THE APPLICATION OF METHODS OF PHYSICS IN SOCIAL PROCESSES

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Abstract: The paper represents an attempt to establish an analogy between gas molecule absorption and social processes. Reallocation of electoral votes is estimated on the basis of analogy of the electoral process and absorption of gases. According to the analysis conducted here, one could say that this idea has a good perspective.

Key words: irreversible absorption, reversible absorption, electoral votes

1. Introduction

This paper represents an attempt to establish an analogy between gas molecule absorption and social processes such as investigation and legal proceedings. A similar attempt was made in the Paper (Lj.Mašković, S.Jaćimovski, B.Popović, 2006.), where the analogy with electric current in $R - L$ and $L - C$ circuits was used instead of irreversible and reversible absorption. It is well-known that there are two types of absorption: irreversible and reversible. With irreversible absorption, the absorbed molecules do not return to the environment they left, while in case of reversible absorption they can return several times.

In the course of investigation and legal proceedings, evidence points, which measure the degree of suspicion or guilt, can reliably determine guilt or innocence. Such reliable points are obtained by means of forensic expertise. Evidence points can also be unreliable, e.g. statements of witnesses (it is well-known that sometimes witnesses change their statements several times).

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2. Irreversible and reversible absorption

When it comes to absorption of gas molecules by an absorbent, recombination effects had been ignored for a long time. It was believed that the process of absorption developed in one direction, i.e. the possibility of return of molecules from the absorbent to the original environment was not considered. Such type of absorption, which particularly occurs in cases where the absorbed molecules engage in a chemical reaction and combine with absorbent molecules, is called irreversible absorption. Since molecules bring along their energy, irreversible absorption is accompanied with irreversible absorption of heat energy. The pressure depends on the number of molecules; therefore, irreversible absorption of molecules may lead to irreversible change of pressure. On the basis of empirical facts, the law of irreversible absorption is formulated in the following manner: the change in the number of molecules with time is proportionate to the current number of molecules.

$$\frac{dn}{dt} = -Pn$$

(2.1)

P is called irreversible absorption frequency, while n is the number of not-yet-absorbed molecules. By solving (2.1), for the initial condition $n(0) = n_0$, the following is obtained:

$$n(t) = n_0 e^{-Pt}$$

(2.2)

It should be noted that equations analogous to the equation (2.1) are obtained both for the change of temperature with time and for the change of pressure with time. In addition, the calculated changes in the number of molecules, and changes of temperature and pressure are read compared to certain reference values (Avogadro's number, temperature equal to 0ºC, atmospheric pressure, etc).

It was observed for the first time in thermodynamic research (M.G.Gulić, 1973) that temperature did not decrease exponentially over time in case of irreversible absorption. The author of the quoted paper included periodic functions in temperature formulation, since temperature with time had quasi-periodic property. In Paper (U.Timotić, 1990) quasi-periodicity was attributed to irreversible absorption processes. Reversible absorption means that a number of molecules absorbed by the absorbent leave the absorbent and return to the environment they left. After some time, these molecules go to the absorbent again and the process is periodically repeated. Paper (U.Timotić, 1990) formulates the law of reversible absorption: the change in the number of molecules with time is proportionate to the time mean value of n absorbed molecules:

$$\frac{dn}{dt} = -A \frac{1}{t} \int_0^t n(t)dt$$

(2.3)

As it can be seen, the reversible absorption is based on the idea of cumulativeness of absorption, i.e. the idea that absorption depends on the sum of all absorbed molecules over time. The coefficient A is called reversible absorption frequency. In order to obtain n, (2.3) relation should be differentiated by time. The following is obtained:

$$\frac{d^2n}{dt^2} = -\frac{An}{t} - A\frac{1}{t}\int_0^t n(t)dt \tag{2.4}$$

(2.3) yields:

$$A\frac{1}{t}\int_0^t n(t)dt = -\frac{dn}{dt} \tag{2.5}$$

When this is plugged in (2.4), the second-order differential equation is obtained:

$$\frac{d^2n}{dt^2} + \frac{1}{t}\frac{dn}{dt} + \frac{A}{t}n = 0 \tag{2.6}$$

The solution to this equation is zero-index Bessel function:

$$n(t) = J_0(\sqrt{4At}) \tag{2.7}$$

For $t = 0$, Bessel function equals one, has infinite number of zeros the distance of which is approximately π and decreases over time according to $J_0 \approx t^{-1/2}$ rule.
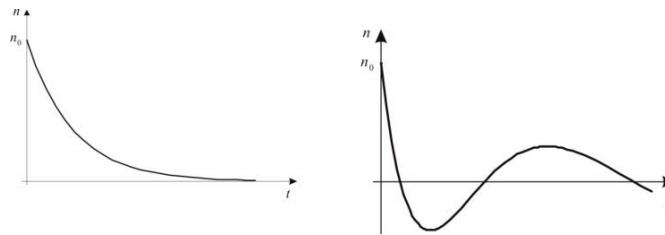

Figure 2.1: Diagram of irreversible absorption (left) and reversible absorption (right)

As it can be seen, the solution has quasi-periodic property. The derived formula for irreversible absorption has been experimentally tested in Paper (S.Rackov, 1990), where carbon-dioxide overpressures were measured in a vessel containing water. After some time (about two hours), overpressure turned into under pressure, after which it started approaching barometric pressure. This corresponds to the described behaviour of Bessel function. It should be noted that with the reversible absorption as well the quantities of temperature, pressure and number of particles should be read starting from certain reference val-

ues. Micro theory of reversible absorption *A* frequency, based on the calculation of probability of gas absorption tunneling is given in (U.Timotic, 1991).

3. Calculation of the number of gas molecules in case of absorption

In general case, in a vessel containing gas and absorbent both irreversible and reversible absorption processes take place. If the absorbent is a highly volatile substance, then absorption can take place in both directions: gas-absorbent and absorbent-gas. Markov graph corresponds to such situation.
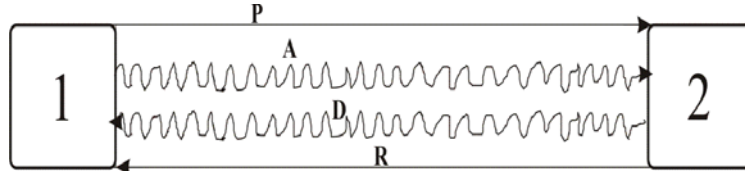

Figure 3.1: Markov graph for reversible and irreversible processes

Cell 1 of the graph represents a part of the vessel containing gas. Cell 2 represents absorbent. Straight lines represent irreversible absorption processes, while sinuous lines stand for reversible absorption processes. The direction of absorption is marked with an arrow. If the number of molecules in Cell 1 is $n_1(t)$, the number of molecules in Cell 2 is $n_2(t)$, and the number of molecules is constant and totals n_0, then the following relation is valid:

$$n_1(t) + n_2(t) = n_0 = const \tag{3.1}$$

$$\frac{dn_1}{dt} = -Pn_1 - \frac{A}{t}\int_0^t n_1 dt + Rn_2 + \frac{D}{t}\int_0^t n_2 dt \tag{3.2}$$

$$\frac{dn_2}{dt} = Pn_1 + \frac{A}{t}\int_0^t n_1 dt - Rn_2 - \frac{D}{t}\int_0^t n_2 dt \tag{3.3}$$

$$n_1(0) = n_0 \quad n_2(0) = n_0 \tag{3.4}$$

The system is solved in the following manner: in (3.1) n_2 is expressed through n_1 and n_0 and differentiated:

$$\frac{d^2 n_1}{dt^2} + (P + R + \frac{1}{t})\frac{dn_1}{dt} + \frac{A + D + P + R}{t}n_1 = \frac{(R+D)n_0}{t} \tag{3.5}$$

A general solution to this equation is given as (R.Maksimović, 1993)

$$n_1(t) = \frac{A+P}{A+D+P+R} n_0 e^{-(P+R)t} K_\lambda[(P+R)t] + \frac{A+P}{A+D+P+R} n_0 \qquad (3.6)$$

where $K_\lambda[(P+R)t]$ is Kumar's function (G.Korn and T.Korn,1961) given as

$$K_\lambda[(P+R)t] = \Gamma(\lambda+1) \sum_{\nu=0}^{\infty} \frac{(-1)^\nu}{(\nu!)^2 \Gamma(\lambda-\nu+1)} [(P+R)t]^\nu \qquad (3.7)$$

($\Gamma(x)$ is the so-called Euler's gamma function). First terms of Kumar's function are given as

$$K_0(\theta) = 1; K_1(\theta) = 1 - \theta; K_2(\theta) = \frac{1}{2}\theta - 2\theta + 1$$

Solutions to the system of equations (3.2) - (3.3) are given as

$$W_1(t) = \frac{n_1(t)}{n_0} = \frac{R+D}{A+D+P+R} \{1 + \frac{A+P}{R+D} e^{-(P+R)t} K_\lambda[(P+R)t]\} \qquad (3.8)$$

$$W_2(t) = \frac{n_2(t)}{n_0} = \frac{A+P}{A+D+P+R} \{1 - e^{-(P+R)t} K_\lambda[(P+R)t]\} \qquad (3.9)$$

The function $W_1(t)$ has the horizontal asymptote

$$\lim_{t\to\infty} W_1(t) = \frac{R+D}{A+D+P+R} \qquad (3.10)$$

while the function $W_2(t)$ has the horizontal asymptote

$$\lim_{t\to\infty} W_2(t) = \frac{A+P}{A+D+P+R} \qquad (3.11)$$

In the domain of finite times, W_1 and W_2 can cut their horizontal asymptotes, while x-coordinates are obtained from the following equation:

$$K_\lambda[(P+R)t] = 0 \qquad (3.12)$$

As it can be seen from the formulas (3.8) and (3.9), relative numbers W_1 and W_2 and their behaviour with time significantly depend on Kumar's functions.

4. Stationary problem

Previous analyses have shown that the number of particles n_1 and n_2 have horizontal asymptotes. It means that in case of big t values, i.e. sufficiently long times having passed, the numbers n_1 and n_2 hardly change with time. That is the reason why analyses of this kind use stationary approximation, which is useful for big time values:

$$\frac{dn_1}{dt} \approx 0; t \gg 1$$

$$\frac{dn_2}{dt} \approx 0; t \gg 1 \tag{4.1}$$

If we use approximation (4.1) in the system of equations (3.2) and (3.3), which means that $n_1 \approx const$ and $n_2 \approx const$, we get the following system of equations:

$$-(P + A)n_1 + (R + D)n_2 = 0$$
$$(P + A)n_1 - (R + D)n_2 = 0 \tag{4.2}$$

The obtained equations are identical, just one of them should be solved by means of the equation $n_1 + n_2 = n_0$. It means that in case of a stationary problem we get a system of equations:

$$(P + A)n_1 - (R + D)n_2 = 0$$
$$n_1 + n_2 = n_0 \tag{4.3}$$

It follows that

$$n_1 = \frac{(R + D)n_0}{P + A + R + D} \tag{4.4}$$

$$n_2 = \frac{(P + A)n_0}{P + A + R + D} \tag{4.5}$$

As it could have been assumed, the solutions to the stationary problem are horizontal asymptotes of the functions $n_1(t)$ and $n_2(t)$.

5. Forecast outcome of voting on the basis of the experimental group

In the early work (Maksimović, 1993) the analogy between gas molecules and evidence points was used, which can lead to investigation. Secure evidence corresponds to irreversible processes of absorption of gas molecules, while the uncertain indications compared with the gas molecules that are reversibly absorbed.

It is completely obvious that the analogy between gas molecules and indications can be transmitted in the domain choice. Surely votes for candidates who match the molecules absorb irreversible, while the votes of those who chose not definitive corresponding molecules of gas which reversibly absorb.

You will be presented the mathematical formalism of this analogy and using it will show on the way which may predict the outcome of the vote with great probability, if the choice is to be made between two candidates.

There are a certain number of votes within the electorate which is definitely committed to one candidate.

Second, a number of voters will surely vote for the other candidate. Based on these facts, it is appropriate to introduce the maximum number definitive oriented voters, but such that half of that number belongs to one and the other half to another candidate. This number will be marked with N_0 the analogy to represent the number of molecules in a closed court, which creates atmospheric pressure. If the total electorate has N votes, where $N > N_0$ the difference:

$$N - N_0 = n_0 \tag{5.1}$$

can be compared to a surplus of molecules in a court that creates overpressure. It is obvious that variation in n_0 number of votes resolves the outcome of the vote.

If you are with the $n_A(t)$ mark the number of votes a candidate A gets, and the $n_B(t)$ the number of votes for candidate B, it can be taken to:

$$n_A(t) + n_B(t) = n_0 \tag{5.2}$$

Change the number to the $n_A(t)$ and $n_B(t)$ in time to a symbolic Markof graph:
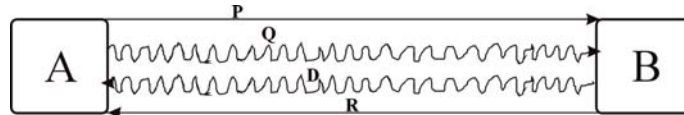

Figure 5.1: Markof graph for electorate case

which corresponds to the system integer-differential one act:

$$\frac{dn_A}{dt} = -Pn_A - \frac{Q}{t}\int_0^t n_A dt + Rn_B + \frac{D}{t}\int_0^t n_B dt \tag{5.3}$$

$$\frac{dn_B}{dt} = Pn_A + \frac{Q}{t}\int_0^t n_A dt - Rn_B - \frac{D}{t}\int_0^t n_B dt \tag{5.4}$$

Initial conditions for this case are:

$$n_A(0) = n_{0A} \qquad n_B(0) = n_{0B} \quad n_{0A} + n_{0B} = n_0 \tag{5.5}$$

The full line indicates the macroscopic graph cost with P and R corresponding to irreversible voice, and wavy lines indicate prices with Q and D corresponding to reversible (insecure voice).

The system is one act of (5.3) while (5.4) is reduced to hiper-geometric degenerated differential equation and system solutions to $n_A(t)$ and $n_B(t)$ are expressed through Kumar's functions. Solving process is complicated, and will seek a solution in common for these cases, in stationary approximation.

5.1. Probabilities of choice in stationary approximation

Based on the analysis of paragraph 1 and paragraph 2, it is known that solutive systems act (5.3) and (5.4) have a horizontal asymptote. Stationary approximation consists of the fact that a function of time at $n_A(t)$ and $n_B(t)$ replaces the constant value of its asymptote (3.10)-(3.11). Based on this it can be taken that:

$$\frac{dn_A}{dt} = \frac{dn_B}{dt} \approx 0; \int_0^t n_A dt \approx t n_A; \int_0^t n_B dt \approx t n_B$$

(5.6)

Based on (5.6) both make (5.3) and (5.4) are reduced to $(P + Q)n_A = (R + D)n_B$, whence follows

$$\frac{n_A}{n_B} = \frac{R+D}{P+Q}$$

(5.7)

A probabilistic choice candidate or candidate B are indicated with W_A and W_B and are given the by following terms:

$$W_A = \frac{n_A}{n_0}; W_B = \frac{n_B}{n_0}$$

(5.8)

Because $n_A + n_B = n_0$ from (5.8) it follows that:

$$W_A + W_B = 1$$

(5.9)

Equality (5.9) can be written as:

$$\frac{W_A}{W_B} = \frac{R+D}{P+Q}$$

(5.10)

The system of equations (5.9) and (5.10) is easily solved and solutions are:

$$W_A = \frac{(R+D)}{P+Q+R+D}$$

(5.11)

$$W_B = \frac{(P+Q)}{P+Q+R+D}$$

(5.12)

As you can see the probability of choice W_A and W_B depends exclusively on the absorptive coefficients P, Q, R and D. These coefficients can determine or accurately estimate based on the successive test sample, which represents a particular group of voters.

5.2. Determination coefficient and irreversible movement
of reversible votes

Select the group of G of which half voters were told to vote for candidate A, and other half will vote for candidate B. This group of voters test the M times in equal intervals. The testing can happen to reduce the number of votes for candidate A and that the reduction in the number of votes for candidate B equals zero. Tests with this score are taken into account when determining the size of P, Q, R and D because the line P (on graph) is in charge of movement of one-directedness of votes. The same goes for reducing the number of votes for candidate B: the calculation includes only those tests where the reduction in votes for a candidate is equal with zero. This is held one-way line R (on graph). It is clear that they can be different from zero and reduce the number of voters for candidate A and reducing the number of voters for candidate B, but these test results do not take into account, because they do not maintain one-way line P or R. If a group of voters is greater, the greater number of test results for coefficients P, Q, R and D will be reliable. It is realistic to assume that the experimental group has about 1000 voters, and that the current tests at least at the moment are 10. If time t_K, states that the number of voters for candidate A decreased value Δ_A compared to the previous test, then the number of voters for candidate B increases for value $\tilde{\Delta}_B$, while not necessarily $\tilde{\Delta}_B = \Delta_A$ as Δ_A part of the voters decide for the candidate B, and the other part remains undefined. If the M_A finds moments of time reducing the number of voters for candidate A, then the remaining $M-M_A$ moments of time, states can increase the number of voters for candidate A, and reducing the number of voters for candidates B. Increasing the number of voters for candidate A, will be marked $\tilde{\Delta}_A$, while reducing the number of voters for candidate B, will be marked with Δ_B.

Coefficient reversible process determined so as to reduce the total number Δ_K of shares of tests, where it appears and multiplies the frequency reduction factor, where T is the total time of the tests and it is usually 3 to 6 months. On the basis of this it is:

$$P = \frac{\sum_{K=1}^{M_A} \Delta_{KA}}{M_A} \frac{G}{T}$$

(5.13)

$$R = \frac{\sum_{K=1}^{M-M_A} \Delta_{KB}}{M - M_A} \frac{G}{T}$$

(5.14)

For coefficients reversible process by definition these regulations, the reduction and increasing the number of votes must be taken into account. Therefore, the reversible coefficients Q and D, determined as the sum of absolute value, increase minimize the sum of the decrease, which divides the actual number of tests M and multiplies the frequency factor

$$Q = \frac{\left| \sum_{K=1}^{M-M_A} \tilde{\Delta}_{KA} - \sum_{K=1}^{M_A} \Delta_{KA} \right|}{M} \frac{G}{T} \tag{5.15}$$

$$D = \frac{\left| \sum_{K=1}^{M} \tilde{\Delta}_{KB} - \sum_{K=1}^{M-M_A} \Delta_{KB} \right|}{M} \frac{G}{T} \tag{5.16}$$

The obtained formulae (5.13), (5.14) (5.15) and (5.16), are fundamental to predicting the outcome of elections.

5.3. Illustrative example

The sample of 1000 voters tested 10 times in equal intervals. Time analysis of the experimental group was 4 months and followed $T = 86400 \cdot 120 = 10308000s; \frac{G}{T} = 9.645 \cdot 10^{-5}$ Hz

number of tests	A	undecided	B	undecided
0	500		500	
1	$\Delta_{1A}=5$	2	$\tilde{\Delta}_{1B}=3$	
2	$\Delta_{1A}=4$	3	$\tilde{\Delta}_{1B}=1$	
3	$\tilde{\Delta}_{1A}=6$		$\Delta_{1B}=10$	4
4	$\Delta_{1A}=2$		$\tilde{\Delta}_{1B}=2$	
5	$\tilde{\Delta}_{1A}=4$		$\Delta_{1B}=5$	1
6	$\Delta_{1A}=6$	3	$\tilde{\Delta}_{1B}=3$	
7	$\tilde{\Delta}_{1A}=2$		$\Delta_{1B}=4$	2
8	$\Delta_{1A}=10$	3	$\tilde{\Delta}_{1B}=7$	
9	$\tilde{\Delta}_{1A}=4$		$\Delta_{1B}=4$	
10	$\Delta_{1A}=2$		$\tilde{\Delta}_{1B}=2$	

Based on the formulae (5.13)-(5.16) we can calculate:

$$P = \frac{5+4+2+6+10+2}{6} \cdot 9.645 \cdot 10^{-5} = 4.66 \cdot 10^{-4} \quad \text{Hz} \qquad (5.17)$$

$$R = \frac{10+5+4+4}{4} \cdot 9.645 \cdot 10^{-5} = 5.55 \cdot 10^{-4} \quad \text{Hz} \qquad (5.18)$$

$$Q = \frac{\left|6+4+2+4-(5+4+2+6+10+2)\right|}{10} \cdot 9.645 \cdot 10^{-5} = 1.25 \cdot 10^{-4} \quad \text{Hz} \quad (5.19)$$

$$D = \frac{\left|3+1+2+3+7+2-(10+5+4+4)\right|}{10} \cdot 9.645 \cdot 10^{-5} = 9.645 \cdot 10^{-4} \quad \text{Hz} \quad (5.20)$$

When the (5.17) - (5.20) replaced in (5.11) and (5.12) for the choice probability it is obtained:

$$W_A = \frac{6.4145}{12.405} = 0.525$$

$$W_B = \frac{5.91}{12.405} = 0.475$$

$$(5.21)$$

which means that we should expect a close election victory of candidate *A*.

6. Conclusion

This paper describes the processes of reversible and irreversible absorption of gas molecules. It should be noted that the irreversible absorption of long-introduced in the gas and the thermodynamic theory. As reversible absorption, its recent research and initiated the fact that quasi-periodic behavior of temperature and pressure could not explain over the irreversible absorption. The description of absorption of gas molecules exposed in paragraph 1 and in paragraph 3, reallocation of electoral votes is estimated on the basis of analogy of the electoral process and absorption of gases. Firmly committed voters have a flow of votes as the molecules that are irreversibly absorbed, while the undecided voter votes are analogous molecules that are reversibly absorbed.

This is one of the first attempts to use physical laws to social problems. According to the analysis conducted here, one could say that this idea has a good perspective.

7. References

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PRIMENA METODA FIZIKE U DRUŠTVENIM PROCESIMA

Rezime

Ranijih godina je bilo pokušaja da se prenesu ideje i metodi iz jedne oblasti delatnosti u drugu, radi boljeg razumevanja kompleksnih fenomena i procesa što je doprinelo usavršavanju i jedne i druge delatnosti. Posebno je matematičko modelovanje prodrlo u ne samo u druge oblasti nauke, veći i gotovo u sve oblasti života i rada. Teško je zamisliti savremenu nauku i savremeni život bez široke primene metemetičkog modeliranja. Zamena proučavanog projekta njegovim likom - matematičkim modelom i njegovom analizom i proučavanjem je suština metodologije matematičkog modelovanja. Takodje, treba istaći postojanje tendencije da se društvena kretanja analiziraju, a njihova kretanja predvidjaju, na bazi stanardnih stohastičkih fizičkih zakonitosti uz primenu teorije fluktuacija. Ove analogije su nesumnjivo korisne i mogu da ubrzaju razvoj drugih nauka, ali naravno, uz jedno ograničenje: treba tačno utvrditi do koje se granice mogu i smeju korisititi analogijie: svako prekoračenje ovih granica moglo bi da dovede do krupnih zabluda (H. Haken, 1977). U radu su opisani procesi ireverzibilne i reverzibilne apsorpcije gasnih molekula. Treba napomenuti da je ireverzibilna apsorpcija davno uvedena u gasne i termodinamičke teorije. Što se tiče reverzibilnih apsorpcija, njena istraživanja su novijeg datuma i inicirana su činjenicom da se kvaziperiodično ponašanje temperature i pritiska nije moglo objasniti preko ireverzibilne apsorpcije.

U slučaju izbornog procesa kada imamo samo dva kandidata preraspodela izbornih glasova procenjena je na osnovu analogije izbornog postupka i apsorpcije gasova. Čvrsto opredeljeni glasači imaju tok glasova kao molekuli koji se ireverzibilno apsorbuju, dok su neopredeljeni glasovi glasača analog molekulima koji se reverzibilno apsorbuju. Ovo je jedan od prvih pokušaja da se fizičke zakonitosti koriste u socijalnim problemima. Prema analizama koje su ovde izvršene, moglo bi se reći da ova ideja ima dobru perspektivu.

Summary

In recent years, an effort has been present to transfer ideas and methods from one area of science to another in order to understand complex phenomena and processes as well as to develop both areas. In particular, mathematical modelling is present in almost all spheres of human activity. The substitution of the subject of study with its image – a mathematical model – and its study is the essence of the mathematical modelling methodology. The research of the model instead of the subject (phenomenon or process) gives a possibility to examine the behaviour of the subject itself without any effort, quickly and cost-effectively, and, as a rule, in all situations imaginable. There have been attempts to analyze social phenomena and predict their development on the basis of standard stochastic physical laws with the application of the theory of fluctuations. The application of analogies is, without doubt, useful and may foster the development of other sciences, with a limitation, of course: it should be determined precisely to what limit analogies may and should be used: each stepping over these limits could lead to major misconceptions (H. Haken, 1977).

The description of absorption of gas molecules exposed in paragraph 1 and paragraph 3, reallocation of electoral votes is estimated on the basis of analogy of the electoral process and absorption of gases. Firmly committed voters have a flow of votes as the molecules that are irreversibly absorbed, while the undecided voter votes analogous molecules that are reversibly absorbed.

This is one of the first attempts to use physical laws to social problems. According to the analysis conducted here, one could say that this idea has a good perspective.