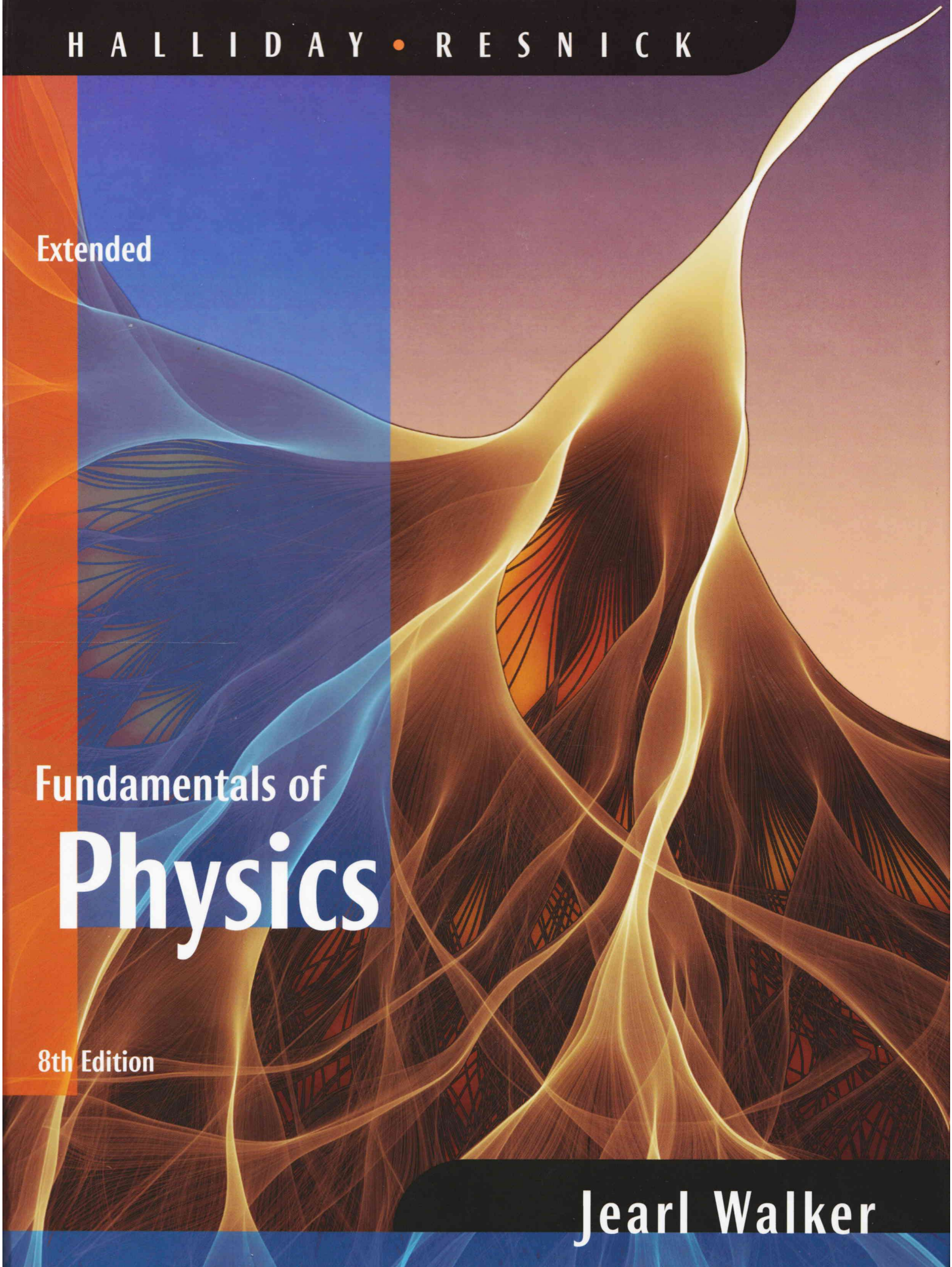
HALLIDAY • RESNICK

Extended

Fundamentals of Physics

8th Edition



Jearl Walker

About The Cover

The front cover is an image by Eric J. Heller depicting electron flow over a microscopically bumpy surface. The paths of the 100,000 electrons begin at the upper right but branch and fold back on one another in a surprising pattern as they spread toward the lower left.

Electron flow is the subject of several chapters in this book and is especially important in the discussion of electric sparks. Some sparks are amusing, such as those generated when someone chomps down on a wintergreen LifeSaver—the brief blue glow that illuminates the mouth can be seen in a dark room (Chapter 21). Other sparks are quite dangerous, such as those in electrostatic discharges that can accidentally cause airborne dust to explode (Chapter 25).

Take Your Seat—The Show's About To Begin!

This 8th edition of **Fundamentals of Physics** includes hundreds of items about curious effects in the everyday world, written in the spirit of Jearl Walker's **The Flying Circus of Physics**. The original edition of **The Flying Circus of Physics**—in print for over 30 years in 10 languages—is a cult classic among physics students, physics instructors, and the general public.

Electronic links to the new 2nd Edition of **The Flying Circus of Physics** are available in the electronic version of 8th edition of **Fundamentals of Physics** that is part of *WileyPLUS*, one of the online homework systems available with this book. *WileyPLUS* also includes electronic versions of all the end-of-chapter problems in **Fundamentals of Physics** and the interactive tutorials (several hundred) and hints (several thousand) written by author Jearl Walker.

You can find out more about The Flying Circus of Physics at www.flyingcircusofphysics.com.

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Mathematical Formulas*

Quadratic Formula

$$\text{If } ax^2 + bx + c = 0, \text{ then } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Binomial Theorem

$$(1 + x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \cdots \qquad (x^2 < 1)$$

Products of Vectors

Let θ be the smaller of the two angles between $\vec{a}$ and $\vec{b}$. Then

$$\vec{a} \cdot \vec{b} = \vec{b} \cdot \vec{a} = a_x b_x + a_y b_y + a_z b_z = ab \cos \theta$$

$$\vec{a} \times \vec{b} = -\vec{b} \times \vec{a} = \begin{vmatrix} \hat{\mathrm{i}} & \hat{\mathrm{j}} & \hat{\mathrm{k}} \\ a_x & a_y & a_z \\ b_x & b_y & b_z \end{vmatrix}$$

$$= \hat{\mathrm{i}} \begin{vmatrix} a_y & a_z \\ b_y & b_z \end{vmatrix} - \hat{\mathrm{j}} \begin{vmatrix} a_x & a_z \\ b_x & b_z \end{vmatrix} + \hat{\mathrm{k}} \begin{vmatrix} a_x & a_y \\ b_x & b_y \end{vmatrix}$$

$$= (a_y b_z - b_y a_z)\hat{\mathrm{i}} + (a_z b_x - b_z a_x)\hat{\mathrm{j}} + (a_x b_y - b_x a_y)\hat{\mathrm{k}}$$

$$|\vec{a} \times \vec{b}| = ab \sin \theta$$

Trigonometric Identities

$$\sin \alpha \pm \sin \beta = 2 \sin \tfrac{1}{2}(\alpha \pm \beta) \cos \tfrac{1}{2}(\alpha \mp \beta)$$

$$\cos \alpha + \cos \beta = 2 \cos \tfrac{1}{2}(\alpha + \beta) \cos \tfrac{1}{2}(\alpha - \beta)$$

*See Appendix E for a more complete list.

Derivatives and Integrals

$$\frac{d}{dx} \sin x = \cos x \qquad \int \sin x \, dx = -\cos x$$

$$\frac{d}{dx} \cos x = -\sin x \qquad \int \cos x \, dx = \sin x$$

$$\frac{d}{dx} e^x = e^x \qquad \int e^x \, dx = e^x$$

$$\int \frac{dx}{\sqrt{x^2 + a^2}} = \ln(x + \sqrt{x^2 + a^2})$$

$$\int \frac{x \, dx}{(x^2 + a^2)^{3/2}} = -\frac{1}{(x^2 + a^2)^{1/2}}$$

$$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{x}{a^2(x^2 + a^2)^{1/2}}$$

Cramer's Rule

Two simultaneous equations in unknowns x and y,

$$a_1 x + b_1 y = c_1 \quad \text{and} \quad a_2 x + b_2 y = c_2,$$

have the solutions

$$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{c_1 b_2 - c_2 b_1}{a_1 b_2 - a_2 b_1}$$

and

$$y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}} = \frac{a_1 c_2 - a_2 c_1}{a_1 b_2 - a_2 b_1}.$$

SI Prefixes*

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y

*In all cases, the first syllable is accented, as in ná-no-mé-ter.

Some Physical Constants*

Speed of light	c	2.998×10^{8} m/s
Gravitational constant	G	6.673×10^{-11} N · m^2/kg^2
Avogadro constant	N_A	6.022×10^{23} mol^{-1}
Universal gas constant	R	8.314 J/mol · K
Mass–energy relation	c^2	8.988×10^{16} J/kg
		931.49 MeV/u
Permittivity constant	ε_0	8.854×10^{-12} F/m
Permeability constant	μ_0	1.257×10^{-6} H/m
Planck constant	h	6.626×10^{-34} J · s
		4.136×10^{-15} eV · s
Boltzmann constant	k	1.381×10^{-23} J/K
		8.617×10^{-5} eV/K
Elementary charge	e	1.602×10^{-19} C
Electron mass	m_e	9.109×10^{-31} kg
Proton mass	m_p	1.673×10^{-27} kg
Neutron mass	m_n	1.675×10^{-27} kg
Deuteron mass	m_d	3.344×10^{-27} kg
Bohr radius	a	5.292×10^{-11} m
Bohr magneton	μ_B	9.274×10^{-24} J/T
		5.788×10^{-5} eV/T
Rydberg constant	R	$1.097\,373 \times 10^{7}$ m^{-1}

*For a more complete list, showing also the best experimental values, see Appendix B.

Some Conversion Factors*

Mass and Density
1 kg = 1000 g = 6.02×10^{26} u
1 slug = 14.59 kg
1 u = 1.661×10^{-27} kg
1 kg/m^3 = 10^{-3} g/cm^3

Length and Volume
1 m = 100 cm = 39.4 in. = 3.28 ft
1 mi = 1.61 km = 5280 ft
1 in. = 2.54 cm
1 nm = 10^{-9} m = 10 Å
1 pm = 10^{-12} m = 1000 fm
1 light-year = 9.461×10^{15} m
1 m^3 = 1000 L = 35.3 ft^3 = 264 gal

Time
1 d = 86 400 s
1 y = $365\frac{1}{4}$ d = 3.16×10^{7} s

Angular Measure
1 rad = 57.3° = 0.159 rev
π rad = 180° = $\frac{1}{2}$ rev

Speed
1 m/s = 3.28 ft/s = 2.24 mi/h
1 km/h = 0.621 mi/h = 0.278 m/s

Force and Pressure
1 N = 10^5 dyne = 0.225 lb
1 lb = 4.45 N
1 ton = 2000 lb
1 Pa = 1 N/m^2 = 10 dyne/cm^2
= 1.45×10^{-4} lb/in.^{2}
1 atm = 1.01×10^5 Pa = 14.7 lb/in.^{2}
= 76.0 cm Hg

Energy and Power
1 J = 10^7 erg = 0.2389 cal = 0.738 ft · lb
1 kW · h = 3.6×10^6 J
1 cal = 4.1868 J
1 eV = 1.602×10^{-19} J
1 horsepower = 746 W = 550 ft · lb/s

Magnetism
1 T = 1 Wb/m^2 = 10^4 gauss

*See Appendix D for a more complete list.

Some Physical Properties

Air (dry, at 20°C and 1 atm)	
Density	1.21 kg/m^3
Specific heat at constant pressure	1010 J/kg · K
Ratio of specific heats	1.40
Speed of sound	343 m/s
Electrical breakdown strength	3×10^6 V/m
Effective molar mass	0.0289 kg/mol
Water	
Density	1000 kg/m^3
Speed of sound	1460 m/s
Specific heat at constant pressure	4190 J/kg · K
Heat of fusion (0°C)	333 kJ/kg
Heat of vaporization (100°C)	2260 kJ/kg
Index of refraction (λ = 589 nm)	1.33
Molar mass	0.0180 kg/mol
Earth	
Mass	5.98×10^{24} kg
Mean radius	6.37×10^6 m
Free-fall acceleration at Earth's surface	9.8 m/s^2
Standard atmosphere	1.01×10^5 Pa
Period of satellite at 100 km altitude	86.3 min
Radius of the geosynchronous orbit	42 200 km
Escape speed	11.2 km/s
Magnetic dipole moment	8.0×10^{22} A · m^2
Mean electric field at surface	150 V/m, down
Distance to	
Moon	3.82×10^8 m
Sun	1.50×10^{11} m
Star nearest the Sun	4.04×10^{16} m
Galactic center	2.2×10^{20} m
Andromeda galaxy	2.1×10^{22} m
Edge of the observable universe	$\sim 10^{26}$ m

The Greek Alphabet

Alpha	A	α	Iota	I	ι	Rho	P	ρ
Beta	B	β	Kappa	K	κ	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	T	τ
Delta	Δ	δ	Mu	M	μ	Upsilon	Y	υ
Epsilon	E	ϵ	Nu	N	ν	Phi	Φ	ϕ, φ
Zeta	Z	ζ	Xi	Ξ	ξ	Chi	X	χ
Eta	H	η	Omicron	O	o	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω