60161 - Low temperature physics

Guía docente para el curso 2013 - 2014

Curso: 1, Semestre: 0, Créditos: 8.0

Información básica

Profesores

- **Juan José Mazo Torres** juanjo@unizar.es

Recomendaciones para cursar esta asignatura

The course describes, through a historical perspective, the main phenomena and experimental methods associated with the region of low temperatures. Emphasis is made on the emergence of quantum effects in the properties of materials and their applications. It is recommended for students who have a previous background in Quantum Physics, Statistical Physics and Solid State Physics, although this previous knowledge is not essential. Other courses of the Master complementary to the present one are “Técnicas experimentales en Física” (first semester) and “Materiales funcionales”, “Physics of Materials in Big Installations” and “Nanoscience and Nanotechnology” (second semester).

Actividades y fechas clave de la asignatura

- First course date: In the date indicated by the Science Faculty Board
- Last course date: In the date indicated by the Science Faculty Board
- Theory and problems: Monday and tuesday from 11:00 to 13:00 in "Seminario de Tercer Ciclo de Física Aplicada"
- Lab classes. To be announced by the professor.

Inicio

Resultados de aprendizaje que definen la asignatura

El estudiante, para superar esta asignatura, deberá demostrar los siguientes resultados...

1:
The student is capable of describing the basics of some phenomena and material properties characteristics of the low temperature region ($T < 77$ K).

2:
The student is able to solve problems related with these phenomena.

3:
The student is able to design experimental set-ups to measure physical properties (electrical and magnetic) at low temperatures.

Introducción

Breve presentación de la asignatura

The last one or two decades have witnessed a renewed interest in physical phenomena associated with the quantum nature of matter and which occur almost exclusively in the region of low temperatures. These phenomena are also at the foundation of very promising technologies in diverse areas.

The course describes, through a historical perspective, the main phenomena and experimental methods associated with the region of low temperatures. Emphasis is made on the emergence of quantum effects in the properties of materials and their applications.

Contexto y competencias

Sentido, contexto, relevancia y objetivos generales de la asignatura

La asignatura y sus resultados previstos responden a los siguientes planteamientos y objetivos:

The course in Low Temperature Physics can be recommended to any student who is interested in learning about fascinating phenomena, such as superconductivity, superfluidity and Bose-Einstein condensation, or about the properties of cryogenic liquids, quantum nanomagnets and macroscopic quantum systems, all of which are associated with the region of low temperatures. The goal is to make him familiar with theoretical concepts and experimental techniques that are employed in rapidly developing areas of research at the forefront of modern physics and technology. At the end of the course, the student should be able to use and apply some of these techniques to real scientific and even practical problems of his interest.

Contexto y sentido de la asignatura en la titulación

Together with the courses on “Técnicas experimentales en Física” (first semester) and “Materiales funcionales”, “Physics of Materials in Big Installations” and “Nanoscience and Nanotechnology” (second semester), the present course forms a very complementary and profound introduction to the concepts, experimental tools and applications of the research in modern Condensed Matter Physics and new materials.

Al superar la asignatura, el estudiante será más competente para...

1:
The student will gain competence in understanding basic concepts and physical phenomena related with low temperatures.

2:
The student will gain competence in calculating the physical properties and response of materials and cryogenic liquids at low temperatures.

3:
The student will gain competence in the design of experimental set-ups appropriate for measuring the properties of materials at low temperatures, as well as with the interpretation, analysis and presentation of the results.

4:
The student will gain competence in the use of cryogenic liquids and of auxiliary experimental techniques, such as cryostats, vacuum systems, leak detectors, etc.

Importancia de los resultados de aprendizaje que se obtienen en la asignatura:

The last one or two decades have witnessed a renewed interest in physical phenomena associated with the quantum nature

of matter and which occur almost exclusively in the region of low temperatures. These phenomena are also at the foundation of very promising technologies in diverse areas that include information technology (quantum computation and communication), cryogenic sensors for several applications ranging from Medicine to Astronomy, energy efficient and green refrigeration techniques, etc. A profound knowledge of these phenomena and techniques will therefore enable the student to apply them to solve scientific or technological problems.

On the other hand, this course will also enable the student to develop his analytical skills, helping him in the process of making decisions on any question related to his scientific or professional activities. His education will then be completed in aspects that go beyond the purely academic ambit.

Evaluación

Actividades de evaluación

El estudiante deberá demostrar que ha alcanzado los resultados de aprendizaje previstos mediante las siguientes actividades de evaluacion

1:

Evaluation tests for students who are able to attend the course.

1. A continued evaluation will take into account the personal work of the students throughout the course. The students will receive a questionnaire for each of the different sections of the course. The evaluation (75% of the final mark) will reflect the quality of the solutions given to these questionnaires.
2. The course will also comprise two practical exercises at the laboratory. A fraction of the final mark (10%) will be based on the quality of the work done by the students during these exercises. A further 15% will reflect the analysis of the obtained results and their description in a written summary.

2:

Evaluation tests for students who are not able to attend the course on site or who fail to go through at the first attempt.

The course has been designed for students who are able to attend the lectures on site. However, there will also be an evaluation test for those students who are either unable to attend these lectures or who fail in their first evaluation. The test will consist of solving a questionnaire connected with the expected results of the course. The questionnaire will consist of the following two parts:

1. One part will contain 7 questions related with the main concepts discussed in the course. The student will be given three hours to solve this part. It will be evaluated from 0 to 10 and the result will count as 75 % of the final mark.
2. A practical exercise in which the student will be asked to describe the elements and configuration of an experimental set-up appropriate to measure a given material property at low temperatures. The student will then be asked to mount the set-up in the laboratory. Allocated time: three hours. It will be evaluated from 0 to 10 and the result will count as 25 % of the final mark.

Actividades y recursos

Presentación metodológica general

El proceso de aprendizaje que se ha diseñado para esta asignatura se basa en lo siguiente:

The results programmed for this course include achieving theoretical as well as practical expertises in the field of research of phenomena associated with the region of low temperatures. In order to get these results, we have programmed activities which improve the students active and continuous implication within the different topics. The course consists of two well separated training activities: theoretical lectures, including problem discussion and resolutions, and laboratory work, where

he will get acquainted with the experimental tools and phenomena.

Actividades de aprendizaje programadas (Se incluye programa)

El programa que se ofrece al estudiante para ayudarle a lograr los resultados previstos comprende las siguientes actividades...

1:

In the first part, the student will learn basic concepts about those phenomena and techniques that are associated with the region of low temperatures. This activity will be carried out by means of theoretical lectures describing the topics listed on the programme below. These lectures will be supported by practical lectures, with a direct participation of the students. These practical lectures will be devoted to discussing different aspects of the course, as well as to solving problems.

2:

The second activity will consist of the realization of two practical exercises at the laboratory, enabling the student to apply the concepts learnt in the theoretical lectures. Each of these practical sessions will last for four hours. The students will work under the guidance of the professor in charge. They will be asked to register the results of the experiments and then discuss these results and the conclusions emanating from them in a written summary.

Planificación y calendario

Calendario de sesiones presenciales y presentación de trabajos

I Introduction (coordinator F. Luis): 1T.

I.1. Primitive evolution of low temperature physics and methods. Hours 1. Prof.: F. Luis. Date: 2010-10-04

II Cryogenic methods (coordinator: A. Camón): 9T + 2 P

II.1. Properties of matter at low temperatures. Hours: 2. Prof.: A. Camón. Date: 2010-10-04/05

II.2. Thermal contact and thermal isolation. Hours: 1. Prof.: A. Camón. Date: 2010-10-05

II.3. Refrigeration techniques. Hours: 5. Prof.: A. Camón. Date: 2010-10-18/25

II.3.1. Cryoliquids

II.3.2. Helium-4 cryostats

II.3.3. Helium-3 cryostats

II.3.4. ^{3}He-^{4}He dilution refrigerator

II.3.5. Adiabatic demagnetization refrigeration

II.3.6. Cryo-coolers

II.4. Thermometry. Hours: 1. Prof.: A. Camón. Date: 2010-10-25

Problem evaluation. Description. Hours: 2. Prof.: A. Camón. Date: 2010-11-29

Laboratory

A.1. From room temperature to mK. Hall effect experiments. 4 hours. A. Camón

III Superconductivity (coordinator J. J. Mazo): 10T + 2 P

III.1 General notions and theoretical models. Hours: 4. Prof.: J. J. Mazo. Date: 2010-10-26 and 2010-11-02

III.2 Josephson effect and superconducting circuits based on Josephson junctions. Hours: 3. Prof.: J. J. Mazo. Date: 2010-11-08/09

III.3 Applications of superconductivity. Hours: 3. Prof.: A. Camón. Date: 2010-11-09/15

Problem evaluation. Description. Hours: 2. Prof.: J. J. Mazo. Date: 2010-12-14

Laboratory.

B.1. SQUID Practice. Hours: 3. Prof.: A. Camón. Date: 2010-11-09/15

IV Quantum gases and quantum liquids (coordinator F. Luis): 6T+ 1P

IV.1 Hydrogen and Helium as quantum fluids. Hours: 2. Prof.: F. Luis. Date: 2010-11-16

IV.2 Superfluidity of ^{4}He and ^{3}He. Hours: 2. Prof.: F. Luis. Date: 2010-11-22

IV.3 Bose-Einstein condensates with gases: theoretical basis and experimental realizations. Hours: 2. Prof.: F. Luis. Date: 2010-11-23

Problem evaluation. Description. Hours: 1. Prof.: F. Luis. Date: 2011-01-17

V Magnetism at very low temperatures (coordinator F. Luis): 4T + 1P

V.1. Micro-refrigeration techniques with superconducting and magnetic materials. Hours: 2. Prof.: M. Evangelisti. Date: 2010-11-30

V.2. Magnetism with weak couplings: RKKY and dipolar interactions Models and realizations. Hours: 1. Prof.: F. Luis. Date: 2010-12-13

V.3. Nuclear magnetism: nuclear magnetic moment, nuclear magnetic refrigeration, nuclear magnetic ordering (models and examples). Hours: 1. Prof.: F. Luis. Date: 2010-12-13

Problem evaluation. Description. Hours: 1. Prof.: F. Luis. Date: 2011-01-17

Laboratory

C.1. Adiabatic cooling experiments below 1 K with molecular nanomagnets. Hours: 4. Prof.: M. Evangelisti.

VI Quantum puzzles and quantum technologies (coordinator D. Zueco): 10T + 4P

VI.1. Decoherence and the quantum-to-classical transition. Hours: 8. Prof.: D. Zueco. Date: 2010-12-20 until 2011-01-11

VI.2. Quantum technologies: quantum metrology and quantum computation. Simulating physics with physics. 6 hours. Hours: 6. Prof.: D. Zueco. Date: 2011-01-18 until 2011-01-25

VII Quantum Phase Transitions. (coordinator F. Bartolomé): 4T

VII.1. Quantum phase transitions: models and examples. Hours: 4. Prof.: F. Luis. Date: 2011-01-31 and 2011-02-01

DEADLINES FOR PRESENTATION OF PROBLEMS

Chapter II (2011-11-29)

Chapter III (2011-12-14)

Chapter IV (2012-01-17)

Chapter V (2012-01-17)

Chapter VI (2012-01-25)

Bibliografía

Bibliografía básica recomendada

Referencias bibliográficas de la bibliografía recomendada