PHYS-E6571 - Fuel Cells and Hydrogen Technology

Course book: O'Hayre, R., Cha, S. W., Prinz, F. B., & Colella, W. (2016). Fuel cell fundamentals. John Wiley & Sons.

This table shows the core learning content in the cource book according to their relevance toward the learning objectives.

The scope of the exam are sections marked with "x" or a number in columns A - C.

Excluded from the exam are sections marked in column D.

	А	В	С	D	E
Book section	Essential	Often useful	Sometimes	Not included in	Total pages in
			useful	this course	the book
Pages total:	182	47	42	234	505
1 Introduction 3	23	0	0	0	23
1.1 What Is a Fuel Cell? / 3	Х				
1.2 A Simple Fuel Cell / 6	Х				
1.3 Fuel Cell Advantages / 8	Х				
1.4 Fuel Cell Disadvantages / 11	Х				
1.5 Fuel Cell Types / TZ 1.6 Pasic Eucl Coll Operation / 14	X				
1.7 Euel Cell Performance / 18	x v				
1.8 Characterization and Modeling / 20	x				
1.9 Fuel Cell Technology / 21	x				
1.10 Fuel Cells and the Environment / 21	X				
1.11 Chapter Summary / 22	х				
Chapter Exercises / 23	х				
2 Fuel Cell Thermodynamics 25	30	12	4	5	51
2.1 Inermodynamics Review / 25		9			
2.2 Heat Potential of a Fuel: Enthalpy of Reaction 7 34	v	3			
2.5 WOLK POLEITING OF a FUEL GIBDS FLEE EITERY 7.57 2.4 Predicting Reversible Voltage of a Fuel Cell under Non Standard State	X				
Conditions / 47	x excent.				
2 4 4 Concentration cells	х, слеерт.			5	
2.5 Fuel Cell Efficiency / 60	х			-	
2.6 Thermal and Mass Balances in Fuel Cells / 65	х				
2.7 Thermodynamics of Reversible Fuel Cells / 67			4		
2.8 Chapter Summary / 71	Х				
Chapter Exercises / 72	Х				
3 Fuel Cell Reaction Kinetics 77	20	2	1	7	40
3.1 Introduction to Electrode Kinetics / 77	χ	5		,	40
3.2 Why Charge Transfer Reactions Have an Activation Energy / 82	X				
3.3 Activation Energy Determines Reaction Rate / 84	х				
3.4 Calculating Net Rate of a Reaction / 85	х				
3.5 Rate of Reaction at Equilibrium: Exchange Current Density / 86	Х				
3.6 Potential of a Reaction at Equilibrium: Galvani Potential / 87	Х				
3.7 Potential and Rate: Butler–Volmer Equation / 89	Х				
3.8 Exchange Currents and Electrocatalysis: How to Improve Kinetic					
Performance / 94	Х				
3.9 Simplified Activation Kinetics: Talei Equation / 97	Х	2			
3.10 Different Fuel Cell Reactions Produce Different Kinetics / 100	v	3			
3.12 Quantum Mechanics: Framework for Understanding Catalysis in Fuel	Λ				
Cells / 104				3	
3.13 The Sabatier Principlefor Catalyst Selection / 107			1	Ū	
3.14 Connecting the Butler–Volmer and Nernst Equations (Optional) / 108				4	
3.15 Chapter Summary / 112	Х				
Chapter Exercises / 113	х				
4 Fuel Cell Charge Transport 117	18	9	3	20	50
4.1 Charges Move in Response to Forces / 117	X		2		00
4.2 Charge Transport Results in a Voltage Loss / 121	х				
4.3 Characteristics of Fuel Cell Charge Transport Resistance / 124	Х				
4.4 Physical Meaning of Conductivity / 128	Х				

4.5 Review of Fuel Cell Electrolyte Classes / 132	x, except:				
4.5.1 Ionic Conduction in Aqueous Electrolytes/Ionic Liquids	-			3	
4.5.2 Ionic Conduction in Polymer Electrolytes, p. 135 - 137			3		
4.5.2 Ionic Conduction in Polymer Electrolytes, p. 138 - 137				7	
4.5.3 Ionic Conduction in Ceramic Electrolytes		7			
4.5.4 Mixed Ionic–Electronic Conductors		2			
4.6 More on Diffusivity and Conductivity (Optional) / 153				6	
4.7 Why Electrical Driving Forces Dominate Charge Transport (Optional) /				1	
100 4.9 Quantum Machanics, Deced Simulation of Ion Conduction in Ovide				I	
4.8 Qualitum Mechanics-Based Simulation of for conduction in Oxide				n	
A 9 Chapter Summary / 163	v			3	
Chanter Exercises / 164	x				
	~				
5 Fuel Cell Mass Transport 167	19	4	0	12	35
5.1 Transport in Electrode versus Flow Structure / 168	х				
5.2 Transport in Electrode: Diffusive Transport / 170	х				
5.3 Transport in Flow Structures: Convective Transport / 183	(*)				
5.3.1 - 5.3.3 (Theoretical part of convective transport in FC)				12	
5.3.4 Flow Structure Design		4			
5.4 Chapter Summary / 199	х				
Chapter Exercises / 200	х				
(*) Only the physical principles and design ideas , not equations or calculat	ions				
6 Eucl Coll Modeling 203	4	1	4	24	22
4.1 Dutting It All Together: A Basic Fuel Cell Medel / 202	4		4	24	33
6.2 A 1D Evel Cell Model / 206	x			21	
6.3 Evel Cell Models Based on Computational Eluid Dynamics (Ontional) /				21	
227				3	
6 4 Chapter Summary / 230		1		5	
Chapter Exercises / 231		·	4		
7 Fuel Cell Characterization 237	17	3	2	12	34
7.1 What Do We Want to Characterize? / 238	х				
7.2 Overview of Characterization Techniques / 239		2			
7.3 In Situ Electrochemical Characterization Techniques / 240		x, except:			
EIS and Equivalent Circuit Modeling, p. 250 - 257				7	
7.3.5 Current Interrupt Measurement				3	
7.3.6 Cyclic Voltammetry				2	
7.4 Ex Situ Characterization Techniques / 265	х				
7.5 Chapter Summary / 268		1	2		
Chapter Exercises / 209			2		
II FUEL CELL TECHNOLOGY					
8 Overview of Fuel Cell Types 273	19	0	0	12	31
8.1 Introduction / 273	х				
8.2 Phosphoric Acid Fuel Cell / 274	х				
8.3 Polymer Electrolyte Membrane Fuel Cell / 275	х				
8.4 Alkaline Fuel Cell / 278	х				
8.5 Molten Carbonate Fuel Cell / 280	х				
8.6 Solid-Oxide Fuel Cell / 282	х				
8.7 Other Fuel Cells / 284				12	
8.7.11 Electrolysis and Reversible Fuel Cell–Electrolyzers	X				
8.8 Summary Comparison / 298	x				
Chapter Evercises / 201	x				
chapter Exercises 7 301	~				
9 PEMFC and SOFC Materials 303	0	12	14	17	43
9.1 PEMFC Electrolyte Materials / 304				4	
9.2 PEMFC Electrode/Catalyst Materials / 308				10	
9.3 SOFC Electrolyte Materials / 317		0			
9.4 SOFC Electrode/Catalyst Materials / 326		9			
0.5 Material Stability, Durchility, and Lifetime (22)		9	11		
9.5 Material Stability, Durability, and Lifetime 7 336		9	11	3	
9.5 Material Stability, burability, and Lifetime 7 336 9.6 Chapter Summary / 340		3	11	3	
9.5 Material stability, burability, and Lifetime 7 336 9.6 Chapter Summary / 340 Chapter Exercises / 342		3	11 3	3	
9.5 Material stability, burability, and Lifetime / 336 9.6 Chapter Summary / 340 Chapter Exercises / 342		3	11 3	3	
9.5 Material Stability, burability, and Lifetime / 336 9.6 Chapter Summary / 340 Chapter Exercises / 342 10 Overview of Fuel Cell Systems 347	23	3	11 3 14	3	45

 10.2 Thermal Management Subsystem / 353 10.3 Fuel Delivery/Processing Subsystem / 357 10.4 Power Electronics Subsystem / 364 10.5 Case Study of Fuel Cell System Design: Stationary Combined Heat and Power Systems / 369 10.6 Case Study of Fuel Cell System Design: Sizing a Portable Fuel Cell / 383 10.7 Chapter Summary / 387 Chapter Exercises / 389 	x x x x	3	14	5	
11 Fuel Processing Subsystem Design 393	0	0	0	29	29
 11.1 Fuel Reforming Overview / 394 11.2 Water Gas Shift Reactors / 409 11.3 Carbon Monoxide Clean-Up / 411 11.4 Reformer and Processor Efficiency Losses / 414 11.5 Reactor Designfor Fuel Reformers and Processors / 416 11.6 Chapter Summary / 417 Chapter Exercises / 419 				X X X X X X	
12 Thermal Management Subsystem Design 423	0	0	0	23	23
12.1 Overview of Pinch Point Analysis Steps / 424 12.2 Chapter Summary / 440 Chapter Exercises / 441				x x x	
13 Fuel Cell System Design 447	0	0	0	33	33
 13.1 Fuel Cell Design Via Computational Fluid Dynamics / 447 13.2 Fuel Cell System Design: A Case Study / 462 13.3 Chapter Summary / 476 Chapter Exercises / 477 				X X X X	
14 Environmental Impact of Fuel Cells 481	0	0	0	35	35
 14.1 Life Cycle Assessment / 481 14.2 Important Emissions for LCA / 490 14.3 Emissions Related to Global Warming / 490 14.4 Emissions Related to Air Pollution / 502 14.5 Analyzing Entire Scenarios with LCA / 507 14.6 Chapter Summary / 510 Chapter Exercises / 511 				x x x x x x x	