

AUTOMOTIVE TECHNICIAN TRAINING

THEORY: LEVELS 1/2/3

Automotive Technician Training eLearning

THE INSTITUTE OF THE MOTOR INDUSTRY

Works alongside ATT Automotive VLE material



Contents

	eface cknow	vledgements	viii ix
1	ATT	interactive	1
	1.1	Introduction 1	2
	1.2	Learning activities 🚹	3
2	Wor	king safely	7
	2.1	Personal and vehicle protection	8
		2.1.1 Personal protective equipment 1	8
		2.1.2 Vehicle safety 🚹	8
		2.1.3 Moving loads 🚺	9
	2.2	Housekeeping	10
		2.2.1 Working environment 1	10
		2.2.2 Equipment maintenance 🚺	10
	2.3	Health and safety	11
		2.3.1 Introduction 1	11
		2.3.2 Regulations and laws 🚹	12
		2.3.3 Health and Safety law 🚺	13
	2.4	Hazards and risks	14
		2.4.1 Hazards 🚺	14
		2.4.2 Fire 1	15
		2.4.3 Signage 🚹	17
	2.5	Personal responsibilities	18
		2.5.1 Safety procedures 🚺	18
		2.5.2 Environmental protection 1	18
3	Auto	omotive industry	19
	3.1	The motor trade 🚺	20
	3.2	Information and systems 🚹	25
		Communication 🚹	27
	3.4	Documentation 🚹	30
	3.5	Working relationships	35
		3.5.1 Colleagues 🚹	35
		3.5.2 Customers 🚹	36
4	Wor	kshop skills	39
	4.1	Hand tools and measuring	40
		4.1.1 Hand tools 🚺	40
		4.1.2 Measurement 🚹	43
	4.2	Equipment	47
		4.2.1 Workshop equipment 🚺	47
		4.2.2 Test equipment 🚺 2	51

	4.3	Mater	ials and fabrication	55
		4.3.1	Materials 1 2	55
		4.3.2	Metal cutting and shaping 🚺	56
		4.3.3	Joining 🚹 2	59
		4.3.4	Nuts, screws, washers and	
			bolts 1	60
		4.3.5	Adhesives ┨ 2	65
		4.3.6	Soldering, brazing and	
			welding 1 2	66
		4.3.7	Shrinking 2	67
		4.3.8	Riveting 1	68
		4.3.9	Gaskets, sealants and oil seals 1	69
5	Mai	ntenan	ce	71
	5.1	Vehicl	e overview	72
		5.1.1	Maintenance and inspections 🚺	72
		5.1.2	Layouts 1	72
		5.1.3	Body design 🚺	74
		5.1.4	Main systems 🚹	76
	5.2	Servic	ing and inspections	77
		5.2.1		77
		5.2.2	Rules and regulations 1	78
		5.2.3	-	79
		5.2.4	Road test 3	80
		5.2.5	Effects of incorrect	
			adjustments 🚺	80
		5.2.6	Information sources 1	81
6	Eng	ine sys	tems	83
	6.1	Mech	anical	84
		6.1.1	Operating cycles 🚹	84
		6.1.2	Engine components 🚹	91
		6.1.3	Engine variations 🚹	91
		6.1.4	Engine operating details 🚺	96
		6.1.5	Terminology and systems 🚺	102
		6.1.6	Cylinder components 🕗	113
		6.1.7	Valves and valve gear 2	114
		6.1.8	Engine designs 23	116
		6.1.9	Cylinder deactivation 🕄	124
	6.2	Lubric		125
		6.2.1	Friction and lubrication 🚹	125
		6.2.2	Oils and specifications 🗻	126
		6.2.3	Lubrication system operation 1	127

		6.2.4	Oil pumps and filtration 1	128	
		6.2.5	Oil lubrication systems 🕗	131	
		6.2.6	Other lubrication components 2	133	
	6.3	Cooling	-	134	
		6.3.1	Cooling introduction 1	134	
		6.3.2	Components and operation 🚹	137	
		6.3.3	Cooling and heating 🚹	140	7.3
		6.3.4	Antifreeze 1	141	
		6.3.5	Components 2	141	
		6.3.6	Heater 2	145	
	6.4	Fuel		146	
		6.4.1		146	
		6.4.2	Electronic fuel injection 12	149	_
		6.4.3	Bosch DI-Motronic 🕄	160	7.4
		6.4.4	Diesel introduction 1	164	
		6.4.5	Bosch VE system 2	170	
		6.4.6	Bosch VR system 2	174	
		6.4.7	Bosch CR system 3	178	
		6.4.8	ECU calibration 3	182	
		6.4.9	Alternative fuels 3	184	
	6.5	Ignition		188	
		6.5.1	Ignition overview 1	188	
		6.5.2	Electronic ignition 12	190	
		6.5.3	Electronic spark advance 2	193	_
		6.5.4	Distributorless ignition 2	196	7.
		6.5.5	Coil on plug ignition 2	197	
	~ ~	6.5.6	Spark plugs and leads 12	198	
	6.6		bly, exhaust and emissions	200	
		6.6.1	Air pollution 1	200	
		6.6.2	Engine combustion 1	201	
		6.6.3	Environmental protection 1	202	
		6.6.4	Air supply 1	204	7
		6.6.5	Exhaust systems	207	7.
		6.6.6	Catalyst systems 2	209	
		6.6.7	Diesel particulate filters 3	211	
		6.6.8 6.6.9	Emission control systems 🕄	215	
		0.0.9	Pressure charging 🕄	218	
7	Elec	ctrical sy	vstems	221	
	7.1		cal and electronic principles	222	
		7.1.1	Electricity and the atom 1	222	7.
		7.1.2	Basic circuits and magnetism 1	223	
		7.1.3	Electrical components 1	225	
		7.1.4	Electronic components 2	231	
		7.1.5	Digital systems 3	235	
		7.1.6	Vehicle computer systems 3	239	
		7.1.7	Central electrical control 3	241	
	7.2		e electrical	248	7.
		7.2.1	Battery construction 1	248	7.0
		7.2.1	Battery state of charge 1	251	
		7.2.3	Battery types and charging 1	254	
		7.2.4	Testing batteries 1	257	
		7.2.5	Battery diagnostics 2	259	
			, –		

7.2.6 Battery charging 2

88 7.2.7 Starting system 12 263 7.2.8 Starting system testing 2 269 7.3 7.2.9 Charging system 12 271 7.4 7.2.10 Charging system 12 273 7.2.11 Stop-start control 3 283 7.3 Lighting and indicators 283 7.3 Lighting system 3 285 7.3.1 Lighting expense 3 285 7.3.2 Stoplights and reverse lights 3 289 7.3.4 Lighting circuits 2 291 7.3.6 Other lighting technology 3 292 7.4 Body electrical 297 7.4.1 Washers, wipers and 302 7.4.2 Horns, obstacle avoidance and 217 7.4.3 Mobile multimedia 1 302 7.4.4 Seats, mirrors, roofs and 306 7.4.5 Security systems 2 309 7.4.6 Starting, alarming and locking 3 310 7.4.7 Safety systems 2 321 7.5 Monitoring and instrumentation 319 7.5.2 Gauges					
33 7.2.9 Charging system ?? 271 44 7.2.10 Charging system testing ? 277 44 7.2.11 Alternator developments ? 279 77 7.2.12 Stop-start control ? 283 77 7.3.1 Lighting and indicators 285 7.3.1 Lighting system ? 285 7.3.2 Stoplights and reverse lights ? 288 7.3.4 Lighting circuits ? 291 6 7.3.4 Lighting circuits ? 291 6.6 7.3.4 Lighting technology ? 292 7.4 Body electrical 297 300 7.4 Body electrical 207 300 7.4.1 Washers, wipers and screens ? 207 302 7.4.3 Mobile multimedia ? 302 302 7.4.4 Seats, mirrors, roofs and locking ? 301 7.4.5 Security systems ? 303 7.4.7 Safety systems ? 314 7.6 Sanges ? 313 7.5.1 Sensors ? 322 7.5.5 <td>.8</td> <td></td> <td>7.2.7</td> <td>Starting system 1 2</td> <td>263</td>	.8		7.2.7	Starting system 1 2	263
44 7.2.10 Charging system testing 2 277 744 7.2.11 Alternator developments 3 279 77 7.2.12 Stop-start control 3 283 70 7.3 Lighting and indicators 285 7.3 Lighting systems 3 285 7.3.1 Lighting systems 3 285 7.3.2 Stoplights and reverse lights 3 288 7.3.5 Indicators and hazard lights 2 292 7.3.6 Other lighting technology 3 297 7.4 Body electrical 297 7.4.1 Washers, wipers and screens 3 297 7.4.1 Washers, wipers and locking 3 300 7.4.2 Horns, obstacle avoidance and cruise control 2 300 7.4.4 Seats, mirrors, roofs and locking 3 310 7.4.7 Safety systems 2 309 7.4.6 Starting, alarming and locking 3 310 7.4.7 Safety systems 2 313 7.5 Security systems 2 321 7.6 Kauyes 1 224 7.5 Digital instrumentation 319 </td <td>81</td> <td></td> <td>7.2.8</td> <td>Starting system testing 2</td> <td>269</td>	81		7.2.8	Starting system testing 2	269
44 7.2.11 Alternator developments (2) 279 7.2.12 Stop-start control (2) 283 7.3 Lighting and indicators 285 7.3.1 Lighting systems (1) 285 7.3.2 Stoplights and reverse lights (1) 288 7.3.3 Interior lighting (1) 289 7.3.4 Lighting circuits (2) 291 7.3.5 Indicators and hazard lights (2) 292 7.3.6 Other lighting technology (2) 295 7.4 Body electrical 297 7.4.4 Washers, wipers and 202 7.4.7 Horns, obstacle avoidance and cruise control (1) 2) 7.4.3 Mobile multimedia (1) 300 7.4.4 Seats, mirrors, roofs and locking (2) 305 7.4.3 Mobile multimedia (1) 302 314 7.4.4 Seats, mirrors, roofs and locking (2) 305 8 7.4.5 Security systems (2) 314 7.5 Monitoring and instrumentation 319 7.5.1 Sensors (1) 324 7.5.2 Gauges (1)	3		7.2.9	Charging system 12	271
7.7 7.2.12 Stop-start control • 283 7.3 Lighting and indicators 285 7.3.1 Lighting systems • 285 7.3.2 Stoplights and reverse lights • 288 7.3.4 Lighting circuits • 291 7.3.5 Indicators and hazard lights • 292 7.3.6 Other lighting technology • 295 7.4 Body electrical 297 7.4.1 Washers, wipers and 202 7.4.2 Horns, obstacle avoidance and cruise control • 300 7.4.3 Mobile multimedia • 302 304 7.4.4 Seats, mirrors, roofs and locking • 301 7.4.5 Security systems • 303 303 7.4.6 Starting, alarming and locking • 310 7.4.7 Safety systems • 313 309 7.5.1 Sensors • 2 324 7.6 Monitoring and instrumentation 319 7.5.2 Gauges • 2 324 7.6 Global positioning system • 320 7.5.6 Global po	34		7.2.10	Charging system testing 🕗	277
07.3Lighting and indicators2857.3.1Lighting systems 12857.3.2Stoplights and reverse lights 12887.3.3Interior lighting 12897.3.4Lighting circuits 22917.3.5Indicators and hazard lights 22927.3.6Other lighting technology 22957.4Body electrical2977.4.1Washers, wipers and screens 22977.4.2Horns, obstacle avoidance and cruise control 23007.4.3Mobile multimedia 13027.4.4Seats, mirrors, roofs and locking 23057.4.5Security systems 23097.4.6Starting, alarming and locking 33107.4.7Safety systems 23147.5Monitoring and instrumentation3197.5.1Sensors 23217.5.4Vehicle condition monitoring 23277.5.5Digital instrumentation system 33297.5.6Global positioning system 33297.5.7Drowsiness detection 33347.6.1Ventilation system 33357.6.2Vehicle heating 23367.6.3Air conditioning components 33407.6.4Air conditioning systems 33427.6.5Air conditioning systems 33427.6.6Air conditioning systems 33427.6.7Other heating systems 33427.6.6Air conditioning systems 33427.6.7Othe	34		7.2.11	Alternator developments 🕄	279
1 7.3.1 Lighting systems 1 285 1 7.3.2 Stoplights and reverse lights 1 288 15 7.3.3 Interior lighting 1 289 16 7.3.4 Lighting circuits 2 291 16 7.3.5 Indicators and hazard lights 2 292 16 7.3.6 Other lighting technology 2 295 17 Kady electrical 297 297 18 7.4.1 Washers, wipers and screens 2 297 14 7.4.1 Washers, norofs and cruise control 2 300 12 7.4.3 Mobile multimedia 2 302 14 7.4.4 Seats, mirrors, roofs and locking 2 305 16 7.4.5 Security systems 2 309 10 7.4.6 Starting, alarming and locking 3 310 10 7.4.7 Safety systems 2 313 17 7.5.1 Sensors 2 321 16 7.5.4 Vehicle condition monitoring 2 327 16 7.5.5 Digital instrumentation system 3 329 17 7.5.5	37		7.2.12	Stop-start control 🕄	283
1 7.3.2 Stoplights and reverse lights 1 288 15 7.3.3 Interior lighting 1 289 16 7.3.4 Lighting circuits 2 291 16 7.3.5 Indicators and hazard lights 2 292 16 7.3.6 Other lighting technology 3 295 16 7.4.1 Washers, wipers and screens 1 297 17.4 Body electrical 297 17.4 Particle and the screens 1 297 17.4 Washers, wipers and screens 1 202 18 7.4.1 Washers, wipers and cruise control 1 2030 19 7.4.3 Mobile multimedia 1 202 10 7.4.4 Seats, mirrors, roofs and locking 2 300 10 7.4.5 Security systems 2 309 10 7.4.6 Starting, alarming and locking 3 310 10.7 7.5.1 Sensors 1 2 321 10 7.5.2 Gauges 1 2 321 10 7.5.3 Instrument displays 1 2 322 11 7.5.6	0	7.3	Lightin	g and indicators	285
55 7.3.3 Interior lighting 1 289 66 7.3.4 Lighting circuits 2 291 7.3.5 Indicators and hazard lights 2 292 7.3.6 Other lighting technology 3 295 7.4 Body electrical 297 7.4 Washers, wipers and screens 1 297 7.4.1 Washers, wipers and cruise control 1 2 7.4.2 Horns, obstacle avoidance and cruise control 1 2 7.4.3 Mobile multimedia 1 2 7.4.4 Seats, mirrors, roofs and locking 2 300 7.4.5 Security systems 2 309 7.4.6 Starting, alarming and locking 3 310 7.4.7 Safety systems 2 314 7.6 Monitoring and instrumentation 319 7.5.1 Sensors 1 2 321 7.5.3 Instrument displays 1 2 324 7.5.4 Vehicle condition monitoring 2 327 7.5.5 Digital instrumentation system 3 329 7.5.6 Global positioning system 3 334 7.6.6 Aric conditioning fun	1		7.3.1		285
66 7.3.4 Lighting circuits 2 291 7.3.5 Indicators and hazard lights 2 3 292 7.4 Body electrical 297 7.4 Body electrical 297 7.4 Vashers, wipers and screens 2 297 7.4 Vashers, wipers and screens 2 297 7.4.1 Washers, wipers and screens 2 297 7.4.2 Horns, obstacle avoidance and cruise control 2 300 7.4.3 Mobile multimedia 2 302 7.4.4 Seats, mirrors, roofs and locking 2 305 7.8 7.4.5 Security systems 2 309 7.4.6 Starting, alarming and locking 3 310 7.4.7 Safety systems 2 313 7.5.8 Monitoring and instrumentation 319 7.5.1 Sensors 2 321 7.5.2 Gauges 2 321 7.5.3 Instrument displays 2 324 7.5.4 Vehicle condition monitoring 2 327 7.5.5 Digital instrumentation system 3 329 7.5.6 Global positioning system 3 336	1		7.3.2	Stoplights and reverse lights 🚹	
66 7.3.5 Indicators and hazard lights ? ? 292 7.4 Body electrical 297 7.4 Body electrical 297 7.4 Vashers, wipers and screens ? 297 7.4 Vashers, wipers and cruise control ? 300 7.4.1 Washers, wipers and cruise control ? 300 7.4.2 Horns, obstacle avoidance and cruise control ? 300 7.4.3 Mobile multimedia ? 302 7.4.4 Seats, mirrors, roofs and locking ? 309 7.4.5 Security systems ? 309 7.4.6 Starting, alarming and locking ? 310 7.4.7 Safety systems ? 319 7.5 Monitoring and instrumentation 319 7.5.1 Sensors ? 221 7.5.3 Instrument displays ? 224 7.5.4 Vehicle condition monitoring ? 327 7.5.5 Digital instrumentation system ? 329 7.5.6 Global positioning system ? 336 7.6.1 Ventilation and AC 335 7.6.2 Vehicle heating ? 340	-5			0	289
99 7.3.6 Other lighting technology (2) 295 7.4 Body electrical 297 7.4.1 Washers, wipers and screens (2) 297 7.4.2 Horns, obstacle avoidance and cruise control (2) 300 7.4.3 Mobile multimedia (2) 302 7.4.4 Seats, mirrors, roofs and locking (2) 305 88 7.4.5 Security systems (2) 309 90 7.4.6 Starting, alarming and locking (2) 310 7.4.7 Safety systems (2) 319 90 7.4.6 Starting, alarming and locking (2) 311 91 7.5.1 Sensors (2) 321 92 7.5.3 Instrumentation 319 93 7.5.4 Vehicle condition monitoring (2) 327 94 7.5.5 Digital instrumentation system (2) 324 95 7.6.6 Global positioning system (2) 324 96 7.6.1 Vehicle condition monitoring (2) 327 97 7.6.6 Global positioning system (2) 336 96 7.6.1 Vehicle condition ing components (3)				0 0	
7.4Body electrical2977.4.1Washers, wipers and screens2977.4.2Horns, obstacle avoidance and cruise control3007.4.3Mobile multimedia27.4.4Seats, mirrors, roofs and locking3027.4.4Seats, mirrors, roofs and locking3097.4.5Security systems3097.4.6Starting, alarming and locking3107.4.7Safety systems3137.5Monitoring and instrumentation3197.5.1Sensors23217.5.5Digital instrument displays27.5.6Global positioning system3297.5.7Drowsiness detection3347.6Heating, ventilation and AC3357.6.1Ventilation systems3357.6.2Vehicle heating27.6.3Air conditioning systems3447.6.4Air conditioning fundamentals33887.6.4Air conditioning systems3427.6.5Air conditioning systems3427.6.7Other heating systems3447.6.7Other heating systems3457.7.1Overview3467.7.2Controller area network3487.7.3CAN data signal3507.7.4Local interconnect network3517.7.5FlexRay3527.7.6Diagnostics3547.8Hybrid cars overview3567.7.4Local interconnect net	-6			_	
44 7.4.1 Washers, wipers and screens 1 2 297 74 7.4.2 Horns, obstacle avoidance and cruise control 1 2 300 72 7.4.3 Mobile multimedia 1 2 302 74 7.4.4 Seats, mirrors, roofs and locking 2 305 78 7.4.5 Security systems 2 309 7.4.6 Starting, alarming and locking 3 310 7.4.7 Safety systems 2 3 314 7.5 Monitoring and instrumentation 319 7.5 Monitoring and instrumentation 319 7.5 Security systems 2 3 324 7.5 Monitoring and instrumentation 319 7.5 Senges 1 2 321 7.5 Monitoring and instrumentation system 3 327 7.5 Digital instrumentation system 3 329 7.5.5 Digital instrumentation system 3 330 7.5.6 Global positioning system 3 336 7.6 Heating, ventilation and AC 335 7.6 Heating, ventilation systems 3 340 7.6.6 Arit conditioning comp	.9				
20 screens 2 297 24 7.4.2 Horns, obstacle avoidance and cruise control 2 300 25 7.4.3 Mobile multimedia 2 302 24 7.4.4 Seats, mirrors, roofs and locking 2 305 28 7.4.5 Security systems 2 309 20 7.4.6 Starting, alarming and locking 3 310 23 7.4.7 Safety systems 2 314 26 7.5 Monitoring and instrumentation 319 27 7.5.1 Sensors 1 2 28 7.5.2 Gauges 1 2 29 7.5.4 Vehicle condition monitoring 2 327 210 7.5.4 Vehicle condition monitoring 2 329 21 7.5.6 Global positioning system 3 330 22 7.5.6 Global positioning system 3 335 23 7.6.1 Ventilation systems 3 335 24 7.6.2 Vehicle heating 2 336 25 7.6.4 Air conditioning components 3 340 26 7.6.4 Air conditioning s		7.4	'		297
4 7.4.2 Horns, obstacle avoidance and cruise control 2 300 78 7.4.3 Mobile multimedia 2 302 74 7.4.4 Seats, mirrors, roofs and locking 2 305 78 7.4.5 Security systems 2 309 70 7.4.6 Starting, alarming and locking 3 310 7.4 Safety systems 2 314 7.5 Monitoring and instrumentation 319 7.5 Monitoring and instrumentation 319 7.5 Monitoring and instrumentation 319 7.5.1 Sensors 1 2 7.5 Mosile instrument displays 2 324 7.5.4 Vehicle condition monitoring 2 327 7.5.5 Digital instrumentation system 3 329 7.5.6 Global positioning system 3 330 7.5.7 Drowsiness detection 3 344 7.6 Heating, ventilation and AC 335 7.6 Heating, ventilation systems 3 342 7.6.1 Ventilation systems 3 342 7.6.2 Vehicle heating 1 338 7.6.4 <			7.4.1		
8 cruise control [2] 300 82 7.4.3 Mobile multimedia [2] 302 84 7.4.4 Seats, mirrors, roofs and locking 2 305 88 7.4.5 Security systems 2 309 90 7.4.6 Starting, alarming and locking 3 310 90 7.4.6 Starting, alarming and locking 3 310 90 7.4.7 Safety systems 2 3 314 90 7.4.7 Safety systems 2 3 314 91 7.5.1 Sensors 1 2 319 92 7.5.1 Sensors 1 2 321 90 7.5.4 Vehicle condition monitoring 2 327 91 7.5.5 Digital instrumentation system 3 329 92 7.5.6 Global positioning system 3 330 93 7.6.1 Ventilation and AC 335 94 7.6.1 Ventilation systems 3 336 95 7.6.1 Ventilation systems 3 340 96 7.6.1 Ventilation systems 3 342 97 7.6.6 Antir conditioning systems 3					297
227.4.3Mobile multimedia2302347.4.4Seats, mirrors, roofs and locking305387.4.5Security systems309307.4.6Starting, alarming and locking310337.4.7Safety systems314367.5Monitoring and instrumentation319377.5.1Sensors2321307.5.2Gauges2321307.5.3Instrument displays2324307.5.4Vehicle condition monitoring327307.5.5Digital instrumentation system329307.5.6Global positioning system330317.6.6Heating, ventilation and AC335317.6.1Ventilation systems335317.6.2Vehicle heating2327.6.3Air conditioning fundamentals338357.6.4Air conditioning systems344367.7.1Overview345377.6Antihistamines345327.7Multiplexing346337.7.1Overview351347.7.3CAN data signal350357.7.4Local interconnect network351367.7.4Local interconnect network351357.7.5FlexRay352367.8.1Safety35637.8Hybrid cars overview35638 <td< td=""><td></td><td></td><td>7.4.2</td><td></td><td></td></td<>			7.4.2		
7.4.4 Seats, mirrors, roofs and locking 2 305 88 7.4.5 Security systems 2 309 90 7.4.6 Starting, alarming and locking 3 310 93 7.4.7 Safety systems 2 3 314 96 7.5 Monitoring and instrumentation 319 97 7.5.1 Sensors 1 2 321 98 7.5.2 Gauges 1 2 321 90 7.5.3 Instrument displays 1 2 324 90 7.5.4 Vehicle condition monitoring 2 327 91 7.5.5 Digital instrumentation system 3 330 92 7.5.6 Global positioning system 3 330 93 7.6.1 Ventilation systems 3 335 94 7.6.1 Ventilation systems 3 335 95 7.6.1 Ventilation systems 3 336 96 7.6.4 Air conditioning components 3 340 97.6.5 Air conditioning systems 3 342 98 7.6.4 Air conditioning systems 3 342 97 7.6.6 Antihistamines 3					
100 1					302
88 7.4.5 Security systems 2 309 90 7.4.6 Starting, alarming and locking 3 310 93 7.4.7 Safety systems 2 3 314 96 7.5 Monitoring and instrumentation 319 97 7.5.1 Sensors 1 2 321 98 7.5.2 Gauges 1 2 321 90 7.5.3 Instrument displays 1 2 324 90 7.5.4 Vehicle condition monitoring 2 327 91 7.5.5 Digital instrumentation system 3 329 92 7.5.6 Global positioning system 3 330 94 7.5.7 Drowsiness detection 3 334 95 7.6.1 Ventilation and AC 335 96 7.6.2 Vehicle heating 1 2 336 97 7.6 Heating, ventilation ing components 3 340 98 7.6.4 Air conditioning systems 3 342 99 7.6.6 Antihistamines 3 344 90 7.6.7 Other heating systems 3 342 91 7.7.1 Overvie			7.4.4		~ ~ -
107.4.6Starting, alarming and locking §3107.4.7Safety systems § §3147.5Monitoring and instrumentation3197.5.1Sensors § 23217.5.2Gauges § 23217.5.3Instrument displays § 23247.5.4Vehicle condition monitoring 23277.5.5Digital instrumentation system §3307.5.6Global positioning system §3307.5.7Drowsiness detection §3347.6Heating, ventilation and AC3357.6.1Ventilation system §3367.6.2Vehicle heating § 23367.6.3Air conditioning fundamentals 23387.6.4Air conditioning components §3447.6.5Air conditioning systems §3427.6.6Antihistamines §3447.6.7Other heating systems §3457.7Multiplexing3467.7.2Controller area network §3487.7.3CAN data signal §3507.7.4Local interconnect network §3517.7.5FlexRay §3527.7.6Diagnostics §3547.8Hybrid cars overview3567.8.1Safety §3587.8.2Electrical hybrid §27.8Aydraulic hybrid §27.8Safety §3587.8Hydraulic hybrid §2					
7.4.7Safety systems 2 S 3147.5Monitoring and instrumentation3197.5.1Sensors 1 2 3217.5.2Gauges 1 2 3247.5.3Instrument displays 1 2 3247.5.4Vehicle condition monitoring 2 3277.5.5Digital instrumentation system 3 3297.5.6Global positioning system 3 3307.5.7Drowsiness detection 3 3347.6Heating, ventilation and AC3357.6.1Ventilation systems 1 3367.6.2Vehicle heating 1 2 33657.6.3Air conditioning fundamentals 2 3387.6.4Air conditioning components 3 3447.6.5Air conditioning systems 3 3427.6.6Antihistamines 3 3447.6.7Other heating systems 3 3457.7Multiplexing3467.7.1Overview 2 3 3507.7.4Local interconnect network 3 3517.7.5FlexRay 3 3527.7.6Diagnostics 3 3547.8Hybrid cars overview3567.8.1Safety 1 3587.8.2Electrical hybrid 13 7.8.3Hydraulic hybrid 13					
667.5Monitoring and instrumentation3197.5.1Sensors 1 23217.5.2Gauges 1 23217.5.3Instrument displays 1 23247.5.4Vehicle condition monitoring 23277.5.5Digital instrumentation system 33297.5.6Global positioning system 33307.5.7Drowsiness detection 33347.6Heating, ventilation and AC3357.6.1Ventilation system 33357.6.2Vehicle heating 233657.6.3Air conditioning fundamentals 23387.6.4Air conditioning components 33407.6.5Air conditioning systems 33427.6.6Antihistamines 33447.6.7Other heating systems 33427.6.8Air conditioning systems 33457.7Multiplexing3467.7.1Overview 2 33467.7.2Controller area network 33517.7.4Local interconnect network 33517.7.5FlexRay 33527.7.6Diagnostics 33547.8Hybrid cars overview3567.8.1Safety 13567.8.2Electrical hybrid 1 23587.8.3Hydraulic hybrid 1 2360					
777.5.1Sensors2319887.5.2Gauges2321907.5.3Instrument displays2324907.5.4Vehicle condition monitoring327917.5.5Digital instrumentation system329927.5.6Global positioning system330947.5.7Drowsiness detection334957.6.1Ventilation and AC335967.6.1Ventilation systems335977.6Heating, ventilation guadamentals338987.6.3Air conditioning fundamentals338997.6.4Air conditioning systems340907.6.5Air conditioning systems342917.6.6Antihistamines344927.6.7Other heating systems342937.7.1Overview345947.7.2Controller area network348957.7.4Local interconnect network351957.7.4Local interconnect network351957.7.5FlexRay352967.7.6Diagnostics354977.8.1Safety356987.8.1Safety356997.8.2Electrical hybrid2358907.8.2Electrical hybrid2358917.8.3Hydraulic hybrid2350					
7.5.2Gauges 1 2 3217.5.3Instrument displays 1 2 3247.5.4Vehicle condition monitoring 2 3277.5.5Digital instrumentation system 3 3297.5.6Global positioning system 3 3307.5.7Drowsiness detection 3 3347.6Heating, ventilation and AC3357.6.1Ventilation system 1 3367.6.2Vehicle heating 1 2 3367.6.3Air conditioning fundamentals 2 3387.6.4Air conditioning components 3 3407.6.5Air conditioning systems 3 3427.6.6Antihistamines 3 3447.6.7Other heating systems 3 3457.7Multiplexing3467.7.1Overview 2 3 3467.7.2Controller area network 3 3517.7.3CAN data signal 6 3527.7.4Local interconnect network 3 3517.7.5FlexRay 3 3527.7.6Diagnostics 3 3547.8Hybrid cars overview3567.8.1Safety 1 3587.8.3Hydraulic hybrid 1 2 3587.8.3Hydraulic hybrid 1 2 358		7.5			
007.5.3Instrument displays2324007.5.4Vehicle condition monitoring327017.5.5Digital instrumentation system329027.5.6Global positioning system330047.5.7Drowsiness detection334077.6Heating, ventilation and AC33517.6.1Ventilation systems33657.6.1Ventilation systems33867.6.2Vehicle heating27.6.3Air conditioning fundamentals33877.6.4Air conditioning components3407.6.5Air conditioning systems3427.6.6Antihistamines3447.6.7Other heating systems345227.7Multiplexing3467.7.1Overview3503507.7.2Controller area network3517.7.3CAN data signal3507.7.4Local interconnect network3517.7.5FlexRay3527.7.6Diagnostics3547.8Hybrid cars overview3567.8.1Safety3567.8.2Electrical hybrid2357.8.3Hydraulic hybrid2367.8.3Hydraulic hybrid2					
7.5.4Vehicle condition monitoring 23277.5.5Digital instrumentation system 33297.5.6Global positioning system 33307.5.7Drowsiness detection 33347.6Heating, ventilation and AC3357.6Heating, ventilation systems 13357.6Ventilation systems 13367.6.1Ventilation systems 13367.6.2Vehicle heating 123.87.6.4Air conditioning fundamentals 233887.6.4Air conditioning systems 33407.6.5Air conditioning systems 33427.6.6Antihistamines 33447.6.7Other heating systems 33457.7Multiplexing3467.7.1Overview 23467.7.2Controller area network 33517.7.4Local interconnect network 33517.7.5FlexRay 33527.7.6Diagnostics 33547.8Hybrid cars overview3567.8.1Safety 13587.8.3Hydraulic hybrid 13587.8.3Hydraulic hybrid 1358					
7.5.5Digital instrumentation system S 3297.5.6Global positioning system S 3307.5.7Drowsiness detection S 3347.6Heating, ventilation and AC3357.6.1Ventilation systems 1 3367.6.2Vehicle heating 1 2 3367.6.3Air conditioning fundamentals 2 3387.6.4Air conditioning components 3 3407.6.5Air conditioning systems S 3427.6.6Antihistamines S 3447.6.7Other heating systems S 3457.7Multiplexing3467.7.1Overview 2 S 3467.7.2Controller area network S 3487.7.3CAN data signal S 3507.7.4Local interconnect network S 3517.7.5FlexRay S 3527.7.6Diagnostics S 3547.8Hybrid cars overview3567.8.1Safety 1 3587.8.3Hydraulic hybrid 1 2 360					
127.5.6Global positioning system 3 3307.6Heating, ventilation and AC3357.6Heating, ventilation systems 1 3357.6.1Ventilation systems 1 3357.6.2Vehicle heating 1 33657.6.3Air conditioning fundamentals 2 33887.6.4Air conditioning components 3 3407.6.5Air conditioning systems 3 3427.6.6Antihistamines 3 3427.6.7Other heating systems 3 34527.7Multiplexing3467.7.1Overview 23 3507.7.2Controller area network 3 3517.7.5FlexRay 3 3527.7.6Diagnostics 3 3547.8Hybrid cars overview3567.8.1Safety 1 3587.8.3Hydraulic hybrid 12 3647.8.3Hydraulic hybrid 13					
7.67.6Drowsiness detection (s)3347.6Heating, ventilation and AC3357.6F.6.1Ventilation systems (s)33517.6.2Vehicle heating (s)33657.6.3Air conditioning fundamentals (s)33887.6.4Air conditioning components (s)3407.6.5Air conditioning systems (s)3427.6.6Antihistamines (s)3447.6.7Other heating systems (s)345227.7Multiplexing3467.7.1Overview (s) (s)3487.7.2Controller area network (s)3487.7.3CAN data signal (s)3507.7.4Local interconnect network (s)3517.7.5FlexRay (s)3527.7.6Diagnostics (s)3547.8T.8.1Safety (s)3567.8.1Safety (s)3587.8.3Hydraulic hybrid (s)2360				-	
7.6Heating, ventilation and AC335197.6.1Ventilation systems 133517.6.2Vehicle heating 133657.6.3Air conditioning fundamentals 233887.6.4Air conditioning components 33407.6.5Air conditioning systems 33427.6.6Antihistamines 33447.6.7Other heating systems 3345227.7Multiplexing3467.7.1Overview 23467.7.2Controller area network 33507.7.4Local interconnect network 335187.8Hybrid cars overview3567.8.1Safety 13567.8.2Electrical hybrid 12358447.8.3Hydraulic hybrid 12360					
997.6.1Ventilation systems 133517.6.2Vehicle heating 133657.6.3Air conditioning fundamentals 233887.6.4Air conditioning components 33407.6.5Air conditioning systems 33427.6.6Antihistamines 33447.6.7Other heating systems 3345227.7Multiplexing346237.7.1Overview 2346247.6.2Controller area network 3348257.7.2Controller area network 3350267.7.4Local interconnect network 3351297.7.5FlexRay 33527.7.6Diagnostics 33547.8Tybrid cars overview3567.8.1Safety 1358347.8.3Hydraulic hybrid 12358347.8.3Hydraulic hybrid 12360		76			
17.6.2Vehicle heating 1233657.6.3Air conditioning fundamentals 233887.6.4Air conditioning components 33407.6.5Air conditioning systems 33427.6.6Antihistamines 33447.6.7Other heating systems 334527.7Multiplexing3467.7.1Overview 2 \$3467.7.2Controller area network 33487.7.3CAN data signal \$3507.7.4Local interconnect network 33517.7.5FlexRay 33527.7.6Diagnostics 335487.8Hybrid cars overview3567.8.1Safety 1358347.8.3Hydraulic hybrid 12358		7.0			
5 7.6.3 Air conditioning fundamentals 2 338 8 7.6.4 Air conditioning components 3 340 7.6.5 Air conditioning systems 3 342 7.6.6 Antihistamines 3 344 7.6.7 Other heating systems 3 345 7.7 Multiplexing 346 7.7.1 Overview 2 3 346 7.7.2 Controller area network 3 348 7.7.3 CAN data signal 3 350 7.7.4 Local interconnect network 3 351 7.7.5 FlexRay 3 352 7.7.6 Diagnostics 3 354 7.8 Hybrid cars overview 356 7.8.1 Safety 1 358 34 7.8.2 Electrical hybrid 1 2 358 34 7.8.3 Hydraulic hybrid 1 2 360					
8 7.6.4 Air conditioning components 3 340 7.6.5 Air conditioning systems 3 342 7.6.6 Antihistamines 3 344 7.6.7 Other heating systems 3 345 7.7 Multiplexing 346 7.7.1 Overview 2 3 348 7.7.2 Controller area network 3 348 7.7.3 CAN data signal 3 350 7.7.4 Local interconnect network 3 351 7.7.5 FlexRay 3 352 7.7.6 Diagnostics 3 354 7.8 T.8.1 Safety 1 356 7.8.2 Electrical hybrid 12 358 34 7.8.3 Hydraulic hybrid 12 360				-	
7.6.5 Air conditioning systems 3 342 7.6.6 Antihistamines 3 344 7.6.7 Other heating systems 3 345 7.7 Multiplexing 346 7.7 Multiplexing 346 7.7.7 Multiplexing 346 7.5 7.7.1 Overview 2 (3) 346 7.5 7.7.2 Controller area network (3) 348 7.7 CAN data signal (3) 350 7.7.4 Local interconnect network (3) 351 8 7.7.5 FlexRay (3) 352 7.7.6 Diagnostics (3) 354 8 7.8 Hybrid cars overview 356 7.8.1 Safety (1) 358 64 7.8.3 Hydraulic hybrid (1) (2) 360	_			-	
7.6.6 Antihistamines (3) 344 7.6.7 Other heating systems (3) 345 7.7 Multiplexing 346 7.7 Overview (2) (3) 346 7.7 Overview (2) (3) 346 7.7 Controller area network (3) 348 7.7.3 CAN data signal (3) 350 7.7.4 Local interconnect network (3) 351 7.7.5 FlexRay (3) 352 7.7.6 Diagnostics (3) 354 8 7.8 Hybrid cars overview 356 7.8.1 Safety (1) 358 7.8.2 Electrical hybrid (1) (2) 358 64 7.8.3 Hydraulic hybrid (1) (2) 360	0				
22 7.6.7 Other heating systems ③ 345 22 7.7 Multiplexing 346 23 7.7.1 Overview ② ⑤ 346 25 7.7.2 Controller area network ③ 348 26 7.7.3 CAN data signal ⑤ 350 25 7.7.4 Local interconnect network ⑤ 351 29 7.7.5 FlexRay ⑥ 352 21 7.7.6 Diagnostics ⑤ 354 28 7.8 Hybrid cars overview 356 21 7.8.1 Safety ① 356 23 7.8.2 Electrical hybrid ① ② 358 24 7.8.3 Hydraulic hybrid ① ② 360	1				
22 7.7 Multiplexing 346 33 7.7.1 Overview 2 S 346 43 7.7.2 Controller area network S 348 7.7.3 CAN data signal S 350 7.7.4 Local interconnect network S 351 7.7.5 FlexRay S 352 7.7.6 Diagnostics S 354 8 7.8 Hybrid cars overview 356 7.8.1 Safety 1 358 34 7.8.3 Hydraulic hybrid 1 2 360					
33 7.7.1 Overview 2 € 346 35 7.7.2 Controller area network € 348 31 7.7.3 CAN data signal € 350 35 7.7.4 Local interconnect network € 351 39 7.7.5 FlexRay € 352 31 7.7.6 Diagnostics € 354 38 7.8 Hybrid cars overview 356 36 7.8.1 Safety € 358 34 7.8.2 Electrical hybrid € 358 34 7.8.3 Hydraulic hybrid € 360		77			
25 7.7.2 Controller area network ③ 348 21 7.7.3 CAN data signal ③ 350 25 7.7.4 Local interconnect network ③ 351 29 7.7.5 FlexRay ④ 352 21 7.7.6 Diagnostics ④ 354 28 7.8 Hybrid cars overview 356 28 7.8.1 Safety ① 356 26 7.8.2 Electrical hybrid ① ② 358 24 7.8.3 Hydraulic hybrid ① ② 360		/./		•	
81 7.7.3 CAN data signal § 350 85 7.7.4 Local interconnect network § 351 89 7.7.5 FlexRay § 352 91 7.7.6 Diagnostics § 354 98 7.8 Hybrid cars overview 356 98 7.8.1 Safety 1 356 91 7.8.2 Electrical hybrid 1 2 358 94 7.8.3 Hydraulic hybrid 1 2 360					
7.7.4 Local interconnect network 3 351 9 7.7.5 FlexRay 3 352 1 7.7.6 Diagnostics 3 354 1.8 7.8 Hybrid cars overview 356 1.8 7.8.1 Safety 1 356 1.1 7.8.2 Electrical hybrid 1 2 358 1.4 7.8.3 Hydraulic hybrid 1 2 360					
89 7.7.5 FlexRay 3 352 11 7.7.6 Diagnostics 3 354 18 7.8 Hybrid cars overview 356 18 7.8.1 Safety 1 356 10 7.8.2 Electrical hybrid 1 2 358 14 7.8.3 Hydraulic hybrid 1 2 360					
1 7.7.6 Diagnostics 3 354 .8 7.8 Hybrid cars overview 356 .8 7.8.1 Safety 1 356 .1 7.8.2 Electrical hybrid 1 2 358 .4 7.8.3 Hydraulic hybrid 1 2 360					
8 7.8 Hybrid cars overview 356 8 7.8.1 Safety 1 356 61 7.8.2 Electrical hybrid 1 2 358 64 7.8.3 Hydraulic hybrid 1 2 360					
8 7.8.1 Safety 1 356 51 7.8.2 Electrical hybrid 1 2 358 54 7.8.3 Hydraulic hybrid 1 2 360		7.8		-	
i17.8.2Electrical hybrid 1 2 358i47.8.3Hydraulic hybrid 1 2 360			-		
4 7.8.3 Hydraulic hybrid 2 360				-	
	57		7.8.4	Compressed air hybrid 1 2	361

Advance material - not for resale

8	Cha	ssis sys	stems	363
	8.1	Suspe	nsion	364
		8.1.1	Reasons for suspension 🚺	364
		8.1.2	Springs 🚺	367
		8.1.3	Dampers/shock absorbers 🚹 2	371
		8.1.4	Front suspension layouts 🕗	374
		8.1.5	Rear suspension layouts 2	376
		8.1.6	Active suspension 🕄	379
		8.1.7	Delphi MagneRide 🕄	382
	8.2	Steerir	ng	383
		8.2.1	Steering introduction 🚺	383
		8.2.2	Steering racks and boxes 🚹 2	385
		8.2.3	Power steering introduction 12	388
		8.2.4	Steering geometry 2	390
		8.2.5	Advanced wheel alignment 3	395
		8.2.6	Hydraulic power steering 🕗	398
		8.2.7	Electric power steering 2 3	400
	8.3	Brakes	3	406
		8.3.1	Brakes introduction 🚺	406
		8.3.2	Disc, drum and parking	
			brakes 🚹 2	408
		8.3.3	Hydraulic components 🚺 2	411
		8.3.4	Brake servo operation 2	413
		8.3.5	Braking force control 2	415
		8.3.6	Anti-lock brake systems 2 🕄	417
		8.3.7	Bosch ABS 🕄	422
		8.3.8	Electric parking brakes 2 	425
		8.3.9	Traction control 🕄	428
		8.3.10	Electronic stability program 🕄	429
	8.4	Wheel	s and tyres	432
		8.4.1	Types of wheel 🚹	432
		8.4.2	Wheel rims and fixings 🚹	434
		8.4.3	Tyres introduction 🚹	437
		8.4.4	Tyre construction 🛛	439
		8.4.5	Functions of the tyre 2	441
		8.4.6	Wheel balancing 1 2	442
-	_			
9			on systems	445
	9.1	Clutch		446
		9.1.1	Purpose of the clutch	446
		9.1.2	Clutch mechanisms	447
		9.1.3	Coil spring clutch 12	449
		9.1.4	Diaphragm clutch 12	450
		9.1.5	Other types of clutch 2	454
		9.1.6	Electronic clutch 🕄	456

9.1.6	Electronic clutch 3	

	9.2	Manua	l gearbox	457
		9.2.1	Gearbox operation 🚹	457
		9.2.2	Gear change mechanisms ┨ 2	459
		9.2.3	Gears and components 🚹 2	461
		9.2.4	Synchromesh mechanisms 🕗	462
		9.2.5	Front- and rear-wheel drive 2	464
	9.3	Autom	atic transmission	466
		9.3.1	Torque converter 🚺 2	466
		9.3.2	Automatic transmission ┨ 2	468
		9.3.3	Electronic and hydraulic control 3	470
		9.3.4	Constantly variable	
			transmission 🕄	472
		9.3.5	Transaxle transmission 🕄	475
		9.3.6	Direct shift gearbox 🕄	478
	9.4	Drivelir		483
		9.4.1	Propshafts 🚹 2	483
		9.4.2	Driveshafts 🚹 2	486
		9.4.3	Rear-wheel drive bearings 🚺 2	487
		9.4.4	Front-wheel drive bearings 12	489
		9.4.5	Four-wheel drive systems 🕄	489
	9.5		rive and differential	492
		9.5.1	Final drive 1 2	492
		9.5.2	Differential operation 12	494
		9.5.3	Limited slip differentials 3	495
		9.5.4	Other differentials and units 🕄	497
10	Adva	nced d	liagnostics	499
	10.1	Diagno	stic techniques	500
		10.1.1	Introduction 1 2 3	500
		10.1.2	Diagnostic process 2 	501
			Data sources 2 🕄	506
			Diagnostics on paper 🕄	507
			Mechanical diagnostics 🕄	508
			Electrical diagnostics 🕄	511
	10.2		scope diagnostics	517
			Introduction 🕄	517
			Sensors 3	517
			Actuators 3	524
			Ignition system 🕄	527
			Other components 3	529
	10.3		ard diagnostics	531
			Introduction 🕄	531
		10.3.2	OBD monitors 🕄	536

10.3.3 Scanners 🕄

10.3.4 ECU fuel trim diagnostics 3

542

551



ATT interactive



After successful completion of this chapter you will be able to show you have achieved these objectives:

- Understand the various icons and symbols and structure used in this book and online.
- Understand how to use the learning activities and other features.



Advance material - not for resale

1.1 Introduction **1**

This textbook should be used in conjunction with the ATT multimedia materials: it is not intended to be a stand-alone resource. But it is designed to help you learn . . .

... and the best way to learn anything new is to interact with it. In other words, be an active learner. Sitting back being passive and expecting your brain to remember stuff doesn't work!



You will find this button on all our multimedia learning screens - click it and see what happens!

As you work through this book you will see this symbol next to some paragraphs:



>>> This means that there is a video or animation associated with the text. You can access this online or from the locally installed version of ATT. This is a good way to interact.

The other image you will see at the start of each chapter is a QR code (as on p. 1). If you have suitable software on your computer (and a camera) or a smartphone app, pointing at this image will link to some useful resources.

Note that the practical sections are not in this book (to save space) but they are all available in full multimedia online.

Online learning link: www.automotivett.org

Qualification levels This book contains all the theory/ technology content for study at levels 1, 2 and 3. The materials are presented as chapters, subjects and then sections. Each section is marked as follows:

- _ study only these sections if working on a level 1 qualification
- **n**a -

61

- read these sections if working on a level 1 qualification, study in detail on a level 2 qualification
- 2 - study these sections and those marked level 1 (unless done previously) if working on a level 2 gualification



- read these sections if working on a level 2 qualification, study in detail on a level 3 qualification
- **3** study these sections and those marked level 1 and level 2 (unless done previously) if working on a level 3 qualification

Screen title Most of the paragraphs of text in this book start with a title in bold as shown here! This is the title that you will see on the multimedia learning screen. And to help you interact even more and make

learning about automotive technology fun as well as interesting, we have developed ATT interactive. All of the activities in this book can be carried out using features on the interactive website. Paper and pencils will also work in most cases, so you can still work if you don't have internet access.

Visit: www.automotivett.org to access a demonstration of the amazing and unique features of ATT interactive:

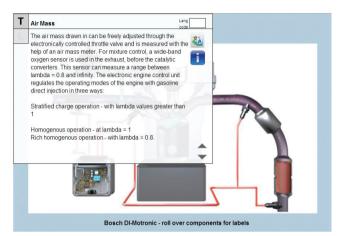


Figure 1.1 Example screen showing the interactive and translate buttons

The translate feature is available on all our learning screens. Enter the language code in the small box and then click the Google translate button. I used 'es' (Spanish) and the result is shown in Figure 1.2.

Translate From: English 👻 🐄 To: Spanish 👻 Transla	te
English Spanish French Detect language	Spanish English Arabic
the electronically controlled throttle valve and is measured with the help of an air mass meter. For mixture control, a wide-ban oxygen sensor is used in the exhaust, before the catalytic conveters. This sensor can measure a range between lambd 0.8 and infinity. The electronic engine control unit regulates the threas ways. Statistical chargo geogration - with lambda values greater than Homogenito chargo experiation - with lambda values greater than Homogenitor, sing handba = 0.8.	 d electrónicamente y se mide con la ayuda de un medidor de masa de aire. Para el control de mezcla, un sensor de oxígeno de bandi a = ancha se utiliza en los gases de escape, antes de que los e convertidores catalíticos. Este sensor puede medir un rango entre

Figure 1.2 Google translate website

Now although this machine translation is very good it is not perfect and so fluent speakers will notice some amusing errors (filing metal and filing papers can be mixed up for example!). However, the feedback we have received is that it is a great help for people working in English as a second language.

Clicking the blue interactive button takes you to the website shown in Figure 1.3. We are working on this all the time so new options may become available but it will remain very similar.

You can also translate at this point and if you entered a language code then the search features will use that language. If not, it will default to English.



Figure 1.3 ATT interactive website

Clicking one of the buttons on the site may take you to an external website where, you will appreciate, we cannot be responsible for the content! There are currently 12 main headings and some of these have several associated buttons. Experiment as much as you like. These 12 options also relate to the different learning activities that are used in this book and are discussed in the next section.



Now complete the multiple-choice quiz associated with this topic/subject area.

1.2 Learning activities []

Lots of learning activities are included in the ATT textbooks, and they provide a great way to interact and learn. In most cases the best option will be to follow the ATT *interactive* link from a learning screen. The answers to questions or notes/bullet/labels and other activities can be written directly in the textbook, on a separate notebook or perhaps even better as a computer document or in an electronic notebook.

Some activities will just show an icon (add labels to a diagram, for example) while others will give further instructions and maybe a space for the work to be completed. For all the activities in this section, I have included an example of what you could do. (Tip: Pressing PrtScr will copy the screen to the clipboard for pasting into your electronic notebook (Word document or whatever). Better still, use the annotator supplied as part of the ATT system or available from http://getgreenshot.org.

Note: The activities suggested in the text are recommended but you can do different types. Remember, the more you do the more you will learn!

Information search This activity will usually be something similar to this:



Use a library or the interactive web search tools to examine the subject in this section in more detail. Here is the link I found useful after searching on the interactive site for one of the key words in the text: http://en.wikipedia.org/wiki/ Catalytic_converters

Looking in other textbooks in a library is a good way to see the subject explained in a different way. Perhaps even better is to use the Info search option on the interactive site. Clicking any of the buttons in this row (see Figure 1.3) will search for the screen title, 'Air Mass' in this example, or you can select a word or phrase in the text and it will search for that instead.

Media search This activity is very similar to the previous one except it asks you to search for images and videos.



Use the interactive media search tools to look for pictures and videos to examine the subject in this section in more detail. Searching for Catalytic converter I found this rather nice image on Flickr:



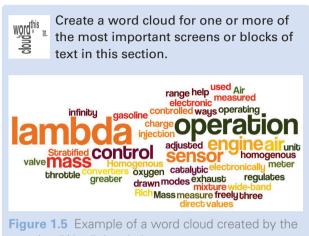
Figure 1.4 Daimler catalytic converter (Source: Flickr Creative Commons)

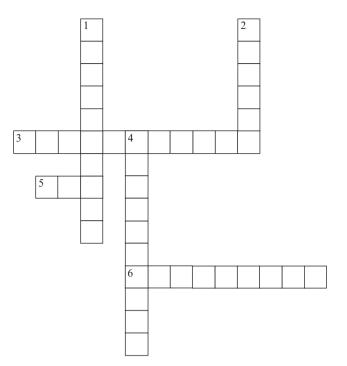
The buttons in this row search for the screen title or selected text in the same way as before.

Word cloud A word cloud shows the most common words in a block of text in a larger font. It is a great

1 ATT interactive

way to focus in on the important aspects of a learning screen or paragraph of text. There are a few different options available on the interactive site. Here is an example of a word cloud I created based on the example screen shown earlier. Note that clicking the interactive button also copies the text onto the clipboard for pasting elsewhere.





amazing 'Wordle' website

Word puzzles Crossword and wordsearch puzzles are a great way to learn new important words and the associated technologies. A good method is to work in pairs so you each create a puzzle and then swap and try to complete the answers.

Construct a crossword puzzle using ABCD important words from this section. Hint: Use the ATT glossary where you can copy the words and definitions (clues!). About 20 words is a good puzzle. OR Construct a wordsearch grid using some

key words from this section. About 10 words in a 12×12 grid is usually enough.

There is also an option for creating anagrams in this row of interactive features – I am not sure how useful that is, but it is fun! Here is a crossword I prepared earlier:

Across

- **3** To join in with an activity is to be...
- **5** Mode of transport
- 6 Technical reading material

Down

- 1 Look for connected letters in a grid
- 2 What you are doing now
- 4 Subject of this book

Figure 1.6 Crossword puzzle (Source: TeachersCorner.net)

Mind map/wall These activities work fine either with pen and paper or by using the online features. Figure 1.7 is an example of a simple mind map I created about brakes, using a link on the interactive site.

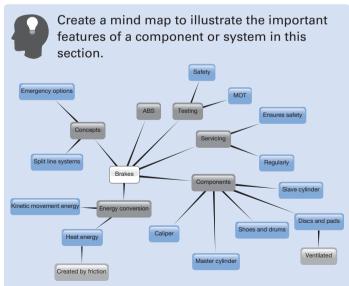


Figure 1.7 Brakes mind map (more work needed!)

OR

Create an information wall to illustrate the important features of a component or system in this section.

Notes/bullets Three great tools for keeping notes electronically are Evernote, Microsoft OneNote and Google Drive. My favourite at the moment is OneNote but I find all these tools easy to work with – they can be used online or offline and also synched to or from my smartphone. Of course, using any word processor is fine – as is using a pen. The following is an example of some key bullet points relating to an introduction to brakes:



Look back over the previous section and write out a list of the key bullet points.

- Brakes work by converting movement energy into heat.
- The foot brake acts on all wheels and the parking brake usually on two.
- Friction is used to create the heat.
- Main components are pads and discs or shoes and drums (pads most common).
- Hydraulic fluid is used to transfer the pressure from the accelerator pedal.

Labels Many of the diagrams in this book have numbers but no labels. Use the multimedia version to find out what they are and write them into the book (or copy the image and do it electronically).

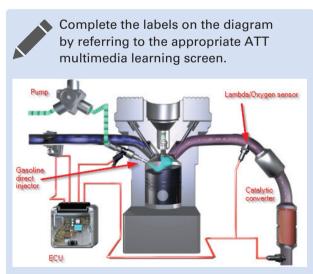


Figure 1.8 Labelled diagrams can be saved in your electronic notebook

OR: List the items separately.

- The components on this diagram are:
- 1 Lambda sensor
- 2 Catalytic converter
- 3 High-pressure pump
- 4 Injector

I added labels and the arrows to the diagram above using the Greenshot annotator.

Social If you are working on a college or school network you may not be allowed to access these sites, but you certainly can in your own time. It is a great way to keep in touch, share ideas with your mates and communicate with us here at ATT.



Follow the tweets, Facebook, and blog posts from our automotive website linked from www.atttraining. com/auto. You could also set up a Facebook discussion group to talk about specific automotive technology subjects.

Questions Short-answer questions are used at the end of all the technology sections of this book. Write the answers in the box provided or keep them electronically and note the page number so you can refer back to them.



Answer the following questions either here in your book or electronically.

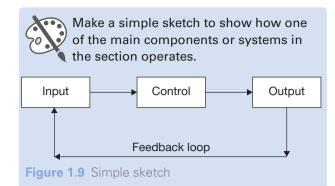
- 1 What is the address of the ATT interactive web site? www.atttraining.com/auto
- 2 What is your favourite type of car? One that starts every time and is comfortable and reliable (oh, and is ideally a Ferrari).

At the end of each main subject area you could carry out the associated multiple-choice test online or on the DVD/offline version. This box will show as a reminder:



Now complete the multiple-choice quiz associated with this topic/subject area.

Sketch Making a simple sketch to help you remember how a component or system works is a good way to learn. You can use a pencil or the online features or any drawing program – even word processors have quite good drawing tools now. The sketch here is my representation of a closed loop control system:



Presentation Preparing and making a presentation to your mates is a great way to learn about something new because you have to study it in detail first! It can be a bit nerve-racking at first but is also good fun so don't worry.

There are some great online tools for this or you can use PowerPoint or a similar program to prepare some slides that you then explain in more detail.

Using images and text, put together a short presentation that you will deliver to your classmates to show how an important component of a system from this section works.

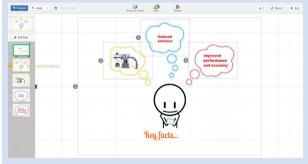


Figure 1.10 A basic presentation I started making using the online tool: Prezi

Practical Clearly practical work is the most important thing we do as automotive technicians.



Refer to the appropriate worksheets and carry out the practical task(s) related to this section – but only when directed by your teacher or instructor.

Summary In this chapter we have looked at some of the key features of this book that make learning more effective as well as more fun. As well as options to examine videos and more as part of the electronic learning screens, including translation features, there are lots of different learning activities in this book. Each one has an associated link on the online interactive site at www.automotivett.org

Good luck with your studies and I hope you find this book useful – remember, get involved in your learning and interact and it is much more interesting!



Now complete the multiple-choice quiz associated with this unit.



Engine systems



After successful completion of this chapter you will be able to show you have achieved these objectives:

- Understand how the main light vehicle engine mechanical systems operate.
- Understand how light vehicle engine lubrication systems operate.
- Understand how light vehicle engine cooling, heating and ventilation systems operate.
- Understand how light vehicle engine fuel systems operate.
- Understand how light vehicle engine ignition systems operate.
- Understand how light vehicle engine air supply and exhaust systems operate.
- Understand how to check, replace and test light vehicle engine mechanical, lubrication, cooling, fuel, ignition, air and exhaust system units and components.
- Understand how to diagnose and rectify faults in light vehicle engine systems.





Create an information wall to illustrate the important features of a component or system in this section.

Now complete the multiple-choice quiz associated with this topic/subject area.

6.5 Ignition

6.5.1 Ignition overview

Purpose The purpose of the ignition system is to supply a spark inside the cylinder, near the end of the compression stroke, to ignite the compressed charge of air/fuel vapour. For a spark to jump across an air gap of 1.0mm under normal atmospheric conditions, (1 bar) a voltage of 4 to 5kV is required. For a spark to jump across a similar gap in an engine cylinder, having a compression ratio of 8:1, approximately 10kV is required. For higher compression ratios and weaker mixtures, a voltage up to 20kV may be necessary. The ignition system has to transform the normal battery voltage of 12V to approximately 8 to 20kV and, in addition, has to deliver this high voltage to the right cylinder, at the right time. Some ignition systems will supply up to 40kV to the spark plugs.



Figure 6.327 Combustion taking place (Source: Ford Media)

Conventional ignition is the forerunner of the more advanced systems controlled by electronics. It is worth mentioning at this stage, however, that the fundamental operation of most ignition systems is very similar. One winding of a coil is switched on and off causing a high voltage to be induced in a second winding. The basic types of ignition system can be classified as shown in the table.

Туре	Conventional	Electronic	Programmed	Distributorless
Trigger	Mechanical	Electronic	Electronic	Electronic
Advance	Mechanical	Mechanical	Electronic	Electronic
Voltage source	Inductive	Inductive	Inductive	Inductive
Distribution	Mechanical	Mechanical	Mechanical	Electronic

Engine management Modern ignition systems now are part of the engine management, which controls fuel delivery, ignition, and other vehicle functions. These systems are under continuous development and reference to the manufacturer's workshop manual is essential when working on any vehicle. The main ignition components are the engine speed and load sensors, knock sensor, temperature sensor and the ignition coil. The ECU reads from the sensors, interprets and compares the data, and sends output signals to the actuators. The output component for ignition is the coil.

Developments Ignition systems continue to develop and will continue to improve. However, keep in mind that the simple purpose of an ignition system is to ignite the fuel/air mixture every time at the right time. And, no matter how complex the electronics may seem, the high voltage is produced by switching a coil on and off.

Generation of high voltage If two coils (known as the primary and secondary) are wound on to the same iron core, then any change in magnetism of one coil will induce a voltage in to the other (see Chapter 7 for more details). This happens when a current is switched on and off to the primary coil. If the number of turns of wire on the secondary coil is more than the primary, a higher voltage can be produced. This is called transformer action and is the principle of the ignition coil.

Value of this 'mutually induced' voltage depends upon:

- primary current
- turns ratio between primary and secondary coils
- the speed at which the magnetism changes.

The two windings are wound on a laminated iron core to concentrate the magnetism. This is how all types of ignition coil are constructed.

Ignition timing For optimum efficiency, the ignition timing (or advance angle) should be such as to cause the maximum combustion pressure to occur about 10° after TDC. The ideal ignition timing is dependent on two main factors, engine speed and engine load. An increase in engine speed requires the ignition timing to be advanced. The cylinder charge, of air/fuel mixture, requires a certain time to burn (something like 2ms). At higher engine speeds the time taken for the piston to travel the same distance reduces. Advancing the time of the spark ensures full burning is achieved.

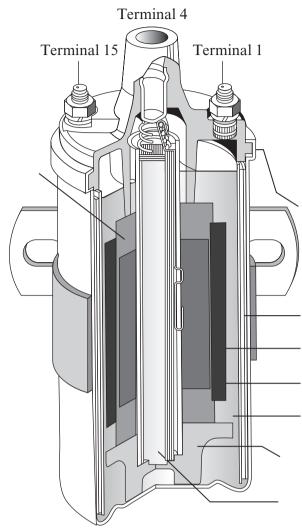


Figure 6.328 Traditional ignition coil

Engine load A change in timing due to engine load is also required as the weaker mixture used on lowload conditions burns at a slower rate. In this situation further ignition advance is necessary. Greater load on the engine requires a richer mixture, which burns more rapidly. In this case some retardation of timing is necessary. Overall, under any condition of engine speed and load an ideal advance angle is required to ensure maximum pressure is achieved in the cylinder just after top dead centre. The ideal advance angle may also be determined by engine temperature and any risk of detonation.

Spark advance is achieved in a number of ways, the simplest of these being the mechanical system comprising of a centrifugal advance mechanism and a vacuum (load sensitive) control unit. Manifold depression is almost inversely proportional to the engine load. However, I prefer to consider manifold pressure instead of vacuum or depression even though it is lower than atmospheric pressure. The manifold absolute pressure (MAP) is therefore proportional to engine load. Digital ignition systems adjust the timing in relation to the temperature as well as speed and load. The values of all ignition timing functions are combined either mechanically or electronically in order to determine the ideal ignition point.

Energy storage takes place in the ignition coil. The energy is stored in the form of a magnetic field. To ensure the coil is charged before the ignition point, a dwell period is required. Ignition timing is at the end of the dwell period as the coil is switched off.

Early ignition system Very early cars used something called a magneto, which is a story for another time, but here is a nice picture of one anyway!



Figure 6.329 First Bosch high-voltage magneto ignition system with spark plug in 1902 (Source: Bosch Media)

Mechanical switching For many years ignition systems were mechanically switched and distributed. The following table gives an overview of the components of this earlier system.



Figure 6.330 Contact breaker system

Spark plug	Seals electrodes for the spark to jump across in the cylinder. Must withstand very high voltages, pressures and temperatures
Ignition coil	Stores energy in the form of magnetism and delivers it to the distributor via the HT lead. Consists of primary and secondary windings
lgnition switch	Provides driver control of the ignition system and is usually also used to cause the starter to crank
Contact breakers (breaker points)	Switches the primary ignition circuit on and off to charge and discharge the coil. The contacts are operated by a rotating cam in the distributor
Capacitor (condenser)	Suppresses most of the arcing as the contact breakers open. This allows for a more rapid break of primary current and hence a more rapid collapse of coil magnetism which produces a higher voltage output
Distributor	Directs the spark from the coil to each cylinder in a preset sequence
Plug leads	Thickly insulated wires to connect the spark from the distributor to the plugs
Centrifugal advance	Changes the ignition timing with engine speed. As speed increases the timing is advanced
Vacuum advance	Changes timing depending on engine load. On conventional systems the vacuum advance is most important during cruise conditions



Figure 6.331 Traditional ignition coil

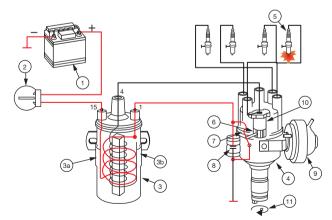


Figure 6.332 Ignition circuit of an early system: 1 Battery, 2 Ignition key switch, 3 Coil, a: primary, b: secondary winding, 4 Distributor body containing centrifugal (speed) advance/retard mechanism, 5 Spark plugs, 6 Cam (with a lobe for each cylinder), 7 Contact breakers (points), 8 Condenser (capacitor), 9 Vacuum (load) advance/retard mechanism



Figure 6.333 Traditional system using a distributor

Modern systems All current vehicle ignition systems are electronically switched and most are now digitally controlled as part of the engine management system. However, there are many vehicles out there still using conventional electronic ignition so the next main section will give an overview of these systems.

4	A+	h
5		ני

Look back over the previous section and write out a list of the key bullet points.

ABCD
I

Construct a crossword puzzle using important words from this section. Hint: Use the online ATT glossary where you can copy the words and definitions (clues!). About 20 words is a good puzzle.

6.5.2 Electronic ignition 12

Early ignition systems had some major disadvantages:

- Mechanical problems with the contact breakers not least of which is the limited lifetime.
- Current flow in the primary circuit is limited to about 4A or damage will occur to the contacts – or at least the lifetime will be seriously reduced.
- Legislation requires stringent emission limits which means the ignition timing must stay in tune for a long period of time.
- Weaker mixtures require more energy from the spark to ensure successful ignition, even at very high engine speed.

These problems were overcome by using a power transistor to carry out the switching function and a pulse generator to provide the timing signal.

6 Engine systems



Figure 6.334 Power transistor

Dwell The term 'dwell' when applied to ignition is a measure of the time during which the ignition coil is charging, in other words when primary coil current is flowing. The dwell in traditional systems was simply the time during which the contact breakers were closed, and in these early electronic systems it is the time that the transistor is switched on. Whilst this was a very good system in its time, constant dwell still meant that, at very high engine speeds, the actual time available to charge the coil would only produce a lower power spark. Note that as engine speed increases dwell angle or dwell percentage remains the same but the actual time is reduced. All systems nowadays are known as constant energy, ensuring high performance ignition even at high engine speed.

Constant energy In order for a constant energy electronic ignition system to operate, the dwell must increase with engine speed. This will only be of benefit, however, if the ignition coil can be charged up to its full capacity in a very short time (the time available for maximum dwell at the highest expected engine speed). To this end, constant energy coils are very low resistance so a high current will flow quickly. Constant energy means that, within limits, the energy available to the spark plug remains constant under all operating conditions.

Pulse generator This was achieved by using a pulse generator in the distributor to 'tell' an ignition module the engine position and speed so that the module could determine the switch on (start of dwell) and switch off point (end of dwell and ignition timing spark). Two types of pulse generator (sensors) were most common:

- 1 Hall Effect
- 2 Inductive



Figure 6.335 Distributor with ECU fitted (Source: Bosch Media)

Hall Effect As the central shaft of the Hall Effect distributor rotates, the chopper plate attached under the rotor arm alternately covers and uncovers the Hall chip. The number of vanes corresponds with the number of cylinders. In constant dwell systems, the dwell is determined by the width of the vanes. The vanes cause the Hall chip to be alternately in and out of a magnetic field. The result of this is that the device will produce almost a square wave output, which can then easily be used to switch further electronic circuits. The three terminals on the distributor are marked '+', '0' and '-'; the terminals + and – are for a voltage supply and terminal 0 is the output signal.



Figure 6.336 Hall effect distributor

Hall sensor output Typically the output from a Hall Effect sensor will switch between 0V and a few volts (systems vary). The supply voltage is taken from the ignition ECU and on some systems is stabilised at about 10V to prevent changes to the output of the sensor when the engine is being cranked. Hall Effect distributors are very common due to the accurate signal produced and their long

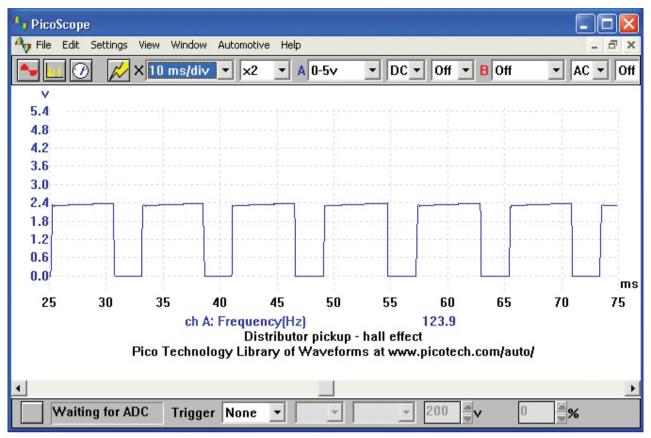


Figure 6.337 Hall sensor output

term reliability. They produced a kind of square wave output signal.

Inductive pulse generators use the basic principle of induction to produce a signal. Many forms exist but all are based around a coil of wire and a permanent magnet. The distributor shown in Figure 6.338 has the coil of wire wound on the pick-up and, as the reluctor rotates, the magnetic flux varies due to the peaks on the reluctor. The number of peaks or teeth on the reluctor corresponds to the number of



Figure 6.338 Inductive distributor

engine cylinders. The gap between the reluctor and pick-up can be important and manufacturers have recommended settings. These systems produce a form of sinewave output.

High energy Due to the high-energy nature of constant energy ignition coils, the coil cannot be allowed to remain switched on for more than a certain time. This is not a problem when the engine is running as the variable dwell or current limiting circuit prevents the coil overheating. Some form of protection must be provided for, however, when the ignition is switched on but the engine is not running. This is known as stationary engine primary current cut off.



Look back over the previous section and write out a list of the key bullet points.

Create an information wall to illustrate the important features of a component or system in this section.

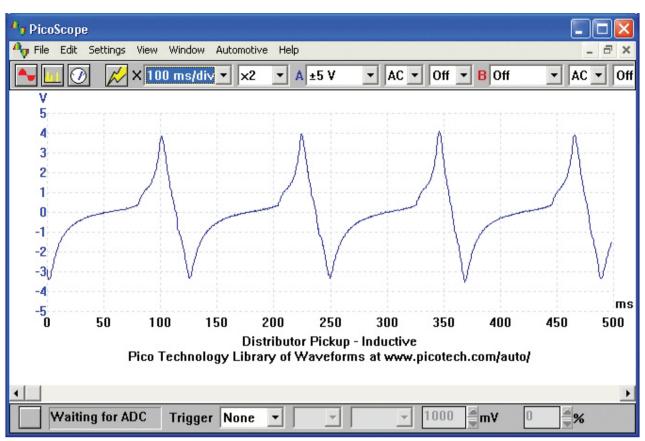


Figure 6.339 Inductive sensor output



Figure 6.340 Electronic ignition module (Source: Bosch Media)

6.5.3 Electronic spark advance 2

Overview Constant energy electronic ignition was a major step forwards and is still used on most vehicles. However, limitations lie in having to rely upon mechanical components for speed and load advance characteristics. In many cases this does not ideally match the requirements of the engine.

Electronic spark advance (ESA) ignition systems have a major difference compared with earlier systems in that they operate digitally. Information about the operating requirements of a particular engine is programmed into the memory inside the electronic control unit. The data for storage in ROM are obtained from rigorous testing on an engine dynamometer and from further development work on the vehicle under various operating conditions. ESA ignition has several advantages.

- The ignition timing can be accurately matched to the individual application under a range of operating conditions.
- Other control inputs can be utilized such as coolant temperature and ambient air temperature.
- Starting is improved and fuel consumption is reduced, as are emissions, and idle control is better.
- Other inputs can be taken into account such as engine knock.
- The number of wearing components in the ignition system is considerably reduced.

ESA (also referred to as programmed ignition), can be a separate system but is now most likely to be included as part of the full engine management system.

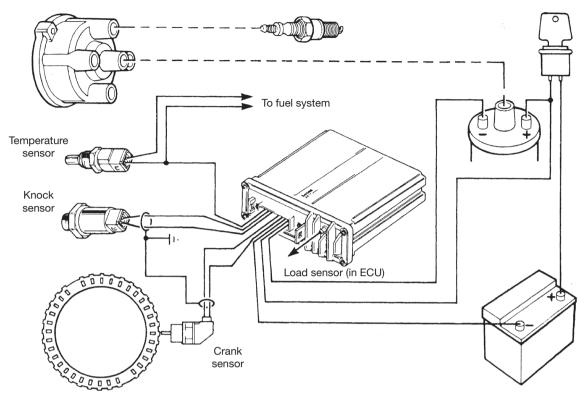
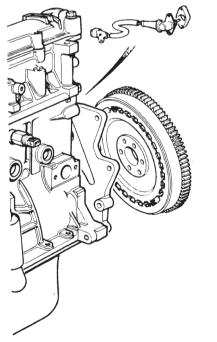


Figure 6.341 Programmed ignition or Electronic Spark Advance (ESA)

Sensors and input information A typical early ESA system is shown in Figure 6.341. In order for the ECU to calculate suitable timing and dwell outputs, certain input information is required.

Engine speed and position – crankshaft sensor This sensor is a reluctance sensor positioned as shown in Figure 6.342. The device consists of a permanent magnet, a winding and a soft iron core. It is mounted in proximity to a reluctor disc. The disc has 34 teeth, spaced at 10° intervals around the periphery of the disc. It has two teeth missing, 180° apart, at a known position before TDC (BTDC). Many manufacturers use this technique with minor differences. As a tooth from the reluctor disc passes the core of the sensor, the reluctance of the magnetic circuit is changed. This induces a voltage in the winding, the frequency of the waveform being proportional to the engine speed. The missing tooth causes a 'missed' output wave and hence the engine position can be determined.

Engine load – manifold absolute pressure sensor Engine load is proportional to manifold pressure in that high-load conditions produce high pressure and lower load conditions – such as cruise – produce lower pressure. Load sensors are therefore pressure transducers. They are either mounted in the ECU or as a separate unit and are connected to the inlet manifold with a pipe. The pipe often incorporates a restriction to damp out fluctuations and a vapour trap to prevent petrol fumes reaching the sensor.





Engine temperature – coolant sensor Coolant temperature measurement is carried out by a simple thermistor, and in many cases the same sensor is used for the operation of the temperature gauge and to provide information to the fuel control system. A separate memory map is used to correct the basic timing settings. Timing may be retarded when the engine is cold to assist in more rapid warm-up.



Figure 6.343 Temperature sensor

Detonation Combustion knock can cause serious damage to an engine if sustained for long periods. This knock, or detonation, is caused by over-advanced ignition timing. At variance with this is that an engine will, in general, run at its most efficient when the timing is advanced as far as possible. To achieve this, the data stored in the basic timing map will be as close to the knock limit of the engine as possible. The knock limit is also known as the detonation border line (DBL). The knock sensor provides a margin for error.

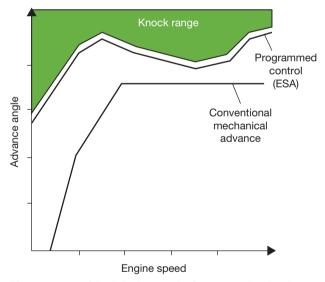


Figure 6.344 Ideal timing angle for an engine is close to the knock limit

Knock sensor The sensor itself is an accelerometer often of the piezoelectric type. It is fitted in the engine block between cylinders two and three on inline four-cylinder engines. Vee engines require two sensors, one on each side. The ECU responds to signals from the knock sensor in the engine's knock window for each cylinder – this is often just a few degrees each side of TDC. This prevents clatter from the valve mechanism being interpreted as knock. The signal from the sensor is also filtered in the ECU to remove unwanted noise. If detonation is detected, the ignition timing is retarded on the fourth ignition pulse after detection (four-cylinder engine) in steps until knock is no longer detected. The steps vary between manufacturers, but about 2° is typical. The timing is then advanced slowly in steps of, say, 1° over a number of engine revolutions until the advance required by memory is restored. This fine control allows the engine to be run very close to the knock limit without risk of engine damage.



Figure 6.345 Knock sensor

Battery voltage Correction to dwell settings is required if the battery voltage falls, as a lower voltage supply to the coil will require a slightly larger dwell figure. This information is often stored in the form of a dwell correction map.

Electronic control unit As the sophistication of systems has increased, the information held in the memory chips of the ECU has also increased. The earlier versions of a programmed ignition system achieved accuracy in ignition timing of 1.8° whereas a mechanical distributor is 8°. The information, which is derived from dynamometer tests as well as running tests in the vehicle, is stored in ROM. The basic timing map consists of the correct ignition advance for a range of engine speeds and load conditions. This is shown using a cartographic representation. A separate three-dimensional map is used that has speed and temperature-related settings. This is used to add corrections for engine coolant temperature to the basic timing settings. This improves drivability and can be used to decrease the warm-up time of the engine.

Ignition output The output of a system, such as this programmed ignition, is very simple. The output stage, in common with most electronic ignitions, consists of a heavy-duty transistor that forms part of, or is driven by, a Darlington pair. This is simply to allow the high ignition primary current to be controlled. The switch off point of the coil will control ignition timing and the switch on point will control the dwell period.

Remember! There is a multimedia version of this textbook that includes additional images and interactive features: www.automotivett.org

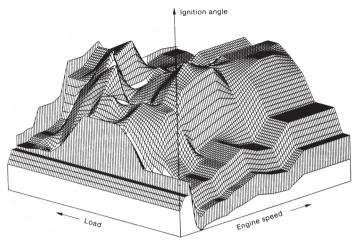


Figure 6.346 Cartographic map representing how ignition timing is stored in the ECU

HT distribution The high tension distribution is similar to a more conventional system. The rotor arm however is mounted on the end of the camshaft with the distributor cap positioned over the top.



Look back over the previous section and write out a list of the key bullet points.

Make a simple sketch to show how one of the main components or systems in this section operates.

6.5.4 Distributorless ignition 2

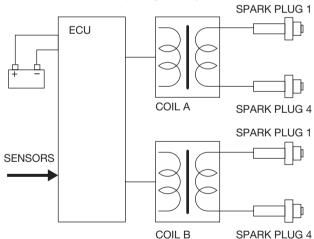
Distributorless ignition systems (DIS) use a special type of ignition coil, which outputs to the spark plugs without the need for an HT distributor.



Figure 6.347 Distributorless ignition coil in position

Lost spark The basic principle is that of the 'lost spark'. The distribution of the spark is achieved by using two double-ended coils, which are fired alternately by the ECU. The timing is determined from a crankshaft speed and position sensor as well as a load (MAP) sensor and other corrections such as engine temperature. When one of the coils is fired, a spark is delivered to two engine cylinders, either 1 and 4, or 2 and 3. The spark delivered to the cylinder on the compression stroke will ignite the mixture as normal. The spark produced in the other cylinder will have no effect as this cylinder will be just completing its exhaust stroke.

Operation Because of the low compression, and the exhaust gas in the 'lost spark' cylinder, the voltage used for the spark to jump the gap is only about 3kV. The spark produced in the compression cylinder is therefore not affected. An interesting point here is that the spark on one of the cylinders will jump from the earth electrode to the spark plug centre. Many years ago this would not have been acceptable as the spark quality when jumping this way would not have been as good as when it jumps from the hotter centre electrode. However, the energy available from modern constant energy systems will result in a spark of high quality regardless of its polarity.



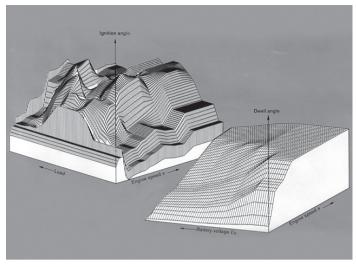
Wasted Spark Ignition System

Figure 6.348 DIS simplified circuit (wasted spark ignition system)

DIS components The DIS system consists of three main components – the electronic control unit (ECU), a crankshaft position sensor and the DIS coil. A manifold absolute pressure sensor is integrated in the module or mounted separately. The module uses an electronic spark advance system. Data on ideal dwell and timing is held in memory maps for a wide range of speed, load and voltage conditions. This can be described as an electronic spark advance (ESA) system

Advance material - not for resale

6 Engine systems





Crank position sensor (CPS) The crankshaft position sensor is similar in operation to the one described in the fuel section. It is an inductive sensor and is positioned against the front of the flywheel or against a reluctor wheel just behind the front crankshaft pulley. The tooth pattern usually consists of 35 teeth. These are spaced at 10° intervals with a gap where the 36th tooth would be. The missing tooth is positioned at 90° BTDC for numbers one and four cylinders. This reference position is placed a fixed number of degrees before top dead centre, in order to allow the timing or ignition point to be calculated as a fixed angle after the reference mark.

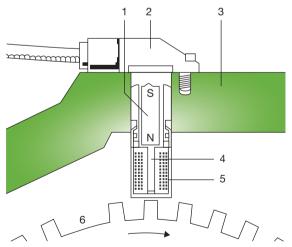


Figure 6.350 Inductive sensor: 1 Magnet, 2 Cover, 3 Engine, 4 Core, 5 Winding

Coil The primary winding is supplied with battery voltage to a centre terminal. The appropriate half of the winding is then switched to earth in the module. The high tension windings are separate and are specific to cylinders one and four, or two and three (or

as appropriate if a six-cylinder engine). On most cars now the ignition system is combined with the fuel system so that even more accurate control of outputs is possible and input data from sensors can be shared.



Figure 6.351 DIS coil and plug leads



Look back over the previous section and write out a list of the key bullet points.

Use a library or the interactive web search tools to examine the subject in this section in more detail.

6.5.5 Coil on plug ignition 2

Coil on plug (COP) or direct ignition is a further improvement on distributorless ignition. This system utilises an inductive coil for each engine cylinder. These coils are mounted directly on the spark plugs. The use of an individual coil for each plug ensures that the charge time is very fast (full coil charge in a very small dwell angle). This ensures that a very high voltage, high-energy spark is produced. This voltage, which can be in excess of 40kV, provides efficient initiation of the combustion process under cold starting conditions and with weak mixtures.

Ignition timing and dwell are controlled in a manner similar to the previously described electronic spark advance (ESA) system. The one important addition to this on most systems is a camshaft sensor to provide information as to which cylinder is on the compression stroke. A system which does not require a sensor to determine which cylinder is on compression (engine position is known from a crank sensor) determines the information by initially firing all of the coils. The voltage

6 Engine systems



Figure 6.352 Six direct ignition coils in position

across the plugs allows measurement of the current for each spark and will indicate which cylinder is on its combustion stroke. This works because a burning mixture has a lower resistance. The cylinder with the highest current at this point will be the cylinder on the combustion stroke.

Flooding A further feature of some systems is the case when the engine is cranked over for an excessive time making flooding likely. The plugs can all fire with multi-sparks for a period of time after the ignition is left on to burn away any excess fuel. During difficult starting conditions, multi-sparking is also used by some systems during 70° of crank rotation before TDC. This assists with starting and then, once the engine is running, the timing will return to its normal calculated position.



Look back over the previous section and write out a list of the key bullet points.

Create a word cloud for one or more of the most important screens or blocks of text in this section.

6.5.6 Spark plugs and leads 1 2

Overview The simple requirement of a spark plug is that it must allow a spark to form within the combustion chamber to initiate combustion. In order to do this, the plug has to withstand a number of severe conditions. It must withstand severe vibration and a harsh chemical environment. Finally, but perhaps most importantly, the insulation properties must withstand voltage pressures up to 40kV.

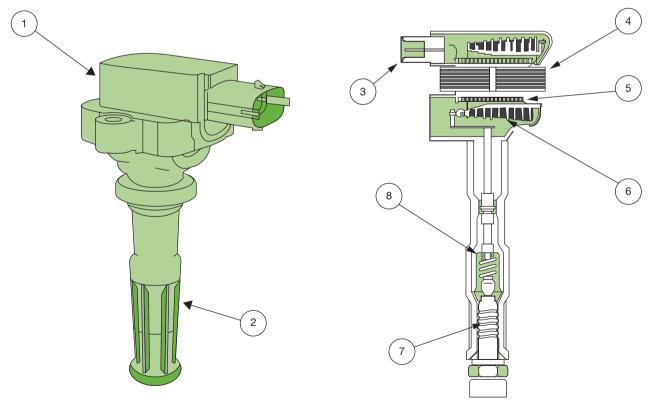


Figure 6.353 Direct ignition coil features: 1 Direct ignition coil, 2 Spark plug connector, 3 Low voltage connection, outer, 4 Laminated iron core, 5 Primary winding, 6 Secondary winding, 7 Spark plug, 8 High voltage connection, inner, via spring contact



Figure 6.354 Modern high-performance spark plug

Standard spark plug The centre electrode is connected to the top terminal by a stud. The electrode is constructed of a nickel-based alloy. Silver and platinum are also used for some applications. If a copper core is used in the electrode this improves the thermal conduction properties. The insulating material is ceramic based and of a very high grade. Flash over or tracking down the outside of the plug insulation is prevented by ribs which effectively increase the surface distance from the terminal to the metal fixing bolt, which is of course earthed to the engine.



Figure 6.355 Cutaway section of a spark plug

Temperature Due to many and varied constructional features involved in the design of an engine, the range of temperatures a spark plug is exposed to can vary significantly. The operating temperature of the centre electrode of a spark plug is critical. If the temperature becomes too high then pre-ignition may occur where the fuel/air mixture may be ignited due to the incandescence of the plug electrode. If the electrode temperature is too low, then carbon and oil fouling can occur as deposits are not burnt off. The ideal operating temperature of the plug electrode is between 400 and 900°C.

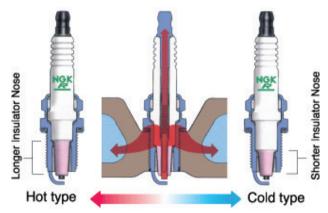


Figure 6.356 Heat-loss paths: the cold plug is able to transfer heat more easily so is suitable for a hot engine

The **heat range** of a spark plug is a measure of its ability to transfer heat away from the centre electrode. A hot running engine will require plugs with a higher thermal ability than a colder running engine. Note that hot and cold running of an engine in this sense refers to the combustion temperature, not to the cooling system.

Spark plug electrode gaps, in general, have increased as the power of the ignition systems driving the spark has increased. The simple relationship between plug gap and voltage required is that as the gap increases so must the voltage (leaving aside engine operating conditions). Further, the energy available to form a spark at a fixed engine speed is constant, which means that a larger gap using higher voltage will result in a shorter duration spark. A smaller gap will allow a longer duration spark. For cold starting an engine and for igniting weak mixtures, the duration of the spark is critical. Likewise the plug gap must be as large as possible to allow easy access for the mixture to prevent quenching of the flame. The final choice is therefore a compromise reached through testing and development of a particular application. Plug gaps in the region of 0.6 to 1.2mm seem to be the norm at present.

6 Engine systems



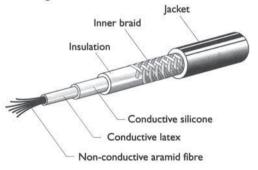
Figure 6.357 A range of spark plugs (Source: Bosch Media)

High tension (HT) is just an old fashioned way of saying high voltage. HT components, such as plug leads, must meet or exceed stringent ignition product requirements, such as:

- ▶ insulation to withstand 50 000V
- ▶ temperatures from 40°C to 260°C (40°F to 500°F)
- radio frequency interference suppression
- 160 000km (100 000 mile) product life
- resistance to ozone, corona, and fluids
- ▶ ten-year durability.

HT cables must meet the increased energy needs of lean-burn engines without emitting electromagnetic interference (EMI). The cables shown in Figure 6.358 offer metallic and non-metallic cores, including

Resistive ignition cable



Wire-wound ignition cable



composite, high-temperature resistive and wire-wound inductive cores. Conductor construction includes copper, stainless steel, Delcore, CHT, and wirewound. Jacketing materials include silicone.



Look back over the previous section and write out a list of the key bullet points.

Create a mind map to illustrate the important features of a component or system in this section.

Now complete the multiple-choice quiz associated with this topic/subject area.

6.6 Air supply, exhaust and emissions

6.6.1 Air pollution

Atmospheric pollution has become a serious problem for the environment and the health of people. Many urban areas are now heavily polluted, with people suffering medically from the effects of vehicle exhaust pollution.



Fossil fuels There have been many changes in climatic conditions in the world. Many of these have occurred over a long period and animals and plants have adapted to the changes naturally. However, the rapid burning of fossil fuels during this century has increased carbon dioxide levels in the atmosphere.

Vehicle designs are concentrating on weight reduction, aerodynamics, reducing rolling resistance, and on fuel-efficient engines. Alternative fuel sources to reduce fossil-fuel usage and to conserve the world's stock of these fuels have also been developed.

Carbon dioxide allows the sun's heat in but reduces the ability of the heat to radiate outward, causing the Earth to warm up. Many studies of the warming process indicate that the rate of Earth warming is increasing too quickly and preventing animals and Advance material - not

AUTOMOTIVE TECHNICIAN TRAINING



A blended e-learning approach to automotive engineering at levels one to three

- Written specifically to work alongside ATT's online multimedia system in order to create a blended e-learning experience
- Full colour layout with links throughout to extensive online multimedia materials
- Well respected author with both industry and academic experience of the automotive market

Produced alongside the ATT online learning resources, this textbook covers all the theory and technology sections that students need to learn in order to pass levels one, two and three automotive courses. It is recommended by the Institute of the Motor Industry and is also ideal for exams run by other awarding bodies. Unlike the current textbooks on the market though, this title takes a blended learning approach, using interactive features that make studying more enjoyable as well as more effective.

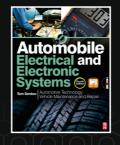
When linked with the ATT online resources it is a comprehensive package that includes activities, video footage, assessments and further reading. Information and activities are set out in sequence so as to meet teacher and learner needs as well as qualification requirements. If you don't have access to the ATT materials via your college, company or school then this can be accessed at a special price. Visit *www.automotivett.org* for details.

Tom Denton is the leading UK automotive author with a teaching career spanning from lecturer to head of automotive engineering in a large college. His eleven automotive textbooks published since 1995 are bestsellers and led to his authoring of the Automotive Technician Training multimedia system that is in common use in the UK, USA and several other countries.

Also by Tom Denton:



Advanced Automotive Fault Diagnosis 978-0-080-96955-8



Automotive Electrical and Electronic Systems 978-0-080-96942-8



Visit the companion website at: www.automotivett.org



AUTOMOTIVE ENGINEERING

