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Universal Gravitation
Falling Around

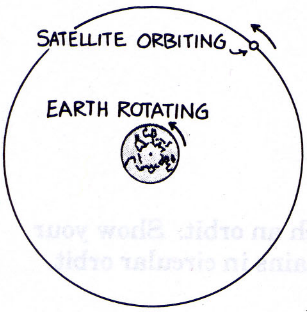
Purpose

To investigate the conditions required for geosynchronous orbit.

Required Equipment and Supplies

"Falling Around" simulation
Apple II Series computer

Discussion



The "Falling Around" simulation provides you with an opportunity to experiment by trial and error with orbiting rockets and satellites. Rather then incur the danger and expense of actual rockets or satellites, you'll do as researchers do and make use of computer technology. With the computer you will be able to launch rockets from the surface of the earth, from a space station near the earth, and from various points in space far from the earth. Thruster rockets may be fired at any time to increase or decrease the speed of the rocket. The advent of computer technology has made this otherwise impractical experimental technique very useful to space scientists. No rocket is launched into orbit without being flown on the screen of a computer first! Like a space scientist, you will use "Falling Around" to simulate and test the launch conditions you devise for your rocket.

Boot the "Falling Around" simulation and familiarize yourself with its operation. The "flight assignments" are tasks that you may accomplish using this simulation program. When you select a particular assignment, the computer displays an explanation of the mission you are to carry out. When you finish reading this information, you press [Return] to continue. The program then sets things up for the particular assignment. The graphics are displayed, and the launch site is selected and drawn. You then take control and try to accomplish your mission.

The launch site is marked with a "+". Decide on a launch speed and enter it in km/s. Do not type in the units. Typical values range from 3 to 15 km/s. The speed you enter will be given to the rocket instantly at lift-off.

Now choose the launch angle. A diagram showing how the angles are defined is displayed in the corner of the screen. As indicated in the diagram, angles are in degrees and negative angles may be used.

When you launch the rocket, you hear a roaring sound (the rocket engines) and the rocket leaves the launch site. The rocket's position is calculated using Newtonian physics for every 2 minutes of its simulated motion. Of course, the motion appears on the screen much faster. The heading, speed, and distance from the center of the earth are displayed continuously at the bottom of the screen. You can correct the path of the rocket by using small thruster rockets on the rocket. The right arrow key fires the thruster so that the speed of the rocket increases. The left arrow key fires the thruster so that the speed of the rocket decreases. You hear a sound whenever the thruster is fired. Each use of the thruster causes an acceleration of 0.3 m/s^2. This acceleration acts over the entire 2 minute time interval so that acting alone, it would cause a change of speed of 0.036 km/s. The thrusters may be used repeatedly to cause larger changes in the speed.

The motion of the rocket is plotted until the rocket crashes, or until you interrupt the motion. Do this by pressing [Return]. When you interrupt the motion of the rocket, you are presented with several choices to allow you to try again or move on. Simply press [Return] to launch again without clearing the screen.

In this lab, your assignment is to launch a rocket from a spot thousands of kilometers from the surface of the earth. This launch site has been carefully chosen so that if you obtain a circular orbit going through this point (the launch site), the rocket will be geosynchronous—this is, it will orbit the earth every 24 hours. "Falling Around" has been programmed to obey Newton's Law of Gravitation,

$$F_g = \frac{Gm_1m_2}{r^2}$$

Procedure

Step 1. Calculate how far the launch site, r_{geo}, is from the surface of the earth. Show your reasoning.

r_{geo} = __________

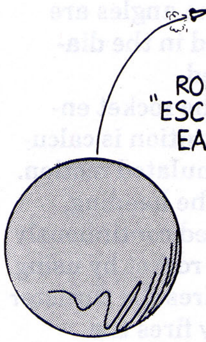
Step 2. Calculate the proper launch speed, for such an orbit. Show your reasoning. Then launch the rocket and see if it remains in circular orbit.

v_{geo} = __________

1. What happens if the rocket is launched with v_{geo} at a distance greater than r_{geo}? Less than r_{geo}?

Going Further

Escape Velocity



In this assignment, you are to launch a rocket from the surface of the earth so that it "escapes". Escape velocity, v_{esc}, is the *minimum* speed at which a rocket can be launched so that the work done by the earth's gravitational field decreases the rocket's speed to zero at *infinity* and the rocket therefore escapes from the gravitational field of the earth. At this great distance, the gravitational potential energy equals the kinetic energy at launch.

Step 3. Calculate the escape velocity, v_{esc}. Show your reasoning. How does the rocket behave when launched at this speed?

v_{esc} = __________

Analysis

2. Rockets are launched from the earth's surface at speeds far less than v_{esc}. How is this accomplished?

3. What is the maximum possible speed of impact upon the surface of the earth for a far-away object initially at rest that falls to earth by virtue of the earth's gravity alone?

4. Show why an acceleration of 0.1 m/s^2 for two minutes causes a change of speed equal to 0.012 km/s.