PUBBLICAZIONE, AI SENSI DELLôART. 19 DEL D.LGS N. 33 DEL 14 MARZO 2013, MODIFICATO DALLôART. 18 DEL D.LGS N. 97 DEL 25 MAGGIO 2016

INTEGRATO DALLôART.1 C. 145 DELLA LEGGE 27 DICEMBRE 2019 N. 160

BANDO N. 367.354.

CONCORSO PUBBLICO PER TITOLI ED ESAMI PER LôASSUNZIONE CON CONTRATTO DI LAVORO A TEMPO PIENO E INDETERMINATO DI 1 UNITÀ DI PERSONALE PROFILO TECNOLOGO, III LIVELLO PROFESSIONALE PRESSO LôISTITUTO OFFICINA DEI MATERIALI (IOM) DEL CONSIGLIO NAZIONALE DELLE RICERCHE - TRIESTE

SETTORE TECNOLOGICO: SUPPORTO ALLA RICERCA

TRACCE DELLE PROVE D’ESAME ORALE ESTRATTE A SORTE

ALLEGATO 1

Serie 1

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri come configurare e come gestire un apparato sperimentale che deve operare in regime di ultra-alto vuoto.

Il candidato legga e traduca il seguente testo:
Charles Kittel “*Introduction to Solid State Physics*” Wiley International Edition Eighth Edition (2005)

CHAPTER 1: CRYSTAL STRUCTURE

PERIODIC ARRAYS OF ATOMS

The serious study of solid state physics began with the discovery of x-ray diffraction by crystals and the publication of a series of simple calculations of the properties of crystals and of electrons in crystals. Why crystalline solids rather than noncrystalline solids? The important electronic properties of solids are best expressed in crystals. Thus the properties of the most important semiconductors depend on the crystalline structure of the host, essentially because electrons have short wavelength components that respond dramatically to the regular periodic atomic order of the specimen. Noncrystalline materials, notably glasses, are important for optical propagation because light waves have a longer wavelength than electrons and see an average over the order, and not the less regular local order itself.

Serie 2

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva una tecnica per la caratterizzazione strutturale della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 3: CRYSTAL BINDING AND ELASTIC CONSTANTS

In this chapter we are concerned with the question: What holds a crystal together? The attractive electrostatic interaction between the negative charges of the electrons and the positive charges of the nuclei is entirely responsible for the cohesion of solids. Magnetic forces have only a weak effect on cohesion, and gravitational forces are negligible. Specialized terms categorize distinctive situations: exchange energy, van der Waals forces, and covalent bonds. The observed differences between the forms of condensed matter are caused in the final analysis by differences in the distribution of the outermost electrons and the ion cores (Fig. 1).

The cohesive energy of a crystal is defined as the energy that must be added to the crystal to separate its components into neutral free atoms at rest, at infinite separation, with the same electronic configuration. The term lattice energy is used in the discussion of ionic crystals and is defined as the energy that must be added to the crystal to separate its component ions into free ions at rest at infinite separation.

Serie 3

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva una tecnica per la caratterizzazione della composizione chimica e/o della struttura elettronica della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 2: WAVE DIFFRACTION AND THE RECIPROCAL LATTICE

DIFFRACTION OF WAVES BY CRYSTALS

The Bragg law

We study crystal structure through the diffraction of photons, neutrons, and electrons (Fig. 1). The diffraction depends on the crystal structure and on the wavelength. At optical wavelengths such as 5000 Å, the superposition of the waves scattered elastically by the individual atoms of a crystal results in ordinary optical refraction. When the wavelength of the radiation is comparable with or smaller than the lattice constant, we may find diffracted beams in directions quite different from the incident direction.

W. L. Bragg presented a simple explanation of the diffracted beams from a crystal. The Bragg derivation is simple but is convincing only because it reproduces the correct result. Suppose that the incident waves are reflected specularly from parallel planes of atoms in the crystal, with each plane reflecting only a very small fraction of the radiation, like a lightly silvered mirror. In specular (mirrorlike) reflection the angle of incidence is equal to the angle of reflection. The diffracted beams are found when the reflections from parallel planes of atoms interfere constructively, as in Fig. 2. We treat elastic scattering, in which the energy of the x-ray is not changed on reflection.

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Serie 6

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva le caratteristiche principali dei sistemi di pompaggio per ottenere basso, alto e ultra-alto vuoto.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 6: FREE ELECTRON FERMI GAS

In a theory which has given results like these, there must certainly be a great deal of truth.
H. A. Lorentz

We can understand many physical properties of metals, and not only of the simple metals, in terms of the free electron model. According to this model, the valence electrons of the constituent atoms become conduction electrons and move about freely through the volume of the metal. Even in metals for which the free electron model works best, the charge distribution of the conduction electrons reflects the strong electrostatic potential of the ion cores. The utility of the free electron model is greatest for properties that depend essentially on the kinetic properties of the conduction electrons. The interaction of the conduction electrons with the ions of the lattice is treated in the next chapter.

The simplest metals are the alkali metals—lithium, sodium, potassium, cesium, and rubidium. In a free atom of sodium the valence electron is in a 3*s* state; in the metal this electron becomes a conduction electron in the 3*s* conduction band.

Serie 7

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva le caratteristiche tecniche dell'apparato sperimentale e le procedure da seguire in un esperimento di crescita di materiali.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 7: ENERGY BANDS

The free electron model of metals gives us good insight into the heat capacity, thermal conductivity, electrical conductivity, magnetic susceptibility, and electrodynamics of metals. But the model fails to help us with other large questions: the distinction between metals, semimetals, semiconductors, and insulators; the occurrence of positive values of the Hall coefficient; the relation of conduction electrons in the metal to the valence electrons of free atoms; and many transport properties, particularly magnetotransport. We need a less naïve theory, and fortunately it turns out that almost any simple attempt to improve upon the free electron model is enormously profitable.

The difference between a good conductor and a good insulator is striking. The electrical resistivity of a pure metal may be as low as 10^{-10} ohm-cm at a temperature of 1 K, apart from the possibility of superconductivity. The resistivity of a good insulator may be as high as 10^{22} ohm-cm. This range of 10^{32} may be the widest of any common physical property of solids.

Serie 9

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva le informazioni che possono essere ottenute utilizzando fasci di fotoni o di elettroni per lo studio di campioni solidi.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 9: FERMI SURFACES AND METALS

The Fermi surface is the surface of constant energy ϵ_F in **k** space. The Fermi surface separates the unfilled orbitals from the filled orbitals, at absolute zero. The electrical properties of the metal are determined by the volume and shape of the Fermi surface, because the current is due to changes in the occupancy of states near the Fermi surface.

The shape may be very intricate as viewed in the reduced zone scheme below and yet have a simple interpretation when reconstructed to lie near the surface of a sphere. We exhibit in Fig. 1 the free electron Fermi surfaces constructed for two metals that have the face-centered cubic crystal structure: copper, with one valence electron, and aluminum, with three. The free electron Fermi surfaces were developed from spheres of radius k_F determined by the valence electron concentration. The surface for copper is deformed by interaction with the lattice. How do we construct these surfaces from a sphere? The constructions require the reduced and also the periodic zone schemes.

Serie 10

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva i componenti di una camera sperimentale dedicata alla caratterizzazione di campioni solidi in ultra alto vuoto.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 10: SUPERCONDUCTIVITY

The electrical resistivity of many metals and alloys drops suddenly to zero when the specimen is cooled to a sufficiently low temperature, often a temperature in the liquid helium range. This phenomenon, called superconductivity, was observed first by Kamerlingh Onnes in Leiden in 1911, three years after he first liquified helium. At a critical temperature T_c the specimen undergoes a phase transition from a state of normal electrical resistivity to a superconducting state, Fig. 1.

Superconductivity is now very well understood. It is a field with many practical and theoretical aspects. The length of this chapter and the relevant appendices reflect the richness and subtleties of the field.

EXPERIMENTAL SURVEY

In the superconducting state the dc electrical resistivity is zero, or so close to zero that persistent electrical currents have been observed to flow without attenuation in superconducting rings for more than a year, until at last the experimentalist wearied of the experiment.

Serie 11

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva le infrastrutture necessarie per l'allestimento di un laboratorio dedicato alla caratterizzazione fine della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 11: DIAMAGNETISM AND PARAMAGNETISM

Magnetism is inseparable from quantum mechanics, for a strictly classical system in thermal equilibrium can display no magnetic moment, even in a magnetic field. The magnetic moment of a free atom has three principal sources: the spin with which electrons are endowed; their orbital angular momentum about the nucleus; and the change in the orbital moment induced by an applied magnetic field.

The first two effects give paramagnetic contributions to the magnetization, and the third gives a diamagnetic contribution. In the ground $1s$ state of the hydrogen atom the orbital moment is zero, and the magnetic moment is that of the electron spin along with a small induced diamagnetic moment. In the $1s^2$ state of helium the spin and orbital moments are both zero, and there is only an induced moment. Atoms with all filled electron shells have zero spin and zero orbital moment: finite moments are associated with unfilled shells.

Serie 12

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri i requisiti da implementare in un apparato sperimentale per poter caratterizzare in vuoto un campione solido in funzione della temperatura.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 12: FERROMAGNETISM AND ANTIFERROMAGNETISM

FERROMAGNETIC ORDER

A ferromagnet has a spontaneous magnetic moment—a magnetic moment even in zero applied magnetic field. The existence of a spontaneous moment suggests that electron spins and magnetic moments are arranged in a regular manner. The order need not be simple: all of the spin arrangements sketched in Fig. 1 except the simple antiferromagnet have a spontaneous magnetic moment, called the **saturation moment**.

Curie Point and the Exchange Integral

Consider a paramagnet with a concentration of N ions of spin S. Given an internal interaction tending to line up the magnetic moments parallel to each other, we shall have a ferromagnet. Let us postulate such an interaction and call it the **exchange field**.[1] The orienting effect of the exchange field is opposed by thermal agitation, and at elevated temperatures the spin order is destroyed.

We treat the exchange field as equivalent to a magnetic field $\mathbf{B}_E$. The magnitude of the exchange field may be as high as 10^7 gauss (10^3 tesla). We assume that $\mathbf{B}_E$ is proportional to the magnetization $\mathbf{M}$.

Serie 13

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato descriva la strumentazione da installare in un apparato sperimentale per la caratterizzazione chimica e/o elettronica e/o strutturale e/o morfologica della superficie di un campione solido.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 21: DISLOCATIONS

This chapter is concerned with the interpretation of the plastic mechanical properties of crystalline solids in terms of the theory of dislocations. Plastic properties are irreversible deformations; elastic properties are reversible. The ease with which pure single crystals deform plastically is striking. This intrinsic weakness of crystals is exhibited in various ways. Pure silver chloride melts at 455°C, yet at room temperature it has a cheeselike consistency and can be rolled into sheets. Pure aluminum crystals are elastic (follow Hooke's law) only to a strain of about 10^{-5}, after which they deform plastically.

Theoretical estimates of the strain at the elastic limit of perfect crystals may give values 10^3 or 10^4 higher than the lowest observed values, although a factor 10^2 is more usual. There are few exceptions to the rule that pure crystals are plastic and are not strong: crystals of germanium and silicon are not plastic at room temperature and fail or yield only by fracture. Glass at room temperature fails only by fracture, but it is not crystalline. The fracture of glass is caused by stress concentration at minute cracks.

Serie 14

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri le modalità di gestione, di utilizzo e di stoccaggio di sostanze pericolose in laboratori di caratterizzazione fine della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 15: OPTICAL PROCESSES AND EXCITONS

The dielectric function $\epsilon(\omega,\mathbf{K})$ was introduced in the preceding chapter to describe the response of a crystal to an electromagnetic field (Fig. 1). The dielectric function depends sensitively on the electronic band structure of a crystal, and studies of the dielectric function by optical spectroscopy are very useful in the determination of the overall band structure of a crystal. Indeed, optical spectroscopy has developed into the most important experimental tool for band structure determination.

In the infrared, visible, and ultraviolet spectral regions the wavevector of the radiation is very small compared with the shortest reciprocal lattice vector, and therefore it may usually be taken as zero. We are concerned then with the real ϵ' and imaginary ϵ'' parts of the dielectric function at zero wavevector; $\epsilon(\omega) = \epsilon'(\omega) + i\epsilon''(\omega)$, also written as $\epsilon_1(\omega) + i\epsilon_2(\omega)$.

Serie 15

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato elenchi le principali tecniche di indagine sperimentale della materia condensata che conosce e illustri quali sono le principali informazioni che se ne ricavano

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 17: SURFACE AND INTERFACE PHYSICS

Reconstruction and Relaxation

The **surface** of a crystalline solid in vacuum is generally defined as the few, approximately three, outermost atomic layers of the solid that differ significantly from the bulk. The surface may be entirely clean or it may have foreign atoms deposited on it or incorporated in it. The bulk of the crystal is called the **substrate**.

If the surface is clean the top layer may be either **reconstructed** or, sometimes, unreconstructed. In unreconstructed surfaces the atomic arrangement is in registry with that of the bulk except for an interlayer spacing change (called multilayer relaxation) at the top surface.

The shrinking of the interlayer distance between the first and second layer of atoms with respect to subsequent layers in the bulk is a rather dominant phenomenon. The surface may be thought of as an intermediate between a diatomic molecule and the bulk structure. Because the interatomic distances in

Serie 16

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Tra le tecniche di indagine sperimentale della materia alcune utilizzano elettroni per sondare la materia, altre fotoni. Si illustrino le differenze fondamentali che possono motivare l'utilizzo dell'una o dell'altra sonda.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 18: NANOSTRUCTURES

The previous chapter addressed solids with spatial confinement at the nanometer scale along one direction: surfaces, interfaces, and quantum wells. These systems were effectively two-dimensional, which we define as extended in two directions but of nanometer scale in the third. Only a small number of quantized states—often only one—are occupied in the confined direction. In this chapter we discuss solids confined in either two or three orthogonal directions, creating effectively one-dimensional (1D) or zero-dimensional (0D) **nanostructures**. Important 1D examples are carbon nanotubes, quantum wires, and conducting polymers. Examples of 0D systems include semiconductor nanocrystals, metal nanoparticles, and lithographically patterned quantum dots. Some examples are shown in Figs. 1 to 3. We will almost exclusively focus on nanostructures that are created from confined periodic solids. Nonperiodic nanostructures are of great interest in other fields, such as molecular assemblies in chemistry and organic macromolecules in biology.

Serie 17

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Una delle moderne frontiere della fisica sperimentale della materia è l'utilizzo di impulsi ultra brevi per la caratterizzazione dinamica della materia, sia sotto forma di impulsi laser sia prodotti da sorgenti Free Electron Laser. Il candidato illustri le sue conoscenze riguardo a questo argomento.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 19: NONCRYSTALLINE SOLIDS

The terms amorphous solid, noncrystalline solid, disordered solid, glass, or liquid have no precise structural meaning beyond the description that the structure is "not crystalline on any significant scale." The principal structural order present is imposed by the approximately constant separation of nearest-neighbor atoms or molecules. We exclude from the present discussion disordered crystalline alloys (Chapter 22) where different atoms randomly occupy the sites of a regular crystal lattice.

DIFFRACTION PATTERN

The x-ray or neutron diffraction pattern of an amorphous material such as a liquid or a glass consists of one or more broad diffuse rings, when viewed on the plane normal to the incident x-ray beam. The pattern is different from the diffraction pattern of powdered crystalline material which shows a large number of fairly sharp rings as in Fig. 2.17 of Chap. 2. The result tells us that a liquid does not have a unit of structure that repeats itself identically at periodic intervals in three dimensions.

Serie 18

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Negli esperimenti in cui si rivelano elettroni o fotoni sono necessari strumenti in grado di fornire informazioni sulla loro energia. Si illustri il funzionamento di almeno un dispositivo per la discriminazione dell'energia degli elettroni o dei fotoni.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 20: POINT DEFECTS

The common point imperfections in crystals are chemical impurities, vacant lattice sites, and extra atoms not in regular lattice positions. Linear imperfections are treated under dislocations, Chapter 21. The crystal surface is a planar imperfection, with electron, phonon, and magnon surface states.

Some important properties of crystals are controlled as much by imperfections as by the composition of the host crystal, which may act only as a solvent or matrix or vehicle for the imperfections. The conductivity of some semiconductors is due entirely to trace amounts of chemical impurities. The color and luminescence of many crystals arise from impurities or imperfections. Atomic diffusion may be accelerated enormously by impurities or imperfections. Mechanical and plastic properties are usually controlled by imperfections.

TRACCE DELLE PROVE DõESAME ORALE NON ESTRATTE

Serie 4

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri le caratteristiche di un programma di acquisizione dati in un esperimento di caratterizzazione della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel “*Introduction to Solid State Physics*” Wiley International Edition Eighth Edition (2005)

CHAPTER 4: PHONONS I. CRYSTAL VIBRATIONS

VIBRATIONS OF CRYSTALS WITH MONATOMIC BASIS

Consider the elastic vibrations of a crystal with one atom in the primitive cell. We want to find the frequency of an elastic wave in terms of the wavevector that describes the wave and in terms of the elastic constants.

The mathematical solution is simplest in the [100], [110], and [111] propagation directions in cubic crystals. These are the directions of the cube edge, face diagonal, and body diagonal. When a wave propagates along one of these directions, entire planes of atoms move in phase with displacements either parallel or perpendicular to the direction of the wavevector. We can describe with a single coordinate u_s the displacement of the plane s from its equilibrium position. The problem is now one dimensional. For each wavevector there are three modes as solutions for u_s, one of longitudinal polarization (Fig. 2) and two of transverse polarization (Fig. 3).

Serie 5

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri i principali aspetti inerenti alla sicurezza che regolano la gestione di un laboratorio di caratterizzazione della materia.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 7: ENERGY BANDS

When I started to think about it, I felt that the main problem was to explain how the electrons could sneak by all the ions in a metal. . . . By straight Fourier analysis I found to my delight that the wave differed from the plane wave of free electrons only by a periodic modulation.

F. Bloch

Every solid contains electrons. The important question for electrical conductivity is how the electrons respond to an applied electric field. We shall see that electrons in crystals are arranged in **energy bands** (Fig. 1) separated by regions in energy for which no wavelike electron orbitals exist. Such forbidden regions are called **energy gaps** or **band gaps**, and result from the interaction of the conduction electron waves with the ion cores of the crystal.

Serie 8

Il candidato illustri il proprio curriculum scientifico e professionale mettendo in evidenza le sue competenze con riferimento alla tematica concorsuale.

Il candidato illustri tra le tecniche di caratterizzazione di sua conoscenza quelle utili per lo studio della superficie e quelle utili per lo studio del volume di un campione solido.

Il candidato legga e traduca il seguente testo:
Charles Kittel "*Introduction to Solid State Physics*" Wiley International Edition Eighth Edition (2005)

CHAPTER 8: SEMICONDUCTOR CRYSTALS

Carrier concentrations representative of metals, semimetals, and semiconductors are shown in Fig. 1. Semiconductors are generally classified by their electrical resistivity at room temperature, with values in the range of 10^{-2} to 10^{9} ohm-cm, and strongly dependent on temperature. At absolute zero a pure, perfect crystal of most semiconductors will be an insulator, if we arbitrarily define an insulator as having a resistivity above 10^{14} ohm-cm.

Devices based on semiconductors include transistors, switches, diodes, photovoltaic cells, detectors, and thermistors. These may be used as single circuit elements or as components of integrated circuits. We discuss in this chapter the central physical features of the classical semiconductor crystals, particularly silicon, germanium, and gallium arsenide.

Some useful nomenclature: the semiconductor compounds of chemical formula *AB*, where *A* is a trivalent element and *B* is a pentavalent element, are called III-V (three-five) compounds. Examples are indium antimonide and