelectric materials exhibit a stretch or contraction in response to an applied voltage. My scanning tunneling microscope uses a piezoelectric cylinder that converts a voltage into displacement, scanning a tip step-by-step over a surface with the displacement directly proportional to the change in voltage applied to the piezoelectric element: $\Delta x = \alpha \Delta V$. The voltage to the piezoelectric is generated by a computer via a digital-to-analog converter (DAC). The piezoelectric coefficient $\alpha = 8.0$ nanometers/volt; that is to say 1 volt applied to the piezoelectric element moves the tip 8 nm.
(a) If I use a 12-bit DAC followed by some high voltage op-amp circuitry to produce an analog voltage that can range from -100 to +100 V applied to the piezoelectric, what is the largest distance I can scan over?
(b) What is the smallest step size I can take? How does this compare to a typical interatomic distance in a solid?
(c) If I upgrade to a 16-bit DAC with the same range of output voltages ($\pm 100\,\mathrm{V}$), what is the smallest step I can now take?