



Principles *of* Helicopter Flight

Second Edition

W.J. Wagtendonk

Principles of Helicopter Flight

Walter J. Wagtendonk OBE

Second U.S. Edition, Revised 2006

Aviation Supplies & Academics, Inc.
7005 132nd Place, SE
Newcastle, Washington 98059-3153 U.S.A.

First published in New Zealand by Walter J. Wagtendonk, 1992

©2006 Walter J. Wagtendonk

All rights reserved.

Second edition, published 2006 by Aviation Supplies & Academics, Inc.

No part of this manual may be reproduced in any manner whatsoever including electronic, photographic, photocopying, facsimile, or stored in a retrieval system, without the prior written permission of the publisher.

Nothing in this manual supersedes any operational documents or procedures issued by the Federal Aviation Administration, aircraft and avionics manufacturers, flight schools, or the operators of aircraft.

Cover photo © iStockphoto.com/Johan Ramberg

Published in the United States of America

10 09 08 07 06 9 8 7 6 5 4 3 2 1

ASA-PHF-2

ISBN 1-56027-649-5

978-1-56027-649-4

Library of Congress Cataloging-in-Publication Data:

Wagtendonk, Walter J., 1929

Principles of helicopter flight / Walter J. Wagtendonk.

p. cm.

Includes index.

ISBN 1-56027-649-5

1. Helicopters—Aerodynamics. 2. Helicopters—Piloting

1. Title.

TL716.W32 1995

629.132' 5252—dc20

95-52965

CIP

Acknowledgments

United States

Amy Laboda, Editor

Don Fairbanks
Cardinal Helicopter Training,
Batavia, Ohio

Associate Professor W. (Bill) Hopper
Dept. of Aerospace and Technology,
Parks College of St Louis University
Cahokia, Illinois

Connie Reeves, Major (ret) US Army,
Dowell, Maryland

McDonnell Douglas
Seattle, Washington

Special thanks to Raymond W. Prouty
Westlake Village, California, for valuable
advice and permission to use copyright
material.

New Zealand

Flight Lieutenant Phil Murray,
Royal New Zealand Air Force (ret)

John Reid, MBE

Peter Tait
Helicopters NZ Ltd

Colin Bint

Andy Smith
Nelson Aviation College

Keith Broady, Nelson

Bill Conning
Helicopter Operations Ltd

Ann Wagtendonk

Air Commodore Stewart Boys CBE AFC
Royal New Zealand Air Force (ret)

Contents

Foreword **xi**
Preface **xii**

1. Physics 1

Newton's Laws **1** *Newton's First Law 1 Newton's Second Law 2
Newton's Third Law 3 Conclusion 3*
Mathematical Terms **3** *Velocity 3 Acceleration 3 Equilibrium 4
Gravitational Forces 4 Centripetal Force 5*
Vector Quantities **5**
Moments and Couples **6** *Moments 6 Couples 6*
Energy **6** *Pressure Energy 6 Dynamic (Kinetic) Energy 7*
Units of Measurement **7**
Graphs **8**
Review 1 10

2. The Atmosphere 11

Atmospheric Pressure **11** *Air Temperature 11 Combined Effects 12
Moisture Content 12 The Standard Atmosphere (ISA) 12
Pressure Altitude 13 Density Altitude 13 Summary 13*
Operational Considerations **14**
Review 2 14

3. Lift 15

Definitions **15**
The Lift Formula **18** *Dynamic Energy 20 Summary 20 Indicated
Airspeed and True Airspeed 21*
Center of Pressure **22**
Aerodynamic Center **24**
Review 3 26

4. Drag 27

Types of Drag **28** *Parasite Drag 28 Profile Drag 29 Form Drag 29
Skin Friction 30 Induced Drag 31 Tip Vortices 33 Effect of
Airspeed on Induced Drag 34 Effect of Aspect Ratio 34*
Methods to Reduce Induced Drag **35** *Wash-out 35 Tip Design 35*
Total Drag Curve **36**
Conclusion **37**
Review 4 38

5. Lift/Drag Ratio 39

Best (or Maximum) L/D Ratio **40**
Other Factors Influencing L/D Ratio **41**
Conclusion **41**
Review 5 42

6. Aerodynamic Forces 43

Definitions 43

Rotor Systems 45

Introduction 45

Rotational Airflow (V_r) 46

Blade Angle of Attack 46

Induced Flow 47

Airflow Caused by Aircraft Velocity 48

The Forces 48 *Total Rotor Thrust* 49 *Rotor Drag (Torque)* 49 *Angle of Attack and the Rotor Thrust/Rotor Drag Ratio* 50 *Induced Flow and the Rotor Thrust/Rotor Drag Ratio* 50

Inflow Angle 51

The Force Opposing Weight 52

Factors Influencing Rotor Thrust 53 *Air Density* 53 *Rotor rpm* 54 *Blade Angle* 54 *Disc Area* 54 *Significant Aspects of High Inertia Blades* 55

Conclusion 55

Review 6 56

7. Rotor Blade Airfoils 57

Drag Factors 57

Stress Factors 58

Effect of Local Air Velocity on Blade Design 59

Blade Tip Speeds 59

Development in Blade Design 60

Review 7 60

8. Rotor Drag (Torque) 61

Disc Loading Changes 61

Changes in Gross Weight 62

Changes in Altitude 62

Changes in Configuration 62

Ground Effect 62

Translational Lift 64

Summary 65

Review 8 66

9. The Anti-Torque Rotor 67

Anti-Torque Functions 67 *Mechanical Considerations* 68 *Anti-Torque and Demand for Power* 68 *Effect of the Wind* 69

Translating Tendency (Tail Rotor Drift) 70

Rolling Tendency 71

Tail Rotor Flapping 71

Shrouded Tail Rotors 72

Tail Rotor Design 72

Other Methods of Anti-Torque Control 72 *Strakes and Anti-Torque* 73

Tail Rotor Failure 74

Review 9 76

10. Controls and Their Effects 77

Collective Control 77

Cyclic Control 78

Effect of Controls on Blade Lead-Lag Behavior 78 *Mean Lag Position* 78

The Four Main Causes of Movement about the Lead/Lag Hinge 78

Conservation of Angular Momentum (Coriolis Effect) 78 *Hookes*

Joint Effect 79 *Periodic Drag Changes* 80 *Random Changes* 80

Review 10 80

11. The Hover 81

Hover Out-of-Ground Effect (OGE) and In-Ground Effect (IGE) 81

Factors Affecting Ground Effect 82 *Helicopter Height Above Ground*

Level 82 *Density Altitude and Gross Weight* 82 *Gross Weight*

and Power Required 83 *Nature of the Surface* 83 *Slope* 83

Wind Effect 84

Confined Areas – Recirculation 84 *Factors Determining the Degree of*

Recirculation 84

Over-Pitching 85

Review 11 86

12. Forward Flight 87

Three Basic Aspects of Horizontal Flight 89 *Tilting the Disc with*

Cyclic 89 *An Alternate Explanation of Cyclic Action* 91

Dissymmetry of Lift 91 *Eliminating Dissymmetry of Lift* 92

Blow-Back (Flap Back) 94 *Blow-back (Flap-Back) When Using*

Collective 95

Summary 96

Designs that Reduce Flapping Amplitude 96 *Delta-3 Hinges* 96

Offset Pitch Horns 97

Reverse Flow 98

Translational Lift 99

Transverse Flow Effect 101

Review 12 102

13. Power, Range and Endurance 103

Power 103 *Ancillary Power* 103 *Profile Power* 103 *Induced Power*

104 *Parasite Power* 104

The Total Horsepower Required Curve (the HPR) 105 *Altitude* 106

Weight 107 *Slingload and Parasite Drag Items* 107

Flying the Helicopter for Range 108 *Effect of the Wind* 109 *Engine*

Considerations 110 *Range Summary* 110

Flying the Helicopter for Endurance 111 *Endurance Summary* 111

Review 13 112

14. Climbing and Descending 113

Climbing 113

The Horsepower Available Curve (The HPA) 114

Factors Affecting the Horsepower Available Curve 114 *Altitude 114*
Density Altitude 115 Leaning the Mixture 115 Collective Setting 115

Rate of Climb 115

Angle of Climb 116

Effect of Lowering Horsepower Available Curve 116 *Summary 117*

Effect of the Wind 117

Climb Performance Summary 118

Descending 118

Angle of Descent 119

Effect of the Wind on Descents 120

Descent Performance Summary 121

Review 14 122

15 Maneuvers 123

Turning 123

Rate of Turn 124

Radius of Turn 125

Rate and Radius Interaction 125

The Steep Turn 125 *Power Requirement 126*

The Climbing Turn 127

The Descending Turn 127

Effect of Altitude on Rate of Turn and Radius of Turn 127

Effect of Changes in Gross Weight on Rate and Radius 128

Effect of the Wind on Rate and Radius 128

Effect of the Wind on Indicated Airspeed and Translational Lift 129

Effect of Slingloads 130

Effect of Slipping and Skidding 131

Pull-Out from a Descent 131

Review 15 132

16. The Flare 133

Initial Action 133

Flare Effects 133 *Thrust Reversal 134 Increasing Total Rotor Thrust*
134 Increasing Rotor rpm 134

Management of Collective 135

Review 16 136

17. Retreating Blade Stall 137

Effect of Increasing Airspeed on Stall Angle 137

Factors Affecting the Advancing Blade 138

Symptoms of Retreating Blade Stall 138

Recovery 139

Factors Influencing V_{ne} 140

Conclusion 141

Review 17 142

18 Autorotation 143

Initial Aircraft Reaction **143**

The Lift/Drag Ratio and Forces Involved **143** *The Stalled Region 144*
The Driven (Propeller) Region 145 *The Driving (Autorotative)*
Region 145 *Combined Effects of All Regions 146*

Autorotation and Airspeed **148** *Combined Effect 149* *Effect of*
Forward Speed on the Three Regions 150 *Effect of Airspeed*
Changes on Rotor rpm 150

Autorotation Range and Endurance **150** *Effect of Altitude on Range*
and Endurance 151 *Effect of Gross Weight on Range and*
Endurance 151 *Effect of Parasite Drag and Slingloads on Range*
and Endurance 152

Touchdown **152**

Loss of Power at Low Heights **153**

Factors Influencing Rotor rpm Decay When the Engine Fails **153**

Combination of Airspeed and Height Best Avoided **153**

Review 18 156

19 Hazardous Flight Conditions 157

Vortex Ring State **157** *Effect on the Root Section of the Blade 158*
Effect on the Tip Section of the Blade 158

Flight Conditions Likely to Lead to Vortex Ring State **160**

Symptoms of Vortex Ring State **160**

Recovery from Vortex Ring State **161**

Tail Rotor Vortex Ring State **161**

Ground Resonance **162**

Causes of Ground Resonance **162**

Factors that May Cause Ground Resonance **163** *Rotor Head*
Vibrations 163 *Fuselage Factors 163*

Ground Resonance Recovery Action **164**

Blade Sailing **164**

Dynamic Rollover **165**

Factors Influencing the Critical Angle **165**

Cyclic Limitations **166**

Mast Bumping **167**

Avoiding Mast Bumping **169**

Recovery from Low and Zero g **169**

Mast Bumping Summary **169**

Exceeding Rotor rpm Limits **169**

Reasons for High Rotor rpm Limits **169** *Engine Considerations 169*
Blade Attachment Stress 169 *Sonic Problems 170*

Reasons for Low Rotor rpm Limits **170** *Insufficient Centrifugal Force*
170 *Reduced Tail Rotor Thrust 170*

Rotor Stalls **170**

Recovery from Low Rotor rpm **171**

Review 19 172

20. Helicopter Design and Components 173

Transmission **173**
Main Rotor Gear Box **173**
Freewheeling Unit **174**
Drive Shafts **174**
Tail Rotor Gear Box **174**
Rotor Brake **174**
Clutch **174**
Chip Detectors **175**
Governors **175**
Swashplate (Control Orbit) **176** *Phase Lag* **177** *Advance Angle* **177**
Rotor Blades **179** *Chordwise Blade Balancing* **180** *Spanwise Blade Balancing* **180**
Trim Controls **180** *Bias Control* **180** *Electronic Servo Systems* **180**
Tail Rotors **181** *Tail Rotor Flapping* **181** *Tail Rotor Rotation* **181**
Helicopter Vibrations **181** *Types of Vibrations* **182** *Vertical Vibrations* **182** *Lateral Vibrations* **183** *Combined Vertical and Lateral Vibrations* **183** *High Frequency Vibrations* **183** *Engine Vibrations* **184** *Remedial Action by the Pilot* **184**
Control Functions **184** *Collective* **184** *Twist Grip Throttle* **184**
Engine Cooling **185**
Carburetor Icing **185**
Dual Tachometer Instruments **186**
Rotor Stabilizing Design Systems **187** *The Bell Stabilizing Bar* **187** *The Hiller System* **187** *The Underslung Rotor System* **188**
Rotorless Anti-Torque System **189**
Advantages of the NOTAR System **189**
Components **189** *Air Intake* **190** *Engine-driven Fan* **190** *Slots* **190** *Direct Jet Thruster* **191** *Vertical Stabilizers* **191**
Undercarriages **192** *Skids* **192** *Wheels* **192** *Oleo (Shock) Struts* **193**
Review 20 **195**

21. Stability 195

Static Stability **195**
Dynamic Stability **195**
Stability in the Three Planes of Movement **196**
Longitudinal Stability **197** *Longitudinal Stability Aids* **197**
Lateral Stability **198**
Directional Stability **199** *Directional Stability Aids* **200** *Cross Coupling with Lateral Stability* **200**
Offset Flapping Hinges **200**
Review 21 **202**

22. Special Helicopter Techniques 203

Crosswind Factors **203** *Lateral Blow-back (Flap-back)* **203** *Weathervane Action* **203** *Effect on tail Rotor Thrust* **203**
Different Types of Takeoffs and Landings **204**
Downwind Takeoffs and Landings **204**
Running Takeoff **204**
Cushion-Creep Takeoff **205**
Confined Area Takeoff (Towering Takeoff) **205**
Maximum Performance Takeoff **206**

Running Landing **206**
The Zero-Speed Landing **207**
Operations on Sloping Surfaces **207**
Sling Operations **208**
The Equipment **208** *The Sling* **210**
Ground Handling **211**
Flying Techniques **212** *Snagging of Cable or Strap on the Undercarriage before Liftoff* **212** *Never-Exceed Speed (V_{ne})* **213** *Preflight Rigging* **213** *Length of Cable or Strap* **213** *Number and Type of Slings* **213** *Nets* **213** *Pallets* **214** *Load Center of Gravity* **214** *Pilot Action in Case of Helicopter Oscillation* **214** *The Approach* **215**
Types of Slingload **215** *Horizontal Loads* **215** *Unusual Loads* **216**
Conclusion **219**
Review 22 **220**

23. Mountain Flying 221

Updrafts and Downdrafts **221**
Thermal Currents **223**
Katabatic and Anabatic Winds **224**
Mechanical Turbulence **224** *Wind Strength* **225** *Size and Shape of Mountains* **226** *Stability or Instability of Air* **226** *Wind Direction Relative to Mountain Orientation* **227**
Summary **227**
Valley Flying **227**
Ridgeline Flying **228**
The “Standard” Mountain Approach **228**
General Comments on Mountain Approaches **230** *High Altitude Approach Considerations* **230** *Transition* **232** *Ground Effect Considerations on Mountain Sites* **232** *Determining Wind Change during Critical Phases* **233** *Landing Site Selection* **233** *Surface of Sites* **233** *Flight in Areas Covered in Snow and Ice* **234**
Survival Equipment **235**
Review 23 **236**

24. Helicopter Icing 237

Ice Accretion **237** *Influence of Temperature and Drop Size* **237** *Water Content of Air* **238** *Kinetic Heating* **238** *Shape of Airfoils and Other Aircraft Components* **238** *Mechanical Flexion and Vibration* **239**
Ice Formation on Blades at Different Temperatures **239**
Electrical Anti-Icing **240**
Consequences of Ice Accretion **240**
Engine Intake Icing **241**
Review 24 **242**

25. Helicopter Performance 243

Helicopter Performance Factors **243**

Altitude **243**

Pressure Altitude **244**

Density Altitude **246** *Combined Effect of Pressure and Density Altitude* **247**

Moisture Content of Air **248**

Aircraft Gross Weight **248**

External Stores **248**

The Wind **249**

Power Check **249**

Performance Graphs **250** *Units of Measurement* **251**

Hover Ceiling Graph **252**

Takeoff Distance over a 50-Foot Obstacle **254**

Turbine Engine Power Check **256**

Maximum Gross Weight for Hovering **258**

Climb Performance **260**

Range **261**

Endurance **262**

Review 25 **263**

26. Weight and Balance 265

Definitions **265**

Weight **267**

Balance **267**

Beyond the Center of Gravity Limits **268** *Excessive Forward Center of Gravity* **268** *Excessive Aft Center of Gravity* **269** *Summary* **269**

Calculating the Center of Gravity Position **269** *To Calculate the Longitudinal Center of Gravity Position* **271** *To Calculate the Lateral Takeoff Center of Gravity Position* **271** *Summary* **273**

Effect of External Loads on Center of Gravity Position **273**

Conclusion **274**

Review 26 **274**

Appendix 1 — Sample Examination **277**

Appendix 2 — Temperature Conversion **287**

Appendix 3 — Altimeter Setting Conversion **289**

Appendix 4 — Review and Examination Answers **291**

Glossary — **295**

Index — **299**

If you want to fully understand the principles of helicopter aerodynamics, you must understand certain terms, laws and theorems in physics. This chapter deals with principles of physics that have a direct bearing on helicopter flight.

Newton's Laws

Sir Isaac Newton theorized three basic laws, all of which pertain to flying helicopters.

Newton's First Law

All bodies at rest or in uniform motion along a straight line will continue in that state unless acted upon by an outside force.

Newton's first law defines the principle of *inertia*, which means that bodies tend to keep doing what they are doing. If they are "doing" anything at all while in motion, the path the body travels is a straight line. If change is required, then a force must be applied to achieve that change. For example, getting a locomotive moving down a track requires a force which would be greater than the force required to get a small car rolling along a level road. The fundamental physical difference between a locomotive and a compact car is their mass. Mass means the amount (or quantity) of matter in a body; it is directly proportional to inertia. Thus to change the state of rest of any body, a force is required that must be proportional to the mass of that body. The larger the mass and thus the greater its inertia, the greater the force required.

A body's inertia does not change unless its mass changes. A helicopter at sea level or at altitude, flown fast or slow, has the same inertia, provided its mass does not change.

The term inertia is often confused with momentum. Momentum considers not only the mass of the body concerned, but also the velocity at which it travels. Bodies at rest cannot have momentum, although they do have inertia. For a given mass within a body, the faster it travels, the greater its momentum.

Momentum is formulated as:

$$\text{Momentum} = m \times V$$

where m represents mass and V represents velocity.

When a helicopter travels faster, its momentum increases and a greater force is required to bring it to a halt. Alternatively, if its velocity stays the same, but there are more people on board, then momentum increases, this time because of the increase in mass and again, a greater force is required to bring the aircraft to a stop.

The greater the mass of a body, the greater its inertia and the greater the force required to change its state of rest or uniform motion along a straight line.

This principle applies no matter where the body is or whether it is moving fast, slow or not at all.

For a given mass, however, if it has velocity it will have momentum as well as inertia.

The greater the velocity, the greater the momentum and the greater the force required to change its state of uniform motion along a straight line.

In short, all bodies have mass and inertia, but not all bodies have momentum. Only those bodies that have velocity have momentum, too.

There are many instances in everyday flying where inertia and momentum play an important part in operating a helicopter. Once you understand their influences you can better anticipate the magnitude of control inputs needed to make required changes within a safe distance or time. For example, if a pilot makes an approach into a confined area when the aircraft is at its maximum gross weight and at a high rate of descent, then the helicopter's inertia is high because of its large mass and its momentum is high because of its high vertical velocity. The pilot must arrest the momentum downward with another force, usually involving power, to prevent the ground impact from being the force that arrests the momentum!

Newton's Second Law

Force is proportional to Mass x Acceleration.

To accelerate a body at a given rate, the force used must be proportional to the mass of that body. Alternatively, if a given mass must be accelerated at a higher rate, then the force required must be greater.

The accelerated air (the induced flow) through a rotor system, which produces the required force for sustained flight, is a good example of this law in action. If the amount of air is increased, then its mass is greater, and as a result the acceleration required can be reduced to provide the same upward force. Alternatively, if the aircraft is heavier and the force required to keep it airborne is greater, then for the same mass of air processed through the rotor disc, its acceleration needs to be greater.

Newton's Third Law

For every action there is an equal and opposite reaction.

Newton's third law is often misused by assuming that the word action means force. One force is not always equally opposed by another. Only when no acceleration takes place, either in terms of speed or direction, could one say that all forces are equal and opposite and only then could one say that to each force there is an equal and opposite force.

When a helicopter hovers at precisely one height, all actions (and in this case "forces") have equal and opposite reactions, but this applies only so long as there is no accelerated movement up/down, left/right or fore/aft.

Conclusion

Newton's laws have a fundamental influence on all aspects of helicopter flight. Throughout this book many of these aspects can be referenced to this chapter and it is therefore important that you have a good understanding of the principles.

Mathematical Terms

In explaining Newton's laws (and those that follow) everyday words are used, such as velocity and acceleration. Although these words appear to be simple and straightforward, in mathematical terms they are somewhat more complex and may require re-learning.

Velocity

Velocity means: speed and direction. The problem here is the inclusion of the term "direction" as an integral part of the word velocity. To say that one's car, traveling at 50 mph, has a velocity of 50 mph is wrong unless a direction value is included. You could only say that a car has a velocity of 50 mph if the vehicle travels at that speed in a given direction, for example, due north. Although this aspect is not of earth-shattering importance on its own merits, the issue is vital when other terms are considered that relate to velocity, such as acceleration.

Acceleration

Acceleration is simply the rate of change of velocity. If the term velocity is understood correctly, it is clear that by changing either the speed part of velocity or the direction part of velocity, one has changed velocity and because of that, acceleration has been established.

Imagine a helicopter maintaining exactly 50 knots in a steady turn to the right. Although the aircraft's speed is unchanged, its direction is not; in fact its direction is constantly changing. The aircraft is accelerating because of this continuous change in direction.

Understand then, that by altering either the speed of an object or its direction, or both, the object is accelerating.

In this context, slowing down (commonly referred to as deceleration) is also acceleration, but in a negative sense.

Equilibrium

Equilibrium means: a state of zero-acceleration. When an object travels in a straight line at a constant speed, its velocity is constant (since there is no change in either speed or direction). It can then be said that the object is in equilibrium. If an object travels at a steady 50 mph on a curve, however, it must be accelerating because its direction is constantly changing and it can then not be in equilibrium.

The terms *equilibrium* and *balanced forces* are often confused. Whenever a body travels at a steady speed on a curve, it cannot possibly be in equilibrium because direction is continuously changing. If the curve on which it travels has a perfect and constant radius, however, then all the forces acting on it will be equal and opposite (this assumes there is centrifugal force). Thus it is possible to have balanced forces, yet no equilibrium. To illustrate, a helicopter doing perfect steep turns at a constant altitude, speed and radius is not in equilibrium, but forces acting upon the aircraft are balanced.

Gravitational Forces

Nature's laws dictate that an attractional force exists between all masses. The greater the masses, the greater the force of attraction is between them. In addition to the size of the masses, the distance between them also has an influence: the greater the distance between masses, the less the attractional force.

This law is not always easy to see because any two adjacent masses, or objects, do not always move towards each other. Just because that movement is not evident, however, does not mean that the attractional force isn't there. In most cases, the drag between the objects and the surface they are resting on is greater than the force of attraction between them and so movement is prevented.

The earth is essentially an object of great mass that exerts a large attractional force on any other object in its proximity. The result of this attractional force on any given mass, or object, is called *weight*. The earth's gravitational force originates from its core and acts on the core of any other mass nearby. The farther the object from the earth's core, the less affected it is by the earth's gravity. Since the result of this attraction is called weight, it follows that the mass further removed must have less weight. Indeed, when the distance between earth and a body becomes so large that the attractional force between them becomes negligible, the body is said to be weightless. To say in this instance that it has no weight at all would be technically incorrect because there is still an earth attractional force, but it is now so small as to be unrecognizable.

Earth attractional force has the symbol g , while the mass it acts on has the symbol m . Thus weight can be formulated as:

$$\text{Weight} = m \times g$$

This means that the greater the mass for a given "g" the greater the weight or, the greater the distance away from earth for a given m , the less the weight. Remember that mass does not vary if the number of molecules is not altered, but the weight of this mass will change with significant changes in altitude.

Principles of Helicopter Flight

Second Edition

Principles of Helicopter Flight, by Walter J. Wagtendonk, explains the complexities of helicopter flight in clear, easy-to-understand terms. The worldwide helicopter industry has waited a long time to see a manual of this caliber.

This Second Edition adds discussions on the NOTAR system and strakes, as well as the frequently misunderstood principles of airspeed and high altitude operations. Chapter reviews and a concluding practice exam ensure your grasp of the principles learned from this book.

Helicopter pilots need to thoroughly understand the consequences of their actions, and base them upon sound technical knowledge. This textbook provides the background knowledge explaining why the helicopter flies and, more importantly, why it sometimes doesn't. It examines the aerodynamic factors associated with rotor stalls, mast bumping, wind effect, as well as maneuvering flight to include the hover, forward flight, the flare, and autorotation. Helicopter design and components, performance, and weight and balance is covered, along with special techniques such as different types of takeoffs and landings, operating on sloping surfaces, sling operations, mountain flying, and helicopter icing. Technical knowledge and sound handling are the ingredients that make a pilot safe.

For the student learning to fly helicopters in the 21st century, this book is one of the essential keys to flight.



“Wal” Wagtendonk served in the Royal New Zealand Air Force, retiring as an A-2 instructor in 1960. After working with the Nelson Aero Flight Club as Manager and Chief Flight Instructor, Wal, with his wife Ann, formed the Nelson Aviation College in Motueka,

which blossomed into one of New Zealand's best known theory and flight training establishments. Nelson Aviation College became the first “approved” school to conduct both fixed-wing and helicopter courses, and many experienced helicopter pilots currently flying all over the world started their basic training under Wal's careful instruction.

Wal was born in The Netherlands, and emigrated to New Zealand at age 20. Having retired in 1990, Wal and Ann now reside in the Bay of Plenty on New Zealand's North Island.



Aviation Supplies & Academics, Inc.
7005 132nd Place SE
Newcastle, WA 98059-3153
www.asa2fly.com • 1-800-ASA-2-FLY