Introduction

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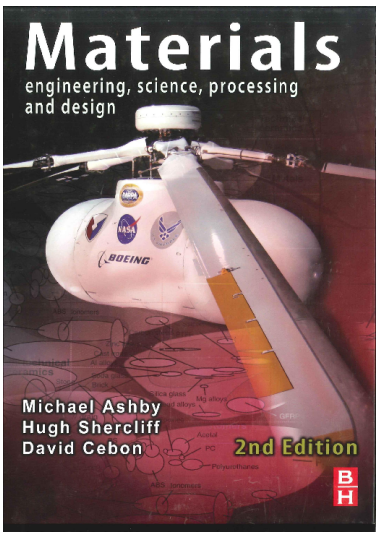
Virtual Materials and Mechanics
Department of Materials Science and Engineering (MSE)
Delft University of Technology

VML

TU Delft

Book



NASA tests of helicopter rotor blades made with piezo-electric materials

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Contents

- Book:
  Materials engineering, science, processing and design
  Michael Ashby, Hugh Shercliff, David Sherbon
  Elsevier Butterworth-Heinemann (Oxford 2010)
  - Chapters 1-11 Tentamenstof
- Supporting lecture notes:
  Based on PowerPoint notes by Prof. John Barnard, University of Pittsburgh (Blackboard)
- Supporting software:
  CES EduPack Eco Edition 2011 (Blackboard)

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Schedule 2011-2012

- Wednesdays + Fridays, 10:45 am - 12:30 pm
- First class on Friday 9 September
- Last class on Wednesday 26 October
- 14 classes
- Perhaps extra class on Friday 28 October

- Office hours: Fridays 4pm-5pm, appointment by e-mail only (B.J.Thijsse@tudelft.nl), max 15 minutes
- I handle course content and personal requests, not organizational matters

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Schedule 2011-2012

#	Day	Date 2011	Book chapter	Special	
1	Fri	9 Sep	Introduction, Ch 1		
2	Wed	14 Sep	Ch 2		
3	Fri	16 Sep	Ch 3		
4	Wed	21 Sep	Ch 4		
5	Fri	23 Sep	Ch 4, Ch 5		
6	Wed	28 Sep	Ch 5		
7	Fri	30 Sep	Ch 6		
8	Wed	5 Oct	Ch 6, Ch 7		
9	Fri	7 Oct	Ch 7		
10	Wed	12 Oct	Ch 8		
11	Fri	14 Oct	Ch 9		
12	Wed	19 Oct	Ch 10		
13	Fri	21 Oct	Ch 11		
14	Wed	26 Oct	Ch 11		
15	Thu	28 Oct		reserve	
		XX Nov	**Examination**		
		XX Jan	**Re-examination (2nd opportunity)**		

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Homework, Testing, Exam

- Homework
  - Yet to be decided
- Testing
  - In class exercises for self-assessment
  - Peer Instruction (Harvard, USA)
  - Laptops, iPads, smart phones for internet connection
- Exam
  - Open Book, no communication devices allowed (iPads, smartphones)

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Lab class

- Lab class Materiaalkunde I (WB6101-11 D2)
  - Self-contained and independent part of the course
  - Final grade for WB6101-11:
    - 80% Exam grade + 20% Lab grade
    - Only if both are 5 or higher
  - Lab class organized by Dr Ton Riemslag and team

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Rules

- Use of laptops, iPads, e-readers in class: allowed – but no sound
- Use of phones in class: allowed only for connection to the Internet – but no sound

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What's so important about materials?

- **Materials are relevant to your life**
  - **Think about it**
    - From baby carriage to rollator

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Why should engineers bother?

- **Engineers make things**
- **They make them out of materials**
  - What are important materials properties in mechanical engineering?
  - Why are different materials different?
  - How will materials behave under extreme conditions?
  - How can engineers change or create materials?
  - How can the best materials for a given device be selected?

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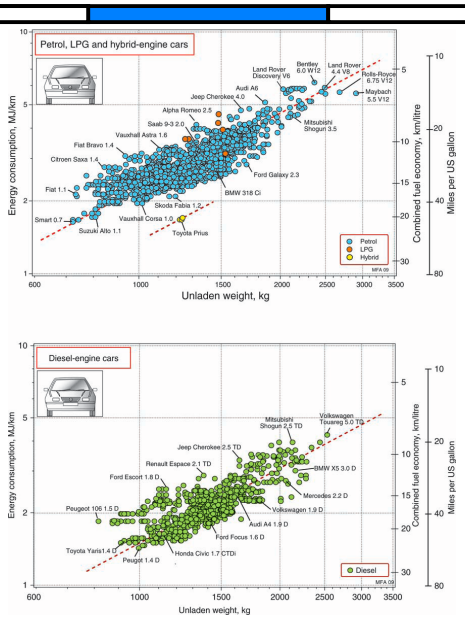
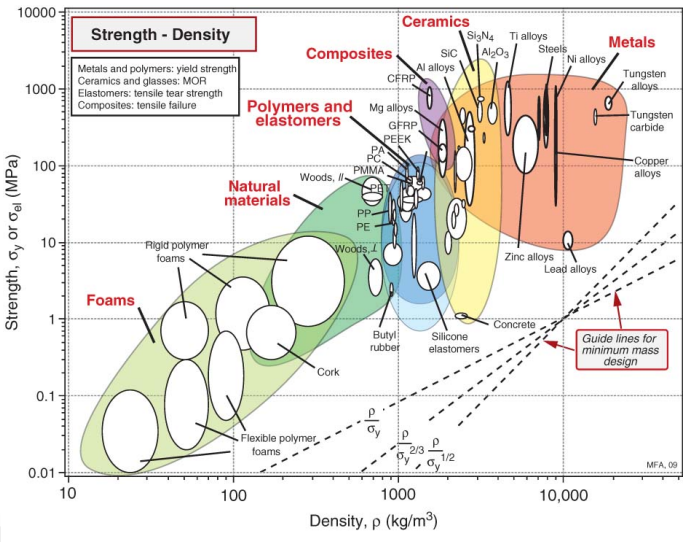
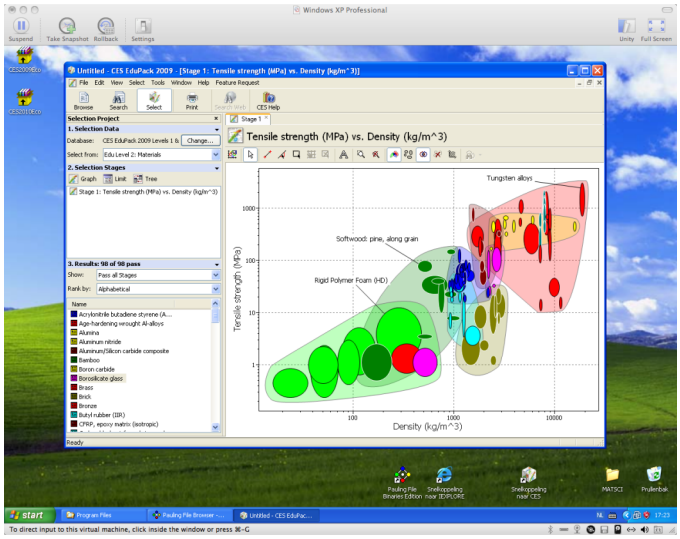
Materials Properties and Choices



Materials Properties and Choices



CES Edupack



Materials in the news

Ferrari roept 1250 auto's terug

ANP/AFP op 02 september '10, 08:14, bijgewerkt 02 september '10, 09:52

Felipe Massa poseert bij een Ferrari 458 Italia (EPA)

ROME - De Italiaanse autofabrikant Ferrari roept wereldwijd 1250 auto's van het type 458 Italia terug naar de garage, omdat de voertuigen in brand kunnen vliegen. Dat heeft Ferrari bekendgemaakt.

De terugroepactie gaat over auto's die zijn gemaakt voor juli 2010. Ferrari begon vorige week een onderzoek, nadat vier voertuigen van het type 458 Italia in brand waren gevlogen. Dat gebeurde in de Verenigde Staten, China, Frankrijk en Zwitserland.

De problemen worden veroorzaakt door een lijm waarmee de hitteschilden zijn aangebracht. Die lijm kan vlam vatten bij extreme hitte.

http://www.mrs.org

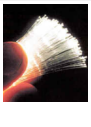
MRS Bulletin August 2011

Mussel adhesive inspires tough coating for living cells

Taking a cue from shellfish, scientists in Korea have developed a coating that could protect living cells during long exposures to intense heat, dryness and other hostile conditions. In the *Journal of the American Chemical Society*, Insung S. Choi and colleagues report that an organic material called polydopamine, which is a chemical analogue of mussel adhesive, protected yeast cells from cell-digesting chemicals while slowing down their rate of cell division, thereby prolonging their life cycles. The researchers liken the coating to the armor that encloses the spores of some bacterial cells, making them difficult to kill. Polydopamine could be used to encapsulate individual cells to create tiny chemical probes, single-cell chemical factories, and perhaps armor for transplanted cells used in anti-cancer therapies.

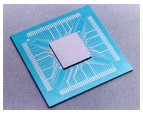
A quasicrystalline-coated pan (right) compared with a Teflon-coated pan (left).

Materials in a global perspective

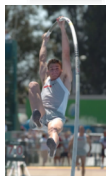


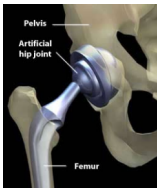


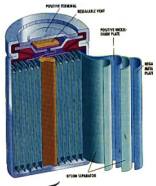

- Communication
- Transportation
- Information
- Energy
- Art and design
- Consumer products
- Sports
- Medicine
- Security
- Infrastructure

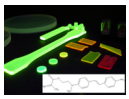




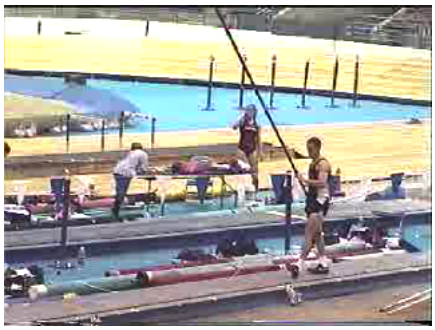
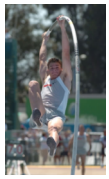






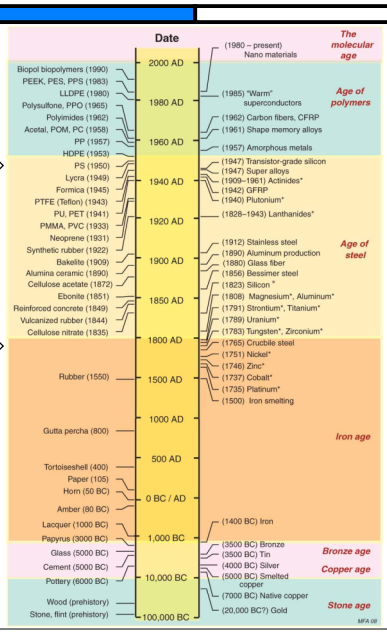
Man depends on materials

Man*kind* depends on materials

Second World War →
Organic Chemistry and
Solid State Physics →
Polymers and Semiconductors

Napoleontic wars →
Inorganic Chemistry and
Electrochemistry →
New metals



Critical elements

Dependence is dangerous

Materials
Energy
Fresh water

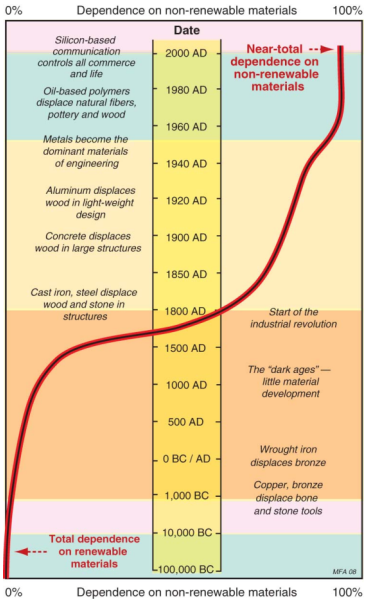
Atoomnummer en commercieel gebruik

21	Scandium	Sc	Stadionverlichting
39	Yttrium	Y	Lasers
57	Lanthaan	La	Accu's elektrische auto's
58	Cerium	Ce	Lenzen polijsten
59	Praseodymium	Pr	Zoeklichten, vliegtuigen
60	Neodymium	Nd	Supersterke magneten
61	Promethium	Pm	Röntgenapparatuur
62	Samarium	Sm	Glas
63	Europium	Eu	Compacte fluorlampen
64	Gadolinium	Gd	Neutronenradiografie
65	Terbium	Tb	Supersterke magneten
66	Dysprosium	Dy	Supersterke magneten
67	Holmium	Ho	Glaskleuring
68	Erbium	Er	Metaallegeringen
69	Thullium	Tm	Lasers
70	Ytterbium	Yb	Roestvrij staal
71	Lutetium	Lu	Geen

Non-renewable materials

Dependence is dangerous

Materials
Energy
Fresh water



Materials consumption in US:

10^4 kg/person/y

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Class testing

- Example of Peer Instruction
- Suppose that I have just presented this power consumption table

TP Anywhere: Window→Showbar

TP Anywhere: Window→Responseware (B.J.Thijsse@tudelft.nl, Gavia incident)

Primary power consumption	
	kW
Electric razor	0.03
Person	0.1
Candle	0.1
Laptop	0.3
Bicycle (extra food)	0.4
Kitchen gas burner	2
Vacuum cleaner	3
Full train per seat	8
Hot shower	10
Medium CV heater	20
Full car per seat	20
Full plane per seat	350

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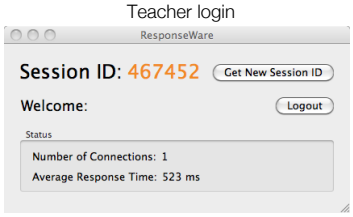
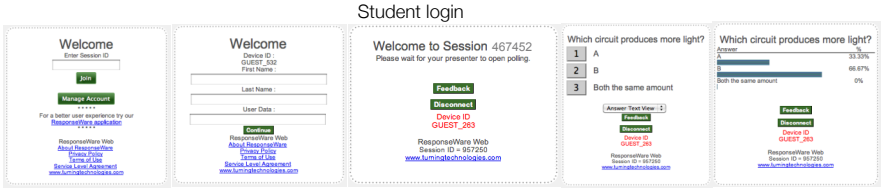
Answering via the internet

http://www.rwpoll.com
User: B.J.Thijsse@tudelft.nl
Password: Gavia incident

Teacher login



Student login



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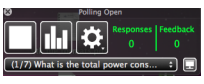
What is the power consumption in Holland, expressed as a 24/7 continuous rate?

1. 60 W per person
2. 600 W per person
3. 6 kW per person
4. 60 kW per person

Question List --> Open Question List
Window --> Showbar



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Materials in a high-level road bike

Wilier Cento (2006)

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Which material is *not* present in the bike?

1. Metal
2. Semiconductor
3. Gas
4. Composite
5. Liquid
6. Ceramic
7. Liquid crystal
8. Polymer
9. They're all there

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Useful background information

- Periodic system
- Units and conversion
- Energy data
  - From: Jo Hermans, *Energie survival gids* (2009)

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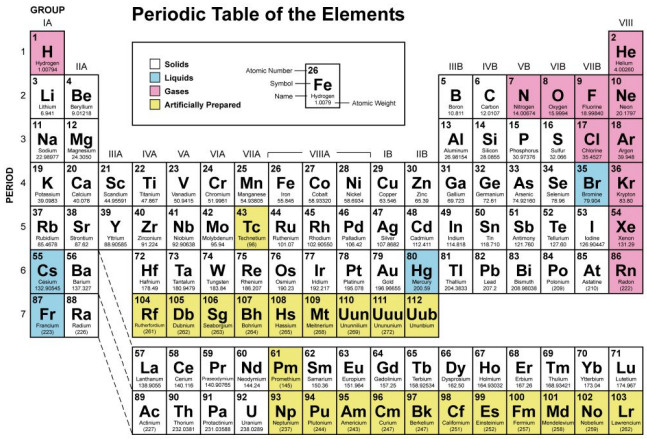
Periodic system



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Units and conversion

Energy units conversion				
	kWh	MJ	kcal	eV
kWh	1	3.6	8.60×10^{2}	2.25×10^{25}
MJ	0.278	1	2.39×10^{2}	6.24×10^{24}
kcal	1.16×10^{-3}	4.18×10^{-3}	1	2.61×10^{22}
eV	4.45×10^{-26}	1.60×10^{-25}	3.83×10^{-23}	1

Time units conversion				
	s	h	d	y
s	1	2.78×10^{-4}	1.16×10^{-5}	3.16×10^{-8}
h	3.60×10^{3}	1	4.17×10^{-2}	1.14×10^{-4}
d	8.64×10^{4}	24	1	2.74×10^{-3}
y	3.16×10^{7}	8.77×10^{3}	3.65×10^{2}	1

Prefixes				
Z	zetta	10^{21}		*triljard*
E	exa	10^{18}		*triljoen*
P	peta	10^{15}	quadrillion	*biljard*
T	tera	10^{12}	trillion	*biljoen*
G	giga	10^{9}	billion	*miljard*
M	mega	10^{6}	million	*miljoen*

Other units conversion tables in book Ashby (inside back cover)	
Stress, pressure	
Power	

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Energy usage and population

Energy usage per person				
	World 2005	USA 2005	EU 2005	Netherlands 2006
Ratio	0.38	1.79	0.80	1
Joules	74 GJ/y 203 MJ/d	350 GJ/y 961 MJ/d	156 GJ/y 428 MJ/d	196 GJ/y 538 MJ/d
Liters oil	5 l/d	25 l/d	11 l/d	14 l/d
Continuous kW	2.3 kW	11.1 kW	4.9 kW	6.2 kW
In terms of food				55 x
Fossil	81 %	86 %	79 %	95 %
Nuclear	5 %	8 %	14 %	4 %
Renewable	14 %	7 %	7 %	1 %

Population (2009)	
World	6.79×10^{9}
China	1.34×10^{9}
EU	5.00×10^{8}
USA	3.07×10^{8}
Netherlands	1.67×10^{7}
Delft	9.62×10^{4}

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Energy production and conversion

Energy and CO_2 production of fossil fuels				
Fuel	Spec. mass (kg/l)	kg OE	Energy	CO_2
Coal, lignite		0.45	20 MJ/kg	1.6 kg/kg
Coal, anthracite		0.72	32 MJ/kg	2.9 kg/kg
Crude oil, diesel	0.86	1	38 MJ/l	3.1 kg/l
Gasoline	0.78	1.05	35 MJ/l	2.9 kg/l
Ethanol	0.74	0.71	23 MJ/l	2.8 kg/l
Liquid nat. gas	0.45	1.2	25 MJ/l	3.0 kg/l

Conversion efficiency (%)	
Mechanical → Electrical	80-98
Heat → Mechanical (steam engine)	40-55
Heat → Mechanical (diesel engine)	35
Heat → Mechanical (gasoline eng.)	20-25
Heat → Electrical (in power plant)	40
Heat → Electrical (from wall outlet)	35
Heat → Heat (kitchen gas burner)	50
Solar radiation → Electrical	12-17
Solar radiation → Biomass	0.2-5
Electrical → Mechanical	80-98
Electrical → Chemical (adv. battery)	85-90
Electrical → Visible light (inc. lamp)	15-20
Food → Mechanical (muscle power)	20-25

Data 2009

Everyday energy costs

Primary power consumption		
	kW	l oil/h m^3 gas/h
Electric razor	0.03	0.003
Person	0.1	0.01
Candle	0.1	0.01
Laptop	0.3	0.03
Bicycle (extra food)	0.4	0.04
Kitchen gas burner	2	0.2
Vacuum cleaner	3	0.3
Full train per seat	8	0.8
Hot shower	10	1
Medium CV heater	20	2
Full car per seat	20	2
Full plane per seat	350	35

Energy cost of production		
	MJ	l oil
1 kg Al (recycled)	7	0.2
1 kg steel (from ore)	15	0.4
1 l milk	16	0.4
1 kg glass	18	0.5
1 kg paper	25	0.6
1 kg cheese	50	1.2
1 kg Al (from ore)	140	0.4
1 kg coffee	300	7
Passenger car	2×10^4	500

Data 2009

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How to produce 1000 MW electricity

Resources needed to produce 1000 MW electrical energy (= 10% of NL electricity usage)	
Power plant, coal	3 x 10^9 kg coal/y
Power plant, oil	2 x 10^9 l oil/y
Power plant, natural gas	3 x 10^9 m^3 gas/y
Power plant, nuclear fission	1 x 10^8 kg U ore/y = 700 kg ^{235}U/y
Power plant, nuclear fusion	100 kg deuterium/y + 150 kg tritium/y
Wind turbines 90 m diameter, offshore	1300 turbines = 600 km^2
Solar cells (15 % efficiency)	60 km^2
Plants and trees	3000 km^2
People on home trainers (8 hours/day)	30 million people

Data 2009

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50 l gasoline and alternatives

Passenger car alternatives for 50 l gasoline		
	Volume (l) (tank included)	Mass (kg) (tank included)
Gasoline	52	60
H_2, high pressure	300	400
H_2, liquid	100	150
H_2, in $LaNi_5H_6$	200	500
Flywheel	400	1000
Lead batteries	1500	3000

Data 2009

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