



energie & arbeid

hoogteverschil 2 m

$100 \text{ kg} \times 9.8 \text{ m/s}^2 \approx 1000 \text{ N}$

Arbeid = Kracht \times Verplaatsing
 $= 1000 \text{ N} \times 2 \text{ m} = 2000 \text{ J}$
 (≈ 92 milligram chocolade)

funny-city.com

behoud van energie?

Gewichtsheffen:
 waar komt de energie vandaan?

behoud van energie?

Spierenergie:
 chemische energie uit oxidatie voedingsstoffen

behoud van energie?

Chemische energie:
 potentiële energie van elektronen in moleculen

behoud van energie?

Potentiële energie:
 uit ons (plantaardige!) eten \rightarrow word vegetariër

hoe doen planten het?

behoud van energie?

Groene planten:
uit het zonlicht via de fotosynthese

Basic Photosynthesis

hoe doen de zon het?

behoud van energie?

Zonlicht:
kernfusie in de zon: $4\text{}^1\text{H} \rightarrow \text{}^4\text{He} + 2\text{e}^+ + \text{energie} + 2\nu_e$

waar komt $\text{}^1\text{H}$ vandaan?

neutrino's: vreemde deeltjes

licht: 1 miljoen jaar!
neutrino's: 8 minuten!

behoud van energie?

Waterstof H_2 :
vanuit de oerknal 14.5 miljard jaar geleden

pre-Oerknal

niets

behoud van energie?

Waterstof H_2 :
vanuit de oerknal 14.5 miljard jaar geleden

Oerknal

energie: de oplossing?

$E_{\text{zon}} \approx M_{\text{zon}} C^2$
 $\approx 2 \times 10^{47} \text{ Ws}$

1000 miljard jaar

efficiëntie van kernfusie:
 $\approx 1\% \Rightarrow 10$ miljard jaar

Op Aarde:
 $\pi(6,400,000)^2 \times 1400 \text{ W}$
 $\approx 1.8 \times 10^{17} \text{ W}$
 $= 180,000 \text{ TW}$

power consumptie mensen op Aarde:
 $\approx 10 \text{ TW}$

$150,000,000 \text{ km}$

Zon levert: $4\pi(150,000,000,000)^2 \times 1400 \approx 4 \times 10^{26} \text{ W}$

hoge-energie fysica

Energie: geen [J] maar [GeV] 1 GeV = 10^9 eV $\sim 1.6 \times 10^{-10}$ J

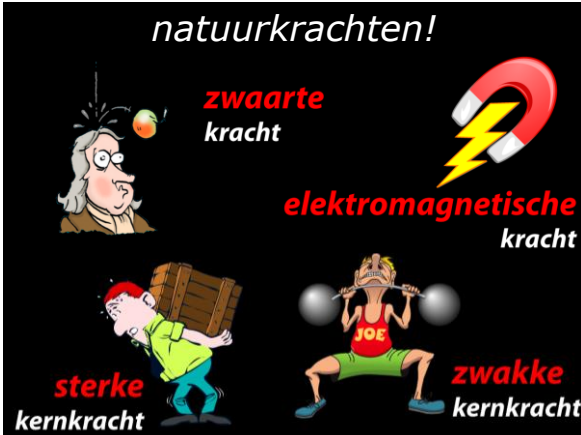
kleinste bouwstenen?



kleinste bouwstenen?



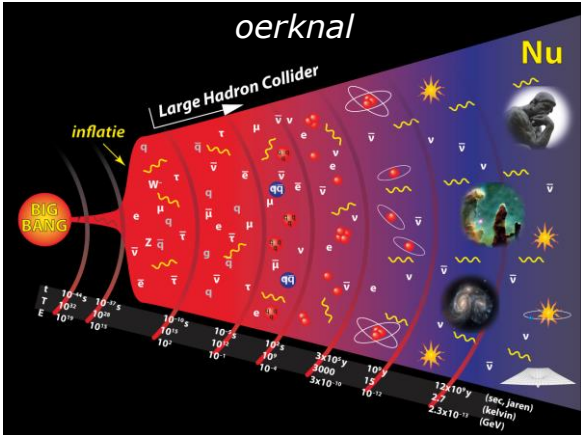
natuurkrachten!



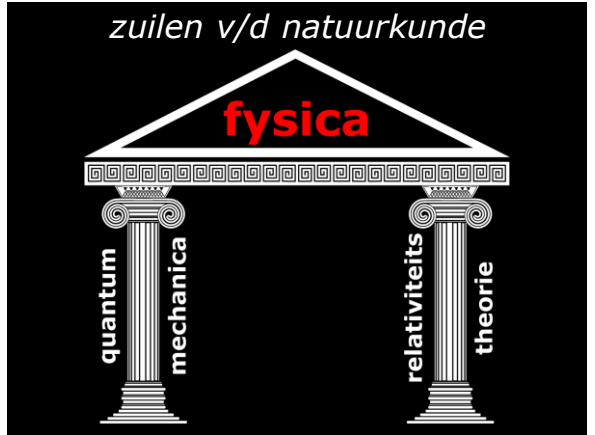
natuurkrachten in actie



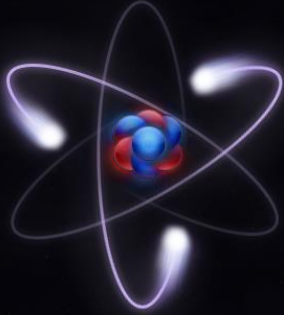
oerknal



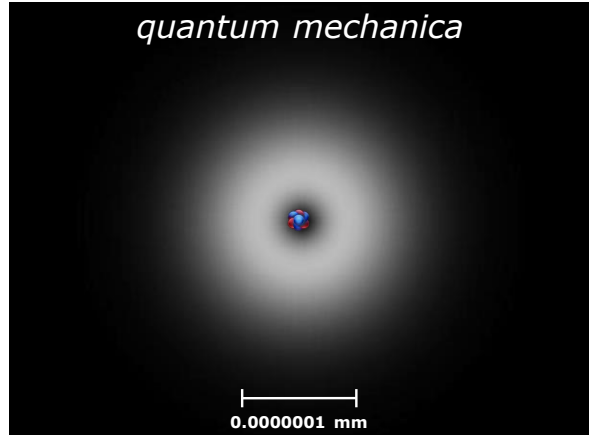
zuilen v/d natuurkunde



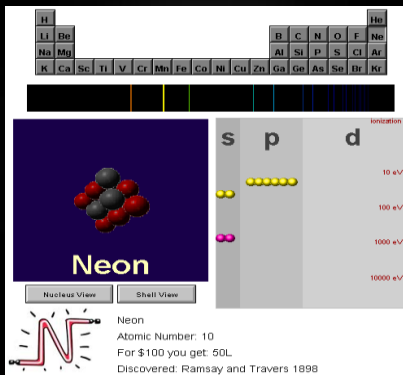
klassieke mechanica



quantum mechanica



quantum mechanica



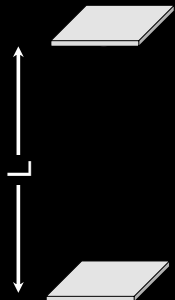
relativiteitstheorie

$c = 299792458 \text{ m/s}$



clock at rest

$c = 299792458 \text{ m/s}$



'heen-en-weer'
periode t van het licht:

$$t = \frac{2L}{c}$$

$c = 299792458 \text{ m/s}$



'heen-en-weer'
periode t' van het licht:

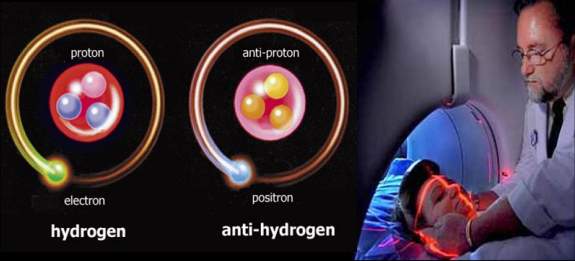
$$t' = \frac{2\sqrt{L^2 + (1/2 vt')^2}}{c}$$

$$(ct')^2 = 4L^2 + (vt')^2$$

$$t' = \frac{2L}{\sqrt{c^2 - v^2}} = \frac{t}{\sqrt{1 - v^2/c^2}}$$

relativistische quantum mechanica

$$(i\gamma^\mu \partial_\mu - m)\psi = 0$$



deeltjes botsingen

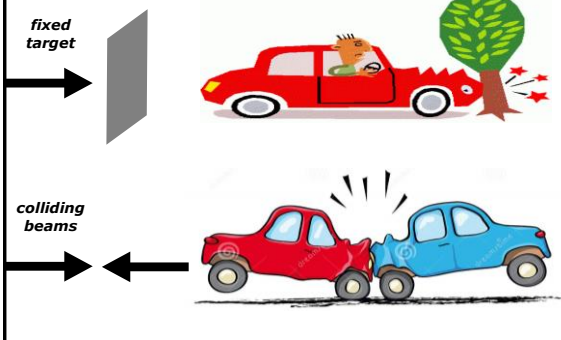
deeltjes botsingen



deeltjes botsingen

$$E = mc^2$$

Fixed target ↔ colliding beams



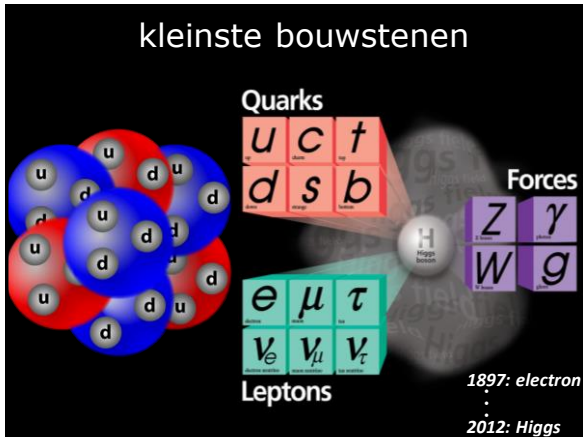
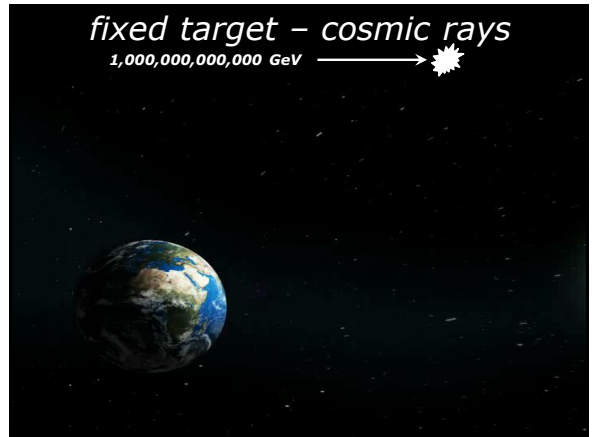
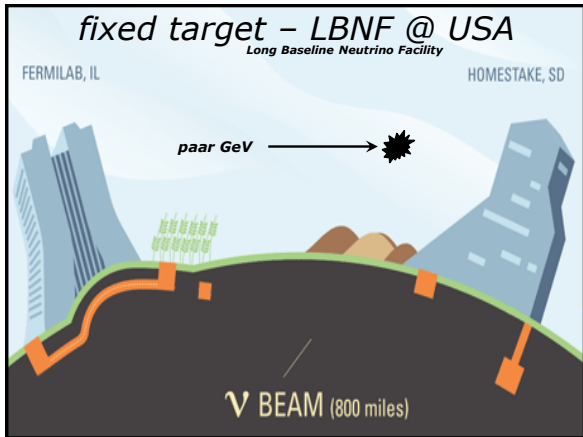
colliding beams – LHC @ CERN

Large Hadron Collider

7000 GeV



7000 GeV



echt perfect begrepen?

Standard Model – deeltjesfysica
 +
Big Bang model – kosmologie

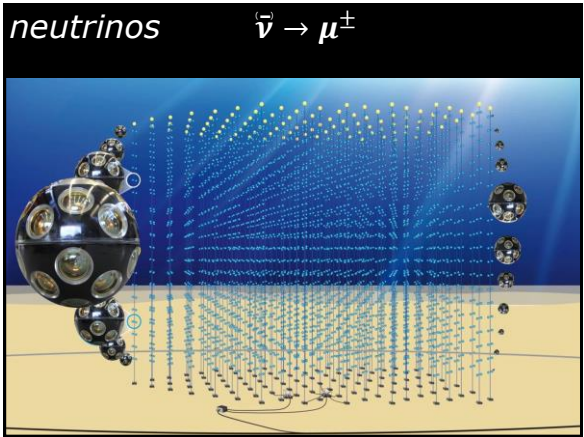
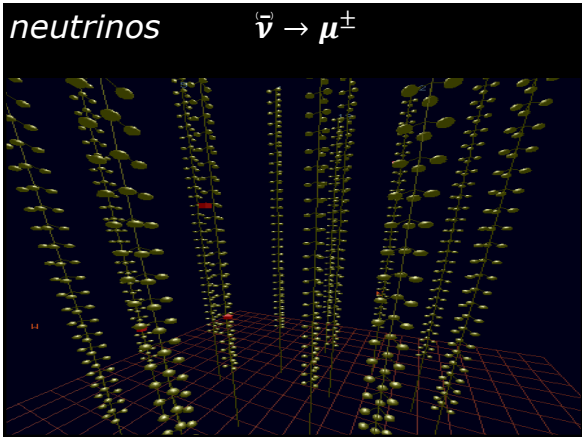
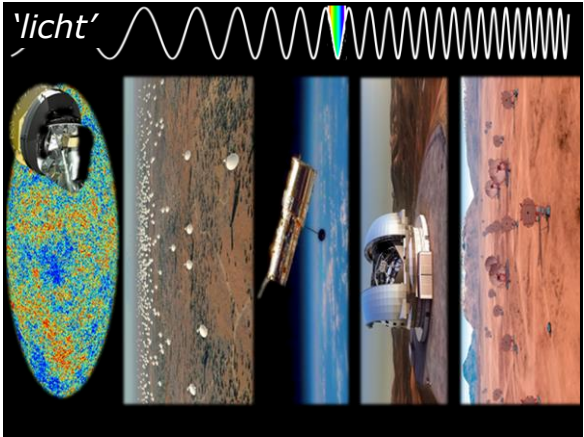
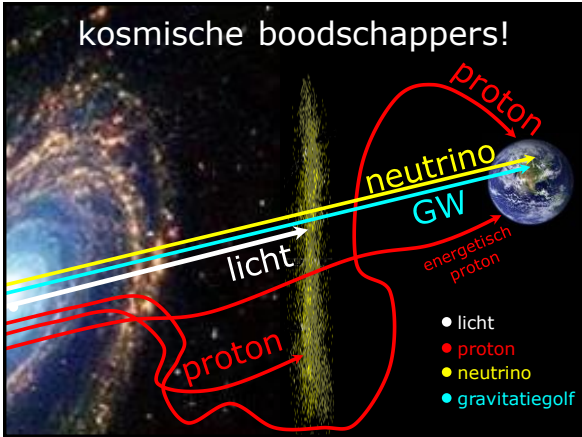
hydrogen (H) helium (He)

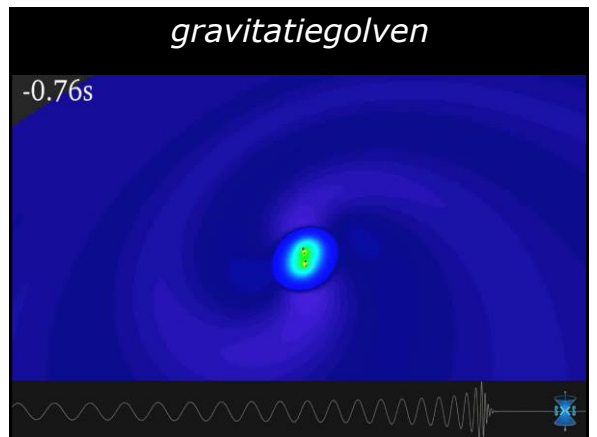
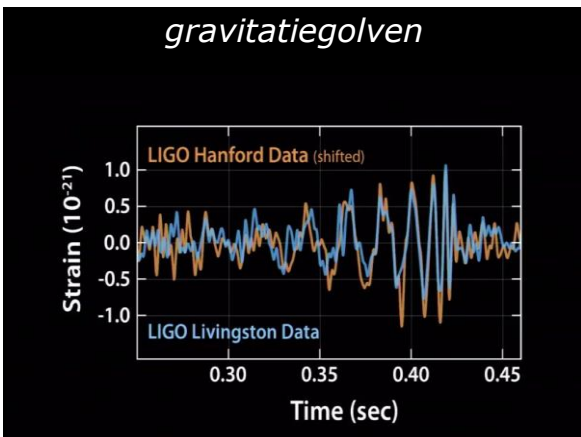
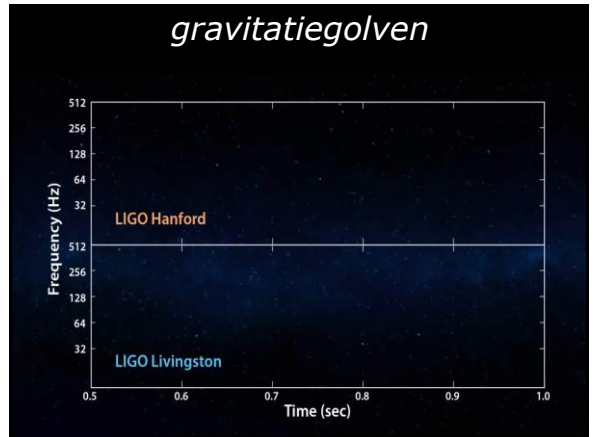
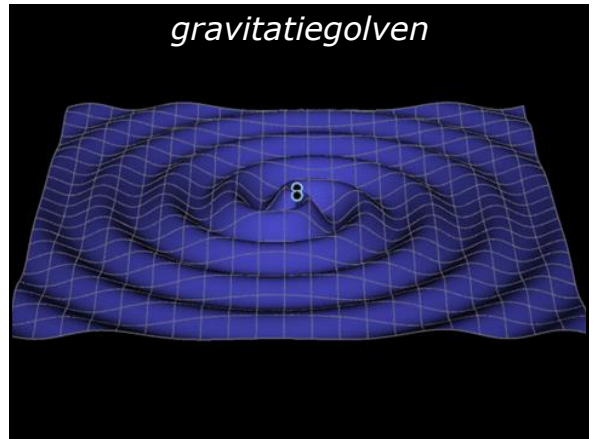
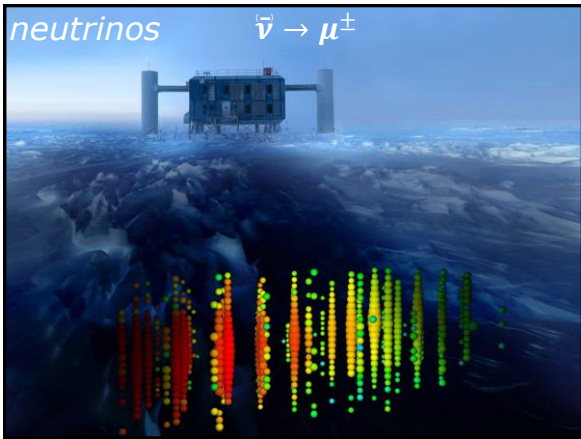
sterrenkunde
 metingen
 samenstelling
 Universum

deeltjesfysica
 metingen
 deeltjes
 eigenschappen

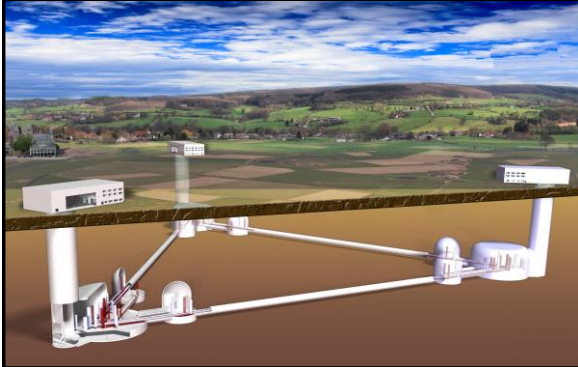
3 'families'

n-levensduur – 880 s

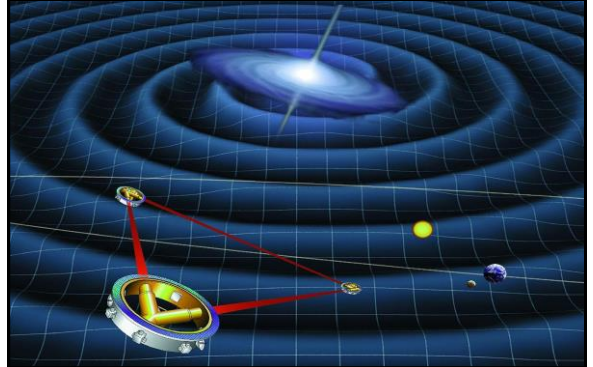




gravitatiegolven: toekomst!



gravitatiegolven: toekomst!



en de (jullie!) toekomst?

- Higgs detail metingen – LHC @ CERN
- nieuwe deeltjes (donkere materie)!
- donkere energie mysterie
- gravitatiegolven schatkamer!
- Het prille Universum vlakbij de Oerknal:
 - primordial gravitatiegolven?
 - primordial neutrinos?
- materie-antimaterie imbalans?

nuttig? **versnellers**

Today worldwide only few accelerators for particle physics



XFEL, Hamburg

Tens of thousands of accelerators for:
and boosted super-conductor industrialisation

Material sciences
Healthcare
Semi-conductor industry
Food Industry
Biology
...

nuttig? **gezondheid**

nuttig? **ICT**

nuttig? paar van jullie?



nuttig? jullie vandaag!

