

# Physics and Engineering (LTFY.01.007)



Location: Room A106

**Lecture Times:** Mon. 12.15 – 14.00 and Fr: Fri. 10.15 - 12.00

**Seminars:** Thur. 14.15 - 16.00, Room A102

#### **Textbook:**

D. Halliday, R. Resnick, J. Walker. Fundamentals of Physics. 5 edition (Wiley, 1997) available (up to 40 copies) in Physicum library at W. Ostwaldi Str. 1.

#### Web materials:

https://sisu.ut.ee/pae/

https://moodle.ut.ee/course/view.php?id=4083

http://www.lightandmatter.com/



### Upon completion of this course, the student should be able to:

- 1. Express the basic principles of the physical concept of the world (such as atomistic principle, energetic minimum, absolute speed, wave-particle dualism, uncertainty principle), and refer to their exertion;
- 2. Possess the knowledge considering the mathematical background and calculus necessary for the description of physical processes (e.g., graphical representations, differentiation and integration, application of complex numbers), and recognize the main attributes and occurrence conditions of main functions present in physics (e.g., linear, power, exponent, harmonic);
- 3. Solve physical problems related with the daily life: mechanics, kinematics, gravity, direct and alternating current, heat and thermodynamics; understand and recognize the reasonable order of magnitude the physical quantities related with these subjects (within the limits of example exercises available via the web support of the course.)
- 4. Use the vocabulary introduced at the lectures to explain the basic principles of some high-tech devices applying physical terminology in a correct way;

#### **Assessment methods**



- With four written test during semester the student can collect 70 % of total points of final examination. The first two tests accounts as a 15 % and the last two test as a 20 % of final examination, respectively. All tests need to be done at more than 50%!
- The rest 30 % can be collected with final examination where learning outcomes 2,3,5 will be tested.
- 20% of the exam is related to an engineering task that can be replaced with a referate on a topic related to the course materials.
- Referates can be submitted during the whole course and are assessed over e-mail communication.



# Introduction to Physics

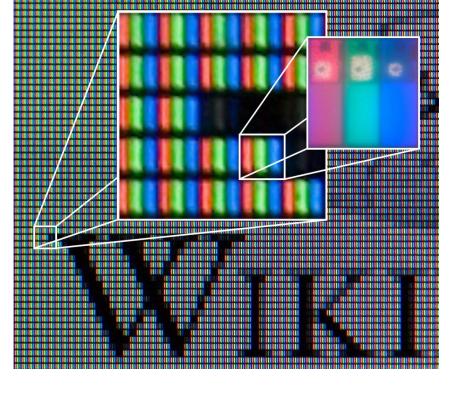
a shot overview of the upcoming topics

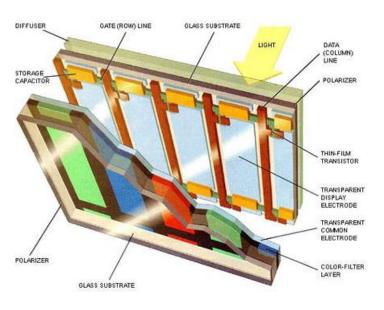
# Topics



- 1. Measurements and units (inc. SI units)
- 2. Fundamental principles of physics
- 3. Mechanics
- 4. Oscillations and waves
- 5. Electromagnetics
- 6. Optics and quantum mechanics
- 7. Thermodynamics and nuclear physics
- 8. Electronics









By understanding the "small" (microscale) we can predict the behaviour of the "big" (macroscale)!

Understanding = defining rules

Finite number of buildingbloks (electronic R,G,B pixels) create infinite number of complex outcomes (like your personal Facebook page)! Many fields of science/technology rely on the principles of physic (IT, electronics, biology, chemistry etc.).

#### Units and measurements

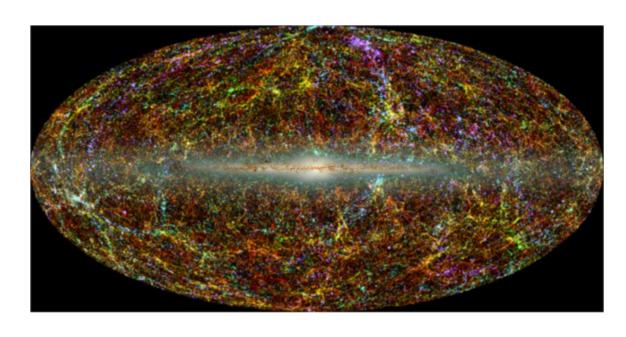
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#### Physics uses the biggest and the smallest numbers!



A minitor ~24 inch or 61 cm in diameter = 6.1x10<sup>-1</sup>m

How many kilometers light travels in a year?



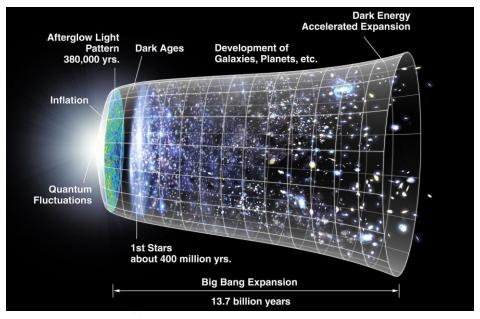
The universe

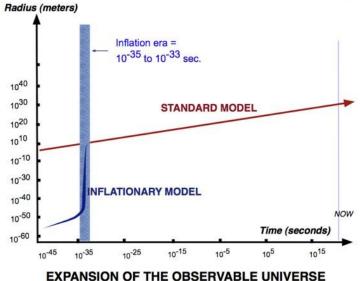
Today universe is ~90 billion light years in diameter = 8.8×10<sup>26</sup> m (880 000 000 000 000 000 000 km)

Speed of light is 300 000 000 m/s

#### Fundamentals of physics: It all started with a Big Bang

Beginning: 10<sup>-43</sup>s: At this point, the universe spans a region of only 10<sup>-35</sup> metres (1 Planck Length), and has a temperature of over 10<sup>32</sup>°C (the Planck Temperature).

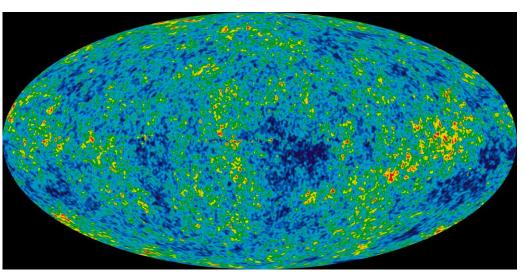






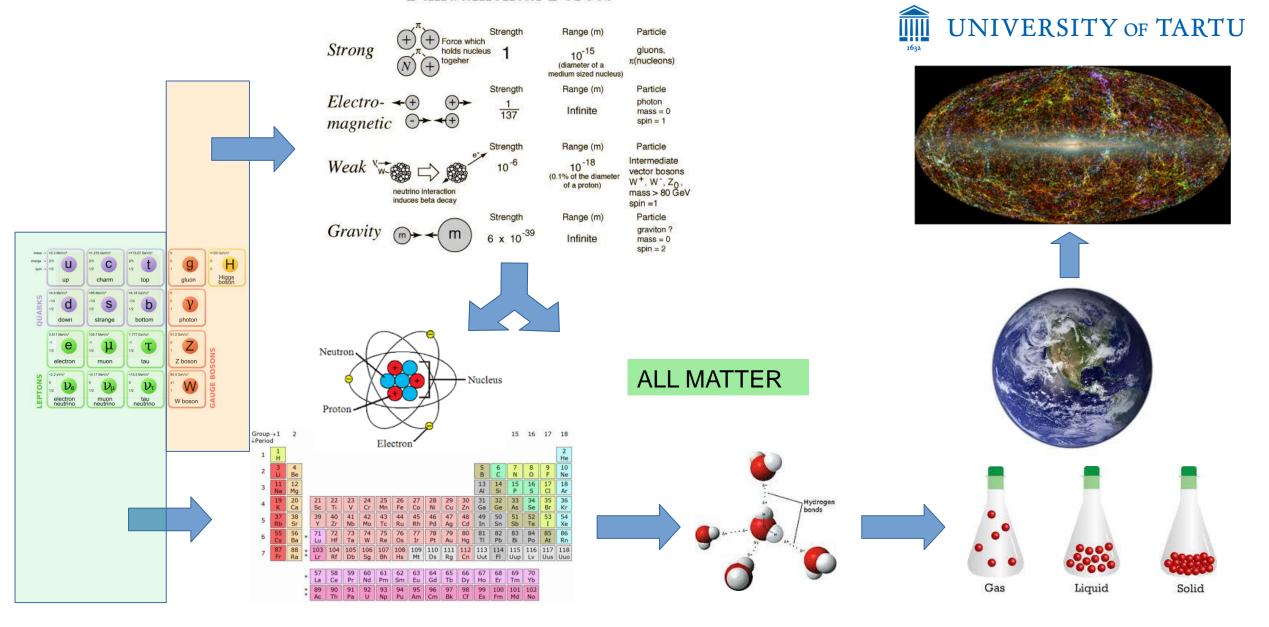
http://www.physicsoftheuniverse.co m/topics\_bigbang\_timeline.html

380 000 years later atoms (hydrogene) formed and light was free to traver through universe.



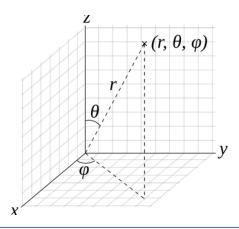
Wilkinson Microwave Anisotropy Probe (observations 2001-2010) (first photo of the universe)

#### **Fundamental Forces**



#### **Mechanics – where and how things move?**

- Physical quantities. Scalars and vectors. Relation with mathematical formalism: power, exponential and harmonic functions.
- Motion, Position and Displacement, coordinate systems, frame of reference, velocity, acceleration. Graphical representation and equations of motions.

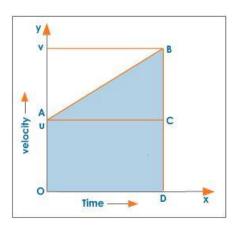


$$Speed = \frac{Distance}{Time}$$

$$Distance = Speed \times Time$$

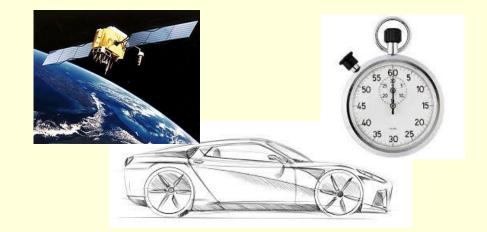
$$Time = \frac{Distance}{Speed}$$

$$egin{align} v &= at + v_0 & [1] \ r &= r_0 + v_0 t + rac{1}{2} a t^2 & [2] \ r &= r_0 + rac{1}{2} \left( v + v_0 
ight) t & [3] \ v^2 &= v_0^2 + 2a \left( r - r_0 
ight) & [4] \ r &= r_0 + v t - rac{1}{2} a t^2 & [5] \ \end{array}$$



#### **Applications:**

- GPS
- Biomechanics
- Robotics
- Mechanical engineering
- Avionics

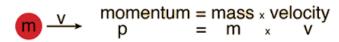


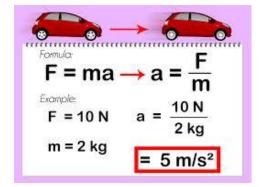


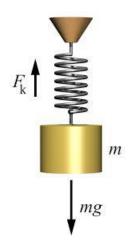


#### Mechanics – what causes motion?

- Newton's laws, momentum, energy, impulse, momentum and conservation of energy.
- Friction force and coefficient of friction. Elasticity: Hooke's law, Modulus of elasticity.
- Rotation, torque, moment of inertia, angular momentum.









#### **Applications:**

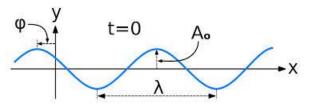
- Mechanical engineering
- Avionics
- Ballistics
- etc.



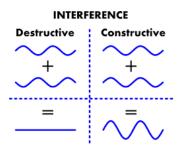


#### Oscillations and waves – everyting oscillates

- Waves in nature. Transverse waves and longitudinal waves. Wavefunction. Interference and diffraction.
- Standing waves harmonics, oscillation mode, superposition and interference. Soundwaves intensity and sound level.
- The Decibel Scale, The Doppler effect.

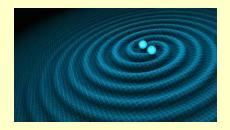


$$\Psi(x,t) = A\sin(kx - \omega t), \quad A\cos(kx - \omega t), \quad Ae^{i(kx - \omega t)}$$

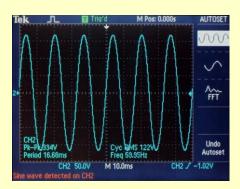


#### **Applications**

Gravitational waves - cosmology



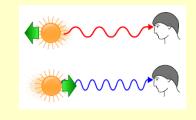
Electric and audio signal processing



Nature - Tsunami simulation



Red shift - cosmology





Radio communication
– signal propagation

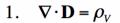


# **Electromagnetic field – how electricity works?**



- Electrostatics (Electric Charge, Coulomb's law, electrostatic field, Capacitance)
- Electric potential and motion through an Electric Field, Magnetic fields and the definition of B, Magnetic Fields Due to Currents Ampere's Law, Induction and Inductance
- Maxwell's Equations; Electromagnetism in Matter
- Electromagnetic oscillations and waves.

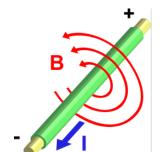
$$C = rac{q}{V}. \hspace{0.5cm} F = rac{1}{4\piarepsilon_0}rac{qQ}{r^2} = k_erac{qQ}{r^2} \,, \hspace{0.5cm} rac{2. \hspace{0.2cm} 
abla\cdot \mathbf{B}=0}{3. \hspace{0.2cm} 
abla imes \mathbf{E}=-rac{\partial \mathbf{B}}{\partial t}}$$



2. 
$$\nabla \cdot \mathbf{B} = 0$$

3. 
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

4. 
$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$



I= V/R (current)

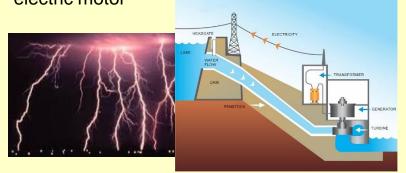
V= IR (voltage)

R= V/I (resistance)

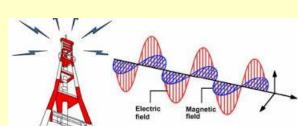
Electrostatics laser printer



Electric field and currents, magnetic fields power generation, electric motor



Alternating electromagentic field – wireless communication



Induction – wireless chargins, power generation

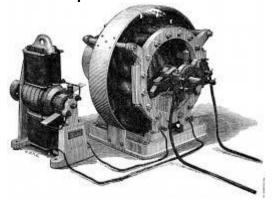


# **Applications of electromagnetism**

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- Electric current and its mechanical models. Resistance capacitance and inductance.
- Basic electronic components (resistor, capacitor, inductor, transistor)
- Circuits with alternating current, phase relation between voltage and current, phasors, and vector representation. (not needed?)
- Electric motors, generators and transformers, electromagnetic data communication

#### Electric power

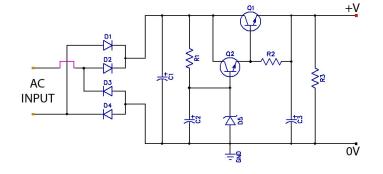








#### **Electronics**



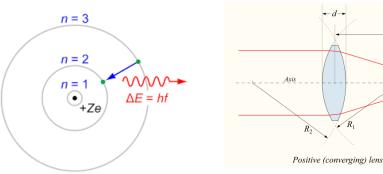


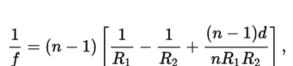


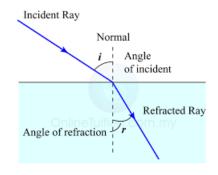
## Quantum mechanics and Optics – everything we see



- Creation of light, light propagation and absorption. Reflection and Refraction. Polarization, diffraction, interference.
- Photoelectric Effect, Light matter interaction, Heat radiation and luminescence.
- Lasers and Laser Light and its applications.















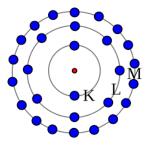
CO2 laser welding

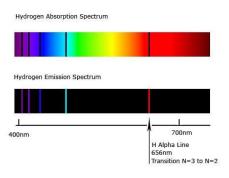


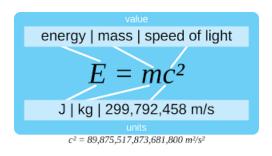


#### Quantum world – how atoms work?

- Models of atoms. The emission and absorption of light according to Bohr model. Spectral series.
- Basic principles of quantum mechanics. Electrons and Matter Waves, Heisenberg's Uncertainty Principle.
- Wave function and Schrödinger's Equation, Tunnelling.
- Modern model of atom. Orbitals, quantum numbers.
- Basic concepts of quantum computing and quantum cryptography

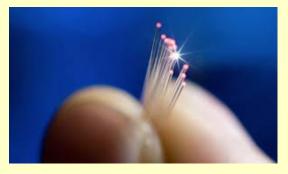


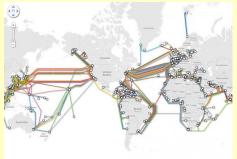




$$\Delta x \Delta p \ge \frac{\hbar}{2}$$

#### Communication via light





Quantum cryptography



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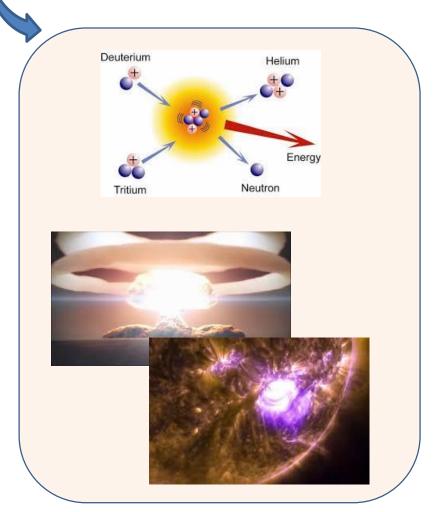
#### • Thermodynamics and nuclear physics

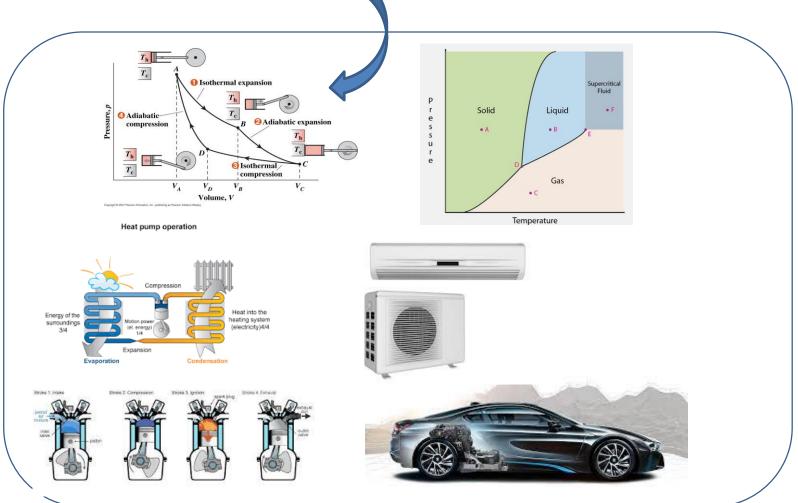
Nuclear Physics: radioactive decay, nuclear reactor. The basic process of thermonuclear Fusion.



• **Temperature pressure and heat.** Three states (phases) of matter and phase transitions. Molecular forces, surface tension and wetting. Main concepts of kinetic theory of gases.

• Laws in thermodynamics. Heat engines and refrigerators.





### Chart of the Electromagnetic Spectrum

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