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LES10A020 Engineering Physics

LES10A020

Engineering Physics

by

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Learning Objectives

- After successfully completing the course, students are able to:
  - Summarize the basics of thermal physics, electricity and wave motion
  - Solve elementary problems related to these topics

- The course has no preliminary requirements

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Passing and Grading

- Alternative 1:
  - Home assignments (50%)
    - Weekly
  - Course examinations (50%)
    - Mid-term examination
    - Final examination
- Extra points available (?):
  - Khan Academy course points (+10%), when feasible

- Alternative 2:
  - Passing Examination (100%)
  - Available once at the beginning of the course
  - If you master the course contents, you pass.

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Core Contents of the Course

- Thermal physics: Physical basics of thermal physics, law of ideal gas, the first law of thermodynamics, phase changes, thermal expansion and heat transfer.
- Electricity and magnetism: Electrostatics (electric force, field and potential), capacitance, resistance, direct-current circuits, magnetism (magnetic force and field), electromagnetic induction, basics for alternating-current circuits.

Core Contents of the Course (cont.)

- Mechanical oscillations (harmonic, damped and forced oscillations), harmonic waves, mechanical and electromagnetic waves, interference, diffraction and polarization.
- SI-system.
- *Detailed contents for preparation of the Passing Examination will be available on course Moodle pages*

Course Support Resources

- Lectures (1 x weekly):
  - Lecture slides,
  - Video recordings of the course lectures,
- Chan Academy learning materials
  - Self learning and support material
- Exercise sessions (1 x weekly):
  - Live support for problem solving
  - Home assignments / Moodle online learning environment
  - Not during the first week

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Contact Teaching Times, Period 1

- **Lectures** (7)
  - Once a week, varying locations and times
  - On weeks 37, 39, and 41 at Lahti campus on Thursdays 10-12
  - Lappeenranta lectures on Wednesday 16-18
- **Exercises** (6)
  - Register at Moodle to the exercise groups that suits your timetable
  - Exercise times for a certain groups may vary weekly

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Contact Teaching Times, Period 2

- **Lectures** (7)
  - Once a week, varying locations and times
  - On weeks 46, 48, and 50 at Lahti campus on Thursdays 10-12
  - Lappeenranta lectures mostly on Thursdays 8-10
- **Exercises** (6)
  - Same groups apply as during Period 1
  - Exercise times for a certain groups may vary weekly

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On Examinations

- Passing Examination will be available online during the weeks 36-37 (details to be announced later)
- Mid-term examination during examination week 43 / online exam
  - Also available on exam rooms during weeks 42-44, if possible.
- Final examination during examination week 51 / online exam
  - Also available on exam rooms during weeks 50-02, if possible.

Staff Contact Info

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- Dr. Juha Ratava
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International System of Units / SI-Units

Introduction

- To measure different physical properties, we need some agreed standard way of measuring them
- That way our measurements can become commeasurable
- There are currently several measurement systems used globally:
  - Metric system
  - British Units

Basic Units to be Defined

- To be able to consistently measure and report physical quantities, a consistent system of seven basic units is needed
- This system includes defining constants related to these units
- All other quantities and units can be derived from the basic seven.

- Basic units to be defined:
  - Time
  - Length
  - Mass
  - Electrical current
  - Thermodynamic temperature
  - Amount of substance
  - Luminous intensity

Metric System = International System of Units (SI)

- SI system originates from 1960
- The figure shows the SI units and related constants
- More information and figure source:

https://en.wikipedia.org/wiki/International_System_of_Units

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Revisiting Elementary Concepts in Thermodynamics

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Thermodynamic System

- On fundamental level, any physical system is formed by a group of particles.
  - In most everyday cases those particles would be atoms.
  - When concerned with basic thermodynamics and forgetting quantum mechanics, we will be ok with just observing the atoms or molecules formed by atoms.
- Thermodynamic system is such a system that can be characterized by temperature T, pressure p, volume V, and the number of particles n.

Thermodynamic Systems Around Us?

- The thermodynamic system can be any kind of collection of molecules and atoms.
- Basically, any whole object on the classroom can be considered a thermodynamic system.
- While we can observe the systems on macroscopic level just by using our senses, more accurate research requires microscopic analysis

Types of Thermodynamic Systems

- **Isolated systems** are not in interaction with their environment
- **Closed systems** can exchange **energy** with their environment, but not matter.
- **Open systems** can exchange anything with their environment
- Examples?
  - Thermos bottle, closed can of soda, glass of milk

Heat and Temperature

- On microscopic level heat energy refers to the jiggling motion that is present in all molecular structures and atoms.
  - The more heat energy, the hotter the system, the more jiggling
  - Some details at https://youtu.be/LL54E5CzQ-A
- On Macroscopic level heat manifests as heat energy transfer from hot to cold
- Temperature T is actually a statistical quantity that is defined based on the average kinetic energy of particles

Extreme Temperatures

- So, what kind of limits does temperature have?
- There is no upper limit to temperature. The energy of particles can increase without limit
- There is a lower limit, however
  - When there is no heat movement of the particles, the system has reached the absolute zero temperature, $T_0 = -273.15℃ = 0K$
- In closed system, temperature differences balance out when enough time has passed
  - This is called thermal equilibrium

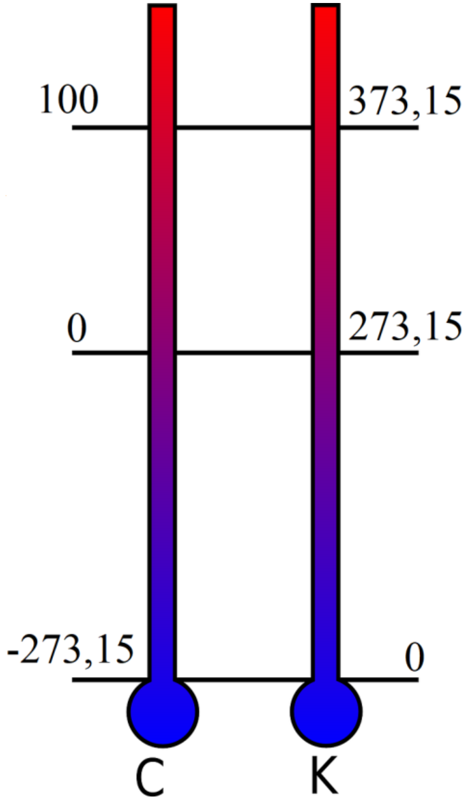

Figure source: https://fys.omaantahtiin.com/

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About Energy

Forms of Energy

- Energy is very fundamental concept to physics and understanding all our environment
- Fundamentally, energy manifests as the ability for a system to do work.
  - Above, the system refers to a thermodynamic system, as discussed above
- Energy manifests in several forms:
  - Chemical energy, radiated energy, kinetic energy, potential energy

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Internal Energy

- The internal energy U of a thermodynamic system is the energy contained within it
  - Includes the energy contained in the movement of particles in the system and their chemical bounds
  - Does not include the kinetic energy of the system as a whole
  - Does not include the potential energy of the system
- Considers the energy changes due to changes in internal state of the system
- Internal energy is kind of “hidden”
  - Changes in internal energy are measurable, but its absolute value is difficult to identify

Conservation of Energy

- Energy can be transformer from one form to another, but the total quantity remains constant
- So, if work is done to an object to increase its energy, the system that did the work lost the same amount of energy.
- Unit of energy is $[E] = 1\ \mathrm{J}$ (joule) $= \mathrm{Nm}$

Potential & Kinetic Energy

- Potential energy is always formed in interaction with an energy field
  - Gravitation field is a common example, but it also applies in electric and magnetic fields and nuclear forces
  - Potential energy in gravitational field: $E_p = mgh$
- Kinetic energy results from movement against some point of reference
  - For a particle with mass m and velocity v, its kinetic energy is $E_k = \frac{1}{2}mv^2$
- Potential energy and kinetic energy are the two forms of mechanical energy

Interaction and Force

Interaction Between Systems

- Energy transfer between two systems requires some form of interaction between them
  - The alternative forms of interactions are called basic interactions
- When considering on macroscopic level and in terms of pushing against something, a force is required
  - That force creates an opposing counter force.
  - This is shown form example in the way Earth’s gravity interacts with our bodies
- Force is an important physical concept we need in order to understand many physics phenomena

Pressure

- Pressure is a phenomenon describing a force effecting an area of a surface
- More accurately the amount of pressure p is the average perpendicular force F effecting a surface area A, so $p = F/A$, while $[p] = \mathrm{Pa} = N/m^2$
- In addition to Pascal, also bar (referring close to normal atmospheric pressure) is often used as a pressure unit
  - Here $1\ \mathrm{bar} = 10^5 \mathrm{Pa}$
- More accurately, the normal pressure (pressure at sea level) is $101325\ \mathrm{Pa} = 1.01325\ \mathrm{bar} = 1\ \mathrm{atm}$

Changing the Energy of a System

- Changes in the energy of a system can be seen either as **work** or **heat**.
- Work requires a force to be applied and transit takes place
- When heat quantity is brought into a system, it connects to the change of internal energy in the system.
- This change in energy is expressed as work $[W] = \mathrm{J}$ or heat quantity $[Q] = \mathrm{J}$

Work

- Work is the energy transferred to or from an object via application of force
- Using a constant force F, the work W done to an object can be calculated by considering the achieved displacement s of the object
- If the force is to the same direction as displacement, then the achieved work is $W = Fs$, where $[W] = \mathrm{J}$
- If the force is not constant, the total work can be calculated as a surface area in a force-displacement plane.
- Using vector notation, we can note $W = \bar{F} \cdot \bar{s}$

Heat Quantity

- Heat Quantity refers to the amount of heat transferred between two systems
- It can take place through any of the three forms of heat transfer
- For example, the heat quantity needed to heat up 1kg of water for $1℃$ requires a total of $Q = 4.19\text{kJ}$ heat

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Mechanisms of Heat Transfer

- Heat transfer includes a group of interactions that happens primarily on microscopical level
- **Conduction** refers to transfer of heat within a substance
  - In practice the faster jiggling of molecules push around the slowly moving, cooler ones
- **Convection** refers to transfer of material within a system and the transfer of heat with it
  - In practice the fast-jiggling molecules move to a new location with their heat energy

Heat Transfer as Radiation

- **Radiation** refers to transfer of heat as electromagnetic thermal radiation often abbreviated as "Infrared" or IR
  - In practice the collisions of fast-jiggling molecules excite electrons within their electron clouds which then release the energy into electromagnetic radiation that transfers the heat energy into a new location and new electron cloud
  - The wavelength λ_{IR} of infrared radiation is in the range of 0.7$\mu\mathrm{m}$−1.0 mm
  - The amount of radiation a surface sends depends on its temperature and the type of the surface (the kind of thermal excitations available on the surface)

Laws of Thermodynamics

Rule of Thumbs

- The laws of thermodynamics can be summarized with two simple rules of thumb:
  - The amount of energy is always conserved
  - The entropy is always increasing

First Rule of Thermodynamics

- The change of total energy in a system is a sum of the work and heat quantity it has received
  - $\Delta E_{kok} = W + Q$
- In thermodynamics the change typically happens in the internal energy of the system, resulting in
  - $\Delta U = W + Q$

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Power and Efficiency

- To fully understand the second law of thermodynamics, we need to understand about efficiency
- Power P describes the how much work W is done against time t:
  - $P = W/t$; $[P] = \mathrm{W} = \mathrm{J/s}$
- Efficiency defines what portion of the energy a machine takes is converted into desired form

$$\eta = \frac{E_{output}}{E_{input}} = \frac{P_{output}}{P_{input}} \quad (0 < \eta < 1)$$

- Efficiency has no unit, and it is often reported as percentile $[0\% < \eta < 100\%]$

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Second Law of Thermodynamics

- The second law defines the direction of natural processes
  - Natural process runs only in one sense, and is not reversible
  - Like heat flowing always from hotter to cooler system
- In another sense, thermodynamic system develops towards the more probable state and equilibrium
- This development of system is described with the term Entropy

Entropy

- Entropy can be considered as the degree of ordering within the system
  - The more order, the less entropy
  - Thus, natural processes have a tendency to increase disorder
- Entropy also connects to the thermodynamic equilibrium.
  - When long enough is waited, the system reaches its equilibrium state

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Entropy and Efficiency

- Entropy manifests also through the efficiency of physical systems
- The system always has efficiency $\eta \leq 1$
- Even unity efficiency is not a fully realistic, so better $\eta < 1$

Thank you for your attention!