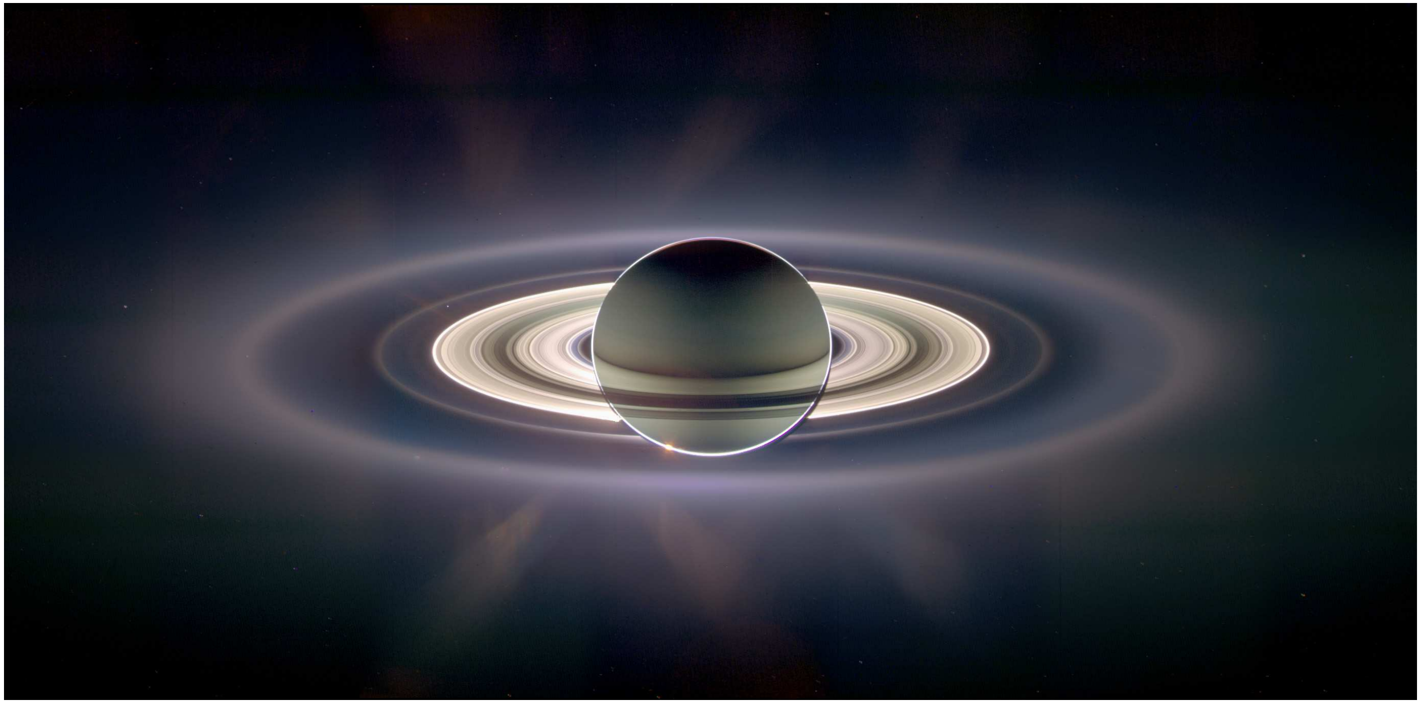
Why Does Saturn Have Rings?

Saturn was discovered by Galileo in 1610, but the geometry of its rings was not understood until the work of Christiaan Huygens in 1659. The photograph is a composite made from 165 images taken by the wide-angle camera on the Cassini spacecraft over nearly three hours on September 15, 2006. Ultraviolet, infrared, and clear-filter images were used and the colors adjusted to resemble natural color.



More information is available at here. Are there any other important objects in the image?

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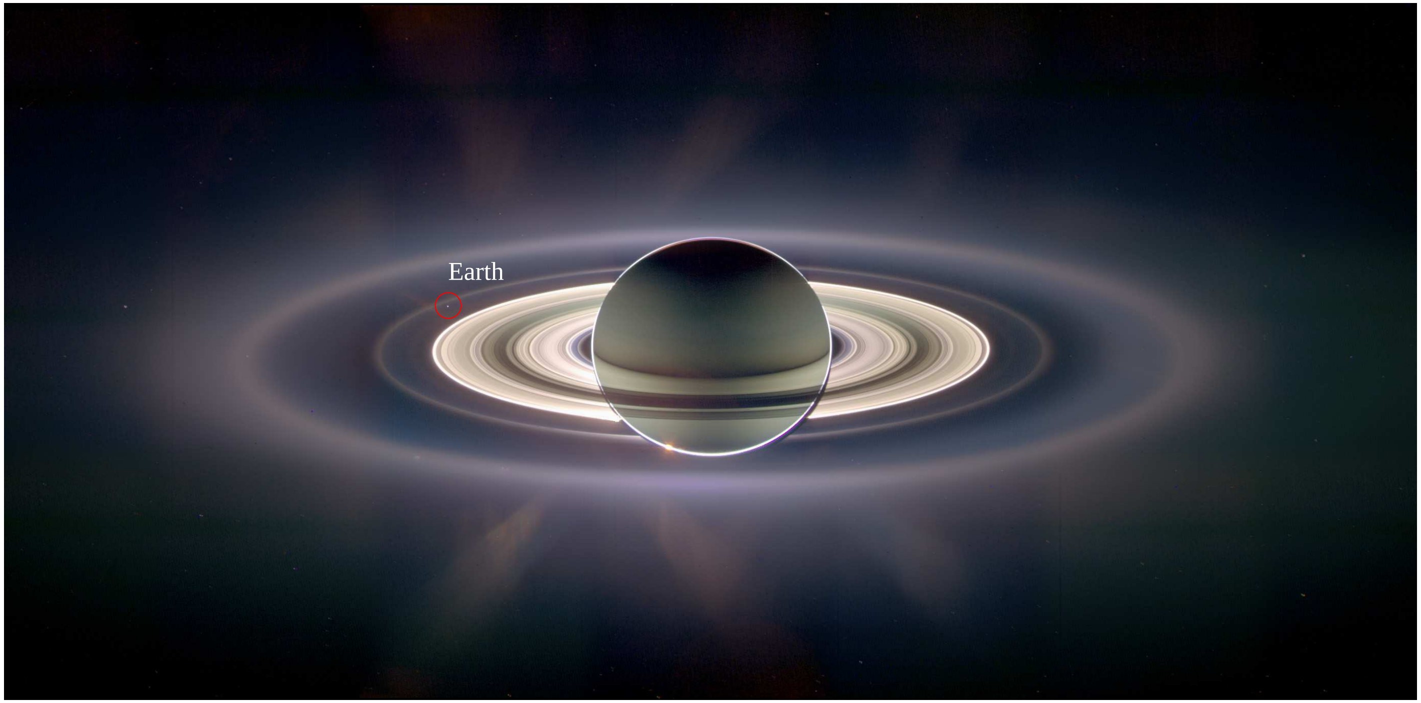
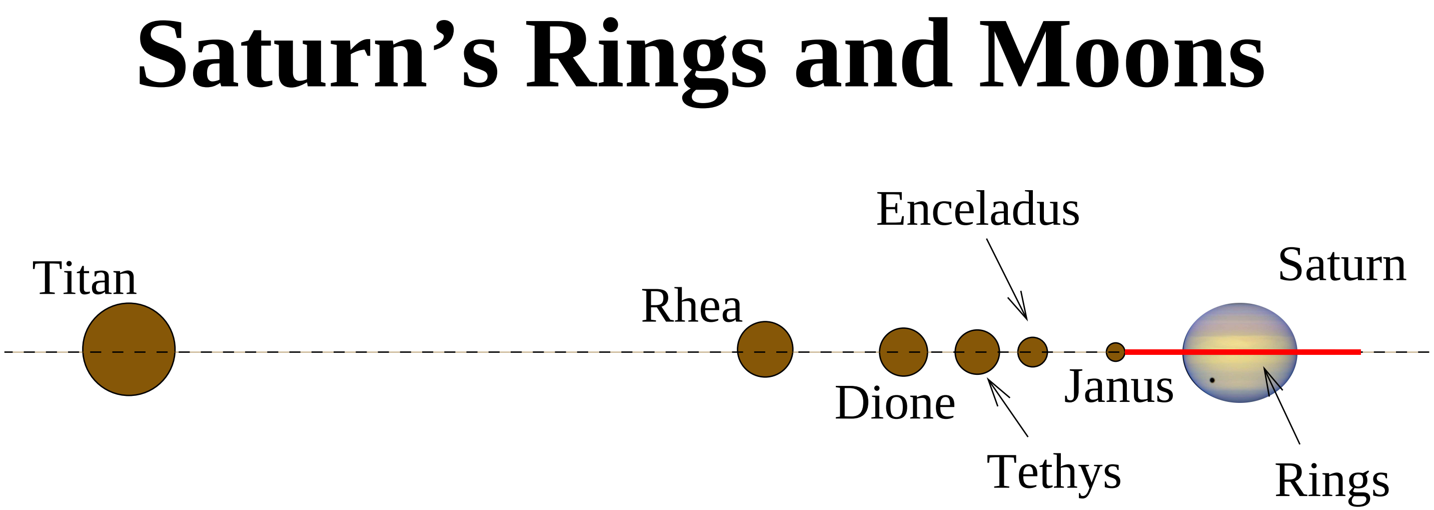


More information is available at here.

Roche’s Limit - The Data

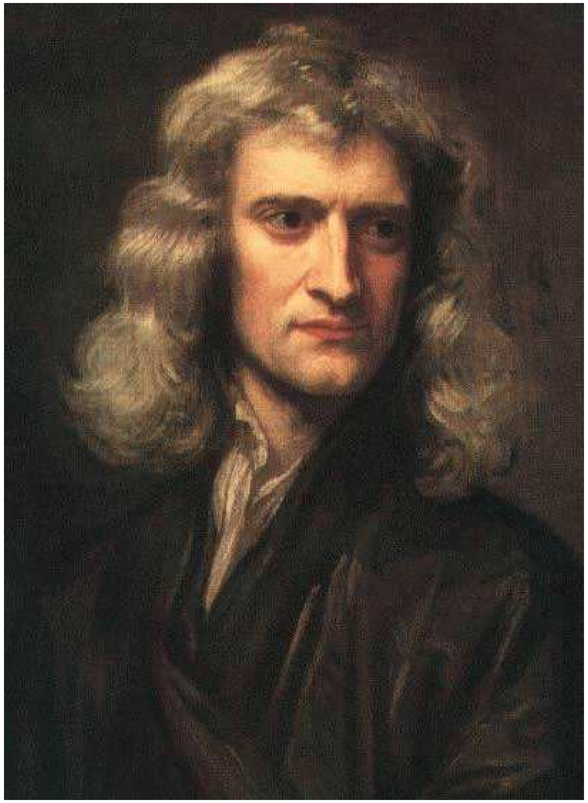
The figure shows the position of Saturn’s rings and the orbital radii of some of Saturn’s satellites. The sizes of Saturn and the satellites are not to scale, but the distances from the center of Saturn are to scale. Roche’s limit is a calculation performed in the mid-nineteenth century by a French physicist Edward Roche to explain the structure of Saturn’s rings and moons. Is Roche’s limit correct?



The shadow cast by Titan can be seen on the image of Saturn. The image of Saturn is from the Hubble Space Telescope. More on recent research about Saturn’s rings can be found here.

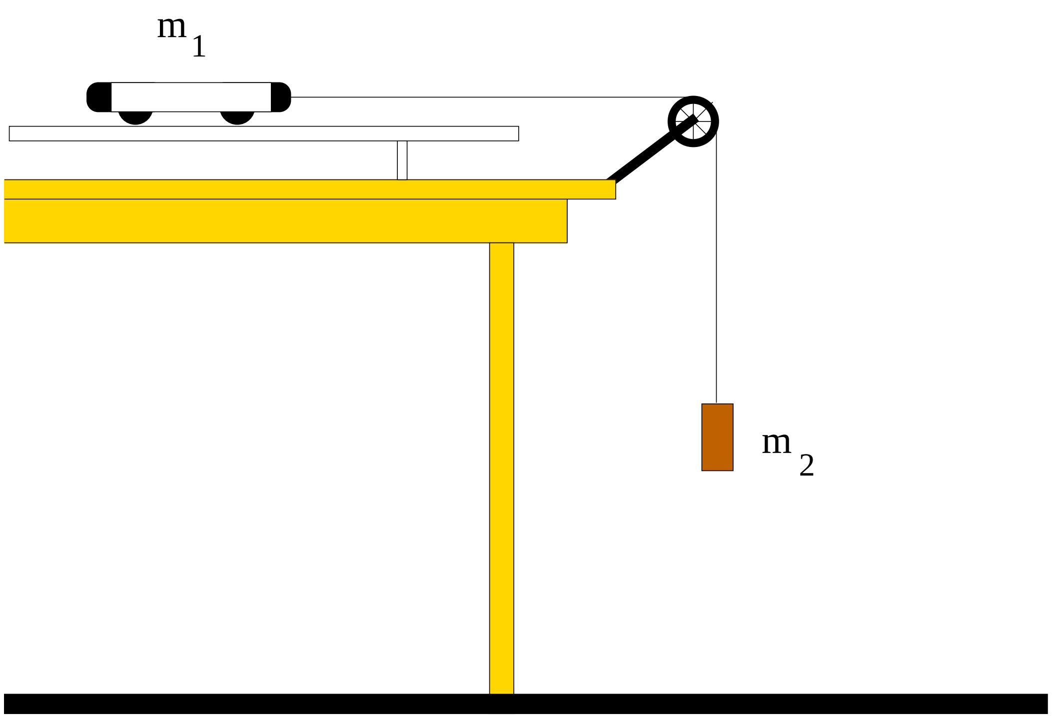
Newton's Laws

1. Consider a body with no net force acting on it. If it is at rest it will remain at rest. If it is moving with a constant velocity it will continue to move at that velocity.
2. For all the different forces acting on a body
$$\Sigma\ \vec{F}_i = m\vec{a} \qquad .$$
3. For every action there is an equal and opposite reaction.
$$\vec{F}_{AB} = -\vec{F}_{BA}$$

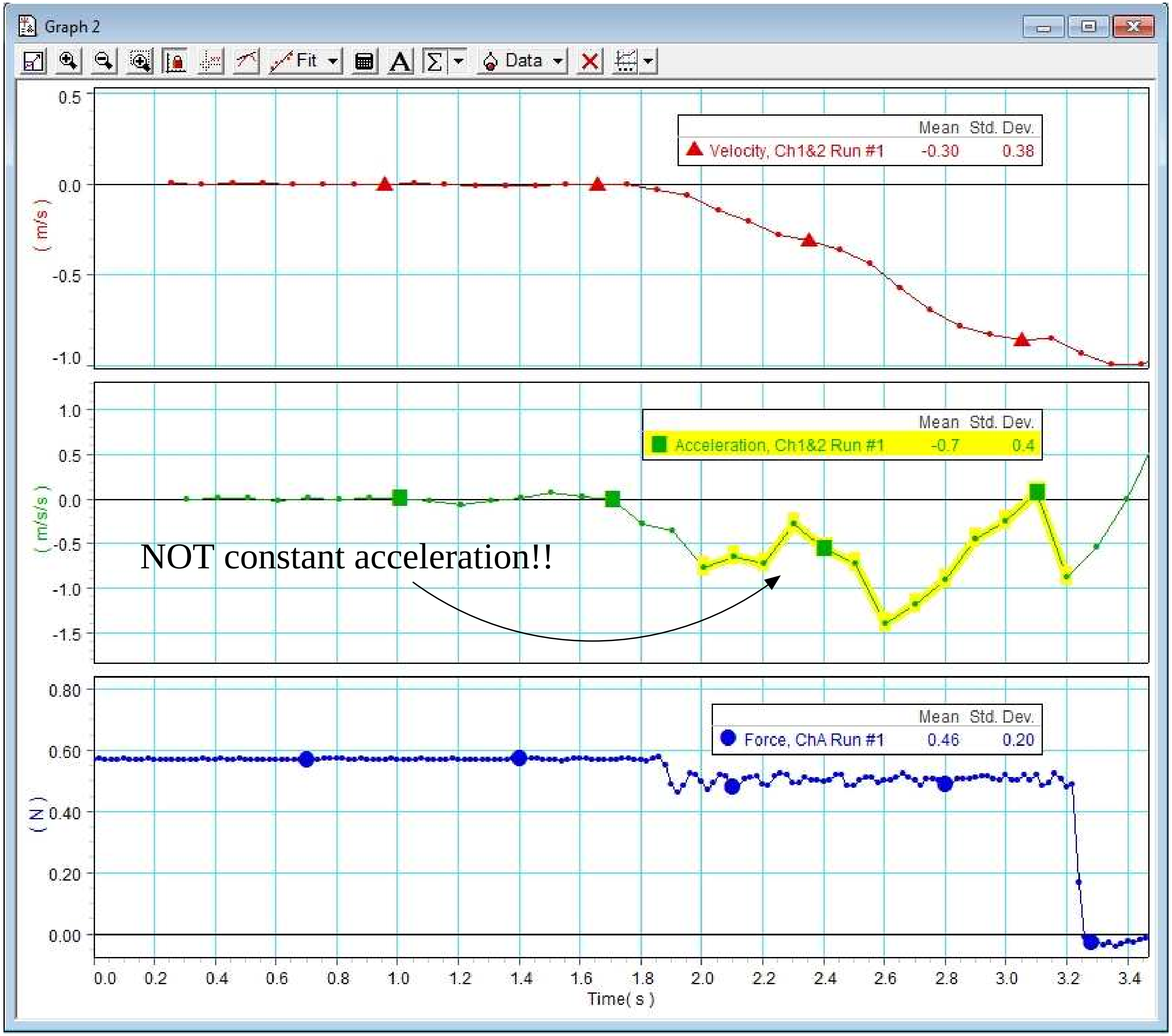


Newton's Laws - An Example

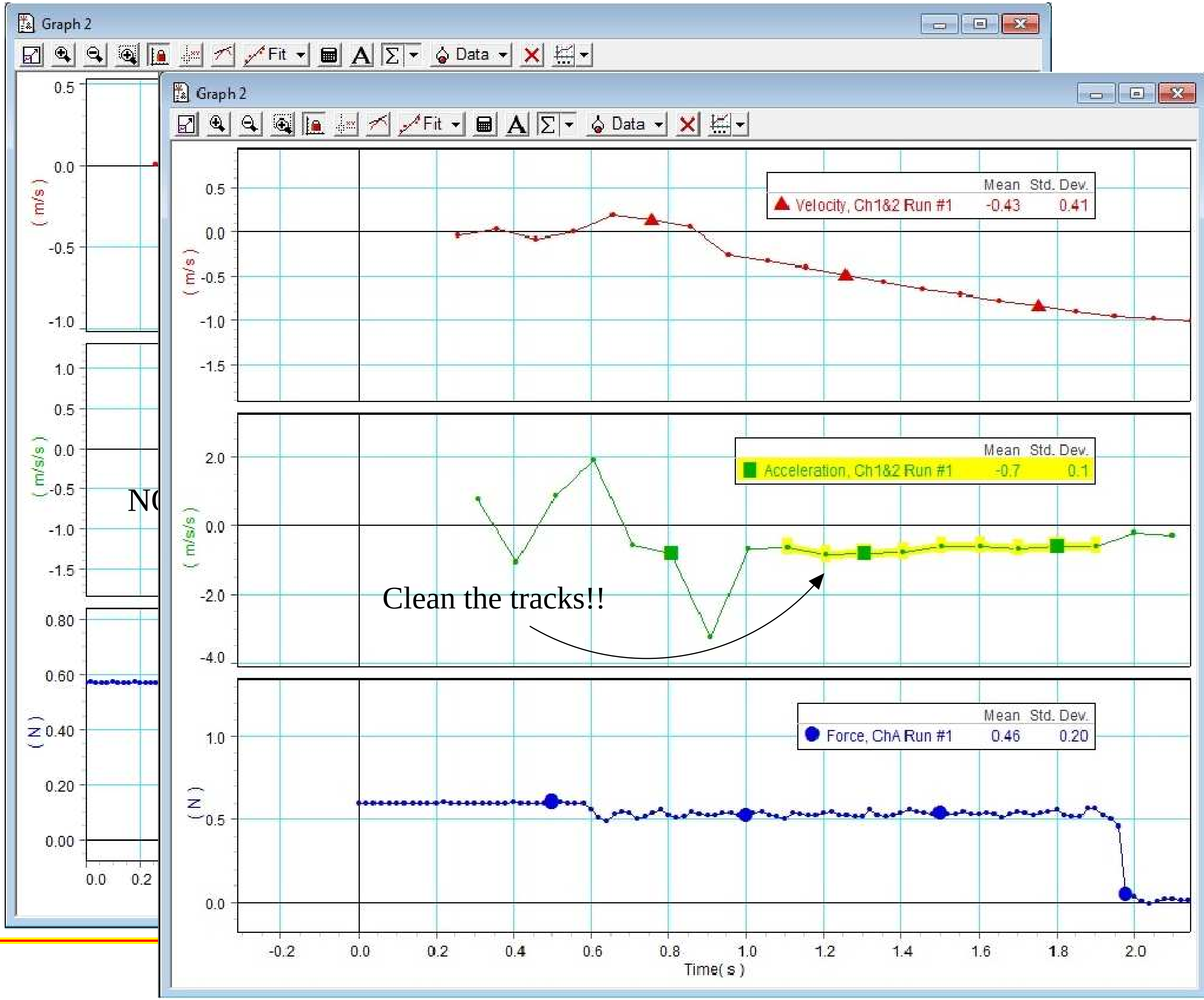
Two blocks are connected by a rope draped over a pulley as shown below. The masses are $m_1 = 1.0\ kg$ and $m_2 = 4.0\ kg$. What is the acceleration of both masses?



Force and Motion 1



Force and Motion 1



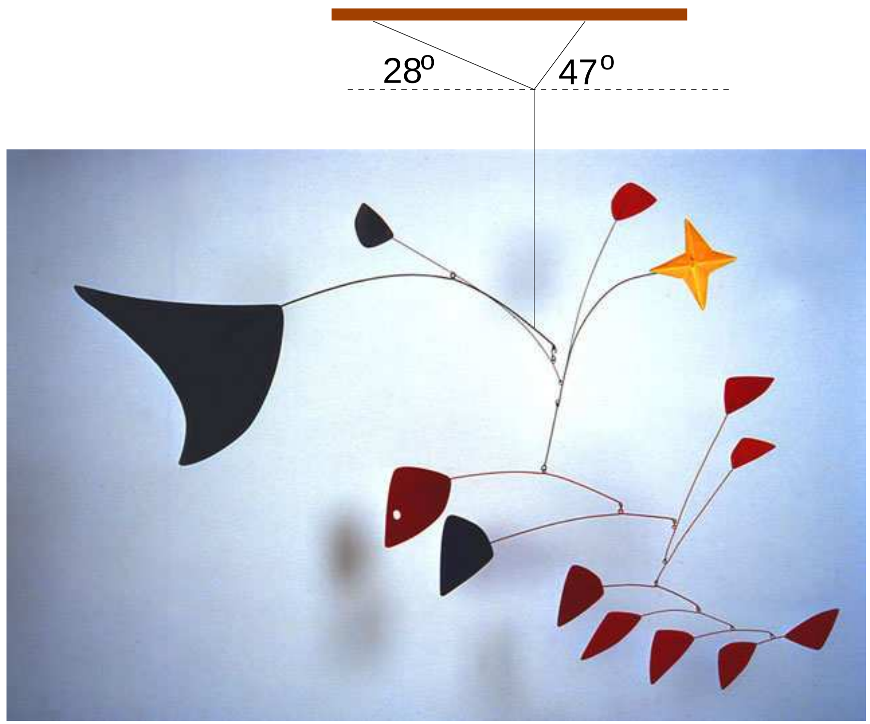
Combining Forces On A Falling Balloon

A hot-air balloon of mass M is descending vertically with a downward acceleration a as shown below. How much ballast m_b must be thrown out to give the balloon the same magnitude acceleration in the opposite direction (up)? Assume the upward force of the hot air does not change as ballast is dropped and express your answer as an equation in M, a, and any necessary constants.

Liberal Arts!!

You are an engineer who has to hang a kinetic sculpture (a mobile) by the famed artist Alexander Calder from the crossbeams of the hall of an art gallery. Consider the two cables used to hold up the mobile of mass $m = 80\ kg$ from a ceiling as shown below. They are attached at two seperate points on the ceiling as shown. What is the tension in each cable?

ALEXANDER CALDER
(American, 1898-1976)
The Star, 1960
Polychrome sheet metal and steel wire
35-3/4 x 53-3/4 x 17-5/8”



The Rotor

The Rotor is an amusement park ride in which a room shaped like a cylinder is spun rapidly forcing the occupants to lean against the wall. When a minimum rotational frequency is reached the floor of the room is suddenly dropped. Of course, the riders remain safely pinned to the walls of the spinning room. What is the minimum rotational frequency for this ride to work properly? The radius of the room is $r = 2.1\ m$ and the coefficient of friction between the walls and the backs of the riders is $\mu = 0.4$.

Coefficients of Friction

Materials	μ_s	μ_k
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Copper on steel	0.53	0.36
Rubber on concrete	1.0	0.8
Wood on wood	0.25-0.5	0.2
Glass on glass	0.94	0.4
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	-	0.04
Ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Human synovial joints	0.01	0.003

The Rotor

The Anaconda is a popular roller coaster at the King's Dominion amusement part north of Richmond. It contains a loop in it's track like the one shown below. If the radius of the loop is $R = 6.3\ m$, then what is the minimum speed at the top of the loop that is necessary to prevent someone from falling out?

Newton's Third Law

A farm worker pulls a cart with a force $\vec{F}_f$. Newton's third law states that the wagon exerts and equal and opposite force on the worker $-\vec{F}_f$. Hence, the wagon remains stationary.

Is this statement correct? Explain.

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Is this statement correct? Explain.

That Professor Goddard with his 'chair' in Clark College and the countenancing of the Smithsonian Institution does not know the relation of action to reaction, and of the need to have something better than a vacuum to react against - to say that would be absurd. Of course, he only seems to lack the knowledge ladled out daily in the high schools.

editorial in the *New York Times*
January 13, 1920

EEEEKKKKK!!!!!

In January, 1942 a Soviet Ilyushin 4 flown by Lieutenant I.M.Chisov was badly damaged by German gunfire. At an altitude of 21,980 feet Lieutenant Chisov fell from the plane. Unfortunately, he did not have a parachute on when he fell. He landed on the slopes of a snow-covered ravine and slid to the bottom. He suffered a fractured pelvis and severe spinal damage, but lived. By 1974 he had become Lieutenant Colonel Chisov. How fast was Lieutenant Chisov moving when he hit the ravine? Use the information listed below. Estimate the minimum time for his fall.

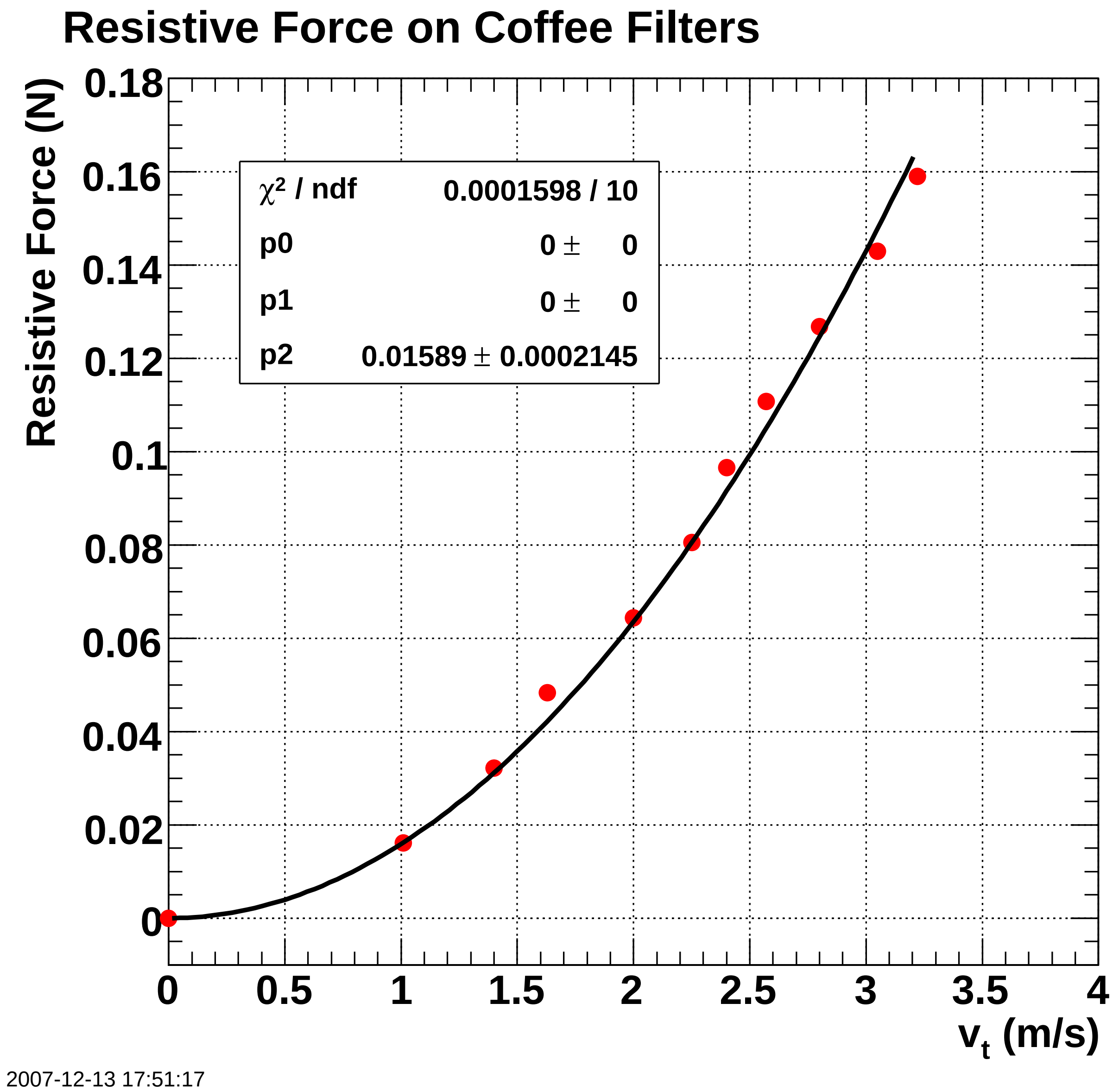
$m = 75\ kg$

$A = 0.70\ m^2$

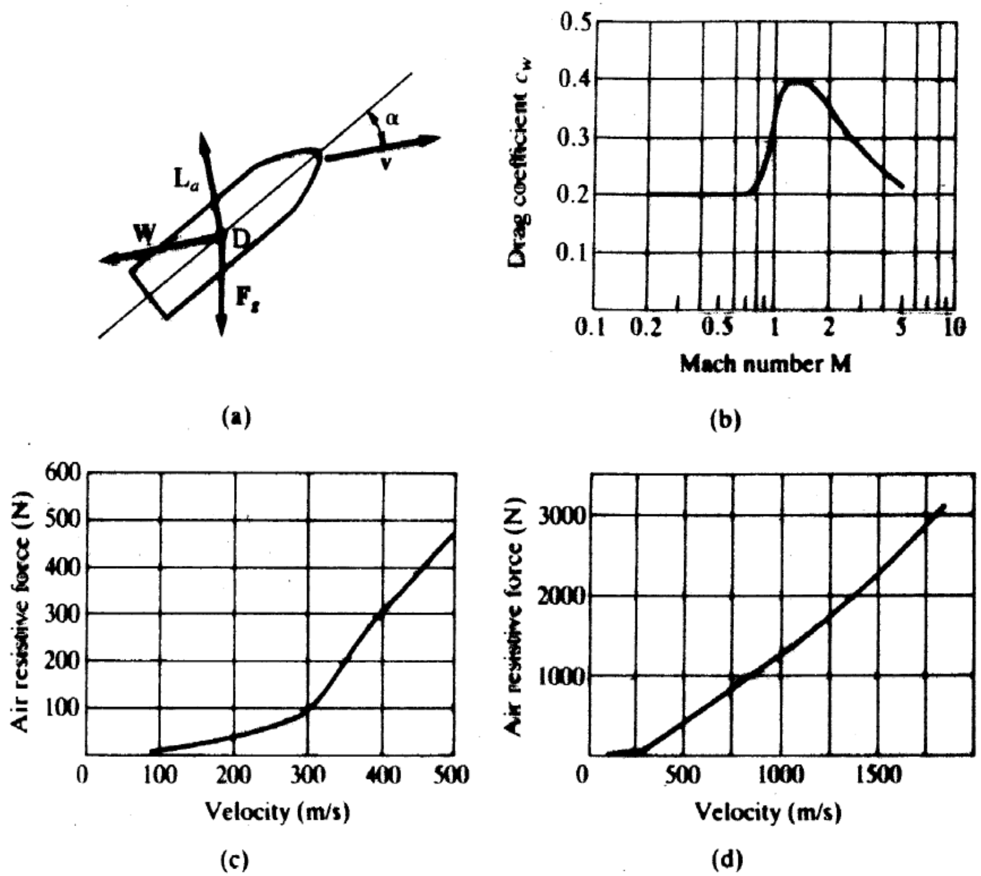
$D = 0.5$

$\rho = 1.2\ kg/m^3$

The Drag Force - 1



The Drag Force - 2



Aerodynamic forces acting on an artillery shell. The force $\vec{W}$ is the drag or air resistive force, $\vec{L}_a$ is the lift, $\vec{F}_g$ is gravity, and the point D is the center of pressure. Note the change in the air resistive force at the speed of sound.

The Drag Force - 3

$$F_D = \frac{1}{2} D \rho A v^2$$

D - drag coefficient.

A - cross sectional area of falling object.

ρ - density of resistive medium.

v - speed.

Table of terminal velocities v_T for different objects.

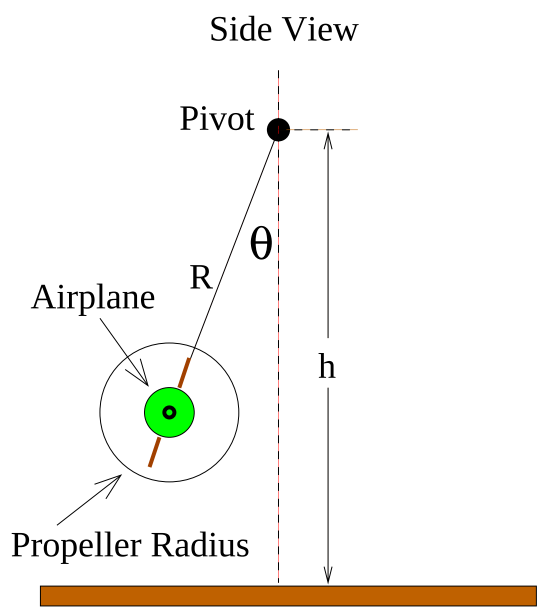
Object	$v_T\ (m/s)$
Skydiver	59
16-lb shot	145
Baseball	42
Raindrop (1.5 mm radius)	7
Ping-Pong ball	9
Tennis ball	31
Parachutist	5

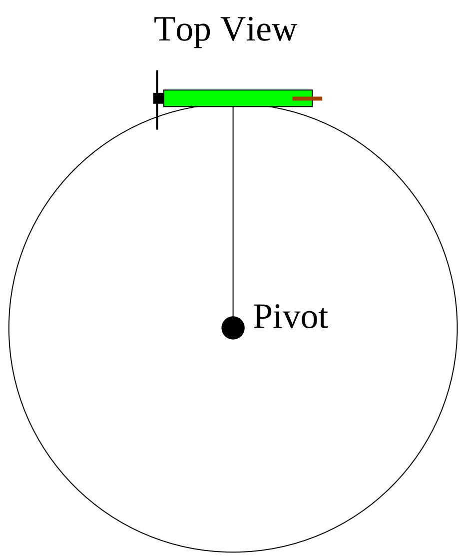
Airplanes on a String

Consider the model airplane hanging from a string and flying in a circle as shown in the figure. The velocity of the plane is $v = 1.2\ m/s$. What is the tension in the string?

Some useful information

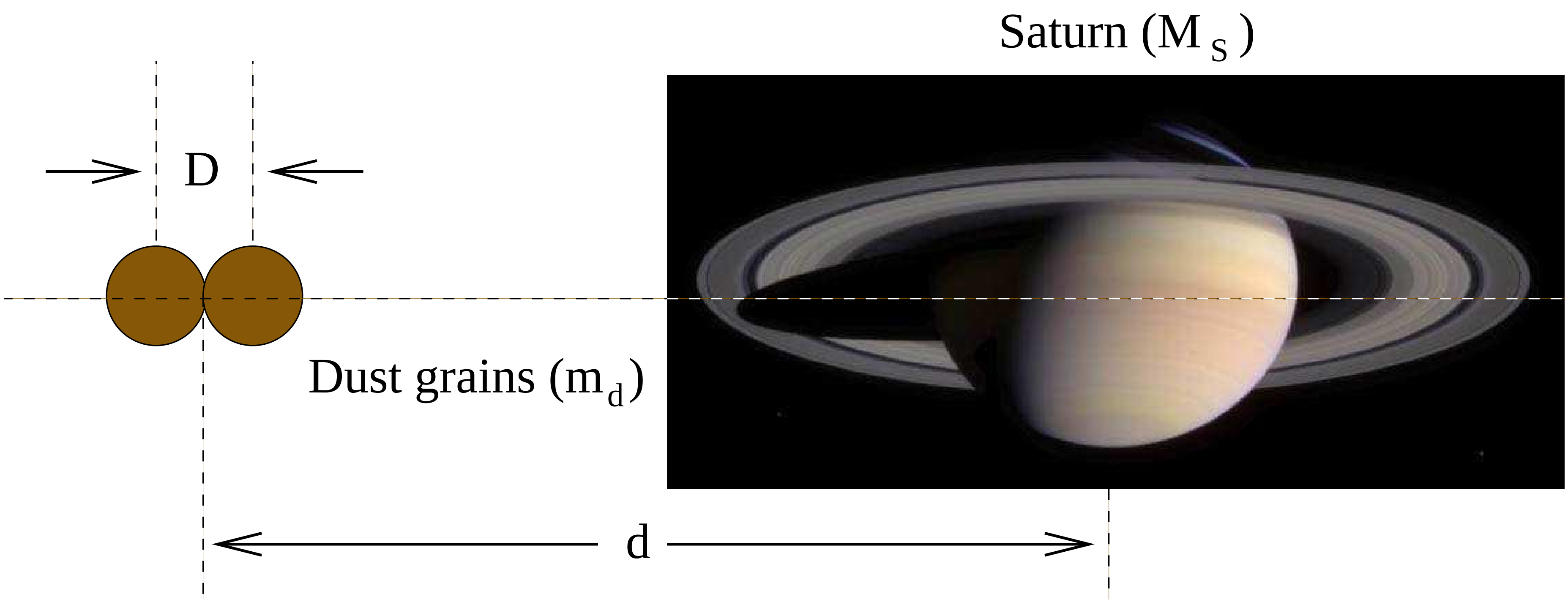
Mass (m)	$0.2\ kg$
Vertical Angle(θ)	25°
String length(R)	$0.7\ m$
Pivot height(h)	$1.3\ m$





Roche's Limit - A Model of the Rings

Two, identical, spherical dust grains of mass m_d are orbiting Saturn just touching one another and aligned along a radius from the planet's center (see figure). If each dust grain moves in a circular orbit, will they maintain the alignment shown in the figure as they orbit Saturn? Ignore any attraction between the dust grains.

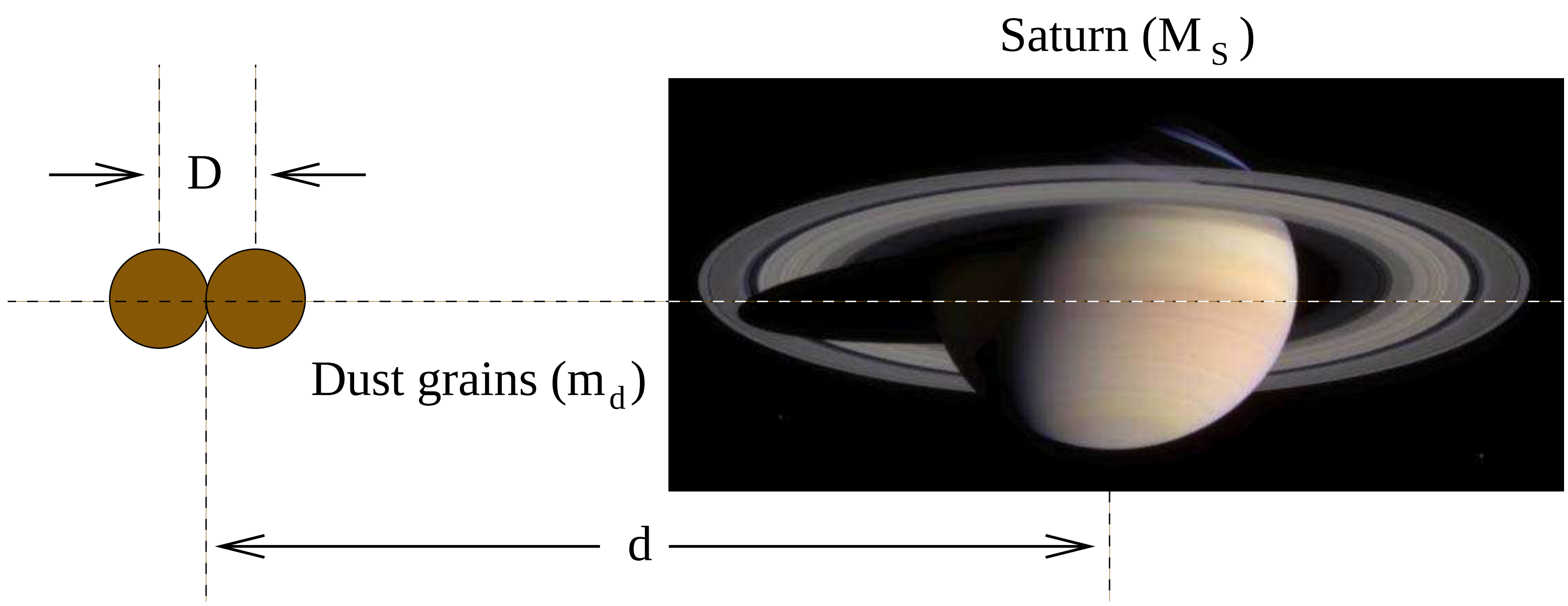


Roche's Limit - Tidal Force

Two, identical, spherical dust grains of mass m_d are orbiting Saturn just touching one another and aligned along a radius from the planet's center (see figure).

1. What happens to the separation of the grains if they are released from rest?
2. What is this difference between the forces on each dust grain in terms of the constants shown in the figure and any other necessary ones?
3. Show that if $d \gg D$ then

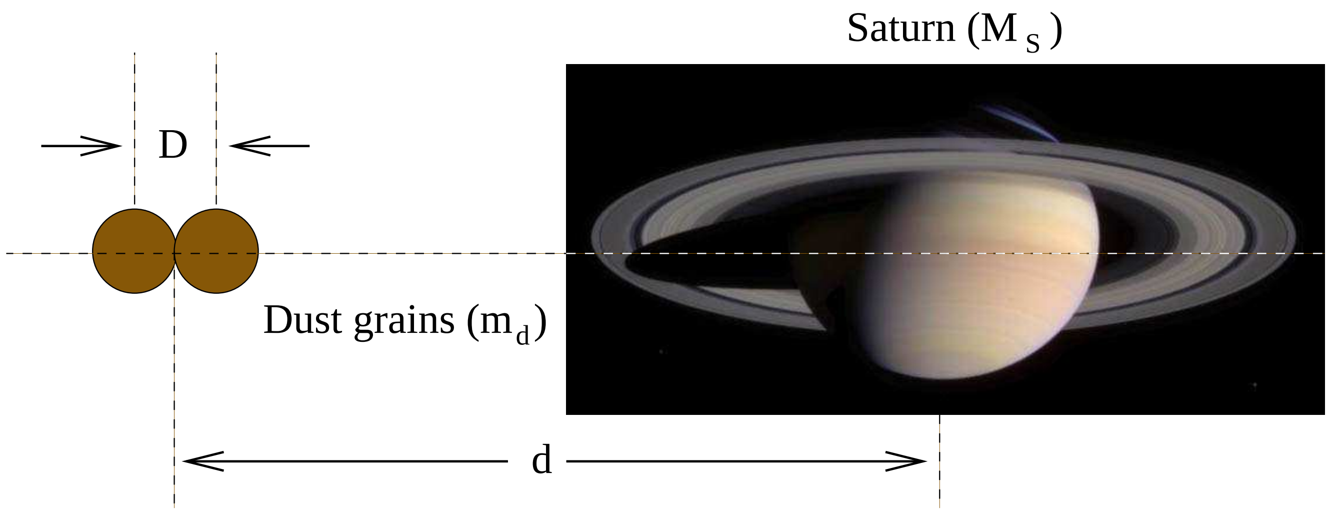
$$\Delta F = F_{tidal} = \frac{2GM_s m_d D}{d^3} \qquad .$$



Roche's Limit for Saturn

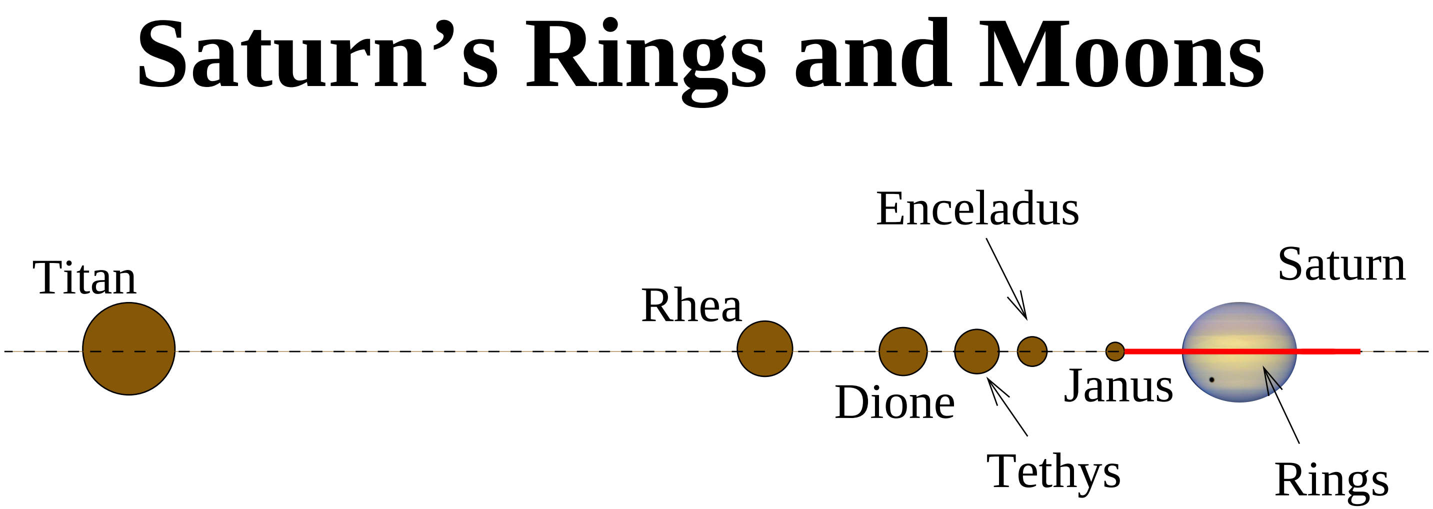
Suppose our dust grains are now held together by their mutual, gravitational attraction.

1. For what range of d will this gravitational attraction overcome the tidal force that separates the dust grains? Get your answer in terms of M_S, m_d, and D. This is Roche's limit.
2. Rewrite the answer above using the definition of the density of the dust grains $\rho = \frac{m_d}{V_d}$ where V_d is the volume of our dust sphere. How does Roche's limit depend on the grain size D?
3. What is Roche's limit for Saturn if $M_S = 5.68 \times 10^{26}\ kg$ and $\rho = 2 \times 10^3\ kg/m^3$? How does this result compare with observation?



Roche's Limit - Does It Work?

The figure shows the position of Saturn's rings and the orbital radii of some of Saturn's satellites. The sizes of Saturn and the satellites are not to scale, but the distances from the center of Saturn are to scale. Is Roche's limit correct?



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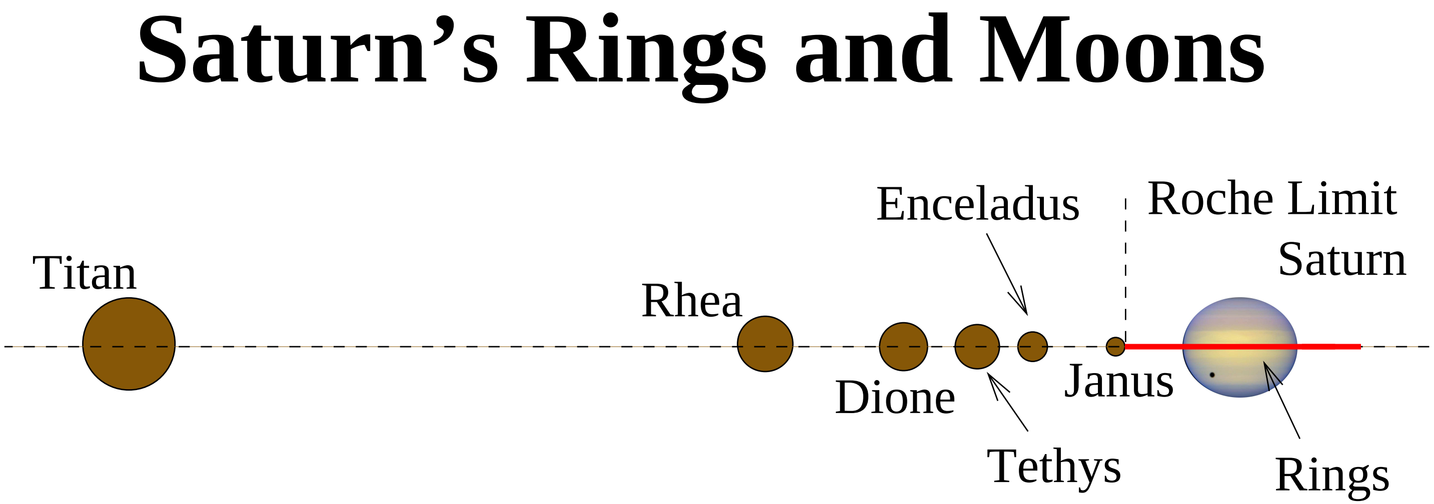

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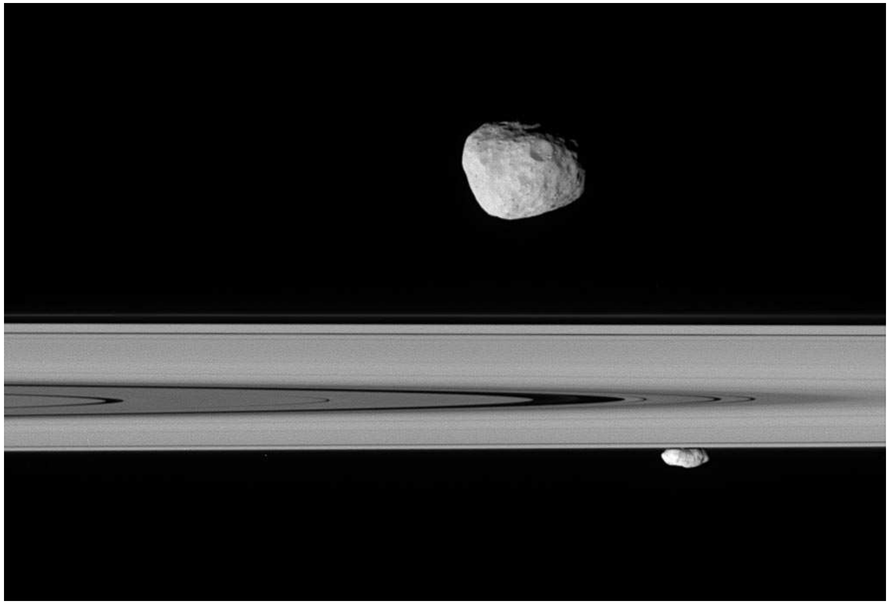
Roche’s Limit - More Data

Planet	Roche Limit (m)	Distance to Nearest Satellite (m)	Roche Period (s)	Orbital Period of Nearest Satellite (s)
Earth	2.3×10^7	38×10^7	8.1×10^3	2500×10^3
Mars	1.1×10^7	0.94×10^7	3.9×10^3	28×10^3
Jupiter	1.5×10^8	1.3×10^8	5.6×10^4	2.5×10^4
Saturn	1.1×10^8	1.4×10^8	3.7×10^4	5.0×10^4
Uranus	5.5×10^7	5.0×10^7	1.9×10^4	2.9×10^4
Neptune	5.8×10^7	3.6×10^7	1.9×10^4	2.5×10^4
Pluto	3.0×10^6	48×10^6	1.1×10^3	550×10^3

Hints for the Centripetal Force lab

1. Align the camera, string, and the plane in the center of the camera's field of view.
2. Use the distance from the hole in the post the string passes through, along the string, to the center of the airplane.
3. The distance in Number 2 should not exceed 45 cm.
4. Let the airplane run for about one minute before taking data to let any oscillations die out.
5. Weigh the plane on the scale.
6. Measure the diameter along the horizontal and vertical axes of your Excel plot. If they are significantly different, consult your instructor.

Some cool pictures



From just beneath the ringplane, Cassini stares at Janus (181 kilometers across) on the near side of the rings and Prometheus (102 kilometers across) on the far side.

A cryovolcanic eruption on Enceladus, a moon of Saturn, can be seen in this Cassini image along with the diffuse ring produced by these eruptions.