Laboratory work № 68

The study of the laws of thermal radiation

Objective: to study the basic laws of thermal radiation and determine the the Stefan-Boltzmann and Planck constants, and the calculation of the surface temperature of the Sun.

The flow of light energy falling on the surface of the body is partially reflected, partly passes through it, and is partially absorbed. absorbed energy turns into other types of energy, more often into the energy of the thermal motion of molecules. Therefore, the bodies absorbing light are heated. In turn, in the heated state, all bodies radiate radiant energy in the form of electromagnetic waves of different lengths, that is, they give a continuous spectrum. With increasing temperature, the intensity of radiation of energy increases

Electromagnetic radiation, which arises from the internal energy (the energy of thermal motion of atoms and molecules) of the radiating body and which depends only on the temperature and optical properties of this body, is called thermal or temperature.

Experience shows that the only kind of radiation that can be in equilibrium with radiating bodies is thermal radiation. Let us imagine a heated body in the middle of a thermally insulated shell with an ideally reflecting surface. The body emits energy that is reflected by the shell and is again partially or completely absorbed by it. Thus, between the body and the radiation, the shell is filled, a continuous exchange of energy takes place. If the energy absorbed by the body is equal to the energy lost by the body upon radiation, then the state of the body-radiation system is called the equilibrium state.

The main characteristics of thermal radiation are: integral energy luminosity (integral viprominuvannost), emissivity, absorbing capacity. The flux of radiant energy, Radiated by the unit surface S of the radiating body in all directions (within the solid angle 2π) in all interval of wavelengths, is called the integral energy luminosity of the body Re

$$Re = \Phi / S. \qquad (1)$$

The flux of radiant energy has a power dimension, therefore [Re] = W / m2.Really depends on temperature. We denote the flux of energy radiated by the unit of the surface of the body in tearing the wavelengths $d\lambda$, through dRe. For a small value of this interval, dRe is proportional to $d\lambda$

$$dRe = r\lambda,T\, d\lambda \qquad (2)$$

The coefficient T $r\lambda$, equal to the energy luminosity in a single wavelength interval, is called the emissivity of the body,

[T $r\lambda$,]=(Bm/m*m*m)

The ability of bodies to absorb radiation incident on them is characterized by the absorbing ability of $a\lambda$, T. It is equal to the ratio of the flux of radiant energy absorbed by the body $\Phi\lambda$, T ′, K to the incident flux $\Phi\lambda$, T

(3)

there are functions of wavelength and temperature.

The body that absorbs all the energy incident on it is called absolutely black. By definition, for an absolutely black body, 1 0 $a\lambda$, T ≡ 1 for all wavelengths and temperatures. (In the following, all the notations relating to an absolutely black body will have an upper index of 0). All real bodies are not absolutely black. However, some of them in a certain wavelength range are close in their properties to them. For example, in the visible light region, the absorbing power of soot, black velvet, platinum black is close to unity. The most perfect model of a black body can serve as a small hole in an opaque closed cavity (Figure 1).A beam of light entering the cavity through the hole is repeatedly reflected from the walls of the cavity and loses energy as a result of absorption. Therefore, the intensity of light emerging from the aperture is many times less than what it gets inside. For the same reason, the windows of the neighboring house appear black even on a sunny day. Along with the concept of a black body, the concept of a gray body is used - a body whose absorptivity is less than one, but is the same for all wavelengths and depends only on the temperature, material and state of the body surface.
Thus, for a gray body 1. $a\lambda$, T = aT = const < 1

Using the laws of thermodynamics, Kirchhoff showed that in thermodynamic equilibrium the ratio of emissivity to absorbing is the same for all bodies and is a function of wavelength and temperature - the Kirchhoff law.

(4)

The value 0, T $r\lambda$ represents the emissivity of an absolutely black body. M. Planck showed theoretically that this universal function satisfies the following relation

(5)

Where h is the Planck limit; k –Postion of Boltzmann; c is the speed of light in a vacuum. Integrating the Planck function over the entire wavelength interval, we obtain

(6)

It follows from (6) that the energy luminosity of an absolutely black body is proportional to the fourth power of the absolute temperature, the Stefan-Boltzmann law. Amount

(7)

is called the Stefan-Boltzmann constant. The radiation of gray bodies is Ta times less than the absolute blackbody

(8)

In this case, Ta is called the blackness coefficient. It depends on the body temperature.

The Stefan-Boltzmann constant in this paper is determined experimentally. Then from (7) we calculate the universal physical constant h - Planck's constant.

(9)

The laws of thermal radiation are used for non-contact measurement of high temperatures (the corresponding device is called an optical pyrometer), in heating engineering, lighting engineering.

Description of the experimental setup

Instruments and accessories: an optical pyrometer with a vanishing thread, a source of constant strings. m, a source of thermal radiation, an ammeter and a voltmeter.

The object of the study in this work is a nichrome spiral 1 heated by a DCA direct current source (Fig. 2a). The temperature of the spiral is measured by an optical pyrometer at different values of the power source current indicated by the instructor. The heating current of the spiral is set by the voltage regulator (variable resistor).

The optical pyrometer (Fig. 2b) includes the following elements: an optical system consisting of a lens 2, an eyepiece 5, a diaphragm and light filters 3 and 6; a pyrometric lamp 4 that is connected to the circuit in series with a battery and a rheostat for regulating the filament current of the lamp filament and which serves as a reference for the measured temperature; measuring instrument (V), the scale of which graduated in degrees Celsius.

The determination of the temperature of the spiral (the body being examined) is reduced to comparing the colors and intensity of the radiation of the heated spiral with the colors and intensity of the graduated standard - the lamp thread of the pyrometer. This thread is heated by a current from a battery of accumulators with a voltage of 2-2.5 V. The current in the lamp is regulated by the rheostat, which is enclosed in the handle of the pyrometer. With the help of the lens 2, the image of the helix surface is obtained. It should be in the plane of the lamp thread 4 of the pyrometer, which is achieved by moving the objective 2. Glasses 5 allow to see the middle part of the lamp thread and the surface of the spiral in an enlarged view. The accuracy of temperature measurement is increased if the comparison of the radiation intensity of the body and the reference source is conducted in monochromatic light. Therefore, a red light filter 6 is placed in the pyrometer. 6. At temperatures above 0-1200 C, a smoke filter 3 with a known absorption coefficient is introduced into the optical system. It, weakening the brightness of the helix radiation, makes it possible not to heat the filament of the lamp more than C 0 1400 and thereby maintain the constant calibration of the filament. The measuring instrument has two scales: from 800 to C0 1400 and from 1200 to C0 2000.

$\Phi = P + \Phi_H$ (10)

According to (1) and (8), we obtain

(11)

At temperatures above C 0800 T << T, therefore, the thermal losses associated with the thermal conductivity of the environment and the material of the helix, and hence the last term in (11), can be neglected. Then for the Stefan-Boltzmann constant we obtain the calculated formula.

(12)

where $S = \pi d \cdot \lambda$ is the surface area of the helix (d is the diameter of the spiral wire, and λ is its length). For a nichrome spiral in the temperature range C 0800 – 1400 αT, we find from the graph f (T).

Task 1. Determination of the Stefan-Boltzmann and Planck constants

1. Set the rotary ring of the pyrometer rheostat to the zero position. Turn the unit on and bring the temperature of the spiral to about 0 800 ° C torn glow). 3. Bring the pyrometer pipe to the expressive appearance of a hot spiral and spill- to clean the filament of a pyrometer lamp with a spiral. rotary the clockwise rheostat rings bring the filament of the lamp up to the same brightness as the brightness of the spiral. Remove the sample temperature by corresponding to the scale of the pyrometer.

1. Set the rotary ring of the pyrometer rheostat to the zero position.

2. Switch on the unit and bring the temperature of the spiral to about 0 800 ° C torn glow).

3. Bring the pyrometer pipe to the expressive appearance of a hot spiral and spill- to clean the filament of a pyrometer lamp with a spiral. rotary the clockwise rheostat rings bring the filament of the lamp up to the same brightness as the brightness of the spiral. Remove the sample temperature by corresponding to the scale of the pyrometer.

4. Make 4 more measurements, increasing each time the glow of the helix by 0.5 A.

5. After finishing the temperature measurement, output the voltage regulator on the spiral and the rheostat of the pyrometer at minimum voltage and exclude installation.

6. From formula (12), calculate the Stefan-Boltzmann constant. using the value obtained $<\sigma>$ Using formula (9), calculate Planck's constant.

7. Record all measured and calculated values in the table.

The size $\Delta\sigma$ is calculated by the standard procedure for statistical data processing of the experiment, Δh
is estimated by finding the differential of formula (9), expressing $h = f(\sigma)$
The final result is written in the form: $\sigma = \langle\sigma\rangle \pm \Delta\sigma$, $h = \langle h\rangle \pm \Delta h$., For α =.

Task 2. Calculation of the surface temperature of the Sun.

Considering the Sun an absolutely black body and knowing the Stefan-Boltzmann constant $<\sigma>$, you can determine the surface temperature of the light. Indeed, the light flux emitted by the Sun is
$\Phi = R\ S = \sigma\ T\ S = \sigma\ T \cdot \pi\ r$,
where SC – is the surface area of the Sun, rC – is the radius of the Sun. This stream radiates the Sun into a sphere, radius a r which is equal to the distance from the Sun to the Earth (the radius of the Earth's orbit). On unit of the surface area of the Earth there is a flow

The quantity K is called the solar constant and is equal to K =1,39·10 Дж(м^2*с)
Then the surface temperature of the Sun will be
Astronomical parameters: ra km 8 = 1.50 ·10, rc km 5 = 6.95·10.

Control questions
1. What radiation is called thermal radiation? What are its features?
2. Define the main characteristics of thermal radiation: the energy world- emitting ability, absorbing capacity.
3. Which body is called absolutely black? Gray?
4. Formulate the laws of thermal radiation: Kirchhoff, Stefan-Boltzmann.
5. What does the black ratio show?

6. Obtain a formula for finding the absolute error in calculating Planck's constant.
7. What is the principle of measuring the temperature of a pyrometer with a vanishing thread? ·

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