Trip to Mars

In this activity, you will plan a trip from Earth to Mars, and back, using a Hohmann transfer orbit. We'll assume that both Earth and Mars have circular orbits. You will calculate the required changes in velocity for your spacecraft when it travels to Mars when Mars is at conjunction (when the Earth, Sun, and Mars are aligned, in that order), as shown in the diagram below. Earth is located at the left end of the arrow marked Δv and Mars is located at the right end of the arrow marked Δv'. **Label the Earth and Mars in the diagram below NOW, BEFORE proceeding.** Note that the diagram is not to scale.

The distance between the Earth and the Sun is called an astronomical unit, and is abbreviated as 1 AU, where 1 AU = 1.496×10^{11} m. The semimajor axis for Earth and Mars refers to their respective distances *from* the Sun. The spacecraft orbit semimajor axis is *half the distance between* the Earth and Mars.

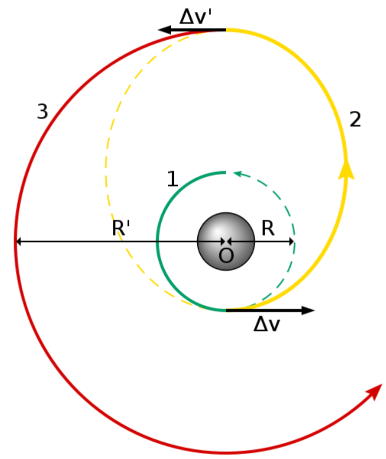
Assume that all distances are in meters and all time units are in seconds, unless specified otherwise. You do not need to include the units in tables since they are already included. Complete Table 1 and Table 2.

mass of the Sun $M_{sun} = 1.989 \times 10^{30}$ kg $G = 6.67 \times 10^{-11}$ N m^2/kg^2

$$g = \frac{GM}{r^2} \qquad a = \frac{r_p + r_a}{2} \qquad e = \frac{r_a - r_p}{r_a + r_p}$$

$$v_{c\ object} = \sqrt{\frac{GM_{sun}}{a_{object}}} \qquad v_p = v_c\sqrt{\frac{1+e}{1-e}} \qquad v_a = v_c\sqrt{\frac{1-e}{1+e}}$$

$$v_r = \sqrt{GM\left(\frac{2}{r} - \frac{1}{a}\right)} \qquad P^2 = a^3 \text{, where } P \text{ is in years and } a \text{ is in AU}$$



1 = Earth's orbit, 2 = spacecraft's Hohmann transfer orbit, 3 = Mars' orbit, and the gray circle in the middle is the Sun
Source: Wikimedia Commons, http://en.wikipedia.org/wiki/File:Hohmann_transfer_orbit.svg

Table 1 Mass and Gravity

		A	B
		Earth	Mars
1	mass M in kg	**5.984×10^{24}**	**6.419×10^{23}**
2	radius r in m	**6.371×10^{6}**	**3.396×10^{6}**
3	acceleration of gravity g in m/s^2		
4	semimajor axis a in AU	**1.00**	**1.52**
5	semimajor axis a in m	**$r_p = 1.496 \times 10^{11}$**	**r_a =**
6	circular velocity v_c in m/s	v_{cEarth} =	v_{cMars} =

Table 2 Orbital Parameters

		A
1	GM_{sun} in N m^2/kg	
2	distance between Earth and Mars in AU	
3	distance between Earth and Mars in meters	
4	spacecraft orbit semimajor axis a in AU	
5	spacecraft orbit semimajor axis a in m	
6	spacecraft orbit eccentricity e	
7	spacecraft circular orbital velocity v_c in m/s	
8	$\sqrt{\frac{1-e}{1+e}}$	
9	spacecraft orbital velocity v_a in m/s at Mars	
10	required change in velocity in m/s at Mars $\vert v_{cMars} - v_a \vert$	
11	$\sqrt{\frac{1+e}{1-e}}$	
12	spacecraft orbital velocity v_p in m/s at Earth	
13	required change in velocity in m/s at Earth $\vert v_{cEarth} - v_p \vert$	
14	time for the trip P in years	
15	time for the trip P in days	