1) In Greek, what does the word “piezo” mean? Briefly, what is a piezoelectric material? 
Briefly describe one engineering application that takes advantage of piezoelectric properties.
ANS: piezo in Greek: to press; pressure; to squeeze (http://wordinfo.info/)
The piezoelectric material is a material that when mechanically squeezed it will produce an 
electrical response (voltage or current). Conversely, when an electrical voltage is place across 
the material, it will mechanically deform. Ultrasonic transducer are one example, as are backup 
alarms on construction equipment.

2) What are carbon nanotubes and what are “Buckyballs”? What are their unique properties, 
and describe a potential application for each.
ANS: Both carbon nanotubes and Bucky-balls (aka Buckminsterfullerene) are allotropic forms 
of carbon – nanotubes are tubular and indefinite in length, Bucky-balls are spherical structured 
molecules (on nanometer scale). Being composed of carbon-carbon bonds, they are extremely 
strong and stable. Neither currently have significant commercial applications, although their 
unique properties are being explored. Bucky-balls have potential in photovoltaic applications. 
Numerous applications for nano-tubes are being explored including medical, structural and 
chemical. (REF: Wikipedia)

3) Sketch each of the following (be sure to identify the axes):
   a) (1 1 0)  b) (1 1 2)  c) (0 0 1)  d) (1 1 0)

4) Determine the Miller indices for the following planes (be sure to identify the axes):
   a) x y z
   b) x y z
   c) x y z
   d) x y z

   MILLER INDEX: (1 2 0)  (2 0 1)  (1 -1 2)  (1 1 1)
5) Determine the atomic radius of aluminum based on in-class measurements of a Charpy bar. Compare with experimentally determined value of 0.143nm. You may also use any of the following facts. Hint: be sure to use units -- they are our friends!
   a) Aluminum forms FCC crystal structure (APF = 0.74, coordination number = 12, \( a = 2(2)^{1/2}R \))
   b) geometry: \( V = (4/3)\pi r^3, \ A = \pi r^2, \ C = 2\pi \)

6) For the Charpy bar in the previous problem, what is the length of the bar in terms of number of atoms?

7) What plane has the highest atomic planar density and what is that density in:
   a) FCC (hint, it's the basal plane - the plane with the hexagonal structure).
   b) BCC

Remember: since unit cells represent the entire crystal, you need only consider 1 unit cell. But remember, corner atoms and face atoms are shared with adjoining unit cells.
Your answer should be expressed as a percentage of area occupied by “atomic circles.”

8) What is the direction with highest linear atomic density in:
   a) FCC -- and what is that linear density?
   b) BCC -- and what is that linear density?

Your answer should be expressed as a percentage of area occupied by “atomic length”. Hint, both have a direction with LD of 1 (100%).
Given: Chorpy bar  mass: 14.94g

Tx W x L",  10 mm x 10 mm x 54 mm
Aluminum (FCC, a/R = 0.74)

Determine atomic radii of aluminum
and compare w/ 0.143 nm as
the experimentally determined value

Assume: alloying elements have negligible effect
V molar volume is negligible.

S0l'n

Volume of bar: (10 mm)^2 64 mm = 5,440 mm^3

Densitiy: \( \frac{14.94 \text{ g}}{5.4 \text{ cm}^3} = 2.779/\text{cc} \)

(2.709/\text{cc is published})

How many atoms in the Chorpy bar?

Atom wt of Al: 26.98 g/mole

1 mole of Al = \( \frac{6.02 \times 10^{23} \text{ atoms}}{26.98 \text{ g}} \) mole Chorpy bar

= \( 3.33 \times 10^{23} \text{ atoms / Chorpy bar} \)
Volume of sphere: \( V = \frac{4}{3} \pi r^3 \)

Since \( \rho_{PF} = 0.74 \) the volume displaced by each atom is:

\[
\frac{1}{0.74} \left( \frac{4}{3} \pi r^3 \right)
\]

There are \( 3.33 \times 10^{23} \) atoms/cm\(^3\) that occupy 5.4 cc

\[
\frac{1}{0.74} \left( \frac{4}{3} \pi r^3 \right) \times 3.33 \times 10^{23} \frac{\text{atoms}}{\text{cm}^3} = 5.4 \text{ cm}^3
\]

\[
r^3 = 2.865 \times 10^{-22} \text{ cm}^3
\]

\[
r = 1.42 \times 10^{-9} \text{ cm}
\]

\[
r = 1.42 \times 10^{-11} \text{ m}
\]

\[
r = 0.142 \text{ mm}
\]

ANS

Composition:

\[
\frac{0.142}{0.14} = 0.1 \%	ext{ diff}
\]
How long is the chainy bar in terms of atoms?

Assume atoms are touching:

\[
\begin{array}{c}
\text{Length: } 5.4 \text{ cm} = 0.054 \text{ m} \\
\text{Length of atom: } 2R = 2(0.142 \text{ nm}) = 0.284 \text{ nm} \\
\text{# of atoms: } \frac{0.054 \text{ m}}{0.284 \times 10^{-9} \text{ m/atom}} = 190,000,000 \text{ atoms} \\
\end{array}
\]
What plane in FCC has highest PD?

Atoms touch along face diagonals of the \(\{111\}\) family of planes are the basal planes.

\[
\frac{60^\circ}{360^\circ} = \frac{1}{6}
\]

3 corner \(\frac{1}{6}\) each \(\frac{1}{2}\) atom
3 face \(\frac{1}{2}\) each \(1\frac{1}{2}\) atoms
2 atoms

Area of atoms in "triangle" = 2 atoms \(\pi r^2\)

Area of triangle = \(\frac{1}{2} b \cdot h\)

\[b = 4r\]
\[h = 2\sqrt{3}r\]

\[
\frac{1}{2} (4r)(2\sqrt{3}r) = 4\sqrt{3}r^2
\]

\[\text{ANS} \quad \text{PD} = \frac{\text{Area of atoms}}{\text{Total Area}} = \frac{2 \pi r^2}{4\sqrt{3}r^2} = 0.907\]
What plan has highest PD in BCC?

Atom touch along corner diagonals, (110) has highest PD

\[
\text{Area of plane} : (a\sqrt{2})(a) = a^2\sqrt{2}
\]

\[
= \left(\frac{4R}{\sqrt{3}}\right)^2\sqrt{2} = \frac{16\sqrt{2} R^2}{3}
\]

\[
\text{PD} = \frac{2\pi R^2}{\frac{16\sqrt{2}}{3} R^2} = 0.833 \quad (\text{less than FCC})
\]
What direction has highest linear density in FCC?
ANS: atoms touch along face diagonals, so any of the \(<110>\) family of directions:

\([110], [011], [10\bar{1}], \text{ and ''negatives'' such as } [\bar{1}10]\)

they are touching so \(LD = 1\)

In BCC? Touch along middle diagonal, so \(\langle 111\rangle\) including \([111]\).

ANS \(LD = 1\) (touching)