Qeios

Why Einstein could not agree with quantum mechanics

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Abstract

Throughout Einstein's research on quantum theory he distinguished between the emission and absorption of radiation by describing them as separate physical processes. Absorption is described as a continuous process acting upon the resonator (quantum oscillator) by means of electromagnetic fields, while emission is described as occurring in integral steps due to the localization and release of discrete energy packets. We follow this aspect of his research as it develops by highlighting passages from his papers published between 1905 and 1917. We reveal in detail why he opposed the standard interpretation by comparing his unfinished theory to that of non-relativistic quantum mechanics which uses the wave function to describe the emission and absorption of radiation as a single process. We show that the conflict between his theory and non-relativistic theories can be resolved by deriving a Lagrangian theory of quantum mechanics.

1. Introduction

Heisenberg, Dirac, and Schrödinger each required approximately a year to derive their theories of non-relativistic mechanics (NRQM), each beginning with a different initial physical assumption. Einstein, on the other hand, spent over ten years on an unsuccessful theory based on the realism of local field theory. He remained opposed to NRQM for his entire life despite being unable to give specific reasons for his beliefs. His calculations and the intuitive hypotheses he derived from them that often led to experimental confirmation were not questioned, rather it was his insistence on the more philosophical aspects such as locality and realism. We review his writings over the 12 year period 1905 – 1917 to try to understand why he refused to abandon his own unfinished theory. The passages that most clearly distinguish his theory from NRQM are highlighted.

2. A review of Einstein's unfinished work on a quantum theory of radiation

2.1 "On a heuristic point of view concerning the production and transformation of light" *Ann Phys* 17 (1905) 132- 148

"For the time being, we disregard the radiation emitted and absorbed by the resonators and look for the condition for dynamic equilibrium corresponding to the interaction (collisions) of molecules and electrons. For such an equilibrium, the kinetic theory of gases provides the condition that the mean kinetic energy of a resonator electron must be equal to the mean kinetic energy of the progressive motion of a gas molecule. If we resolve the motion of the resonator electron into three mutually perpendicular oscillatory motions, we find for the mean value $\bar{E}$ of the energy of such a linear oscillatory motion.

$$\bar{E} = R/N \cdot T$$

where R denotes the universal gas constant, N the number of 'real molecules' in one gram-equivalent, and T the absolute temperature, for because of the equality of the time averages of the resonator's kinetic and potential energies, the energy $\bar{E}$ is 2/3 times as large as the kinetic

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energy of a free monatomic gas molecule. If due to some factor--in our case, due to radiation--the energy of a resonator were to have a time average larger or smaller than $\bar{E}$, the collisions with the free electrons and molecules would lead to an energy transfer to the gas or an energy absorption from the gas that is, on average, different from zero. Thus, in the case we are considering, dynamic equilibrium is possible only if the mean energy of every resonator equals $\bar{E}$."

This next passage refers to the photoelectric effect.

"The simplest possibility is that a light quantum transfers its entire energy to a single electron; we will assume that this can occur. However, we will not exclude the possibility that the electrons absorb only a part of the energy of the light quanta. An electron provided with kinetic energy in the interior of the body will have lost a part of its kinetic energy by the time it reaches the surface."

2.2 "On the theory of light production and light absorption" *Ann Phys* 20 (1906) 199-206

"Let us envision the resonators as ions that could perform rectilinear sinusoidal vibrations about an equilibrium position. The fact that the ions have electrical charges is irrelevant in the calculation of this entropy; we simply have to conceive these ions as mass points (atoms) whose momentary state is completely determined by their instantaneous deviation x from the equilibrium position and by their instantaneous velocity.

The energy of an elementary resonator can only assume values that are integral multiples of $(R/N)\,\delta\nu$; by emission and absorption, the energy of a resonator changes by jumps of integral multiples of $(R/N)\,\delta\nu$. However, this assumption involves yet a second one, because it contradicts the theoretical basis from which equation (3) is developed. For if the energy of a resonator can only change in jumps, then the mean energy of a resonator in a radiation space cannot be obtained from the usual theory of electricity, because the latter does not recognize distinct energy values of a resonator. Thus, the following assumption underlies Planck's theory: Although Maxwell's theory is not applicable to elementary resonators, nevertheless the mean energy of an elementary resonator in a radiation space is equal to the energy calculated by means of Maxwell's theory of electricity. This proposition would be immediately plausible if, in all those parts of the spectrum that are relevant for observation, $e = (R/N)\,\delta\nu$ were small compared with the mean energy $\bar{E}\nu$ of a resonator; however, this is not at all the case, for within the range of validity of Wien's radiation formula, $eB\nu/T$ is large compared with 1."

2.3 "On the present status of the radiation problem" *Phys. Z.* 10 (1909) p. 185 – 193.

In a discussion about the use of retarded potentials to describe electromagnetic radiation Einstein argues as follows: "Putting $f(x,y,z,t) = f_1$, amounts to calculating the electromagnetic effect at the point x,y,z from those motions and configurations of the electric quantities that took place prior to the instant t. Putting $f(x,y,z,t) = f_2$, we are determining the above electromagnetic effects from the motions and configurations that take place after the instant t. In the first case the electric field is calculated from the totality of the processes producing it, and in the second case from the totality of the processes absorbing it. If the whole process occurs in a (finite) space bounded on all sides, then it can be represented in the form $f = f_1$ as well as in the form $f = f_2$

2.4 "Statistical investigation of a resonator's motion in a radiation field" A. Einstein and L. Hopf *Ann Phys* 33 (1910) 1105-1115.

"We consider a mobile electromagnetic oscillator that is, on the one hand, subjected to the effects of a radiation field and, on the other hand, possesses a mass m and enters into interaction with the molecules present in the radiation-filled space. If the above interaction were the only one present, then the mean square value of the momentum associated with the oscillator's translatory motion would be completely determined by statistical mechanics. In our case there also exists the interaction of the oscillator with the radiation field. For a statistical equilibrium to be possible, this latter interaction must not produce any change in that mean value. In other words: The mean square value of the momentum associated with the translatory motion that the oscillator assumes under the influence of the radiation alone must be the same as that which it would assume, in accordance with statistical mechanics, under the mechanical influence of the molecules alone. This reduces the problem to the task of determining the mean square value $(mv)^2$ of the momentum assumed by the oscillator under the sole influence of the radiation field. This mean value must be the same at time $t = 0$ as at time $t = t$.

For what follows, it is expedient to distinguish two kinds of dynamical effects through which the radiation field influences the oscillator, namely

1. The resistive force K, with which the radiation pressure opposes the rectilinear motion of the oscillator. Neglecting the terms of the order of magnitude of $(v/c)^2$ (c = velocity of light), this is proportional to the velocity v, and we can therefore write: $K = - Pv$. If we further assume that the velocity v does not change markedly during time t, then the momentum deriving from this force $= - Pvt$.
2. The fluctuations A of the electromagnetic momentum that arise in the disordered radiation field owing to the motion of the electric masses [electrons]. These can be positive just as well as negative, and are independent - in first approximation - of the circumstance that the oscillator is in motion."

2.5 "Emission and absorption of radiation in quantum theory" *Deutsche Phys Gesellschaft* Verhandlungen 18 (1916).

"We shall distinguish here also two types of transitions:

a) Emission of Radiation.

This will be a transition from state Z_m to state Z_n with emission of the radiation energy $e_m - e_n$. This transition will take place without external influence. One can hardly imagine it to be other than similar to radioactive reactions.

b) Incidence of Radiation. Incidence is determined by the radiation within which the molecule resides; let it be proportional to the radiation density ϱ of the effective frequency. In case of the resonator it may cause a loss in energy as well as an increase in energy; that is, in our case, it may cause a transition $Z_n - Z_m$ as well as a transition $Z_m - Z_n$.

Two kinds of change can be distinguished. First the change $A_1E = -AE\tau$ effected by emission; and second, the change A_2E caused by the work done by the electric field on the resonator. This second change increases with the radiation density and has a "chance"-dependent value and a "chance"-dependent sign. An electromagnetic, statistical consideration yields the mean-value relation $A_2E = B\rho r$. The constants A and B can be calculated in known manner. We call A_1E the energy change due to emitted radiation, A_2E the energy change due to incident radiation.

2.6 “On the quantum theory of radiation” *Phys Z* **18**, 121 1917, p. 63. https://www.informationphilosopher.com/solutions/scientists/einstein/1917_Radiation.pdf Einstein summarizes his previous work on quantum mechanics when he states in the first sentence, “The formal similarity between the chromatic distribution curve for thermal radiation and the Maxwell velocity-distribution law is too striking to have remained hidden for long,” Figures 1 & 2 demonstrate the correctness of his assertion by showing with a graphical representation that the heat energy of classical origin is directly proportional to the radiation energy of quantum mechanical origin.

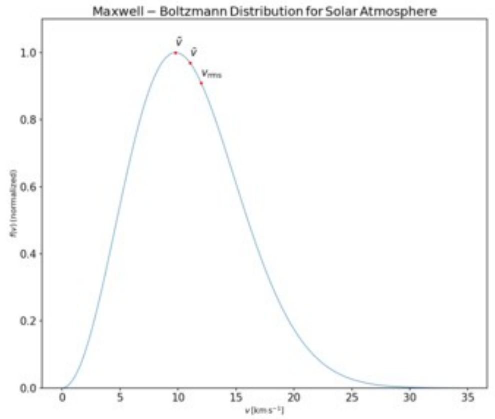

Fig. 1 Maxwell Boltzmann distribution of the sun; Dmcandre wikipedia

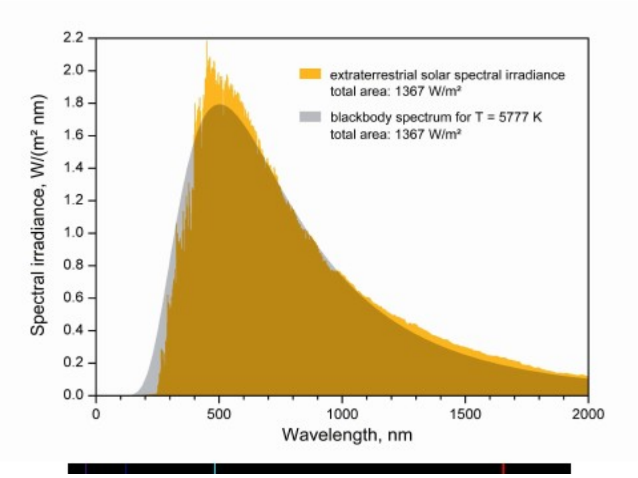

Fig. 2 Planck distribution of the sun; Sch, CC BY-SA 3.0, wikipedia

Fig. 1 gives a comparison of molecular velocity to the probability of finding molecules at that velocity. The distribution curves suggest that a molecule’s kinetic energy, as specified by temperature, determines to close approximation the energy of the photon that it emits, which is in agreement with his theoretical work [1].

In the remainder of the paper he consolidates his previous work by describing radiation processes using classical coordinates K and quantum mechanical coordinates K′. “We now turn to the investigation of the motion which our molecules execute under the influence of radiation. In doing this we use a method which is well known from the theory of Brownian movement, and which I have used repeatedly for calculations of movements in a domain of radiation. In order to simplify the calculation, we carry it out only for the case where movement occurs just in one direction, i.e., in the X- direction of the coordinate system. <u>The molecule can then be treated with ordinary mechanics</u>. . . . Let a molecule of given kind be in uniform motion with speed **v** along the X-axis of the coordinate system K. We inquire about the momentum transferred on the average from the radiation to the molecule per unit time. To calculate this we must consider the radiation from a coordinate system K′ that is at rest with respect to the given molecule. For we have formulated our hypotheses about emission and absorption only for molecules at rest."

The separation of radiation theory formally into two physical processes by means of the coordinate systems K and K′ reflects the need to describe thermal energy with Maxwell Boltzmann statistics and quantum mechanical emissions by Planck statistics. It does not provide measurable values because it is a relativistically correct theory derived in continuous time [2].

2.7 Letter from Einstein to Paul Epstein 11/10/1945 [3]

"Accordingly, the light quantum has a definite localization and a definite color. Naturally one cannot do justice to this by means of a wave function. Thus I incline to the opinion that the wave function does not (completely) describe what is real, but only a to us empirically accessible maximal knowledge regarding that which really exists. . . . This is what I mean when I advance the view that quantum mechanics gives an incomplete description of the real state of affairs."

The wave function ψ(r,t) does not tell us the "color" of a light quantum because it has an insufficient number of coordinates. It needs a set of coordinates to describe the electron in K′ and a set of coordinates to describe the molecule in K.

3.0 Conclusion

Einstein could not accept the Hamiltonian models of NRQM because he has always insisted on a relativistically correct theory described continuously in time by a local field theory. Both conditions are satisfied statistically by his own quantum theory of radiation in 2.6. The equations of motion are derived by a Lagrangian version of quantum mechanics with action integrals [4]. They satisfy the objections 2.1 to 2.6 by including two physically distinct parts; a classically defined action integral describing electron excitation continuously in time,

$$S\left[r\left(t\right)\right]=\int_{R_1}^{R_2}\int_{t_1}^{t_2}\left(\text{T-V}\right)dt$$

and a quantum mechanically defined action integral describing the four-dimensional localization of fields and subsequent emission.

$$S\left[\phi_i\left(t\right)\right]=\int_{R_2}^{R_1}\int_{t_2}^{t_1} L\left(\phi_i\phi_{i,\mu}\right)d^3xdt = E\tau$$

Einstein's requirement in 2.7 that the wave function include wave properties is satisfied by the Lagrangian density, £(φ_i, $\varphi_{i,\mu}$), above.

References

[1] Oldani. R. (2024). “Foundations of Quantum Mechanics Revealed by the Conservation Laws”. Qeios. doi:10.32388/ROFQKG.7.
[2] Oldani, R. “Time Evolution of Energy States”. Preprints 2023, 2023050952. https://doi.org/10.20944/preprints202305.0952.v7, p. 7.
[3] *Sixty-Two Years of Uncertainly* Edited by A. I. Miller Plenum Press, New York, 1990 p. 103.
[4] Oldani, R. “Time Evolution of Energy States”. Preprints 2023, 2023050952. https://doi.org/10.20944/preprints202305.0952.v7, p. 2; Oldani, R. “Galactic Symmetry”. Preprints 2020, 2020090215; https://doi.org/10.20944/preprints202009.0215.v7, p. 7.