МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ОДЕСЬКИЙ ДЕРЖАВНИЙ ЕКОЛОГІЧНИЙ УНІВЕРСИТЕТ

Methodical instructions
for practical work, test performance, distance learning of PhD students in the discipline "Quantum Optics and Laser Physics", Part 3.
(Training of PhD students of the specialty: 104 –"Physics and astronomy")

«Затверджено»
на засіданні групи забезпечення спеціальності
Протокол №1 від 28/08/2021 Голова групи_____Свинаренко А.А.

«Затверджено»
на засіданні кафедри вищої та прикладної математики
Протокол №1 від 28/08/2021 Зав. кафедри _____ Глушков О.В.

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THE MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
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PREFACE

The discipline "Quantum Optics and Laser Physics" is a mandatory discipline in the cycle of professional training of graduate students (third level of education) in the specialty 104-Physics and Astronomy.

It is aimed at mastering (providing) a number of planned competencies, including the study of modern quantum optics and laser physics, as well as new methods of describing, modeling, predicting the properties of light radiation, its propagation, absorption, refraction and reflection in different environments. nature, research of atomic and molecular spectra, interaction of electromagnetic radiation with atoms, molecules, solids, formation of coherent light sources, optical recording of information, etc. and achievement of scientific results that create potentially new knowledge.

The place of the discipline in the structural and logical scheme of its teaching: the knowledge gained in the study of this discipline is used in the study of another compulsory discipline "Computational methods of optics and dynamics of quantum and laser systems" and elective disciplines "Atomic optics and spectroscopy", "Molecular optics" and spectroscopy "," Optics and spectroscopy of a solid body "in the cycle of professional training of graduate students. The basic concepts of the discipline are the obligatory tools of an experienced specialist in the field of physics and astronomy, in particular, optics and laser physics.

The purpose of the discipline is to master (provide) a number of competencies, in particular, mastering the modern apparatus of optics and laser physics, the ability to develop and use new approaches in the theory of light radiation, its propagation, absorption, in environments, research of atomic and molecular spectra, electromagnetic interaction radiation with atoms, molecules, solids, the formation of coherent light sources, optical recording of information, The total amount of study time for the study of the discipline is 300 hours. for full-time education and 300 hours. for distance learning.

After mastering this discipline, the graduate student must be able to develop and use new approaches in the theory of light radiation, its propagation, absorption, in environments of different nature, study of atomic and molecular spectra, interaction of electromagnetic radiation with atoms, molecules, solids, use modern scientific methods results that create new knowledge.

The main topics are as follows: Laser spectroscopy and plasma diagnostics. Methods of collisional plasma diagnostics. Theoretical aspects.

Topics: Laser spectroscopy and plasma diagnostics. Methods of collisional linear plasma diagnostics. Theoretical aspects.

Топіки: Лазерна спектроскопія і діагностика плазми. Методи лінійної спектроскопії та діагностики плазми **(ЛЗ-9)**

I.1. Introduction

Electron-collisional spectroscopy of atoms and multicharged ions is one of the most fast developing branches of modern atomic spectroscopy. The properties of laboratory and astrophysical plasmas have drawn considerable attention over the last decades [1-50]. It is known that multicharged ions play an important role in the diagnostics of a wide variety of plasmas. Similar interest is also stimulated by importance of this information for correct determination of the characteristics for plasma in thermonuclear (tokamak) reactors, searching new mediums for X-ray range lasers.

In the last years an especial interest attracts study of multicharged ions of isoelectronic sequences of the inert atoms (neon, krypton, argon). The sought objects of research, firstly, belong to the class of complex relativistic many-electron atomic systems, in connection with which the approbation of the theory is extremely important and indicative just for such systems. Second, the sought multiply charged ions are of great interest for a number of applications in the field of laser physics and quantum electronics, in particular, the use of the plasma of the corresponding ions as an active medium for short-wavelength lasers, further in the field of diagnostics of astrophysical, laboratory and fusion reactor plasma, tokamak and EBIT devices, as well as, of course, laser plasma

In the case of solving collision problems involving multi-electron atomic systems, as well as low-energy processes, etc., the structure of atomic systems should be described on the basis of rigorous methods of quantum theory. As a rule, the Hartree-Fock (HF) or Hartree-Fock-Slater (HFS) models implemented in the tight-binding approximation were used to describe the wave functions of the bound states of atoms and ions. Another direction is the models of the central potential (model potential, pseudopotential) implemented in the distorted wave approximation (DWA). It should be mentioned the currently widespread and widely used R-matrix method and its various promising modifications, as well as a generalization of the well-known Dirac-Fock method to the case of taking into account multipolarity in the corresponding operators (see, e.g. , [1-

7]). It should be noted that, depending on the perturbation theory (PT) basis used, different versions of the R-matrix method received the corresponding names. For example, in specific calculations such versions as R-MATR-CI3-5R and R-MATR-41 R-matrix method were used using respectively wave functions in the multiconfiguration approximation, in particular, 5- and 41- configuration wave functions.

As numerous applications of the R-matrix method have shown, it has certain advantages in terms of accuracy and consistency over such popular approaches as the first-order PT method, as well as the distorted wave approximation taking into account configuration interaction (CI-DWBA); --- approximation of distorted waves using the HF basis (HF-DWBA), finally, the relativistic approximation of distorted waves with a 1-configuration and multi-configuration wave function of the ground state (SCGS-RDWA, MCGS-RDWA, etc.). Improved models have also appeared in theories of the coupled-channel (VC) type VCDWA (Variational Continuum Distorted Wave), for example, a modification of the Vraun-Scroters type and others (see [1-5]). Various cluster methods have also been widely used (see in more details [1-3,14,15]).

In this paper, we present and use an advanced relativistic energy approach to calculate the electron-ion collision strengths, effective collision strengths and the associated cross sections. The relativistic many-body PT is utilised alongside the gauge-invariant scheme to generate an optimal one-electron representation. The calculated effective collision strengths of the Ne-like krypton excitation are listed.

I.2. Theoretical approach to plasmas: Perturbation theory with The Dirac- Yukawa zeroth approximation

Let us start our consideration from formulation relativistic many-body PT with the Debye shielding model Dirac Hamiltonian for electron-nuclear and electron-electron systems.

Formally, a multielectron atomic systems (multielectron atom or multicharged ion) is described by the relativistic Dirac Hamiltonian (the atomic units are used) as follows:

$$H = \sum_i h(r_i) + \sum_{i>j} V\left(r_i r_j\right). \qquad (1)$$

Here, *h(r)* is one-particle Dirac Hamiltonian for electron in a field of a nucleus and *V* is potential of the inter-electron interaction. According to Refs. [6] it is useful to determine the interelectron potential with accounting for the retarding effect and magnetic interaction in the lowest order on parameter α^2 (α is the fine structure constant) as follows:

$$V\left(r_i r_j\right) = exp\left(i\omega_{ij} r_{ij}\right) \cdot \frac{\left(1 - \alpha_i \alpha_j\right)}{r_{ij}}, \qquad (2)$$

where ω_{ij} is the transition frequency; α_i ,α_j are the Dirac matrices.
In order to take into account the plasmas environment effects already in the PT zeroth approximation we use the known Yukawa-type potential of the following form:

$$V(r_i, r_j) = (Z_a Z_b / |r_a - r_b|) exp\ (-\mu \cdot |r_a - r_b|) \qquad (3)$$

where r_a, r_b represent respectively the spatial coordinates of particles, say, A and B and Z_a, Z_b denote their charges.

The potential (3) is well known (look , for example, [1,12,15] and Refs there) well known, for example, in the classical Debye-Hückel, theory of plasmas. The plasmas environment effect is modelled by the shielding parameter μ , which describes a shape of the long-rang potential.

The parameter μ is connected with the plasma parameters such as the temperature *T* and the charge density *n* as follows:

$$\mu \sim \sqrt{e^2 n / k_B T} \qquad (4)$$

Here e is the electron charge and k_B is the Boltzman constant. The density n is given as a sum of the electron density N_e and the ion density N_k of the k-th ion species with the nuclear charge q_k :

$$n = N_e + \sum_k q_k^2 N_k \ .$$

It is very useful to remind the simple estimates for the shielding parameter. For example, under typical laser plasma conditions of T~ 1keV and n~ 10^{23} cm^{-3} the parameter μ is of the order of 0,1 in atomic units.

By introducing the Yukawa-type electron-nuclear attraction and electron-electron repulsion potentials, the Debye shielding model Dirac Hamiltonian for electron-nuclear and electron-electron subsystems is given in atomic units as follows [15]:

$$H = \sum_i [\alpha cp - \beta mc^2 - Z\exp(-\mu r_i)/r_i] + \sum_{i>j} \frac{\left(1-\alpha_i\alpha_j\right)}{r_{ij}} \exp(-\mu r_{ij}) \qquad (5)$$

where c is the velocity of light and Z is a charge of the atomic ion nucleus.
The formalism of the relativistic many-body PT is further constructed in the same way as the PT formalism in Refs. [16-26]. In the PT zeroth approximation one should use a mean-field potential, which includes the Yukawa-type potential (insist of the pure Coulomb one) plus exchange Kohn-Sham potential and additionally the Lundqvist-Gunnarson correlation potential (with the optimization parameter b) as in Refs. [16-18,23,24]. As alternative one could use an optimized model potential by Ivanova-Ivanov (for Ne-like ions) [6], which is calibrated within the special ab initio procedure within the relativistic energy approach [8,16].

In the PT second order, there are two kinds of the correlation diagrams: polarization and ladder ones. The polarization diagrams take into account the quasiparticle interaction through the polarizable core, and the ladder diagrams account for the immediate quasiparticle interaction.

An effective procedure of their accounting are in details described in Refs. [6-9,20-24].

I.3. Advanced theoretical approach to elementary collision atomic processes in plasmas. Energy approach

The detailed description of our approach was earlier presented (see, for example, Refs. [7-9,13]). Therefore, below we are limited only by the key points. The generalized relativistic energy approach combined with the RMBPT has been in details described in Refs. [6,14-18]. It generalizes earlier developed energy approach [6,16].

The key idea is in calculating the energy shifts ΔE of degenerate states that is connected with the secular matrix M diagonalization [6,16]. To construct M, one should use the Gell-Mann and Low adiabatic formula for ΔE. The secular matrix elements are already complex in the PT second order. The whole calculation is reduced to calculation and diagonalization of the complex matrix M .and definition of matrix of the coefficients with eigen state vectors $B^{IK}_{ie,iv}$ [6,8,9].

To calculate all necessary matrix elements one must use the basis's of the 1QP relativistic functions. Within an energy approach the total energy shift of the state is usually presented as [6,16]:

$$\Delta E = \mathrm{Re}\Delta E + i\,\Gamma/2 \qquad (1)$$

where Γ is interpreted as the level width and decay possibility $P = \Gamma$. The imaginary part of electron energy of the system, which is defined in the lowest PT order as [6]:

$$\mathrm{Im}\Delta E(B) = -\frac{e^2}{4\pi} \sum_{\substack{\alpha>n>f \\ [\alpha<n\le f]}} V^{|\omega_{\alpha n}|}_{\alpha n \alpha n}, \qquad (6)$$

where $\sum_{\alpha>n>f}$ for electron and $\sum_{\alpha<n\le f}$ for vacancy.

The separated terms of the sum in (6) represent the contributions of different channels. It is known that their adequate description requires using the optimized basis's of wave functions. In [6] it has been proposed "ab initio" optimization principle for construction of cited basis's. It uses a minimization of

the gauge dependent multielectron contribution of the lowest QED PT corrections to the radiation widths of atomic levels.

This contribution describes collective effects and it is dependent upon the electromagnetic potentials gauge (the gauge non-invariant contribution δE_{ninv}). The minimization of $Im\delta E_{ninv}$ leads to integral differential equation, that is numerically solved. In result one can get the optimal one-electron basis of the PT [14,16,17]. It is worth to note that this approach was used under solving of multiple problems of modern atomic , nuclear and molecular physics (see [14-25]).

The scattered part of $Im\Delta E$ appears first in the second order of the atomic PT. The collisional de-excitation cross section is defined as follows [6,8,9]:

$$\sigma(IK \to 0) = 2\pi \sum_{j_{in}, j_{sc}} (2j_{sc}+1)\{ \sum_{j_{ie}, j_{iv}} < 0 \mid j_{in}, j_{sc} \mid j_{ie}, j_{iv}, J_i > B^{IK}_{ie,iv}\}^2 \tag{7}$$

,

$$< 0 \mid j_{in}, j_{sc} \mid j_{ie}, j_{iv}, J_i >= \sqrt{(2j_{ie}+1)(2j_{iv}+1)}(-1)^{j_{ie}+1/2} \times \sum_{\lambda}(-1)^{\lambda+J_i} \times$$

$$\times \{\delta_{\lambda,J_i}/(2J_i+1)Q_\lambda(sc,ie;iv,in) + \begin{bmatrix} j_{in}\cdots j_{sc}\ldots J_i \\ j_{ie}\cdots j_{iv}\ldots\ldots\lambda \end{bmatrix} Q_\lambda(ie;in;iv,sc)\} \tag{8}$$

where Q_λ is the sum of the known Coulomb and Breit matrix elements [6,14,16]. The effective collision strength $\Omega(I \to F)$ is associated with a collisional cross section σ as follows (in the Coulomb units):

$$\sigma(I \to F) = \Omega(I \to F) \cdot \pi / \tag{9}$$

$$/\{(2J_i+1)\varepsilon_{in}[(\alpha Z)^2 \varepsilon_{in} + 2]\}$$

where Z is the nucleus charge and α is the fine structure constant, ε_{in} is the incident energy. Further let us firstly consider the Debye shielding model according to Refs. [7-9]. It is known in the classical theory of plasmas developed by Debye-Hückel, the interaction potential between two charged particles is modelled by the Yukawa-type potential, which contains the shielding parameter μ.

The parameter μ is connected with the plasma parameters such as the temperature T and the charge density n as follows: $\mu \sim \sqrt{e^2 n / k_B T}$. Here, as usually, e is the electron charge and $\kappa_Б$ is the Boltzman constant.

It should be noted that indeed the Debye screening for the atomic electrons in the Coulomb field of nuclear charge is well understood due to the presence of the surrounding plasma electrons with high mobility. On the other hand, the contribution due to the Debye screening between electrons would be of smaller magnitude orders.

Majority of the previous works on the spectroscopy study have considered the screening effect only in the electron-nucleus potential where the electron-electron interaction potential is truncated at its first term of the standard exponential expansion for its dominant contribution [3-69]. However, it is also important to take into account the screening in the electron- electron interactions for large plasma strengths to achieve more realistic results in the search for stability of the atomic structure in the plasma environment.

By introducing the Yukawa-type e-N and e-e interaction potentials, an electronic Hamiltonian for N-electron ion in a plasma is in atomic units as follows [7]:

$$H = \sum_i [\alpha cp - \beta mc^2 - Z \exp(-\mu r_i)/r_i] + \sum_{i>j} \frac{\left(1 - \alpha_i \alpha_j\right)}{r_{ij}} \exp(-\mu r_{ij}) \qquad (11)$$

To generate the wave functions basis we use the optimized Dirac-Kohn-Sham potential with one parameter [14,15], which calibrated within the special ab initio procedure within the relativistic energy approach [16,17]. More details, including the procedures of computing amplitudes, radial intagrals, matrix elements etc, can be found in Refs. [7-23]. All calculations are performed on the basis of the code Superatom-ISAN (version 93).

I.4. Results and conclusion

Table 1 shows the values of the cross sections for the excitation of some states of the Kr^{26+} multicharged ion from the ground state (the energy of the incident electron are 4.082 keV) obtained within the framework of the relativistic many-body perturbation theory and relativistic energy formalism [7].

Table 1.

Cross sections for excitation by electron impact of the Kr^{26+} excited states at the incident electron energy of 4.082 keV

Level	BP-R-M	RDWA
$2p^5 3s\ (3/2,1/2)_2$	8.94(-23)	8.80(-23)
$2p^5 3s\ (3/2,l/2)_1$	5.22(-22)	6.63(-22)
$2p^5 3p\ (3/2,l/2)_1$	1.60(-22)	1.73(-22)
$2p^5 3p\ (3/2,1/2)_2$	4.25(-22)	4.72(-22)
$2p^5 3s\ (1/2,l/2)_0$	1.90(-23)	1.76(-23)
$2p^5 3s\ (1/2,l/2)_1$	2.99(-22)	4.16(-22)
$2p^5 3p\ (3/2,3/2)_3$	2.30(-22)	2.20(-22)
$2p^5 3p\ (3/2,3/2)_1$	1.10(-22)	1.06(-22)
$2p^5 3p\ (3/2,3/2)_2$	3.81(-22)	3.90(-22)
$2p^5 3p\ (3/2,3/2)_0$	2.06(-21)	2.05(-21)
$2p^5 3p\ (1/2,l/2)_1$	9.44(-23)	9.09(-23)
$2p^5 3p\ (1/2,3/2)_1$	1.11(-22)	1.11(-22)
$2p^5 3p\ (1/2,3/2)_2$	3.81(-22)	4.31(-22)
$2p^5 3d\ (3/2,3/2)_0$	9.85(-23)	9.97(-23)
$2p^5 3p\ (\ 1/2.1/2)_0$	5.48(-21)	5.40(-21)
$2p^5 3d\ (3/2,3/2)_1$	3.08(-22)	3.11(-22)
$2p^5 3d\ (3/2,3/2)_3$	4.75(-22)	4.66(-22)
$2p^5 3d\ (3/2,5/2)_2$	2.92(-22)	2.90(-22)
$2p^5 3d\ (3/2,5/2)_4$	3.11(-22)	2.99(-22)
$2p^5 3d\ (3/2,3/2)_2$	1.33(-22)	1.26(-22)
$2p^5 3d\ (3/2.5/2)_3$	3.67(-22)	3.61(-22)
$2p^5 3d(3/2,5/2)_l$	1.30(-20)	1.46(-20)
$2p^5 3d\ (1/2,3/2)_2$	1.55(-22)	1.47(-22)
$2p^5 3d\ (1/2,5/2)_2$	2.44(-22)	2.32(-22)
$2p^5 3d\ (1/2,5/2)_3$	4.40(-22)	4.25(-22)

Level	DF-RM	Our data
$2p^5 3s\ (3/2,1/2)_2$	9.98(-23)	9.75(-23)
$2p^5 3s\ (3/2,l/2)_1$	7.29(-22)	7.05(-22)
$2p^5 3p\ (3/2,l/2)_1$	1.85(-22)	1.80(-22)
$2p^5 3p\ (3/2,1/2)_2$	4.88(-22)	4.81(-22)
$2p^5 3s\ (1/2,l/2)_0$	2.01(-23)	1.97(-23)
$2p^5 3s\ (1/2,l/2)_1$	4.52(-22)	4.38(-22)
$2p^5 3p\ (3/2,3/2)_3$	2.34(-22)	2.32(-22)
$2p^5 3p\ (3/2,3/2)_1$	1.20(-22)	1.17(-22)
$2p^5 3p\ (3/2,3/2)_2$	4.17(-22)	4.13(-22)
$2p^5 3p\ (3/2,3/2)_0$	2.02(-21)	1.98(-21)
$2p^5 3p\ (1/2,l/2)_1$	1.01(-22)	9.98(-23)
$2p^5 3p\ (1/2,3/2)_1$	1.21(-22)	1.18(-22)
$2p^5 3p\ (1/2,3/2)_2$	4.41(-22)	4.37(-22)
$2p^5 3d\ (3/2,3/2)_0$	1.04(-22)	1.01(-22)
$2p^5 3p\ (\ 1/2.1/2)_0$	5.08(-21)	5.03(-21)
$2p^5 3d\ (3/2,3/2)_1$	3.34(-22)	3.30(-22)
$2p^5 3d\ (3/2,3/2)_3$	4.78(-22)	4.71(-22)
$2p^5 3d\ (3/2,5/2)_2$	3.00(-22)	2.98(-22)
$2p^5 3d\ (3/2,5/2)_4$	3.17(-22)	3.14(-22)
$2p^5 3d\ (3/2,3/2)_2$	1.42(-22)	1.39(-22)
$2p^5 3d\ (3/2.5/2)_3$	3.62(-22)	3.60(-22)
$2p^5 3d(3/2,5/2)_l$	1.45(-20)	1.42(-20)
$2p^5 3d\ (1/2,3/2)_2$	1.58(-22)	1.57(-22)

In Table 1 there are also listed the data (for the first 26 excited states) of the calculation by the R-matrix method in the Breit-Pauli approximation by Gupta et al (BP-RM), in the relativistic distorted wave approximation (RDWA), R-matrix method in the DF approximation by Griffin et al (MCDF-RM) (e.g. [2] and Refs. therein). Analyzing the presented data, it should be noted that shortened bases are used in the BP-RM methods and the relativistic distorted wave approximation by Reed et al (RDWA), as a result of which, as noted also by Griffin et al [20], the data on the cross sections of state excitation the krypton ion are strongly underestimated.

2. Tests performance

Test Option 1.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.

2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **neon)**.

2). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of neon**).

Test Option 2.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.

2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **helium)**.

2). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of helium**).

Test Option 3.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.
2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **argon)**
3). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of argon**).

Test Option 4.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.
2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **krypton)**.
2). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of krypton**).

Test Option 5.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.
2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **xenon)**.
2). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of xenon**).

Test Option 6.

1). Give the key definitions for laser and collisional atomic spectroscopy and plasma diagnostics and present the main methods of collisional plasma diagnostics. Explain: i) mathematical and physical essense of elementary colisional processes in plasmas for different densities and temperatures ii) calculation of the collision cross-sections and colision in plasmas for different densities and temperatures iii) study of the Rydberg states onctributions v) the plasmas temperature and electron density effects.
2). Construct the theoretical model within aadvanced relativistic energy approach to computing elementary collision atomic processes parameters in plasmas. Present the key formulas (on example of **radon)**.
2). Perform its pracrical realization (using Fortran Power Station , Version 4.0; PC Code: “Superatom”) your theoretical model for calculating the collision cross-sections and colision in plasmas for different densities and temperatures (on example **of radon**).

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