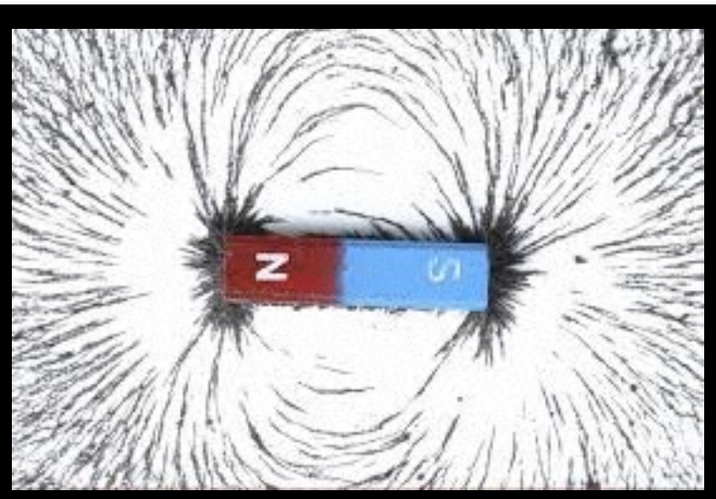
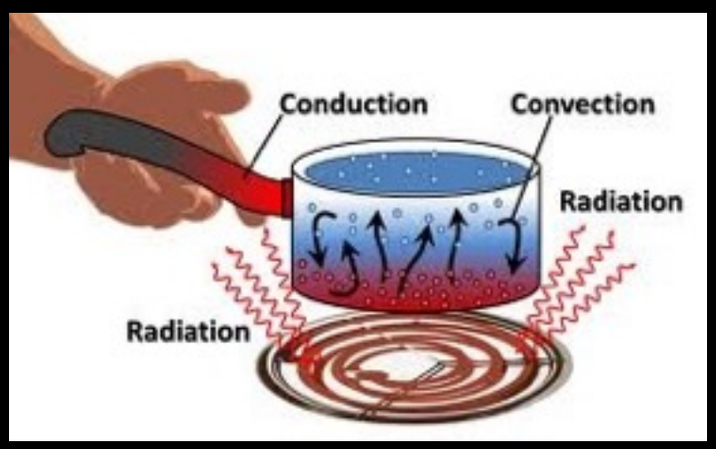
Essential Physics II

英語で物理学の
エッセンス II

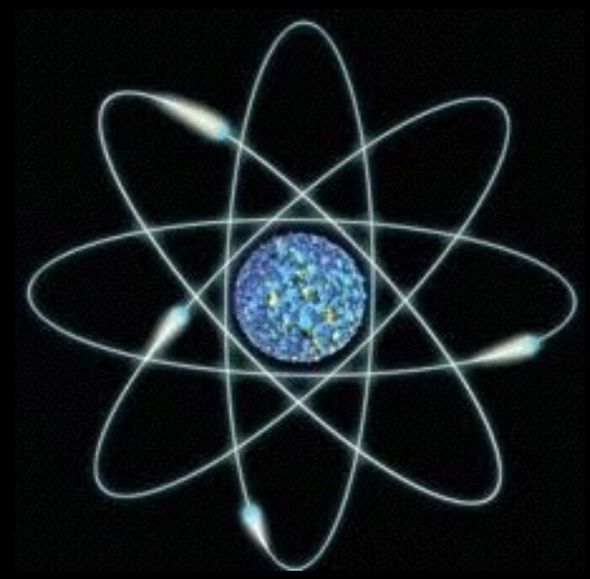
Lecture 14: 18-01-16

Last lecture of EP2!





Congratulations!



This was a hard course.

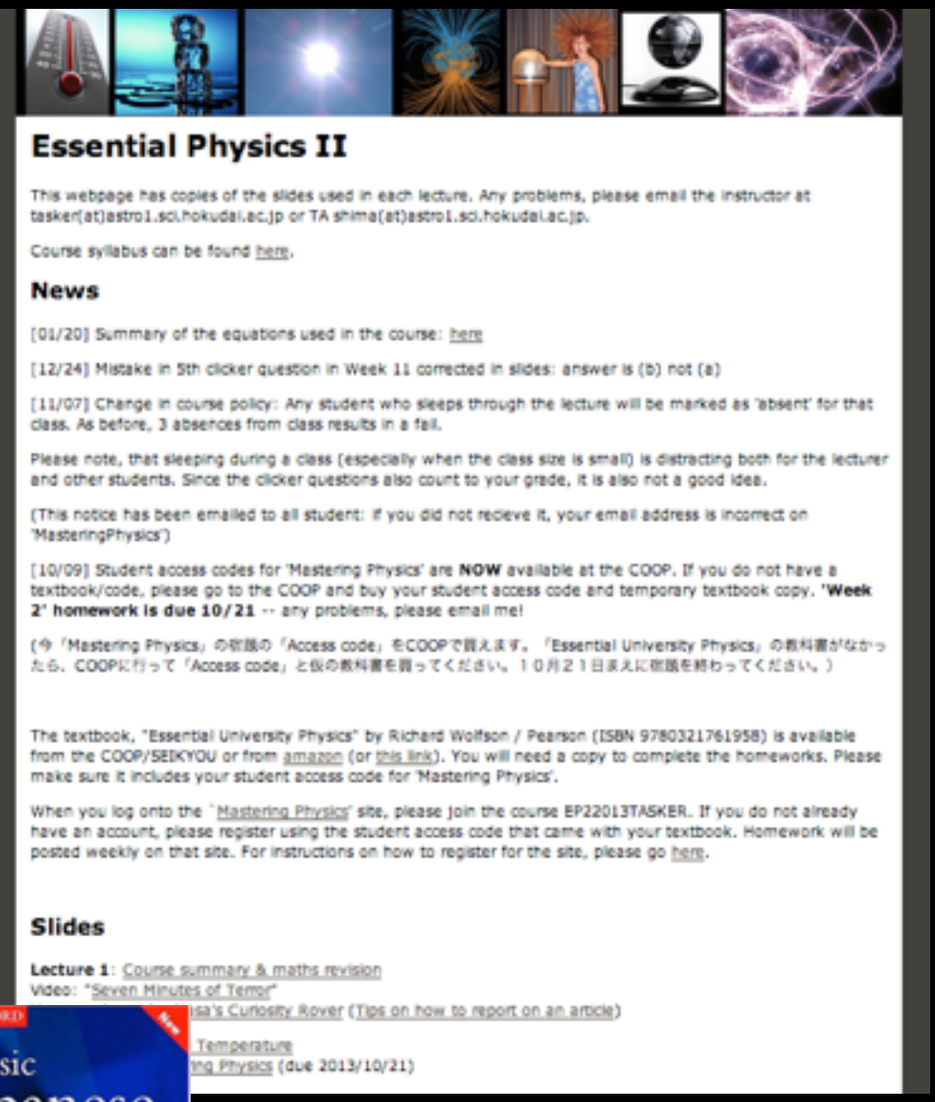
Be proud!

Next week's exam

Next Monday!

All lecture slides on course website:

http://astro3.sci.hokudai.ac.jp/~tasker/teaching/ep2



Essential Physics II

This webpage has copies of the slides used in each lecture. Any problems, please email the instructor at tasker(at)astro1.sci.hokudai.ac.jp or TA shima(at)astro1.sci.hokudai.ac.jp.

Course syllabus can be found here.

News

[01/20] Summary of the equations used in the course: here

[12/24] Mistake in 5th clicker question in Week 11 corrected in slides: answer is (b) not (a)

[11/07] Change in course policy: Any student who sleeps through the lecture will be marked as 'absent' for that class. As before, 3 absences from class results in a fail.

Please note, that sleeping during a class (especially when the class size is small) is distracting both for the lecturer and other students. Since the clicker questions also count to your grade, it is also not a good idea.

(This notice has been emailed to all student: if you did not recieve it, your email address is incorrect on 'MasteringPhysics')

[10/09] Student access codes for 'Mastering Physics' are **NOW** available at the COOP. If you do not have a textbook/code, please go to the COOP and buy your student access code and temporary textbook copy. **'Week 2' homework is due 10/21** -- any problems, please email me!

(今「Mastering Physics」の初回の「Access code」をCOOPで買えます。「Essential University Physics」の教科書がなかったら、COOPに行って「Access code」と仮の教科書を買ってください。１０月２１日までに宿題を終わってください。)

The textbook, "Essential University Physics" by Richard Wolfson / Pearson (ISBN 9780321761958) is available from the COOP/SEIKYOU or from amazon (or this link). You will need a copy to complete the homeworks. Please make sure it includes your student access code for 'Mastering Physics'.

When you log onto the 'Mastering Physics' site, please join the course EP22013TASKER. If you do not already have an account, please register using the student access code that came with your textbook. Homework will be posted weekly on that site. For instructions on how to register for the site, please go here.

Slides

Lecture 1: Course summary & maths revision
Video: "Seven Minutes of Terror"
...sa's Curiosity Rover (Tips on how to report on an article)
... Temperature
...ing Physics (due 2013/10/21)

Remember your calculator!

Dictionary is OK!
(Phone is not)

SHOW ALL WORKING!

Next week's exam

10 multiple choice questions

(A) .....

(B) .....

(C) .....

(D) .....

- 3 thermodynamics
- 5 electromagnetism
- 2 modern physics

Homework	40 %
Attendance / clickers	20 %
Exam	40 %
Total	100 %

- Pass > 60 %

Next week's exam

This is a question.

(A) .....

(B) .....

(C) .....

(D) .....

$$B = \frac{F}{Il\sin\theta} = \frac{F}{l}\frac{1}{I\sin\theta}$$

$$= \frac{0.31\mathrm{N/m}}{(15A)\sin(25°)} = 49\mathrm{mT}$$

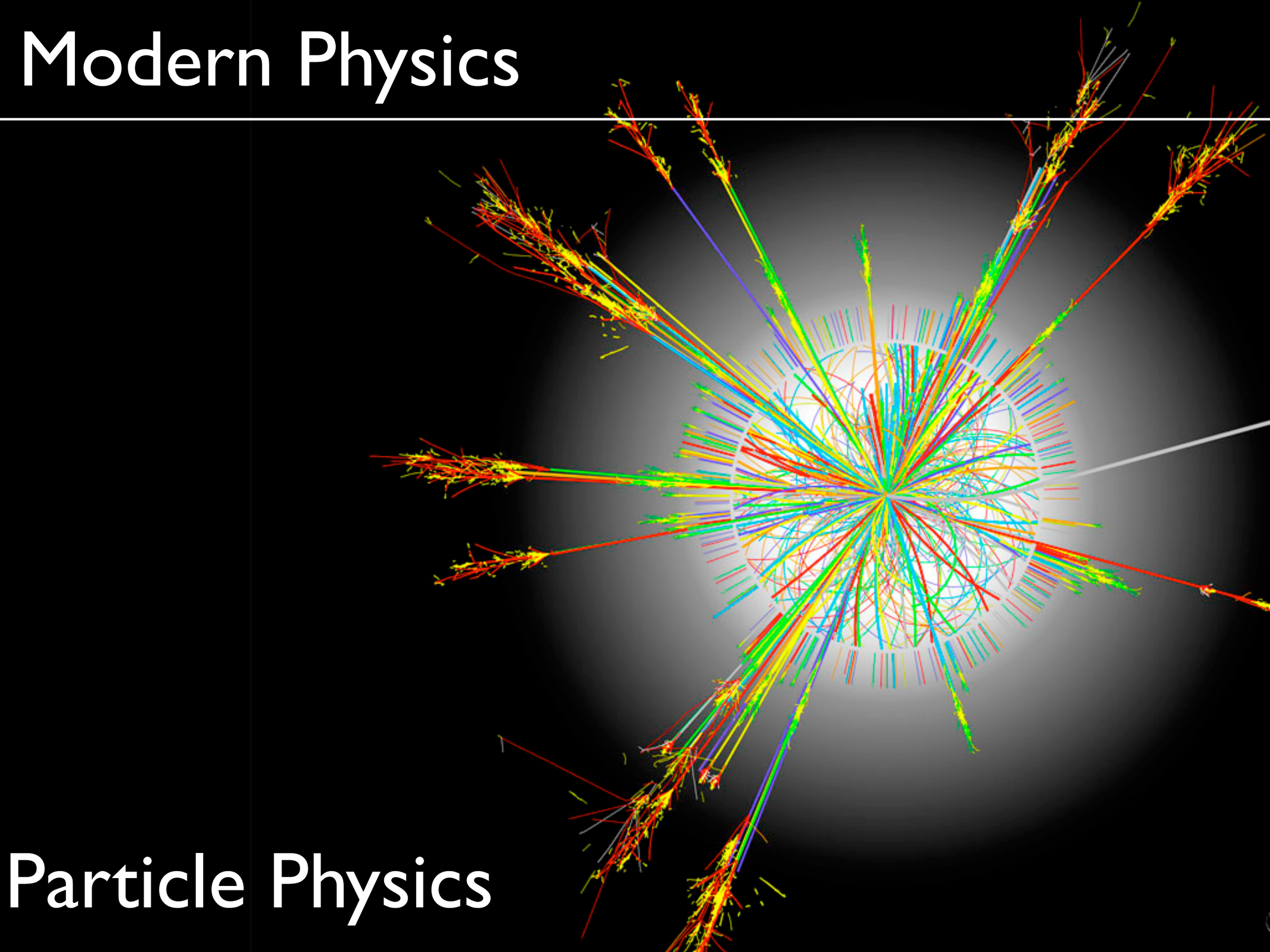
If this is wrong....

But parts of this are right...

You will get marks!

SHOW YOUR WORKING!

Modern Physics

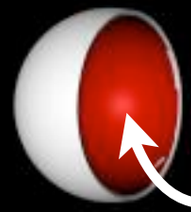


Particle Physics

What are we made from?

In 1924, Physicists thought the Universe was made from:

4 elementary particles



Cannot be divided.

Not made from smaller particles.

Proton

Neutron

Electron ⟷ Positron

Neutrino

charge (q) = 0

Electron antiparticle

Same mass

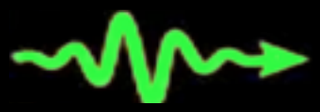
Opposite charge

Every elementary particle has an antiparticle

What are we made from?

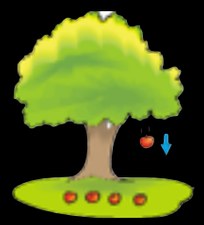
In 1924, Physicists thought the Universe was made from:

Electromagnetic radiation

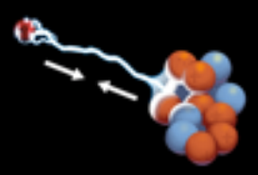


Photon

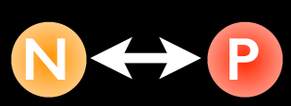
4 Forces



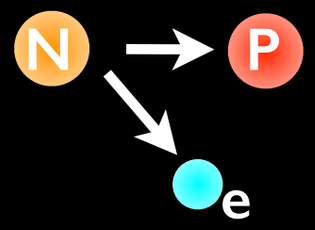
Gravity



Electromagnetic



Nuclear

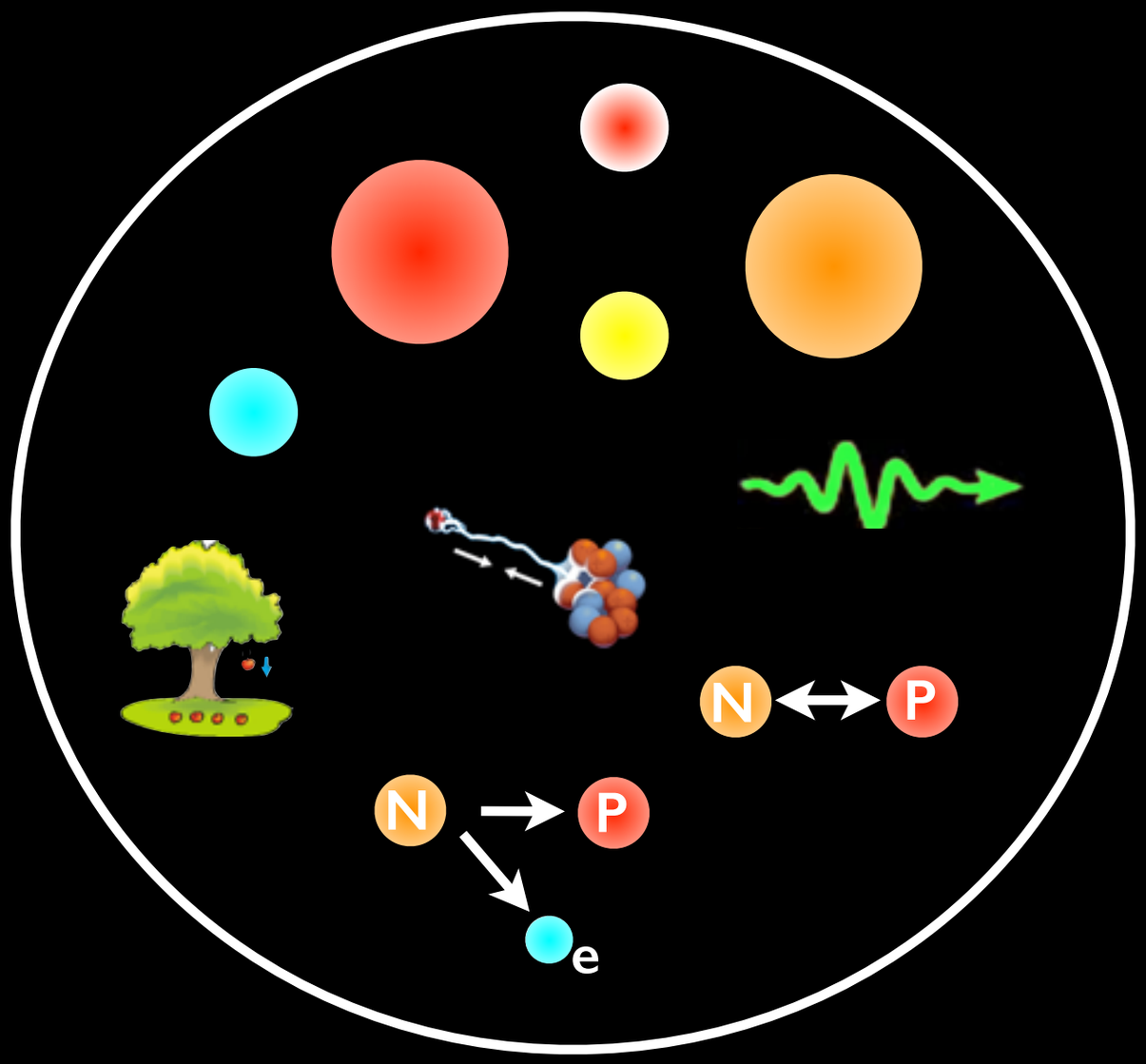


Weak

radioactive decay

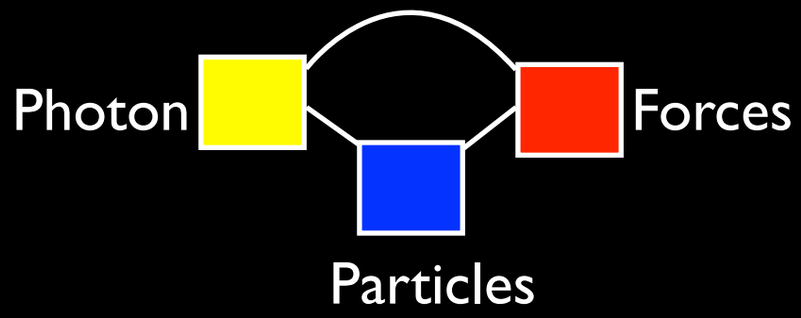
What are we made from?

In 1924, Physicists thought the Universe was made from:



2 questions:

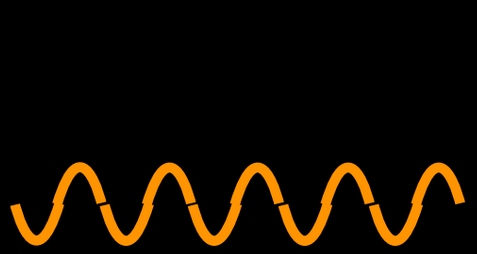
1 How is it connected?



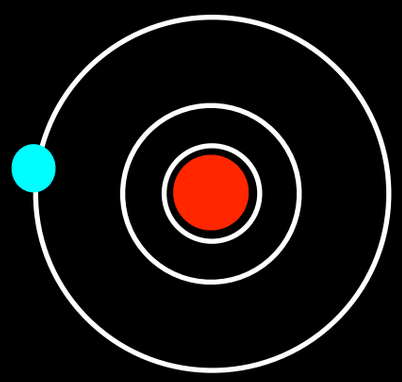
2 Is this everything?

Forces as particles

Lecture 12: Interaction between EM field and matter:

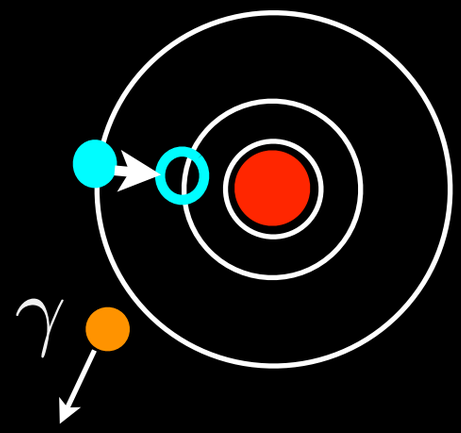


EM field



Matter

Quantum theory



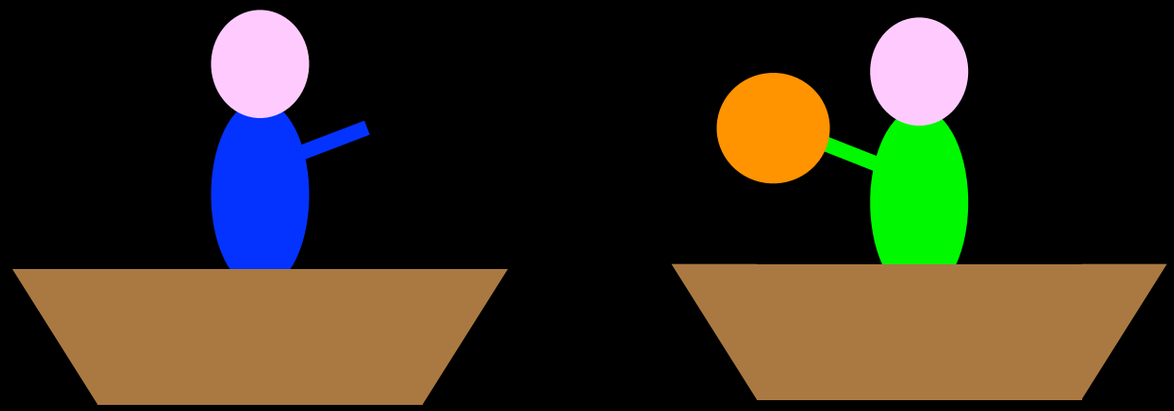
EM field made from *photon particles*.

But photons can also explain the electromagnetic *force*.

Quantum electrodynamics

Forces as particles

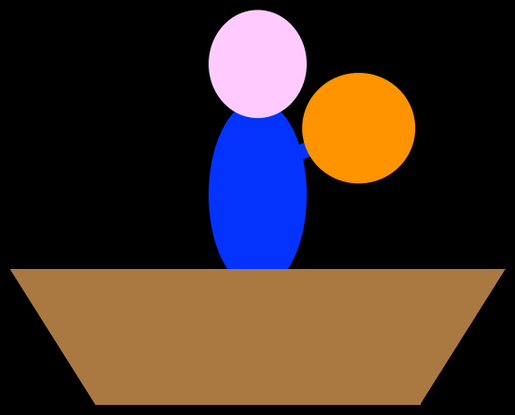
How do photons create a force?

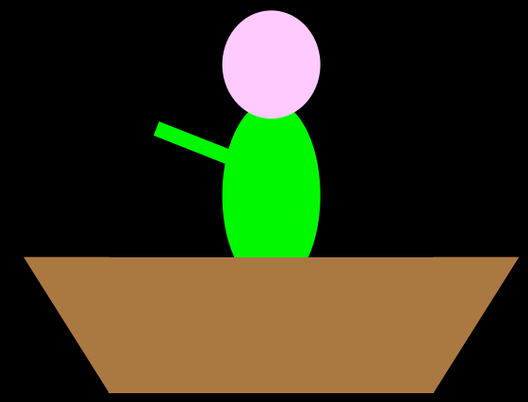


A ball is thrown between two boats.

Forces as particles

How do photons create a force?

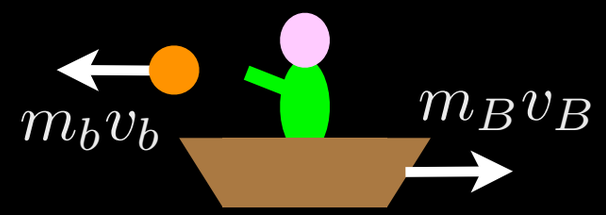




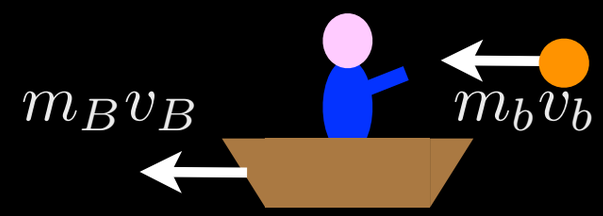
A ball is thrown between two boats.

Conservation of momentum:

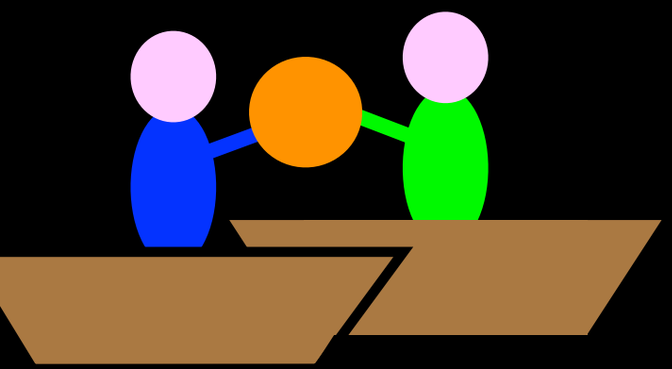
As green man throws the ball, he moves to the right



As blue man catches the ball, he moves to the left



➡ The boats feel a repulsive force

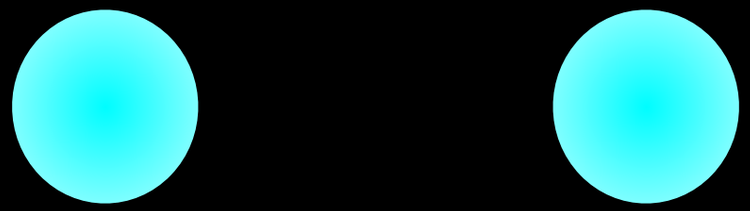


Men fight for the ball

➡ Boats feel an attractive force

Forces as particles

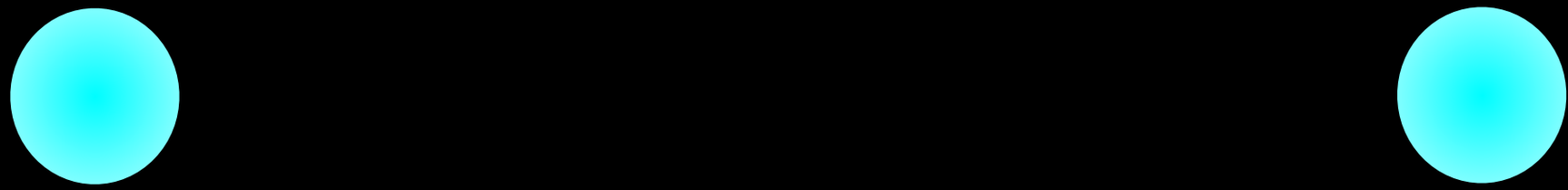
How do photons create a force?



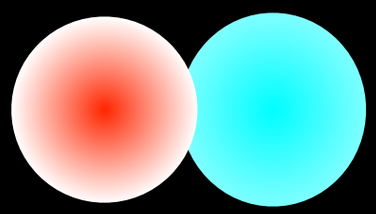
2 electrons are repelled (Coulomb force) by exchanging a photon

Forces as particles

How do photons create a force?



2 electrons are repelled (Coulomb force) by exchanging a photon



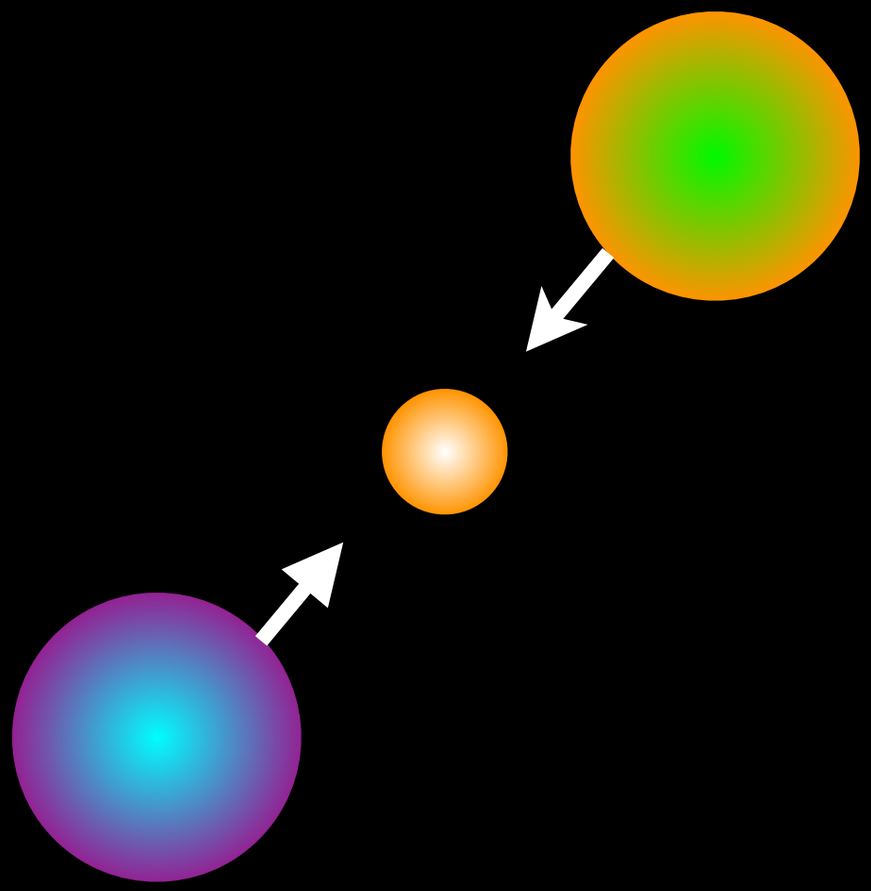
The electron and positron are attracted (Coulomb force) by exchanging a photon

Quantum description of Coulomb force.

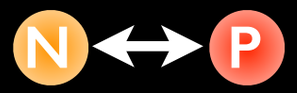
Quantum electrodynamics (QED)

Forces as particles

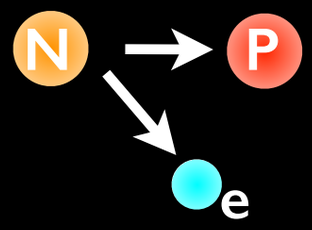
How about other forces?



Gravity



Nuclear



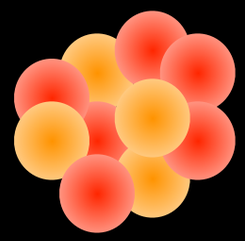
radioactive decay

Weak

Are all forces transmitted by particles?

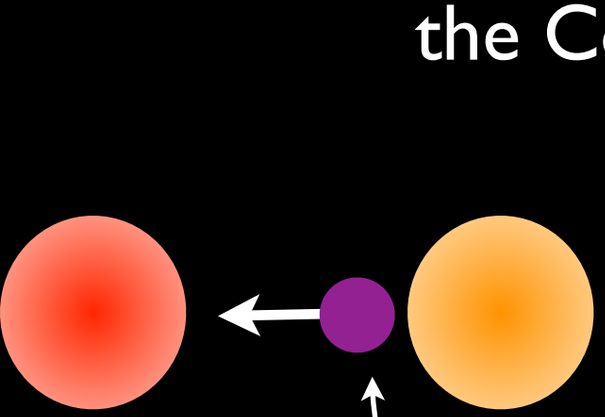
Forces as particles

How about other forces?



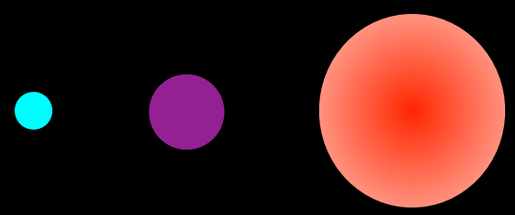
The *nuclear force* holds protons and neutrons together in an atom's nucleus

Without the nuclear force, the protons would be repelled by the Coulomb force.



In 1935, Physicist Hideki Yukawa (日本人) predicted the particle for the nuclear force.

he called it a 'meson'



$$m_e < m_{\text{meson}} < m_p$$

Greek word for 'intermediate'

because he predicted the mass to be between the proton and electron:

But does this particle exist?

Forces as particles

Hunting particles: How do you look for a particle?

Cosmic radiation:

High energy particles from space.

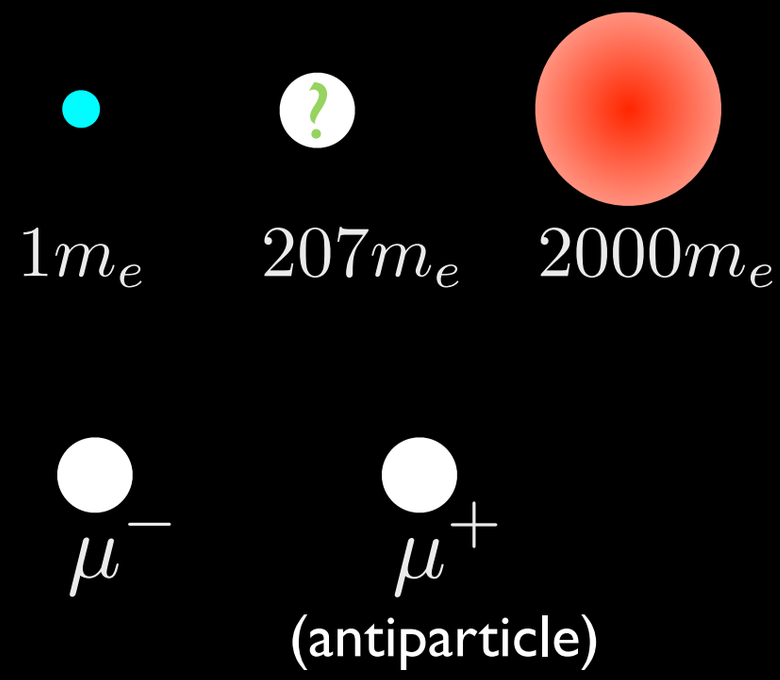
1930s: only source of high energy particles
(Now, we can use particle accelerators: 加速器)

American Physicist Carl Anderson
found particle with mass $207m_e$

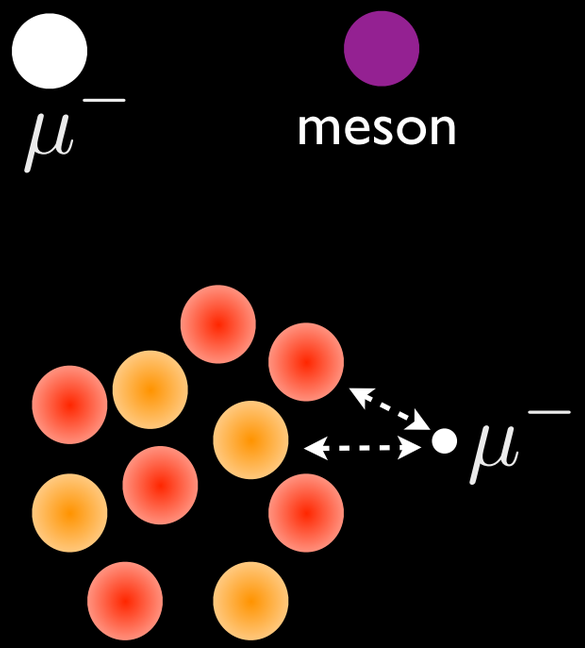
This particle is named the muon.

2 types of muon were found:

Could this muon = the meson?



Forces as particles



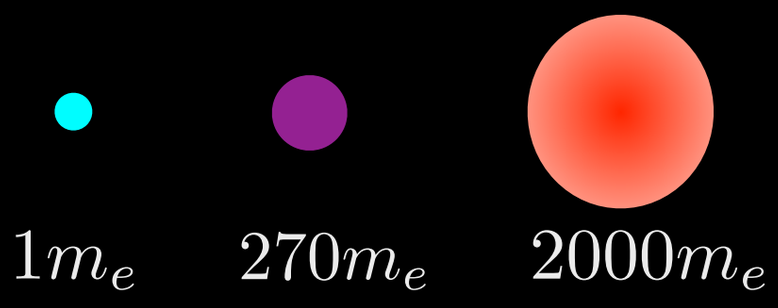
The muon's mass $\simeq$ predicted meson mass

But the muon only interacted *weakly* with the nucleons (protons and neutrons)

➡ Cannot transmit nuclear force.

The muon is not the meson.

In 1947, Yukawa's meson was discovered (also in cosmic radiation).



This meson was named a pion

3 types of pions: π^+ π^- π^0

positive negative neutral

The name 'meson' now means a particle with particular properties.

A pion is a type of meson.

Can we put all particles into groups?

Forces as particles

Quiz

Put these particles in order of mass (lightest to heaviest):

(A) electron, pion, muon, proton

(B) pion, electron, muon, proton

(C) electron, muon, proton, pion

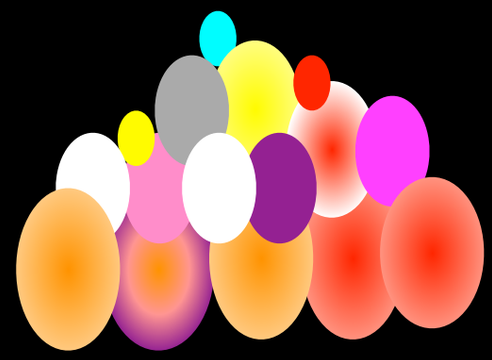
(D) electron, muon, pion, proton

(E) pion, electron, proton, muon

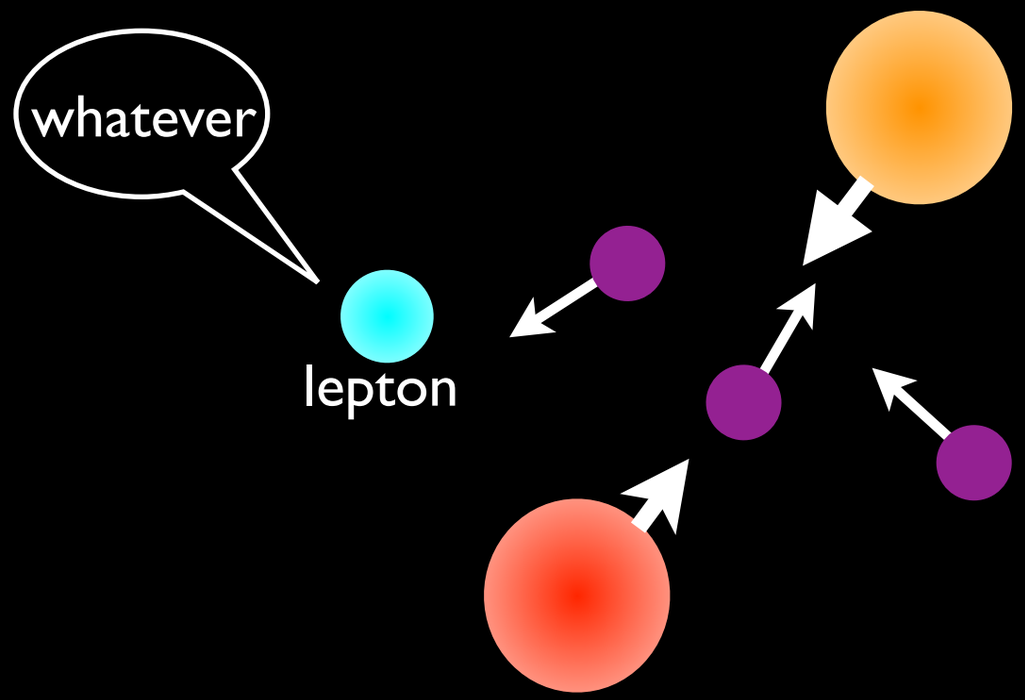
Classifying Particles

By 1980, over 100 particles had been discovered.

Could they be sorted into different particle types?



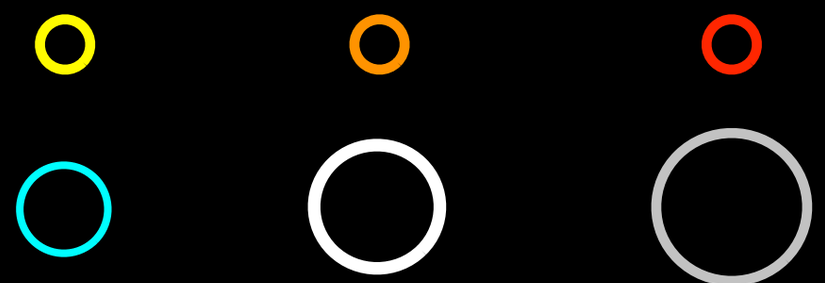
Type 1: Leptons



Leptons don't feel the nuclear force

e	μ	τ
electron	muon	tau
ν_e	ν_μ	ν_τ
electron neutrino	muon neutrino	tau neutrino

anti-particles



Spin: $\frac{1}{2}$

Wait! What is spin?

Spin

Every particle has intrinsic properties:

Always the same
Does not change

e.g. mass (m)

charge (q)

spin (s)

Quantum mechanical property

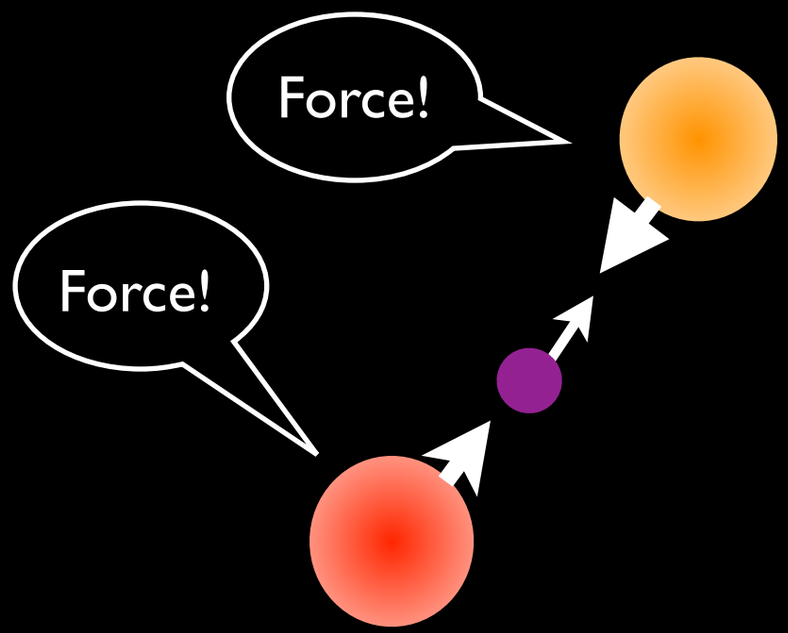
(not used in classical mechanics)

Particles can have spin: $\frac{1}{2}$ ➡ Fermions ⬅ leptons are fermions

1 ➡ Bosons

Classifying Particles

Type II: Hadrons



Hadrons DO feel the nuclear force

2 types of hadrons

Mesons

spin: 1 ➡ Bosons

includes...

pions π^+ π^- π^0

η eta ρ rho K kaon .... and others

Baryons

spin: $\frac{1}{2}$ ➡ Fermions

(**much** higher mass than leptons)

includes...

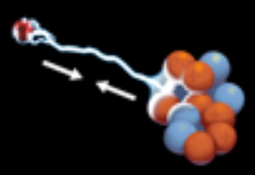
proton neutron Λ lambda Σ sigma

.... and others

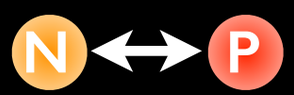
Classifying Particles

Type III: Gauge Bosons: Force carriers

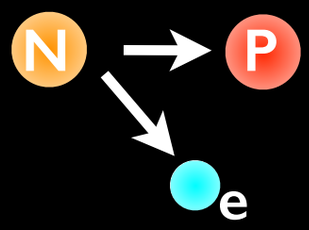
bosons



Electromagnetic (QED) Photon (γ) Spin 1



Nuclear (strong) force Gluon (g) Spin 1



Weak force W and Z bosons W^+ W^- Z Spin 1

Gravity ????? Spin 1

WAIT! Isn't the carrier for a nuclear force a pion?! π^+

Classifying Particles

Quiz

Which is TRUE?

(A) Mesons are bosons, baryons are fermions

Fermions spin $\frac{1}{2}$

Bosons spin 1

(B) Mesons are fermions, baryons are bosons

(C) Mesons are fermions, baryons are fermions

(D) Mesons are bosons, baryons are bosons

Classifying Particles

Leptons

electron muon tau

electron neutrino muon neutrino tau neutrino

anti-particles

Hadrons

Mesons

pions π^+ π^- π^0

η eta ρ rho K kaon

.... and others

Baryons

proton neutron Λ lambda

Σ sigma .... and others

Gauge bosons

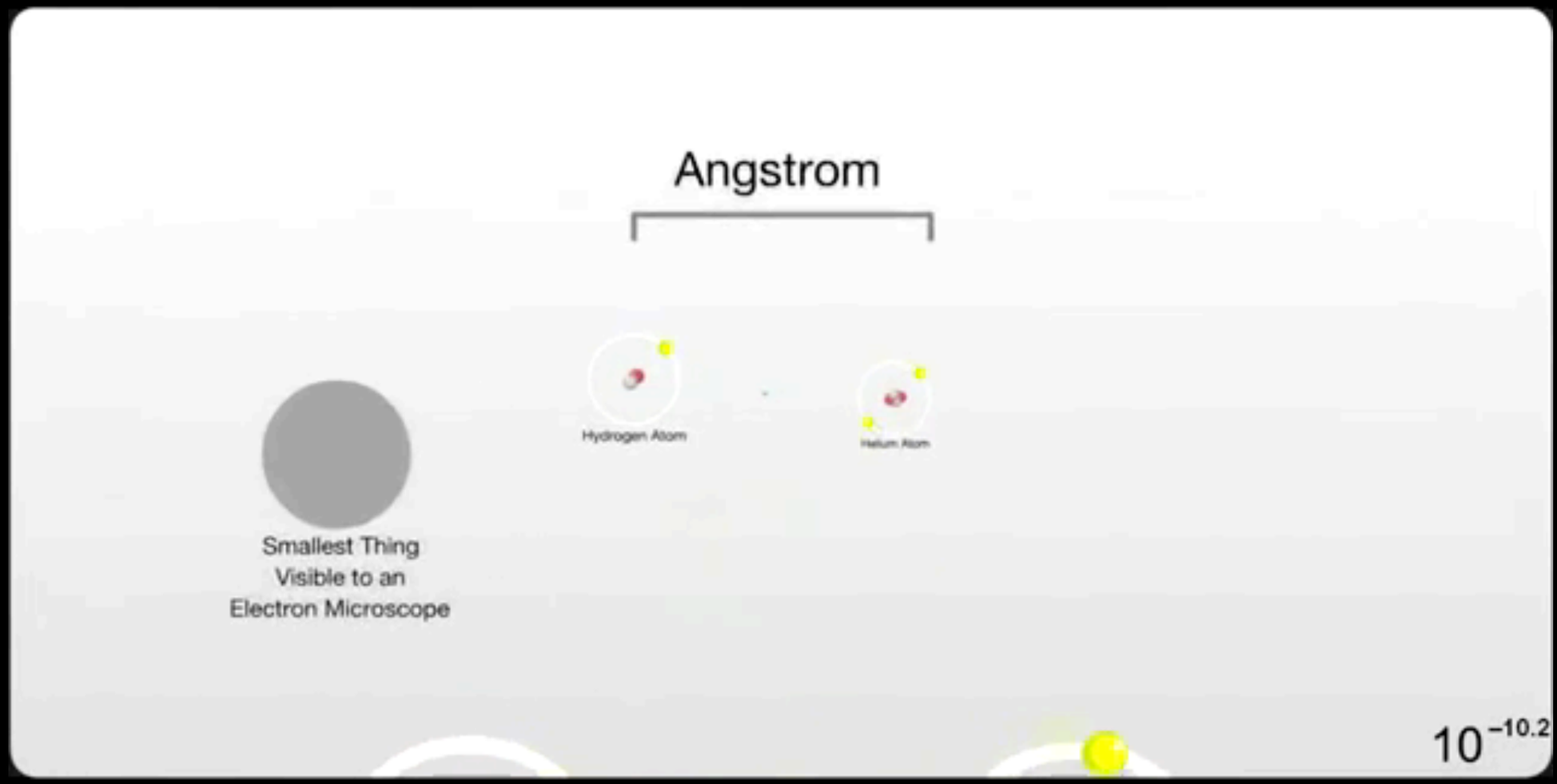
photon gluon

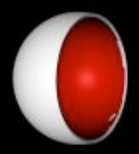
W^+ W^- W bosons Z Z boson

Many many particles!

Are these really elementary?

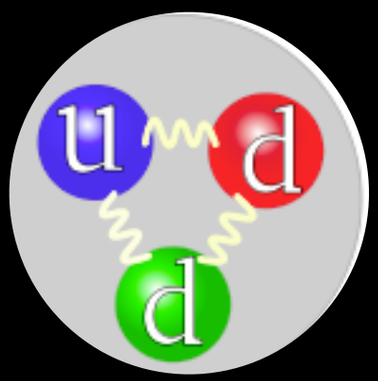
Quarks



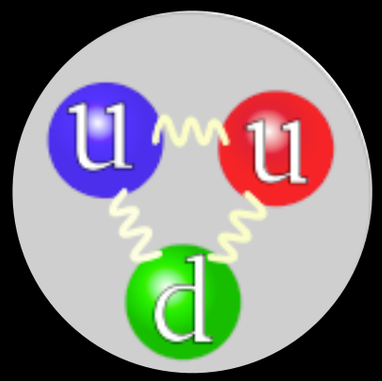


Are hadrons really elementary? No!

They are made from quarks



neutron



proton

Quarks

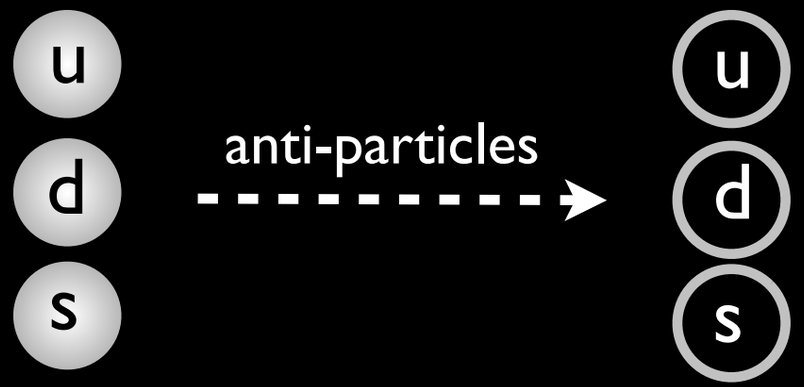
In 1964, physicists Murray Gell-Mann & George Zweig predicted quarks.

They thought hadrons were made from 3 quarks:

up quark

down quark

strange quark



Quarks carry fractional charge!

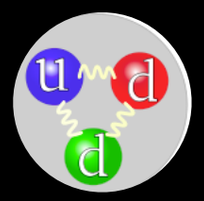
u $+\frac{2}{3}e$ spin $\frac{1}{2}$

d $-\frac{1}{3}e$ spin $\frac{1}{2}$

s $-\frac{1}{3}e$ spin $\frac{1}{2}$

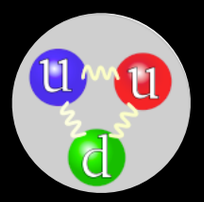
Baryons

3 quarks : spin (1) $\frac{1}{2}$



neutron
(u, d, d)

$q = 0$



proton
(u,u,d)

$q = 1$

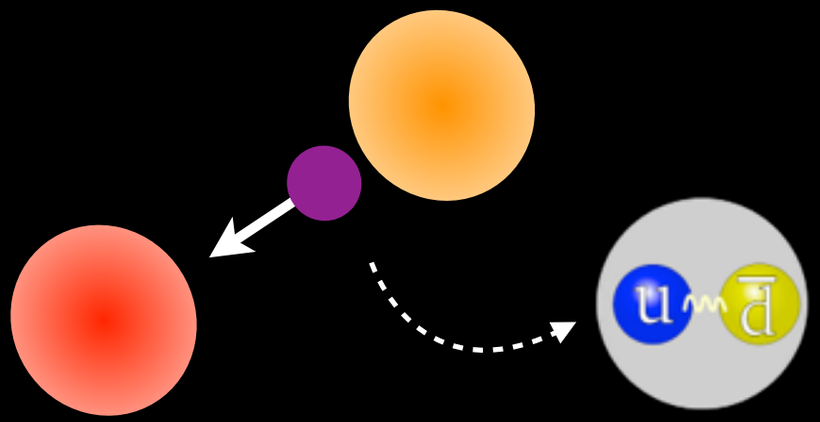
Mesons

quark + anti-quark: spin 1

pion
(u, anti-down)

Quarks

The real nuclear force

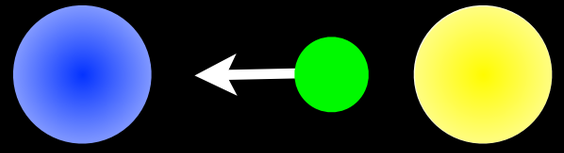


Pions transmit the nuclear force,

but they are made from quarks

The real force is the strong force:

Holds quarks together.



transmitted by the gluon

3 more quarks were later found:

1974, the charm quark was discovered

1977, the bottom quark was discovered

1995, the top quark was discovered

Quarks

Quiz

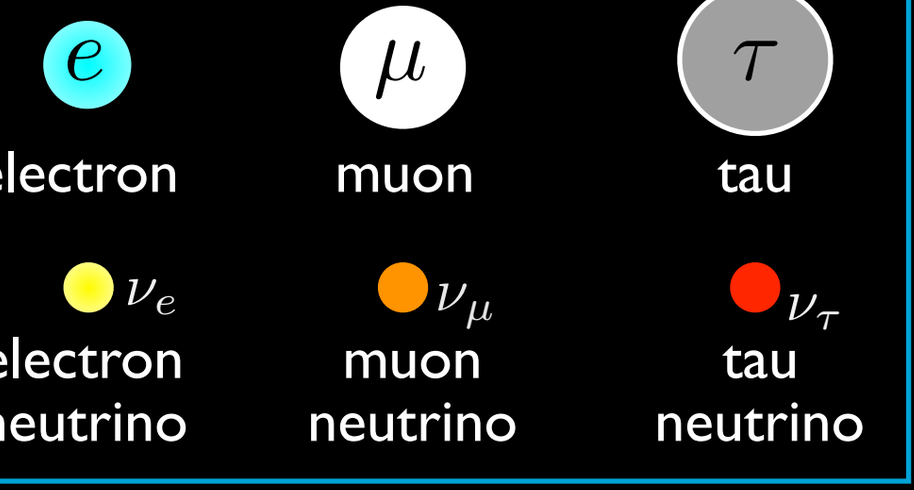
Which contains quarks?

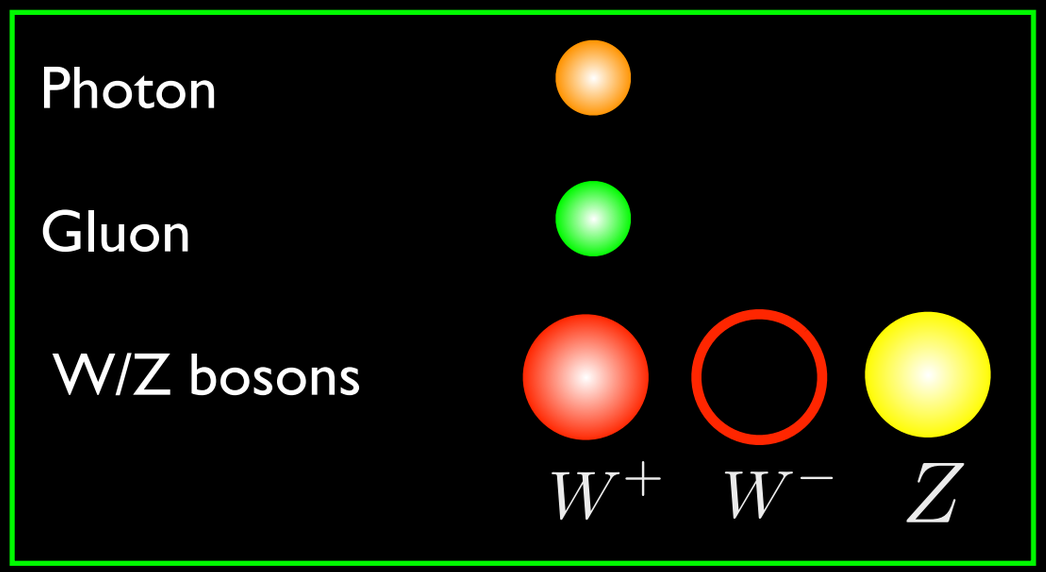
(A) Baryons

(B) Leptons

(C) Gauge Bosons

e.g.





The Standard Model

The discovery of quarks makes sorting particles much simpler!

				Gauge bosons
Quarks	u up	c charm	t top	γ photon
	d down	s strange	b bottom	Z Z boson
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson
	e electron	μ muon	τ tau	g gluon
				H Higgs boson

These particles are called

'The Standard Model'

Gives particles mass

Discovered July 2012

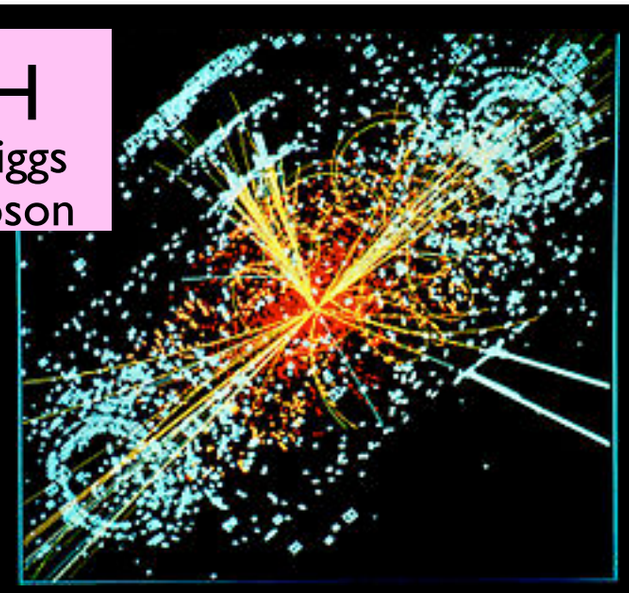
(+ anti-particles)

Are we done?

In 2012, the Higgs boson was discovered.

This was the LAST particle predicted by the Standard Model.

So.... does this explain all Particle Physics?



Professor Naoyuki Haba (Hokkaido University)

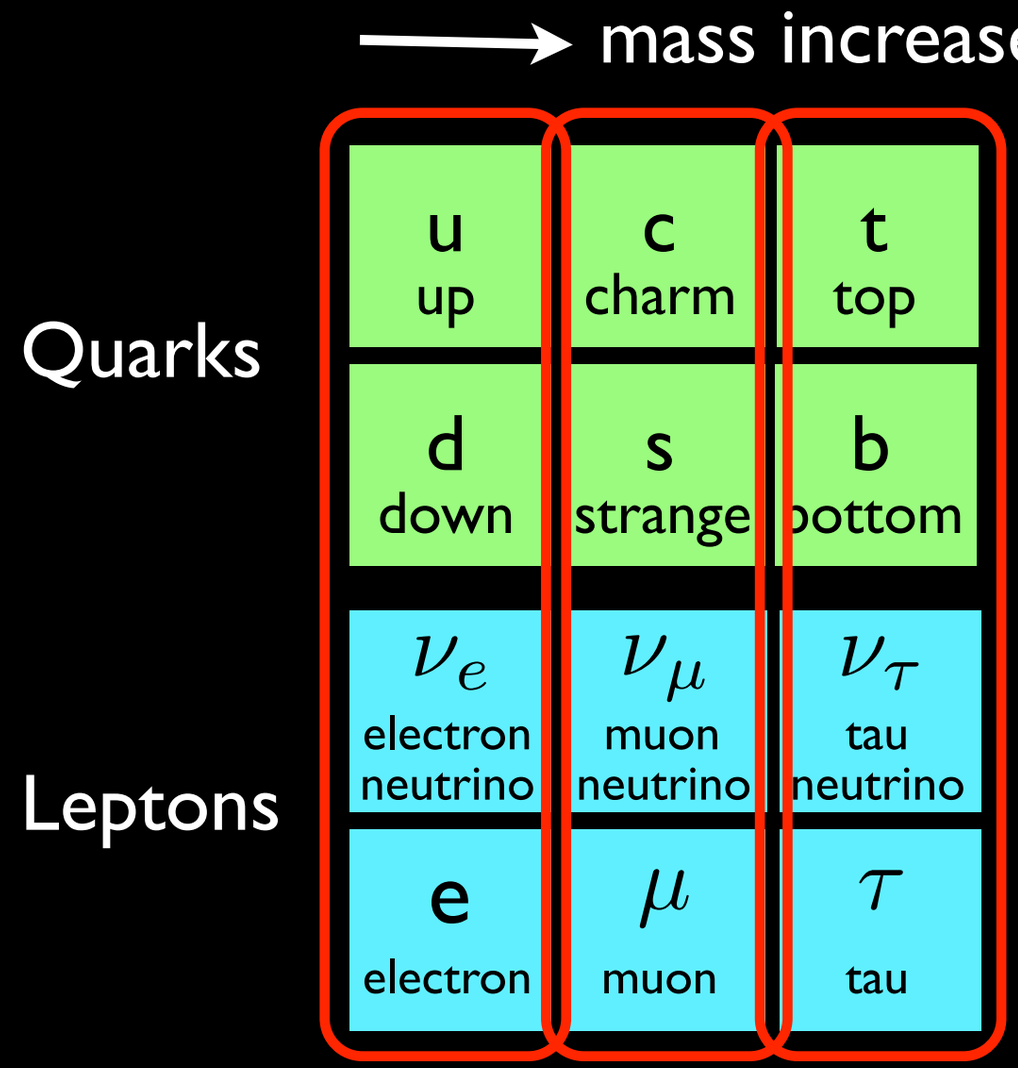
"No!"

The Standard Model leaves questions....

Are we done?

Problem 1:

3 groups of particles: "3 generations"



Difference between generations is mass

Why 3?

Why not 4?

or 2?

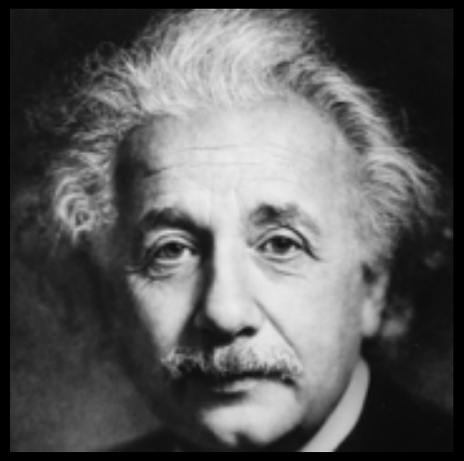
The Standard Model cannot explain this.

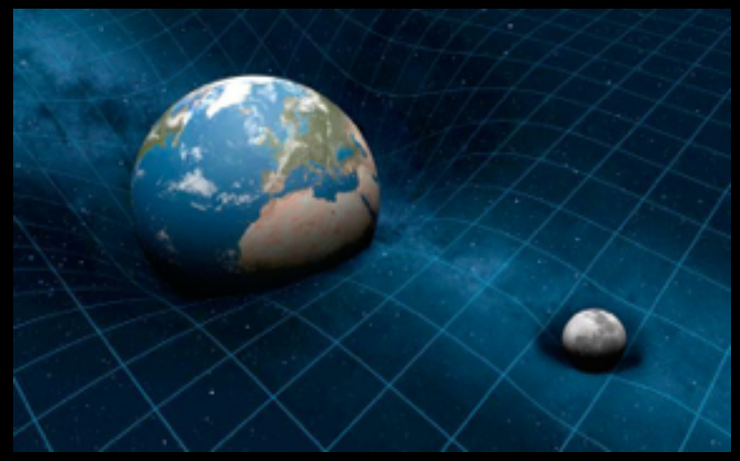
Are we done?

Problem 2:

Gauge bosons

γ photon	Electromagnetic force
Z Z boson	Weak force
W W boson	
g gluon	Strong force
G? Graviton	What about gravity? Is there a 'graviton'?



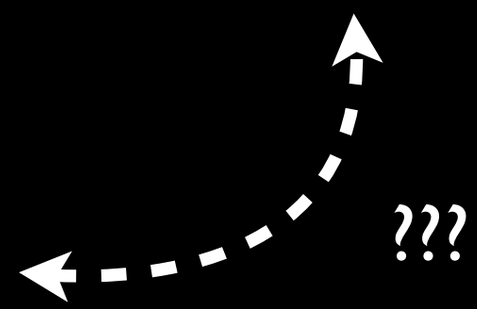


Einstein's theory of General Relativity

Amazingly accurate for gravity

But uses bending of space-time

Not quantum!



Are we done?

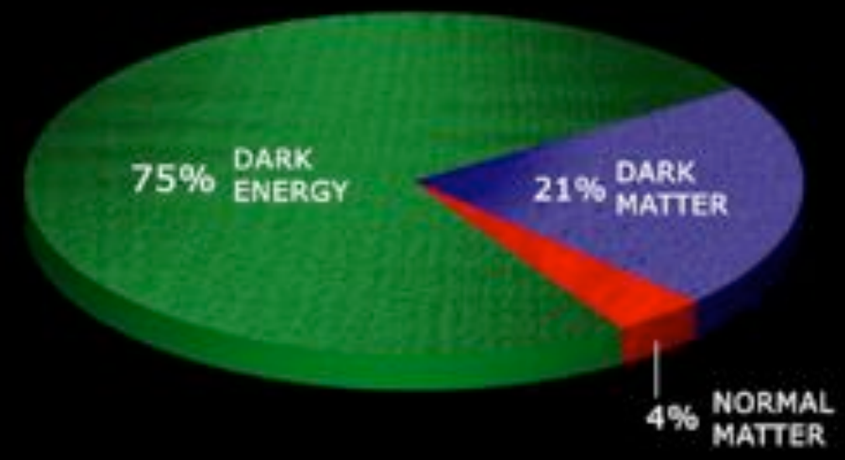
Problem 3:

What is dark matter?

Only ~4% of the Universe is made from atoms

~ 75% is energy

~ 21% is ..... something else??



The Standard Model has no possible particle for dark matter!

The Standard Model

Quiz

What do you need to build a "simple" Universe?

(A) protons, neutrons, electrons

(B) protons, electrons, muons

(C) electrons, pions, Higgs

(D) pions, mesons, muons

The Standard Model

Quiz

At the start of the 20th Century (~1930s), where did physicists find new particles?

(A) particle accelerators

(B) from the sun (northern lights)

(C) cosmic rays

(D) deep underground

The Standard Model

Quiz

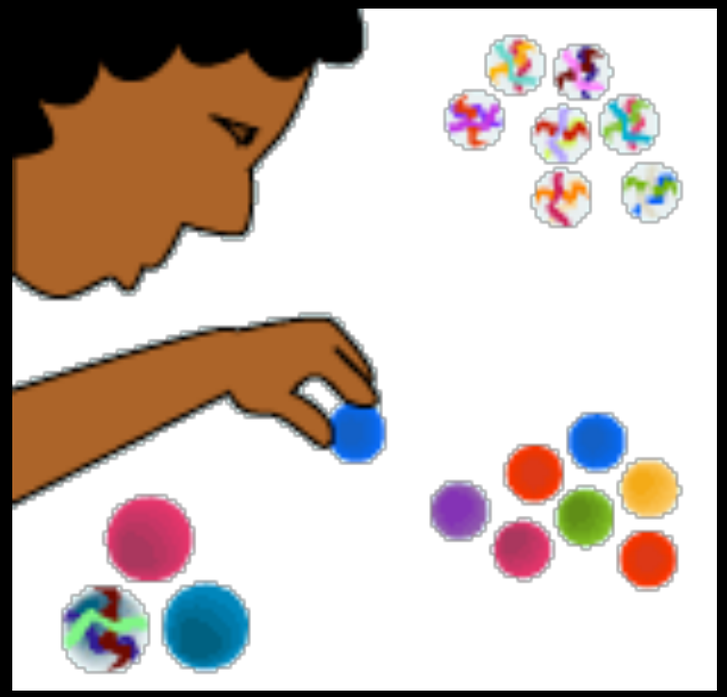
What properties did physicist use to classify (sort) the particle ‘zoo’?

(A) mass, size, colour, charge

(B) charge, shape, spin, density

(C) lifetime, charge, colour, density

(D) mass, charge, spin, lifetime



The Standard Model

Quiz

How was the particle ‘zoo’ simplified (less elementary particles)?

(A) Electrons actually not particles

(B) Many particles were found to be the same

(C) Quarks predicted

(D) Many particles actually molecules

The Standard Model

Quiz

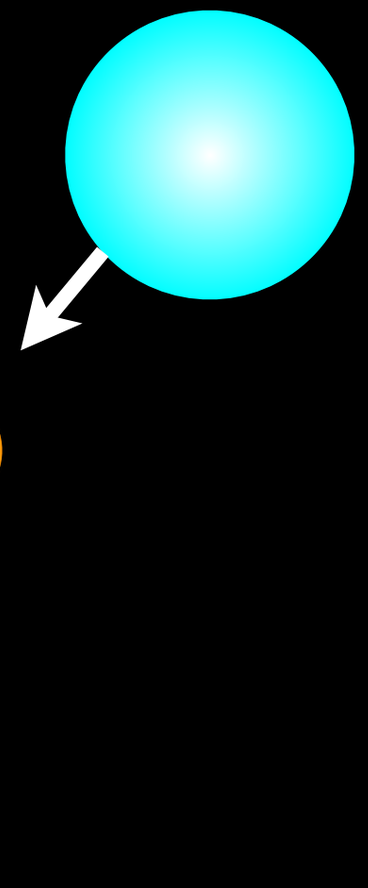
What is the force carrier for the electromagnetic force?

(A) meson

(B) photon

(C) gluon

(D) W and Z bosons



The Standard Model

Quiz

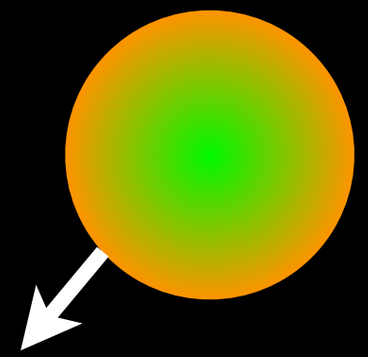
What is the elementary force carrier for the strong force?

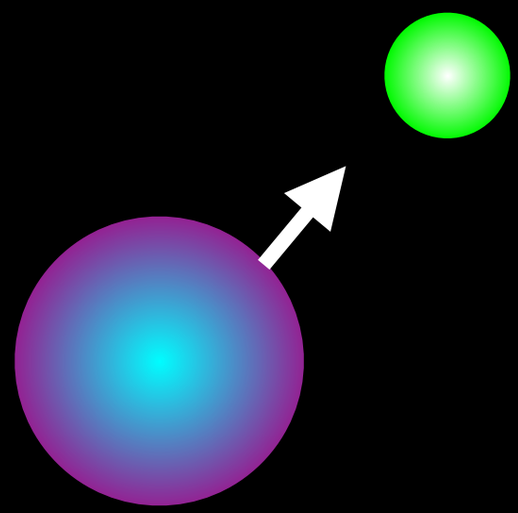
(A) meson

(B) pion

(C) gluon

(D) W and Z bosons





The Standard Model

Quiz

What was the "Holy Grail" of particle physics?

(A) Dark matter

(B) The graviton

(C) The gluon

(D) The Higgs boson

Good luck!

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