MISSION TO
MARS
PROJECT BASED LEARNING

Getting to Mars

Escape velocity

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Launch of the Mars Pathfinder Mission. NASA/JPL.

The first problem facing a potential trip to Mars is leaving Earth. Specifically, this problems deals with the enormous amount of energy necessary to break free from the Earth's gravitational field and start traveling towards Mars, or anywhere else in the Solar System. To find out what energy, and therefore speed, is necessary to escape Earth's gravity, let us consider the energy of a rocket at Earth's surface:

$$E = ½\, m_{rocket}\, v_{initial}^2 – GM_{earth}m_{rocket}/R_{earth}$$

Energy is the sum of kinetic and potential energies. Here, vinitial is the initial velocity, mrocket is the mass of the rocket, and Mearth and Rearth are the mass of the Earth and the radius of the Earth. Now, because the energy of the rocket is constant as it travels upward, we can equate the energy of the rocket at the surface to the energy of the rocket at its maximum altitude:

$$½\, m_{rocket}\, v_{initial}^2 – GM_{earth}\, m_{rocket}\, /R_{earth} = ½\, mv_{final}^2 – GM_{earth}\, m_{rocket}\, /r_{maximum}.$$

Here, v_{final} is the final velocity and $r_{maximum}$ is the maximum height. However, at its maximum height, $v_{final} = 0$, so the equation becomes

$\frac{1}{2} m_{rocket} v_{initial}^2 - GM_{earth} m_{rocket} /R_{earth} = - GM_{earth} m_{rocket} /r_{maximum}$.

Solving for v_i, we have

$v_{initial}^2 = 2GM_{earth}(1/R_{earth} - 1/ r_{maximum})$.

Setting $r_{maximum} = 8$, which is the condition for gravitational escape, $v_{initial}$ becomes v_{escape} and we have

$v_{escape} = \text{sqrt} (2GM_{earth}/R_{earth})$.

The same logic can be applied to any planet, so the equation for escape velocity can be generalized to

$v_{escape} = \text{sqrt} (2GM/R)$.

Thus, the escape velocity from any planet depends on the mass of the planet and the radius of the planet. For example, let us assume that we have a spacecraft on Earth that we are trying to send into space. $M_{earth} = 5.98\text{x}10^{24}$ kg, and $R_{earth} = 6.37\text{x}10^6$ m, so we get:

$v_{escape} = \text{sqrt} (2GM/R)$

$v_{escape} = \text{sqrt} (2(6.67\text{x}10^{-11} \text{Nm}^2/\text{kg}^2)(5.98\text{x}10^{24} \text{ kg})/(6.37\text{x}10^6 \text{ m}))$

$v_{escape} = 1.12 \text{x}10^4$ m/s, or about 11 km/s.

Now, let us assume astronauts have successfully completed their mission on Mars and need to calculate the escape velocity on Mars so they can travel back to Earth. $M_{mars} = 6.42\text{x}10^{23}$ kg, and $R_{mars} = 3.397\text{x}10^6$ m, so we get:

$v_{escape} = \text{sqrt} (2GM/R)$

$v_{escape} = \text{sqrt} (2(6.67\text{x}10^{-11} \text{Nm}^2/\text{kg}^2)(6.42\text{x}10^{23} \text{ kg})/(3.397\text{x}10^6 \text{ m})$

$v_{escape} = 5.0 \text{x}10^3$ m/s, or about 5 km/s.

The Benchmark Lessons were developed with the help of the following sources:

Alpert, Mark. “How To Go To Mars.” *Scientific American*, March 2000, pp. 44-51.
“Cognitave States.” *Discover*, May 2001, pp. 35.

JPL’s Planetary Photojournal, http://photojournal.jpl.nasa.gov/

Murr, Andrew and Giles, Jeff. “The Red Planet Takes a Bow.” *Newsweek*, December 6, 1999, pp. 61.

The NASA Image Exchange, http://nix.nasa.gov/

Oberg, James, and Aldrin, Buzz. “A Bus Between the Planets.” Scientific American, March 2000, pp. 58-60.

Robinson, Kim Stanley. “Why We Should Go to Mars.” *Newsweek*, December 6, 1999, pp. 62.

Serway, Raymond A. *Principles of Physics*. Saunders College Publishing, Harcourt Brace College Publishers, Austin, 1994.

Simpson, Sarah. “Staying Sane in Space.” *Scientific American*, March 2000, pp. 61-62.

Singer, Fred S. “To Mars By Way of Its Moons.” *Scientific American*, March 2000, pp. 56-57.

Weed, William Speed. “Can We Go To Mars Without Going Crazy.” *Discover*, May 2001, pp. 36.

Yam, Philip. “Invaders from Hollywood.” *Scientific American*, March 2000, pp. 62-63.

Zorpette, Glenn. “Why Go To Mars?” *Scientific American*, March 2000, pp. 40-43.

Zurbin, Robert. “The Mars Direct Plan.” *Scientific American*, March 2000, pp. 52-55.

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