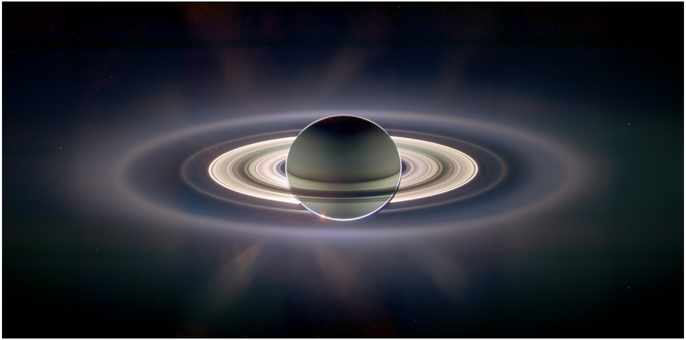
Why Does Saturn Have Rings? 1

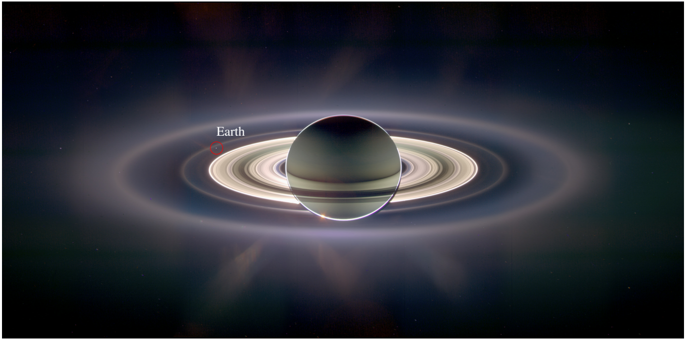
Saturn was discovered by Galileo in 1610, but its rings were not understood until the work of Christiaan Huygens in 1659. The photograph is a composite of 165 images taken by the Cassini spacecraft over nearly three hours on September 15, 2006. UV, IR, and clear-filter images were used and the colors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



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

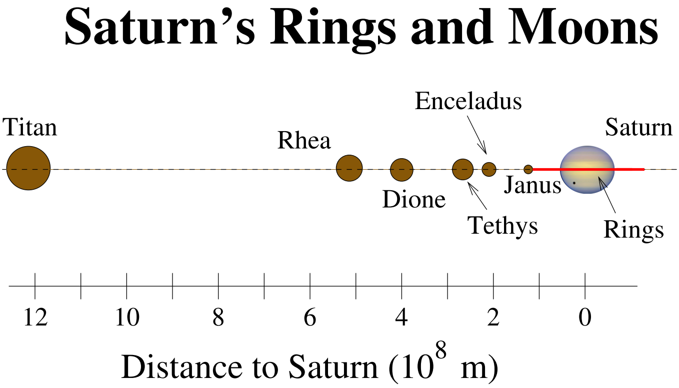
Why Does Saturn Have Rings? 2

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



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

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? More here.

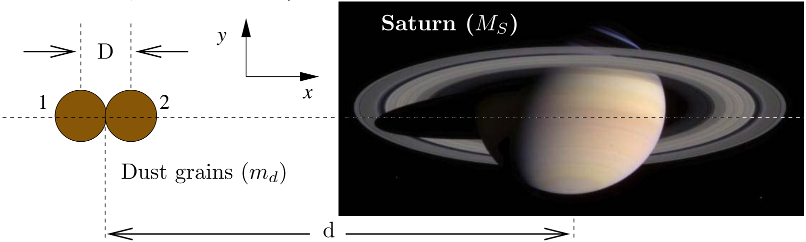


Titan's shadow can be seen on the image of Saturn (from the Hubble Space Telescope).

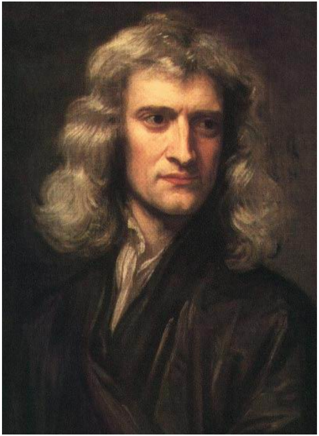
Roche's Limit 4

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

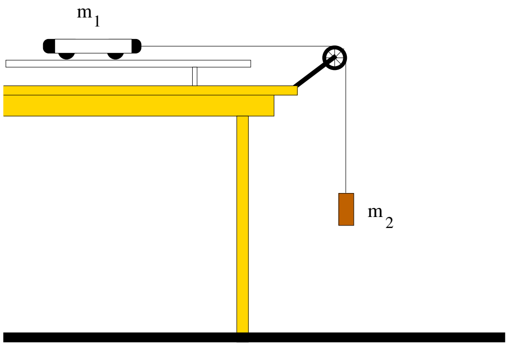
1. What is the time difference between their periods T after one orbit if $d = 10^8\ m$ and $D = 10^{-3}\ m$?
2. What is the difference $\Delta\vec{F} = \vec{F}_2 - \vec{F}_1$ between the forces due to the gravity of Saturn on each dust grain in terms of the constants in the figure and any others?
3. Show that if $d \gg D$ then $|\Delta\vec{F}| = 2GM_s m_d D/d^3$.
4. Compare $\Delta\vec{F}$ with the gravitational attraction between the two dust grains F_{21}. When will the grains stick together? For what values of d?
5. Since we don't know the size of the grains (D) recast the problem in terms of the the density $\rho = 2 \times 10^3\ kg/m^3$ of the dust. What is Roche's limit?



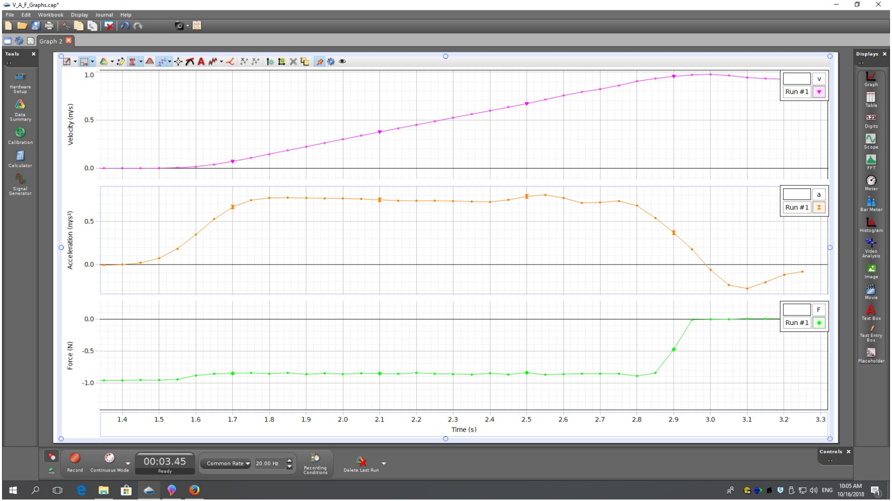
1. Consider a body with no net force acting on it. If it is at rest it will remain at rest. If it is moving with a constant velocity it will continue to move at that velocity.
2. For all the different forces acting on a body
$$\Sigma \vec{F}_i = m\vec{a} \qquad .$$
3. For every action there is an equal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

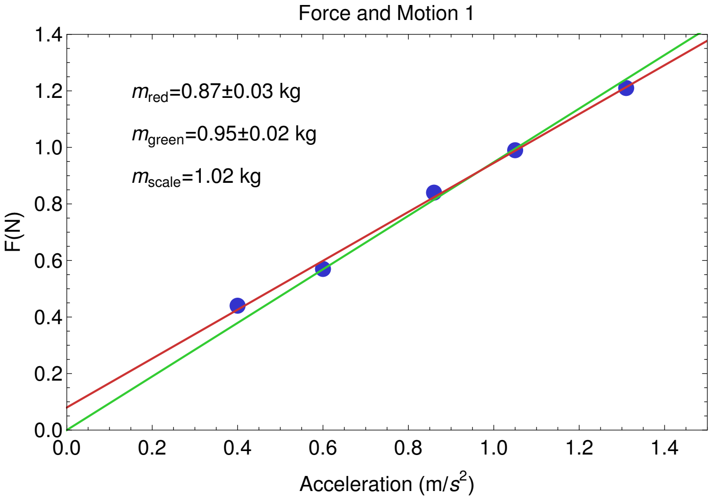


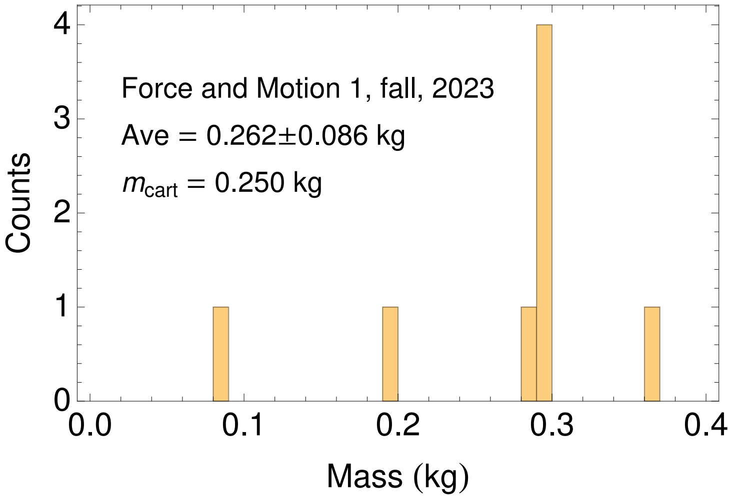
Two blocks are connected by a rope draped over a pulley as shown below. The masses are $m_1 = 1.0\ kg$ and $m_2 = 4.0\ kg$. What is the acceleration of both masses?



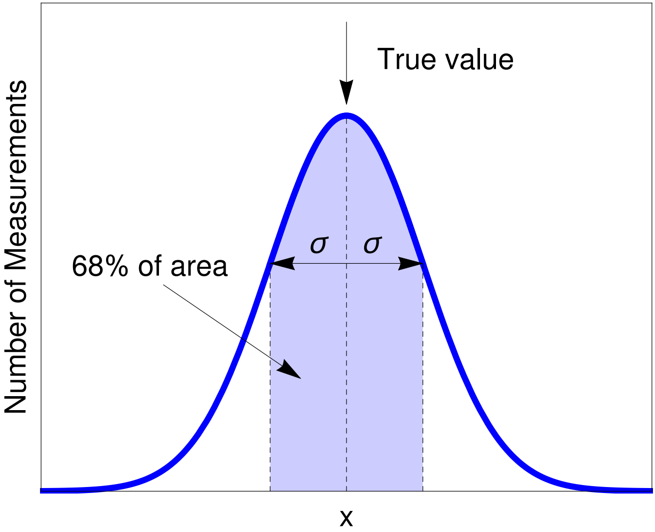
Force and Motion 1 7




Force and Motion 1
m_{red}=0.87±0.03 kg
m_{green}=0.95±0.02 kg
m_{scale}=1.02 kg
F(N)
Acceleration (m/s^2)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4


Force and Motion 1, fall, 2023
Ave = 0.262±0.086 kg
m_{cart} = 0.250 kg
Counts
Mass (kg)
0
1
2
3
4
0.0
0.1
0.2
0.3
0.4

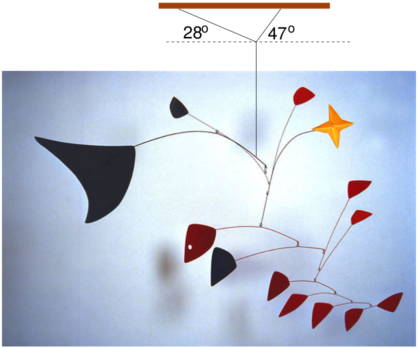
Average and Standard Deviation



Liberal Arts!! 11

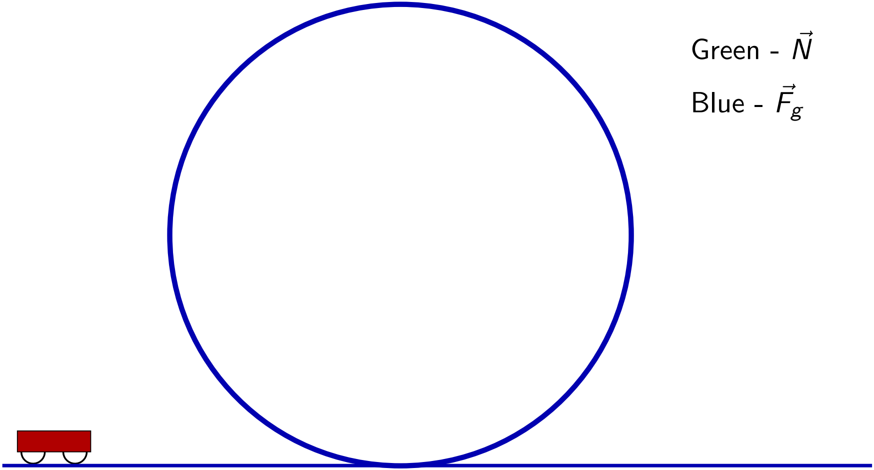
You are an engineer who has to hang a kinetic sculpture (a mobile) by the famed artist Alexander Calder from the crossbeams of the hall of an art gallery. Consider the two cables used to hold up the mobile of mass $m = 210\ kg$ from a ceiling as shown below. They are attached at two seperate points on the ceiling as shown where $\theta_1 = 28^\circ$ and $\theta_2 = 47^\circ$ to the horizontal. 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"



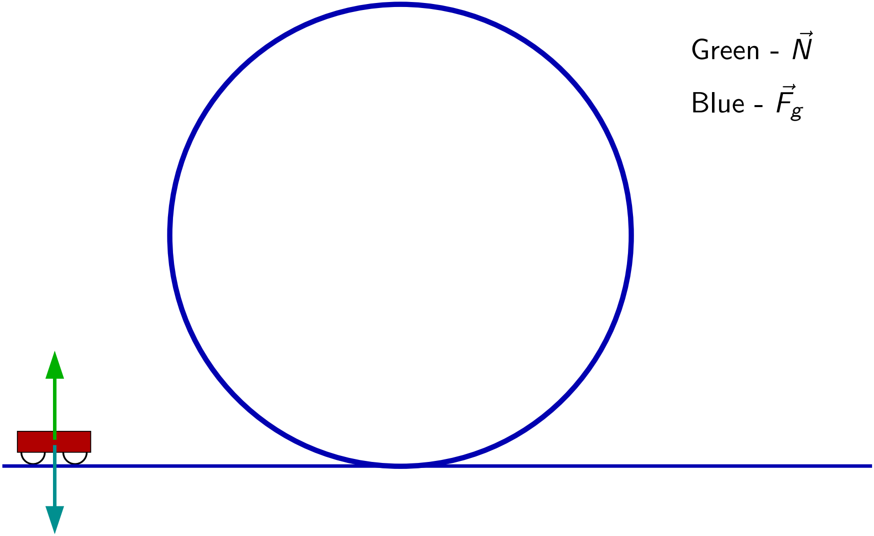
The Anaconda

The Anaconda is a popular roller coaster roller coaster at the King's Dominion amusement part north of Richmond. It contains the loop in it's track 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?



Green - $\vec{N}$

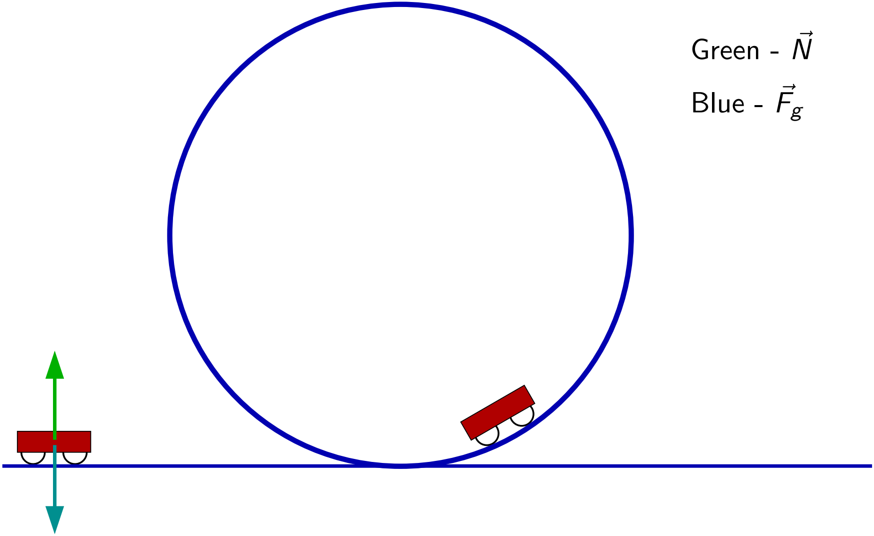
Blue - $\vec{F}_g$



Green - $\vec{N}$

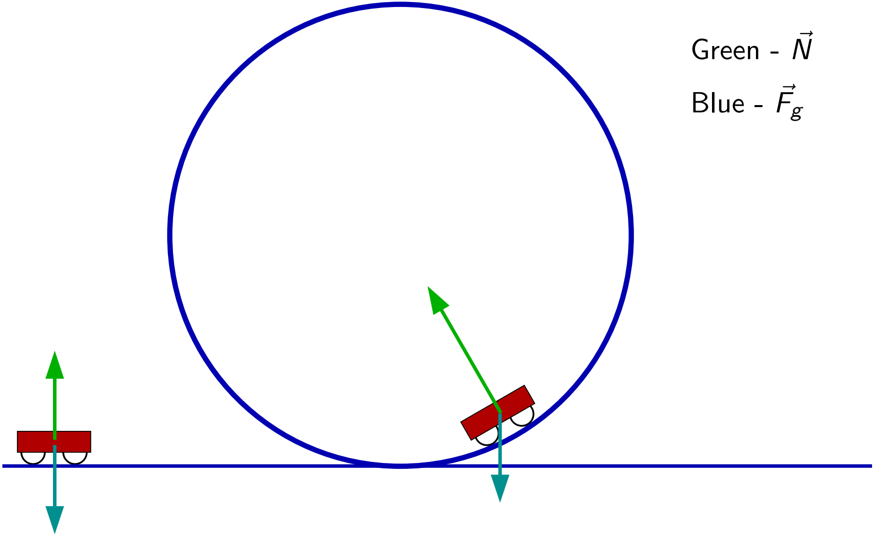
Blue - $\vec{F}_g$

The Anaconda 15



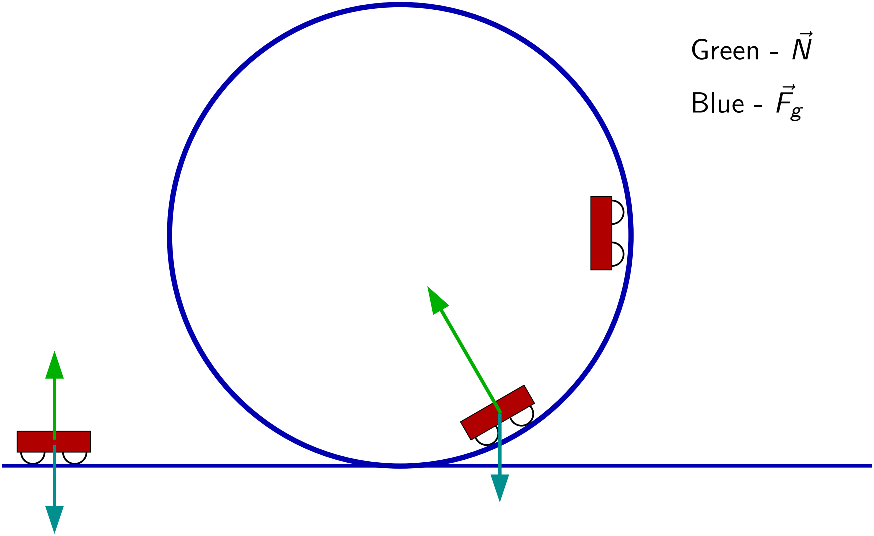
Green - $\vec{N}$

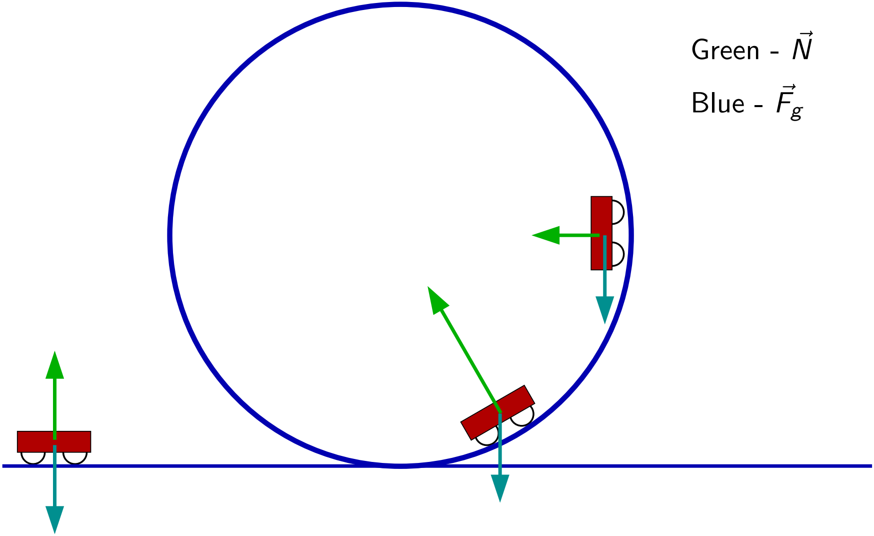
Blue - $\vec{F}_g$



Green - $\vec{N}$

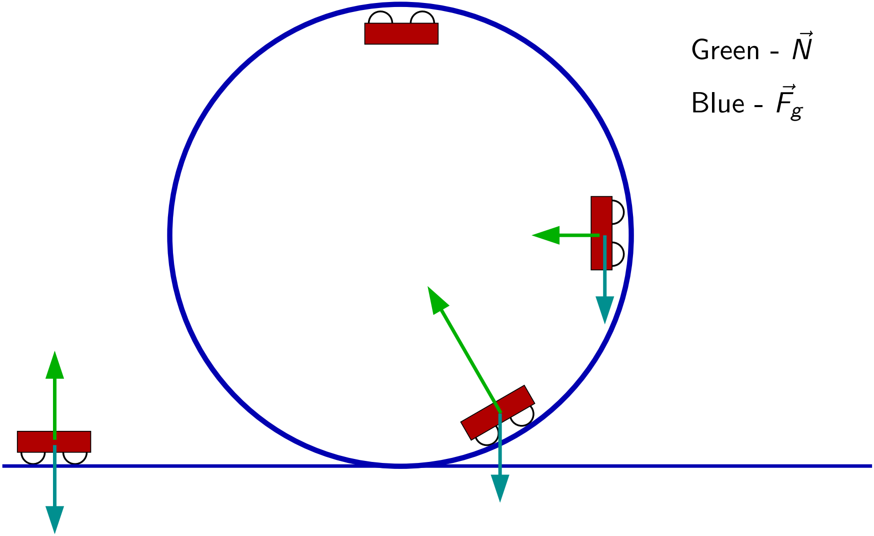
Blue - $\vec{F}_g$


Green - $\vec{N}$
Blue - $\vec{F}_g$



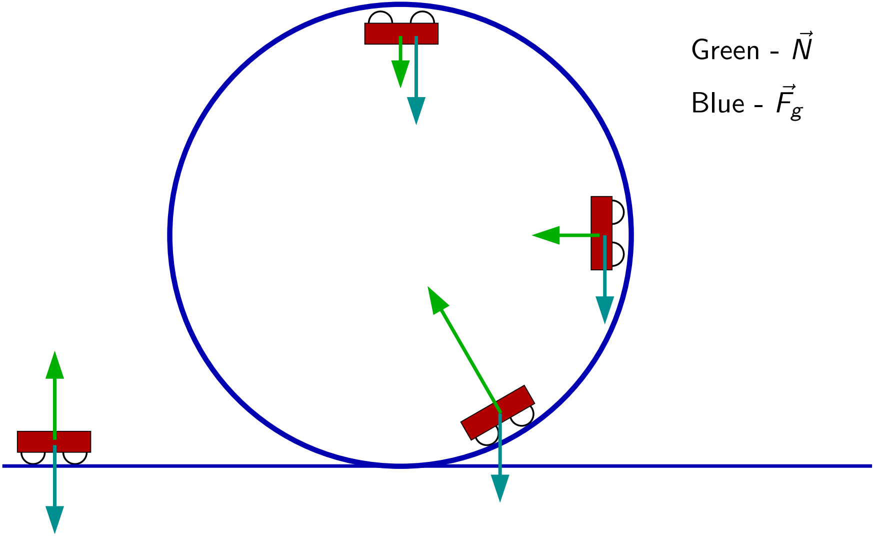
Green - $\vec{N}$

Blue - $\vec{F}_g$



Green - $\vec{N}$

Blue - $\vec{F}_g$



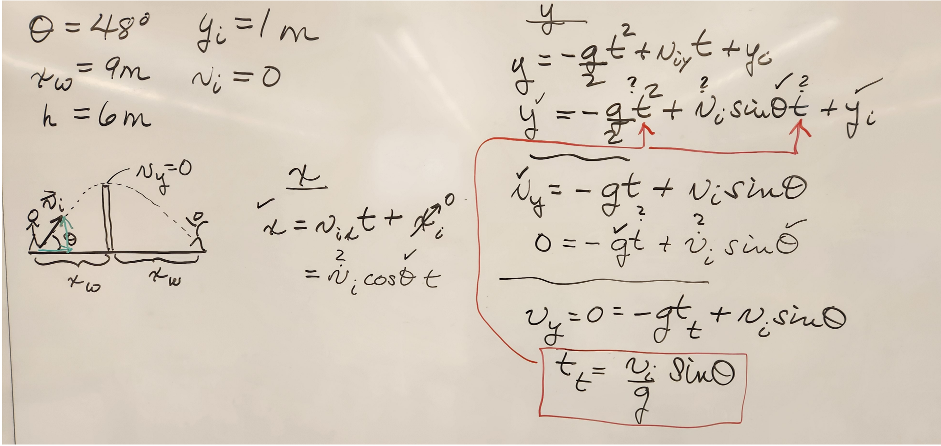
Green - $\vec{N}$

Blue - $\vec{F}_g$

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 22

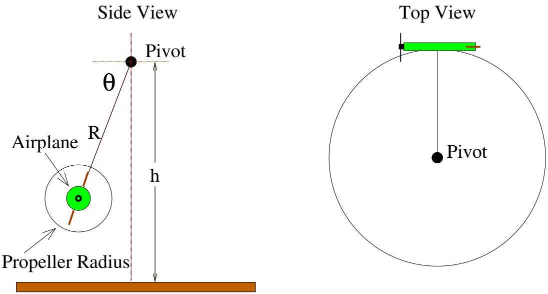
Materials	μ_s	μ_k
Steel on steel	0.74	0.57
Aluminum on steel	0.61	0.47
Copper on steel	0.53	0.36
Rubber on concrete	1.0	0.8
Wood on wood	0.25-0.5	0.2
Glass on glass	0.94	0.4
Waxed wood on wet snow	0.14	0.1
Waxed wood on dry snow	-	0.04
Ice on ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Human synovial joints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

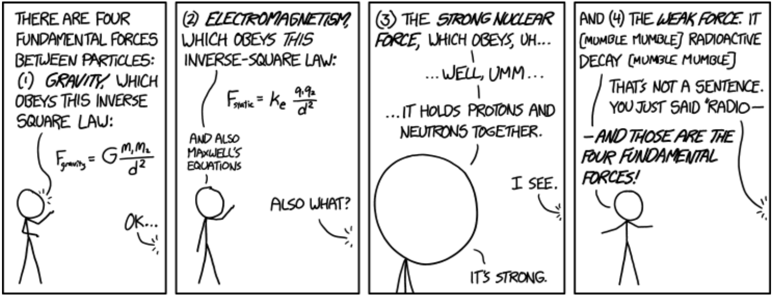

θ = 48°
y_i = 1 m
x_w = 9m
v_i = 0
h = 6m
v_y = 0
v_i
θ
x_w
x_w
x
x = v_ix t + x_i
= v_i cosθ t
y
y = -g/2 t^2 + v_iy t + y_i
y = -g/2 t^2 + v_i sinθ t + y_i
v_y = -gt + v_i sinθ
0 = -gt + v_i sinθ
v_y = 0 = -g t_t + v_i sinθ
t_t = v_i sinθ / g

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
Horizontal Angle(θ)	65°
String length(R)	0.7 m
Pivot height(h)	1.3 m





by xkcd

Force	Relative Strength	Range of Force	Mediating Field Particle	Mass of Field Particle $(\mathrm{GeV/c^2})$
Nuclear	1	Short, 1 fm	Gluon	0
Electromagnetic	10^{-2}	∞	Photon	0
Weak	10^{-5}	Short, 10^{-5} fm	$W^{\pm}, Z^0$	80.4, 80.4, 91.2
Gravitational	10^{-41}	∞	Graviton	0

Roche's Limit

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

1. What is the time difference between their periods T after one orbit if $d = 10^8\ m$ and $D = 10^{-3}\ m$?
2. What is the difference $\Delta\vec{F} = \vec{F}_2 - \vec{F}_1$ between the forces due to Saturn's gravity on each dust grain in terms of constants shown in the figure and any others?
3. Show that if $d \gg D$ then $|\Delta\vec{F}| = 2GM_s m_d D/d^3$.
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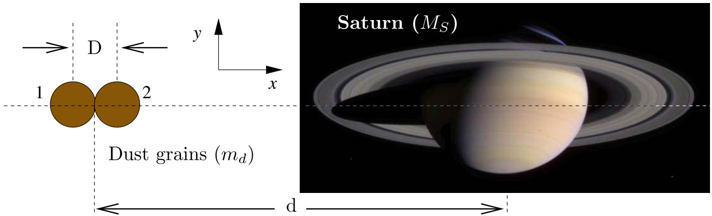

Roche's Limit

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

1. What is the [...] it if $d = 10^8$ m and $D = 1$[...]

How do we test this?

2. What is the difference $\Delta F = F_2 - F_1$ between the forces due to Saturn's gravity on each dust grain in terms of constants shown in the figure and any others?
3. Show that if $d \gg D$ then $|\Delta \vec{F}| = 2GM_s m_d D/d^3$.
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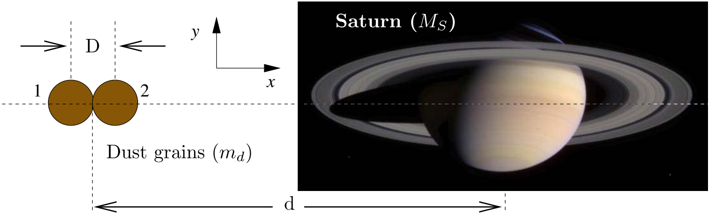
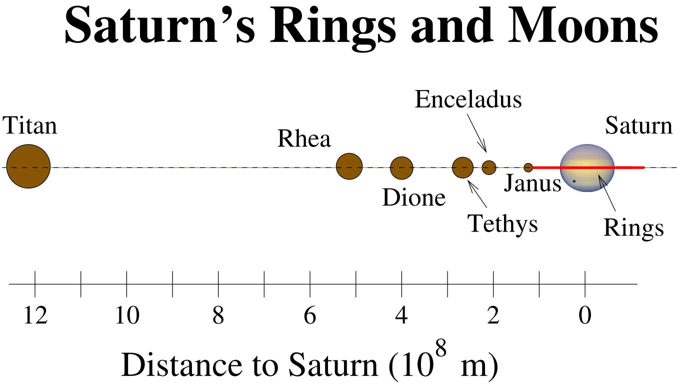


The figure shows the position of Saturn's rings and the orbital radii of some of Saturn's satellites. The sizes of Saturn and the satellites are not to scale, but the distances from the center of Saturn are to scale. Is Roche's limit correct?



Titan's shadow can be seen on the image of Saturn (from the Hubble Space Telescope).

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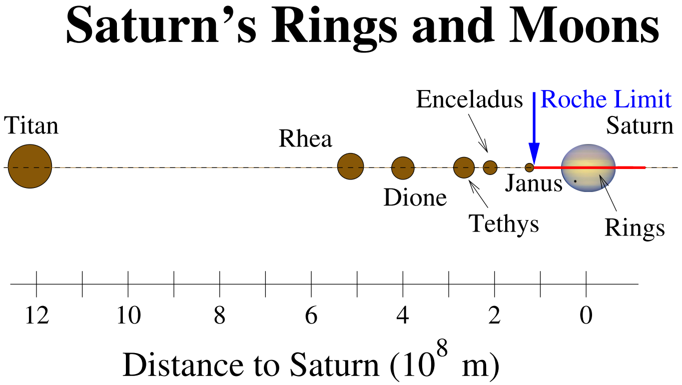
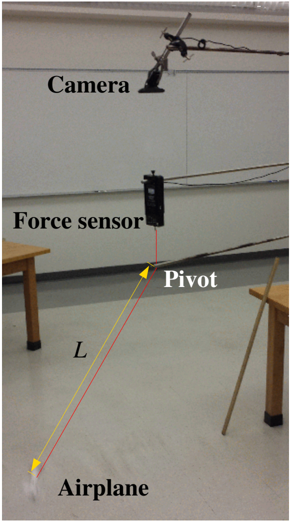


Titan's shadow can be seen on the image of Saturn (from the Hubble Space Telescope).

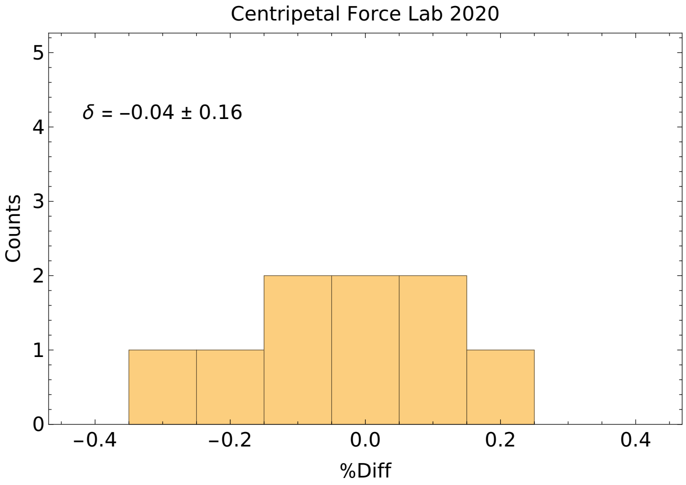
Roche's Limit - More Data

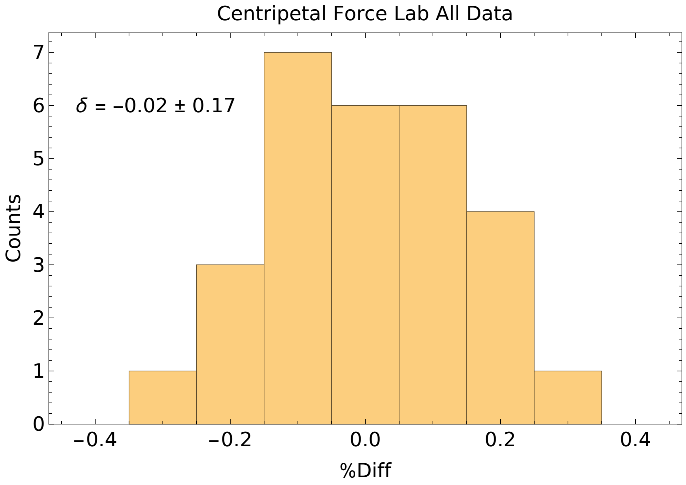
Planet	Roche Limit (m)	Distance to Nearest Satellite (m)
Earth	2.3×10^7	38×10^7
Mars	1.1×10^7	0.94×10^7
Jupiter	1.5×10^8	1.3×10^8
Saturn	1.1×10^8	1.4×10^8
Uranus	5.5×10^7	5.0×10^7
Neptune	5.8×10^7	3.6×10^7
Pluto	3.0×10^6	48×10^6

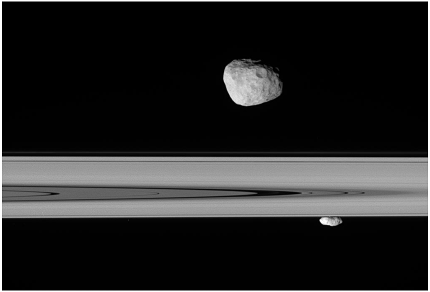
1. Activities 1-4 have already been done in Lab 8. Copy them over.
2. Align the camera, string, and the plane in the center of the field of view. Make sure the camera is pointing straight down.
3. Use the length of the plane to calibrate.
4. Use the distance from the hole in the post to the center of the airplane. It should not exceed about 45 cm.
5. Let the airplane run for about one minute to let any oscillations die out.
6. Weigh the plane on the scale when you're done.
7. Go to `Create` → `Measuring Tools` → `Tape Measure` in *Tracker* to measure the diameter of the plane's trajectory in several places on a Tracker frame showing all your steps. If there is a large variation in your measurement consult your instructor.



Results for the Centripetal Force lab (2020) 32




Centripetal Force Lab All Data
δ = −0.02 ± 0.17
Counts
0
1
2
3
4
5
6
7
−0.4
−0.2
0.0
0.2
0.4
%Diff



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.