The action-reaction asymetry in the string

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Abstract

We consider the string, the left end of which is fixed and the right end of this string is in periodic motion. We, show that the law of the action-reaction symmetry is broken during the string motion.

1 Introduction

According to the third Newton's law of motion, all forces occur in pairs in such a way that if one object exerts a force on another object, then the second object exerts an equal and opposite reaction force on the first. In other words: "To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts" (Halliday et al., 1966).

Now, let us consider the string, the left end of which is fixed and the right end of this string is in a periodic motion. we will easily to see that the third Newton law of action and reaction is broken.

2 The classical derivation of the string motion

The differential equation of motion of string elements can be derived by the following way (Tikhonov et al., 1977). We suppose that the force acting on the element dx of the string is given by the Hook law:

$$T(x,t) = ES\left(\frac{\partial u}{\partial x}\right), \tag{1}$$

where E is the modulus of elasticity, S is the cross section of the string. We easily derive that

$$T(x+dx) - T(x) = ESu_{xx}dx. \tag{2}$$

The mass dm of the element dx is $\varrho ESdx$, where $\varrho = const$ is the mass density of the string matter and the dynamical equilibrium gives

$$\varrho Sdxu_{tt} = ESu_{xx}dx. \tag{3}$$

So, we get

$$\frac{1}{c^2}u_{tt} - u_{xx} = 0; \quad c = \left(\frac{E}{\varrho}\right)^{1/2}. \tag{4}$$

Now, let us consider the following problem of the mathematical physics. The right end of the string is in the periodic motion $u(l,t) = A\sin(\omega t)$. So we solve the mathematical problem:

$$u_{tt} = c^2 u_{xx} \tag{5}$$

with the initial conditions

$$u(x,0) = 0; \quad u_t(x,0) = 0 \tag{6}$$

and with the boundary conditions

$$u(0,t) = 0; \quad u(l,t) = A\sin(\omega t). \tag{7}$$

The equation (5) with the initial and boundary conditions (6) and (7) represents one of the standard problems of the mathematical physics and can be easily solved using the the standard methods . The solution is elementary (Lebedev et al., 1955) and it is the integral part of equations of mathematical physics (Tikhonov et al., 1977):

$$u(x,t) = \frac{Ac}{ES\omega}\left[\frac{\sin\frac{\omega x}{c}}{\frac{\cos\omega l}{c}}\right]\sin(\omega t). \tag{8}$$

So, we see that the string motion is a such that at every point $X \in (0, l)$ there is an oscillator with an amplitude

$$A = \frac{Ac}{ES\omega}\left[\frac{\sin\frac{\omega x}{c}}{\frac{\cos\omega l}{c}}\right]; \quad x \in (0, l). \tag{9}$$

3 Action and reaction inside the string

The force in the form of the local tension inside the string (1) can be easily computed in the left boundary and in the right boundary. So,

$$T(0, t) = ES\left(\frac{\partial u}{\partial x}\right)_{x=0} = A\left[\frac{1}{\frac{\cos\omega l}{c}}\right]\sin(\omega t) \tag{10}$$

and

$$T(l, t) = ES\left(\frac{\partial u}{\partial x}\right)_{x=l} = A\left[\frac{\cos\omega(l/c)}{\frac{\cos\omega l}{c}}\right]\sin(\omega t). \tag{11}$$

So, we see,

$$T(0, t) \neq T(l, t), \tag{12}$$

Q.E.D.

4 Discussion

The string theory can be extended to the quark-quark interaction by the string potential, defined as the quark mass correction to the string potential, which was performed by Lambiase and Nesterenko (1996). It is evident that the relation (12) is valid in such situation. The calculation of the interquark potential generated by a string with massive ends was performed by Nesterenko and Pirozhenko (1997) and others with the validation of the theorem (12). The propagation of a pulse in the real strings and rods which can be applied to the two-quark system of pion and so on, was calculated by author (Pardy, 2005), and the relation (12) is valid. Also, in case of the string model of gravity, leading to the Zitterbewegung of planets and Moon, (Pardy 2020), the theorem (12) is valid. So, it is not excluded that our aproach can be extended to generate the new way of the string theory of matter and space-time.

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