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RESEARCH ARTICLE

CONTROLLING OF VEHICLES IN NEW EPOCH OF SCIENCE CIVILIZATION

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ABSTRACT

Article relate questions driverless travelling. Submit propose considering a completely different way of supporting the organization of this traffic by proposing a new method of controlling and managing the motion of vehicles. Have the use elements of quantum mechanics. Submit quantum mechanics equations. Submit examples.

INTRODUCTION

A look at the 21st century - A flying motorcar? All over the world, engineers work on a vertical take-off (VTO) vehicle for everybody, i.e. a drone to transport people. The objective is mobility without roads, traffic jams, and stress – so far, something like this could only be seen in science-fiction films. The next step is to be the driverless travelling. At present, tests are being carried out with cargo transport systems of this kind, such as e.g. the Amazon Prime Air (http://www.amazon.com/b?node=8037720011). The systems that would control or manage the traffic of such vehicles must ensure, first of all, the collection and processing of data on the number and type of the vehicles in the monitored area as well as on their velocities and the density of traffic. Would it not be worth, therefore, considering a completely different way of supporting the organization of this traffic by proposing a new method of controlling and managing the motion of such vehicles? Can the analogy with quantum physics be made use of? Can the quantum mechanics be employed to describe the phenomena that have been described until now with the use of classic mechanics? Can the quantum mechanics equations be used for controlling the vehicle motion? Quantum mechanics applies to the phenomena that occur in a very small scale, of the order of one-trillionths part of millimetre. It is a theory of very small bodies and it perfectly explains the phenomena that occur within the domain of such bodies. It may be used to describe the motion of bodies. The principles of quantum mechanics define the way of looking at any physical and chemical phenomena, including those that are described with the use of classic mechanics; in the latter case, attempts are chiefly made to show that the boundary between the classic and quantum description is approached [http://www.edunauka.pl/fizschrodinger.php].

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Heisenberg's Indeterminacy Principle

Can a particle be permanently distinguished from other particles that may be present in the neighbourhood, i.e. can the identity of an individual particle during its motion in the traffic be controlled? The microcosm particles show properties that go beyond the limits of the material particle model introduced in the classic (Newtonian) mechanics. Such particles must be described with the use of quantum mechanics rules, where one of the fundamental assumptions made is the impossibility of distinguishing identical particles from each other, i.e. the history of motion of specific particles of this type in a system consisting of many such particles cannot be individually traced. The Heisenberg's indeterminacy principle states that the more precisely the location of a particle is determined the less precisely its momentum can be known, and vice versa.

$$\Delta v_x \cong \frac{h}{4\pi m \Delta x} \qquad (1)$$

$$\Delta x \cong \frac{h}{4\pi m \Delta v_x} \qquad (2)$$

where:
$h = 6.62491\times10^{-34}$ (J×s) – Planck constant,
m (kg) – particle mass,

Δv_x (m/s) – uncertainty of particle velocity,
Δx (m) – uncertainty of particle location.

The impossibility of simultaneous determining of the location and momentum of a particle with a freely chosen accuracy is connected with the fact that the measurement of one of these quantities (coordinate) disturbs the other one (momentum), i.e. individual particles do not have separately defined and well determinable locations and velocities and, thus, their locations and velocities cannot be observed. Instead, a quantum state, consisting of a combination of data on particle location and velocity, is assigned to an individual particle. It is important to emphasize here that Δx and Δv are not measurement errors arising from imperfections of measuring equipment or methods; in this case, they are uncertainties (variance) of measurement results, arising from the nature of the measurement as such. The Heisenberg's indeterminacy principle defines the boundaries outside of which the notions of classic physics become inapplicable. Conversely, the reverse is acceptable, i.e. quantum mechanics may be used to describe the motion of bodies. For the motion of bodies on the surface on the earth, such a task becomes simpler and this solution may be applied relatively "easily". Let us consider the following two examples, where the uncertainties of location of a body and an elementary particle are compared with each other.

Example 1

The location of a body with a mass of m = 1 000 kg is to be determined with an accuracy of atomic radius $\Delta x = r \sim= 10^{-10}$ m. If the body location were determined with such an accuracy (unachievable in practice), the resulting uncertainty of determining the velocity of the body would be Δv_x. This uncertainty may be calculated from equation (1):

$$\Delta v_x \sim= \frac{h}{4\pi m \Delta x} \sim= \frac{6.63\times10^{-34}}{4\pi\times10^{3}\times10^{-10}} \sim= 10^{-27}\ \text{m/s} \qquad (3)$$

Such a Δv_x value is unimaginably small.

Example 2

Now, the location of an electron with a mass of $m \sim= 10^{-30}$ kg is to be determined with an identical accuracy of $\Delta x = r \sim= 10^{-10}$ m. To calculate the uncertainty Δv_x of determining the velocity of this body, equation (1) may be used again:

$$\Delta v_x \sim= \frac{h}{4\pi m \Delta x} \sim= \frac{6.63\times10^{-34}}{4\pi\times10^{-30}\times10^{-10}} \sim= 10^{6}\ \text{m/s} \qquad (4)$$

The value $\Delta v_x \sim= 10^6$ m/s means that the uncertainty of knowledge of electron velocity is of the same order as the electron velocity in the Bohr model ($v = 2.2\cdot10^6$ m/s) (Wróblewski and Zakrzewski, 1984). To elaborate upon example 1, the problem may be solved for the case that the body motion velocity is known and the uncertainty of body location is to be found. The data assumed for the calculation are as follows: body mass is m = 1 000 kg and accuracy of determining the body motion velocity is $\Delta v_x = 10^{-2}$ m/s.

The uncertainty of body location is determined from equation (2):

$$\Delta x \sim= \frac{h}{4\pi m \Delta v_x} \sim= \frac{6.63\times10^{-34}}{4\pi\times10^{3}\times10^{-2}} \sim= 10^{-35}\ \text{m} \qquad (5)$$

Thus, the uncertainty of body location is so small that it actually has no impact on the measurement accuracy: for comparison, the atomic radius is $\Delta x = r \sim= 10^{-10}$ m (Wróblewski and Zakrzewski, 1984).

However, the physical objects that are much bigger than the Planck length (*lp* = 1.616229(38) m) do not have such properties. As an example, the momentum of a object with a mass of 0.1 g and overall length of 1 mm, which covers a distance of 1 mm in a time of 1 s, is 0.1 g×mm/s. According to the indeterminacy principle, the location and momentum of the ant can be measured with no better accuracy than up to 10 decimal places. The accuracy like this is definitely sufficient in everyday measurements and any quantum effects are unobservable in such a case (Wróblewski and Zakrzewski, 1984).

Schrödinger equation

The Schrödinger equation is the basic and most important equation in the nonrelativistic quantum mechanics, i.e. in the quantum theory applicable to the cases where velocities are low in comparison with the velocity of light. The Schrödinger equation is equally important as the Newton's second law, with its equation making it possible to determine the location of a particle at any time if the forces acting on the particle are known [http://www.edunauka.pl/fizschrodinger.php].

Time-Independent Schrödinger Equation [Hollyday *et al.,* 2011 and Pointon and Elwell, 1978]

For a one-dimensional case, the time-independent Schrödinger equation may be written in the following form:

$$\frac{\sigma^2\psi}{\sigma x^2} + \frac{8\pi^2 m(W-U)\psi}{h^2} = 0 \qquad (6)$$

where: m – mass, W – total energy, U – potential energy, $h = 6.62491\times10^{-34}$ (J×s) – Planck constant, ψ – wave function

The quantity ψ^2 at any predefined point represents a measure of the probability that the particle is situated near this point (Hollyday and Resnick , 1974). Equation (6) should be interpreted as follows: a particle is moving in the x direction in an area where the forces acting on the particle cause it to have a potential energy of U, with energy W being the total mechanical energy (i.e. the sum of potential and kinetic energy) of the particle. In nonrelativistic problems, and this is the case discussed here, the rest energy of a particle is not taken into consideration (Hollyday and Resnick, 2011). If the potential energy is equal to zero then equation (6) describes a free particle, i.e. a moving particle that is not under the influence of any resultant force. In such a case, the total energy of the particle is its kinetic energy amounting to ½ mv^2. Fig. 1 shows the dependence of the probability density for a free particle $|\psi|^2$ on x for the free particle.

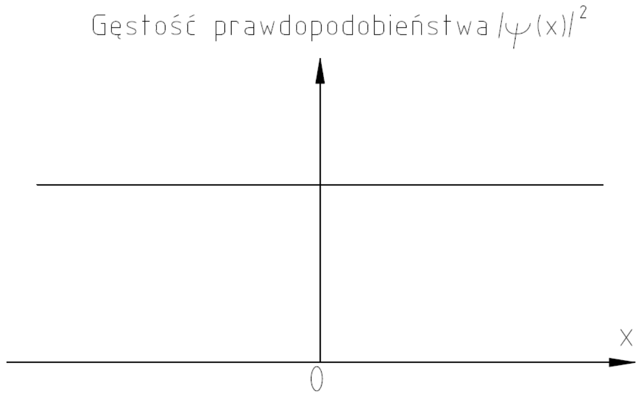

Fig. 1. Probability density curve for a free particle moving in the positive direction x (Hollyday *et al.*, 2011)

The probability of detecting the presence of the particle at a specific point along the particle path x is equal for all such points, Fig. 1. In a three-dimensional space, this equation takes the form:

$$\nabla^2\psi + \frac{8\pi^2 m(W-U)\psi}{h^2} = 0 \qquad (7)$$

where:

$$\nabla = (\frac{\sigma}{\sigma x}, \frac{\sigma}{\sigma y}, \frac{\sigma}{\sigma z}) = i\frac{\sigma}{\sigma x} + j\frac{\sigma}{\sigma y} + k\frac{\sigma}{\sigma z}$$

(Nabla operator [5]) (8)

If an assumption is made that a particle with a mass of m is moving between two walls spaced apart by a distance of *l* then equation (6) may be presented in the form [1]:

$$E = n^2\frac{h^2}{8ml^2} \qquad (9)$$

where: n = 1, 2, 3, … (Fig. 2).

This equation shows that such a particle cannot have energy of any value except for the values given by equation (9).

Example 3

A body with a mass of m = 1 000 kg is moving on a line segment 10 m long. Find the energy value for the stationary state where n= 1 (Fig. 2). To solve this problem, equation (9) should be used:

$$E = n^2\frac{h^2}{8ml^2} = 1^1 \times \frac{(6.6\times10^{-34})^2}{8\times1000\times10^2} = 54.4\times10^{-40}\ \text{J}$$

Similarly, for n = 2 (Fig. 2), the energy value will be $E = 217.6\times10^{-40}$ J and

for n = 3 (Fig. 2) , the energy value will be $E = 489.6\times10^{-40}$ J.

These conditions are so extreme that no difference between the cases with n = 1 and n = 3 can be experimentally detected. The classic physics, which completely fails in relativistic quantum mechanics, is well applicable in this case.

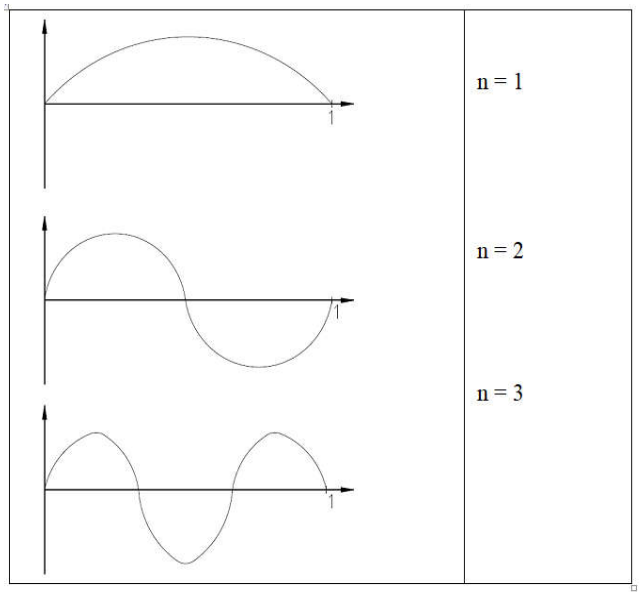

Fig. 2. Example three quantum states for a vibrating string: n = 1, n = 2, n = 3

Time-Dependent Schrödinger Equation

The time-dependent Schrödinger equation may be written in the following form [6]:

$$-(\hbar^2/2m)(\partial^2\Psi/\partial x^2 + \partial^2\Psi/\partial y^2 + \partial^2\Psi/\partial z^2) + V\Psi = i\hbar\,\partial\Psi/\partial t \qquad (10)$$

where: i – imaginary unit, ħ – Planck constant (h) divided by 2π, m – particle mass, Ψ – wave function, V – potential V(x,y,z).

This equation holds for every nonrelativistic particle in a potential field. Equation (10) should be read as follows: a sum of the second derivatives of the wave function with respect to time, each of them being multiplied by $-h^2/2m$, plus a product of the potential and the wave function is equal to the product of the time derivative of this function and iħ. This equation is solved by finding the wave function Ψ, which depends on time and spatial coordinates. The knowledge of the solution of this equation will enable us to determine the quantum state of the particle at any time and to predict the way in which this state will change with time.

Recapitulation

Classic mechanics is a special case of a more general theory, i.e. quantum mechanics. It seems possible to apply the quantum mechanics approach to the analysis of motion of bodies with velocities very much lower than the velocity of light. Every vehicle is a complex dynamic system. It can, or even should be, assumed that every vehicle is a "particle" having a defined mass and energy. It should be stressed here that energy is in this case a convenient parameter because it covers the mass and velocity of a body. In turn, a group of vehicles is a set of such "particles" and, in this case, it is possible to consider the dynamics of the particles in relation to each other. Hence, the indeterminacy principle may be used for determining the uncertainty of vehicle's location on a road, especially in the conditions of intensive traffic and the resulting high density of vehicles. This may be useful in identifying the location of motor vehicles in the conditions of traffic control. As regards travelling in a three-dimensional rather than two-dimensional spatial system, a question arises whether the traffic of this type can be controlled at high density of the moving objects. In aviation, this is a relatively simple problem because the distances between individual objects are very big (measured in kilometres). In the case of "flying vehicles" in an urban area, the traffic density is high; therefore, the distances between individual vehicles are dramatically reduced. It should be emphasized that the traffic of vehicles moving in such conditions is not, and must not be, chaotic. If otherwise, the vehicles would collide with each other. Since the vehicles must move without collisions, an assumption must be made that the parameters of their motion (velocity, momentum, energy) must be defined. Therefore, the indeterminacy principle and the Schrödinger equations may be used for describing the motion of such vehicles on the one hand and for controlling their motion on the other hand. These issues become particularly important in the situation that concepts of driverless travelling and autonomous vehicles are being developed.

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