**Name of the module:** Magnetic Materials and Devices

**Number of module:** 365-1-4995

BGU Credits: 3.5

ECTS credits: 5

Academic year: 2012-2013

Semester: Fall

Hours of instruction: 3 lecture hours and 1 exercise class hour per week.

Location of instruction: will be defined.

Language of instruction: Hebrew

Cycle: first

Position: a mandatory module for 4th year undergraduate students, Electronic Materials program, Materials Engineering Department

Field of Education: Materials Engineering

Responsible department: Materials Engineering

General prerequisites: students should complete modules ‘Physics 3B’ (203.1.2421), ‘The Physics of Solid State’ (365.1.3841) and ‘Electrical Properties of Solids’ (365.1.3141).

Grading scale: the grading scale determined on a scale of 0 – 100 (0 would indicate failure and 100 complete success), passing grade is 56.

Course Description:

The course introduces students to magnetic materials focusing on the technological application of information storage, e.g. hard disk drives.

The course reviews the theoretical background necessary to understand the design considerations and practical manufacturing of information storage devices.

The first part of the course explains the motivation for the course in terms of the information storage industry and its place within the electronics industry. Then, a recap on the relation of electricity and magnetism is presented along with basic physical definitions required for characterizing magnetic materials.

The second part discusses quantum mechanical aspects of magnetic materials, in the form of Hund’s rules as well as molecular field theory of magnetic materials.

The third part of the course discusses magnetic properties of ferromagnetic metals focusing on the Slater-Pauling curve, and discussing the band structure of these materials as well as the rigid-band model.

The fourth part of the course discusses energy contributions in magnetic materials that can explain their micromagnetic structure. Understanding these energy terms then enables to discuss the formation of domain walls and the mechanism of magnetization reversal, in particular the Stoner-Wohlfarth theory. Experimental methods for imaging domains are presented.

The fifth part of the course discusses the magnetic structure in fine particles leading to the nanometer scale magnetic phenomenon of superparamagnetism.

The sixth part reviews soft and hard magnetic materials including applications.

The final section applies theoretical background to explain magnetic storage devices.

Aims of the module:

Students will be introduced into the field of magnetic materials with emphasis on the technological application of information storage devices.

Objectives of the module:

Students will learn fundamental physical concepts related to magnetic materials. Students will understand the energy terms that determine the micromagnetic structure of materials. The students will understand the design and production process of information storage devices based on magnetic materials, in particular hard disk drives, tape storage and magnetic tunnel junctions.

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Office hours:

Monday, from 10am to 12pm

Module evaluation: at the end of the semester the students will evaluate the module, in order to draw conclusions, and for the University's internal needs.

Confirmation: the syllabus was confirmed by the faculty academic advisory committee to be valid on 2012-2013.

Last update: 06.08.2012

Learning outcomes of the module: On successful completion of the course, the student should be able to:

1. Explain and quantify the origin of magnetic moments both from a classical approach (Ampere and Biot Savart) and quantum mechanical approach (Hund’s rules).
2. Explain the types of magnetic materials and differentiate between them based on experimental data.
3. Explain and calculate the relation between magnetization and temperature based on the molecular field theory for ferro-, ferri- and antiferro- magnetic materials as well as paramagnetic materials. Explain and quantify the phase transition temperature, Curie and Neel temperatures.
4. Explain and quantify the micromagnetic structure based on energy considerations. Quantify the micromagnetic structure using a finite-element calculation based on the Landau-Lifshitz-Gilbert equation.
5. Explain the phenomenon of superparamagnetism and its influence on information storage.
6. Familiarize with experimental methodologies for measuring the macro-magnetic properties and imaging the micromagnetic structure of materials.
7. Explain the components and function of the following information storage devices: hard disk drives, tape storage, magnetic tunnel junction.

Attendance regulation: Mandatory attendance in class and exercises (at least 80%).

Teaching arrangement and method of instruction: lectures and exercises.

Assessment:

1. Exercises (mandatory) 10%
2. Exam 90%

100%

Work and assignments:

Students are expected to review lecture notes and read relevant bibliography, including assigned papers, after each class.

Student will conduct home works related to the exercises in the class (mandatory to submit solutions).

Exam: at the end of semester (open questions).

Time required for individual work: in addition to attendance in class, the students are expected to do their assignment and individual work: at least 3 hours per week. In advance of the exam, the students are expected to prepare 20 hours.

Module Content\ schedule and outlines:

• Background on the information storage industry based on magnetic materials, comparison to competing technologies. Explanation of the motivation for the course (2 hours)

• Recap: relation between electricity and magnetism; Ampere and Bio-Savat law; definitions of magnetic induction field, magnetic field, magnetic moment, susceptibility, Zeeman energy, etc. (2 hours)

• Basic definitions and classification of materials: dia-, para-, ferro-, antiferro- and ferri- magnetism; (2 hours)

• Relation between quantum mechanics and magnetic moments of atoms ; Hund’s rules (3 hours)

• Molecular field theory of para-, ferro, ferri- and anti-ferromagnetism (5 hours)

• Ferrimagnetic spinel oxides: magnetic structure and superexchange (1 hour)

• Magnetic moments in ferromagnetic metals, Slater-Pauling curve, Band theory of ferromagnetic materials ; Rigid band model (2 hours)

• Macroscopic properties of magnetic materials: magnetization hysteresis curves; Measurement methods (3 hours)

• Energy terms contributing to magnetic properties: exchange, anisotropy (magnetostatic, magnetocrystalline, surface/interface, induced (5 hours)

• Magnetic domains and domain walls; Magnetization reversal (Stoner-Wohlfarth theory ( , Multi-domain states: wall motion and moment rotation, experimental methods for observing domains and domain walls (4 hours)

• Domains in small particles; Superparamagnetism (2 hours)

• Soft and hard magnetic materials – properties and applications (1 hour)

• Magnetic storage: Recording mechanisms – particulate, longitudinal and perpendicular media; Read/write heads; Magneto-optical storage; Future magnetic storage devices. (7 hours)

Required reading:

• ‘Modern Magnetic Materials: Principles and Applications’, O’Handley, R.C., New York, John Wiley & Sons (2000).

• ‘Introduction to Magnetic Materials’, Cullity, B. D. and Graham, C.D., New Jersey, John Wiley & Sons / IEEE Press (2nd Edition, 2009).

• ‘Introduction to Magnetism and Magnetic Materials’, Jiles D., Boca Raton, Chapman & Hall / CRC (2nd Edition , 1998)

Additional literature:

Additional literature will be referred to in the lectures and available to the students on the module's website (high-learn)/ library/ electronic documents available to BGU students.