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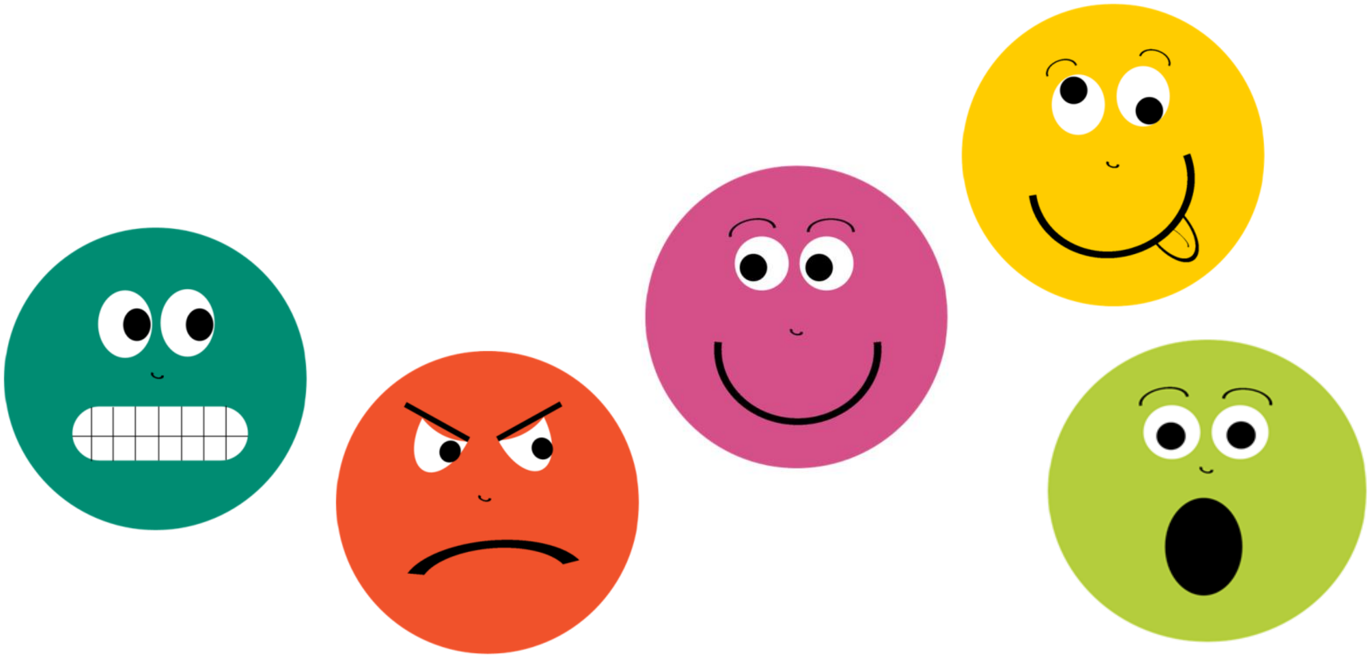
Praedinius GYMNASIUM

Quantumwereld
Wat kunnen we leren van andere landen?

Kirsten Stadermann

- Introductie van Quantumwereld in CE




KWANTUM
Zoeken in de hele catalogus
Home
Gordijnen & raamdecoratie
Vloer
Tuin
Verlichting
Behang & verf
Meubelen
Altijd de laagste prijs
100% Tevredenheidsgarantie
NERGENS
GOEDKOPER

Wat leren ze in andere landen over quantumfysica?

- Background
- Research question
- Method
- **Findings**
- Analysis
- Conclusion
- Future research
- Acknowledgements
- Questions / feedback

Quantum Physics in Secondary Schools

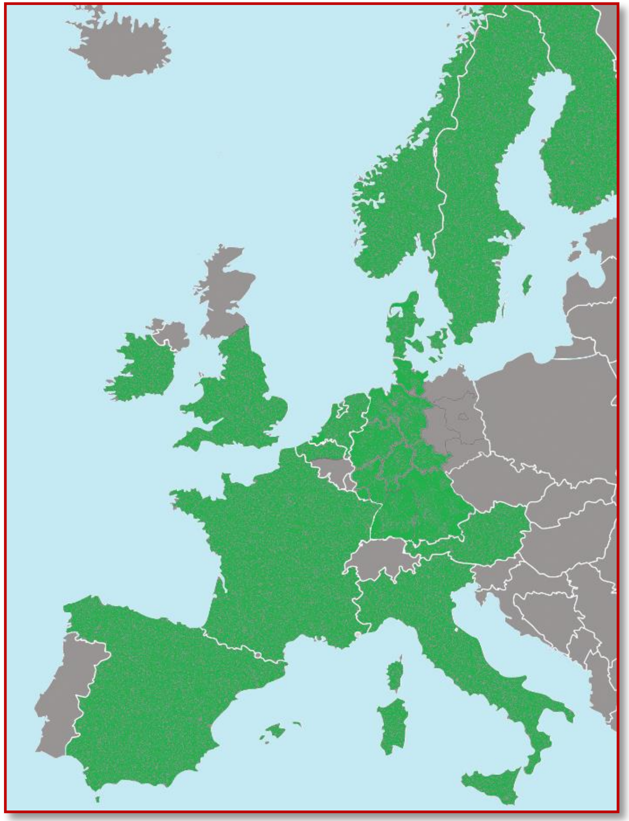
Comparison of some intended learning outcomes in official curricula or syllabi of 15 different countries

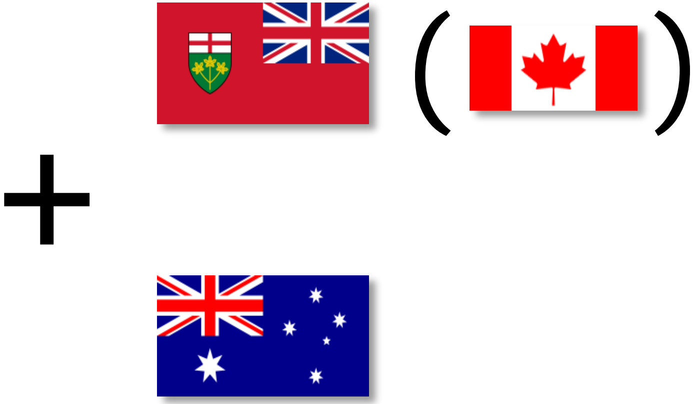
29-06-2017

■ = compulsory
□ = optional

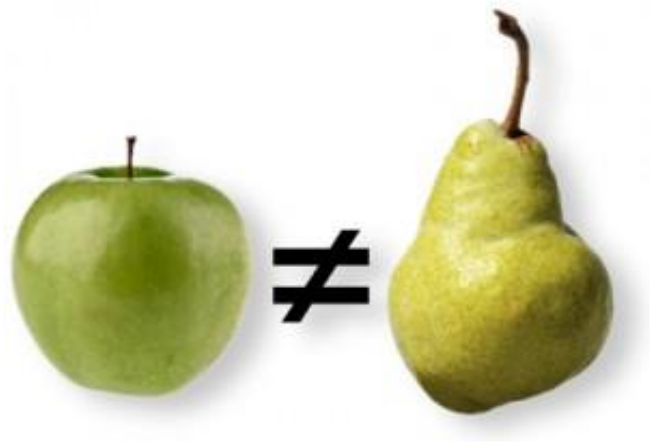
Section	Item	Norway		Finland		Sweden		Denmark		Netherlands	Belgium (Flemish community)		UK (England and Wales)		Ireland		Germany (Lower Saxony)		Germany (NRW)		Germany (Hesse)		Germany (Rhineland Palatinate)		Germany (Baden Württemberg)		Germany (Saxony)		Germany (Bavaria)	Austria	Italy (Liceo Scientifico)	France	Spain	Australia	Canada, (Ontario)
General inform.	Quantum Physics in the curriculum since	?		?		?		?		2014	?		?		-		<1960		<1960		<1960		<1960		<1960		?		<1960	?	?	?	?	?	?
	Grade in which Quantum Physics is taught	12		12		12		12		11/12	11/12		11/12		-		11/12		11/12		11/12		11/12		11/12		11/12		10/11/12	11/12	11/12	11/12	11/12	11/12	11/12
	Implementation year of investigated curriculum/syllabus (first exam)	2006		2005		2011		2008		2016	2015		2014		1999		2009		2014		2016		1998		2016		2012		2011	2014	2010	2012	2015	2016	2009
	Name/abbreviation of physics course	1	2	1	8	2	3	A	B	na	F	K	AS	D	O	H	G	E	G	L	G	L	G	L	2	4	G	L	Ph	Ph	Fi	Fi	F2	4U	4U
	Written leaving exam, centrally set		■	■	■	■	■	■		■			■	■	■	■	■	■	■	■	■	■			■	■	■	■	■		■	■			
	Written leaving exam, set by teacher/school										■	■											■	■						■					
	Oral examination (possible)	■	■	■	■	■	■	■	■								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
Topics mentioned in the official curriculum of a course: (selected items)																																			
Skills	S1 Use of models in physics	■	■	■		■		■	■	■				■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
	S2 Use of IT simulations	■	■				■	■	■	■					■	■			■	■	■	■			■	■	■	■	■	■		■	■		■
	S3 Oral communication skills (discussion, presentation)	■	■			■		■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
NOS	N1 Scientific method (formulation, test and modification of hypotheses)	■	■			■				■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	N2 History of physics			■																■	■	■	□	□	■	■				■		■		■	■
	N3 Reflection on development of models in physics (paradigm shift)		■			■		■	■				■	■			■	■		■	■	■	□	□	■	■	■	■		■	■		■	■	■
	N4 Physics in relation to social, ethical, philosophical or religious issues			■		■		■	■	■	■		■	■	■	■			■	■			■	■	■	■	■	■	■	■		■	■	■	■
Quantum Physics	Q1 Black body radiation				■	■				■																				□	■		■	■	
	Q2 Bohr model of (hydrogen) atom (= electrons on certain allowed orbits)	■			■	■				■		□			■	■				■	■	■					■	■		□	■			■	
	Q3 Discontinuity (energy levels in atom, emis./absorption, line spectrum)	■			■	■		■	■	■		□	■		■	■	■	■		■	■	■	■	■			■	■	■	■	■	■	■	■	■
	Q4 Interactions between light and matter (photoel. effect, Compton effect)		■		■	■				■		□	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■		■	■	■
	Q5 Matter waves (de Broglie wavelength, interference of electrons)		■		■	■				■		□	■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■
	Q6 Wave-particle duality (complementarity, double slit experiment)					■		■	■	■		□	■	■			■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■	■
	Q7 Statistical predictions (probability, Copenhagen interpretation)									■		□					■	■	■	■	■	■	■	■	■	■		■	■	■		■	■		
	Q8 Uncertainty (Heisenberg's Principle)		■				■			■		□					■	■		■		■	□	■		■	■	■	■	□	■		■		
	Q9 Technical applications (e.g. semiconductor, LED, laser, SEM)						■			■		□		■	■	■	■	■				■		□			■		■	□		■	■	■	■
	Q10 Sum over paths approach (phasor representation)																□	□																	
	Q11 Schrödinger equation (one dimensional time independent)						■										□	□											■						
	Q12 Detection probability = sq. of wave function amplitude or phasor length																■	■		■		■													
	Q13 One dimensional model (potential well, particle in a box)						■			■							■	■		■	■	■		□				■	■						
	Q14 Tunneling, Alpha decay						■			■												■		□					■						
	Q15 Atomic orbital model (electron cloud, 3-dimentional potential well)																	■						□				■	■	□			■		
	Q16 Pauli exclusion principle (structure of Periodic Table)						■															■							■						
	Q17 Philosoph. consequences (interpretations, Schr.'s cat, observer role)		■									□						■		■				■				■		□	■				
	Q18 Entanglement (interconnectedness, non-locality, EPR-experiment)		■															■										■							
	Q19 Modern research (e.g. quantum computing, quantum cryptography)											□																		□					■
	Q20 Experimental determination of h (e.g. with LED)																	■		■														■	

Countries of Analysed Curricula





Vergelijken



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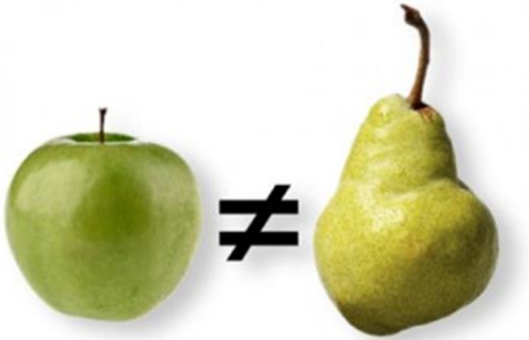

- In welke klas leren ze QF?
- Hoeveel tijd hebben leerlingen ervoor?
- Is het een keuzeonderwerp of verplicht?
- Hoe ziet het eindexamen er uit?

Verzamelde informatie per land

- QF onderwerpen

	Oral examination (possible)		■	■	■	■	■	■	■	■								■	■	■	■
Topics mentioned in the official curriculum of a course: (selected items)																					
Skills	S1 Use of models in physics		■	■	■		■		■	■	■				■				■	■	■
	S2 Use of IT simulations		■	■				■	■	■	■					■	■			■	■
	S3 Oral communication skills (discussion, presentation)		■	■			■		■	■	■	■						■	■	■	■
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	N2 History of physics				■																■
	N3 Reflection on development of models in physics (paradigm shift)			■			■		■	■				■	■			■	■		■
	N4 Physics in relation to social, ethical, philosophical or religious issues				■		■		■	■	■	■		■	■	■	■			■	■
Quantum Physics	Q1 Black body radiation					■	■				■										
	Q2 Bohr model of (hydrogen) atom (= electrons on certain allowed orbits)		■			■	■				■		□			■	■				■
	Q3 Discontinuity (energy levels in atom, emis./absorption, line spectrum)		■			■	■		■	■	■		□	■		■	■	■	■		■
	Q4 Interactions between light and matter (photoel. effect, Compton effect)			■		■	■				■		□	■		■	■	■	■	■	■
	Q5 Matter waves (de Broglie wavelength, interference of electrons)			■		■	■				■		□	■				■	■	■	■
	Q6 Wave-particle duality (complementarity, double slit experiment)						■		■	■	■		□	■	■			■	■	■	■
	Q7 Statistical predictions (probability, Copenhagen interpretation)										■		□					■	■	■	■
	Q8 Uncertainty (Heisenberg's Principle)			■				■			■		□					■	■		■
	Q9 Technical applications (e.g. semiconductor, LED, laser, SEM)							■			■		□		■	■	■	■	■		
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	Q13 One dimensional model (potential well, particle in a box)							■			■							■	■		■
	Q14 Tunneling, Alpha decay							■			■										
	Q15 Atomic orbital model (electron cloud, 3-dimentional potential well)																		■		
	Q16 Pauli exclusion principle (structure of Periodic Table)							■													
	Q17 Philosoph. consequences (interpretations, Schr.'s cat, observer role)			■									□						■		■
	Q18 Entanglement (interconnectedness, non-locality, EPR-experiment)			■															■		
	Q19 Modern research (e.g. quantum computing, quantum cryptography)												□								
	Q20 Experimental determination of h (e.g. with LED)																		■		■

Quantum Physics in Secondary Schools

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29-06-2017

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General inform.	Written leaving exam, centrally set		■	■	■	■	■	■		■			■	■	■	■	■	■	■	■	■	■			■	■	■	■	■		■	■			
General inform.	Written leaving exam, set by teacher/school										■	■											■	■						■					
General inform.	Oral examination (possible)	■	■	■	■	■	■	■	■								■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
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Skills	S2 Use of IT simulations	■	■				■	■	■	■					■	■			■	■	■	■			■	■	■	■	■	■		■	■		■
Skills	S3 Oral communication skills (discussion, presentation)	■	■			■		■	■	■	■						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
NOS	N1 Scientific method (formulation, test and modification of hypotheses)	■	■			■				■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
NOS	N2 History of physics			■																■	■	■	□	□	■	■				■		■		■	■
NOS	N3 Reflection on development of models in physics (paradigm shift)		■			■		■	■				■	■			■	■		■	■	■	□	□	■	■	■	■		■	■		■	■	■
NOS	N4 Physics in relation to social, ethical, philosophical or religious issues			■		■		■	■	■	■		■	■	■	■			■	■			■	■	■	■	■	■	■	■		■	■	■	■
Quantum Physics	Q1 Black body radiation				■	■				■																				□	■		■	■	
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Quantum Physics	Q3 Discontinuity (energy levels in atom, emis./absorption, line spectrum)	■			■	■		■	■	■		□	■		■	■	■	■		■	■	■	■	■			■	■	■	■	■	■	■	■	■
Quantum Physics	Q4 Interactions between light and matter (photoel. effect, Compton effect)		■		■	■				■		□	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	■		■	■	■
Quantum Physics	Q5 Matter waves (de Broglie wavelength, interference of electrons)		■		■	■				■		□	■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■
Quantum Physics	Q6 Wave-particle duality (complementarity, double slit experiment)					■		■	■	■		□	■	■			■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■	■
Quantum Physics	Q7 Statistical predictions (probability, Copenhagen interpretation)									■		□					■	■	■	■	■	■	■	■	■	■		■	■	■		■	■		
Quantum Physics	Q8 Uncertainty (Heisenberg's Principle)		■				■			■		□					■	■		■		■	□	■		■	■	■	■	□	■		■		
Quantum Physics	Q9 Technical applications (e.g. semiconductor, LED, laser, SEM)						■			■		□		■	■	■	■	■				■		□			■		■	□		■	■	■	■
Quantum Physics	Q10 Sum over paths approach (phasor representation)																□	□																	
Quantum Physics	Q11 Schrödinger equation (one dimensional time independent)						■										□	□											■						
Quantum Physics	Q12 Detection probability = sq. of wave function amplitude or phasor length																■	■		■		■													
Quantum Physics	Q13 One dimensional model (potential well, particle in a box)						■			■							■	■		■	■	■		□				■	■						
Quantum Physics	Q14 Tunneling, Alpha decay						■			■												■		□					■						
Quantum Physics	Q15 Atomic orbital model (electron cloud, 3-dimentional potential well)																	■						□				■	■	□			■		
Quantum Physics	Q16 Pauli exclusion principle (structure of Periodic Table)						■															■							■						
Quantum Physics	Q17 Philosoph. consequences (interpretations, Schr.'s cat, observer role)		■									□						■		■				■				■		□	■				
Quantum Physics	Q18 Entanglement (interconnectedness, non-locality, EPR-experiment)		■															■										■							
Quantum Physics	Q19 Modern research (e.g. quantum computing, quantum cryptography)											□																		□					■
Quantum Physics	Q20 Experimental determination of *h* (e.g. with LED)																	■		■														■	

Kernbegrippen: paars

‘Karaktertrekken van QF’

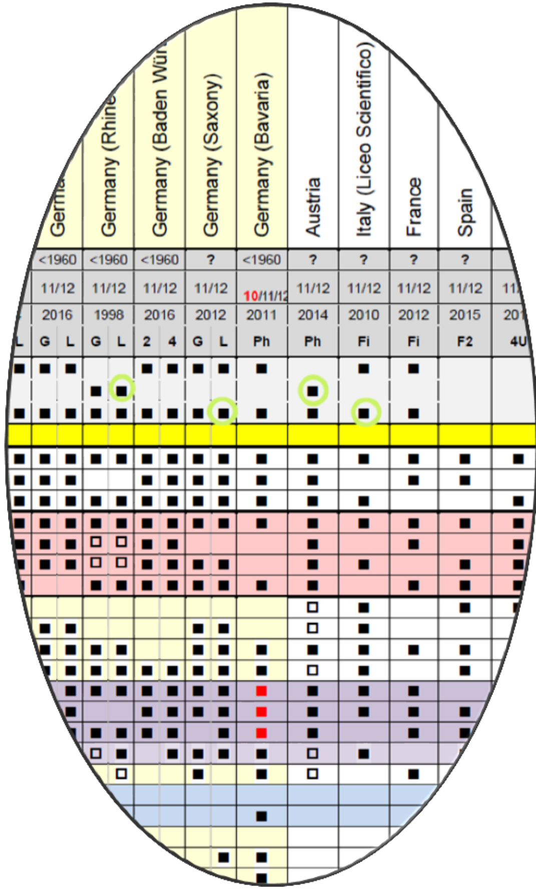
- Stochastisch gedrag en waarschijnlijkheid(Q7)
- Superposition en Interferentie (Q5, Q6)
- Resultaat en invloed van metingen (Q6, Q7, Q8)
- Complementariteit (Q5, Q8)

- Entanglement (Q18)

- **In de meeste landen worden de kernbegrippen behandeld**

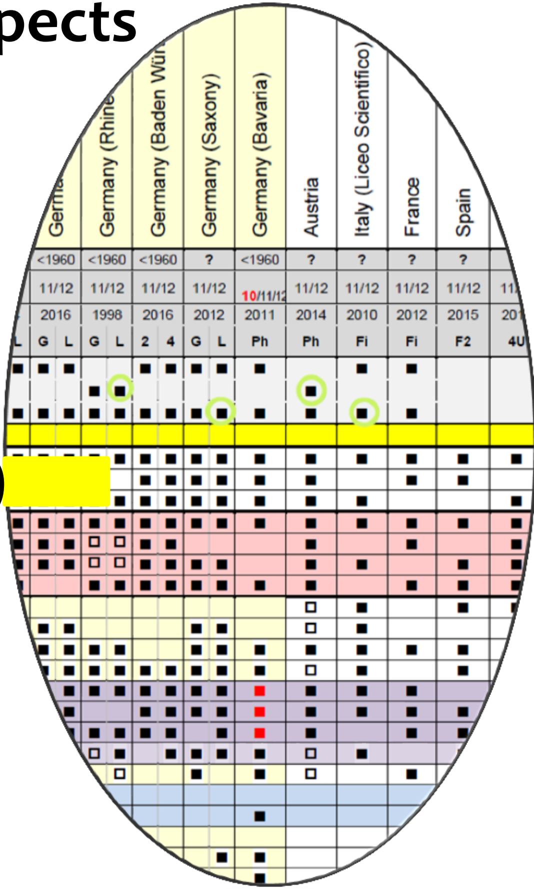
- Ireland ☹

- Beieren ☺



- **Most counties cover these key aspects**
- Ireland ☹
- Bavaria ☺

- **entanglement (Q18)**
- **philosophical consequences (Q17)**
- Vaak als keuzeonderwerp
- Norwegen bewust wel.

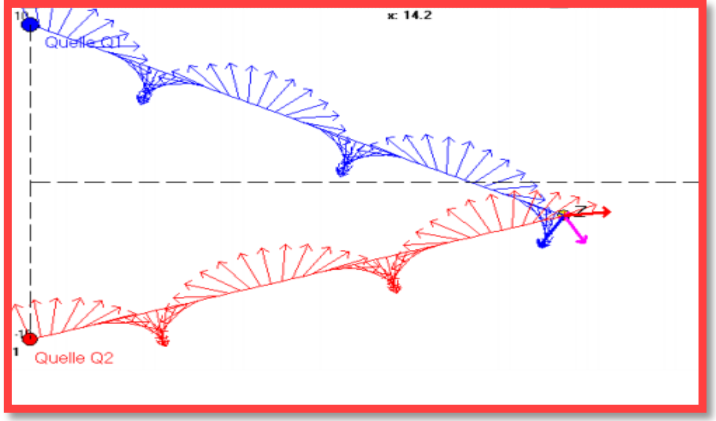


Wiskundige beschrijvingen?

- differentiaalvergelijkingen

$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2} + V(x,t)\Psi(x,t) = i\hbar\frac{\partial\Psi(x,t)}{\partial t}$$

- of phasor representatie



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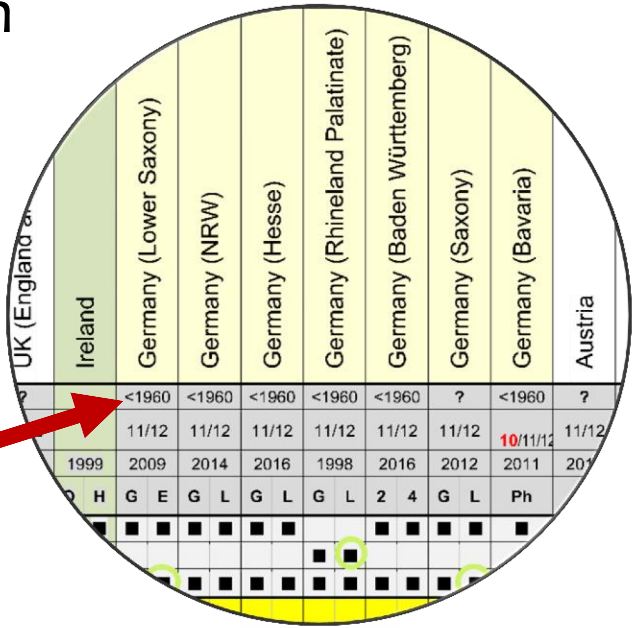
Wiskundige beschrijvingen

- Alleen in Duitse deelstaten
- Lange traditie



Al meer dan 50 jaar in het vwo-curriculum

Waarom quantenfysica?

- **Belangrijke tak van de moderne natuurkunde**

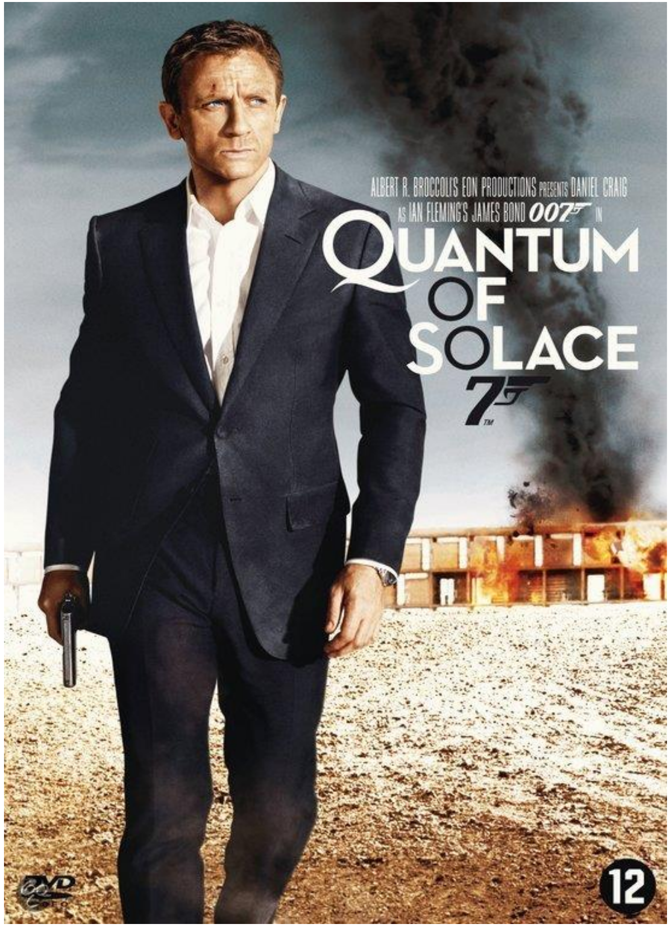
Als de quantenfysica in staking zou gaan, zou elk moderne apparaat uitvallen met alle gevolgen van dien.

Het is zo'n grote en belangrijke theorie als de evolutietheorie en elk mens met een goede schoolopleiding moet ervan weten.

Waarom quantenfysica?

- **Belangrijke tak van de moderne natuurkunde**
- **Motivatie**

  Quantum is cool


ALBERT R. BROCCOLI'S EON PRODUCTIONS PRESENTS DANIEL CRAIG
AS IAN FLEMING'S JAMES BOND 007 IN
QUANTUM OF SOLACE
12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XBOX ONE EXCLUSIVE
QUANTUM BREAK
MATURE 17+
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EVEN FIGHTS SPOTS AND RESIDUES FOR A SPARKLING SHINE
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POWERBALL
SUPER CHARGED
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Waarom quantenfysica?

- Belangrijke tak van de moderne natuurkunde
- Motivatie
- Belangrijk voor het begrijpen van wetenschap

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Bungum (Norway)

“There have been discussions on the topic entangled photons, some teachers and physicists don’t like to have it in the curriculum since there are no clear answers to what the phenomenon is.

But this is why it was put in the curriculum, to show that physics has unsolved problems.”

Nature of Science (NoS) =
de natuur van de wetenschap

Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more a science than a heap of stones is a house.

Henri Poincare

“Een verzameling van wetenschappelijke feiten is net zo min wetenschap als een stapel stenen een huis is.”

Misvattingen over NoS:

- Er bestaat één wetenschappelijke methode.
- Wetenschappers volgen alleen die regels
- Wetenschappelijke kennis is eenduidig en onveranderlijk"
- OF: Omdat wetenschappelijke kennis kan veranderen, kun je het niet vertrouwen ("Het is ook maar een mening")
- Wetenschappers zijn niet creatief.
- Wetenschap inspireert technologie, maar niet andersom.

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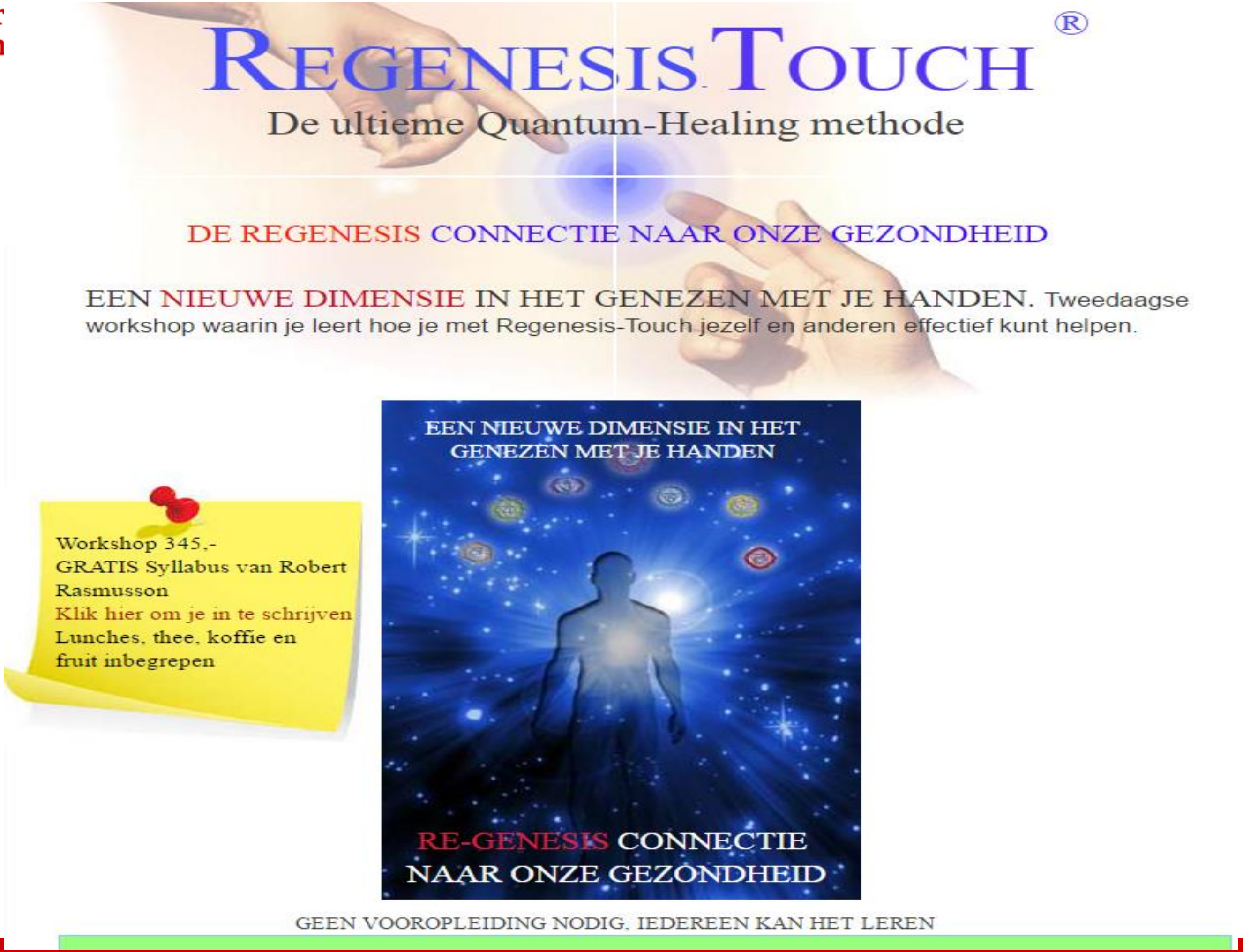
gronin

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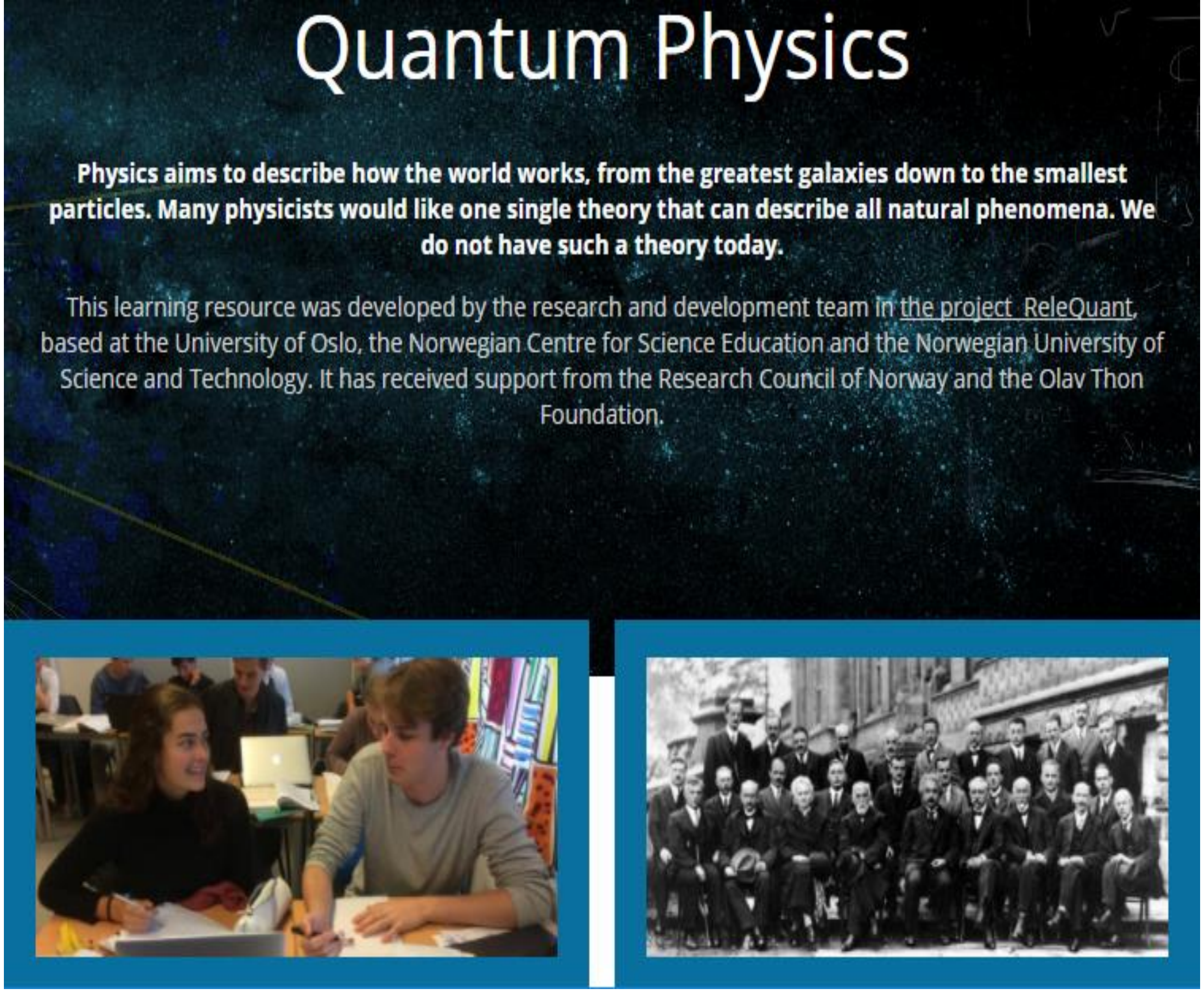
In feite kan elke les natuurkunde een les over NoS zijn.
Maar met quantenfysica zijn we gedwongen om het ook te behandelen.

Oostenrijk

Noorwegen:

- ReleQuant



ReleQuant's objectives

- to develop digital resources in quantum physics and general relativity that are in line with the Norwegian physics curriculum
- let pupils develop their understanding of physics collaboratively by „talking physics“ and „writing physics“
- make use of IT resources such as animations and simulations where appropriate
- motivate by showing the relevance of modern physics for pupils' interests and for their educational and career plans
- encourage reflections on historical and philosophical perspectives on science - for example by presenting physicists and their various interpretations of physical phenomena
- clarify the principles that classical physics is built upon to make clear that modern physics drastically changes these underlying principles

Duitsland: Leifi

Duitsland: milq

milq

milq | milq10 | U-Einheit S·P·Q·R | Spezialgebiete | Materialien | Kontakt

Quantenphysik in der Schule

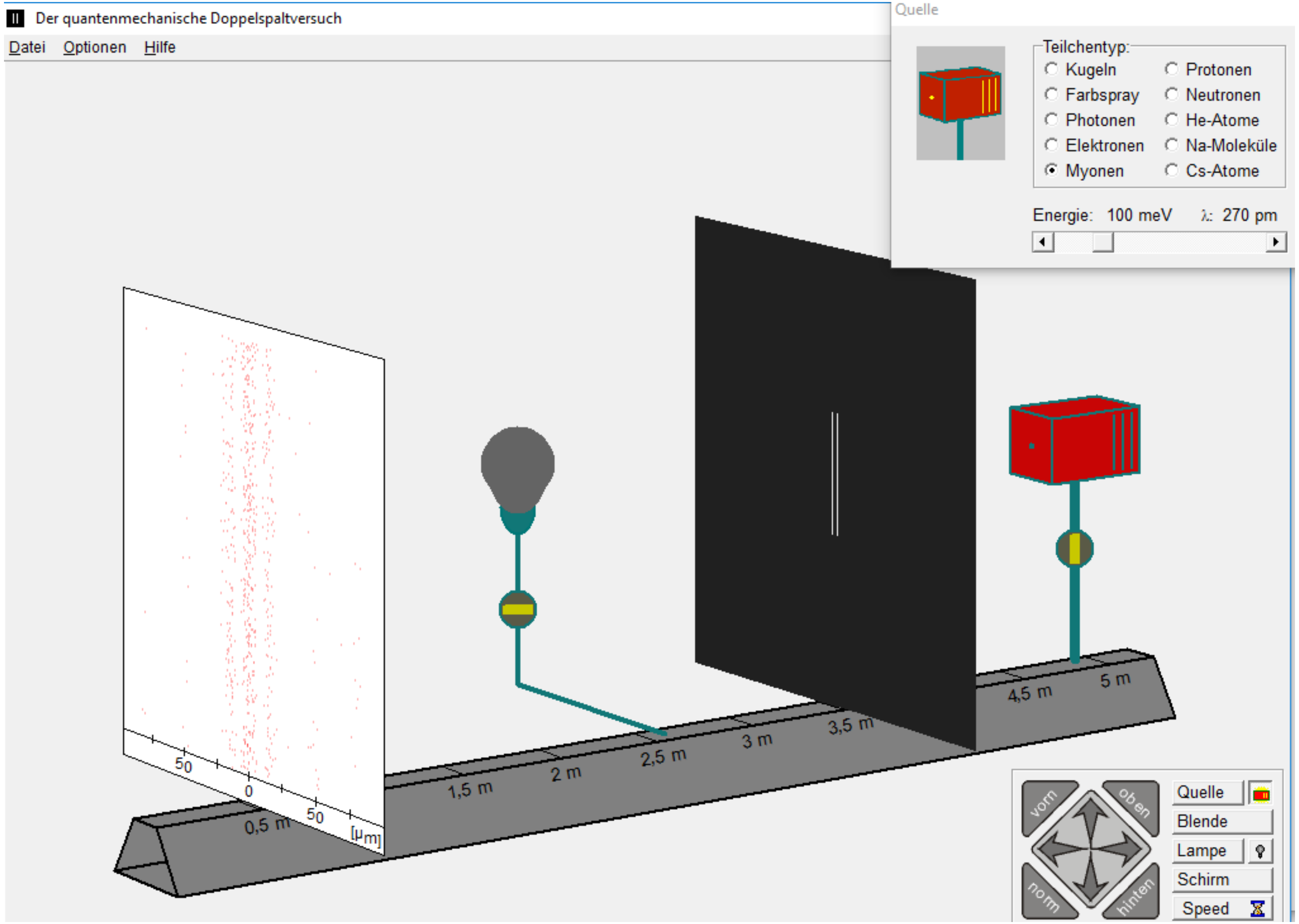
Die Quantenmechanik wird nicht nur von Schülern als schwierig empfunden. Sie ist es wirklich. Den außerordentlich schwierigen begrifflichen Problemen, die sie aufwirft, muss sich jeder Unterrichtende stellen. Das Internetportal **milq** richtet sich an alle, die in der Schule Quantenphysik unterrichten und/oder sich gerne noch etwas ausführlicher damit beschäftigen wollen.

Im Menü können Sie folgende Bereiche auswählen:

Der milq-Lehrgang: Hier findet man an den Unterricht angepasstes begriffliches Hintergrundwissen.

Der milq10-Lehrgang: Hier ensteht eine geänderte Version von milq für die 10 Jahrgangsstufe

Das Schülerprogramm zur Quantenreflexion (S·P·Q·R) bietet ein auf dem milq-Lehrgang basierendes Unterrichtskonzept für die Oberstufe.



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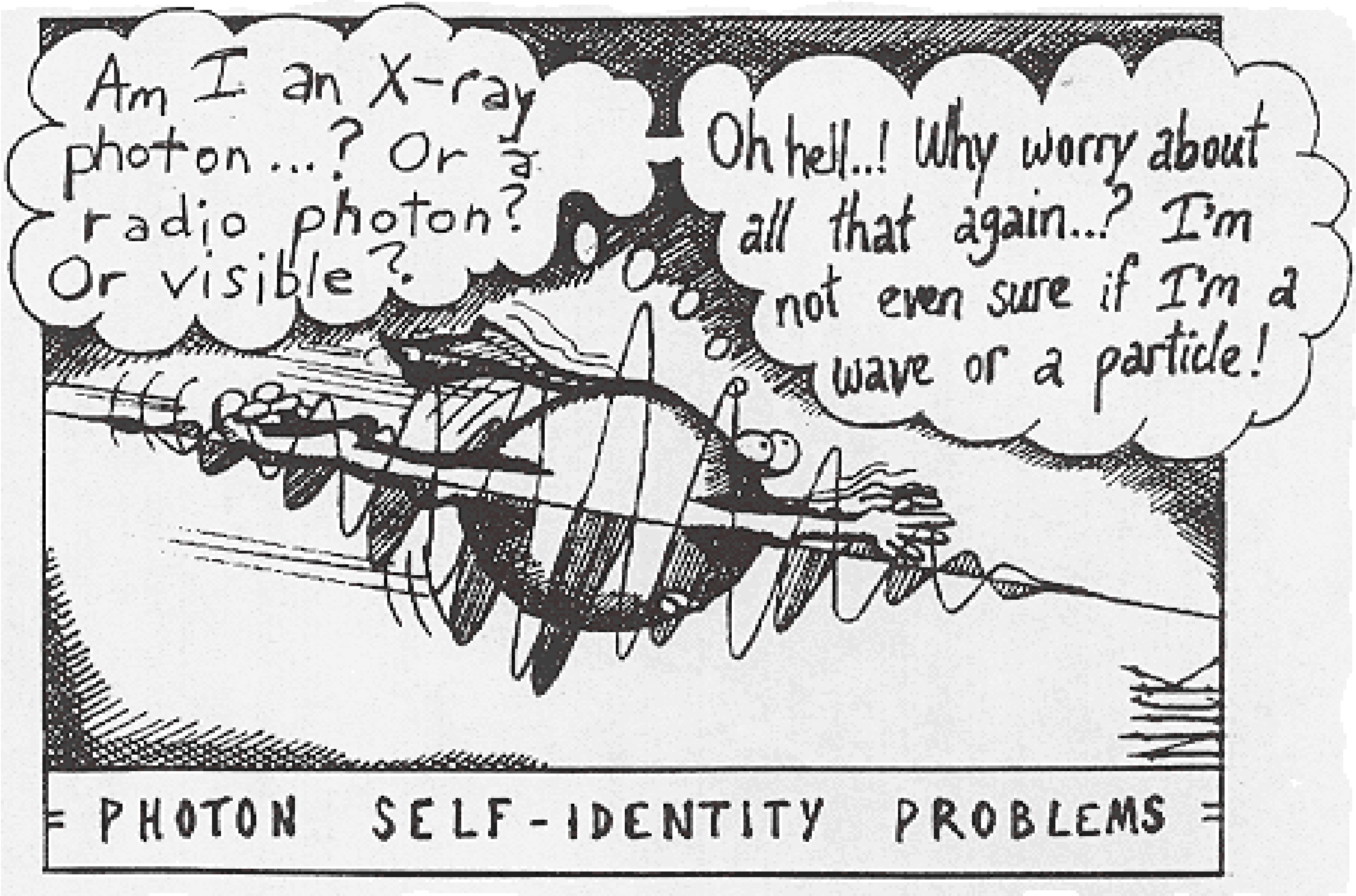

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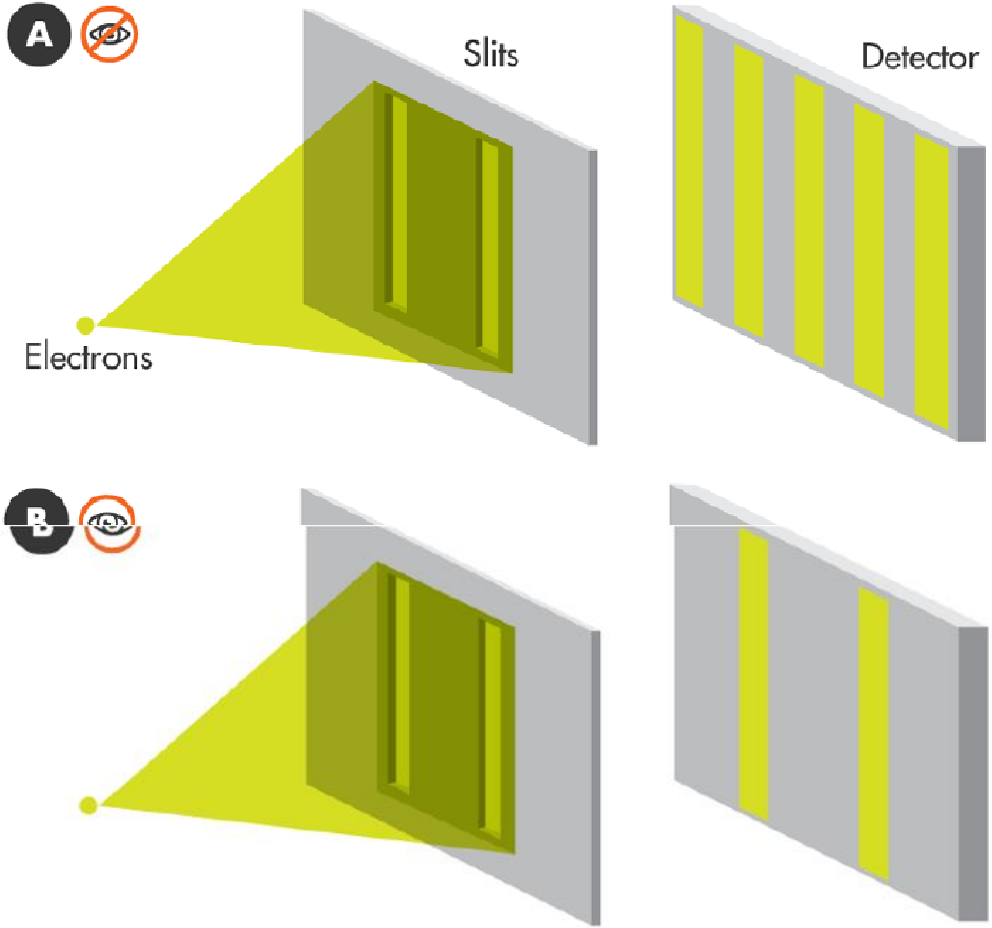

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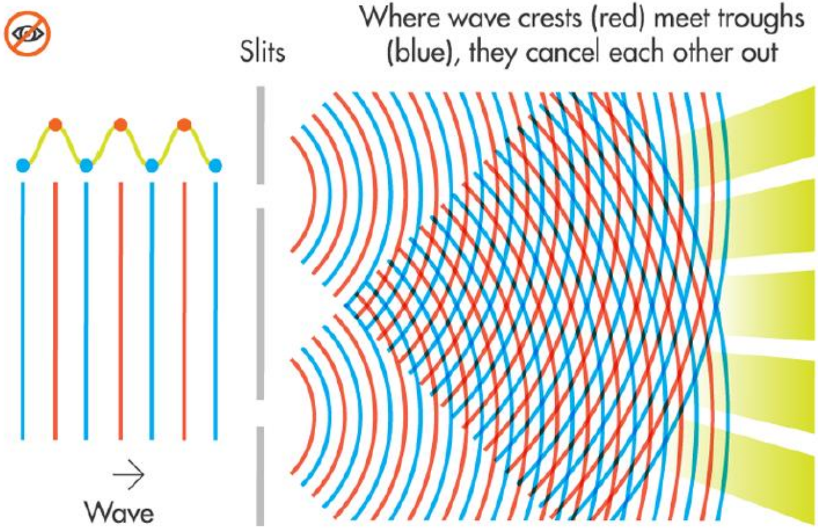
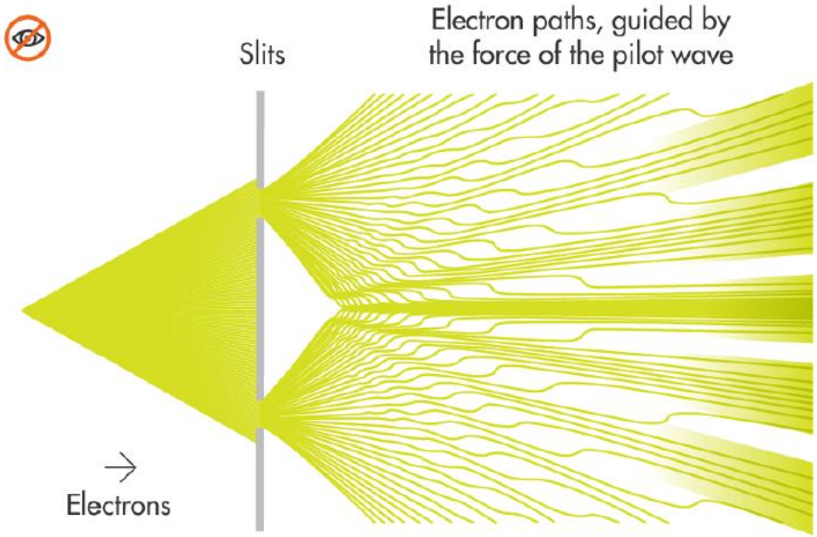
The Copenhagen Interpretation

So long as no observation is being made, electrons do not have definite positions. Each electron spreads out like a wave, passes through both slits simultaneously, and interferes with itself to form the bright and dark bands on the detector screen. Yet as soon as an observer checks to see which slit each electron is passing through, the observation instantaneously "collapses" each electron's position to a point, thus ruining the interference pattern.

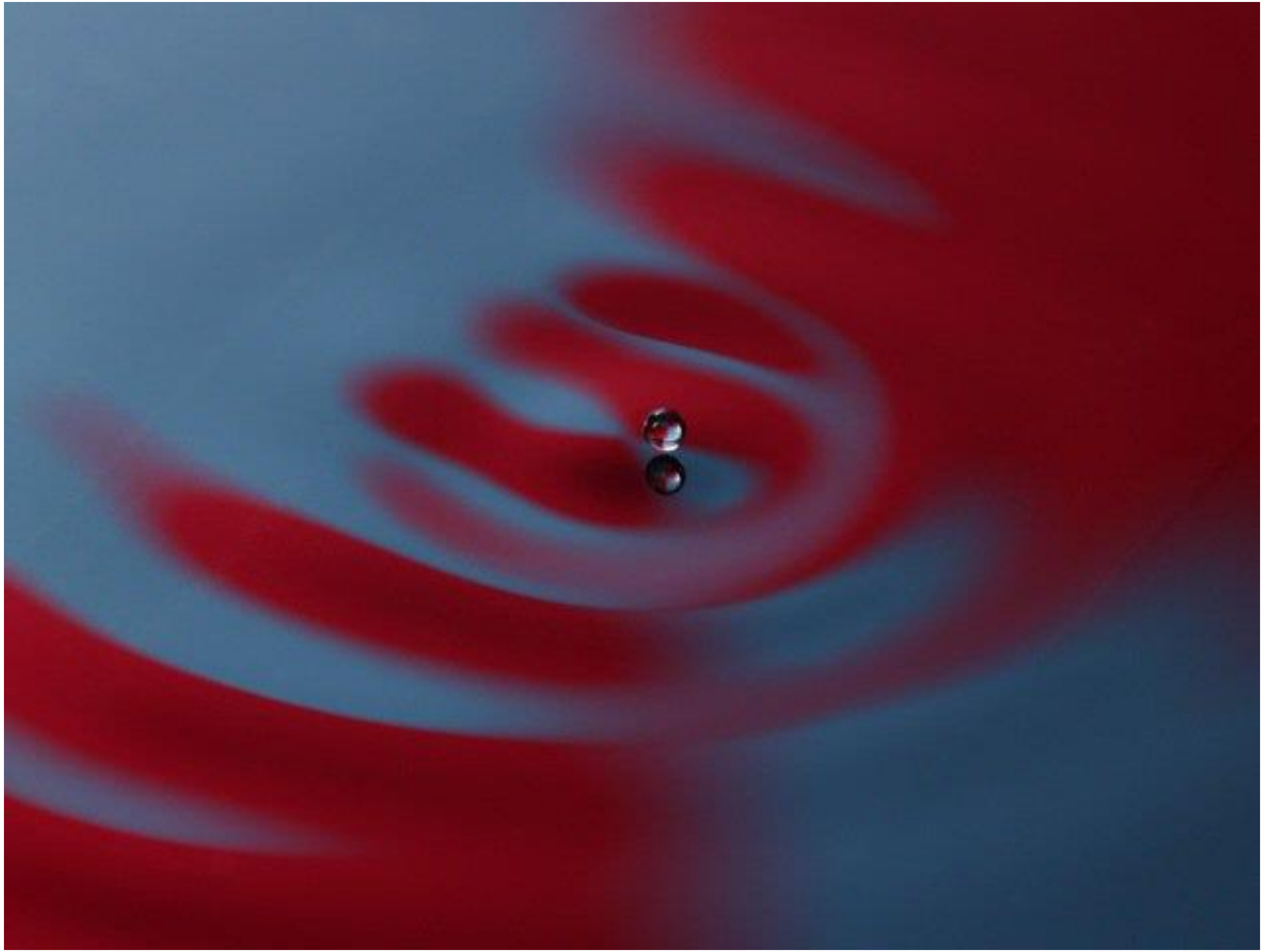


The Pilot-Wave Interpretation

In Bohmian mechanics, every electron always has a definite position, even if observers are ignorant of what it is. An electron is pushed around by a guiding "pilot wave" that influences the electron's location. While each electron travels through one slit or the other, the pilot wave passes through both slits simultaneously. Interference in the pilot wave leads to the observed interference pattern. A measurement at the slits will collapse the pilot wave and reveal where the electron was all along.

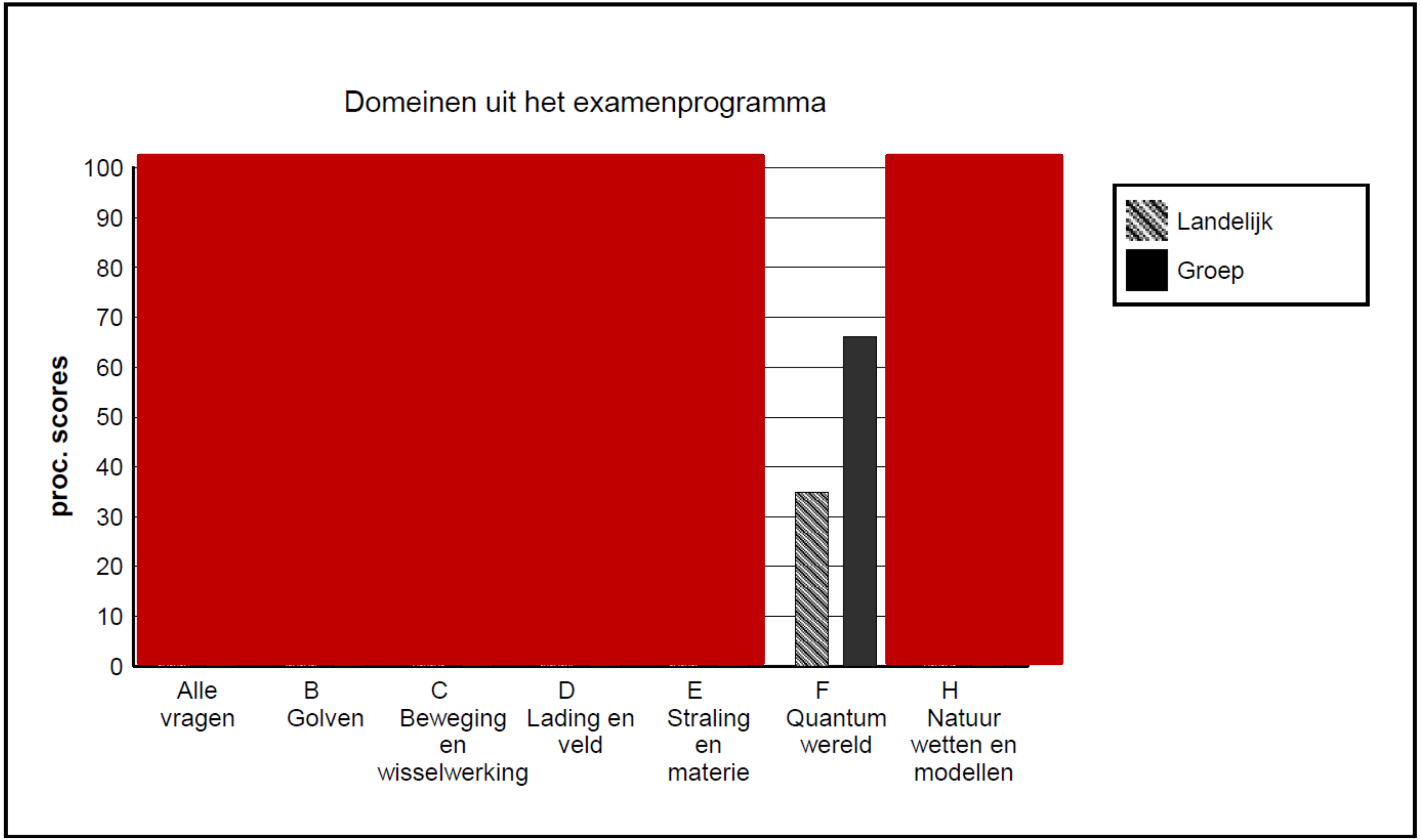


Pilot wave



Pilot wave

wolf 2017



Domeinen uit het examenprogramma
proc. scores
100
90
80
70
60
50
40
30
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10
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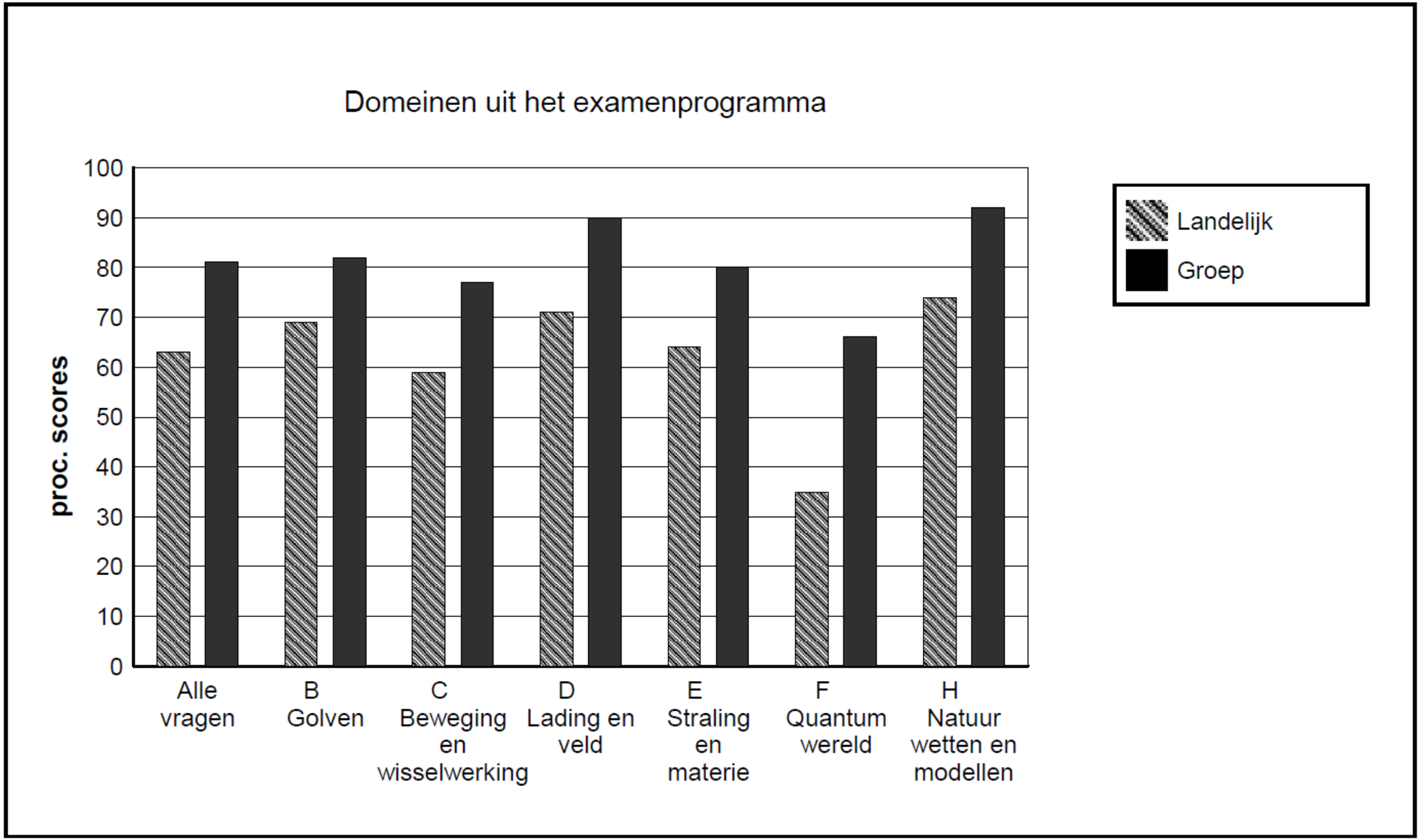
Alle vragen
B Golven
C Beweging en wisselwerking
D Lading en veld
E Straling en materie
F Quantum wereld
H Natuur wetten en modellen
Landelijk
Groep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