Name: _____ EID: _____

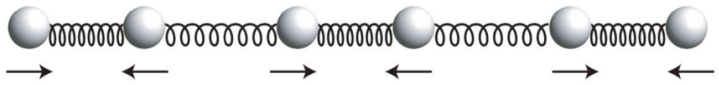
PHY 375S – Midterm 1

Prof. Edoardo Baldini

1. How many acoustic phonon branches exist in an infinite 1D chain with monoatomic primitive basis? D

A. 0 B. 1 C. 2 D. 3

2. What type of phonon mode is the one in the figure? C



A. LA at the BZ center B. TO at the BZ center
C. LA at the BZ boundary D. TO at the BZ boundary

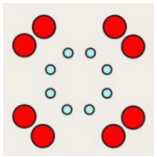
3. Which of these lattice systems can have face-centered cells? C

A. Monoclinic B. Tetragonal C. Orthorhombic D. Hexagonal E. Triclinic

4. A neutron with wavelength 3.5 Å scatters off a crystal inelastically. The wavelength of the outcoming neutron is 3.0 Å. What is the frequency of the phonon mode that was involved in the scattering process? B

A. 0.032 THz B. 0.58 THz C. 4.68 THz D. 10.54 THz

5. How many rotational axes do you see in the following crystal structure? E



A. 0 B. 1 C. 2 D. 3 E. 4

6. What is the packing fraction of the simple cubic lattice? B

A. 34% B. 52% C. 68% D. 74% E. 92%

7. Suppose a plane intercepts an axis along the $\mathbf{a}_1$ lattice vector, but does not have an intercept with the $\mathbf{a}_2$ and $\mathbf{a}_3$ axes. The Miller indices for such a plane are: A

A. (100) B. (001) C. (1∞∞) D. (∞∞1)

8. If two points in a crystal experience the same arrangement of atoms and can be connected by a translational vector $\mathbf{T} = u\mathbf{a} + v\mathbf{b} + w\mathbf{c}$, where (u, v, w) are arbitrary integers, the vectors (a, b, c) are said to be primitive. A

A. True B. False

9. A close-packed structure that is not a Bravais lattice is the: D

A. Simple cubic B. BCC C. FCC D. hcp

10. Which of these lattice systems can have base-centered cells? A

A. Monoclinic B. Tetragonal C. Cubic D. Hexagonal E. Triclinic

11. The reciprocal lattice of the FCC lattice is the: B

A. simple cubic lattice B. BCC lattice C. FCC lattice D. hcp lattice

12. How many lattice points are contained in each BCC unit cell? B

A. 1 B. 2 C. 4 D. 8 E. 12

13. What is the group velocity of an acoustic phonon mode in the vicinity of the Brillouin zone center? A

A. The sound velocity B. The light velocity C. 0

14. What is the typical energy scale of optical phonons at the Brillouin zone center? B

A. μeV B. meV C. eV

15. X-ray reflections are allowed in FCC crystals if the indices (v_1, v_2, v_3) in the reciprocal lattice are: C

A. any non-zero integer B. sum to an even integer C. all odd or all even

16. A solid has 1 atom in the primitive cell. The number of optical phonon branches is A

A. 0 B. 2 C. 3 D. 4 E. 6

17. Metallic Na has the BCC structure. What of the following reflections is present in its x-ray diffraction pattern? B

A. (100) B. (200) C. (001) D. (111) E. (221)

18. How many distinct Bravais lattices exist in 2D? B

A. 3 B. 5 C. 7 D. 9 E. 12 F. 14

19. Which 3D Bravais lattice has all angles of the primitive cell equal to 90 degrees and sides different from each other? A

A. Orthorhombic B. Triclinic C. Monoclinic D. Tetragonal E. Rhombohedral

20. Due to periodic boundary conditions, what values of $\boldsymbol{k}$ can be found within the first Brillouin zone of a 1D chain? (in the following expressions, a is the interatomic spacing, m is an integer, and N is the number of atoms in the 1D chain). A

A. $(2\pi m)/(aN)$ B. $(aN)/(2\pi m)$ C. $(2\pi N)/(am)$ D. $(am)/(2\pi N)$

21. What is the frequency of an x-ray beam with a photon energy of 1240 eV? E

A. 30 THz B. 300 THz C. 3 PHz D. 30 PHz E. 300 PHz

22. Which rotational symmetry is compatible with translational symmetry? A

A. $2\pi/3$ B. $2\pi/5$ C. $2\pi/7$

23. What is the coordination number of a lattice point in the FCC Bravais lattice? E

A. 1 B. 2 C. 6 D. 8 E. 12

24. Which phonon modes can absorb light? D

A. LA B. LO C. TA D. TO

25. What is the volume of an orthorhombic face-centered cell with dimensions a, b, and c? C

A. abc B. abc/2 C. abc/4 D. abc/8 E. abc/12

Problem 1

Consider a 2D hexagonal lattice in reciprocal space, sometimes also known as triangular lattice. Construct the first 2 Brillouin zones, tracing all Bragg planes. How do their areas compare?

Problem 2

Consider a one-dimensional linear chain of atoms with alternating masses M_1 and M_2, where the force constant between nearest neighbors is γ. Let the equilibrium distance between adjacent atoms be $a/2$. In the harmonic approximation, and by accounting only for interactions between nearest neighbors, derive the expression for the phonon dispersion relation $\omega(k)$. Additionally, calculate the energy gap between the acoustic and optical phonon branches at the Brillouin zone boundary.