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Similar to (1.82), (1.83) and (1.87), (1.88) we include the useful formulations

(2.85) $\langle p_j|\hat{q}_j|p'_j\rangle = \; i\frac{\partial}{\partial p_j}\cdot\delta(p_j - p'_j)\,,$

(2.86) $\langle q_j|\hat{p}_j|q'_j\rangle = -i\frac{\partial}{\partial q_j}\cdot\delta(q_j - q'_j)\,.$

Here δ is the Dirac delta function.

2.2.7.2. The Measurable Expectation Values of Quantum Mechanics

For a physical ***entity*** Ψ with observable or at least identifiable ***quantities*** q_j, with canonical conjugated ***momenta*** p_j, we must expect different probabilities

$\psi_{q_j} = \psi(q_j)$ and $\psi_{p_j} = \psi(p_j)$ to measure the different variations in their values.

Most often the probability functions are described abstract as ψ, where the dependency argument input is omitted, but these must be implicit given the context.

A real ***quantity*** q_j represented by the Hermitian operator $\hat{q}_j$ can then act on the associated probability function ψ, $\hat{q}_j|\psi\rangle$. Just as defined in (2.45) we write the expectation value of the observable ***quantity*** for the operator $\hat{q}_j$

(2.87) $\langle\hat{q}_j\rangle_\psi = \langle\psi|\hat{q}_j|\psi\rangle = \langle\psi|\hat{q}_j\psi\rangle \sim \int_{-\infty}^{\infty}\psi^*(y)\,\hat{q}_j\,\psi(y)\,dy \sim \int_{-\infty}^{\infty} q_j\,|\psi|^2 dq_j\,.$

Generally, we just write the expectation value of $\hat{q}_j$ as $\langle\psi|\hat{q}_j|\psi\rangle$.

Similarly, writing the observable expectation value of $\hat{p}_j$ as $\langle\psi|\hat{p}_j|\psi\rangle$.

2.3. A classical Formulation of the Cyclic Rotation Oscillation

2.3.1. Hamilton Formulation for the Harmonic Oscillator

In section 1.7.6 for the oscillator in physics, we got formulas for $\dot{q}_\omega$ (1.76) and $\dot{p}_\omega$ (1.79).

Inserting these in Hamilton's canonical equations (2.21) and (2.22) we get

(2.88) $\dot{q}_\omega = \frac{\partial H_\omega}{\partial p_\omega} = \frac{p_\omega}{m_\omega}$

(2.89) $\dot{p}_\omega = -\frac{\partial H_\omega}{\partial q_\omega} = -m\omega^2 q_\omega$

Now we can create the simplest possible Hamilton function for the harmonic oscillator.

From the stationary differential (2.20) $\mathrm{d}H = \dot{q}\,\mathrm{d}p - \dot{p}\,\mathrm{d}q$, and rewriting by (1.76) to

(2.90) $\mathrm{d}H_\omega = \dot{q}_\omega \mathrm{d}p_\omega + m_\omega\omega^2 q_\omega \mathrm{d}q_\omega\,,$

we get by antiderivative integration

(2.91) $H_\omega(q_\omega, p_\omega) = \frac{1}{2}p_\omega\dot{q}_\omega + \frac{1}{2}m_\omega\omega^2 q_\omega^2 = \frac{p_\omega^2}{2\,m_\omega} + \frac{1}{2}m_\omega\omega^2 q_\omega^2.$

To make this equation reliable, we must from the definition require $p_\omega^2 \equiv p_\omega m\dot{q}_\omega$.

The last form has the advantage that the parameter t is not included. But then there is a minor problem, the first term in the sum H_ω of this formula is undefined if $m_\omega = 0$. [66]

[66] $0/0$ need not be 0, or neither a constant without change, but an arbitrary variable with all values simultaneously. This is solved by the fact that $m_\omega \neq 0$ is a factor in the *internal* impedance of the oscillator, and not the *external* mass.

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2.3.1.2. The Energy of an Oscillator

Classic, the first part in the sum has been attributed to the kinetic energy T, and the second part has been attributed to the potential energy V, so $H = T + V$, whereby

(2.92) $T_\omega = \frac{1}{2}p_\omega\dot{q}_\omega = \frac{(p_\omega)^2}{2\,m_\omega}$ and $V_\omega = \frac{1}{2}m_\omega\omega^2 q_\omega^2$, hence $H_\omega = T_\omega + V_\omega$.

Since the first part is written $T_\omega = \frac{1}{2}p_\omega\dot{q}_\omega$, we from (2.17) conclude $H_\omega = 2T_\omega - L_\omega$ and from which we draw the *portable energy*

(2.93) $L_\omega = T_\omega - V_\omega$

Hereby, L_ω represent the difference between kinetic and potential energy.

Stated differently, the portable energy L_ω of an ***entity*** Ψ_ω in physics consists of the free kinetic energy T_ω, minus the energy V_ω of the bindings to some fundamental surroundings.

We will distinguish between; the internal bindings of the oscillator ***entity*** Ψ_ω, that has a proportionality factor we call m_ω; and an external binding energy to the surroundings V_Ψ of a total physical ***entity*** Ψ characterised by a proportionality factor m, that in classical physics is called the mass of Ψ. It is important in the following to distinguish between the internal factor m_ω of the oscillator, from any external m, for a total physical ***entity*** Ψ.

2.3.1.3. The Lagrange Function for the Cyclical Rotating Oscillator

By using $T_\omega = \frac{1}{2}\dot{q}_\omega p_\omega = \frac{1}{2}m_\omega\dot{q}_\omega^2$ for the first part, we can now rewrite (2.93) to

(2.94) $L_\omega(q_\omega, \dot{q}_\omega) = \frac{1}{2}(\dot{q}_\omega^2 - \omega^2 q_\omega^2).$

The easy way to set $L_\omega = 0$ e.g. for a photon is to set $m_\omega = 0$, but then we lose the knowledge of the structure for the oscillator, on the other hand, the inner cyclical balance can be maintained by demanding $\frac{1}{2}(\dot{q}_\omega^2 - \omega^2 q_\omega^2) = 0$, hence we achieve that $L_\omega(q, \dot{q}) = 0$, independent of $m_\omega \neq 0$.

When both parts $\dot{q}_\omega^2$ and $\omega^2 q_\omega^2$ are constant and equal it is a circular oscillation. Thus, the ***entity*** $\Psi_\omega \leftrightarrow \frac{1}{2}((\dot{q}_\omega)^2 - \omega^2 q_\omega^2) = 0$ as a subject is interpreted as a cyclic oscillation through the complex unit circle $e^{\pm i\omega t}$ as an object to our intuition.

Its noumenon (idea in science) is the Euler circle as a ***primary quality*** of a plane idea in physics.

Another way of expressing $L_\omega(q, \dot{q}) = 0$ is simply by letting $T_\omega - V_\omega = 0$ in (2.93).

To let the Lagrange function disappear, $L_\omega = 0$ for a harmonic oscillator is the same as to claim, that it doesn't carry any portable energy through the surroundings in physics, but that the internal binding energy V_ω balance the kinetic energy T_ω, that is

(2.95) $L_\omega = T_\omega - V_\omega = 0.$

When the harmonic oscillator has non-external binding $V_\omega^{extern} = 0$ to the surroundings, it will move freely through the surroundings with kinetic energy T_ω.

In this way, the free harmonic oscillator Ψ_ω has the total energy as the Hamilton function

(2.96) $H_\omega = T_\omega + V_\omega = 2T_\omega,$ in that $L_\omega = T_\omega - V_\omega = 0.$

This gives the idea of the nature of light, through electromagnetic oscillation, which will now be described by employing of the ***quantum harmonic oscillator*** joint by the noumenon idea of a rotating circle oscillation in a ***quantum field***.

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