This sequence shows the launch of the MSL mission from the Kennedy Space Center Launch Complex 49 on November 27, 2011 at 10:02 EST. The four images were taken, from bottom to top, at times 10:02:48 EST, 10:02:50 EST, 10:02:51 EST and 10:02:52 EST. At the distance of the launch pad, the width of each image is 400 meters.

**Problem 1** - With the help of a millimeter ruler, what is the scale of each image in meters/mm?

**Problem 2** - For each image, what is the distance between the bottom of the image and the base of the rocket nozzle for the Atlas V rocket in each scene?

**Problem 3** - What is the estimated distance from the base of the launch pad to the rocket nozzle in each image?

**Problem 4** - From the time information, what is the average speed of the rocket between A) Image 1 and 2? B) Image 2 and 3? C) Image 3 and 4?

**Problem 5** - From the speed information in Problem 4, what is the average acceleration between A) Image 1 and Image 3? B) Image 2 and Image 4?

**Problem 6** - Graph the height of the rocket versus the time in seconds since launch.

**Problem 7** - Graph the speed of the rocket versus time in seconds after launch. For the time, use the midpoint time for each speed interval.

**Problem 8** - Graph the acceleration of the rocket versus time in seconds after launch. For the time, use the midpoint time for each acceleration interval.

This sequence of stills was obtained from a YouTube.com video of the launch of MSL by United Space Alliance available at

http://www.youtube.com/watch?v=0cxsvVBemHY

Space Math                                http://spacemath.gsfc.nasa.gov
Problem 1 - Answer: Width = 69 mm, so scale = 400 m/69 mm = \textbf{5.8 meters/mm}

Problem 2 - Answer: 8mm, 18mm, 24mm and 32mm so using the scale of the image, the actual distances are \textbf{46m, 104m, 139m and 186 meters}.

Problem 3 – Answer: Take the differences in the measurements relative to the first image at the moment of launch to get \(h_1 = 46m-46m = 0m\), \(h_2=104m-46m = 58m\), \(h_3=139m-46m = 93 m\) and \(h_4 =186m-46m = 140 m\).

Problem 4 – Answer: A) \(v= \text{distance/time}, \ v_1 = (58m-0m)/2sec = 29\text{m/sec}\) B) \(v_2 = (93m-58m)/1sec = 35\text{ m/sec}\), C) \(v_3 = (140m-93m)/1sec = 47\text{ m/sec}\).

Problem 5 – Answer: A) \(a_1 = (v_2-v_1)/3sec = (35-29)/3 = 2 \text{ m/sec}^2\). B) \(a_2 = (V_3-v_2)/2sec = (47-35)/2sec = 6 \text{ m/sec}^2\).

Problem 6 – Graph the height of the rocket versus the time in seconds since launch.

![Graph](image1)

Problem 7 – Graph the speed of the rocket versus time in seconds after launch. For the time, value, use the midpoint time for each speed interval. Answer: Left Above. For the first speed, the two height measurements are made at \(T=0\) and \(T=2\), so the speed \(V_1\) will be plotted at the midpoint time: \(T=(2-0)/2 = 1 \text{ sec}\)

![Graph](image2)

Problem 8 – Graph the acceleration of the rocket versus time in seconds after launch. For the time value, use the midpoint time for each acceleration interval. Answer: Right Above.