

# CONTENTS, Exploring Black Holes, Second Edition

Constants and Conversion Factors, Questions

Inside Front Cover

## Chapter 1. Speeding

Background in special relativity. Invariance; interval; worldline; energy and momentum from the Principle of Maximal Aging; limits on the local inertial frame due to spacetime curvature.

## Chapter 2. The Bridge: SR to GR

Curvature of Earth's surface as an analog to curvature of spacetime. Local and global metrics for both space and spacetime. Road map of Kansas, USA as analog to the local inertial frame in which we make every measurement in curved spacetime. The difference between space and spacetime. Goodbye "distance," goodbye "time."

## Chapter 3. Curving

Describe curved spacetime outside Earth and down to the center of a non-spinning black hole. Global coordinates and the Schwarzschild global map of events. One-way event horizon.

## Chapter 4. The Global Positioning System (GPS)

Locate yourself anywhere on Earth with a hand-held device whose operation depends crucially on general relativity.

## Chapter 5. Global and Local Metrics

The global metric describes curved spacetime with global "map" coordinates that we choose arbitrarily. Over a small enough spacetime patch, however, curved spacetime is effectively flat, so special relativity applies. Our rule: Describe every experiment and observation in a local inertial frame on a flat patch.

## Chapter 6. Diving

Dive into a black hole. How fast do you move? How do you feel? How long do you live? Global map energy as a constant of motion from the Principle of Maximal Aging. Local rain frame. Local gravitational acceleration.

## Chapter 7. Inside the Black Hole

A relaxed life with spectacular effects behind and ahead of you, and an ending certain. Global rain coordinates. Tetrad forms of the metric.

## Chapter 8. Circular Orbits

Map angular momentum as a constant of motion. Your spaceship rides in a circular "parking orbit" around a black hole. Predict this orbit at a glance.

## Chapter 9. Orbiting

Insert your spaceship into a circular orbit. Transfer between circular orbits. Look out! Killer tides threaten humans and robots.

## Chapter 10. Advance of Mercury's Perihelion

An early victory of Einstein's brand new general relativity theory.

## Chapter 11. Orbits of Light

Trajectories of light around a black hole. Predict these orbits at a glance. Which light beam connects that star with this observer?

## Chapter 12. Diving Panoramas

A diver rides her local rain frame to the center of a black hole. What changing panoramas surround her? What is the last thing she sees?

### **Chapter 13. Gravitational Mirages**

Stars, galaxies, and black holes act like distorting lenses that magnify distant structures and help us to take a census of mass in the Universe. Einstein's surprise: Space curvature affects the bending of light rays.

### **Chapter 14. Expanding Universe**

The shape in space and time of an expanding Universe derived from signals emitted by stars and galaxies in the past. The Friedmann-Robertson-Walker global metric. Constant of galaxy motion from Principle of Maximal Aging.

### **Chapter 15. Cosmology**

Composition of the Universe: ordinary matter, dark matter, and dark energy. Development of the Universe since the Big Bang. Alternative cosmic futures.

### **Chapter 16. Gravitational Waves**

Gravitational waves penetrate where light cannot go and bring information from cosmic catastrophes, coalescence of orbiting black holes, regions close to monster black holes, and early instants of the Universe.

### **Chapter 17. Spinning Black Hole**

Global structure of the spinning black hole: irresistible motion, two horizons, map energy, map angular momentum, and the raindrop. Rain, static, and ring observers and their tetrads.

### **Chapter 18. Circular Orbits around the Spinning Black Hole**

Circular orbits outside and—strangely—inside the event horizon. Accretion disks power quasars.

### **Chapter 19. Orbiting the Spinning Black Hole**

Insert your spaceship into a circular orbit around the spinning black hole. Transfer a probe from one circular orbit to smaller ones. Look out! Killer tides again threaten humans and robots.

### **Chapter 20. Orbits of Light around the Spinning Black Hole**

What do we see as we orbit around and plunge into the spinning black hole?

### **Chapter 21. Inside the Spinning Black Hole**

Where can maneuvers inside the spinning black hole allow us to travel? Can we return?

### **Chapter 22. Deriving the Metric**

Einstein's field equations for static spherical spacetimes; derive the Schwarzschild metric. Metrics for spherical stars, charged black holes, white holes, wormholes, and inflationary cosmology.

### **Appendix A: Wheeler's Rules**

Motivate! Simplify! Self-descriptive terminology, the dullness of simply being, and other rules of writing.

### **Appendix B: Glossary**

Where to find the definitions of terms. List of words not used in this book.

**General Relativity Briefing**

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**Graphic: Organization of Topics**

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