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Corresponding Author:
Dr. Kang Cheng,
Scientist, Biomedical InfoPhysics, Science Research Institute - United States of America

Submitting Author:
Dr. Kang Cheng,
Scientist, Biomedical InfoPhysics, Science Research Institute - United States of America

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Author(s): Cheng K, Zou C

Abstract

In our recent previous study, we in anatomy and histology modeled meridian channels as a physiological system based on published biomedical data. We think, the meridian system is mostly constructed with interstices in or between other physiological systems; major components in the meridians are loosen connective tissues that consist of electrolytes, cells and proteins; the electrolytes provide rich fluids and ions for processing, propagation or transportation of information, matter and energy in the meridians. In this research, we propose infophysics models to answer how information, matter and energy are processed, propagated, or transported in the meridians. We apply thermodynamics to macroscopically present relationships of entropy, energy, work, heat, pressure, volume and temperature; physics involves the two laws of thermodynamics, van der Waal’s equation, Gibbs equation and Maxwell’s equations of thermodynamics. We apply classic statistical mechanics to microscopically elucidate information amount and matter (or energy) flux for the complicated irreversible process; physics involves Gibbs entropy, Onsager method or formulation, such as heat conduction density (Fourier law), particle diffusion density (Fick law), electric current density (Ohm law), or shear stress of viscosity (Newton law), Poisson-Boltzmann equation and Boltzmann equation. We apply electrodynamics to macroscopically describe electromagnetic fields and ions motion; physics involves Maxwell’s equations of electrodynamics, Newtonian momentum transfer equation, Ohm’s law, Lorentz forces, Bernoulli’s separation method, conservations of charges and masses, and Poynting’s theorem. We apply constitutive equation in fluid mechanics to indicate stress-strain relationship. We apply Schrodinger equation in quantum statistical mechanics to estimate ion channel currents. We also think information has different expressions and levels (forms). In a view of sciences, there are expressions of physics, chemistry, physiology, medicine, et al. In a view of arts, there are expressions of songs, music, photos, draws, tables, words, et al. In a view of physics, the highest level of information contains related or correlated equations, such as Maxwell equations of electromagnetism or thermodynamics, Newton’s laws of mechanics, Einstein’s relativities; the higher level of information is a theoretic formula, such as Schrodinger equation, Boltzmann entropy formula, Newton’s gravitational law; the middle level of information is a function, such as a natural exponential function; the basic level of information is a property or an attribute of a function, e.g., a frequency of a wave function. Lower level information can be resolved or expressed with or included in higher level information, e.g., dual properties of wave and particle of an electron can be expressed with a probability wave function, and the function can be included in and resolved with Schrodinger equation.

Keywords: Interstices, Electrolytes, Thermodynamics, Electrodynamics, Entropy, Statistical, Fluid

Introduction

Scientists or clinicians have proposed many models or hypotheses to discover the mechanisms of meridian (-collateral) channels in human bodies. One of hypotheses is that the Chinese medicine system is a special channel network comprising of the skin with abundant nerves and nociceptive receptors of various types and deeper connective tissues inside the body with the flowing interstitial fluid system [1]. Another hypothesis of multi-factors is involved in direct communication pathway of the cell junction (specially keeping the relevant cellular direct communication relation in individual development), the extra-cellular matrix stress network system and its biophysical message transmission--force--meridian signs transformation-inter-cellular massage integration [2] Mathematical [3], informative [4] and birdcage [5] models have been proposed too. However the mechanism of the meridian channel system is still unclear.

In our recent previous study [6], we in anatomy and histology modeled meridian channels as a physiological system based on published biomedical data [7-9]. We think, the meridian system is mostly constructed with interstices in or between systems of the integumentary, the nervous, the muscular, the cardiovascular, the skeletal, the lymphatic, the endocrine, the respiratory, the digestive, the urinary and the reproductive; major components in the
meridians are loose connective tissues that consist of electrolytes, cells and proteins; the electrolytes provide rich fluids and ions for processing, propagation or transportation of information, matter and energy in the meridians. The meridian system is mostly in longitudinal direction (ascending from toes or fingers), is approximately symmetric about the middle line (from the nose to the umbilicus or spinal cord), and is roughly parallel to systems of the integumentary, the nervous, the muscular, the cardiovascular, the skeletal, the lymphatic, and the endocrine. We hypothesized the orientation, the symmetry and the parallel of the systems are formed during the embryo’s development. Similar to systems of the nervous, the cardiovascular, the lymphatic, the endocrine, the respiratory, the digestive and the urinary, the meridian system should be unblocked according to the theory of Chinese medicine. If the systems are blocked, some diseases could occur.

However, we have not modeled how information, matter and energy are processed, propagated or transported in the meridian system and we have not found any related report in a view of biomedical infophysics. We think storage, propagation (or transportation) and processing of information are physical. In this paper, we consider infophysics as a combination of information and physics, and present our infophysics models for processing, transportation or propagation of information, matter and energy in the meridian system. We believe our models in this paper will be helpful to keep health people from or treat patients with the meridian diseases.

Models

We think information has different expressions and levels (forms) [6]. In a view of sciences, there are expressions of physics, chemistry, physiology, medicine, et al. In a view of arts, there are expressions of songs, music, photos, draws, tables, words, et al. In a view of physics, the highest level of information contains related or correlated equations, such as Maxwell equations of electromagnetism or thermodynamics, Newton’s laws of mechanics, Einstein’s relativities; the higher level of information is a theoretic formula, such as Schrodinger equation, Boltzmann entropy formula, Newton’s gravitational law; the middle level of information is a function, such as a natural exponential function; the basic level of information is a property or an attribute of a function, e.g., a frequency or an amplitude of a wave function. Lower level information can be (approximately) resolved or expressed with or included in higher level information, e.g., dual properties of wave and particle of an electron can be expressed with a probability wave function, and the function can be included in and resolved with Schrodinger equation. The levels from the middle to the highest are correspondent to approach the natural laws; the basic levels are correspondent to approach properties or attributes of the natural objects. See Fig. 1.

Fig. 2 illustrates our framework of main networks of information, matter and energy in a human body. In this investigation, we focus on the meridian network; and we first introduce our meridian models in physiology; then based on the physiological model, we propose our models for processing, transportation or propagation of information, matter and energy in the meridians in physics.

A. Biomedicine

Fig. 3 shows our model of meridian channel system for human embryos in physiology, anatomy and histology. The meridians are interstices around systems of the nervous, the cardiovascular, the digestive and the urinary. We believe the meridian system is formed during embryos developing in parallel to other physiological systems, such as the nervous, the cardiovascular, the digestive and the skeletal. The nervous system samples, collects, encodes, decodes, transmits and processes information from other systems and controls the other systems [1]. Our modeling results suggest that, the meridian system is mostly constructed with interstices in or between systems of the integumentary, the nervous, the muscular, the cardiovascular and the skeletal. The nervous system samples, collects, encodes, decodes, transmits and processes information from other systems and controls the other systems [1].

Fig. 4 shows our model of meridian channel system of human adults. The meridians are interstices in or between systems of the integumentary, the nervous, the muscular, the cardiovascular and the skeletal. The nervous system samples, collects, encodes, decodes, transmits and processes information from other systems and controls the other systems [1].

Our modeling results suggest that, the meridian system is mostly constructed with interstices in or between other physiological systems; major components in the meridians are loose connective tissues that consist of electrolytes, cells and proteins, the electrolytes provide rich fluids and ions for processing, transportation or propagation of information, matter and energy in the meridians[6].

B. Infophysics

A biological system obeys laws of physics and chemistry [10]. We mostly model processing, propagation or transportation of information, matter and energy in the meridian system with laws and theorems in physics, though chemistry is involved too. The dominant laws and theorems in physics involve thermodynamics, classic statistical mechanics, electrodynamics, fluid mechanics and dynamics, quantum statistical mechanics.

Application
A. Electric shock
If we accidentally get an electric shock by touching a charged object with our hands, we will feel externally applied electric currents flow along our arms. The externally applied electric currents or fields approximately follow Ohm's law of electricity (equation 14), ions motion approximately follows equations 18 or 22. We would like explain the phenomenon in this way: the externally applied electric currents or fields flow in our meridian channel system, the applied fields stimulate our nervous sensors along the meridians, the sensors sample and collect the information, the nerves transmit the information to our brains, see Fig. 4. This evidently strongly supports our models of meridian channel system.

B. Interstitial fluid flow
Experimental data of interstitial fluid flow [1, 26] could be described with equations 26 and 27.

C. Interstices
We can see interstices when we cut fresh meat, such as beefs or porks. We consider the interstices as the meridian channels.

Discussion
Though, we can solve the equations with the boundary conditions in theory, it is very difficult to obtain analytical solutions of the equations today. Future study could be how to solve the equations analytically or digitally; and how to fit the experimental data with the calculated results. We believe our models are also applicable to other biomedical systems in principle.

Conclusion
Information has different expressions and levels (forms). In a view of sciences, there are expressions of physics, chemistry, physiology, medicine, et al. In a perspective of physics, the highest level of information contains related or correlated equations, such as Maxwell equations of electromagnetism or thermodynamics, Newton’s laws of mechanics, Einstein’s relativities; the higher level of information is a theoretic formula, such as Schrödinger equation, Boltzmann entropy formula, Newton’s gravitational law; the middle level of information is a function, such as a natural exponential function; the basic level of information is a property or an attribute of a function. Lower level information can be resolved or expressed with or included in higher level information.

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Illustrations
Illustration 1

Fig 1

Framework of Information Levels

High

Related Equations

An Equation

A Function

To approach the natural laws.

Basic

A Property or a Tribute of a function

To approach a property or a tribute of a natural object.

FIG. 1. Our framework of information levels (forms).
Illustration 2

**FIG. 2.** Our framework of main networks of information, matter and energy in a human body. The arrows indicate exchanges of information, matter and energy.
Illustration 3

FIG. 3. Our model of meridian channels for a part of selected cross section of a human embryo during the 5th week, the directions of meridian channel currents are assumed. The biological data and draw is from published references [9].
Illustration 4

FIG. 4. Our model of meridian channels of human adults. The directions of meridian channel currents are assumed.
1. Thermodynamics

Thermodynamics plays very important roles in biological systems [10]. Therefore, thermodynamics should do so in the meridian channel system too.

The first law of thermodynamics is,

\[ dU = dQ - dW \quad \text{(1)} \]

where, U, Q and W respectively denote energy, heat and work for the meridian system. The first law indicates conservation of energy.

The second law of thermodynamics in mathematics is [11 – 12],

\[ dS \geq \frac{dQ}{T} \quad \text{(2)} \]

where S, Q and T respectively denote entropy, heat and absolute temperature of a system. Equation 2 represents a theorem of entropy increase for the meridian and other physiological systems and their environments.

For equilibrium isotherms states of a meridian system, we apply van der Waal’s equation,

\[ (P + \frac{n^2a}{V^2})(V - nb) = nRT \quad \text{(3)} \]
where, \( P, V \) and \( T \) are respectively pressure, volume and absolute temperature; \( n \) is mole number; \( R \) is gas constant per mole; \( a \) and \( b \) are constants.

For nonequilibrium states system, the Postulate of Local (cellular) Equilibrium has been introduced. Gibbs equation has been applied to each cell in the system [11 – 12],

\[
TdS = dU + PdV - \sum_i \mu_i dn_i
\]  

Equation (4)

where \( \mu_i \) is defined as the chemical potential by Gibbs and \( n_i \) is the number of moles of components. Equation 4 also means energy conservation.

Maxwell’s equations of thermodynamics present relationships of entropy, temperature, pressure and volume, they are,

\[
\left( \frac{\partial T}{\partial V} \right)_s = -\left( \frac{\partial P}{\partial S} \right)_T
\]

Equation (5)

\[
\left( \frac{\partial T}{\partial P} \right)_s = \left( \frac{\partial V}{\partial S} \right)_p
\]

Equation (6)

\[
\left( \frac{\partial S}{\partial V} \right)_T = \left( \frac{\partial P}{\partial T} \right)_V
\]

Equation (7)

\[
\left( \frac{\partial V}{\partial T} \right)_p = -\left( \frac{\partial S}{\partial P} \right)_T
\]

Equation (8)

Equation 5 means that changing pressure in a constant volume and in an entropy domain is equivalent to changing temperature with constant entropy and in a volume domain. In a similar way, we can describe equations 6 - 8. We consider Equations 1 – 8 as thermodynamics expression of information.
2. Classic statistical mechanics

Classic statistical mechanics is a microscopic state description for macroscopic thermodynamics. Based on Boltzmann’s statistical entropy of equilibrium states of a system, Gibbs proposed a more general statistical entropy to describe the order for the both equilibrium and non-equilibrium systems [13]. Gibbs entropy formula involves partition function and microstate energies [13 – 14], and it is,

$$S_G = -k_B \sum_{n=1} p_n \ln p_n$$  \hspace{1cm} (9)

where

$$p_n = \frac{1}{\Xi} \exp\left(-\frac{U_n + N_n \mu_n}{k_B T}\right)$$  \hspace{1cm} (10)

$$\Xi = \sum_n \exp\left(-\frac{U_n + N_n \mu_n}{k_B T}\right)$$  \hspace{1cm} (11)

where, $k_B$ is Boltzmann’ constant; $n$ denotes a microstate, $N_n$ is the number of microstates, $\mu_n$ is a chemical potential and $p_n$ is its probability that it occurs during the system's fluctuations. We consider equations 9 - 11 as information expressions in microscopic statistical mechanics and represent entropy, i.e., orders or disorders for the meridian system states. And we also apply Gibbs entropy formula to calculate the correspondent information amount, based on Shannon’s information concept [15 – 16],
\[ \Delta I_G = \Delta S_G = S_{G,b} - S_{G,a} \]  \hspace{1cm} (12)

\[ \Delta I_G = k_B \left( -\sum_i p_{i,b} \log p_{i,b} + \sum_i p_{i,a} \log p_{i,a} \right) \]  \hspace{1cm} (13)

where, subscript \( a \) and \( b \) are respectively after and before.

Schrodinger discussed genetic information in a biological system with order, disorder and Boltzmann’s entropy in 1945 [17]. Shannon clearly proposed his definition of information (amount) with entropy for a communication channel system in 1948 [15 – 16]. We think, Shannon’s information concept for a communication channel system is in principle equivalent to equation 13 with Gibbs entropy formula for a meridian channel (classical statistical mechanical) system.

Onsager method or formulation is suitable to describe the complicated irreversible process. The formulation is based on the Principle of Microscopic Reversibility [12]. We can write a flux (transportation), for a linear procedure in thermodynamics, as:
\[ J_k = \sum_l L_{kl} X_l \]  \hspace{1cm} (14)

\[ L_{nk} = L_{kl} \]  \hspace{1cm} (15)

where, respectively, \( J_k \) is kth thermodynamic flux, such as heat conduction density (Fourier law), particle diffusion density (Fick law), electric current density (Ohm law), or shear stress of viscosity (Newton law); \( X_l \) is lth thermodynamic force, such as temperature gradient (\( \nabla T \)), concentration gradient (\( \nabla C \)), electric potential gradient (\( \nabla V \)), or velocity gradient (\( \nabla v \)); \( L_{kl} \) is the direct (or cross) force coefficient, such as heat convention coefficient, diffusion coefficient, conductivity, or coefficient of viscosity. Equation 15 is Onsager relation. Formula for a non-linear procedure is more complicated, but the Onsager relation is still valid. The local entropy production rate is,

\[ \frac{dS}{dt} = \sum_k J_k X_k \]  \hspace{1cm} (16)

Poisson-Boltzmann equation of electric potential \( \phi \) is \([11-12]\),

\[ \nabla^2 \phi(x, y, z) = -\frac{\rho(x, y, z)}{\varepsilon} = -\frac{\varepsilon}{\varepsilon} \sum_i z_i C_i \exp\left[-\frac{z_i e \phi(x, y, z)}{k_B T}\right] \]  \hspace{1cm} (17)
where $\nabla^2 r$ is a 3-D spatial Laplace mathematic operator, $\rho$ is charge density, $\varepsilon$ is electric permittivity, $-e$ is electron charge, $z_i$ is number of charges on the ion, $C_i$ is the average number of ions of kind $i$ in unit volume of tissue fluid.

If we considered the electrolytes as quasi liquid plasma in physics [18], Boltzmann equation is [19],

\[
\frac{\partial f_i}{\partial t} + u_i \cdot \nabla_r f_i + \frac{z_i |e|}{m_i} (E + u_i X B) \cdot \nabla_u f_i = \left( \frac{\partial f_i}{\partial t} \right)_{\text{collisions}}; f_i = f_i(r, u_i, t) \tag{18}
\]

\[
\frac{\partial f_n}{\partial t} + u_n \cdot \nabla_r f_n = \left( \frac{\partial f_n}{\partial t} \right)_{\text{collisions}}; f_n = f_n(r_n, u_n, t) \tag{19}
\]

where, $i$ and $n$ respectively denote ions and neutral particles; $f$ denotes a Boltzmann distribution function; $u$ and $r$ respectively denote velocities and space coordinates; $\nabla_r$ is a 3D spatial nabla mathematic operator.
3. Electrodynamics

Biological fluids in the meridian system are mostly electrolytes. Electrodynamics (or electromagnetism) must play very important roles for the meridian systems [6]. Maxwell’s two complementary equations of electromagnetism present relationships of electric field, magnetic field and electric current, and they are,

\[ \nabla \times \mathbf{H} = \frac{\partial \mathbf{E}}{\partial t} + \gamma \mathbf{E} \quad (20) \]

\[ \nabla \times \mathbf{E} = -\frac{\partial (\mu \mathbf{H})}{\partial t} \quad (21) \]

where, \( \mathbf{E} \) and \( \mathbf{H} \) are respectively electric and magnetic field intensity vectors; \( \mathbf{\varepsilon} \), \( \gamma \) and \( \mu \) are respectively tensors of permittivity, conductivity and permeability. Equations 20 and 21 mean temporal changing electric (magnetic) field produces spatial rotational magnetic (electric) field. Temporal and spatial frequencies may be involved. If we considered the electrolytes as quasi liquid plasma in physics [18], a Newtonian momentum transfer equation for macroscopic particles (e.g. ions) in an electro – hydrodynamic system is [19],

\[ \frac{d(v_i n_i m_i)}{dt} = -\nabla P_i + n_i q_i (E + v_i XB) - n_i m_i c_i v_i + F_v \quad (22) \]
where, \( v_i, m_i, n_i, c_i \) and \( q_i \) are respectively the velocity, the mass, the particle concentration, the effective collision frequency (Ohm’s law related) and the electric charge of the free ions. \( P_i \) represents the pressure in the fluid. \( E \) and \( B \) are electric and magnetic fields respectively; \( \times \) means a mathematical cross product (Lorentz forces related). \( F_V \) is a sum of externally applied hydrodynamic volume forces (force/volume) [19].

The related electric charge density is \( \rho_c(x, y, z, t) = n_i q_i \) in meridians. The longitudinal direction is along a (changing) \( z \) axis, \( x \) and \( y \) are in the transversal directions; \( t \) is time; we assume, Bernoulli’s separation method and superposition principle are applicable to the spatial and temporal variables [20] and \( x, y, z \) and \( t \) are independent from each other, to simplify our models and to get analytic solutions.

Based on principle of conservation of charges, we can obtain related equations of electric field intensity (EFI),

\[
\nabla_r \cdot (J_e) = \nabla_r \cdot (\gamma E) = -\frac{\partial}{\partial t} \rho_c(x, y, z, t) \tag{23}
\]
where \( J_e \) is the electric current density. An expression of conservation of masses is similar to equation 23, but mass density replaces charge density and mass flow density replaces the electric current density. We defined EFI as information intensity (II) in our previous study\(^{21}\) and we think an object claims its teritory with its II produced with its matter (charge or mass) and informs its targets how to respond to its claim: to leave or to come.

Poynting’s theorem also plays important roles in processing, propagation or transportation of information, matter and energy in electrodynamics\(^{21}\). We consider Equations 20 – 23 as electrodynamics expression of information.

We approximately used Fourier series (FS) to model (electric) acupuncture information or signals received by nervous sensors in the meridians\(^6\), it is,

\[
Q(z,t) = -\left[ \sum_{n=0}^{\infty} a_n \sin(n\omega t) \right] \left[ \sum_{m=0}^{\infty} b_m \sin(mk_z z) \right]
\]

\[
= -\sum_{n=1}^{\infty} \sum_{m=1}^{\infty} a_n b_m \sin(n\omega t) \sin(mk_z z)
\]

\[
= -\frac{1}{2} \sum_{n=1}^{\infty} \sum_{m=1}^{\infty} a_n b_m \left[ \cos(n\omega t - mk_z z) - \cos(n\omega t + mk_z z) \right]
\]

(24)
Where, Q is electric charge; we assume Bernoulli’s separation method is applicable to the spatial (z) and temporal (t) variables [20]; $k_z$ is a wave number in z (information propagation) direction; $\omega = 2\pi f$, $\omega$ and $f$ are fundamental angular frequency and frequency, respectively; $a_n$ and $b_m$ are constants. After the 1/2 and signs are included in the $a_n$ or $b_m$, the electric current in z propagation direction is:

$$i_z(z, t) = \frac{dQ}{dt} = \sum_{n=1}^{\infty} \sum_{m=1}^{\infty} a_n b_m \omega [\sin(n\omega t - mk_z z) - \sin(n\omega t + mk_z z)] z_0$$ \hspace{1cm} (25)

where $z_0$ is a unit vector in z direction. The current is frequency encoded. We can execute the superposition theory for two signals, one is pain and another one is acupuncture, in pairs for m and n numbers in equation 25, to explain analgesia with acupuncture [6].
4. Fluid mechanics

Constitutive equation is also very important to describe the meridian system. Interstitial fluid can be considered as quasi incompressible Newtonian viscous fluid [22 – 23]. Therefore, a constitutive equation can be used to represent its stress - strain (tensors) relationship,

\[ \sigma_{ij} = -p\delta_{ij} + \lambda V_{kk}\delta_{ij} + 2\mu V_{ij} \]  

where \( \delta_{ij} \) is Kronecker delta, and

\[ V_{ij} = \frac{1}{2} \left( \frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} \right) \]  

is the strain rate tensor, and \( \lambda \) and \( \mu \) are two material constants. We consider Equations 26 – 27 are information expression in fluid mechanics.
5. Quantum statistical mechanics

In quantum statistical mechanics, Schrodinger equation for motion of a microscopic particle in a cylindrical coordinate system is,

\[ \frac{ih}{2\pi} \Psi(r, \theta, z, t) = H\Psi(r, \theta, z, t) \quad (28) \]

where \( \Psi \) is a probability wave function, \( H \) is Hamilton’s energy operator (Hamiltonian operating) and \( h \) is Plank constant. We define \( -\nabla \Psi \) as a probability field intensity, where \( \nabla \) is a spatial mathematic nabla operator. A general solution for a stationary state Schrodinger equation in quantum statistical mechanics is,

\[ \Psi(r, \theta, z, t) = \sum_{n=1} c_n \psi_n(r, \theta, z) \exp \left( \frac{-i2\pi E_n t}{h} \right) \quad (29) \]
where potential field is assumed to be independent of time, r, \( \theta \), z and t are spatial and temporal coordinates respectively; \( n \) denotes a integer, \( c_n, \psi_n \) and \( E_n \) are constants, probability wave functions and energies for microstates. The equation and the function have been assumed to be suitable to describe particle movements in very narrow spaces such as cellular ion channels \([24 – 25]\). Equation 29 is an information expression of probability wave function; and the related probability density (PD) can be obtained from equation 29, and it is,

\[
PD = |\Psi(r, \theta, z, t)|^2 = \Psi(r, \theta, z, t)\Psi^*(r, \theta, z, t)
\]

\[
= \left\{ \sum_{n=1} c_n\psi_n(r, \theta, z) \exp\left(\frac{-i2\pi E_n t}{\hbar}\right) \right\} \left\{ \sum_{n} c_n^*\psi_n^*(r, \theta, z) \exp\left(\frac{+i2\pi E_n t}{\hbar}\right) \right\}
\]

\[
= \sum_{n2=1}^{n1+1} c_{n2}^*c_{n1}\psi_{n2}(r, \theta, z)\psi_{n1}^*(r, \theta, z) \exp\left(\frac{-i2\pi(E_{n2} - E_{n1}) t}{\hbar}\right)
\]

when \( n1 \neq n2 \), the terms in equation 28 are interferences. Equation 28 is an information expression of probability density and demonstrates where particles exist probably. Comparing equations 9 and 30, we think \( c_{n2}c_{n1}^*, \psi_{n2}\psi^*_{n1} \) and \( \exp() \) terms in equation 30 respectively play the same roles as \( K_B \), \( P_n \) and \( \ln() \) terms do in equation 9. We consider Equations 28 – 30 as information expression in quantum statistical mechanics.
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