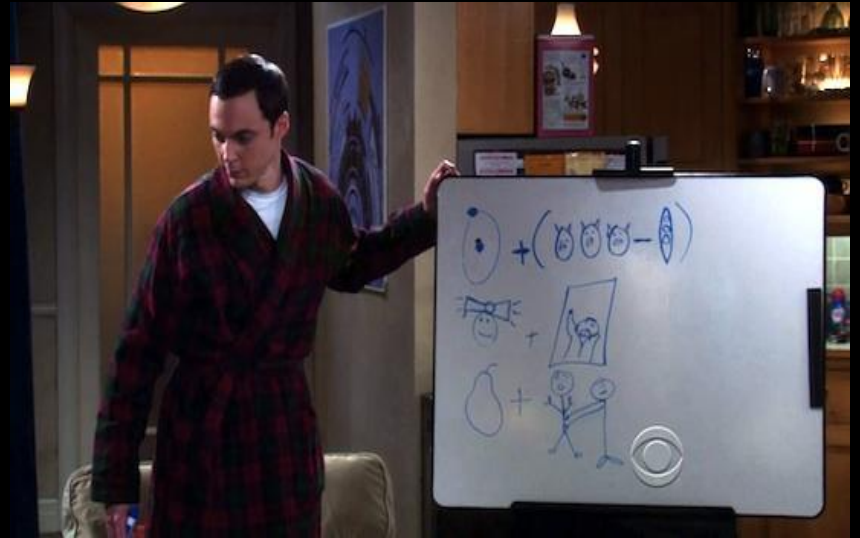
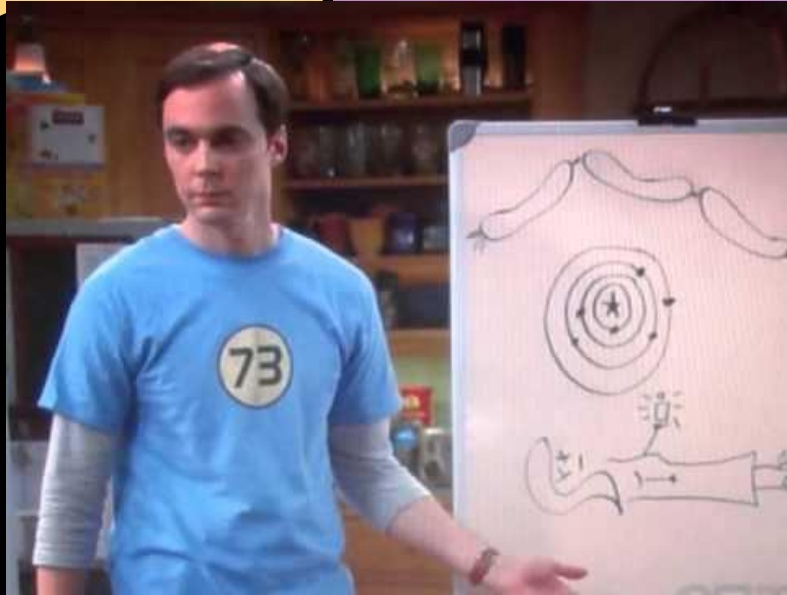




# Games Group

Anne, Gurpreet, Livia, Mike, Natasa,  
Patrick, Patsy, Scott, Sun

# Example: Charades



# Games

- Why use games?
- What makes a good game?
- Types of games
- Examples

# Why use games?

Student-centered learning

Use to: engage, explore, explain, elaborate,  
evaluate

Collaboration, inquiry, applications

# What makes a good game?

Clear learning objectives

Adapt to different schedules, curricula,  
cultures

Fun?????

# Objectives

Focus on Particle Physics

Examples of “Games”

Uses/pro's and con's

Resources

# Computer Games

## Games:

Game collections:

Particle Clicker

Virtual Atom Smasher

LHC Control Room

Baryon & Meson Maker

Velocity Raptor

Agent Higgs

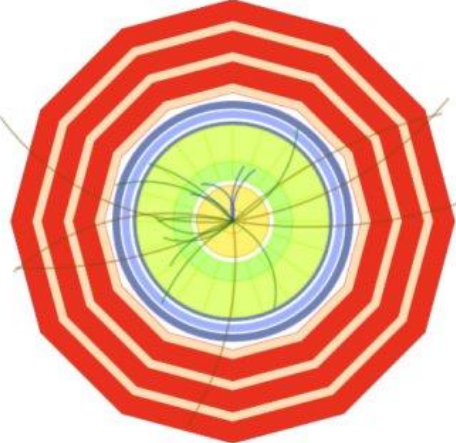
# Computer Games

Particle Clicker | Achievements | Statistics | Saved: 14:21 | GitHub | Social

### Research

- CP violation** Level 23  
CP symmetry is broken!  
Research yields 3 reputation.  
7.2M data
- J/ψ** Level 9  
The J/ψ meson consists of a c and an anti-c quark.  
Research yields 6 reputation.  
47.4k data
- τ lepton** Level 5  
The third generation charged lepton.  
Research yields 33 reputation.  
104.9k data
- ?????  
200.0k data
- ?????  
3.0M data
- ?????  
32.0M data

### Give your lab an awesome name!



**Data**  
26.9M+20.3k

**Reputation**  
268

**Funding**  
JTN 2.0M1.3k

### HR

- Cheap and enthusiastic workforce, they can save you a lot of work.**  
Produce 24 data per second.  
JTN 2.3k
- PhD Students** 9  
They decided to do a PhD. Now they are working hard.  
Produce 96 data per second.  
JTN 17.0k
- Postdocs** 3  
These brilliant minds are here only to serve your needs.  
Produce 75 data per second.  
JTN 154.9k
- Research Fellows** 5  
You pay them a lot. They work a lot.  
Produce 100 data per second.  
JTN 358.7k
- Permanent Staff** 2  
Somebody who gets a permanent position in physics has to be good.  
Produce 9.0k data per second.  
JTN 1.2M

### Upgrades

- Higher Travel Allowances**  
Let your Postdocs go to more conferences.  
Postdocs produce twice as much data per second.  
JTN 750.0k
- Video Meetings**  
Participate but also get work done.  
Fellows produce +4k data per second.  
JTN 600.0k
- ⚡ √s = 1.4 GeV**  
Increased centre-of-mass energy.  
Double the amount of data per click.  
JTN 200
- ⊙ L = 1 × 10<sup>21</sup> cm<sup>-2</sup>s<sup>-1</sup>**  
Increased instantaneous luminosity.  
+3 data per click.  
JTN 800



# Computer Games

## pros



## cons



# Hands-on Games

Quark Workbench

The Universe (Board Game)

Charades

ATLAS Legos

Jig Saw

Rolling for Rutherford





Lego Meson and Baryon

Maker

Elementary Particle Cards

Quarkle

Particle Zoo (plush toys)

	<b>CHARM QUARK</b> CATEGORY: Quarks		<b>THE WHOLE ZOO of 36 particles (WITH antiparticles):</b> Down Quark, Up Quark, Strange Quark, Charm Quark, Bottom Quark, Top Quark, Positron, Muon, Tau, Z Boson, Electron-Neutrino, Muon-Neutrino, Tau-Neutrino, Neutron, Proton, Gluon, Graviton, W Boson, Dark Matter, Electron, Photon, Higgs Boson, Antitau, Antilepton Quark, Antidown Quark, Antistrange Quark, Anticharm Quark, Antibottom Quark, Antitop Quark <b>\$354.99 + shipping</b>
	<b>BOTTOM QUARK</b> CATEGORY: Quarks		
	<b>TOP QUARK</b> CATEGORY: Quarks		
			<b>ANTIPARTICLE 14-pack:</b> Antiproton, Antineutron, Positron, Antimuon, Antitau, Antilepton Quark, Antidown Quark, Antistrange Quark, Anticharm Quark, Antibottom Quark, Antitop Quark <b>\$140.99 + Shipping</b>

# THE SMALLEST THINGS



Up quark.  
Charge  $+2/3$



Down quark.  
Charge  $-1/3$



Strange quark.  
Charge  $-1/3$



Antiup quark.  
Charge  $-2/3$



Antidown quark.  
Charge  $+1/3$



Antistrange quark.  
Charge  $+1/3$

# SLIGHTLY BIGGER THINGS

## Baryons



Neutron



Proton

## Mesons



$k^+$



$k^0$



$k^-$

## Kaons



$\pi^+$



$\pi^0$



$\pi^0$



$\pi^-$

## Pions

# Card Games

12 x  $u$   $d$

6 x  $\bar{u}$   $\bar{d}$

6 x  $s$   $\bar{s}$

4 x  $e$

$u$   $\bar{s}$

$u$   $d$   $d$

$u$   $u$   $d$   $e$

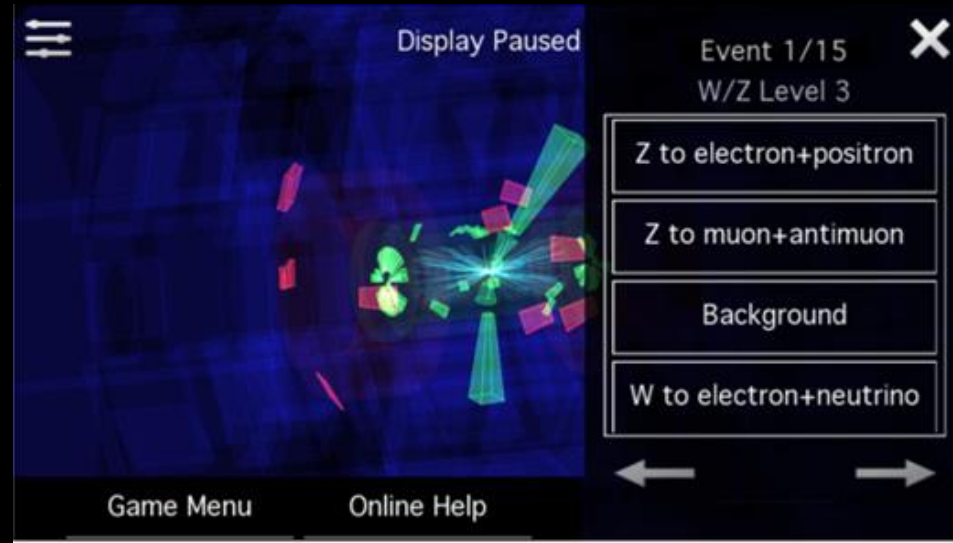
1 qrk = 10

3 qrk = 15

atom = 20

# Smart Device App Games

Agent Higgs  
Particle Zoo  
Tiny Hadron Collider  
LHSee  
Collider



# Introduction/Vocabulary

The Universe Game  
Card Game  
Particle Clicker  
Agent Higgs

<p><b>UP QUARK</b> DISCOVERED: 1969</p> <p>MATTER PARTICLE</p> <p>Mass: <math>2 \text{ MeV}/c^2</math> Electric Charge: <math>+\frac{2}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>+\frac{1}{2}</math> Lifetime: unlimited</p>	<p><b>CHARM QUARK</b> DISCOVERED: 1974</p> <p>MATTER PARTICLE</p> <p>Mass: <math>1300 \text{ MeV}/c^2</math> Electric Charge: <math>+\frac{2}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>+\frac{1}{2}</math> Lifetime: <math>10^{-12} \text{ s}</math></p>	<p><b>TOP QUARK</b> DISCOVERED: 1995</p> <p>MATTER PARTICLE</p> <p>Mass: <math>173 \cdot 10^3 \text{ MeV}/c^2</math> Electric Charge: <math>+\frac{2}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>+\frac{1}{2}</math> Lifetime: <math>6 \cdot 10^{-25} \text{ s}</math></p>
<p><b>DOWN QUARK</b> DISCOVERED: 1969</p> <p>MATTER PARTICLE</p> <p>Mass: <math>5 \text{ MeV}/c^2</math> Electric Charge: <math>-\frac{1}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>-\frac{1}{2}</math> Lifetime: 900 s</p>	<p><b>STRANGE QUARK</b> DISCOVERED: 1969</p> <p>MATTER PARTICLE</p> <p>Mass: <math>100 \text{ MeV}/c^2</math> Electric Charge: <math>-\frac{1}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>-\frac{1}{2}</math> Lifetime: <math>5 \cdot 10^{-8} \text{ s}</math></p>	<p><b>BOTTOM QUARK</b> DISCOVERED: 1977</p> <p>MATTER PARTICLE</p> <p>Mass: <math>4200 \text{ MeV}/c^2</math> Electric Charge: <math>-\frac{1}{3}</math> Strong Charges: blue, red, green Weak Charge: <math>-\frac{1}{2}</math> Lifetime: <math>2 \cdot 10^{-12} \text{ s}</math></p>

# In-depth Games

LHC Control Room  
Virtual Atom Smasher  
LHSee  
Collider App



# Middle School Games

The Universe Game  
CERNland  
Agent Higgs  
Particle Zoo  
LHC Control Center  
Microboy







# Example

## Quark Workbench

**MESON  
WORKBENCH**  
*BUILD MESONS HERE*




**BARYON  
WORKBENCH**  
*BUILD BARYONS HERE*




- Quark pieces must fit together like puzzle pieces: no overlapping.
- There must be no empty spots on the inside of the particle formed:


ALLOWED




ALLOWED

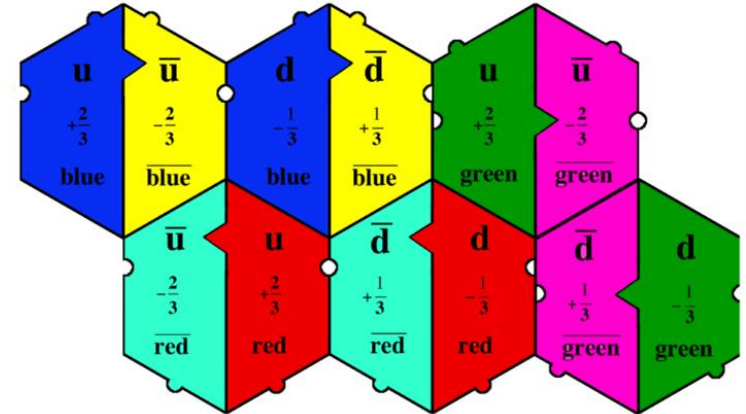


FORBIDDEN



FORBIDDEN





**TEACHER:** Cut out each Quark puzzle piece beforehand. Each will be one color (or anti-color). Discard the white dots. Card stock will make better pieces than plain white paper.

**Recommendation:** Print out many extra copies of this page, to help represent that up and down quarks comprise the particles common to our experience.

**QUARK PIECES pg. 1 of 3**

# Questions and Discussion



resource summary



# APPENDIX

everything after this slide is for reference.

## THE SMALLEST THINGS



Up quark.  
Charge  $+2/3$



Down quark.  
Charge  $-1/3$



Strange quark.  
Charge  $-1/3$



Antiup quark.  
Charge  $-2/3$



Antidown quark.  
Charge  $+1/3$



Antistrange quark.  
Charge  $+1/3$

As science has evolved, we have been able to look deeper and deeper into the heart of matter, finding ever smaller things – first atoms, then protons and neutrons, and finally quarks. These particles combine in different ways to make everything around us. All of the matter we see every day is made of two types of quark: up quarks and down quarks. However, there are 6 types of quark in total, some of which are only seen inside particle accelerators and other physics experiments, like the LHC. The other types of quark form particles which decay – turn into other particles, made of up and down quarks – very quickly.

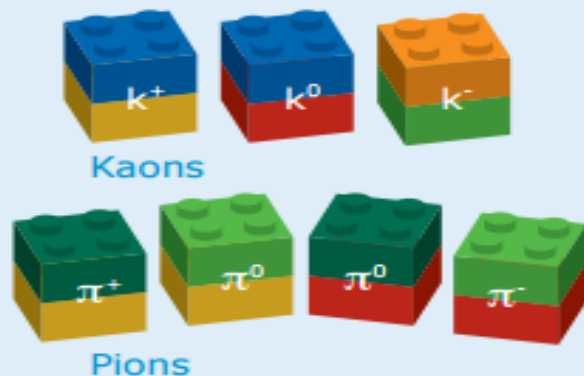
Here are the lightest three quarks: up, down and strange, along with their antiparticles. Antiquarks (represented by a bar above the letter denoting the type of quark) are particles which are the exact opposite of their partner particle: they have the same mass, but they interact with the world in the opposite way to ordinary matter, as they have the opposite electric charge. If antimatter meets with its matter twin, they annihilate, disappearing in a flash of energy. There are also three other types of quark – charm, top and bottom. Charm and bottom can also combine with up, down and strange to make particles, but top is too heavy, decaying into other things before it has time to combine with other quarks.

## SLIGHTLY BIGGER THINGS

### Baryons



### Mesons



### Leptons



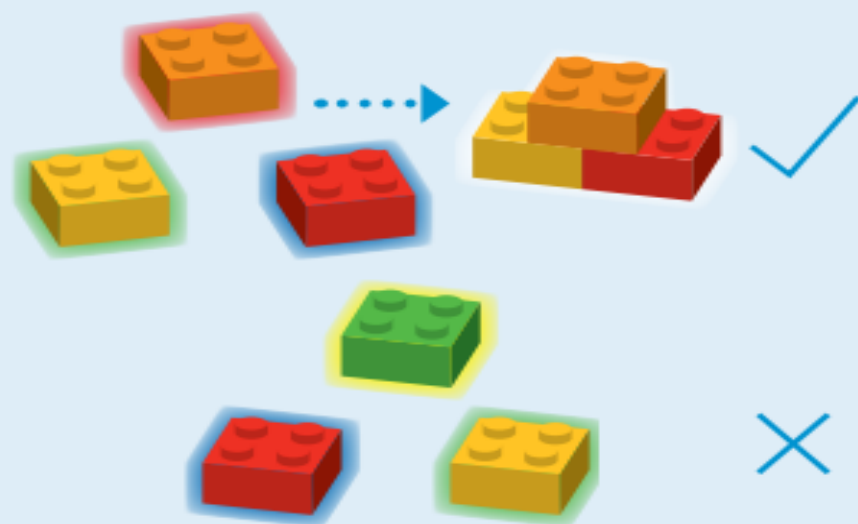
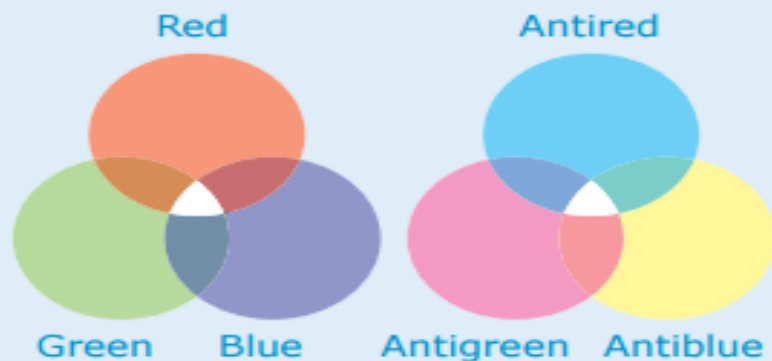
Any particle made of quarks is called a hadron. They come in two types:

**Baryons.** These are made of three quarks. A proton, made of two up quarks and a down quark, is a baryon. Its antiparticle is the antiproton, made up of two antiup quarks and an antidown quark.

**Mesons.** These are made of one quark and one antiquark. The  $\pi^+$  (a positively charged pion) contains an up and an antidown quark. The antiparticle is the opposite of the particle – swapping quarks for antiquarks and vice versa.

There is also a class of particles called leptons. These include the electron, and are not made up of quarks – in fact we don't think they are made up of anything smaller at all. The muon is like a heavy electron, and the neutrino is a ghostly particle which is very light, and doesn't often interact with normal matter.

## RULES FOR COMBINATIONS: COLOUR



Quarks have a strange property called colour - they can be red, green or blue, whilst antiquarks are antired, antigreen or antiblue. Any quark can have any colour, although antiquarks must have anticolours. This doesn't refer to a real colour, it's just a (rather odd) name for a property, like charge or baryon number. Particles must be colour neutral: that is the colours of the quarks must combine to make white. So a particle with three quarks is fine, as one quark will be red, one blue and one green. A particle with a quark and an antiquark is fine too, as the quark can be red, and the antiquark antired. But if you try to make a particle with two quarks and an antiquark, you won't be able to combine the colours to make white, so it isn't a possible real particle.

# INTERACTIONS QUIZ

Charge  
Baryon number  
Lepton number  
Strangeness



Lambda  
Baryon

Proton



Pion



Charge  
Baryon number  
Lepton number  
Strangeness


Charge  
Baryon number  
Lepton number  
Strangeness


What force is it? \_\_\_\_\_

Charge  
Baryon number  
Lepton number  
Strangeness



Pion

Antimuon



Neutrino



Charge  
Baryon number  
Lepton number  
Strangeness

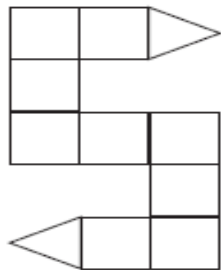
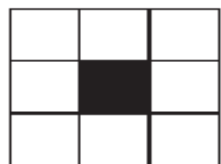
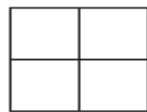
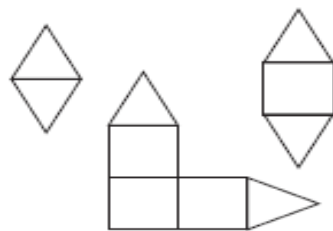

Charge  
Baryon number  
Lepton number  
Strangeness

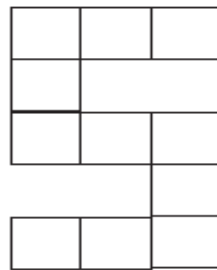
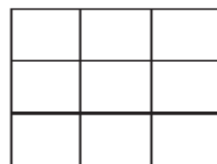
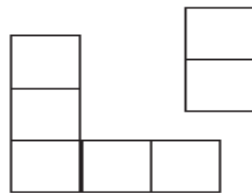

What force is it? \_\_\_\_\_

Here are some interactions between particles. Work out the strangeness, charge and forces involved.

OBSERVED



NOT OBSERVED





# SLIGHTLY BIGGER THINGS

## Baryons



## Mesons



## Leptons



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## THE SMALLEST THINGS



Up quark.  
Charge  $+2/3$



Down quark.  
Charge  $-1/3$



Strange quark.  
Charge  $-1/3$



Antiup quark.  
Charge  $-2/3$



Antidown quark.  
Charge  $+1/3$



Antistrange quark.  
Charge  $+1/3$

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