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The system of organization of the IWS and IWST studies by the example of «Transport phenomena»

The article is devoted to the development of methods for conducting independent work of students in the conditions of credit technology of education. The main idea is the need to change the accent position – first the IWS, then the IWST using the example of a specific section of molecular physics: «Transport». Transport phenomena are experimental justification and confirmation of the fundamentals of molecular-kinetic theory. This section is practically not considered in the school course of physics because of its complexity, but with careful study of the material, it can be given in classes with a physical and mathematical bias. The article selected and analyzed the problems of increased complexity, which students of secondary schools offer no sense, since they are very complex in physical essence and require a mathematical apparatus at the level of at least differential equations. The students were offered two laboratory works - one contact, which is classical and does not need special comments, and one is virtual with the expectation that they can be used both in university and in school. Assignments on the topic within the framework of the IWS with different number of answers were selected and tested, and questions requiring careful study by students using literary sources. The results of the physical dictation, colloquium, testing in the system of EVEA, control work were carried out and analyzed. The proposed system of organizing the IWS and IWST for many years was developed in the educational process for general courses of physics and special courses of the appropriate profile, during the performance of the theses, during pedagogical practices, was presented in reports at conferences.

Keywords: diffusion, thermal conductivity, viscosity, ultra rarefied gas, mass, momentum, energy, credit technology training, IWS, IWST.

The system of organizing classes in terms of credit technology training involves a sequence: lectures, hands-on exercises to solve problems, laboratory exercises, IWST, IWS. We believe that such a sequence is not entirely reasonable. Naturally, without lecture, practical and laboratory, that is, classroom organization of the IWS is impossible, especially since the conduct of all classes is determined by the schedule.

In the thesis work the system of organization of IWS and IWST is considered on the example of the section of molecular physics: «Transport phenomena».

Transport phenomena are experimental substantiation and confirmation of the fundamentals of the molecular-kinetic theory of ideal gases [1].

Depending on the transfer of what physical characteristics the researcher is interested in, three transport phenomena are distinguished: diffusion, viscosity and thermal conductivity [2].

Diffusion is a process of gradual mutual penetration of two adjoining substances. Thermal conductivity is the process of heat transfer from more heated parts of the body to less heated ones. Viscosity, or internal friction, occurs when the layers of a gas or liquid are relatively displaced [3]. Analyze the example transport phenomena of increased complexity problems.

1. Two identical parallel disks whose axes coincide are located at a distance h from each other. The radius of each disc is a, and $a >> h$. One disc is rotated at a slight angular velocity ω , another disk is stationary. Find the moment of frictional forces acting on the fixed disk, if the viscosity of the gas between the disks is η [4; 109] (Fig. 1).

Given:
h
a
a>>h
ω
η

M_{fr} = ?

Solution:

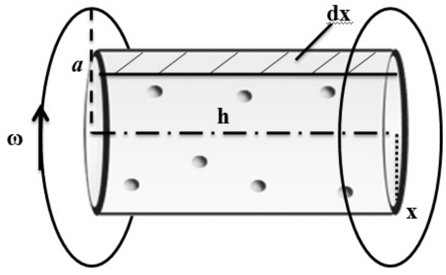

Figure 1. Gas between discs

We divide the volume of gas between the disks into elementary coaxial cylindrical layers and consider one of them of radius *x* and depth *dx*.

Within its limits:

$dF_{fr} = \eta \frac{\omega x}{h} 2\pi x dx$ (on the basis of the law of viscosity).

$$dM_{fr} = dF_{fr} \cdot x = 2\pi\eta \frac{\omega}{h} x^3 dx.$$

We integrate, obtain:

$$M_{fr} = 2\pi\eta \frac{\omega}{h} \int_0^a x^3 dx = \frac{\pi\eta\omega a^4}{2h}.$$

The basic indication is that $a >> h$. This means that the motion of molecules involved in the process between the disks can be considered one-dimensional.

2. Decide the previous problem, considering that between the disks there is an ultra- rarefied gas of molar mass *M*, temperature *T* and pressure *p* [4; 110].

Given:
h
a
a>>h
ω
M
T
p

M_{fr} = ?

Solution:

We use the picture of the previous problem. But, since the gas is in an ultra-rarefied condition, there can be no question of any viscosity. Gas molecules colliding with disks, transfer from one to another the impulse. Within any of the coaxial cylindrical layers:

$$dK = \frac{1}{6} m_0 \omega x n \cdot 2\pi x dx \langle \upsilon \rangle ,$$

where m_0 – mass of a gas molecule; n – its concentration; $\langle \upsilon \rangle$ – the average velocity of chaotic motion of gas molecules.

Since dK – momentum, carried by gas molecules per unit time, then according to Newton's law II we have:

$$dK = \frac{1}{6} \frac{M}{N_{Av}} \omega x \frac{p}{kT} 2\pi x dx \sqrt{\frac{8RT}{\pi M}} = dF_{fr}.$$

We turn to the moment of forces:

$$dM_{fr} = dF_{fr}.$$

Integrating, we obtain:

$$M_{fr} = p \frac{\omega a^4}{3} \sqrt{\frac{\pi M}{2RT}}.$$

3. The space between the large horizontal plates is filled with helium. The distance between the plates is *l* = 50 mm. The lower plate is maintained at a temperature T_1 = 290 К, the upper plate at T_2 = 330 К. The gas pressure is close to normal. Find the heat flux density [4; 110] (Fig. 2).

Given:
He
$M = 4 \cdot 10^{-3}$ kg/mol
$i = 3$
$l = 0{,}05$ m
$T_1 = 290$ К
$T_2 = 330$ К
$p \sim p_{\text{norm}}$

Q_0 = ?

Solution:

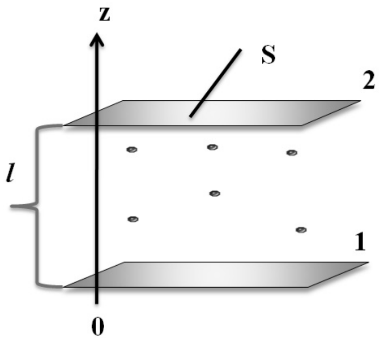

Figure 2. Gas between plates

Since the temperature of the lower plate is less than the upper one, convection is excluded. The gas pressure between the plates is unknown, but it is close to normal, so heat is transferred due to viscosity. And, finally, since by the condition of the problem, the plates are large, the process of heat transfer can be considered one-dimensional.

According to the Fourier law:

$$Q = +\aleph \frac{dT}{dz} S,$$

where $Q = Q_0 \cdot S$ – heat transported per unit time.

Regarding the signs: one «minus» takes into account the fact that the primary heat transfer occurs towards the temperature, that is, from the upper plate to the lower plate, the other – that this happens in the direction opposite to the *z* axis.

$$\aleph = \frac{1}{3} \rho c_V \langle \lambda \rangle \langle \upsilon \rangle;$$

$$Q_0 \cdot S = \frac{1}{3} m_0 n \frac{\frac{3}{2} R}{M} \cdot \frac{1}{\sqrt{2} \pi d_{eff}^2 n} \cdot \sqrt{\frac{8RT}{\pi m_0}} \frac{dT}{dz} \cdot S.$$

We separate the variables, integrate, previously using the known relations, we obtain:

$$Q_0 = \frac{2}{3} \frac{R^{3/2} (T_2^{3/2} - T_1^{3/2})}{\pi^{3/2} l d^2 N_{Av} \sqrt{m}}.$$

Calculate: Q_0 = 40 W/m^2, where the effective diameter of the helium atom is replaced by its geometric diameter.

4. Helium at pressure p = 1 Pa is located between two large parallel plates spaced from each other by l = 5 mm. One plate is maintained at a temperature t_1 = 17 ºC, and the other at t_2 = 37 ºC. Find the mean free path of helium atoms and the density of heat fluxes [4; 110].

Given:
He
$p = 1$ Pa
$i = 3$
$l = 5$ mm
$T_1 = 290$ K
$T_2 = 310$ K
$p \sim p_{\text{norm}}$

$\langle \lambda \rangle = ?$
$Q_0 = ?$

Solution:

Using the drawing of the previous problem. Determine the mean free path of molecules not by given conditions:

$$\langle \lambda \rangle = \frac{k \langle T \rangle}{\sqrt{2} \pi d_{eff}^2 p} \cong \frac{1{,}38 \cdot 10^{-23} \cdot 300 \cdot 10^3}{1{,}4 \cdot 3{,}14 \cdot 4 \cdot 10^{-20} \cdot 1} \cong 23\text{mm} > l.$$

That is, helium is in an ultra-rarefied condition, which means that there cannot be any thermal conductivity, and heat transfer from one plate to another is carried out by transferring the thermal energy between them by the He molecules.

$$Q_0 = \frac{1}{6} \left(\frac{i}{2} k T_2 - \frac{i}{2} k T_1 \right) n \langle \upsilon \rangle = \frac{1}{6} \frac{3}{2} k (T_2 - T_1) \cdot \frac{p}{k \langle T \rangle} \sqrt{\frac{8R \langle T \rangle}{\pi m_0}} = p \sqrt{\frac{R}{2\pi M \langle T \rangle}} (T_2 - T_1) \cong 22 \text{W/m}^2.$$

5. Determine the thickness of the ice formed during a given time *t* on the calm surface of the lake. Consider that the ambient temperature *T* is constant all the time and is equal to the temperature of the outer surface of the ice ($T < T_{mel}$,where T_{mel} - is the melting temperature of the ice). Calculate numerically, assuming that t = 10 ºC. For ice $\aleph$ = 2,2 W/m·K, $\lambda = 3{,}4 \cdot 10^5$ J/kg, $\rho = 10^3$ kg/m^3 [5] (Fig. 3).

Given:

$T_0 = 263\text{K}$

$T_0 = const$

$T_{mel} = 273\text{K}$

$\aleph$ = 2,2 W/m·K

$\lambda = 3{,}4 \cdot 10^5$ J/kg

$\rho = 10^3$ kg/m^3

τ = day

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z = ?

Solution:

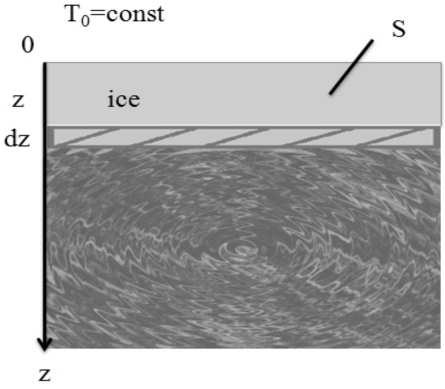

Figure 3. Lake

z – the thickness of the ice formed by the time. Heat, which is released when the next elementary layer freezes:

$$\delta Q = -\lambda\rho S dz$$

(The «minus» sign is due to the fact that the heat is given off by freezing water.)

This heat leaves through a layer of ice «z» thickness due to the thermal conductivity to the outside:

$$\delta Q = -\aleph \frac{T_{mel} - T_0}{z} S dt.$$

(The «minus» sign takes into account the fact that the transfer of heat is carried out in the direction opposite to the *z* axis.)

$$+\lambda\rho S dz = +\aleph \frac{T_{mel} - T_0}{z} \lambda dt;$$

$$z dz = \frac{\aleph}{\lambda\rho}(T_{mel} - T_0) dt.$$

Integrate

$$z = \sqrt{\frac{2\aleph(T_{пл} - T_0)\tau}{\lambda\rho}}.$$

Calculate: $z \cong$ 11 cm.

An important role in the deeper mastery of the physics course is played by laboratory exercises. On the theme, students are offered one contact laboratory work: «Determination of the viscosity of the liquid by the Stokes method», which is quite classical and does not need special comments, and one virtual laboratory work: «Determination of the mean free path of molecules» [6].

Let's consider virtual laboratory work.

In this laboratory work Brownian particles are investigated. Exercise 1 introduces 25 particles with a diameter of 350 conventional units. The temperature is set to 1000 K. Then the diameter is changed from 350 conventional units to 100 conventional units, with a step of 50 conventional units. Determine the corresponding $\langle\lambda\rangle$. The results of the measurements are given in Table 1 and Figure 4.

Table 1

Results of exercise 1

d, conv. units	$\langle\lambda\rangle$, conv. Units
350	2000
300	2200
250	2400
200	2700
150	3300
100	8500

In the second exercise, the particle diameter is fixed to d = 250 conventional units. The temperature is 1000 K. The particle concentration varies from 25 to 5 with a step of 5 particles. $\langle\lambda\rangle$ is determined. The results are presented in Table 2 and Figure 5 [7].

Table 2

Results of exercise 2

N	$\langle\lambda\rangle$, conv. Units
25	2600
20	2800
15	4200
10	6400
5	17500

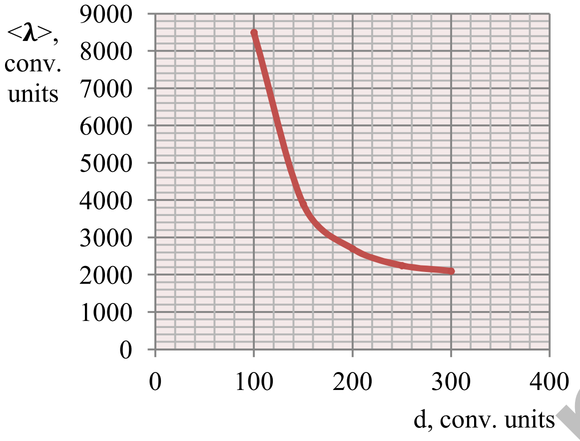

Figure 4. Dependence of the mean free path of molecules on the diameter

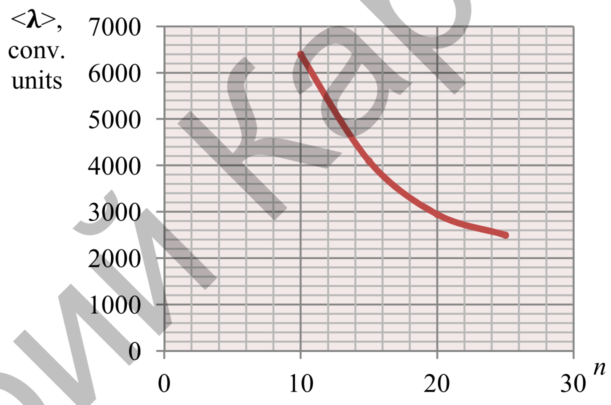

Figure 5. Dependence of the mean free path of molecules on the its concentration

The credit system of education requires the qualitative organization and appropriate independent work of students (IWS).

The main types of independent work of students without the participation of teachers are the formation and assimilation of the content of the lecture notes on the basis of the educational literature recommended by the lecturer, including information educational resources (electronic textbooks, electronic libraries, etc.); writing essays; preparation for classes, laboratory works, their design; compilation of an annotated list of articles from relevant journals by field of knowledge; preparation of reviews for the article, allowance; implementation of micro-surveys; preparation of practical developments; the fulfilment of homework in the form of solving individual problems, performing standard calculations, calculating computer and individual work on separate sections of the content of disciplines, etc.; operating self-monitoring and control of academic progress on the basis of electronic training and evaluation tests. Depending on the features of the discipline studied, the list of types of work can be expanded and changed [8].

IWS promotes the assimilation of knowledge, the formation of professional ability and skills, ensures the formation of professional competencies for the future graduate.

The goal of independent work is to teach the learner to make sense and independently work first with educational material, then with scientific information, lay the foundations for self-organization and self-education in order to instill the ability to continuously improve his skills in the future.

Let us consider the organization of IWS (in questions and answers) on the example of transport phenomena [9].

1. Construct the correct statements about the correspondence of the transferred quantity to this transfer process.

1.1. In the process of …	2. … is transferred …
a) … diffusion …	a) … momentum …
b) … viscosity …	b) … energy …
c) … thermal conductivity …	c) … mass …

2. Specify the correct formulas relating to diffusion in gases:

2.1. $dm = D\left|grad\rho\right|dSd\tau$;
2.2. $dm = D\left|grad\rho\right|dS$;
2.3. $dm = -D\left|grad\rho\right|dSd\tau$;
2.4. $\vec{j} = -Dgrad\rho d\tau$;
2.5. $\vec{j} = Dgrad\rho$;
2.6. $\vec{j} = -Dgrad\rho$;
2.7. $\vec{j} = -Dgrad\rho dS$;
2.8. $\vec{j} = -Dgrad\rho dSd\tau$;
2.9. $D = -\langle\lambda\rangle\langle\upsilon\rangle$;
2.10. $D = -\frac{1}{3}\langle\lambda\rangle\langle\upsilon\rangle$;
2.11. $D = \frac{1}{3}\langle\lambda\rangle\langle\upsilon\rangle$;
2.12. $D = \langle\lambda\rangle\langle\upsilon\rangle$.

3. Specify the correct formulas relating to the viscosity in gases:

3.1. $dK = -\eta\frac{du}{dx}dS$;
3.2. $dF = -\eta\frac{du}{dx}$;
3.3. $dK = -\eta\frac{du}{dx}dSd\tau$;
3.4. $\eta = \frac{1}{3}\langle\lambda\rangle\rho$;
3.5. $dF = -\eta\frac{du}{dx}dS$;
3.6. $dF = -\eta\frac{du}{dx}d\tau$;
3.7. $dK = -\eta\frac{du}{dx}d\tau$;
3.8. $\eta = \langle\lambda\rangle\langle\upsilon\rangle\rho$;
3.9. $dF = \eta\frac{du}{dx}dS$;
3.10. $\eta = \frac{1}{3}\langle\lambda\rangle\langle\upsilon\rangle\rho$;
3.11. $dK = \eta\frac{du}{dx}dSd\tau$;
3.12. $\eta = -\frac{1}{3}\langle\lambda\rangle\langle\upsilon\rangle\rho$;
3.13. $dF = -\eta\frac{du}{dx}dSd\tau$;
3.14. $\eta = \frac{1}{3}\langle\upsilon\rangle\rho$.

4. Specify the correct formulas relating to the thermal conductivity of gases:

4.1. $\delta Q = \aleph\left|gradT\right|dSd\tau$;
4.2. $\aleph = -\langle\lambda\rangle\langle\upsilon\rangle\rho c_V$;
4.3. $\vec{q} = -\aleph gradTdS$;
4.4. $\aleph = \frac{1}{3}\langle\lambda\rangle\langle\upsilon\rangle\rho c_V$;
4.5. $\aleph = \langle\lambda\rangle\langle\upsilon\rangle\rho$;
4.6. $\vec{q} = \aleph gradTdS$;
4.7. $\aleph = \frac{1}{3}\langle\lambda\rangle\rho c_V$;
4.8. $\vec{q} = -gradT$;
4.9. $\delta Q = -\aleph\left|gradT\right|dSd\tau$;
4.10. $\aleph = -\langle\lambda\rangle\rho c_V$;
4.11. $\vec{q} = -\aleph gradT$;
4.12. $\aleph = -\frac{1}{3}\langle\lambda\rangle\rho c_V$.

When a credit system for teaching technology was introduced, it was assumed that the number of hours allocated to a particular section of physics by linear technology and by credit technology should be the same, provided that according to the curriculum the IWST is given the same number of hours as for traditional classroom classes (lectures, practical and laboratory classes). At first, it was so. Then the hour on the IWST was reduced to a minimum. In our view, this approach is discredited the very idea of credit education technology. This, in the first place. And, secondly, for several years it is simply impossible to work out any system of education, especially not traditional. Nevertheless, some experience is accumulated.

How, in our view, should be the content of training IWST?

1) The development of theoretical material with the mandatory conduct of a physical dictation and colloquium.

2) Solution of problems with compulsory control work, and if the traditional practical training to solve problems, the main work is done by the teacher, the students work on IWST (on board, on the ground), homework, that is, under the guidance of a teacher.

3) Protection of laboratory work, and not so much individual, as by the principle of holding a «round table».

4) In the abstracts there is no need, because their writing turns into an «empty» formality.

5) Control testing is not excluded, according to the old system or in the EVEA (external evaluation of educational achievements) system.

With such an organization of the educational process, specific content is included in each current evaluation (and there are 5 of them during the semester with the number of credits not less than 3).

And, finally, it becomes obvious that students are compelled to systematically prepare for such studies, that is, to work with literature, the Internet, etc. This is the independent work of students (IWS). That's why the IWS must precede the IWST [10].

We give the content of the physical dictation.

1. Thermal motion is called …
2. The effective cross-section of the molecule is …
3. The effective diameter of the molecule is …
4. The mean free path of molecules is determined by the formula...
5. The average number of collisions of a molecule with other molecules per unit time is determined by:
6. The mean free path at T = const depends on the pressure so:
7. Diffusion is …
8. The basic law of diffusion:
9. Unit of measurement of the diffusion coefficient in the SI system:
10. The formula for the diffusion coefficient:
11. Mass flux is …
12. Thermal conductivity is the process …
13. Unit of measurement of thermal conductivity in the SI system:
14. Formula for the coefficient of thermal conductivity:
15. The heat flux is defined as:
16. The impulse flux is …
17. Unit of measurement of the viscosity coefficient in the SI system:
18. Formula for the coefficient of viscosity:
19. Relaxation time …
20. The dependence of the mean free path on temperature at constant pressure …
21. The dependence of the average number of collisions on the pressure …
22. Stationary transfer process is called …
23. Nonstationary transfer process is called …
24. In the process of diffusion is transferred …
25. In the process of heat conduction is transferred …

Colloquium on transport phenomena:

1. σ_{eff} ; $\langle z \rangle$; $\langle \lambda \rangle$; ϑ ; $\langle l \rangle = \frac{2}{3}\langle \lambda \rangle$.
2. The viscosity coefficient from the point of view of the molecular-kinetic theory of ideal gases.
3. General characteristics of transport phenomena (the laws of Fick, Newton, Fourier).
4. The thermal conductivity coefficient from the point of view of the molecular-kinetic theory of ideal gases.
5. The stationary transport equation in general form.
6. Comparison of the transport coefficients.
7. Peculiarities of transport phenomena in vacuum.
8. The diffusion coefficient from the point of view of the molecular-kinetic theory of ideal gases.

Control work:

1. Nitrogen is under normal conditions. Find: a) the number of collisions experienced on average by each molecule in one second; b) the number of all collisions between molecules per cubic centimetre of nitrogen every second.
2. How do the average mean free path and the number of collisions of each molecule per unit time depend on the ideal gas temperature T in the following processes: a) isochoric; b) isobaric?
3. Find the temperature distribution in the space between two coaxial cylinders with radii R_1 and R_2 filled with a homogeneous heat-conducting substance if the cylinder temperatures are equal to T_1 and T_2.

Testing in the EVEA system:

$$$ 1

The viscosity equation looks like as (where Δk is the momentum transferred by molecules):

A) $\Delta k = -\eta \frac{\Delta U}{\Delta z} \Delta S \Delta t$.

B) $\Delta k = \eta \frac{\Delta U}{\Delta z} \Delta S \Delta t$.

C) $\Delta k = \eta \frac{\Delta T}{\Delta z} \Delta S \Delta t$.

D) $\Delta k = -\eta \frac{\Delta T}{\Delta z} \Delta S \Delta t$.

E) $\Delta k = -\eta \frac{\Delta \rho}{\Delta z} \Delta S \Delta t$.

$$$ 2

Stationary thermal conductivity equation looks like this:

A) $\Delta Q = -\aleph \frac{\Delta T}{\Delta x} \Delta S \Delta t$.

B) $\Delta Q = \aleph \frac{\Delta T}{\Delta x} \Delta S \Delta t$.

C) $\Delta Q = -\frac{\Delta T}{\Delta x} \Delta S \Delta t$.

D) $\Delta Q = -\aleph \frac{\Delta T}{\Delta x} \Delta t$.

E) $\Delta Q = \aleph \frac{\Delta T}{\Delta x} \Delta S$.

$$$ 3

The diffusion equation looks like this:

A) $\Delta m = -D \frac{\Delta \rho}{\Delta x} \Delta S \Delta t$.

B) $\Delta m = D \frac{\Delta \rho}{\Delta x} \Delta S \Delta t$.

C) $\Delta m = -D \frac{\Delta \rho}{\Delta x} \Delta S$.

D) $\Delta m = -D \frac{\Delta \rho}{\Delta x} \Delta t$.

E) $\Delta m = \frac{\Delta \rho}{\Delta x} \Delta S \Delta t$.

$$$ 4

The mean free path is determined by the formula:

A) $\langle \lambda \rangle = \langle \upsilon \rangle \tau$.

B) $\langle \lambda \rangle = \frac{\tau}{\langle \upsilon \rangle}$.

C) $\langle \lambda \rangle = \frac{\langle \upsilon \rangle}{\tau}$.

D) $\langle \lambda \rangle = \frac{1}{\sqrt{2} \pi n \sigma^2}$.

E) $\langle \lambda \rangle = \frac{1}{\sqrt{2} \pi \sigma^2}$.

F) $\langle \lambda \rangle = \frac{1}{\sqrt{2\pi} n \sigma^2}$.

G) $\langle \lambda \rangle = \frac{n}{\sqrt{2} \pi \sigma^2}$.

$$$ 5

The average number of collisions per unit time is determined by the formula:

A) $\langle z \rangle = \sqrt{2} \pi n \sigma^2 \langle \upsilon \rangle$.

B) $\langle z \rangle = \pi \sigma^2 \langle \upsilon \rangle$.

C) $\langle z \rangle = \sqrt{2} \pi n \sigma \langle \upsilon \rangle$.

D) $\langle z \rangle = \sqrt{2} \pi \sigma \langle \upsilon \rangle$.

E) $\langle z \rangle = \sqrt{2} \pi \sigma$

$$$ 6

The diffusion coefficient is numerically equal to:

A) The mass transferred per unit area per unit time with a density gradient equal to unity.

B) The amount of heat transferred per unit area per unit time with a temperature gradient of unity.

C) The momentum transferred per unit area per unit time with a velocity gradient of unity.

D) The force acting per unit area with a velocity gradient of unity.

E) The momentum of the force transferred through the given area for a given time interval with a temperature gradient equal to unity.

$$$ 7

Coefficient of thermal conductivity:

A) ~ $T^{1/2}$ for $P=const$.

B) ~ $T^{1/2}$ for $V=const$.

C) ~ $T^{3/2}$ for $P=const$.

D) ~ $T^{3/2}$ for $V=const$.

E) ~ $T^{6/2}$ for $P=const$.

Checking the level of training of students on the topic was conducted in the FOR-101 group. The results are shown in Figure 6.

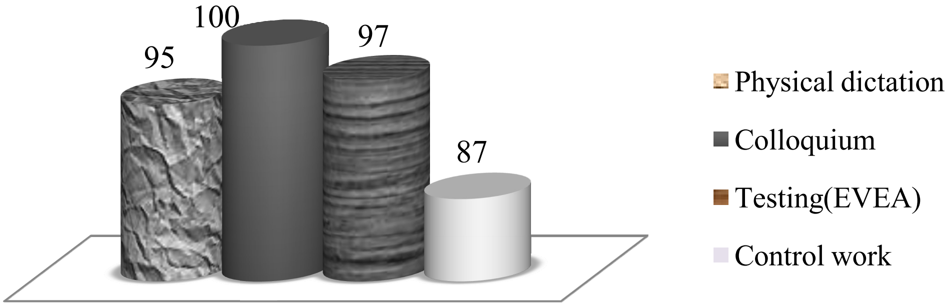

Figure 6. Comparison of the results of the types of control as a percentage

Our proposed system of organization of the IWS and IWST for many years worked out in the educational process of general physics courses and special courses corresponding profile when performing theses, during the teaching practice, it appears in the reports at the conferences at various levels, in publications, in teaching complexes, educational and teaching aids, etc.

On all graduation theses the acts of introduction into the educational process were made both at the physics and technology faculty of the university, and in the schools of the city and the region.

So, we believe that the system we propose is first the IWS, then the IWST has the right to exist. But it is also clear that its implementation requires a purposeful, labor-intensive and, unfortunately, not always sufficiently effective work of both the teacher and the student. Of course, its further development and testing is necessary.

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«Тасымалдау құбылыстары» бөлімінің мысалында СӨЖ және СОӨЖ ұйымдастыру жүйесі

Мақала кредиттік технологиясымен оқыту жағдайында студенттердің өзіндік жұмысының әдістерін дамытуға арналған. Негізгі ойы – акцентті өзгертудің қажеттілігінде: молекулалық физиканың нақты бөлімі «Тасымалдау құбылыстары» негізінде алдымен СӨЖ, содан кейін СОӨЖ ұйымдастыруы. Тасымалдау құбылыстары молекулалық-кинетикалық теориясының эксперименттік растауы және дәлелдеуі болып табылады. Бұл бөлім мектептің физика курсында қарастырылмайды, бірақ материалды тереңірек оқу барысында физика-математикалық бағытта оқитын сыныптарға беруге болады. Мақалада орта мектептің оқушыларына ұсынуға келмейтін қиындығы жоғары есептер таңдалып, талданған. Себебі олар физикалық тұрғыда күрделі және математикалық аппаратты, кем дегенде, дифференциалдық теңдеулерді қажет етеді. Студенттерге екі зертханалық жұмыстары ұсынылды: біріншісі – классикалық жұмыс және арнайы түсіндірмені қажет етпейді, екіншісі – виртуалды, яғни оны жоғары оқу орындарында да, мектепте де қолдануға болады. Әдеби көздерін қолдану арқылы студенттердің мұқият оқуын қажет ететін, саны жағынан әртүрлі жауаптары бар СӨЖ бойынша тапсырмалар таңдалды. Физикалық диктант, коллоквиум, ОЖСБ жүйесі бойынша тест және бақылау жұмыстары жүргізіліп, нәтижелері көрсетілген. Мақалада ұсынылып отырған СӨЖ және СОӨЖ жүйелерін ұйымдастыру физиканың жалпы профильге сәйкес курстары мен арнайы курстарында, дипломдық жұмысты орындау барысында, педагогикалық тәжірибелерден өту барысында көптеген жылдар бойы өңделіп әзірленді және конференцияларда баяндалды.

Кілт сөздер: диффузия, жылуөткізгіштік, тұтқырлық, масса, импульс, кредиттік оқыту технологиясы, СӨЖ, СОӨЖ.

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Система организации СРС и СРСП на примере раздела «Явления переноса»

Статья посвящена разработке методики проведения самостоятельной работы студентов в условиях кредитной технологии обучения. Основная идея заключается в необходимости изменения расстановки акцентов – сначала СРС, затем СРСП, на примере конкретного раздела молекулярной физики «Явления переноса». Явления переноса являются экспериментальным обоснованием и подтверждением основ молекулярно-кинетической теории. Этот раздел практически не рассматривается в школьном курсе физики в силу его сложности, но при тщательной проработке материала его можно дать в классах с физико-математическим уклоном. В статье подобраны и проанализированы задачи повышенной сложности, которые учащимся средних школ предлагать не имеет смысла, так как они весьма сложны по физической сути и требуют математического аппарата на уровне, как минимум, дифференциальных уравнений. Студентам были предложены две лабораторные работы — одна контактная, которая является классической и в особых комментариях не нуждается, вторая — виртуальная, с тем расчетом, что их можно использовать как в вузе, так и в школе. Подобраны и апробированы задания по теме в рамках СРС с разным количеством ответов на вопросы, требующие тщательной проработки их студентами с использованием литературных источников. Проведены и проанализированы результаты физического диктанта, коллоквиума, тестирования в системе ВОУД, контрольной работы. Предлагаемая система организации СРС и СРСП в течение многих лет отрабатывалась в учебном процессе по общим курсам физики и спецкурсам соответствующего профиля, при выполнении дипломных работ, в период педагогических практик, представлялась в докладах на конференциях.

Ключевые слова: диффузия, теплопроводность, вязкость, ульраразреженный газ, масса, импульс, энергия, кредитная технология обучения, СРС, СРСП.

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