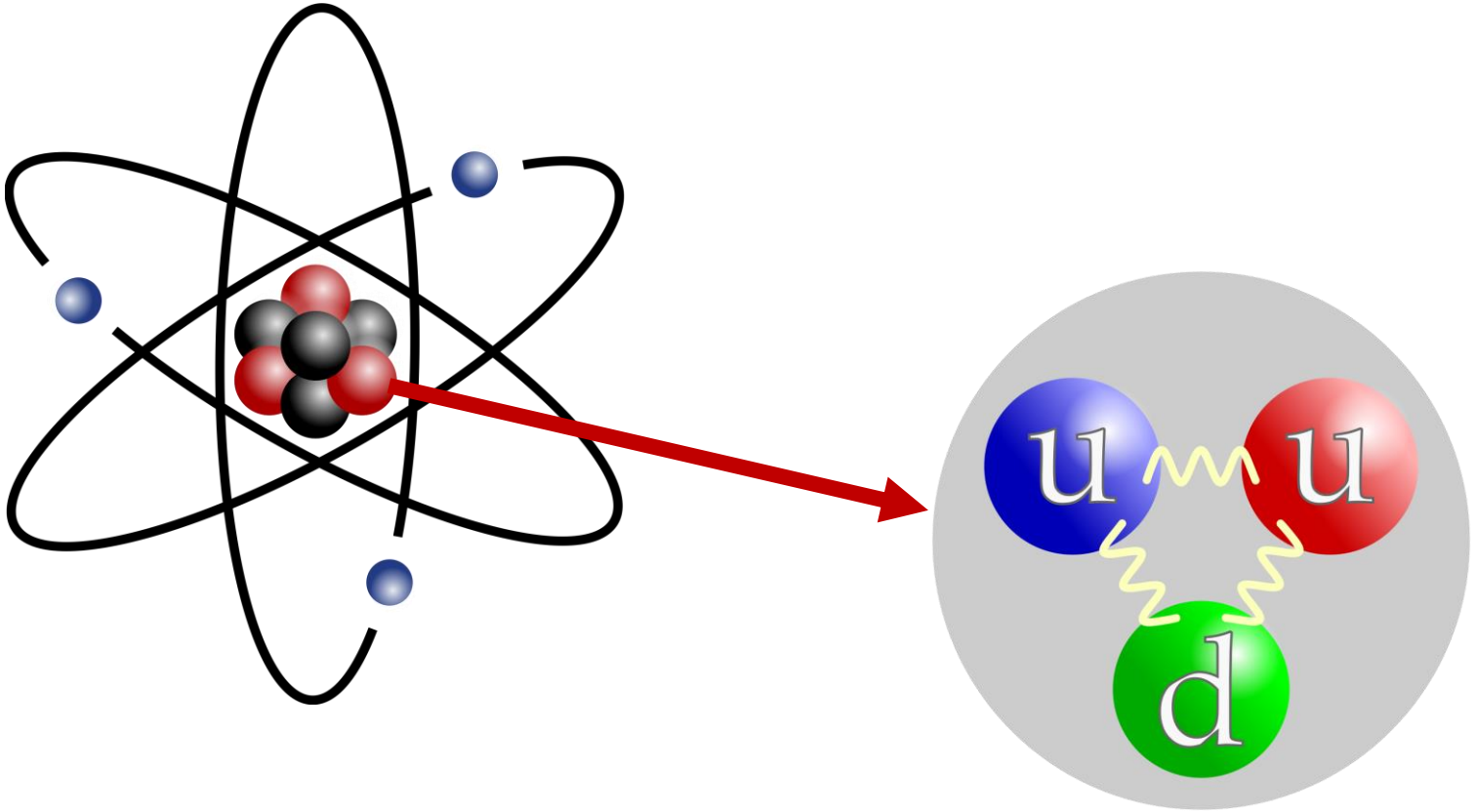
Particles and the Standard Model

IB PHYSICS | ATOMIC PHYSICS

What is the “Fundamental Particle”?



Fundamental Particles

Charge	Quarks			Baryon Number
$\frac{2}{3}$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}$	d	s	b	$\frac{1}{3}$

All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of –1

Charge	Leptons		
-1	e	μ	τ
0	ν_e	ν_μ	ν_τ

All leptons have a lepton number of 1 and antileptons have a lepton number of –1

Symbol	Name
u	Up
d	Down
c	Charm
s	Strange
t	Top
b	Bottom

Symbol	Name
e	Electron
μ	Muon
τ	Tau
ν_e	Electron Neutrino
ν_μ	Muon Neutrino
ν_τ	Tau Neutrino

Antiparticles have the opposite charge as their corresponding particle and have a bar over their symbol

Symbol	Name	Charge
s	Strange	$-\frac{1}{3}$
$\bar{s}$	Antistrange	$+\frac{1}{3}$

IB Physics Data Booklet

Sub-topic 7.1 – Discrete energy and radioactivity	Sub-topic 7.2 – Nuclear reactions
$E = hf$ $\lambda = \frac{hc}{E}$	$\Delta E = \Delta m\, c^2$

Sub-topic 7.3 – The structure of matter

Charge	Quarks			Baryon number
$\frac{2}{3}e$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}e$	d	s	b	$\frac{1}{3}$

All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of –1

Charge	Leptons		
–1	e	μ	τ
0	υ_e	υ_μ	υ_τ

All leptons have a lepton number of 1 and antileptons have a lepton number of –1

	Gravitational	Weak	Electromagnetic	Strong
Particles experiencing	All	Quarks, leptons	Charged	Quarks, gluons
Particles mediating	Graviton	W^+, W^-, Z^0	γ	Gluons

Fundamental Particles

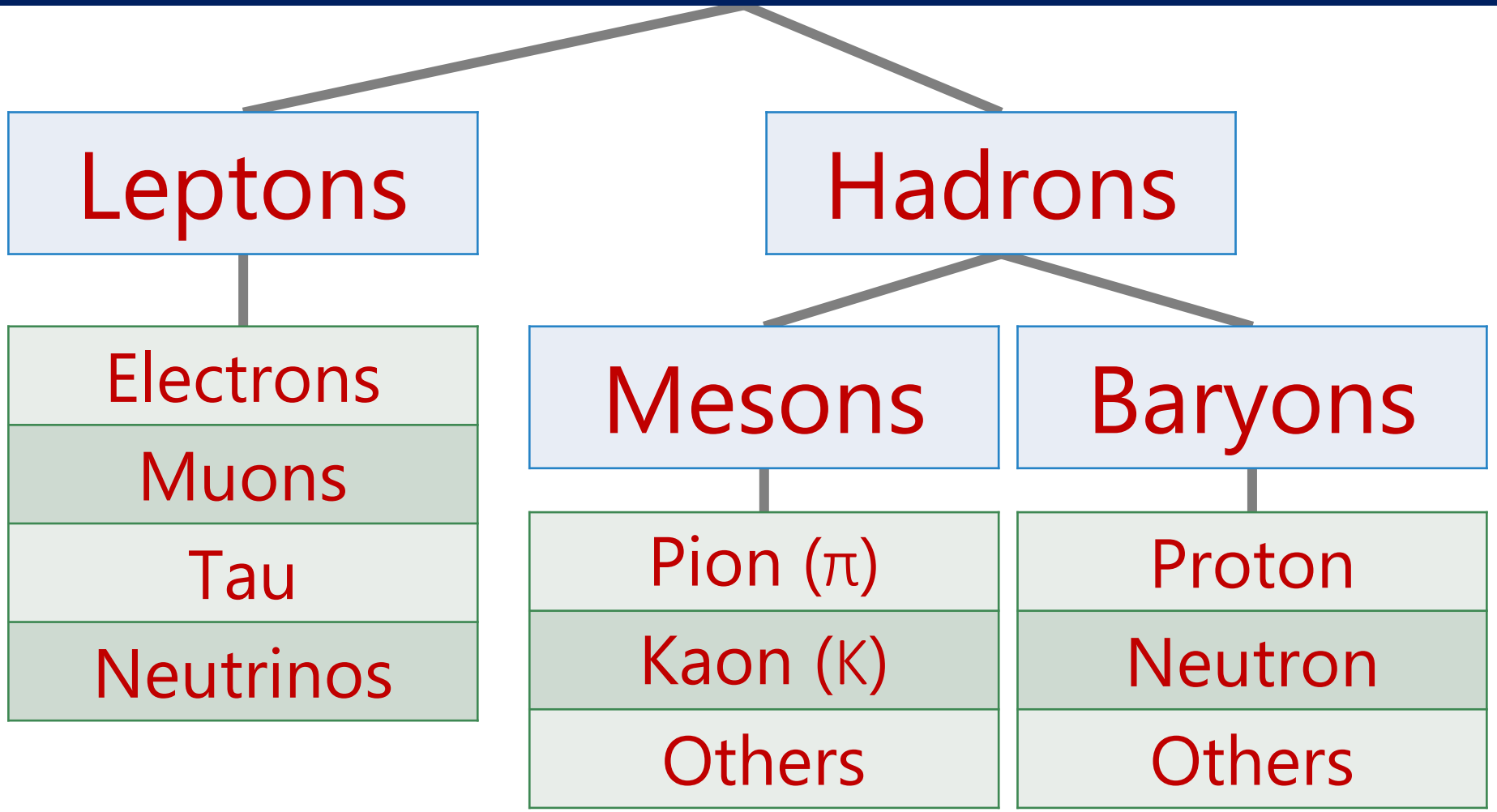
Symbol	Name	Charge	Baryon #
u	Up	$+\frac{2}{3}$	$\frac{1}{3}$
d	Down	$-\frac{1}{3}$	$\frac{1}{3}$
c	Charm	$+\frac{2}{3}$	$\frac{1}{3}$
s	Strange	$-\frac{1}{3}$	$\frac{1}{3}$
t	Top	$+\frac{2}{3}$	$\frac{1}{3}$
b	Bottom	$-\frac{1}{3}$	$\frac{1}{3}$

Symbol	Name	Charge	Lepton #
e	Electron	-1	1
μ	Muon	-1	1
τ	Tau	-1	1
ν_e	Electron Neutrino	0	1
ν_μ	Muon Neutrino	0	1
ν_τ	Tau Neutrino	0	1

Symbol	Name	Charge	Baryon #
$\bar{u}$	Antiup	$-\frac{2}{3}$	$-\frac{1}{3}$
$\bar{d}$	Antidown	$+\frac{1}{3}$	$-\frac{1}{3}$
$\bar{c}$	Anticharm	$-\frac{2}{3}$	$-\frac{1}{3}$
$\bar{s}$	Antistrange	$+\frac{1}{3}$	$-\frac{1}{3}$
$\bar{t}$	Antitop	$-\frac{2}{3}$	$-\frac{1}{3}$
$\bar{b}$	Antibottom	$+\frac{1}{3}$	$-\frac{1}{3}$

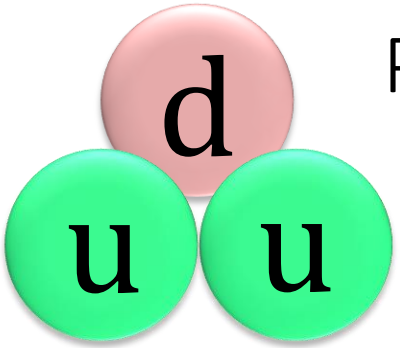
Symbol	Name	Charge	Lepton #
$\bar{e}$	Antielectron (positron)	$+1$	-1
$\bar{\mu}$	Antimuon	$+1$	-1
$\bar{\tau}$	Antitau	$+1$	-1
$\bar{\nu}_e$	Electron Antineutrino	0	-1
$\bar{\nu}_\mu$	Muon Antineutrino	0	-1
$\bar{\nu}_\tau$	Tau Antineutrino	0	-1

Classifying Particles



Baryons

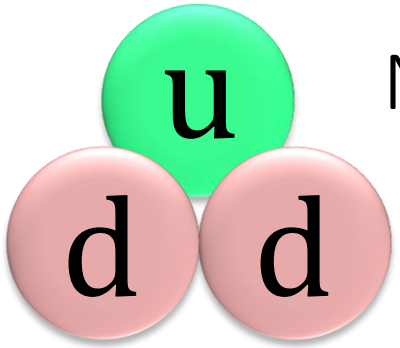
All Baryons are formed from a combination of 3 quarks or antiquarks



Proton

+1

(uud)



Neutron

0

(udd)

Rule:	Charge must be an integer value (-1, 0, or +1)

Up Quark

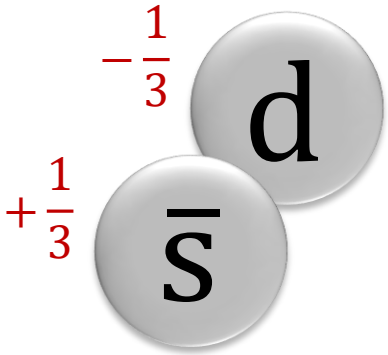
Charge = 2/3

Down Quark

Charge = -1/3

Mesons

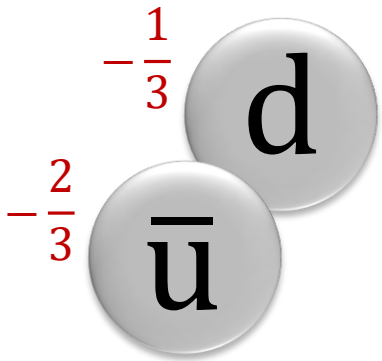
All Mesons are formed from a combination of a quark and antiquark



Kaon

0

Rule:	Charge must be an integer value (-1, 0, or +1)



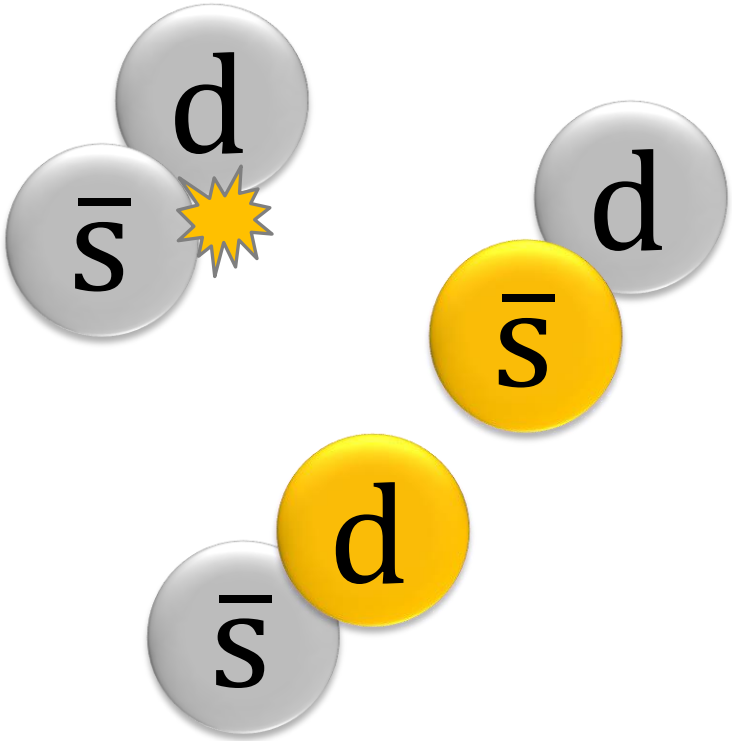
D-Meson

-1

Charge	Quarks			Baryon Number
$\frac{2}{3}$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}$	d	s	b	$\frac{1}{3}$
All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of –1				

Quark Confinement

Quarks have never been observed on their own



The amount of energy required to overcome the strong nuclear force holding the quarks together gets converted into mass and forms a new quark pair

Conservation

For an interaction to be possible, the following must stay conserved:

Baryon #	Lepton #	Charge	Strangeness

$$n \rightarrow p + e^{-} + \bar{\nu}_e$$

Baryon #	1	1	0	0
Lepton #	0	0	1	-1
Charge	0	1	-1	0

This interaction is valid because all properties are conserved

Conservation

$$p + e^- \rightarrow n + \nu_e$$

Baryon #	1	0		1	0
Lepton #	0	1		0	1
Charge	+1	-1		0	0

Yes
Valid

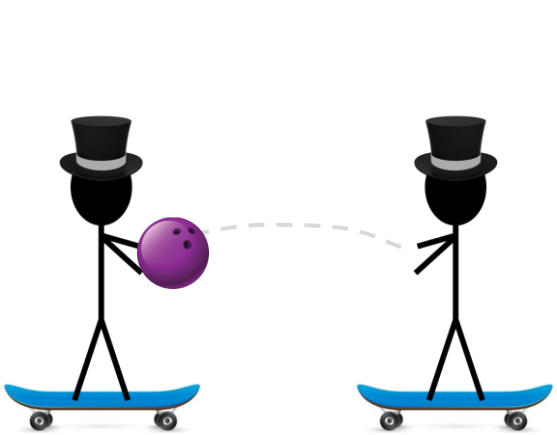
$$n + p \rightarrow e^+ + \bar{\nu}_e$$

Baryon #	1	1		0	0
Lepton #	0	0		-1	-1
Charge	0	+1		+1	0

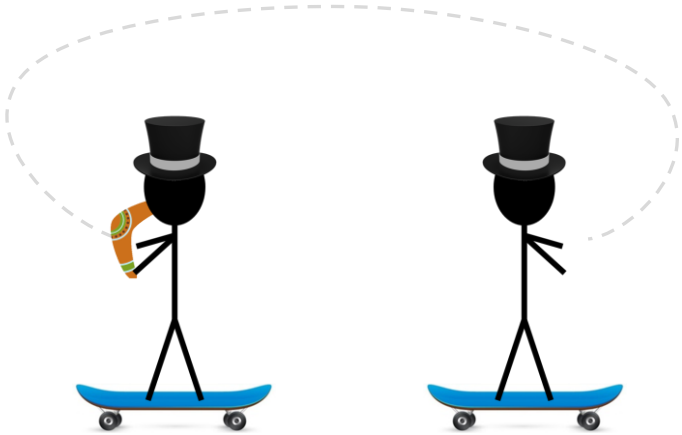
No
Invalid

Exchange Particles

At the fundamental level of particle physics, forces are explained in terms of the transfer of **exchange particles** (**gauge bosons**) between the two particles experiencing the force



Repulsion



Attraction

These interactions are not observable, so we call them ***virtual particles***

Types of Forces

	Gravitational	Weak	Electromagnetic	Strong
Particles experiencing	All	Quarks, leptons	Charged	Quarks, gluons
Particles mediating	Graviton	W^+, W^-, Z^0	γ photon	Gluons

Weakest

Strongest

Sample IB Question

26. Which of the following lists three fundamental forces in increasing order of strength?

A. electromagnetic, gravity, strong nuclear

B. weak nuclear, gravity, strong nuclear

C. gravity, weak nuclear, electromagnetic

D. electromagnetic, strong nuclear, gravity

	Gravitational	Weak	Electromagnetic	Strong
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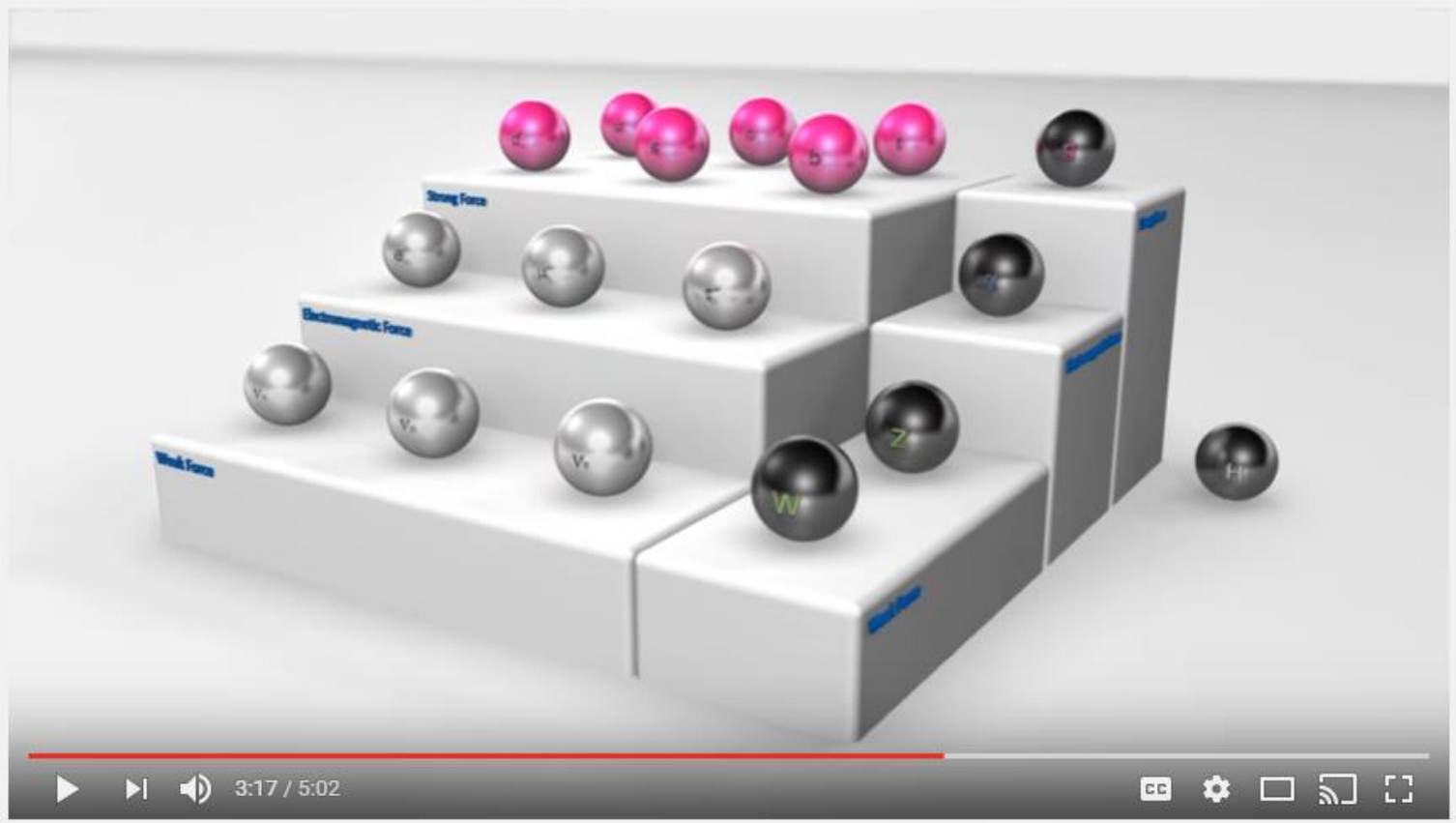
The Standard Model



CERN: The Standard Model Of Particle Physics

Sample IB Question

27. For which reason were quarks first introduced?

A. To explain the existence of isotopes

B. To describe nuclear emission and absorption spectra

C. To account for patterns in properties of elementary particles

D. To account for the missing energy and momentum in beta decay

The Standard Model