

We numerically study a version of the synchronous circular restricted three-body problem, where an infinitesimal mass body is moving under the Newtonian gravitational forces of two massive bodies. The primary body is an oblate spheroid while the secondary is an elongated asteroid of a combination of two equal masses forming a rotating dipole which is synchronous to the rotation of the primaries of the classic circular restricted three-body problem. In this paper, we systematically examine the existence, positions, and linear stability of the equilibrium points for various combinations of the model's parameters. We observe that the perturbing forces have significant effects on the positions and stability of the equilibrium points as well as the regions where the motion of the particle is allowed. The allowed regions of motion as determined by the zero-velocity surface and the corresponding isoenergetic curves as well as the positions of the equilibrium points are given. Finally, we numerically study the binary system Luhman-16 by computing the positions of the equilibria and their stability as well as the allowed regions of motion of the particle. The corresponding families of periodic orbits emanating from the collinear equilibrium points are computed along with their stability properties.