

Fermilabyrinth

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Law 'n Order

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- [Four Forces \(Shockwave - E&M last\)](#)
- [Four Forces \(Shockwave - Weak 1\)](#)
- [Four Forces \(Shockwave - Weak 2\)](#)
- [Four Forces \(Shockwave - Weak 3\)](#)
- [Four Forces \(Shockwave - Weak last\)](#)
- [Four Forces \(Shockwave - Strong 1\)](#)
- [Four Forces \(Shockwave - Strong 2\)](#)
- [Four Forces \(Shockwave - Strong 3\)](#)
- [Four Forces \(Shockwave - Gravity 1\)](#)
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Fermilabyrinth



Warp Speed



Ghost Bustin'



Code Crackin'



Law 'n Order

Students - Educators - Lederman Science Center

Security, Privacy, Legal

$$E=mc^2$$

Law 'n Order

IDEAS: Scientists Discover Nature's Laws

Warp
Speed

Ghost
Bustin'

New
Player

Code
Crackin'

Diggin'
Deeper



Read
the Story



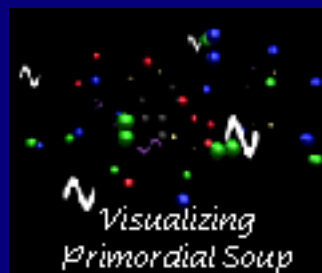


Ideas: Discovering Nature's Laws $E=mc^2$



There is an amazing beauty and symmetry in nature. Think of snowflake, a daisy or a honeycomb. The shapes of these and all other natural objects depend on an underlying structure of matter. For centuries scientists have wondered what this structure might be. Their studies have led to a search for particles that are the smallest, simplest building blocks of matter, and for the forces that control their behavior. The particles are quarks and leptons; the forces are gravity, electromagnetism, the weak force and the strong force. Fermilab scientists are leading this international search to learn how the universe works.

When scientists study the subatomic particles and forces that bind them together, they also learn about the early history of the universe and how it began with the "Big Bang." When the universe was very young, atoms didn't exist, because it was too hot for them to form. The only form of matter was a sort of "primordial soup," consisting of the most basic particles, such as quarks and electrons. At Fermilab, scientists use the Tevatron to make the ingredients of primordial soup by smashing together protons and antiprotons at very high energies. The earlier we look in time, the fewer and more basic the particles become, and the fewer forces are needed to control their behavior. The laws of physics are valid in the whole universe and throughout the whole of time.



[Law 'n Order](#)

Can You Make Particles with Nature's Building Blocks?

Physicists developed the Standard Model in the late 1960s and early '70s to explain the particles in the Particle Zoo.

Physicists proposed that the Particle Zoo contained basic particles called Leptons, force carriers called Bosons and compound particles made of basic particles called Quarks.

Do quarks have structure?

Someday, maybe you will find the answer!

ν_τ p π^+ D^+ τ^-
 K^0 n Ξ^0 μ^- e^- Z
 ϕ ψ \bar{K}^0 Y γ Λ_c^+ ν_μ
 Δ^- \bar{K}^0 Λ_b^0 Ω J/ψ B^0
 B_s^0 D_s^+ Λ_b^0 ν_e

ALL THIS VARIETY RESULTS FROM A FEW SIMPLE BUILDING BLOCKS.



Baryon Bonanza

Law 'n Order

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Last Update: April 28, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/activity.html

Δ^{++} ?	p ?	n ?	Δ^{-} ?		
Σ_c^{++} ?	Σ^+ ?	Λ_c^+ ?	Λ ?	Σ_c^0 ?	Σ^- ?
Ξ_{cc}^{++} ?	Ξ_c^+ ?	Ξ^0 ?	Ξ_{cc}^+ ?	Ξ_c^0 ?	Ξ^- ?
Ω_{ccc}^{++} ?	Ω_{cc}^+ ?	Ω_c^0 ?	Ω^- ?		

Baryon Name:

u **d** **c**

Select three quarks and hit TEST.

Baryon Bonanza

EACH BARYON IN THE CHART CONSISTS OF THREE QUARKS.

TEST DIFFERENT COMBINATIONS OF UP, DOWN, STRANGE AND CHARM QUARKS TO DISCOVER WHICH BARYON THEY MAKE.



You've earned \$ Einstein Bucks!

When finished, click below to

[Law 'n Order](#)

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Last Update: April 28, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/baryon_table.html

Δ^+ ?	p ?	n ?	Δ^- ?		
Σ_c^{++} ?	Σ^+ ?	Λ_c^+ u d c	Λ ?	Σ_c^0 ?	Σ^- ?
Ξ_{cc}^{++} u c c	Ξ_c^+ ?	Ξ^0 ?	Ξ_c^+ ?	Ξ_c^0 ?	Ξ^- ?
Ω_{cc}^+ ?	Ω_c^+ ?	Ω_c^0 ?	Ω^- ?		

Baryon Name:



Select three quarks and hit TEST.

Baryon Bonanza

CONGRATULATIONS!
YOU MADE A
BARYON.
**YOU WON
\$50!**
FILL A WHOLE ROW
AND EARN A
BONUS.



You've earned \$ Einstein Bucks!

When finished, click below
to

[Law 'n Order](#)

[Making
Baryons](#)

[Matter/
Antimatter](#)

[Antibaryons](#)

[Mesons](#)

[Hadrons](#)

Making Baryons: Some quark combinations can actually make more than one baryon, but the game only shows one to make it simpler. You could make even more baryons if you combined these four quarks with the bottom quark, but not the top quark. The top quark lives for such a short time that it cannot combine with other quarks to form a baryon.

Matter/Antimatter: For every kind of particle there is a corresponding kind of antiparticle. This almost doubles the size of the Particle Zoo. When a particle and its antiparticle get together, they can annihilate into pure energy or into other particles. This happens at Fermilab when protons and antiprotons collide in the Tevatron. The Tevatron Collider is the only place in the world where physicists can make all the observed particles.



Proton/Antiproton Collision

Antibaryons - Even More Baryons: For every quark combination that makes a baryon, you can make an antiquark combination. For example, if you combine an antidown, antiup and antiup quark, you get an antiproton! But Nature does not combine quarks and antiquarks in baryons.

Mesons: Quarks and antiquarks combine to make a whole new set of particles called mesons. For example, up and antidown make a pion; an strange and antiup make a kaon. These quark pairs add many more particles to the Particle Zoo.

Hadrons: are particles made from quarks. Mesons and baryons are hadrons.

[Making
Baryons](#)

[Matter/
Antimatter](#)

[Antibaryons](#)

[Mesons](#)

[Hadrons](#)

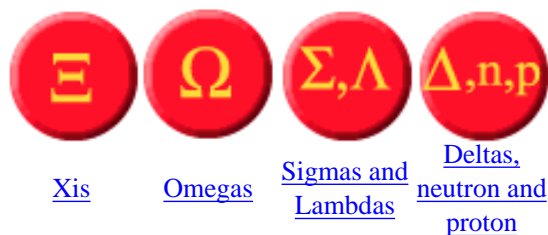
Close this window when you are done.

Welcome to Double Delight where you can go home with double the bucks you came in with by answering a question.

Δ^{++} uuu	p uud	n udd	Δ^{-} ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		

Physicists named baryons with Greek letters like you see on the buttons below. What letter(s) did they give baryons made of two up or down quarks and one charm and strange quarks?

Study the chart to see which Greek letters they used and then click below on the matching letter(s).



[Law 'n Order](#)

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http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/baryon_bucks4.html

Great! You Made The Correct Choice!
You doubled your Einstein Bucks!!

The sigmas and lambdas are made up of two up or down and one strange or charm quarks.



Δ^{++} uuu	p uud	n udd	Δ^{-} ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		



Print Your Bucks



[Go Back](#)

Fermilabyrinth
Batavia, IL 60510

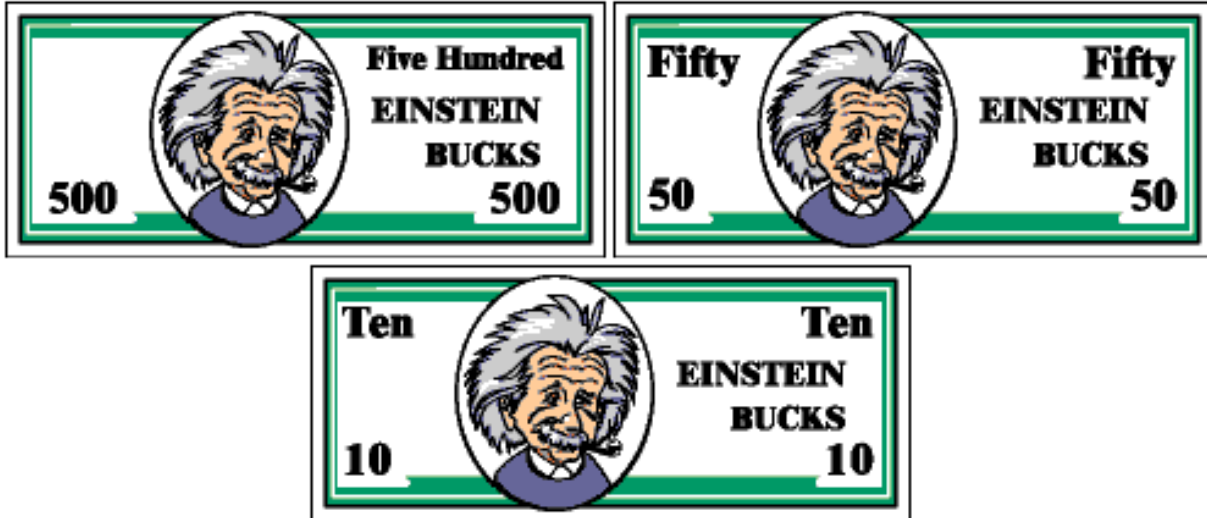
10/5/01



Pay to the order of: Marilyn Fox

560 Einstein Bucks

For: Baryon Bonanza

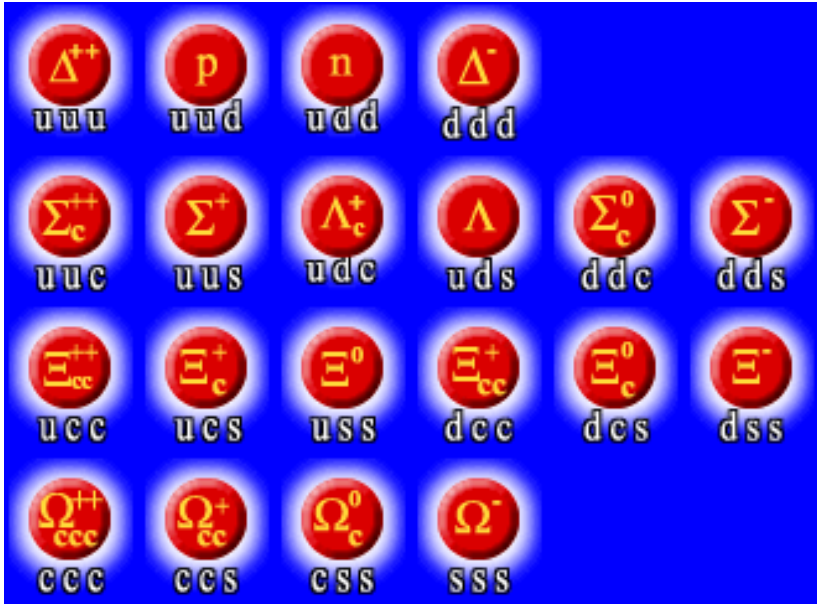


[See The High Scores](#)

If you do not see your name on the check, try resizing the window. Close this window when you have printed out your Einstein bucks or have looked at the high scores.

Sorry! You made the wrong choice! The correct answer is
sigmas and lambdas

The sigmas and lambdas are made up of two up or down and one strange or charm quarks.



Δ^{++} uuu	p uud	n udd	Δ^{-} ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		



Print Your Bucks



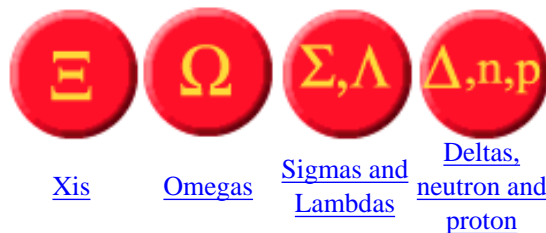
[Go Back](#)

Welcome to Double Delight where you can go home with double the bucks you came in with by answering a question.

Δ^{++} uuu	p uud	n udd	Δ^- ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		

Physicists named baryons with Greek letters like you see on the buttons below. What Greek letter(s) did they give **baryons made of only up and down quarks**?

Study the chart to find baryons with the right quarks, look at what Greek letters they have and then click on the matching letter(s) below.



[Law 'n Order](#)

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http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/baryon_bucks1.html

Welcome to Double Delight where you can go home with double the bucks you came in with by answering a question.

Δ^{++} uuu	p uud	n udd	Δ^- ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		

- Find the row of baryons made of **only charm and strange quarks** in the chart on the left.
- See the strange letters physicists used to label them? They're mainly letters in the Greek alphabet.
- Click on the matching letter(s) below.



[Xi](#)

[Omegas](#)

[Sigmas and
Lambdas](#)

[Deltas,
neutron and
proton](#)

[Law 'n Order](#)

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http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/baryon_bucks2.html

Welcome to Double Delight where you can go home with double the bucks you came in with by answering a question.

Δ^{++} uuu	p uud	n udd	Δ^{-} ddd		
Σ_c^{++} uuc	Σ^+ uus	Λ_c^+ udc	Λ uds	Σ_c^0 ddc	Σ^- dds
Ξ_{cc}^{++} ucc	Ξ_c^+ ucs	Ξ^0 uss	Ξ_{cc}^+ dcc	Ξ_c^0 dcs	Ξ^- dss
Ω_{ccc}^{++} ccc	Ω_{cc}^+ ccs	Ω_c^0 css	Ω^- sss		

Physicists named baryons with Greek letters like you see on the buttons below. What letter(s) did they give **baryons made of one up or down and two strange or charm quarks?**

Study the chart to see which Greek letters they used and then click below on the matching letter(s).



[Xi](#)

[Omegas](#)

[Sigmas and
Lambdas](#)

[Deltas,
neutron and
proton](#)

[Law 'n Order](#)


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http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/standard_model/baryon_bucks3.html

Particle Families		
Imaginary Families		
Level 1	Introduction	200 Points per Game
Level 2	Geometry 1	400 Points per Game
Level 3	Geometry 2	800 Points per Game
Real Families		
Level 4	Physics	1600 Points per Game

CHOOSE A LEVEL
OR
CLICK ON ME FOR MORE INSTRUCTIONS.



Quit Particle Families	Einstein Bucks <input type="text" value="0"/>	Next Family	New Level Intro - Geom1 - Geom2 - Physics	Double Your Bucks
--	---	-----------------------------	---	-----------------------------------

Level 2 Game - 100 Einstein Bucks Per Game

All of these are Guinons.



None of these are Guinons.



Which of these are Guinons?



Guinon A

Guinon B

Guinon C

Guinon D

GOOD JOB!
THAT'S CORRECT.
CLICK ON
"NEXT FAMILY".



Number of tries:

[Check Your Answers](#)

[Get Answer](#)

[Quit Particle Families](#)

Einstein Bucks: 70

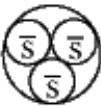



[Next Family](#)

New Level
[Intro](#) - [Geom1](#) - [Geom2](#) - [Physics](#)





[Double Your Bucks](#)

Level 4 Game - 400 Einstein Bucks Per Game


All of these are Baryons.


None of these are Baryons.


Which of these are Baryons?




Baryon A



Baryon B




Baryon C



Baryon D

WHICH OBJECTS BELONG TO THIS FAMILY?



Number of tries:

Check Your Answers
Get Answer

[Quit Particle Families](#)

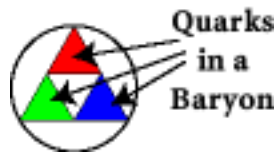
Einstein Bucks
270

Next Family

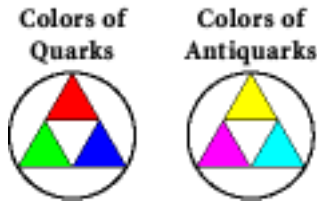
New Level
[Intro -](#)
[Geom1 -](#)
[Geom2 -](#)
[Physics](#)

[Double Your Bucks](#)

Explanation of the Color of Quarks in Baryons



In this representation, each baryon consists of three quarks or antiquarks shown as triangles within the larger circle.

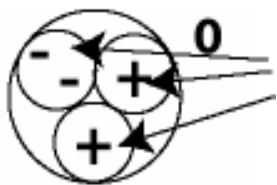


The colors of each quark represent a property physicists call color. The quarks aren't really colored, but it is a convenient way to represent the property. Quarks can be red, blue, or green while antiquarks can be yellow, cyan, or magenta.



The three quarks or antiquarks in a baryon must have different colors and combine to make white. Baryons cannot be made from a mixture of quark and antiquark colors. For example, a mixture of two antiquark colors (yellow and magenta) and one quark color (green) would not mix to make white so it is illegal.

Explanation of the Charge on Baryons

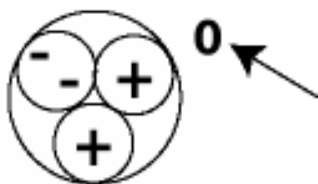


Each baryon consists of three quarks represented by small circles within the larger circle.

$$\begin{matrix} - \\ - \end{matrix} = -2/3$$

$$\begin{matrix} + \\ + \end{matrix} = +1/3$$

The pluses and minuses in each quark represent the charge of each quark where each plus represents $1/3$ of a charge and each minus represents $-1/3$ of a charge.



To be a baryon, the sum of all the charges has to equal an integer (e.g., -1, 0, 1). In the example, the sum is zero shown in the upper right corner.

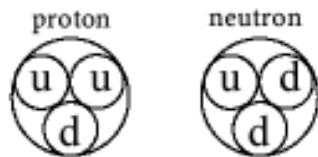
Explanation of Quarks in Baryons

Quarks			Antiquarks		
u	c	b	\bar{u}	\bar{c}	\bar{b}
d	s	t	\bar{d}	\bar{s}	\bar{t}

Physicist believe there are six quarks - up (u), down (d), charm (c), strange (s), top (t), and bottom (b) and their antiquarks - antiup, antidown, anticharm, antistrange, antibottom, and antitop. Antiquarks are labeled with a letter with a bar over it.



Each baryon consists of three quarks or three antiquarks represented by small circles within the larger circle. Quarks are labeled with a letter. A baryon cannot be made of a mixture of quarks and antiquarks.



The most familiar baryons are protons and neutrons. They make up the nucleus of atoms and are made up of top and bottom quarks. In fact, everything you see in the world, for example, your computer or your body, is made of top and down quarks and electrons. They are truly the building blocks of matter.

Explanation of Quarks in Mesons

Quarks			Antiquarks		
u	c	b	\bar{u}	\bar{c}	\bar{b}
d	s	t	\bar{d}	\bar{s}	\bar{t}

Physicist believe there are six quarks - up (u), down (d), charm (c), strange (s), top (t), and bottom (b) and their antiquarks - antiup, antidown, anticharm, antistrange, antibottom, and antitop. Antiquarks are labeled with a letter with a bar over it.

quark and antiquark



two quarks



two antiquarks



Each meson consists of one quarks and one antiquark represented by small circles within the larger circle. Quarks are labeled with a letter. A meson cannot be made of two quarks or two antiquarks.

pion



kaon



Examples of mesons are the pion and the kaon.

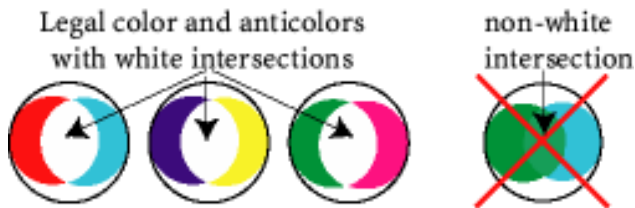
Explanation of the Colors of Quarks and Antiquarks in Mesons



In this representation, each meson consists of one quark and one antiquark shown as intersecting circles within the larger circle.



The colors of each quark represent a property physicists call color. The quarks aren't really colored, but it is a convenient way to represent the property. Quarks can be red, blue, or green while antiquarks can be cyan, yellow, or magenta.



The one quark and one antiquark in a meson must have colors that combine to make white. Only the anticolor of a color combines to make white. Red's anticolor is cyan; blue's anticolor is yellow; green's anticolor is magenta. The part of the two circles that overlaps represents the mixture of the colors of the two quarks.

TO DOUBLE YOUR BUCKS,
READ ABOUT PARTICLE
FAMILIES AND ANSWER
THE QUESTION AT THE END
CORRECTLY.



What is a Particle FAMILY?

One reason scientists study particles is to find their similarities and differences.

What is a family?

Science often begins by grouping things.

Zoologists classify animals so that tigers, cheetahs, and tabbies end up in the family of "cats" (felines).



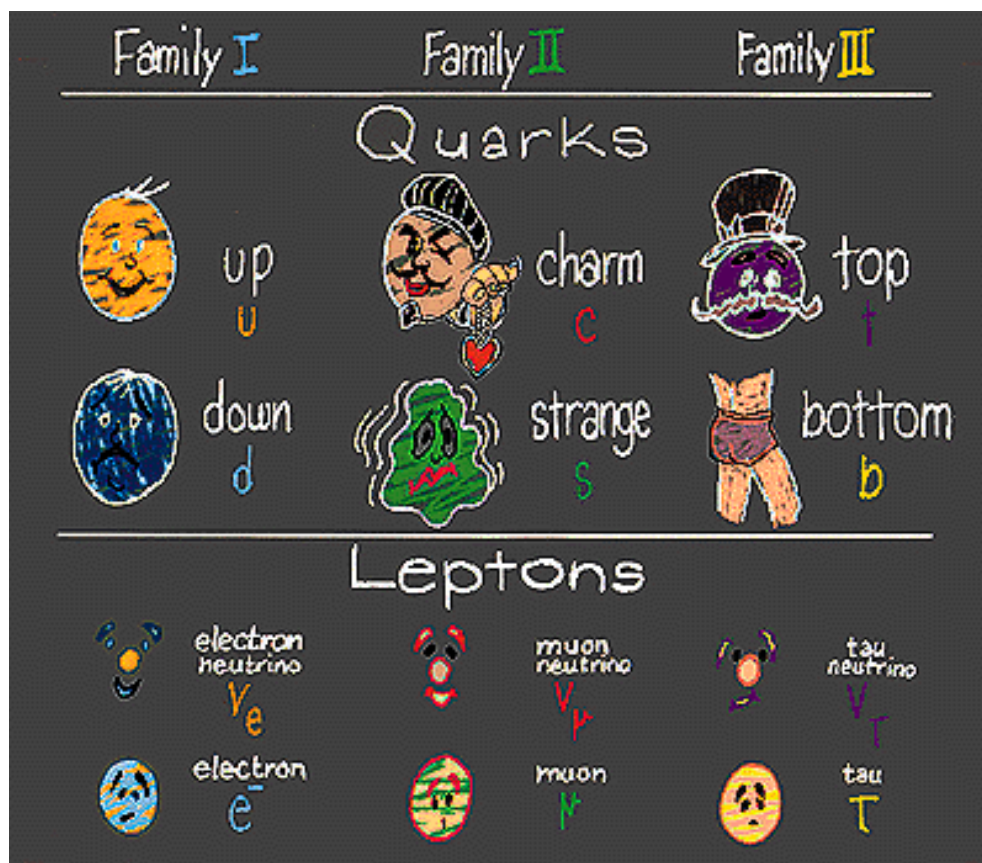
The Russian scientist, Dmitri Mendeleev, grouped elements in the Periodic Table according to their chemical properties and atomic weights. It was many years after Mendeleev that chemists understood WHY elements belonged to certain groups.

THE PERIODIC TABLE OF THE ELEMENTS

I																0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
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What is a particle family?

Physicists group particles called quarks and leptons into "families."



Today, physicists are trying to understand WHY quarks and leptons belong to particular groups.

Not so long ago scientists discovered so many new particles (several hundred) they called them a Particle Zoo. The picture was simplified with the discovery of more basic particles - quarks and leptons - that physicists group into families. In the Particle Family Game, you grouped the imaginary particles by identifying common characteristics as physicists do.

QUESTION: Does the electron belong to the Family of Quarks or Leptons?

[Quarks](#) - [Leptons](#)

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Last Update: June 11, 1998

Nature's Scale



You don't
have
Shockwave.
Get it!

This activity needs Shockwave. If you don't see the animation above,

click



[Go to Game](#)



[Law 'N Order](#)

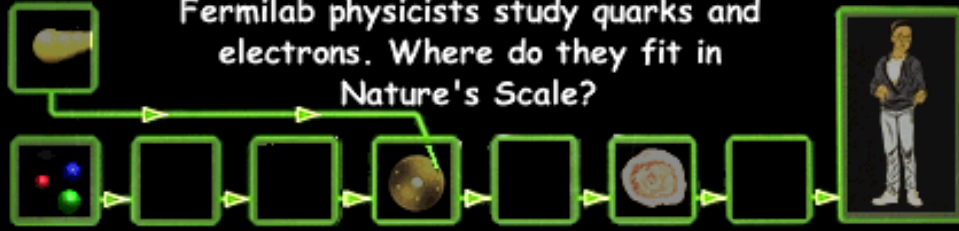
Web Maintainer: ed-webmaster@fnal.gov

Last Update: May 11, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/natures_scale/activity.html

Can You Play Nature's Scale?

Fermilab physicists study quarks and electrons. Where do they fit in Nature's Scale?



Score:
\$1000

Label the keys in Nature's Scale from small to large by dragging the labels on the left to the keyboard.

Nucleus	Heart	Proton & Neutron
	DNA Molecule	

Labels for Keys

Electron & Quarks			Atom			Cell		Human
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Law 'N Order

New Game

Stop Game

Double Your Bucks

To restart, reload the Web page.

Macromedia Shockwave Movie by: [Liz Quigg - liz@fnal.gov](mailto:liz@fnal.gov)

Web Maintainer: ed-webmaster@fnal.gov

Last Update: May 16, 2000

http://www-ed.fnal.gov/projects/labyrinth/lawnorder/natures_scale.html

Quarks Proton and Neutron Nucleus Atom

$>10^{-15}$ mm. 10^{-12} mm. 10^{-11} mm. 10^{-7} mm.

Score:
\$ 200

Zoom In Zoom Out Test All Done

Atom

0.0000001 mm
 10^{-7} or mm

Fermilab scientists explore quarks, objects more than one hundred million times smaller than an atom! Click the **Zoom In** button to move from an atom to a quark. (Each click of the button lets you look at an object 10 times smaller than the previous object.) Once you think you've reached the quark size, click **Test**. See if you can double your bucks!

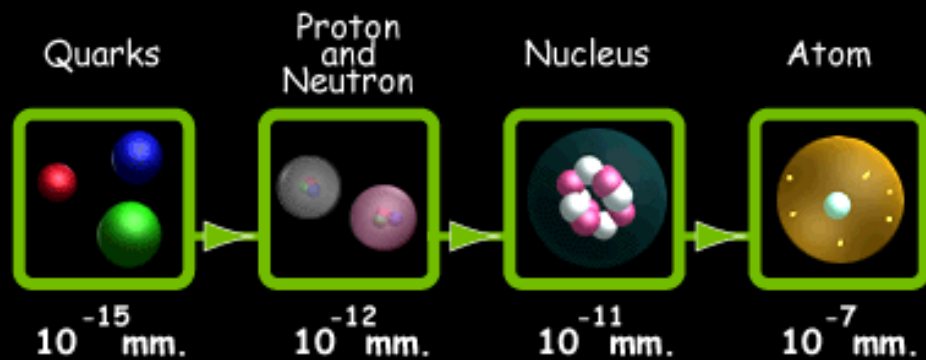
Law 'N Order

Congratulations! You earned Einstein Bucks in Nature's Scale!!

Quarks are the smallest objects physicists have discovered.

Are they made of something smaller?

Print out your bucks or go back to Law 'n Order.



Print Your Bucks



[Go Back](#)

Web Maintainer: ed-webmaster@fnal.gov

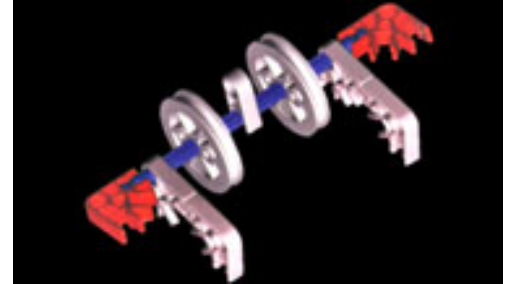
Last Update: May 16, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/natures_scale/done.html

What are the Basic Forces Between Particles?

The Standard Model describes how the fundamental particles affect each other—how they interact, the forces they feel.

You may think of forces as pushes and pulls. Particle physicists think of forces as **interactions between particles** that produce structure—from protons to galaxies. The Standard Model would not be complete if it did not explain how particles behave together. It would be like having a set of K'nex without the rods—you couldn't build much.



[Continue](#)

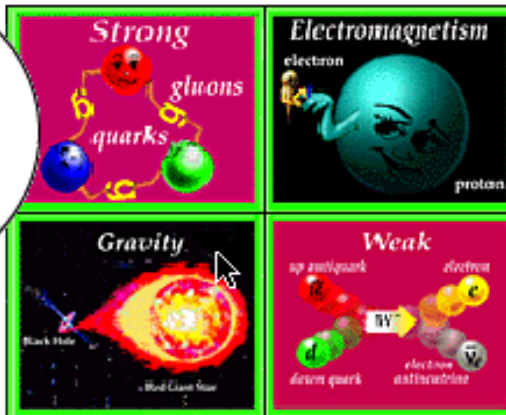
[Law 'n Order](#)

Web Maintainer: ed-webmaster@fnal.gov

Shockwave Movie by Liz Quigg: liz@fnal.gov

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/four_forces/intro.html

What are the Basic Forces between Particles?



You have Shockwave

Continue

This activity needs Shockwave. If you can't see the animation, click

GET SHOCKWAVE

Law 'n Order

ed-webmaster@fnal.gov

by Liz Quigg: liz@fnal.gov

al.gov/projects/fermilabyrinth/games/lawnorder/four_forces/activity.html

No Slabs in Place
All Forces Exist

Strong	Electro-magnetic
Gravity	Weak

All Done

00:00

\$200

I'm the force fiend.
I control the forces in this imaginary world.

The screenshot shows a game interface with a light blue background and a dark red border. In the top left, a text box reads "No Slabs in Place" and "All Forces Exist". Below this is a 2x2 grid of colored boxes: top-left is pink with "Strong", top-right is black with "Electro-magnetic", bottom-left is black with "Gravity", and bottom-right is pink with "Weak". In the top right, there is a pink "All Done" button, a timer showing "00:00", and a score box showing "\$200". A large white speech bubble in the center contains the text: "You are surrounded by forces that keep the building and the world around you in place." The main scene features a character in a red suit with a yellow cape standing on a green grassy area. Behind the character is a tall, textured stone tower with a grid-like window. To the left of the character are two stacks of wooden planks. At the character's feet are two circular icons: a red one with a white plus sign and a yellow one with a white minus sign.

No Slabs in Place
All Forces Exist

Strong	Electro-magnetic
Gravity	Weak

All Done

00:00

\$200

Your job is to give the Fermilab hirise a face-lift by dragging the slabs on the left onto the building.

The image shows a game interface with a superhero character in a red suit and orange cape standing on a green field. Behind him is a large, textured, conical building with a grid-like structure on its side. To the left of the character are two stacks of wooden planks. The interface includes a status bar at the top with the text 'No Slabs in Place' and 'All Forces Exist', a table of force types, a timer showing '00:00', and a score of '\$200'. A speech bubble from the character explains the objective: 'Your job is to give the Fermilab hirise a face-lift by dragging the slabs on the left onto the building.' The character is holding a red circle with a white plus sign and a red circle with a white minus sign.

The screenshot shows a game interface with a light blue background and a dark red border. In the top left, the text reads "No Slabs in Place" and "All Forces Exist". Below this is a 2x2 grid of colored boxes: top-left is pink with "Strong", top-right is black with "Electro-magnetic", bottom-left is black with "Gravity", and bottom-right is pink with "Weak". In the top right, there is a pink "All Done" button, a timer showing "00:00", and a score box showing "\$200". A large white speech bubble in the center contains the text: "Find out what would happen if I came and took away one of the four forces" and "Good luck!". At the bottom center, a character in a red suit with a yellow cape stands on a green grassy area. To the left of the character are two stacks of wooden planks. In front of the character are two red circular buttons with a white plus sign and a white minus sign. In the background, a stone tower with a grid-like window is visible.

9 of 18 Slabs Done
All Forces Exist

Strong	Electro-magnetic
Gravity	Weak

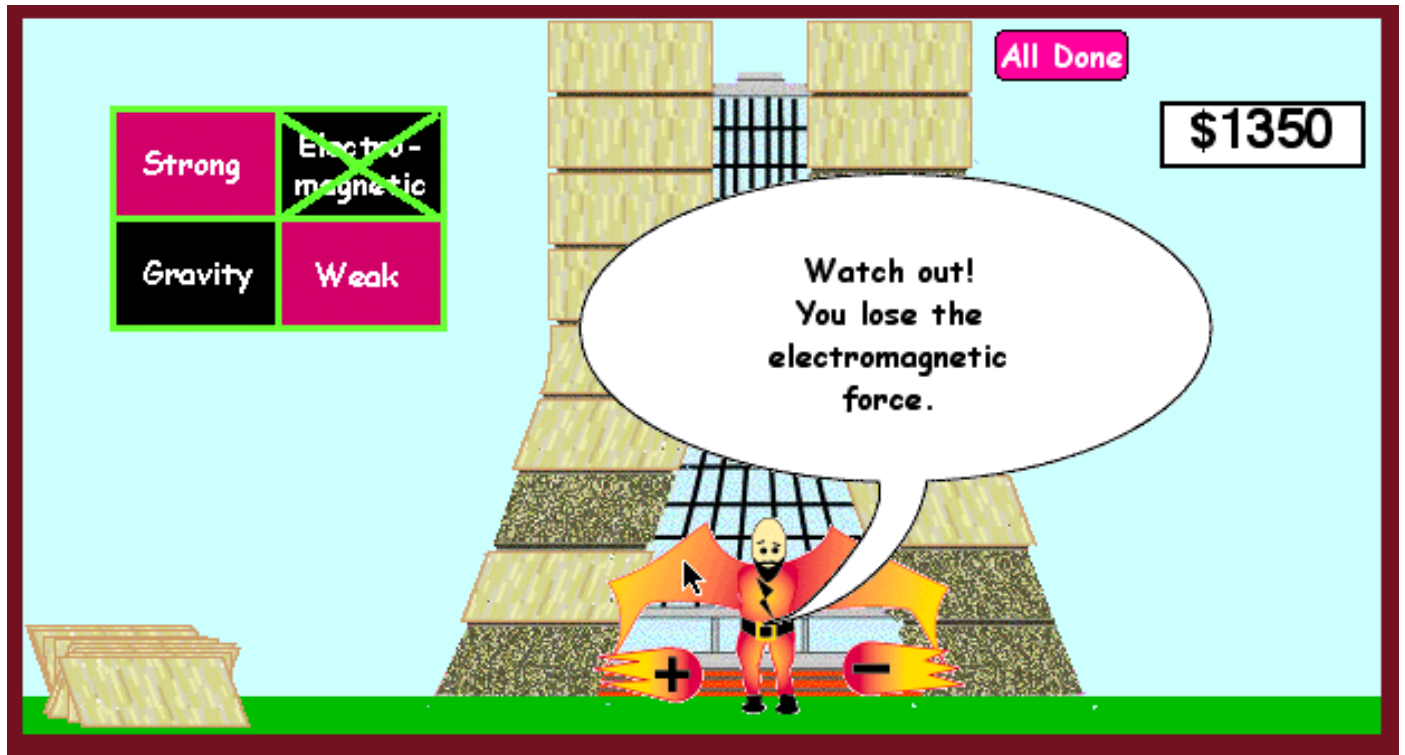
All Done

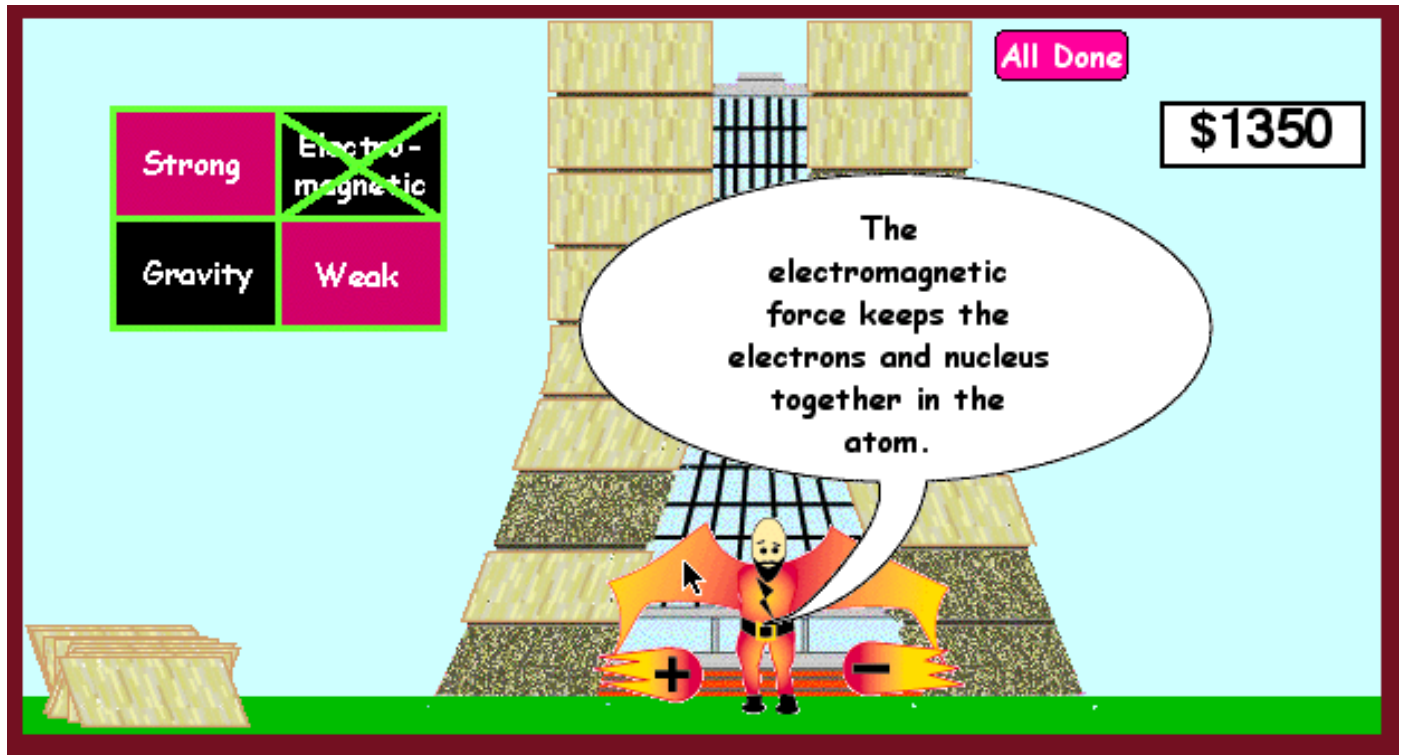
00:14

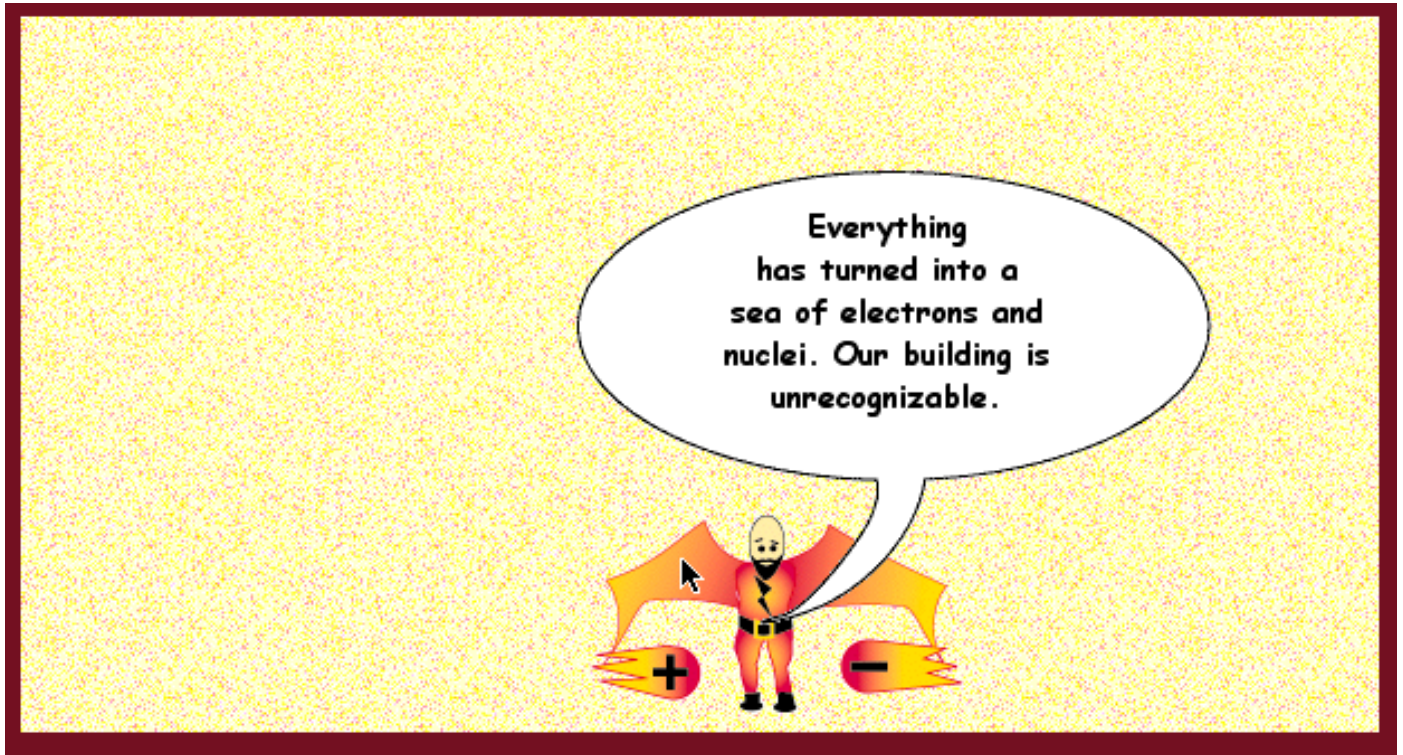
\$650

You lose a force!

Select a force in the panel above.
Click on the book to help you choose.









9 of 18 Slabs Done
3 Forces Active

Strong	Electro-magnetic
Gravity	Weak

All Done

00:14

\$650

Good choice!

The weak force is responsible for radioactive beta decay.

9 of 18 Slabs Done
3 Forces Active

Strong	Electro-magnetic
Gravity	Weak

All Done

00:14

\$650

Losing the weak force won't affect your repair to the hirise, at least not for a million years.

9 of 18 Slabs Done
3 Forces Active

Strong	Electro-magnetic
Gravity	Weak

All Done

00:14

\$650

In a million years, the sun will cool and release its last radiation and everything will be dark.

9 of 18 Slabs Done
3 Forces Active

Strong	Electro-magnetic
Gravity	Weak


All Done

00:14


\$650

But for now,
you can keep putting up
the slabs on the
building.





The quarks escape
and cause a big flash.
Everything is gone.



**The building
is gone!**

Click to start again.

12 of 18 Slabs Done
2 Forces Active

Strong	Electro-magnetic
Gravity	Weak

Gravity!
With gravity, a slab will fall.

+

-

12 of 18 Slabs Done
2 Forces Active

Strong	Electro-magnetic
Gravity	Weak

Without gravity,
a slab just floats!
Check it out.

Learn about the four forces and the Fermilab physicists who study them.

[Chart](#) - [Strong](#) - [Electromagnetic](#) - [Gravity](#) - [Weak](#) - [Return to Game](#)

<i>Force</i>	<i>Range</i>	<i>Carrier</i>	<i>Acts on</i>
Strong	<i>nuclear distances</i>	<i>gluon</i>	<i>quarks, gluons, particles made of quarks</i>
Electromagnetic	<i>all distances</i>	<i>photon</i>	<i>electrically charged particles</i>
Weak	<i>subnuclear distances</i>	<i>W⁺, W⁻, Z⁰</i>	<i>quarks, leptons, particles made of quarks</i>
Gravity	<i>all distances</i>	<i>graviton (not yet observed)</i>	<i>all particles</i>

The forces are listed from strongest to weakest.

Learn about the four forces and the Fermilab physicists who study them.

[All](#) - [Strong](#) - [Electromagnetic](#) - [Gravity](#) - [Weak](#) - [Return to Game](#)

<i>Force</i>	<i>Range</i>	<i>Carrier</i>	<i>Acts on</i>
<i>Strong</i>	<i>nuclear distances</i>	<i>gluon</i>	<i>quarks, gluons, particles made of quarks</i>
<i>Electromagnetic</i>	<i>all distances</i>	<i>photon</i>	<i>electrically charged particles</i>
<i>Weak</i>	<i>subnuclear distances</i>	<i>W^+, W^-, Z^0</i>	<i>quarks, leptons, particles made of quarks</i>
<i>Gravity</i>	<i>all distances</i>	<i>graviton</i> <i>(not yet observed)</i>	<i>all particles</i>

The forces are listed from strongest to weakest.

Strong

quarks

gluons

u

\bar{d}

gluon

\bar{d}

time

Electronic Signature of a Quark Antiquark Collision

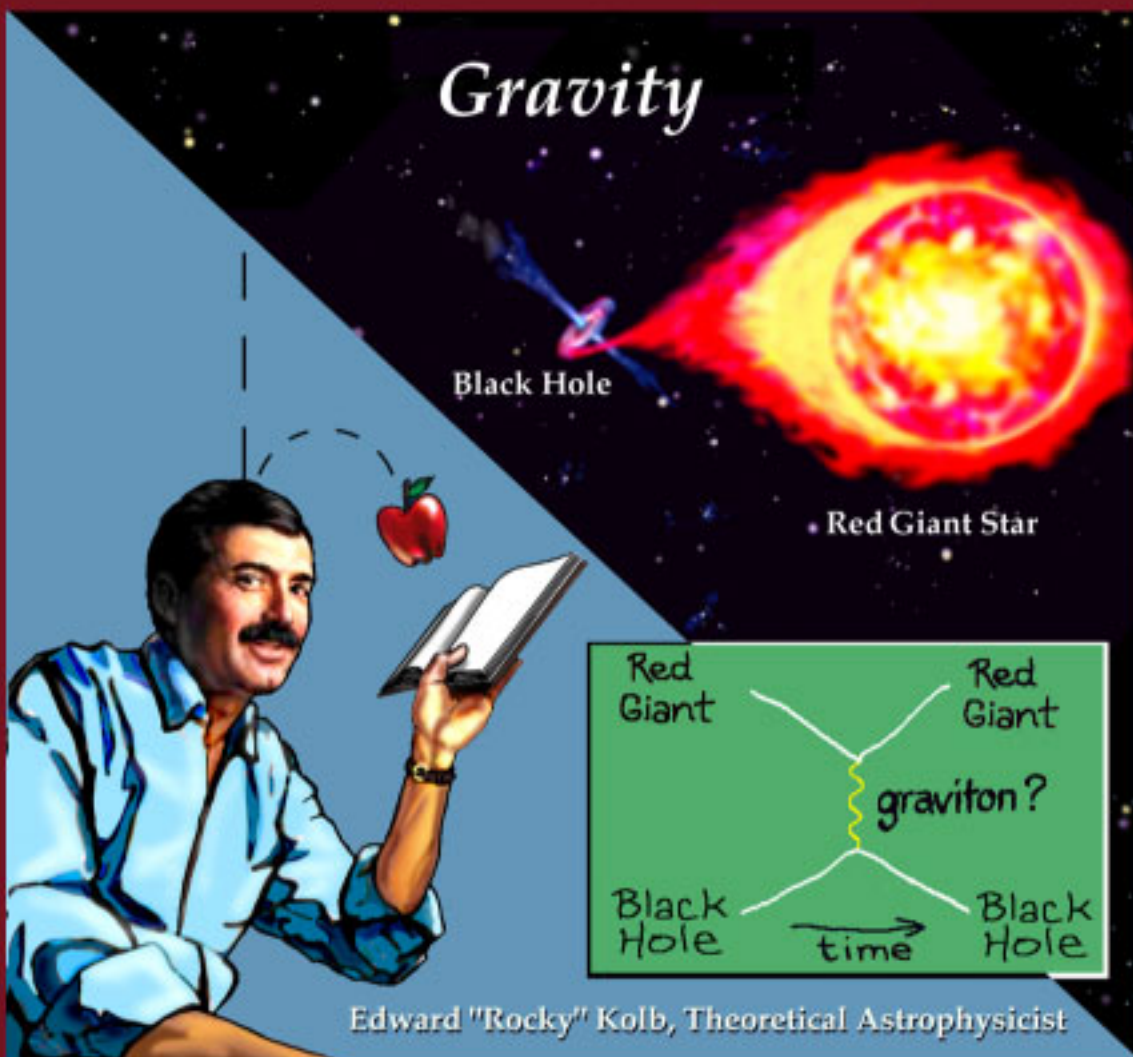
Bill Bardeen, Theoretical Physicist

[All](#) - [Chart](#) - [Strong](#) - [Electromagnetic](#) - [Gravity](#) - [Weak](#) - [Return to Game](#)

Electromagnetic

The image is a composite illustration. At the top center, the word "Electromagnetic" is written in a white, serif font. Below this, on the left, is a Feynman diagram on a green background showing two electrons (e^-) interacting via a photon (γ). The diagram shows two incoming electron lines from the bottom, a wavy photon line connecting them, and two outgoing electron lines to the right. An arrow labeled "time" points to the right. To the right of the Feynman diagram is a cartoon illustration of a small yellow electron character holding a large blue proton character. The electron is labeled "electron" and the proton is labeled "proton". Below the Feynman diagram is a circular inset showing a cross-section of a particle accelerator. In the bottom left, a woman with short grey hair, wearing a red jacket and a blue shirt, is smiling. A thought bubble above her head shows the same particle accelerator. To her right, a battery is connected to a solenoid (a coil of wire). Blue lightning bolts emanate from the solenoid, and a compass is shown nearby, with its needle deflected. At the bottom center, the text "Helen Edwards, Accelerator Physicist" is written in white.

[All](#) - [Chart](#) - [Strong](#) - [Electromagnetic](#) - [Gravity](#) - [Weak](#) - [Return to Game](#)



Edward "Rocky" Kolb, Theoretical Astrophysicist

Weak

up antiquark \bar{u}

down quark d

electron e

electron antineutrino $\bar{\nu}_e$

W^-

time

\bar{u}

d

W^-

e^-

$\bar{\nu}_e$

time

Electronic Signature of a W Particle

Chris Quigg,
Theoretical Physicist

Double Your Bucks

Fill out the following chart to indicate which forces affect the particles along the left. Click on the circle next to **Yes** if they feel the force and **No** if they don't. Some of the answers may surprise you, but you can double your bucks if you answer most of them correctly.

Refer to the chart in the other [window](#) or the glossary below if you need help.

Particles	Four Forces							
	Gravity		Electromagnetic		Weak		Strong	
neutron	Yes	No	Yes	No	Yes	No	Yes	No
neutrino	Yes	No	Yes	No	Yes	No	Yes	No
quark	Yes	No	Yes	No	Yes	No	Yes	No
proton	Yes	No	Yes	No	Yes	No	Yes	No
photon	Yes	No	Yes	No	Yes	No	Yes	No
electron	Yes	No	Yes	No	Yes	No	Yes	No

Click the button to .

Glossary

electron

A negatively charged particle belonging to the family of leptons. It has mass and combines with the nucleus to make atoms.

neutrino

An elusive particle because it barely interacts with other particles. It has zero or very little mass. Scientists are trying to determine if it has mass. It has no electrical charge and belongs to the family of leptons. There are three types of neutrinos: electron neutrinos, tau neutrinos, and mu neutrinos, corresponding to their lepton partners, the electron, tau, and mu.

neutron

A particle with no charge made up of three quarks, one up and two downs. The neutron and proton make up the nucleus of an atom.

photon

A particle with no mass or electrical charge. Photons are the carriers of the electromagnetic force.

proton

A particle with positive electrical charge made up of three quarks, two ups and one down. The neutron and proton make up the nucleus of an atom.

quark

One of the basic building blocks of matter. There are six types of quarks: up, down, charm, beauty, bottom, and top. Three of them combine to make baryons, for example, the proton and neutron. Two combine to make mesons. They have mass and electrical charge.

You can learn more about different particles in
Particle Families and Baryon Bonanza in Law 'n Order.

[Law 'n Order](#)

Web Maintainer: ed-webmaster@fnal.gov

Last Update: May 31, 2000

http://www-ed.fnal.gov/projects/fermilabyrinth/games/lawnorder/four_forces/four_forces_bucks.html

**You did not double your Einstein Bucks. You got 6 out of 24 correct.
You earned 200 Einstein Bucks in the Four Forces!!**

Here are the correct answers. Those with a red background, you answered incorrectly.

All the particles experience **gravity**. If a particle has energy, it feels **gravity**. The **neutrino** and **photon** do not feel the **electromagnetic force** because they have no charge. You might think that the **neutron** might not feel it, but it does because it is made up of charged particles. All the particles except the **photon** experience the **weak force**. Only **quarks** and **hadrons** feel the **strong force**, so that leaves out the **photon, electron** and **neutrino**. Remember to have the structure around us, we need the four forces.

After you study the table, print out your bucks or go back to Law 'n Order.

Particles	Four Forces			
	Gravity	Electromagnetic	Weak	Strong
neutron	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No
neutrino	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No
quark	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No
proton	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No
photon	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No
electron	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input checked="" type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input checked="" type="radio"/> No



[Print Your Bucks](#)



[Go Back](#)