

Donald P. Shiley School of Engineering
EGR 221 Materials Science
Assignment 3, Fall 2015

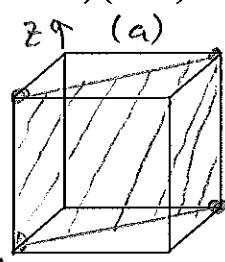
- 1) In Greek, what does the word “piezo” mean? Briefly, what is a piezoelectric material?
Briefly describe one engineering application that takes advantage of piezoelectric properties.
*ANS: piezo in Greek: to press; pressure; to squeeze (<http://wordinfo.info/>)
The piezoelectric material is a material that when mechanically squeezed it will produce an electrical response (voltage or current). Conversely, when an electrical voltage is placed 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.

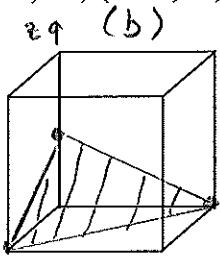
ANS: Both carbon nanotubes and Bucky-balls (aka Buckminsterfullerene) are allotropic forms of carbon – nanotubes are tubular and indefinite in length, Bucky-balls are spherical structured molecules (on nanometer scale). Being composed of carbon-carbon bonds, they are extremely strong and stable. Neither 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):

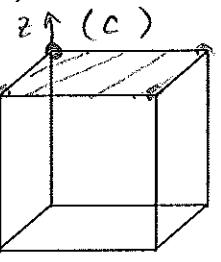
a) (1 1 0) b) (1 1 2) c) (0 0 1) d) (1 1 0)



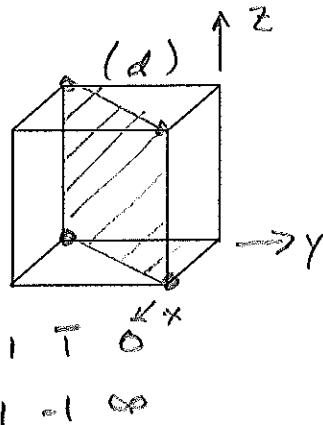
Index	1	1	0
Inverse	1	1	∞



1 1 2
1 1 1/2

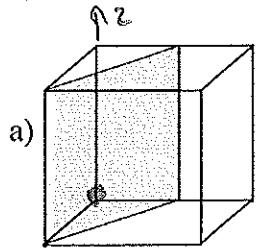


0 0 1
20 06 1

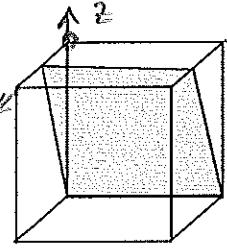


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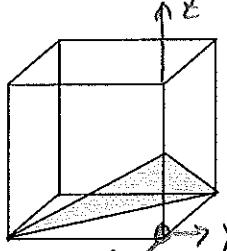
- 4) Determine the Miller indices for the following planes (be sure to identify the axes):



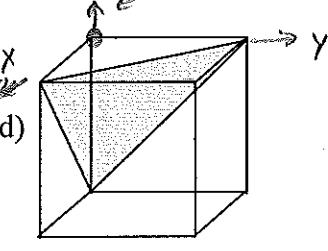
XIS INTERS.



x^{∞}	x	y	z	x	y	z
Axes Inters.	1	$\frac{1}{2}$	∞	$\frac{1}{2}$	∞	-1
Inverse	1	2	0	2	0	-1



$$\begin{array}{ccc} x & y & z \\ -1 & -1 & \frac{1}{2} \\ -1 & -1 & 2 \end{array}$$



x	y	z
1	1	-1
1	1	-1

SIMPLIFY

HILLER: INDEX: (1 2 0)

(205)

($\bar{1} \bar{1}^2$)

(117)

- 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!
- Aluminum forms FCC crystal structure ($APF = 0.74$, coordination number = 12, $a = 2(2)^{1/2}R$)
 - 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:
- FCC (hint, it's the basal plane - the plane with the hexagonal structure).
 - 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:
- FCC – and what is that linear density?
 - 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: Charpy bar mass: 14.94 g

TXWXL: 10mm x 10mm x 54mm

Aluminum (FCC, $\rho_F = 0.74$)

Determine atomic radii of aluminum

and compare w/ 0.143nm as

the experimentally determined value

Assume: alloying elements have negligible effect
Volume volume is negligible

Sol:

$$\text{Volume of bar: } (10\text{ mm})^2 \times 54\text{ mm} = 5400 \text{ mm}^3 \\ = 54 \text{ cm}^3$$

$$\text{Density: } \frac{14.94 \text{ g}}{5.4 \text{ cc}} = 2.719 \text{ /cc}$$

(2.709/cc is published)

How many atoms in the Charpy bar?

Atom wt of Al: 26.98 g/mole

1 mole of Al, 6.02×10^{23} atoms, 14.94g

26.98g mole Charpy bar

$= 3.33 \times 10^{23}$ atom / charpy bar

$$\text{Volume of sphere: } V = \frac{4}{3}\pi r^3$$

Since APP = 0.74 the volume displaced by each atom is:

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

There are 3.33×10^{23} atoms / cubic box
that occupy 5.4 cc

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

$$r^3 = 2.865 \times 10^{-21} \text{ cm}^3$$

$$r = 14.2 \times 10^{-9} \text{ cm}$$

$$r = 14.2 \times 10^{-11} \text{ m}$$

$$r = 0.142 \times 10^{-9} \text{ m}$$

$$\underline{r = 0.142 \text{ nm}}$$

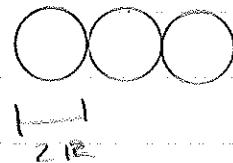
ANS

ANS

$$\text{Comparison: } \frac{0.142 - 0.143}{0.143} \approx 1\% \text{ diff}$$

How long is the copper bar in terms
of atoms?

Assume atoms are touching!



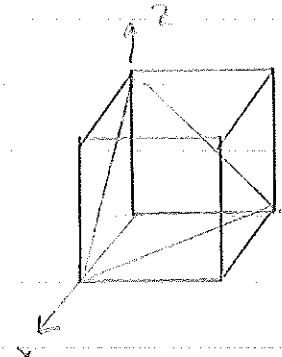
$$\text{Length} = 5.4\text{cm} = 0.054\text{m}$$

$$\text{Length of atom: } 2R = 2(0.142\text{nm}) = 0.284\text{nm}$$

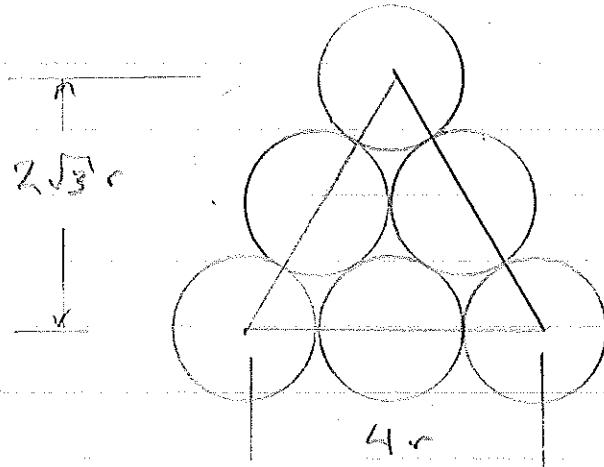
$$\# \text{ atoms: } \frac{0.054\text{m}}{0.284 \times 10^{-9}\text{m/atom}} = \underline{\underline{190,000,000 \text{ atoms}}} \\ 190 \times 10^6 \text{ atoms}$$

ANS

What plane in FCC has highest PD?



atoms touch along
face diagonals.
the $\{111\}$ family
of planes
are the basal planes.



$$\frac{60^\circ}{360^\circ} = \frac{1}{6}$$

$$3 \text{ corner} : \frac{1}{6} \text{ each} = \frac{1}{2} \text{ atom}$$

$$3 \text{ face} : \frac{1}{2} \text{ each} = \underline{\underline{1\frac{1}{2} \text{ atoms}}}$$

2 atoms

$$\text{Area of atoms in "triangle"} = 2 \text{ atoms} (\pi r^2)$$

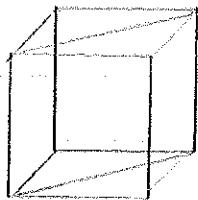
$$\text{Area of triangle} = \frac{1}{2} b \cdot h \quad b = 4r \\ h = 2\sqrt{3}r$$

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

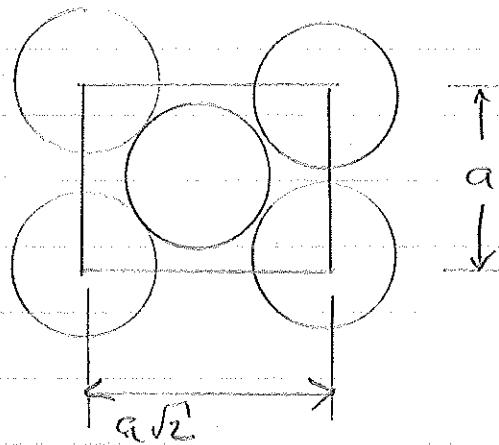
ANS

$$\text{PD} = \frac{\text{Area of atoms}}{\text{TOTAL AREA}} = \frac{2\pi r^2}{4\sqrt{3}r^2} = \underline{\underline{0.907}}$$

What plane has highest PD in BCC?



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



$$\text{for BCC } a = \frac{4R}{\sqrt{3}}$$

Area of atoms: $\frac{1}{4} \cdot 4 \text{ corners} \Rightarrow 1$
1 cell $\Rightarrow 1$

2 atoms in plane

$$A_{\text{atoms}} = 2 \text{ atoms} (\pi R^2)$$

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

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

$$\text{ANS} \quad \text{PD} = \frac{2\pi R^2}{\frac{16\sqrt{2}}{3}R^2} = \underline{\underline{0.833}} \quad (100\% \text{ than FCC})$$

What direction has highest linear density
in FCC?

ANS: along $\langle 110 \rangle$ face diagonals,
so any of the $\langle 110 \rangle$ family of
directions:

$[110]$ $[011]$ $[101]$ and "negatives"
such as $[1\bar{1}0]$

ANS They are touching so $\underline{LD=1}$

In BCC? touch along middle diagonal,
so $\langle 111 \rangle$ including $[111]$.

ANS $\underline{LD=1}$ (touching)