LTFY.01.007 ***Physics and Engineering*****, an examination task assessing the 4th learning outcome** (The student should be able to use the vocabulary introduced at the lectures to explain the basic principles of some engineering devices applying physical terminology in a correct way).

Please explain in the right side of the table the physical phenomena, physical laws, special features of the materials on which is based the statement formulated in the left side.

Some typical questions with the expected answers are shown below:

AC generator: periodically changing electromotive force (EMF) is created on the output terminals of the generator. This EMF depends on the rotation frequency of the rotor.	The rotor of the AC generator is an permanent magnet or electromagnet, which is rotated using an external mechanical energy. The time-varying magnetic flux Φ produced by the rotor induces a time-varying EMF in the stator according to the Faraday-Maxwell law of electromagnetic induction: $E_{\text{ind}} = -\mathrm{d}\Phi/\mathrm{d}t$. The amplitude of this EMF is proportional to the rotation frequency ω and the amplitude of the magnetic flux (BS): $E_{\text{ind}} = -\mathrm{d}/\mathrm{d}t\,(BS\cos\omega t) = \omega BS\sin\omega t = E_{\max}\sin\omega t$
Antenna: Radio will work better if its external antenna is brought near a vertical water pipe. It is not necessary to bring the antenna into contact with the pipe.	An antenna is an electrical device which creates or receives electromagnetic (EM) waves. In this case, the water pipe works as an extension to the antenna. A vertical pipe works better, as it is perpendicular to the direction of the EM wave travel direction, which is almost horizontal. An EM wave is a transverse wave, which means the electric and magnetic fields are perpendicular to the direction of energy transfer. The contact is not necessary because the frequency is high and the current is able to flow through the capacitor formed on the base of the pipe and antenna.
Antistatic protection device: Workers at an electronics factory have to wear grounded conducting wrist straps.	Electrostatic charge can build up on the human body in a dry room as a result of the friction between the body and the clothes. The generated voltage can be in the order of magnitude of tens of kilovolts. This voltage is high enough to create a dielectric breakdown in the oxide layer of MOSFETs. Wearing a grounded wrist strap allows the charges to flow from the body to the ground. Antistatic devices are also required for working with computer components.
AC asynchronous motor: alternating current (AC) asynchronous motor works without electrical connections to the rotor.	An asynchronous motor is a type of an induction motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the rotating magnetic field of the stator. The current in the rotor creates a magnetic field, which due to Lenz's law, is trying to compensate the changes of the stator's rotating magnetic field. So the rotor's magnetic field is trying to hold the same direction as the rotating field created by the stator. It means that the rotating magnetic field of the stator will bring the rotor also into rotation. The torque acting on the rotor exists only when it rotates at a smaller frequency than the rotating magnetic field of the stator, hence the term asynchronous.
Bimetallic circuit breaker is a resettable circuit breaker, in contrast to a fuse.	The bimetallic circuit breaker is a device consisting of two strips of different metals which are riveted together and have different thermal expansion coefficients. If a higher than wanted current is flowing thorough the breaker, the device will warm up, the length of both strips will increase in a different way, the bimetallic strip bends sideways and breaks the circuit. If the strip cools down, it unbends and the circuit breaker can be reused.
Bipolar junction transistor is a current-controlled transistor, unlike the field-effect transistor.	A bipolar junction transistor contains two pn junctions. These junctions separate three regions, which are called emitter, base and collector. In typical operation, the base-emitter junction is forward biased and the base-collector junction is reverse biased. Increasing the base current allows the majority charge carriers of the emitter to enter the base. This increases the conductivity of the base and the base-collector junction is opened. A small change in the base current induces a large change in the collector current. The bipolar transistor is almost not used nowadays because it is a current-operated device and needs too much power.

Charge-coupled device (CCD) stores the brightness of a pixel as the charge of the capacitor.	A charge-coupled device uses a large number of metal-oxide-semiconductor (MOS) capacitors to record the image. Each pixel (*picture element*) is represented by one capacitor. Electron-hole pairs are created in the junction by incoming photons and the electrons of the pairs are drawn toward the oxide layer of the capacitor. This charge is moved between the bins of capacitors toward the edge of the device, where it is amplified and stored. This is done in serial way for each individual pixel. In a CCD camera, the charge of every pixel is measured separately. It allows the brightnesses of pixels to vary. Most professional cameras contain a CCD.
CMOS-camera is a camera based on complementary metal-oxide-semiconductor technology.	In a CMOS-camera, each pixel consists of a pair of complementary MOS transistors. One of transistors is p-type and the other is n-type. In the first transistor, incoming photons create electron-hole pairs, which cause the transistor to open. This causes the other transistor to close, signaling the illumination of the pixel. The signal from each pixel is transmitted and stored. CMOS-camera is a purely digital device – every pixel can only be in two states, illuminated or not.
Curie point: Magnetic memory is erased when the memory device is heated to an excessive temperature.	In the case of magnetic memory (the hard disks of computers, for instance) the working ferromagnetic substance possesses a domain structure. In every domain all the magnetic fields of ions are oriented in the same direction. So each domain is able to store one bit of information. All ferromagnetic materials have a certain temperature, called the Curie point, above which the domain structure is lost due to thermal disorder. In the heating process, the hysteresis loop will also vanish and the stored information will be lost. A wide hysteresis loop of the memory material and a high Curie point are required for magnetic memory applications.
Diesel engine is a heat engine, which, unlike the Otto (or: gazoline) engine does not use a spark ignition system.	A diesel engine, also known as a compression-ignition engine, is an internal combustion engine where the ignition of the mixture of air and fuel is achieved by rapid adiabatical compressing of the mixture. An adiabatic process is a process where no heat is exchanged with the environment. In an adiabatic process, the external work done on a gas increases its internal energy, which is proportional to its temperature. For that reason, adiabatical compression of a gas increases its temperature to the values, which in diesel engine is sufficient for ignition of the fuel mixture. Modern diesel engines also have so-called glow plugs, which pre-heat the mixture for use in the case of a cold engine.
Direct current (DC) motor is an electrical motor, which works on a direct current source. Direct current motors require permanent magnets to operate.	The stationary part of the DC motor called stator contains permanent magnets which create a stationary magnetic field in the position of the rotor, which is the moving part of the motor. The rotor consists of windings of copper wire through which flows the direct current. A current-carrying wire with the length l experiences a magnetic force $F_m = B\,I\,l$ in the magnetic field B, which creates a torque. In the case of multiple windings, the current is directed only through the ones that experience the maximal instantaneous torque.
Electric arc discharge can happen at normal pressure, while strong rarification of the gas is needed for a **glow discharge**. The arc discharge has a lot of applications.	An electric arc discharge is an electrical breakdown in the initially non-conducting gas that produces an ongoing electrical discharge. After starting, the heat from the arc will ionize additionally the gas molecules. In the case of arc discharge the temperature of the conducting gas and the concentration of charge carriers are very high. So the big currents (hundreds of amperes) are reached at quite low voltages (tens of volts). The arc discharge is used for the electrical welding of metals and also in fluorescent and gas discharge lamps. The source of the exciting UV light in the fluorescent lamp is the arc discharge in mercury. In a glow discharge, the gas is ionized directly by the effect of the electric field, which requires a high mean-free path and hence, a low density of particles. The voltages are high (hundreds of volts), the currents are small (some milliamperes).

Electrical grounding: All modern electrical devices have three terminals - phase, neutral and ground terminal.	Phase terminal is the terminal possessing a periodically changing voltage with respect to the earth or ground. Neutral is the terminal which connects to the wire that carries current back to the source and has a negligible voltage with respect to the earth (ground). Ground terminal is the terminal which provides a low-resistance path to the ground from the casing of the device. In case when the casing comes into a faulty contact with the phase terminal, the ground terminal leads the strong current away from the person using the device and into the earth while also triggering a fuse or circuit breaker.
Electrical shielding: An electrical device which is sensitive to external electric disruptions is placed in a box or net of wires made from conducting material.	Electric shielding works on the principle, that the electric field inside a conductor is always zero. The external field induces charges on the surface of a conductor. The field of induced charges exactly cancel the external field. An enclosure for shielding external fields is called a Faraday cage. In the case of coaxial cable the inner wire carrying the electrical signal (periodically changing voltage) is shielded by cylindrical net of copper wires. This shielding net is typically grounded.
Electrical transport in the city is economical, because the kinetic energy from a decelerating trolley car or a tram can be used for other trolleys.	DC motors are reversible. The engine of a decelerating trolley car or a tram can be used as a generator, which converts the kinetic energy of a decelerating vehicle to the electrical energy. This energy can be transmitted to other vehicles through the electrical network. In a regular car, in the case of braking the kinetic energy of the car is converted completely to heat in the brakes. So the kinetic energy is lost.
Electromagnet: If the driver turns the starter key, it activates the starter relay, which brings the starter into mechanical contact with the engine.	The starter relay is a strong electromagnet, which is driven by a current from the battery. When a strong current passes through the relay, it magnetizes its iron core armature, which puts the starter electrical motor into contact with the battery. Also the movement of the iron core pushes out a pinion on the starter drive shaft, putting the electric starter motor into a mechanical contact with the engine of the car. The automatic locking system of the car doors is also driven by the electromagnets.
Electron microscope is a microscope that uses a beam of high-energy electrons as a source of illumination.	As the wavelength of an electron can be up to 10^5 times shorter than the wavelength of visible light photons, electron microscopes have a higher resolving power than light microscopes and can reveal the structure of smaller objects. A transmission electron microscope (TEM) can achieve a resolution 0.1 nm and magnifications of up to about 10^7 times whereas most of light microscopes are diffractionally limited by resolution about 200 nm and useful magnifications below 2000 times. The wavelength of electrons λ can be easily controlled by adjustment of the acceleration voltage U, because $\lambda = h/(2meU)^{1/2}$.
Field effect transistor (FET) is a transitor, that unlike the bipolar junction transistor, uses the electric field instead of current to control the electrical resistance of a transistor.	The field-effect transistor consists of only one pn junction. The device possesses an active channel through which electrons or holes flow from the source to the drain. If the gate terminal is forward biased, it creates an electric field which increases the width of the conducting channel – the transistor is opened. In the case of reverse bias, the depletion region of the pn junction is expanding, the width of the channel is reduced and the transistor is effectively closed.
Ground fault circuit interrupter: Ground fault interrupters protect humans effectively from electrical shock.	A ground fault circuit interrupter (CFCI) is a circuit breaker which is designed to protect people from electrical shock. It monitors the current in the neutral wire and phase wire of the circuit. As soon as the phase wire comes into direct contact with the ground (there is a short circuit), a current difference between the neutral wire and phase wire is created and the interrupter breaks the circuit. The time in which the interrupter reacts (ca 10 ms) is much shorter than the working cycle of the human heart and so the dangerous equipment is switched out before the heart of the operating person is damaged. Therefore the CFCI protects the person very effectively in the case of contact with the faulty wire.

Hall sensor: The Hall effect is most commonly used to measure the magnetic flux density (or magnetic induction) B.	Hall effect is the creation of a voltage difference across a current-carrying conductor or semiconductor in the case of applied magnetic field. The charge carriers moving in a magnetic field experience a Lorentz force in the direction perpendicular both to the current and the magnetic field. This force creates a charge separation, which generates the Hall voltage U_H between the ends of the conductor. The Hall voltage is proportional to the current and the magnetic flux density B: $U_H = \text{const}\ I\,B/d$. Hence we can measure the magnetic flux density B by measuring the voltage.
Heat engine is a device that operates between a hot and a cold environment, converting thermal energy into mechanical energy.	A heat engine is a device that extracts some amount of heat energy Q_1 from the hotter environment, converts some of it to the useful mechanical work W and delivers the rest amount of heat Q_2 to the colder environment. The efficiency of the heat engine relates how much useful work is output for a given amount of heat energy input: $\eta = W/Q_1 = (Q_1 - Q_2)/Q_1$. The maximum efficiency of the heat engine is determined by the temperatures of hot (T_1) and cold (T_2) environments, respectively: $\eta_{max} = (T_1 - T_2)/T_1$.
High voltage transmission line: Wires of the transmission line are separated from the poles or pylons by long suspended insulators.	The power line wires have a high voltage with respect to the ground. The poles or pylons supporting the wires are in electrical contact with the ground and are usually made of conducting materials. Longer insulating suspensions that insulate the wires from the supporting structures allow for smaller electric field value in the material ($E = U / l$), which reduces the possibility of a breakdown.
Incandescent light bulb: The filament of the light bulb is glowing hot, while the connecting copper wires remain cold.	The cross-section area A of the filament is much smaller than that of the wires. So the resistance $R = \rho\, l/A$ of the unit length l of the filament is bigger than the resistance of unit length of the connecting wire. Also are the filaments made from tungsten (W), which has a higher resistivity than that of the copper wires. For that reason, the power P dissipated per unit length is much greater in the filament than in the wires, as $P = I^2 R$ and the same current I is flowing through the filament and wires.
Inductor spark: Breaking a circuit causes a spark in the breaker, while closing the circuit does not. This can happen even in the case of a low voltage circuit.	This happens if the inductance of the circuit is great enough. Closing the circuit allows current to flow in the inductor, which generates the electromotive force (EMF) of self-induction in the inductor. According to Lenz' law, this EMF opposes the external voltage source and does not let the current to change instantaneously. While opening the circuit however, the inductor acts as though to conserve the current and thus the generated EMF is added to the voltage of the external source. So the net voltage is high enough for a spark to form. This mechanism has been used, for example in spark plugs of the car engines.
Integrated circuit (microchip) Is a set of electronic circuits consisting of p-n junctions, capacitors and resistors on a small flat piece of semiconductor material.	In integrated circuits, a semiconducting substrate (called *wafer*), usually made from silicon is covered with nanoscale layers of some conducting metals and dielectric materials. These layers can be used to construct the components of the circuits. For example an area of two layers of conducting materials with a dielectrics in between forms a tiny capacitor. Placing all the elements on the same substrate creates a similar working temperature for the all components. Also the cost and power consumption of the microchips is greatly reduced in comparison with the circuit consisting of separated components. An integrated circuit uses less material and less power. Integrated circuits are ubiquitous in modern electronics.

Laser is a device that emits light based on the stimulated emission of electromagnetic radiation, e.g photons with the same frequency, phase and polarization.	Working principle of a laser is based on: a) the inversion created in the quantum system and b) use of the optical cavity. The inversion means that the higher energy level is occupied more probably than the lower levels. There are a lot of particles ready to emit light quanta with certain properties. In the lasers, the system generating the inversion called the pumping system, should be always in use. An optical cavity is an arrangement of mirrors that forms a standing wave. Light confined in the cavity reflects multiple times on the mirrors producing standing waves for certain resonance frequencies. So the probability for generating a twin for some photon always existing in the cavity, is enhanced.
Light emitting diode (LED) is a device that creates visible light from electrical energy.	Light emitting diode (LED) is a forward biased PN junction which generates light using the energy of electric field. PN junction is the region in the semiconductor where n-conducting and p-conducting parts are in contact. In n-conducting part, the dominating charge carriers are (negative) electrons. In the p-conducting part the dominating carriers are (positive) holes. In the case of forward biasing, the positive pole of outer voltage source is connected to the p-conducting part of semiconductor, and the negative pole of the source is is connected to the n-conducting part. The electric field generated by the source is bringing the electrons and holes together. When an electron meets the hole, then the hole is filled by the electron and the energy of electron-hole pair is transmitted to the generated photon.
Liquid crystal display (LCD) The liquid crystal display is one the most used display types, because it has smaller power consumption and is made of relatively cheap materials.	In the LCD display, light is usually generated by LEDs. The generated light is polarized and sent through a thin layer of liquid crystal molecules, which are sandwiched between two transparent conducting sheets. The light passes the liquid crystal only when the axis of the crystals are aligned with the plane of polarization of the passing light. The alignment of the liquid crystal molecules can be changed by applying a voltage on the conducting sheets, thereby allowing to change the brightness of individual pixels.
Luminous efficacy is a measure of how well a light source produces visible light. Its maximal theoretical value is **…… lm/W (**fill the gap!) Luminous efficacy greately differs for different light sources.	Luminous efficacy is ratio of luminous flux of a light source to consumed electrical power, measured in lumens per watt. The maximal value of the luminous efficacy is **683** lm/W. It is an luminous efficacy of a light source that converts all consumed electrical power into monochromatic light at a frequency of 540 THz, on which the human eye responds best. The efficacy of real light sources is much lower: 10-15 lm/W for incandescent lamp, 20-35 lm/W for halogen lamp, 50-100 lm/W for a fluorescent lamp, 50-150 lm/W for a LED lamp, and up to 200 W/lm for a gas discharge lamp.
Magnetic crane: Scrap metal is separated by a magnetic crane, which attracts scrap iron or steel, but not copper.	A magnetic crane works as an electromagnet. As iron is a ferromagnetic material,it will be strongly magnetized in the magnetic field created by the electromagnet, which causes attraction between the metal scraps and the magnet. No such effect can be seen in the case of copper, because copper is is diamagnetic material and is effected only slightly by the electromagnet.
Magnetic memory: The material used in a magnetic memory device is not suited to be used as the core of a transformer or an electromagnet.	The hysteresis loop of a magnetic memory material is wide and has a large area. The area of the hysteresis loop is equal to the work done per unit volume for one cycle of magnetization. An electromagnet made of a magnetic memory material would exhibit high energy losses, would be hard to control due to wide hysteresis loop and would exhibit a non-linear $B = f(I)$ -dependence (output voltage of a transformer would not be proportional to the input voltage).
Measuring transformer: An electrician checks a suspisious wire with a clamp meter.	A clamp meter or a current probe is an electrical device for measuring the current without an electrical contact with the wire. It consists of two conducting and ferromagnetic „jaws“ which clamp around the wire. This creates a magnetic circuit, where a periodically changing magnetic flux is created. This in turn creates an alternating current through the secondary winding, which can be measured.

Metal detector cannot be used by archaeologists to search for bones, ceramics or thoroughly corroded metal objects.	The main component of a metal detector consists of an oscillator creating an alternating current that passes through a coil producing an alternating magnetic field. If a piece of electrically conductive metal is close to the coil, eddy currents will be induced in the material. This causes the current through the coil to suddenly drop, as energy is released as heat in the material. This method is applicable to search for conducting materials only, as a non-conducting material does not allow for high enough eddy currents to be induced.
MOSFET: The gate electrode of the MOSFET must be separated from the semiconducting material by a thin layer of dielectric material possessing a high relative permittivity.	The positive gate electrode acts to draw the minority charge carriers of the semiconductor near the gate electrode, creating a conducting channel between the source and drain contacts. The dielectric layer between the gate and the substrate must be thin and must have a high permittivity, so that the capacitance of the capacitor consisting of the gate electrode and semiconducting substrate would be as high as possible and a greater charge could be attracted into the conducting channel by a smaller voltage.
Old battery: A radio with an old battery works quieter. If it is turned off and then on again, it will work louder for some time.	The internal resistance of an old battery is large, because almost all of the reactants have been used up and the products of the reaction disturb the directed motion of the charge carriers. If the internal resistance is large, only a small current can be drawn from the battery. If the radio is turned off for some time, the products of the chemical reaction can diffuse away, which lets the reaction to proceed. Understandably, this will only last for some time.
Piezoelectric sensors produce an electric signal in response to a force, piezoelectric actuators use the reverse effect to very accurately change the dimensions of some detail.	Piezoelectricity is the generation of electric charge of some types of materials due to external stress or force exerted on the material. The converse piezoelectric effect is the changing of the dimensions of a material due to an external voltage. Due to the applied mechanical stress, positive and negative ions in the material are displaced in opposing directions, thereby changing its polarization, which induces the surface charges. The magnitude of this displacement and therefore also the created electric field are proportional to this displacement.
PN junction: In the case of forward bias, a PN junction conducts electricity, but in the case of reverse bias it does not.	In the case of forward bias, the positive terminal of the voltage source is connected to the p-type side of the PN junction and the n-type side is connected with the negative terminal. The electric field created by the external voltage source pushes the holes in the p-type region and the electrons in the n-type region toward the junction, which start to neutralize the depletion region, reducing its width until to zero. So the PN junction is opened. In the case of reverse bias, the positive terminal of the voltage source is connected to the n-type side and the negative terminal is connected to the p-type side of the PN junction. The width of the depletion region or length l in the formula of its resistance $R = \rho l / S$ increases and so the PN junction remain closed.
Power line: high voltage is used to transfer electrical power, although from the formula $P = U^2/R$ it could be reasoned, that increasing the power increases the power losses.	Increasing the voltage allows to decrease the electrical current for the same transmission power as $P = I U$. The losses due to heating in the power line can be calculated as $P = I^2 R$, so that decreasing the current also decreases the losses. High transmission voltage means a high voltage between the power line and ground. The voltage in the formula for losses $P = U^2/R$ is the voltage between the ends of the power line. This voltage is made so low as possible using low resistance transmission wires.

Quartz clock: A quartz lock uses an electronic oscillator that is regulated by a quartz crystal to keep time.	Quartz is a piezoelectric material, that is when a quartz crystal is subjected to the mechanical stress, such as bending, it creates a voltage between its ends. Also reversely, if a voltage is applied, the dimensions of the quartz crystal will change, with so-called reverse piezoelectric effect. The quartz crystal is oscillating, the dimensions and the mass of the crystal determine its frequency and period. The time is measured as the certain number of periods. The losses are compensated by electrical energy from battery of the clock.
Rectifier is a device that converts alternating current (AC) to direct current (DC). Full-wave rectifier does so more efficiently than a half-wave rectifier.	Half-wave rectifier requires only a single semiconductor diode (one PN junction) which permits current to flow during the half-period of positive voltage, when the diode is forward-biased. In the other half-period when the diode is reverse-biased, no current will flow. Modern rectifiers are full-wave rectifiers. This device reverses the direction of the current during the negative half-period and typically requires 2 or 4 diodes. For the two diode case, one diode permits current to flow during one half-period and the other diode during the other half-period. In case of 4 diode setup, the diodes are set in a bridge configuration where 2 diodes permit current to flow during the positive half-period and 2 for the negative half-period.
Refrigerator and the heat pump: Does the freezer and the heat pump violate the second law of thermodynamics?	A refrigerator is a device to produce low temperatures in some local region. Heat is drawn from the interior of the device by the means of the refrigerant to the radiator, where it is dissipated as heat to the surroundings. A heat pump is is a device to extract heat from the colder environment to heat the inner, warmer one. Both the refigerator and the heat pump allow heat to flow from the region with lower temperature to the one with higher temperature, but only by doing mechanical work. The entropy of the cooled region decreases, while the temperature of the hotter one increases by a larger amount. The total entropy of the whole world increases, so the second law of thermodynamics is satisfied.
Security gate at an airport reacts to some metal object on a person.	Security gate consists of an oscillator producing an alternating current, which passes through a coil which produces an alternating magnetic field. If a conducting body is brought close to the coil, eddy currents will be induced in the body, which create a magnetic field of its own. Another coil can be used to measure this magnetic field. Another possibility is to measure the energy loss caused by the eddy currents because they convert the electric energy into the thermal energy. Non-conducting object cannot be detected by this method, as no eddy currents are induced in a non-conducting body.
Scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.	To scan means to direct a finely focused beam of light or electrons in a systematic pattern (in serial way) over a surface in order to reproduce or sense and subsequently transmit an image. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography of sample and its composition. The electron beam is generally scanned in a raster scan pattern, and the information considering the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer.
Scanning tunnelling microscope (STM) is an instrument for imaging surfaces at the atomic level.	The STM is based on the concept of quantum tunnelling. Tunnelling is the quantum mechanical phenomenon where an object is going through a barrier not penetrable according to the classical mechanics. When a conducting tip is brought very near to the surface to be examined, a voltage applied between the tip and the surface can allow electrons to tunnel through the vacuum between them. The resulting tunneling current is a function of tip position, applied voltage, and the local density of electronic states of the sample.

Semiconductor lasers and LEDs are most commonly made of gallium-arsenide-phosphide GaAsP (red LED) or gallium nitride GaN (white LED).	Semiconductor laser is a semiconductor LED, which is placed inside an optical cavity. The energy of the photon emitted by a laser or LED is roughly equal to the width of the band gap of the semiconductor E_g. This is the minimal energy required to create an electron-hole pair. The electron-hole pairs recombine in the forward-biased pn junction, emitting photons. For gallium-arsenide (GaAs) E_g = 1,35 eV, gallium phosphide (GaP) 2,24 eV. In case of a mixture ($GaAs_xP_{1-x}$) E_g can be tuned between those two values. In the case of GaN the band gap is 3,4 eV which makes violet (405 nm) LED possible. This violet light is used as an exciting radiation for photoluminescent LED lamps emitting the white light.
Solar cell is an electrical device, that converts the energy of light directly into electrical energy.	Solar cells operate by converting the energy of light into electrical energy through the photovoltaic effect. The cell contains a p-n junction where the incoming photons excite the electrons to create electron-hole pairs. Due to the electric field of the junction, these created electrons and holes will drift in the opposing directions – electrons toward the n region and holes toward the p region. Only photons whose energy is greater than the band gap of the semiconductor will create electron-hole pairs. If the energy of the photon is greater than the band gap, the rest is absorbed as heat.
Thermal electromotive force is the temperature dependent electrical potential difference (voltage) produced between two junctions of two dissimilar metals.	The contact potential difference, also called the Volta potential, is the electrostatic potential difference between two metals that are in contact. This potential difference is created by the difference of work functions between those two metals. Thermal electromotive force is created in a closed circuit, if the contacts are held at different temperatures. The created voltage is proportional to the temperature difference between the contacts. This allows to measure the temperature difference of the contacts.
Thermistor: The electrical resistance of a semiconductor thermoresistor (thermistor) rapidly diminishes with increasing temperature. This allows a thermistor to be used to measure temperature.	Semiconductor thermistors are commonly used at temperatures, where the thermal energy excites an electron from the donor or a hole from the acceptor. This increases the concentration of charge carriers and the resistivity $\rho = m / \tau q^2 n$ is decreased. At a higher temperature, the intrinsic conductivity of the semiconductor (the thermal creation of the electron-hole pairs in it) can be used for the same purpose.
Thermocouple: A millivoltmeter which is connected to the wires of an experimental device is used to measure the temperature of the device.	In the case of thermocouple, the thermoelectric effect is used to measure the temperature. Two dissimilar metals form a closed circuit with two electrical junctions, which are held at different temperatures. A thermal electromotive force in the order of 0.1 mV/K is created in the circuit. Unfortunately, the created voltages are normally too low for producing of electrical energy, but they are sufficient for measuring the temperature.
Tuning: The receiver of a television or radio programs is tuned to receive the signal of a particular station.	The antenna of a radio contains a resonant LC circuit. A resonant circuit is an electrical circuit consisting of an inductor and a capacitor. A resonant circuit periodically tranforms the energy of the electric field of the capacitor into the magnetic field energy of the inductor. A large current can be generated in the circuit if the antenna receives an electromagnetic wave possessing the same frequency as the resonant frequency of the circuit ω_r . To tune to a certain channel, the resonant frequency $\omega_r \approx 1/\sqrt{LC}$ is changed by changing the capacitance C.
Varicap: The capacitance of a capacitor in the resonant circuit of a modern radio is varied by changing the voltage.	A varicap diode is a semiconducting device, which consists of one reverse-biased PN junction. The amount of reverse bias voltage controls the thickness of the depletion zone. So the distance between the „plates“ of the capacitor or the length l of the non-conducting area is changed. The capacitance C is inversely proportional to the distance l between the plates of the capacitor: $C = \varepsilon_0 \varepsilon_r A / l$