Juno Spacecraft Rocket Launch

This sequence of images was taken of the launch of the Juno spacecraft on August 5, 2011 from Cape Canaveral.

The images were taken, from left to right, at T+21, T+23 and T+25 seconds after launch, which occurred at 12:25:00 pm EDT.

The distance from the base of the Atlas-Centaur rocket to its top is 45 meters (148 feet).

As the video was produced, the camera zoomed out between the T+21 image and the T+23 image. Both the T+23 and T+25 images were taken at exactly the same zoom scale.

Problem 1 - From the information given, find the speed of the rocket in meters/sec and kilometers/hr between A) 21 and 23 seconds after launch and B) 23 to 25 seconds after launch.

Problem 2 - What is the average acceleration of the rocket in meters/sec2 between 21 and 25 seconds after launch?

Problem 3 - At the average acceleration of this rocket, about when will it be traveling faster then the speed of sound (Mach 1) which is 340 meters/sec?

Mars Lab Rocket Launch

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 - What is the scale of each image in meters/mm?

Problem 2 - What is the distance between the bottom of the image and the base of the rocket nozzle for the Atlas V rocket in each image?

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

Problem 4 – 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 – What is the average acceleration between A) Image 1 and Image 3? B) Image 2 and Image 4?

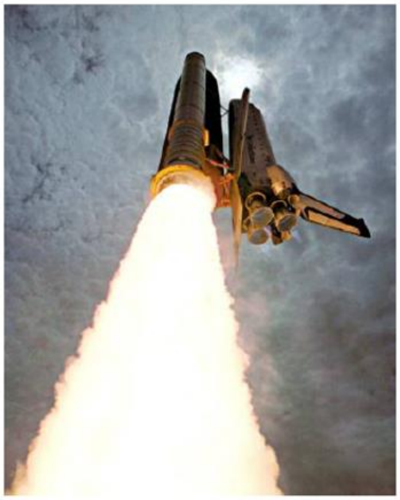
Problem 6 – Graph the height of the rocket versus the time in seconds.

This sequence of stills was obtained from **https://www.youtube.com/watch?v=1QCNsKricls**

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

Gravity and Escape Speed



Every planet, asteroid or other object in the universe has its own speed limit because of the pull of gravity. Scientists call this the escape speed or escape velocity.

If you move slower than this speed, you will stay on the object. If you move faster than this speed you will escape into space.

For Earth, the escape speed V in kilometers/second (km/s) at a distance R from Earth's center in kilometers, is given by:

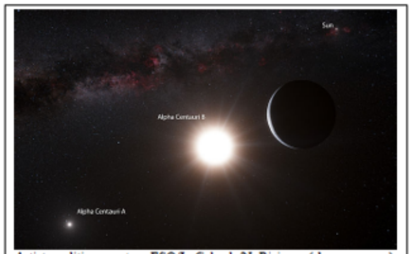
$$V = \frac{894}{\sqrt{R}}$$

Problem 1 - What is the escape speed for a rocket located on Earth's surface where R = 6378 km?

Problem 2 – An Engineer proposes to launch a rocket from the top of Mt Everest (altitude 8.9 km) because its summit is farther from the center of Earth. Is this a good plan?

Problem 3 – A spacecraft is in a parking orbit around Earth at an altitude of 35,786 km. What is the escape speed from this location?

Alpha Centauri Bb


Artist rendition courtesy ESO/L. Calçada/N. Risinger (skysurvey.org)

Time (hours)	Speed (cm/sec)	Time (hours)	Speed (cm/sec)
6	170	48	50
10	150	56	70
21	110	71	130
33	60	83	170

Alpha Centauri is a binary star system located 4.37 light years from our sun. Astronomers used the 3.6 meter telescope in Chile to detect the motion of Alpha Centauri B caused by an earth-sized planet in close orbit around this star. The planet, called *Alpha Centauri Bb,* orbits at a distance of only six million kilometers from its parent star (closer than Mercury is to the sun).

The astronomers made hundreds of measurements of the speed of the Alpha Cen B star to search for a periodic change in its speed through space. They found a change (amplitude) of about 50 cm/sec that increased and decreased with a precise period, which would only be expected from an orbiting object. (This discovery is still being confirmed through independent observations by other astronomers.)

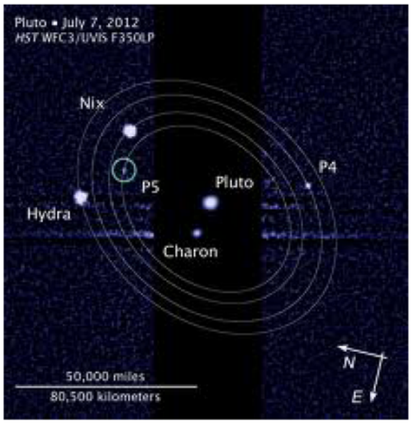
Problem 1 – Graph the speed data. Draw a smooth curve through the data (which need not go through all the points) and estimate the period (in days) of the speed curve to get the orbit period of the proposed planet.

Problem 2 – Kepler's Third Law can be used to relate the period of the planet's orbit (T in years) to its distance from its star (D in Astronomical Units) using the formula:

$$T^2 = D^3$$

where 1 Astronomical Unit equals the distance from Earth to our sun (150 million km). Using your estimated planet period, what is the orbit distance of the new planet from Centauri B in A) Astronomical Units? B) kilometers?

Problem 3 – What is the temperature T (in kelvins) of the new planet if its average temperature at a distance of D
Astronomical Units is given by the formula: $T = \frac{310}{\sqrt{D}}$



Name	Discovery	Diameter (km)	Distance (km)	Period (hours)
Pluto V	2012	10 to 25	42,000	485
Nix	2005	46 to 137	48,700	598
Pluto IV	2011	13 to 34	59,000	770
Hydra	2005	61 to 167	65,000	917

Pluto's Fifth Moon

The most distant well-known object in our solar system, Pluto, is an irresistible object for Hubble Space Telescope investigations. In July, 2012, Hubble scientists released an image of Pluto showing a new moon called P5.

It is irregularly shaped, about 15 km in diameter, and probably made from ice. Its average orbit radius is 47,000 km and appears to lie in the same orbit plane as the other four moons, and takes about 20 days to make one orbit.

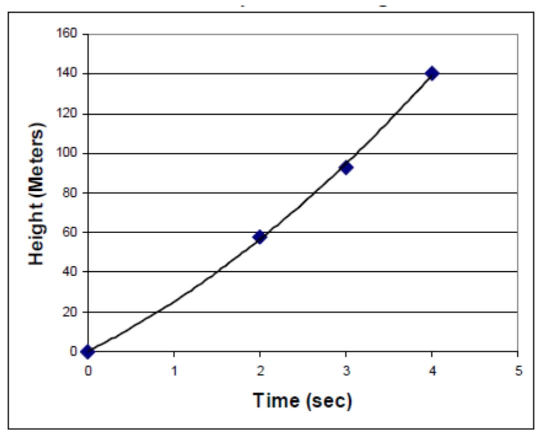
Problem 1 – Compute for each moon the cube of the distance, D^3, and the square of the period, P^2. Calculate the value $R = D^3/P^2$ for each moon. What do you notice about the values for R? What is the average value for R using the data from the five moons?

Problem 2 – Suppose future observations discover a new moon, P6, orbiting at a distance of 35,000 km from Pluto. What would you predict as the orbit period for this satellite?

Problem 3 - The mass of a body can be determined from Kepler's Third Law, which you verified in Problem 1. By using the formula $M = 6.9 \times 10^{10}$ R, where R is in units of $km^3/days^2$, what is the mass of Pluto in kilograms?

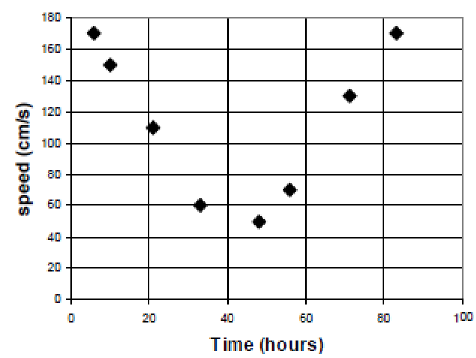
ANSWER KEY

1. Juno Rocket Launch
    a. 60 m/s (216 km/hr), 119 m/s (428 km/hr)
    b. 15 m/s^2
    c. 40 sec



2. Mars Lab Lunch
    a. 5.8 m/mm
    b. 46m, 104m, 139m , 186m
    c. 0m, 58m, 93m, 140m
    d. 29m/s, 35m/s, 47m/s
    e. $2m/s^2$, $6m/s^2$

3. Gravity and Escape Speed
    a. 11.18m/s
    b. 11.18m/s
    c. 4.35m/s



4. Alpha Centauri Bb
    a. 0.043 AU (6.4 million km)
    b. 1500K

5. Pluto's Fifth Moon!
    a. 3.28×10^8 km^3/hr^2
    b. 361 hours = 15.1 days
    c. Mass = 1.3×10^{22} kg
    (which is equal to 0.02 earths!)

Juno Rocket Launch

Image:

A → B : 21 → 23 sec

B → C : 23 → 25 sec

height = 45 m (actual)

measured from image

Scale:

A → 5.5 mm = 45/5.5 = 8.2 m/mm

B → 4.0 mm = 45/4 = 11.3 m/mm

C → 3.0 mm = 45/3 = 15 m/mm

Distance Traveled → measure height from bottom of rocket to horiz. pt (water line below exhaust)

A) $35\,mm\left(8.2\,\frac{m}{mm}\right) = 287\,m$

B) $36\,mm\left(11.3\,m/mm\right) = 407\,m$

C) $43\,mm\left(15\,m/mm\right) = 645\,m$

Speed ⇒ for Image A to B: $\left[\text{speed} = \frac{\text{distance}}{\text{time}}\right]$ (d, t)

$$V_{AB} = \text{Speed}_{A \to B} = \frac{407 - 287\,m}{23 - 21\,sec} = \boxed{60\,\frac{m}{s}}\ A \to B$$

$$V_{BC} = \text{Speed}_{B \to C} = \frac{645 - 407}{25 - 23\,sec} = \boxed{119\,\frac{m}{s}}\ B \to C$$

Convert to $\frac{km}{hr}$ ⇒

$$V_{AB} = 60\,\frac{m}{sec}\left(\frac{3600\,sec}{1\,hr}\right)\left(\frac{1\,km}{1000\,m}\right) = \boxed{216\,\frac{km}{hr}}\ V_{A-B}$$

$$V_{BC} = 119\,\frac{m}{s}\left(\frac{3600\,sec}{1\,hr}\right)\left(\frac{1\,km}{1000\,m}\right) = \boxed{428\,\frac{km}{hr}}\ V_{B-C}$$

Juno Rocket launch

#2)

acceleration = $\frac{\text{change in speed}}{\text{time}}$

$$\text{accel} = \frac{119 - 60 \text{ m/s}}{(25 - 21 \text{ s})} = \boxed{15 \text{ m/s}^2} = \text{accel.}$$

#3) Mach 1 = 340 m/s = V

speed = (inital speed) + (accel)(time) ← equation

[$V = V_0 + a t$]

solve for "t":

$V_0 = 119$ m/s, $V = 340$ m/s, $a = 15$ m/s²

$$\frac{V - V_0}{a} = t = \frac{340 - 119 \text{ m/s}}{15 \text{ m/s}^2} = 15 \text{ sec}$$

total time = 15 + 25 sec (actual ~ 51 sec)

⇒ $\boxed{t = 40 \text{ sec}}$

Mars Lab Rocket Launch

Measure width = 69mm

Scale = $\frac{400m}{69mm}$ = $5.8 \frac{m}{mm}$ #1

measure each image:

1) 8 mm(5.8 m/mm) = 46m
2) 18mm (5.8 m/mm) = 104m
3) 24mm (5.8 m/mm) = 139m
4) 32mm (5.8 m/mm) = 186 m

#2

Take diff in meas. above:

h_1 = 46 - 46m = 0m
h_2 = 104 - 46m = 58m
h_3 = 139 - 46m = 93m
h_4 = 186 - 46 m = 140 m

#3

Avg. Speed: [Speed = $\frac{\text{distance}}{\text{time}}$]

image #

1-2: $V_{12} = \frac{58-0\,m}{2\,sec}$ = 29 m/s

2-3: $V_{23} = \frac{93-58\,m}{1\,sec}$ = 35 m/s

3-4: $V_{34} = \frac{140m - 93m}{1\,sec}$ = 47 m/s

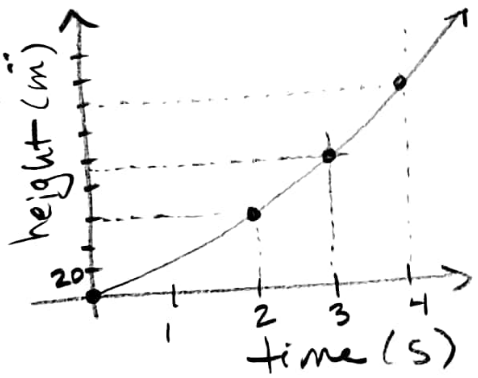
Mars lab Launch

acceleration = $\frac{\text{change in speed}}{\text{time}}$

$$a_{13} = \frac{V_{23} - V_{12}}{\text{time}} = \frac{35 - 29}{3\text{ sec}} = \boxed{2\ \frac{m}{s^2}}$$

$$a_{24} = \frac{V_{34} - V_{23}}{\text{time}} = \frac{47 - 35}{2\text{ sec}} = \boxed{6\ \frac{m}{s^2}}$$

Graph:



note - not a straight line!

Gravity & Escape Speed

$$V = \frac{894}{\sqrt{R}}$$

V = velocity (km/s)
R = dist from center of Earth (in km)

① V = ? on surface of Earth?

Diameter of earth = 12,756 km
so Radius = $\frac{1}{2}$ Dia = $\frac{1}{2}$(12,756 km) = 6,378 km

$$V = \frac{894}{\sqrt{6378}} = \boxed{11.19 \frac{km}{sec}}$$

② Launch from Mt. Everest?

Add to radius: 6,378 + 8.9 km = 6386.9 km

$$V = \frac{894}{\sqrt{6386.9}} = \boxed{11.18\ km/sec}$$

③ Launch from orbit?

$$V = \frac{894}{\sqrt{(6378 + 35,786)}} = \boxed{4.35\ km/s}$$

↳ add altitude to radius!

Alpha Centauri Bb

Graph data + estimate period ~ 77 hrs

$$77\text{ hrs}\left(\frac{1\text{ day}}{24\text{ hrs}}\right) = 3.2\text{ days}$$

Kepler's 3rd Law: $T^2 = D^3$ {T in years, D in AU's}

(1 AU = 150E6 km)

$$T^2 = D^3 \Rightarrow D = \sqrt[3]{T^2} = T^{2/3}$$

first find T in years $\Rightarrow$ $T = 3.2\text{ days}\left(\frac{1\text{ yr}}{365\text{ days}}\right) = 0.00877\text{ yrs}$

then ^2

$T^2 = 0.000\ 076\ 862$

now take cube root

to get distance $\rightarrow$ $= \boxed{0.043\text{ AU}} = D$

now convert AU to km:

$$0.043\text{ AU}\left(\frac{150E6\text{ km}}{1\text{ AU}}\right) = \boxed{6.4E6\text{ km}}$$

Temperature: $T = \frac{310}{\sqrt{D}} = \frac{310}{\sqrt{0.043}} \Rightarrow \boxed{T = 1500\text{ K}}$

(must be in "AU")

Pluto's 5th moon! ("P5")

#1 Find $R = \frac{D^3}{P^2}$ for all objects:

average is: $3.28E8 \frac{km^3}{hrs^2}$

ex: Pluto V: $\frac{D^3}{P^2} = \frac{(42{,}000\,km)^3}{(485\,hr)^2} = 3.15E8 \frac{km^3}{hr^2}$

Pluto IV: $\frac{D^3}{P^2} = \frac{(59{,}000\,km)^3}{(770\,hr)^2} = 3.46E8 \frac{km^3}{hr}$

#2 P6 : 35,000 km = D, what is P?

$3.28E8 \frac{km^3}{hr^2} = \frac{D^3}{P^2} = R$

Solve for P: $P^2 = \frac{D^3}{R}$ so $P = \sqrt{\frac{D^3}{R}}$

$P = \sqrt{\frac{(35{,}000\,km)^3}{(3.28E8 \frac{km^3}{hr^2})}} = 361$ hours

$P = 361\,\cancel{hr} \left(\frac{1\,day}{24\,\cancel{hr}}\right) = 15.1$ days

Pluto's new moon

#3 What is mass?

$M = 6.9E10\,R$ $R \to \frac{km^3}{days^2}$

$$R = \left(3.28E8 \frac{km^3}{hrs^2}\right)\left(\frac{24\,hr}{1\,day}\right)^2$$

so $R = 1.88\,E11 \frac{km^3}{day^2}$

Now: $M = (6.9E10)(1.88E11) = 1.3E22\,kg$

Compare: $M_{earth} = 6.0E24\,kg$

so $\frac{M_{Pluto}}{M_{earth}} = \frac{1.33E22}{6.0E24} = 0.002$

So Pluto has a mass equal to about 0.002 earths!