

TABLE OF CONTENTS

About the Book

Licensing

About the Authors

0: Review of Mathematics

- 0.0: Scientific Notation
- 0.1: Manipulating Numbers in Scientific Notation
- 0.2: The Metric System
- 0.3: Special Units Used in Astronomy
- 0.4: Comparing Sizes and Converting Units
- 0.5: Problem Solving and Thinking About Your Answers
- 0.6: Measurement Accuracy and Uncertainty
- 0.7: Wrapping It Up

1: Size and Scope

- 1.0: Size and Scope Introduction
- 1.1: Your Model of the Universe
- 1.2: Our Solar System
- 1.3: Our Galaxy - The Milky Way
- 1.4: Other Galaxies and Large-scale Structures in the Universe
- 1.5: The Smallest Stuff- Particles, Atoms, and Molecules
- 1.6: Hierarchy- How the Objects Are Arranged
- 1.7: Scale the Universe
- 1.8: Wrapping It Up 1 - Size, Scope, and Units
- 1.9: Mission Report 1 - Size, Scope, and Units

2: Light

- 2.0: Light Introduction
- 2.1: The Wave Nature of Light
- 2.2: The Particle Nature of Light
- 2.3: The Electromagnetic Spectrum
- 2.4: What a Spectrum of Light Can Tell Us About Matter
- 2.5: Continuous Spectra - a Planck Spectrum Tells us the Temperature of Objects
- 2.6: Lines Spectra- Emission and Absorption Lines
- 2.7: Determining the Composition of an Unknown Gas
- 2.8: Wrapping It Up 2 - The Properties of Light
- 2.9: Mission Report 2 - The Properties of Light

3: Telescopes

- 3.0: Telescope Introduction
- 3.1: Designing Telescopes Across the Spectrum
- 3.2: Location, Location, Location
- 3.3: Imaging Astronomical Objects
- 3.4: Determining the Brightness of Astronomical Objects

- 3.5: Wrapping It Up 3 - Light, Telescopes, and Astronomical Images
- 3.6: Mission Report 3 - Light, Telescopes, and Astronomical Images

4: Moving Through Space

- 4.0: Moving Through Space Introduction
- 4.1: Relationship Between Distance, Speed, and Time
- 4.2: Measuring Motion - the Doppler Shift
- 4.3: Astronomical Objects in Motion
- 4.4: Wrapping It Up 4 - The Andromeda Shift
- 4.5: Mission Report 4 - The Andromeda Shift

5: Moving Through Time

- 5.0: Moving Through Time Introduction
- 5.1: Measuring the Ages of Objects - Radiometric Dating
- 5.2: Measuring Ages - Lifetimes of Stars
- 5.3: Change Over Time - Evolution of Stars
- 5.4: Evolution of Galaxies and the Universe Itself
- 5.5: Wrapping It Up 5 - Cosmic Timeline
- 5.6: Mission Report 5 - Cosmic Timeline

6: Measuring Cosmic Distances

- 6.0: Measuring Cosmic Distances Introduction
- 6.1: Geometrical Methods
- 6.2: Standard Ruler
- 6.3: Standard Candle
- 6.4: The Cosmic Distance Ladder
- 6.5: Wrapping It Up 6 - The Supernova of 1885
- 6.6: Mission Report 6 - Distance Measurement

7: Classical Physics- Gravity and Energy

- 7.0: Classical Physics - Gravity and Energy Introduction
- 7.1: Gravity on Earth
- 7.2: Force, Mass, and Weight
- 7.3: Gravity Is a Universal Force
- 7.4: Gravity and Orbits
- 7.5: Forms of Energy
- 7.6: Conservation of Energy
- 7.7: Wrapping It Up 7 - The Galilean Moons of Jupiter
- 7.8: Mission Report 7 - The Galilean Moons of Jupiter

8: Dark Matter

- 8.0: Dark Matter Introduction
- 8.1: Making Models for Rotation
- 8.2: Velocities, Mass, and Gravity - The Solar System
- 8.3: Gravity and Models for Different Mass Distributions
- 8.4: Velocity and Mass Distributions in Galaxies
- 8.5: Velocity and Mass Distributions in Galaxy Clusters
- 8.6: Possible Explanations for the Missing Mass in Galaxies and Clusters
- 8.7: Wrapping It Up 8 - What Is the Matter With NGC 3198?
- 8.8: Mission Report 8 - What Is the Matter With NGC 3198?

9: Special Relativity

- 9.0: Special Relativity Introduction
- 9.1: The Principles of Special Relativity
- 9.2: Time Dilation
- 9.3: Length Contraction
- 9.4: The Geometry of Special Relativity - Spacetime
- 9.5: Applications of Spacetime
- 9.6: Mass and Energy
- 9.7: Faster Than Light?
- 9.8: Wrapping It Up 9 - A Trip to Alpha Centauri
- 9.9: Mission Report 9 - A Trip to Alpha Centauri

10: General Relativity

- 10.0: General Relativity Introduction
- 10.1: Einstein's Equivalence Principle
- 10.2: Gravity and Curvature
- 10.3: What is Curvature?
- 10.4: Tests of General Relativity
- 10.5: The Source of Gravity
- 10.6: Wrapping It Up 10 - Curved Spacetime Around Astronomical Objects
- 10.7: Mission Report 10: Curved Spacetime Around Astronomical Objects
- 10.8: Formulae, Constants, and Conversion Factors for Chapter 10

11: Black Holes

- 11.0: Black Holes Introduction
- 11.1: What Are Black Holes?
- 11.2: Spacetime Near Black Holes
- 11.3: Quantum Effects Near Black Holes
- 11.4: Astrophysical Black Holes
- 11.5: Wrapping It Up 11 - Black Hole Densities
- 11.6: Mission Report 11 - Black Hole Densities

12: Gravitational Lenses

- 12.0: Gravitational Lensing Introduction
- 12.1: What Are Gravitational Lenses?
- 12.2: Lensing by Point Masses
- 12.3: Lensing by Extended Mass Distributions
- 12.4: Weak Lensing
- 12.5: Wrapping It Up 12 - Measuring Gravitational Lenses
- 12.6: Mission Report 12 - Measuring Gravitational Lenses

13: The Expansion of the Universe

- 13.0: The Expansion of the Universe Introduction
- 13.1: Some History
- 13.2: The Hubble Law
- 13.3: The Universe is Expanding
- 13.4: The Age of the Universe
- 13.5: The Basic Big Bang Model
- 13.6: Wrapping It Up 13 - How Well Do We Know the Expansion Rate and Age of the Universe?
- 13.7: Mission Report 13 - How Well Do We Know the Expansion Rate and Age of the Universe?

14: The Growth of Structure

- 14.0: The Growth of Structure Introduction
- 14.1: Large Scale Structure
- 14.2: The Formation of Galaxy Clusters and Groups
- 14.3: The Formation and Evolution of Galaxies
- 14.4: The First Stars
- 14.5: Wrapping It Up 14 - Map the Universe
- 14.6: Mission Report 14 - Map the Universe

15: The Cosmic Microwave Background

- 15.0: The Cosmic Microwave Background Introduction
- 15.1: Observations of the CMB Spectrum
- 15.2: Implications of the CMB Temperature and Spectrum
- 15.3: Observations of Variations in the CMB
- 15.4: Understanding the Variations in the CMB
- 15.5: Comparing Models and Data - The CMB and the Curvature of Space
- 15.6: Wrapping It Up 15 - Using CMB Data to Determine Cosmological Parameters
- 15.7: Mission Report 15: Using CMB Data to Determine Cosmological Parameters

16: The Early Universe

- 16.0: The Early Universe Introduction
- 16.1: The Formation of the Lightest Elements
- 16.2: Particle Soup
- 16.3: Inflation
- 16.4: The Beginning
- 16.5: Wrapping It Up 16 - Timeline of the Early Universe
- 16.6: Mission Report 16 - Timeline of the Early Universe

17: Dark Energy and the Fate of the Universe

- 17.0: Dark Energy and the Fate of the Universe Introduction
- 17.1: Evidence for Dark Energy
- 17.2: Candidates for Dark Energy
- 17.3: The Friedmann Equation and the Fate of the Universe
- 17.4: Cosmic Concordance and Cosmological Parameters
- 17.5: Summary
- 17.6: Wrapping It Up 17 - Cosmological Parameter Estimation
- 17.7: Mission Report 17 - Cosmological Parameter Estimation

Knowls

- 18: Big Ideas JS code
 - 0.5: Meters To Kilometres
 - 0.5: Sun Moon Distance
 - 18.0: 15_4_how_cosmological_parameters_affect_the_cmb_cold_dark_matter
 - 18.1: 15_4_how_cosmological_parameters_affect_the_cmb_regular_matter
 - 18.2: 16_2_4_particle_creation_timeline
 - 18.3: bigIdeasActivityOne
 - 18.4: ch16_particle_classification
 - 18.5: ch4pg1lightminute
 - 18.6: ch4pg1lightyear

- [18.7: ch4pg1powersoftentimescales](#)
- [18.8: ch4pg2boatwavedemobcmovingsource](#)
- [18.9: ch4pg2boatwavedemosourceofwavesstationary](#)
- [18.10: ch4pg2dopplershiftofhydrogen](#)
- [18.11: ch4pg2quantitativedopplershift](#)
- [18.12: ch4pg2twowaysofrepresentingaspectrum](#)
- [18.13: ch4pg3relativemotion](#)
- [18.14: ch4wiu4theandromedashift](#)
- [18.15: ch6pg2standardruler](#)
- [18.16: ch6pg3animatedfigure612](#)
- [18.17: ch6pg3fluxvsdistance](#)
- [18.18: ch6pg3mainsequencematchingforclustersofdifferentdistances](#)
- [18.19: ch6pg3standardcandle](#)
- [18.20: ch6pg3supernovaetypelaanddistances](#)
- [18.21: ch6pg3tullyfisher](#)
- [18.22: ch6pg4matchthetechniquetothe distance](#)
- [18.23: ch7pg2accelerationandmass](#)
- [18.24: ch7pg2netforceofanobject](#)
- [18.25: ch7pg3animatedfigure75](#)
- [18.26: ch7pg3howdoestheforceofgravitydependondistance](#)
- [18.27: ch7pg3howdoestheforceofgravitydependonmass](#)
- [18.28: ch7wiu7thegalileanmoonsofjupiter](#)
- [18.29: chapter2pg1photonraceroundone](#)
- [18.30: chapter2pg5planckspectrum](#)
- [18.31: chapter2pg6viewingorientation](#)
- [18.32: chapter2pg7determiningthecomposition](#)
- [18.33: chapter3pt1lightcollectingarea](#)
- [18.34: chapter3pt4afindingthesourceandsubtractingthebackground](#)
- [18.35: chapter3pt4bcolorizingccdimages](#)
- [18.36: chapter_11_2_falling_into_a_black_hole_tidalforces](#)
- [18.37: chapter_11_2_time_dilation_spacetime_dialation](#)
- [18.38: chapter_12_2_lensing_by_a_point_mass_gravitationallensing_simple](#)
- [18.39: chapter_12_2_macho_light_curve](#)
- [18.40: chapter_12_2_the_einstein_radius_einsteinring](#)
- [18.41: chapter_12_3_different_types_of_lenses_glbining](#)
- [18.42: chap_2_1_wave_generator_NEW](#)
- [18.43: comovingcoords](#)
- [18.44: expandinguniverse1](#)
- [18.45: explodinguniverse](#)
- [18.46: explosionvsexpansiondensity](#)
- [18.47: orbitsimulator](#)
- [18.48: testjQueryUI](#)
- [18.49: var1](#)
- [18.50: wiu15_a_curvature](#)
- [18.51: wiu15_b_amount_of_baryonic_matter](#)
- [18.52: wiu15_c_amount_of_cold_dark_matter](#)
- [18.53: wiu6thesupernovaof1885](#)
- [18.54: wiu_12_1_determining_masses_of_lenses_grav_len_mass_measurement](#)
- [18.55: wiu_12_1_determining_masses_of_lenses_mass_calculator](#)
- [18.56: wiu_16_cosmic_timeline](#)
- [Kilometres To Miles](#)
- [Pop ups](#)

- [Math Exploration 13.1](#)
- [Math Exploration 13.2](#)

[Index](#)

[Glossary](#)

[Detailed Licensing](#)

[Resources: Formulae, Constants, and Conversions](#)