Contents

Preface ix

Foreword x

Acknowledgements xi

List of Symbols xiii

I Mathematics and Physics 1

1 Mathematical Concepts 3

1.1 Arithmetic . . . 3
1.2 Working with Algebraic Expressions . . . 13
1.3 Quadratic Formula Derivation . . . 24
1.4 Function Notation . . . 26
1.5 Geometry . . . 28
1.6 Trigonometry . . . 52
1.7 Coordinate Systems . . . 63
1.8 Simultaneous Equations . . . 69
1.9 Triangulation . . . 74
1.10 Calculus . . . 76
1.11 Centroids and Average Values . . . 95

2 Standards for Measurement 107

2.1 Measurement . . . 107
2.2 Physical Quantities and Units of Measure . . . 107
2.3 Accuracy and Precision . . . 123
2.4 Numerical Precision . . . 125
2.5 Quantifying Uncertainty . . . 128

Copyright

3 Vectors **131**

3.1 Vector and Scalar Quantities . . . 131
3.2 Vector Basics and Drawing Vectors . . . 133
3.3 Length of a Vector . . . 135
3.4 Vector Addition . . . 137
3.5 Vector Subtraction . . . 139
3.6 Vector Multiplication . . . 140
3.7 Resolving a Vector into Components . . . 145

4 Motion In One Dimension **149**

4.1 The Study of Motion: Kinematics . . . 149
4.2 Rectilinear Motion . . . 151
4.3 Uniformly Accelerated Motion . . . 157
4.4 Variable Acceleration . . . 162
4.5 Relative Motion . . . 174

5 Motion in More than One Dimension **179**

5.1 Degrees of Freedom . . . 179
5.2 Motion in Space . . . 179
5.3 Displacement . . . 181
5.4 Speed and Velocity . . . 182
5.5 Acceleration . . . 185
5.6 Uniform Projectile Motion . . . 186

6 Dynamics and Newton's Laws of Motion **193**

6.1 Newton's First Law . . . 193
6.2 Newton's Second Law . . . 194
6.3 The Concepts of Mass and Weight . . . 195
6.4 Newton's Third Law . . . 196
6.5 The Concept of Friction . . . 196
6.6 Free Body Diagrams . . . 198
6.7 The Concept of Torque . . . 199
6.8 The Concept of Equilibrium . . . 202
6.9 Center of Mass . . . 207
6.10 Dynamic Weight Shift . . . 215

Copyright

7 Work and Energy **221**
7.1 Work . . . 221
7.2 Mechanical Energy . . . 226
7.3 Conservation of Energy . . . 229
7.4 Work–Energy Theorem . . . 233
7.5 Derivation of the Kinetic Energy Formula . . . 234
7.6 Power . . . 236

8 Linear Momentum **245**
8.1 Linear Momentum and Impulse . . . 245
8.2 Conservation of Linear Momentum . . . 251
8.3 In-Line Momentum . . . 252
8.4 Elastic and Inelastic Collisions . . . 257
8.5 The Presence of External Forces . . . 263

9 Rotational Mechanics **273**
9.1 Uniform Circular Motion . . . 273
9.2 Lateral Acceleration . . . 275
9.3 Rotational Motion . . . 279
9.4 Mass Moment of Inertia . . . 280
9.5 Newton's Second Law for Rotation . . . 286
9.6 Changing Torque and Gear Ratios . . . 287
9.7 Rotational Kinetic Energy . . . 290
9.8 Angular Momentum . . . 292
9.9 Eccentric Collision Analysis Using Rotational Mechanics . . . 302

II Selected Topics in Traffic Crash Reconstruction **315**

10 Friction and Acceleration Factors **317**
10.1 Coefficient of Friction . . . 317
10.2 Acceleration (Drag) Factor . . . 318
10.3 Evidence of Maximum Friction . . . 320
10.4 Determining Drag Factors . . . 322
10.5 Effects of Uneven Braking on Drag Factor . . . 326
10.6 Gathering Road Friction Data . . . 328
10.7 Determining Drag Factors from Test Data . . . 337
10.8 The Friction Circle and Lateral Friction . . . 338

Copyright

11 Speed Equations **341**
11.1 Work–Energy Theorem . . . 341
11.2 Basic Speed Equation . . . 342
11.3 Multiple Surfaces . . . 345
11.4 Combined Speed Equation . . . 348
11.5 Work Done by Each Wheel . . . 349
11.6 Adjusting the Drag Factor for a Changing Slope . . . 354
11.7 Speed from a Spin Analysis . . . 358
11.8 Rules For Combining Speeds . . . 362

12 Time–Distance Relationships **371**
12.1 Review of Definitions . . . 371
12.2 Velocity Equations . . . 372
12.3 Time Equations . . . 379
12.4 Distance Equations . . . 387
12.5 Acceleration and Drag Factor Equations . . . 393
12.6 Acceleration Rate . . . 401
12.7 Sample Time–Distance Work Problems . . . 402
12.8 Perception–Response Time . . . 418

13 Critical Speed Yaw **435**
13.1 Definition of Critical Speed Yaw . . . 435
13.2 Characteristics of the Tire Mark Evidence . . . 436
13.3 Measuring Protocol for the Tire Mark Evidence . . . 438
13.4 Determining the Lateral Acceleration Factor . . . 442
13.5 Calculation Methodologies . . . 446
13.6 Derivation of the Critical Speed Yaw Equation . . . 453
13.7 Case Study . . . 464
13.8 Nontraditional Critical Speed Yaw Analysis . . . 470

14 Lane Change and Turn-Away Equations **475**
14.1 Derivation of the Lane Change Equation . . . 476
14.2 Turn-Away Equations . . . 479
14.3 Using the Lane Change Equations . . . 480
14.4 Speed Computations . . . 484
14.5 A Comparison of Steady-State and Transient Behavior . . . 485
14.6 Validation Testing . . . 487

Copyright

15 Airborne Analysis **491**
15.1 Developing the Airborne Equation . . . 491
15.2 Evidence of Projectile Trajectory . . . 494
15.3 Magnitude and Direction of Velocity at Landing . . . 496
15.4 Maximum Flight Height Attained if Takeoff Velocity Is Known . . . 498
15.5 Horizontal Distance Traveled if Takeoff Velocity Is Known . . . 499
15.6 Minimum Takeoff Speed–Same Landing Height . . . 506
15.7 Minimum Take Off Speed for Any Height . . . 509
15.8 Applications of Airborne Analysis . . . 511

16 Collision Analysis Using Conservation of Linear Momentum **523**
16.1 Introduction . . . 523
16.2 Collision Types and Configurations . . . 524
16.3 Collision Analysis Examples in One Dimension . . . 525
16.4 Collision Analysis in Two Dimensions . . . 531
16.5 Evidence Required for COLM Analysis . . . 554
16.6 Special Considerations and Limitations . . . 556
16.7 Summary . . . 570

17 Collision Analysis Using Damage Momentum **575**
17.1 Review of Conservation of Linear Momentum Analysis . . . 575
17.2 Using Damage Momentum Analysis . . . 577
17.3 In-Line Collisions Between Two Vehicles . . . 583
17.4 Non-Central or Offset Collision Analysis . . . 594

18 Damage (Crush) Collision Analysis **609**
18.1 The General Energy Model . . . 609
18.2 CRASH III Deformation Model . . . 611
18.3 Calculating $\Delta\mathbf{v}$ Using the Effective Mass Ratio . . . 633
18.4 Collision Forces and Collision Times . . . 635
18.5 PDOF and Direction of $\Delta\mathbf{v}$ . . . 639
18.6 Damage Profile Measuring Procedures . . . 645
18.7 Crush Equation Summary . . . 666
18.8 Limitations of Crush Analysis . . . 669

19 Using Simultaneous Equations to Solve In-Line Collisions **675**
19.1 Conservation of Linear Momentum . . . 675
19.2 Energy Balance . . . 680

Copyright

19.3 Simultaneous Equations 685
19.4 Summary 689

20 Introduction to Rollover Analysis 691
20.1 Introduction 691
20.2 Rollover Taxonomy 692
20.3 Scene Evidence 695
20.4 Evidence from the Vehicle 697
20.5 Rollover Dynamics 707
20.6 Who was Driving? 715
20.7 Summary 716

A Off-Tracking In Low Speed Turns 717
A.1 Off-Tracking 717
A.2 Turning Geometry 719
A.3 Turning Radius 721
A.4 Calculating Off-Track Distance 726
A.5 Summary 736

B Vehicle Speed from Engine/Transmission Considerations 737

C Crush Energy Factors 739

Bibliography 741

Index 747

Copyright