Ministry of Health of Ukraine
Ukrainian Medical Stomatological Academy

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Methodical instructions
for students' self-preparation work at preparation for a practical lesson
at home and at the classroom

Subject matter	**Medical and biological physics**
The unit	2. Bases of medical physics
Theme of lecture:	**A thermal irradiation of the bodies, it characteristics. Thermography.**
Year	1
Faculty	Medical
Speciality	Medicine

Poltava - 2020

The topic significance:

Temperature measurements are very important diagnostical methods. Wide them using, modern them development for detail study of distribution of heat production in patient's body makes them study necessary for future doctor.

Any body radiates electromagnetic waves if its absolute temperature is higher than zero. It is thermal radiation. Any body can absorb the thermal radiation of other bodies. Emission and absorption of thermal radiation by bodies are described by some laws.

Specific targets:

- To acquire concepts: temperature, heat, heat irradiation, absolute black body, grey body. (α=II)
- To know a basic laws of body thermal irradiation .
- To know a basic characteristics of Sun irradiation, infrared and ultraviolet irradiation .
- To acquaint with main methods of heat irradiation using at diagnostic .
- To acquaint with main devices that used at thermodiagnostic .
- To acquaint with main methods of thermal measurement .
- To be able explain using of thermal irradiation in medicine at diagnostics .

Basic knowledge, experience, skills necessary for studying the topic in connection with other subjects:

Disciplines	Obtainable skills
Previous (providing disciplines): physics, chemistry, biology	Idea of temperature. Laws of thermal movement. Temperature measurements. To explain mechanism of thermal irradiation appearance. To use these concepts at tasks decision
The subsequent disciplines:	Mechanism of heat irradiation. Devices that are used in medicine.

Normal physiology Pathologic physiology	To explain mechanism of thermal irradiation using in medicine. To adhere to safety laws.

List of main term, parameters, characteristics, which student have to learn at preparation to class:

Term	Definition
Radiation flux	Energy of radiation which falls at the given area during one second.
Radiation intensity	Energy of the IR radiation, falling a unit area for one second
Radiant emittance	***Radiance*** (*R*) is the ratio of the radiation flux of thermal radiation (Φ) emitted by a surface to the area of this surface (*S*): $R=\Phi/S$.
Radiation coefficient	
Absorption constant (absorption factor)	The capacity of a body to absorb thermal radiation is characterized by the absorption factor. Absorption coefficient is natural logarithm of relation passed light stream to incoming light stream and to the distance passed through substance. It is coefficient, which depends on materials nature and radiation wave lengths.
Monochromatic absorption constant	Absorption constant determined for certain wavelength.
Black body	Body which absorbs all incident radiation.
Grey body	A body having monochromatic absorption factor is less than unity and does not depend on the radiation wavelength.
Thermography	Method of registration of thermal irradiation of a body

Theoretical questions to class:
1. Causes of the thermal irradiation.
2. Thermal radiation spectrum.
3. Absorption factor. Write down and analyse the formula for absorption factor.
4. The emissive and an absorbing ability of bodies, an absolute black body.
5. Grey body.
6. Write down and analyse the formula for Kirchhoff law.
7. A Planck radiation law. Describe and explain it.
8. Write down and analyse the formula for Stefan – Boltzmann law.
9. Wien's displacement law.
10. Thermal irradiation of human body.
11. Explain meaning of medical method of thermography.
12. A structure and a principle of action of thermographic devices.

Practice work executed at class:
The material equipment: tables, the medical thermometer, the electrothermometer, a film for heat-indicating diagnostic.

b) *The list of operations which are subject to accomplishment:*
To familiarize with liquid-cristal films;
To familiarize with the block diagram of the thermograph;
To familiarize with a principle of operation of the electrothermometer.

c) *The list of practical habits with which are necessary for seizing:*
To be able to take the temperature the person by the medical thermometer and electric thermometer.

Contens of the topic.

Abbreviations:

IRI – infrared irradiation

EMF – electromagnetic field
EF – electric field
MF – magnetic field

The caloradiance (thermal radiation) is an electromagnetic radiation. It is an information source, is used for diagnostic and treatment.

Thermal radiation takes in a spectrum of electromagnetic waves a place between visual light and radiowaves, i.e. over the range 0,76 microns up to 1 mm. All gamut of thermal radiation is divided into some fields (table 1).

Wave length (micron)	*The name of area*
0,76-1,5	Short-range IR-radiation
1,5-5,5	Short-wave IR-radiation
5,6-25	The long-wave IR-radiation
25-1000	Long-range IR-radiation

This division is conventional, but it takes into account properties of IR radiation and its practical use. IR beams have wave and quantum properties, spread and are absorbed by quantums. Energy of quantum depends on a wave length:

$$E = h\nu = hc/\lambda,$$

where E – energy, c – velocity of light, h – the Planck constant, λ – a wave length.

The basic performance of IR radiation is radiated power (radiant flux) – energy of radiation which falls at the given area during one second.

Energy of the IR radiation, falling a unit area for one second, is termed as radiation intensity [radiation rate, strength of radiation]. Unity of intensity is W/m^2.

IR radiation is absorbed, reflected, diffracted and scattered.

Absorption. Absorption of IR beams obeys the Bouger-Beer law:

$$\Phi = \Phi_o e^{kl},$$

Where Φ_o - a stream of an incoming radiation on material, Φ - a stream which has passed through material, l - depth of material, k - coefficient which depends on materials nature and radiation wave lengths (absorption coefficient).

Absorption coefficient is natural logarithm of relation passed light stream to incoming light stream and to the distance passed through substance.

From the given formula it is clear, that uptake is promptly incremented with magnification of depth of an immersing layer. For example, if the layer in 1 mm attenuates radiation twice the layer depth will attenuate of 5 mm in 32 times, and the layer of 10 mm – attenuates more, than in 1000 times.

Tissues of an organism absorbs IR radiation differently; it depends on IRI wave length. An example can be a human skin.

Reflection. Metal surfaces well reflect as visual, and IR radiation. But the pattern of reflection will be different and will differ from usual. The grass, leaves, well reflecting IR radiation, seem much more lighter, the same as also an eye iris, a dark hair. The text written by different paints, can variate in IR beams depending on a mineral and molecular composition of a paint which are used in different views of examination.

The human skin absorbs and reflects IR radiation differently. It is used for recognition of dermal sicknesses in forensic medicine and criminalistics.

Refraction*. The refractive index* for IRI is less than for visual beams, they are less reflected at transition from one medium in another, that it is necessary to take into account at photographing in IR beams.

Scattering. IR beams are scattered less than visual light. The scattering of any radiation by small particles (a fog, a dust, gas bubbles) depends by nature, size and shapes of particles, and also on a wave length. If the particles sizes are small in relation to a wave length of radiation, dependence is featured by the formula of Rayleigh:

$I \sim (n-l)^2/(N_0\lambda^4)$,

i.e. a scattering in inverse proportion to the fourth power of a wave length.

Dependence on a wave length will be more weak for bigger particles. Lesser, than for visual light, scattering of IR beams enables to use them in aeroobservations even in requirements of the poor vision.

THERMAL RADIATION

Condition of thermal equilibrium of much body system is ***Kirchhoff law.***

Kirchhoff law:

Relation of body radiation ability E_f,T to body absorption ability A_f,T don't depend on body material and equal to radiation ability of absolute black body that is function of frequency and temperature: $$\frac{E_{f,T}}{A_{f,T}} = \varepsilon_{f,T},$$

where *f* – wave frequency, *T* – absolute temperature.

The ***radiation flux*** (*Φ*) is energy transferred by radiation through a surface per second (radiation power). The unit of the radiation flux is *watt* (W).

Radiance (*R*) is the ratio of the radiation flux of thermal radiation (*Φ*) emitted by a surface to the area of this surface (*S*): $R=\Phi/S$. The unit of radiance is *watt par square meter* (W/m^2).

Thermal radiation has a continuous spectrum.

Spectrum is set of all values of physical quantity, which characterize some system or process. *Continuous spectrum* is spectrum in which all values are possible, whithout exception. On the contrary, discontinuous [discrete] spectrum has limited quantity of possible values.

Spectral radiance (r) is characteristics of dependence of intensity on wavelength: $r=dR/d\lambda$, where *dR* is the radiance of radiation within the wavelength range of λ to $\lambda+d\lambda$. The unit of the spectra! radiance is *watt per cubic meter* (W/m^3).

The spectral radiance of a body vs. the radiation wavelength dependence is known as the *thermal radiation spectrum* of this body.

Absolute black body irradiation

A *black body* has monochromatic absorption factor at all wavelengths is equal to unity. A black body absorbs all incident radiation.

The temperature radiance dependence is known as the ***Stefan-Boltzmann law***:

$R = \sigma \bullet T^4$,

where $\sigma \approx 5{,}7 \bullet 10^{-8}\ W/(m^2K^4)$;

where **σ** – is **Stefan-Boltzmann constant**.

The dependence of spectral radiance of a black body on the temperature is represented on fig.1.

Wien's displacement law:

The wavelength ($\boldsymbol{\lambda_m}$) of the thermal radiation spectrum maximum of the black body spectral radiance is equal to: $$\lambda_m = \frac{b}{T},$$

where ***b*** is a constant (if ***T*** expressed in Kelvin degrees, Wien constant $\boldsymbol{b}=2886 \bullet 10^{-6} m \bullet K$).

Wien's displacement law manifests in next phenomenon: bodies at habitual temperatures (in interval -50° – +100°C) radiate energy in infrared range mainly.

From Wien's displacement law it follows that the wavelength, corresponding to the maximum of the thermal radiation

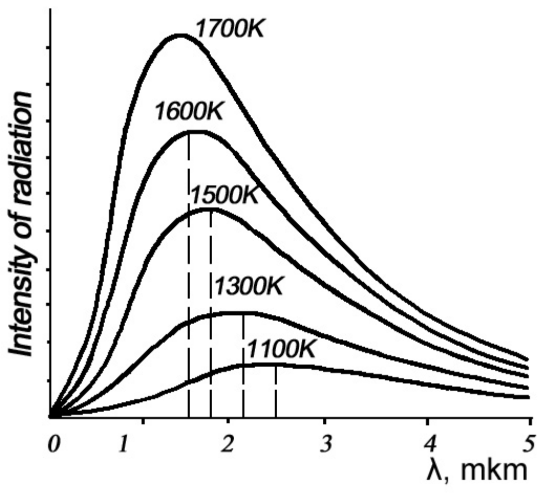


Fig.1. Absolute black body irradiation at various temperatures of black body.

spectrum of a body, is completely defined by the temperature of the body. Hence, by finding the value λ_m, can be determined the temperature of a body. This method of determining the temperature of a body is known as optical ***pyrometry***.

Grey body is a body having monochromatic absorption factor is less than unity and does not depend on the radiation wavelength.

Naturally grey bodies do not exist, but some bodies within some wavelength range can be considered grey. For example, a human body is considered grey in the infrared range. Its absorption factor is about 0.9.

Human body produces energy in process of chemical reactions. This energy is used for work partly and dissipates as heat partly. Production of heat in an organism is a side effect of a metabolism processes according to thermodynamics laws. However for homoitherm metabolic heat is necessary for maintenance of a constant level of activity irrespective of environmental temperature as intensity of energy transmutations grows proportionally to temperature**.** Normal temperature of a human body in near 37ºC in so-called body core – organs that need with constant temperature of activity: brain, heart, liver, digestive system.

Body heat interchange occurs by some ways: radiation (absorption), thermal conduction, convection and evaporation. Heat can be radiated more than be absorbed or conversely. Allocation of volumes of heat dissipation between these processes depends on many factors: states of an organism (temperature, physical activity, emotional state, etc.), states of a surrounding medium (temperature, humidity, motion of air, etc.), clothes (a material, thickness, a shape, etc.).

The heat dissipation as the long-wave infrared irradiation emitted by a skin (in which the conducting medium does not accept participation), is strictly featured by Stefan-Boltzmann equation, i.e. radiation is function of the fourth degree from a Kelvin temperature. The maximum of spectral density of an energy brightness of a body of the person at temperature of a skin surface near 32°C is approximately equal 9,5 nm (according to the Wien’s law) and energy loss is near 120J/s. The skin irradiates almost precisely as much energies in a gamut of the long-wave infrared radiation, how many «the complete emitter», or absolutely black body. In case of short-wave infrared radiation (let out by such emitters as electroradiators or the Sun) both emitting, and absorbing skin abilities become much less than 1 (0,5–0,8) and appear dependent from a dermal pigmentation. Correspondingly, the ***Stefan-Boltzmann law*** is used in form for grey bodies:

$R = \alpha \cdot \sigma \cdot T^4$, where α is absorption coefficient of skin or clothes.

As body allocates in environment with temperature differed from absolute zero, exact form of ***Stefan-Boltzmann law is:*** $R = \alpha \cdot e \cdot \sigma \cdot (T^4 - T_0^4)$, where T – body temperature, T_0 – environment temperature, $e = 0{,}98$ – coefficient of skin emittance. Absorption coefficient α for cotton fabric is 0,73, for wool or silk – 0,76.

Radiation from open body parts can consist near 50% of heat dissipation.

Use of thermal radiation in medicine.

Development and improvement of devices and electrooptical transducers has enabled to use photographing, a microscopy, a spectrometry in IR beams in medical practice widely. The infra-red photography is used for survey of the surface veins. The light absorption by blood depends on contents in it oxyhemoglobin (oxygenated hemoglobin – compound of a haemoglobin with oxygen) and a reduced haemoglobin. In IR area these colorants absorbs weakly and almost equally. Therefore blood rather transparent for IR beams irrespective of a extent of a haemoglobin saturation. A scattering by blood is small also. IR radiation, which impinges on a blood vessel, transits through them and inpours into more deeper layers of a skin or subcutaneous adipose tissue, than in those places where vessels are not present. Therefore the field where the vein transits, will differ in a photo. Visibility of veins appreciably depends on specific features of the person (amount of blood in vessels, a hypodermic fatty layer, diameters of vessels, a sex, age). It is used for examination of a vascular system and a circulation and for diagnostic.

IR beams in medicine are widely used for examination of a state of a crystalline lens, an iris and other eye structures at presence of a cataract or opacity of a cornea (albugo). The able-bodied crystalline lens is transparent for IR beams, and at inappreciable opacity IR beams are reflected from a crystalline lens and gives the image in a photo. Mature cataracts are well visible and the structure of a cataract is clear.

Wide use of night viewing devices enables to use IR beams in military medicine (it is possible to find wounded peaple on distances of 150-200 m for evacuation and giving of the first medical aid).

Important role IR beams play in forensic medicine and examination for determination of distance of a shot, the sizes of a wound, tattooes.

Diagnostic of dermal diseases is carried out well: lupus, a skin cancer, infringements of a skin pigmentation, psoriasis, eczema; it is well visible border of pathological changes tissue.

IR beams are used in parasitology.

The molecular structure of medical preparations, antibiotics, vitamins, hormones is studied with help of an IR spectroscopy. Moleculas have the characteristic IR spectrums, on which it is possible to determine presence of particular molecular bonds. A set of energy levels (oscillatory and rotary) corresponds to each interatomic bond; the nuclear environment influences on which precise energy values also. These levels and the relevant nuclear groups are determined by the reference lines IR of a spectrum.

One of the first expedients of reception of a thermal pattern of a body surface was use of liquid crystal films, in which composition there were cholesteric mesomorphous bodies (***liquid crystals***), sensing in different temperature ranges. The color of the liquid-crystal indicators depends on their temperature, i.e. the temperature of the area on the body where they are placed.A film, sensing in the necessary range, imposed on a zone subject to examine, and on a film the distribution pattern of heat on a skin showed.

Thermography

It is method of registration of thermal irradiation of a body. The thermal radiation emitted by the human body can be measured with special infrared sensors (the main transduction elements). Infrared camera consists of IR optics, sensor panel, cooler, amplifying circuit, monitor and computing system. Sensors convert the infrared radiation emitted by the surface of the skin to electrical voltage values proportional to the measured temperatures. IR beams coming on panel with IR sensores, cooled by liquid nitrogen usually, call photoeffect, and electric current amplified in next amplifying circuit, is used for creation of thermogram (heats pattern). Various voltage values can be displayed on a monitor by means of a specific software using different colours, from blue to red.

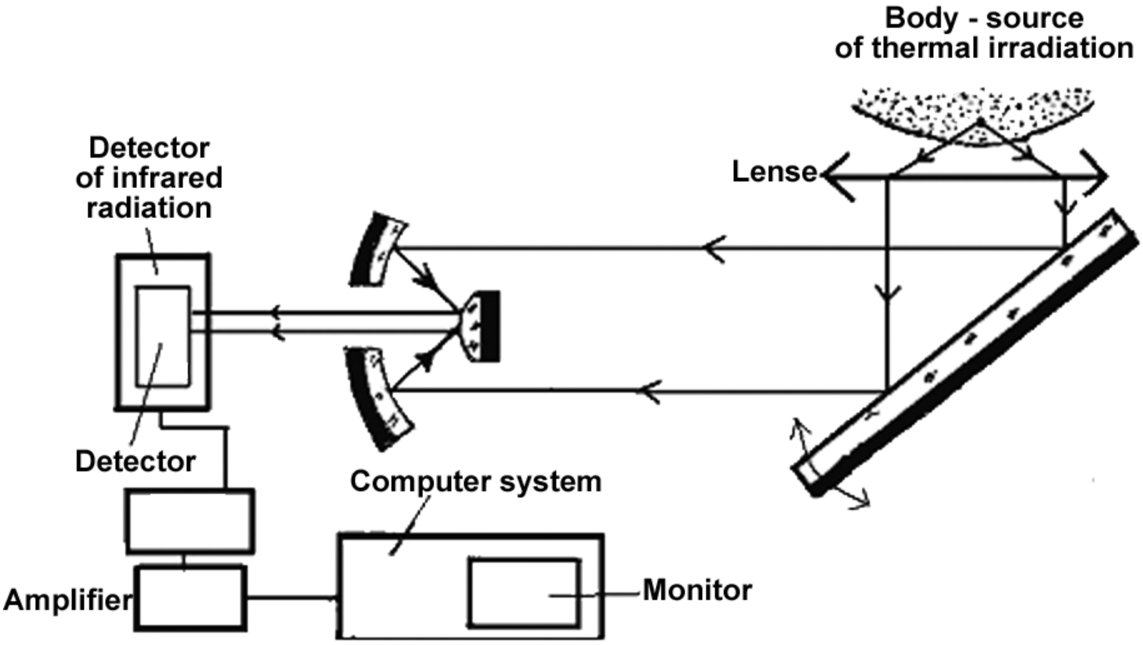
Medical radio thermal diagnostics is thermography using radio band close to IR. These waves penetrate from deep layers of body, as IR radiates from skin surface as it is absorbed easyly in passing from deep zones. Combination of IR and radio thermography with different wave ranges allows to obtain detailed picture of temperature distribution inside the body.

Different types and models of infrared cameras exist on the market. Most of them are used for technical applications such as: night time monitoring, fire fighting devices etc., which require different spectral bands and sensitivity.

Application of a thermography in clinical medicine

Thermographic examinations widely include into medical practice with the purpose of reception of the additional data for diagnostic of different diseases.

Such devices have names as ***thermograph***, thermovision camera, infrared scanner, temperature control unit.



Oncological diseases*.* Development of tumours is accompanied very frequently by occurrence on a heat zone of a thermogram. However the thermal picture of tumours is influenced with many factors; thermo-negative tumours are discovered also.

Thermographic diagnostic of a mammary gland cancer in the best designed. A focal hyperthermia refers to its basic criteria, when a hot spot is found in a field of one mammary gland, which (spot) sizes can change from several millimetres up to 2–3 quadrants (a quadrant – a quarter of mammary gland). Thus the opposite mammary gland remains more cold. The warming of all mammary gland with intensified light emission of a vascular grid is frequently observed; a hot spots are detected in the locations of the lymph nodes involved in an inflammation process, more often - axillary, subclavicular and parasternal.

Thermographic differential diagnostic of a mammalian cancer from a non-cancerous growths and hormonal mastopathy is not so reliable, but it allows to estimate safety and promptly intensity of pathological process and its abundance, to differentiate states, which require urgent interfering, to determine the affected organs, thus potentially dangerous manipulations are expelled.

Diseases of cardiovascular system*.* Disturbed blood supply of the limbs changes their temperature and, hence, the pattern of thermal radiation. *Thermography* it is used in a complex with other research techniques of blood vessels. At patients with an obliterating atherosclerosis and endarteritis on heats pattern caloric radiation of the knocked finiteness is reduced, it ***«thermal amputation»*** is observed. The ischemic infringements is more, the more a temperature gradient between big toe and of a foot and a medial third of hip, which can reach 8°C.

Such examination is very important in survey of patients with a diabetes. It is very important for early detection of microangiopathies, for example, in close relatives of patients that promote duly preventive prophylaxis.

Thermography enables to watch a healthy state after a heart attack. At it state early stage in a heart projection the hypothermic zone with precise temperature drop is observed.

Diseases of a respiratory organs*.* Hyperthermia zone appears in 70-80% of patients on an initial stage of an acute pneumonia on the lesion side. Thermal asymmetry attains 1–3°C. Thermographic changes typical for an acute inflammation, are observed at third of patients, in which the pneumonia is not detected during a X-ray inspection.

***Diseases of digestion orhans*.** Thermography gives the valuable information at diagnostic of different forms of a pancreatitis, a hepatite and other inflammations of abdominal cavity organs. It enables to differentiate affected organs, for example, inflammations of uterine appendages of a uterus from appendicitis.

Self-control material:

B. Test tasks :

1) What phenomena influence temperature of a human skin?
   a) Boiling
   b) Transpiration
   c) Temperature of air
   d) Radiation
   e) A body temperature
   f) Ventilation
   g) Clothes
3) What itself represents a liquid crystal, which use in heat-indicating diagnostic?
   a) Crystals of glass compounds
   b) Crystals of elastic polymeric compounds
   c) Crystals of metals compounds
   d) Crystals of cholesteric polymeric compound
4) What does the heat-indicating film contain?
   a) acetylsalicylic acid
   b) Polyethylene
   c) Lavsan
   d) Catran
   e) Liquid crystal
5) What are basic elements of the Thermograph?
   a) A radio receiver
   b) A television receiver
   c) The refrigerating block
   d) The heat receiver
   e) The transformer of thermal signals in electrical.
6) What is basic feature of the thermograph?
   a) Receives electrical waves in length of 9-23 m.
   b) Receives electrical waves in length 9-23 sm.
   c) Receives electrical waves in length 9-23 microns.
   d) Receives electrical waves in length of 9-23 mm.

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