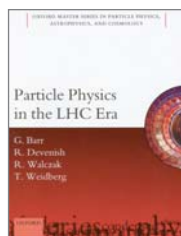


Particle Physics in the LHC Era

G. Barr, R. Devenish, R. Walczak, and T. Weidberg

Oxford U. Press, 2016. \$125.00 (432 pp.). ISBN 978-0-19-874855-7



Particle physics is undergoing a midlife crisis. Born out of nuclear physics and cosmic-ray physics in the second half of the 20th century, it went through a turbulent adolescence of rapid discoveries in the 1960s and 1970s and entered an adult phase of spectacular recognition and success during which precision measurements confirmed earlier intuitions one by one. With the discovery of the Higgs boson at the Large Hadron Collider (LHC) in 2012, particle physics checked its last dream off the list and settled into a somewhat affluent lifestyle. In the short span of half a century, the discipline has made enormous progress and has achieved a precise understanding of the fundamental building blocks of ordinary matter.

And yet something is missing. Something big, actually. We know that most of the universe is made of mysterious substances—namely, dark matter and dark energy—which we do not yet understand. We also have no firm grasp on the origin of the parts of the universe that we do understand. The LHC, the same shiny machine that has delivered some incredibly satisfying results, has also so far disappointed hopes that it would unveil what lies ahead.

So, if particle physics were a person, they might decide to go into therapy. The therapist might suggest sitting down and writing out all their past deeds, how those incredible feats were achieved, and what it all means. The result would be something very close to *Particle Physics in the LHC Era* by Giles Barr, Robin Devenish, Roman Walczak, and Tony Weidberg.

This is indeed a valuable textbook, written by recognized experts in experimental particle physics and aimed at students at the advanced undergraduate or early graduate level. It has two ambitious goals. The first is to cover the whole field of particle physics. Its topics range from the hardware details of particle detectors to the intrinsic properties of the Higgs boson, from explaining why LHC

magnet coils are made of peculiarly twisted filaments to discussing the cosmological constant and the accelerating expansion of the universe.

The second goal is, in the words of the authors, to “teach the maximum amount of physics with the minimum level of maths.” The book starts with a self-contained chapter that introduces the basics and covers such mathematical tools as fundamental symmetries and some group theory. It moves on to a discussion of the hardware of particle physics, specifically accelerators and detectors, and then covers the different aspects of the standard model and its experimental tests. Along the way, the authors discuss the Klein–Gordon and Dirac equations, the principle of gauge symmetry, electroweak interactions, quantum chromodynamics, charge–parity violation, neutrino oscillations, and the Higgs boson. Both goals are largely achieved.

As with any ambitious endeavor, there are weaknesses and omissions. The most obvious, reflected even in the title, is the admitted bias toward LHC physics.

As a result, some parts of the book might soon be outdated, and more importantly, experimental programs such as those involving neutrino or astroparticle physics receive a somewhat cursory treatment. On a more formal level, the treatment of Feynman diagrams, the fundamental tool for actual computations in quantum field theory, falls slightly short: Given the amount of theoretical material already covered in the initial chapters, simply providing the fundamentals of Dirac matrix algebra would have empowered the reader to compute basic amplitudes and processes, but those mathematical preliminaries are instead left to the Further Reading sections. Other topics that perhaps deserved mention are statistics and data analysis, which are crucial for budding particle physicists.

Overall, though, *Particle Physics in the LHC Era* is a very successful enterprise. The book is a worthy successor to classic texts like Donald Perkins’s *Introduction to High Energy Physics* (Addison-Wesley, 1972) and Francis Halzen and Alan Martin’s *Quarks and Leptons: An Introductory Course in Modern Particle Physics* (Wiley, 1984). This volume has the potential to bring a new generation of particle physicists to the brink of current knowledge and help prepare them to go out and push the frontier.

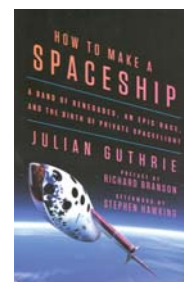
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How to Make a Spaceship

A Band of Renegades,
an Epic Race, and the Birth of Private
Space Flight

Julian Guthrie

Penguin Press, 2016. \$28.00 (448 pp.). ISBN 978-1-59420-672-6



Hanging in the National Air and Space Museum’s Boeing Milestones of Flight Hall is *SpaceShipOne*, the winner of the Ansari XPrize in 2004. The \$10 million prize was awarded for the first piloted, non-governmental spacecraft to fly twice in two weeks above 100 kilometers—the now widely accepted, if arbitrary, definition of where outer space begins. The XPrize’s aim was to stimulate private space tourism. A dozen years after the prize was

awarded, we are still waiting for sub-orbital tourist flights to begin.

Julian Guthrie’s book about the XPrize, *How to Make a Spaceship: A Band of Renegades, an Epic Race, and the Birth of Private Space Flight*, is structured around intertwined biographical segments. The first half is largely about Peter Diamandis, the XPrize’s creator. The son of a doctor in the New York City suburbs, Diamandis was eight years old when he watched Neil Armstrong and Buzz

Aldrin walk on the Moon. He satisfied family expectations by finishing Harvard Medical School, but he remained obsessed with space.

When the “New Space” movement sprang up in the 1970s and 1980s out of frustration with NASA’s human space-flight programs—stuck in low Earth orbit after the end of the Apollo missions—Diamandis became one of the movement’s most creative members. He and two friends formed Students for the Exploration and Development of Space, which targets high school and university students, and established the International Space University, which offers both a summer program and a master’s degree in space studies.

In the early 1990s, inspired by the Orteig Prize that Charles Lindbergh had won for the first nonstop flight from New York City to Paris, Diamandis decided to create the XPrize to stimulate spaceflight. However, he struggled for years to find sponsors for the prize money. Eventually he gave the Ansari family naming rights in return for a substantial donation. Diamandis then used that money to make a payment on an unusual insurance contract—effectively placing a bet that someone would win the prize before it expired at the end of 2004. If anyone successfully completed the challenge, the insurance payout would provide the \$10 million reward.

The second half of the book features Burt Rutan, the famous aviation designer who created the prize-winning craft, and his team. Guthrie details the construction of Rutan’s *SpaceShipOne*, its test flights, the personal dramas of its pilots, and the team’s ultimate triumph. Alongside Rutan’s story, Guthrie includes chapters about Erik Lindbergh, who overcame physical disabilities to raise additional prize funds by restaging his grandfather’s 1927 flight, and other XPrize competitors, notably ones in Romania and Britain.

No one should mistake this work for history, or even objective journalism. Guthrie, an experienced freelance journalist, bases her account on interviews with participants she obviously admires. The subjects opened their diaries and personal documents to her—but those valuable sources deepen the book’s dependence on the principals’ points of view. The book also has an annoying quirk: Guthrie includes many asides in

tiny print at the bottom of pages. But *How to Make a Spaceship* will be enjoyed by its intended audience and will provide a starting point for a more academic history.

One question Guthrie avoids is why a suborbital tourism market has been so slow to develop, despite the optimism in 2004. Clues can be found in *SpaceShipOne*’s test flights and in the 2014 crash of its successor, *SpaceShipTwo*, which resulted in the death of one of the

copilots. Spaceflight was supposed to become routine, but Rutan’s winged design, with its unique mechanism for tilting the tail boom up during reentry, requires expert piloting. Piles of money are needed to build a spacecraft safe for tourists, and several suborbital ventures have already failed for lack of capital.

SpaceShipTwo continues because of the deep pockets of Virgin Group founder Richard Branson, who bought the rights to Rutan’s technology for his

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company Virgin Galactic and who wrote the foreword for *How to Make a Spaceship*. However, Virgin Galactic only recently resumed test flights and may soon be surpassed by its rival Blue Origin, owned by Amazon billionaire Jeff Bezos. Blue Origin's automated, vertically launched *New Shepard* rocket includes a booster that can be recovered and reused and a crew capsule for a parachute landing. It has already flown without passengers; Blue Origin plans to launch em-

ployees this year and tourists next year. Bezos and Elon Musk of SpaceX, who appear briefly in *How to Make a Spaceship*, have displaced Guthrie's main actors to become the new faces of New Space. Perhaps the next few years will produce the space-tourism breakthrough that Diamandis has long tried to facilitate.

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Sound

A Very Short Introduction

Mike Goldsmith

Oxford U. Press, 2016. \$11.95 paper (144 pp.). ISBN 978-0-19-870844-5

Sound helps shape how we experience the world, and an understanding of sound is critical in domains as diverse as psychology, linguistics, architecture, animal behavior and evolution, oceanography, and, of course, music. Thus the physics and technology of acoustics are inherently of interest to a great many people, scientists and the lay public alike.

The special place of sound in science and culture, and a general fascination with the topic, inspired physicist and science writer Mike Goldsmith to write *Sound: A Very Short Introduction*. At 144 pages, the book, part of Oxford University Press's Very Short Introductions series, lives up to its title. Within its eight brief chapters, *Sound* covers the diverse fields noted above and more, and it includes some basic physics. The author has written other popular and children's books on science, and his experience comes through in the engaging, easy-to-read style of *Sound*. Equations are kept to a bare minimum, and most phenomena are explained with familiar examples. Goldsmith has worked at the National Physical Laboratory in Teddington, UK, and his specific background in the measurement of sound, notably its speed in various media, is conspicuous in several chapters.

The book opens at the absolute beginning, the Big Bang, and progresses through acoustic landmarks in biological and human history toward the present. Following a basic treatment of acoustics that focuses on measurements and on

the wave nature of sound, there are chapters on music, hearing and speech, technologically produced sound, sounds we cannot hear (infrasound and ultrasound), sounds in liquids and solids, and noise.

For readers who are not physicists or engineers, however, some fundamental issues should have been clarified early in the book. For example, although Goldsmith extensively discusses the wave aspect of sound, he does not mention the particle velocity aspect—longitudinal movement of molecules in the fluid medium that carries a sound wave—despite noting in a later section on microphones how some instruments respond to that velocity.

For readers who are biologists, some of the evolutionary and physiological explanations are certain to raise eyebrows. The book's introduction rather glibly states that the main impetus to the evolution of animal hearing was communication. Most current analyses, however, indicate that hearing evolved for defense, as predators inevitably make some noise when moving. Additionally, hearing generally precedes sound communication in the evolutionary tree; many animal groups hear but do not use sound for communication.

A fair amount of discussion is devoted to echolocation in bats via ultrasound signals, an excellent example of acoustic autocommunication. Indeed, those signals, not studied until the late 1930s, inspired much of the development

