GLOBAL EDITION

Conceptual Physics

TWELFTH EDITION

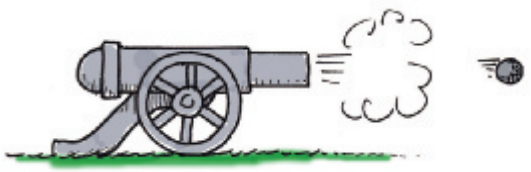
Paul G. Hewitt





ALWAYS LEARNING

PEARSON



A Conceptual Approach to Physics—Now with MasteringPhysics®!

Since defining this course 30 years ago, Paul Hewitt's best-selling text continues as the benchmark by which all others are judged. In **Conceptual Physics with MasteringPhysics®, Twelfth Edition,** Paul Hewitt integrates a compelling text and the most advanced media to make physics interesting, understandable, and relevant for non-science majors. The **Twelfth Edition** will delight students with informative and fun Hewitt-Drew-It screencasts, updated content, applications, and new learning activities in **MasteringPhysics**.

NEW! A new interior design provides an attractive, fresh, and accessible new look, updating a classic text to be even more student friendly.

NEW! Over 200 QR codes throughout the book allow students to use a mobile device to instantly watch Paul Hewitt's video demonstrations and Hewitt-Drew-It screencasts to prepare for lecture and gain a better conceptual understanding of physics.

NEW! Updated applications are available for digital technology, environment, and energy. These topics are at the forefront of everyone's consciousness these days and an intelligent awareness of their scientific foundations will give rise to better decision making in the political arena.

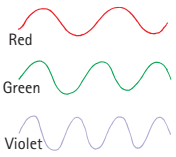


FIGURE 26.5
INTERACTIVE FIGURE

Relative wavelengths of red, green, and violet light. Violet light has nearly twice the frequency of red light and half the wavelength.

different wavelengths—waves of low frequencies have long wavelengths, and waves of high frequencies have short wavelengths. For example, since the speed of the wave is 300,000 km/s, an electric charge oscillating once per second (1 Hz) will produce a wave with a wavelength of 300,000 km. This is because only one wavelength is generated in 1 second. If the frequency of oscillation were 10 Hz, then 10 wavelengths would be formed in 1 second, and the corresponding wavelength would be 30,000 km. A frequency of 10,000 Hz would produce a wavelength of 30 km. So, the higher the frequency of the vibrating charge, the shorter the wavelength of radiant energy.[3]

We tend to think of space as empty, but only because we cannot see the montages of electromagnetic waves that permeate every part of our surroundings. We see some of these waves, of course, as light. These waves constitute only a microportion of the electromagnetic spectrum. We are unconscious of radio and cellphone waves, which engulf us every moment. Free electrons in every piece of metal on Earth's surface continuously dance to the rhythms of these waves. They jiggle in unison with the electrons being driven up and down along their transmitting antennae. A radio or television receiver is simply a device that sorts and amplifies these tiny currents. There is radiation everywhere. Our first impression of the universe is one of matter and void, but actually the universe is a dense sea of radiation occupied only occasionally by specks of matter.

SCREENCAST: Speed of Light

CHECK POINT

Are we correct to say that a radio wave is a low-frequency light wave? And that a radio wave is also a sound wave?

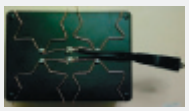
CHECK YOUR ANSWERS

Yes and no. Both a radio wave and a light wave are electromagnetic waves emitted by vibrating electrons; radio waves have lower frequencies than light waves, so a radio wave may be considered to be a low-frequency light wave (and a light wave, similarly, may be considered to be a high-frequency radio wave). But a sound wave is a mechanical vibration of matter and is fundamentally different from an electromagnetic wave. So a radio wave is definitely not a sound wave.

FRACTAL ANTENNAS

For quality reception of electromagnetic waves, a conventional antenna has to be about one-quarter wavelength long. That's why, in early mobile devices, antennas had to be pulled out before the device was used. Nathan Cohen, a professor at Boston University, was troubled by a rule in Boston at the time that prohibited the use of large external antennas on buildings. So he fashioned a small antenna by folding aluminum foil into a compact fractal shape (a Van Koch figure—check *fractals* on the Internet). It worked. He then engineered and patented many practical fractal antennas, as did Carles Puente, an inventor in Spain. Both formed fractal-antenna companies.

Fractals are fascinating shapes that can be split into parts, each of which is (or approximates) a reduced copy of the whole. In any fractal, similar shapes appear at all levels of magnification. Common fractals in nature include snowflakes, clouds, lightning bolts, shorelines, and even cauliflower and broccoli.



The fractal antenna, like other fractals, has a shape that repeats itself. Because of its folded self-similar design, a fractal antenna can be compressed and fit into the body of the device—it can also simultaneously operate at different frequencies. Hence the same antenna can be used for mobile-phone conversations and for GPS navigation.

How nice that these devices fit in your pocket. Cheers for compact fractal antennas!

[3]The relationship is $c = f\lambda$, where c is the wave speed (constant), f is the frequency, and λ is the wavelength.

Conceptual Physics, Global Edition

Table of Contents

Cover
Title
Copyright
Contents
Conceptual Physics Photo Album
To the Student
To the Instructor
Acknowledgments
1 About Science
- 1.1 Scientific Measurements
  - How Eratosthenes Measured the Size of Earth
  - Size of the Moon
  - Distance to the Moon
  - Distance to the Sun
  - Size of the Sun
  - MathematicsThe Language of Science
- 1.2 Scientific Methods
  - The Scientific Attitude
- 1.3 Science, Art, and Religion
  - Pseudoscience
- 1.4 Science and Technology
  - Risk Assesment
- 1.5 PhysicsThe Basic Science
- 1.6 In Perspective

Part One Mechanics
- 2 Newtons First Law of MotionInertia
  - 2.1 Aristotle on Motion
    - Copernicus and the Moving Earth
    - Aristotle (384322 bc)
  - 2.2 Galileos Experiments

Pearson

Table of Contents

Leaning Tower

Inclined Planes

Galileo Galilei (15641642)

2.3 Newtons First Law of Motion

Personal Essay

2.4 Net Force and Vectors

Force Vectors

2.5 The Equilibrium Rule

Practicing Physics

2.6 Support Force

2.7 Equilibrium of Moving Things

2.8 The Moving Earth

3 Linear Motion

3.1 Motion Is Relative

3.2 Speed

Instantaneous Speed

Average Speed

3.3 Velocity

Constant Velocity

Changing Velocity

3.4 Acceleration

Acceleration on Galileos Inclined Planes

3.5 Free Fall

How Fast

How Far

Hang Time

How Quickly How Fast Changes

3.6 Velocity Vectors

4 Newtons Second Law of Motion

4.1 Force Causes Acceleration

4.2 Friction

4.3 Mass and Weight

Mass Resists Acceleration

4.4 Newtons Second Law of Motion

4.5 When Acceleration Is gFree Fall

4.6 When Acceleration Is Less Than gNonfree Fall

5 Newtons Third Law of Motion

5.1 Forces and Interactions

5.2 Newtons Third Law of Motion

Table of Contents

Defining Your System

5.3 Action and Reaction on Different Masses

Practicing Physics: Tug-of-War

5.4 Vectors and the Third Law

5.5 Summary of Newtons Three Laws

6 Momentum

6.1 Momentum

6.2 Impulse

6.3 Impulse Changes Momentum

Case 1: Increasing Momentum

Case 2: Decreasing Momentum Overa Long Time

Case 3: Decreasing Momentum Overa Short Time

6.4 Bouncing

6.5 Conservation of Momentum

Conservation Laws

6.6 Collisions

6.7 More Complicated Collisions

7 Energy

7.1 Work

Power

Mechanical Energy

7.2 Potential Energy

7.3 Kinetic Energy

7.4 WorkEnergy Theorem

7.5 Conservation of Energy

Energy and Technology

Circus Physics

Recycled Energy

7.6 Machines

7.7 Efficiency

7.8 Sources of Energy

Junk Science

8 Rotational Motion

8.1 Circular Motion

Whels on Railroad Trains

8.2 Rotational Inertia

8.3 Torque

8.4 Center of Mass and Center of Gravity

Table of Contents

Locating the Center of Gravity

Stability

8.5 Centripetal Force

Practicing Physics:Water-Bucket Swing

8.6 Centrifugal Force

Centrifugal Force in a Rotating Reference Frame

Simulated Gravity

8.7 Angular Momentum

8.8 Conservation of Angular Momentum

9 Gravity

9.1 The Universal Law of Gravity

9.2 The Universal Gravitational Constant, G

9.3 Gravity and Distance: The Inverse-Square Law

9.4 Weight and Weightlessness

9.5 Ocean Tides

Tides in the Earth and Atmosphere

Tidal Bulges on the Moon

9.6 Gravitational Fields

Gravitational Field Inside a Planet

Einsteins Theory of Gravitation

9.7 Black Holes

9.8 Universal Gravitation

10 Projectile and Satellite Motion

10.1 Projectile Motion

Projectiles Launched Horizontally

Projectiles Launched at an Angle

Practicing Physics: Hands-On Dangling Beads

Hang Time Revisited

10.2 Fast-Moving ProjectilesSatellites

10.3 Circular Satellite Orbits

10.4 Elliptical Orbits

World Monitoring by Satelite

10.5 Keplers Laws of Planetary Motion

Finding Your Way

10.6 Energy Conservation and Satellite Motion

10.7 Escape Speed

Part Two Properties of Matter

11 The Atomic Nature of Matter

Table of Contents

- 11.1 The Atomic Hypothesis
  - Faling Alice
- 11.2 Characteristics of Atoms
- 11.3 Atomic Imagery
- 11.4 Atomic Structure
  - The Elements
- 11.5 The Periodic Table of the Elements
  - Relative Sizes of Atoms
- 11.6 Isotopes
- 11.7 Compounds and Mixtures
- 11.8 Molecules
- 11.9 Antimatter
  - Dark Matter

12 Solids

- 12.1 Crystal Structure
  - Crystal Power
- 12.2 Density
- 12.3 Elasticity
- 12.4 Tension and Compression
  - Practicing Physics: stick strength
- 12.5 Arches
  - Additive Manufacturing or 3-D Printing
- 12.6 Scaling

13 Liquids

- 13.1 Pressure
- 13.2 Pressure in a Liquid
- 13.3 Buoyancy
- 13.4 Archimedes Principle
- 13.5 What Makes an Object Sink or Float?
- 13.6 Flotation
  - Floating Mountains
- 13.7 Pascals Principle
- 13.8 Surface Tension
- 13.9 Capillarity

14 Gases

- 14.1 The Atmosphere
- 14.2 Atmospheric Pressure
  - The Barometer

Table of Contents

14.3 Boyles Law

14.4 Buoyancy of Air

14.5 Bernoullis Principle

Applications of Bernoullis Principle

Practicing Physics

14.6 Plasma

Plasma in the Everyday World

Plasma Power

Part Three Heat

15 Temperature, Heat,and Expansion

15.1 Temperature

15.2 Heat

Measuring Heat

15.3 Specific Heat Capacity

15.4 The High Specific Heat Capacity of Water

15.5 Thermal Expansion

Expansion of Water

Life at the Extremes

16 Heat Transfer

16.1 Conduction

16.2 Convection

Practicing Physics

16.3 Radiation

Emission of Radiant Energy

Absorption of Radiant Energy

Reflection of Radiant Energy

Cooling at Night by Radiation

16.4 Newtons Law of Cooling

16.5 The Greenhouse Effect

16.6 Climate Change

16.7 Solar Power

Practicing Physics

16.8 Controlling Heat Transfer

17 Change of Phase

17.1 Phases of Matter

17.2 Evaporation

17.3 Condensation

Condensation in the Atmosphere

Table of Contents

Fog and Clouds

17.4 Boiling

Geysers

Boiling Is a Cooling Process

Boiling and Freezing at the Same Time

17.5 Melting and Freezing

Regelation

17.6 Energy and Changes of Phase

Practicing Physics

18 Thermodynamics

18.1 Thermodynamics

18.2 Absolute Zero

Internal Energy

18.3 First Law of Thermodynamics

18.4 Adiabatic Processes

18.5 Meteorology and the First Law

18.6 Second Law of Thermodynamics

Heat Engines

Thermodynamics Dramatized!

18.7 Energy Tends to Disperse

18.8 Entropy

Part Four Sound

19 Vibrations and Waves

19.1 Good Vibrations

Vibration of a Pendulum

19.2 Wave Description

19.3 Wave Motion

Practicing Physics

Transverse Waves

Longitudinal Waves

19.4 Wave Speed

19.5 Wave Interference

Standing Waves

19.6 Doppler Effect

19.7 Bow Waves

19.8 Shock Waves

20 Sound

20.1 Nature of Sound

Table of Contents

Origin of Sound

Media That Transmit Sound

20.2 Sound in Air

Loudspeaker

Speed of Sound in Air

Practicing Physics

Energy in Sound Waves

20.3 Reflection of Sound

20.4 Refraction of Sound

20.5 Forced Vibrations

Natural Frequency

20.6 Resonance

20.7 Interference

20.8 Beats

Radio Broadcasts

21 Musical Sounds

21.1 Noise and Music

21.2 Pitch

21.3 Sound Intensity and Loudness

21.4 Quality

21.5 Musical Instruments

21.6 Fourier Analysis

21.7 From Analog to Digital

Part Five Electricity and Magnetism

22 Electrostatics

22.1 Electricity

Electrical Forces

22.2 Electric Charges

22.3 Conservation of Charge

Electronics Technology and Sparks

22.4 Coulombs Law

22.5 Conductors and Insulators

Semiconductors

Superconductors

22.6 Charging

Charging by Friction and Contact

Charging by Induction

22.7 Charge Polarization

Table of Contents

22.8 Electric Field

Microwave Oven

Electric Shielding

22.9 Electric Potential

Electric Energy Storage

Van de Graaff Generator

23 Electric Current

23.1 Flow of Charge and Electric Current

23.2 Voltage Sources

23.3 Electrical Resistance

23.4 Ohms Law

Ohms Law and Electric Shock

23.5 Direct Current and Alternating Current

Converting AC to DC

23.6 Speed and Source of Electrons in a Circuit

23.7 Electric Power

23.8 Lamps

23.9 Electric Circuits

Series Circuits

Fuel Cels

Parallel Circuits

Parallel Circuits and Overloading

Safety Fuses

24 Magnetism

24.1 Magnetism

24.2 Magnetic Poles

24.3 Magnetic Fields

24.4 Magnetic Domains

24.5 Electric Currents and Magnetic Fields

Practicing Physics

24.6 Electromagnets

Superconducting Electromagnets

24.7 Magnetic Forces

On Moving Charged Particles

On Current-Carrying Wires

Electric Meters

Electric Motors

24.8 Earths Magnetic Field

Cosmic Rays

Table of Contents

24.9 Biomagnetism

MRI: Magnetic Resonance Imaging

25 Electromagnetic Induction

25.1 Electromagnetic Induction

25.2 Faradays Law

25.3 Generators and Alternating Current

25.4 Power Production

Turbogenerator Power

MHD Power

25.5 Transformers

25.6 Self-Induction

25.7 Power Transmission

25.8 Field Induction

Part Six Light

26 Properties of Light

26.1 Electromagnetic Waves

26.2 Electromagnetic Wave Velocity

26.3 The Electromagnetic Spectrum

Fractal Antenas

26.4 Transparent Materials

26.5 Opaque Materials

Shadows

26.6 Seeing LightThe Eye

27 Color

27.1 Color in Our World

27.2 Selective Reflection

27.3 Selective Transmission

27.4 Mixing Colored Lights

Primary Colors

Complementary Colors

27.5 Mixing Colored Pigments

27.6 Why the Sky Is Blue

27.7 Why Sunsets Are Red

Practicing Physics

27.8 Why Clouds Are White

27.9 Why Water Is Greenish Blue

28 Reflection and Refraction

Table of Contents

28.1 Reflection

Principle of Least Time

28.2 Law of Reflection

Plane Mirrors

Diffuse Reflection

28.3 Refraction

Index of Refraction

Mirage

28.4 Cause of Refraction

28.5 Dispersion and Rainbows

28.6 Total Internal Reflection

28.7 Lenses

Image Formation by a Lens

Practicing Physics

28.8 Lens Defects

29 Light Waves

29.1 Huygens Principle

29.2 Diffraction

29.3 Superposition and Interference

29.4 Thin-Film Interference

Single-Color Thin-Film Interference

Interference Colors

Practicing Physics

29.5 Polarization

Three-Dimensional Viewing

29.6 Holography

30 Light Emission

30.1 Light Emission

30.2 Excitation

30.3 Emission Spectra

30.4 Incandescence

30.5 Absorption Spectra

30.6 Fluorescence

30.7 Phosphorescence

30.8 Lamps

Incandescent Lamp

Fluorescent Lamp

Compact Fluorescent Lamp

Light-Emitting Diode

Table of Contents

30.9 Lasers

31 Light Quanta

31.1 Birth of the Quantum Theory

31.2 Quantization and Plancks Constant

31.3 Photoelectric Effect

31.4 WaveParticle Duality

31.5 Double-Slit Experiment

31.6 Particles as Waves: Electron Diffraction

31.7 Uncertainty Principle

31.8 Complementarity

Predictability and Chaos

Part Seven Atomic and Nuclear Physics

32 The Atom and the Quantum

32.1 Discovery of the Atomic Nucleus

32.2 Discovery of the Electron

32.3 Atomic Spectra: Clues to Atomic Structure

32.4 Bohr Model of the Atom

32.5 Explanation of Quantized Energy Levels: Electron Waves

32.6 Quantum Mechanics

32.7 Correspondence Principle

Higs Boson

33 The Atomic Nucleus and Radioactivity

33.1 X -rays and Radioactivity

33.2 Alpha, Beta, and Gamma Rays

33.3 Environmental Radiation

Units of Radiation

Doses of Radiation

Radioactive Tracers

33.4 The Atomic Nucleus and the Strong Force

33.5 Radioactive Half-Life

33.6 Radiation Detectors

33.7 Transmutation of Elements

Natural Transmutation

Artificial Transmutation

33.8 Radiometric Dating

Food Irradiation

34 Nuclear Fission and Fusion

Table of Contents

34.1 Nuclear Fission

34.2 Nuclear Fission Reactors

Plutonium

34.3 The Breeder Reactor

34.4 Fission Power

34.5 MassEnergy Equivalence

Physics at Airport Security

34.6 Nuclear Fusion

34.7 Controlling Fusion

Part Eight Relativity

35 Special Theory of Relativity

35.1 Motion Is Relative

MichelsonMorley Experiment

35.2 Postulates of the Special Theory of Relativity

35.3 Simultaneity

35.4 Spacetime and Time Dilation

Clockwatching on a Troley Car Ride

The Twin Trip

35.5 Addition of Velocities

Space Travel

Century Hoping

35.6 Length Contraction

35.7 Relativistic Momentum

35.8 Mass, Energy, and E 5 mc 2

35.9 The Correspondence Principle

36 General Theory of Relativity

36.1 Principle of Equivalence

36.2 Bending of Light by Gravity

36.3 Gravity and Time: Gravitational Red Shift

36.4 Gravity and Space: Motion of Mercury

36.5 Gravity, Space, anda New Geometry

36.6 Gravitational Waves

36.7 Newtonian and Einsteinian Gravitation

Epilogue

Appendix A On Measurement and Unit Conversions

Appendix B More About Motion

Appendix C Graphing

Table of Contents

Appendix D Vector Applications
Appendix E Exponential Growth and Doubling Time
Odd-Numbered Answers
Glossary
Credits
Index

Pearson