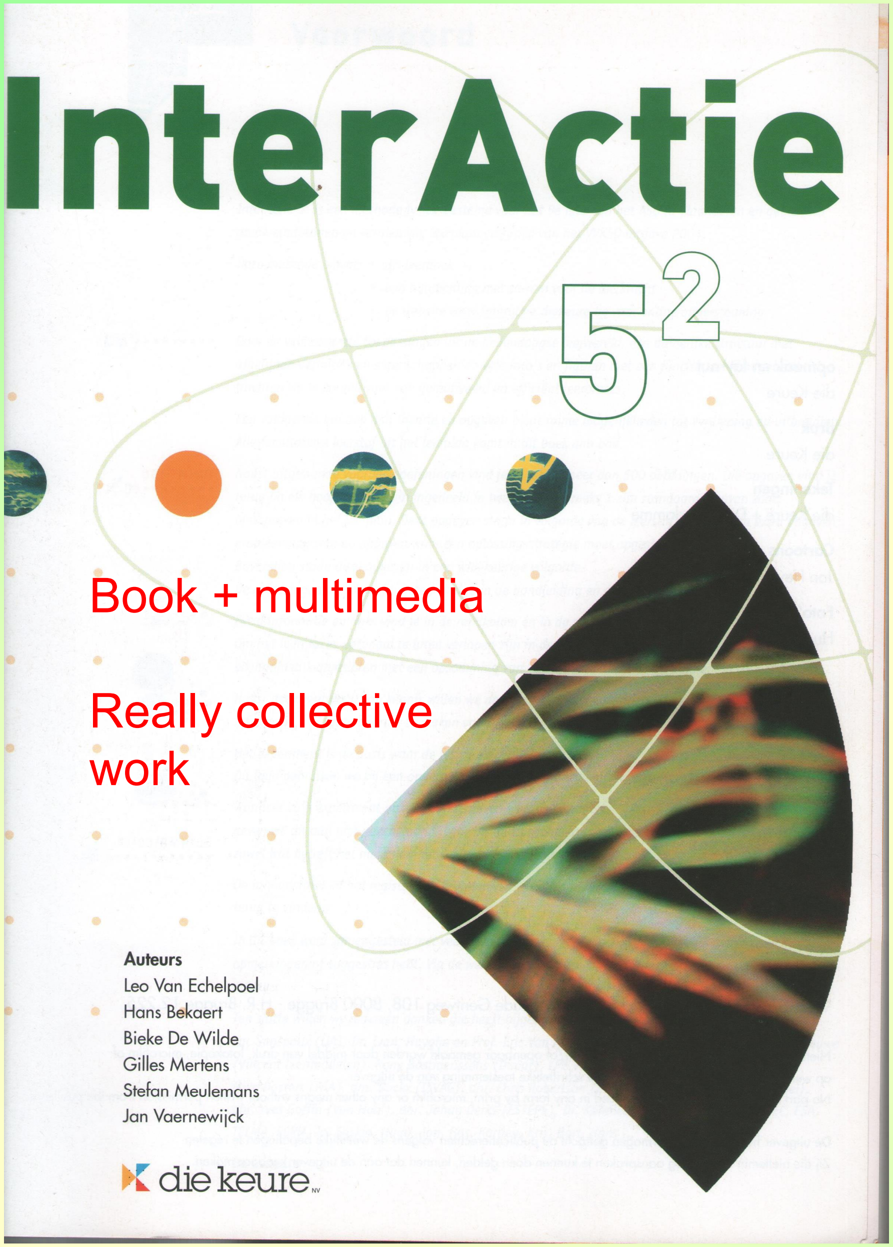
Innovative methods of didactics

Lecture 3
Textbooks – some examples, not only in physics
Part II Physics: Secondary

Grzegorz Karwasz
Didactics of Physics Division UMK, Toruń, Head

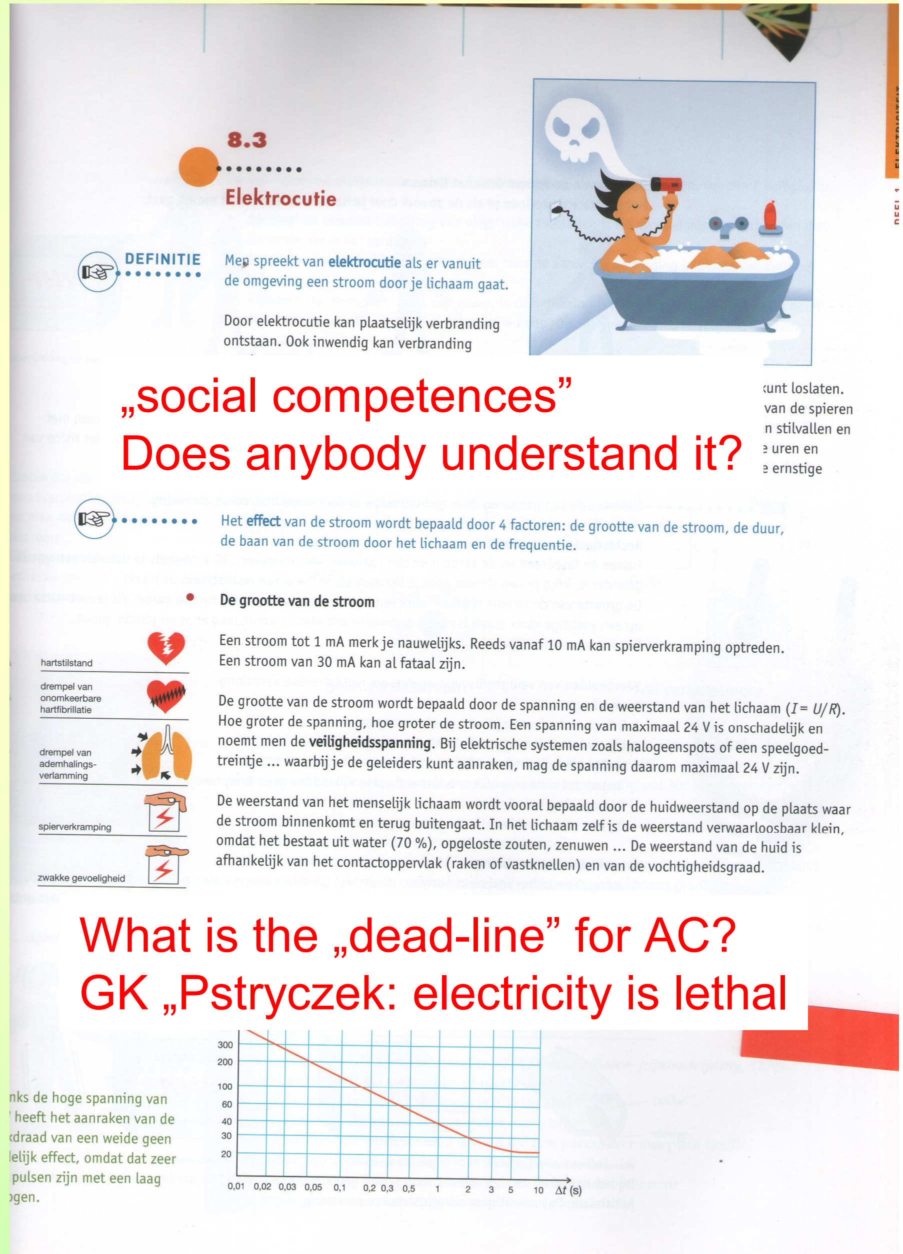
a/a 2020/2021

Interactive Physics (Belgium/ Holland)



Book + multimedia

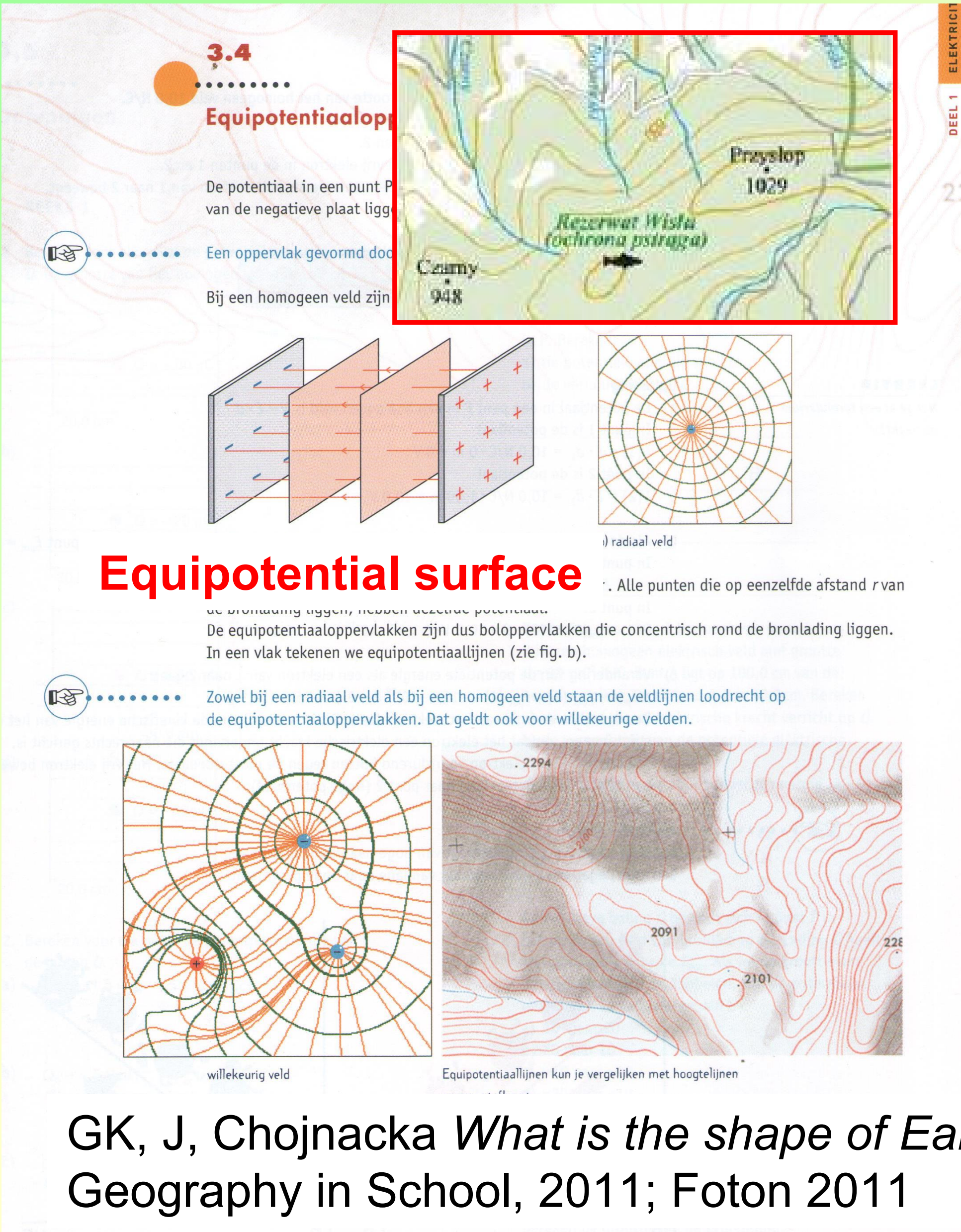
Really collective work



„social competences”
Does anybody understand it?

What is the „dead-line” for AC?
GK „Pstryczek: electricity is lethal

Interactive Physics (Belgium/ Holland)


3.4

Equipotentiaalopp

De potentiaal in een punt P
van de negatieve plaat ligg

Een oppervlak gevormd doo

Bij een homogeen veld zijn

) radiaal veld

. Alle punten die op eenzelfde afstand *r* van

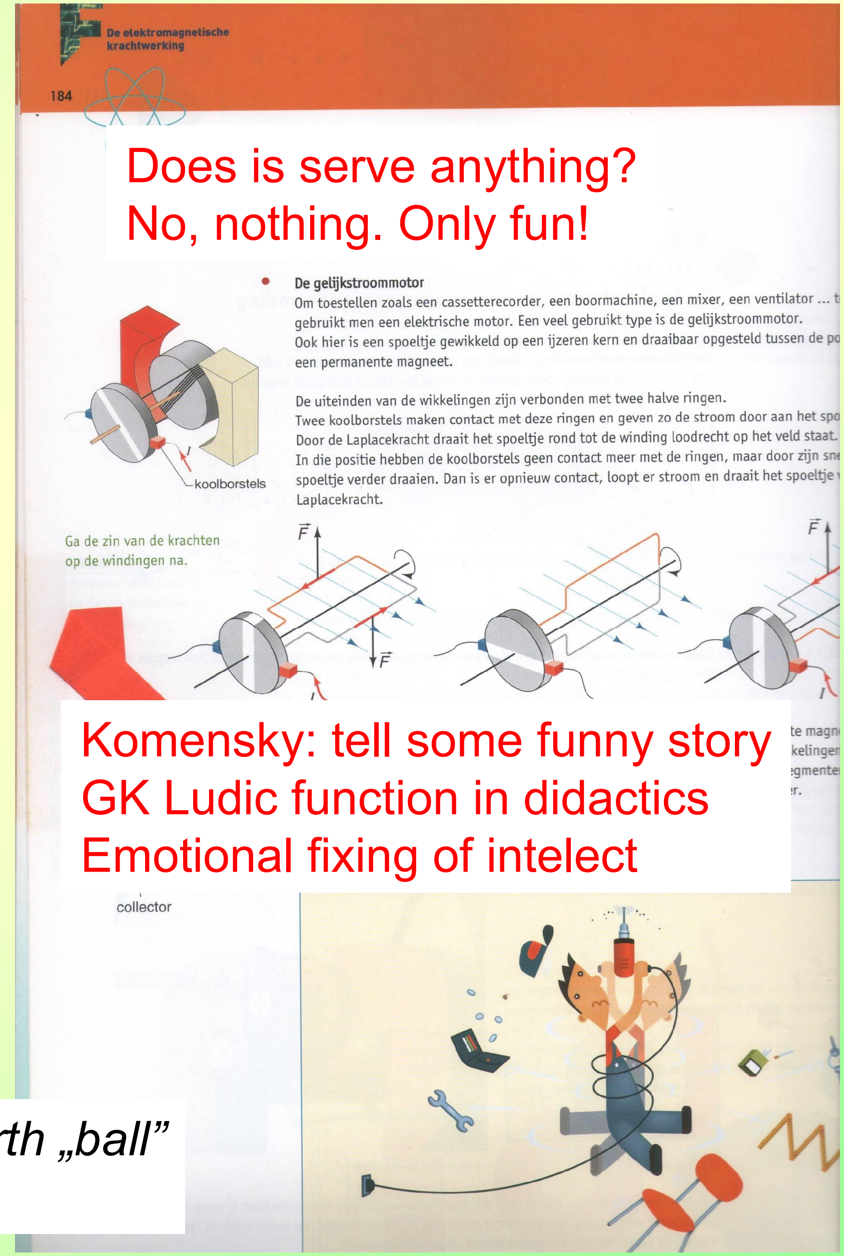
De equipotentiaaloppervlakken zijn dus bolopervlakken die concentrisch rond de bronlading liggen.
In een vlak tekenen we equipotentiaallijnen (zie fig. b).

Zowel bij een radiaal veld als bij een homogeen veld staan de veldlijnen loodrecht op de equipotentiaaloppervlakken. Dat geldt ook voor willekeurige velden.

willekeurig veld

Equipotentiaallijnen kun je vergelijken met hoogtelijnen

Equipotential surface


De elektromagnetische krachtwerking

184

De gelijkstroommotor

Om toestellen zoals een cassetterecorder, een boormachine, een mixer, een ventilator ... t
gebruikt men een elektrische motor. Een veel gebruikt type is de gelijkstroommotor.
Ook hier is een spoeltje gewikkeld op een ijzeren kern en draaibaar opgesteld tussen de po
een permanente magneet.

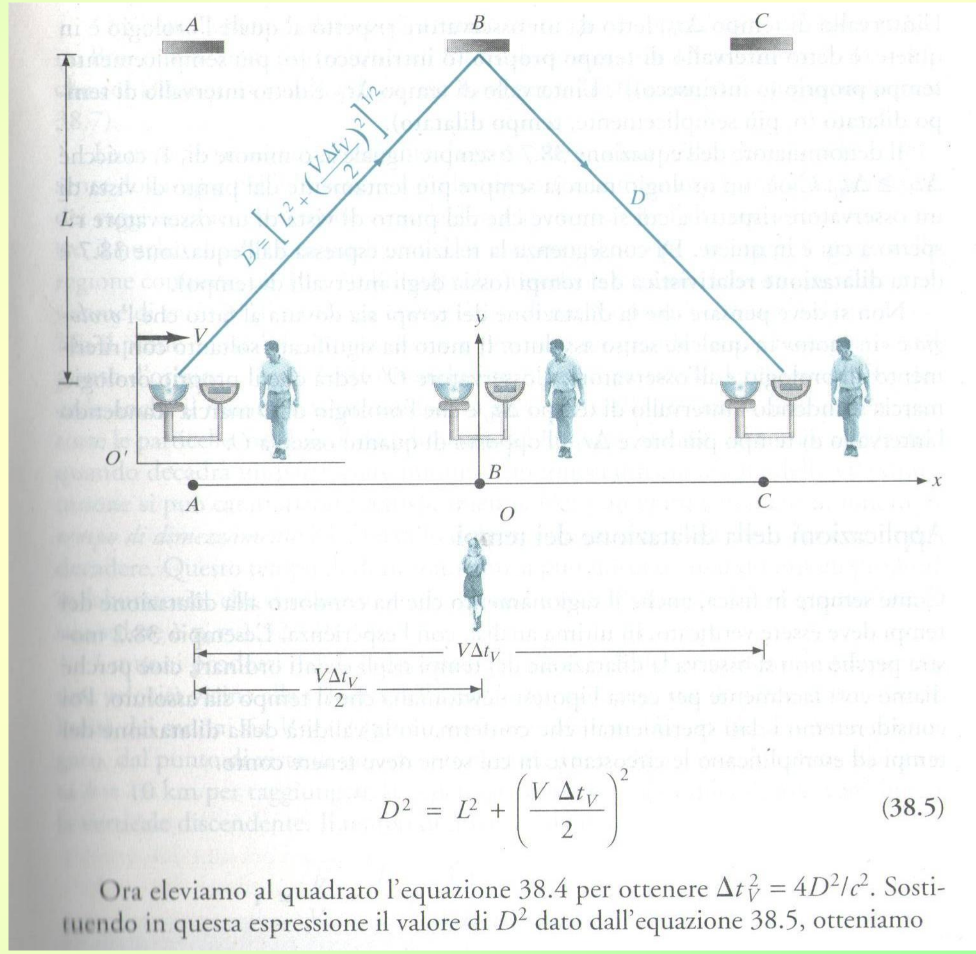
De uiteinden van de wikkelingen zijn verbonden met twee halve ringen.
Twee koolborstels maken contact met deze ringen en geven zo de stroom door aan het spo
Door de Laplacekracht draait het spoeltje rond tot de winding loodrecht op het veld staat.
In die positie hebben de koolborstels geen contact meer met de ringen, maar door zijn sne
spoeltje verder draaien. Dan is er opnieuw contact, loopt er stroom en draait het spoeltje v
Laplacekracht.

Does is serve anything?
No, nothing. Only fun!

Komensky: tell some funny story
GK Ludic function in didactics
Emotional fixing of intelect

GK, J, Chojnacka *What is the shape of Earth „ball”*
Geography in School, 2011; Foton 2011

Modern Physics



$$D^2 = L^2 + \left(\frac{V\,\Delta t_V}{2}\right)^2 \qquad (38.5)$$

Ora eleviamo al quadrato l'equazione 38.4 per ottenere $\Delta t_V^2 = 4D^2/c^2$. Sostituendo in questa espressione il valore di D^2 dato dall'equazione 38.5, otteniamo

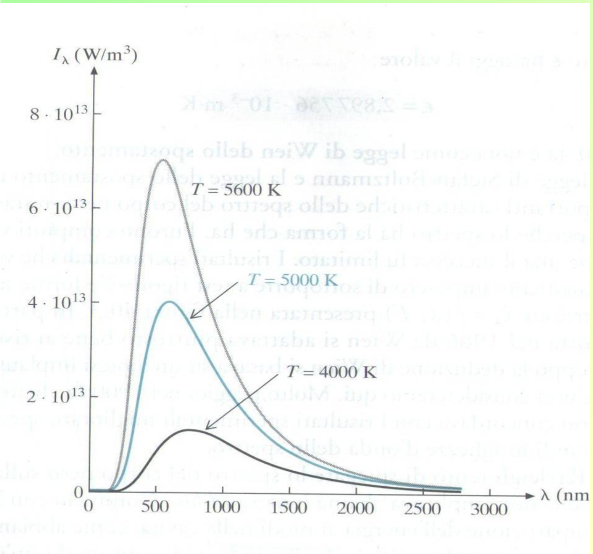
Time dilatation: „drop an eye" (in movement)

Lawrence Lerner, *Physics for scientists and engineers*, Jones & Balrett, 1996

Black body

$I = \sigma T^4$

Stephan-Boltzmann
Experimental law



$\lambda_{max} T = \varepsilon$

Wien law
(experimental)

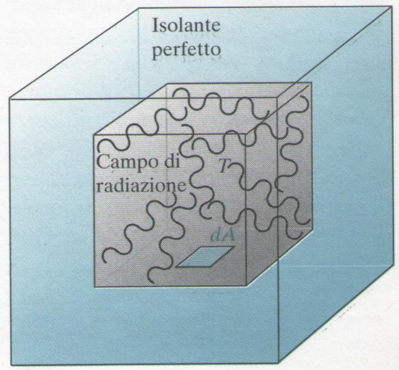
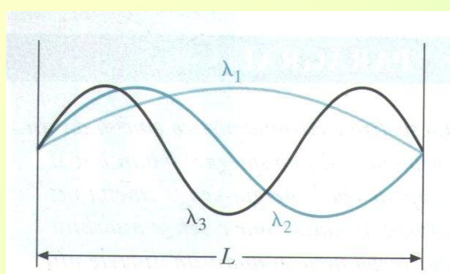
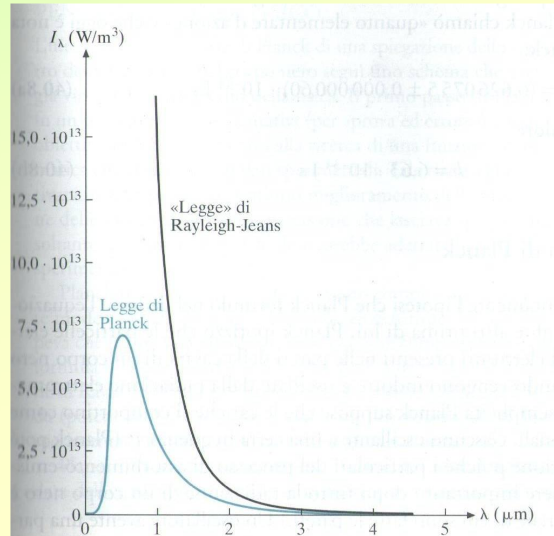


Figura 40.1 Un corpo nero ideale. Il recipiente in cui è stato fatto il vuoto è circondato da un isolante termico perfetto. Le pareti interne sono alla temperatura *T*. La cavità è piena di radiazione elettromagnetica di varie lunghezze d'onda. In condizione di equilibrio termico ogni quantità c… to di… dall'… Perciò l'intero corpo nero (campo di radiazione e pareti della cavità) è in equilibrio.

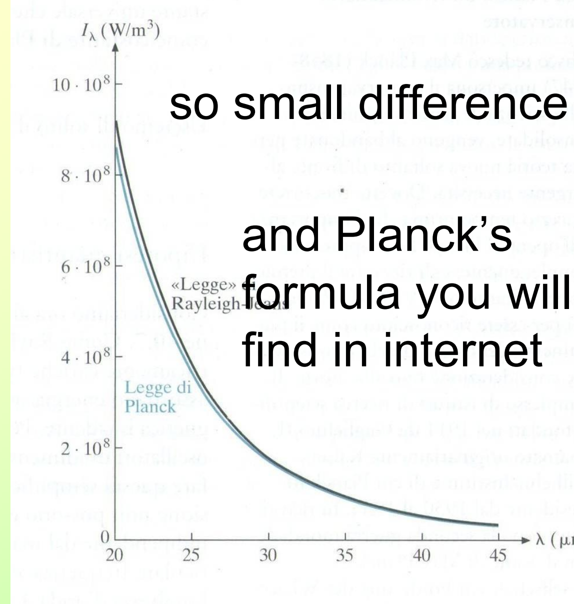
„resonant cavity"

Rayleigh-Jeans





Un'analisi particolareggiata conduce all'equazione 40.5, rappr… te nella figura 40.4.



so small difference

and Planck's formula you will find in internet

…esentata graficamen-

Figura 40.4 Confronto tra uno spettro del co… po nero e la «legge» di Rayleigh-Jeans (equa… zione 40.5). La parte (b) estende il confront…

Lawrence Lerner, *Physics for scientists and engineers*, Jones & Barlett, 1996

Nuclear physics

Problem: lifetimes of nuclides change from second to billion years. Why so much?

$$^{238}\mathrm{U} \xrightarrow{\alpha} {}^{234}\mathrm{Th} \xrightarrow{\beta} {}^{234}\mathrm{Pa} \xrightarrow{\beta} {}^{234}\mathrm{U} \xrightarrow{\alpha} {}^{230}\mathrm{Th} \xrightarrow{\alpha} {}^{226}\mathrm{Ra} \xrightarrow{\alpha} {}^{222}\mathrm{Rn} \xrightarrow{\alpha}$$

$$\rightarrow {}^{218}\mathrm{Po} \xrightarrow{\alpha} {}^{214}\mathrm{Pb} \xrightarrow{\beta} {}^{214}\mathrm{Bi} \quad {}^{214}\mathrm{Bi} \xrightarrow{\beta} {}^{214}\mathrm{Po} \xrightarrow{\alpha} {}^{210}\mathrm{Pb} \xrightarrow{\beta} {}^{210}\mathrm{Bi} \xrightarrow{\beta} {}^{210}\mathrm{Po} \xrightarrow{\alpha}$$

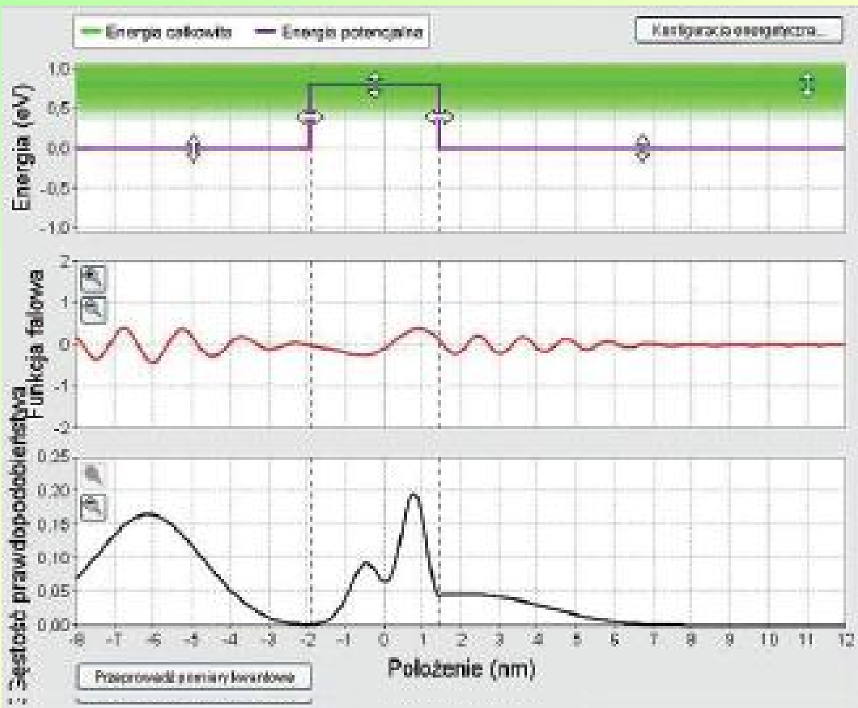
$$\rightarrow {}^{206}\mathrm{Pb}\ \text{(stabilny)} \qquad (3.9)$$

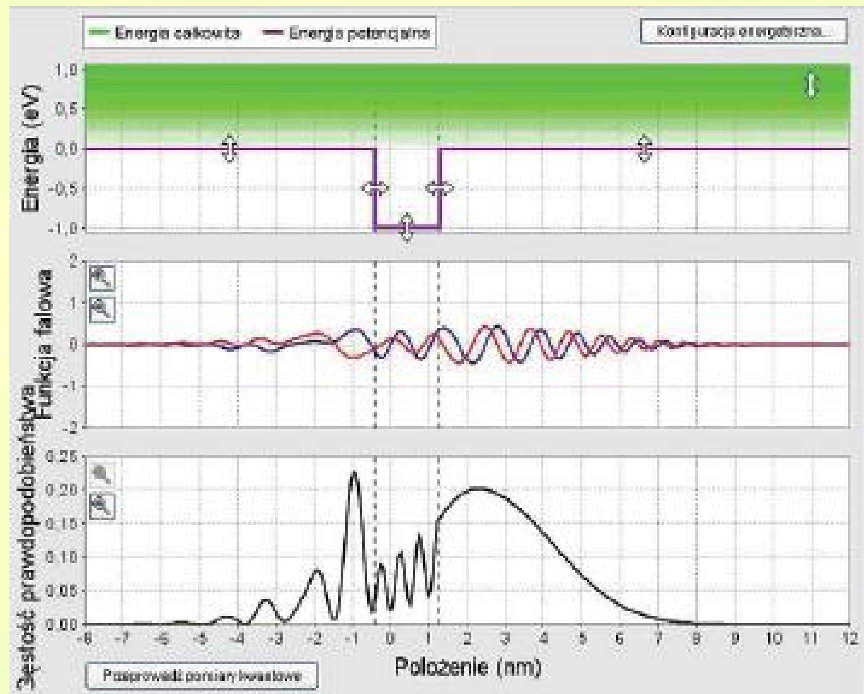
Czasy połowicznego rozpadu dla różnych izotopów mogą bardzo odbiegać od siebie: oprócz czasów „geologicznych", jak wspomnianych ^{238}U i ^{40}K, izotopy nawet tego samego pierwiastka chemicznego mogą mieć bardzo różne czasy połowicznego rozpadu[16]. Wymienione w cyklu rozpadu uranu, ryc. 3.6, produkty przejściowe mają odmienne czasy połowicznego rozpadu: rad $^{26}_{88}$Ra – 1600 lat, gaz radon $^{222}_{86}$Rn – 3,8 dnia, polon $^{218}_{84}$Po – 3 minuty, ołów $^{214}_{82}$Pb – 27 minut (ten rozpada się przez proces β); bizmut $^{214}_{83}$Bi – 20 minut; w kolejnym rozpadzie β powstaje ponownie polon, ale inny izotop, $^{214}_{84}$Po, żyjący zaledwie 0,16 milisekundy itd. Spośród różnych izotopów nowego sztucznego pierwiastka o liczbie atomowej $Z = 112$ (czy-

G. Karwasz, *Toruński po-ręcznik do fizyki. Part IV. Modern Physics and Astrophysics*

because of Quantum Physics

α-decay is tunneling through a potential barrier





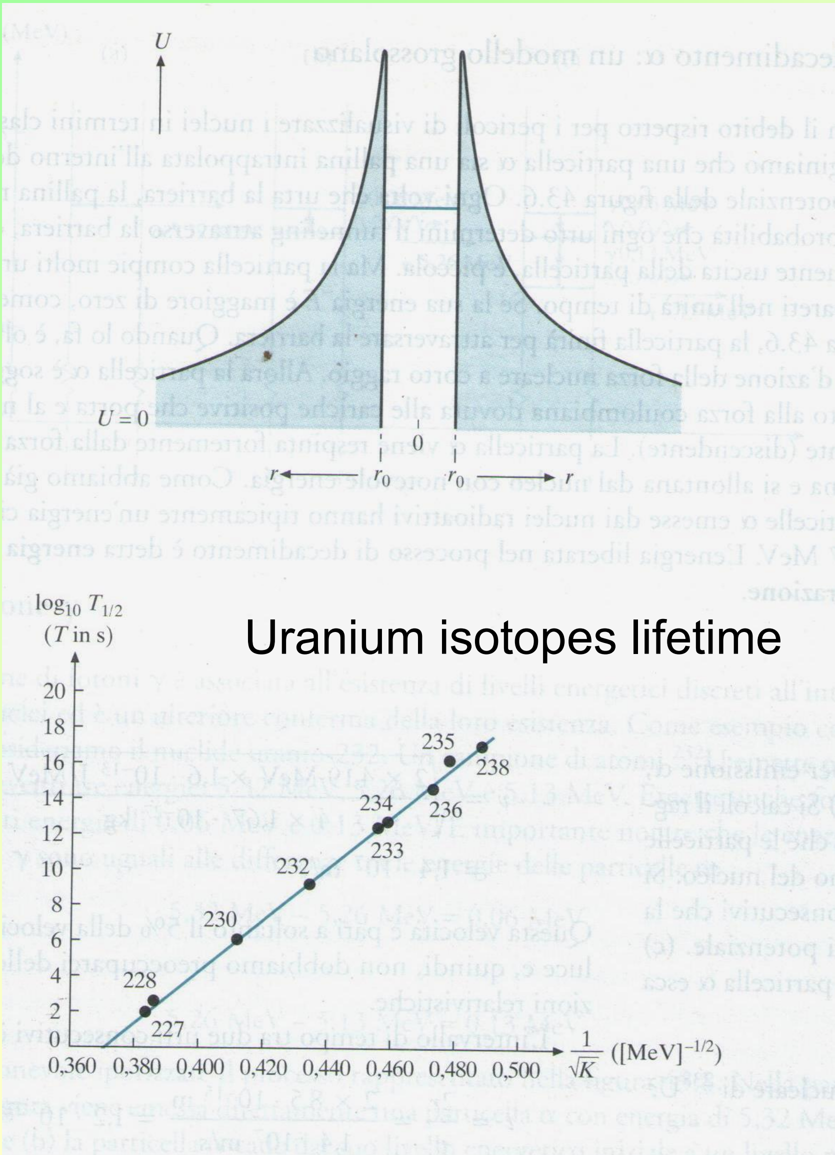
Probability of transmission depends very strongly on barrier's width

By the way, the wave does reflect also from a well

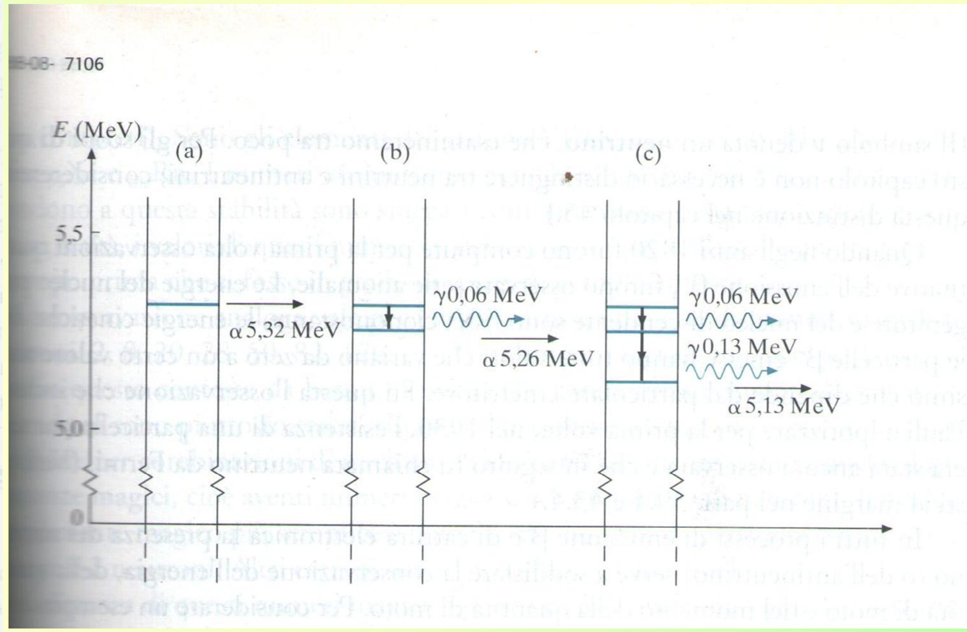
Model: phet.colorado.edu

G. Karwasz, *Toruński po-ręcznik do fizyki. Part IV. Modern Physics and Astrophysics*

Look into detail



Uranium isotopes lifetime



Uranium ^{238}U decay modes
Note low energy of γ-rays

Also **plutonium** has low γ-energies
But is extremely (chemically) **poisonous**

Lawrence Lerner, *Physics for scientists and engineers*, Jones & Barlett, 1996

We may check it in excellent book

- CRC Handbook of Physics and Chemistry:

a „Bibble” of the researcher

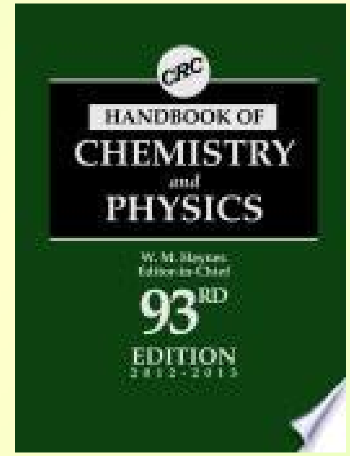


Table of the Isotopes 11-5

4.27 MeV

1.2 bln yrs

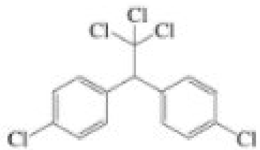
β+

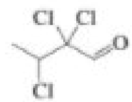
Elem. or Isot.	Natural Abundance (Atom %)	Atomic Mass or Weight	Half–life/ Resonance Width (MeV)	Decay Mode/ Energy (/MeV)	Particle Energy/ Intensity (MeV/%)	Spin ($h/2\pi$)	Nuclear Magnetic Mom. (nm)	Elect. Quadr. Mom. (b)	γ-Energy/ Intensity (MeV/%)
^{13}N		13.0057386	9.97 m	β+ /2.2204	1.190/100.	½-	0.3222		
^{14}N	99.636(20)	14.003074005				1+	+0.403761	+0.02044	
^{15}N	0.364(20)	15.00010898				½-	−0.283189		
^{16}N		16.006102	7.13 s	β- /10.419	4.27/68.	2-			6.129/68.8
^{39}K	93.2581(44)	38.9637067				3/2+	+0.39146	+0.049	
^{40}K	0.0117(1)	39.9639985	1.248×10^9 a	β- /1.3111	1.312/89.	4-	−1.29810	−0.074	ann.rad./
				β+, EC/1.505	1.50/10.7				1.4608/10.5
^{41}K	6.7302(44)	40.9618258				3/2+	+0.21487	+0.071	
^{42}K		41.9624028	12.36 h	β- /3.525	1.97/19.	2-	−1.1425		0.31260(2)/0.3
^{63}Cu	69.15(15)	62.929598				3/2-	+2.2273	−0.211	
^{64}Cu		63.929764	12.701 h	β- /38/0.579	0.578/	1+	−0.217		ann.rad./35.1
				β+ /19/1.6751	0.65/				1.3459(3)/0.47

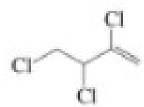
https://books.google.pl/books?redir_esc=y&id=c1rNBQAAQBAJ&q=nuclides#v=snippet&q=nuclides&f=false

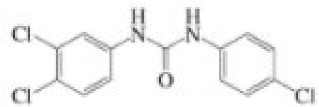
Excellent also in chemistry

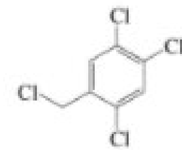
Physical Constants of Organic Compounds 3-521


10212
1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane


10213
2,2,3-Trichlorobutanal


10214
2,3,4-Trichloro-1-butene


10215
3,4,4'-Trichlorocarbanilide


10216
1,2,4-Trichloro-5-(chloromethyl)benzene


10217
Trichloro(chloromethyl)silane

Crystallographic Data on Minerals 4-147

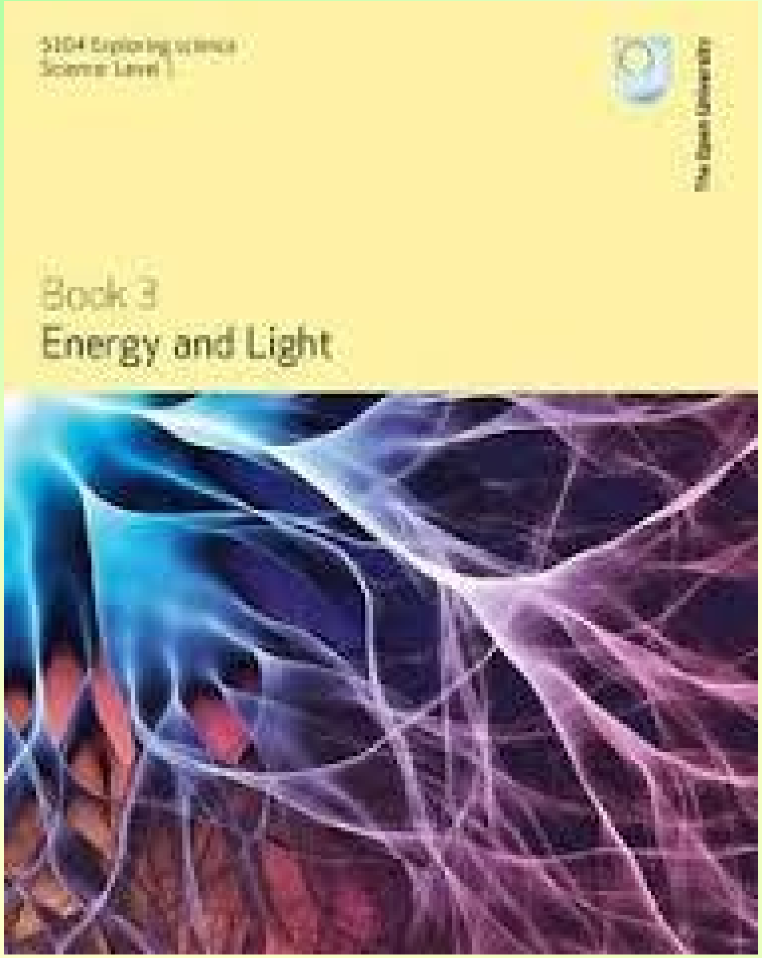
Name	Formula	Crystal system	Structure type	Z	*a*/Å	*b*/Å	*c*/Å	α	β	γ
Datolite	$CaBSiO_4(OH)$	monocl		4	9.62	7.60	4.84		90.15°	
Daubreeite	$FeCr_2S_4$	cubic	spinel	8	9.966					
Diamond	C	cubic	diamond	8	3.5670					
Diaspore	AlO(OH)	orth		4	4.401	9.421	2.845			

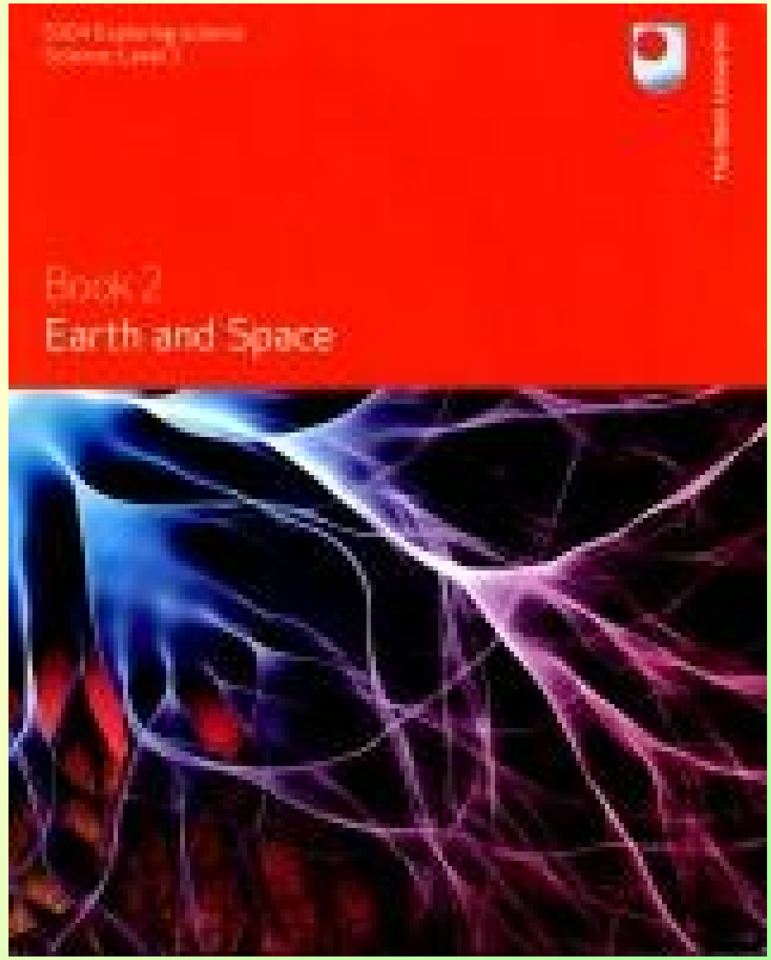
5-88 **Electrochemical Series**

Reaction	$E°$/V	Reaction	$E°$/V
$Ni^{2+} + 2e \rightleftharpoons Ni$	−0.257	$NbO_2 + 4H^+ + 4e \rightleftharpoons Nb + 2H_2O$	−0.690
$PbCl_2 + 2e \rightleftharpoons Pb + 2Cl^-$	−0.2675	$Ag_2S + 2e \rightleftharpoons 2Ag + S^{2-}$	−0.691
$H_3PO_4 + 2H^+ + 2e \rightleftharpoons H_3PO_3 + H_2O$	−0.276	$AsO_4^{3-} + 2H_2O + 2e \rightleftharpoons AsO_2^- + 4OH^-$	−0.71
$Co^{2+} + 2e \rightleftharpoons Co$	−0.28	$Ni(OH)_2 + 2e \rightleftharpoons Ni + 2OH^-$	−0.72

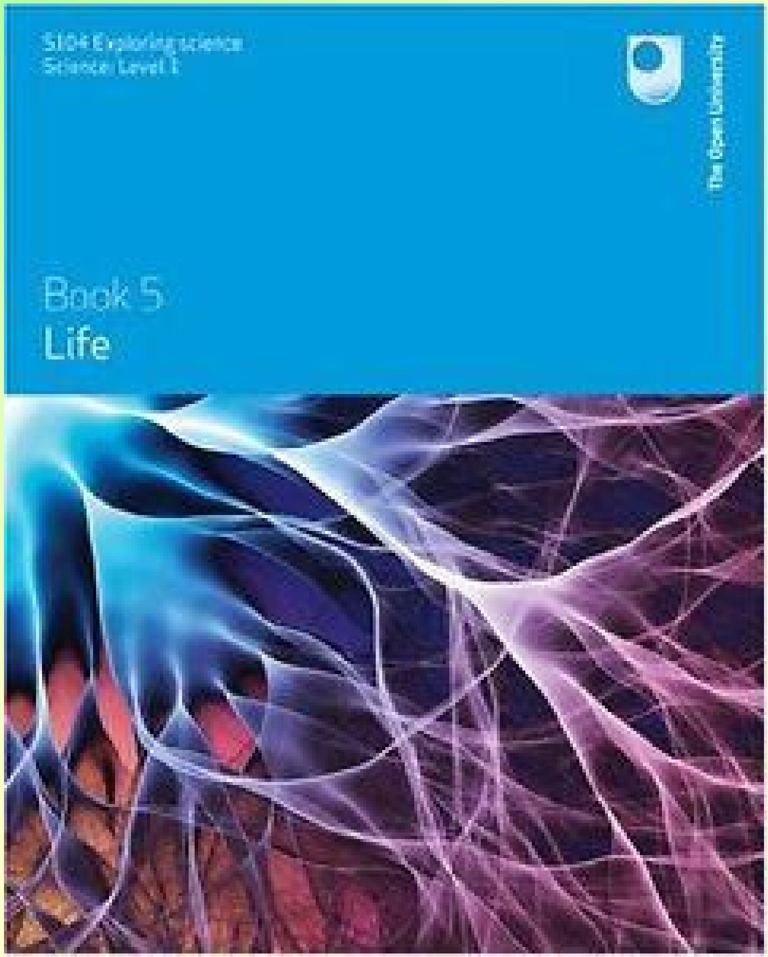
https://books.google.pl/books?redir_esc=y&id=c1rNBQAAQBAJ&q=nuclides#v=snippet&q=nuclides&f=false

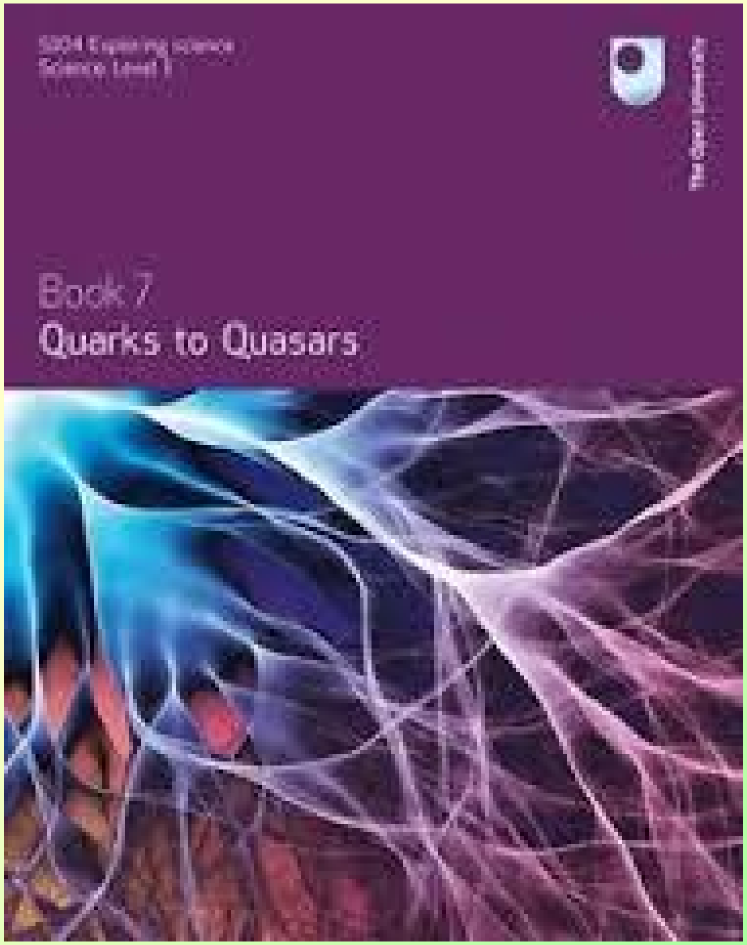
Open University: Introducing Science





Open University: Introducing Science





Reference to social sensitivity

Part I Climate changes

Figure 2.1 Cuttings from newspaper stories focusing on some of the more extreme consequence warming.

Figure 2.2 Photograph showing considerable damage to houses caused by a tornado in an area of the UK's second largest city, Birmingham, in July 2005.

Figure 2.3 If you wait long enough, you too could roll five sixes (although, admittedly it may take a while – on average you will get five sixes every 8000 or so rolls). So, the unlikely event does occasionally happen.

Tranversal competences

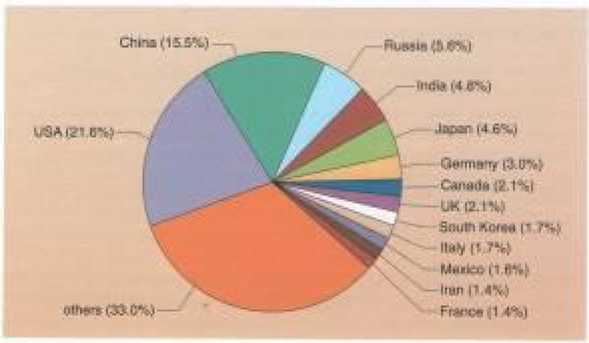
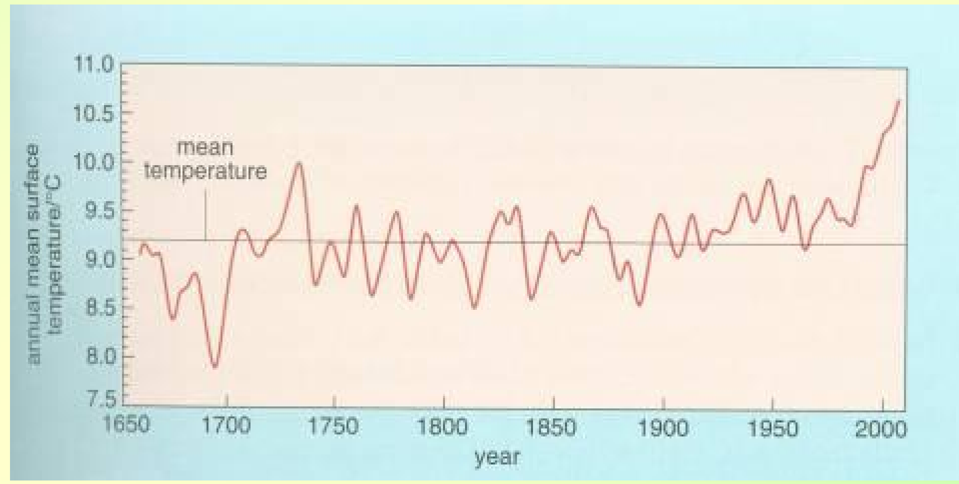
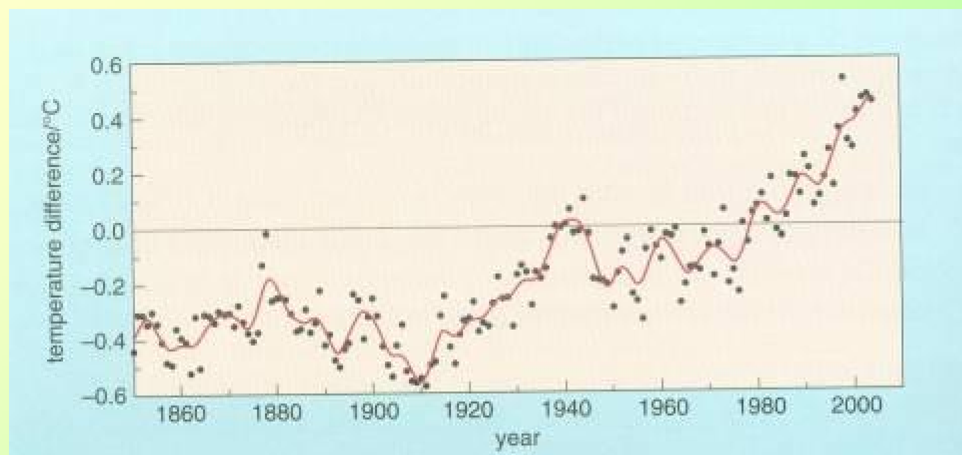


Figure 2.8 Pie chart showing the proportion of carbon emitted globally into the atmosphere in 2004. The pie chart has 14 slices, with 13 slices representing the 13 countries that emitted more than 100 million tonnes of carbon each, and the remaining slice representing the contributions from all other countries combined. The 13 specified countries account for 67.0% of the world's total carbon emission.

Table 2.1 Anthropogenic emissions of carbon dioxide into the atmosphere in 2004, expressed in terms of the mass of carbon in millions of tonnes, and their proportions of the total world emissions. Countries that emitted over 100 million tonnes of carbon are listed individually. (You may have noted that the percentage values actually add up to 100.1%. This is because the individual values are only quoted to the nearest 0.1%, and this leads to what is known as a rounding error.)

Country	Mass of carbon/million tonnes	Proportion of total world emissions/%
USA	1580	21.6
China	1130	15.5
Russia	407	5.6
India	347	4.8
Japan	336	4.6
Germany	220	3.0
Canada	154	2.1
UK	152	2.1
South Korea	124	1.7
Italy	122	1.7
Mexico	114	1.6
Iran	104	1.4
France	104	1.4
All other countries	2410	33.0

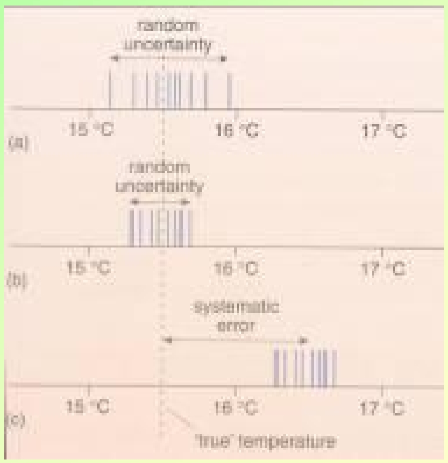


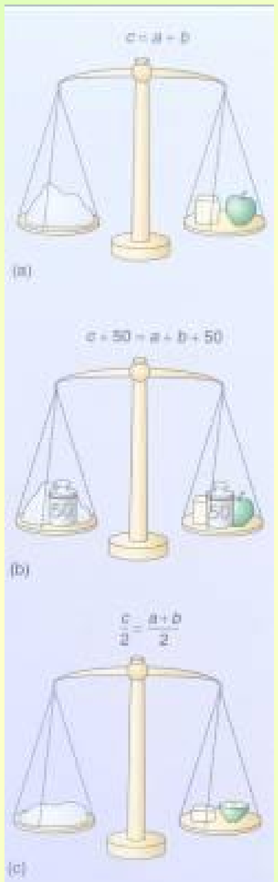


„walking" everage

Requiring only what was taught

Figure 3.2 Two thermometers, A and B, measuring the air temperature in the same place. Thermometer A has scale divisions of 1 °C whereas thermometer B ha[s] scale divisions of 0.1 °C.





Systematic error

How to make evaluation

■ To how many significant figures are each of the following measurements given: (a) 6.4×10^2 m; (b) 5.405×10^2 m; (c) $5.405\ 00 \times 10^2$ m?

□ (a) Two significant figures; (b) four significant figures; (c) six significant figures.

Box 3.2 Scientific notation and its use with a calculator

Scientific notation is a useful way of writing numbers, particularly very large or very small numbers. Scientific notation relies on the fact that *any* value can be rewritten as a number that is *equal to or greater than 1 but less than 10*, multiplied by a simple power of ten. Take, for example, a number such as 123. In scientific notation this becomes 1.23×10^2. Similarly, 12 345 in scientific notation becomes 1.2345×10^4. In these two examples, the powers of ten are 10^2 (i.e. 100) and 10^4 (i.e. 10 000). When converting values that are less than one into scientific notation, the power of ten becomes negative. For example, 0.000 123 45 is 1.2345×10^{-4} in scientific notation. This is because 0.000 123 45 is equal to 1.2345×0.0001 and

$$0.0001 = \frac{1}{10\,000} = \frac{1}{10^4} = 10^{-4}$$

Note that 1 and 10 can also be written as powers of ten. You know that 100 is 10^2 and 0.1 is 10^{-1}; perhaps you can see that the 'in between' powers of ten are thus: $10 = 10^1$ and $1 = 10^0$. So, in scientific notation, 12.3 is 1.23×10^1 and 1.23 is 1.23×10^0. Note that any number written using a power of ten could be referred to as being in 'powers of ten' notation. Hence, 23.4×10^4 is in powers of ten notation; however, it is only when written as 2.34×10^5 that it would be in proper scientific notation.

You should ensure that you can type numbers in scientific notation into your calculator correctly. For example, you should know the difference in entering, say, -6.78×10^6 as opposed to 6.78×10^{-6} (or indeed, -6.78×10^{-6}). Also, do not fall into the trap of entering a simple power of ten, such as 10^4, as 10×10^4 (which is actually 10^5). This is avoided if you remember that 10^4 is actually 1×10^4 in scientific notation. Finally, take care not to enter (or write), say, 3.46×10^4 as 3.46^4.

Ensure you are comfortable with entering scientific notation and powers of ten into your calculator by checking you get the following answers to these multiplications and divisions.

$2.45 \times 10^5 \times 3.2 \times 10^7 = 7.84 \times 10^{12}$

$3 \times 10^8 \times 6.6 \times 10^{-34} = 1.98 \times 10^{-25}$

$6.666 \times 10^{-34} \div 2.222 \times 10^0 = 3 \times 10^{-34}$

$-2.1 \times 10^4 \times 2.1 \times 10^{-4} = -4.41$ (i.e. -4.41×10^0)

$10^6 \times 10^6 = 10^{12}$ (i.e. 1×10^{12})

$10^8 \div 10^{-34} = 10^{42}$ (i.e. 1×10^{42})

$10^4 \times 3.14 = 31\,400$ or 3.14×10^4

Scientific notation

Ilustrative, step-by-step, resolving doubts

9.1.2 Amplitude

So much for the periodicity of waves; what of the assertion that they transport energy from one place to another? Again, waves on the sea provide a convenient example. Waves may be generated far out to sea by winds, where energy is imparted to the wave and transported by it until the wave finally breaks on the shore, and the energy is released.

- What is the evidence for this release of energy when a wave breaks on the seashore?
- When the wave breaks, kinetic energy is imparted to pebbles and other debris, causing them to move. Also, the sound of the crash is heard, which is further evidence for the release of energy.

How does the energy transported by a wave on the sea depend on the properties of the wave? Again your experience probably tells you that, if the vertical distance between the trough and crest of a wave is greater (that is, if the waves are 'higher'), more energy is released as they crash onto the shore. As you will see at the beginning of the *Making Waves* video sequence, the waves on the sea during a storm tend to be very high. Storms can result in a great deal of damage to breakwaters and sea defences; clearly, higher waves carry more energy. The **amplitude** of a wave is conventionally defined as half the trough-to-crest height, or (equivalently) the maximum deviation of the wave from its mean position. Therefore, the amplitude of a wave is a measure of how much energy it carries. It turns out that the energy carried by a wave is actually proportional to the *square* of its amplitude, which explains why big breakers are so powerful.

The meanings of the wavelength and amplitude of a wave are summarised in Figure 9.2.

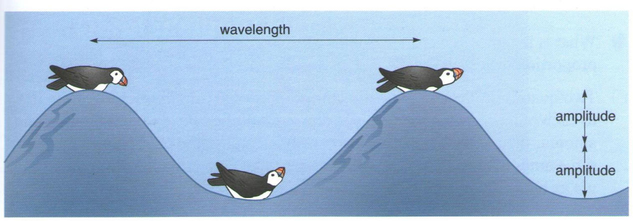


Figure 9.2 Wavelength and amplitude of a water wave.

The preceding discussion of waves in terms of natural water waves on the sea was rather qualitative. The problem is that waves on the sea are uncontrollable; they are not generally well behaved and regular, they are not strictly periodic, and one wave crest breaking on a beach is often quite different in nature to that immediately preceding or following it – just ask a surfer! This makes them difficult to study and therefore waves on the sea are not an ideal subject

9.1.3 Frequency and wave speed

As you saw in the *Making Waves* video sequence, a wave may be characterised by its amplitude A, its wavelength λ, its **frequency** f (or period $T = \frac{1}{f}$), and its propagation speed v. The units of frequency can be thought of as 'cycles per second' or simply s^{-1}, and an equivalent unit is the **hertz** (symbol Hz), where $1\ Hz = 1\ s^{-1}$. (Remember that λ is the Greek letter lambda – wavelengths are always represented by this symbol.)

As you discovered in Activity 9.1 Task 1, a wave may be represented gra[...] either by its profile in space at a particular instant of time, or by its varia[...] with time at a particular point in space. Examples of these two representa[...] are shown in Figure 9.5. The speed of a wave v is related to its frequency [...] wavelength by the equation:

$$v = f\lambda$$

With λ in the SI units of metres and f in the SI units of hertz (or s^{-1}), the [...] of the wave is expressed in the SI units of $m\ s^{-1}$. The speed of light (and electromagnetic radiation) in a vacuum is given the special symbol c and is $2.997\ 924\ 58 \times 10^{8}\ m\ s^{-1}$. If light is travelling through a material such glass, it travels at a slower speed.

http://dydaktyka.fizyka.umk.pl/zabawki1/files/mech/sprezyny.jpg

Book 1, Box 3.1 for advice on rounding).

So for light, or any other electromagnetic radiation, Equation 9.1 can be written as:

$$c = f\lambda \qquad (9.2)$$

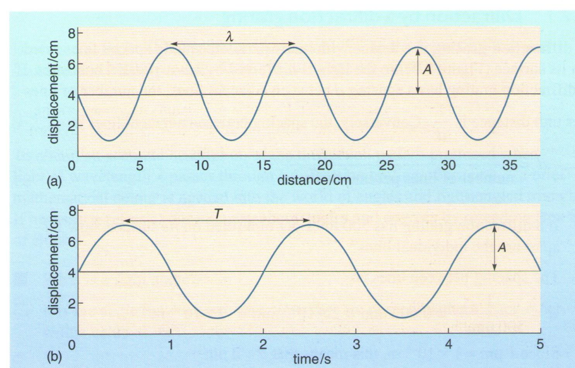
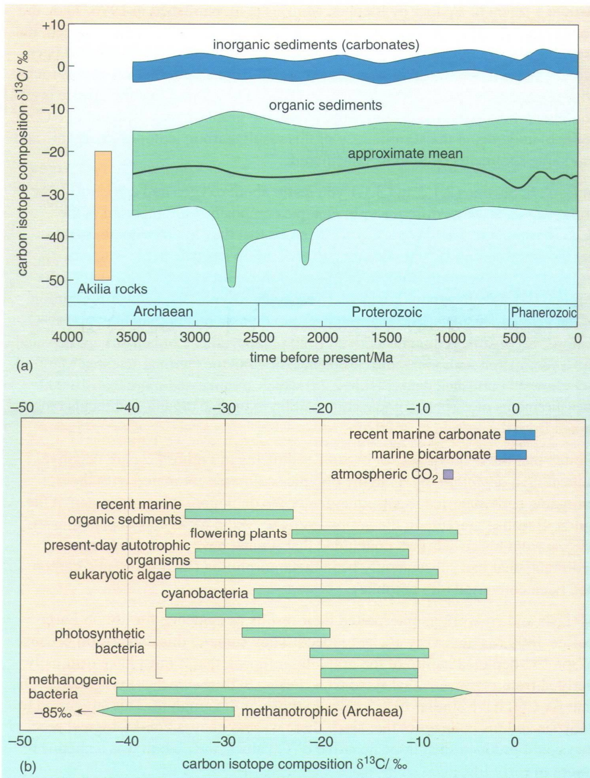


Figure 9.5 The space and time representations of a wave. In each case, the horizontal line at 4 cm represents the mean displacement of the wave. (a) A graph showing a wave profile at a fixed instant of time, illustrating how the displacement varies with position. The distance between two adjacent positions where the profile has the same displacement, and where the displacement is changing in the same way, is equal to the wavelength λ. (b) A graph showing how the displacement at a fixed point in space varies with time. The interval between two successive times when the displacement is the same, and when the displacement is changing in the same way, is equal to the period T.

Energy and LIght

Inter-disciplinary, involving

Figure 2.2 (a) Variations in carbon isotopic composition ($\delta^{13}C$) in organic carbon sediments (lighter shading in pale green) and inorganic carbonate sediments (darker shading in blue) over 3800 Ma of the Earth's history. The height of the bands indicate the ranges of the measured values, and the line within the green band is the mean value. Most of the data are from the 1988 paper by Schidlowski. The paler-coloured box at the far left of the diagram are data for graphite from the Akilia rocks taken from the paper by Mojzsis et al. (1996). (b) Carbon isotopic composition of various types of living autotrophs that fix CO_2 and of recent marine organic and inorganic sediments.



paleontology

■ What inference can you draw from the discrepancy between the findings of the original scientists and those of the second team working on the same samples 10 years later?

□ That advances in instruments and techniques can completely overturn apparently sound scientific conclusions, and so great care must be taken when analysing tiny amounts of material.

If carbon isotope data from rocks around 3800 Ma old is no longer evidence for the earliest appearance of life of Earth, what should we be looking for? Perhaps fossilised microorganisms rather than their chemical traces might be

„Life in the Universe”

In the first part of the extract, Zahnle considers the composition of the atmosphere immediately following formation of the Moon. In the final part of the extract, he looks at how the presence of an ocean of liquid water would influence the atmosphere. The details of this are not important for the purposes of this book, but are interesting given current concerns about global warming and the greenhouse effect.

The period of time that the author covers takes us up to about 3600 Ma ago, just before we have evidence for life on Earth. The period known as the late heavy bombardment is one of the final events of the Hadean era.

After reading the article, carry out the tasks below which give you practice at extracting information. Have a quick look at the tasks now so that you can make notes as you read.

Task 1

Describe the probable composition of the Earth's earliest atmosphere after the Moon formed.

Task 2

Use Figure 2.7 to describe how the temperature of the Earth's surface changed through the Hadean era.

You should now read Article 3, consider your responses to the two tasks and then compare your answers with those in the comments on this activity at the end of this book.

climatology

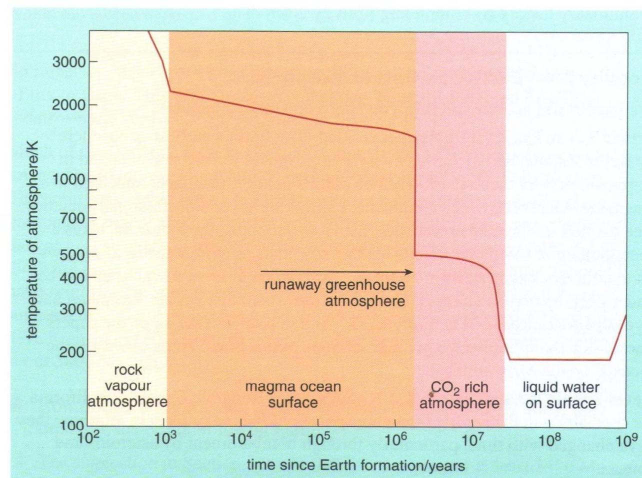


Figure 2.7 The figure is adapted from Figure 3 of Zahnle (2006), and shows how the Earth's surface temperature was thought to vary during the Hadean, from just after the Moon-forming impact up until the Late Heavy Bombardment. Note that both axes are logarithmic scales.

Exotic, visible real pre-life

sandstone?
Glued with?

Activity 2.1 (continued) Earth's timeline

We expect this activity will take you approximately 5 minutes.

You can now add two more dates to the timeline in Figure 2.1: the ages of 3850 Ma (for possible chemical trace fossils in the Akilia rocks) and 3500 Ma (for biological tracers in the Apex Chert). Like the date for the first presence of water on Earth, the ages of the chemical and biological tracers are uncertain and subject to much argument, and so should be added in your second colour or text style.

There are, however, other features present in ancient rocks that can indicate the presence of biological matter. The first is the occurrence of stromatolites. These are finely layered rocks (Figure 2.4) produced in shallow marine environments by the trapping of sediments by colonies of cyanobacterial cells, forming microbial mats (Book 6 Section 3.1).

Figure 2.4 Modern stromatolites in Shark Bay, Western Australia. The flat, rounded mounds are up to about 1m across, and around 30 cm high.

The oldest stromatolites (around 3300 to 3400 Ma) have been found in at least two locations, one at Strelley Pool in Western Australia, and the other in South Africa ... Chert). Great care must be taken in interpreting features as ... cause, as for the features in the slightly older Apex Chert, there ... al instances where characteristics initially interpreted as being ... re subsequently reinterpreted as being of non-biological origin.

stromatolites
Western Australia

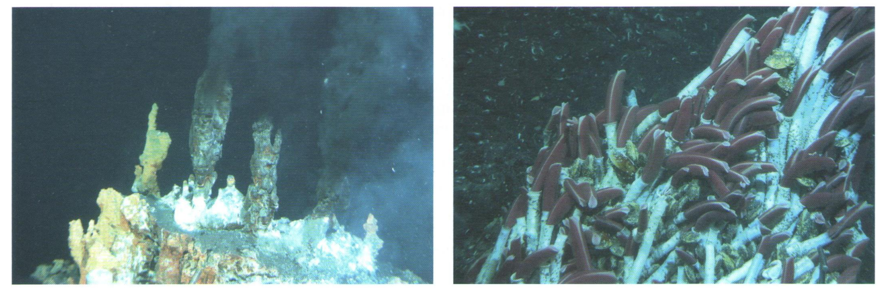
... onvinced about the biological origin of a feature, it is clear that relying solely on shape is not enough. The geological environment must also be considered, i.e. were the rocks originally igneous or sedimentary? In the case of Strelley Pool and Buck Reef, the host rocks seem clearly to have been sedimentary, laid down in shallow seas, and thus appropriate for the formation of stromatolites. So it looks as if the first traces of life on Earth occurred at least around 3400 Ma ago.

This series is available at IF UMK library

bottom water, there is an instant chemical reaction and sulfides precipitate out from the water, colouring it black. The sulfides build up rapidly to form 'chimneys' reaching heights of several tens of metres.

Discovery of the vents revealed that, despite the depth and darkness, parts of the ocean floor are home to an unusual collection of animals such as clams, mussels and tubeworms (Figure 2.8b), feeding on the Bacteria and Archaea that flourish in these very hot conditions.

The discovery of a successful ecosystem based on chemical energy rather than photosynthesis has raised the possibility that life may not have arisen in surface waters, as original theories suggested. Discovering communities entirely supported by chemoautotrophs has given the impetus to the search for life in other deep oceans, especially on Jupiter's satellite, Europa, where a liquid water ocean is thought to occur below the visible crust of ice (Section 3.2.3).



(a) (b)

Figure 2.8 Hydrothermal vents on the ocean floor. (a) Three 'chimneys' or black smokers; (b) vent fauna that live around the chimneys include tubeworms, clams and mussels.

2.5.3 An extraterrestrial origin for life?

An alternative view to chemical evolution is that of **panspermia**, in which life had ...

volcanic chimneys = lab of evolution

The astronomer Sir Fred Hoyle (1915–2001) resolutely maintained that an extraterrestrial origin for life must be the case because it was just too unlikely that chemical evolution could have led to life on Earth in the time available.

- See also: Nick Lane, *Life ascending*

It increases the time available. In Activity 2.2, you read that there had been a claim that traces of life had been found in rocks around 3850 Ma old. Given that Earth formed 4600 Ma ago, that only left 750 Ma years to progress from a molten Earth to an inhabited Earth (even though by bacteria). It is now thought that the first indisputable traces of life are in rocks 3400 Ma old, a period of 1200 Ma since the formation of the Earth.

and now we move to astronomy

The answer to Question 3.3 suggests that, at face value, life is at least possible. But there is a serious problem for any aspiring life forms. Any dust particles

The most beautiful picture apart He lines

So it seems reasonable to proceed on the basis that life on, or within, the giant planets looks unlikely. However, their satellites are a different issue. Each planet has a number of satellites, and there are a few that are relatively large, equivalent in size to Mercury, or to the Earth's Moon, i.e. Ganymede, Callisto, Io, Europa, (all orbiting Jupiter; Figure 3.6a), Titan (orbiting Saturn; Figure 3.6b) and Triton (orbiting Neptune; Figure 3.6c). Thus, in the context of life in the Solar System these bodies should be added to the list of interesting places to consider. All of

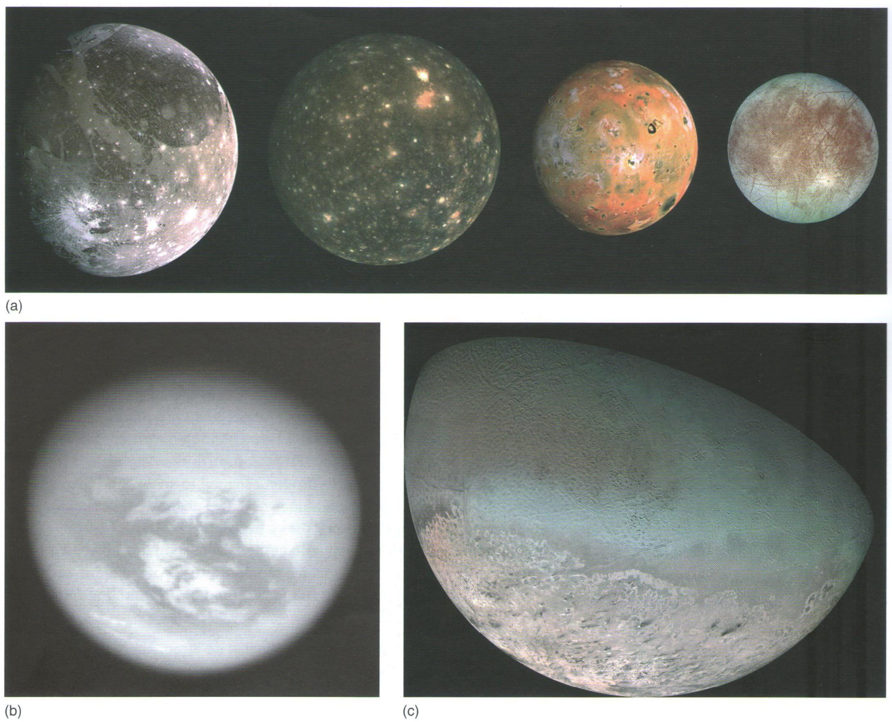


Figure 3.6 Satellites of the giant planets. (a) A collage of the four Galilean satellites of Jupiter, to correct relative sizes. On the far left is Ganymede, then Callisto, Io and Europa; (b) an image taken by the *Cassini* mission of Saturn's largest satellite Titan; (c) an image of part of the surface of Neptune's satellite Triton.

„Life in the Universe"

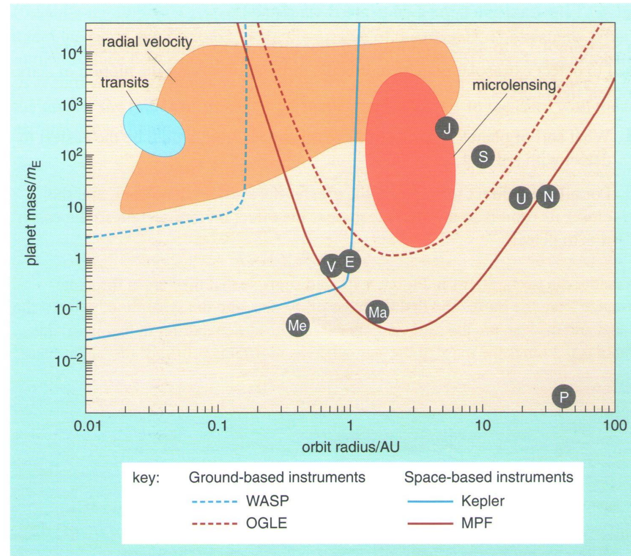


Figure 4.9 A plot to show the detection limits of planet size and orbit for different observation techniques. Radial velocity observations fall in the orange area, those from transit techniques in the blue area and gravitational microlensing in the red area. The solid and dashed lines define the regions on the figure within which planets are detectable by the specified instruments. Kepler is a NASA space telescope launched in 2009. Abbreviations: OGLE – Optical Gravitational Lensing Experiment (uses a ground-based telescope in Chile, described in Section 4.1.5); MPF – Microlensing Planet Finder (a proposed NASA space telescope under consideration); WASP – Wide Angle Search for Planets (uses two robotic ground-based telescopes, described in Section 4.1.4). The grey dots show where our Solar System objects would lie on this diagram. The plot is adapted from Figure 2 in Dominik et al. (2006).

Task 1

Why are the space-based instruments (solid) lines lower than the ground-based instruments (dashed) lines?

Task 2

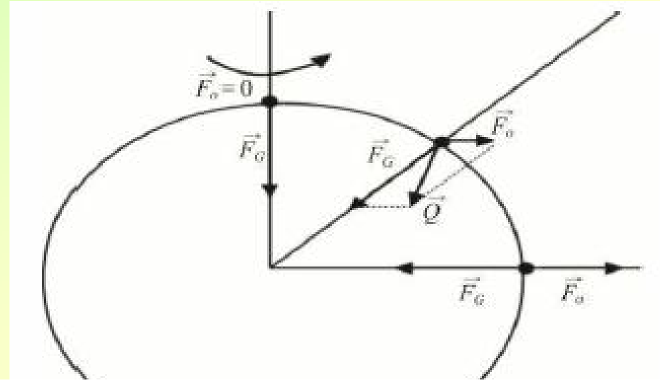
(a) Which of the different techniques can detect the planet furthest away from its star? (b) Why is this? (c) Which technique will detect the smallest planet?

Now look at the comments on this activity at the end of this book.

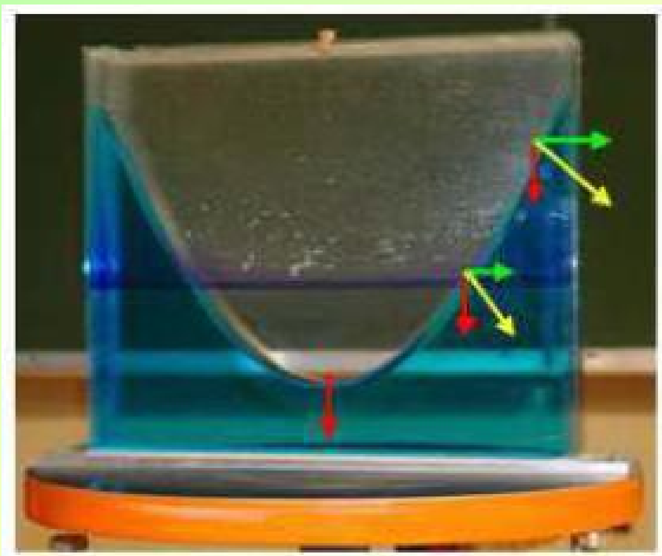
Many methods to search exo-planets

Earth’s shape and ocean tides

Kopernik: „why water stays on (spherical) Earth?”

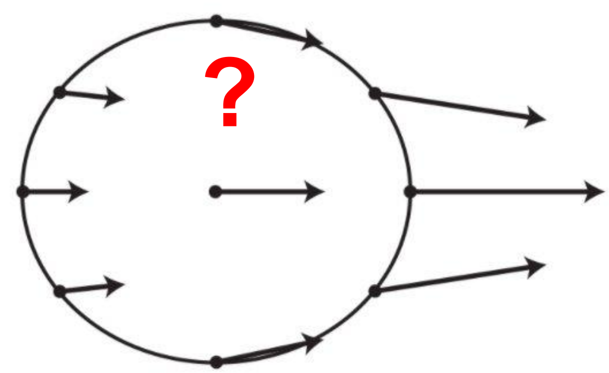


The shape is equi-potential surface of gravity + centrifugal potential



On the side of Earth farthest from the Moon, the Moon's gravitational pull is at its weakest. At the center of Earth is approximately the average of the Moon's gravitational pull on the whole planet.

Why high tides occur on other side of Earth?



Arrows represent the force of the Moon's gravitational pull on Earth. To get the tidal force—the force that causes the tides—we subtract this average gravitational pull on Earth from the gravitational pull at each location on Earth.

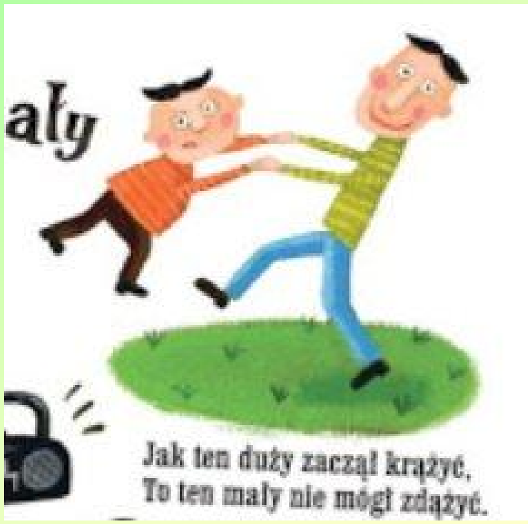
https://scijinks.gov/tides/

What is the shape of Earth? „Geoid”? This us tautology

G, Karwasz, J. Chojnacka
Foton, 2011; Geografia w Szkole 2011

Demtröder: „Experimental Physics”

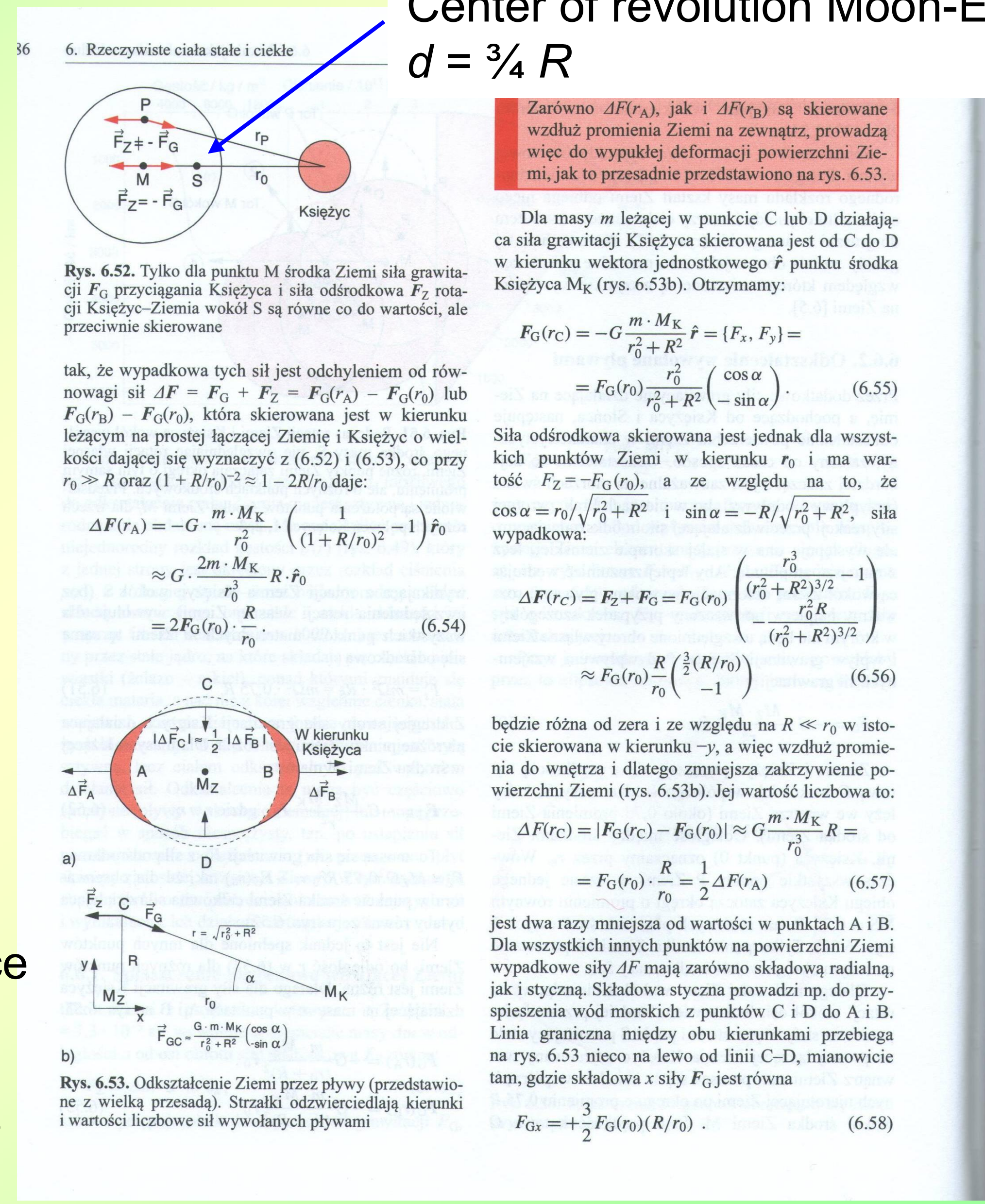
Why high tides occur on the „other” side of Earth?



These are both Earth and Moon that rotate, every 28 days, around the common center of mass (that is 1700 km below Earth surface

https://opencaching.pl/viewcache.php?cacheid=47297

Center of revolution Moon-Earth
d = ¾ *R*



36 6. Rzeczywiste ciała stałe i ciekłe

Rys. 6.52. Tylko dla punktu M środka Ziemi siła grawitacji F_G przyciągania Księżyca i siła odśrodkowa F_Z rotacji Księżyc–Ziemia wokół S są równe co do wartości, ale przeciwnie skierowane

tak, że wypadkowa tych sił jest odchyleniem od równowagi sił $\Delta F = F_G + F_Z = F_G(r_A) - F_G(r_0)$ lub $F_G(r_B) - F_G(r_0)$, która skierowana jest w kierunku leżącym na prostej łączącej Ziemię i Księżyc o wielkości dającej się wyznaczyć z (6.52) i (6.53), co przy $r_0 \gg R$ oraz $(1 + R/r_0)^{-2} \approx 1 - 2R/r_0$ daje:

$$\Delta F(r_A) = -G \cdot \frac{m \cdot M_K}{r_0^2} \cdot \left(\frac{1}{(1 + R/r_0)^2} - 1\right)\hat r_0 \approx G \cdot \frac{2m \cdot M_K}{r_0^3} R \cdot \hat r_0 = 2F_G(r_0)\frac{R}{r_0} \cdot \quad (6.54)$$

Rys. 6.53. Odkształcenie Ziemi przez pływy (przedstawione z wielką przesadą). Strzałki odzwierciedlają kierunki i wartości liczbowe sił wywołanych pływami

Zarówno $\Delta F(r_A)$, jak i $\Delta F(r_B)$ są skierowane wzdłuż promienia Ziemi na zewnątrz, prowadzą więc do wypukłej deformacji powierzchni Ziemi, jak to przesadnie przedstawiono na rys. 6.53.

Dla masy *m* leżącej w punkcie C lub D działająca siła grawitacji Księżyca skierowana jest od C do D w kierunku wektora jednostkowego $\hat r$ punktu środka Księżyca M_K (rys. 6.53b). Otrzymamy:

$$F_G(r_C) = -G\frac{m \cdot M_K}{r_0^2 + R^2}\hat r = \{F_x, F_y\} = F_G(r_0)\frac{r_0^2}{r_0^2 + R^2}\begin{pmatrix}\cos\alpha \\ -\sin\alpha\end{pmatrix} \cdot \quad (6.55)$$

Siła odśrodkowa skierowana jest jednak dla wszystkich punktów Ziemi w kierunku r_0 i ma wartość $F_Z = -F_G(r_0)$, a ze względu na to, że $\cos\alpha = r_0/\sqrt{r_0^2 + R^2}$ i $\sin\alpha = -R/\sqrt{r_0^2 + R^2}$, siła wypadkowa:

$$\Delta F(r_C) = F_Z + F_G = F_G(r_0)\begin{pmatrix}\frac{r_0^3}{(r_0^2 + R^2)^{3/2}} - 1 \\ \frac{r_0^2 R}{(r_0^2 + R^2)^{3/2}}\end{pmatrix} \approx F_G(r_0)\frac{R}{r_0}\begin{pmatrix}\frac{3}{2}(R/r_0) \\ -1\end{pmatrix} \quad (6.56)$$

będzie różna od zera i ze względu na $R \ll r_0$ w istocie skierowana w kierunku $-y$, a więc wzdłuż promienia do wnętrza i dlatego zmniejsza zakrzywienie powierzchni Ziemi (rys. 6.53b). Jej wartość liczbowa to:

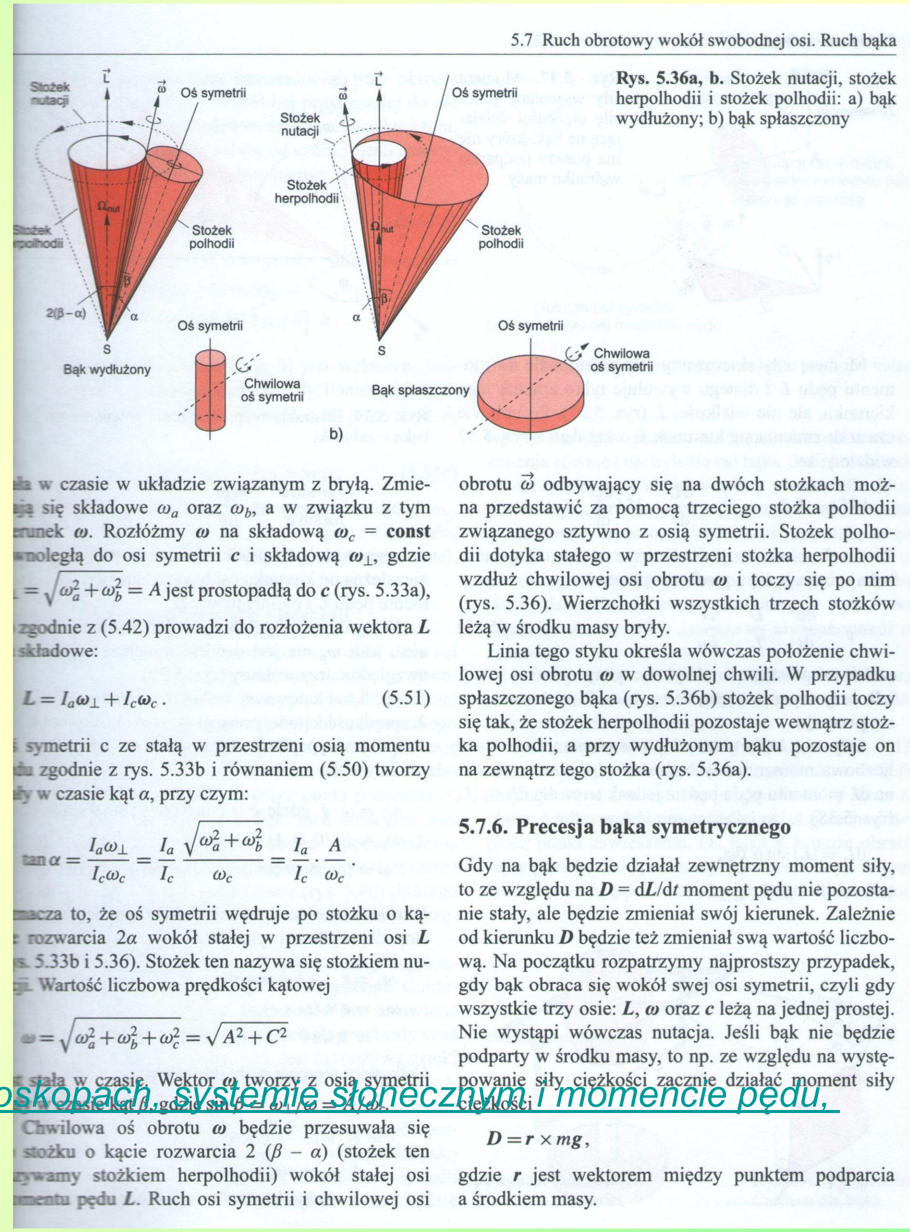
$$\Delta F(r_C) = |F_G(r_C) - F_G(r_0)| \approx G\frac{m \cdot M_K}{r_0^3}R = F_G(r_0) \cdot \frac{R}{r_0} = \frac{1}{2}\Delta F(r_A) \quad (6.57)$$

jest dwa razy mniejsza od wartości w punktach A i B. Dla wszystkich innych punktów na powierzchni Ziemi wypadkowe siły ΔF mają zarówno składową radialną, jak i styczną. Składowa styczna prowadzi np. do przyspieszenia wód morskich z punktów C i D do A i B. Linia graniczna między obu kierunkami przebiega na rys. 6.53 nieco na lewo od linii C–D, mianowicie tam, gdzie składowa *x* siły F_G jest równa

$$F_{Gx} = +\frac{3}{2}F_G(r_0)(R/r_0) \; . \quad (6.58)$$

„Experimental physics”

Why tops are flat or slim?



Rys. 5.36a, b. Stożek nutacji, stożek herpolhodii i stożek polhodii: a) bąk wydłużony; b) bąk spłaszczony

...ła w czasie w układzie związanym z bryłą. Zmie...ją się składowe ω_a oraz ω_b, a w związku z tym ...runek $\boldsymbol{\omega}$. Rozłóżmy $\boldsymbol{\omega}$ na składową $\boldsymbol{\omega}_c$ = **const** ...noległą do osi symetrii $\boldsymbol{c}$ i składową $\boldsymbol{\omega}_\perp$, gdzie ...$= \sqrt{\omega_a^2+\omega_b^2} = A$ jest prostopadłą do $\boldsymbol{c}$ (rys. 5.33a), ...zgodnie z (5.42) prowadzi do rozłożenia wektora $\boldsymbol{L}$ ...składowe:

$$L = I_a\boldsymbol{\omega}_\perp + I_c\boldsymbol{\omega}_c\,. \tag{5.51}$$

...symetrii c ze stałą w przestrzeni osią momentu ...du zgodnie z rys. 5.33b i równaniem (5.50) tworzy ...ły w czasie kąt α, przy czym:

$$\tan\alpha = \frac{I_a\omega_\perp}{I_c\omega_c} = \frac{I_a}{I_c}\frac{\sqrt{\omega_a^2+\omega_b^2}}{\omega_c} = \frac{I_a}{I_c}\cdot\frac{A}{\omega_c}\,.$$

...acza to, że oś symetrii wędruje po stożku o ką... rozwarcia 2α wokół stałej w przestrzeni osi $\boldsymbol{L}$ ...s. 5.33b i 5.36). Stożek ten nazywa się stożkiem nu...cji. Wartość liczbowa prędkości kątowej

$$\omega = \sqrt{\omega_a^2+\omega_b^2+\omega_c^2} = \sqrt{A^2+C^2}$$

...stała w czasie. Wektor $\boldsymbol{\omega}$ tworzy z osią symetrii ...w czasie kąt β, gdzie $\sin\beta = \omega_\perp/\omega = A/\omega_c$. Chwilowa oś obrotu $\boldsymbol{\omega}$ będzie przesuwała się ...stożku o kącie rozwarcia 2 $(\beta-\alpha)$ (stożek ten ...ywamy stożkiem herpolhodii) wokół stałej osi ...mentu pędu $\boldsymbol{L}$. Ruch osi symetrii i chwilowej osi obrotu $\vec{\omega}$ odbywający się na dwóch stożkach można przedstawić za pomocą trzeciego stożka polhodii związanego sztywno z osią symetrii. Stożek polhodii dotyka stałego w przestrzeni stożka herpolhodii wzdłuż chwilowej osi obrotu $\boldsymbol{\omega}$ i toczy się po nim (rys. 5.36). Wierzchołki wszystkich trzech stożków leżą w środku masy bryły.

Linia tego styku określa wówczas położenie chwilowej osi obrotu $\boldsymbol{\omega}$ w dowolnej chwili. W przypadku spłaszczonego bąka (rys. 5.36b) stożek polhodii toczy się tak, że stożek herpolhodii pozostaje wewnątrz stożka polhodii, a przy wydłużonym bąku pozostaje on na zewnątrz tego stożka (rys. 5.36a).

5.7.6. Precesja bąka symetrycznego

Gdy na bąk będzie działał zewnętrzny moment siły, to ze względu na $\boldsymbol{D} = \mathrm{d}\boldsymbol{L}/\mathrm{d}t$ moment pędu nie pozostanie stały, ale będzie zmieniał swój kierunek. Zależnie od kierunku $\boldsymbol{D}$ będzie też zmieniał swą wartość liczbową. Na początku rozpatrzymy najprostszy przypadek, gdy bąk obraca się wokół swej osi symetrii, czyli gdy wszystkie trzy osie: $\boldsymbol{L}$, $\boldsymbol{\omega}$ oraz $\boldsymbol{c}$ leżą na jednej prostej. Nie wystąpi wówczas nutacja. Jeśli bąk nie będzie podparty w środku masy, to np. ze względu na występowanie siły ciężkości zacznie działać moment siły ciężkości

$$\boldsymbol{D} = \boldsymbol{r}\times m\boldsymbol{g}\,,$$

gdzie $\boldsymbol{r}$ jest wektorem między punktem podparcia a środkiem masy.

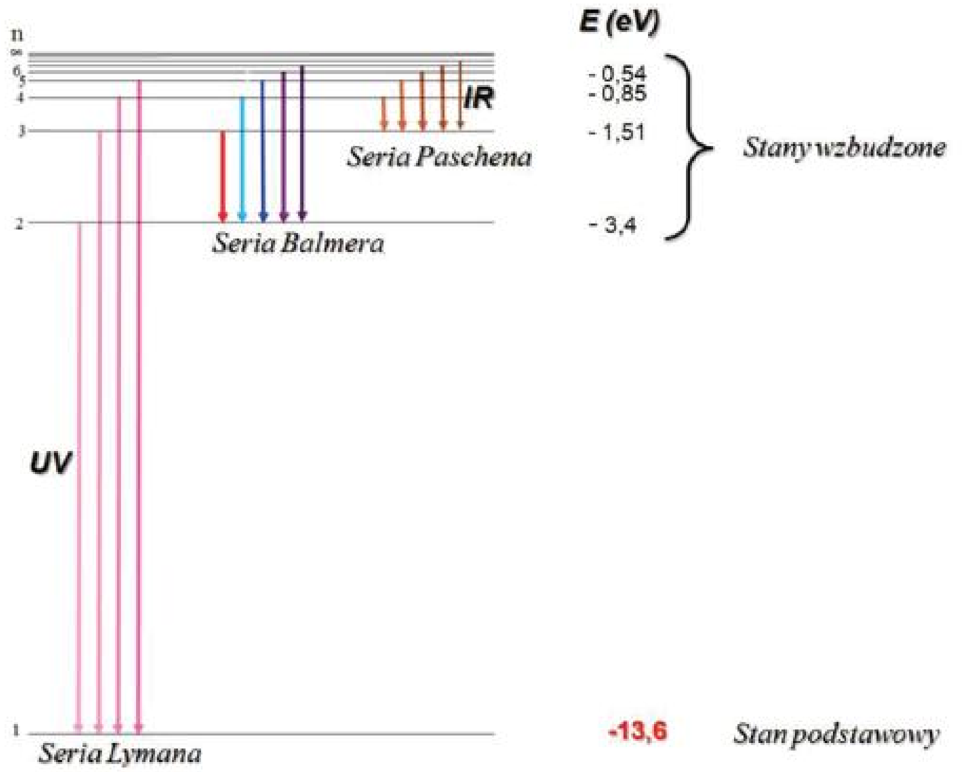
K. Służewski, G. Karwasz,
Fizyka i zabawki - wyjść poza fenomenologię.O żyroskopach, systemie słonecznym i momencie pędu,
Fizyka w Szkole, 3/2014, 25-32.
(wersja multimedialna)

dydaktyka.fizyka.umk.pl/zabawki1/files/mech/giro-en.html

Domtröder, *Experimental Physics*

Bands in semiconductors, and metals

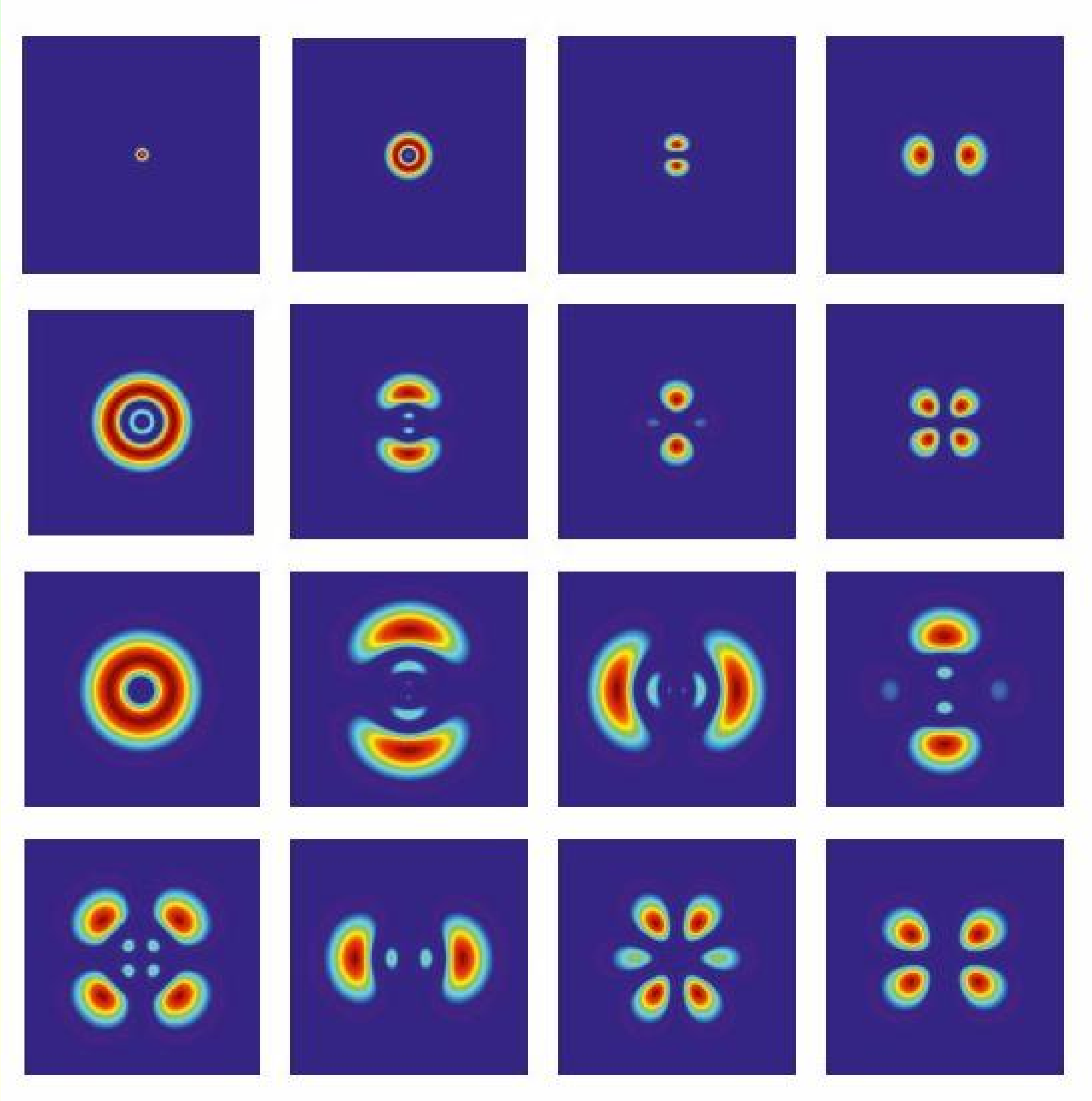
where do they come from?



Ryc. 2.22. Układ poziomów energetycznych w atomie wodoru, w modelu Bohra; leżąca w zakresie widzialnym czerwona linia serii Balmera odpowiada przeskokom elektronów z orbity o $n = 3$ na orbitę o $n = 2$. Rys. Magdalena Sadowska

In atoms we have only well-defined *levels*

or, better, we should speak about orbitals

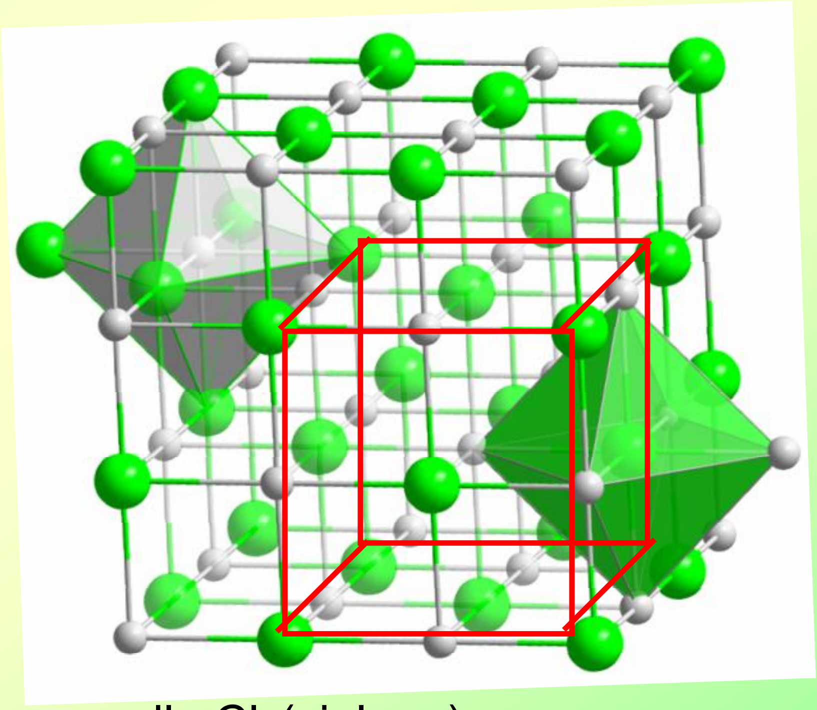


←1*s*, 2*s*, $2p_y$, $2p_x$

1*s* Ψ is non-zero
at *r* = 0

2*s* is made of layers

Regular (cubic system): NaCl



Układ regularny **ściennie centrowany** dla Cl^- (zielone) z jonami Na^+ (szare) w lukach oktaedrycznych

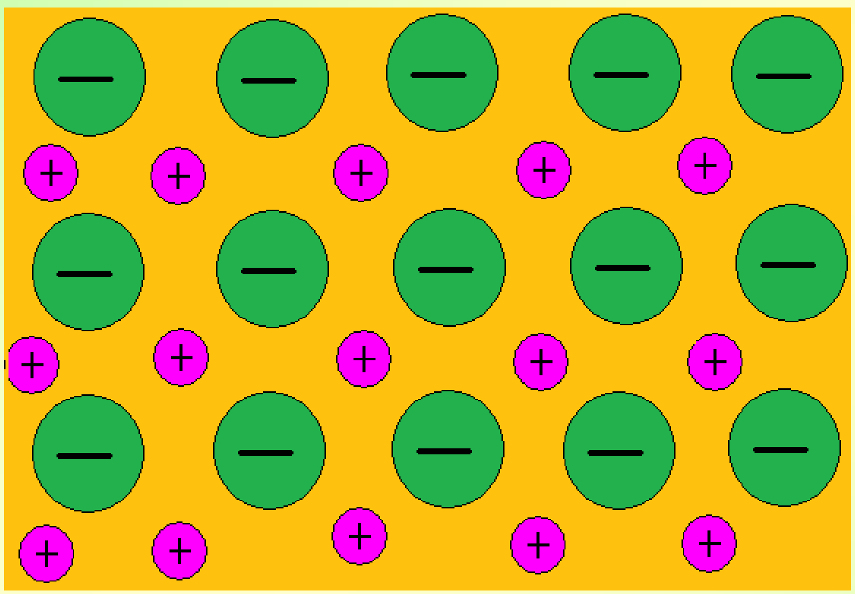
$R_{Na+} < R_{Cl-}$

http://pl.wikipedia.org/wiki/S%C3%B3l_kamienna

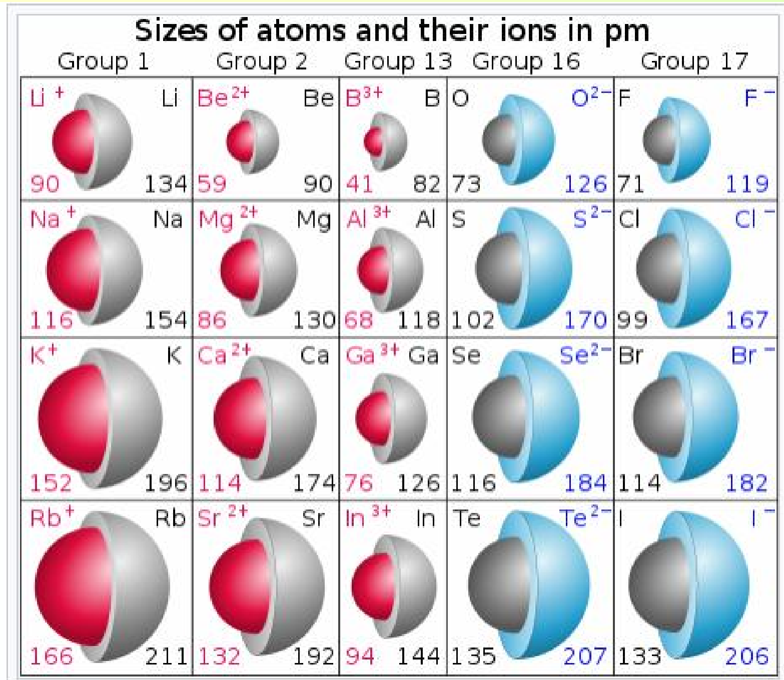
Why does salt dissolve so easy in water?

- Because NaCl is a *ionic* crystal.
- And why NaCl is a *ionic* crystal?

https://en.wikipedia.org/wiki/Ionic_radius

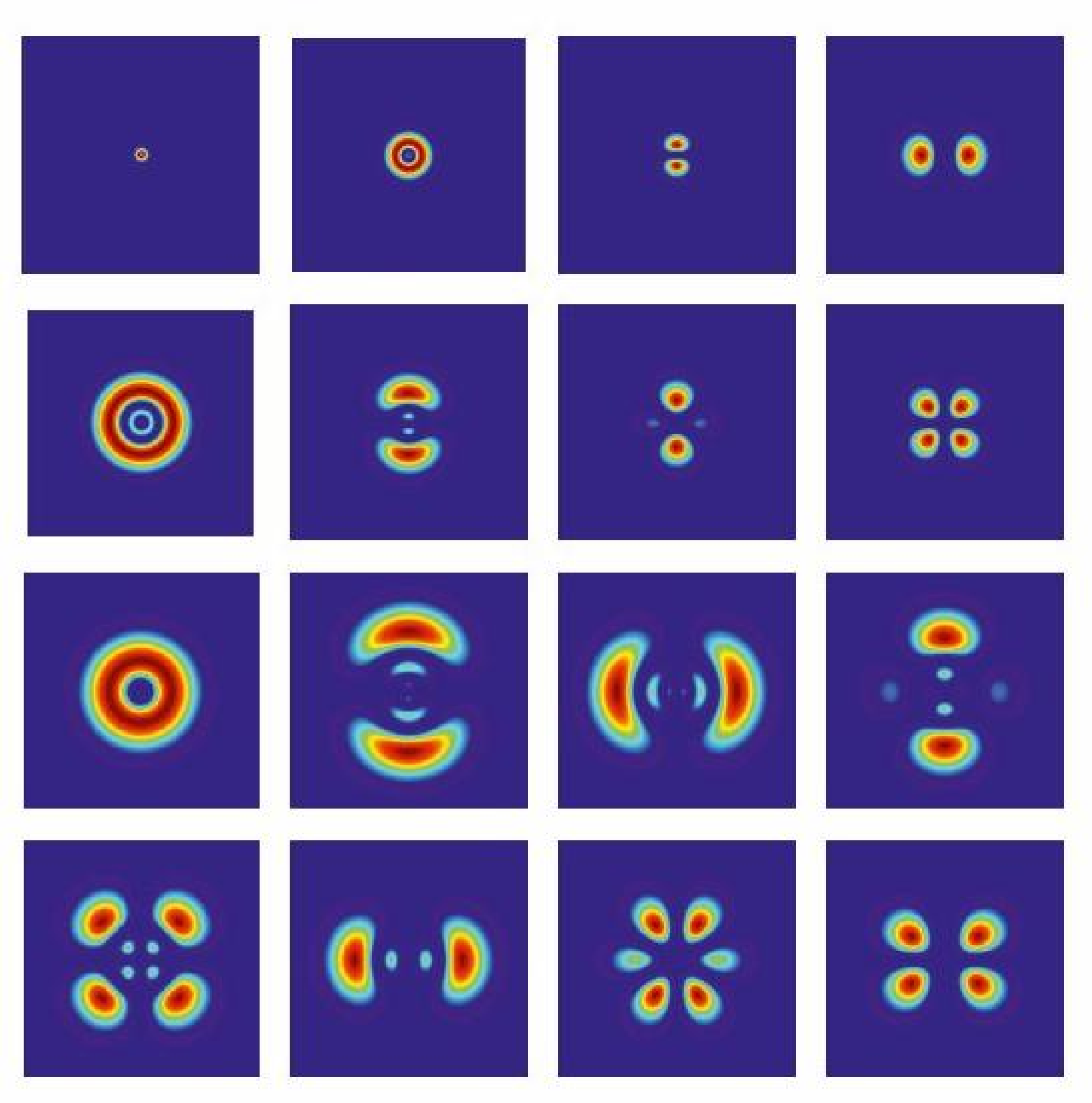


Why Na^+ is so small on this picture?



Relative radii of atoms and ions. The neutral atoms are colored gray, cations red, and anions blue.

Why Na is so big? And Na^+ so small?



←1*s*, 2*s*, 2p_y, 2p_x

2*s* is made of layers

Because 2*s* in hydrogen-like atom is huge

Why gold does form so thin wires?

Gold is ductile: It can be drawn out into the thinnest wire. One ounce of gold can be drawn into 80 kilometers (50 miles) of thin gold wire, five microns, or five millionths of a meter, thick. This sample is 0.20 millimeters (0.008 inches) in diameter.

1g → 2 km wire

Real-object evidence: practical application & triggering interest

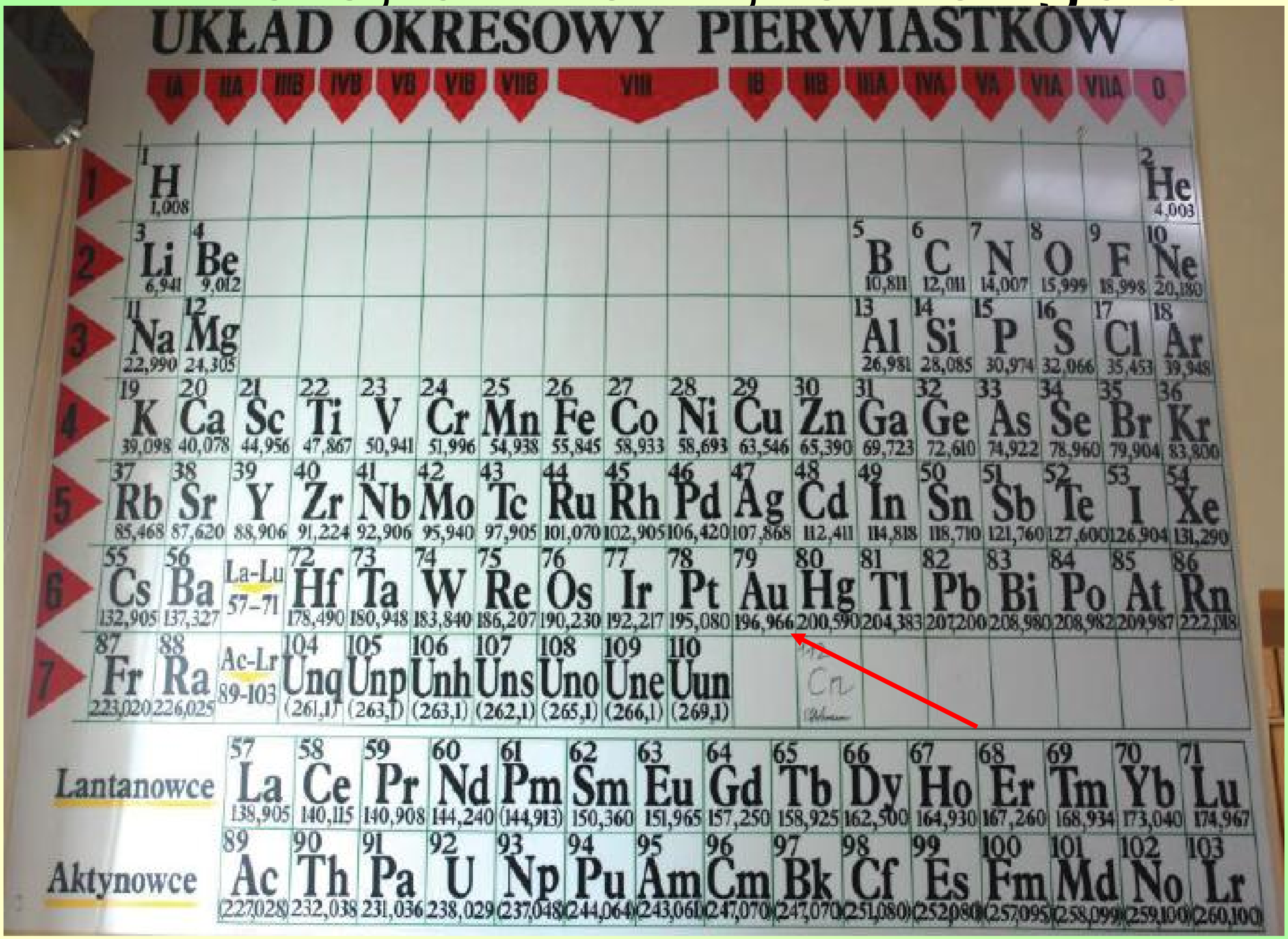
Gold is malleable, so it can be flattened into extremely thin sheets. The walls of the Gold Room are covered with approximately 28 square meters (300 square feet) of 23-karat gold leaf representing 3 ounces of gold metal. Gold leafing--also known as gilding--is an ancient technique. Traditional artisans beat raw gold between pieces of leather until it was almost too thin to be seen. One ounce of gold may be hammered thin enough to cover more than 9 square meters (96.9 square feet) of a surface. The gold leaf may be only 0.18 microns (seven millionths of an inch) thick; a stack of 7,055 sheets would be no thicker than a dime.

st malleable metal—can be flattened into extremely thin sheets. The walls in the Gold
pproximately 300 square feet of 23-karat gold leaf representing three ounces of gold
metal, the equivalent volume of three U.S. half-dollar coins.
© AMNH / Denis Finnin

0.18μm
i.e. $2\lambda_{red}$

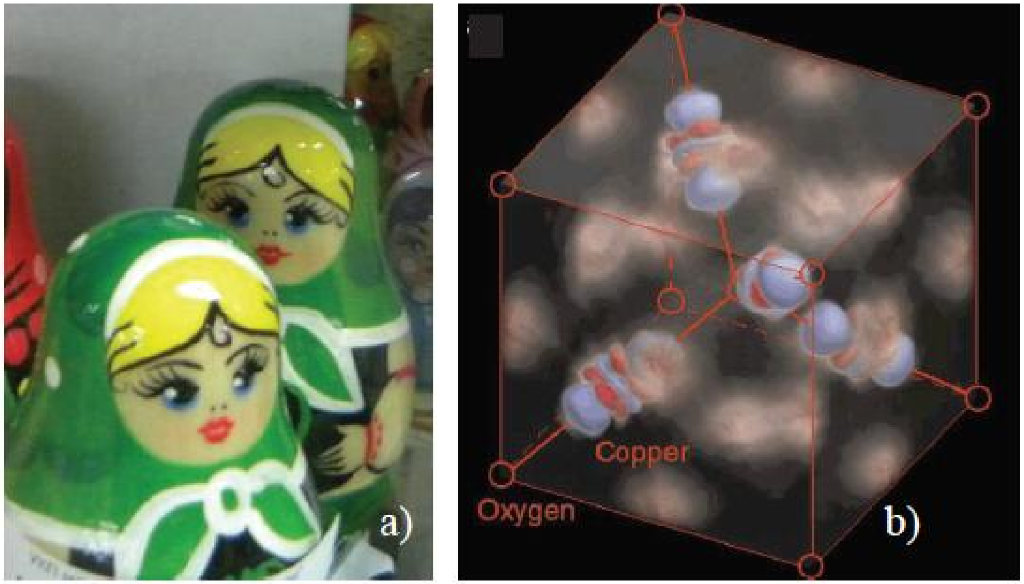
American Museum of Natural History
https://www.amnh.org/exhibitions/gold/incomparable-gold/gold-properties

Where, on Earth, is that gold?



Obviously, we have infinity of printed Mendeleyev tables, but this one is a real object

or, better, we should speak about orbitals



Ryc. 2.36. **a)** Rosyjska matrioszka – jedna w drugiej jak rozkład gęstości elektronów na orbitalu 2*s* w atomie wodoru (fot. M.K.); **b)** rzeczywisty (zmierzony za pomocą promieni Röntgena) rozkład gęstości elektronów w krysztale tlenku miedziawym Cu_2O – orbitale *d*.

Źródło: J. M. Zuo i in. *Direct observation of* d*-orbitals and Cu-Cu bonding in* Cu_2O „Nature" 1999, vol. 401, s. 49.

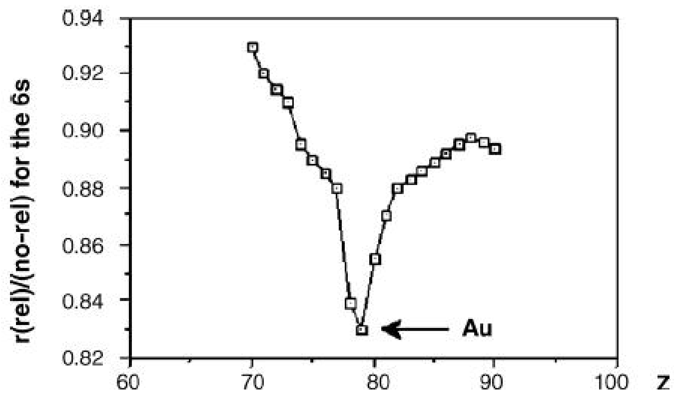


Figure 1.1 Ratio of *r*(rel)/*r*(non-rel) versus atomic number for the 6s

Small (relativistic) radius for 6*s* electrons

„Gold has absorption from 2.4 eV, from $5d^{10} \rightarrow 6s^2$

[Xe] $4f^{14}\ 5d^{10}\ 6s^1$

Principle of visualisation (GK: neo-realism)
Three functions: fun, didacitcs and science

M. Concepción GImeno, Chemistry of Gold, 2008

https://application.wiley-vch.de/books/sample/3527320296_c01.pdf

Electronic structure

- Electronic structure of atoms –

Periodic system of elements:

1) Electrons in an atom occupy positions starting from bottom

Just opposite than pigeons (in Australia, but there also people walk with heads upside-down.)

[Attention: just a joke]

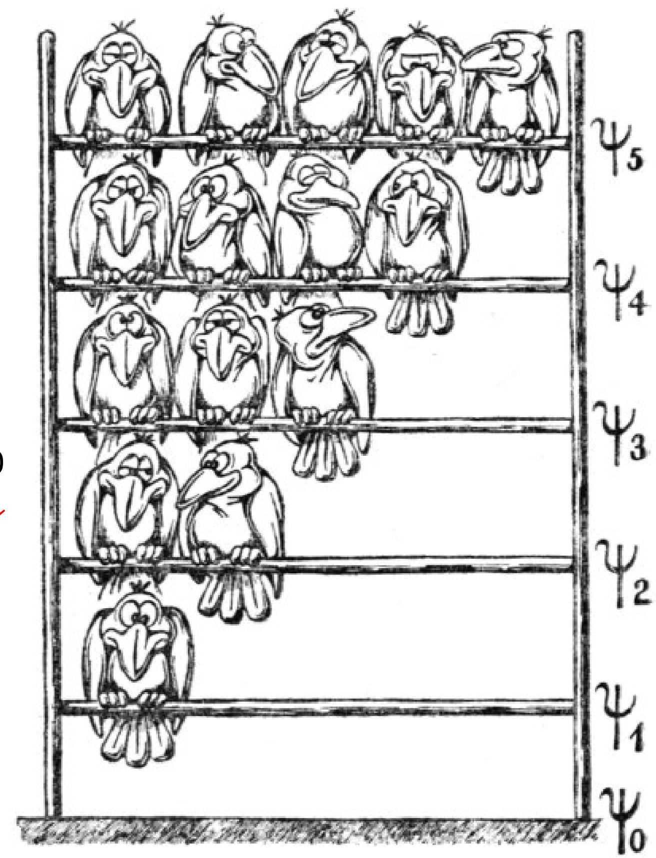
http://www.karwasz.it/modern/australia.html
Sydney park, photo GK, 2004.

From: G. Karwasz, *Introduction to chemistry and physics of novel materials,* 1st year of „Novel materials” UMK, 2009

Elektrony zajmują poziomy energetyczne od dołu

Opis poniżej nie jest poprawny,
ale rysunek mniej więcej - tak:

- na niższych poziomach mieści się mniej elektronów, np. na
1º orbicie (*K*) dwa: $1s^2$
2º orbicie (*L*) osiem $2s^2p^6$
3º orbicie (*M*) osiemnaście $3s^2p^6d^{10}$



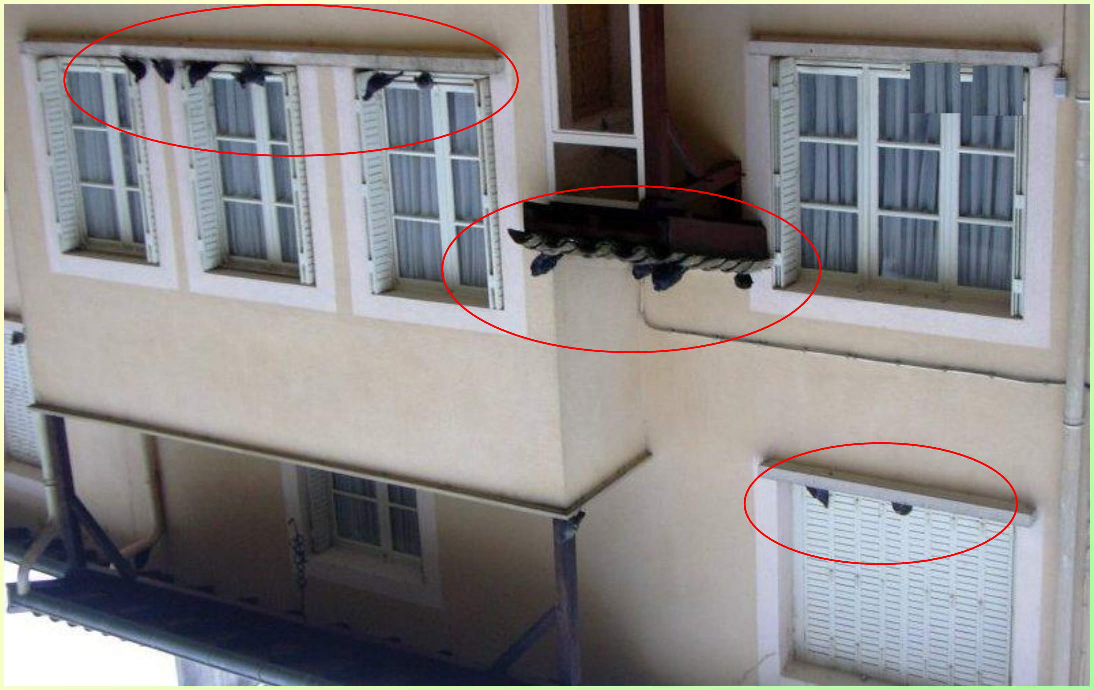
Rys. 3.5. Bozony-fotony (ptaszki) „obsiadają" szczeble drabiny poziomów oscylatora kwantowego. Liczba bozonów 0, 1, 2, 3, ... odpowiada stopniowi wzbudzenia 0, 1, 2, 3, ... Na szczeblu zerowym nie ma ani jednego bozonu, lecz energia nie jest równa zeru

Arkadiusz Góral, Meandry Fizyki

Elektrony occupy energy levels from bottom

Jak widać na zdjęciu obok, elektrony na określonej orbicie lokują się kolejno na podpoziomach, np. na 3º orbicie

- s^2
- p^6
- d^{10}



Tours, Francja, XII 2005
[żart]

But in solids we have bands, not levels: where do they come from?

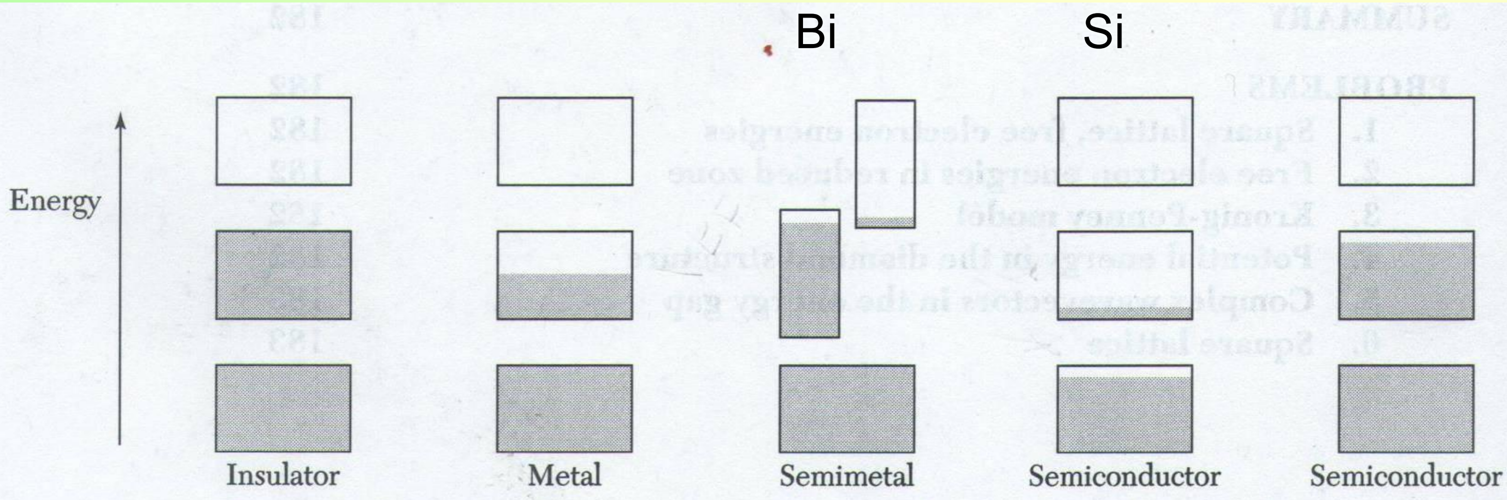


Figure 1 Schematic electron occupancy of allowed energy bands for an insulator, metal, semimetal, and semiconductor. The vertical extent of the boxes indicates the allowed energy regions; the shaded areas indicate the regions filled with electrons. In a **semimetal** (such as bismuth) one band is almost filled and another band is nearly empty at absolute zero, but a pure **semiconductor** (such as silicon) becomes an insulator at absolute zero. The left of the two semiconductors shown is at a finite temperature, with carriers excited thermally. The other semiconductor is electron-deficient because of impurities.

162

Charles Kittel, *Introduction to Solid State Physics*, 8th ed. 2005

A crystal is a lattice of atoms

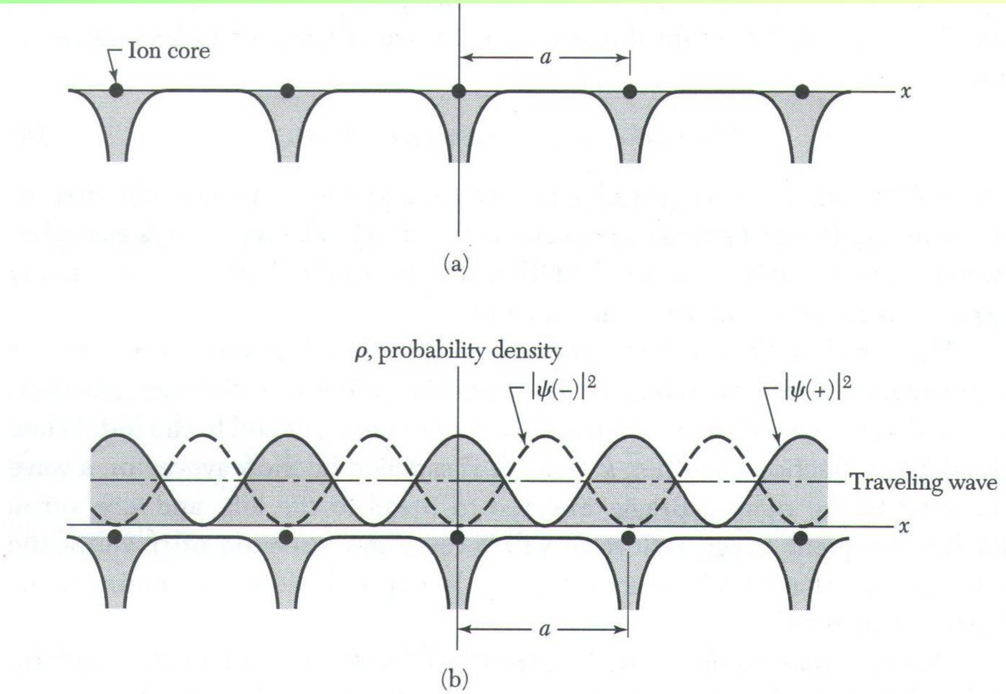


Figure 3 (a) Variation of potential energy of a conduction electron in the field of the ion cores of a linear lattice. (b) Distribution of probability density ρ in the lattice for $|\psi(-)|^2 \propto \sin^2 \pi x/a$; $|\psi(+)|^2 \propto \cos^2 \pi x/a$; and for a traveling wave. The wavefunction $\psi(+)$ piles up electronic charge on the cores of the positive ions, thereby lowering the potential energy in comparison with the average potential energy seen by a traveling wave. The wavefunction $\psi(-)$ piles up charge in the region between the ions, thereby raising the potential energy in comparison with that seen by a traveling wave. This figure is the key to understanding the origin of the energy gap.

Sure, a solid is a lattice of atoms, positioned quite close (1 - 2 Å)

So, an electron „belongs" to more than one atom

One should consider levels at different distances

GK: „Didactics is finding difficulties in learning process, and solving them

So, how the energy changes with distance?

- We could show it (see binding energies of atoms in a molecule)

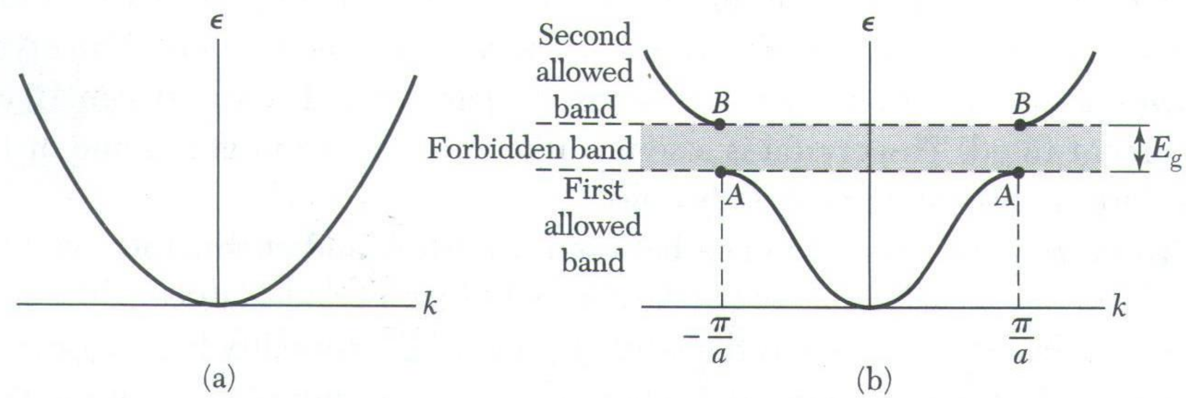


Figure 2 (a) Plot of energy ϵ versus wavevector k for a free electron. (b) Plot of energy versus wavevector for an electron in a monatomic linear lattice of lattice constant a. The energy gap E_g shown is associated with the first Bragg reflection at $k = \pm\pi/a$; other gaps are found at higher energies at $\pm n\pi/a$, for integral values of n.

- But we can also show $E(k)$, where k is the wave vector ($p=\hbar k$, and $E=\hbar^2 k^2/2m$)

Metal, insulators, semiconductors

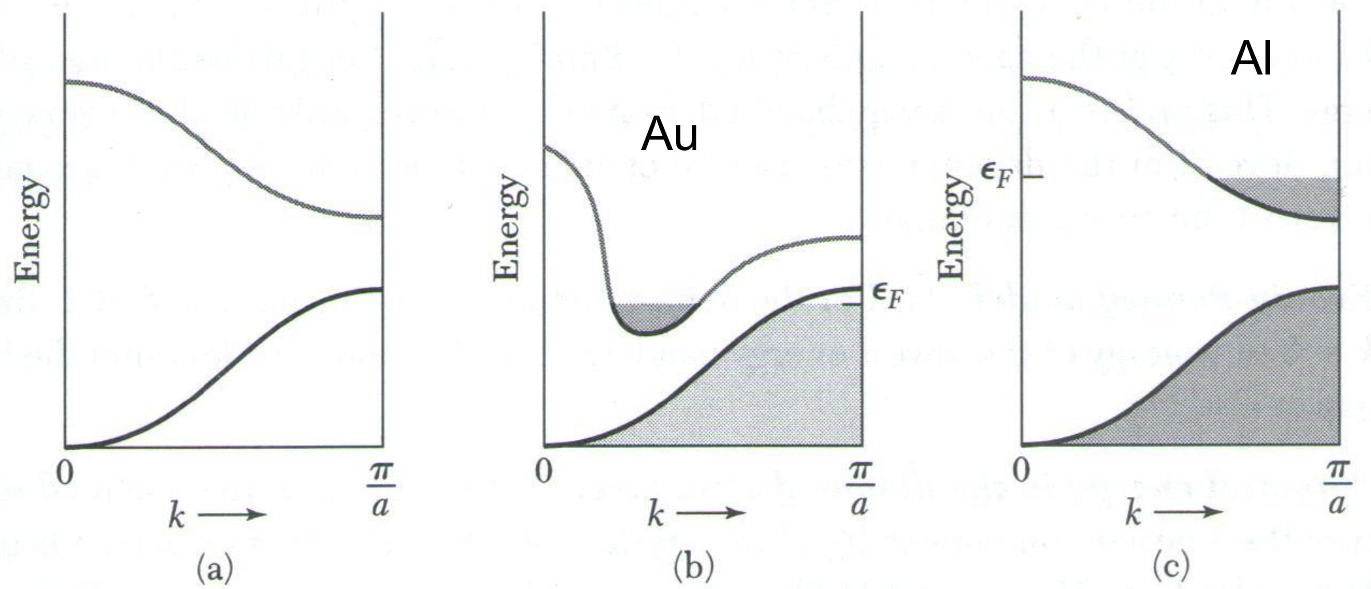


Figure 11 Occupied states and band structures giving (a) an insulator, (b) a metal or a semimetal because of band overlap, and (c) a metal because of electron concentration. In (b) the overlap need not occur along the same directions in the Brillouin zone. If the overlap is small, with relatively few states involved, we speak of a semimetal.

Charles Kittel, *Introduction to Solid State Physics*, 8th ed. 2005, p. 181

Fermi level, Fermi surface

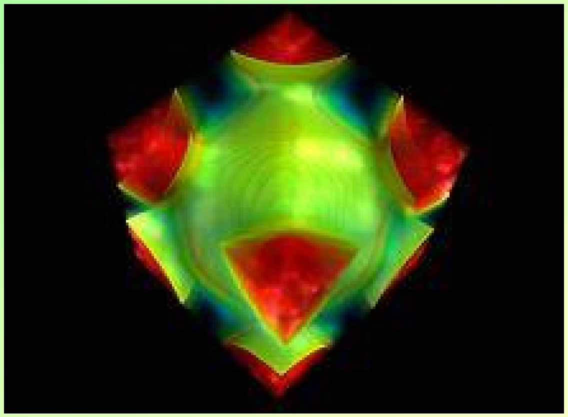


Figure 1. Fermi surface and electron momentum density of copper in the reduced zone schema measured with 2D ACAR.[6], i.e. with positron-annihilation angular spectra

https://en.wikipedia.org/wiki/Fermi_surface

Fermi surface nesting and magnetic structure of $ErGa_3$

M. Biasini, G. Ferro

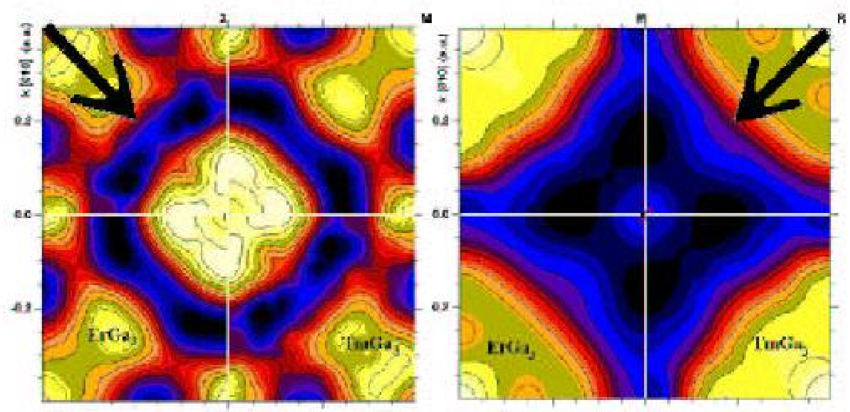
ENEA, Via don Fiammelli 2 40129 Bologna, Italy

G. Kontrym-Sznajd and A. Czopnik

W. Trzebiatowski Institute of Low Temperature and Structure Research, P.O.Box 937 Wroclaw, Poland.

More details in Phys. Rev. B (2002)

A three dimensional mapping of the Fermi Surface (FS) of the rare-earth compound $ErGa_3$ was determined via measurements of the angular correlation of the electron-positron annihilation radiation. The topology of the electronlike FS does show nesting properties which are consistent with the modulated antiferromagnetic structure of the system.
We determine the density of states at the Fermi energy $N(E_F)$ and the electronic contribution to the gamma constant to be $N(E_F)$ =16 states/Ryd/cell and γ=2.7 (mJ/mole K^2), respectively.



Densities $\rho(\mathbf{k})$ of $ErGa_3$ and $TmGa_3$ in the k_z=0 and k_z= π/a plane of the Brillouin zone reconstructed from 2D ACAR data. . The arrow highlights the nesting feature attributed to $TmGa_3$ [1] and $ErGa_3$ (left and right sides, respectively).

https://arxiv.org/ftp/cond-mat/papers/0209/0209196.pdf

Fermi surface (wiki)

Reset Password | Roczniki Filozof | Kokpit | Fermi surface - Wikipedia

en.wikipedia.org/wiki/Fermi_surface

Upload file

Tools

What links here
Related changes
Special pages
Permanent link
Page information
Cite this page
Wikidata item

Print/export

Download as PDF
Printable version

Languages

Deutsch
Español
Français
Italiano
Русский
Українська
中文

3 more

Edit links

Theory [edit]

Consider a spin-less ideal Fermi gas of N particles. According to Fermi–Dirac statistics, the mean occupation number of a state with energy ϵ_i is given by[7]

$$\langle n_i \rangle = \frac{1}{e^{(\epsilon_i - \mu)/k_B T} + 1},$$

where,

- $\langle n_i \rangle$ is the mean occupation number of the i^{th} state
- ϵ_i is the kinetic energy of the i^{th} state
- μ is the chemical potential (at zero temperature, this is the maximum kinetic energy the particle can have, i.e. Fermi energy E_F)
- T is the absolute temperature
- k_B is the Boltzmann constant

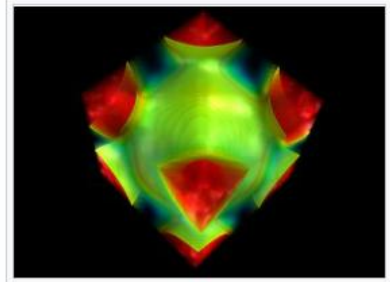


Figure 1. Fermi surface and electron momentum density of copper in the reduced zone schema measured with 2D ACAR.[6]

Suppose we consider the limit $T \to 0$. Then we have,

$$\langle n_i \rangle \approx \begin{cases} 1 & (\epsilon_i < \mu) \\ 0 & (\epsilon_i > \mu) \end{cases}.$$

By the Pauli exclusion principle, no two fermions can be in the same state. Therefore, in the state of lowest energy, the particles fill up all energy levels below the Fermi energy E_F, which is equivalent to saying that E_F is the energy level below which there are exactly N states.

In momentum space, these particles fill up a sphere of radius k_F, the surface of which is called the Fermi surface.[8]

The linear response of a metal to an electric, magnetic or thermal gradient is determined by the shape of the Fermi surface, because

Wpisz tu wyszukiwane słowa

23:50
10.11.2020

Fermi surface: experimental

en.wikipedia.org/wiki/Fermi_surface

The state occupancy of fermions like electrons is governed by Fermi–Dirac statistics so at finite temperatures the Fermi surface is accordingly broadened. In principle all fermion energy level populations are bound by a Fermi surface although the term is not generally used outside of condensed-matter physics.

Experimental determination [edit]

Electronic Fermi surfaces have been measured through observation of the oscillation of transport properties in magnetic fields H, for example the de Haas–van Alphen effect (dHvA) and the Shubnikov–de Haas effect (SdH). The former is an oscillation in magnetic susceptibility and the latter in resistivity. The oscillations are periodic versus $1/H$ and occur because of the quantization of energy levels in the plane perpendicular to a magnetic field, a phenomenon first predicted by Lev Landau. The new states are called Landau levels and are separated by an energy $\hbar\omega_c$ where $\omega_c = eH/m^*c$ is called the cyclotron frequency, e is the electronic charge, m^* is the electron effective mass and c is the speed of light. In a famous result, Lars Onsager proved that the period of oscillation ΔH is related to the cross-section of the Fermi surface (typically given in Å^{-2}) perpendicular to the magnetic field direction $A_\perp$ by the equation

$$A_\perp = \frac{2\pi e \Delta H}{\hbar c}.$$

Positron annihilation, de Haas – van Alphen effect

we will come back to that

Thus the determination of the periods of oscillation for various applied field directions allows mapping of the Fermi

Why do gold (and silver) reflect so well light (in mirrors)?

Apollo 11 Space Helmet ReplicaGold is highly reflective. The visors of astronauts' space helmets receive a coating of gold so thin that it is partially transparent. The astronauts can see through it, but, even at that thinness, the gold film reduces glare and heat from sunlight.

Gold is highly reflective of heat and light. The visors of astronauts' space helmets receive a coating of gold so thin (0.00005 millimeters, or 0.000002 inches) that it is partially transparent. The astronauts can see through it, but even at that thinness the gold film reduces glare and heat from sunlight.

0.050 µm
i.e. ~300 atomic layers

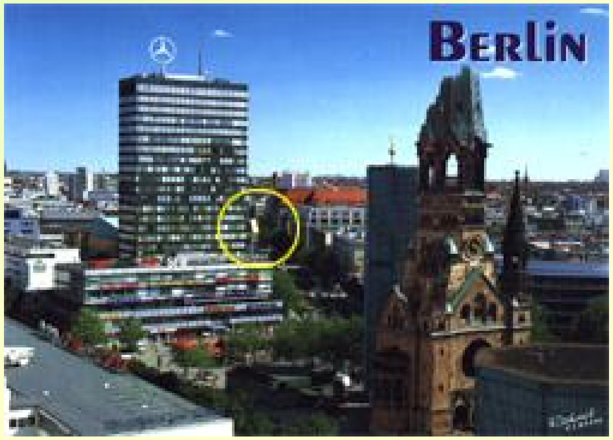
See, to believe:
„neo-realism”

https://www.amnh.org/exhibitions/gold/incomparable-gold/gold-properties

Why these Berlin windows are bluish?

Observe the world:„neo-realism”

dydaktyka.fizyka.umk.pl/zabawki1/files/optyka/okulary-sun-en.html



dydaktyka.fizyka.umk.pl/zabawki/files/optyka/wierza.html
(not gold here (TiN?), but the principle is similar

The color of gold. Gold has an absorption beginning at 2.4 eV, attributed to a transition from the filled 5d band to the Fermi level (essentially the 6s band). It therefore reflects red and yellow light and strongly absorbs blue and violet. The analogous absorption for silver, however, lies in the ultraviolet, at around 3.7 eV. [M. Concepción GImeno, *Chemistry of Gold*, 2008]

With the same term „Fermi level” we explain different phenomena

Kittel: Solid state physics

- Why gold is transparent and green in thin foils?
-
- Because alkali metals are transparent in UV

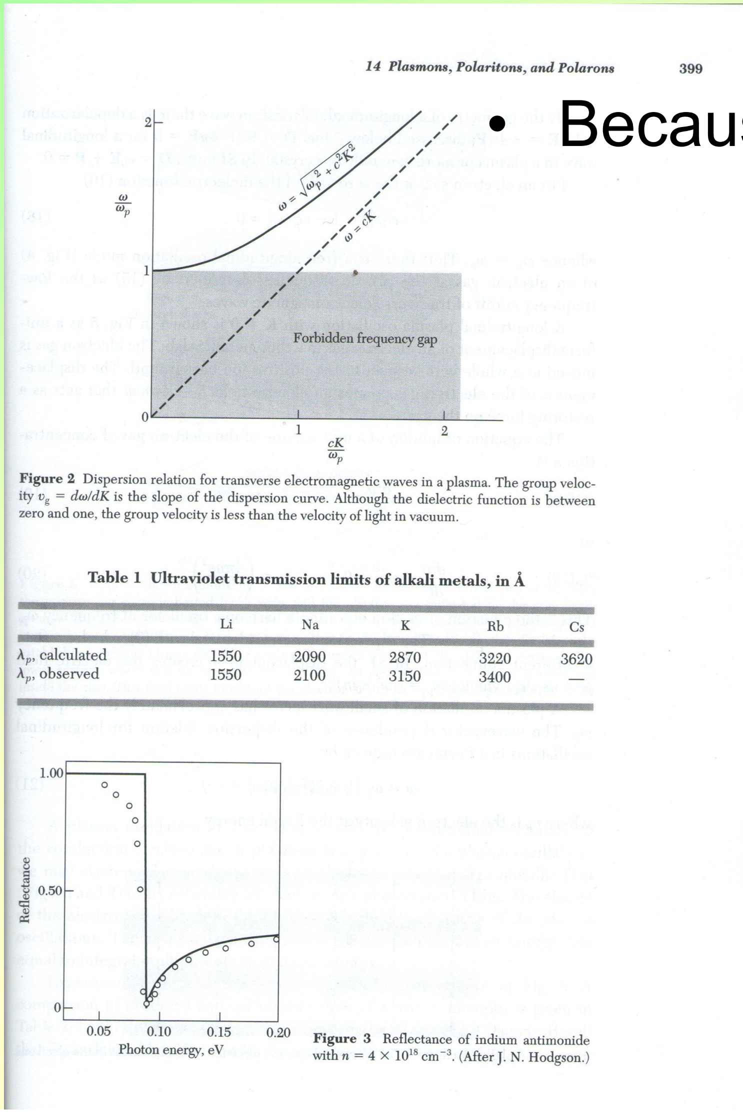


Figure 2 Dispersion relation for transverse electromagnetic waves in a plasma. The group velocity $v_g = d\omega/dK$ is the slope of the dispersion curve. Although the dielectric function is between zero and one, the group velocity is less than the velocity of light in vacuum.

Table 1 Ultraviolet transmission limits of alkali metals, in Å

	Li	Na	K	Rb	Cs
λ_p, calculated	1550	2090	2870	3220	3620
λ_p, observed	1550	2100	3150	3400	—

Figure 3 Reflectance of indium antimonide with $n = 4 \times 10^{18}$ cm^{-3}. (After J. N. Hodgson.)

Berlin ash-tray with Au-nanodroplets (object & photo GK)

Kittel: Solid state physics

The dielectric function of the free electron gas follows from (6) and (7):

GS) $\epsilon(\omega) = 1 - \frac{4\pi ne^2}{m\omega^2}$; (SI) $\epsilon(\omega) = 1 - \frac{ne^2}{\epsilon_0 m\omega^2}$. (8)

The **plasma frequency** ω_p is defined by the relation

GS) $\omega_p^2 = 4\pi ne^2/m$; (SI) $\omega_p^2 \equiv ne^2/\epsilon_0 m$. (9)

plasma is a medium with equal concentration of positive and negative rges, of which at least one charge type is mobile. In a solid the negative rges of the conduction electrons are balanced by an equal concentration of itive charge of the ion cores. We write the dielectric function (8) as

$$\epsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2} , \quad (10)$$

tted in Fig. 1.

If the positive ion core background has a dielectric constant labeled $\epsilon(\infty)$ entially constant up to frequencies well above ω_p, then (8) becomes

$$\epsilon(\omega) = \epsilon(\infty) - 4\pi ne^2/m\omega^2 = \epsilon(\infty)[1 - \bar{\omega}_p^2/\omega^2] , \quad (11)$$

ere $\bar{\omega}_p$ is defined as

Plasma resonant frequency

tice that $\epsilon = 0$ at $\omega = \bar{\omega}_p$.

persion Relation for Electromagnetic Waves

In a nonmagnetic isotropic medium the electromagnetic wave equation is

GS) $\partial^2\mathbf{D}/\partial t^2 = c^2\nabla^2\mathbf{E}$; (SI) $\mu_0\partial^2\mathbf{D}/\partial t^2 = \nabla^2\mathbf{E}$. (13)

look for a solution with $\mathbf{E} \propto \exp(-i\omega t)\exp(i\mathbf{K}\cdot\mathbf{r})$ and $\mathbf{D} = \epsilon(\omega,\mathbf{K})\mathbf{E}$; then have the dispersion relation for electromagnetic waves:

GS) $\epsilon(\omega,\mathbf{K})\omega^2 = c^2K^2$; (SI) $\epsilon(\omega,\mathbf{K})\epsilon_0\mu_0\omega^2 = K^2$. (14)

s relation tells us a great deal. Consider

real and > 0. For ω real, K is real and a transverse electromagnetic wave ropagates with the phase velocity $c/\epsilon^{1/2}$.

real and < 0. For ω real, K is imaginary and the wave is damped with a haracteristic length $1/|K|$.

complex. For ω real, $\mathbf{K}$ is complex and the waves are damped in space.

Plasma reflects EM radiation
So the ionosphere allows radio transmission in short-wave range over the globe
Dielectric constant may be negative (or better: is always complex number)
„plasmons" = collective oscillations of electrons

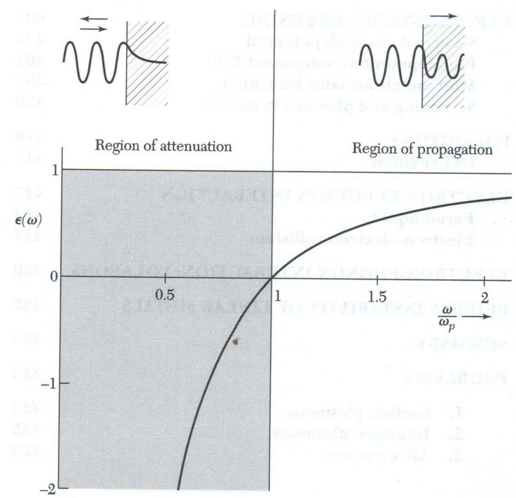


Figure 1 Dielectric function $\epsilon(\omega)$ or $\epsilon(\omega, 0)$ of a free-electron gas versus frequency in units of the plasma frequency ω_p. Electromagnetic waves propagate without damping only when ϵ is positive and real. Electromagnetic waves are totally reflected from the medium when ϵ is negative.

De Haas – van Alphen effect

De Haas–van Alphen effect

From Wikipedia, the free encyclopedia

The **de Haas–van Alphen effect**, often abbreviated to **dHvA**, is a quantum mechanical effect in which the magnetic susceptibility of a pure metal crystal oscillates as the intensity of the magnetic field B is increased. Other quantities also oscillate, such as the electrical resistivity (Shubnikov–de Haas effect), specific heat, and sound attenuation and speed.[1][2][3] It is named after Wander Johannes de Haas and his student Pieter M. van Alphen.[4] The dHvA effect comes from the orbital motion of itinerant electrons in the material. An equivalent phenomenon at low magnetic fields is known as Landau diamagnetism.

Contents [hide]

is a quantum mechanical effect in which the magnetic susceptibility of a pure metal crystal oscillates as the intensity of the magnetic field *B* is increased.

Description [edit]

The differential magnetic susceptibility of a material is defined as

$$\chi = \frac{\partial M}{\partial H}$$

where H is the applied external magnetic field and M the magnetization of the material. Such that $B = \mu_0(H + M)$, where μ_0 is the vacuum permeability. For practical purposes, the applied and the measured field are approximately the same $B \approx \mu_0 H$ (if the material is not ferromagnetic).

The oscillations of the differential susceptibility when plotted against $1/B$, have a period P (in teslas^{-1}) that is inversely proportional to the area S of the external orbit of the Fermi surface (m^{-2}), in the direction of the applied field, that is

$$P\left(B^{-1}\right) = \frac{2\pi e}{\hbar S},$$

Even in wiki so little!

where $\hbar$ is Planck constant and e is the elementary charge.[5]

The modern formulation allows the experimental determination of the Fermi surface of a metal from measurements performed with different orientations of the magnetic field around the sample.

History [edit]

Experimentally it was discovered in 1930 by W.J. de Haas and P.M. van Alphen under careful study of the magnetization of a single crystal of bismuth. The magnetization oscillated as a function of the field.[4] The inspiration for the experiment was the recently discovered Shubnikov–de Haas effect by Lev Shubnikov and de Haas, which showed oscillations of the electrical resistivity as function of a strong magnetic field. De Haas thought that the magnetoresistance should behave in an analogous way.[6]

The theoretical prediction of the phenomenon was formulated before the experiment, in the same year, by Lev Landau,[7] but he discarded it as he thought that the magnetic fields necessary for its demonstration could not yet be created in a laboratory.[8][9][6] The effect was described mathematically using Landau quantization of the electron energies in an applied magnetic field. A strong homogeneous magnetic field — typically several teslas — and a low temperature are required to cause a material to exhibit the dHvA effect.[10] Later in life, in private discussion, David Shoenberg asked Landau why he thought that an experimental demonstration was not possible. He answered by saying that Pyotr Kapitsa, Shoenberg's advisor, had convinced him that such homogeneity in the field was impractical.[6]

After the 1950s, the dHvA effect gained wider relevance after Lars Onsager (1952),[11] and independently, Ilya Lifshitz and Arnold Kosevich (1956),[12] pointed out that the phenomenon could be used to image the Fermi surface of a metal.[6]

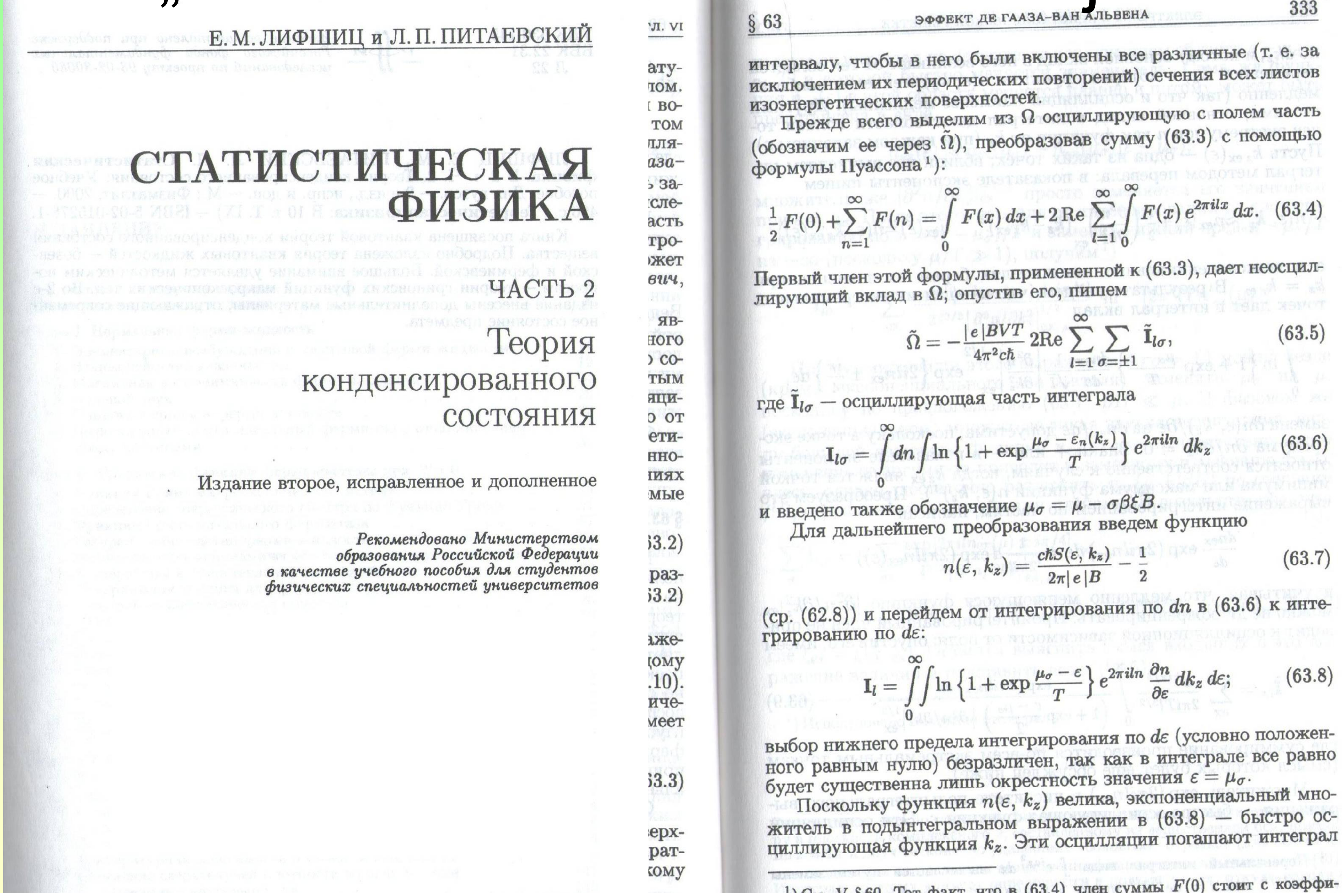
References [edit]

1. ^ Zhang Mingzhe. "Measuring FS using the de Haas-van Alphen

5. ^ Kittel, Charles (2005). *Introduction to Solid-State Physics* (8th

10. ^ Harrison, Neil. "de Haas-van Alphen Effect". National High

„Landau – Lifshitz – Pitaevskij”



Е. М. ЛИФШИЦ и Л. П. ПИТАЕВСКИЙ

СТАТИСТИЧЕСКАЯ ФИЗИКА

ЧАСТЬ 2

Теория конденсированного состояния

Издание второе, исправленное и дополненное

Рекомендовано Министерством образования Российской Федерации в качестве учебного пособия для студентов физических специальностей университетов

интервалу, чтобы в него были включены все различные (т. е. за исключением их периодических повторений) сечения всех листов изоэнергетических поверхностей.

Прежде всего выделим из Ω осциллирующую с полем часть (обозначим ее через $\tilde{\Omega}$), преобразовав сумму (63.3) с помощью формулы Пуассона[1]):

$$\frac{1}{2}F(0)+\sum_{n=1}^{\infty}F(n)=\int_0^{\infty}F(x)\,dx+2\,\mathrm{Re}\sum_{l=1}^{\infty}\int_0^{\infty}F(x)\,e^{2\pi ilx}\,dx. \quad (63.4)$$

Первый член этой формулы, примененной к (63.3), дает неосциллирующий вклад в Ω; опустив его, пишем

$$\tilde{\Omega}=-\frac{|e|BVT}{4\pi^2ch}\,2\mathrm{Re}\sum_{l=1}^{\infty}\sum_{\sigma=\pm1}\tilde{\mathrm{I}}_{l\sigma}, \quad (63.5)$$

где $\tilde{\mathrm{I}}_{l\sigma}$ — осциллирующая часть интеграла

$$\mathrm{I}_{l\sigma}=\int_0^{\infty}dn\int\ln\left\{1+\exp\frac{\mu_\sigma-\varepsilon_n(k_z)}{T}\right\}e^{2\pi iln}\,dk_z \quad (63.6)$$

и введено также обозначение $\mu_\sigma=\mu-\sigma\beta\xi B$.

Для дальнейшего преобразования введем функцию

$$n(\varepsilon,k_z)=\frac{chS(\varepsilon,k_z)}{2\pi|e|B}-\frac{1}{2} \quad (63.7)$$

(ср. (62.8)) и перейдем от интегрирования по dn в (63.6) к интегрированию по $d\varepsilon$:

$$\mathrm{I}_l=\int_0^{\infty}\!\!\int\ln\left\{1+\exp\frac{\mu_\sigma-\varepsilon}{T}\right\}e^{2\pi iln}\frac{\partial n}{\partial\varepsilon}\,dk_z\,d\varepsilon; \quad (63.8)$$

выбор нижнего предела интегрирования по $d\varepsilon$ (условно положенного равным нулю) безразличен, так как в интеграле все равно будет существенна лишь окрестность значения $\varepsilon=\mu_\sigma$.

Поскольку функция $n(\varepsilon,k_z)$ велика, экспоненциальный множитель в подынтегральном выражении в (63.8) — быстро осциллирующая функция k_z. Эти осцилляции погашают интеграл

[1]) См. V § 60. Тот факт, что в (63.4) член суммы $F(0)$ стоит с коэффи-

Einstein: this is experiment which verifies the validity of the theory

Karwasz: no valid experiment is posible without reading some theory before

Conclusions (on books)

- Books present infinity of didactical and cognitive solutions
- Book, ordered on a shell is the quickest (apart from own brain) the source of information
- Reading a book brings usually unexpected surprises
- „Didactics” = searching of nodes in learning, can be beautifully executed by „random” comparison of books
- Do not hesitate to search in unknown sectors
- Some books, like „Feynman”, „Landau-Lifshitz-Pitaevski” are classics, like Dante and Shakespeare
- Own library is a treasure, more than bank account

Thank you

Didactical conclusions (*from* books)

- Good books follow the principles of didactics, independently from their level: elementary or PhD
- First, attention of the student must be caught: for ex.

by a „touchable” evidence, like shining gold

- The problem, must be explained step-by-step
- Obviously, one can say: „Principle of Pauli assures…” or „Fermi surface means…”
- But giving pictures, funny o colourful, for sure will fix better in memory.
- Teaching must be inter-disciplinary: from the structure of concrete in architecture to oyster shells and ceramics.
- Careful and constant observing of the world is essential for being interdisciplinary (and interesting)
- And, last but first, teaching must be pleasant.

Thank you again