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Thermodynamics of Internal Combustion Engines without Carnot Axioms

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THERMODYNAMICS OF INTERNAL COMBUSTION ENGINES
Without Carnot Axioms

2. PREFACE

Thermodynamics, as a discipline, has its history and is related to the technology of heat engines. We will consider the processes that occur in internal combustion engines and the cycles that take place therein. It seems there are so many different works on thermodynamics that one might wonder what a new one is needed for. To understand this question, let's consider the following:

"The change in the ideal Otto air cycle compression ratio is shown by the upper curve in Fig. 16-5. Comparing this curve with the corresponding curve for a real Otto internal combustion engine (Fig. 16-5) shows that the study of the ideal air cycle gives a compression ratio significantly higher than that of a real engine, although in general the curves are similar." (Ref. 1. Page 149).

This fact directly points to the discrepancy between theory and practice. In this situation, the necessity of revising the theory and bringing it in line with practice becomes obvious. And is this really necessary when we have cars, planes, rockets, etc.? But this is fundamentally a question of the relationship between theory and practice.

Only that theory is correct which reflects the properties and relationships of the material world.

We say that the law of correspondence is observed, or what we show on paper or any other information carrier is identical to what exists in nature.

Any other opinion is fraught with errors and misconceptions, leading to a distorted understanding of the world, followed by a subsequent adjusting the theory to fit the practice.

We will systematically examine all the processes that make up the power cycle of a machine, so that it will become obvious how a heat engine works and how it is connected with the properties of the material world. Because we cannot invent heat engines as we wish. A heat engine can only include what exists in nature, or in other words, a heat engine can only utilize the possibilities given by nature.

3. Introduction

Comparison with the height of a lifted load

Here, we have to specify the methods we use to illustrate and analyze thermodynamics. Thermodynamics encompasses two components: first, what takes place or proceeds in nature, and second, quantitative representations of the processes taking place in nature and thermal engines. The processes examined by thermodynamics are, in one way or another, associated with mechanical work, and the goal of quantitative representations is to determine how much work we need to expend, or how much work we can obtain, or what gain in work we can achieve, and so forth. To obtain these estimates, we use the method of comparison of all the processes under consideration with the height of a lifted load. The load is represented by some object existing in nature. If the lifting of the load can be accomplished by a person, the falling of the load occurs in nature independently of human will. The processes investigated by thermodynamics also occur in nature, and by comparing them with the height of a lifted load, we bring them or their entirety into a single, common measure of work expressed in the same units, which allows us to compare the separate processes with each other as well as their combinations and totalities.

Another extremely important property of a lifted load is the precise observance of the laws of conservation. Namely, we can take a certain load and lift it to a certain height; then, we release the load, and it begins to fall. But in this case, the following takes places: the work done to lift the load takes the form of potential energy and is represented as $A = gh$, where A - mechanical work, g - the weight of the load, and h - the height of the lifted load.

During the falling of the load, work is released in the form of kinetic energy, and the amount of work released is shown by $A = gh$. Thus, the law of energy conservation is presented as follows: the amount of work expended to lift the load is equal to the amount of work obtained during the load’s falling. So by demonstrating one of the forms of the law of energy conservation, we indicate that we derive this law from nature, and this law and nature possess correlation. But here, however, we have to specify under what limiting conditions the law of work conservation remains valid.

This question pertains to the physical sense of our actions performed on an object. When lifting a load, we are thus taking some amount of energy away from the Earth. During the falling of the load, the Earth brings back the energy that was taken away.

And now, let's assume that we lift a load and maintain its height for a certain period. During this period of time, the Earth undergoes certain changes, and the load itself may change somehow. Therefore, the limiting condition for the implementation of the law of energy conservation is the execution of actions on material objects over a short period of time. Such a limiting condition ensures a reliable approximation to the truth in understanding the nature. Hence, by comparing the undergoing processes with the height of a lifted load, we can always evaluate them from the point of their adherence to the law of energy conservation, both separately and in total.

Now, we need to pause and consider the quantitative or numerical methods used in thermodynamics.

4. Numerical Methods Used in Thermodynamics

What is a number? This question remains unclear in modern mathematics, and there is a common belief that numbers are virtual and invisible, leading to the absence of a concrete definition of a number. Some even hold the view that numbers come from a divine source, and so on. Such views of numbers are of limited use for understanding thermodynamics in particular and physics as a whole, mainly because the concept of numbers is deeply saturated with idealism, which can entail false notions about the material world.

That's why, in order to understand what a number is and what its nature is, we will start with a materialistic view of numbers, which represents a comprehensive generalization of all known mathematical experience. And after that we will provide a philosophical definition of a number.

A number is a philosophical category reflecting the properties of the material world.

The world presented to us possesses a multitude of properties. Let's consider some of them. In the material world, we have objects - bodies that possess the property of volume. These bodies exist in space, which, in turn, also possesses the property of volume. Thus, the property of volume is common to the material world. Numbers, as a reflection of the material world's properties, also possess the property of volume. But now the question arises: how can we see and understand this?

To comprehend the nature of numbers, we will undertake a series of actions with material objects. For the sake of clearness, let's take a body and a water

droplet. Ancient philosophers used to say that the whole world is reflected in a water droplet! We will illustrate all actions performed on the body (Fig. 4.1).

Here, we specially specify the most important point - we do not use various axioms and postulates.

We are guided exclusive by the law of correlation.

It is known that numbers have the property of sequence. Therefore, we take identical water droplets and arrange them in a sequence as shown in Fig. 4.1, Series A). We number them using the digits 1, 2, 3, 4, ..., and our sequence gains meaning. The sequence itself is presented as steps, i.e. one number follows the other, so in this way we represent the quantity of natural objects. It may seem that this is what numbers are. But as a matter of fact, we have shown not the number itself but only a set of some units.

Sequence and set form just one of the properties of numbers. And to achieve a more comprehensive understanding of what a number is, we will perform the following.

We will repeat Fig. 4.1, Series A, and place it above Series A, but shifted one unit to the right. We can repeat this action as many times as we wish. The result of our actions is shown in Fig. 4.2. Now, above any digit, we can see the quantity of our units: above the digit 4 we have four water droplets, and to the left of the digit we also have four units. Thus, choosing any digit, we see an equal number both above and to the left of the digit, which creates structure and form. This form is called a triangular number. Please note: a triangular number includes an orthogonal feature, or a rectangular triangular number.

The orthogonal feature is one of the properties of the material world. Structure, form, sequence and set are also the properties of the material world. A triangular number has one more name – sum.

Now, let's consider the reason behind this phenomenon. Let's take a unit (Series B), add a similar unit to it and read the result above the number 2. Then we add one more unit and read the result above the number 3. We can repeat this action as many times as we wish.

This action is called addition, or figuratively speaking, we put all the eggs in one basket. But now, we will perform the following action: we will take a glass and start filling it drop by drop with water. But then we will find out that there is a certain amount of water in our glass, but we cannot distinguish a single

water droplet in it. The process of droplet merger is summation of up to the whole, and the final result is called a sum.

Now let's build a new series of natural quantities (Series C). To construct this series, we take a natural quantity - a water droplet - and place it in Series C under the number 1. Then we take two water droplets, find their sum, get a new droplet of water and place it under the number 2. We can continue this operation as many times as we wish. Consisting of the whole natural quantities, Series C has certain features. The quantity located under the number 1 is considered to be the initial one and is taken as figure 1. The quantity located under the number 2, being a whole quantity, is twice as much as the initial one. The quantity located under the number 3 is three times greater than the initial one, and so on. All subsequent quantities located under the number N are N times greater than the initial one.

Series C represents a set of whole natural commensurate quantities, or units. But now, there exists a clear mutual correlation between Series C and Series B. Series C, i.e. the sum, can be factorized into a triangular number. This possibility shows us another property of numbers, called divisibility. In other words, we can take any quantity in Series C and divide it into a number of equal units. For example, let's take a whole commensurate quantity – figure 5, divide it into five equal parts, and we'll get a set of whole natural quantities of figure 5, where each unit is equal to the initial one in Series C and Series B alike. Series C, or the sum, can be constructed by taking any quantity as a unit, including infinitesimal quantities. The law of distribution of natural commensurate quantities, units, remains constant and is formally expressed as:

$$A = n + 1$$

Рис. 4.1

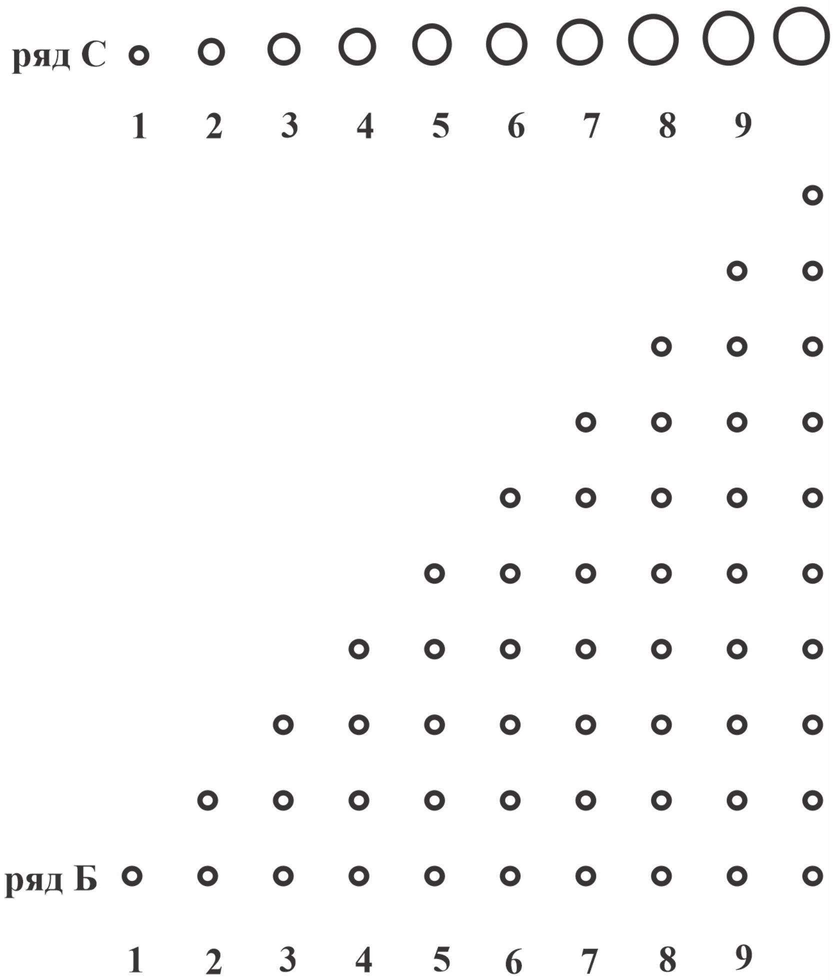

Рис. 4.2

Now, we are going to investigate a new property of numbers, which is called difference. We say "to subtract", i. e. to perform an action, and that is why we'll continue to perform actions with natural quantities. To do this, we'll take the natural quantity located above N 9 in Series C and subtract the unit located above N 1. We will illustrate this action in Series B.

Series B was constructed as a triangular number, a sum. However, difference is an action that is opposite to addition. Therefore, we will place a natural quantity-unit to the left of the ninth unit and above the units located above N 8. Under these conditions, we can read the result under the units, which is 9-1=8. Then we take two units, place them sequentially, one above the other, above the units located above N 7. Under these conditions, we can read the result under the units, which is 9-2=7. We will continue to perform our actions, but here we need to consider the action 9-9 = 0. This action can popularly be depicted as taking place within our field of vision or perception.

Let's imagine a table with no objects on it. We say that the table is empty, but we can still see the table and its surface. In essence, this is our field of perception. We have deliberately limited this field to the surface of the table to facilitate the consideration of subsequent actions. However, it's important to remember that our field of perception is the entire world.

Suppose there are nine units in our field of perception. We sequentially perform the subtraction action and consequently remove the subtracted natural units from our field of perception. Eventually, we reach a state where there are no natural quantities-units. In formal notation, this state is represented as 9 - 9 = 0. The symbol 0 is pronounced as "zero" and means the absence of anything. There is another meaning of the symbol 0, which is used in mathematics: 0 is null, which originates from the Latin word ORIGO, meaning "beginning." Suppose we place one natural quantity into our field of perception, and therefore, null signifies the beginning of some actions.

And now, let's look at Fig. 4.3. We see a set of orderly arranged bodies, units, forming a square. Let's draw a line connecting the first and ninth units, and this line takes on the meaning of the square's diagonal.

Now, if we cover everything lying above the square's diagonal, we will see a triangular number, sum. Then, if we cover everything below the square's diagonal, we will see a triangular number, difference. Pay attention to the units lying on the square's diagonal; they belong both to the triangular number - sum and the triangular number - difference.

This property indicates that the properties of addition and subtraction belong to or are attributes of exactly natural quantities.

We have factorized the whole natural commensurate quantities in Series C, using the ordered number, into the structure of a square that includes both the properties of sum and difference, which, in fact, represents a number. Thus, a series of whole natural numbers-squares unambiguously corresponds to a series of whole natural commensurate quantities. Let's continue to consider the properties of a number.

We can regard the whole natural quantity-unit, from which a natural number-square is constructed, as an infinitesimal quantity. Figuratively, we can think that as a natural number-square is formed from natural quantities, represented by atoms of a certain chemical element. The whole natural number-square will be shown as a plane.

In the real world, we encounter objects that have surfaces. A flat number allows us to perform calculations of any surfaces, because a flat number encompasses all kinds of geometry on a plane, or in other words, a flat number is primary, while geometry is secondary. It may seem that geometry is independent of numbers, since it covers various kinds of construction with the use of a compass and a ruler.

Let's go on considering the properties of numbers. To do this, let's express the number shown in Fig. 4.3 as a relatively infinitesimal quantity. We will obtain a number-square consisting of cubes. The natural quantity-unit in a series of whole natural numbers represents a sizeable square indicated in Fig. 4.4. The series of whole natural numbers has a cubic or lattice structure, which constitutes one of the properties of the material world. A whole natural number-square encompasses the properties of both addition and subtraction.

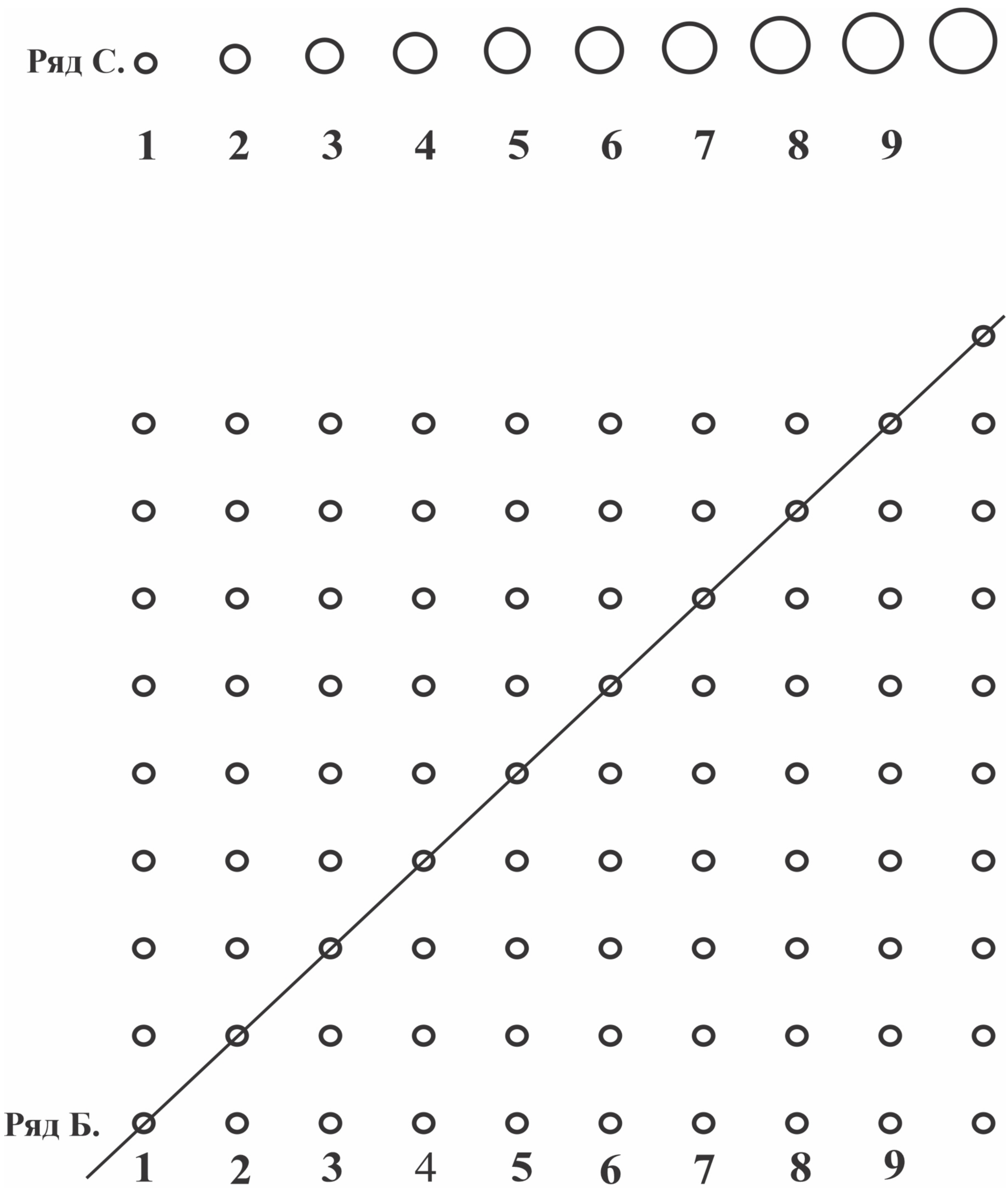

Рис 4.3.

Now, let's consider the next property of numbers, which is called product or multiplication. Multiplication is not an operation on natural quantities. For example, if we take any two natural quantities and try to multiply them by at least two, we won't achieve four natural quantities. Therefore, we will illustrate multiplication as a property of orderly arranged bodies.

But first of all, we will investigate the following question: what symbols do we use or what does a set "1234..." mean? People have long believed that these are numbers. The word "number" itself comes from the word "numerosity." We use - 0123456789; these are none other than letters, symbols, digits that we use to indicate numerosity or a set. Then comes the enumerated sequence and then - counting. And now, actually, this is none other than a written and oral form of communication, which is used to convey information from one person to another. Understanding the question of what a number means at the level of "1234..." is essentially "narrow or primitive", because a set is just one property of the material world and, as a consequence, just one property of numbers, since a product or number is a philosophical category that reflects the properties of the material world.
Multiplication... If we look in an arithmetic textbook, we will see the following (Fig. 4.5).

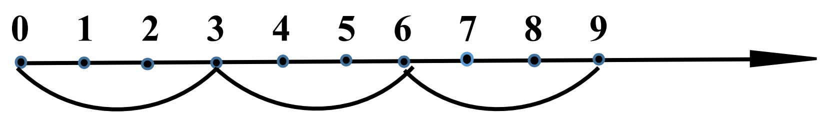

Рис. 4.5

On the number axis, we indicate a segment equal to three units. Then, we take similar segments three times. In this way, we have multiplied three units by three, resulting in nine units. Such a demonstration of multiplication is only an interpretation, which does not provide us with a complete understanding of multiplication or exponentiation.

That's why we will consider multiplication as a property of orderly arranged bodies. Multiplication inherently includes an orthogonal feature or rectangularity, and this is vividly demonstrated in Fig. 4.4.

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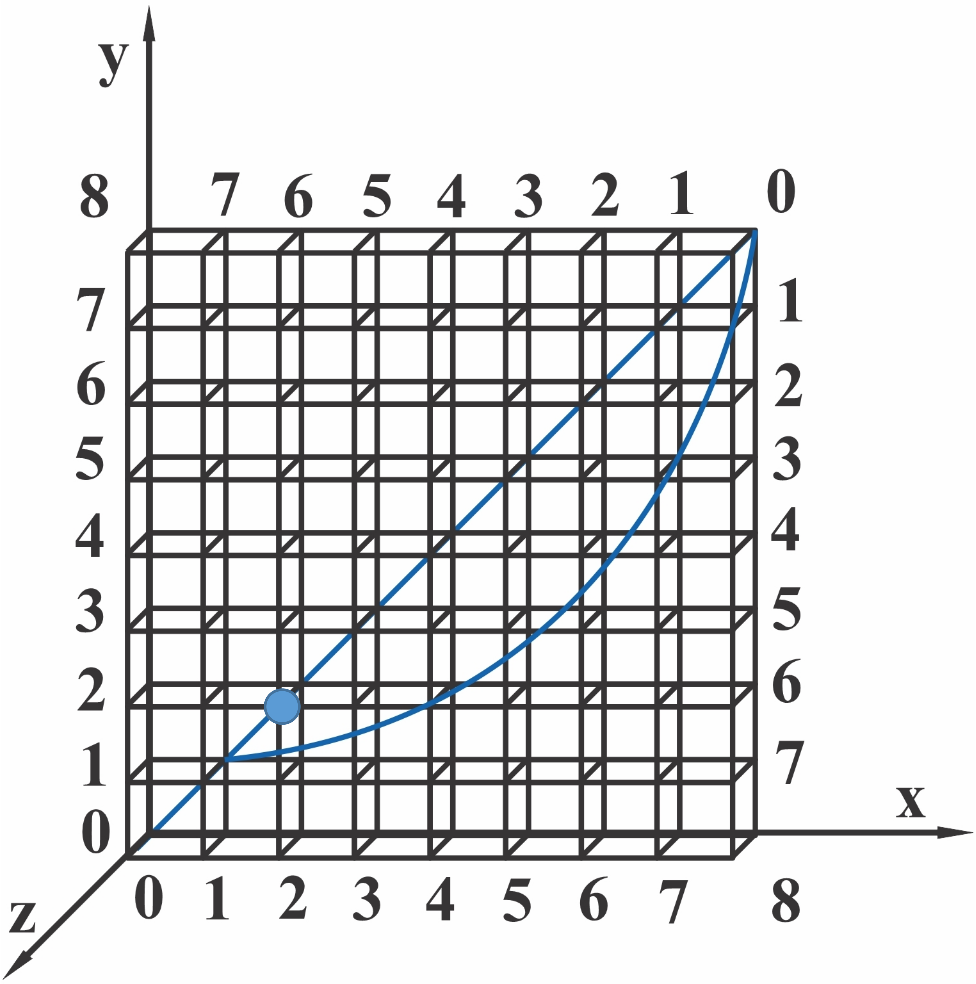


Рис 4.4

The orthogonal feature reflects the property of Earth's gravitational field and other fields. A whole natural number-square identically corresponds to a natural commensurate quantity. In formal notation, a number is characterized by parameters, where X-axis represents the abscissa or the horizontal direction of number distribution, the Y-axis represents the ordinate or the vertical direction of number distribution and the Z-axis represents the z-axis or the distribution of number by thickness. Let's consider the example mentioned above. For this purpose, we'll take a whole natural commensurate quantity that is twice as large as a unit. It identically corresponds to a whole natural number-square.

In formal notation, its parametric form looks as follows $X = 2\,R^3$, $Y = 2\,R^3$, $Z = R^3$, where the symbol R denotes the proportionality of the number, indicating that this formal notation belongs to the series of whole natural numbers, where each whole unit is a cube.

Let's show the second form of formal notation: $X = 2l$, $Y = 2l$, $Z = l$, where the symbol l denotes the proportionality of the number, indicating the length of the edge of a single cube.

And correspondingly: $R^3 = l \times l \times l$ **.**
$R^2 = l \times l$ **represents the proportionality of a flat number-square or a facet of a cube. Thus, the product is directly connected with the number's structure and represents a characteristic of the location of a natural quantity.**

The square of a geometric figure. This concept is used in geometry and other applications. Let's consider a simple example. In Fig. 4.4, we indicate the location of the natural quantity 2 with a colored dot.

A whole natural number-square identically corresponds to this quantity, and in parametric form it is represented as $Y=2R^3$; $X=2R^3$; $Z=R^3$. In formal notation the square looks as follows: $2^2\,R^3$, and the area of the square is $2R^3 \times 2R^3 = 4R^3$. The linear form of square representation is $X= 4R^3$, or the measurement of the square. We convert all our actions on numbers into a linear form of number representation or measurement. It is through measurement that we can compare: how many times one is greater or smaller than another.

Let's provide another one more example of product or multiplication (Fig. 4.6). We show the whole natural number 3, to which the natural quantity 3 corresponds. The whole natural number, in parametric form, looks like $X=3R^3$; $Y=3R^3$; $Z=R^3$, and is represented as the square 3^2R^3. The square is represented as $3R^3 \times 3R^3 = 3^2R^3$. It becomes evident that the orthogonal feature is an attribute of a product and, consequently, an attribute of the square since it belongs to a natural number. Furthermore, the square can be represented as $3R^3 \times 3R^3 = 9R^3$. This is the linear form of square representation at the level of numerosity or a set of natural units. However, understanding a product as it is demonstrated in Fig. 4.5 remains narrow or one-sided, and therefore incomplete. A product is a characteristic of the location of a natural quantity and in this connection multiplication is not an operation on numbers.

Let's provide another example of multiplication (Fig. 4.7).

For this purpose, we take our square and multiply it by its side, with the number being correspondingly represented as $3R^3 \times 3R^3 \times 3R^3 = 3^3R^3$. Such number is called a cube. The physical meaning of such number is the location of the natural quantity 3, which is represented as $X=3R^3$; $Y=3R^3$; $Z=3R^3$. We indicate the location of the natural quantity with a dot. We can show the linear form of cube representation as $3^3R^3 = 27R^3$. Using the orthogonal feature, we can show the number to the fourth power as $3^3R^3 \times 3R^3 = 3^4R^3$. To demonstrate the number representation, let's perform the substitution $3^3R^3 = F^3$. And the entire number to the fourth power is represented as $3F^3$, i.e., this is a linear form of the number. Thus, we demonstrate the very possibility of performing substitution, provided it does not contradict the laws of number distribution.

Let's show the number to the fifth power using the orthogonal attribute $F^3 \times 3F^3 = 3^2F^3$, i.e., the number to the fifth power is represented by a square. Let's express this number in the following dimension R^3; $(3^{3+2}R^3 = 3^5R^3)$

In this manner, we can show numbers to any power, and the essential point here is that a product is a characteristic of both the location of a natural quantity and its movement. We demonstrate exactly the property and potential of a product, which does not go beyond the three-dimensional representation of the number, because the number inherently has a volume, and the product b is the number's attribute.

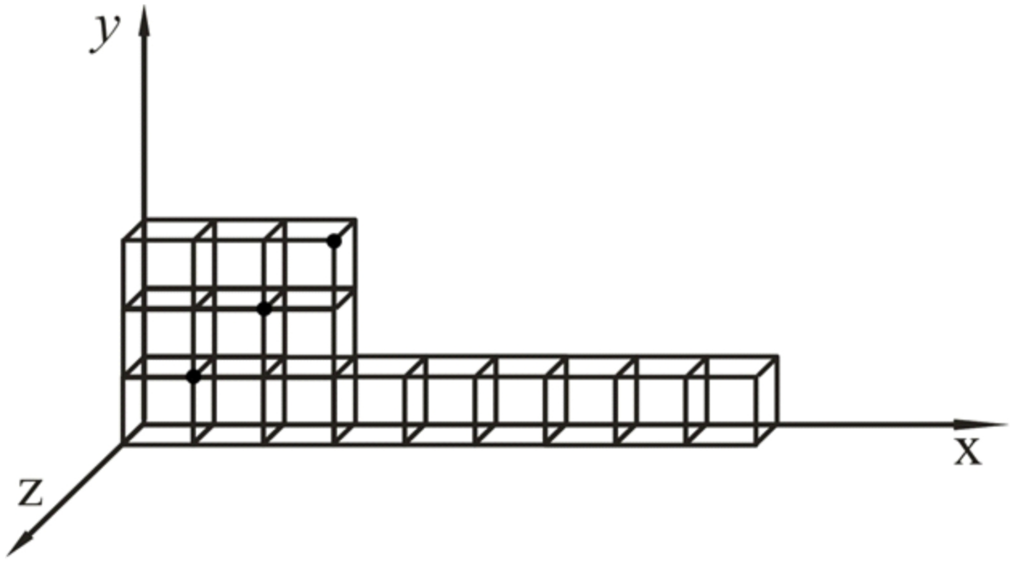


Рис. **4.6**

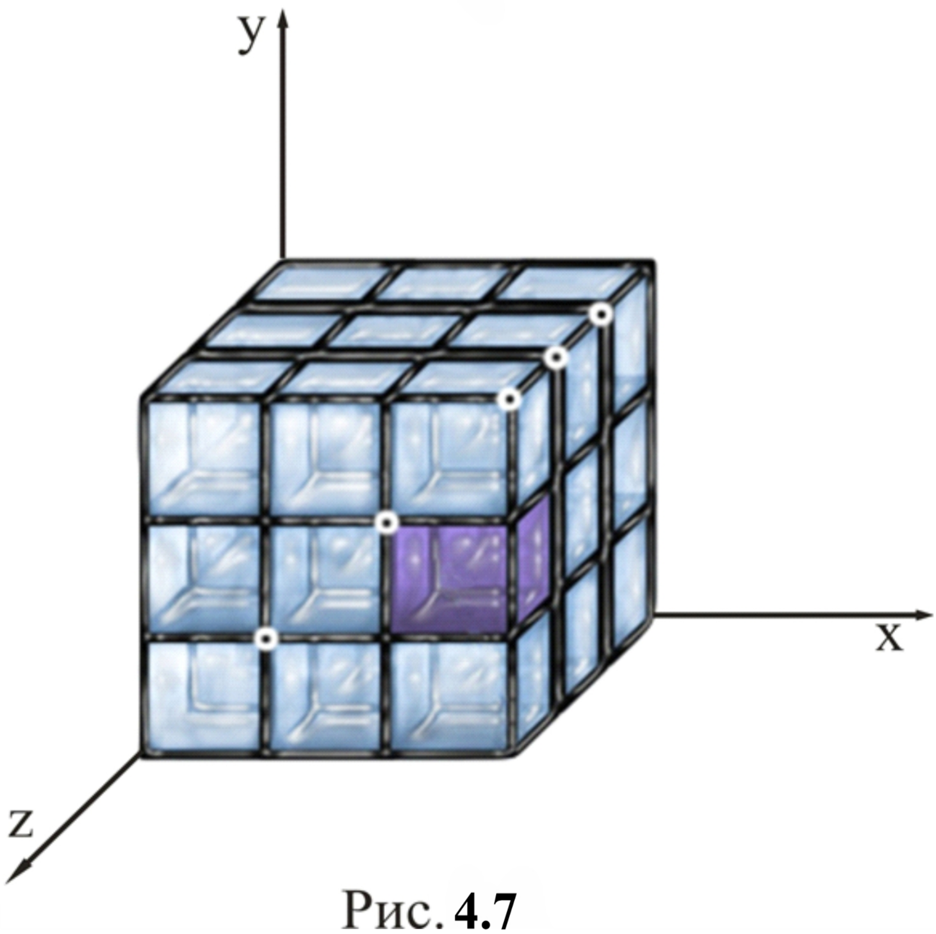


Рис. **4.7**

Proceeding in a similar manner, we can demonstrate numbers to any power, and the significant aspect here is that a product is a characteristic of both the location of a natural quantity and its movement. We highlight exactly the property and potential of a product, which does not exceed the boundaries of three-dimensional number representation, because the number inherently has a volume, and a product is the number's attribute.

And now we are going to consider the next property of the number - divisibility.

DIVISIBILITY OF NUMBERS: We derive the general concept of a fractional number from common notions of the number. In Fig. 4.2, we show the interconnection between the quantities located in Series (C) and those in Series (B). By using this interconnection, it is not difficult to see that if we take a quantity equal to one located in Series C under N 5, we can break this unit into 5 equal parts, with the size of one part being equal to the initial unit under N 1.

Thus, one and the same quantity, in different counting systems, takes on different values. For example, a quantity located in Series C under N 5 in Series B's calculus system is represented by five whole quantities equal to the initial one. But if we take the quantity equal to one and located under N 5 as a standard, then the quantity equal to one and located in Series B will be five times smaller than a given one, which highlights the relative properties of calculus.

A fractional number, like a whole number, is relative and has a numerator and a denominator. In the denominator, we indicate how many physical units the standard quantity is divided into, and in the numerator, we indicate how many units we take from the denominator's quantity. Thus, both the numerator and the denominator are expressed in one and the same standard system and are commensurate, while the numerator is represented by a simple number.

In the notation, a fractional number is represented as aR^3/bR^3, where $a < b$. Such numbers are called the rational fractional numbers.

It becomes evident that the property of number divisibility is a possibility inherent in the unit at the beginning - the genome of a number, i.e. dimension. To illustrate this, we will construct it in the R^3 coordinate system (Fig. 4.8). The first division yields R^3 / 2, i.e. two halves of a cube, from which we take only one half. Figuratively, this can be represented as a transparent vessel in the shape of a cube, located horizontally, into which we'll pour some water.

The water in the cube will occupy its position, and the water level h in the vessel characterizes its fullness. We take only its filled part, i. e. half of the cube. Next, we can perform the following division of the cube, i.e. $R^3 / 3$; $R^3 / 4$; R^3 / N; but each time, we will obtain $R^3 / N = hR^3$, if $h \to 0$, we will get a plane - a square. This plane is the ZX plane. The very concept of a plane is, in fact, a boundary between the two media. Obviously, we use properties of the material world, not geometric representations.

Let's show the parametric form of divisibility for R^3:

- **$Y = R^3 / N$; $X = 1$; $Z = 1$**
- **Similarly, $Y = 1$; $X = R^3 / N$; $Z = 1$**
- **Similarly, $Y = 1$; $X = 1$; $Z = R^3 / N$**
- **Similarly, $Y = R^3 / N$; $X = R^3 / N$; $Z = R^3 / N$**

Obviously, if $N = 2$, then $Y = R^3 / 2$; $X = R^3 / 2$; $Z = R^3 / 2$, we'll get a new cube t^3, where $R^3 = 8\ t^3$. By performing this action, we have calculated R^3 with regard to t^3, i. e. we have found the volume of the cube = $8\ t^3$, the area of the cube = $8\ t^3$, the length of the cube = $8\ t^3$. We can evidently continue to divide the cube, but each time, we will get smaller and smaller cubes $ti^3 = R^3 / n^3$, for which we can calculate a cube and any of its parts with any desired approximation.

Next, we will consider how the property of divisibility of a unit works for rational numbers, or, in essence, the law of difference. Our conclusion is as follows: the number-to-number ratio is an action on quantities and, correspondingly, on numbers.

Numbers, which are called prime numbers, or numbers that cannot be factorized, are numbers, whose ratio is irreducible. However, the result of division of these numbers does not depend on these properties, since when we perform the operation of division on these numbers, we pursue a certain goal. Let's demonstrate how the division of prime numbers is carried out.

Given: numbers a and b, find the ratio of these prime numbers. Let's impose the following condition: $a < b$, and give these numbers a parametric form:

- **$YR^3 \cdot ZR^3 \cdot aXR^3$**
- **$YR^3 \cdot ZR^3 \cdot bXR^3$**

In Fig. 4.9, we construct these numbers. We show two numbers, located one above the other.

When considering the physical properties of numbers, we talk about their structure and form, but here the content of numbers is considered, too. Obviously, we are talking about the space represented by volume, but what are the properties of this space? We can consider such space as mobile or flowing. We can draw an analogy, for example, considering the number's volume as a material liquid, for instance, water.

Now, let's think as follows: let the number aR^3 be a vessel filled with water, having the shape of the number aR^3, and let bR^3 be an empty vessel, having the shape of the number aR^3, while the number bR^3 is an empty vessel, having the shape of the number bR^3.

We will pour the water from the vessel aR^3, which represents a volume, into the vessel bR^3, provided the vessel bR^3 is placed horizontally. The liquid in the number bR^3 will take on some position, which will be represented in parametric form. Each unit in the number bR^3 will be represented by a square with a base $XR \times ZR$ and a height hYR.

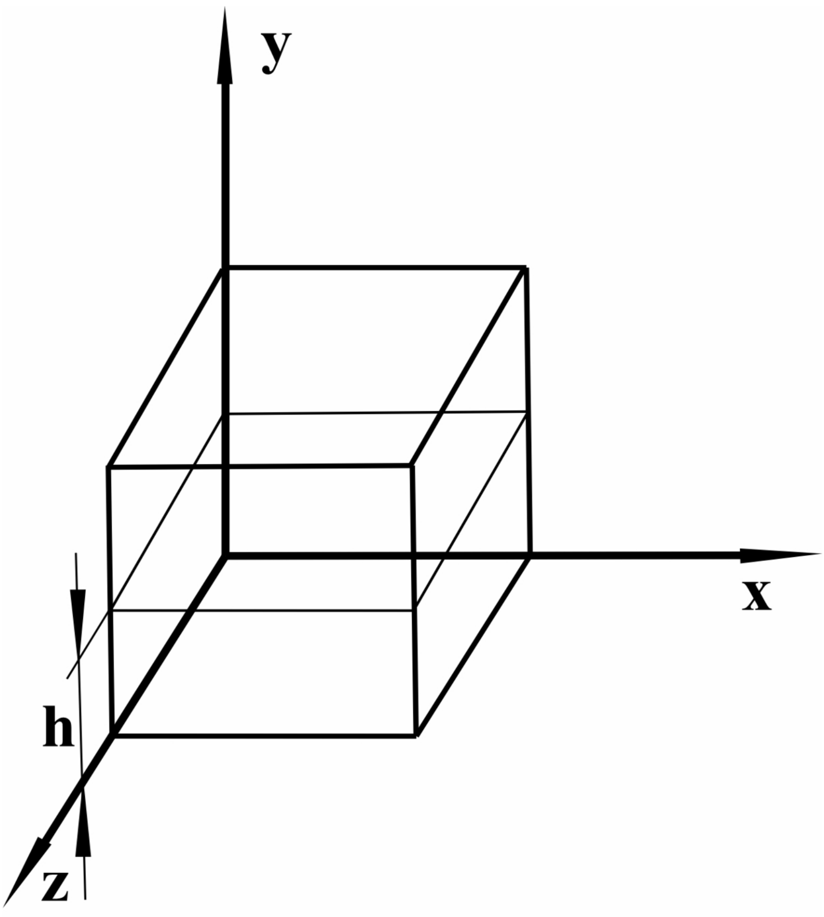


Рис. 4.8.

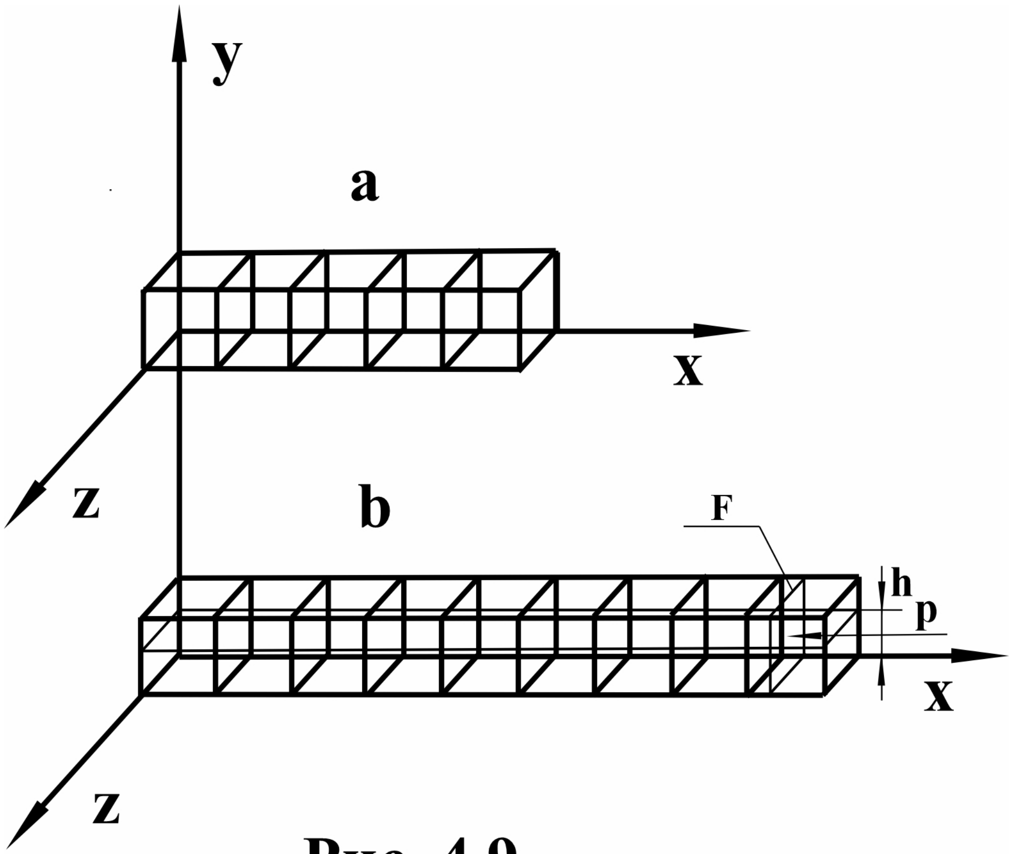


Рис. 4.9.

The height h we have found is the ratio of two numbers: $aR^3/bR^3 = hR^3$.

Such a number is a whole number in terms of its base, because it is represented by a square, and it is a fractional number in terms of its height. Let's provide a definition for an empty number: an empty number is an imaginary number that possesses only a structure, a form of a whole natural number.

We can perform the division of a prime number by a full prime number, i.e. $aR^3/bR^3 = (1 + h)R^3$. But in this case, we obtain the sum of two prime numbers: $aR^3 + bR^3 = b(1 + h)R^3 = CR^3$. We can also obtain the difference between two prime numbers: $bR^3 - aR^3 = b(1 - h)R^3$. Besides, we can express the number aR^3 relative to bR^3 as follows: $bR^3 \cdot hR^3 = aR^3$.

And now let's explain the principle of obtaining the number aR^3 relative to the number bR^3. To do this, we'll construct the number $bR^3 \cdot hR^3$ (Fig. 4.9).

Let's think as follows: suppose we have the number bR^3, composed of units hR^3 which are filled with water up to the height h, where $h < (YR = 1)$. In this number, there is a partition F, which we smoothly move along the number bR^3, thus displacing the liquid up to the partition. As a result, the height h increases, while an empty number remains beyond the partition.

As the liquid is displaced, we come to a state where some units up to the partition turn out to be complete, i. e. they'll have the volume $R^3=1^3$, while some units reach their full volume simultaneously. Let's provide a simple example: Given: $aR^3 = 3R^3$; $bR^3= 7R^3$. Find the ratio $aR^3/bR^3= 3R^3/7R^3= hR^3= 0.428571R^3$

$aR^3=bhR^3=0.428571 \times 7 = 3R^3$.

The number bR^3 is the smallest whole number multiplied by h that gives the whole number aR^3. When multiplying the number $(b\pm1)R^3$ by h, we obtain only a fractional number.

The unit represented as $XR \times ZR \times hYR$ is not a complete cube, and we can transform it in two forms.

The first form is to take the product $ZR \times hYR$ and obtain from this number a square $(ZR\cdot hYR)^{1/2}=\ell^2$ However, such a square is a fractional number, and the volume of the body will become $XR \times Z\ell \times Y\ell$. But such a number has only one edge XR, about which we say that it is represented by a whole unit. The remaining two edges, $Z\ell$ and $Y\ell$, are represented by fractional numbers, since $\ell < 1$.

The second form of transforming an incomplete cube: let's take the product $XR \times ZR \times hYR$ and transform it into a cube $(XR\cdot ZR\cdot hYR)^{1/3} = t^3$. Such a cube is a fractional number, since $R^3=1^3>t^3$ is a different dimension of the number. The volumes of these numbers are equal: $hR^3= XR\times Z\ell\times Y\ell = t^3$.

Now let's consider the division of a square by a square.

The theorem states: Given a^2 and b^2, find the ratio of these squares. We impose the condition $a < b$. Then we give these squares a parametric form: for a^2; $Y = R^3$; $X = aR^3$; $Z = aR^3$. For b^2; $Y = R^3$; $X = bR^3$; $Z = bR^3$. Let's perform the construction (Fig. 4.10). We'll think in the following way: let the square $a^2 R^3$ be a vessel filled with water, and the square $b^2 R^3$ be an empty vessel. Let's transfer the water from the vessel $a^2 R^3$ to the vessel $b^2 R^3$, on condition that the vessel $b^2 R^3$ takes a horizontal state.

The liquid in the vessel $b^2 R^3$ will take its position, and we'll see the level h, or the filling of the number $b^2 R^3$.

However, the following question arises here: how can we find the quantity h? The numbers $a^2 R^3$ and $b^2 R^3$ are volumetric bodies, for which the properties of numbers - volume, square and length - are correct, they are quantitatively equal. That's why, we represent each number in a linear form, i.e., as a simple number of the form nR^3, $a^2R^3 = n_1R^3$; $b^2R^3 = n_2R^3$.

The ratio will take the following form: $n_1R^3 / n_2R^3 = hR^3$.

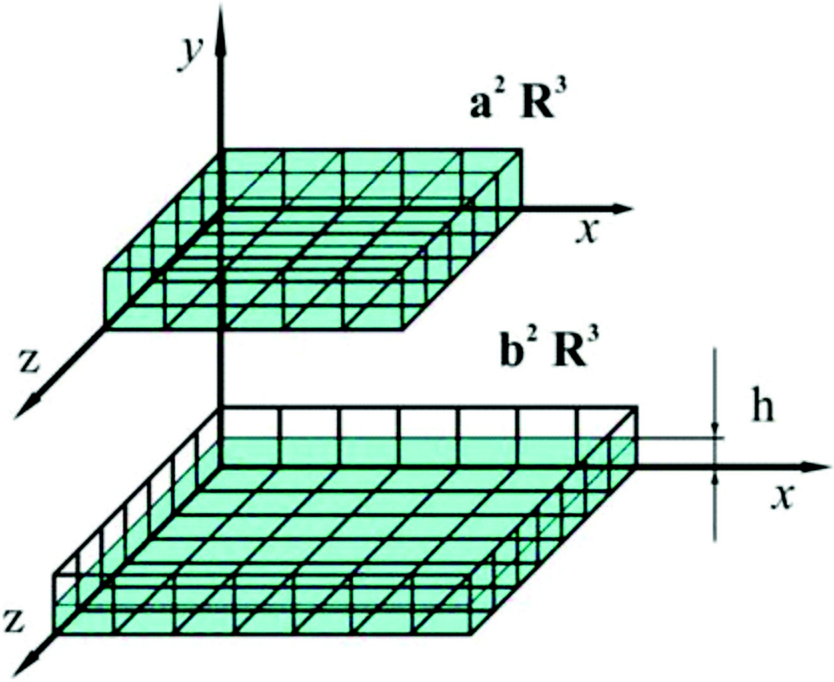


Рис.4.10

In Fig. 4.11, we will demonstrate the construction of rational numbers. To do this, let's take any rational number, for example, 3/5. It is read as three-fifths, and we will find the construction of this number in the series of whole natural numbers.

The number's denominator is represented by a whole natural quantity located in Series A. We will find this quantity in the series of whole natural numbers, it is represented as $Y = 5R^3$; $X = 5R^3$. We will arrange the entire series of whole natural numbers vertically (Fig. 4.11), and we'll denote the position of the whole natural quantity 5 with a dot. However, we'll take only three units out of these five units, i.e. three-fifths.

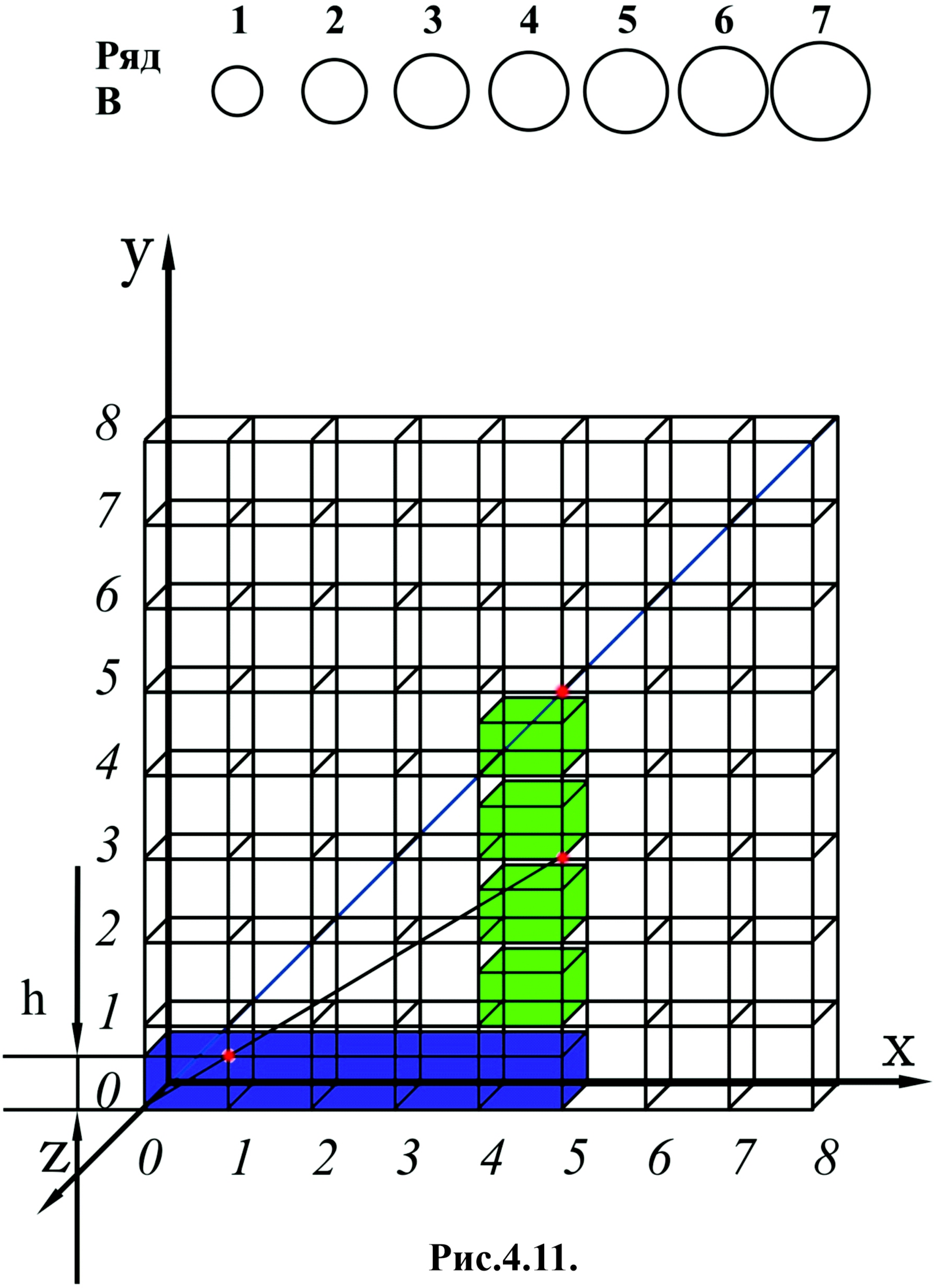


Рис.4.11.

The ratio of these quantities can be shown in two forms. Let's show the first form: we will distribute the volume $3R^3$ within the volume $5R^3$. However, since $5R^3$ is arranged vertically, we will show the filling level (h) for each $5R^3$ cube. In this way, we have shown the rational number $3R^3 / 5R^3$. Now, let's show the second form of the rational number, paying attention to the fact that the base is $X = 5R^3$; $Y = R^3$. We will distribute $3R^3$ within the number $X = 5R^3$; $Y = R^3$ and show the filling level (h).

But now, we can see the entire rational number as a whole. For this purpose, we connect the point $Y = 3R^3$; $X = 5R^3$ with the beginning of the series of whole natural numbers, i.e., $X = 0$; $Y = 0$; $Z = 1$, and get a triangular number in the base $X = 5R^3$; $Z = R^3$; $Y = R^3$, with the height $Y = 3R^3$; $X = 5R^3$; $Z = R^3$. Please note that the hypotenuse of the triangular number intersects the edge R^3 in the ratio $3R^3 / 5R^3 = hR^3$. Thus, we can see the entire rational number and the resulting ratio of two whole natural quantities.

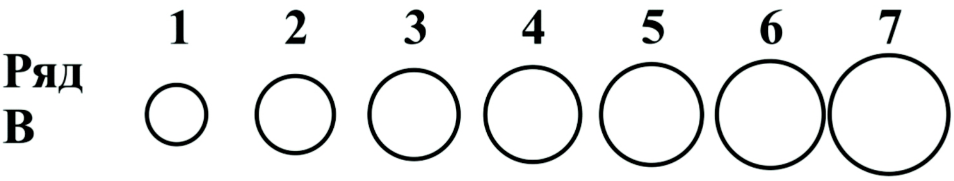
It becomes evident that we are solving the fundamental problem of mathematics, and a series of whole natural numbers serves as a means of solving this problem.

It becomes possible to solve the problem of the ratio of any quantities to any quantity.

Let's pay attention to the fact that if we take any natural quantity $Y = aR^3$; $X = aR^3$, place it on $Y = nR^3$, where n represents the number or a set of identical units, and specify the location of the natural quantity along X, we can construct, on each unit, a triangular rational number of the form $R^3 / n = hR^3$. In this way, we can find 1/2, 1/3, 1/4, …, 1/n, i. e. fractions of R^3. And we can take as many of these fractions as we wish. The construction procedure is demonstrated in Fig. 4.12. It becomes evident that a series of whole natural numbers forms a field of rational numbers. The field of rational numbers is divided by the square's diagonal, under which all rational numbers of the form $aR^3 / bR^3 = hR^3 < 1$ are located. Lying above the diagonal of the square are all rational numbers of the form $aR^3 / bR^3 = hR^3 > 1$, for example, $4R^3 / 2R^3 = 2R^3 = hR^3$.

Today, however, the so-called irrational numbers and transcendental numbers are known, but these are only intermediate numbers between rational numbers with values of hR^3. Let's take a closer look at these numbers.

We show the construction of divisibility of numbers in Fig. 4.12. In this Figure, we demonstrate the construction of divisibility of numbers using a planar number or a comparator, provided $Z = 0$.



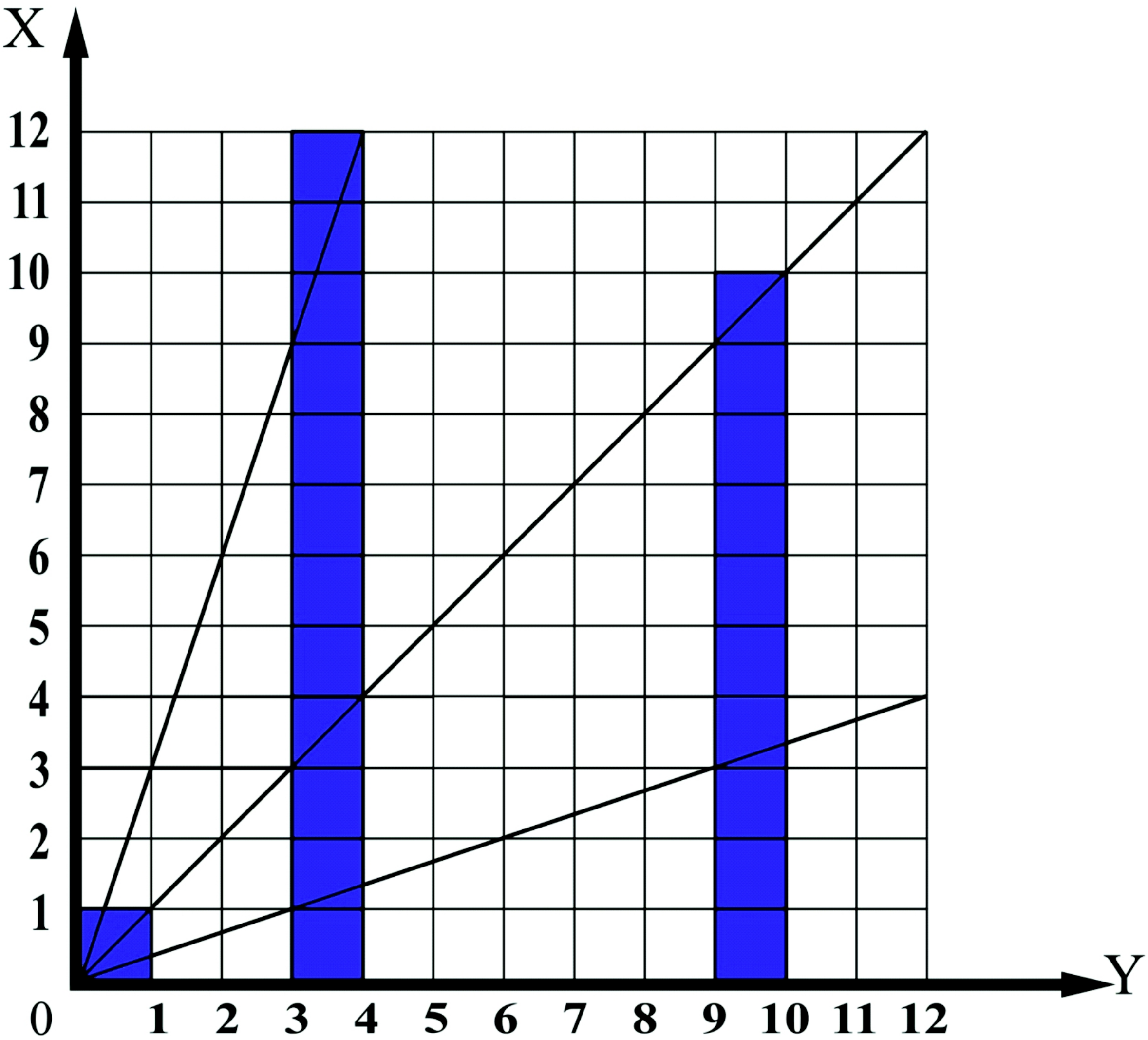


Рис.4.12.

Let's take a square with the base $12R^2$. Inside this square, we will take a square with the base $3R^2$. The side of this square, along the YR^2-axis, is divided into three equal parts without a remainder. This results in the construction of a triangular number $R^2 / 3R^2$; $X = 3R^2$; $Y = R^2$.

The diagonal of the triangular number divides the side R^2, $X = R^2$; $Y = R^2$, in the ratio of one-third. Obviously, we use the similarity of squares, which arises from the properties of a series of whole natural numbers.

We use the decimal system of notation, and since we have 10 digits, we will construct the rational number $10R^2$ and extend the hypotenuse of the triangular number $R^2 / 3R^2 = hR^2$, which will intersect the rational number $10R^2$.

Now, we can read the result in the decimal system, i.e., three tenths (0.3). We can see that this result does not fully solve the problem, because we have some remainder. However, let's pay attention to the fact that the square four tenths, which is intersected with the extended hypotenuse of the triangular number R^2 / $3R^2$, has the same intersection as R^2 at the beginning of the coordinate system. Therefore, we repeat this construction, but for R^2 four tenths. Similarly, we divide the side of the square four tenths into 10 equal parts, but now these will be hundredths of the square. Again, by taking three squares, we obtain (0.33). It becomes evident that we will obtain a new remainder similar to the first one, and a subsequent division will give us the same result but for thousandths of the unit.

We can continue subsequent divisions as many times as we like, but each time we will get the same result, i.e., an infinite approximation to the intersection of the side of the rational number $10R^2$ and the hypotenuse of the triangular number - h = 0.333....

However, this solution already settles the stated problem, since the essence of the problem is defined by the fact that we come across the presence of irrational numbers. But they do not change our understanding of the unity of numbers; on the contrary, they reveal one more property of numbers - periodicity or cyclicity.

The presented method of number divisibility clearly demonstrates that we can find any ratio of rational numbers. For example, the hypotenuse of the triangular number R^2 / $3R^2$ divides all rational numbers below the diagonal of the square into three parts. Below the hypotenuse, we can read the result: $6R^2$ / $3R^2 = 2R^2$; $9R^2$ / $3R^2 = hR^2$, and so on. We can see the result of division: $12R^2$ / $4R^2 = hR^2$, where $h = 3R^2$, or in the rational form, $3R^2 / R^2 = hR^2$.

Returning to the ratio of two squares, it becomes evident that we need to express the squares in the linear form and look for a ratio in rational numbers. However, this also applies to numbers of the form $a^nR^2 / b^nR^3 = hR^3$; $\frac{a \cdot b \cdot c \ldots R^3}{q \cdot f \cdot u \ldots R^3} = ¿$ hR^3, since the principle of number divisibility is common.

We will illustrate this with a small example. Let's take any rational number, for example, 3/5, and construct this number (Fig. 4.13). To construct this number, we'll use several series of rational numbers, for example, 5. We'll express such a number in the parametric form. Since in the numerator, we have the quantity of Series B, the parametric form is represented as $Y = aR^3$; $X = aR^3$; $Z = R^3$. Similarly, we'll show the denominator as $Y = bR^3$; $X = bR^3$; $Z = R^3$.

However, the quantity 3 of the rational number belongs to the square 5, and the numerator will take the form $Y = 3R^3$; $X = 5R^3$. Next, we'll get $3 \cdot 5R^3$, but since we take $Z = 5R^3$, the numerator has the form $3 \cdot 5 \cdot 5R^3$, and the denominator is represented as $Y = bR^3$; $X = bR^3$; $Z = bR^3$, or $5 \cdot 5 \cdot 5R^3$. Thus, the entire rational number is represented as:

$3 \cdot 5 \cdot 5R^3 / 5 \cdot 5 \cdot 5R^3$

$$\frac{Y \cdot X \cdot Z R^3}{Y \cdot X \cdot Z R^3} = \frac{a \cdot b \cdot b R^3}{b \cdot b \cdot b R^3} = \frac{3 \cdot 5 \cdot 5 R^3}{5 \cdot 5 \cdot 5 R^3} = \mathbf{hR^3}$$

The construction is shown in Fig. 4.13.

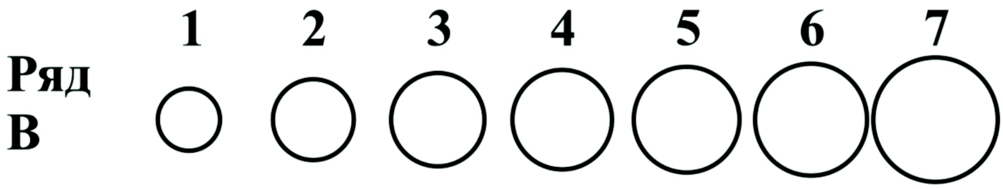
So, it becomes evident that any cube, except R^3, which is expressed relative to a series of whole natural numbers, is a rational number.

We have not discussed transcendental numbers because this topic stands somewhat apart. We will show what transcendental numbers look like using cubic equations as examples, because by specifying what rational and irrational numbers are, we have demonstrated both the property and result of manipulations on numbers, as a consequence of the properties of a series of whole natural numbers resulting from the laws to which the series of whole natural numbers is subject.

The number theory is presented briefly; you can familiarize yourself with it more thoroughly in Ref. 2.

It is clear that the theory of numbers doesn't finish here, and further we will demonstrate its development using examples of solving different problems.

Let's get acquainted with another property of numbers, which we illustrate in Fig. 4.14.



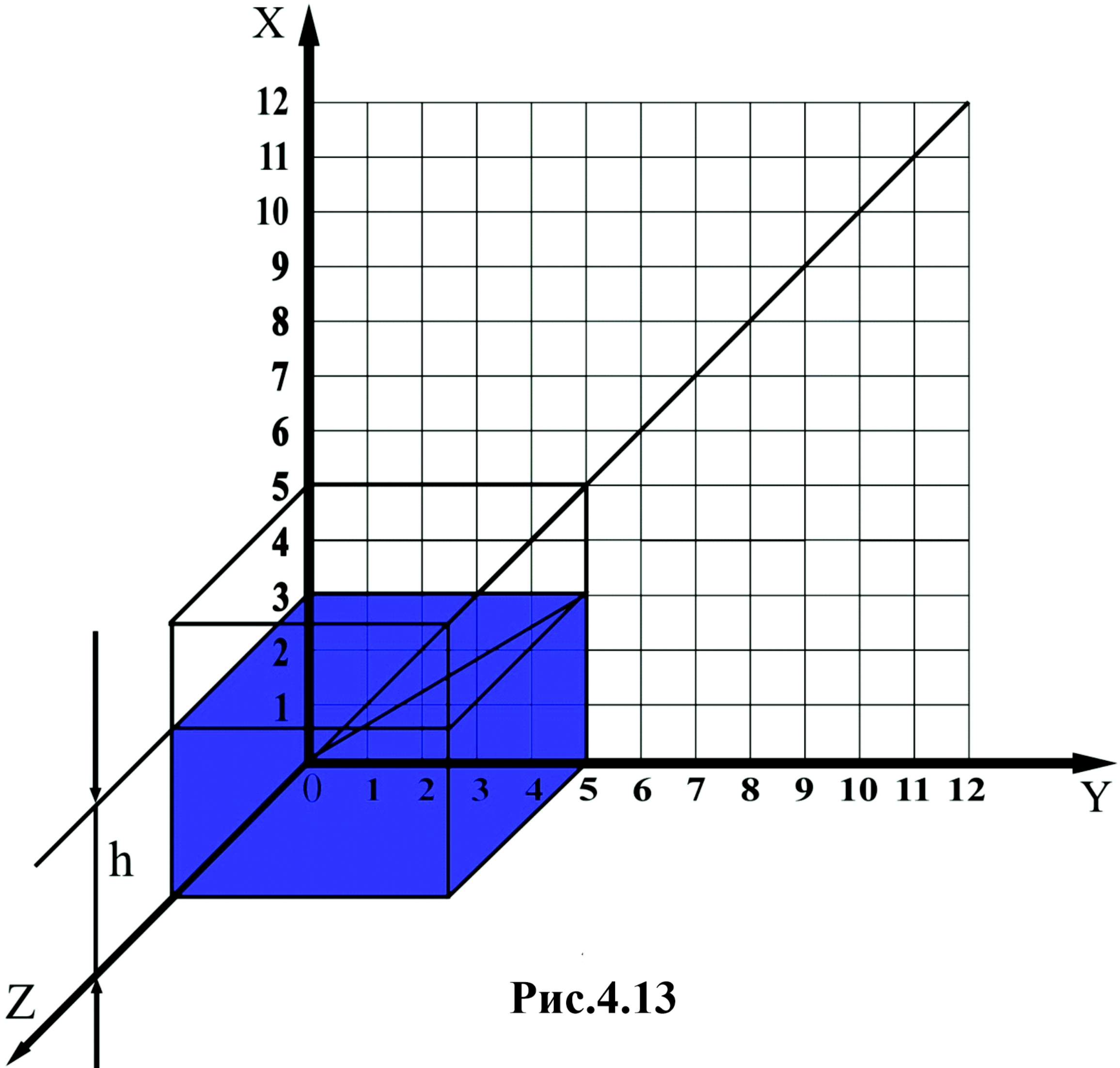


Рис.4.13

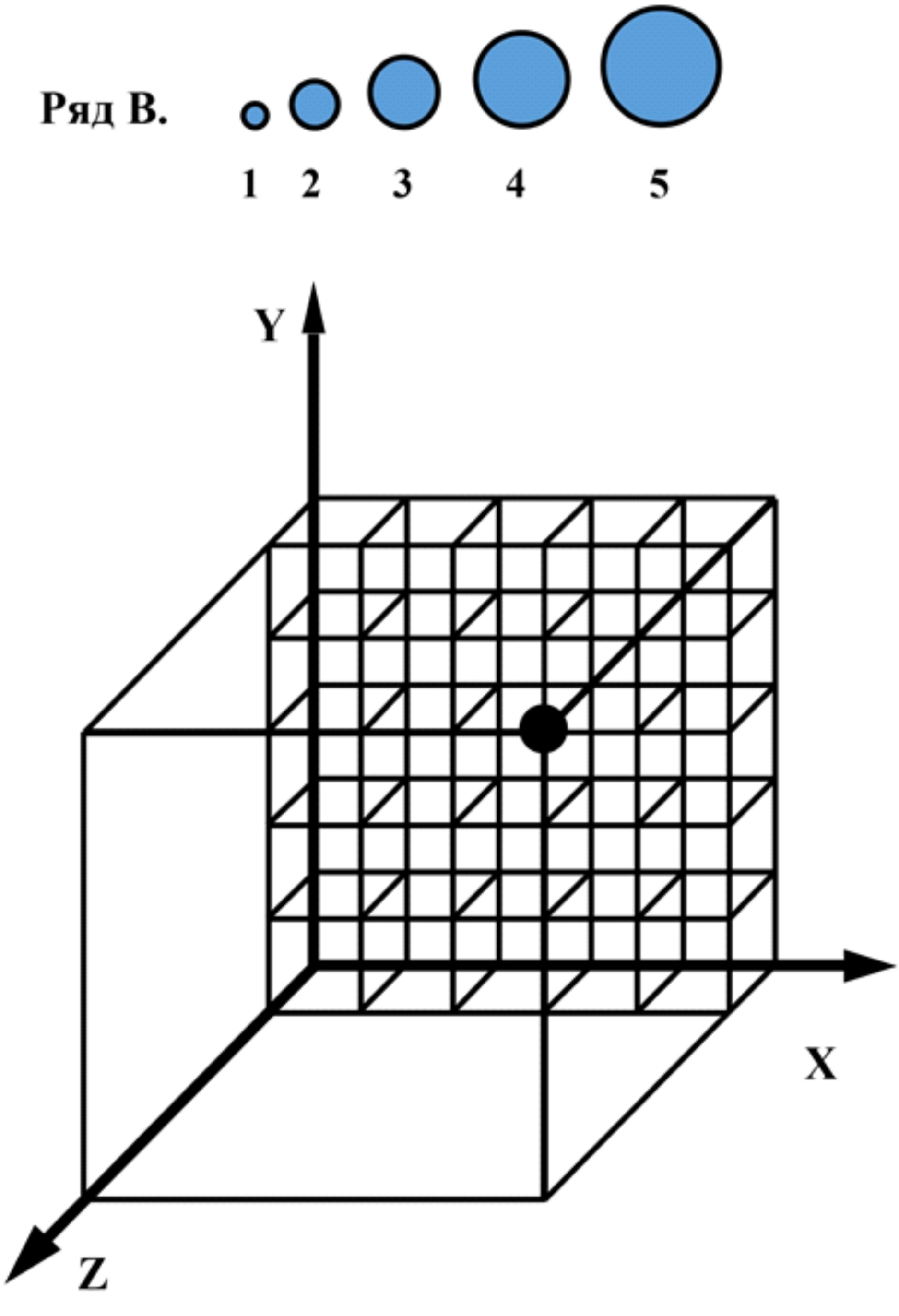


Рис.4.14

Система координат.

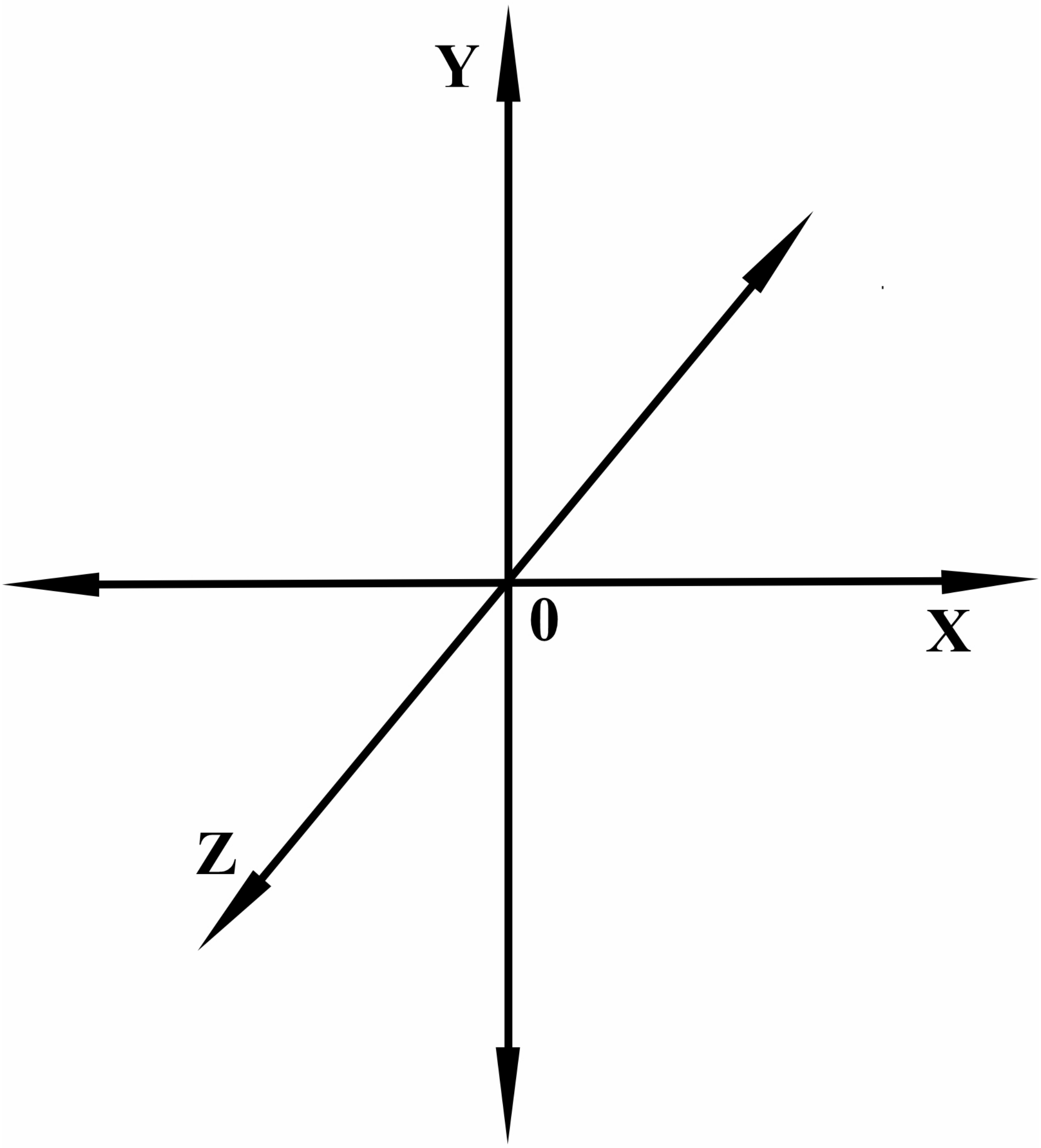


Рис.4.15.

In Fig. 4.14, the whole natural unit 1 is shown. In Series B, it is represented as the relative quantity 5. The whole natural number 1 directly corresponds to this natural quantity represented by a cube. In this cube, we show a series of whole natural numbers expressed in the formula $Y = 5R^3$; $X = 5R^3$.

Now, we can calculate the volume of the cube by taking 5 series of whole natural numbers. We demonstrate this operation in the formal notation: $Y = 5R^3$; $X = 5R^3$; $Z = 5R^3$, or 5^3R^3.

And now, we can clearly see that the cube on the YX plane is represented by a flat square. The series of whole natural numbers is also represented by a flat square. The flat square on the YX plane is precisely the projection of the cube, just as the series of whole natural numbers also has a projection, which is a flat square.

Any natural number has three projections represented on the planes: YX - frontal plane; XZ - horizontal plane; YZ - lateral plane.

A projection, in essence, has one more definition - a shadow. Let's provide an example. In nature, there are certain bodies with a spherical shape, and the projection of a sphere is represented by a circle. In nature, we observe bodies with various shapes, and the projections of these bodies are also diverse. Thus, the number encompasses all possible geometries, and these geometries are only elements of the number. The number possesses the property of the direction of number distribution, represented by the XYZ axes. Such a direction of number distribution is called a quadrant, or the first quadrant. However, if we want to consider all directions of number distribution, we need eight quadrants.

In Fig. 4.15, these quadrants are presented, because in Fig. 4.15, we show the coordinate system, or the distribution of whole natural numbers.

The orthogonal coordinate system is also called the Cartesian coordinate system. However, René Descartes demonstrated only how to use the coordinate system but did not provide a complete and detailed derivation of the coordinate system and its connection with the material world and further to numbers. It creates the impression that René Descartes borrowed the coordinate system from someone, and we assume that it was nobody else than Pierre Fermat.

5. The First Law of Thermodynamics

In various literary sources, the First Law of Thermodynamics is formulated as follows. It is the law of conservation and transformation of energy, and it constitutes a fundamental law of nature with universal significance.

It states: energy neither disappears nor appears again; it only transfers from one form to another in various physical and chemical processes.

Or put differently, for any isolated system (i.e., a thermodynamic system that does not exchange heat, work, or matter with its surroundings), the total quantity of energy within that system remains constant.

The law of energy conservation is a fundamental principle that serves as a foundation for understanding the world. And in this context, it is extremely crucial to understand how the laws of conservation are represented and interact with numbers. We have presented the number theory that relies precisely on the law of natural quantity conservation.

In this connection, all the properties of the law of natural quantity conservation, and, as a consequence, the law of energy conservation, are given, specified and exist in the coordinate system. Further, we will explore the processes that occur in nature, as well as how they are reflected in the coordinate system, and how this complies with the laws of conservation.

6. Thermodynamic Processes

The adiabatic process is a process that occurs in a closed system with external supply or removal of mechanical work, or in other words, it's a process of compressing or expanding a gas or a working substance, which proceeds without heat exchange with the external environment. Let's examine how this process is represented in various literary sources.

"If we take the P-V coordinate system, a process defined by the condition P = f(V) will be represented in the form of a curve 1-2-3 (Fig. 6.1). The elementary work of gas on this diagram will be shown as a hatched area, while the work of gas in the process of changing its state from the point 1 to the point 3 will be shown as an area limited by the process' curve 1-2-3, the extreme ordinates and the abscissa axis, i. e. by the area 123561. For the process depicted by the curve 1-4-3, the work will be determined by the area 143561.

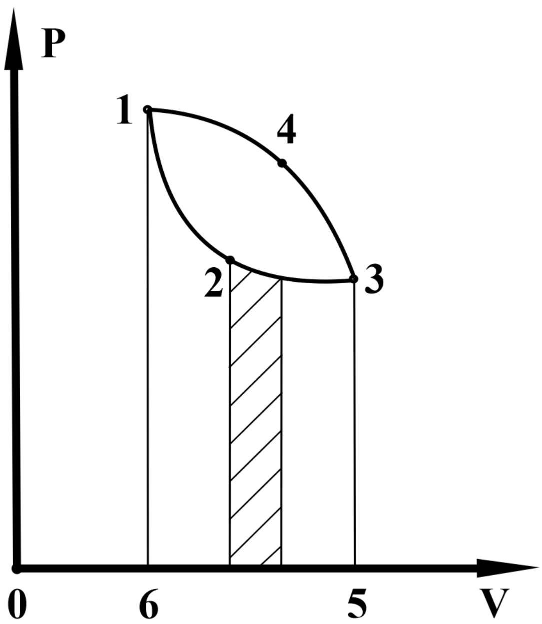


Рис. 6.1

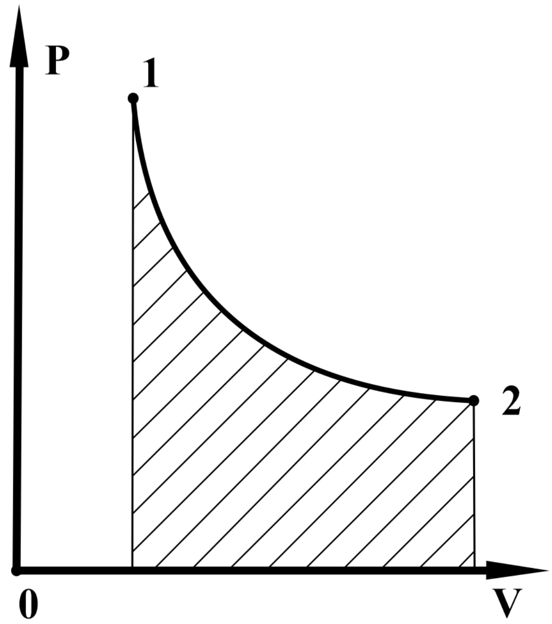


Рис. 6.2

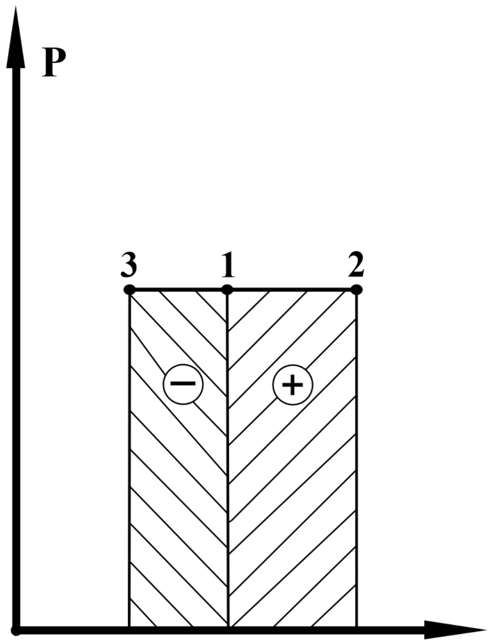


Рис. 6.3

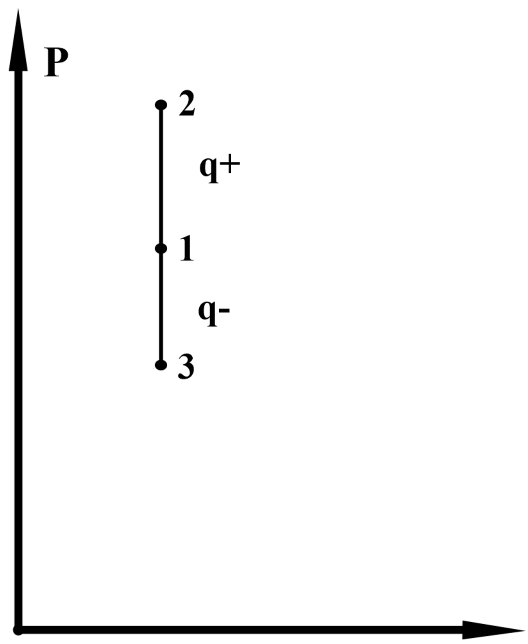


Рис. 6.4

On the basis of what have been mentioned above, we can determine the work of gas, provided we know the functional ratio P = f (V)” [Ref. L.3, page 46]

$$L = \int_1^2 p\, dV. \quad \textbf{(6.1)}$$

"It is convenient to calculate the work of system expansion, defined by the equation (6.1), with the help of the P-V diagram. Let's consider the depiction in this diagram of the process of transformation of the system's volume from V1 to V2 (Fig. 6.2). The states that the system undergoes during the change in volume are located on the process curve between the points 1 and 2. It is evident from the equation (4.1) that the work of the system's expansion is represented on the P-V diagram by the area under the process curve (it is shaded in Fig. 6.2)." [Ref. L.4, page 24].

It gives the impression that the adiabatic process doesn't have any contradictions with the law of energy conservation.

We have examined the adiabatic process that proceeds without the supply or removal of heat, and now we will consider the processes that proceed with the supply or removal of heat.

"The isobaric process is a process that occurs with the supply or removal of heat at constant pressure. The work of gas in the isobaric process is determined by the following expression:

$$L=P\,(V_2 - V_1), \quad L= R\,(T_2 - T_1).$$

The isobaric process on the P-V diagram is represented by a straight line parallel to the x-axis. If the initial state of gas is characterized by the point 1 (Fig. 6. 3), then the process can either proceed towards expansion to the point 2 or towards compression to the point 3. In the first case, as the volume increases, the gas performs the work of expansion, determined by the area of the rectangle 12451. At the same time, the gas becomes hot, which means that the heat is supplied from the outside both for heating the gas and performing the work of expansion. In the second case, the gas contracts, which means that it is subject to some compression work from outside, but this work is converted into heat; since the gas not only heats up but also cools down, and it is necessary to remove to the surrounding environment all the heat, including that taken from the body's internal energy and that, which is equivalent to the compression work." (Ref. 3, page 55)

Now, let's consider the next process.

"A process that proceeds at a constant volume is called isochoric. Using the equation of state at V = const, we find that

$$P_2/P_1 = T_2/T_1. \quad \textbf{(6.5)}$$

In the isochoric process, the pressure of gas is proportional to the absolute temperature. Since dv = 0, the gas doesn't perform any work in this process, and the equation of the first law of thermodynamics looks as follows: dq = du, or

$$q = Cv\ (T_2 - T_1).$$

On the P-V diagram (Fig. 6.4), the isochore is shown in the form of a straight line parallel to the pressure axis. The upward direction of the process from the initial point 1, on the basis of the equation (6.5), signifies an increase in internal energy and heating of the gas, while its downward direction signifies the cooling of the gas by removing heat to the surrounding environment (Ref. 3, page 59).

We have demonstrated both the isobaric and isochoric processes, and it seems that they do not contradict the law of energy conservation. And now let's consider one more process, called an isothermal process. The isothermal process is a process that proceeds at the constant temperature.

"From which it follows, that

$$P_1V_1 = P_2V_2 \quad \text{или} \quad V_2/V_1 = P_1/P_2,$$

i.e. in this process, the volumes of gas change inversely proportional to pressures (the Law of Boyle and Mariotte). Since the temperature remains constant in this process, the internal energy of the gas also remains constant, and du = 0. Therefore, the equation of the first law of thermodynamics for this process looks like dq = dw, or all the heat supplied is converted into the work of gas expansion, and, conversely, all the work spent on gas compression must be removed to the surrounding environment in the form of heat.

The work of gas in this process is determined from the general equation of work, provided that

pv = RT = const.».

On the P-V diagram, the process's curve is represented by the equation pv = const, i.e. by a rectangular hyperbola, for which the coordinate axes are asymptotes.

Hence, if the point 1 (Fig. 6.6) represents the initial state of gas, then the process can proceed towards the point 2, at the same time the expansion of gas occurs. The gas performs the work determined by the area 12451, and it is necessary to supply heat to this area, which is equivalent to this work. If the process proceeds towards the point 3, then the compression of gas occurs, and the work spent on it is determined by the area 13651. At the same time, the heat equivalent to this work is removed to the surrounding environment.

Since the product of PV increases with an increase in temperature, the farther an isotherm is from the start of coordinates, the higher the temperature it represents". [Ref. L.3, page 56.]

We have demonstrated one more process in a way it is described approximately similar in various literary sources.

However, it may seem that there are no contradictions to the first law of thermodynamics. But now we can compare different processes and see how the law of energy conservation is observed. It is convenient to show this comparison in P-V coordinates, using the isothermal process as a base.

In the comparison demonstrated in Fig. 6.7, we see the isothermal expansion process 1-2, and accordingly, all the work we can obtain is represented by the area under the process curve 12341.

But now let's ask ourselves: is the isothermal process simple or complex? Our answer is: it is a complex process. Then another question arises: is it possible to divide the isothermal process into simpler processes? Our answer is: yes, it is possible.

In its physical essence, the isotherm is a gas expansion process, so the isotherm includes the adiabatic gas expansion process. But this process proceeds with heat supply, that's why the similar amount of heat supplied between the points 1-2 will be supplied to the isobaric process 1-5, and then we'll perform the adiabatic expansion process up to the point 2. The temperature at the point 2 will be equal to the temperature of the isotherm. The work area in these processes will be equal to 152341, but this area is greater than the area under the isotherm 12341.

But here a new question arises: is it possible to receive even more work? The answer is: yes, it is possible, but how? To achieve this, we supply similar amounts of heat to the isotherm and to the point 1 through the isochoric process, i.e., 1-7, then the heat is expanded adiabatically up to the point 2. At this point, the temperature of gas will be equal to the isotherm's temperature. The work area in such processes will be equal to 72347, but this area is greater than the isotherm's area and greater than in cases where heat is supplied at constant pressure (isobaric).

It becomes evident that there are contradictions to the law of energy conservation, because if we obtain all the work in the isothermal process, and this work is represented by a certain area, then in any other process, where the same amount of heat is supplied, the areas representing work must be equal to the area under the isotherm. Otherwise, the law of energy conservation is directly violated.

Let's mention specifically that the processes, which take place in the material world (Fig. 6.7), do not contradict the law of energy conservation.

Therefore, these contradictions result from the assertion that the work performed is equal to the area under the process. And here again, the following question arises: where did this assertion appear? Various literary sources explain this question in the following way (we highlight it briefly).

In 1824, Sadi Carnot, in his work "Reflections on the Motive Power of Fire and on Machines Capable of Developing this Power" introduced the Carnot cycle (Fig. 6.8). It is presented as a circular process 1-2-3-4-1 and consists of adiabats 2-3 and 4-1, followed by isotherms 1-2 and 3-4. The direct cycle is completed along 1-2-3-4-1.

The process 1-2 (isothermal expansion):
The gas performs work determined by the area 12681 and is equal to:
$L_{1-2} = mRT_1 \ln V_2 / V_1$

Heat equivalent to this work is supplied from the heater:
$Q_{1-2} = Q_1 = mRT_1 \ln V_2/V_1$

The process 2-3 (adiabatic expansion):
The gas performs work determined by the area 23562 and is equal to:
$L_{2-3} = mR(T_1 - T_2)/(k - 1)$. $Q_{2-3} = 0$.
The temperature of gas decreases to T_2.

The process 3-4 (isothermal compression):
The work spent on gas compression is determined by the area 43574 and is equal to:
$L_{3-4} = mRT_2 \ln V_4/V_3 = - mRT_2 \ln V_3/V_4$.

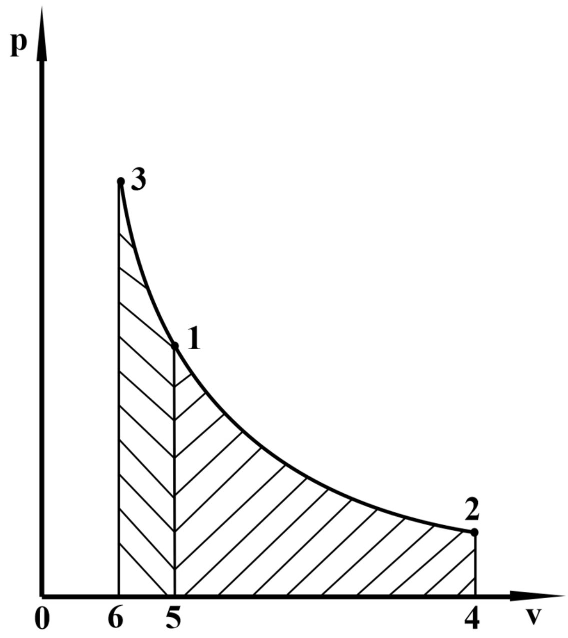


Рис. 6.6

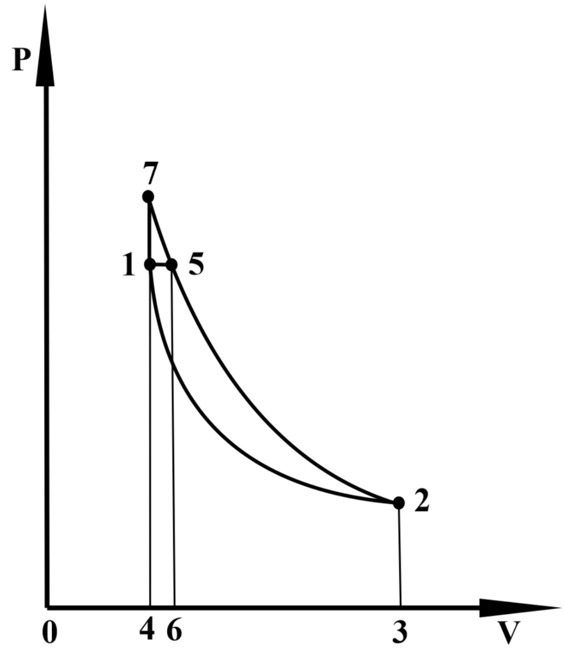


Рис.6.7

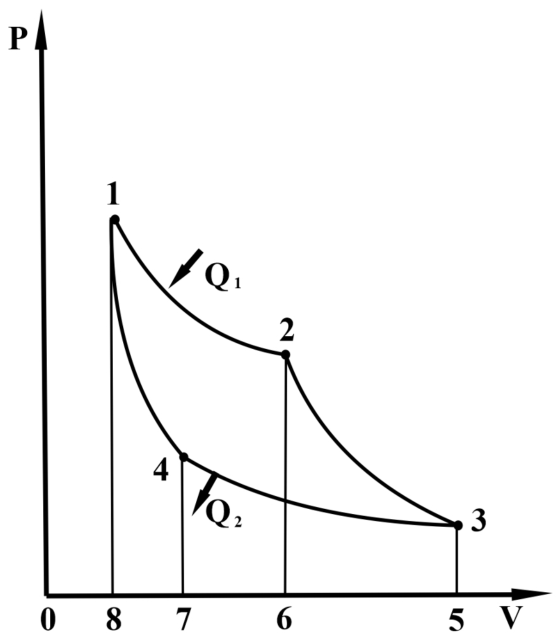


Рис. 6.8

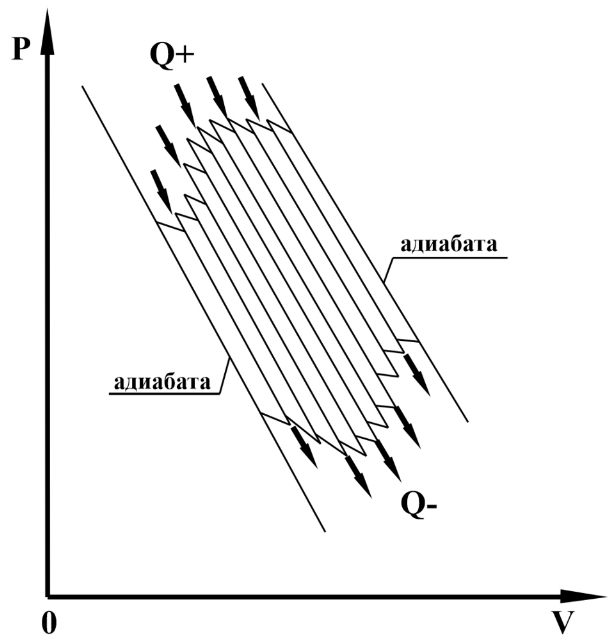


Рис.6.9

The heat equivalent to this work is removed to the cooler at the temperature T_2.

$Q_{3-4} = Q_2 = L_{3-4} = mRT_2 \ln V_3/V_4$

The process 4-1 (adiabatic compression). The work spent on gas compression is determined by the area 14781, and is equal to:

$L_{4-1}= mR(T_2 – T_1)/(k – 1) = – mR(T_1 – T_2)/(k – 1)$, $Q_{4-1} = 0$

The gas is heated to the temperature T_1.

The results of the cycle are as follows. The cycle's useful work is determined by the sum of works performed by the gas during the entire cycle. Summing up the areas that represent the work of gas in individual processes, taking into account the signs of the work, we find: Area 12341 = Area 12681 + Area 23562 – Area 43574 – Area 14781." [Ref. L.3, page 67].

"The aforementioned information is explained as follows (Fig. 6.9). Any reversible cycle of arbitrary configuration can be imagined as a combination of elementary Carnot cycles, consisting of two adiabatic curves and two isotherms. In each of these cycles, the supply and removal of heat are performed along the isotherms. The sum total of elementary Carnot cycles determines the area of any cycle, and so on." [Ref. L.4, pages 55-56.]

We can go on quoting various literary sources, but none of them contradict the law of energy conservation. And contradictions may seem to be absent. And here we stipulate the very possibility of performing various processes, since if any process can occur in the material world, it does not contradict the laws of energy conservation, i.e. if it is natural and proceeds without human intervention. However, another question arises here: where do such contradictions with the laws of energy conservation come from? And now let's notice that the work is determined by the area under the process. In various literary sources, this statement does not have a concrete scientific basis and, apparently, constitutes an axiom. In thermodynamics, two axioms are used:

The first axiom: Work in the adiabatic process lies beneath the process.

The second axiom: Work in the isothermal process lies beneath the process.

Therefore, to understand the gnosiology (epistemology) of these questions, we will return to a more detailed consideration of thermodynamic processes, starting with the adiabatic process.

7. The Adiabatic Process

Let's pay attention to Fig. 7.1. The process of compression or expansion has been carried out experimentally, measured in detail and represented in P-V coordinates. But now the following question arises: what is a flat coordinate system, and how is it connected with the properties of the material world? From the perspective we presented in the number theory, a flat coordinate system is a projection, or, another term, a shadow. And now one more question crops up: is it possible, through the solution of the problem at the shadow level, to obtain a complete and exhaustive idea of the object under study? And the next question: can we solve the problem using P-V parameters without a direct connection with the weight and, consequently, with the mass of gas? The answer is obvious: no! That's why let's provide a more complete notion of the adiabatic process in Fig. 7.1. In this figure, the adiabatic process is represented by the curve 1-2 in the P-V-g coordinate system, where: P – the pressure of gas, V – the volume of gas, g – the specific weight or mass of gas. The product E = P×V×g represents an element of internal energy. The product V×g represents the weight or mass of gas, which remains constant in the adiabatic process.

We show any arbitrary point B on the curve 1-2, but since the adiabatic process has three projections, the point B also has three projections. All the projections share the property of unity, because they represent or reflect one and the same state of gas or in other words, characterize the state of the natural quantity represented by gas. Now let's look at the projection of the adiabatic process on the V-g plane. On this plane, the projection of the adiabatic process is represented by a curve that characterizes the value of the gas's weight or mass. The Point B has a projection represented by the Point B1, which characterizes the state of gas, and the area B1-C1-0-C3-B1 characterizes the weight, or mass of the gas.

Any point of the weight or mass of gas on this curve is represented by the product V×g = const. But now if we ask anyone: how many points are there on this curve, we will get the answer: an infinite set of points. However, such an answer is false! But why? We show the state of gas under the piston in the Figure on the right, from which it follows that we have only one mass of gas, and only one point on the curve corresponds specifically to this mass of gas."

Адиабатный процесс

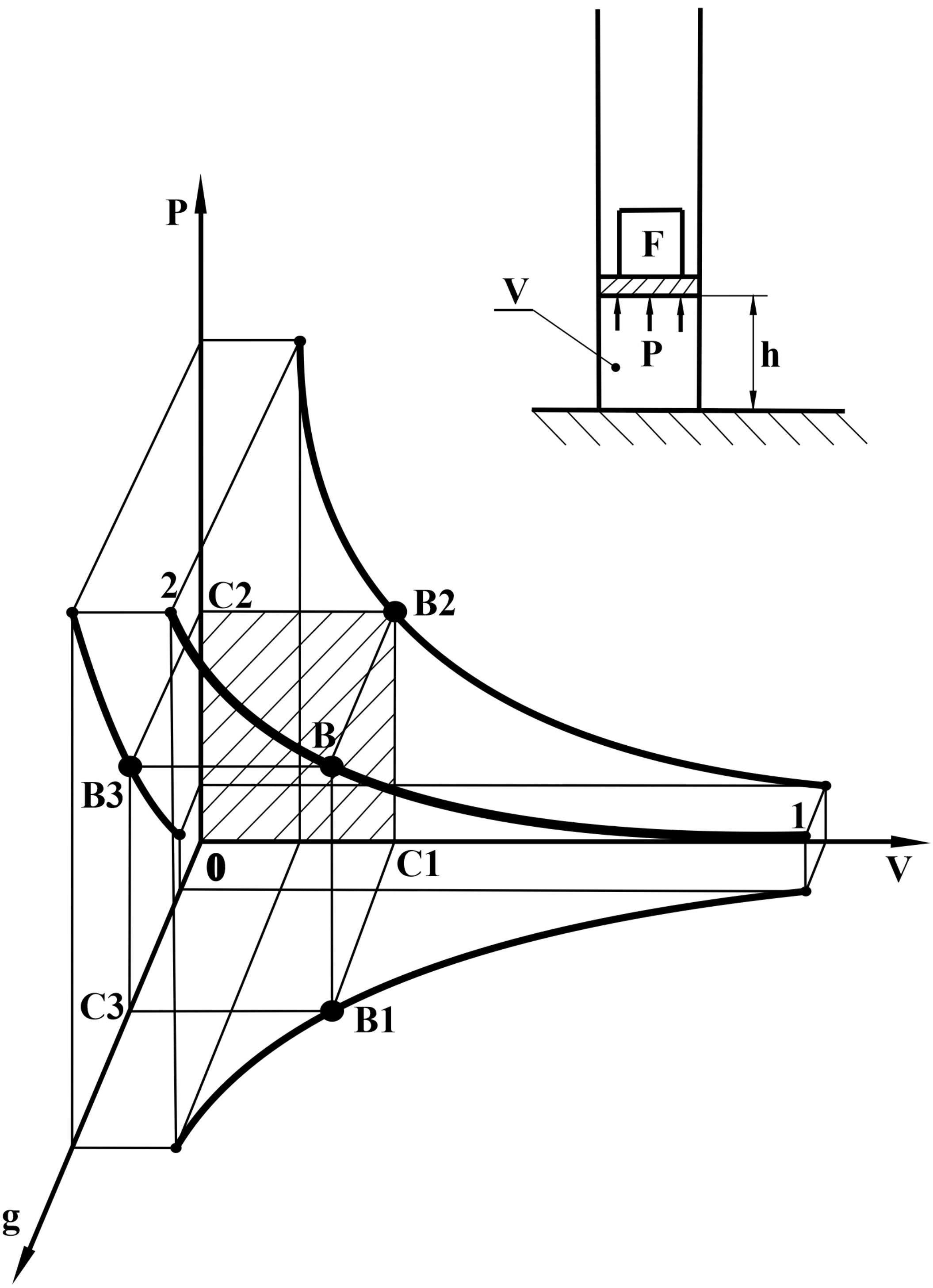


Рис.7.1

Now we have to provide a definition of the curve: a given curve is a possible location of only one point.

Let's look at the P-V plane, where we see the curve of the adiabatic process and the projection of Point B on the P-V plane - Point B2. The location of this point is described by the product P×V, which represents all the mechanical work existing in a closed system; it is represented by the area B2-C2-0-C1-B2.

But now the following question arises: where is the area under the process? There is no such area in P-V coordinates at all. And again, we wonder why it is so. The answer is simple: only a single point corresponds to a given state of gas, to which the indicated area corresponds, because we cannot claim that the gas can exist in two or more states simultaneously. And now let's look at the area under the process; this area is imaginary; it is not connected directly with the mechanical work in the adiabatic process. Carnot's axioms are based on a purely geometric perception of the question that directly violates the law of correlation, and as a result, violates the law of energy conservation. And here one more question arises: what represents the work of gas? At the formal level it is A= P×V; this ratio is called Boyle - Mariotte's Law; it was found empirically. But neither Boyle nor Mariotte showed how the work of gas is represented in P-V coordinates. An attempt to fill the gap was undertaken by Carnot. Let's show the way how the formula A= P×V is defined.

To do this, let's refer to Fig. 7.1, where we show a cylinder with a piston on the right, with a load, the gas pressure balances the piston with the load. And now let's see how this position of the load is expressed in numbers. Pay attention to Fig. 7.2, where we show a certain natural real number that characterizes a natural quantity and its location in the coordinate system. We will represent our load on the piston as a natural quantity: $F = 4\ R^3$ on the X-axis. We will represent the load's height as $h = 5\ R^3$ on the Y-axis. The load's potential work is equal to A= F×h, which represents the number's area. Now let's express the potential work of gas in numbers. The height of gas under the piston is $Y=h = 5R^3$. But the height has the dimension R^3, which is the dimension of elementary volume, and this dimension has an area R^2, which accounts for the specific gas pressure P. The specific potential work of gas is represented by $A= 5R^3 \times 1P$, $A= 5R^3 \times FP$ or in formal notation A= P × V.

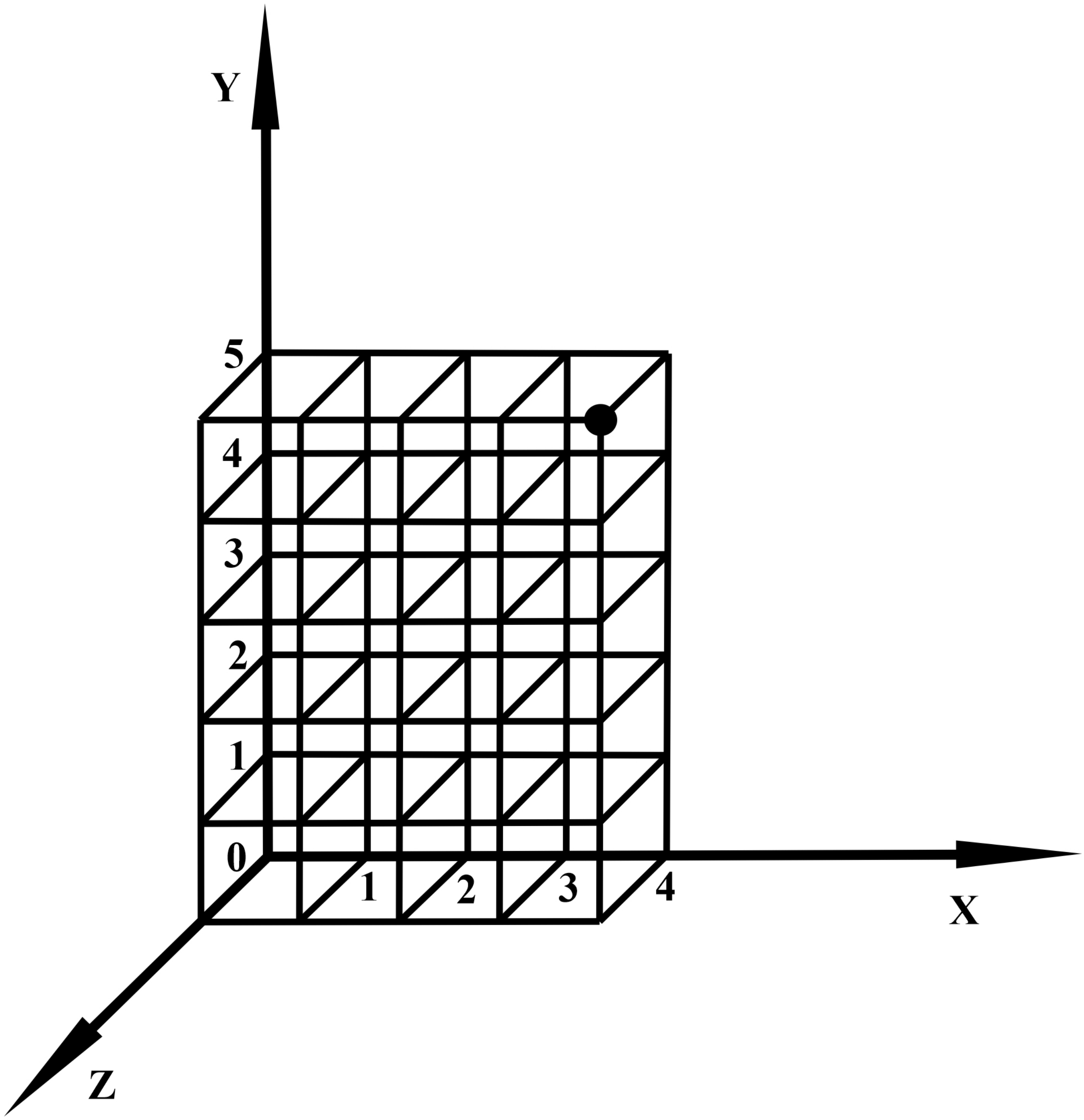


Рис.7.2

Let's look at Fig. 7.1, where we show a cylinder with a piston on the right, with a load placed on it. The gas pressure balances the piston with the load. Now let's see how this position of the load is represented in numbers (Fig. 7.2). In this figure, we show a certain natural real number that characterizes a natural quantity and its location in the coordinate system. We will present our load on the piston as a natural quantity: $F = 4\ R^3$ on the X-axis. The height of the load is $h = 5\ R^3$ on the Y-axis. The potential work of the load is equal to $A = F \times h$, which represents the number's area. Now let's express the potential work of gas in numbers. The height of gas under the piston is $Y=h = 5R^3$. But the height has the dimension R^3, however it is the dimension of elementary volume, and the area of this dimension is R^2, to which the specific pressure of gas P is applicable. The specific potential work of gas is represented by $A= 5R^3 \times 1P$. $A= 5R^3 \times FP$, or in formal notation, $A = P \times V$, where P is represented on the Y-axis, and V is represented on the X-axis. The work in the coordinate system is given by the number's area $A= YR^3 \times XR^3$, or in physical quantities, $A= Pf/R^2 \times VR^3$. The potential work of the load and gas is equal, and in the flat coordinate system, they are represented by the same area. When considering the representation of work in numbers for both the lifted load and gas, we once again see the inconsistency of Carnot's axioms with the requirements of thermodynamics, physics and mathematics.

The next process we will consider is the isobaric process. The work in the isobaric process lies beneath the process and is shown in the flat coordinate system in Fig. 6.3. Such a representation of work in the isobaric process does not contradict the law of correlation, and consequently, the law of energy conservation.

The next process we will examine is the isochoric process.

8. The Isochoric Process

The isochoric process proceeds in a closed system with a constant volume. The interaction with the mass of gas is determined in the same way as in the adiabatic process. We illustrate the isochoric process in Fig. 8.1.

Изохорный поцесс

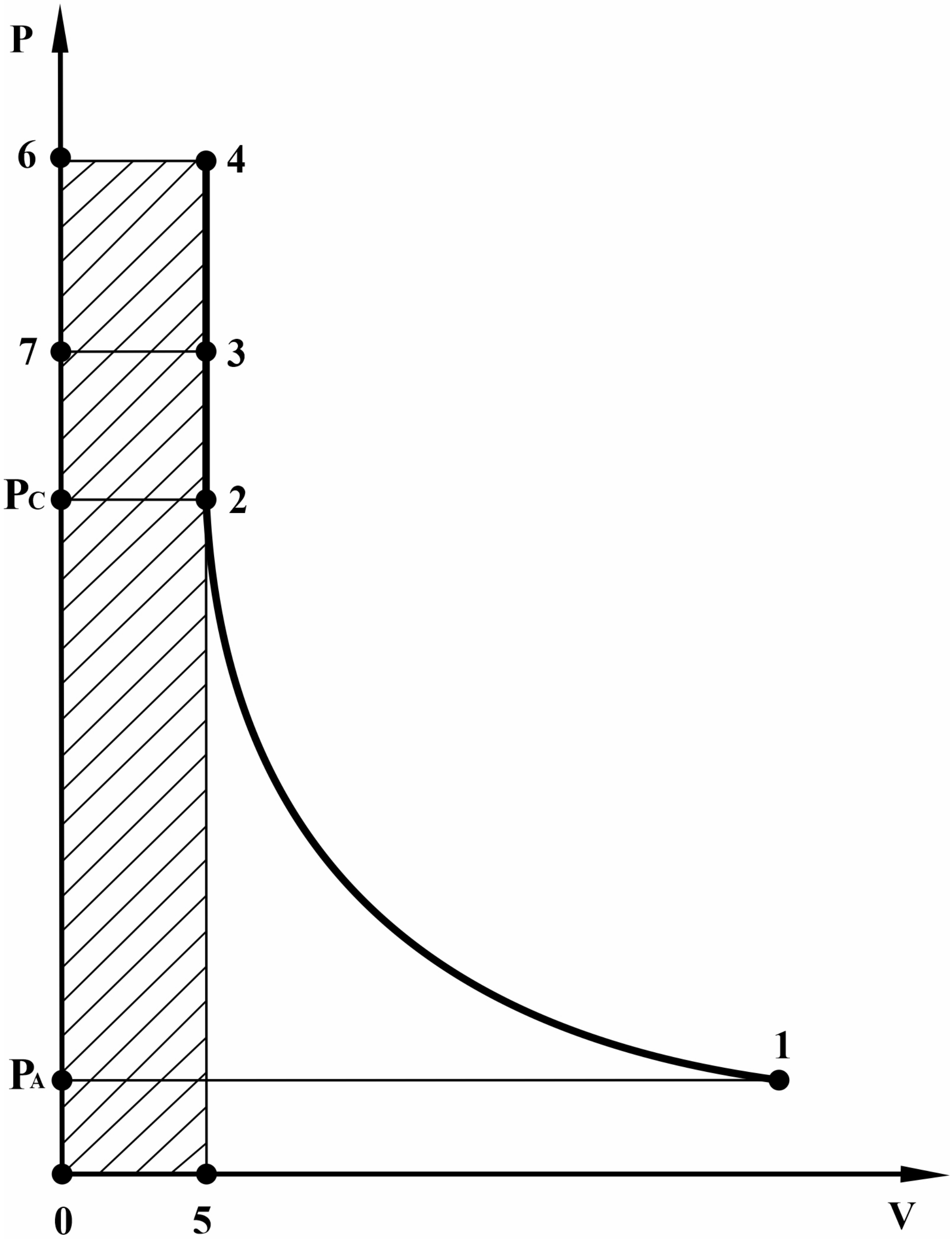


Рис. 8.1

The supply of heat to the gas from Point 2 to Point 4 at the constant volume results in an increase in pressure and, consequently, the amount of potential work in the system, represented by the area 2-4-6-Pc-2, increases proportionally. In cases where the heat is removed in the isochoric process from Point 4 to Point 3, the work lost by the system is represented by the area 4-6-7-3-4.

If the isochoric process is performed from Point 2 to Point 4, the total work in the system is represented by the area 4-6-0-5-4, which is represented not only by the work in the isochoric process but also by also the work in some other process, such as the adiabatic process.

The next process we will consider is the isothermal process.

9. The Isothermal Process

The isothermal process proceeds in a closed system, with the heat supplied during the expansion process in such a way that the gas temperature remains constant. It is obvious that the isothermal process is a complex one, but the key point here is that, all the heat in this process is converted into mechanical work, and all the mechanical work is given to an external consumer. This means the complete compliance with the law of energy conservation.

The isothermal process is shown in Fig. 9.1 by the curve 2-3. However, it is clear now that we will not be able to perform the isothermal process, if the gas is not compressed beforehand. That's why, we show the adiabatic curve of compression 1-2, but in this way, we consider the processes in the pressure range between Pa and Pc. Further, we can also consider the processes between P0 and Pc, but in both cases, the processes are typical.

And now, another question arises: how much work can we obtain in the isothermal process? It is not possible to see this on the graph of the isothermal process, because some portion of heat is supplied to the process, while some portion of mechanical work is removed.

We'll be able to see the entire work in the isothermal process, if we divide it into simpler processes, namely: the isobaric heat supply followed by the adiabatic expansion process, where in the isobaric process, we'll supply heat, whose amount is equal to the amount of heat supplied in the isothermal process.

Изотермический процесс

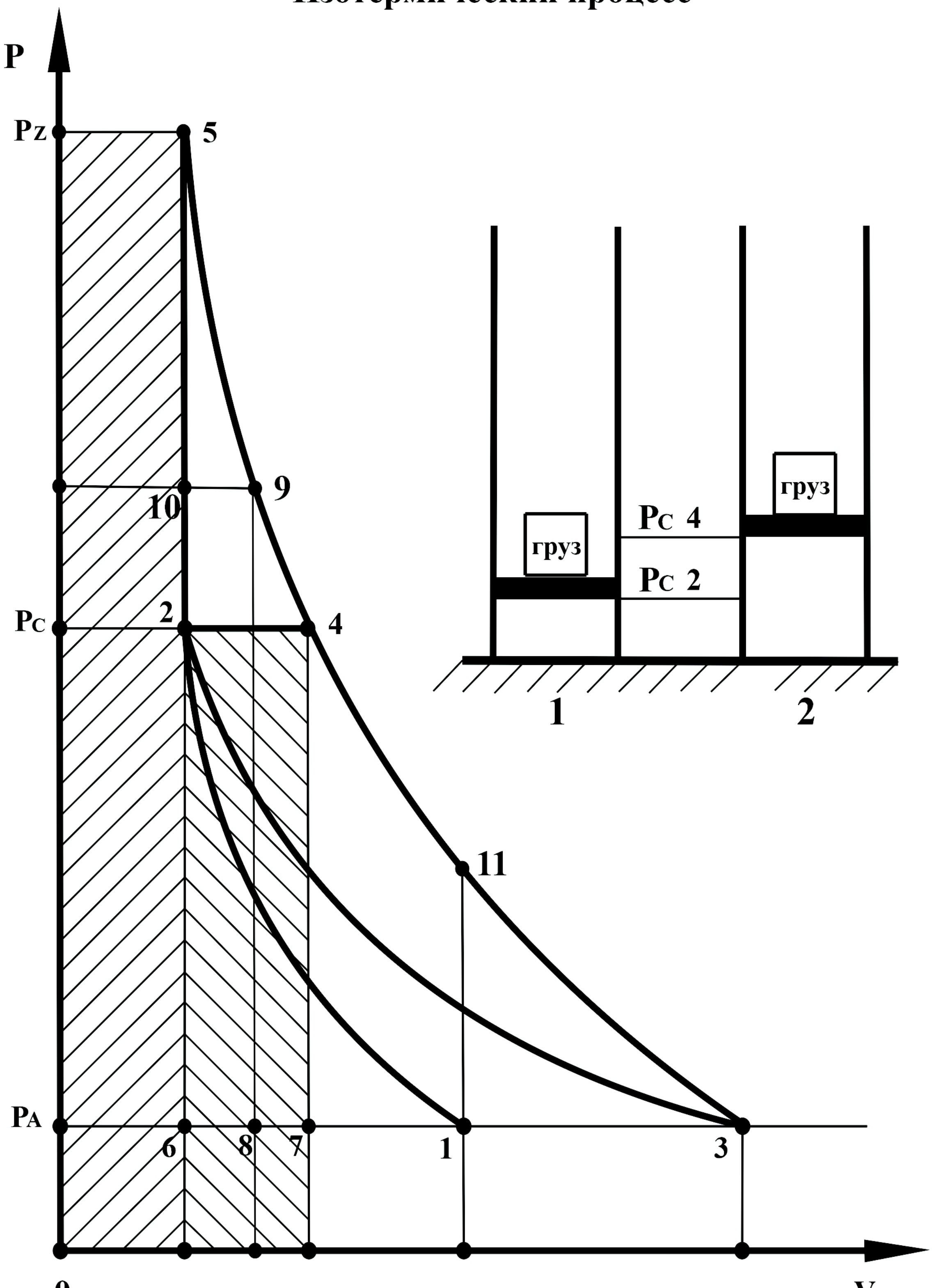


Рис.9.1.

Such an action leads to the state of gas corresponding to Point 4. It's not difficult to see that while performing the isobaric supply of heat, the initial temperature at Point 2 is represented by a certain temperature (T). After the supply of heat, the temperature at Point 4 is represented by (T+Δt); then from Point 4, we perform the adiabatic process of gas expansion and appear at Point 3. By performing this adiabatic process from Point 4 to Point 3, we'll reduce the temperature from (T+Δt) to (T). In other words, the gas at Point 2 and Point 3 has the same temperature (T), which indicates that the same amount of work is delivered to the external consumer during both the isothermal and isobaric processes, followed by the adiabatic expansion process.

We can perform a reverse process as well, i. e. we can perform the adiabatic compression process starting from Point 3 to reach Point 4 and receive the gas temperature (T+Δt). Then, we perform the isobaric removal of heat equal to the value of temperature Δt and get to Point 2, whose temperature is (T). This once again points to the equality of the works done, or in other words, one and the same amount of heat produces one and the same amount of useful work. This work is represented by the area under the isobaric curve 2-4-7-6-2 and constitutes all the potential useful work, which can be received by the external consumer. The receipt of work in excess of the indicated one directly contradicts the law of energy conservation.

This work has a concrete physical meaning. The system's state in Point 2 is demonstrated in the diagram on the right (position 1). The gas under the piston is at the end of compression, where the pressure is equal to (Pc). During the isobaric supply of heat, the working body increases its volume at the constant pressure (Pc), which leads to the lifting of a load corresponding to position (Pc4). That is precisely what represents the change in potential, or in the system's internal energy.

At Point 4, the system performs the total work, which includes both the expended work and useful work. By conducting the adiabatic expansion process 4-3, the system delivers to the external consumer its total work, represented by the area PA-Pc-2-4-7-6-PA. The expended work is reversible, and so the useful work is the difference between the total work and expended work. The equality of the initial and final parameters of gas can serve as a criterion for the complete fulfillment of the process. For example, we can perform the isothermal process on condition that the adiabatic process 1-2 is available, whereupon the isothermal process 2-3 is performed. The Points 1 and 3 lie on the isobaric curve Pa. Point 2 lies on the isobaric curve Pc.

For the isobaric heat supply, Point 2 serves as a common point and lies on Pc. We perform the adiabatic process from Point 4 and arrive to Point 3, which lies on PA. Therefore, the initial and final parameters of gas are equal. The gas temperature at Point 2 is the same for both the isothermal and isobaric heat

supply at Point 3. We have compared two processes of heat supply, and now let's consider a third one and compare it with the isothermal heat supply process.

10. Comparison of Isochoric and Isothermal Processes

The isochoric process of heat supply is illustrated in Fig. 9.1. It is represented by Points 2-5, on condition that the amount of heat supplied in the isochoric and the isothermal processes is similar. Next, from Point 5 we'll perform the adiabatic process of gas expansion 5-4-3, paying attention to the fact that the initial and final parameters of gas are equal, i. e. the beginning of the isochoric process is located at Point 2 and is common to both the isothermal and the isobaric processes. The adiabatic process starts from Point 5 and ends at Point 3, with the isotherm ending also at Point 5.

Now the following question arises: how much useful work can we obtain? The amount of work in the isochoric process is known and is represented by the area of total work 6-PA-Pz-5-6, which includes the area of expended work 6-PA-Pc-2-6 and the difference between the total work and expended work. The useful work is represented by the area 2-Pc-Pz-5-2. But now another question arises: what represents the work expended during the implementation of the adiabatic process 5-4-3? To answer the question, let's consider how this process proceeds within a cylinder under a piston. Fig. 9.1 (on the right, position 1) shows a cylinder with a piston, whose position corresponds to the completion of gas compression in the cylinder, where the gas pressure is Pc and the gas volume is Vc.

We consider the isochoric heat supply process as a rapid one, leading to a rapid increase in pressure under the piston. However, since there is a load on the piston possessing a significant inertia, the piston with the load will begin to rise slowly upwards. And as the pressure decreases down to Pc, the state of equilibrium will be reached and the piston will stop. This position corresponds to Point 4 in Fig. 9.1.

The physical meaning of the process 5-4 is determined by the fact that it involves the lifting of a load. It can be shown that the potential work in Point 4 is represented by the area 4-7-6-2-4. This work is equal to the potential work in the isothermal and isobaric heat supply processes. The following adiabatic expansion from Point 4 to Point 3 shows that the external consumer receives the same amount of work, regardless of the form of heat supply used, which fully satisfies the law of energy conservation.

Let's notice how the quantitative assessment of work is conducted. Any quantitative assessment is relative, meaning it shows how many times one quantity is greater or smaller than the other. But now we need to take a certain amount of work as a unit. It is convenient to take the expended work as a unit, and the ratio of total work to expended work shows how many times the total work is greater than the expended work.

The expended work is characterized by the degree of compression, which indicates how many times we have compressed the gas, while the degree of expansion indicates how many times we have expanded the gas. In the adiabatic process, the degrees of compression and expansion are equal, which determines the amount of work expended on gas compression exactly as equal to that obtained in the process of gas expansion. And it is precisely this condition that satisfies the law of energy conservation for an adiabatic curve.

Now you can see two forms of measuring work: in the isochoric process, the total work is represented as A = Pz × V5, while in the isobaric process, the total work is represented as A = Pc × V4. The complete equation looks as follows:

$$Pz \times V5 = Pc \times V4 \qquad (8.1)$$

This type of equation has long been known in thermodynamics and represents the law of conservation of gas internal energy.

11. The Combined Method of Heat Supply

Let's consider another method of heat supply - a combined method, which includes both the isochoric and the isobaric supply of heat, as shown in Fig. 9.1. Heat is supplied along both the isochoric curve 2-10 and the isobaric curve 10-9. Then, the process of adiabatic expansion 9-3 takes place, but this adiabatic curve has a section 9-4, where Point 4 lies on the isobaric curve Pc.

A given example of isochoric and isobaric heat supply shows that it is a change in the internal energy of gas, which should be measured by the height of a lifted load. However, the amounts of heat supplied to the gas in both the isochoric process 2-10 and the isobaric process 10-9 are equal to the amount of heat supplied in the isothermal or isobaric processes. Therefore, the combined method of heat supply results in the same height of a lifted load.

Then the adiabatic process 4-3 comes into play – or the delivery of total work to the external consumer, which is the same for all forms of heat supply.

The criterion for delivering the total work to the external consumer is the equality of the degree of compression and the degree of expansion, where the start of expansion degree in the cycle lies on Pc.

When considering the processes of heat supply, we can see that any heat supply processes that take place above Pc are directly connected with the change in the potential energy of gas, which is expressed as the height of a lifted load. And as a result, all the processes of heat supply that proceed above Pc must be brought to the isobar Pc, because the start of delivering the total work to the external consumer lies on Pc; in our example, it is Point 4.

12. Cycles of Heat Engines

The aggregate of thermodynamic processes that yield a positive outcome is called a cycle. Let's examine a cycle in a heat engine with the isothermal heat supply, as shown in Fig. 6.8. This cycle includes the following stages:

1. **Isothermal process of heat supply (1-2)**
2. **Adiabatic process of gas expansion (2-3)**
3. **Isothermal process of gas compression (3-4)**
4. **Adiabatic process of gas compression (4-1)**

Such a cycle is known as the Carnot cycle. It is a reversible cycle, with the area of useful work in this cycle being equal to zero.

In terms of its processes, the Carnot cycle itself does not contradict the law of energy conservation. Further, on the basis of Carnot's axioms, the following assertion is deduced: the useful work in any cycle is equal to its area. In fact, this assertion is absurd.

Now, let's consider the question of a heat engine's efficiency factor (η) – "for a thermal efficiency factor of the Carnot cycle":

$$\eta_T = (T_1 - T_2) / T_1 \qquad (3.32).$$

As can be seen from (3.32), the value of η_T depends on T_1 and T_2. At the same time, η_T is greater when the difference between T_1 and T_2 is larger. The thermal efficiency factor (η) in the Carnot cycle becomes equal to a unit in two practically unattainable cases: either when $T_1=\infty$ or when $T_2=0$. (Ref. 4, page 54). Such an assessment of the heat engine's thermal efficiency factor is rather abstract and does not facilitate the comprehension of the very nature of the heat engine.

Now, we will be able to demonstrate why the efficiency factor in the Nikolaus August Otto air cycle is significantly higher than in the really measured cycle.

The Otto cycle illustrated in Fig. 12.1 encompasses the following processes:

1. **Gas compression process (1-2)**
2. **Isochoric process of heat supply (2-3)**
3. **Gas expansion process (3-5)**
4. **Process that conditionally conclude the removal of heat (5-1)**

According to Carnot's axioms, the useful work in the Otto cycle is represented by the area of the cycle 1-2-3-5-1, which is obtained as the difference between the area under the process 3-5 and the area under the process 1-2. Consequently, the area 2-3-4-2, as part of the useful work in the cycle, is located above Pc (critical pressure). However, we cannot in principal obtain the useful work above Pc, because it is directly at variance with the law of energy

conservation, not to mention the fact that it contradicts even the very definition of useful work.

Since the useful work is the difference between the total work and the expended work, we will gradually examine all the processes involved in the Otto cycle, relying on the law of correlation, and compare the work performed in the processes with the height of a lifted load.

The process 1-2 (gas compression) is the first process that needs to be performed. We will represent it as a gradual increase in the load on the piston. As the load increases, the compression of gas also increases. And at a certain value of the load on the piston, the gas pressure, which balances the weight of the load, will have the value Pc (critical pressure). The work stored in the gas will be represented by the area 8-2-Pc-Pa-8, and it is the total work in the gas that exists in the closed system above Pa.

The next process 2-3, the isochoric heat supply, is represented by the area of work 2-3-Pz-Pa-2. The total or all the work in the closed system after heat supply above Pa is represented by the area 8-3-Pz-Pa-8 and described by the equation Ap = V2 × (Pz – Pa). We consider the isochoric heat supply process as a rapid process that involves a rapid increase in pressure under the piston, and as a result, the piston with the load moves upwards, and this motion finishes when the pressure under the piston reaches the value Pc. In Fig. 12.1, we show the piston's position in Position 2.

The process of increasing the gas volume under the piston is shown by the adiabatic curve 3-4. The total work in the closed system is represented by the equation Ap = (Pc – Pa) ×V4. The process 3-4 is a change in the specific energy of gas, which does not result in the delivery of useful work. It is characterized as the coefficient of preliminary expansion ρ= V4/V2, indicating how many times the total work increased and became greater than the expended work, because the total work in this process is conservable and represented by the equation:

$$(Pc-Pa) \times V4 = V2 \times (Pz-Pa)$$

Цикл Отто

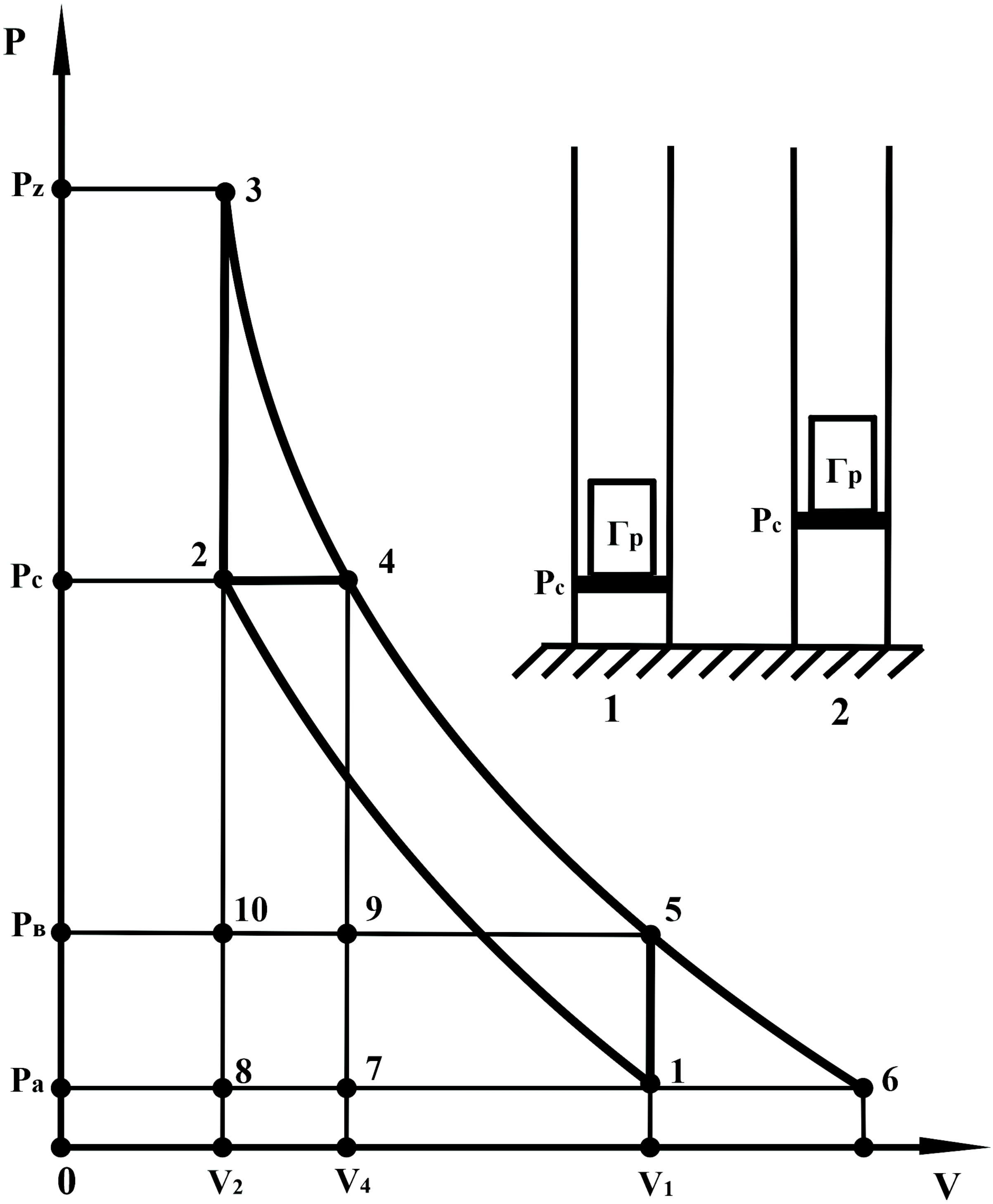


Рис. 12.1

From which it follows that the supply of heat above Pc can proceed in various processes, but they do not affect the amount of work obtained, because the crucial factor here is the amount of supplied heat, which is determined by the value $\rho = V4/V2$.

The delivery of total work to the external consumer begins exactly within the cycle and is represented by Point 4, which lies on Pc, followed by the subsequent movement of the piston and, as a result, a decrease in the load on the piston. The process of delivering the total work to the external consumer is represented by the adiabatic curve 4-6, or 4-5 in the Otto cycle. The Otto cycle belongs to the category of incomplete cycles. And now we want to understand what a complete cycle is.

The complete cycle is a cycle, in which the delivery of total work has a limit determined by natural capacities. It includes the gas compression process, represented by the compression rate $\varepsilon c = V1/V2$. The process of heat supply in any form is characterized by $\rho = V4/V2$. The gas expansion process is determined by the expansion rate $\varepsilon p = V6/V4$. In this case, the complete cycle proceeds above Pa (atmospheric pressure), and its characteristic is $\varepsilon c = \varepsilon p$, which means that the gas volume V4 obtained after the supply of heat must be expanded εc times, making it possible to reach a pressure equal to Pa. The entire process of gas expansion in the complete cycle, including the supply of heat, is $\varepsilon p \times \rho$ times. For the sake of illustration, let's show the complete cycle in figures, with the rate of compression $\varepsilon c = \varepsilon p = 10$, for the supply of heat $\rho = V4/V2 = 2$, and the total expansion rate $\varepsilon p \times \rho = 20$.

On these conditions, all the maximum possible total work that can be obtained between Pa and Pc is delivered to the external consumer.

The next stage in the cycle's implementation is to bring the system back to its initial state. This can be accomplished in two ways. The first way involves the proceeding of the cycle in a closed system, so after reaching the pressure Pa, the gas goes to the heat exchanger, where it cools down and then compresses to V1. Then the cycle repeats itself. The second way involves the discharge of the used gas into the atmosphere and the intake of fresh gas from the atmosphere with initial parameters, which allows the cycle to repeat itself. To accomplish this, the compression process must be performed. The work expended on gas compression is recoverable and subtracted from the total work, whereupon the external consumer receives the useful work.

Now, from this position, let's look at the Otto cycle. In the formula of thermal efficiency factor for the Otto cycle, the equality $\varepsilon c = \varepsilon p$ is accepted, but it applies to the geometric movement of the piston during the processes of compression and adiabatic expansion 1-2 and 2-1. The rate of expansion, exactly in this cycle and then in any other cycle, including the Otto cycle, is determined by the ratio of total expansion in the cycle, $\varepsilon p \times \rho = \varepsilon p$. Now showing this example in the numerical form, we obtain $\varepsilon p \times 2 = 10$ and $\varepsilon p = 5$, which clearly

points to a flaw in the determination of the thermal efficiency factor in the Otto cycle. That is the result of an axiomatic approach to understanding the work of a heat engine, leading to an absurd result, and as a consequence, the theoretical thermal efficiency factor is significantly higher than the real one, because the theoretical thermal efficiency factor absolutely does not take into account the real losses of work in the Otto cycle, which are demonstrated.

The process of gas expansion with the delivery of total work to the external consumer begins at Point V4, which lies on Pc, and ends at Point 5. However, since the expansion process is incomplete (εp = 5), the gas pressure at Point 5 significantly exceeds Pa and is called the exhaust pressure. As a result, a portion of the total work, including both the useful and expended work, is lost. This portion is represented by the area 1-5-Pв-Pa-1. The subsequent process of gas compression proceeds at the expense of the reverse work, which is incomplete, and this deficiency is compensated from the useful work.

Such losses are not necessary; they are the result of engine design imperfections, meaning that the design does not meet thermodynamic requirements.

Now, let's consider whether the useful work is available above Pc. By definition, the useful work is the difference between the total work and the expended work. In real internal combustion engines (IC engines) with the Otto cycle, the total work is delivered to the flywheel. Then, the flywheel expends a portion of the total work on gas compression, leaving the useful work on the flywheel. However, it is principally impossible to receive the useful work above Pc.

If the external consumer receives the useful work above Pc, then later the external consumer should also have to receive the total work during the expansion process 4-6. In other words, the external consumer will receive both the total work and the useful work above Pc, which is impossible in principle, because such a receipt of the useful work directly contradicts the law of energy conservation. To reiterate, the total work is all the work that can be delivered to the external consumer.

Let's illustrate the availability or absence of useful work above Pc in a somewhat different way. We can supply heat to the gas in a closed system through the isochoric process, where the area of total work is represented as 8-3-Pz-Pa-8.

Now, let's supply a similar amount of heat to the gas by the isobaric process, where the total work is represented by the area 7-4-Pc-Pa-7. According to the law of energy conservation, a similar amount of supplied heat produces a similar amount of useful work.

The useful work in the isochoric process is represented by the area 2-3-Pz-Pc-2.

The useful work in the isobaric process is represented by the area 7-4-2-8-7. These areas are equal, and the areas of total work are also equal.

The location of these areas clearly shows that the availability of useful work above Pc is impossible, since such an area of useful work contradicts the law of energy conservation. Such contradictions with the law of energy conservation exist as a result of Carnot's axioms, which create a distorted understanding of the nature of heat engines.

And now we'll consider the next cycle of heat engine. It is a cycle with the isobaric heat supply. For the first time, an internal combustion engine was patented by Rudolf Diesel. We'll illustrate it in Fig. 12.2. It encompasses the following processes: the process of gas compression 1-2, the isobaric process of heat supply 2-4, the process of expansion or delivery of the total work to the external consumer 4-5 and the conditionally closing process 5-1.

It is clear that the Diesel cycle is incomplete, and in the same way as the Otto cycle, has non-productive losses of total work at the moment of exhaust, which clearly highlights the fact that the design of internal combustion engines is at variance with the requirements of thermodynamics.

The next cycle we are going to consider is a cycle with the combined heat supply, which includes the following processes: gas compression, the supply of a portion of heat by the isochoric process and then later the supply of heat by the isobaric process and, finally, the delivery of total work to the external consumer.

This cycle is known as the Trinckler-Sabate cycle. It is also incomplete, with no useful work above Pc. Moreover, as in the Diesel cycle, there are big unproductive losses at the moment of total work exhaust there. And what's more, the cycle under discussion has heat losses as all other kinds of internal combustion engines. The ecological effects of exhaust gases are poor and leave much to be desired.

Let's examine one more cycle, which is known as the Carnot cycle (Fig. 12.2). The classical Carnot cycle consists of two isotherms and two adiabates, but the presence or absence of adiabates in the cycle in no way changes the physical or quantitative meaning of the heat engine cycle.

ЦИКЛ КАРНО

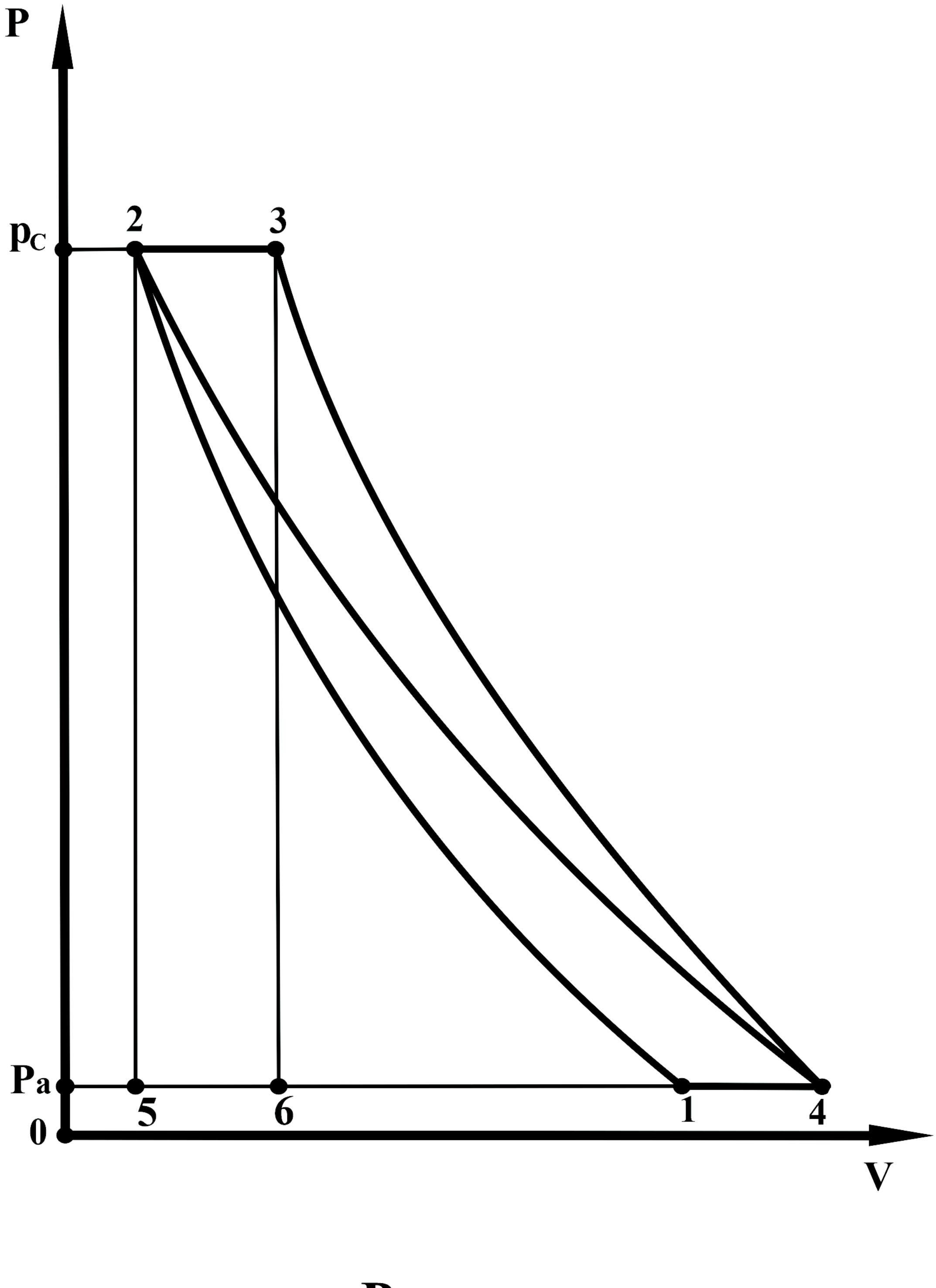


Рис. 12.2

Since the isothermal process is essentially the adiabatic process with heat supply, where the temperature remains constant, we consider a heat engine cycle consisting of two isotherms.

Let's supply heat through the isotherm 2-4, but the isotherm is a complex process. And for a clearer understanding of the nature of heat engines, we'll break down the isotherm into simpler processes, i.e. the isobaric heat supply process 2-3 and the adiabatic expansion process 3-4. It becomes evident that in the isothermal process 2-4, we deliver all the work to the external consumer. However, in the course of the isobaric heat supply process 2-3, followed by adiabatic expansion 3-4, we also deliver all the work to the external consumer. As an element of the cycle, the paths 2-4 and 2-3-4 are energetically equivalent.

Now, from Point 4, we can perform the isothermal process 4-2, creating a reversible cycle that includes two isotherms. And here the following question arises: what determines the useful work in such a cycle? We cannot represent all the useful work in the isothermal process, because in Point 2, the area 2-Pc-Pa-5-2 is represented, which shows the amount of work expended on gas compression.

After the isothermal process is performed in Point 4, the gas has already delivered all the possible work and retains some residual work represented under the isobar Pa. In any intermediate point between Point 2 and Point 4, the state of gas will have only a portion of the total work, which results from the combined heat supply and the delivery of total work to the external consumer. However, since the same amount of heat produces the same amount of mechanical work, we can factorize the isotherm into an isobar, followed by the delivery of total work to the external consumer.

The total work lies under the isobar Pc-3 and is represented by the area Pc-3-6-Pa-Pc. This is the total work for both the cycle with isothermal heat supply and the cycle with isobaric heat supply. And now let's perform the reverse isothermal process 4-2. In this process, the external consumer returns the total work to the system, leaving the consumer with 0 work. It becomes clear that if we perform the classical Carnot cycle, the amount of useful work is also zero. The following question then arises: in what way can the external consumer obtain the useful work?

Let's illustrate the cycle with heat supply through the isotherm. From Point 2, we perform the isothermal process 2-4. At the same time, the external consumer will receive the entire work, whose area is equal to Pc-3-6-Pa-Pc. Then to continue the cycle's realization, we remove heat by the isobaric process 4-1, expending some work on gas compression.

Next, we perform gas compression by the adiabatic process 1-2, subtracting the work spent on compression from the total work delivered to the external consumer. The external consumer retains the useful work, represented by the area 2-3-6-5-2.

Now, let's show an equivalent cycle with isobaric heat supply. From Point 1, we perform the adiabatic gas compression process 1-2, followed by the isobaric

heat supply process 2-3, followed by the adiabatic gas expansion process, with the delivery of total work to the external consumer, 3-4. After that, we remove heat by the isobaric process 4-1, expending some work on gas compression. Finally, we compress the gas by the adiabatic process 1-2, subtracting the work spent on compression from the total work delivered to the external consumer. The external consumer is left with the useful work, represented by the area 2-3-6-5-2. These areas are identical, and the amounts of useful work in these cycles are also equal. The isotherm acts as a diagonal of the entire cycle.

Now, let's consider the question of thermal efficiency factor (TEF) for the heat engine. It might seem that we can use the Carnot formula, but it provides a subjective result, because heat and temperature are only conditions for the potential realization of a heat engine. But what does a useful action (thermal efficiency) mean? For us, a useful action is a mechanical work, and it is essential to understand how much useful work we can obtain and what the maximum possible work is. Clearly, work is directly connected with such a gas parameter as pressure. The heat engine makes use exactly of pressure differences, and its thermal efficiency can be evaluated as follows:

$$TEF = \frac{P_c - P_к}{P_c}$$

Where:

- Pc - the final pressure of compression
- Pk - the final pressure of the gas expansion process

Evidently, the thermal efficiency factor (η) does not depend on the thermal capacity of gas. It becomes clear that it is necessary to increase a compression rate for the purpose of enhancing the efficiency of internal combustion engines (IC engines). The compression rate also has another physical meaning: it represents the heat engine’s specific power capacity.

We have presented all the known forms of heat supply and possible thermodynamic cycles. It becomes evident now that an engine’s thermal efficiency is determined by the realization of exactly a complete cycle. A complete cycle, in turn, can be performed with isochoric heat supply, combined isochoric-isobaric heat supply, isobaric heat supply, isothermal heat supply and other forms of heat supply. Given such a diversity of heat supply methods, it is quite appropriate to ask here: and which cycle is the best for internal combustion engines (IC engines)? To have a clear understanding of this question, let's explore a very important fact, which we illustrate in Fig. 12.3.

In the T-S (temperature-entropy) diagram, we show a complete cycle consisting of the compression process 1-2, the isochoric heat supply process 2-3, the complete expansion process 3-4, and the closing isobaric process 4-1. This

cycle is known as the Atkinson cycle. For gasoline IC engines, the compression rates for both the Otto cycle and the Atkinson cycle are equal, ε = 8-10. Now at the same compression rate we'll show the supply of heat by the isobare 2-5, on condition that the amounts of heat in the isobaric and isochoric processes are equal. It is now seen in the diagram that the compression rates for the Otto cycle and the Atkinson cycle are equal ε= 8-10.

And now, at the same compression rate, let's show the supply of heat by the isobar 2-5, on condition that the amounts of heat supplied in the isochoric and isobaric processes are equal. It is clearly seen in the diagram now that the upper temperature limit in Point 5 is significantly lower than in cases where the heat is supplied by the isochoric process in Point 3.

Today, the possibilities to increase the compression rates in the isochoric process for modern IC engines are practically exhausted, and the temperature in Point 3 is most optimized for fuel combustion. That's why we will keep the temperature in Point 3 unchanged. This raises the question however: is there a way to increase the compression rate for gasoline IC engines? Our answer is: yes, such a possibility exists, and we will demonstrate it.

To achieve this, we will increase the compression rate by the amount of temperature difference 5-3 and obtain the temperature of compression rate in Point 6. From this Point, we will perform the isobaric heat supply process and obtain the temperature in Point 3. The entire cycle will be represented as follows: gas compression 1-6; isobaric heat supply 6-3; the expansion process with the delivery of all the total work to the external consumer 3-4; isobaric heat removal in the cycle 4-1.

ИЗОБАРНЫЙ И ИЗОХОРНЫЙ ПРОЦЕСС

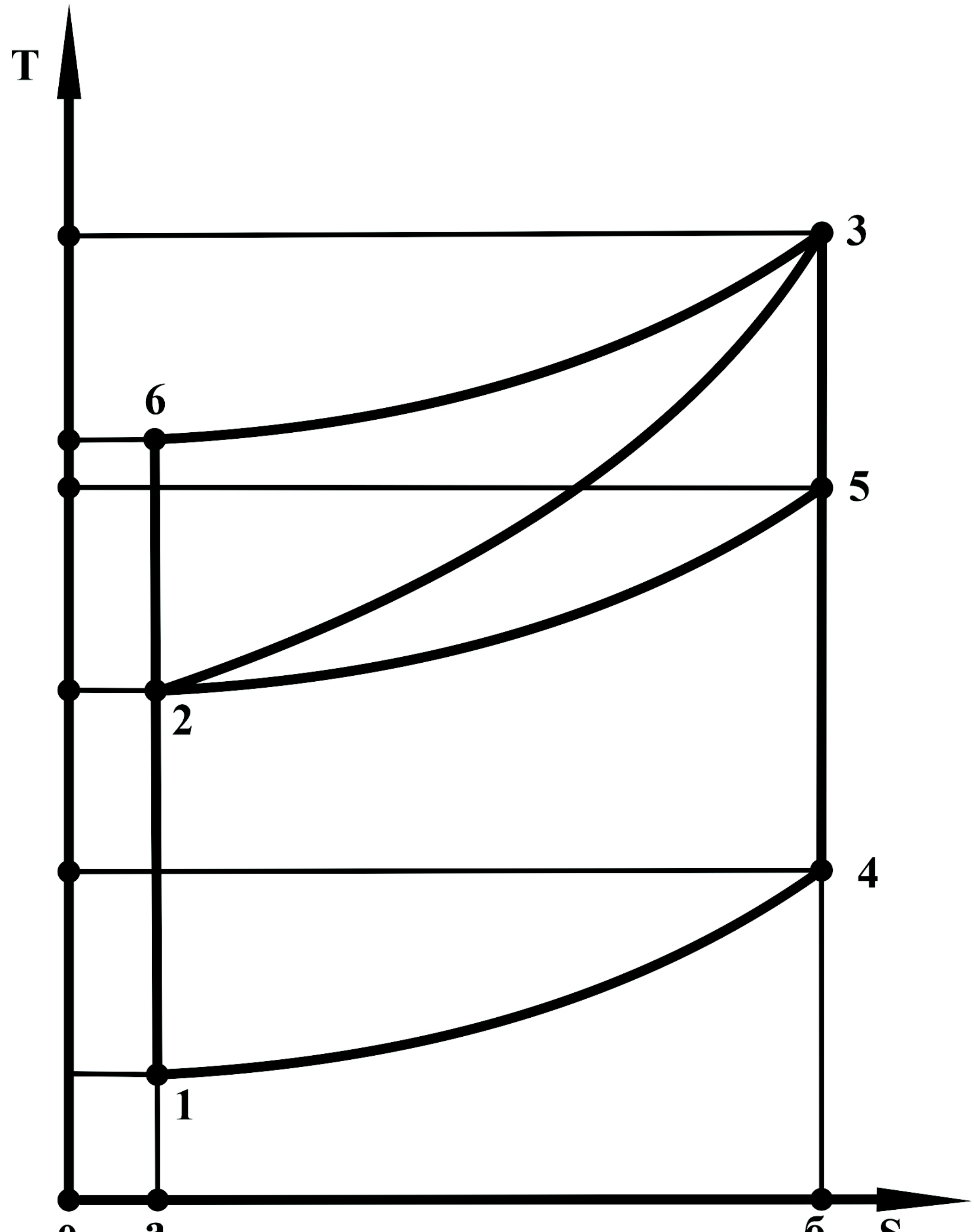


Рис.12.3.

Such a cycle is a complete cycle with isobaric heat supply, and the compression rate in such a cycle can be significantly higher than that in the Otto cycle.

Known as the Briton cycle, it is used in gas turbine engines. And now let's compare all the known cycles used in internal combustion engines.

The internal combustion engines with the Diesel cycle are more efficient than those with the Otto cycle. The internal combustion engines with the Trinkler cycles are also more efficient than those with the Otto cycle. The internal combustion engines with the Briton cycle, which have even a lower compression rate, are more efficient than the engines with the Otto cycle at the expense of a more complete expansion rate.

From this brief comparison of known internal combustion engines, it becomes evident that the internal combustion engines with the Otto cycle are the least efficient. This raises the question: why aren't gas turbine engines used in automobiles? The answer is simple: the gas turbine engines cannot operate at low speeds, and their engine parameters are unsatisfactory at low power levels. The gas turbine engines exhibit good characteristics at power levels of around 1000 horsepower or higher.

At the same time, it is important to note that the environmental impact of stroke-based internal combustion engines leaves much to be desired. And now, it is necessary to examine the reasons behind such an unsatisfactory state of affairs in this field.

To do this, we will examine the working principle of internal combustion engines as well as their construction, which is schematically shown in Fig. 12.4.

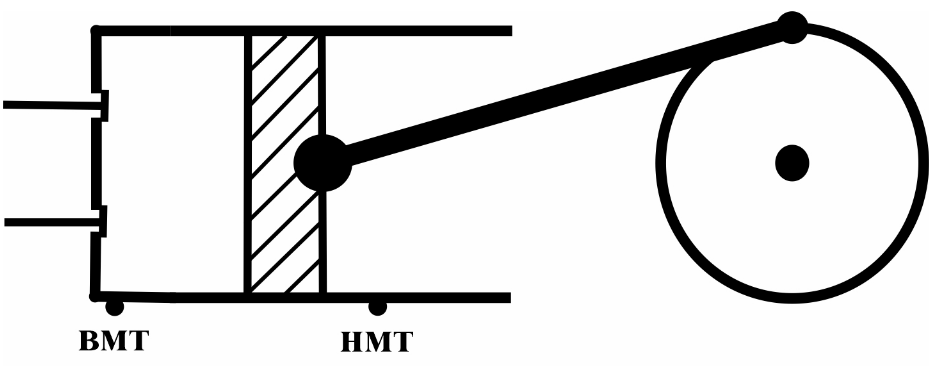


Рис.12.4

The internal combustion engines (ICE) are divided into four-stroke and two-stroke ones, but both modifications include the same structural elements, such as a crankshaft, a connecting rod, a piston, a cylinder, fuel delivery and ignition systems. The piston moves in the cylinder from the top dead center (TDC) to the bottom dead center (BDC). The piston and the cylinder above the piston create a closed space, whose volume increases or decreases as the piston moves. When the piston is at the TDC, a chamber for fuel combustion is formed above it. Looking at this heat engine scheme, it is easy to see that with the valves being closed, a closed volume of the chamber of fuel and fuel-air mixture combustion is formed above the piston, and the entire fuel combustion process is connected with the piston's movement.

The stroke-based operational cycle in the internal combustion engine (ICE) dictates the engine's cyclic operation, where a cycle is realized either in two strokes or four strokes. However, in both two-stroke and four-stroke ICEs an incomplete Otto cycle is realized, resulting in significant losses in overall efficiency. The use of ICEs in automobiles leads to the situation where such engines operate with an alternating number of the crankshaft's rotations, resulting in insufficient time for the fuel combustion process.

This method of fuel combustion entails the incomplete fuel combustion as well as the formation of toxic components in exhaust gases, both in gasoline and diesel internal combustion engines, which deteriorates the environmental situation, especially in cities.

Now, it seems that something can be changed for the better, and such an attempt has been made by realizing the Atkins cycle. However, it has failed. Presented below is a brief explanation of the reasons behind its failure.

The realization of the Atkins cycle in a stroke-based engine proceeds as follows: the piston, being in the TDC position with the opened intake valve, draws in the fuel-air mixture while moving towards the BDC position. And as the piston reaches the midpoint of its running, the intake valve closes, and the piston's further movement proceeds with the thinning of gas above it. As the piston reaches the BDC position, it starts the compression stroke, in which the actual compression of the fuel-air mixture occurs after the piston reaches the midpoint of its running, with the degree of compression determined by the gasoline grade. As the piston reaches the TDC position, the fuel-air mixture ignites, and after passing the TDC position, the power stroke begins, which runs from the TDC position to the BDC position. Then the exhaust valve opens, and the exhaust stroke takes place. After that the cycle recurs.

The Atkins cycle we have described above can be considered to be a complete cycle; in our case, we have chosen the coefficient of pre-expansion equal to two.

It becomes evident that the functional efficiency with such a cycle will improve significantly, but at the same time the engine's metal-consumption will double, making the realization of this possibility less promising.

These issues regarding ICEs are well-known, and we have presented them briefly to demonstrate that the internal combustion engine with the Otto cycle is the worst of all possible options, since just the engine's design does not meet the thermodynamic requirements. Now, it seems that a new design is needed. When surveying the global patent fund, we see a great number of various ICE designs. Let's pay attention to one of them.

It is a Wankel rotary engine. The design of this engine is quite original, and it implements the Otto cycle. But in fact, it is just a new design rather than a new engine. One of the design's positive features is its level of metal consumption, which is three times lower than that of four-stroke internal combustion engines (ICEs). However, other characteristics leave much to be desired, that's why its use is limited.

As for other engines indicated in the patent fund, we are inclined to note that they are indeed new designs that implement the Otto cycle. As a result, they are not widely used.

Such a situation appears solely as a result of that thermodynamics which is based on Carnot's axioms. We have shown a new thermodynamics, and now we are going to briefly demonstrate the possibilities of a new engine, which can be compared with all the known ones.

RPD. BR. Olkh. is a new engine with a new operating principle and a new design, which makes it possible to implement a complete cycle with the isobaric heat supply. And consequently, when using gasoline, it becomes possible to use $\varepsilon = 16$, which makes it possible to achieve the highest efficiency.

The full-flow combustion chamber has a continuous fuel supply, which ignites during the launch and burns continuously during the entire course of engine operation. The full-flow combustion chamber enjoys a significantly longer period of time for the complete combustion of fuel than in stroke-based internal combustion engines, which results in an almost 100 per cent fuel utilization coefficient. This creates the possibility of a cleaner exhaust. The lubrication system is separate.

The full-flow combustion chamber is equipped with an insulation system, whose inner surface reaches a high temperature during engine operation, contributing to a more complete combustion of fuel.

The partition's surface and the surfaces of the pistons facing the chamber also have thermal insulation. The use of thermal insulation has no impact on the operational principle of the RPD; on the contrary, the RPD's operational

principle makes it possible to use thermal insulation, which significantly reduces heat losses.

The isobaric heat combustion process in the combustion chamber at different RPD rotation speeds is maintained by changing the piston's TDC position in relation to the combustion chamber's windows, making it possible to regulate the inflow and outflow of the working medium in the combustion chamber. The RPD can be designed for different types of fuel, since it is possible to re- adjust the compression rate without changing the overall design. The metal consumption of the RPD is significantly lower than that of traditional ICEs, ranging from 0.3 to 0.5 of metal consumption of four-stroke ICEs.

The RPD is a high-speed engine, and a given characteristic does not depend on the type of fuel chosen.

The RPD's operational principle makes it possible to use the engine with the external supply of fuel.

For this purpose, it is necessary to connect the heat exchanger's pipes up to the intake and exhaust windows of the tank course instead of the combustion chamber. These actions have no impact at all on the RPD's operational principle; the connection of the heat exchanger influences only the engine's launching time, i.e. the time required to create in the heat exchanger the pressure corresponding to the design compression rate.

Now we can say that a given RPD meets the requirements of thermodynamics and invite all our opponents to present an engine better than this one.

In conclusion, we will quote Albert Einstein's words regarding classical thermodynamics:

"The theory makes the bigger impression the simpler its premises are, the broader variety of objects it links, and the wider field of its application is. It is this very thing in classical thermodynamics that has made the deepest impression on me. It is the only physical theory of general application, in whose respect I am sure that within the framework of applicability of its basic concepts, it will never be overturned (to the special notice of skeptics)." (Ref. 4, p. 407).

One is inclined to add to this remark: "Blessed are those who believe in axioms and postulates." In physics, only laws based on correlation are valid.

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