PHYS-E6571 - Fuel Cells and Hydrogen Technology 2019

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.

	A	B	C	D	E
Book section	Essential	Often useful	Sometimes useful	Not included in this course	Total pages in the book
Pages total:	182	47	42	234	505
I FUEL CELL PRINCIPLES					
1 Introduction 3	23	0	0	0	23
1.1 What Is a Fuel Cell? / 3	x				
1.2 A Simple Fuel Cell / 6	x				
1.3 Fuel Cell Advantages / 8	x				
1.4 Fuel Cell Disadvantages / 11	x				
1.5 Fuel Cell Types / 12	x				
1.6 Basic Fuel Cell Operation / 14	x				
1.7 Fuel Cell Performance / 18	x				
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	x				
Chapter Exercises / 23	x				
2 Fuel Cell Thermodynamics 25	30	12	4	5	51
2.1 Thermodynamics Review / 25		9			
2.2 Heat Potential of a Fuel: Enthalpy of Reaction / 34		3			
2.3 Work Potential of a Fuel: Gibbs Free Energy / 37	x				
2.4 Predicting Reversible Voltage of a Fuel Cell under Non-Standard-State Conditions / 47	x, *except:*				
2.4.4 Concentration cells				5	
2.5 Fuel Cell Efficiency / 60	x				
2.6 Thermal and Mass Balances in Fuel Cells / 65	x				
2.7 Thermodynamics of Reversible Fuel Cells / 67			4		
2.8 Chapter Summary / 71	x				
Chapter Exercises / 72	x				
3 Fuel Cell Reaction Kinetics 77	29	3	1	7	40
3.1 Introduction to Electrode Kinetics / 77	x				
3.2 Why Charge Transfer Reactions Have an Activation Energy / 82	x				
3.3 Activation Energy Determines Reaction Rate / 84	x				
3.4 Calculating Net Rate of a Reaction / 85	x				
3.5 Rate of Reaction at Equilibrium: Exchange Current Density / 86	x				
3.6 Potential of a Reaction at Equilibrium: Galvani Potential / 87	x				
3.7 Potential and Rate: Butler–Volmer Equation / 89	x				
3.8 Exchange Currents and Electrocatalysis: How to Improve Kinetic Performance / 94	x				
3.9 Simplified Activation Kinetics: Tafel Equation / 97	x				
3.10 Different Fuel Cell Reactions Produce Different Kinetics / 100		3			
3.11 Catalyst–Electrode Design / 103	x				
3.12 Quantum Mechanics: Framework for Understanding Catalysis in Fuel Cells / 104				3	
3.13 The Sabatier Principlefor Catalyst Selection / 107			1		
3.14 Connecting the Butler–Volmer and Nernst Equations (Optional) / 108				4	
3.15 Chapter Summary / 112	x				
Chapter Exercises / 113	x				
4 Fuel Cell Charge Transport 117	18	9	3	20	50
4.1 Charges Move in Response to Forces / 117	x				
4.2 Charge Transport Results in a Voltage Loss / 121	x				
4.3 Characteristics of Fuel Cell Charge Transport Resistance / 124	x				
4.4 Physical Meaning of Conductivity / 128	x				

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) / 160				1	
4.8 Quantum Mechanics–Based Simulation of Ion Conduction in Oxide Electrolytes (Optional) / 161				3	
4.9 Chapter Summary / 163	x				
Chapter Exercises / 164	x				
5 Fuel Cell Mass Transport 167	19	4	0	12	35
5.1 Transport in Electrode versus Flow Structure / 168	x				
5.2 Transport in Electrode: Diffusive Transport / 170	x				
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	x				
Chapter Exercises / 200	x				
(*) Only the physical principles and design ideas , not equations or calculations					
6 Fuel Cell Modeling 203	4	1	4	24	33
6.1 Putting It All Together: A Basic Fuel Cell Model / 203	x				
6.2 A 1D Fuel Cell Model / 206				21	
6.3 Fuel Cell Models Based on Computational Fluid Dynamics (Optional) / 227				3	
6.4 Chapter Summary / 230		1			
Chapter Exercises / 231			4		
7 Fuel Cell Characterization 237	17	3	2	12	34
7.1 What Do We Want to Characterize? / 238	x				
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	x				
7.5 Chapter Summary / 268		1			
Chapter Exercises / 269			2		
II FUEL CELL TECHNOLOGY					
8 Overview of Fuel Cell Types 273	19	0	0	12	31
8.1 Introduction / 273	x				
8.2 Phosphoric Acid Fuel Cell / 274	x				
8.3 Polymer Electrolyte Membrane Fuel Cell / 275	x				
8.4 Alkaline Fuel Cell / 278	x				
8.5 Molten Carbonate Fuel Cell / 280	x				
8.6 Solid-Oxide Fuel Cell / 282	x				
8.7 Other Fuel Cells / 284				12	
8.7.11 Electrolysis and Reversible Fuel Cell–Electrolyzers	x				
8.8 Summary Comparison / 298	x				
8.9 Chapter Summary / 299	x				
Chapter Exercises / 301	x				
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		9			
9.4 SOFC Electrode/Catalyst Materials / 326			11		
9.5 Material Stability, Durability, and Lifetime / 336				3	
9.6 Chapter Summary / 340		3			
Chapter Exercises / 342			3		
10 Overview of Fuel Cell Systems 347	23	3	14	5	45
10.1 Fuel Cell Subsystem / 348	x				