Indoor Lab
A TRIP TO MARS

PURPOSE:	To learn about orbits and how to send a probe from one planet to another.
RELEVANT TEXT:	Chapter on gravitation.
PREREQUISITES:	None.
DEMONSTRATION OF COMPETENCE:	Answer the questions and achieve the goals that follow. An instructor may require a written report.
EQUIPMENT:	PC with an internet connection for the first part, Mac or PC with internet connection for second part; calculator; note paper.

INTRODUCTION

In this lab you will learn about something called a Hohmann transfer orbit, which is the least energy way to get from one planet to another.

In the first part of the lab, you will try your hand at some simple orbital engineering and see if you can calculate the parameters of the Hohmann orbit that would send a probe from Earth to Mars, by using the Dynamical Astronomy JavaLab *Voyages* information and applet from Chris Mihos at Case-Western.

In the second part of the lab, you will develop your intuition about what the magnitude and direction of the initial velocity needs to be to put an object into such an orbit, by first experimenting with the *My Solar System* applet from the PhET collaboration at CU–Boulder, and then using the *Astronautics* applet from Chris Dolan at UW–Madison.

NOTE: The JavaLab *Voyages* applet does not work correctly on Mac OSX web browsers, so you will need a Windows web browser for the first part of this lab.

My Solar System and the *Astronautics* applet work on both Mac and PC web browsers, so the second part of the lab can be done anywhere.

INVESTIGATION 1. ORBIT PARAMETERS

Open a browser on a PC and go to the Dynamical Astronomy JavaLab website (google **JavaLab**)[1].

Click on the **Applets** link and select **Voyages** (at the bottom of the list of applets on the main page). You should see a Voyages welcome screen with a sidebar containing links to background, instructions, and applets.

There are two applets available: *Mission to Mars* and *Grand Tour.* You'll use just the first one (*Mission to Mars*).

YOUR GOAL: Use the information provided in the "Background" and "Lab" section of the website to figure out the semi-major axis a, eccentricity e, and Mars orbit angle ϕ of the Hohmann transfer orbit needed to get a probe from Earth to Mars.

To get checked off you need to show not only that your parameters work, but also how to calculate them. Make sure you write your solution down, with enough notes to remind yourself how to explain each step.

HINT 1: Try filling in the missing steps in the Jupiter probe example given in the **Background** section. If you are stuck, an instructor will be happy to walk you through this example.

HINT 2: You can find the semi-major axes and periods of planet orbits in your textbook.

HINT 3: Hit the **<enter>** key on your keyboard after changing parameters in the applet, *before* hitting the **Run** button. (Otherwise your changes will not take effect.)

[1] Or try http://burro.astr.cwru.edu/JavaLab

INVESTIGATION 2. LAUNCHING A PROBE

In this investigation you will try your hand at launching a probe. First you will get a feel for how to put a probe into a Hohmann transfer orbit from a circular orbit.

Circular Orbits and Hohmann Orbits

Open a web browser (on a PC or Mac) and start the PhET *My Solar System* applet (google **PhET solar system**)[2].

You should see a star (body 1) and a planet (body 2).

Change the mass of the star to **1000** and the mass of the planet to **1**. Keep the star at position **x = 0**, **y = 0** and change its initial velocity to **x velocity = 0**, **y velocity = 0**. Change the planet's position to **x = 200**, **y = 0**. Turn on **System Centered**, **Show Traces**, and **Show Grid**.

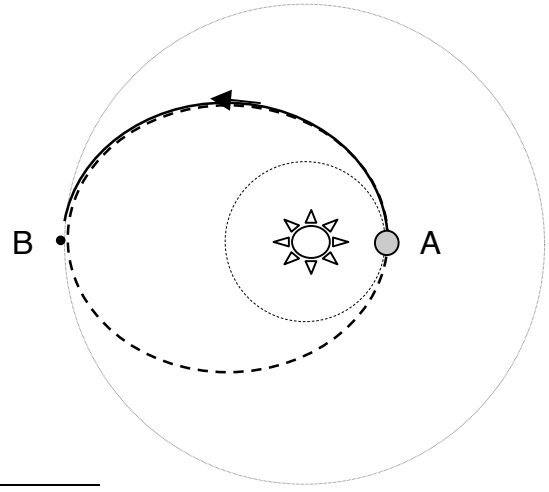
Experiment with the initial velocity of the planet until you get it going in a perfect **circle**, counterclockwise as seen on the screen. You will know it is a circle, not an ellipse, when the orbit is exactly centered on the star. (Use the grid to check.)

QUESTION 1: What is the initial velocity needed to make the planet orbit in a circle? (Check your answer with an instructor.)

x velocity _____ y velocity _____

QUESTION 2: Suppose you want to change the circular orbit so it resembles the Hohmann transfer orbit shown below (point A is the starting point, point B is a point outside the current circular orbit). What should you do to body 2's initial velocity? (Check your answer with the simulation.)

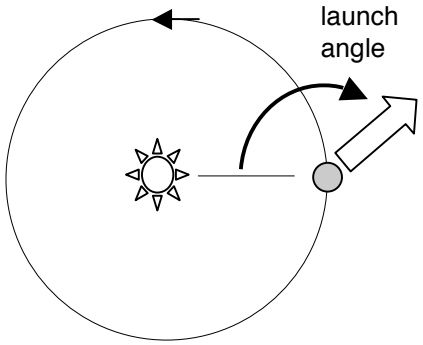
x velocity:	(a) increase	(b) decrease	(c) keep same
y velocity:	(a) increase	(b) decrease	(d) keep same



[2] Or try the address http://phet.colorado.edu/simulations/orbits/orbits.swf

QUESTION 3: Now suppose you want to launch a probe when the planet reaches point A in the previous diagram and have the probe travel a Hohmann transfer orbit to point B. Remember that the probe starts with the velocity of the planet; the launch just adds or subtracts from that velocity. What should the launch angle be, measured clockwise from the star? (Ignore the gravity of the planet.) Make your best guess; you will check your answer below.

Launch angle: (a) $< 90°$ (b) $= 90°$ (c) $> 90°$



Astronautics

Now you are ready to launch.

Go to Chris Dolan's *Astronautics* applet by googling **Dolan astronautics applet**.[3]

Once the applet is open, you should see dots representing planets in our solar system. Clicking **Run** will start the planets orbiting the Sun. You can slow the simulation down by decreasing the time step.

To launch a probe, stop the simulation and open **Options**. You can control the launch angle, launch velocity, and number of days until launch. Remember the probe already has the orbital speed of Earth (29.5 km/s).

YOUR GOAL: Get a probe out to the orbit of Mars on a Hohmann transfer orbit, with the launch point at the orbit's perihelion and a spot on Mars' orbit at the aphelion.

You do not have to actually land the probe on Mars to be checked off, although you are certainly welcome to try!

EAP 1/2008

[3] Or try http://www.astro.wisc.edu/~dolan/java