

Contents

<i>Preface</i>	viii	2.2.5 AC electric shock	21
<i>Acknowledgements</i>	ix	2.2.6 DC electric shock	23
		2.2.7 Protection devices	24
1 Electric vehicles introduction	1	2.3 Safe work process	25
1.1 EVs and hybrids	1	2.3.1 Risks of working with EVs	25
1.1.1 Types of electric vehicle	1	2.3.2 Work categories	26
1.1.2 Electric vehicle market	2	2.3.3 Before work starts	28
1.1.3 The EV experience	3	2.3.4 During the work	28
1.1.4 History	5	2.3.5 Interruption to work	28
1.1.5 Formula-e	7	2.3.6 Completion of work	29
1.2 Costs and emissions	8	2.4 Hazard management	29
1.2.1 Electricity costs	8	2.4.1 Initial assessment	29
1.2.2 End of life	10	2.4.2 Fire	30
1.2.3 CO ₂ emissions	10	2.5 Tools and equipment	30
1.2.4 Emissions	11	2.5.1 Introduction	30
1.3 Autonomous cars	11	2.5.2 Hand tools	30
1.3.1 Introduction	11	2.5.3 Test equipment	31
1.3.2 Google self-driving car	12	2.5.4 Workshop equipment	33
1.3.3 Hacking	12	2.5.5 High-voltage tools	34
		2.5.6 On-board diagnostics	35
2 Safe working, tools and hazard management	15	3 Electrical and electronic principles	39
2.1 General safety precautions	15	3.1 Basic electrical principles	39
2.1.1 Introduction	15	3.1.1 Introduction	39
2.1.2 Safety	15	3.1.2 Electron and conventional flow	40
2.1.3 General safety guidance	17	3.1.3 Effects of current flow	41
2.1.4 General risks and their reduction	18	3.1.4 Fundamental quantities	41
2.2 High-voltage safety precautions	18	3.1.5 Describing electrical circuits	42
2.2.1 Introduction to high voltages	18	3.1.6 Conductors, insulators and semiconductors	42
2.2.2 Low and high voltage	18	3.1.7 Factors affecting the resistance of a conductor	42
2.2.3 Personal protective equipment (PPE)	20	3.1.8 Resistors and circuit networks	42
2.2.4 High-energy cables and components	20		

Contents

3.1.9	Magnetism and electromagnetism	44	5.2.6	Fuel cells	84
3.1.10	Electromagnetic induction	44	5.2.7	Super-capacitors	87
3.1.11	Mutual induction	45	5.2.8	Flywheels	88
3.1.12	Definitions and laws	45	5.2.9	Summary	88
3.2	Electronic components	48	6 Motors and control systems	91	
3.2.1	Introduction	48	6.1	Introduction	91
3.2.2	Components	50	6.1.1	Types of motor	91
3.2.3	Integrated circuits	52	6.1.2	Trends	91
4 Electric vehicle technology	55		6.2	Construction and function of electric motors	91
4.1	Electric vehicle layouts	55	6.2.1	AC motors: basic principle	91
4.1.1	Identifying electric vehicles	55	6.2.2	Asynchronous motor	91
4.1.2	Single motor	56	6.2.3	Synchronous motor: permanent excitation	92
4.1.3	Wheel motors	57	6.2.4	DC motor: series wound	92
4.2	Hybrid electric vehicle layouts	58	6.2.5	DC motor: separately excited shunt wound	93
4.2.1	Introduction	58	6.2.6	Motor torque and power characteristics	93
4.2.2	Classifications	59	6.2.7	Electronically commutated motor	94
4.2.3	Operation	60	6.2.8	Switched reluctance motor	96
4.2.4	Configurations	62	6.2.9	Motor efficiency	97
4.2.5	Hybrid with a 48-V system	66	6.3	Control system	98
4.2.6	Hybrid control systems	67	6.3.1	Introduction	98
4.3	Cables and components	68	6.3.2	Power control	99
4.3.1	High-voltage cables	68	6.3.3	Sensors	100
4.3.2	Components	68	6.3.4	Battery	101
4.3.3	ECE-R100	71	7 Charging	105	
4.4	Other systems	72	7.1	Charging, standards and infrastructure	105
4.4.1	Heating and air conditioning	72	7.1.1	Infrastructure	105
4.4.2	Brakes	73	7.1.2	Charging time	107
4.4.3	Power-assisted steering	74	7.1.3	Cost	107
5 Batteries	77		7.1.4	Standardization	108
5.1	Overview	77	7.1.5	Charging methods	109
5.1.1	Battery range	77	7.1.6	Charging modes	110
5.1.2	Battery life and recycling	77	7.1.7	Communication	113
5.2	Types of battery	78	7.1.8	EU system	113
5.2.1	Lead-acid batteries (Pb–PbO ₂)	78	7.1.9	Charging plugs	114
5.2.2	Alkaline (Ni–Cad, Ni–Fe and Ni–MH)	80	7.1.10	Vehicle-to-grid technology	116
5.2.3	Sodium–nickel chloride (Na–NiCl ₂)	81	7.1.11	Tesla Powerwall	116
5.2.4	Sodium–sulphur (Na–S)	82	7.2	Wireless power transfer	116
5.2.5	Lithium-ion (Li-ion)	82	7.2.1	Introduction	116

7.2.2	Stationary WPT	118	9.4.4	Range extender	149
7.2.3	Dynamic WPT	121	9.5	Tesla Roadster	150
7.3	Solar charging case study	122	9.5.1	Overview	150
7.3.1	Introduction	122	9.5.2	Motor	150
7.3.2	Latest results	126	9.5.3	Motor control	152
			9.5.4	Battery	153
			9.5.5	Power control	155
			9.5.6	Software	157
8	Maintenance, repairs and replacement	127	9.6	Honda FCX Clarity	158
8.1	Before work commences	127	9.6.1	Overview	158
8.1.1	Introduction	127	9.6.2	Hydrogen	159
8.1.2	Technical information	127	9.6.3	Energy efficiency and the environment	162
8.1.3	De-energizing	128	9.6.4	Core technologies	164
8.2	Maintenance	129	9.6.5	Driving dynamics	169
8.2.1	Repairs affecting other vehicle systems	129	9.6.6	Safety: hydrogen and high voltage	170
8.2.2	Inspect high-voltage components	129	9.7	Toyota Mirai	171
8.3	Remove and replace	131	9.7.1	Overview	171
8.3.1	High-voltage components	131	9.7.2	Toyota fuel cell system (TFCS)	172
8.3.2	Battery pack	132	9.7.3	Safety	173
8.3.3	Low-voltage components	133	9.7.4	Refuelling process	173
8.4	Completion of work	134	9.8	Honda light hybrids	174
8.4.1	Re-energizing	134	9.8.1	Overview	174
8.4.2	Results, records and recommendations	134	9.8.2	IMA battery	174
8.5	Roadside assistance	135	9.8.3	IMA motor	178
8.5.1	Introduction	135	9.8.4	Hybrid IMA control system	180
8.5.2	Roadside repairs	135	9.9	Bosch parallel full-hybrid	185
8.5.3	Recovery	137	9.9.1	Overview	185
8.5.4	Emergency response	139	9.9.2	Power boost	186
8.5.5	Pro-Assist hybrid mobile app	140	9.9.3	Control system	187
			9.9.4	Hybrid and GDi engines	187
			9.9.5	Optimized components	187
9	Case studies	145	9.10	Volkswagen Golf GTE	188
9.1	Introduction	145	9.10.1	Overview	188
9.2	General motors EV-1	145	9.10.2	Motor and power electronics	188
9.2.1	Overview	145	9.10.3	Internal combustion engine and transmission	189
9.2.2	EV-1 details	145	9.10.4	Battery	189
9.3	Nissan LEAF 2016	147	9.10.5	Driver's control systems	189
9.3.1	Overview	147			
9.3.2	Remote control	147			
9.4	GM Volt 2016 (USA version)	147			
9.4.1	Overview	147			
9.4.2	Battery	148			
9.4.3	Two-motor drive unit	148			
			<i>Index</i>		191