What Is This?

The Louvre in Paris

La Bohemienne (1630)

The Painter - Frans Hals

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The Painter - Frans Hals

How do you know it's not a fake?

How Much Would You Pay For This Painting?

La Bohemienne (1630)

The Painter - Frans Hals

How do you know it's not a fake?

SCIENCE!

La Bohemienne (1630)

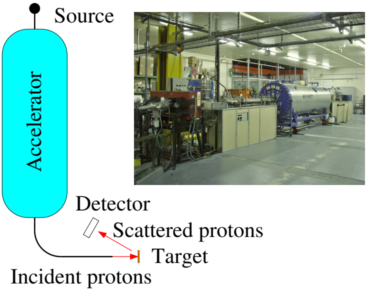
The Painter - Frans Hals

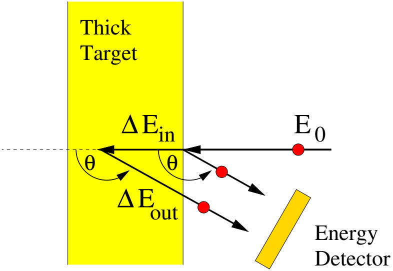
How do you know it's not a fake?

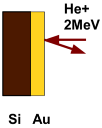
LIBERAL ARTS!

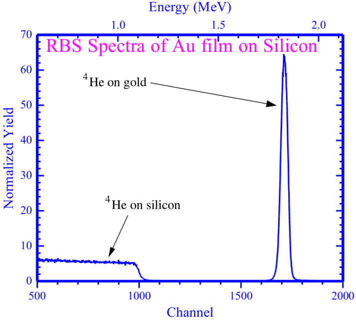
SCIENCE!

1. Ion Beam Analysis (IBA) is used at the Louvre to study the structure of paintings and test their authenticity.
2. The Louvre has it's own accelerator!
3. The figure shows the accelerator and Elastic Backscattering (EBS) setup.
4. The spectrum shows the elastic backscattering of ^{4}He from a target consisting of a thin gold layer and a thick silicon layer.









Nuclear Physics at the Louvre

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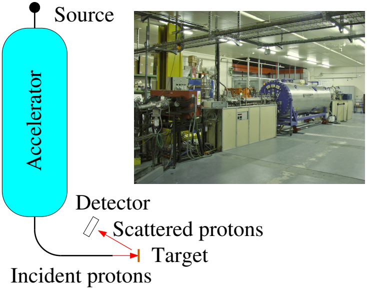
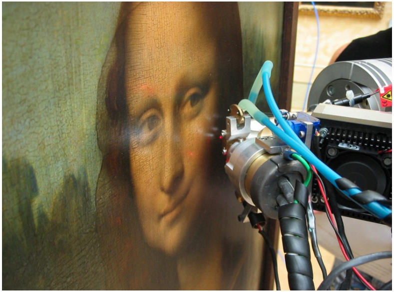
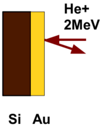
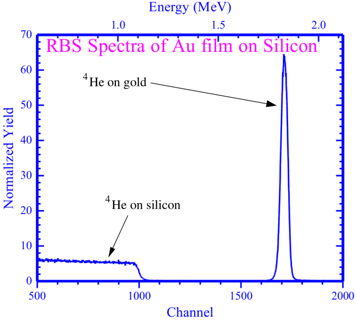


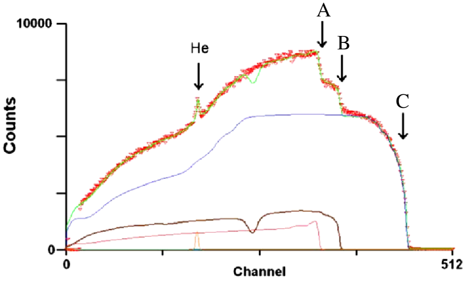






A beam of protons of energy $E_{proj} = 2.964\ \mathrm{MeV}$ strikes a fragment of the painting 'La Bohemienne'. The scattered protons are detected at an angle $\theta = 150^\circ$ and their energies measured producing the spectrum below. The peak labeled 'He' is from protons elastically scattered off $^4\mathrm{He}$ nuclei and has energy $E_{He} = 1.133\ \mathrm{MeV}$. The shoulders labeled A, B, and C are from protons elastically scattering off other, unknown nuclei.

1. What is the ratio of the elastically scattered proton kinetic energy K_1 to its incident energy K_0 in terms of the masses and scattering angles?
2. The shoulder at A corresponds to a scattered proton energy $E_A = 2.214\ \mathrm{MeV}$. What is the mass of the nucleus that creates this shoulder?



L.Beck *et al.*, NIM B266, 1871 (2008).

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

$$\sum \vec{F}_i = m\vec{a} = \frac{d\vec{p}}{dt} \qquad .$$

3. For every action there is an equal and opposite reaction.

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

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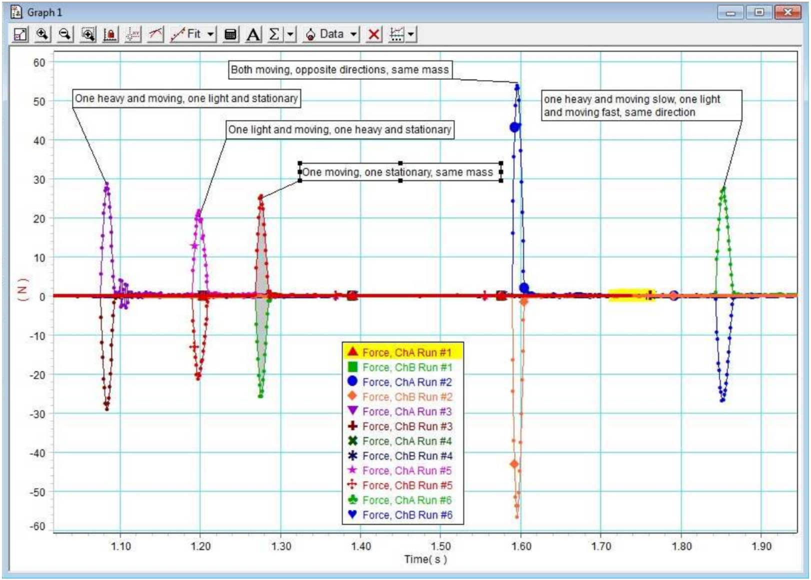
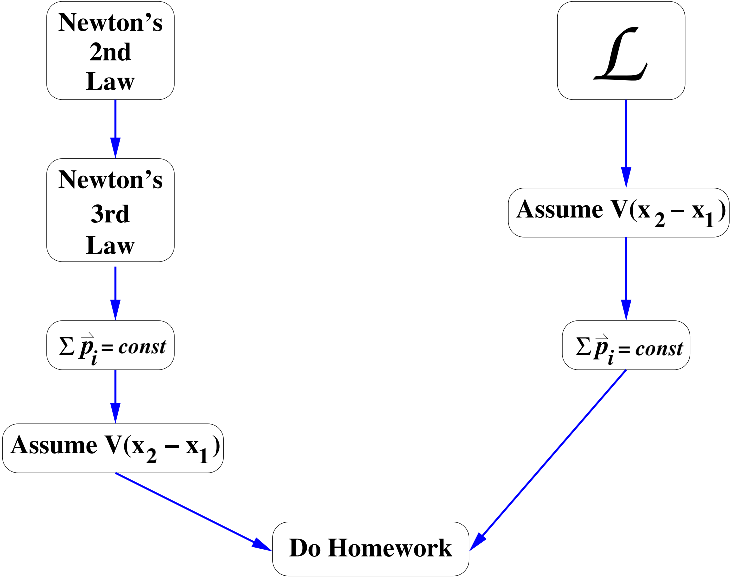
4. Starting with Newton's Third Law derive the conservation of momentum for two objects A and B colliding.


Graph 1
Fit
Data
Both moving, opposite directions, same mass
One heavy and moving, one light and stationary
One light and moving, one heavy and stationary
one heavy and moving slow, one light and moving fast, same direction
One moving, one stationary, same mass
Force, ChA Run #1
Force, ChB Run #1
Force, ChA Run #2
Force, ChB Run #2
Force, ChA Run #3
Force, ChB Run #3
Force, ChA Run #4
Force, ChB Run #4
Force, ChA Run #5
Force, ChB Run #5
Force, ChA Run #6
Force, ChB Run #6
(N)
Time(s)
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
1.90

How the Lagrangian Fits In



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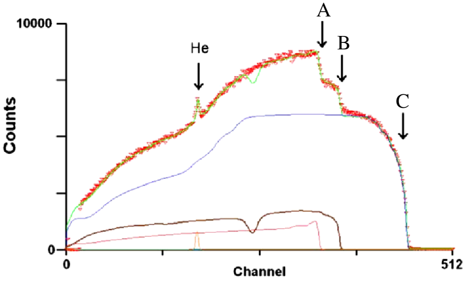
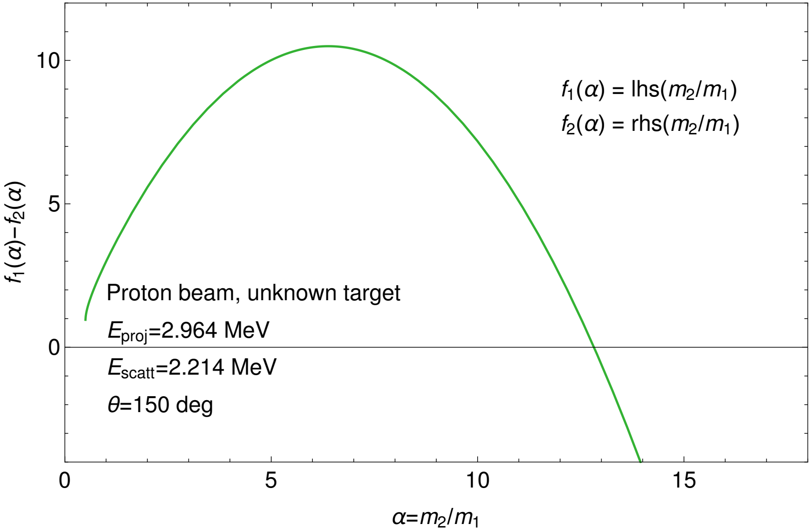
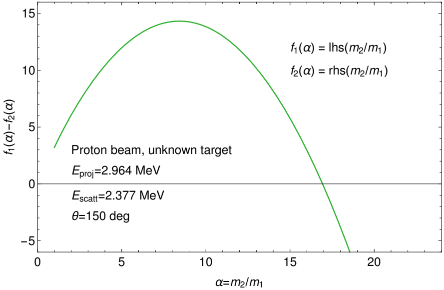
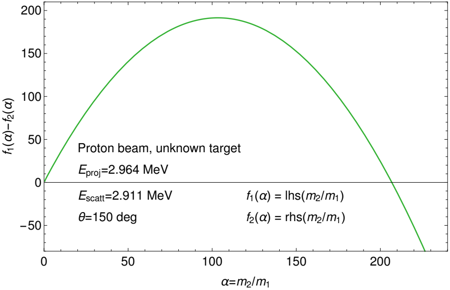


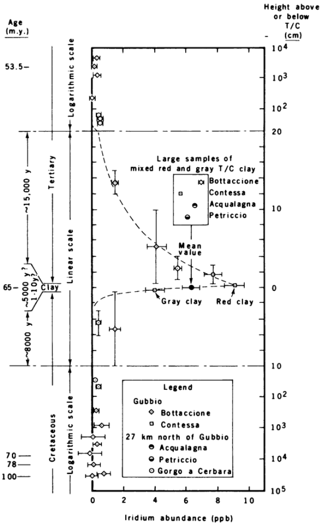
L.Beck *et al.*, NIM B266, 1871 (2008).

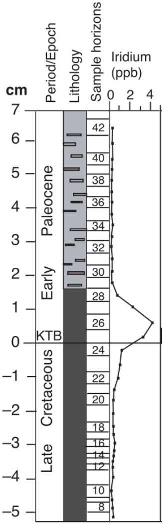

10
5
0
0
5
10
15
$f_1(\alpha)-f_2(\alpha)$
$\alpha=m_2/m_1$
$f_1(\alpha)$ = lhs(m_2/m_1)
$f_2(\alpha)$ = rhs(m_2/m_1)
Proton beam, unknown target
E_{proj}=2.964 MeV
E_{scatt}=2.214 MeV
θ=150 deg


$f_1(\alpha) = \mathrm{lhs}(m_2/m_1)$
$f_2(\alpha) = \mathrm{rhs}(m_2/m_1)$
Proton beam, unknown target
E_{proj}=2.964 MeV
E_{scatt}=2.377 MeV
θ=150 deg
$f_1(\alpha)-f_2(\alpha)$
$\alpha=m_2/m_1$
15
10
5
0
−5
0
5
10
15
20


Proton beam, unknown target
E_{proj}=2.964 MeV
E_{scatt}=2.911 MeV
θ=150 deg
$f_1(\alpha) = \mathrm{lhs}(m_2/m_1)$
$f_2(\alpha) = \mathrm{rhs}(m_2/m_1)$
$f_1(\alpha)-f_2(\alpha)$
$\alpha=m_2/m_1$
200
150
100
50
0
−50
0
50
100
150
200

What happened to them?

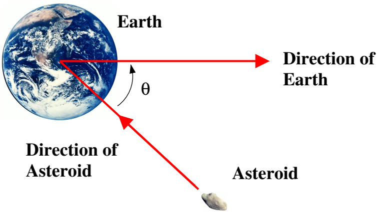




Alvarez, *et al* data (1980). Vajda and McLoughlin data (2004).

It is now believed the dinosaurs and many other species were driven to extinction 65 million years ago by an ecological disaster brought on by the collision of an asteroid with the Earth. Consider the following scenario. The asteroid collides with the Earth as the Earth orbits the Sun and sticks to the surface as shown in the figure (a perfectly inelastic collision). How much does the velocity of the Earth change? How much energy is released in the collision? How does this compare with the energy released by the Hiroshima atomic bomb ($6.8 \times 10^{13}\ J$)?

Asteroid mass:	$m_A = 3.4 \times 10^{14}\ kg$
Asteroid speed:	$v_A = 2.5 \times 10^{4}\ m/s$
Earth mass:	$m_E = 6.0 \times 10^{24}\ kg$
Earth speed:	$v_A = 3.0 \times 10^{4}\ m/s$
Angle:	$\theta = 30^\circ$

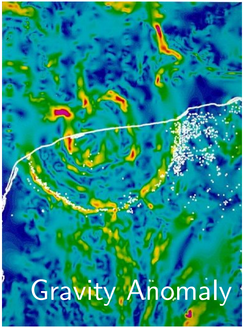


Effects of the Chicxulub Asteroid Strike

1. Megatsunamis as high as 5 kilometers (3.1 mi); enough to completely inundate even large islands such as Madagascar.
2. Excavated material along with pieces of the impactor, ejected out of the atmosphere by the blast, would have been heated to incandescence upon re-entry, broiling the Earth's surface and possibly igniting wildfires.
3. Colossal shock waves would have triggered global earthquakes and volcanic eruptions.
4. The emission of dust and particles could have covered the entire surface of the Earth for years, possibly a decade. Photosynthesis by plants would be interrupted, affecting the entire food chain.
5. Sunlight would have been blocked from reaching the surface of the earth by the dust particles in the atmosphere, cooling the surface dramatically.
6. It is estimated that 75% or more of all species on Earth vanished.

1. An impact crater the right size and age is on the Yucatan Peninsula containing shocked crystals and melted rock.
2. There is abundant evidence of other cataclysmic collisions with Solar System debris.
3. Frequency of impacts:

Pea-size meteoroids	10 per hour
Walnut-size	1 per hour
Grapefruit-size	1 every 10 hours
Basketball-size	1 per month
50-m rock	1 per 100 years
1-km asteroid	1 per 100,000 years
2-km asteroid	1 per 500,000 years



Event	Energy Released (J)	Fatalities
Hiroshima (1945)	6.3×10^{13}	75,000 prompt, 250,000 delayed
Soviet Test (1961)	2.7×10^{17}	None we know of.
Krakatoa (1883)	6.9×10^{18}	36,000
Tambora (1815)	Unknown	92,000

Effect of 5-km-wide asteroid striking the mid-Atlantic.

Watch

CO_2 Normal Modes HW Instructions

1. Your homework solution should be written out by hand on paper and the Mathematica notebook stapled to it. The written solution should include the items below. The Mathematica notebook should clearly show how you obtained those items.
2. Clearly and legibly write out the matrix for the CO_2 molecule, the eigenvalues of the matrix, and the eigenvectors.
3. Show that each eigenvector behaves properly with its associated eigenvalue.
4. Clearly write out the general solution to the CO_2 problem and its first derivative with respect to time.
5. State your initial conditions. See list here.
6. Clearly write out the equations the coefficients in the general solution must satisfy.
7. Obtain the coefficients for the particular solution in terms of parameters in the initial conditions.