

Fundamentals of  
**PHYSICS**

David Halliday

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# PHYSICS

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# Preface

During the past few years, we have observed gradual but steady changes in the character of the calculus-based introductory physics course. In a large number of schools, less time is available than was previously the case. In others, it appears that not so much attention may be given to a careful and detailed explanation of the subject matter. Also, changes in course requirements at the upper levels of science and engineering curricula have indicated the need for a shorter book than *Physics*.\*

For these reasons and others, we have been persuaded to prepare an alternate version of the earlier book. The modifications have taken several forms. One has been to remove a large amount of the supplementary material and some of the appendix material that appear in *Physics*. Another has been to condense several chapters and to combine some of them. This necessarily led to careful rewriting and we took advantage of this opportunity to revise some of the material of Part II as well. Other alterations were made in the questions and problems. Many new problems have been added and some, such as those applying to deleted material, have been removed. A number of the new problems fall into what we describe as a “confidence-building” category.

The effect of this surgery has been to decrease appreciably the size of the book and to reduce somewhat its level of sophistication without sacrificing a broad coverage of the fundamentals. *Fundamentals of Physics* emerges then as both a shorter and an easier alternative to *Physics*. This book consequently will be relevant to those courses in which time and prior preparation of the student do not permit the use of the more thorough treatment and somewhat more rigorous pace set by *Physics*.

Authors are perhaps the least qualified persons to engage in an abridgment of their works. We were very fortunate to have had the active assistance of Farrell Edwards and John Merrill, both of Utah State University, in this task. Professors Edwards and Merrill have taught a one-year physics course at their school for some time and are experienced in ways to achieve the objectives we sought. They discussed with us in detail where material ought to be removed or condensed. They joined us in doing much of the required rewriting and contributed a number of new problems. And, equally important, they did much of the work involved in seeing the book safely through production. To them go our heartfelt thanks. Completing this book in a reasonable length of time would not have been possible without their contributions.

We are grateful to Wiley for its outstanding cooperation and especially to Donald

\* David Halliday and Robert Resnick, *Physics*, Wiley, New York, 1966.

Deneck, Physics Editor, whose management of this task was superb. Richard Martin, of Alfred University, was also helpful in providing additional material for the problem sets of most of the chapters.

We believe that *Fundamentals of Physics* is relevant and appropriate to a new spectrum of students and courses, and hope it will contribute to the improvement of physics education.

*January, 1970*

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# Contents

<b>1</b>	
<b>Measurement</b>	<b>1</b>
1-1 Physical Quantities, Standards, and Units	<b>1</b>
1-2 Reference Frames	<b>2</b>
1-3 Standard of Length	<b>3</b>
1-4 Standard of Time	<b>4</b>
1-5 Systems of Units	<b>7</b>
<b>2</b>	
<b>Vectors</b>	<b>11</b>
2-1 Vectors and Scalars	<b>11</b>
2-2 Addition of Vectors, Geometrical Method	<b>12</b>
2-3 Resolution and Addition of Vectors, Analytic Method	<b>13</b>
2-4 Multiplication of Vectors	<b>18</b>
<b>3</b>	
<b>Motion in One Dimension</b>	<b>25</b>
3-1 Mechanics	<b>25</b>
3-2 Particle Kinematics	<b>25</b>
3-3 Average Velocity	<b>26</b>
3-4 Instantaneous Velocity	<b>27</b>
3-5 One-Dimensional Motion—Variable Velocity	<b>28</b>
3-6 Acceleration	<b>31</b>
3-7 One-Dimensional Motion—Variable Acceleration	<b>32</b>
3-8 One-Dimensional Motion—Constant Acceleration	<b>32</b>
3-9 Consistency of Units and Dimensions	<b>35</b>
3-10 Freely Falling Bodies	<b>36</b>

**4****Motion in a Plane 43**

- 4-1 Displacement, Velocity, and Acceleration 43
- 4-2 Motion in a Plane with Constant Acceleration 44
- 4-3 Projectile Motion 45
- 4-4 Uniform Circular Motion 48
- 4-5 Relative Velocity and Acceleration 51

**5****Particle Dynamics 59**

- 5-1 Introduction 59
- 5-2 Classical Mechanics 59
- 5-3 Newton's First Law 61
- 5-4 Force 62
- 5-5 Mass; Newton's Second Law 63
- 5-6 Newton's Third Law 65
- 5-7 Systems of Mechanical Units 68
- 5-8 The Force Laws 69
- 5-9 Weight and Mass 70
- 5-10 A Static Procedure for Measuring Forces 72
- 5-11 Some Applications of Newton's Laws of Motion 72
- 5-12 Frictional Forces 78
- 5-13 The Dynamics of Uniform Circular Motion 82

**6****Work and Energy 95**

- 6-1 Introduction 95
- 6-2 Work Done by a Constant Force 96
- 6-3 Work Done by a Variable Force—One Dimensional Case 99
- 6-4 Work Done by a Variable Force—Two-Dimensional Case 101
- 6-5 Kinetic Energy and the Work-Energy Theorem 102
- 6-6 Significance of the Work-Energy Theorem 105
- 6-7 Power 105

**7****The Conservation of Energy 109**

- 7-1 Introduction 109
- 7-2 Conservative Forces 109

- 7-3 Potential Energy **113**
- 7-4 One-Dimensional Conservative Systems **116**
- 7-5 Total Energy and the Potential Energy Curve **120**
- 7-6 Two- and Three-Dimensional Conservative Systems **121**
- 7-7 Nonconservative Forces **123**
- 7-8 The Conservation of Energy **125**
- 7-9 Mass and Energy **126**

## **8**

### **Conservation of Linear Momentum 135**

- 8-1 Center of Mass **135**
- 8-2 Motion of the Center of Mass **139**
- 8-3 Linear Momentum of a Particle **141**
- 8-4 Linear Momentum of a System of Particles **142**
- 8-5 Conservation of Linear Momentum **143**
- 8-6 Some Applications of the Momentum Principle **144**

## **9**

### **Collisions 153**

- 9-1 What is a Collision? **153**
- 9-2 Impulse and Momentum **155**
- 9-3 Conservation of Momentum during Collisions **155**
- 9-4 Collisions in One Dimension **157**
- 9-5 Collisions in Two and Three Dimensions **161**
- 9-6 Cross Section **164**
- 9-7 Reactions and Decay Processes **165**

## **10**

### **Rotational Kinematics 173**

- 10-1 Rotational Motion **173**
- 10-2 Rotational Kinematics—The Variables **174**
- 10-3 Rotation with Constant Angular Acceleration **176**
- 10-4 Relation between Linear and Angular Kinematics for a Particle in Circular Motion **177**

## **11**

### **Rotational Dynamics and the Conservation of Angular Momentum 183**

- 11-1 Introduction **183**
- 11-2 Torque Acting on a Particle **183**



11-3	Angular Momentum of a Particle	<b>186</b>
11-4	Systems of Particles	<b>189</b>
11-5	Kinetic Energy of Rotation and Rotational Inertia	<b>190</b>
11-6	Rotational Dynamics of a Rigid Body	<b>193</b>
11-7	Conservation of Angular Momentum	<b>199</b>
11-8	Rotational Dynamics—A Review	<b>204</b>
<b>12</b>		
	<b>Equilibrium of Rigid Bodies</b>	<b>209</b>
12-1	The Equilibrium of a Rigid Body	<b>209</b>
12-2	Center of Gravity	<b>211</b>
12-3	Examples of Equilibrium	<b>213</b>
<b>13</b>		
	<b>Oscillations</b>	<b>223</b>
13-1	Oscillations	<b>223</b>
13-2	The Simple Harmonic Oscillator	<b>225</b>
13-3	Simple Harmonic Motion	<b>228</b>
13-4	Energy Considerations in Simple Harmonic Motion	<b>232</b>
13-5	Applications of Simple Harmonic Motion	<b>236</b>
13-6	Relation between Simple Harmonic Motion and Uniform Circular Motion	<b>238</b>
13-7	Combinations of Harmonic Motions	<b>241</b>
<b>14</b>		
	<b>Gravitation</b>	<b>247</b>
14-1	The Law of Universal Gravitation	<b>247</b>
14-2	The Constant of Universal Gravitation, $G$	<b>250</b>
14-3	Inertial and Gravitational Mass and the Principle of Equivalence	<b>253</b>
14-4	Gravitational Effect of a Spherical Distribution of Mass	<b>255</b>
14-5	Gravitational Acceleration, $g$	<b>258</b>
14-6	The Gravitational Field	<b>261</b>
14-7	The Motions of Planets and Satellites	<b>262</b>
14-8	Gravitational Potential Energy	<b>265</b>
14-9	Potential Energy for Many-Particle Systems	<b>268</b>
14-10	Energy Considerations in the Motions of Planets and Satellites	<b>269</b>
<b>15</b>		
	<b>Fluid Mechanics</b>	<b>277</b>
15-1	Fluids	<b>277</b>
15-2	Pressure and Density	<b>277</b>

15-3	The Variation of Pressure in a Fluid at Rest	<b>278</b>
15-4	Pascal's Principle and Archimedes' Principle	<b>281</b>
15-5	Measurement of Pressure	<b>283</b>
15-6	Fluid Dynamics	<b>284</b>
15-7	Streamlines and the Equation of Continuity	<b>286</b>
15-8	Bernoulli's Equation	<b>287</b>
15-9	Applications of Bernoulli's Equation and the Equation of Continuity	<b>289</b>

## **16**

### **Waves in Elastic Media 299**

16-1	Mechanical Waves	<b>299</b>
16-2	Types of Waves	<b>300</b>
16-3	Traveling Waves	<b>302</b>
16-4	Wave Speed in a Stretched String	<b>305</b>
16-5	Power and Intensity in Wave Motion	<b>308</b>
16-6	The Superposition Principle	<b>309</b>
16-7	Interference of Waves	<b>310</b>
16-8	Standing Waves	<b>313</b>
16-9	Resonance	<b>316</b>

## **17**

### **Sound Waves 323**

17-1	Audible, Ultrasonic, and Infrasonic Waves	<b>323</b>
17-2	Propagation and Speed of Longitudinal Waves	<b>324</b>
17-3	Traveling Longitudinal Waves	<b>327</b>
17-4	Vibrating Systems and Sources of Sound	<b>329</b>
17-5	Beats	<b>332</b>
17-6	The Doppler Effect	<b>334</b>

## **18**

### **Temperature 343**

18-1	Macroscopic and Microscopic Descriptions	<b>343</b>
18-2	Thermal Equilibrium—The Zeroth Law of Thermodynamics	<b>344</b>
18-3	Measuring Temperature	<b>345</b>
18-4	Ideal Gas Temperature Scale	<b>347</b>
18-5	The Celsius and Fahrenheit Scales	<b>348</b>
18-6	The International Practical Temperature Scale	<b>349</b>
18-7	Temperature Expansion	<b>350</b>

**19****Heat and the First Law of Thermodynamics 357**

- 19-1 Heat, a Form of Energy 357
- 19-2 Quantity of Heat and Specific Heat 358
- 19-3 Heat Conduction 360
- 19-4 The Mechanical Equivalent of Heat 362
- 19-5 Heat and Work 363
- 19-6 The First Law of Thermodynamics 365
- 19-7 Some Applications of the First Law of Thermodynamics 366

**20****Kinetic Theory of Gases 375**

- 20-1 Introduction 375
- 20-2 Ideal Gas—A Macroscopic Description 376
- 20-3 Ideal Gas—A Microscopic Description 378
- 20-4 Kinetic Calculation of the Pressure 379
- 20-5 Kinetic Interpretation of Temperature 382
- 20-6 Specific Heats of an Ideal Gas 383
- 20-7 Equipartition of Energy 386
- 20-8 Mean Free Path 391
- 20-9 Distribution of Molecular Speeds 393

**21****Entropy and the Second Law of Thermodynamics 401**

- 21-1 Introduction 401
- 21-2 Reversible and Irreversible Processes 401
- 21-3 The Carnot Cycle 403
- 21-4 The Second Law of Thermodynamics 407
- 21-5 The Efficiency of Engines 409
- 21-6 Entropy—Reversible Processes 411
- 21-7 Entropy—Irreversible Processes 413
- 21-8 Entropy and the Second Law 415

**22****Charge and Matter 421**

- 22-1 Electromagnetism 421
- 22-2 Electric Charge 422
- 22-3 Conductors and Insulators 423
- 22-4 Coulomb's Law 423

- 22-5 Charge is Quantized **427**
- 22-6 Charge and Matter **427**
- 22-7 Charge is Conserved **429**

## **23**

### **The Electric Field 433**

- 23-1 The Electric Field **433**
- 23-2 The Electric Field **E** **434**
- 23-3 Lines of Force **435**
- 23-4 Calculation of **E** **437**
- 23-5 A Point Charge in an Electric Field **440**
- 23-6 A Dipole in an Electric Field **442**

## **24**

### **Gauss's Law 449**

- 24-1 Flux of the Electric Field **449**
- 24-2 Gauss's Law **452**
- 24-3 Gauss's Law and Coulomb's Law **452**
- 24-4 An Insulated Conductor **453**
- 24-5 Experimental Proof of Gauss's and Coulomb's Laws **454**
- 24-6 Gauss's Law—Some Applications **455**

## **25**

### **Electric Potential 465**

- 25-1 Electric Potential **465**
- 25-2 Potential and the Electric Field **468**
- 25-3 Potential Due to a Point Charge **470**
- 25-4 A Group of Point Charges **472**
- 25-5 Potential Due to a Dipole **474**
- 25-6 Electric Potential Energy **475**
- 25-7 Calculation of **E** From  $V$  **478**
- 25-8 An Insulated Conductor **480**
- 25-9 The Electrostatic Generator **481**

## **26**

### **Capacitors and Dielectrics 489**

- 26-1 Capacitance **489**
- 26-2 Calculating Capacitance **492**

- 26-3 Parallel-Plate Capacitor with Dielectric **494**
- 26-4 Dielectrics—An Atomic View **496**
- 26-5 Dielectrics and Gauss's Law **498**
- 26-6 Energy Storage in an Electric Field **499**

## **27**

### **Current and Resistance 507**

- 27-1 Current and Current Density **507**
- 27-2 Resistance, Resistivity, and Conductivity **510**
- 27-3 Ohm's Law **512**
- 27-4 Resistivity—An Atomic View **514**
- 27-5 Energy Transfers in an Electric Circuit **516**

## **28**

### **Electromotive Force and Circuits 521**

- 28-1 Electromotive Force **521**
- 28-2 Calculating the Current **523**
- 28-3 Other Single-Loop Circuits **524**
- 28-4 Potential Differences **525**
- 28-5 Multiloop Circuits **528**
- 28-6 *RC* Circuits **530**

## **29**

### **The Magnetic Field 537**

- 29-1 The Magnetic Field **537**
- 29-2 The Definition of **B** **538**
- 29-3 Magnetic Force on a Current **541**
- 29-4 Torque on a Current Loop **542**
- 29-5 The Hall Effect **545**
- 29-6 Circulating Charges **546**
- 29-7 The Cyclotron **548**
- 29-8 Thomson's Experiment **550**

## **30**

### **Ampère's Law 557**

- 30-1 Ampère's Law **557**
- 30-2 **B** Near a Long Wire **561**
- 30-3 Lines of **B** **562**

- 30-4 Two Parallel Conductors **563**
- 30-5 **B** for a Solenoid **565**
- 30-6 The Biot-Savart Law **568**

## **31**

### **Faraday's Law 577**

- 31-1 Faraday's Experiments **577**
- 31-2 Faraday's Law of Induction **578**
- 31-3 Lenz's Law **579**
- 31-4 Induction—A Quantitative Study **581**
- 31-5 Time-Varying Magnetic Fields **584**
- 31-6 The Betatron **587**

## **32**

### **Inductance 597**

- 32-1 Inductance **597**
- 32-2 Calculation of Inductance **598**
- 32-3 An *LR* Circuit **600**
- 32-4 Energy and the Magnetic Field **603**
- 32-5 Energy Density and the Magnetic Field **605**

## **33**

### **Magnetic Properties of Matter 611**

- 33-1 Poles and Dipoles **611**
- 33-2 Gauss's Law for Magnetism **614**
- 33-3 Paramagnetism **615**
- 33-4 Diamagnetism **617**
- 33-5 Ferromagnetism **619**

## **34**

### **Electromagnetic Oscillations 625**

- 34-1 *LC* Oscillations **625**
- 34-2 Analogy to Simple Harmonic Motion **628**
- 34-3 Electromagnetic Oscillations—Quantitative **629**
- 34-4 Induced Magnetic Fields **632**
- 34-5 Displacement Current **634**
- 34-6 Maxwell's Equations **635**

**35****Electromagnetic Waves 639**

- 35-1 Introduction 639
- 35-2 Radiation Sources 640
- 35-3 Traveling Waves and Maxwell's Equations 641
- 35-4 Energy and the Poynting Vector 646
- 35-5 Momentum 648
- 35-6 Polarization 649
- 35-7 The Electromagnetic Spectrum 653
- 35-8 The Speed of Light 654
- 35-9 Moving Sources and Observers 657
- 35-10 Doppler Effect 660

**36****Geometrical Optics 669**

- 36-1 Geometrical Optics 669
- 36-2 Reflection and Refraction—Plane Waves and Plane Surfaces 669
- 36-3 Huygens' Principle 672
- 36-4 The Law of Refraction 673
- 36-5 Total Internal Reflection 675
- 36-6 Brewster's Law 676
- 36-7 Spherical Waves—Plane Mirror 678
- 36-8 Spherical Waves—Spherical Mirror 681
- 36-9 Spherical Waves—Spherical Refracting Surface 686
- 36-10 Thin Lenses 689

**37****Interference 703**

- 37-1 Wave Optics 703
- 37-2 Young's Experiment 705
- 37-3 Coherence 708
- 37-4 Intensity of Interfering Waves 710
- 37-5 Interference from Thin Films 714
- 37-6 Michelson's Interferometer 718

**38****Diffraction, Gratings, and Spectra 725**

- 38-1 Diffraction 725
- 38-2 Single Slit 728

38-3	Diffraction from a Single Slit—Qualitative	730
38-4	Diffraction from a Single Slit—Quantitative	732
38-5	Diffraction from a Circular Aperture	735
38-6	Diffraction from a Double Slit	738
38-7	Multiple Slits	741
38-8	Diffraction Gratings	744
38-9	Resolving Power of a Grating	746
38-10	X-ray Diffraction	748

## 39

### Light and Quantum Physics 757

39-1	Sources of Light	757
39-2	Cavity Radiators	758
39-3	Planck's Radiation Formula	760
39-4	Photoelectric Effect	763
39-5	Einstein's Photon Theory	765
39-6	The Compton Effect	766
39-7	Line Spectra	770
39-8	Atomic Models—The Bohr Hydrogen Atom	771
39-9	The Correspondence Principle	776

## 40

### Waves and Particles 781

40-1	Matter Waves	781
40-2	Atomic Structure and Standing Waves	784
40-3	Wave Mechanics	784
40-4	Meaning of $\Psi$	787
40-5	The Uncertainty Principle	789

## Appendices

A	Physical Standards and Constants	795
B	Some Terrestrial Data	797
C	The Solar System	798
D	Periodic Table of the Elements	799
E	Conversion Factors	800
F	Mathematical Symbols and the Greek Alphabet	807
G	Mathematical Formulas	808
H	Values of Trigonometric Functions	811
I	Nobel Prize Winners in Physics	813

<b>Index</b>	<b>817</b>
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# Measurement

## 1-1 Physical Quantities, Standards, and Units

The building blocks of physics are the physical quantities in terms of which the laws of physics are expressed. Among these are force, time, velocity, density, temperature, charge, magnetic susceptibility, and numerous others. Many of these terms, such as force and temperature, are part of our everyday vocabulary. When these terms are so used, their meanings may be vague or may differ from their scientific meanings.

For the purposes of physics the basic quantities must be defined clearly and precisely. One view is that the definition of a physical quantity has been given when the procedures for measuring that quantity are specified. This is called the *operational* point of view because the definition is, at root, a set of laboratory operations leading to a number with a unit. The operations may include mathematical calculations.

Physical quantities are often divided into *fundamental quantities* and *derived quantities*. Such a division is arbitrary in that a given quantity can be regarded as fundamental in one set of operations and as derived in another. Derived quantities are those whose defining operations are based on measurements of other physical quantities. Examples of quantities usually viewed as derived are velocity, acceleration, and volume. Fundamental quantities are not defined in terms of other physical quantities. The number of quantities regarded as fundamental is the minimum number needed to give a consistent and unambiguous description of all the quantities of physics. Examples of quantities usually viewed as fundamental are length and time. Their operational definitions involve two steps: first, the choice of a *standard*, and second, the establishment of procedures for comparing the standard in such a way that a number and a unit are determined as the measure of that quantity.