Binary Orbital Motion of Electrically Charged Spheres

Interim Report

Rhodes College

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Abstract

The similar mathematical forms of Coulomb's Law of Electrostatics and Newton's Law of Gravitation suggest that two oppositely charged spheres should be able to move in a binary orbit about their center of mass using only the electric force as the force of attraction. To test this idea, we will attempt to achieve a binary orbit between oppositely charged graphite coated Styrofoam spheres. This experiment will be tested as part of NASA's Microgravity University.

Introduction

Microgravity University, a subdivision of NASA, allows undergraduate student teams to conduct an experiment aboard a modified C-9 aircraft that creates a weightless environment. The student microgravity team, the Rhodes Binary Orbit Team (RhoBOT), submitted a proposal on October 30, 2007 which was accepted by Microgravity University. Our experiment will fly during the week of July 14th .

Test Objective

The objective of this experiment is to establish a purely electrostatic binary orbit between two oppositely charged graphite coated Styrofoam spheres. The spheres will have a mass of 1.6 grams, radius of 1.5 cm and will be charged to a surface voltage of 20 kV. Initially the spheres will be separated by a center to center distance of 15 cm. Once charged, the spheres will be launched in opposite directions (perpendicular to the line adjoining their centers). A successful orbital attempt will result in the two spheres orbiting one another about their center of mass.

We expect to learn if binary electrostatic orbits are possible in a microgravity environment, being motivated by the mathematical similarities between Coulomb's Law of Electrostatics and Newton's Law of Gravitation[2]. These are given in Equations 1 and 2, respectively:

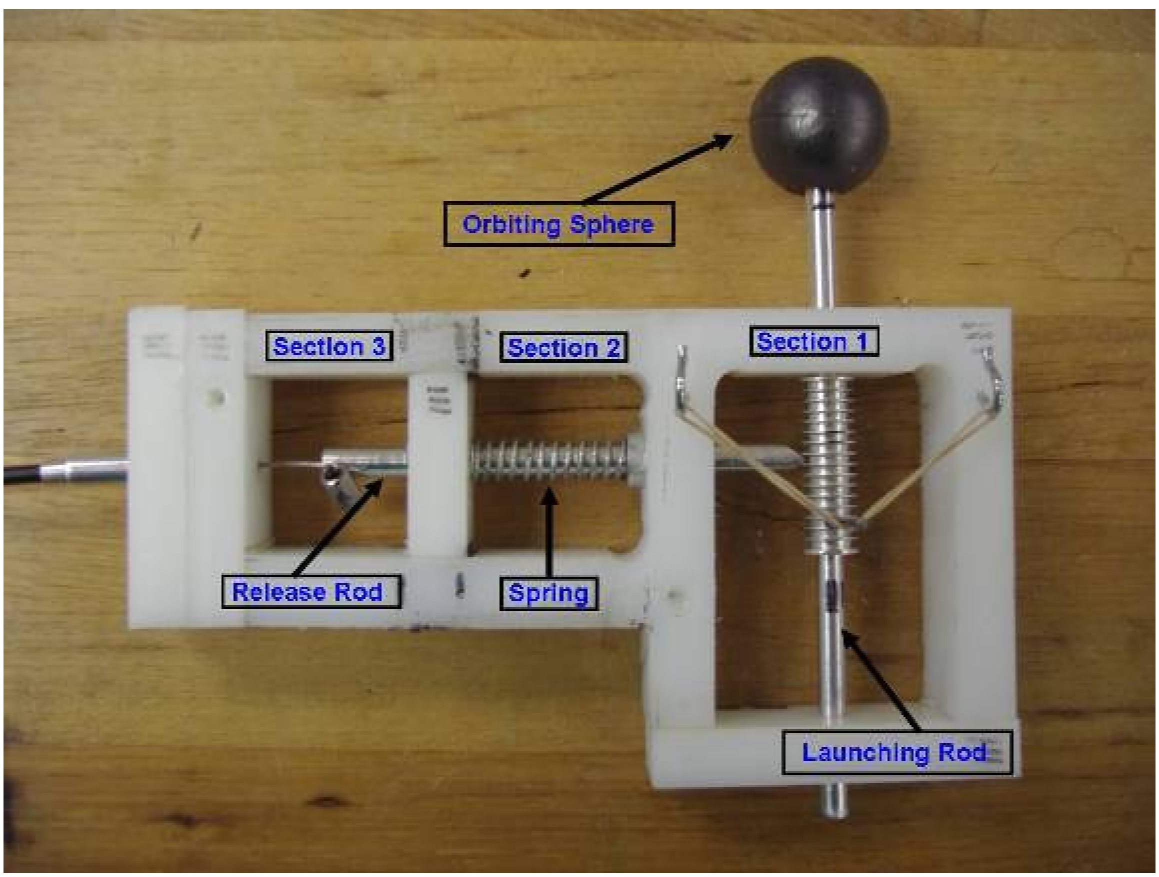
(1) $$F_E = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$$ (2) $$F_G = \frac{G m_1 m_2}{r^2}$$

These equations suggest that oppositely electrically charged spheres should be able to move in a binary orbit about their center of mass in which the attractive force between the spheres is the electric force. This is analogous to the orbital motion of a binary star system in which gravity is the attractive force between the orbiting bodies[3].

Current Progress

Beginning in January, our team has worked on designing and manufacturing a specialized apparatus to contain, charge, and launch the orbiting spheres. Currently, we have constructed a prototype apparatus consisting of a wooden frame measuring 55.5 in. x 21 in x 55.5 in, two launching platforms with launching systems, and two charging platforms with chargers. The sphere launching system (SLS) consists of two polypropylene L-shaped frames measuring 7.3 in x 0.98 in x 3.9 in, bicycle brake cables with housing, and a lever. A launching frame is shown in Figure 1.

Figure 1: Frame for Launching Mechanism



A stretched rubber band accelerates the launching rod to launch the sphere which is placed on the end of the launching rod. There are 7 usable grooves in the launching rod allowing for the testing of 7 different launch speeds. To hold the rod in place before launching the sphere, a release rod measuring 4.0 in runs through sections 1, 2, and 3, perpendicular to the launching rod. It has a wedge shaped tip that allows it to fit into the grooves machined into the launching rod. A spring is located in section 2, which holds the release rod in one of the grooves. The launcher is actuated using a bicycle brake cable to pull the release rod from the groove. The bicycle brake cables are connected to both launching mechanisms and are connected to a single bicycle brake lever via a cable splitter so that both launchers can be actuated at the same time. Small holes will be drilled in the spheres in which the metal launching rod will be inserted. The SLS will be attached to a moveable platform so that it can be retracted out of the way after the spheres are launched. A high voltage power supply with electrodes will be used to charge the spheres.

The sphere chargers are located on adjustable platforms secured to the frame. The chargers consist of electrodes from the HVPS which are mounted to an articulated arm with dimensions (in inches) 11 x 1.5 x 0.75. Positioning of the articulated arms is assisted by a damped self closing hinge mechanism. When the sphere chargers are in the charging position, they will be held by a mechanical latch that is attached to the moveable launch platforms. After the spheres have been charged the latches will be released, allowing the sphere chargers to retract to their starting positions.

We anticipate using an initial orbital separation of 15 cm between the spheres, however the apparatus will allow us to adjust this value as needed. The two orbiting spheres will be graphite coated Styrofoam balls (m = 5 grams, R = 1.5 cm). Data will be collected by analyzing the video footage of the orbits. Nominal (or anticipated) values of parameters relevant to this experiment are provided in the table below.

Description	Symbol	Nominal Value
Orbital separation	*r*	15 cm
Radius of spheres	R	1.5 cm
Mass of spheres	*m*	1.6 g
Orbital speed	*v*	~18 cm/s
Voltage on spheres	*V*	20 kV

Additional data will be gathered using a Vernier LabQuest and Wireless Dynamics Sensor System equipped with sensors to measure x-y-z acceleration, air pressure, humidity, temperature, and oxygen concentration. Data gathered with these sensors will characterize the in-flight environment and may be used in our outreach activities and/or published to aid in the development of future microgravity experiments.

Time Schedule

RhoBOT will conduct their experiment at Microgravity University during the week of July 10-19. The spring semester and this summer have been devoted to preparing for the experiment. The fall semester will be spent analyzing the results of the experiment and preparing them for publication.

References

1. Banerjee, S., K. Andring, D. Campbell, J. Janeski, D. Keedy, S. Quinn and B. Hoffmeister, "Orbital motion of electrically charged spheres in microgravity," The Physics Teacher (in press).

2. Griffiths, David J. Introduction to Electrodynamics, 2nd ed. Upper Saddle River: Prentice Hall, 1989.

3. Fowles, Grant R., and George L. Cassidy, Analytical Mechanics, 7th ed. Pacific Grove: Brooks Cole, 2005.

Budget

Microgravity University provides no funding for the selected teams.

Sensor Package

- Humidity/Temperature/Dew Point Sensor -$70
- Absolute Pressure Sensor- $90
- Oxygen Gas Sensor- $190

Supplies

- Teflon Needles (3 boxes of 50) - $145
- Graphite Coated Styrofoam Spheres (99 Spheres)- $95
- Lumber- $50
- Polypropylene- $50
- Plexiglas- $55
- High Voltage Power Supply charging cables- $700
- Precision Track Roller Guide Blocks- $500
- T-Slot Rails- $35
- Vinyl tubing and connectors for pneumatic launch- $20

Total Requested Amount- $2000

Actual Expenditures to Date

Sensor Package

- Wireless Dynamics Sensor System-$249.00
- O2 Gas Sensor - $188.00
- Relative Humidity Sensor-$69.00
- Stainless Steel Temperature Probe-$29.00
- Barometer-$69.00

Supplies

- Teflon Needles (3 boxes of 50)- $165.14
- Graphite Coated Styrofoam Spheres (99 Spheres)-$95.00
- Polypropylene- We received a donation from a Memphis supplier
- Plexiglas- $54.38
- High Voltage Power Supply charging cables-$640.00
- Precision Track Roller Guide Blocks- $492.54
- T-Slot Rails- $32.65
- Vinyl tubing and connectors for pneumatic launch – We are no longer pursuing this method

Total Spent on Requested Budget Items-$2083.71