**Name of the module:** Themodynamics 1

**Number of module: 365-1-2111**

BGU Credits: 4

ECTS credits: 6

Academic year: 2013- 2014

Semester: Fall

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

Location of instruction: room 302 bulding 28

Language of instruction: Hebrew

Cycle: First cycle

Position: a mandatory module for 2nd year undergraduate students in the Department of Materials Engineering to be taken on Fall semester

Field of Education: Materials Engineering

Responsible department: Materials Engineering

General prerequisites: students should complete modules mathematical analysis

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

Lecturer: Prof. Roni Shneck

Contact details: room 9, building 59

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Office hours: Tuesday, from 11 to 13AM.

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.

Course Description

A thorough course on the basics of thermodynamics: the first and second laws and their microscopic interpretation.

The course starts with the definitions of basic notions of ideal gas, system, work, heat, temperature, internal energy and heat capacity. The interpretation of pressure, temperature and internal energy by the kinetic theory of gases is introduced. The nature of work and heat as transfer forms of energy and as path dependent quantities are confronted with the path independence of the energy. The first law for closed systems is deduced. The law is applied to analyze simple processes: isothermal, adiabatic, isobaric, isochoric and cyclic processes. For isobaric processes the enthalpy is defined and shown to be related to the heat transfer at constant pressure. The conservation of enthalpy in isobaric chemical reactions (Hess law) is deduced and applied for thermochemical calculations. The zero of enthalpy is defined as pure stable elements at 298K.

The second law of thermodynamics is deduced in the classical Carnot-Kelvin-Clausius approach. Although conversion of energy from any form to another is always possible, natural processes are directional: heat is conducted only down the temperature gradient, the production of work never exceeds that in reversible processes (from mechanical analysis) and in cyclic processes the net production of work is limited. The limiting efficiency of Carnot cycle is derived and serves to deduce the thermodynamic definition of temperature and the existence of a new law of nature that defines the direction of natural processes. It is expressed by the statement that the entropy of the universe increases or remains constant in any natural process. The macroscopic approach to calculate entropy changes in several processes is thoroughly studied and used to illustrate the increase of the entropy in the universe in mechanical, thermal and chemical processes.

Finally the microscopic-statistical origin of the natural processes is studied. Every macro-state is a collection of a huge number of microstates, each having the same probability. The random sampling of the available thermal and spatial microstates allows to understand irreversible processes like heat transfer, performance of work, gas filling of the space and to understand the peculiarity of reversible processes. The equilibrium state is the limiting state of the irreversible processes since it is the most probable distribution. It links to the identification of entropy with the number of microstates. Consideration of two bodies in thermal equilibrium allowed the exact identification of the logarithm of the number of microstates with the entropy by Boltzmann. Boltzmann's definition is used to derive the entropy change during mixing of materials and to obtain the equilibrium Maxwell-Boltzmann, Bose-Einstein and Fermi Dirac equilibrium distributions. The application of the Bose-Einstein distribution to derive the heat capacity of solids as a fundamental achievement of the microscopic theory is illustrated.

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Confirmation: the syllabus was confirmed by the faculty academic advisory committee to be valid on 2013-2014.

Last update:

Objectives

1. Gain knowledge about the notions of thermodynamics: work, heat, temperature, heat capacity, internal energy and enthalpy.

2. Gain a thorough understanding of the first and second laws of thermodynamics and the microscopic-statistical interpretation of the entropy and the second law.

3. Knowledge to analyze mechanical, thermal and thermochemical processes and cycles and determine their efficiency.

4. Knowledge to estimate the degree of irreversibility in natural processes.

Aims

Develop a foundation of understanding of the basic notions and laws of thermodynamics and their microscopic interpretation. Develop knowledge to apply thermodynamics for general engineering processes.

Learning outcomes of the module:

On successful completion of the course the students should

1. Understand the generalized law of conservation of energy. Understanding the path dependence of heat and work and independence of path of state functions. Be familiar with the definitions of internal energy, enthalpy, heat capacity(at constant volume and in constant pressure), system and its interactions. Able to apply the first law to closed systems, simple processes and cycles.
2. Able to calculate enthalpy changes of materials with temperature, in particular during phase changes. Calculate heat of chemical reactions (Hess law) and its applications.
3. Analyze simple heat engines and refrigerators, calculation of heat and work balances and thermodynamic efficiency. Calculate entropy changes in reversible and in natural processes along equivalent reversible paths. Show that the entropy of the universe increases in natural processes. Determine the direction of natural processes by calculation of the entropy.
4. Understand the microscopic interpretation of the entropy and the second law. Definition of macrostates, microstates, distributions, most probable distribution, equilibrium distributions. Provide simple illustrations of the increase of the number of microstates in natural processes. Explain the microscopic difference between reversible and irreversible processes.

Attendance regulation: attendance and participation in class is recommended.

Teaching arrangement and method of instruction: The module consists of lectures and exercises.

Assessment:

1. Exam 65% (or 85% for the student who has lower grade in the quiz)
2. Quiz 20% (not mandatory)
3. Homeworks 15%

100%

Work and assignments: Student will conduct 6 home works related to the exercises in the class.

Quiz: midterm, open questions.

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 two hours per week, 10 hours before the quiz and 24 hours before exam.

Module Content\ schedule and outlines:

Lectures:

Introduction to materials processing 2h

Extractive metallurgy of metals 5h

Extraction of Mg and Al by electrolysis 4h

Introduction to casting technologies 2h

Advantageous and disadvantageous of various casting technologies 4h

Defects originated from casting process 4h

Introduction to powder metallurgy 2h

Fabrication of metal and ceramic powders 2h

Compaction and shaping of powders 2h

Compaction and shaping of powders 2h

Sintering of metal and ceramic powders 2h

Cold working processes. Advantageous and disadvantageous 4h

The effect of cold working on mechanical and physical properties of metals 2h

Post deformation heat treatment (recovery, recrystallization and grain growth) 4h

Multistage cold working 2h

Module Content / schedule and outlines

1. *The first law* Discussion and definition of force, work, temperature and heat their relations and properties 3h Introduction of the internal energy and the first law of thermodynamics 3h

Calculation of external work and heat 2h

Calculation of changes in the internal energy, the heat capacity at constant volume of different materials 2h

Simple processes: adiabatic, isothermal, refrigerating cycle, isochoric and isobaric processes 3h

Enthalpy and thermochemistry 4h

1. *The second law*

Introduction to the second law: definition of reversible process, the limiting properties of reversible processes 3h

Carnot cycle of ideal gas, limited efficiency of a heat engine 1h

The Clausius, the Kelvin and the Carnot statements of the second law and their equivalence 3h

Definition of the thermodynamic temperature, Clausius inequality, entropy and the quantitative statement of the second law 4h

Applications of the second law, calculation of entropy in reversible and irreversible processes 3h

1. *Microscopic interpretation*

Introduction to statistical thermodynamics: macrostates, microstates, most probable distribution 2h

The microscopic interpretation of natural processes: heat transfer and the Boltzmann definition of entropy and temperature, entropy of mixing 3h

Thermal and configurational entropy, discussion of the microscopic interpretation of reversible and irreversible processes 2h

Equilibrium distributions and heat capacity of solids 1h

Exercises:

The ideal gas, state functions

Calculation of heat, work and internal energy change in real and ideal gases

Application of the first law to analyze processes and cycles

Enthalpy and thermochemistry

Introduction to the second law- reversible and irreversible processes

Analysis of heat engines and refrigerators

Calculations of entropy changes in reversible and irreversible processes: thermal, mechanical and chemical irreversibilities

Simple calculations of number of microstates

Applications of Boltzmann definition of entropy

Examples of the microscopic interpretation of reversible and irreversible processes

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|  |  |  | [Zemansky, Mark Waldo, 1900-](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58344?func=service&doc_number=001449826&line_number=0010&service_type=TAG%22);) |
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|  |  |  | 7th ed., McGraw-Hill International |
|  |  |  | [New York : McGraw-Hill, 199](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58346?func=service&doc_number=001449826&line_number=0013&service_type=TAG%22);) |

Required reading:

1. E. Fermi, Thermodynamics, [New York : Dover Publications, [1956, C1937)](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-08572?func=service&doc_number=001057119&line_number=0011&service_type=TAG%22);) (QC 311.F47 1956)

2. .Dilip Kondepudi and Ilya Prigogine, Modern thermodynamics , C[hichester, England : Wiley, 2005.](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-53738?func=service&doc_number=001938875&line_number=0011&service_type=TAG%22);) (QC 311.K66 2005) or

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| 3. M.W. Zemansky and R.H. Dittman, [Heat and thermodynamics, [New York : McGraw-Hill, 1997](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58346?func=service&doc_number=001449826&line_number=0013&service_type=TAG%22);)](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58345?func=service&doc_number=001449826&line_number=0011&service_type=TAG%22);) (QC 254.Z45 1997) |
| 3. Lecture notes (in Hebrew): *(a) First law of thermodynamics. (b) Second law of thermodynamics*  *(c) Statistical interpretation of the second law*  Additional literature:  1 [Merle C. Potter, Craig W. Somerto](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-51846?func=service&doc_number=002014480&line_number=0011&service_type=TAG%22);) Schaum’s outline of thermodynamics for engineers,  N[ew York : McGraw-Hill, 2006.](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-51847?func=service&doc_number=002014480&line_number=0014&service_type=TAG%22);)( TJ 265.P682 2006)   |  |  |  |  | | --- | --- | --- | --- | | 2. H. B. Callen, T[hermodynamics and an introduction to Thermostatics ,  [New York : Wiley, c198](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-05597?func=service&doc_number=001010973&line_number=0012&service_type=TAG%22);)5 (QC 311.C25 1985) .](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-05596?func=service&doc_number=001010973&line_number=0010&service_type=TAG%22);) |  |  | [Potter, Craig W. Somerton.](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-51846?func=service&doc_number=002014480&line_number=0011&service_type=TAG%22);) | |  |  | [Zemansky, Mark Waldo, 1900-](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58344?func=service&doc_number=001449826&line_number=0010&service_type=TAG%22);) |
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|  |  |  | 7th ed., McGraw-Hill International |
|  |  |  | [New York : McGraw-Hill, 199](javascript:open_window(%22https://lib20.bgu.ac.il/F/PDXG3X8DEAKLFV2T8Q65AAD73LLJ2BSF2RGKLQ68NF5G6MPG1M-58346?func=service&doc_number=001449826&line_number=0013&service_type=TAG%22);) |

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