

MODULE 02

FOR B1 & B2 CERTIFICATION

PHYSICS

Aviation Maintenance Technician Certification Series



72413 U.S. Hwy 40
Tabernash, CO 80478-0270 USA

www.actechbooks.com

+1 970 726-5111

WELCOME

The publishers of this Aviation Maintenance Technician Certification Series welcome you to the world of aviation maintenance. As you move towards EASA certification, you are required to gain suitable knowledge and experience in your chosen area. Qualification on basic subjects for each aircraft maintenance license category or subcategory is accomplished in accordance with the following matrix. Where applicable, subjects are indicated by an "X" in the column below the license heading.

For other educational tools created to prepare candidates for licensure, contact Aircraft Technical Book Company.

We wish you good luck and success in your studies and in your aviation career!

REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2013 12	Module Creation and Release
002	2016 11	Format Update - Appearance Update
003	2018 07	Sections adjusted for improved alignment with Part 66 Appendix 1
		Content added for increased depth in the following areas: Sub-Module 01 - Elasticity; Sub-Module 02 – Harmonics, Velocity Ratio, Inertia, Total Energy, Coefficient of Friction, Compressibility; Sub-Module 04 – Reflection; Sub-Module 05 – Wave Motion, Production of Sound

FORWARD

PART-66 and the Acceptable Means of Compliance (AMC) and Guidance Material (GM) of the European Aviation Safety Agency (EASA), Appendix 1 establishes the Basic Knowledge Requirements for those seeking an aircraft maintenance license. The information in this Module of the Aviation Maintenance Technical Certification Series published by the Aircraft Technical Book Company meets or exceeds the breadth and depth of knowledge subject matter referenced in Appendix 1 of the Implementing Rules. However, the order of the material presented is at the discretion of the editor in an effort to convey the required knowledge in the most sequential and comprehensible manner. Knowledge levels required for Category A1, B1, B2, and B3 aircraft maintenance licenses remain unchanged from those listed in Appendix 1 Basic Knowledge Requirements. Tables from Appendix 1 Basic Knowledge Requirements are reproduced at the beginning of each module in the series and again at the beginning of each Sub-Module.

How numbers are written in this book:

This book uses the International Civil Aviation Organization (ICAO) standard of writing numbers. This method displays large numbers by adding a space between each group of 3 digits. This is opposed to the American method which uses commas and the European method which uses periods. For example, the number one million is expressed as so:

ICAO Standard	1 000 000
European Standard	1.000.000
American Standard	1,000,000

SI Units:

The International System of Units (SI) developed and maintained by the General Conference of Weights and Measures (CGPM) shall be used as the standard system of units of measurement for all aspects of international civil aviation air and ground operations.

Prefixes:

The prefixes and symbols listed in the table below shall be used to form names and symbols of the decimal multiples and submultiples of International System of Units (SI) units.

MULTIPLICATION FACTOR	PREFIX	SYMBOL
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^9	giga	G
1 000 000 = 10^6	mega	M
1 000 = 10^3	kilo	k
100 = 10^2	hecto	h
10 = 10^1	deca	da
0.1 = 10^{-1}	deci	d
0.01 = 10^{-2}	centi	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	p
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a

International System of Units (SI) Prefixes

EASA LICENSE CATEGORY CHART

Module Number and Title		A1 Airplane Turbine	B1.1 Airplane Turbine	B1.2 Airplane Piston	B1.3 Helicopter Turbine	B2 Avionics
1	Mathematics	X	X	X	X	X
2	Physics	X	X	X	X	X
3	Electrical Fundamentals	X	X	X	X	X
4	Electronic Fundamentals		X	X	X	X
5	Digital Techniques / Electronic Instrument Systems	X	X	X	X	X
6	Materials and Hardware	X	X	X	X	X
7A	Maintenance Practices	X	X	X	X	X
8	Basic Aerodynamics	X	X	X	X	X
9A	Human Factors	X	X	X	X	X
10	Aviation Legislation	X	X	X	X	X
11A	Turbine Aeroplane Aerodynamics, Structures and Systems	X	X			
11B	Piston Aeroplane Aerodynamics, Structures and Systems			X		
12	Helicopter Aerodynamics, Structures and Systems				X	
13	Aircraft Aerodynamics, Structures and Systems					X
14	Propulsion					X
15	Gas Turbine Engine	X	X		X	
16	Piston Engine			X		
17A	Propeller	X	X	X		

GENERAL KNOWLEDGE REQUIREMENTS

MODULE 02 SYLLABUS AS OUTLINED IN PART-66, APPENDIX 1

Level 1

A familiarization with the principal elements of the subject.

Objectives:

- The applicant should be familiar with the basic elements of the subject.
- The applicant should be able to give a simple description of the whole subject, using common words and examples.
- The applicant should be able to use typical terms.

Level 2

A general knowledge of the theoretical and practical aspects of the subject and an ability to apply that knowledge.

Objectives:

- The applicant should be able to understand the theoretical fundamentals of the subject.
- The applicant should be able to give a general description of the subject using, as appropriate, typical examples.
- The applicant should be able to use mathematical formula in conjunction with physical laws describing the subject.
- The applicant should be able to read and understand sketches, drawings and schematics describing the subject.
- The applicant should be able to apply his knowledge in a practical manner using detailed procedures.

Level 3

A detailed knowledge of the theoretical and practical aspects of the subject and a capacity to combine and apply the separate elements of knowledge in a logical and comprehensive manner.

Objectives:

- The applicant should know the theory of the subject and interrelationships with other subjects.
- The applicant should be able to give a detailed description of the subject using theoretical fundamentals and specific examples.
- The applicant should understand and be able to use mathematical formula related to the subject.
- The applicant should be able to read, understand and prepare sketches, simple drawings and schematics describing the subject.
- The applicant should be able to apply his knowledge in a practical manner using manufacturer's instructions.
- The applicant should be able to interpret results from various sources and measurements and apply corrective action where appropriate.

PHYSICS

Welcome	iii
Revision Log.....	iii
Forward.....	iv
EASA License Category Chart	v
General Knowledge Requirements	v
Contents	ix

SUB-MODULE 01

MATTER

Knowledge Requirements	1.1
2.1 - Matter.....	1.2
Nature Of Matter	1.2
Isotopes	1.4
Chemical Compounds.....	1.5
States Of Matter	1.5
Plasma	1.5
Solid	1.5
Liquid	1.5
Gas	1.5
Changes Between States	1.5
Catalyst	1.6
Questions	1.7
Answers	1.8

SUB-MODULE 02

MECHANICS

Knowledge Requirements	2.1
2.2.1 - Statics	2.2
Forces, Moments And Couples	2.2
Center Of Gravity	2.2
Elements Of Stress, Strain, And Stress	2.2
Elements Of Theory Of Stress	2.2
Tension	2.2
Compression.....	2.3
Torsion	2.3
Shear	2.3
Bending Stress	2.3
Strain	2.4
Elasticity	2.4
Pressure and Buoyancy In Liquids	2.4
Fluid Pressure	2.4
Buoyancy	2.6
2.2.2 - Kinetics.....	2.8
Motion	2.8
Linear Movement	2.8
Speed And Velocity.....	2.8

Acceleration.....	2.9
Newton's Laws Of Motion	2.9
First law	2.9
Second Law	2.9
Third Law.....	2.10
Rotational Movement	2.10
Periodic Movement	2.11
Pendular Motion.....	2.11
Theory Of Vibration, Harmonics, Resonance.....	2.11
Vibration	2.11
Harmonics.....	2.12
Resonance	2.12
Velocity Ratio, Mechanical Advantage And Efficiency	2.12
Velocity Ratio	2.12
Simple Machine	2.12
Mechanical Advantage	2.13
The Lever	2.13
The Pulley.....	2.15
The Gear.....	2.15
Inclined Plane	2.18
The Wedge	2.19
Efficiency.....	2.19
2.2.3 - Dynamics	2.19
(A) Mass And Weight	2.19
Force	2.19
Inertia	2.19
Work	2.20
Power	2.20
Torque.....	2.21
Energy	2.22
Potential Energy.....	2.22
Kinetic Energy	2.23
Total Energy	2.23
Heat And Efficiency	2.23
(B) Momentum	2.23
Conservation Of Momentum	2.23
Impulse.....	2.24
Gyroscopic Principles	2.24
Friction	2.26
Static Friction.....	2.26
Sliding Friction	2.26
Rolling Friction	2.27
Coefficient Of Friction.....	2.27
2.2.4 - Fluid Dynamics	2.27
Density.....	2.27
Specific Gravity	2.28
Viscosity.....	2.29

CONTENTS

Fluid Resistance.....	2.29
Pascal's Law	2.30
Streamlining	2.32
Compressibility	2.32
Bernoulli's Principle	2.32
Questions	2.35
Answers	2.36

SUB-MODULE 03 THERMODYNAMICS

Knowledge Requirements	3.1
2.3 - Thermodynamics	3.2
Temperature.....	3.2
Thermal Expansion/Contraction	3.2
Heat Energy Units	3.3
Thermometers	3.3
Non-Electric Temperature Indicators	3.3
Electrical Temperature Indication	3.4
Electrical Resistance Thermometers	3.5
Ratiometer Electrical Resistance Thermometers	3.6
Thermocouple Temperature Indicators	3.6
Heat Definition	3.8
Specific Heat	3.8
Heat Transfer.....	3.9
Conduction	3.9
Convection	3.10
Radiation.....	3.11
Thermodynamic Laws	3.11
First Law.....	3.11
Second Law.....	3.11
Gas Laws	3.12
Boyle's Law	3.12
Charles' Law	3.13
General Gas Law	3.13
Dalton's Law	3.13
Ideal Gas Law	3.13
Work And Expanding Gases	3.14
Adiabatic	3.14
Isothermal	3.14
Engine Cycles	3.14
Constant Volume	3.14
Constant Pressure	3.15
Thermal Efficiency	3.15
Refrigeration And Heat Pumps	3.16
Latent Heat	3.17
Thermal Energy	3.17
Heat Of Combustion	3.17

Questions	3.19
Answers	3.20

SUB-MODULE 04 OPTICS (LIGHT)

Knowledge Requirements	4.1
2.4 - Optics.....	4.2
The Nature Of Light	4.2
Speed of Light.....	4.2
Reflection	4.2
Refraction	4.3
Lenses	4.3
Fiber Optics	4.4
Cable Construction	4.4
Fiber Modes	4.4
Termination And Splicing	4.5
Fiber Optic Data Link	4.6
Questions	4.9
Answers	4.10

SUB-MODULE 05 WAVE MOTION AND SOUND

Knowledge Requirements	5.1
2.5 - Wave Motion And Sound	5.2
Wave Motion	5.2
Mechanical Waves	5.2
Transverse Waves.....	5.2
Longitudinal Waves.....	5.2
Surface Waves	5.2
Electromagnetic Waves	5.3
Sinusoidal Wave Motion	5.3
Interference Phenomena	5.3
Standing Waves	5.3
Sound	5.3
Sound Waves.....	5.4
Speed Of Sound	5.5
Mach Number	5.5
Production of Sound.....	5.5
Sound Intensity.....	5.6
Pitch And Quality	5.6
Loudness	5.6
Doppler Effect	5.7
Questions	5.9
Answers	5.10
Acronym Index.....	A.1
Index	I.1

PERIODIC TABLE of the ELEMENTS

ELEMENT STATE at 0°C and 1 atm		
*	Solid	
**	Liquid	
***	Gas	

ELEMENT CATEGORIES									
■	■	■	■	■	■	■	■	■	■
ALKALI METALS	ALKALI EARTH METALS	LANTHANIDES	ACTINIDES	TRANSITION ELEMENTS	OTHER METALS	METALLOIDS	OTHER NONMETALS	HALOGENS	NOBLE GASES
UNKNOWN CHEMICAL PROPERTIES									

ALUMINUM 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 *** Gas Liquid ***																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118																	
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 4																	

Figure 1-2. The periodic table of elements.

a fourth shell starts to fill if the element still has more electrons. However, when the fourth shell contains eight electrons, the number of electrons in the third shell begins to increase again until a maximum of 18 is reached. (*Figure 1-3*)

The outer most orbital shell of any atom's electrons is called the valence shell. The number of electrons in the valence shell determines the chemical bonding properties of the material as well as other characteristics such as conductivity. When the valence shell has the maximum number of electrons, it is complete and the electrons tend to be bound strongly to the nucleus. Materials with this characteristic are chemically stable. It takes a large amount of force to move the electrons in this situation from one atom valence shell to that of another. Since the movement of electrons is called electric current, substances with complete valence shells are known as good insulators because they resist the flow of electrons (electricity). (*Figure 1-4*)

In atoms with an incomplete valence shell, that is, those without the maximum number of electrons in their valence shell, the electrons are bound less strongly to the nucleus. The material is chemically disposed to combine with other materials or other identical atoms to fill in the unstable valence configuration and bring the number of electrons in the valence shell to maximum. Two or more substances may share the electrons in their valence shells and form a covalent bond. A covalent bond is the

Shell or Orbit Number	1	2	3	4	5
Maximum Number Of Electrons	2	8	18	32	50

Figure 1-3. Maximum number of electrons in each orbital shell of an atom.

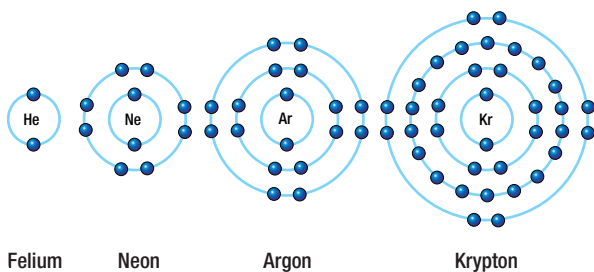


Figure 1-4. Elements with full valence shells are good insulators. Most insulators used in aviation are compounds of two or more elements that share electrons to fill their valence shells.

method by which atoms complete their valence shells by sharing valence electrons with other atoms. Molecules are formed this way.

Electrons in incomplete valence shells may also move freely from valence shell to valence shell of different atoms or compounds. In this case, these are known as free electrons. As stated, the movement of electrons is known as electric current or current flow. When electrons move freely from atom to atom or compound to compound, the substance is known as a conductor. (*Figure 1-5*)

ISOTOPES

When atoms of the same element have different numbers of neutrons, they are called isotopes. Because of the differing numbers of neutrons, various isotopes of the same element have different masses. Mass is the word for how much matter something has and therefore how much it weighs. Because different isotopes have different numbers of neutrons, they do not all weigh the same. Different isotopes of the same element have the same atomic number because they have the same number of protons. The atomic number is decided by the number of protons. (*Figure 1-6*)

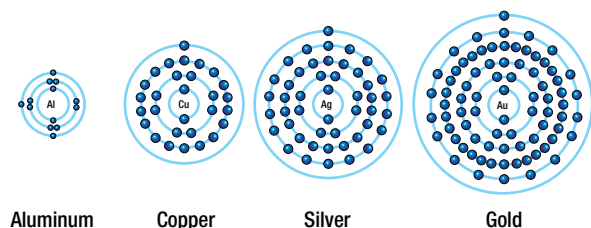


Figure 1-5. The valence shells of elements that are common conductors have one (or three) electrons.

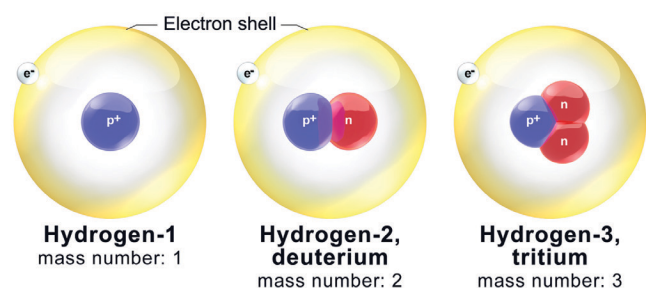


Figure 1-6. Isotopes of hydrogen.

Isotopes of the same element also have the same number of electrons and the same electronic structure. Because how an atom acts is decided by its electronic structure, isotopes are almost the same chemically, but they are different physically because of their different masses.

Hydrogen, the most common element, has three common isotopes. Its most common isotope with only one proton and no neutrons is called protium (^1H). A hydrogen atom with one proton and one neutron (atomic mass of 2) is called deuterium (^2H). A hydrogen atom with one proton and two neutrons (atomic mass of 3) is called tritium (^3H). Protium and deuterium are stable isotopes, while tritium is a radioactive isotope.

CHEMICAL COMPOUNDS

Materials made up of two or more elements that have chemically bonded are known as compounds. Compounds have properties different than the elements from which they are made. They can only be separated through chemical reaction. They have a unique chemical structure with a fixed ratio of atoms of different elements that are bonded together chemically. Compounds should not be confused with mixtures. Mixtures are atoms and molecules that are physically mixed together but are not chemically bonded. The properties and characteristics of a mixture are closely related or dependent on the properties of the individual constituents. Mixtures can usually be separated by filtering, evaporation or some other mechanical means.

STATES OF MATTER

Matter exists in four common states; solids, liquids, gases and plasma. A state of matter is the physical condition of a substance. Solids, liquids and gases are the primary states of matter of concern for the aviation maintenance professional. The compound(s) from which a substance is made do not change, regardless of the state of matter. Atoms and molecules that make up a substance are always in a state of motion due to heat energy in the material. The physical state of matter is related to the degree of motion between these particles with solids having the least motion and gases and plasma having the most.

PLASMA

Plasma is a unique state of matter comprised of ionized gas consisting of positive ions and free electrons in proportions resulting in a relatively neutral electric

charge. Its particles are close enough together that they act collectively when exposed to a magnetic field. Plasma is also electrically conductive. It is sustained easily at the extremely high temperatures present in stars and as such is the most common form of matter in the universe.

SOLID

Matter is said to be solid when it has a definite volume and shape. The molecules of a solid are tightly bound to each other. They resist changing shape or volume. Solids may be geometrically or irregularly structured. They are incompressible and do not contain enough movement of the molecules to permit a physical change of shape.

LIQUID

Liquid matter is characterized by molecules that have more energy and increased movement. This causes the molecules to be able to flow and not take a rigid shape such as a solid. Liquids take the shape of their container even though the volume of a liquid does not change significantly. Liquids are said to be incompressible. While liquid molecules are able to slide past each other, they are still closely packed enough that the application of pressure does little to change the volume. The molecules are also closely bound enough to each other that surface tension is created. Surface tension keeps liquids from complete freedom of expansion. It can be observed when a container is filled with a liquid to slightly over the brim yet the liquid does not spill over.

GAS

Matter also exists as a gas. This type of matter contains even more heat energy and movement in its molecules. The bonding that causes surface tension in a liquid does not exist in a gas. A greater space between molecules exists. Gases take the shape of their container but unlike liquids, gases are compressible. When pressure is applied, the molecules can be made to exist closer to each other. It is possible to put a gas under so much pressure that it changes to a liquid state.

CHANGES BETWEEN STATES

Matter can change between the states by adding or removing energy. The chemical composition of the material remains the same during all states of matter but the energy level causes it to be a solid, liquid, or gas. For example, water is always H_2O , millions of pairs of hydrogen atoms covalently bonded to a single oxygen atom loosely held next to each other in a liquid state.

When energy is removed and water becomes ice, it is still H_2O . However, the motion of the molecules is greatly reduced and they no longer have the energy to slide past one another as a liquid. The same is true when heat energy is added to water. Water vapor is formed as the motion of the molecules causes more freedom of movement between molecules. But the water existing as a gas (vapor) is still formed from millions of H_2O molecules.

The heat energy added or subtracted to a substance is typically measured by temperature. The higher the temperature of a substance, the more energy it contains. Heat always flows from hot to cold. These terms (hot and cold) express the relative amount of energy present in the substance. They do not measure the absolute amount of heat present. Without a difference in energy levels, there is no transfer of energy (heat).

Adding heat to a substance does not always raise its temperature. When a substance changes state, such as when a liquid changes into a vapor, heat energy is absorbed. This is called latent heat. When a vapor condenses into a liquid, this heat energy is given off. The temperature of a substance remains constant during its change of state. All energy absorbed or given off, the latent heat, is used for the change process. Once the change of state is complete, heat added to a substance raises the temperature of the substance. After a substance changes state into a vapor, the rise in temperature of the vapor caused by the addition of still more heat is called superheat.

The temperature at which a substance changes from a liquid into a vapor when heat is added is known as its boiling point. This is the same temperature at which a vapor condenses into a liquid when heat is removed. The boiling point of any substance varies directly with pressure. When pressure on a liquid is increased, its boiling point increases, and when pressure on a liquid is decreased, its boiling point also decreases. For example, water boils at 100°C (212°F) at normal atmospheric pressure (14.7 psi). When pressure on liquid water is increased to 20 psi, it does not boil at 100°C . More energy is required to overcome the increase in pressure. It boils at approximately 108°C (226.4°F). The converse is also true. Water can also boil at a much lower temperature simply by reducing the pressure upon it. With only 10 psi of pressure upon liquid water, it boils at 90°C (194°F). (*Figure 1-7*)

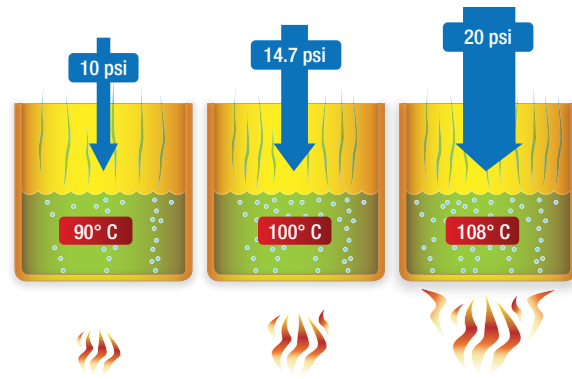


Figure 1-7. Boiling point of water changes as pressure changes.

Vapor pressure is the pressure of the vapor that exists above a liquid that is in an enclosed container at any given temperature. The vapor pressure developed by various substances is unique to each substance. A substance that is said to be volatile, develops high vapor pressure at standard day temperature 15°C (59°F). This is because the boiling point of the substance is much lower. The vapor pressure of any substance varies directly with temperature.

CATALYST

A catalyst is a substance that causes or accelerates a chemical reaction without itself being affected. A two part epoxy mix is a good example of a catalyst. The main ingredient is the epoxy resin itself. The second ingredient, when mixed with the resin, causes the resin to harden faster and then remains as part of the epoxy resin mix. The opposite of a catalyst is an inhibitor. Inhibitors slow down reactions.