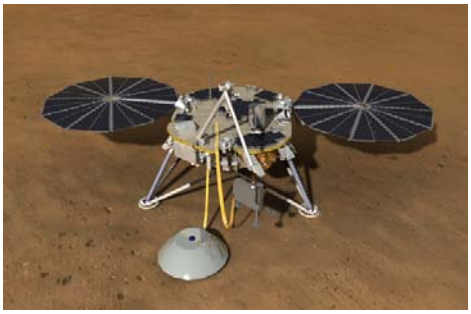

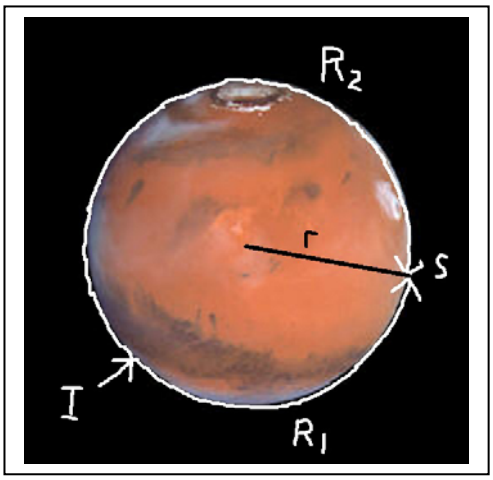

NASA's new mission to Mars called InSight will be launched in March, 2016. It will land on September 20, 2016 in a region of Mars located near the equator and deploy a seismographic station to study the interior of Mars.

Each time a large meteor strikes the surface of Mars, one seismic wave will travel to the InSight station along a clockwise path around mars, and a second seismic wave will travel in the opposite direction to the station.

InSight will measure the arrival times of the two waves, called R1 and R2. From this timing data and the 5 km/s speed of the seismic wave along the martian surface, InSight will calculate where the impact occurred. The radius of Mars is r=3,397 kilometer.

In the following problems, use π = 3.1416, and round all answers to the nearest kilometer and second.

Problem 1 – Suppose that the impact occurred at Point I on the above figure, and the time between the arrival of the R1 and R2 waves was exactly 1423 seconds. How far did the R1 and R2 waves travel to get to the InSight station?

Problem 2 – For a large enough impact, InSight scientists expect that after the R1 and R2 waves are detected by the seismometer, that the waves will continue to 'orbit' the surface of Mars and return once again as a second pair of weaker seismic signals called R3 and R4, followed later on by a third pair of even-weaker signals called R5 and R6. For the example in Problem 1, what are the arrival times of all 6 seismic signals if R1 was detected at the clock time of 13:00:00 local time at the lander site?

Problem 3 - Because of a glitch in the recording of the seismic data, InSight scientists were able to detect the R3 and R6 seismic waves, which arrived at 15:25:30 and 17:00:00 Local Mars Time. How far from the Lander did the impact occur, and when would the arrival times for all 6 seismic waves have occurred in the data?

Problem 1 – Suppose that the impact occurred at Point I on the above figure, and the time between the arrival of the R1 and R2 waves was exactly 1423 seconds. How far did the R1 and R2 waves travel to get to the InSight station?

Answer: To travel once around the circumference of Mars, the wave has to travel $2 \pi r = 2 (3.1416) (3397 \text{ km}) = 21344 \text{ km}$, so the round trip time is T = 21344 km / (5 km/s) = 4269 seconds. We know that T2 – T1 = 1423 seconds, so the R2 wave had to travel the same distance as the R1 wave plus an additional 1423 seconds. Since 1423 seconds = 1/3 of the full circumference time of 4269 seconds, that means that R1 traveled 1423 seconds from the impact site, I, and R2 traveled 2 x 1423 = 2846 seconds from the impact site. The distance to the impact site using the R1 wave data is 1423 sec x 5 km/sec = **7,115 kilometers**

Problem 2 – For a large enough impact, InSight scientists expect that after the R1 and R2 waves are detected by the seismometer, that the waves will continue to 'orbit' the surface of Mars and return once again as a second pair of weaker seismic signals called R3 and R4, followed later on by a third pair of even-weaker signals called R5 and R6. For the example in Problem 1, what are the arrival times of all 6 seismic signals if R1 was detected at the clock time of 13:00:00 local time at the lander site?

R1 = **13:00:00**
R2 = 13:00:00 + 1423 seconds = 13:00:00 + 23m 43s = **13:23:43**
R3 = 13:00:00 + 4269 seconds = 13:00:00 + 1h 11m 9s = **14:11:09**
R4 = 13:23:43 + 4269 seconds = 13:23:43 + 1h 11m 9s = **14:34:52**
R5 = 14:11:09 + 4269 seconds = 14:11:09 + 1h 11m 9s = **15:22:18**
R6 = 14:34:52 + 4269 seconds = 14:34:52 + 1h 11m 9s = **15:46:01**

Problem 3 - Because of a glitch in the recording of the seismic data, InSight scientists were able to detect the R3 and R6 seismic waves, which arrived at 15:25:30 and 17:00:00 Local Mars Time. How far from the Lander did the impact occur, and when would the arrival times for all 6 seismic waves have occurred in the data?

Answer: R3 is the R1 wave which has orbited Mars one additional time so that R3-R1 = 4269 seconds. R6 is the R2 wave which has orbited Mars two additional times so that R6-R2 = 2(4269 seconds). The R5 wave would have arrived one full orbit (4269 seconds) after the R3 wave, so the time intervals are as follows:

R1 = 15:25:30 – 4269 seconds = 15:25:30 – 1h 11m 9s = **14:14:21**
R2 = 17:00:00 – 8538 seconds = 17:00:00 – 2h 22m 18s = **14:37:42**
R3 = **15:25:30**
R4 = 17:00:00 – 4269 seconds = 17:00:00 – 1h 11m 9s = **15:48:51**
R5 = 15:25:30 + 4269 seconds = 15:25:30 + 1h 11m 9s = **16:36:39**
R6 = **17:00:00**

Time interval = R2-R1 = 23:21 = 1401 seconds.

R1 + R2 = 4269 seconds
R1 – R2 = 1401 seconds. Then adding the two equations we get 2R1 = 5670 so R1 = 2835 seconds. Traveling at 5 km/sec, the R1 wave originated **14,175 km from the landing site.**