Peculiarities of behavior of composite charged particles in the electric field.

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The motion of one-dimensional and two-dimensional charged composite particles in a constant electric field is considered.

Using the billiard formalism, precise laws of motion for a one-dimensional particle with a small number of internal degrees of freedom are established, and the laws of motion for a two-dimensional particle are numerically integrated

Within the framework of the billiard formalism, motion regimes for such particles in a constant field are obtained. The existence of periodic motion regimes for such particles was demonstrated

It has been shown that acceleration of a composite particle exceeds that of a monolithic particle with the same mass.

The presence of periodic components is interesting for the creation of emitting nanodevices, especially in the case of zero net charge, when the emitting device can be stationary and emit radiation under the influence of a constant electric field.

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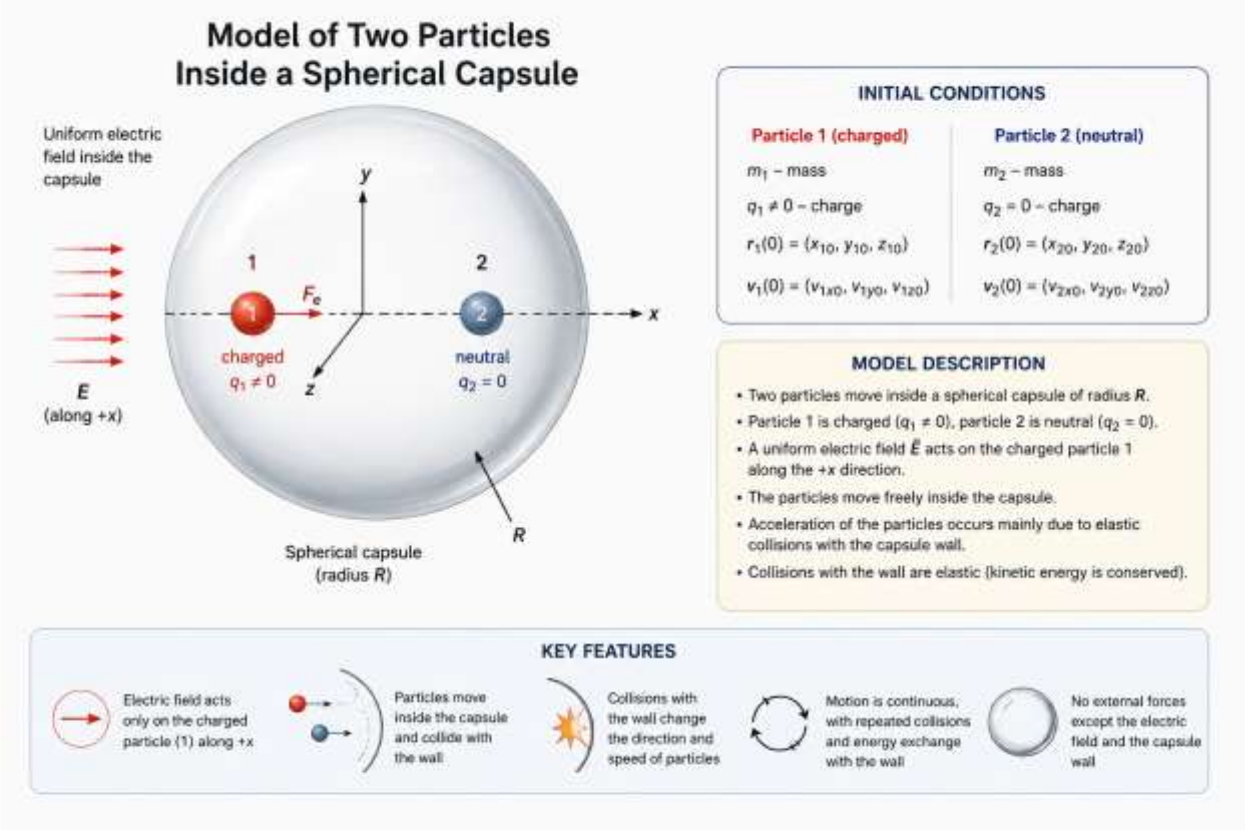

Initial Conditions

- Total mass: $m_{tot} = 6$
- Sphere radius: $R = 10$
- Coulomb interaction: $k = 0.0001$
- Initial states: **random (non-symmetric)**

Method

- Analytical propagation:

$$x(t) = \frac{1}{2}at^2 + v_0 t + x_0, \quad v(t) = at + v_0$$

- Event time from:

$$f(t) = r_{ij}(t)^2 - R^2 = 0 \quad \text{(solved by fzero)}$$

- Collision (elastic rule):

$$\vec{v}' = \vec{v} - 2(\vec{v} \cdot \hat{r})\hat{r}$$

Main results

1. Kinetic energy corresponding to degrees of freedom *parallel* to electric field.

- Contributions of each particle and a capsule are proportional to their masses.

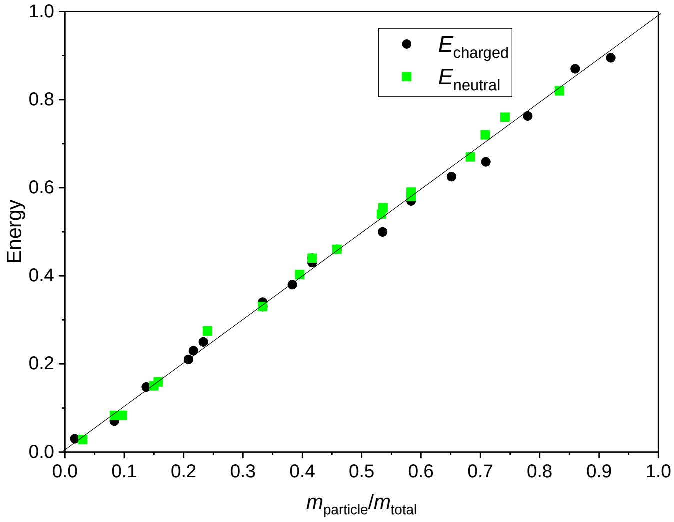

Fig.1. Contribution of particles to the total energy (degrees of freedom *parallel* to electric field) as function of their masses related to the total mass of the system

- Mean square deviations of energy contributions tend to zero with time

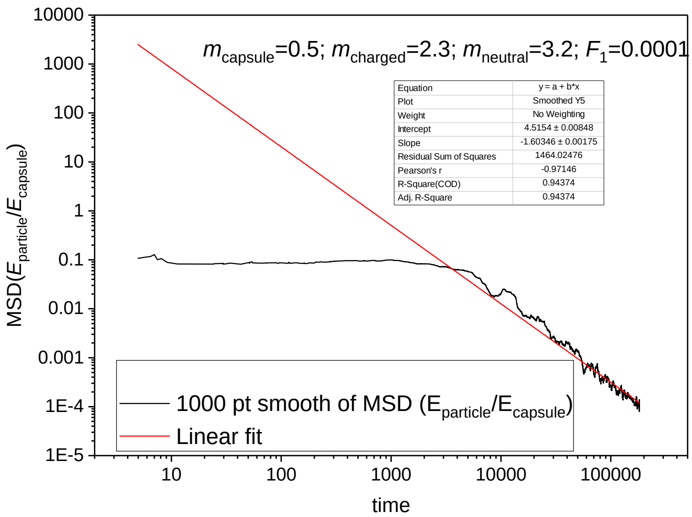

Fig.2. Time dependence of mean square deviations of particles energy contributions

2. Kinetic energy corresponding to degrees of freedom *orthogonal* to electric field.

- These freedom degrees *loose* energy during the simulation
- Energy distribution between freedom degrees *nonuniform*
- Charged particle has *greater* energy

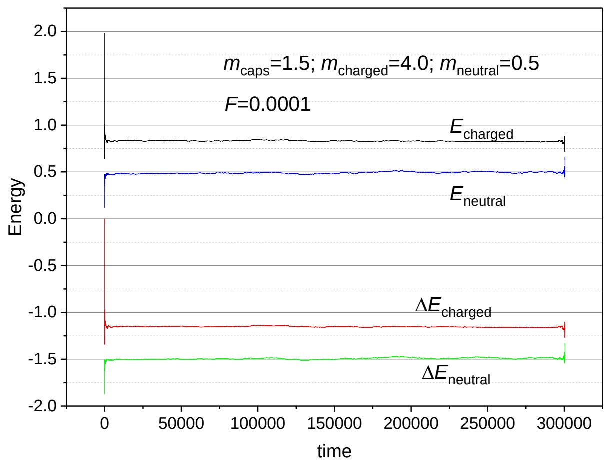

Fig.3. An example of time dependence of particles kinetic energy corresponding to degrees of freedom *orthogonal* to electric field.

3. Acceleration of charged particles exceeds greatly that of monolite particle due to collision with the sphere .

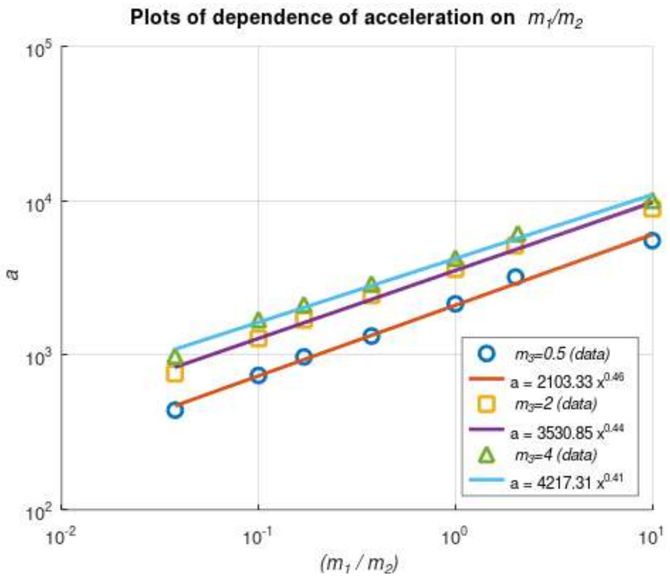

Fig.4. Acceleration of a charged particle (in the units of acceleration of the monolite particle with the same charge and total mass) as a function of its mass related to the mass of the capsule (for different masses of the neutral particle).

4. The collision frequency has 2 maxima, whose position depends on the mass distribution between particles and a shell that gives possibility to adjust the emitted signal. .The sharp peak can be used in applications of composite particles *as an antenna for transmitting electrical signals.*

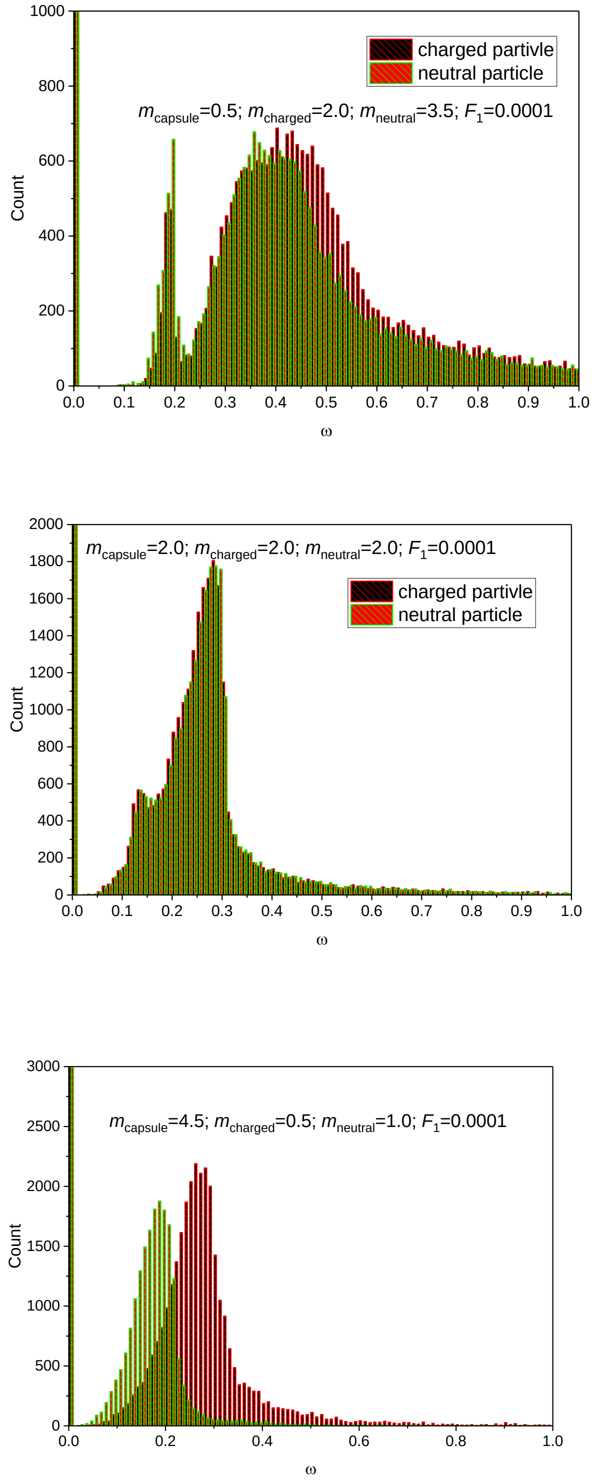

Fig.5. Positions of peaks of collision frequency distribution depend on the mass distributions of the particles.

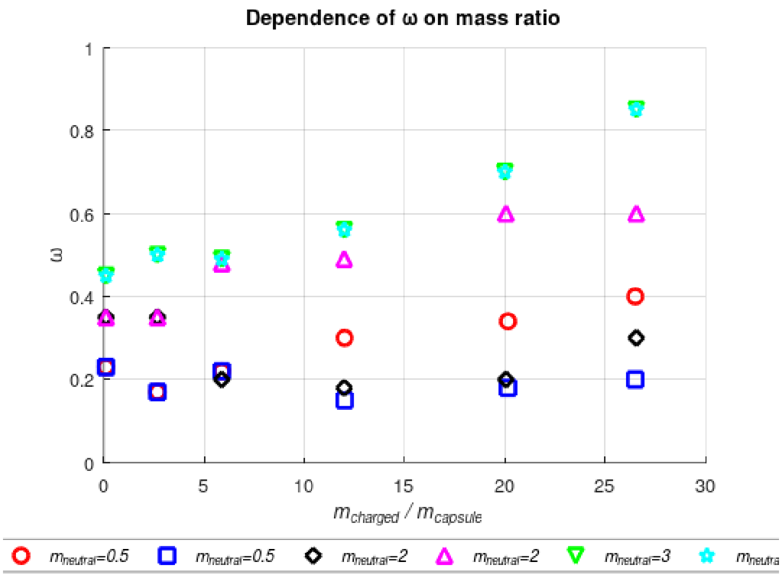

Fig.6. Positions of maxima of collision frequency ω as a function of its mass related to the mass of the capsule (for different masses of the neutral particle).

Conclusions:

Composite charged particles in the electric field demonstrate unusual properties.

Acceleration of charged particles exceeds greatly that of monolite particle due to collisions of charged particles with the shell, while signal frequency can be adjusted via regulating relations of particles and shell masses.

This makes such systems perspective for applications as antennas for transmitting electrical signals.

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